First Series:

Defensive Technical Surveillance Countermeasures Doctrine

Volume 11

Receivers, Spectrum Analyzers, Software-Defined Radios, and RF Measurement Chains

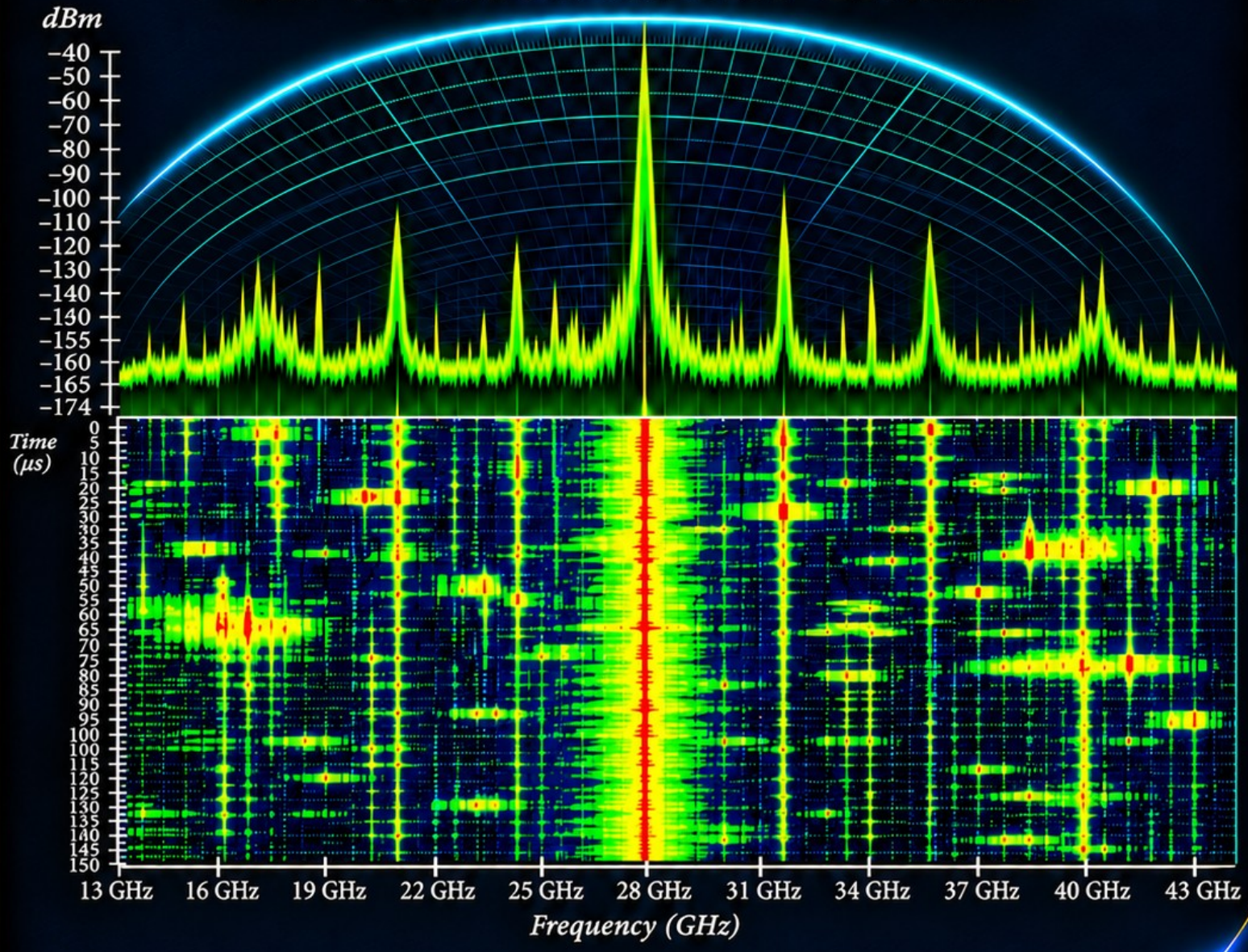

By: James M. Atkinson, PhD

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Receiver measurements are configuration-dependent. The practitioner must verify authority, instrument configuration, calibration, bandwidth, reference planes, overload state, environmental conditions, and the governing law or standard before acting on a method or conclusion.

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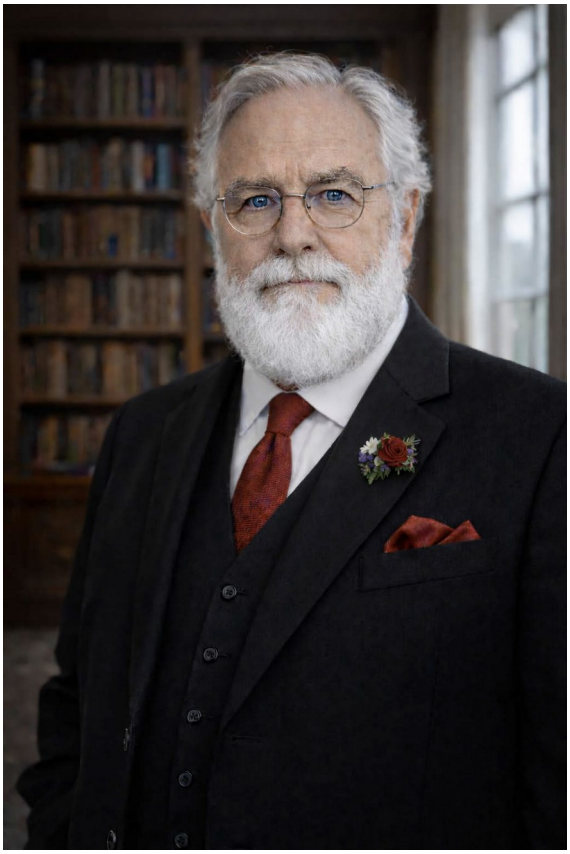

A receiver does not merely display a frequency. It transforms electromagnetic energy through antennas, cables, filters, gain stages, mixers, clocks, detectors, digitizers, software, and decision rules. Every stage can preserve information, remove it, distort it, or create an artifact that resembles a signal of interest.

The purpose of this volume is to place receiver behavior inside a controlled measurement model. Sensitivity, selectivity, dynamic range, phase noise, timing, bandwidth, probability of intercept, and demodulation quality are treated as state-dependent quantities rather than catalog labels. The text repeatedly distinguishes a detected energy component from a classified waveform, an attributed emitter, recovered information, and a legally supportable finding.

The practitioner is expected to challenge the receiver as aggressively as the environment. Alternate preselection, attenuation, reference sources, antennas, clocks, digitizers, locations, polarizations, and analysis methods are used to separate external phenomena from receiver-generated products. A technically responsible report records those controls and the uncertainty that remains.

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Scope, Prerequisites, Exclusions, and Reader Route

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Authoritative Scope

This volume owns receiver-chain theory, spectrum-analyzer and software-defined-radio architecture, front-end and frequency-conversion behavior, IF and detector paths, spectral estimation, dynamic range, clock and phase integrity, calibration, recording, and defensive interpretation. It supports but does not replace V010 for survey antennas and fixtures, V058 for training instrumentation, V074 for monitoring-receiver deployment and survey-data governance, V099 and V104 for general test equipment and methods, or V100 for communications-system theory.

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Prerequisites

Readers should understand complex quantities, logarithmic units, thermal noise, sampling, modulation, transmission lines, antennas, and uncertainty. V024, V060, V084 through V101, V104, and V110 provide the principal prerequisites.

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Exclusions and Safety Boundary

The volume does not teach unauthorized interception, content exploitation, surveillance, evasion, or unlawful access. It does not treat one displayed spectral line, decoded identifier, or recovered fragment as proof of hostile purpose. Energized RF and microwave measurements require attention to exposure, equipment ratings, high voltage, electrostatic discharge, and the consequences of inserting or removing components.

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Reader Route

Chapters 1 through 5 establish receiver architecture, noise, gain, conversion, and IF behavior. Chapters 6 through 10 address analog and digital demodulation, swept and FFT analysis, and software-defined radios. Chapters 11 through 15 develop dynamic range, timing, reference-plane integration, calibration, and recording. Chapter 16 integrates artifact challenge testing, survey use, reporting, acceptance, and lifecycle control.

Worked applications and case adjudications use hypothetical or explicitly stipulated inputs unless a cited passage identifies a particular published measurement. They demonstrate a declared model and its limits. They are not records of a field engagement or acceptance tests of an unspecified instrument.

Study formats and laboratory requirements. This volume is suitable for independent study or an instructor-led two-semester course at a college, university, military school, technical academy, or other institute of learning. Instructor-led teaching requires substantial, appropriately calibrated RF laboratory equipment, including receivers, software-defined radios, spectrum analysers, signal generators, antennas, test accessories, and acquisition systems. Students must undertake supervised RF measurements in a properly isolated or shielded chamber and on designated indoor and outdoor test ranges. These complementary environments permit controlled calibration alongside realistic investigation of propagation, multipath, interference, and measurement uncertainty. All exercises must be authorised, safety-assessed, frequency-coordinated where necessary, and conducted in accordance with applicable law.

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The First Series contains 120 self-contained volumes, numbered S001-V001 through S001-V120. The present book is S001-V011. The following catalogue lists the 119 companion volumes by stable identifier and short title. Every essential definition, derivation, safety qualification, measurement method and worked example remains in this book. Links inside this manuscript navigate to catalogue entries; the availability of a companion manuscript is not implied. Title assignments retained from earlier archives require final catalogue authority review.

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IEC CISPR 16-1-1:2019, edition 5.0, published May 22, 2019. The official public scope identifies radio-disturbance measuring apparatus from 9 kHz to 18 GHz, including EMI receivers and spectrum analyzers. This scope check is not a reading of the complete standard or a compliance claim. https://webstore.iec.ch/en/publication/60774.

IEEE 1241-2023, IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters, published October 6, 2023. The official record lists this published edition as active. Only public status and scope were checked; instrument compliance requires the controlling standard and applicable test evidence. https://standards.ieee.org/ieee/1241/6797/.

IEEE 1057-2017, IEEE Standard for Digitizing Waveform Recorders, published January 26, 2018. The official record lists this edition as active. The active revision project is not a published replacement. Only public status and scope were checked. https://standards.ieee.org/ieee/1057/5945/.

Kast, Manurkar, Remley, Williams, and Horansky, “System-Level Calibration of a Millimeter-Wave Vector Signal Analyzer with Uncertainties,” IEEE Transactions on Microwave Theory and Techniques 73, no. 11 (November 2025): 9085–95. The NIST-hosted manuscript’s method and results text on pages 1–9 was read for the published calibration example in Chapter 14. Full citation and read scope appear in the footnote and bibliography. https://doi.org/10.1109/TMTT.2025.3597240.

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Chapter 1. Receiver-System Boundaries, Mission Authority, and Evidence Formation

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1.1 Receiver as a Measurement System

A receiver should be modeled as a sequence of physical and computational transformations rather than as a frequency display. Energy enters through an antenna or conducted port, encounters protection and preselection, is amplified or attenuated, translated in frequency, filtered, detected or digitized, and finally represented by software. Each boundary has a reference impedance, bandwidth, gain, linearity limit, noise contribution, timing state, and configuration identity. A finding is only as defensible as the least controlled transformation in that chain. When the selected input, preamplifier state, local oscillator, detector, sample rate, or analysis window is unknown, a numerical readout can be precise while the measurand remains undefined.[1]

The system boundary extends beyond the instrument enclosure. Antenna pattern and polarization, cable loss, adapters, external filters, bias tees, splitters, limiters, attenuators, remote digitizers, computers, drivers, and scripts can change what is observed. Even passive components can introduce mismatch, common-mode current, temperature drift, or nonlinear contact behavior. The receiver log therefore identifies every component between the environment and the stored result, including the physical location to which amplitude and phase are referred. This chain record

1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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permits a later reviewer to distinguish an environmental signal from an effect created by the measurement system.

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1.2 Mission Authority and Collection Boundaries

Technical authority defines what may be energized, disconnected, recorded, demodulated, retained, and disclosed. A lawful spectrum survey may authorize measurement of occupancy and technical characteristics while prohibiting recovery of communications content. Another engagement may permit controlled laboratory analysis of a seized device but not continuous monitoring of unrelated emitters. The receiver plan converts those legal and institutional limits into frequency ranges, locations, times, detector modes, recording policies, minimization rules, and stop conditions. This is an engineering control because acquisition settings determine what information is captured.

Minimization begins before collection. The practitioner selects only the bandwidth, duration, channels, and metadata needed to answer the defensive question, and separates incidental content from technical evidence. Triggered recording, masked bands, reduced audio output, cryptographic access control, retention limits, and documented deletion can all reduce unnecessary acquisition. A capable receiver does not justify the broadest available configuration. The record states the authorized objective, the data actually collected, deviations, and who approved any extension.

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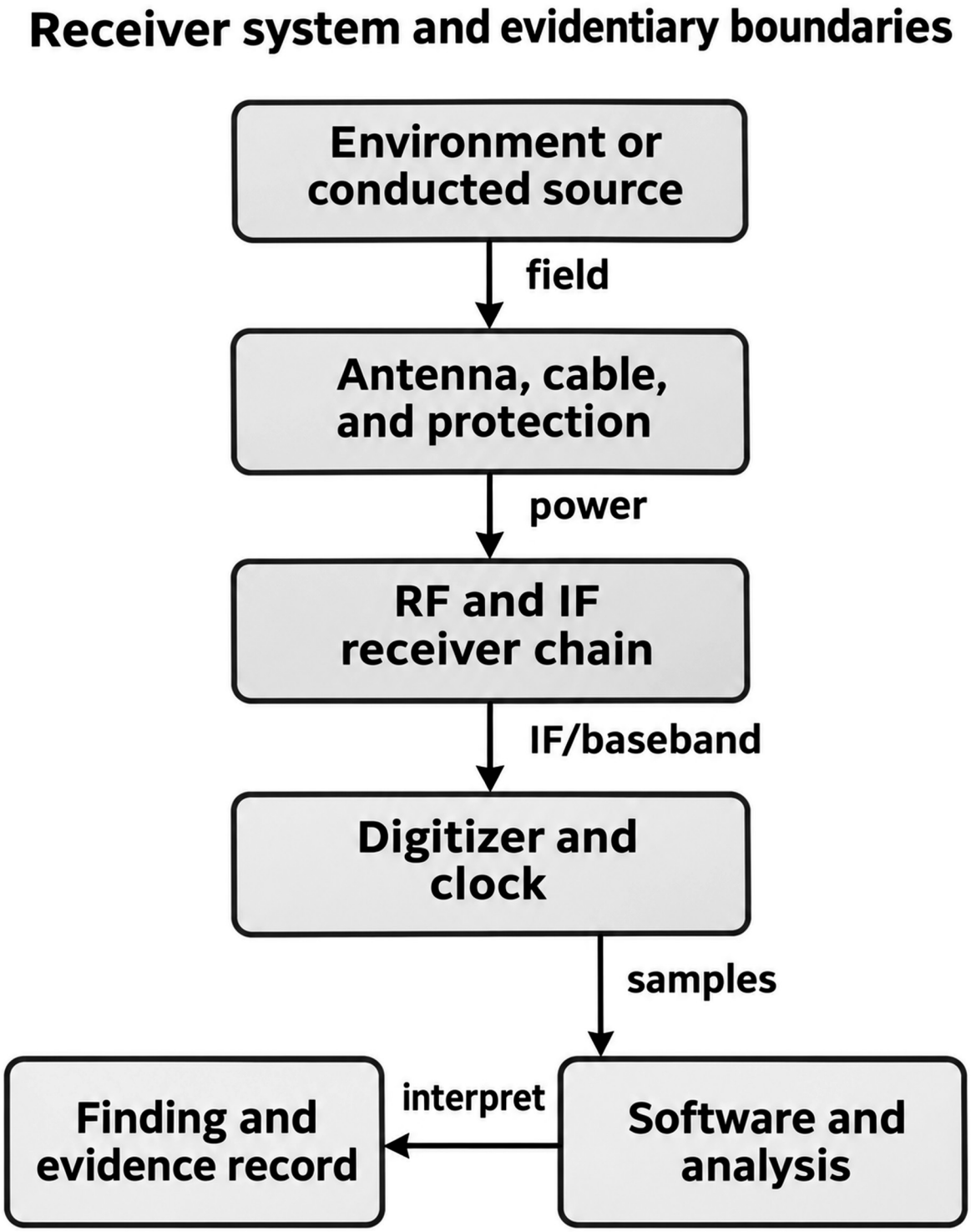

Figure 1. Receiver-system evidentiary boundaries.

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1.3 Observation, Classification, Attribution, and Content Recovery

Receiver evidence supports several different propositions, and they must not be collapsed. Detection establishes that energy or a structured component exceeded a stated decision rule. Classification associates the component with a waveform family, modulation, timing behavior, or service type. Attribution links it to a physical emitter or system through direction, timing, identifiers, controlled state changes, or other evidence. Content recovery reconstructs information carried by the signal. Each successive proposition demands additional controls and can fail even when the preceding proposition is sound.

A narrow peak may be real but unmodulated, or it may be a local oscillator leak, analyzer spur, clock harmonic, or intermodulation product. A decoded network name may identify a configuration string without proving the device location or owner. A waveform that correlates with activity may show state dependence without revealing intelligible content. Reports should therefore use verbs such as detected, classified, correlated, localized, attributed, or recovered according to the evidence actually obtained. This language prevents a receiver display from becoming an unsupported narrative.

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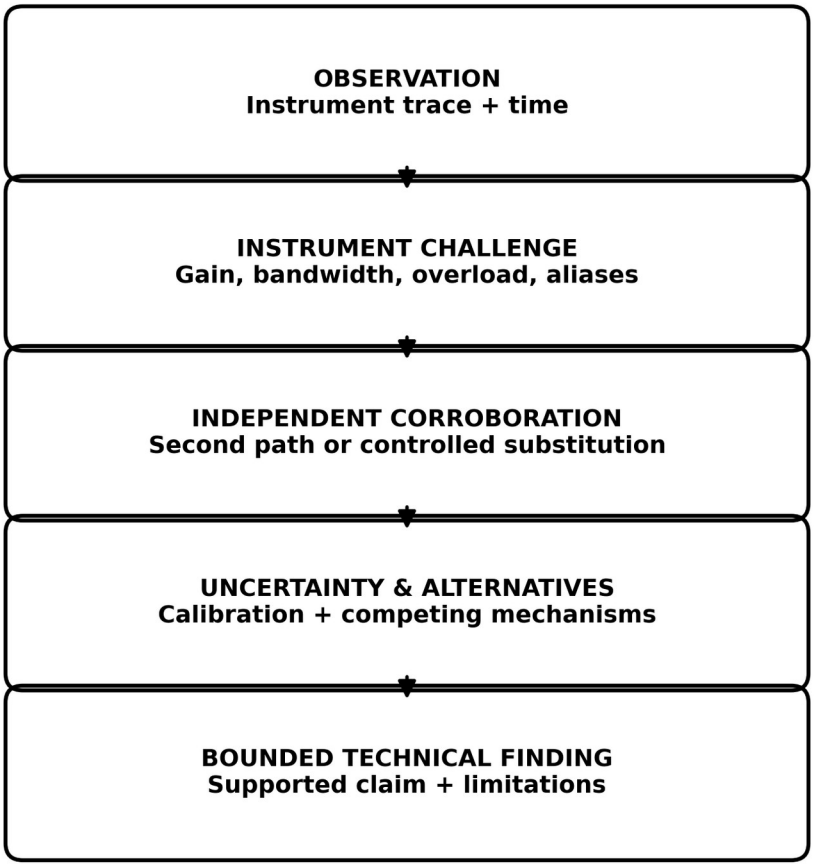

Observation → test → corroborate → qualify → report

Figure 2. Receiver observations and defensible evidence.

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1.4 Reference Planes and Configuration Identity

Cross-volume technical interface. S001-V010(Survey Antennas Probes Fixtures and Direction Finding Apparatus) develops the geometrical and probe-specific provenance of the antenna-side reference plane;S001-V020(Field Operations Evidence Handling Chain of Custody and Litigation Support) treats the continuity of custody after the instrument record is created. In the present volume, the measured quantity must nevertheless be defined at a named reference plane, with cable loss, gain state, mismatch, and software correction explicitly attached to the observation before any attribution is attempted.

Reference planes are declared at the antenna terminals, cable ends, preamplifier input and output, receiver input, digitizer, and software output whenever corrections cross those points. A reading at the display is not automatically the field strength at the antenna or the power at the source. Converting among those quantities requires antenna factor or effective aperture, cable and adapter loss, mismatch, gain state, detector response, and geometry. If one element changes, the prior calibration may no longer apply.

Configuration identity includes hardware serial numbers, option keys, firmware, driver, software build, calibration data, preselector state, attenuation, gain, detector, sweep or sample parameters, reference source, and clock arrangement. Automatic modes are documented because they can silently alter these settings. Screenshots are useful illustrations, but native trace files and setup exports are stronger evidence. The examiner

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preserves enough information to reproduce the observation on a verified system.

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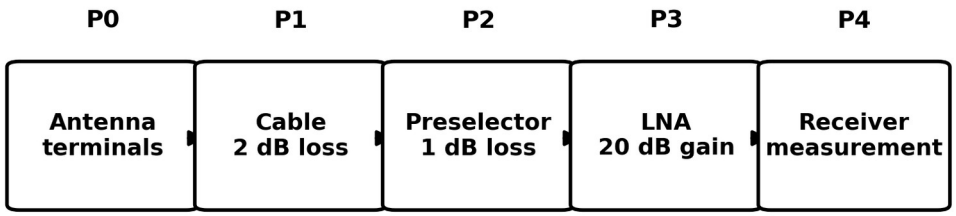

Example: reference-plane correction

$$P_{ant} = P_{rx} + L_{cable} + L_{filter} - G_{LNA}$$

$$-103 + 2 + 1 - 20 = -120 \text{ dBm}$$

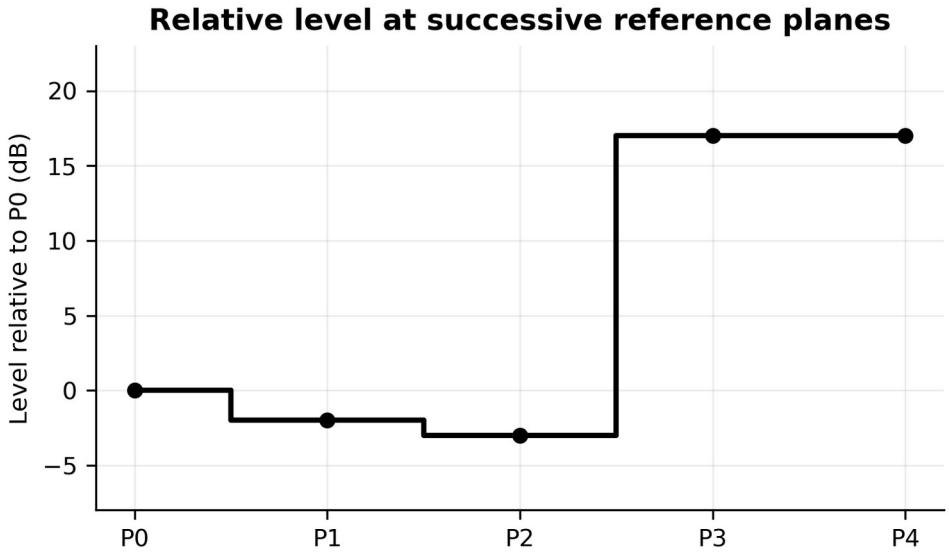

TECHNICAL INTERPRETATION

The indicated receiver power is not automatically antenna-terminal power.
Every gain, loss and calibration correction must state its reference plane.

Figure 3. Receiver measurement reference planes.

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1.5 Define the measurement before choosing the receiver mode

Begin a receiver investigation by writing the quantity or proposition that the observation is intended to resolve. Received power in a stated bandwidth, a carrier frequency, a modulation characteristic, an event time, and the presence of an authorized device are different targets. Each requires a different chain of transformations and a different supporting record. A wide scan may discover an unexpected component without supplying the amplitude calibration needed to quantify it. A narrow coherent capture may measure phase accurately while providing little information about emissions outside its instantaneous passband.

Translate that target into a reference plane, frequency interval, time interval, receiver state, estimator, and decision criterion. The reference plane fixes where power, voltage, or phase is defined. The frequency and time intervals identify which signal energy and events can contribute. The state fixes the gains, filters, clocks, and adaptive functions. The estimator defines the mathematical operation that turns retained data into a number. The decision criterion explains how the number will be used and which uncertainty or validity conditions must be met before it can support that use.

This discipline prevents a display label from carrying more meaning than its calibration supports. A power marker may describe a detector bucket, an integrated channel, or a fitted tone. A frequency marker may be an FFT-bin label, an interpolated estimate, or a swept local-oscillator setting. A timestamp may identify a sample aperture, a trigger comparator, or

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software receipt. The chapters that follow develop these distinctions individually; the system record must keep them connected so a correction applied at one stage does not silently redefine another.

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1.6 Treat configuration changes as changes in the measurement law

Equation 1 represents the configured transformation of the input into the recorded output. Its operator can include memory, frequency conversion, sampling, nonlinear limits, and adaptive control. It is therefore a system description, not a promise that every receiver obeys one linear time-invariant law. A local linear model becomes useful only after its operating state and range are declared. Model 2B, for example, assumes specified scalar gain and noise relations in the selected equivalent channel; Model 4A fixes a conversion convention; Model 5A identifies a bounded dynamic control response.

An automatic gain change can alter amplitude calibration, overload margin, recovery time, and the validity of a previously measured noise floor at once. A sample-rate change can alter alias locations, digital filter responses, sample timing, and recording throughput. A preselector change can improve blocker rejection while adding loss and phase delay. Record the transition and retain separate state intervals. Combining them into one average is justified only when the intended estimator and calibration explicitly account for the different transformations.

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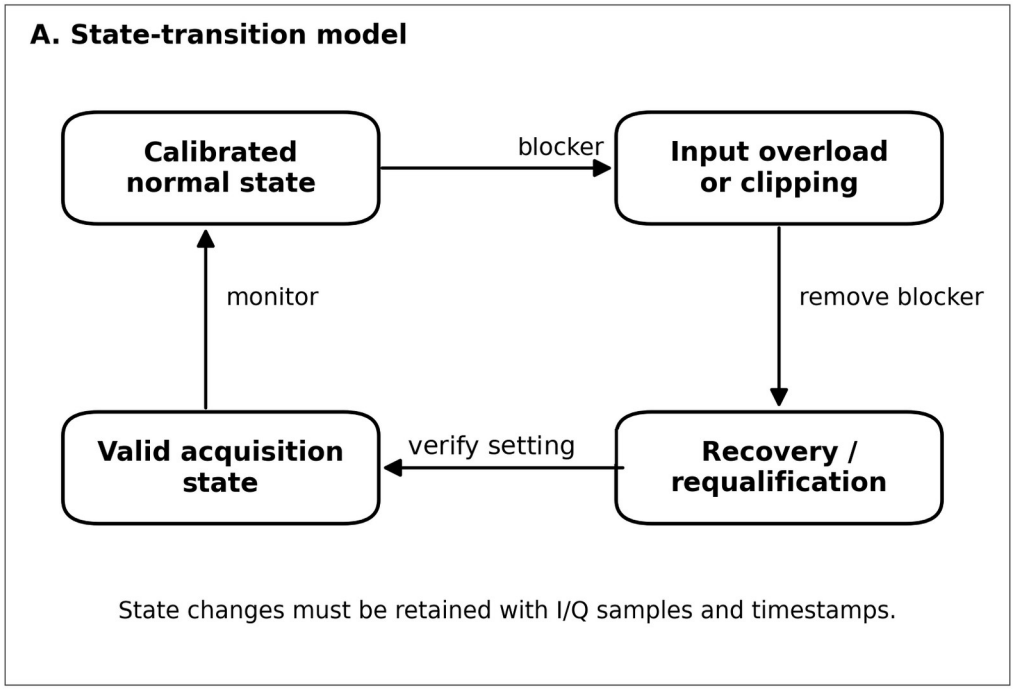

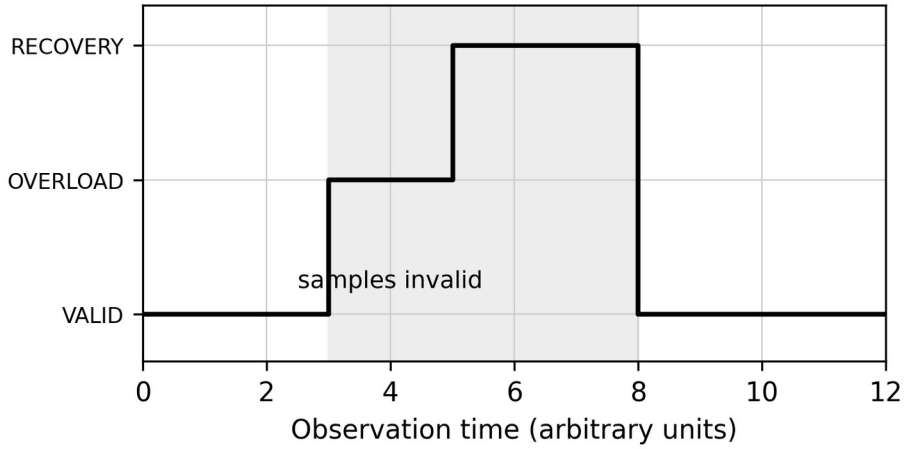

Recommendation: encode gain, attenuation, overload, clock-lock and calibration changes in the evidence log.

Figure 4. Receiver state transitions.

A useful configuration identity is sufficiently detailed to distinguish states that would produce different answers to the question. It need not reproduce irrelevant menu settings, but it must include concealed automatic behavior when that behavior changes the measurand. Exported setups, machine-

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readable logs, and operator notes complement each other. The setup records the requested configuration, the status log records the accepted or actual state where available, and the observation record shows what was captured. A disagreement among them is a measurement issue to resolve before averaging away its effects.

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1.7 Keep the evidence chain reversible to its declared inputs

Preserve native samples or traces before applying corrections that discard information. A scalar path correction can be reversible when its value and state are known. Clipping, magnitude detection, decimation without adequate rejection, and loss of samples generally remove information that cannot be restored by a later offset. A derived spectrum can still be useful, but its limits should be tied to the actual retained representation. Chapter 9 distinguishes spectral estimators, Chapter 10 follows sample-domain transformations, and Chapter 15 binds those transformations to recording continuity and metadata.

Calibration also has a direction. A level referred to the receiver connector is not automatically the level at an antenna terminal, and neither is automatically field strength at a location. Chapter 13 treats the passive and protective path, while Chapter 14 defines the correction and uncertainty model. Keep the original indication, each correction, the applicable reference plane, and the result. That record exposes whether a loss was counted twice, a gain belonged to another state, or a correction crossed a boundary that was never calibrated.

Separate evidence from the model used to interpret it. A measured pair of tone levels is evidence; a cubic law explaining their intermodulation is a bounded model. A phase-noise curve is evidence under its stated normalization; a reciprocal-mixing prediction requires blocker power, conversion gain, weighting, and cross-power conditions. A list of usable acquisition intervals is evidence; a capture probability requires an event-start distribution and a capture criterion. The distinction is productive

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because it tells the reviewer which additional observation could challenge the interpretation.

Table 1A. Route the measurement question to the developed model

Question at the system boundary	Developed treatment	Condition that must travel with the result
How much desired signal and noise reach the selected channel?	Model 2B and Chapters 3, 13 and 14	Reference planes, gains, temperatures, bandwidth and calibration state
Which RF component becomes the observed IF or complex frequency?	Model 4A and Chapter 10	Signed conversion, image rejection, filtering and sample-clock convention
How does control or demodulation alter the observation?	Models 5A, 6A, 6B and 7A	Valid dynamics, phase alignment, normalization and held-out checks
Can a weak event survive strong signals and timing limits?	Models 11A, 11B, 12A, 12B and 15A	Working range, blocker state, covariance, usable windows and event criterion

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1.8 Evidence Record and Closing Verification

A complete receiver record includes time basis, location, antenna and polarization, orientation, height, cable route, reference-plane corrections, environmental conditions, instrument configuration, overload indicators, raw or native data, analysis steps, and operator notes. Synchronization sources and clock uncertainty are recorded when several channels or sensors are compared. The record also identifies any omitted bands, blanked transmitters, failed captures, or inaccessible settings. Negative and unsuccessful tests are retained because they constrain competing explanations.

Closing verification challenges the measurement chain after the important observation. A known source or injected reference tests the functions actually traversed or exercised, in the state and at the time of the check. Functions bypassed by the injection path require complementary checks. A successful closing check alone does not establish uninterrupted validity throughout the preceding acquisition. Alternate attenuation or preselection can challenge receiver linearity within the tested conditions. A second receiver, different antenna, moved location, or changed reference clock alters the error structure. Agreement is persuasive only when the tests are sufficiently independent. The closing record states what was verified, what remained untested, and whether the observation survived the challenge.

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1.9 Operational Decision Discipline

Receiver operations are planned around decision points rather than around the available instrument menus. The operator identifies which observation would support continued search, which result would require a configuration challenge, and which condition would terminate collection or trigger specialist escalation. This prevents indefinite accumulation of traces without a defensible analytical purpose. Decision points include receiver overload, inability to reproduce a result, loss of clock lock, unauthorized content exposure, unverified calibration, and evidence that the measurement system has altered the environment.

The chapter's methods are released to field use only through a controlled survey plan, trained operators, known reference sources, and a record system capable of preserving configuration and native data. Lessons learned from one instrument or site are treated as hypotheses for future validation, not universal rules. The practitioner distinguishes procedure from judgment and records deviations so that subsequent reviewers can determine whether the technical conclusion remains valid.

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1.10 Quantitative Model for Receiver-System Boundaries, Mission Authority, and Evidence Formation

Equation 1. Configured receiver-chain representation

$$y(t) = H\left(x(t)\right) + n_{\text{int}}(t)$$

The recorded output $y(t)$ is represented as the configured receiver transformation H acting on input $x(t)$, plus internally generated noise and artifacts $n_{\text{int}}(t)$. H includes analog and digital filtering, gain, frequency translation, detection, sampling, and software processing. The relation is not assumed linear when overload, limiting, quantization, or adaptive control is present.

Equation 1 defines the system boundary; it does not assert a linear, time-invariant receiver. The scalar noise path in Model 2B, frequency conversion in Model 4A, control response in Model 5A, and the digital treatments in Chapter 10 each replace part of this representation with a narrower, testable model.

Equation 2. Corrected input power

$$P_{\text{in,dBm}} = P_{\text{ind,dBm}} + L_{\text{path,dB}} - G_{\text{ext,dB}}$$

Input power at the declared reference plane equals the indicated power plus passive path loss and minus external gain, with all terms using compatible calibration conditions. Mismatch, detector correction, antenna conversion, and uncertainty must be added when applicable.

This backward level correction is the logarithmic form of the scalar transfer used in Model 2B. Chapters 3 and 13 establish the physical path and Chapter 14 works the correction signs and uncertainty. A correction cannot repair overload or restore a component that the selected filter removed.

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1.11 Model 1A: configured transfer, correction and recoverability

Equations 1 and 2 answer different parts of one measurement question: what transformation produced the retained indication, and which input quantity can be recovered from it? Equation 1 names the complete configured operation. Equation 2 is an inverse for one restricted part of that operation. A calculation can be arithmetically reversible while the acquisition that supplied its inputs is not. The VIM distinguishes a measurement model from the function or algorithm used to obtain its output value. Here that distinction requires a physical domain for the inverse, not merely a formula that accepts numbers.[2]

In Equation 1, time t is measured in seconds. The input x may be a real waveform, a complex representation, or another explicitly identified input record. The output y and the residual contribution at that output must use compatible quantity types and units. The operator H includes any conversion of units or representation; it is not necessarily a dimensionless gain. For sampled data, the sample times and indexing belong to its definition. The internal residual need not be independent of the input or state. No independence, stationary noise law, or unique inverse follows from writing an additive residual at the output.

---

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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The scalar specialization uses mean powers referred to specified planes and one declared observation band. Let P be the desired input power, S the indicated output power before external software offsets, and N a separately characterized additive output contribution. These physical powers are nonnegative and are all measured in watts. Let a be the positive dimensionless power transfer from the selected input to that output. A gain G and loss L denote numerical values in decibels, so a is ten raised to (G minus L) divided by ten. The power level p is the numerical value expressed in dBm, with one milliwatt as its reference. An exponent or logarithm therefore acts on a dimensionless number.

Equation 2A. Power coordinates and fixed-state transfer

$$P_0 = 1\ \text{mW}\,;\, p(P) = 10\log_{10}\left(\frac{P}{P_0}\right)$$
$$P = P_0 \cdot 10^{\frac{p}{10}}\,;\, a = 10^{\frac{G-L}{10}}$$

For an isolated component in a linear, characterized path, output signal power is input signal power multiplied by a. If a separate contribution has zero mean cross-power with that signal under the stated averaging operation, its mean power can be added as N. This is the bounded power-combination condition used in Model 2B. Coherent components, a changed loading condition or a different detector statistic need their own justified relation. The word noise does not establish zero cross-power by itself.

Equation 2B. The qualified forward law and its inverse

$$S = aP + N\,;\, a > 0\,;\, P \geq 0\,;\, S \geq 0\,;\, N \geq 0$$
$$P = \frac{S-N}{a}\,;\, S - N \geq 0$$
$$p_{\text{in}} = p_{\text{sig,out}} + L - G$$

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The last expression requires a strictly positive signal-only output, with $p_{\mathrm{sig,out}}$ obtained from S minus N in linear power. Equation 2 follows when the original indication already represents that signal power, or when the added contribution is negligible at the required accuracy. Subtracting two dBm values yields a power ratio in decibels; it does not subtract two physical powers. A negative estimated difference cannot become a negative physical signal power or a finite logarithmic result merely by passing it to software.

The inverse is useful only while its inputs describe the actual observation. Require a supported gain and loss at the relevant frequency, reference planes, loading, state and level; a compatible bandwidth and detector; retained correction conventions; and evidence that limiting or discarded information has not defeated the desired inference. Several differently configured measurements can be combined only after each is referred to the same defined quantity. For nonoverlapping intervals with known durations, the following expression averages their corrected mean powers. It does not average their logarithmic labels.

Equation 2C. Average after each interval has its own valid correction

$$\overline{P}=\sum_{j} w_j \frac{S_j - N_j}{a_j}$$
$$w_j=\frac{\Delta t_j}{\sum_{k} \Delta t_k}$$
$$\sum_{j} w_j=1$$

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Here j and k index the retained intervals, each duration is in seconds, and the weights are dimensionless and nonnegative. The sum of durations is positive. Each interval must have a valid state and its stated within-interval mean; overlapping records or unequal sampling probabilities require further treatment. The result covers the retained intervals. It covers a wider time span only if omitted intervals are also represented by justified observations or explicit bounds.

Uncertainty in an applicable correction differs from uncertainty about whether the correction applies at all. For the affine level relation, Chapter 14's Model 14B gives the variance from the signed sensitivities and the input covariance matrix. Zero covariance must be stipulated or supported. Deterministic ranges instead give admissible results through the extrema of the same relation. A range is not a standard uncertainty, and a set of possible states is not a probability distribution. NIST's uncertainty guidance requires the measurement function to represent the measurement process and significant influences; a wider numerical interval cannot repair a missing physical premise.[3]

Equation 2D. Bound a positive signal-level correction without inventing a distribution

$$p_{\min} = p_{\mathrm{sig,min}} + L_{\min} - G_{\max}$$
$$p_{\max} = p_{\mathrm{sig,max}} + L_{\max} - G_{\min}$$

---

3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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Equation 2D supplies a conservative enclosure when the stated ranges hold jointly. If dependencies exclude a corner combination, the corresponding endpoint may not be attainable. When several separate states remain possible, retain the union of their enclosures rather than silently filling every intervening value or choosing the midpoint. For an additive power contribution, first bound the positive linear-power difference, then transform it. The ten applications below use this same configured-transfer family and concrete failures of its inverse. Their data are synthetic teaching assumptions, not measurements or performance claims about an instrument.

Table 1. Chapter 1 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Authority and minimization	Written objective, frequency scope, content limits, retention, and stop conditions	Defines what the receiver may collect and how the data can be used	Technical capability does not create legal authority
System configuration	Hardware, firmware, options, gain, attenuation, detector, sample or sweep settings	Makes the transformation reproducible	Automatic modes may change state without obvious notice
Reference planes	Antenna, cable, receiver, digitizer, and software correction points	Permits physically meaningful amplitude and phase statements	A display value is not automatically an environmental quantity

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Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Evidence state	Native data, time basis, overload indicators, negative tests, closing checks	Separates observation from interpretation	Screenshots alone omit settings and data lineage

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1.12 Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation

A receiver indicates -71.4 dBm. A preamplifier provides 18.6 dB measured gain, and the cable and adapters between its output and the receiver input introduce 4.8 dB loss. The corrected power at the preamplifier input is -85.2 dBm before mismatch and uncertainty. If the preamplifier was bypassed during part of the survey, traces from the two states cannot be combined without separate corrections.

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1.12.1 Application 1A.1. Complete a reference-plane correction in both directions

Complete the preceding −71.4 dBm illustration by declaring its domain. The indication describes one isolated component at the receiver connector. The preamplifier has 18.6 dB power gain and the following cable and adapters have 4.8 dB loss at that component's frequency. Stipulate linear operation, compatible matching and detector conditions, and negligible additive power at the required accuracy. The desired result is power at the preamplifier input, not field strength or transmitter output.

The net forward gain is 13.8 dB, giving a power ratio of 23.988329. Convert the receiver indication using Equation 2A: its power is 72.443596 pW. Dividing by that ratio gives 3.019952 pW at the input. In logarithmic coordinates, $-71.4+4.8-18.6=-85.2\ \mathrm{dBm}$. Predicting forward again gives $-85.2+18.6-4.8=-71.4\ \mathrm{dBm}$. Both directions describe the same named planes and provide an immediate check on the signs.

For a separate illustrative uncertainty budget, assign standard uncertainties of 0.20 dB to the indication, 0.10 dB to the loss and 0.15 dB to the gain, with zero covariance among these three inputs. The sensitivities are plus one, plus one and minus one. Their squared contributions sum to 0.0725 dB squared, so the combined standard uncertainty is 0.269258 dB. No coverage probability follows merely from this standard uncertainty; none is assigned here.

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The numerical result is conditional on the stated path. An omitted mismatch contribution, an incorrect gain state or compression is not shown to be covered by the three-term budget. A useful released record would retain the original indication, the two component calibrations and their applicability, and the input-plane result. Agreement between the forward and inverse arithmetic checks implementation; it does not independently establish those physical premises.

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1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction

Use the same physical chain as Application 1A.1, but suppose the export is explicitly documented to include the 4.8 dB cable correction already. Its displayed value is therefore −66.6 dBm, obtained by adding 4.8 dB to the raw −71.4 dBm indication. The export is referred to the preamplifier output under this convention. The remaining task is to move it to the preamplifier input.

Subtract only the 18.6 dB amplifier gain: $-66.6-18.6=-85.2\ \mathrm{dBm}$. Alternatively, recover the raw indication by subtracting the known software offset, then apply the complete original correction: $-66.6-4.8+4.8-18.6=-85.2\ \mathrm{dBm}$. These are two bookkeeping routes through the same relation. Adding the cable loss a second time instead gives −80.4 dBm, an error of plus 4.8 dB and a power overstatement by a factor of 3.019952.

The original 0.269258 dB standard-uncertainty budget still applies if exactly the same three inputs from Application 1A.1 produced the export. Do not add another independent cable uncertainty simply because the same correction appears in both an export and a calculation record. Those occurrences refer to one input, not two independent calibrations. A separate uncertainty would require a separate physical or numerical contribution.

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If the export's correction state is lost, the problem changes. Under the explicit restricted alternatives that −66.6 dBm is either raw or already corrected for that one loss, the compatible input levels are −80.4 dBm and −85.2 dBm before their uncertainties. The file's numerical precision cannot select between them. Resolve the correction-state evidence or preserve the alternatives; their midpoint would not be a demonstrated calibration result.

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1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels

Two consecutive four-second intervals are fully observed. In interval A, amplifier gain is 20 dB, path loss is 2 dB and the raw mean output level is −62 dBm. In interval B, amplifier gain is zero, the same path loss is 2 dB and the raw mean output level is −92 dBm. The state has settled throughout each interval, and each output value is the logarithm of that interval's mean signal power. Additive output contributions are negligible for this example.

Correct A to $-62+2-20=-80\ \mathrm{dBm}$, or 10 pW. Correct B to $-92+2-0=-90\ \mathrm{dBm}$, or 1 pW. Equal durations give weights of one half. Equation 2C therefore yields 5.5 pW over the combined eight seconds, whose level is −82.596373 dBm. The arithmetic mean of the two corrected dBm values is −85 dBm, 2.403627 dB lower; it represents a different averaging operation.

A second tempting shortcut also fails. Averaging the raw powers first gives −65.005959 dBm, while averaging the two gain values in decibels gives 10 dB. Correcting that aggregate by the average net gain of 8 dB produces −73.005959 dBm. It is not the mean input power because the two output powers were produced by different transfers. The inverse must be attached to each interval before the requested input-plane average is formed.

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To isolate a shared calibration effect, suppose both corrected input levels may contain the same unknown additive offset between −0.20 dB and +0.20 dB, with all other quantities exact in this constructed bound. The same multiplicative factor then acts on both linear powers, so the combined level has exactly the same ±0.20 dB bound. It does not shrink by taking two intervals. The result covers these eight observed seconds; it does not describe an unrecorded transition or establish a probability of capturing some different event.

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1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge

A controlled comparison inserts an additional attenuator with nominal loss 10.0 dB while the receiver's gain state is held fixed. A known reference changes from −70.0 dBm to −80.2 dBm. Stipulate maximum magnitude errors of 0.10 dB for each reference indication, 0.10 dB for the attenuator's actual loss and 0.10 dB for possible reference-source change between observations. These are deterministic bounds for this comparison, not standard deviations.

An unchanged input under the nominal transfer would give −80.0 dBm after insertion. Define the challenge residual as after-level minus before-level plus inserted loss. The observed reference residual is $-80.2-(-70.0)+10.0=-0.2\ \mathrm{dB}$. The four stated bounds sum to 0.4 dB, so this residual is compatible with the reference comparison's stated enclosure. Compatibility does not prove that every unmodeled influence is absent.

Now a candidate component changes from −71.4 dBm to −78.4 dBm under the same nominal intervention. Its residual is $-78.4-(-71.4)+10.0=+3.0\ \mathrm{dB}$. Under a hypothesis of unchanged candidate input, the two 0.10 dB indication bounds and the 0.10 dB loss bound give only ±0.30 dB for this residual. The observed departure lies outside that enclosure. The complete unchanged-input, fixed-transfer hypothesis cannot account for this pair under those assumptions.

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The failed prediction does not uniquely locate an internally generated product. A changed candidate input, a consequential connection or loading change, an unrecorded state transition, or a receiver response outside the calibrated domain could break the hypothesis. The reference tests its own input class and conditions. Preserve both comparisons and choose the next intervention to distinguish the remaining explanations. A calibration challenge is strongest when its rejected assumption is stated more precisely than the phrase receiver artifact.

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1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown

An acquisition is known to be settled in one of two calibrated gain states, but the state identifier was lost. The indication is −74.0 dBm with a deterministic ±0.20 dB bound. Path loss lies between 2.9 dB and 3.1 dB. State A has gain between 11.9 dB and 12.1 dB; state B has gain between 17.9 dB and 18.1 dB. These are the only allowed states, and the signal-only scalar relation is stipulated valid in both. The task is to report what the surviving evidence permits.

For A, the nominal correction gives $-74+3-12=-83\ \mathrm{dBm}$. The minimum uses the lowest indication and loss with the highest gain: $-74.2+2.9-12.1=-83.4\ \mathrm{dBm}$. The maximum uses the opposite extrema: $-73.8+3.1-11.9=-82.6\ \mathrm{dBm}$. For B the same calculation gives a nominal −89 dBm and an enclosure from −89.4 dBm to −88.6 dBm.

The supported set is the union of those two intervals. A single outer enclosure from −89.4 dBm to −82.6 dBm is conservative, but it conceals the gap and should be labeled as an enclosure. A midpoint estimate of −86 dBm belongs to neither state's calculated interval. Treating the two states as equally probable would introduce information that the record does not contain.

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The useful next action is to recover state evidence or make a new qualified observation. It is not to average the gains until one convenient answer appears. If the record had instead allowed continuous gain variation or an unsettled transition, these two intervals would no longer describe all possibilities. The construction distinguishes bounded calibration error within a valid state from missing evidence about which measurement law was active.

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1.12.6 Application 1A.6. Subtract an additive contribution in linear power before referring it backward

A fixed receiver chain has net power gain 10.0 dB. Its mean output power with a controlled signal present is 2.00 pW, and a compatible signal-off observation gives an additive contribution of 1.50 pW. The observation band, loading, gain and detector are unchanged. Stipulate zero mean cross-power between the signal and added contribution under the defined averaging operation. Turning the controlled signal off changes only that signal in this hypothetical experiment.

Equation 2B gives output signal power of $2.00 - 1.50 = 0.50\ \mathrm{pW}$. The net power ratio is ten, so input signal power is 0.050 pW, or $5.0 \times 10^{-14}\ \mathrm{W}$. Its level is −103.010300 dBm. If the total 2.00 pW output were instead treated as signal-only, subtracting 10 dB from its −86.989700 dBm level would give −96.989700 dBm. The result would overstate the input signal by 6.020600 dB, because the total output is four times the signal-only output.

For a bounded version, let the total output range from 1.98 pW to 2.02 pW, the added contribution from 1.48 pW to 1.52 pW, and the net gain from 9.9 dB to 10.1 dB. The signal-only output is enclosed by 0.46 pW and 0.54 pW. Transforming the lower power with the highest gain and the upper power with the lowest gain gives input-level bounds of −103.472422 dBm and −102.576062 dBm. The positive lower difference makes both logarithms defined.

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The subtraction is not justified merely by having an antenna-connected reading and a terminated reading. A termination may change the coupling, loading or added contribution itself. Coherence can also invalidate the additive-power law. If the admissible linear difference reaches zero, there is no finite lower dBm bound; if some differences are negative, the supplied estimates and model need reconciliation. Do not conceal that boundary by replacing the result with an arbitrary small positive power.

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1.12.7 Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse

Use a concrete voltage version of Equation 1 to test recoverability. An ideal memoryless stage multiplies a real input voltage by a dimensionless voltage gain of two, then clips the output at ±0.50 V. The retained samples contain only the clipped voltage and a correct saturation flag. The nominal transfer is $H(x)=\min(0.50\ \mathrm{V},\max(-0.50\ \mathrm{V},2x))$. This is a counterexample to applying a linear inverse beyond its domain, not a device-specific recovery model.

For input samples 0.10 V, 0.30 V, 0.60 V and −0.60 V, the retained outputs are 0.20 V, 0.50 V, 0.50 V and −0.50 V. Dividing by two recovers the first input, but gives 0.25 V, 0.25 V and −0.25 V for the clipped samples. The two different positive inputs have become the same stored value. A positive saturation flag establishes only that the nominal input reached at least 0.25 V; it supplies no finite upper bound without additional information.

Now allow the positive clipping level to lie between 0.49 V and 0.51 V and the voltage gain between 1.98 and 2.02. The possible positive input threshold extends from $\frac{0.49}{2.02}=0.242574\ \mathrm{V}$ to $\frac{0.51}{1.98}=0.257576\ \mathrm{V}$. A reliable positive clipping flag therefore gives a conservative lower bound of 0.242574 V, still with no finite upper bound. This is not a symmetric amplitude uncertainty around the naive inverse.

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For contrast, an explicitly unsaturated output reading of 0.200 V with ±0.005 V bounded reading error under the same gain range gives an input enclosure from $\frac{0.195}{2.02} = 0.096535\ \mathrm{V}$ to $\frac{0.205}{1.98} = 0.103535\ \mathrm{V}$. The gain inverse is useful there because the state remains inside its declared domain. Preserve the saturation flag and narrow the claim for clipped intervals; a later passed calibration cannot reconstruct the amplitudes that were discarded.

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1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase

Two hypothetical inputs have complex RMS voltage phasors $0.6+j0.8\ \mathrm{V}$ and $0.6-j0.8\ \mathrm{V}$ across the same real 50 Ω input reference impedance. The output reference impedance is also real 50 Ω. The imaginary unit j has square −1. Angles denote counterclockwise rotation in the complex plane, with a positive-complex-exponential time convention. Their magnitudes are both 1 V, while their phases are +53.130102 degrees and −53.130102 degrees. A known complex transfer multiplies each phasor by a voltage gain of two and rotates phase by +30 degrees. The recorder then retains only output magnitude.

Both records contain the same magnitude, 2 V, although the output phases before detection are +83.130102 degrees and −23.130102 degrees. Each input power is 1 squared divided by 50, or 20 mW, corresponding to 13.010300 dBm. Each output power is 80 mW, or 19.030900 dBm. The power gain is four, equivalent to 6.020600 dB, and subtracting it correctly recovers the input power level. Thus a valid scalar power correction coexists with irreversible phase loss.

For a magnitude bound, let the recorded output magnitude be 2.00 ± 0.02 V and the calibrated voltage-gain magnitude be 2.00 ± 0.01, with both reference resistances exact in this constructed example. Input magnitude is enclosed by $\frac{1.98}{2.01}=0.985075\ \mathrm{V}$ and $\frac{2.02}{1.99}=1.015075\ \mathrm{V}$. Squaring and dividing by 50 Ω gives 19.407440 mW through 20.607560 mW, or 12.879683 dBm through 13.140266 dBm. The monotonic transformation is valid because all magnitudes are positive.

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Those amplitude bounds supply no phase recovery. In fact, any input phasor on the nominal unit-magnitude circle produces the same stored magnitude under this transfer. Knowing the +30-degree rotation does not invert the magnitude detector. If the authorized question needs coherent phase, retain a compatible complex record and its reference. If it needs only power, report the supported power result without implying that the missing phase was measured.

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1.12.9 Application 1A.9. Correct resolved frequency components before forming a channel total

A channel contains two continuous resolved tones at 100 MHz and 101 MHz. Use a rectangular one-millisecond mean, so their cross term integrates to zero, and stipulate negligible added receiver power for the required accuracy. The measured net power gains are 10 dB at the first tone and 4 dB at the second. The corresponding output tone levels are −70 dBm and −76 dBm. The requested quantity is their combined input power at one common plane.

Correcting each component gives $-70-10=-80\ \mathrm{dBm}$ and $-76-4=-80\ \mathrm{dBm}$. Each input is 10 pW, so their total is 20 pW, or −76.989700 dBm. At the output, the powers are 100 pW and 25.118864 pW, totaling 125.118864 pW or −69.026772 dBm. Subtracting an arithmetic average gain of 7 dB from that aggregate gives −76.026772 dBm, which is 0.962928 dB too high.

The effective gain for this particular two-tone input is the ratio of total output to total input, 6.255943, or 7.962928 dB. It depends on the input power distribution across the two gains. It is not a universal channel correction inferred from the two endpoint values. A different distribution between the same frequencies would change that effective gain even if the physical path remained unchanged.

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As a bounded calibration example, let each tone's net gain have a ±0.20 dB error bound and treat the output tone powers as exact. Each corrected tone then lies between −80.20 dBm and −79.80 dBm. The total is enclosed by −77.189700 dBm and −76.789700 dBm, because both lower endpoints and both upper endpoints bound the monotone power sum. This enclosure does not require independence. The method fails if the tones are not separable under the stated observation or if a component has been rejected entirely; a correction cannot infer its missing power from the retained total alone.

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1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval

A recorded interval extends from 10.000 s to 10.040 s. Independent timing evidence confines the actual start of a gain-state change to 10.019–10.021 s, and settling takes between zero and 0.002 s after that start. State A has 20 dB gain and 2 dB loss; state B has zero gain and 2 dB loss. No output samples during possible transition or settling are accepted for amplitude inference. These time bounds are stipulated evidence, not a uniform distribution of transition times.

The guaranteed valid A interval lasts from 10.000 s to 10.019 s, or 19 ms. The guaranteed valid B interval starts at the latest possible settled time, 10.023 s, and lasts to 10.040 s, or 17 ms. The 4 ms interval between them remains unresolved. Valid retained time is therefore 36 ms out of 40 ms, or 90 percent. That is a coverage fraction, not an event-capture probability.

Suppose the raw mean levels in those valid portions are −62 dBm for A and −82 dBm for B. Applying their respective corrections gives −80 dBm, or 10 pW, in both portions. Their combined valid-interval mean is consequently 10 pW. Their retained input energy is 10 pW multiplied by 36 ms, or $3.6 \times 10^{-13}\ \mathrm{J}$. Equality of the two corrected means does not supply the missing transition energy or prove constant input throughout the gap.

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If additional, independently justified information bounds input power during the entire 4 ms gap between zero and 100 pW, the missing energy lies between zero and $4.0 \times 10^{-13}\ \mathrm{J}$. Over the full 40 ms, the mean power is then enclosed by 9 pW and 19 pW, corresponding to −80.457575 dBm and −77.212464 dBm. Without that independent upper bound, nonnegative power supplies the same lower bound but no finite upper bound for the full-interval mean. Report the valid-interval result and any separately justified wider enclosure; do not replace the missing interval by an assumed continuation of the convenient −80 dBm level.

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1.13 Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation

During a conference-room survey, a stable component appears at 433.920 MHz only when the receiver's automatic preamplifier is enabled. Inserting 10 dB input attenuation causes the displayed component to rise relative to the calibrated external reference, while a second receiver does not show it. These observations favor an internally generated product or overload interaction. The report records a configuration-dependent component consistent with a receiver artifact and preserves the raw traces. A comparison that retains the relevant sensitivity, reference plane, frequency coverage, and observation interval is needed before the second receiver's nondetection can exclude an external contribution.

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1.14 Frame a bounded finding from the completed observation

Consider a constructed survey in which a component is detected during one configured dwell and a later wide scan shows no matching peak. The two results are not contradictory until their time and frequency coverage, detector behavior, and strong-signal conditions have been compared. The later scan may simply have missed the event, admitted a different blocker, or averaged a different statistic. The first task is to reconcile the measurement definitions, then ask whether the remaining difference supports a physical change in the environment.

A defensible finding identifies the observation, the conditions under which it was valid, the alternatives that were challenged, and the uncertainty that remains. It may support continued measurement without supporting attribution. It may establish a receiver artifact without identifying every internal coupling path. It may establish a calibrated absence of events meeting one defined criterion while leaving other event classes untested. Preserving those boundaries makes the finding useful to the next technical decision and prevents a later reader from treating an incomplete inference as a broader conclusion.

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1.15 Assurance cases for receiver-derived evidence under changing system identity

A scientific receiver investigation can be described as an assurance case rather than a succession of apparently persuasive displays. The top-level proposition is deliberately narrow: a stated physical or statistical quantity was measured by a specified instrument chain during specified eligible intervals, and the conclusion is supported by identified observations, operating conditions and tests of alternative explanations. Beneath that proposition lie subclaims about authority, acquisition fidelity, timing, calibration applicability, processing integrity and inferential limits. Each subclaim must link to an actual record. The record for clock integrity is not interchangeable with the record for front-end linearity; a stable timestamp cannot establish that an amplifier remained below compression, and a successful amplitude reference does not validate digital sample continuity. A disciplined assurance structure exposes a missing premise before the final wording becomes more confident than the available evidence. It also gives the reviewing engineer a rational means of deciding whether one additional experiment would change the conclusion.

Treat configuration identity as an interval-valued variable, not a file-wide declaration. Let $S(t)$ denote the actual instrument state at physical time t, and let $A(S)$ represent the corresponding acquisition transformation. In a simplified record $r[k] = A(S(t_k))\{x(t_k)\} + e[k]$, the sampling instant t_k, unknown electromagnetic input x, recorded data r and residual e must be separately defined. An operator command $C(t)$ is only evidence of requested behaviour; it becomes evidence of actual $S(t)$ only after acknowledgement

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and independent status or response checks. If a relay changes at an unknown instant within a known bracket, the affected interval should be excluded from any calculation that assumes either settled state. The same principle applies to automatic notch placement, reference-clock switching, adaptive decimation and gain changes triggered by a blocker. Recording one final configuration screenshot cannot retrospectively transform an uncertain state history into a unique measurement law.

An evidential traceability matrix can be constructed with columns for proposition, observation, instrument state, dependency, independent challenge, uncertainty and permitted report language. Consider a hypothetical finding that a weak component persisted for twelve minutes. If the receiver was observing its frequency for only 480 seconds, the directly observed coverage is eight minutes; the remaining four minutes are not negative observations and do not support uninterrupted persistence. If every captured event occurred in a single twelve-second gain state, an assertion about the other states requires a separate transport argument or experiment. This illustrates why measured duration, monitored duration, event count and demonstrated probability of intercept are different quantities. They cannot be rescued by increasing the number of digits in a timestamp or by presenting a particularly smooth waterfall.

A final assurance case should record rejected hypotheses as carefully as its favoured hypothesis. A source-disconnected test can weaken the external-origin explanation only if the disconnection is understood and the instrument remains in a comparable state. A second receiver is independent only to the extent that the relevant inputs, clocks, supply arrangements and processing faults are not shared. A challenged observation may remain

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scientifically useful even when no individual emitter can be attributed. By making the conditions and failed alternatives explicit, the report permits a later analyst to revise the inference without altering the original evidence, and it reduces the risk that a carefully obtained technical fact is transformed into an unsupported assertion about intent or ownership.

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1.16 Advanced technical expansion. The receiver as a causal experimental instrument

A receiver is not merely a conduit between incident field and digital display. It is a stateful experiment in which an operator has selected a hypothesis, an observation interval, a transduction chain and an admissible class of conclusions. That proposition becomes operationally useful when the entire apparatus is represented by an ordered causal graph. The graph begins at the electromagnetic field or conducted test port, includes coupling and propagation into a declared antenna reference plane, and continues through protection, selection, gain, conversion, sampling, estimation and storage. Each directed connection represents an observable transformation, not simply a component label. Where a stage changes its law in response to a blocker, temperature, command or previous exposure, the graph must have state variables and transitions. A chain drawn without memory may reproduce a small-signal calibration yet fail to account for a delayed gain recovery or a burst missing from the recorded interval. The question for a forensic examiner is consequently not whether each box bears a familiar name, but whether the particular transformation connecting the observations to the conclusion has been established under the actual conditions of interest.

A useful formal representation defines a state vector $s(t)$, an external electromagnetic input $x(t)$, an acquisition configuration $u(t)$, an environmental disturbance $e(t)$, and a retained output record $y[n]$. The notation $y[n] = F(x, s, u, e; n)$ states that sampling and subsequent computation form an indexed record; it does not assert that F is linear,

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memoryless, invertible or even stationary. The state vector may include attenuator position, preselector bank, oscillator lock, converter clock, gain-control voltage, filter memory, thermal condition and packet-buffer occupancy. For a numerical example, suppose a commanded gain step occurs at 12.000 seconds, a status register reports its acceptance at 12.001 seconds, and a controlled weak reference returns within tolerance only at 12.004 seconds. It is unwarranted to label the whole four-millisecond transition as a settled new gain state. A conservative validity ledger assigns the affected samples to a transition class until an independently defined acceptance criterion is met. These timings are hypothetical. Their purpose is to demonstrate a method for separating commanded, reported and experimentally validated state.

Counterfactual challenge testing follows directly from this graph. Consider a narrow component at the receiver output: hypotheses may include a genuine external emission, nonlinear mixing at the first amplifier, clock-related leakage or contamination introduced by an export routine. An input attenuator upstream of the amplifier changes the first two hypotheses differently from software scaling performed after conversion; a preselector can reject a distant blocker without necessarily affecting a genuine in-band emitter; an independent reference clock changes a clock-related hypothesis; a raw-sample comparison tests export processing. A useful test is one for which competing models predict measurably different outcomes. Merely making the displayed peak disappear is not enough if the intervention simultaneously reduces sensitivity below the level needed to observe an external counterpart. In an assurance case, every challenge should state the prediction, the actual intervention plane, the observable statistic, the

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acceptance tolerance and the alternatives that remain compatible with the result.

The semantics of negative evidence deserve the same attention. Let V denote the union of intervals during which the chosen receiver path is demonstrated valid, and let C denote the signal family to which the test is demonstrably sensitive. The statement 'no member of C was detected in V' is narrower than 'no transmitter operated'. Quantifying a probability of capture requires a model of event timing, dwell opportunity, threshold behaviour and failures, rather than an invocation of an attractive noise-floor number. If 72 seconds of valid observation occurred during a two-minute engagement, coverage by duration is 0.60; it is not automatically a 0.60 capture probability. A transmitter could operate solely during the excluded 48 seconds, or could occupy a band outside the receiver's admitted filter. The reporting template should therefore record valid time, valid frequency, tested signal classes, sensitivity conditions, tested interventions and remaining unobserved domains separately.

The evidential release package can be modelled as a dependency graph rather than as an undifferentiated folder of screenshots. Each reported finding points to native record identifiers, sample-index ranges, calibration states, original measurements, software transformations, analyst decisions and the precise experiment used to challenge alternative explanations. Each derivation needs an identifiable input, versioned algorithm and reproducible numerical calculation. A digest of an exported figure establishes integrity of that figure from the time of hashing; it does not certify the antenna state that generated the original signal. The same discipline applies to legal scope: an engineering operation may be technically possible without being

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authorised by the engagement, and a carefully constructed evidential chain must record collection restrictions rather than silently infer permission from capability. This is a system property, not a footnote added after a technically expansive acquisition.

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Chapter Summary

Receiver evidence begins with authority and a declared measurement chain. Detection, classification, attribution, and content recovery are separate claims, and every correction or inference must remain traceable to a configuration and reference plane.

Define the authorized objective before selecting the receiver mode. Scope, acquisition, retention and disclosure must follow that objective. The installed antenna path, accessories, receiver transformations and software together form the measurement chain; consequential actual states belong to its configuration identity.

Fix the quantity or proposition, reference plane, frequency and time intervals, estimator and decision criterion. Preserve the original indication and ordered corrections so that sign errors, double counting and calibration from an incompatible state remain detectable. Requested settings do not establish settled operation, and scalar corrections cannot restore clipped or discarded information.

Retain native records, state transitions and the evidence needed to reproduce derived products. Challenge plausible alternatives with comparable observation capability. Closing checks support only the functions and conditions exercised at the check time; they do not prove uninterrupted earlier validity. Report the valid observation, uncertainty, coverage and unresolved alternatives at the strength the evidence supports.

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Chapter 1 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C01-MCQ-001. Which statement most completely describes the receiver-system boundary used in this chapter?

A. The selected input connector and final display, excluding intervening accessories

B. The analog stages up to the first digitizer, excluding subsequent processing

C. Only the stages named in the instrument calibration certificate

D. The physical and computational path from environmental input to retained result

Answer: D. An external filter, computer process, or correction can change the result. The declared system therefore includes every consequential transformation, even when it occurs outside the instrument enclosure. Source: §1.1 Receiver as a Measurement System (p. 53)

Why the selected alternative fits: The physical and computational path from environmental input to retained result.

Distinguishing consideration: compare this with option A, “The selected input connector and final display, excluding intervening accessories”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-MCQ-002. A receiver reports a stable frequency with many decimal places, but its active input and clock source were not recorded. Which conclusion is best supported?

A. The uncertainty can be inferred from the number of displayed decimal places

B. Unknown settings can be ignored if the same trace is obtained twice

C. The numerical precision does not establish a defined, reproducible measurement

D. A stable indication establishes frequency accuracy even without the reference record

Answer: C. A precise number can refer to an inadequately specified measurand. Input selection and clock state affect what was observed and how the frequency scale was formed. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: The numerical precision does not establish a defined, reproducible measurement.

Distinguishing consideration: compare this with option A, “The uncertainty can be inferred from the number of displayed decimal places”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-MCQ-003. An external adapter is added between the antenna cable and receiver. Why must it enter the system record?

A. Its effect is fully described by the connector designation without installation evidence

B. Its passive construction guarantees that only a constant loss can occur

C. Its effect can be omitted because the receiver input impedance is nominally unchanged

D. Its loss, mismatch, coupling, or nonlinear behavior may affect the observation

Answer: D. The chapter explicitly extends the boundary to passive accessories. Recording the adapter permits the reviewer to determine which changes matter and which earlier configuration remains valid. Source: §1.1 Receiver as a Measurement System (p. 53)

Why the selected alternative fits: Its loss, mismatch, coupling, or nonlinear behavior may affect the observation.

Distinguishing consideration: compare this with option A, “Its effect is fully described by the connector designation without installation evidence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-MCQ-004. Which system description is consistent with Equation 1?

A. A universal linear time-invariant receiver

B. A statement that every observed component originated externally

C. A guarantee that all processing can be inverted

D. A configured transformation that may include memory, sampling, conversion, and nonlinear behavior

Answer: D. Equation 1 is a boundary description. The narrower assumptions needed for a linear model must be established separately for the operating state and range. Source: Equation 1. Configured receiver-chain representation (p. 71)

Why the selected alternative fits: A configured transformation that may include memory, sampling, conversion, and nonlinear behavior.

Distinguishing consideration: compare this with option A, “A universal linear time-invariant receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Equation 1. Configured receiver-chain representation; Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Equation 1. Configured receiver-chain representation; Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-005. A remote digitizer feeds a computer that scales the samples. Where does the measurement chain end for a reported spectrum?

A. At the digitizer input connector

B. At the first analog-to-digital conversion

C. At the retained spectrum and its documented processing, with earlier representations preserved as required

D. At the computer's network interface

Answer: C. The reported spectrum depends on scaling and analysis after conversion. Those operations belong to the transformation that must be documented for the result to be reproduced. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: At the retained spectrum and its documented processing, with earlier representations preserved as required.

Distinguishing consideration: compare this with option A, “At the digitizer input connector”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Receiver as a Measurement System.

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V011-C01-MCQ-006. Which item most directly distinguishes a reference plane from a device name?

A. The declared location at which the reported quantity is defined

B. The name assigned to the retained trace

C. The correction value applied to the display

D. The instrument model used at that location

Answer: A. A reference plane fixes the location of a quantity such as power or phase. A device name alone cannot identify which input, output, or corrected boundary the result represents. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: The declared location at which the reported quantity is defined.

Distinguishing consideration: compare this with option B, “The name assigned to the retained trace”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-MCQ-007. An examiner exchanges two apparently identical cables without recording the exchange. What has been weakened?

A. The definition of a reference plane, which changes automatically whenever a cable is exchanged

B. The ability to connect observations to the actual installed path

C. The validity of every earlier measurement, including those completed before the exchange

D. The reproducibility of unrelated calculations that never used either cable

Answer: B. The cables may differ in relevant loss, mismatch, routing, or condition. The missing exchange record prevents a later reviewer from reliably assigning each observation to its physical path. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: The ability to connect observations to the actual installed path.

Distinguishing consideration: compare this with option A, “The definition of a reference plane, which changes automatically whenever a cable is exchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Receiver as a Measurement System.

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V011-C01-MCQ-008. Which question should precede the selection of a receiver mode?

A. Which mode produced the clearest result in an earlier unrelated engagement?

B. Which mode spans the largest frequency range in the least time?

C. What quantity or proposition must the observation resolve?

D. Which mode maximizes retained information regardless of the target quantity?

Answer: C. A measurement objective determines the appropriate reference plane, interval, state, estimator, and decision rule. Choosing the mode first can capture data that do not answer the intended question. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: What quantity or proposition must the observation resolve?.

Distinguishing consideration: compare this with option A, “Which mode produced the clearest result in an earlier unrelated engagement?”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-009. An operator treats the displayed marker value as field strength without recording antenna conversion or geometry. What is the central defect?

A. The conversion crosses an unsupported measurement boundary

B. An antenna-terminal reading always equals the receiver-input reading after cable loss is removed

C. A valid frequency calibration supplies the missing field-amplitude conversion

D. The detector bandwidth alone determines the field-strength reference plane

Answer: A. A receiver indication and field strength are different quantities. The chapter requires the relevant antenna conversion, path corrections, and geometry before the field statement can be supported. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: The conversion crosses an unsupported measurement boundary.

Distinguishing consideration: compare this with option B, “An antenna-terminal reading always equals the receiver-input reading after cable loss is removed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-MCQ-010. Why is the least controlled transformation consequential to the final finding?

A. An uncontrolled stage affects reproducibility only, never the meaning of the reported quantity

B. The best-characterized stage determines the validity of the complete measurement

C. It can limit what the complete chain supports, even when other stages are well characterized

D. A well-calibrated final detector automatically compensates for every earlier uncontrolled stage

Answer: C. The evidential claim depends on the complete transformation. Strong controls elsewhere cannot supply missing validity or configuration information at a consequential uncontrolled stage. Source: §1.1 Receiver as a Measurement System (p. 53)

Why the selected alternative fits: It can limit what the complete chain supports, even when other stages are well characterized.

Distinguishing consideration: compare this with option A, “An uncontrolled stage affects reproducibility only, never the meaning of the reported quantity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-MCQ-011. A survey permits occupancy measurements but prohibits recovery of communications content. Which implementation best reflects that authority?

A. Retain incidental content indefinitely without review

B. Enable all demodulators because the receiver supports them

C. Record every available channel in case later review is useful

D. Select technical measurement modes and recording limits that implement the permitted objective

Answer: D. The receiver plan translates authority into technical settings and retention rules. Instrument capability does not enlarge the information the engagement permits the examiner to acquire. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: Select technical measurement modes and recording limits that implement the permitted objective.

Distinguishing consideration: compare this with option A, “Retain incidental content indefinitely without review”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-012. When should minimization first influence the acquisition design?

A. Only when storage becomes full

B. Only after unauthorized content has been distributed

C. Only after a final report is written

D. Before collection begins

Answer: D. Selecting needed bandwidth, duration, channels, and metadata before acquisition can prevent unnecessary collection. Later handling controls complement, but do not replace, that initial limitation. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: Before collection begins.

Distinguishing consideration: compare this with option A, “Only when storage becomes full”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-013. Which proposed reason is insufficient by itself to justify a wider acquisition bandwidth?

A. The authorized objective requires the wider interval

B. The approved technical plan specifies the wider interval

C. The hardware can record the wider bandwidth

D. A documented authorized extension requires the wider interval

Answer: C. Capability describes what the instrument can do. The justified scope follows the authorized objective and plan, including any properly recorded extension. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: The hardware can record the wider bandwidth.

Distinguishing consideration: compare this with option A, “The authorized objective requires the wider interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-014. An operator needs a scope extension during an engagement. Which record is most relevant?

A. The available bandwidth and storage capacity without the actual authorized objective

B. The deviation, its technical purpose, and who approved the extension

C. The extended acquisition settings without the reason or approving authority

D. The technical desirability of extra coverage without an approval record

Answer: B. The chapter requires the record to connect the authorized objective, actual collection, deviations, and approval. A technical need alone does not document the authority for the extension. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: The deviation, its technical purpose, and who approved the extension.

Distinguishing consideration: compare this with option A, “The available bandwidth and storage capacity without the actual authorized objective”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-015. Which acquisition control most directly limits unnecessary observation duration?

A. Reduce the recorded bandwidth while leaving acquisition time unchanged

B. Lower the display refresh rate while retaining the same continuous samples

C. A recording interval selected to answer the authorized question

D. Apply more averaging after recording the same interval

Answer: C. Duration affects what information is collected. A deliberately bounded interval is therefore a substantive minimization measure, unlike changes confined to presentation or organization. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: A recording interval selected to answer the authorized question.

Distinguishing consideration: compare this with option A, “Reduce the recorded bandwidth while leaving acquisition time unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-016. A masked frequency band is omitted from a survey. How should the omission be handled?

A. Record it as a coverage exclusion relevant to the finding

B. Erase all reference to the mask

C. Treat it as a band in which no signal existed

D. Describe it as fully examined because neighboring bands were measured

Answer: A. An omitted band was not tested under the stated acquisition. Its explicit exclusion prevents a later reader from extending a negative finding into unobserved coverage. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: Record it as a coverage exclusion relevant to the finding.

Distinguishing consideration: compare this with option B, “Erase all reference to the mask”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-017. Which event belongs among the chapter's potential stop or escalation conditions?

A. A successful closing reference check

B. A clearly stated reference plane

C. Unauthorized content exposure

D. A useful native setup export

Answer: C. Unauthorized exposure concerns the permitted scope of collection. The operational plan should define the response instead of allowing technically convenient acquisition to continue without control. Source: §1.9 Operational Decision Discipline (p. 70)

Why the selected alternative fits: Unauthorized content exposure.

Distinguishing consideration: compare this with option A, “A successful closing reference check”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Operational Decision Discipline; Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Operational Decision Discipline; Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-018. Why is mission authority an engineering concern in this chapter?

A. Authority supplies a correction for receiver nonlinearity

B. Institutional approval makes configuration evidence unnecessary

C. Acquisition settings determine which information is captured

D. A permitted objective guarantees that every available detector mode is appropriate

Answer: C. Legal and institutional limits must be implemented through concrete frequency, time, mode, and recording choices. That translation makes authority part of measurement-system design. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: Acquisition settings determine which information is captured.

Distinguishing consideration: compare this with option A, “Authority supplies a correction for receiver nonlinearity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-019. Which statement about a laboratory engagement follows the chapter's boundary approach?

A. Any laboratory permission authorizes all nearby collection

B. A laboratory location removes retention limits

C. A receiver's calibration certificate establishes legal scope

D. Permission to analyze a seized device need not authorize continuous monitoring of unrelated emitters

Answer: D. The chapter distinguishes the authorized target and purpose from neighboring activity. Location or technical capability does not silently broaden the collection boundary. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: Permission to analyze a seized device need not authorize continuous monitoring of unrelated emitters.

Distinguishing consideration: compare this with option A, “Any laboratory permission authorizes all nearby collection”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-020. Which record most clearly supports review of a minimization decision?

A. The information needed for the objective and the acquisition limits chosen to obtain it

B. An assurance that unnecessary material will be identified after unlimited acquisition

C. The maximum tuning and recording capability of the chosen receiver

D. The total storage capacity available during the engagement

Answer: A. A reviewable decision connects the authorized question with bandwidth, duration, channels, metadata, retention, and disclosure controls. The justification must be recoverable from the record. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: The information needed for the objective and the acquisition limits chosen to obtain it.

Distinguishing consideration: compare this with option B, “An assurance that unnecessary material will be identified after unlimited acquisition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-MCQ-021. A component exceeds a declared decision threshold. Which proposition is established first?

A. Physical attribution to a named owner

B. Detection under the stated criterion

C. Recovery of intelligible content

D. Proof of hostile intent

Answer: B. Detection concerns the observation crossing a criterion. Classification, attribution, content recovery, and intent require additional evidence that a threshold crossing does not itself provide. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: Detection under the stated criterion.

Distinguishing consideration: compare this with option A, “Physical attribution to a named owner”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-022. The examiner identifies a waveform family from modulation and timing features. Which verb best describes that result?

A. Recovered all content

B. Classified

C. Attributed to an owner

D. Proved unauthorized

Answer: B. Classification connects observed features to a waveform family or service type. It does not by itself establish the physical source, ownership, or legal status of the emission. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: Classified.

Distinguishing consideration: compare this with option A, “Recovered all content”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-023. A decoded network name appears in a capture. What should the report avoid claiming without additional evidence?

A. That the decoder produced a particular output

B. That a configuration string was recovered

C. That the name proves device location and ownership

D. That the capture used a specified receiver state

Answer: C. An identifier can describe a configuration string without locating the emitting hardware or proving its owner. The stronger attribution requires corroborating evidence. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: That the name proves device location and ownership.

Distinguishing consideration: compare this with option A, “That the decoder produced a particular output”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-024. A waveform changes when activity in a room changes, but no intelligible information is recovered. Which finding is appropriately bounded?

A. The waveform is correlated with the recorded activity under the tested conditions

B. Repeatable state dependence establishes recovery of the information involved in the activity

C. The activity correlation alone attributes the signal to the device being used

D. A lack of intelligible content proves that the component cannot be external

Answer: A. State dependence can be informative while leaving content and mechanism unresolved. The report should preserve the observed relationship and the conditions of the comparison. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: The waveform is correlated with the recorded activity under the tested conditions.

Distinguishing consideration: compare this with option B, “Repeatable state dependence establishes recovery of the information involved in the activity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-025. Which observation most directly belongs to attribution rather than mere classification?

A. A controlled state change that links a component to a particular physical emitter

B. A peak exceeding the display threshold

C. A general modulation-family label

D. An unverified signal-strength screenshot

Answer: A. Attribution requires a supported connection to a physical emitter or system. A controlled state change can contribute to that connection when its assumptions and alternative explanations are addressed. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: A controlled state change that links a component to a particular physical emitter.

Distinguishing consideration: compare this with option B, “A peak exceeding the display threshold”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-026. Which description of content recovery is correct?

A. Recording only that energy exceeded a threshold

B. Reconstructing information carried by the signal

C. Assigning a waveform family without decoding information

D. Determining cable insertion loss

Answer: B. The chapter separates reconstruction of carried information from detecting energy and recognizing waveform characteristics. The distinction matters both technically and for collection authority. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: Reconstructing information carried by the signal.

Distinguishing consideration: compare this with option A, “Recording only that energy exceeded a threshold”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-027. An unexplained narrow peak is stable. Which alternative remains compatible with that observation?

A. Only an external surveillance transmitter

B. Only measurement noise with no structure

C. Only a legitimate broadcast station

D. A receiver clock harmonic

Answer: D. Stability does not distinguish all external signals from internally generated components. The chapter lists clock harmonics, oscillator leakage, spurs, and intermodulation among the competing explanations. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: A receiver clock harmonic.

Distinguishing consideration: compare this with option A, “Only an external surveillance transmitter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-028. Which reporting verb requires the strongest support for a claim about where a component originated?

A. Displayed

B. Observed

C. Detected

D. Attributed

Answer: D. Attribution connects the observation to a source. It therefore demands more than reporting a display feature or a threshold crossing under a documented measurement state. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: Attributed.

Distinguishing consideration: compare this with option A, “Displayed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-MCQ-029. Two sensors agree, but both share the same clock and input route. What limits the evidential value of agreement?

A. Separate hardware makes the shared reference irrelevant to error independence

B. Agreement removes the need to characterize the common input path

C. Shared errors can explain the common result

D. A common clock establishes physical attribution whenever both channels show the component

Answer: C. Agreement is persuasive only to the degree that the comparisons change relevant error sources. Shared hardware or references can preserve the same artifact in both observations. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: Shared errors can explain the common result.
Distinguishing consideration: compare this with option A, “Separate hardware makes the shared reference irrelevant to error independence”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.
Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-030. Which sentence preserves the distinction between observation and interpretation?

A. A component was detected in the declared interval; the tested changes favored a receiver artifact

B. A decoded identifier established the owner before any source comparison

C. The absent comparator peak excluded an external signal without a sensitivity check

D. A stable component was classified as hostile because it appeared repeatedly

Answer: A. The preferred sentence states what was observed and the bounded interpretation supported by tests. It does not expand that interpretation into unsupported ownership or intent. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why the selected alternative fits: A component was detected in the declared interval; the tested changes favored a receiver artifact.

Distinguishing consideration: compare this with option B, “A decoded identifier established the owner before any source comparison”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Observation, Classification, Attribution, and Content Recovery; Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery; Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

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V011-C01-MCQ-031. A receiver indicates minus 71.4 dBm, with 4.8 dB path loss and 18.6 dB external gain. What is the corrected preamplifier-input level before other corrections?

A. Minus 48.0 dBm

B. Minus 57.6 dBm

C. Minus 94.8 dBm

D. Minus 85.2 dBm

Answer: D. Equation 2 gives indicated level plus loss minus gain: minus 71.4 plus 4.8 minus 18.6 equals minus 85.2 dBm. The result retains the stated reference plane and calibration conditions. Source: §1.12 Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 78)

Why the selected alternative fits: Minus 85.2 dBm.

Distinguishing consideration: compare this with option A, “Minus 48.0 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Equation 2. Corrected input power.

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V011-C01-MCQ-032. When referring a downstream receiver indication backward across a passive loss, which sign applies to the loss term in Equation 2?

A. Subtract the loss in decibels

B. Add the loss in decibels

C. Replace the indicated power with the loss

D. Square the loss in decibels

Answer: B. The downstream signal has been reduced by the loss. Recovering the upstream level adds that known loss, subject to compatible state and reference-plane conditions. Source: Equation 2. Corrected input power (p. 71)

Why the selected alternative fits: Add the loss in decibels.

Distinguishing consideration: compare this with option A, “Subtract the loss in decibels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-MCQ-033. When referring a downstream indication backward across an external amplifier, which sign applies to its gain?

A. Add the external gain in decibels

B. Ignore gain whenever a cable follows it

C. Multiply the indicated dBm value by the gain in decibels

D. Subtract the external gain in decibels

Answer: D. The amplifier raised the downstream level. Removing its contribution requires subtracting the external gain from the indication after accounting for the intervening loss. Source: Equation 2. Corrected input power (p. 71)

Why the selected alternative fits: Subtract the external gain in decibels.

Distinguishing consideration: compare this with option A, “Add the external gain in decibels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-MCQ-034. A gain correction restores the displayed level after an amplifier is bypassed. What still requires separate review?

A. Only whether both traces use the same displayed amplitude range

B. Only whether the corrected central values match after rounding

C. Whether the actual state, noise, and validity conditions support combining the records

D. Only whether the same file format was used for both records

Answer: C. A corrected central value does not establish equal noise or operating validity. The chapter requires state-specific corrections and examination of the transformations before combining observations. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: Whether the actual state, noise, and validity conditions support combining the records.

Distinguishing consideration: compare this with option A, “Only whether both traces use the same displayed amplitude range”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-C01-MCQ-035. Which case cannot be repaired merely by adding a scalar path correction?

A. An overloaded receiver record

B. A valid calibrated passive-loss correction

C. A known constant scale factor in a reversible path

D. A documented correction at the declared plane

Answer: A. Overload can discard or distort information through a nonlinear transformation. Adding an offset cannot recreate the input information lost during that event. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: An overloaded receiver record.

Distinguishing consideration: compare this with option B, “A valid calibrated passive-loss correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse.

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V011-C01-MCQ-036. An operator applies the same cable-loss correction twice. Which retained information most readily exposes the error?

A. The original indication and each separately identified correction

B. Only the receiver setup without the retained indication

C. Only the cable identifier without the sequence of applied corrections

D. Only the final corrected value and its rounded display

Answer: A. Preserving the correction chain permits the result to be reconstructed. A final number alone hides whether a loss has been counted twice or assigned to the wrong boundary. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: The original indication and each separately identified correction.

Distinguishing consideration: compare this with option B, “Only the receiver setup without the retained indication”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-037. Which information is necessary before treating an antenna-terminal power as field strength?

A. Only the antenna model name without the applicable conversion conditions

B. The applicable antenna conversion and relevant geometry, along with path conditions

C. Only the cable-loss value and the nominal receiver impedance

D. Only the calibrated receiver indication and its resolution bandwidth

Answer: B. A terminal quantity and a field quantity are connected through a physical conversion model. The chapter requires the corresponding antenna and geometric conditions rather than an automatic relabeling. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: The applicable antenna conversion and relevant geometry, along with path conditions.

Distinguishing consideration: compare this with option A, “Only the antenna model name without the applicable conversion conditions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-MCQ-038. The preselector is changed after calibration. Which response best follows the chapter?

A. Assess whether the calibration still applies to the new path and state

B. Assume all passive filters are transparent

C. Reuse the old calibration without identifying the change

D. Declare every prior measurement false

Answer: A. A filter change can alter loss, phase, rejection, and mismatch. The earlier record remains associated with its earlier state, while validity for the new state must be established. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: Assess whether the calibration still applies to the new path and state.

Distinguishing consideration: compare this with option B, “Assume all passive filters are transparent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-039. For Equation 2, what does a common logarithmic unit convention accomplish?

A. It proves that every component is linear

B. It eliminates uncertainty

C. It makes the gain and loss corrections compatible with the indicated power calculation

D. It establishes the transmitter's radiated power

Answer: C. Compatible dB and dBm conventions permit the scalar level calculation. They do not establish its physical assumptions, eliminate uncertainty, or extend the result beyond the declared plane. Source: Equation 2. Corrected input power (p. 71)

Why the selected alternative fits: It makes the gain and loss corrections compatible with the indicated power calculation.

Distinguishing consideration: compare this with option A, “It proves that every component is linear”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Equation 2. Corrected input power; Chapter 1 — Equation 2A. Power coordinates and fixed-state transfer.

Review: Chapter 1 — Equation 2. Corrected input power; Chapter 1 — Equation 2A. Power coordinates and fixed-state transfer.

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V011-C01-MCQ-040. A result is referred to the receiver input, but the report labels it as source power. What is missing?

A. A frequency calibration at the same receiver input

B. A repeat of the same scalar receiver-input correction

C. A supported transfer model between those two reference locations

D. A narrower resolution bandwidth at the receiver plane

Answer: C. The source and receiver are separated by a propagation and measurement path. The receiver-input correction does not by itself establish the power at the source. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: A supported transfer model between those two reference locations.

Distinguishing consideration: compare this with option A, “A frequency calibration at the same receiver input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-MCQ-041. A trace was collected through a software-controlled external gain stage. Which omitted item most directly threatens a backward amplitude correction?

A. The identifier assigned to an unchanged retained record

B. The compression setting of a lossless export file

C. The order in which already acquired traces are displayed

D. The actual gain state during the trace

Answer: D. The actual gain state determines the scalar transfer applied to the observation. An unchanged record identifier, display order, or lossless export setting does not supply that missing physical gain value. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: The actual gain state during the trace.

Distinguishing consideration: compare this with option A, “The identifier assigned to an unchanged retained record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-C01-MCQ-042. A command requests one sample rate while the status log reports another. Which rate should govern analysis of the retained samples?

A. The established actual rate for the relevant record

B. The average of all advertised rates

C. The largest rate the hardware supports

D. The requested rate without further review

Answer: A. A command expresses intent, not proof of execution. Timing, frequency mapping, and throughput must be tied to the actual state supported by the status and observation records. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: The established actual rate for the relevant record.

Distinguishing consideration: compare this with option B, “The average of all advertised rates”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-043. Why may an undocumented automatic mode be more consequential than an omitted cosmetic setting?

A. Its requested setting is sufficient evidence of the actual state

B. It guarantees improved sensitivity in every installed state

C. Its effects disappear when corrected traces have the same central value

D. It may change the measurement law while the observation continues

Answer: D. Configuration identity is driven by consequences for the measurand. An automatic change to gain, filtering, timing, or another transformation can invalidate a previously assumed state. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: It may change the measurement law while the observation continues.

Distinguishing consideration: compare this with option A, “Its requested setting is sufficient evidence of the actual state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-044. After a sample-rate change, which group of consequences is identified in the chapter?

A. Only file size, because frequency mapping remains unchanged at every sample rate

B. Alias locations, digital filtering, timing, and recording throughput

C. Only display span, because the physical sample intervals are set by the file format

D. Only alias locations, with digital filtering and timing guaranteed unchanged

Answer: B. The rate affects the mapping and handling of sampled data. A transition therefore requires a separate state record and examination of the analysis applied to each interval. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: Alias locations, digital filtering, timing, and recording throughput.

Distinguishing consideration: compare this with option A, “Only file size, because frequency mapping remains unchanged at every sample rate”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-045. What is a state interval in this chapter?

A. The complete service life of an instrument regardless of settings

B. A declared part of a record for which the relevant configuration and calibration remain applicable

C. A period in which one center frequency is selected

D. Any period selected after seeing a convenient result

Answer: B. State intervals connect samples or traces to a valid measurement transformation. They must follow consequential configuration changes rather than conceal them within an undifferentiated average. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: A declared part of a record for which the relevant configuration and calibration remain applicable.

Distinguishing consideration: compare this with option A, “The complete service life of an instrument regardless of settings”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

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V011-C01-MCQ-046. Which comparison can reveal that a requested configuration was not achieved?

A. Two repetitions of the requested command without an actual-state record

B. The command log compared only with the nominal instrument capability

C. Setup export versus status log versus observed record

D. Two screenshots generated from the same exported trace

Answer: C. The setup describes the request, the status may describe accepted state, and the data show what was captured. Their disagreement can expose a consequential configuration failure. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: Setup export versus status log versus observed record.

Distinguishing consideration: compare this with option A, “Two repetitions of the requested command without an actual-state record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-047. An operator averages traces acquired before and after an undocumented gain change. What is the principal concern?

A. Equal display units establish that the two transformations are interchangeable

B. Averaging automatically converts the two gain states to one common reference plane

C. The average may combine different transformations without a valid common calibration

D. A sufficiently long average removes every state-dependent calibration difference

Answer: C. A numerical mean does not reconcile state-dependent gain, noise, or validity. The estimator and correction model must explicitly support combining the different intervals. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: The average may combine different transformations without a valid common calibration.

Distinguishing consideration: compare this with option A, “Equal display units establish that the two transformations are interchangeable”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Equation 2C. Average after each interval has its own valid correction.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Equation 2C. Average after each interval has its own valid correction.

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V011-C01-MCQ-048. Which configuration record is most useful for a reproducible result?

A. The receiver model and nominal bandwidth without accessories or software identity

B. The consequential hardware, software, calibration, accessory, and acquisition states

C. The final corrected value without the state that produced it

D. Only nominal path labels without actual operating-state records

Answer: B. The chapter calls for enough identity to distinguish states that would change the answer. Relevant hidden or automatic behavior matters more than exhaustive recording of unrelated interface preferences. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: The consequential hardware, software, calibration, accessory, and acquisition states.

Distinguishing consideration: compare this with option A, “The receiver model and nominal bandwidth without accessories or software identity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-049. Firmware changes between two surveys. What should the examiner do before treating the results as directly comparable?

A. Use the previous calibration without checking the firmware-dependent behavior

B. Assume identical hardware serial numbers establish an unchanged transformation

C. Determine whether the change affects the measurement or processing state

D. Combine the surveys first and inspect state differences only if their means disagree

Answer: C. Firmware belongs to configuration identity. The comparison requires an assessment of its effect on the actual transformation, with each original state preserved in the record. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: Determine whether the change affects the measurement or processing state.

Distinguishing consideration: compare this with option A, “Use the previous calibration without checking the firmware-dependent behavior”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-MCQ-050. Which record best connects a configuration transition to retained data?

A. A time-linked record of the command, accepted state, settling, and affected samples

B. A single requested setup saved before all subsequent transitions

C. A status sample taken after the survey without a link to the affected data

D. A final setup export assumed to describe the complete preceding acquisition

Answer: A. The relevant question is which valid state produced each observation. A time-linked transition record prevents requested, transient, and settled states from being treated as interchangeable. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: A time-linked record of the command, accepted state, settling, and affected samples.

Distinguishing consideration: compare this with option B, “A single requested setup saved before all subsequent transitions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

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V011-C01-MCQ-051. Which measurement definition is most complete for an amplitude result?

A. The displayed level and center frequency without the acquisition interval

B. The maximum marker value without a specified plane or estimator

C. Power at a named plane, over stated frequency and time intervals, using a declared state and estimator

D. The receiver model and nominal sensitivity without the active measurement state

Answer: C. The definition must identify the quantity and how it was formed. Plane, intervals, state, estimator, and decision conditions make the result interpretable and reproducible. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: Power at a named plane, over stated frequency and time intervals, using a declared state and estimator.

Distinguishing consideration: compare this with option A, “The displayed level and center frequency without the acquisition interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-052. A wide discovery scan reveals a component. What further support is needed before assigning a calibrated amplitude?

A. Only the nominal sensitivity specification of the instrument

B. The applicable amplitude measurement definition and calibration

C. Only the maximum scan span used to locate the candidate

D. Only repeated visibility of the component in the discovery mode

Answer: B. Discovery and quantitative amplitude measurement are different tasks. The scan may locate a candidate without establishing the detector, bandwidth, reference-plane, and calibration conditions needed for its level. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: The applicable amplitude measurement definition and calibration.

Distinguishing consideration: compare this with option A, “Only the nominal sensitivity specification of the instrument”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-053. A narrow coherent capture provides good phase information. Which claim does that achievement alone fail to support?

A. Phase analysis within the declared capture conditions

B. Use of the retained samples for the intended estimator

C. A documented observation within the captured interval

D. Comprehensive coverage of emissions outside its instantaneous passband

Answer: D. A measurement can be strong for one target while leaving other targets unobserved. Narrow passband phase performance does not establish broader spectrum coverage. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: Comprehensive coverage of emissions outside its instantaneous passband.

Distinguishing consideration: compare this with option A, “Phase analysis within the declared capture conditions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-054. Why must the estimator be named in a measurement definition?

A. It proves that adaptive or nonlinear behavior is absent from the receiver

B. It makes the physical reference plane unnecessary once a unit is attached

C. It establishes source identity whenever the same value is reproduced

D. It identifies the operation that converts retained data into the reported number

Answer: D. A detector bucket, integrated channel, and fitted tone can yield different numerical quantities. Naming the estimator prevents a display label from concealing those differences. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: It identifies the operation that converts retained data into the reported number.

Distinguishing consideration: compare this with option A, “It proves that adaptive or nonlinear behavior is absent from the receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-055. Two instruments report a value labeled power. What should be reconciled before comparing the numbers?

A. Whether both labels are expressed in the same units, without examining the estimators

B. Whether their central frequencies match, regardless of bandwidth and time coverage

C. Whether they measure the same plane, bandwidth, interval, state, and statistic

D. Whether both instruments passed a self-test, regardless of the installed paths

Answer: C. Matching labels do not establish matching measurands. The comparison must first establish which energy, transformation, and mathematical summary each result represents. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: Whether they measure the same plane, bandwidth, interval, state, and statistic.

Distinguishing consideration: compare this with option A, “Whether both labels are expressed in the same units, without examining the estimators”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-056. Which timestamp description is insufficient for multichannel interpretation?

A. A stated sample-aperture time

B. A time value with no definition of the event it marks

C. A stated trigger-comparator time

D. A stated software-receipt time

Answer: B. Different timestamp events can have different delays and uncertainties. The time basis must identify which event the number marks before channels are compared. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: A time value with no definition of the event it marks.

Distinguishing consideration: compare this with option A, “A stated sample-aperture time”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-057. What does the frequency interval in the measurement definition delimit?

A. Whether the acquisition contains the entire time history of the event

B. Which physical emitter owns the observed component

C. Whether the reported estimator is unbiased under every signal condition

D. Which signal components can contribute to the reported quantity

Answer: D. The interval defines the admitted frequency scope. Ownership and broader authority remain separate evidential and institutional questions. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: Which signal components can contribute to the reported quantity.

Distinguishing consideration: compare this with option A, “Whether the acquisition contains the entire time history of the event”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-058. What does the decision criterion add to a numerical estimate?

A. A universal acceptance threshold transferable to every receiver state

B. The conditions under which the number may support the intended use

C. A replacement for the uncertainty and validity conditions of the measurement

D. An automatic source attribution from any threshold crossing

Answer: B. The criterion connects a result to an action or conclusion, including relevant uncertainty and validity conditions. A value alone does not specify how it should be used. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: The conditions under which the number may support the intended use.

Distinguishing consideration: compare this with option A, “A universal acceptance threshold transferable to every receiver state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-059. A frequency marker could be an FFT-bin label or an interpolated estimate. Why does the distinction matter?

A. The event times that were not included in the recorded acquisition

B. The source ownership implied by the chosen frequency label

C. The full physical bandwidth of the emitter, regardless of the acquired path

D. The reported quantity and estimation assumptions differ

Answer: D. The same display role can represent different mathematical constructions. Its interpretation must follow the actual estimator rather than a generic marker name. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: The reported quantity and estimation assumptions differ.

Distinguishing consideration: compare this with option A, “The event times that were not included in the recorded acquisition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-MCQ-060. An amplitude correction changes the reference plane. What must remain explicit?

A. Only the final rounded number

B. Only the display scale chosen for the report

C. Only the instrument's model designation

D. The original indication, correction, destination plane, and applicable state

Answer: D. Preserving the complete correction chain makes the transformation reviewable and exposes sign, state, and boundary errors. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: The original indication, correction, destination plane, and applicable state.

Distinguishing consideration: compare this with option A, “Only the final rounded number”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-MCQ-061. Which operation can be reversible under the chapter's stated conditions?

A. Clipping an unknown waveform

B. Replacing complex data with magnitude alone

C. A known scalar path correction applied in its valid state

D. Discarding samples with no continuity record

Answer: C. A known scalar correction may be undone when its value and applicability are retained. Information-discarding operations generally do not share that property. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: A known scalar path correction applied in its valid state.

Distinguishing consideration: compare this with option A, “Clipping an unknown waveform”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-C01-MCQ-062. Why retain native data before magnitude detection when the objective may later require phase?

A. Magnitude detection retains the original phase whenever enough bins are stored

B. The phase can always be reconstructed from the corrected power level

C. Magnitude detection can discard the phase information needed for that analysis

D. A later calibration offset can restore phase removed from the retained representation

Answer: C. The retained representation controls which later analyses remain possible. A magnitude-only record cannot be assumed to contain the original complex information. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: Magnitude detection can discard the phase information needed for that analysis.

Distinguishing consideration: compare this with option A, “Magnitude detection retains the original phase whenever enough bins are stored”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase.

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V011-C01-MCQ-063. A processing chain clips a waveform and later reduces its displayed amplitude. What remains true?

A. The original peaks are determined uniquely by the surviving clipped samples

B. The later scale change does not restore the clipped information

C. A smaller reported level establishes that the original input was within range

D. The later reduction reverses the nonlinear limiting at each sample

Answer: B. Clipping is an information-losing transformation. A later offset or scale factor changes the representation of the surviving data, not the lost waveform detail. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: The later scale change does not restore the clipped information.

Distinguishing consideration: compare this with option A, “The original peaks are determined uniquely by the surviving clipped samples”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse.

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V011-C01-MCQ-064. An analysis deletes missing-sample locations and joins the remaining samples. Which concern should be recorded?

A. The joined sequence can retain the original time basis without any missing-index record

B. The retained sequence may no longer preserve the original timing relationship

C. A checksum of the joined file proves that no acquisition samples were lost

D. Deleting gaps establishes a continuous physical-time record at the nominal rate

Answer: B. Loss and removal of samples can change the relationship between stored order and physical time. The analysis must preserve the limits of the representation it actually uses. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: The retained sequence may no longer preserve the original timing relationship.

Distinguishing consideration: compare this with option A, “The joined sequence can retain the original time basis without any missing-index record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-065. Which retained pair most directly supports reconstruction of a scalar correction?

A. The acquisition file name and the default setup used on another day

B. The final result and a nominal accessory specification without the applied state

C. Two separately rounded copies of the corrected result

D. The uncorrected indication and the applicable correction value

Answer: D. A reversible correction requires the starting value and the transformation. State and reference-plane information are also needed to establish that the correction applies. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: The uncorrected indication and the applicable correction value.

Distinguishing consideration: compare this with option A, “The acquisition file name and the default setup used on another day”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-066. A derived spectrum is the only surviving record. Which statement is appropriate?

A. Its usefulness is limited by the information retained in that representation

B. The retained spectrum establishes the same timing information as the original acquisition

C. Every later estimator can be reproduced from a magnitude-only export

D. All original complex samples can be recovered because frequency bins are retained

Answer: A. A spectrum may answer defined questions while omitting phase, timing, or processing context. The report must tie its claims to what the representation actually retains. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: Its usefulness is limited by the information retained in that representation.

Distinguishing consideration: compare this with option B, “The retained spectrum establishes the same timing information as the original acquisition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-067. Which example illustrates evidence being distinguished from an explanatory model?

A. A fitted law is labeled as a field observation

B. A predicted trace replaces the original measurement

C. A model coefficient is treated as the transmitter's identity

D. Measured tone levels are retained separately from the cubic law used to interpret a product

Answer: D. The distinction preserves both what was observed and the assumptions used to interpret it. It also identifies what further evidence could challenge the model. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: Measured tone levels are retained separately from the cubic law used to interpret a product.

Distinguishing consideration: compare this with option A, “A fitted law is labeled as a field observation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-068. A phase-noise curve is available. What additional conditions can a reciprocal-mixing prediction require?

A. Only the oscillator curve at one offset, independent of admitted blocker level

B. Only the final resolution-bandwidth label, independent of channel weighting

C. Only the receiver gain value, with no condition on the blocker or cross-power

D. Blocker level, conversion gain, weighting, and cross-power conditions

Answer: D. The curve is evidence under its normalization, but the prediction concerns a configured system. The chapter names the additional inputs and assumptions that must accompany the inference. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: Blocker level, conversion gain, weighting, and cross-power conditions.

Distinguishing consideration: compare this with option A, “Only the oscillator curve at one offset, independent of admitted blocker level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-069. A list of usable observation windows is known. What is still needed for a probability-of-capture statement?

A. An event-start distribution and a capture criterion

B. Only the total recording duration, without defining successful capture

C. Only the longest usable window, with every event phase treated as equivalent

D. Only the number of windows, independent of their placement and the event model

Answer: A. Usable intervals are observations about coverage. A probability claim additionally depends on how events are modeled and what counts as successful capture. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: An event-start distribution and a capture criterion.

Distinguishing consideration: compare this with option B, “Only the total recording duration, without defining successful capture”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-070. Which action best preserves analytical reversibility?

A. Retain the original record and document each derived transformation

B. Overwrite the original with a corrected plot

C. Retain only a favorable screenshot

D. Discard the processing configuration after export

Answer: A. Preserving inputs and transformations permits reconstruction of the result and evaluation of alternative processing. Irrecoverable operations must be identified rather than obscured. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: Retain the original record and document each derived transformation.

Distinguishing consideration: compare this with option B, “Overwrite the original with a corrected plot”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-071. Why retain unsuccessful challenge tests?

A. They can constrain competing explanations and show what was actually attempted

B. They can be discarded once another test produces a preferred result

C. They automatically count as successful verification of the measurement chain

D. They establish absence independently of the capability of the attempted test

Answer: A. An unsuccessful or negative test carries information about the examination and its limits. Its meaning depends on the test's capability and conditions, not merely on its outcome. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: They can constrain competing explanations and show what was actually attempted.

Distinguishing consideration: compare this with option B, “They can be discarded once another test produces a preferred result”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-072. Which record is particularly important when comparing several sensors in time?

A. Only file-creation timestamps without their event definitions

B. Only nominally equal sample rates without a time-reference record

C. Only matching display times without clock-state or uncertainty information

D. Synchronization sources and clock uncertainty

Answer: D. Temporal comparison requires a defined time basis and its limitations. Shared or different references can change the error structure and the interpretation of apparent coincidence. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: Synchronization sources and clock uncertainty.

Distinguishing consideration: compare this with option A, “Only file-creation timestamps without their event definitions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-073. What is the immediate purpose of a closing reference check?

A. To establish that every earlier acquisition state was identical to the closing state

B. To test specified measurement-chain functions at the time of the closing check

C. To convert an unresolved source hypothesis into attribution

D. To replace missing native data with a later known-reference observation

Answer: B. A known or injected reference tests the functions exercised at the time of the check. It does not by itself establish uninterrupted validity during earlier acquisition, source attribution, or authority. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: To test specified measurement-chain functions at the time of the closing check.

Distinguishing consideration: compare this with option A, “To establish that every earlier acquisition state was identical to the closing state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-074. A second receiver fails to show a component seen by the first. Which condition is essential before using that nondetection against an external-source explanation?

A. Equal total recording durations despite different instantaneous coverage

B. A nominally lower advertised noise floor without testing the relevant state

C. Comparable relevant sensitivity, coverage, reference plane, and observation opportunity

D. Matching center-frequency labels despite unverified sensitivity

Answer: C. A nondetection can reflect inadequate capability or different coverage. The chapter requires a comparison that preserves the conditions needed to observe the component before the absence becomes discriminating evidence. Source: §1.13 Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 99)

Why the selected alternative fits: Comparable relevant sensitivity, coverage, reference plane, and observation opportunity.

Distinguishing consideration: compare this with option A, “Equal total recording durations despite different instantaneous coverage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-075. Which challenge most directly changes the receiver's admitted spectral conditions?

A. A preselection change

B. Renormalizing an already retained trace at the display

C. Relabeling the frequency axis without changing acquisition

D. Changing the vertical axis on the same retained samples

Answer: A. Preselection can alter admitted blockers, desired transfer, and phase. Its consequence should be measured and interpreted as a change to the physical transformation. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: A preselection change.

Distinguishing consideration: compare this with option B, “Renormalizing an already retained trace at the display”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-076. What does moving an antenna potentially change in a challenge comparison?

A. Only propagation distance, with installed coupling and polarization unchanged

B. Both environmental coupling and the installed measurement conditions

C. Only desired-signal amplitude, with all artifact paths guaranteed unchanged

D. Only source direction, so a disappearance establishes localization directly

Answer: B. Location is part of the system record. Movement may help discriminate explanations, but it also changes coupling and must be interpreted within the declared measurement definition. Source: §1.1 Receiver as a Measurement System (p. 53)

Why the selected alternative fits: Both environmental coupling and the installed measurement conditions.

Distinguishing consideration: compare this with option A, “Only propagation distance, with installed coupling and polarization unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-077. Which closing statement is most reviewable?

A. The closing state proves every earlier gain and clock state was valid

B. The reference passed the stated checks; untested functions and remaining limits are listed

C. The tested function passed, so all untested functions are also accepted

D. A successful reference demonstrates that the chain cannot generate artifacts

Answer: B. A closing check supports only the functions it exercised. Recording untested functions prevents the result from being silently extended into a universal instrument assurance. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: The reference passed the stated checks; untested functions and remaining limits are listed.

Distinguishing consideration: compare this with option A, “The closing state proves every earlier gain and clock state was valid”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-078. Why are native trace files generally stronger supporting evidence than screenshots alone?

A. They automatically preserve every hidden setting regardless of the export content

B. Their native format guarantees the absence of acquisition errors

C. Their existence alone supplies any missing authority for collection

D. They can preserve data and configuration information needed for reconstruction

Answer: D. Screenshots are useful illustrations but omit aspects of data lineage and settings. Native records can support reconstruction, provided their actual content and configuration are retained. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: They can preserve data and configuration information needed for reconstruction.

Distinguishing consideration: compare this with option A, “They automatically preserve every hidden setting regardless of the export content”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-MCQ-079. Which item belongs in a receiver evidence record even when no desired event is found?

A. Only the final setup, assumed to describe every attempted acquisition

B. Failed captures and inaccessible settings

C. Only a negative conclusion, without the conditions of unsuccessful captures

D. Only successful detections, because failed attempts cannot affect interpretation

Answer: B. The record must show both successful observations and limitations. Failed captures or unavailable settings may change which negative conclusion can responsibly be drawn. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: Failed captures and inaccessible settings.

Distinguishing consideration: compare this with option A, “Only the final setup, assumed to describe every attempted acquisition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-080. What makes an alternate instrument comparison more persuasive?

A. It reproduces the same analysis on the same native record

B. It uses separate hardware while retaining the same unchallenged shared fault path

C. It produces a closer numerical match after selecting only favorable intervals

D. It changes relevant error sources while preserving the observation capability needed for the test

Answer: D. Independence concerns the mechanisms capable of producing the error, not the appearance of separate instruments. Adequate comparable capability remains necessary. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: It changes relevant error sources while preserving the observation capability needed for the test.

Distinguishing consideration: compare this with option A, “It reproduces the same analysis on the same native record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-081. A stable component appears only with the automatic preamplifier enabled. Which next interpretation is most cautious and useful?

A. The component is configuration-dependent and warrants an artifact or overload challenge

B. The gain dependence by itself establishes an external emitter operating near the threshold

C. The component can be attributed to the preamplifier circuit without further discrimination

D. A stable frequency makes the gain-state dependence irrelevant to interpretation

Answer: A. The observed state dependence narrows the technical question. It does not by itself identify the source or establish the information carried by the component. Source: §1.13 Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 99)

Why the selected alternative fits: The component is configuration-dependent and warrants an artifact or overload challenge.

Distinguishing consideration: compare this with option B, “The gain dependence by itself establishes an external emitter operating near the threshold”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

Review: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

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V011-C01-MCQ-082. In the chapter's hypothetical 433.920 MHz case, why is the second receiver's nondetection qualified?

A. A lower advertised noise floor alone establishes equivalent comparator capability

B. Nondetection excludes an external source regardless of instantaneous coverage

C. A second enclosure supplies independence even when the relevant measurement conditions differ

D. Its capability and observation conditions must support the comparison

Answer: D. The case favors an artifact explanation but retains the possibility that comparison conditions differ. Sensitivity, coverage, reference plane, and timing determine the force of the negative test. Source: §1.13 Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 99)

Why the selected alternative fits: Its capability and observation conditions must support the comparison.

Distinguishing consideration: compare this with option A, “A lower advertised noise floor alone establishes equivalent comparator capability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

Review: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

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V011-C01-MCQ-083. A later wide scan fails to reproduce a component found during an earlier dwell. What should be compared first?

A. The nominal instrument sensitivity specifications without the active states

B. The final peak values after forcing both plots to the same scale

C. The two measurement definitions and usable coverage

D. The total number of stored traces without their acquisition definitions

Answer: C. Different time coverage, detectors, blockers, or statistics can explain the apparent disagreement. Physical change should not be inferred before these measurement differences are reconciled. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why the selected alternative fits: The two measurement definitions and usable coverage.

Distinguishing consideration: compare this with option A, “The nominal instrument sensitivity specifications without the active states”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-MCQ-084. Which finding remains useful without establishing attribution?

A. An unrestricted absence claim based on one valid but limited interval

B. A calibrated observation supporting a specified next measurement

C. A source attribution inferred only from repeated detection

D. An owner assignment inferred solely from a stable frequency label

Answer: B. The chapter treats findings as inputs to bounded decisions. A well-defined observation can justify additional work while leaving source identity unresolved. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why the selected alternative fits: A calibrated observation supporting a specified next measurement.

Distinguishing consideration: compare this with option A, “An unrestricted absence claim based on one valid but limited interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-MCQ-085. Which statement best expresses a bounded negative finding?

A. No events meeting the defined criterion were observed within the demonstrated valid coverage

B. No possible emitter exists anywhere

C. Nothing happened outside the measured interval

D. Every conceivable waveform was excluded

Answer: A. The finding must remain limited to the event class, sensitivity, intervals, and conditions actually tested. Unobserved classes or intervals cannot be included by implication. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why the selected alternative fits: No events meeting the defined criterion were observed within the demonstrated valid coverage.

Distinguishing consideration: compare this with option B, “No possible emitter exists anywhere”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-MCQ-086. What is the appropriate consequence of loss of clock lock during a timing-dependent observation?

A. Apply an amplitude correction to compensate for the missing clock-state evidence

B. Apply the planned stop or escalation condition and identify the affected interval

C. Combine the affected interval with locked intervals before judging timing validity

D. Continue using timestamps as valid because the nominal sample rate is unchanged

Answer: B. Clock validity affects the time basis. The operational response and data treatment should follow the declared plan, with the affected interval preserved in the record. Source: §1.9 Operational Decision Discipline (p. 70)

Why the selected alternative fits: Apply the planned stop or escalation condition and identify the affected interval.

Distinguishing consideration: compare this with option A, “Apply an amplitude correction to compensate for the missing clock-state evidence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-MCQ-087. A field lesson from one receiver is applied to another model. What status should it initially have?

A. A substitute for examining the new receiver architecture

B. A hypothesis requiring validation for the new configuration

C. A calibration result transferable without checking the new installed path

D. An established universal rule because the original observation was carefully documented

Answer: B. The chapter restricts transfer of lessons to what the evidence supports. A different architecture or state can change the mechanisms and validity conditions.

Source: §1.9 Operational Decision Discipline (p. 70)

Why the selected alternative fits: A hypothesis requiring validation for the new configuration.

Distinguishing consideration: compare this with option A, “A substitute for examining the new receiver architecture”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-MCQ-088. Why plan receiver operations around decision points?

A. To connect observations with justified next actions and prevent purposeless trace accumulation

B. To ensure that every unreproduced component is classified as an artifact

C. To collect the greatest number of traces before defining their analytical purpose

D. To make the available menu sequence determine the authorized objective

Answer: A. Decision points specify when to continue, challenge, stop, or escalate. They give acquisition a defined analytical purpose without pretending to eliminate professional judgment. Source: §1.9 Operational Decision Discipline (p. 70)

Why the selected alternative fits: To connect observations with justified next actions and prevent purposeless trace accumulation.

Distinguishing consideration: compare this with option B, “To ensure that every unreproduced component is classified as an artifact”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-MCQ-089. Which record best supports review of a procedure deviation?

A. The deviation, its reason, the affected state or data, and its consequence for the conclusion

B. The original procedure alone, omitting how actual execution differed

C. The receiver identity without a connection to the affected data

D. The final favorable result without the changed conditions

Answer: A. A reviewer needs to determine whether the conclusion remains valid under the actual procedure. The deviation must therefore be connected to the measurement and its interpretation. Source: §1.9 Operational Decision Discipline (p. 70)

Why the selected alternative fits: The deviation, its reason, the affected state or data, and its consequence for the conclusion.

Distinguishing consideration: compare this with option B, “The original procedure alone, omitting how actual execution differed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-MCQ-090. Which report claim exceeds a successful bounded artifact challenge?

A. Every internal coupling path has been identified

B. The component depends on the tested receiver state

C. Further mechanism localization may require additional observations

D. The tested changes favor an artifact explanation under the stated conditions

Answer: A. An artifact finding can be useful without fully resolving the internal mechanism. Establishing every coupling path demands evidence beyond a limited diagnostic comparison. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why the selected alternative fits: Every internal coupling path has been identified.

Distinguishing consideration: compare this with option B, “The component depends on the tested receiver state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-MCQ-091. A receiver indicates minus 60 dBm after 3 dB path loss and 10 dB external gain. Which reference-plane result follows Equation 2 before other corrections?

A. Minus 67 dBm

B. Minus 53 dBm

C. Minus 73 dBm

D. Minus 47 dBm

Answer: A. The backward correction is minus 60 plus 3 minus 10, giving minus 67 dBm. This arithmetic remains conditional on the declared path, gain state, and absence of invalidating behavior. Source: Equation 2. Corrected input power (p. 71)

Why the selected alternative fits: Minus 67 dBm.

Distinguishing consideration: compare this with option B, “Minus 53 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-MCQ-092. An unamplified path has 6 dB calibrated loss and the receiver indicates minus 90 dBm. What upstream level does the scalar correction give?

A. Minus 96 dBm

B. Minus 15 dBm

C. Minus 84 dBm

D. Minus 540 dBm

Answer: C. With zero external gain, Equation 2 adds the 6 dB loss to the indication. The result is minus 84 dBm at the stated upstream plane, before any additional applicable corrections. Source: Equation 2. Corrected input power (p. 71)

Why the selected alternative fits: Minus 84 dBm.

Distinguishing consideration: compare this with option A, “Minus 96 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-MCQ-093. The receiver indication is minus 50 dBm, with 2 dB loss and 20 dB gain. A report states minus 28 dBm upstream. What sign error is present?

A. Path loss was correctly omitted

B. The reference plane is proved by the number

C. The calculation correctly implements Equation 2

D. External gain was added instead of subtracted

Answer: D. The correct scalar result is minus 68 dBm. Adding the 20 dB gain reverses the backward correction and creates a 40 dB error relative to the stated model. Source: Equation 2. Corrected input power (p. 71)

Why the selected alternative fits: External gain was added instead of subtracted.

Distinguishing consideration: compare this with option A, “Path loss was correctly omitted”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-MCQ-094. Two records have identical corrected power but different noise floors. Which conclusion is justified?

A. A lower corrected noise floor establishes the physical identity of the component

B. Equal corrected values establish equal sensitivity despite different noise floors

C. Equal corrected level alone does not establish equal observation capability

D. A scalar amplitude correction makes the two detection criteria equivalent

Answer: C. Sensitivity and validity are properties of the complete state. Matching a corrected signal value does not show that weak components or negative findings are equally supported. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why the selected alternative fits: Equal corrected level alone does not establish equal observation capability.

Distinguishing consideration: compare this with option A, “A lower corrected noise floor establishes the physical identity of the component”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-MCQ-095. A report uses an image of a spectrum as proof that an acquisition mode was configured as intended. What should supplement the image?

A. Setup export, actual-state information, and native record lineage

B. A second screenshot of the same unchanged display

C. The requested mode alone without evidence that it was accepted

D. The description of the mode in the instrument manual without the acquired configuration

Answer: A. A screenshot can show a display but may omit hidden settings, transitions, and actual processing. The complementary records help establish what transformation produced it. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why the selected alternative fits: Setup export, actual-state information, and native record lineage.

Distinguishing consideration: compare this with option B, “A second screenshot of the same unchanged display”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-MCQ-096. An examiner selects only intervals containing the strongest response and then describes the result as representative of the whole survey. What must be addressed?

A. Only the receiver calibration certificate, without the interval-selection rule

B. The selection rule and the scope of the resulting estimate

C. Only the number of selected files, without their time coverage

D. Only the peak value after normalization across the selected records

Answer: B. The time interval and estimator define the measurand. A selected subset can support a conditional result, but its relation to the full survey must be justified and disclosed. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: The selection rule and the scope of the resulting estimate.

Distinguishing consideration: compare this with option A, “Only the receiver calibration certificate, without the interval-selection rule”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Equation 2C. Average after each interval has its own valid correction.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Equation 2C. Average after each interval has its own valid correction.

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V011-C01-MCQ-097. The same processing script gives matching results on two computers. Which issue remains unresolved by that agreement alone?

A. A shared algorithm or configuration error

B. That the same named script was used for both executions

C. That two separate computer executions were performed

D. That the two executions produced matching reported values

Answer: A. Two executions can agree because they share the same transformation and fault. Independence must be assessed in terms of relevant error mechanisms, not merely separate machines. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: A shared algorithm or configuration error.

Distinguishing consideration: compare this with option B, “That the same named script was used for both executions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-098. Which final record most clearly distinguishes measurement from model-based extrapolation?

A. A fitted law establishes that all unobserved configurations behaved identically

B. The observed interval is stated separately from any assumption about unobserved intervals

C. The predicted unobserved interval is described as directly measured coverage

D. The model assumptions replace the need to state the original observation interval

Answer: B. A model can support a conditional extension, but it does not convert unobserved conditions into measurements. The evidence and its interpretive assumptions must remain distinguishable. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why the selected alternative fits: The observed interval is stated separately from any assumption about unobserved intervals.

Distinguishing consideration: compare this with option A, “A fitted law establishes that all unobserved configurations behaved identically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

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V011-C01-MCQ-099. A known reference passes after a survey, but a recording channel was never exercised by the check. Which statement is justified?

A. The untested recording path is accepted because the analog reference response passed

B. A later reference pass supplies any missing earlier sample record

C. The untested recording function remains outside the closing assurance

D. The check establishes successful export even when the export path was not exercised

Answer: C. A check validates only the function and conditions it actually tests. Its scope must identify the recording path as untested if that path was not exercised.

Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why the selected alternative fits: The untested recording function remains outside the closing assurance.

Distinguishing consideration: compare this with option A, “The untested recording path is accepted because the analog reference response passed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-MCQ-100. Which overall practice best implements Chapter 1?

A. Acquire the widest possible record and infer authority from its later usefulness

B. Define authority and measurand, preserve consequential states and native evidence, challenge alternatives, and bound the finding

C. Retain only final corrected values once the original processing has succeeded

D. Treat repeated detection as source attribution whenever the display is stable

Answer: B. The chapter connects institutional scope, measurement definition, configuration, evidence preservation, and discriminating tests. A defensible finding retains the limits established by that complete chain. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why the selected alternative fits: Define authority and measurand, preserve consequential states and native evidence, challenge alternatives, and bound the finding.

Distinguishing consideration: compare this with option A, “Acquire the widest possible record and infer authority from its later usefulness”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Frame a bounded….

Review: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Frame a bounded finding from the completed observation.

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Fill-in-the-Blank Questions

V011-C01-FIB-001. The receiver is modeled as a sequence of physical and computational _____, rather than as a frequency display alone.

Answer: transformations. The reported result depends on successive changes to the input. The model therefore includes analog hardware and digital processing.

Source: §1.1 Receiver as a Measurement System (p. 53)

Why this term is required: “transformations” completes the stated technical proposition.

Question context: The receiver is modeled as a sequence of physical and computational _____, rather than as a frequency display alone

Basis and qualification: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-FIB-002. The declared location to which a power or phase statement refers is its reference _____.

Answer: plane. This location gives the quantity a physical or mathematical boundary and determines which corrections belong in the calculation. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why this term is required: “plane” completes the stated technical proposition.

Question context: The declared location to which a power or phase statement refers is its reference _____

Basis and qualification: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-FIB-003. A precise readout can remain poorly defined when the intended _____ has not been specified.

Answer: measurand. Numerical precision is distinct from knowing which quantity was measured under which conditions. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “measurand” completes the stated technical proposition.

Question context: A precise readout can remain poorly defined when the intended _____ has not been specified

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-004. The measurement boundary can extend beyond the instrument _____.

Answer: enclosure. External accessories, antennas, computers, and scripts can change the observation and must be included when consequential. Source: §1.1 Receiver as a Measurement System (p. 53)

Why this term is required: “enclosure” completes the stated technical proposition.

Question context: The measurement boundary can extend beyond the instrument _____

Basis and qualification: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-FIB-005. An antenna's pattern and _____ can affect what reaches the receiver.

Answer: polarization. The antenna response is part of the environmental-to-terminal transformation and belongs in the installed-system record. Source: §1.1 Receiver as a Measurement System (p. 53)

Why this term is required: “polarization” completes the stated technical proposition.

Question context: An antenna's pattern and _____ can affect what reaches the receiver

Basis and qualification: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-FIB-006. Even a passive connection can contribute mismatch or common-mode _____.

Answer: current. The passive label does not establish that the component is transparent to the installed measurement. Source: §1.1 Receiver as a Measurement System (p. 53)

Why this term is required: “current” completes the stated technical proposition.

Question context: Even a passive connection can contribute mismatch or common-mode _____

Basis and qualification: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-FIB-007. The instrument record should identify every consequential component between the environment and the stored _____.

Answer: result. This complete path permits review of both external phenomena and effects introduced by the measurement system. Source: §1.1 Receiver as a Measurement System (p. 53)

Why this term is required: “result” completes the stated technical proposition.

Question context: The instrument record should identify every consequential component between the environment and the stored _____

Basis and qualification: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-FIB-008. The operating state includes the receiver's linearity limit as well as gain, bandwidth, and noise _____.

Answer: contribution. A valid observation depends on several coupled properties of the active state, not merely on signal gain. Source: §1.1 Receiver as a Measurement System (p. 53)

Why this term is required: “contribution” completes the stated technical proposition.

Question context: The operating state includes the receiver's linearity limit as well as gain, bandwidth, and noise _____

Basis and qualification: Chapter 1 — Receiver as a Measurement System.

Review: Chapter 1 — Receiver as a Measurement System.

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V011-C01-FIB-009. The quantity represented at the software output can depend on analog and _____ filtering.

Answer: digital. Both types of filtering belong to the configured transformation and can change the retained signal representation. Source: §1.1 Receiver as a Measurement System (p. 53)

Why this term is required: “digital” completes the stated technical proposition.

Question context: The quantity represented at the software output can depend on analog and _____ filtering

Basis and qualification: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Equation 1. Configured receiver-chain representation.

Review: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Equation 1. Configured receiver-chain representation.

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V011-C01-FIB-010. A component added after calibration can require reassessment of calibration _____.

Answer: applicability. The earlier calibration is associated with its defined path and state. Applicability to the changed system must be established. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why this term is required: “applicability” completes the stated technical proposition.

Question context: A component added after calibration can require reassessment of calibration _____

Basis and qualification: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-FIB-011. Technical _____ defines what may be energized, disconnected, recorded, retained, and disclosed.

Answer: authority. The chapter requires legal and institutional limits to be translated into concrete receiver operations. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “authority” completes the stated technical proposition.

Question context: Technical _____ defines what may be energized, disconnected, recorded, retained, and disclosed

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-012. Limiting bandwidth, duration, channels, and metadata before collection is an example of _____.

Answer: minimization. Precollection design can prevent unnecessary acquisition rather than leaving all control to later data handling. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “minimization” completes the stated technical proposition.

Question context: Limiting bandwidth, duration, channels, and metadata before collection is an example of _____

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-013. Permission to measure occupancy does not necessarily permit recovery of communications _____.

Answer: content. Technical characteristics and carried information are different collection objects and may have different authorization boundaries. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “content” completes the stated technical proposition.

Question context: Permission to measure occupancy does not necessarily permit recovery of communications _____

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-014. The receiver plan translates scope into ranges, locations, times, modes, recording policies, and _____ conditions.

Answer: stop. Predetermined conditions connect measurement or authority failures to an operational response. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “stop” completes the stated technical proposition.

Question context: The receiver plan translates scope into ranges, locations, times, modes, recording policies, and _____ conditions

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Operational Decision Discipline.

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V011-C01-FIB-015. A scope extension should record both the deviation and who _____ it.

Answer: approved. The record must establish the authority for the actual collection, not merely the operator's technical reason for wanting it. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “approved” completes the stated technical proposition.

Question context: A scope extension should record both the deviation and who _____ it

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-016. Selecting only the acquisition duration required by the objective limits unnecessary _____ coverage.

Answer: time. Duration determines which events and information can enter the record and is therefore a substantive acquisition control. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “time” completes the stated technical proposition.

Question context: Selecting only the acquisition duration required by the objective limits unnecessary _____ coverage

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-017. Masked bands should be recorded as _____ from the examined coverage.

Answer: exclusions. An omitted band cannot support the same negative conclusion as a band actually examined under valid conditions. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “exclusions” completes the stated technical proposition.

Question context: Masked bands should be recorded as _____ from the examined coverage

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-018. The broadest available receiver configuration is not justified merely by technical _____.

Answer: capability. What can be acquired and what is authorized or necessary are separate questions. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
Why this term is required: “capability” completes the stated technical proposition.
Question context: The broadest available receiver configuration is not justified merely by technical _____
Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.
Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-019. Documented retention limits govern how long collected information is _____.

Answer: retained. The handling policy forms part of the collection plan and the reviewable record of the engagement. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “retained” completes the stated technical proposition.

Question context: Documented retention limits govern how long collected information is _____

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-020. Cryptographic access controls address who can access retained information; they do not alone authorize broader _____.

Answer: collection. Controls after acquisition complement the initial scope restriction but do not create additional mission authority. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

Why this term is required: “collection” completes the stated technical proposition.

Question context: Cryptographic access controls address who can access retained information; they do not alone authorize broader _____

Basis and qualification: Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-FIB-021. Energy exceeding a declared decision rule first supports _____.

Answer: detection. That observation is narrower than identifying a waveform family, source, or carried information. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “detection” completes the stated technical proposition.

Question context: Energy exceeding a declared decision rule first supports _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-022. Association with a modulation family or timing behavior is called _____.

Answer: classification. Classification concerns signal characteristics and does not itself establish physical source or ownership. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “classification” completes the stated technical proposition.

Question context: Association with a modulation family or timing behavior is called _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-023. Linking an observed component to a physical emitter or system is called _____.

Answer: attribution. This stronger proposition needs source-linking evidence such as controlled state changes or other corroborating observations. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “attribution” completes the stated technical proposition.

Question context: Linking an observed component to a physical emitter or system is called _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-024. Reconstructing information carried by a signal is content _____.

Answer: recovery. Recovery must be distinguished from observing energy or recognizing a waveform family. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “recovery” completes the stated technical proposition.

Question context: Reconstructing information carried by a signal is content _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-025. A decoded network name may be a configuration string without proving device location or _____.

Answer: ownership. The meaning of the decoded identifier must not be extended beyond what the evidence supports. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “ownership” completes the stated technical proposition.

Question context: A decoded network name may be a configuration string without proving device location or _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-026. A component correlated with recorded activity can demonstrate state dependence without establishing intelligible _____.

Answer: content. Correlation may narrow the technical problem while leaving the carried information and source mechanism unresolved. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “content” completes the stated technical proposition.

Question context: A component correlated with recorded activity can demonstrate state dependence without establishing intelligible _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-027. A stable narrow peak can originate from local-oscillator _____ rather than an external emitter.

Answer: leakage. Stability does not by itself separate genuine external components from instrument-generated ones. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “leakage” completes the stated technical proposition.

Question context: A stable narrow peak can originate from local-oscillator _____ rather than an external emitter

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-028. Reports should choose verbs according to the evidence actually _____.

Answer: obtained. Detected, classified, localized, attributed, and recovered express different propositions and evidential burdens. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “obtained” completes the stated technical proposition.

Question context: Reports should choose verbs according to the evidence actually _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-029. A receiver-generated spectral component is one possible measurement _____.

Answer: artifact. The apparatus can introduce observations that resemble environmental signals, requiring suitable challenge tests. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

Why this term is required: “artifact” completes the stated technical proposition.

Question context: A receiver-generated spectral component is one possible measurement _____

Basis and qualification: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-030. An attribution claim should retain unresolved alternative _____.

Answer: explanations. A bounded conclusion shows which alternatives were tested and which remain plausible under the available evidence. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why this term is required: “explanations” completes the stated technical proposition.

Question context: An attribution claim should retain unresolved alternative _____

Basis and qualification: Chapter 1 — Frame a bounded finding from the completed observation; Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

Review: Chapter 1 — Frame a bounded finding from the completed observation; Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-FIB-031. Equation 2 refers a downstream indication backward by adding passive path _____.

Answer: loss. The upstream signal is higher than the downstream indication by the applicable loss, within the scalar model. Source: Equation 2. Corrected input power (p. 71)

Why this term is required: “loss” completes the stated technical proposition.

Question context: Equation 2 refers a downstream indication backward by adding passive path _____

Basis and qualification: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-FIB-032. Equation 2 refers a downstream indication backward by subtracting external _____.

Answer: gain. The amplifier raised the downstream level, so its contribution is removed when estimating the upstream level. Source: Equation 2. Corrected input power (p. 71)

Why this term is required: “gain” completes the stated technical proposition.

Question context: Equation 2 refers a downstream indication backward by subtracting external _____

Basis and qualification: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-FIB-033. In the chapter's calculation, minus 71.4 plus 4.8 minus 18.6 gives minus _____ dBm.

Answer: 85.2. The result is the preamplifier-input level under the stated model, before mismatch and uncertainty are included. Source: §1.12 Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 78)

Why this term is required: “85.2” completes the stated technical proposition.

Question context: In the chapter's calculation, minus 71.4 plus 4.8 minus 18.6 gives minus _____ dBm

Basis and qualification: Chapter 1 — Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Equation 2. Corrected input power.

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V011-C01-FIB-034. An indication of minus 90 dBm through an unamplified 6 dB loss corresponds to minus _____ dBm upstream.

Answer: 84. With zero external gain, the scalar backward correction simply adds the calibrated loss to the receiver indication. Source: Equation 2. Corrected input power (p. 71)

Why this term is required: “84” completes the stated technical proposition.

Question context: An indication of minus 90 dBm through an unamplified 6 dB loss corresponds to minus _____ dBm upstream

Basis and qualification: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-FIB-035. An indication of minus 60 dBm, 3 dB loss, and 10 dB gain gives minus _____ dBm at the upstream plane.

Answer: 67. The calculation is minus 60 plus 3 minus 10. Its applicability remains conditional on the actual chain and calibration state. Source: Equation 2. Corrected input power (p. 71)

Why this term is required: “67” completes the stated technical proposition.

Question context: An indication of minus 60 dBm, 3 dB loss, and 10 dB gain gives minus _____ dBm at the upstream plane

Basis and qualification: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-FIB-036. The gain and loss terms in Equation 2 are expressed in _____, while absolute power is expressed in dBm.

Answer: decibels. Compatible logarithmic units permit the additive correction without equating a ratio with an absolute power. Source: Equation 2. Corrected input power (p. 71)

Why this term is required: “decibels” completes the stated technical proposition.

Question context: The gain and loss terms in Equation 2 are expressed in _____, while absolute power is expressed in dBm

Basis and qualification: Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Equation 2. Corrected input power.

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V011-C01-FIB-037. The original indication and every applied correction should be retained as a correction _____.

Answer: chain. This record exposes double counting, wrong signs, and corrections belonging to a different state or reference plane. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “chain” completes the stated technical proposition.

Question context: The original indication and every applied correction should be retained as a correction _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-038. A display level is not automatically a measurement of environmental field _____.

Answer: strength. The conversion requires an applicable antenna relationship, geometry, and the rest of the measurement path. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why this term is required: “strength” completes the stated technical proposition.

Question context: A display level is not automatically a measurement of environmental field _____

Basis and qualification: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-FIB-039. Adding a scalar correction cannot repair receiver _____.

Answer: overload. An invalid nonlinear record can lose information that a later numerical offset does not restore. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “overload” completes the stated technical proposition.

Question context: Adding a scalar correction cannot repair receiver _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse.

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V011-C01-FIB-040. If a preamplifier is bypassed, records from the two states require _____ corrections before they can be compared or combined.

Answer: separate. Each interval must remain tied to its actual transformation and calibration conditions. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “separate” completes the stated technical proposition.

Question context: If a preamplifier is bypassed, records from the two states require _____ corrections before they can be compared or combined

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Hypothetical Applied Calculation: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

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V011-C01-FIB-041. Configuration identity includes hardware serial numbers, firmware, drivers, software builds, and calibration _____.

Answer: data. These identify the consequential hardware and computational state that produced the observation. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why this term is required: “data” completes the stated technical proposition.

Question context: Configuration identity includes hardware serial numbers, firmware, drivers, software builds, and calibration _____

Basis and qualification: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-FIB-042. An automatic mode must be documented when it can silently change measurement _____.

Answer: settings. Hidden changes can alter the measurand, validity, or applicable corrections even when the operator makes no manual adjustment. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “settings” completes the stated technical proposition.

Question context: An automatic mode must be documented when it can silently change measurement _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-043. The requested setup and the accepted or actual state are not necessarily _____.

Answer: identical. A command can be rejected, delayed, or followed by an automatic change, so status and observation records are needed. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “identical” completes the stated technical proposition.

Question context: The requested setup and the accepted or actual state are not necessarily _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-044. A gain change can affect amplitude calibration, overload margin, recovery time, and noise _____.

Answer: floor. These coupled effects prevent a gain-state change from being treated solely as a display offset. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “floor” completes the stated technical proposition.

Question context: A gain change can affect amplitude calibration, overload margin, recovery time, and noise _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-045. A sample-rate change can move alias locations and alter recording _____.

Answer: throughput. The rate affects both the measurement mapping and the handling of the sampled record. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “throughput” completes the stated technical proposition.

Question context: A sample-rate change can move alias locations and alter recording _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-046. A preselector can improve blocker rejection while adding loss and phase _____.

Answer: delay. The gain in selectivity may carry other measurement consequences that must remain visible in the comparison. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “delay” completes the stated technical proposition.

Question context: A preselector can improve blocker rejection while adding loss and phase _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-047. Separate state _____ identify portions of a record governed by applicable configurations and calibrations.

Answer: intervals. State-dependent transformations should not be hidden within one undifferentiated average. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “intervals” completes the stated technical proposition.

Question context: Separate state _____ identify portions of a record governed by applicable configurations and calibrations

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-048. A setup export principally records the _____ configuration.

Answer: requested. The accepted state and captured observation provide additional evidence needed to determine what actually occurred. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “requested” completes the stated technical proposition.

Question context: A setup export principally records the _____ configuration

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-049. A status log may record the accepted or _____ receiver state.

Answer: actual. Status information can expose a difference between the intended setup and the state associated with the data. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “actual” completes the stated technical proposition.

Question context: A status log may record the accepted or _____ receiver state

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-050. Configuration detail is relevant when it would change the answer to the measurement _____.

Answer: question. The chapter calls for consequential identity rather than indiscriminate recording of every cosmetic menu preference. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “question” completes the stated technical proposition.

Question context: Configuration detail is relevant when it would change the answer to the measurement _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-051. The measurement definition should specify a reference plane, frequency interval, time interval, state, estimator, and decision _____.

Answer: criterion. Together these identify what is measured, how the result is formed, and how it will be used. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “criterion” completes the stated technical proposition.

Question context: The measurement definition should specify a reference plane, frequency interval, time interval, state, estimator, and decision _____

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-052. The mathematical operation that converts retained data into a reported number is the _____.

Answer: estimator. Different estimators can produce different quantities even when the display uses a similar label. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “estimator” completes the stated technical proposition.

Question context: The mathematical operation that converts retained data into a reported number is the _____

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-053. A discovery scan can reveal a component without establishing the amplitude _____ needed to quantify it.

Answer: calibration. Locating a candidate and measuring its level are distinct tasks with different supporting conditions. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “calibration” completes the stated technical proposition.

Question context: A discovery scan can reveal a component without establishing the amplitude _____ needed to quantify it

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-054. A narrow phase capture provides limited information outside its instantaneous _____.

Answer: passband. Strong performance for one bounded measurement does not imply comprehensive spectral coverage. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “passband” completes the stated technical proposition.

Question context: A narrow phase capture provides limited information outside its instantaneous _____

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-055. A power marker may represent a detector bucket, integrated channel, or fitted _____.

Answer: tone. The displayed marker must be interpreted according to its actual estimator and normalization. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “tone” completes the stated technical proposition.

Question context: A power marker may represent a detector bucket, integrated channel, or fitted _____

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-056. A frequency marker may represent an FFT-bin label, an interpolated estimate, or a swept local-oscillator _____.

Answer: setting. These are different constructions and cannot be treated as interchangeable merely because they appear on the same axis. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “setting” completes the stated technical proposition.

Question context: A frequency marker may represent an FFT-bin label, an interpolated estimate, or a swept local-oscillator _____

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-057. A timestamp may identify sample aperture, trigger comparison, or software _____.

Answer: receipt. The event marked by a time value must be stated before delays or cross-channel timing are interpreted. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “receipt” completes the stated technical proposition.

Question context: A timestamp may identify sample aperture, trigger comparison, or software _____

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-058. The decision criterion should identify the uncertainty and _____ conditions required for the intended use.

Answer: validity. A numerical estimate does not by itself specify whether the result is adequate to support the proposed decision. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “validity” completes the stated technical proposition.

Question context: The decision criterion should identify the uncertainty and _____ conditions required for the intended use

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-059. The frequency and time intervals identify which energy and _____ can contribute to the estimate.

Answer: events. Those intervals define the observation scope and limit the conclusions supported by the result. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “events” completes the stated technical proposition.

Question context: The frequency and time intervals identify which energy and _____ can contribute to the estimate

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-060. A change to one processing stage must not silently _____ another part of the measurand.

Answer: redefine. The measurement definition connects the stages so that corrections and state changes remain consistent with the intended quantity. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “redefine” completes the stated technical proposition.

Question context: A change to one processing stage must not silently _____ another part of the measurand

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-FIB-061. Preserve native samples or traces before processing that discards _____.

Answer: information. Retained inputs permit later review of transformations and reveal which analyses remain possible. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “information” completes the stated technical proposition.

Question context: Preserve native samples or traces before processing that discards ____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-062. A known scalar correction may be reversible when its value and _____ are known.

Answer: state. The numerical correction is useful only where its applicability to the actual configuration is established. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “state” completes the stated technical proposition.

Question context: A known scalar correction may be reversible when its value and _____ are known

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-063. Clipping and magnitude detection can be _____ transformations.

Answer: information-losing. The discarded waveform or phase information cannot generally be recreated merely by applying a later offset. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “information-losing” completes the stated technical proposition.

Question context: Clipping and magnitude detection can be _____ transformations

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-064. Loss of samples can compromise the record's sample _____.

Answer: continuity. Stored order and physical acquisition history must remain connected when timing and processing depend on the sample sequence. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “continuity” completes the stated technical proposition.

Question context: Loss of samples can compromise the record's sample _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-065. A derived spectrum's limitations should be tied to the representation actually _____.

Answer: retained. A later analyst cannot assume that information absent from the stored representation remains recoverable. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “retained” completes the stated technical proposition.

Question context: A derived spectrum's limitations should be tied to the representation actually _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-066. A measured pair of tone levels is evidence; a cubic relation used to interpret a product is a _____.

Answer: model. The observation and explanatory assumptions must remain separately identifiable. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “model” completes the stated technical proposition.

Question context: A measured pair of tone levels is evidence; a cubic relation used to interpret a product is a _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-067. A reciprocal-mixing prediction requires relevant blocker power and conversion _____.

Answer: gain. A phase-noise curve alone does not characterize the complete configured measurement path. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “gain” completes the stated technical proposition.

Question context: A reciprocal-mixing prediction requires relevant blocker power and conversion _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-068. A capture probability requires both an event-start distribution and a capture _____.

Answer: criterion. Usable windows are evidence about coverage; the probability adds assumptions about events and success. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “criterion” completes the stated technical proposition.

Question context: A capture probability requires both an event-start distribution and a capture _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-069. Recording each processing step creates a reviewable analytical _____.

Answer: lineage. The record connects the retained input to the derived output and supports reconstruction or challenge. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “lineage” completes the stated technical proposition.

Question context: Recording each processing step creates a reviewable analytical _____

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-070. Reversibility is weakened when the corrected output _____ the only copy of the native input.

Answer: overwrites. Preserving the original representation prevents later processing choices from erasing the evidence on which the result rests. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

Why this term is required: “overwrites” completes the stated technical proposition.

Question context: Reversibility is weakened when the corrected output _____ the only copy of the native input

Basis and qualification: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-FIB-071. A complete receiver record includes antenna orientation, height, polarization, and cable _____.

Answer: route. Installed geometry and routing can affect coupling and must accompany a reproducible observation. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “route” completes the stated technical proposition.

Question context: A complete receiver record includes antenna orientation, height, polarization, and cable _____

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-072. When sensors are compared, record synchronization sources and clock _____.

Answer: uncertainty. A common displayed time does not by itself establish the accuracy or independence of the underlying time bases. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “uncertainty” completes the stated technical proposition.

Question context: When sensors are compared, record synchronization sources and clock _____

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-073. Negative and unsuccessful tests are retained because they constrain competing _____.

Answer: explanations. Their evidential value depends on the capability and conditions of the test, including any limitations. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “explanations” completes the stated technical proposition.

Question context: Negative and unsuccessful tests are retained because they constrain competing _____

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-074. A known source or injected reference can support closing _____ of the measurement chain.

Answer: verification. The check assesses specified functions at its own time and conditions. It alone does not establish uninterrupted validity throughout the preceding acquisition. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “verification” completes the stated technical proposition.

Question context: A known source or injected reference can support closing _____ of the measurement chain

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-075. Alternate attenuation or preselection can challenge receiver _____.

Answer: linearity. The response to a controlled state change can help distinguish external components from overload-related or instrument-generated behavior.

Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “linearity” completes the stated technical proposition.

Question context: Alternate attenuation or preselection can challenge receiver _____

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-076. Agreement between instruments is persuasive only when relevant errors are sufficiently _____.

Answer: independent. Separate displays may still share an input route, clock, or processing fault that explains common behavior. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “independent” completes the stated technical proposition.

Question context: Agreement between instruments is persuasive only when relevant errors are sufficiently _____

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-077. The closing record should identify both verified functions and functions that remained _____.

Answer: untested. A bounded assurance prevents the check result from being extended to capabilities it never exercised. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “untested” completes the stated technical proposition.

Question context: The closing record should identify both verified functions and functions that remained _____

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-078. Native trace files and setup exports generally preserve stronger supporting evidence than screenshots _____.

Answer: alone. Images can illustrate an observation while omitting data and configuration needed for reconstruction. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why this term is required: “alone” completes the stated technical proposition.

Question context: Native trace files and setup exports generally preserve stronger supporting evidence than screenshots _____

Basis and qualification: Chapter 1 — Reference Planes and Configuration Identity.

Review: Chapter 1 — Reference Planes and Configuration Identity.

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V011-C01-FIB-079. Failed captures and inaccessible settings are examples of record _____.

Answer: limitations. They identify aspects of coverage or control that may restrict the resulting finding. Source: §1.8 Evidence Record and Closing Verification (p. 69)

Why this term is required: “limitations” completes the stated technical proposition.

Question context: Failed captures and inaccessible settings are examples of record ____

Basis and qualification: Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-080. A suitable alternate receiver must retain the observation _____ relevant to the negative comparison.

Answer: capability. Nondetection is not discriminating when sensitivity, frequency coverage, or timing prevented the comparator from observing the candidate.

Source: §1.13 Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 99)

Why this term is required: “capability” completes the stated technical proposition.

Question context: A suitable alternate receiver must retain the observation _____ relevant to the negative comparison

Basis and qualification: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-FIB-081. Receiver operations should be organized around decision _____ rather than menu availability.

Answer: points. These connect observations to continuation, challenge, stopping, and escalation actions. Source: §1.9 Operational Decision Discipline (p. 70)

Why this term is required: “points” completes the stated technical proposition.

Question context: Receiver operations should be organized around decision _____ rather than menu availability

Basis and qualification: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-FIB-082. Loss of clock lock is one potential reason to stop or _____ a timing-dependent examination.

Answer: escalate. The operational plan should define a response to validity failures and preserve the affected interval. Source: §1.9 Operational Decision Discipline (p. 70)

Why this term is required: “escalate” completes the stated technical proposition.

Question context: Loss of clock lock is one potential reason to stop or _____ a timing-dependent examination

Basis and qualification: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-FIB-083. An inability to reproduce a result should trigger examination of the configuration and measurement _____.

Answer: conditions. Nonreproduction can arise from changed state or coverage and should not be converted immediately into a broad environmental conclusion.

Source: §1.9 Operational Decision Discipline (p. 70)

Why this term is required: “conditions” completes the stated technical proposition.

Question context: An inability to reproduce a result should trigger examination of the configuration and measurement _____

Basis and qualification: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-FIB-084. Lessons learned from one instrument or site become _____ for validation elsewhere.

Answer: hypotheses. The evidence does not establish a universal rule for every architecture or installed state. Source: §1.9 Operational Decision Discipline (p. 70)

Why this term is required: “hypotheses” completes the stated technical proposition.

Question context: Lessons learned from one instrument or site become _____ for validation elsewhere

Basis and qualification: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-FIB-085. A deviation record allows later reviewers to assess whether the conclusion remains _____.

Answer: valid. The reason, affected data, and consequence of the change must be available for that judgment. Source: §1.9 Operational Decision Discipline (p. 70)

Why this term is required: “valid” completes the stated technical proposition.

Question context: A deviation record allows later reviewers to assess whether the conclusion remains _____

Basis and qualification: Chapter 1 — Operational Decision Discipline.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-FIB-086. A later wide scan and an earlier dwell may differ because their time and frequency _____ differ.

Answer: coverage. The apparent disagreement may reflect different observation opportunities rather than a physical change in the environment. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why this term is required: “coverage” completes the stated technical proposition.

Question context: A later wide scan and an earlier dwell may differ because their time and frequency _____ differ

Basis and qualification: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-FIB-087. A defensible finding identifies the observation, valid conditions, challenged alternatives, and remaining _____.

Answer: uncertainty. Those boundaries show what the record can support and what further work may be required. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why this term is required: “uncertainty” completes the stated technical proposition.

Question context: A defensible finding identifies the observation, valid conditions, challenged alternatives, and remaining _____

Basis and qualification: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-FIB-088. A useful finding may support continued measurement without supporting source _____.

Answer: attribution. The next technical decision can be justified before emitter identity has been established. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why this term is required: “attribution” completes the stated technical proposition.

Question context: A useful finding may support continued measurement without supporting source _____

Basis and qualification: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-FIB-089. A calibrated absence claim applies to the defined event _____ that was tested.

Answer: class. Other waveforms, durations, levels, or times can remain outside the demonstrated observation. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why this term is required: “class” completes the stated technical proposition.

Question context: A calibrated absence claim applies to the defined event _____ that was tested

Basis and qualification: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-FIB-090. Identifying a receiver artifact does not necessarily identify every internal coupling _____.

Answer: path. A bounded diagnostic result can be useful while detailed mechanism localization remains incomplete. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

Why this term is required: “path” completes the stated technical proposition.

Question context: Identifying a receiver artifact does not necessarily identify every internal coupling _____

Basis and qualification: Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C01-FIB-091. The unexpected 433.920 MHz component in the chapter's case appeared only with the automatic _____ enabled.

Answer: preamplifier. Its dependence on that setting motivates a configuration-specific artifact or overload challenge. Source: §1.13 Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 99)

Why this term is required: “preamplifier” completes the stated technical proposition.

Question context: The unexpected 433.920 MHz component in the chapter's case appeared only with the automatic _____ enabled

Basis and qualification: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

Review: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

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V011-C01-FIB-092. The second receiver's nondetection cannot exclude an external contribution without comparable sensitivity and observation _____.

Answer: interval. A difference in opportunity to observe the event can explain the negative result independently of its source. Source: §1.13 Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation (p. 99)

Why this term is required: “interval” completes the stated technical proposition.

Question context: The second receiver's nondetection cannot exclude an external contribution without comparable sensitivity and observation _____

Basis and qualification: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

Review: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

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V011-C01-FIB-093. Comparing an indication at the receiver connector with an antenna-terminal value requires a supported _____ between the planes.

Answer: correction. The quantities occupy different boundaries and cannot be equated merely because both are expressed as power levels. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why this term is required: “correction” completes the stated technical proposition.

Question context: Comparing an indication at the receiver connector with an antenna-terminal value requires a supported _____ between the planes

Basis and qualification: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Equation 2. Corrected input power.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Equation 2. Corrected input power.

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V011-C01-FIB-094. In Equation 1, the recorded output is denoted by _____.

Answer: y \(t \). The symbol represents the output after the configured receiver transformation and internal contribution. Source: Equation 1. Configured receiver-chain representation (p. 71)

Why this term is required: “” completes the stated technical proposition.

Question context: In Equation 1, the recorded output is denoted by _____

Basis and qualification: Chapter 1 — Equation 1. Configured receiver-chain representation.

Review: Chapter 1 — Equation 1. Configured receiver-chain representation.

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V011-C01-FIB-095. In Equation 1, the input to the configured transformation is denoted by _____.

Answer: x \(t \). The boundary of that input must be stated before the transformation and resulting evidence can be interpreted. Source: Equation 1. Configured receiver-chain representation (p. 71)

Why this term is required: “” completes the stated technical proposition.

Question context: In Equation 1, the input to the configured transformation is denoted by _____

Basis and qualification: Chapter 1 — Equation 1. Configured receiver-chain representation.

Review: Chapter 1 — Equation 1. Configured receiver-chain representation.

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V011-C01-FIB-096. In Equation 1, the configured receiver transformation is denoted by _____.

Answer: H. The symbol can represent several physical and computational operations and is not automatically a linear time-invariant operator. Source: Equation 1. Configured receiver-chain representation (p. 71)

Why this term is required: “” completes the stated technical proposition.

Question context: In Equation 1, the configured receiver transformation is denoted by _____

Basis and qualification: Chapter 1 — Equation 1. Configured receiver-chain representation.

Review: Chapter 1 — Equation 1. Configured receiver-chain representation.

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V011-C01-FIB-097. In Equation 1, internally generated noise and artifacts are represented by _____.

Answer: n_{int} \(t \). That internal contribution distinguishes observed output from an assumption that every component arrived from the environment. Source: Equation 1. Configured receiver-chain representation (p. 71)

Why this term is required: “” completes the stated technical proposition.

Question context: In Equation 1, internally generated noise and artifacts are represented by _____

Basis and qualification: Chapter 1 — Equation 1. Configured receiver-chain representation.

Review: Chapter 1 — Equation 1. Configured receiver-chain representation.

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V011-C01-FIB-098. The declared domain of a local linear model includes its operating state and working _____.

Answer: range. A useful approximation needs boundaries that exclude invalidating overload or adaptive behavior where applicable. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “range” completes the stated technical proposition.

Question context: The declared domain of a local linear model includes its operating state and working _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Equation 1. Configured receiver-chain representation.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Equation 1. Configured receiver-chain representation.

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V011-C01-FIB-099. An observation record should connect what was commanded, what state was accepted, and what was _____.

Answer: captured. These complementary records establish which transformation actually generated the retained data. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

Why this term is required: “captured” completes the stated technical proposition.

Question context: An observation record should connect what was commanded, what state was accepted, and what was _____

Basis and qualification: Chapter 1 — Treat configuration changes as changes in the measurement law.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-FIB-100. The final conclusion should remain traceable to the actual configuration and declared reference _____.

Answer: plane. That connection prevents a numerical result or observation from being given a broader physical meaning than its evidence supports. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

Why this term is required: “plane” completes the stated technical proposition.

Question context: The final conclusion should remain traceable to the actual configuration and declared reference _____

Basis and qualification: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Frame a bounded finding from the completed observation.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C01-ESSAY-001. Develop a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and analysis script. Explain why the instrument enclosure is an inadequate boundary.

- Opening: Present a thesis that answers this precise question: Develop a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and analysis script. Identify which evidence would falsify the proposed conclusion Source: §1.1 Receiver as a Measurement System (p. 53)
- Core terminology and scope: Define defensible, remote, digitizer in the question's particular technical setting; explain how script, enclosure, inadequate differ if that distinction would change the analysis of "Develop a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and analysis script" Source: §1.1 Receiver as a Measurement System (p. 53)
- Problem statement and purpose: Frame the actual measurement or decision in the question. A strong answer follows the physical and computational transformations to the reported result Source: §1.1 Receiver as a Measurement System (p. 53)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and… to the claimed result, following "Reference Planes and Configuration Identity";

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name the intermediate states and measurable outputs Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and…. It identifies input and output planes, path loss and gain, filtering, reference and clock states, digitization, and processing Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.5. Retain separate admissible results when the settled state is unknown” that resolves the question about a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and…; derive the relevant result with units and stated validity conditions Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and…. It explains which accessories or software choices could change the measurand, rather than merely listing equipment Source: §1.1 Receiver as a Measurement System (p. 53)
- Worked application or illustrative case: Build a worked example of “a defensible system boundary for a receiver connected to an antenna,

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remote amplifier, switching path, digitizer, computer, and…", addressing this associated condition: Explain why the instrument enclosure is an inadequate boundary. A strong answer follows the physical and computational transformations to the reported result Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and…". Using "Application 1A.5. Retain separate admissible results when the settled state is unknown", specify a discriminator and the result expected under each explanation Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and…, including the effect of missing measurements and inconsistent operating conditions Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)
- Scholarly synthesis and implications: Explain what the result about a defensible system boundary for a receiver connected to an antenna, remote amplifier, switching path, digitizer, computer, and… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.1 Receiver as a Measurement System (p. 53)
- Closing: Conclude by answering "Develop a defensible system boundary for a receiver connected to an antenna, remote amplifier,

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switching path, digitizer, computer, and analysis script" using only the demonstrated evidence; state the remaining decisive verification step Source: §1.1 Receiver as a Measurement System (p. 53)

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V011-C01-ESSAY-002. Explain how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited. Address both initial settings and subsequent handling.

- Opening: Present a thesis that answers this precise question: Explain how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited. Address both initial settings and…. Identify which evidence would falsify the proposed conclusion Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Core terminology and scope: Define authorized, occupancy, translated in the question's particular technical setting; explain how settings, subsequent, handling differ if that distinction would change the analysis of "Explain how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited. Address both initial settings and…" Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the technical objective and permitted observations before choosing receiver modes Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited to the claimed result, following "Define the measurement before choosing the receiver mode"; name the intermediate states and measurable

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outputs Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited. Explain how frequency ranges, duration, channels, detector settings, recording, and metadata implement that objective Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Observation, Classification, Attribution, and Content Recovery” that resolves the question about how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited; derive the relevant result with units and stated validity conditions Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited. Discuss incidental information, access, retention, deletion, and stop conditions without inventing a universal legal rule Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Worked application or illustrative case: Build a worked example of “how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is

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prohibited", addressing this associated condition: Address both initial settings and subsequent handling. Define the technical objective and permitted observations before choosing receiver modes Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited". Using "Observation, Classification, Attribution, and Content Recovery", specify a discriminator and the result expected under each explanation Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited, including the effect of missing measurements and inconsistent operating conditions Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Scholarly synthesis and implications: Explain what the result about how an authorized occupancy survey can be translated into an acquisition plan when communications-content recovery is prohibited authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Closing: Conclude by answering "Explain how an authorized occupancy survey can be translated into an acquisition plan when

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communications-content recovery is prohibited. Address both initial settings and…" using only the demonstrated evidence; state the remaining decisive verification step Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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V011-C01-ESSAY-003. Compare detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey. State the additional evidence needed to move between propositions.

- Opening: Present a thesis that answers this precise question: Compare detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey. Identify which evidence would falsify the proposed conclusion Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Core terminology and scope: Define classification, attribution, content in the question's particular technical setting; explain how hypothetical, lawful, propositions differ if that distinction would change the analysis of "Compare detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey" Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The answer should begin with a declared detection criterion and then distinguish waveform characterization, a supported link to a physical emitter, and reconstruction of carried information Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey to the

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claimed result, following “Mission Authority and Collection Boundaries”; name the intermediate states and measurable outputs Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey. It should show that success at one stage does not establish the next Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.5. Retain separate admissible results when the settled state is unknown” that resolves the question about detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey; derive the relevant result with units and stated validity conditions Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)
- Evidence and method: Specify the native observations, control records and calculations that would resolve detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey. Suitable examples include a stable peak, a modulation-family label, an identifier, and a controlled device-state comparison Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Worked application or illustrative case: Build a worked example of “detection, classification, attribution, and content recovery using

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one hypothetical component observed during a lawful survey", addressing this associated condition: State the additional evidence needed to move between propositions. The answer should begin with a declared detection criterion and then distinguish waveform characterization, a supported link to a physical emitter,... Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey". Using "Application 1A.5. Retain separate admissible results when the settled state is unknown", specify a discriminator and the result expected under each explanation Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey, including the effect of missing measurements and inconsistent operating conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Scholarly synthesis and implications: Explain what the result about detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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- Closing: Conclude by answering “Compare detection, classification, attribution, and content recovery using one hypothetical component observed during a lawful survey” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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V011-C01-ESSAY-004. Analyze why a power value cannot be interpreted adequately without its reference plane. Include a backward correction through a known amplifier and passive path.

- Opening: Present a thesis that answers this precise question: Analyze why a power value cannot be interpreted adequately without its reference plane. Include a backward correction through a known amplifier and passive path. Identify which evidence would falsify the proposed conclusion Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Core terminology and scope: Define interpreted, adequately, Include in the question's particular technical setting; explain how backward, amplifier, passive differ if that distinction would change the analysis of "Analyze why a power value cannot be interpreted adequately without its reference plane. Include a backward correction through a known amplifier and passive path" Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the indication, desired upstream plane, gain, loss, and compatible calibration state Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a power value cannot be interpreted adequately without its reference plane to the claimed result, following "Application 1A.1. Complete a reference-plane correction in both directions"; name the

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intermediate states and measurable outputs Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a power value cannot be interpreted adequately without its reference plane. Apply Equation 2 with correct signs and retain the original indication and each correction Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.2. Remove a software offset before applying the remaining correction” that resolves the question about why a power value cannot be interpreted adequately without its reference plane; derive the relevant result with units and stated validity conditions Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a power value cannot be interpreted adequately without its reference plane. Explain why the scalar result does not automatically become field strength or source power Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Worked application or illustrative case: Build a worked example of “why a power value cannot be interpreted adequately without its reference plane”, addressing this associated condition: Include a backward correction through a known amplifier and passive path. State the indication, desired upstream plane, gain, loss, and

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compatible calibration state Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a power value cannot be interpreted adequately without its reference plane”. Using “Application 1A.2. Remove a software offset before applying the remaining correction”, specify a discriminator and the result expected under each explanation Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a power value cannot be interpreted adequately without its reference plane, including the effect of missing measurements and inconsistent operating conditions Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Scholarly synthesis and implications: Explain what the result about why a power value cannot be interpreted adequately without its reference plane authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Closing: Conclude by answering “Analyze why a power value cannot be interpreted adequately without its reference plane. Include a backward correction through a known amplifier and passive path” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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V011-C01-ESSAY-005. Explain how commanded configuration, accepted state, and observed data can disagree. Propose an evidence record that permits the disagreement to be investigated.

- Opening: Present a thesis that answers this precise question: Explain how commanded configuration, accepted state, and observed data can disagree. Propose an evidence record that permits the disagreement to be investigated. Identify which evidence would falsify the proposed conclusion Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Core terminology and scope: Define commanded, accepted, disagree in the question's particular technical setting; explain how permits, disagreement, investigated differ if that distinction would change the analysis of "Explain how commanded configuration, accepted state, and observed data can disagree. Propose an evidence record that permits the disagreement to be investigated" Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish the setup request from the state that actually governed acquisition Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how commanded configuration, accepted state, and observed data can disagree to the claimed result, following "Application 1A.10. Separate a valid corrected level from an unobserved transition interval"; name the

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intermediate states and measurable outputs Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how commanded configuration, accepted state, and observed data can disagree. Discuss rejection, transition, settling, and automatic changes Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Treat configuration changes as changes in the measurement law” that resolves the question about how commanded configuration, accepted state, and observed data can disagree; derive the relevant result with units and stated validity conditions Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how commanded configuration, accepted state, and observed data can disagree. Link commands, status events, and data intervals through the declared time basis Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Worked application or illustrative case: Build a worked example of “how commanded configuration, accepted state, and observed data can disagree”, addressing this associated condition: Propose an evidence record that permits the disagreement to be investigated. Distinguish the setup request from the state that actually governed

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acquisition Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how commanded configuration, accepted state, and observed data can disagree”. Using “Treat configuration changes as changes in the measurement law”, specify a discriminator and the result expected under each explanation Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how commanded configuration, accepted state, and observed data can disagree, including the effect of missing measurements and inconsistent operating conditions Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Scholarly synthesis and implications: Explain what the result about how commanded configuration, accepted state, and observed data can disagree authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Closing: Conclude by answering “Explain how commanded configuration, accepted state, and observed data can disagree. Propose an evidence record that permits the disagreement to be investigated” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.8 Evidence Record and Closing Verification (p. 69)

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V011-C01-ESSAY-006. Construct a complete measurement definition for a reported component level and contrast it with a definition for an event time. Explain the consequences for acquisition and interpretation.

- Opening: Present a thesis that answers this precise question: Construct a complete measurement definition for a reported component level and contrast it with a definition for an event time. Explain the consequences for acquisition and…. Identify which evidence would falsify the proposed conclusion Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Core terminology and scope: Define Construct, definition, reported in the question's particular technical setting; explain how contrast, consequences, interpretation differ if that distinction would change the analysis of "Construct a complete measurement definition for a reported component level and contrast it with a definition for an event time. Explain the consequences for acquisition and…" Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Problem statement and purpose: Frame the actual measurement or decision in the question. For each target, specify plane, frequency and time intervals, state, estimator, decision criterion, and relevant validity conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a complete measurement definition for a reported component level and contrast it with a definition for an event time to the claimed result, following "Evidence Record and Closing Verification"; name the

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intermediate states and measurable outputs Source: §1.8 Evidence Record and Closing Verification (p. 69)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a complete measurement definition for a reported component level and contrast it with a definition for an event time. The amplitude definition should explain which energy and detector operation contribute Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Frame a bounded finding from the completed observation” that resolves the question about a complete measurement definition for a reported component level and contrast it with a definition for an event time; derive the relevant result with units and stated validity conditions Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a complete measurement definition for a reported component level and contrast it with a definition for an event time. The timing definition should distinguish sample aperture, trigger event, and software receipt as possible timestamp meanings Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Worked application or illustrative case: Build a worked example of “a complete measurement definition for a reported component level and contrast it with a definition for an event time”, addressing this associated condition: Explain the consequences for acquisition and

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interpretation. For each target, specify plane, frequency and time intervals, state, estimator, decision criterion, and relevant validity conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "a complete measurement definition for a reported component level and contrast it with a definition for an event time". Using "Frame a bounded finding from the completed observation", specify a discriminator and the result expected under each explanation Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a complete measurement definition for a reported component level and contrast it with a definition for an event time, including the effect of missing measurements and inconsistent operating conditions Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Scholarly synthesis and implications: Explain what the result about a complete measurement definition for a reported component level and contrast it with a definition for an event time authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Closing: Conclude by answering "Construct a complete measurement definition for a reported component level and contrast it with a definition for an event time. Explain the consequences for acquisition and…" using only the demonstrated

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evidence; state the remaining decisive verification step Source: §1.5

Define the measurement before choosing the receiver mode (p. 62)

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V011-C01-ESSAY-007. Discuss Equation 1 as a general receiver-chain representation. Explain why its notation does not establish that the receiver is linear and time invariant.

- Opening: Present a thesis that answers this precise question: Discuss Equation 1 as a general receiver-chain representation. Explain why its notation does not establish that the receiver is linear and time invariant. Identify which evidence would falsify the proposed conclusion Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Core terminology and scope: Define Equation, general, representation in the question's particular technical setting; explain how notation, linear, invariant differ if that distinction would change the analysis of "Discuss Equation 1 as a general receiver-chain representation. Explain why its notation does not establish that the receiver is linear and time invariant" Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the input, output, configured transformation, and internal contribution Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Equation 1 as a general receiver-chain representation to the claimed result, following "Model 1A: configured transfer, correction and recoverability"; name the intermediate states and measurable

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outputs Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Equation 1 as a general receiver-chain representation. Explain that conversion, sampling, memory, adaptive control, limiting, and software can belong to the transformation Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Frame a bounded finding from the completed observation” that resolves the question about Equation 1 as a general receiver-chain representation; derive the relevant result with units and stated validity conditions Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Equation 1 as a general receiver-chain representation. A strong answer distinguishes this boundary description from narrower models whose operating domains must be demonstrated Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Worked application or illustrative case: Build a worked example of “Equation 1 as a general receiver-chain representation”, addressing this associated condition: Explain why its notation does not establish that the receiver is linear and time invariant. Identify the input, output, configured transformation, and internal contribution Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Equation 1 as a general receiver-chain representation”. Using “Frame a bounded finding from the completed observation”, specify a discriminator and the result expected under each explanation Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Equation 1 as a general receiver-chain representation, including the effect of missing measurements and inconsistent operating conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Scholarly synthesis and implications: Explain what the result about Equation 1 as a general receiver-chain representation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Closing: Conclude by answering “Discuss Equation 1 as a general receiver-chain representation. Explain why its notation does not establish that the receiver is linear and time invariant” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

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V011-C01-ESSAY-008. Evaluate the evidential consequences of retaining only a magnitude spectrum after a complex sample capture. Distinguish useful remaining analysis from unsupported reconstruction.

- Opening: Present a thesis that answers this precise question: Evaluate the evidential consequences of retaining only a magnitude spectrum after a complex sample capture. Distinguish useful remaining analysis from unsupported.... Identify which evidence would falsify the proposed conclusion Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Core terminology and scope: Define evidential, consequences, retaining in the question's particular technical setting; explain how remaining, unsupported, reconstruction differ if that distinction would change the analysis of "Evaluate the evidential consequences of retaining only a magnitude spectrum after a complex sample capture. Distinguish useful remaining analysis from unsupported..." Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the representation retained and the operations that produced it Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the evidential consequences of retaining only a magnitude spectrum after a complex sample capture to the claimed result, following "Mission Authority and Collection Boundaries"; name the intermediate states

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and measurable outputs Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the evidential consequences of retaining only a magnitude spectrum after a complex sample capture. Explain that magnitude, clipping, sampling loss, and other irreversible transformations can remove information needed for later questions Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.2. Remove a software offset before applying the remaining correction” that resolves the question about the evidential consequences of retaining only a magnitude spectrum after a complex sample capture; derive the relevant result with units and stated validity conditions Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the evidential consequences of retaining only a magnitude spectrum after a complex sample capture. The answer should not claim that every derived spectrum is useless Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Worked application or illustrative case: Build a worked example of “the evidential consequences of retaining only a magnitude spectrum after a complex sample capture”, addressing this associated condition: Distinguish useful remaining analysis from

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unsupported reconstruction. Identify the representation retained and the operations that produced it Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the evidential consequences of retaining only a magnitude spectrum after a complex sample capture”. Using “Application 1A.2. Remove a software offset before applying the remaining correction”, specify a discriminator and the result expected under each explanation Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the evidential consequences of retaining only a magnitude spectrum after a complex sample capture, including the effect of missing measurements and inconsistent operating conditions Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)
- Scholarly synthesis and implications: Explain what the result about the evidential consequences of retaining only a magnitude spectrum after a complex sample capture authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Closing: Conclude by answering “Evaluate the evidential consequences of retaining only a magnitude spectrum after a complex sample capture. Distinguish useful remaining analysis from unsupported…” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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V011-C01-ESSAY-009. Design a configuration-transition record for a survey that changes preselection, gain, and sample rate. Explain how the record controls later comparison and averaging.

- Opening: Present a thesis that answers this precise question: Design a configuration-transition record for a survey that changes preselection, gain, and sample rate. Explain how the record controls later comparison and averaging. Identify which evidence would falsify the proposed conclusion Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Core terminology and scope: Define Design, survey, preselection in the question's particular technical setting; explain how controls, later, averaging differ if that distinction would change the analysis of "Design a configuration-transition record for a survey that changes preselection, gain, and sample rate. Explain how the record controls later comparison and averaging" Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Describe the requested changes, accepted states, transition and settling intervals, and samples assigned to each valid state Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a configuration-transition record for a survey that changes preselection, gain, and sample rate to the claimed result, following "Treat configuration changes as changes in the measurement law"; name the

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intermediate states and measurable outputs Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a configuration-transition record for a survey that changes preselection, gain, and sample rate. Explain the different consequences of preselection, gain, and rate for transfer, blockers, aliasing, timing, and throughput Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.5. Retain separate admissible results when the settled state is unknown” that resolves the question about a configuration-transition record for a survey that changes preselection, gain, and sample rate; derive the relevant result with units and stated validity conditions Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a configuration-transition record for a survey that changes preselection, gain, and sample rate. State when separate corrections are necessary and what would justify combining intervals Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Worked application or illustrative case: Build a worked example of “a configuration-transition record for a survey that changes preselection, gain, and sample rate”, addressing this associated condition: Explain how the record controls later comparison and

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averaging. Describe the requested changes, accepted states, transition and settling intervals, and samples assigned to each valid state Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a configuration-transition record for a survey that changes preselection, gain, and sample rate”. Using “Application 1A.5. Retain separate admissible results when the settled state is unknown”, specify a discriminator and the result expected under each explanation Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a configuration-transition record for a survey that changes preselection, gain, and sample rate, including the effect of missing measurements and inconsistent operating conditions Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)
- Scholarly synthesis and implications: Explain what the result about a configuration-transition record for a survey that changes preselection, gain, and sample rate authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Closing: Conclude by answering “Design a configuration-transition record for a survey that changes preselection, gain, and sample rate. Explain how the record controls later comparison and

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averaging" using only the demonstrated evidence; state the remaining decisive verification step Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

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V011-C01-ESSAY-010. Assess the statement that two agreeing receivers prove the component is external. Use shared and independent error paths to develop your argument.

- Opening: Present a thesis that answers this precise question: Assess the statement that two agreeing receivers prove the component is external. Use shared and independent error paths to develop your argument. Identify which evidence would falsify the proposed conclusion Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Core terminology and scope: Define statement, agreeing, receivers in the question's particular technical setting; explain how prove, shared, argument differ if that distinction would change the analysis of "Assess the statement that two agreeing receivers prove the component is external. Use shared and independent error paths to develop your argument" Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain why agreement can arise from a shared input path, reference, clock, or processing assumption Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the statement that two agreeing receivers prove the component is external to the claimed result, following "Application 1A.4. Use an attenuation prediction as a conditional challenge"; name the intermediate states

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and measurable outputs Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the statement that two agreeing receivers prove the component is external. Identify changes that could alter relevant errors while preserving the capability to observe the component Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Evidence Record and Closing Verification” that resolves the question about the statement that two agreeing receivers prove the component is external; derive the relevant result with units and stated validity conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the statement that two agreeing receivers prove the component is external. Discuss the limits of a comparator's nondetection and the need to match useful sensitivity, coverage, reference plane, and time opportunity Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Worked application or illustrative case: Build a worked example of “the statement that two agreeing receivers prove the component is external”, addressing this associated condition: Use shared and independent error paths to develop your argument. Explain why agreement can arise from a shared input path, reference, clock, or

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processing assumption Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the statement that two agreeing receivers prove the component is external”. Using “Evidence Record and Closing Verification”, specify a discriminator and the result expected under each explanation Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the statement that two agreeing receivers prove the component is external, including the effect of missing measurements and inconsistent operating conditions Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Scholarly synthesis and implications: Explain what the result about the statement that two agreeing receivers prove the component is external authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Closing: Conclude by answering “Assess the statement that two agreeing receivers prove the component is external. Use shared and independent error paths to develop your argument” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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V011-C01-ESSAY-011. Explain how a closing reference check should be designed and reported after an important observation. State what the check cannot establish automatically.

- Opening: Present a thesis that answers this precise question: Explain how a closing reference check should be designed and reported after an important observation. State what the check cannot establish automatically. Identify which evidence would falsify the proposed conclusion Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Core terminology and scope: Define closing, check, designed in the question's particular technical setting; explain how reported, important, automatically differ if that distinction would change the analysis of "Explain how a closing reference check should be designed and reported after an important observation. State what the check cannot establish automatically" Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Tie the known reference to the functions needed for the original claim, including the path, scale, detector, recording, and export where applicable Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how a closing reference check should be designed and reported after an important observation to the claimed result, following "Define the measurement before choosing the receiver mode"; name the

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intermediate states and measurable outputs Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how a closing reference check should be designed and reported after an important observation. Identify which states and functions were exercised and which remained untested Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.2. Remove a software offset before applying the remaining correction” that resolves the question about how a closing reference check should be designed and reported after an important observation; derive the relevant result with units and stated validity conditions Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how a closing reference check should be designed and reported after an important observation. Discuss the time relation to the field observation and the meaning of a pass or failure Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Worked application or illustrative case: Build a worked example of “how a closing reference check should be designed and reported after an important observation”, addressing this associated condition: State what the check cannot establish automatically. Tie the known reference to the functions needed for the original claim,

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including the path, scale, detector, recording, and export where applicable Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how a closing reference check should be designed and reported after an important observation”. Using “Application 1A.2. Remove a software offset before applying the remaining correction”, specify a discriminator and the result expected under each explanation Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how a closing reference check should be designed and reported after an important observation, including the effect of missing measurements and inconsistent operating conditions Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Scholarly synthesis and implications: Explain what the result about how a closing reference check should be designed and reported after an important observation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Closing: Conclude by answering “Explain how a closing reference check should be designed and reported after an important observation. State what the check cannot establish automatically” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.8 Evidence Record and Closing Verification (p. 69)

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V011-C01-ESSAY-012. Examine the chapter's hypothetical 433.920 MHz case. Propose a sequence of follow-up observations that would discriminate an external component from a configuration-dependent artifact.

- Opening: Present a thesis that answers this precise question: Examine the chapter's hypothetical 433.920 MHz case. Propose a sequence of follow-up observations that would discriminate an external component from a configuration-dependent.... Identify which evidence would falsify the proposed conclusion Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Core terminology and scope: Define Examine, hypothetical, sequence in the question's particular technical setting; explain how observations, discriminate, artifact differ if that distinction would change the analysis of "Examine the chapter's hypothetical 433.920 MHz case. Propose a sequence of follow-up observations that would discriminate an external component from a configuration-dependent..." Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin with the stated preamplifier dependence, attenuation behavior, and comparator nondetection Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Examine the chapter's hypothetical 433.920 MHz case to the claimed result, following "Assurance cases for receiver-derived evidence under changing system identity"; name the intermediate states and

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measurable outputs Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Examine the chapter's hypothetical 433.920 MHz case. Identify competing explanations and predict what each follow-up change would test Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Frame a bounded finding from the completed observation” that resolves the question about Examine the chapter's hypothetical 433.920 MHz case; derive the relevant result with units and stated validity conditions Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Examine the chapter's hypothetical 433.920 MHz case. Preserve sensitivity, physical-frequency coverage, relevant reference planes, and observation intervals while changing one useful causal condition Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Worked application or illustrative case: Build a worked example of “Examine the chapter's hypothetical 433.920 MHz case”, addressing this associated condition: Propose a sequence of follow-up observations that would discriminate an external component from a.... Begin with the stated preamplifier dependence, attenuation behavior, and comparator nondetection Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Examine the chapter's hypothetical 433.920 MHz case”. Using “Frame a bounded finding from the completed observation”, specify a discriminator and the result expected under each explanation Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Examine the chapter's hypothetical 433.920 MHz case, including the effect of missing measurements and inconsistent operating conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Scholarly synthesis and implications: Explain what the result about Examine the chapter's hypothetical 433.920 MHz case authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Closing: Conclude by answering “Examine the chapter's hypothetical 433.920 MHz case. Propose a sequence of follow-up observations that would discriminate an external component from a configuration-dependent…” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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V011-C01-ESSAY-013. Explain why an earlier dwell detection and a later wide-scan nondetection need not contradict each other. Develop a reconciliation procedure.

- Opening: Present a thesis that answers this precise question: Explain why an earlier dwell detection and a later wide-scan nondetection need not contradict each other. Develop a reconciliation procedure. Identify which evidence would falsify the proposed conclusion Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Core terminology and scope: Define earlier, dwell, nondetection in the question's particular technical setting; explain how need, contradict, procedure differ if that distinction would change the analysis of "Explain why an earlier dwell detection and a later wide-scan nondetection need not contradict each other. Develop a reconciliation procedure" Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compare the two measurement definitions, including time opportunity, instantaneous frequency coverage, detector behavior, averaging, state, blockers, and validity Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why an earlier dwell detection and a later wide-scan nondetection need not contradict each other to the claimed result, following "Define the measurement before choosing the receiver mode"; name the

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intermediate states and measurable outputs Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why an earlier dwell detection and a later wide-scan nondetection need not contradict each other. Determine whether the later acquisition could have observed the earlier event class Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Assurance cases for receiver-derived evidence under changing system identity” that resolves the question about why an earlier dwell detection and a later wide-scan nondetection need not contradict each other; derive the relevant result with units and stated validity conditions Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why an earlier dwell detection and a later wide-scan nondetection need not contradict each other. Explain how differences in definitions can be resolved through matched or otherwise defensible observations Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Worked application or illustrative case: Build a worked example of “why an earlier dwell detection and a later wide-scan nondetection need not contradict each other”, addressing this associated condition: Develop a reconciliation procedure. Compare the two measurement definitions, including time opportunity, instantaneous

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frequency coverage, detector behavior, averaging, state, blockers, and validity Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why an earlier dwell detection and a later wide-scan nondetection need not contradict each other”. Using “Assurance cases for receiver-derived evidence under changing system identity”, specify a discriminator and the result expected under each explanation Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why an earlier dwell detection and a later wide-scan nondetection need not contradict each other, including the effect of missing measurements and inconsistent operating conditions Source: §1.1 Receiver as a Measurement System (p. 53)
- Scholarly synthesis and implications: Explain what the result about why an earlier dwell detection and a later wide-scan nondetection need not contradict each other authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Closing: Conclude by answering “Explain why an earlier dwell detection and a later wide-scan nondetection need not contradict each other. Develop a reconciliation procedure” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-ESSAY-014. Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation. Address relevance, limitations, and later review.

- Opening: Present a thesis that answers this precise question: Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation. Address relevance, limitations, and later review. Identify which evidence would falsify the proposed conclusion Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Core terminology and scope: Define policy, retaining, unsuccessful in the question's particular technical setting; explain how investigation, limitations, review differ if that distinction would change the analysis of "Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation. Address relevance, limitations, and later review" Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain what each attempted test was intended to discriminate and whether its required capability was demonstrated Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation to the claimed result, following "Assurance cases for receiver-derived evidence under

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changing system identity"; name the intermediate states and measurable outputs Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation. Record the conditions, outcome, failure modes, and any missing coverage Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Define the measurement before choosing the receiver mode" that resolves the question about Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation; derive the relevant result with units and stated validity conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation. Distinguish an instrument failure from a valid nondetection and a nondetection from universal absence Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Worked application or illustrative case: Build a worked example of "Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation", addressing this associated condition: Address relevance, limitations, and later

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review. Explain what each attempted test was intended to discriminate and whether its required capability was demonstrated Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation”. Using “Define the measurement before choosing the receiver mode”, specify a discriminator and the result expected under each explanation Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation, including the effect of missing measurements and inconsistent operating conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Scholarly synthesis and implications: Explain what the result about Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Closing: Conclude by answering “Prepare a reasoned policy for retaining unsuccessful tests and negative observations in a receiver investigation. Address relevance, limitations, and later review” using only the demonstrated evidence; state the remaining decisive

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verification step Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-ESSAY-015. Analyze a report that preserves only the final corrected power and a screenshot. Identify what a reviewer cannot reconstruct and propose proportionate remedies.

- Opening: Present a thesis that answers this precise question: Analyze a report that preserves only the final corrected power and a screenshot. Identify what a reviewer cannot reconstruct and propose proportionate remedies. Identify which evidence would falsify the proposed conclusion Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Core terminology and scope: Define preserves, final, corrected in the question's particular technical setting; explain how screenshot, reviewer, reconstruct differ if that distinction would change the analysis of "Analyze a report that preserves only the final corrected power and a screenshot. Identify what a reviewer cannot reconstruct and propose proportionate remedies" Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Discuss the missing original indication, individual corrections, planes, state, native data, timing, and processing lineage as applicable Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a report that preserves only the final corrected power and a screenshot to the claimed result, following "Evidence Record and Closing Verification";

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name the intermediate states and measurable outputs Source: §1.8 Evidence Record and Closing Verification (p. 69)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a report that preserves only the final corrected power and a screenshot. Explain how their absence can conceal double-counted loss, wrong gain state, detector differences, or overload Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Reference Planes and Configuration Identity” that resolves the question about a report that preserves only the final corrected power and a screenshot; derive the relevant result with units and stated validity conditions Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a report that preserves only the final corrected power and a screenshot. Propose a record adequate for the actual measurement rather than an unlimited checklist Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Worked application or illustrative case: Build a worked example of “a report that preserves only the final corrected power and a screenshot”, addressing this associated condition: Identify what a reviewer cannot reconstruct and propose proportionate remedies. Discuss the missing original indication, individual corrections, planes, state, native data, timing, and processing lineage as applicable Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a report that preserves only the final corrected power and a screenshot”. Using “Reference Planes and Configuration Identity”, specify a discriminator and the result expected under each explanation Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a report that preserves only the final corrected power and a screenshot, including the effect of missing measurements and inconsistent operating conditions Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)
- Scholarly synthesis and implications: Explain what the result about a report that preserves only the final corrected power and a screenshot authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Closing: Conclude by answering “Analyze a report that preserves only the final corrected power and a screenshot. Identify what a reviewer cannot reconstruct and propose proportionate remedies” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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V011-C01-ESSAY-016. Discuss why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence. Use discovery, calibrated amplitude, and coherent phase as separate objectives.

- Opening: Present a thesis that answers this precise question: Discuss why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence. Identify which evidence would falsify the proposed conclusion Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Core terminology and scope: Define selecting, mode, produce in the question's particular technical setting; explain how technically, discovery, coherent differ if that distinction would change the analysis of "Discuss why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence" Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain that each objective requires a different scope and transformation Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence to the claimed result, following "Frame a bounded finding from the completed observation"; name the intermediate states and measurable outputs Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence. A wide scan may locate a component without supporting its calibrated level, while a narrow coherent capture may support phase without broad coverage Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Assurance cases for receiver-derived evidence under changing system identity” that resolves the question about why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence; derive the relevant result with units and stated validity conditions Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence. Identify the plane, intervals, state, estimator, and decision criteria for each Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Worked application or illustrative case: Build a worked example of “why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence”, addressing this associated condition: Use discovery, calibrated amplitude, and coherent phase as separate objectives. Explain that each objective

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requires a different scope and transformation Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence”. Using “Assurance cases for receiver-derived evidence under changing system identity”, specify a discriminator and the result expected under each explanation Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence, including the effect of missing measurements and inconsistent operating conditions Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Scholarly synthesis and implications: Explain what the result about why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Closing: Conclude by answering “Discuss why selecting a receiver mode before defining the question can produce technically impressive but unhelpful evidence” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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V011-C01-ESSAY-017. Explain how passive accessories and installed geometry enter the interpretation of a receiver result. Give a hypothetical example in which an apparently minor change matters.

- Opening: Present a thesis that answers this precise question: Explain how passive accessories and installed geometry enter the interpretation of a receiver result. Give a hypothetical example in which an apparently minor change matters. Identify which evidence would falsify the proposed conclusion Source: §1.1 Receiver as a Measurement System (p. 53)
- Core terminology and scope: Define passive, accessories, installed in the question's particular technical setting; explain how geometry, enter, matters differ if that distinction would change the analysis of "Explain how passive accessories and installed geometry enter the interpretation of a receiver result. Give a hypothetical example in which an apparently minor change matters" Source: §1.1 Receiver as a Measurement System (p. 53)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Consider cable loss and route, adapters, antenna orientation, polarization, external filtering, mismatch, and common-mode paths Source: §1.1 Receiver as a Measurement System (p. 53)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how passive accessories and installed geometry enter the interpretation of a receiver result to the claimed result, following "Evidence Record and Closing Verification"; name the intermediate states and measurable outputs Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how passive accessories and installed geometry enter the interpretation of a receiver result. Explain how an accessory or movement can change the desired transfer or an artifact mechanism Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.4. Use an attenuation prediction as a conditional challenge” that resolves the question about how passive accessories and installed geometry enter the interpretation of a receiver result; derive the relevant result with units and stated validity conditions Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how passive accessories and installed geometry enter the interpretation of a receiver result. The example should preserve the distinction between observed change and assumed cause Source: §1.1 Receiver as a Measurement System (p. 53)
- Worked application or illustrative case: Build a worked example of “how passive accessories and installed geometry enter the interpretation of a receiver result”, addressing this associated condition: Give a hypothetical example in which an apparently minor change matters. Consider cable loss and route, adapters, antenna orientation, polarization, external filtering, mismatch, and common-mode paths Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “how passive accessories and installed geometry enter the interpretation of a receiver result”. Using “Application 1A.4. Use an attenuation prediction as a conditional challenge”, specify a discriminator and the result expected under each explanation Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how passive accessories and installed geometry enter the interpretation of a receiver result, including the effect of missing measurements and inconsistent operating conditions Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Scholarly synthesis and implications: Explain what the result about how passive accessories and installed geometry enter the interpretation of a receiver result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.1 Receiver as a Measurement System (p. 53)
- Closing: Conclude by answering “Explain how passive accessories and installed geometry enter the interpretation of a receiver result. Give a hypothetical example in which an apparently minor change matters” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.1 Receiver as a Measurement System (p. 53)

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V011-C01-ESSAY-018. Develop an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure. Explain why these conditions require different responses.

- Opening: Present a thesis that answers this precise question: Develop an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure. Explain why these conditions require different.... Identify which evidence would falsify the proposed conclusion Source: §1.9 Operational Decision Discipline (p. 70)
- Core terminology and scope: Define decision, overload, unauthorized in the question's particular technical setting; explain how content, exposure, responses differ if that distinction would change the analysis of "Develop an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure. Explain why these conditions require different..." Source: §1.9 Operational Decision Discipline (p. 70)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Connect each event to the validity or authority condition it threatens Source: §1.9 Operational Decision Discipline (p. 70)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure to the claimed result, following "Mission Authority and Collection Boundaries"; name the

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intermediate states and measurable outputs Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure. Define when acquisition stops, when data are marked as affected, when a diagnostic challenge is appropriate, and when specialist or authorized oversight is needed Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Define the measurement before choosing the receiver mode” that resolves the question about an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure; derive the relevant result with units and stated validity conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure. Preserve the actual events, states, and records Source: §1.9 Operational Decision Discipline (p. 70)
- Worked application or illustrative case: Build a worked example of “an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure”, addressing this associated condition: Explain why these conditions require

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different responses. Connect each event to the validity or authority condition it threatens Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure”. Using “Define the measurement before choosing the receiver mode”, specify a discriminator and the result expected under each explanation Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure, including the effect of missing measurements and inconsistent operating conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Scholarly synthesis and implications: Explain what the result about an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.9 Operational Decision Discipline (p. 70)
- Closing: Conclude by answering “Develop an operational decision plan for overload, clock-lock loss, nonreproduction, and unauthorized content exposure. Explain why these conditions require different…” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §1.9 Operational Decision Discipline (p. 70)

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V011-C01-ESSAY-019. Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table.

- Opening: Present a thesis that answers this precise question: Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table. Identify which evidence would falsify the proposed conclusion Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Core terminology and scope: Define models, interpret, examples in the question's particular technical setting; explain how drawn, routing, table differ if that distinction would change the analysis of "Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table" Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Suitable pairs include measured tone levels and a cubic explanation, phase-noise data and a reciprocal-mixing prediction, or usable windows and capture probability Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table to the claimed result, following "Application 1A.4. Use an attenuation prediction as a conditional challenge"; name the intermediate states

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and measurable outputs Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table. Identify the observed quantities and the extra parameters or assumptions required by the model Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.9. Correct resolved frequency components before forming a channel total” that resolves the question about Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table; derive the relevant result with units and stated validity conditions Source: §1.12.9 Application 1A.9. Correct resolved frequency components before forming a channel total (p. 95)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table. Explain what further observation could challenge the interpretation Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Worked application or illustrative case: Build a worked example of “Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table”,

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addressing this associated condition: Suitable pairs include measured tone levels and a cubic explanation, phase-noise data and a reciprocal-mixing.... Suitable pairs include measured tone levels and a cubic explanation, phase-noise data and a... Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table”. Using “Application 1A.9. Correct resolved frequency components before forming a channel total”, specify a discriminator and the result expected under each explanation Source: §1.12.9 Application 1A.9. Correct resolved frequency components before forming a channel total (p. 95)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table, including the effect of missing measurements and inconsistent operating conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Scholarly synthesis and implications: Explain what the result about Distinguish measurement evidence from models used to interpret it through three examples drawn from the chapter's routing table authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Closing: Conclude by answering “Distinguish measurement evidence from models used to interpret it through three examples drawn

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from the chapter's routing table” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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V011-C01-ESSAY-020. Analyze the proposition that an instrument calibration certificate establishes the validity of every result obtained with it. Develop a configuration-specific alternative.

- Opening: Present a thesis that answers this precise question: Analyze the proposition that an instrument calibration certificate establishes the validity of every result obtained with it. Develop a configuration-specific alternative. Identify which evidence would falsify the proposed conclusion Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Core terminology and scope: Define proposition, certificate, establishes in the question's particular technical setting; explain how validity, obtained, alternative differ if that distinction would change the analysis of "Analyze the proposition that an instrument calibration certificate establishes the validity of every result obtained with it. Develop a configuration-specific alternative" Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain how antennas, accessories, state changes, software, estimators, reference planes, and operating limits affect the actual result Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the proposition that an instrument calibration certificate establishes the validity of every result obtained with it to the claimed result, following "Evidence Record and Closing Verification"; name the intermediate

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states and measurable outputs Source: §1.8 Evidence Record and Closing Verification (p. 69)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the proposition that an instrument calibration certificate establishes the validity of every result obtained with it. Identify what the certificate may support and which parts of the installed chain remain outside its scope Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Treat configuration changes as changes in the measurement law” that resolves the question about the proposition that an instrument calibration certificate establishes the validity of every result obtained with it; derive the relevant result with units and stated validity conditions Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the proposition that an instrument calibration certificate establishes the validity of every result obtained with it. A strong answer ties calibration applicability to the declared measurement definition and retained state, then proposes relevant checks Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Worked application or illustrative case: Build a worked example of “the proposition that an instrument calibration certificate establishes the validity of every result obtained with it”, addressing this associated condition: Develop a configuration-specific

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alternative. Explain how antennas, accessories, state changes, software, estimators, reference planes, and operating limits affect the actual result Source: §1.8 Evidence Record and Closing Verification (p. 69)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "the proposition that an instrument calibration certificate establishes the validity of every result obtained with it". Using "Treat configuration changes as changes in the measurement law", specify a discriminator and the result expected under each explanation Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the proposition that an instrument calibration certificate establishes the validity of every result obtained with it, including the effect of missing measurements and inconsistent operating conditions Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Scholarly synthesis and implications: Explain what the result about the proposition that an instrument calibration certificate establishes the validity of every result obtained with it authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Closing: Conclude by answering "Analyze the proposition that an instrument calibration certificate establishes the validity of every result obtained with it. Develop a configuration-specific alternative"

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using only the demonstrated evidence; state the remaining decisive verification step Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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V011-C01-ESSAY-021. Using hypothetical values, demonstrate a forward and backward check of Equation 2. Explain which physical conditions the successful arithmetic does not verify.

- Opening: Present a thesis that answers this precise question: Using hypothetical values, demonstrate a forward and backward check of Equation 2. Explain which physical conditions the successful arithmetic does not verify. Identify which evidence would falsify the proposed conclusion Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Core terminology and scope: Define hypothetical, forward, backward in the question's particular technical setting; explain how successful, arithmetic, verify differ if that distinction would change the analysis of "Using hypothetical values, demonstrate a forward and backward check of Equation 2. Explain which physical conditions the successful arithmetic does not verify" Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Choose an upstream level, external gain, and passive loss, calculate the downstream indication, and then recover the original level by adding loss and subtracting gain Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Using hypothetical values, demonstrate a forward and backward check of Equation 2 to the claimed result, following "Application 1A.2. Remove a software offset before applying the remaining correction";

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name the intermediate states and measurable outputs Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Using hypothetical values, demonstrate a forward and backward check of Equation 2. Define units and reference locations Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 1A.4. Use an attenuation prediction as a conditional challenge” that resolves the question about Using hypothetical values, demonstrate a forward and backward check of Equation 2; derive the relevant result with units and stated validity conditions Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Using hypothetical values, demonstrate a forward and backward check of Equation 2. Discuss state compatibility, mismatch, detector response, uncertainty, and overload as appropriate Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Worked application or illustrative case: Build a worked example of “Using hypothetical values, demonstrate a forward and backward check of Equation 2”, addressing this associated condition: Explain which physical conditions the successful arithmetic does not verify. Choose an upstream level, external gain, and passive loss, calculate

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the downstream indication, and then recover the original level by adding loss and subtracting gain Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Using hypothetical values, demonstrate a forward and backward check of Equation 2”. Using “Application 1A.4. Use an attenuation prediction as a conditional challenge”, specify a discriminator and the result expected under each explanation Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Using hypothetical values, demonstrate a forward and backward check of Equation 2, including the effect of missing measurements and inconsistent operating conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Scholarly synthesis and implications: Explain what the result about Using hypothetical values, demonstrate a forward and backward check of Equation 2 authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Closing: Conclude by answering “Using hypothetical values, demonstrate a forward and backward check of Equation 2. Explain which physical conditions the successful arithmetic does not verify” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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V011-C01-ESSAY-022. Explain how a bounded finding can justify further work without proving source identity or intent. Draft a short hypothetical finding and defend its wording.

- Opening: Present a thesis that answers this precise question: Explain how a bounded finding can justify further work without proving source identity or intent. Draft a short hypothetical finding and defend its wording. Identify which evidence would falsify the proposed conclusion Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Core terminology and scope: Define finding, work, proving in the question's particular technical setting; explain how identity, intent, hypothetical differ if that distinction would change the analysis of "Explain how a bounded finding can justify further work without proving source identity or intent. Draft a short hypothetical finding and defend its wording" Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The proposed finding should state the observed event, valid state and coverage, relevant challenge outcomes, and remaining alternatives Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how a bounded finding can justify further work without proving source identity or intent to the claimed result, following "Observation, Classification, Attribution, and Content Recovery"; name the intermediate states

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and measurable outputs Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how a bounded finding can justify further work without proving source identity or intent. Choose verbs consistent with detection, classification, or limited localization Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Assurance cases for receiver-derived evidence under changing system identity” that resolves the question about how a bounded finding can justify further work without proving source identity or intent; derive the relevant result with units and stated validity conditions Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how a bounded finding can justify further work without proving source identity or intent. Identify the next decision the evidence supports and the information still needed for attribution Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Worked application or illustrative case: Build a worked example of “how a bounded finding can justify further work without proving source identity or intent”, addressing this associated condition: Draft a short hypothetical finding and defend its wording. The proposed finding should state the observed event, valid state and coverage,

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relevant challenge outcomes, and remaining alternatives Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how a bounded finding can justify further work without proving source identity or intent”. Using “Assurance cases for receiver-derived evidence under changing system identity”, specify a discriminator and the result expected under each explanation Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how a bounded finding can justify further work without proving source identity or intent, including the effect of missing measurements and inconsistent operating conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Scholarly synthesis and implications: Explain what the result about how a bounded finding can justify further work without proving source identity or intent authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Closing: Conclude by answering “Explain how a bounded finding can justify further work without proving source identity or intent. Draft a short hypothetical finding and defend its wording” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-ESSAY-023. Develop a record specification for a multisensor comparison where clocks, antennas, and processing may be shared. Explain the distinction between common infrastructure and independent evidence.

- Opening: Present a thesis that answers this precise question: Develop a record specification for a multisensor comparison where clocks, antennas, and processing may be shared. Explain the distinction between common infrastructure and.... Identify which evidence would falsify the proposed conclusion Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Core terminology and scope: Define specification, clocks, antennas in the question's particular technical setting; explain how processing, shared, distinction differ if that distinction would change the analysis of "Develop a record specification for a multisensor comparison where clocks, antennas, and processing may be shared. Explain the distinction between common infrastructure and..." Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify which observations share timing, input, correction, or software paths Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a record specification for a multisensor comparison where clocks, antennas, and processing may be shared to the claimed result, following "Evidence Record and Closing Verification"; name the intermediate

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states and measurable outputs Source: §1.8 Evidence Record and Closing Verification (p. 69)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a record specification for a multisensor comparison where clocks, antennas, and processing may be shared. Define timestamp events and uncertainties, retained native representations, and comparison conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Mission Authority and Collection Boundaries” that resolves the question about a record specification for a multisensor comparison where clocks, antennas, and processing may be shared; derive the relevant result with units and stated validity conditions Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a record specification for a multisensor comparison where clocks, antennas, and processing may be shared. Propose changes that test relevant shared errors without destroying the capability needed for the question Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Worked application or illustrative case: Build a worked example of “a record specification for a multisensor comparison where clocks, antennas, and processing may be shared”, addressing this associated condition: Explain the distinction between common infrastructure and independent evidence. Identify which

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observations share timing, input, correction, or software paths Source: §1.8 Evidence Record and Closing Verification (p. 69)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a record specification for a multisensor comparison where clocks, antennas, and processing may be shared”. Using “Mission Authority and Collection Boundaries”, specify a discriminator and the result expected under each explanation Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a record specification for a multisensor comparison where clocks, antennas, and processing may be shared, including the effect of missing measurements and inconsistent operating conditions Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)
- Scholarly synthesis and implications: Explain what the result about a record specification for a multisensor comparison where clocks, antennas, and processing may be shared authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Closing: Conclude by answering “Develop a record specification for a multisensor comparison where clocks, antennas, and processing may be shared. Explain the distinction between common infrastructure and…” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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V011-C01-ESSAY-024. Evaluate when a field lesson may be transferred to a different receiver or site. Propose a validation argument that respects both prior experience and changed conditions.

- Opening: Present a thesis that answers this precise question: Evaluate when a field lesson may be transferred to a different receiver or site. Propose a validation argument that respects both prior experience and changed conditions. Identify which evidence would falsify the proposed conclusion Source: §1.9 Operational Decision Discipline (p. 70)
- Core terminology and scope: Define transferred, site, validation in the question's particular technical setting; explain how argument, prior, conditions differ if that distinction would change the analysis of "Evaluate when a field lesson may be transferred to a different receiver or site. Propose a validation argument that respects both prior experience and changed conditions" Source: §1.9 Operational Decision Discipline (p. 70)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the original mechanism, configuration, tested domain, and limits Source: §1.9 Operational Decision Discipline (p. 70)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting when a field lesson may be transferred to a different receiver or site to the claimed result, following "Evidence Record and Closing Verification"; name the intermediate states and measurable outputs Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for when a field lesson may be transferred to a different receiver or site. Compare them with the new architecture, accessories, environment, and intended measurement Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Frame a bounded finding from the completed observation” that resolves the question about when a field lesson may be transferred to a different receiver or site; derive the relevant result with units and stated validity conditions Source: §1.14 Frame a bounded finding from the completed observation (p. 100)
- Evidence and method: Specify the native observations, control records and calculations that would resolve when a field lesson may be transferred to a different receiver or site. Determine which assumptions require a fresh check and what evidence would support or contradict transfer Source: §1.9 Operational Decision Discipline (p. 70)
- Worked application or illustrative case: Build a worked example of “when a field lesson may be transferred to a different receiver or site”, addressing this associated condition: Propose a validation argument that respects both prior experience and changed conditions. Identify the original mechanism, configuration, tested domain, and limits Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “when a field lesson may be transferred to

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a different receiver or site". Using "Frame a bounded finding from the completed observation", specify a discriminator and the result expected under each explanation Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to when a field lesson may be transferred to a different receiver or site, including the effect of missing measurements and inconsistent operating conditions Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Scholarly synthesis and implications: Explain what the result about when a field lesson may be transferred to a different receiver or site authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.9 Operational Decision Discipline (p. 70)
- Closing: Conclude by answering "Evaluate when a field lesson may be transferred to a different receiver or site. Propose a validation argument that respects both prior experience and changed conditions" using only the demonstrated evidence; state the remaining decisive verification step Source: §1.9 Operational Decision Discipline (p. 70)

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V011-C01-ESSAY-025. Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report. Explain where the argument could fail and how each failure would be disclosed.

- Opening: Present a thesis that answers this precise question: Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report. Explain where the argument could fail and how each failure would be.... Identify which evidence would falsify the proposed conclusion Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Core terminology and scope: Define argument, authorized, objective in the question's particular technical setting; explain how final, fail, disclosed differ if that distinction would change the analysis of "Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report. Explain where the argument could fail and how each failure would be..." Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Trace the objective through measurement definition, system boundary, configuration identity, acquisition, preservation, correction, challenges, and bounded interpretation Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report to the claimed result, following "Keep the evidence chain reversible to its declared inputs"; name the

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intermediate states and measurable outputs Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report. Identify failures of authority, state knowledge, validity, continuity, comparison capability, or model support Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Mission Authority and Collection Boundaries” that resolves the question about Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report; derive the relevant result with units and stated validity conditions Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report. Explain what evidence remains usable and which claim must be narrowed when a failure occurs Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Worked application or illustrative case: Build a worked example of “Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report”, addressing this associated condition: Explain where the argument could fail and how each failure would be disclosed. Trace the objective through

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measurement definition, system boundary, configuration identity, acquisition, preservation, correction, challenges, and bounded… Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report”. Using “Mission Authority and Collection Boundaries”, specify a discriminator and the result expected under each explanation Source: §1.2 Mission Authority and Collection Boundaries (p. 55)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report, including the effect of missing measurements and inconsistent operating conditions Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)
- Scholarly synthesis and implications: Explain what the result about Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.4 Reference Planes and Configuration Identity (p. 59)
- Closing: Conclude by answering “Synthesize Chapter 1 into an evidence-formation argument from authorized objective to final report. Explain where the argument could fail and how each failure would be…” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C01-DISCUSSION-001. Should a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the authorized question? Develop a position grounded in Chapter 1.

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the authorized question? Develop a position grounded in Chapter 1.” Put this particular dispute to the panel: Should a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the authorized question? Develop a position.... Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 02. Student A, terminology and scope: Agree the operational meanings of survey, storage, acquisition and limited, authorized, position in “Should a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the authorized question? Develop a position...”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the

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outcome and request a specific example from the stated receiver scenario. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.9 Operational Decision Discipline (p. 70)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Operational Decision Discipline”. Identify cases in which native data are necessary and cases in which broader capture exceeds the objective Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.9 Operational Decision Discipline (p. 70)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Operational Decision Discipline”. Identify cases in which native data are necessary and cases in which broader capture exceeds the objective Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.9 Operational Decision Discipline (p. 70)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss analytical reversibility alongside minimization, content limits, retention, and disclosure Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.9 Operational Decision Discipline (p. 70)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…. The discussion should produce a justified acquisition scope and an explicit treatment of incidental information, rather than treating low storage cost as a sufficient reason for indiscriminate… Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that

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would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.9 Operational Decision Discipline (p. 70)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the.... The discussion should produce a justified acquisition scope and an explicit treatment of incidental information, rather than treating low storage cost as a sufficient reason for indiscriminate... Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the... and Develop a position grounded in Chapter 1; exclude protections irrelevant to the scenario Question Student F

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about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the…”, addressing “Develop a position grounded in Chapter 1”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain limited to the authorized question? Develop a position…”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a receiver survey preserve more raw data whenever storage is inexpensive, or should the acquisition remain

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limited to the authorized question? Develop a position grounded in Chapter 1.”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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V011-C01-DISCUSSION-002. How much configuration detail is enough for reproducibility without burdening the record with irrelevant settings?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How much configuration detail is enough for reproducibility without burdening the record with irrelevant settings?” Put this particular dispute to the panel: How much configuration detail is enough for reproducibility without burdening the record with irrelevant settings. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 02. Student A, terminology and scope: Agree the operational meanings of configuration, detail, reproducibility and record, irrelevant, settings in “How much configuration detail is enough for reproducibility without burdening the record with irrelevant settings”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Treat configuration changes as changes in the measurement law”. Compare hardware identity, automatic behavior, software builds, calibration data, and state transitions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how much configuration detail is enough for reproducibility without burdening the record with

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irrelevant settings; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Treat configuration changes as changes in the measurement law”. Compare hardware identity, automatic behavior, software builds, calibration data, and state transitions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish settings that change the answer from cosmetic preferences Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how much configuration detail is enough for reproducibility without burdening the record with

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irrelevant settings: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings. Ask how a later reviewer would detect a consequential difference Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings. Ask how a later reviewer would detect a consequential difference Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how much configuration detail is enough for reproducibility without burdening the record with irrelevant settings and Distinguish settings that change the answer from cosmetic preferences; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how much configuration detail is enough for reproducibility without burdening the record with irrelevant

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settings", addressing "Distinguish settings that change the answer from cosmetic preferences"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "How much configuration detail is enough for reproducibility without burdening the record with irrelevant settings", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "How much configuration detail is enough for reproducibility without burdening the record with irrelevant settings". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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V011-C01-DISCUSSION-003. When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error?” Put this particular dispute to the panel: When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.9 Operational Decision Discipline (p. 70)

- 02. Student A, terminology and scope: Agree the operational meanings of agreement, receivers, meaningful and merely, repeat, error in “When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.9 Operational Decision Discipline (p. 70)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Discuss how to change relevant error structure while retaining comparable capability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When does agreement between two receivers add meaningful evidence, and when can it

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merely repeat the same error; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Discuss how to change relevant error structure while retaining comparable capability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Map shared inputs, clocks, reference sources, software, and correction assumptions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.9 Operational Decision Discipline (p. 70)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.9 Operational Decision Discipline (p. 70)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When does agreement between two receivers add meaningful evidence, and when can it merely

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repeat the same error: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.9 Operational Decision Discipline (p. 70)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would

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lead the panel to retain, qualify or reject the conclusion. Source: §1.9 Operational Decision Discipline (p. 70)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error. Consider whether a different instrument brand or enclosure establishes independence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error. Consider whether a different instrument brand or enclosure establishes independence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error and Map shared inputs, clocks, reference sources, software, and correction assumptions; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When does agreement between two

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receivers add meaningful evidence, and when can it merely repeat the same error", addressing "Map shared inputs, clocks, reference sources, software, and correction assumptions"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.9 Operational Decision Discipline (p. 70)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "When does agreement between two receivers add meaningful evidence, and when can it merely repeat the same error". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.9 Operational Decision Discipline (p. 70)

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V011-C01-DISCUSSION-004. A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. How should it choose and sequence the observations?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. How should it choose and sequence the observations?” Put this particular dispute to the panel: A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. How should it choose and sequence the observations. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 02. Student A, terminology and scope: Agree the operational meanings of collect, broad, discovery and scan, limited, access in “A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. How should it choose and sequence the observations”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team can collect a broad discovery scan or a narrow coherent capture during a limited access period; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define the measurement before choosing the receiver mode”. Compare coverage, calibration, phase, timing, and information preservation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team can collect a broad discovery scan or a narrow coherent capture during a limited access period; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define the measurement before choosing the receiver mode”. Compare coverage, calibration, phase, timing, and information preservation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Start with the authorized decision and the expected event class Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would

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discriminate between them without changing the measurand. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A team can collect a broad discovery scan or a narrow coherent capture during a limited access period: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team can collect a broad discovery scan or a narrow coherent capture during a limited access period; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team can collect a broad discovery scan or a narrow coherent capture during a limited access period: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team can collect a broad discovery scan or a narrow coherent capture during a limited access period, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team can collect a broad discovery scan or a narrow coherent

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capture during a limited access period: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. Discuss what each choice leaves untested and whether discovery can support a targeted follow-up Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team can collect a broad discovery scan or a narrow coherent capture during a limited access period, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. Discuss what each choice leaves untested and whether discovery can support a targeted follow-up Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team can collect a broad discovery scan or a narrow coherent capture during a limited access period and How should it choose and sequence the observations; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team can collect a broad discovery scan or a narrow coherent capture during a limited access period”, addressing “How should it choose and sequence the observations”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. How should it choose and sequence the observations”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team can collect a broad discovery scan or a narrow coherent capture during a limited access period. How should it choose and sequence the observations”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-DISCUSSION-005. What language should a report use when a component is clearly detected but source identity remains unresolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What language should a report use when a component is clearly detected but source identity remains unresolved?” Put this particular dispute to the panel: What language should a report use when a component is clearly detected but source identity remains unresolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 02. Student A, terminology and scope: Agree the operational meanings of language, report, clearly and detected, identity, unresolved in “What language should a report use when a component is clearly detected but source identity remains unresolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What language should a report use when a component is clearly detected but source identity remains unresolved; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. Discuss how different readers might overinterpret an identifier or an unexplained peak Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What language should a

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report use when a component is clearly detected but source identity remains unresolved; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. Discuss how different readers might overinterpret an identifier or an unexplained peak Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare detected, classified, correlated, localized, attributed, and recovered Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What language should a report use when a component is clearly detected but source identity remains unresolved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What language should a report use when a component is clearly detected but source identity remains unresolved; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What language should a report use when a component is clearly detected but source identity

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remains unresolved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What language should a report use when a component is clearly detected but source identity remains unresolved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What language should a report use when a component is clearly detected but source identity remains unresolved: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What language should a report use when a component is clearly detected but source identity remains unresolved. Draft a sentence that is useful for a next decision and preserves the actual evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What language should a report use when a component is clearly detected but source identity remains unresolved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What language should a report use when a component is clearly detected but source identity remains unresolved. Draft a sentence that is useful for a next decision and preserves the actual evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What language should a report use when a component is clearly detected but source identity remains unresolved and Compare detected, classified, correlated, localized, attributed, and recovered; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What language should a report use when a component is clearly detected but source identity remains unresolved”, addressing “Compare detected, classified, correlated, localized, attributed, and recovered”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What language should a report use when a component is clearly detected but source identity remains unresolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What language should a report use when a component is clearly detected but source identity remains unresolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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V011-C01-DISCUSSION-006. How should a team handle an important observation made during an interval of uncertain automatic gain state?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a team handle an important observation made during an interval of uncertain automatic gain state?” Put this particular dispute to the panel: How should a team handle an important observation made during an interval of uncertain automatic gain state. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 02. Student A, terminology and scope: Agree the operational meanings of important, observation, interval and uncertain, automatic, gain in “How should a team handle an important observation made during an interval of uncertain automatic gain state”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a team handle an important observation made during an interval of uncertain automatic gain state; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Treat configuration changes as changes in the measurement law”. Discuss whether a state can be established retrospectively and what must remain qualified if it cannot Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team handle an important observation made during an interval of uncertain

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automatic gain state; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Treat configuration changes as changes in the measurement law”. Discuss whether a state can be established retrospectively and what must remain qualified if it cannot Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider setup exports, status logs, native data, transition timing, and potential reconstruction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a team handle an important observation made during an interval of uncertain automatic gain state: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team handle an important observation made during an interval of uncertain automatic gain state; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a team handle an important observation made during an interval of uncertain automatic gain state: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a team handle an important observation made during an interval of uncertain automatic gain state, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a team handle an important observation made during an interval of uncertain automatic gain state: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a team handle an important observation made during an interval of uncertain automatic gain state. Preserve the original record Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a team handle an important observation made during an interval of uncertain automatic gain state, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a team handle an important observation made during an interval of uncertain automatic gain state. Preserve the original record Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a team handle an important observation made during an interval of uncertain automatic gain state and Consider setup exports, status logs, native data, transition timing, and potential reconstruction; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a team handle an important observation made during an interval of uncertain automatic gain

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state", addressing "Consider setup exports, status logs, native data, transition timing, and potential reconstruction"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "How should a team handle an important observation made during an interval of uncertain automatic gain state", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "How should a team handle an important observation made during an interval of uncertain automatic gain state". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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V011-C01-DISCUSSION-007. Can a closing reference pass repair missing configuration information from the original observation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a closing reference pass repair missing configuration information from the original observation?” Put this particular dispute to the panel: Can a closing reference pass repair missing configuration information from the original observation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 02. Student A, terminology and scope: Agree the operational meanings of closing, pass, repair and missing, information, original in “Can a closing reference pass repair missing configuration information from the original observation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a closing reference pass repair missing configuration information from the original observation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define the measurement before choosing the receiver mode”. Discuss which faults the check could reveal and which historical ambiguities it cannot resolve Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a closing reference pass repair missing configuration information from the original

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observation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define the measurement before choosing the receiver mode”. Discuss which faults the check could reveal and which historical ambiguities it cannot resolve Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish continued function after the event from knowledge of the earlier state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a closing reference pass repair missing configuration information from the original observation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a closing reference pass repair missing configuration information from the original observation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a closing reference pass repair missing configuration information from the original observation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a

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repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a closing reference pass repair missing configuration information from the original observation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a closing reference pass repair missing configuration information from the original observation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a closing reference pass repair missing configuration information from the original observation. Define a useful closing test and a report statement that acknowledges its time and scope Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a closing reference pass repair missing configuration information from the original observation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a closing reference pass repair missing

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configuration information from the original observation. Define a useful closing test and a report statement that acknowledges its time and scope Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a closing reference pass repair missing configuration information from the original observation and Distinguish continued function after the event from knowledge of the earlier state; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a closing reference pass repair missing configuration information from the original observation”, addressing “Distinguish continued function after the event from knowledge of the earlier state”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can a closing reference pass repair missing configuration information from the original observation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can a closing reference pass repair missing configuration information from the original observation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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V011-C01-DISCUSSION-008. What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible?” Put this particular dispute to the panel: What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 02. Student A, terminology and scope: Agree the operational meanings of setup, export, disagree and displayed, trace, looks in “What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 1A.10. Separate a valid corrected level from an unobserved transition interval”. Discuss whether the trace itself can discriminate the states and what additional records are needed Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should happen when a

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setup export and actual-state log disagree but the displayed trace looks plausible; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 1A.10. Separate a valid corrected level from an unobserved transition interval”. Discuss whether the trace itself can discriminate the states and what additional records are needed Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine command timing, acceptance, settling, and automatic behavior Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should happen when a setup export and actual-state log disagree but the displayed trace

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looks plausible: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible. Consider the risks of averaging through the disagreement Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible. Consider the risks of averaging through the disagreement Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible and Examine command timing, acceptance, settling, and automatic behavior; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should happen when a setup export

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and actual-state log disagree but the displayed trace looks plausible", addressing "Examine command timing, acceptance, settling, and automatic behavior"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "What should happen when a setup export and actual-state log disagree but the displayed trace looks plausible". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

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V011-C01-DISCUSSION-009. How can a negative finding remain useful to a client without suggesting universal absence?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How can a negative finding remain useful to a client without suggesting universal absence?” Put this particular dispute to the panel: How can a negative finding remain useful to a client without suggesting universal absence. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 02. Student A, terminology and scope: Agree the operational meanings of negative, finding, remain and useful, universal, absence in “How can a negative finding remain useful to a client without suggesting universal absence”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how can a negative finding remain useful to a client without suggesting universal absence; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define the measurement before choosing the receiver mode”. Discuss which omitted conditions would matter to the client's decision Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how can a negative finding remain useful to a client without suggesting universal absence;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define the measurement before choosing the receiver mode”. Discuss which omitted conditions would matter to the client's decision Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the event class, threshold or sensitivity conditions, frequency and time coverage, and exclusions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how can a negative finding remain useful to a client without suggesting universal absence: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how can a negative finding remain useful to a client without suggesting universal absence; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how can a negative finding remain useful to a client without suggesting universal absence: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how can a negative finding remain useful to a client without suggesting universal absence, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how can a negative finding remain useful to a client without suggesting universal absence: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how can a negative finding remain useful to a client without suggesting universal absence. Draft a negative finding that preserves practical meaning while directing any justified follow-up to an actual gap Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how can a negative finding remain useful to a client without suggesting universal absence, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how can a negative finding remain useful to a client without suggesting universal absence. Draft a negative finding that preserves practical meaning while directing any justified follow-up to an actual gap Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how can a negative finding remain useful to a client without suggesting universal absence and Identify the event class, threshold or sensitivity conditions, frequency and time coverage, and exclusions; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how can a negative finding remain useful to a client without suggesting universal absence”, addressing “Identify the event class, threshold or sensitivity conditions, frequency and time coverage, and exclusions”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How can a negative finding remain useful to a client without suggesting universal absence”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How can a negative finding remain useful to a client without suggesting universal absence”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-DISCUSSION-010. Should every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record?” Put this particular dispute to the panel: Should every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 02. Student A, terminology and scope: Agree the operational meanings of unsuccessful, diagnostic, appear and final, remain, supporting in “Should every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Assurance cases for receiver-derived evidence under changing system identity”. Discuss which tests materially affect alternatives, coverage, or confidence in the finding Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether every unsuccessful

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diagnostic test appear in the final report, or can some remain in the supporting record; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Assurance cases for receiver-derived evidence under changing system identity”. Discuss which tests materially affect alternatives, coverage, or confidence in the finding Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish complete evidence preservation from proportionate presentation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether every unsuccessful diagnostic test appear in the final report, or can some remain in the

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supporting record: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record. Explain how the final report can link to a reviewable record without concealing unfavorable outcomes Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record. Explain how the final report can link to a reviewable record without concealing unfavorable outcomes Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record and Distinguish complete evidence preservation from proportionate presentation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record”, addressing “Distinguish complete evidence preservation from proportionate presentation”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should every unsuccessful diagnostic test appear in the final report, or can some remain in the supporting record”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-DISCUSSION-011. An operator changes an antenna position and the suspect component disappears. What competing explanations should the team discuss before claiming localization?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An operator changes an antenna position and the suspect component disappears. What competing explanations should the team discuss before claiming localization?” Put this particular dispute to the panel: An operator changes an antenna position and the suspect component disappears. What competing explanations should the team discuss before claiming localization. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 02. Student A, terminology and scope: Agree the operational meanings of position, suspect, disappears and competing, explanations, localization in “An operator changes an antenna position and the suspect component disappears. What competing explanations should the team discuss before claiming localization”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the

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outcome and request a specific example from the stated receiver scenario. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An operator changes an antenna position and the suspect component disappears; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. Identify a suitable return or reference comparison Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An operator changes an antenna position and the suspect component disappears; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. Identify a suitable return or reference comparison Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider changed coupling, polarization, path sensitivity, intermittent behavior, and the actual observation opportunity Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An operator changes an antenna position and the suspect component disappears: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An operator changes an antenna position and the suspect component disappears; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An operator changes an antenna position and the suspect component disappears: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An operator changes an antenna position and the suspect component disappears, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An operator changes an antenna position and the suspect

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component disappears: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An operator changes an antenna position and the suspect component disappears. The discussion should separate a useful location-dependent observation from a definitive source location and specify what evidence would narrow the alternatives Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An operator changes an antenna position and the suspect component disappears, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An operator changes an antenna position and the suspect component disappears. The discussion should separate a useful location-dependent observation from a definitive source location and specify what evidence would narrow the alternatives Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An operator changes an antenna position and the suspect component disappears and What competing explanations should the team discuss before claiming localization; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An operator changes an antenna position and the suspect component disappears”, addressing “What competing explanations should the team discuss before claiming localization”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An operator changes an antenna position and the suspect component disappears. What competing explanations should the team discuss before claiming localization”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An operator changes an antenna position and the suspect component disappears. What competing explanations should the team discuss before claiming localization”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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V011-C01-DISCUSSION-012. How should the team distinguish a calibration problem from an information-loss problem?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should the team distinguish a calibration problem from an information-loss problem?” Put this particular dispute to the panel: How should the team distinguish a calibration problem from an information-loss problem. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 02. Student A, terminology and scope: Agree the operational meanings of calibration, problem, information-loss and discussion, Terminology, interpretations in “How should the team distinguish a calibration problem from an information-loss problem”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should the team distinguish a calibration problem from an information-loss problem; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 1A.10. Separate a valid corrected level from an unobserved transition interval”. Discuss which transformations can be reconstructed and which require missing information Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should the team

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distinguish a calibration problem from an information-loss problem; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 1A.10. Separate a valid corrected level from an unobserved transition interval”. Discuss which transformations can be reconstructed and which require missing information Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare a known scalar correction with clipping, magnitude-only retention, missing samples, or inadequate rejection before decimation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should the team distinguish a calibration problem from an information-loss problem: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should the team distinguish a calibration problem from an information-loss problem; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should the team

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distinguish a calibration problem from an information-loss problem: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should the team distinguish a calibration problem from an information-loss problem, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should the team distinguish a calibration problem from an information-loss problem: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should the team distinguish a calibration problem from an information-loss problem. The conclusion should guide preservation and reporting, including when a corrected number would give a false impression of recovery Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should the team distinguish a calibration problem from an information-loss problem, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should the team distinguish a calibration problem from an information-loss problem. The conclusion should guide preservation and reporting, including when a corrected number would give a false impression of recovery Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should the team distinguish a calibration problem from an information-loss problem and Compare a known scalar correction with clipping, magnitude-only retention, missing samples, or inadequate…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should the team distinguish a calibration problem from an information-loss problem”, addressing “Compare a known scalar correction with clipping, magnitude-only retention, missing samples, or inadequate…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should the team distinguish a calibration problem from an information-loss problem”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should the team distinguish a calibration problem from an information-loss problem”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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V011-C01-DISCUSSION-013. What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative?” Put this particular dispute to the panel: What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 02. Student A, terminology and scope: Agree the operational meanings of makes, unexplained, starting and investigation, unsupported, narrative in “What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. Discuss external components and instrument-generated alternatives, then propose discriminating observations Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. Discuss external components and instrument-generated alternatives, then propose discriminating observations Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the detection criterion and configured chain Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What makes an unexplained

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peak a productive starting point for investigation rather than an unsupported narrative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative: specify the

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altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative. Examine how authority, state identity, and valid comparison conditions constrain the next step Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative. Examine how authority, state identity, and valid comparison conditions constrain the next step Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative and State the detection criterion and configured chain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative”, addressing “State the detection criterion and configured chain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What makes an unexplained peak a productive starting point for investigation rather than an unsupported narrative”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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V011-C01-DISCUSSION-014. A later scan fails to reproduce an earlier dwell detection. Under what conditions should the team treat this as evidence of environmental change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A later scan fails to reproduce an earlier dwell detection. Under what conditions should the team treat this as evidence of environmental change?” Put this particular dispute to the panel: A later scan fails to reproduce an earlier dwell detection. Under what conditions should the team treat this as evidence of environmental change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 02. Student A, terminology and scope: Agree the operational meanings of scan, fails, reproduce and earlier, dwell, treat in “A later scan fails to reproduce an earlier dwell detection. Under what conditions should the team treat this as evidence of environmental change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A later scan fails to reproduce an earlier dwell detection; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Discuss what a matched follow-up would establish Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A later scan fails to reproduce an earlier dwell detection; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Discuss what a matched follow-up would establish Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare usable time and frequency coverage, estimator, detector, gain, blockers, and sensitivity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A later scan fails to reproduce an earlier dwell detection: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A later scan fails to reproduce an earlier dwell detection; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A later scan fails to reproduce an earlier dwell detection: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A later scan fails to reproduce an earlier dwell detection, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A later scan fails to reproduce an earlier dwell detection: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A later scan fails to reproduce an earlier dwell detection. Only after those conditions are reconciled should the discussion assess the residual evidence for change Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A later scan fails to reproduce an earlier dwell detection, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A later scan fails to reproduce an earlier dwell detection. Only after those conditions are reconciled should the discussion assess the residual evidence for change Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A later scan fails to reproduce an earlier dwell detection and Under what conditions should the team treat this as evidence of environmental change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A later scan fails to reproduce an earlier dwell detection”, addressing “Under what conditions should the team treat this as evidence of environmental change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A later scan fails to reproduce an earlier dwell detection. Under what conditions should the team treat this as evidence of environmental change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A later scan fails to reproduce an earlier dwell detection. Under what conditions should the team treat this as evidence of environmental change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-DISCUSSION-015. What is the appropriate balance between procedural consistency and expert judgment during a receiver survey?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What is the appropriate balance between procedural consistency and expert judgment during a receiver survey?” Put this particular dispute to the panel: What is the appropriate balance between procedural consistency and expert judgment during a receiver survey. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.9 Operational Decision Discipline (p. 70)

- 02. Student A, terminology and scope: Agree the operational meanings of appropriate, balance, consistency and expert, judgment, survey in “What is the appropriate balance between procedural consistency and expert judgment during a receiver survey”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.9 Operational Decision Discipline (p. 70)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What is the appropriate balance between procedural consistency and expert judgment during a receiver survey; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Mission Authority and Collection Boundaries”. Consider a case in which a rigid menu sequence misses a consequential state change Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is the appropriate balance between procedural consistency and expert judgment during a receiver survey; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Mission Authority and Collection Boundaries”. Consider a case in which a rigid menu sequence misses a consequential state change Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss planned decision points, controlled deviations, specialist escalation, and the evidence needed to assess validity afterward Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.9 Operational Decision Discipline (p. 70)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What is the appropriate balance between procedural consistency and expert judgment during a receiver survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.9 Operational Decision Discipline (p. 70)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is the appropriate balance between procedural consistency and expert judgment during a receiver survey; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What is the appropriate balance between procedural consistency and expert judgment during a

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receiver survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.9 Operational Decision Discipline (p. 70)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What is the appropriate balance between procedural consistency and expert judgment during a receiver survey, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What is the appropriate balance between procedural consistency and expert judgment during a receiver survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §1.9 Operational Decision Discipline (p. 70)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What is the appropriate balance between procedural consistency and expert judgment during a receiver survey. A strong discussion keeps judgment reviewable through reasons and records without pretending that a checklist eliminates technical interpretation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What is the appropriate balance between procedural consistency and expert judgment during a receiver survey, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What is the appropriate balance between procedural consistency and expert judgment during a receiver survey. A strong discussion keeps judgment reviewable through reasons and records without pretending that a checklist eliminates technical interpretation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What is the appropriate balance between procedural consistency and expert judgment during a receiver survey and Discuss planned decision points, controlled deviations, specialist escalation, and the evidence needed to…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What is the appropriate balance between procedural consistency and expert judgment during a receiver survey”, addressing “Discuss planned decision points, controlled deviations, specialist escalation, and the evidence needed to…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.9 Operational Decision Discipline (p. 70)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What is the appropriate balance between procedural consistency and expert judgment during a receiver survey”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What is the appropriate balance between procedural consistency and expert judgment during a receiver survey”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.9 Operational Decision Discipline (p. 70)

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V011-C01-DISCUSSION-016. Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger?” Put this particular dispute to the panel: Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 02. Student A, terminology and scope: Agree the operational meanings of decoded, identifier, support and attribution, argument, stronger in “Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Evidence Record and Closing Verification”. Discuss controlled state changes, physical correlation, timing, and competing mechanisms Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a decoded identifier ever

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support attribution, and what additional evidence would make the argument stronger; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Evidence Record and Closing Verification”. Discuss controlled state changes, physical correlation, timing, and competing mechanisms Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Begin with the chapter's warning that a configuration string does not alone establish location or ownership Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a decoded identifier ever support attribution, and what additional evidence would make the

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argument stronger: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger. Specify which inference each observation supports Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger. Specify which inference each observation supports Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger and Begin with the chapter's warning that a configuration string does not alone establish location or ownership; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a decoded identifier ever support

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attribution, and what additional evidence would make the argument stronger", addressing "Begin with the chapter's warning that a configuration string does not alone establish location or ownership"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Can a decoded identifier ever support attribution, and what additional evidence would make the argument stronger". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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V011-C01-DISCUSSION-017. How should a team decide whether two state intervals can be combined into one reported estimate?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a team decide whether two state intervals can be combined into one reported estimate?” Put this particular dispute to the panel: How should a team decide whether two state intervals can be combined into one reported estimate. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 02. Student A, terminology and scope: Agree the operational meanings of intervals, combined, reported and estimate, measurement, evidence in “How should a team decide whether two state intervals can be combined into one reported estimate”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a team decide whether two state intervals can be combined into one reported estimate; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 1A.5. Retain separate admissible results when the settled state is unknown”. Discuss whether separate corrections or a state-aware model can support the combination Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team decide

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whether two state intervals can be combined into one reported estimate; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 1A.5. Retain separate admissible results when the settled state is unknown”. Discuss whether separate corrections or a state-aware model can support the combination Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare the intended estimator, gains, losses, noise, validity, timing, and calibration applicability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a team decide whether two state intervals can be combined into one reported estimate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team decide whether two state intervals can be combined into one reported estimate; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a team decide

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whether two state intervals can be combined into one reported estimate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a team decide whether two state intervals can be combined into one reported estimate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a team decide whether two state intervals can be combined into one reported estimate: specify the altered receiver

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state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a team decide whether two state intervals can be combined into one reported estimate. Identify what must be retained for reconstruction Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a team decide whether two state intervals can be combined into one reported estimate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a team decide whether two state intervals can be combined into one reported estimate. Identify what must be retained for reconstruction Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a team decide whether two state intervals can be combined into one reported estimate and Compare the intended estimator, gains, losses, noise, validity, timing, and calibration applicability; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a team decide whether two state intervals can be combined into one reported estimate”, addressing “Compare the intended estimator, gains, losses, noise, validity, timing, and calibration applicability”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a team decide whether two state intervals can be combined into one reported estimate”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a team decide whether two state intervals can be combined into one reported estimate”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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V011-C01-DISCUSSION-018. Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain?” Put this particular dispute to the panel: Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.9 Operational Decision Discipline (p. 70)

- 02. Student A, terminology and scope: Agree the operational meanings of matters, defensible, highly and capable, instrument, chain in “Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.9 Operational Decision Discipline (p. 70)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. A capable receiver can be poorly configured, while a controlled system can still lack necessary sensitivity or coverage Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Which matters more for a defensible result: a highly capable instrument or a well-defined

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measurement chain; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frame a bounded finding from the completed observation”. A capable receiver can be poorly configured, while a controlled system can still lack necessary sensitivity or coverage Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use concrete examples to examine the interaction rather than choosing a slogan Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.9 Operational Decision Discipline (p. 70)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.9 Operational Decision Discipline (p. 70)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion

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Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.9 Operational Decision Discipline (p. 70)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.9 Operational Decision Discipline (p. 70)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain. Discuss how the objective determines required capability and how records and checks establish that it was available during the observation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain. Discuss how the objective determines required capability and how records and checks establish that it was available during the observation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain and Use concrete examples to examine the interaction rather than choosing a slogan; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Which matters more for a defensible result: a highly capable instrument or a well-defined measurement

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chain", addressing "Use concrete examples to examine the interaction rather than choosing a slogan"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.9 Operational Decision Discipline (p. 70)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Which matters more for a defensible result: a highly capable instrument or a well-defined measurement chain". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.9 Operational Decision Discipline (p. 70)

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V011-C01-DISCUSSION-019. How should a report distinguish the original measurement from a model-based prediction about conditions that were not observed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a report distinguish the original measurement from a model-based prediction about conditions that were not observed?” Put this particular dispute to the panel: How should a report distinguish the original measurement from a model-based prediction about conditions that were not observed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 02. Student A, terminology and scope: Agree the operational meanings of report, original, prediction and conditions, were, observed in “How should a report distinguish the original measurement from a model-based prediction about conditions that were not observed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Assurance cases for receiver-derived evidence under changing system identity”. Discuss how to label extrapolation and what evidence would test it Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Assurance cases for receiver-derived evidence under changing system identity”. Discuss how to label extrapolation and what evidence would test it Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify retained observations, model parameters, assumptions, and the predicted domain Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed. A useful conclusion preserves the model's analytical value without presenting unobserved intervals or configurations as measured coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a report distinguish the original

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measurement from a model-based prediction about conditions that were not observed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed. A useful conclusion preserves the model's analytical value without presenting unobserved intervals or configurations as measured coverage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a report distinguish the original measurement from a model-based prediction about conditions that

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were not observed and Identify retained observations, model parameters, assumptions, and the predicted domain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a report distinguish the original measurement from a model-based prediction about conditions that were not observed”, addressing “Identify retained observations, model parameters, assumptions, and the predicted domain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a report distinguish the original measurement from a model-based prediction about conditions that were not observed”, specifying the next test, responsible

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measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a report distinguish the original measurement from a model-based prediction about conditions that were not observed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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V011-C01-DISCUSSION-020. What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable capture?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable capture?” Put this particular dispute to the panel: What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable capture. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 02. Student A, terminology and scope: Agree the operational meanings of unauthorized-content, condition, complete and technically, valuable, capture in “What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable capture”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.9 Operational Decision Discipline (p. 70)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Operational Decision Discipline”. Keep technical interest separate from authority Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.9 Operational Decision Discipline (p. 70)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should be done when an

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unauthorized-content stop condition conflicts with the desire to complete a technically valuable…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Operational Decision Discipline”. Keep technical interest separate from authority Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.9 Operational Decision Discipline (p. 70)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss the authorized scope, the operational stop rule, preservation of the incident record, and the process for any valid extension Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should be done when an

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unauthorized-content stop condition conflicts with the desire to complete a technically valuable…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.9 Operational Decision Discipline (p. 70)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable…: specify

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the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable.... The discussion should identify what can be reported about the incomplete acquisition and what additional permission or redesign would be required for further collection Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable..., formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §1.9 Operational Decision Discipline (p. 70)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable.... The discussion should identify what can be reported about the incomplete acquisition and what additional permission or redesign would be required for further collection Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable... and Discuss the authorized scope, the operational stop rule, preservation of the incident record, and the process...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.12.10

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Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable…”, addressing “Discuss the authorized scope, the operational stop rule, preservation of the incident record, and the process…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved.
  Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable capture”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should be done when an unauthorized-content stop condition conflicts with the desire to complete a technically valuable capture”. Allocate the next measurement and documentary action to named student roles,

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and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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V011-C01-DISCUSSION-021. How can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey?” Put this particular dispute to the panel: How can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 02. Student A, terminology and scope: Agree the operational meanings of make, correction, understandable and reviewer, conduct, survey in “How can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Discuss a forward arithmetic check and the limits of the scalar model Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how can a team make a reference-plane correction understandable to a reviewer who did

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not conduct the survey; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Discuss a forward arithmetic check and the limits of the scalar model Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Propose a record containing the original indication, ordered path, gain and loss signs, relevant states, and destination plane Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey. The conclusion should make it possible to identify double counting or unsupported conversion without requiring the reviewer to infer missing settings Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey. The conclusion should make it possible to identify double counting or unsupported conversion without requiring the reviewer to infer missing settings Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey and Propose a record containing the original indication, ordered path, gain and loss signs, relevant states, and…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey”, addressing “Propose a record containing the original indication, ordered path, gain and loss signs, relevant states, and…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How can a team make a reference-plane correction understandable to a reviewer who did not conduct the survey”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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V011-C01-DISCUSSION-022. What is the role of screenshots in an evidence package that already contains native data and setup exports?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What is the role of screenshots in an evidence package that already contains native data and setup exports?” Put this particular dispute to the panel: What is the role of screenshots in an evidence package that already contains native data and setup exports. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 02. Student A, terminology and scope: Agree the operational meanings of screenshots, package, contains and native, data, setup in “What is the role of screenshots in an evidence package that already contains native data and setup exports”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What is the role of screenshots in an evidence package that already contains native data and setup exports; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Evidence Record and Closing Verification”. Consider whether the screenshot documents a display state that the native file omits, while retaining the need for data lineage and actual configuration Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is the role of screenshots in an evidence package that already contains native data and setup

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exports; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.9 Operational Decision Discipline (p. 70)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Evidence Record and Closing Verification”. Consider whether the screenshot documents a display state that the native file omits, while retaining the need for data lineage and actual configuration Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss illustration, communication, context, and the limits of a screen image Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What is the role of screenshots in an evidence package that already contains native data and setup exports: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is the role of screenshots in an evidence package that already contains native data and setup exports; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.9 Operational Decision Discipline (p. 70)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What is the role of screenshots in an evidence package that already contains native data and setup exports: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a

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repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What is the role of screenshots in an evidence package that already contains native data and setup exports, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What is the role of screenshots in an evidence package that already contains native data and setup exports: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What is the role of screenshots in an evidence package that already contains native data and setup exports. A proportionate package uses each representation for its supported purpose and avoids treating visual appearance as complete technical proof Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.9 Operational Decision Discipline (p. 70)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What is the role of screenshots in an evidence package that already contains native data and setup exports, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What is the role of screenshots in an evidence

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package that already contains native data and setup exports. A proportionate package uses each representation for its supported purpose and avoids treating visual appearance as complete technical proof Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.9 Operational Decision Discipline (p. 70)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What is the role of screenshots in an evidence package that already contains native data and setup exports and Discuss illustration, communication, context, and the limits of a screen image; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What is the role of screenshots in an evidence package that already contains native data and setup exports”, addressing “Discuss illustration, communication, context,

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and the limits of a screen image"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "What is the role of screenshots in an evidence package that already contains native data and setup exports", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "What is the role of screenshots in an evidence package that already contains native data and setup exports". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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V011-C01-DISCUSSION-023. When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the finding?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the finding?” Put this particular dispute to the panel: When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the finding. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 02. Student A, terminology and scope: Agree the operational meanings of explanation, strongly, localization and necessary, reporting, finding in “When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the finding”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Assurance cases for receiver-derived evidence under changing system identity”. Discuss whether the tested configuration dependence supports a bounded artifact finding, what alternatives remain, and what would justify naming a particular circuit Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Assurance cases for receiver-derived evidence under changing system identity”. Discuss whether the tested configuration dependence supports a bounded artifact finding, what alternatives remain, and what would justify naming a particular circuit Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Connect the

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required depth to the decision and evidence Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 08. Student D, answer to Student E: Design a discriminating experiment involving When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is

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missing. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…. The conclusion should not demand unlimited investigation, but it must distinguish a useful diagnostic result from complete mechanism identification Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When an artifact explanation is strongly

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favored, how much internal mechanism localization is necessary before reporting the..., formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the.... The conclusion should not demand unlimited investigation, but it must distinguish a useful diagnostic result from complete mechanism identification Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When an artifact explanation is strongly favored, how much internal mechanism localization is necessary

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before reporting the… and Connect the required depth to the decision and evidence; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the…”, addressing “Connect the required depth to the decision and evidence”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When an artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the finding”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When an

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artifact explanation is strongly favored, how much internal mechanism localization is necessary before reporting the finding". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

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V011-C01-DISCUSSION-024. How should lessons from one receiver incident enter training for other instruments and sites?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should lessons from one receiver incident enter training for other instruments and sites?” Put this particular dispute to the panel: How should lessons from one receiver incident enter training for other instruments and sites. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.9 Operational Decision Discipline (p. 70)

- 02. Student A, terminology and scope: Agree the operational meanings of lessons, incident, enter and training, instruments, sites in “How should lessons from one receiver incident enter training for other instruments and sites”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.9 Operational Decision Discipline (p. 70)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should lessons from one receiver incident enter training for other instruments and sites; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 1A.4. Use an attenuation prediction as a conditional challenge”. Discuss how to present the lesson as a hypothesis or bounded procedure requiring validation in the new setting Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should lessons from one

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receiver incident enter training for other instruments and sites; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 1A.4. Use an attenuation prediction as a conditional challenge”. Discuss how to present the lesson as a hypothesis or bounded procedure requiring validation in the new setting Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the observed mechanism, operating domain, record quality, and failed alternatives Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.9 Operational Decision Discipline (p. 70)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should lessons from one receiver incident enter training for other instruments and sites: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.9 Operational Decision Discipline (p. 70)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should lessons from one receiver incident enter training for other instruments and sites; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should lessons from one receiver incident enter training for other instruments and sites: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.9 Operational Decision Discipline (p. 70)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should lessons from one receiver incident enter training for other instruments and sites, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should lessons from one receiver incident enter training for other instruments and sites: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §1.9 Operational Decision Discipline (p. 70)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should lessons from one receiver incident enter training for other instruments and sites. Propose a training exercise that tests transfer rather than encouraging uncritical repetition of an anecdote Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should lessons from one receiver incident enter training for other instruments and sites, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.12.4 Application 1A.4. Use an attenuation prediction as a conditional challenge (p. 85)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should lessons from one receiver incident enter training for other instruments and sites. Propose a training exercise that tests transfer rather than encouraging uncritical repetition of an anecdote Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should lessons from one receiver incident enter training for other instruments and sites and Identify the observed mechanism, operating domain, record quality, and failed alternatives; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should lessons from one receiver

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incident enter training for other instruments and sites", addressing "Identify the observed mechanism, operating domain, record quality, and failed alternatives"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.9 Operational Decision Discipline (p. 70)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "How should lessons from one receiver incident enter training for other instruments and sites", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "How should lessons from one receiver incident enter training for other instruments and sites". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.9 Operational Decision Discipline (p. 70)

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V011-C01-DISCUSSION-025. What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited?” Put this particular dispute to the panel: What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, receiver, finding and useful, properly, limited in “What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Evidence Record and Closing Verification”. Identify the most important open alternative and the next observation that could address it Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited; explain what each record can establish State what

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the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Evidence Record and Closing Verification”. Identify the most important open alternative and the next observation that could address it Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Construct a coherent argument from authority and measurement definition to valid state, retained inputs, corrections, challenges, and conclusion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited. The discussion should demonstrate that explicit limits improve the decision value of the finding without substituting repeated generic caution for technical evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited. The discussion should demonstrate that explicit limits improve the decision value of the finding without substituting repeated generic caution for technical evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited and Construct a coherent argument from authority and measurement definition to valid state, retained inputs,...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited”, addressing “Construct a coherent argument from authority and measurement definition to valid state, retained inputs,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What evidence would convince a skeptical reviewer that a receiver finding is both useful and properly limited”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

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Chapter 1 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C01-ESSAY-001 — A strong answer follows the physical and computational transformations to the reported result. It identifies input and output planes, path loss and gain, filtering, reference and clock states, digitization, and processing. It explains which accessories or software choices could change the measurand, rather than merely listing equipment. The answer should show how the boundary permits external signals to be distinguished from measurement-system effects and how native data and configuration identity support later reconstruction.

Review: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

V011-C01-ESSAY-002 — Define the technical objective and permitted observations before choosing receiver modes. Explain how frequency ranges, duration, channels, detector settings, recording, and metadata implement that objective. Discuss incidental information, access, retention, deletion, and stop conditions without inventing a universal legal rule. A complete answer identifies who may approve a scope extension and what must be recorded. It should distinguish technical capability from authority and connect minimization to actual data acquired.

Review: Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-ESSAY-003 — The answer should begin with a declared detection criterion and then distinguish waveform characterization, a supported link to a physical emitter, and reconstruction of carried information. It should show that success at one stage does not establish the next. Suitable examples include a stable peak, a modulation-family label, an identifier, and a controlled device-state comparison. Credit depends on explicit conditions and alternative explanations, including receiver artifacts and identifiers that do not establish ownership.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

V011-C01-ESSAY-004 — State the indication, desired upstream plane, gain, loss, and compatible calibration state. Apply Equation 2 with correct signs and retain the original indication and each correction. Explain why the scalar result does not automatically become field strength or source power. A complete answer identifies mismatch, detector response, uncertainty, and invalidating overload as matters outside the simple correction when relevant. Numerical inputs must be labeled hypothetical and the arithmetic must be shown.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Equation 2. Corrected input power.

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V011-C01-ESSAY-005 — Distinguish the setup request from the state that actually governed acquisition. Discuss rejection, transition, settling, and automatic changes. Link commands, status events, and data intervals through the declared time basis. The answer should identify what remains unresolved when one record is absent and explain why averaging across the disagreement can conceal a measurement defect. It should give a concrete example, such as a rate or gain change, and retain both the original records and the resulting limitation.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

V011-C01-ESSAY-006 — For each target, specify plane, frequency and time intervals, state, estimator, decision criterion, and relevant validity conditions. The amplitude definition should explain which energy and detector operation contribute. The timing definition should distinguish sample aperture, trigger event, and software receipt as possible timestamp meanings. The comparison should show why one acquisition configuration may suit one target while leaving the other inadequately supported, without treating precision alone as proof of accuracy.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-ESSAY-007 — Identify the input, output, configured transformation, and internal contribution. Explain that conversion, sampling, memory, adaptive control, limiting, and software can belong to the transformation. A strong answer distinguishes this boundary description from narrower models whose operating domains must be demonstrated. It should use an example such as gain control or overload to show how a global linear interpretation can fail while a local, explicitly bounded approximation remains useful.

Review: Chapter 1 — Equation 1. Configured receiver-chain representation; Chapter 1 — Treat configuration changes as changes in the measurement law.

V011-C01-ESSAY-008 — Identify the representation retained and the operations that produced it. Explain that magnitude, clipping, sampling loss, and other irreversible transformations can remove information needed for later questions. The answer should not claim that every derived spectrum is useless. Instead, state which bounded quantity it can still support and what additional phase, timing, or estimator claims would require the missing native data. Conclude with a preservation and processing-lineage policy tied to the intended objective.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase.

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V011-C01-ESSAY-009 — Describe the requested changes, accepted states, transition and settling intervals, and samples assigned to each valid state. Explain the different consequences of preselection, gain, and rate for transfer, blockers, aliasing, timing, and throughput. State when separate corrections are necessary and what would justify combining intervals. The answer should avoid treating a common display scale as proof of comparability and should preserve unresolved state information explicitly.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

V011-C01-ESSAY-010 — Explain why agreement can arise from a shared input path, reference, clock, or processing assumption. Identify changes that could alter relevant errors while preserving the capability to observe the component. Discuss the limits of a comparator's nondetection and the need to match useful sensitivity, coverage, reference plane, and time opportunity. A strong answer gives a bounded conclusion from the proposed comparison rather than claiming that independence can be established merely by using different enclosures.

Review: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

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V011-C01-ESSAY-011 — Tie the known reference to the functions needed for the original claim, including the path, scale, detector, recording, and export where applicable. Identify which states and functions were exercised and which remained untested. Discuss the time relation to the field observation and the meaning of a pass or failure. The answer should preserve the original data and avoid converting a limited functional check into proof of source identity, unrestricted validity, or authorization.

Review: Chapter 1 — Evidence Record and Closing Verification.

V011-C01-ESSAY-012 — Begin with the stated preamplifier dependence, attenuation behavior, and comparator nondetection. Identify competing explanations and predict what each follow-up change would test. Preserve sensitivity, physical-frequency coverage, relevant reference planes, and observation intervals while changing one useful causal condition. A strong answer records actual rather than merely requested states and retains unsuccessful results. The conclusion should express whether alternatives are favored, weakened, or still unresolved without asserting complete mechanism localization prematurely.

Review: Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-ESSAY-013 — Compare the two measurement definitions, including time opportunity, instantaneous frequency coverage, detector behavior, averaging, state, blockers, and validity. Determine whether the later acquisition could have observed the earlier event class. Explain how differences in definitions can be resolved through matched or otherwise defensible observations. Only then discuss what residual disagreement might support about environmental change. Preserve both records and explicitly separate untested intervals from demonstrated negative coverage.

Review: Chapter 1 — Frame a bounded finding from the completed observation; Chapter 1 — Define the measurement before choosing the receiver mode.

V011-C01-ESSAY-014 — Explain what each attempted test was intended to discriminate and whether its required capability was demonstrated. Record the conditions, outcome, failure modes, and any missing coverage. Distinguish an instrument failure from a valid nondetection and a nondetection from universal absence. A complete answer shows how this evidence constrains later interpretation, prevents selective reporting, and guides the next experiment without imposing indiscriminate retention beyond the authorized objective.

Review: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Frame a bounded finding from the completed observation; Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-ESSAY-015 — Discuss the missing original indication, individual corrections, planes, state, native data, timing, and processing lineage as applicable. Explain how their absence can conceal double-counted loss, wrong gain state, detector differences, or overload. Propose a record adequate for the actual measurement rather than an unlimited checklist. The answer should distinguish information that can still be recovered from logs or exports from information irreversibly lost and should narrow the report's claim accordingly.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Reference Planes and Configuration Identity.

V011-C01-ESSAY-016 — Explain that each objective requires a different scope and transformation. A wide scan may locate a component without supporting its calibrated level, while a narrow coherent capture may support phase without broad coverage. Identify the plane, intervals, state, estimator, and decision criteria for each. Credit depends on showing concrete tradeoffs and a sequence that connects discovery to a justified follow-up, not merely asserting that one instrument mode is always superior.

Review: Chapter 1 — Define the measurement before choosing the receiver mode.

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V011-C01-ESSAY-017 — Consider cable loss and route, adapters, antenna orientation, polarization, external filtering, mismatch, and common-mode paths. Explain how an accessory or movement can change the desired transfer or an artifact mechanism. The example should preserve the distinction between observed change and assumed cause. Identify records and a suitable comparison that would help isolate the effect, and state how earlier observations remain bound to the earlier installation.

Review: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Reference Planes and Configuration Identity.

V011-C01-ESSAY-018 — Connect each event to the validity or authority condition it threatens. Define when acquisition stops, when data are marked as affected, when a diagnostic challenge is appropriate, and when specialist or authorized oversight is needed. Preserve the actual events, states, and records. A strong answer avoids a single automatic response for all failures and shows how the plan protects both evidential integrity and the permitted scope of the engagement.

Review: Chapter 1 — Operational Decision Discipline; Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C01-ESSAY-019 — Suitable pairs include measured tone levels and a cubic explanation, phase-noise data and a reciprocal-mixing prediction, or usable windows and capture probability. Identify the observed quantities and the extra parameters or assumptions required by the model. Explain what further observation could challenge the interpretation. The answer should preserve the usefulness of modeling while rejecting the substitution of a prediction for an actual field observation.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Table 1A. Route the measurement question to the developed model.

V011-C01-ESSAY-020 — Explain how antennas, accessories, state changes, software, estimators, reference planes, and operating limits affect the actual result. Identify what the certificate may support and which parts of the installed chain remain outside its scope. A strong answer ties calibration applicability to the declared measurement definition and retained state, then proposes relevant checks. It should not dismiss calibration; it should show how to use calibration evidence within its supported boundary.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-ESSAY-021 — Choose an upstream level, external gain, and passive loss, calculate the downstream indication, and then recover the original level by adding loss and subtracting gain. Define units and reference locations. Discuss state compatibility, mismatch, detector response, uncertainty, and overload as appropriate. A complete answer recognizes that algebraic consistency verifies signs and arithmetic, while empirical validity requires separate evidence about the installed chain.

Review: Chapter 1 — Equation 2. Corrected input power; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

V011-C01-ESSAY-022 — The proposed finding should state the observed event, valid state and coverage, relevant challenge outcomes, and remaining alternatives. Choose verbs consistent with detection, classification, or limited localization. Identify the next decision the evidence supports and the information still needed for attribution. Credit depends on precise scope and a useful consequence, not on making the finding sound more conclusive than the evidence allows.

Review: Chapter 1 — Frame a bounded finding from the completed observation; Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

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V011-C01-ESSAY-023 — Identify which observations share timing, input, correction, or software paths. Define timestamp events and uncertainties, retained native representations, and comparison conditions. Propose changes that test relevant shared errors without destroying the capability needed for the question. A strong answer explains why agreement and disagreement are both conditional on the design and retains a bounded interpretation rather than assigning unsupported numerical confidence.

Review: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Define the measurement before choosing the receiver mode.

V011-C01-ESSAY-024 — Identify the original mechanism, configuration, tested domain, and limits. Compare them with the new architecture, accessories, environment, and intended measurement. Determine which assumptions require a fresh check and what evidence would support or contradict transfer. Treat the earlier lesson as an informed hypothesis until the relevant conditions are established. Record deviations and avoid replacing a configuration-specific argument with a universal rule.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-ESSAY-025 — Trace the objective through measurement definition, system boundary, configuration identity, acquisition, preservation, correction, challenges, and bounded interpretation. Identify failures of authority, state knowledge, validity, continuity, comparison capability, or model support. Explain what evidence remains usable and which claim must be narrowed when a failure occurs. A strong synthesis connects the elements causally and preserves the difference between a documented observation and a stronger conclusion that requires further support.

Review: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Frame a bounded finding from the completed observation.

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Discussion Guidance

V011-C01-DISCUSSION-001 — Discuss analytical reversibility alongside minimization, content limits, retention, and disclosure. Identify cases in which native data are necessary and cases in which broader capture exceeds the objective. The discussion should produce a justified acquisition scope and an explicit treatment of incidental information, rather than treating low storage cost as a sufficient reason for indiscriminate collection.

Review: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

V011-C01-DISCUSSION-002 — Distinguish settings that change the answer from cosmetic preferences. Compare hardware identity, automatic behavior, software builds, calibration data, and state transitions. Ask how a later reviewer would detect a consequential difference. A useful conclusion states a criterion for relevance and identifies circumstances in which the required detail increases.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Reference Planes and Configuration Identity.

V011-C01-DISCUSSION-003 — Map shared inputs, clocks, reference sources, software, and correction assumptions. Discuss how to change relevant error structure while retaining comparable capability. Consider whether a different instrument brand or enclosure establishes independence. End with a bounded statement of what a proposed comparison would and would not test.

Review: Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-DISCUSSION-004 — Start with the authorized decision and the expected event class. Compare coverage, calibration, phase, timing, and information preservation. Discuss what each choice leaves untested and whether discovery can support a targeted follow-up. The result should be a reasoned measurement definition and an explicit residual gap, not a preference based on display appearance.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Mission Authority and Collection Boundaries.

V011-C01-DISCUSSION-005 — Compare detected, classified, correlated, localized, attributed, and recovered. Discuss how different readers might overinterpret an identifier or an unexplained peak. Draft a sentence that is useful for a next decision and preserves the actual evidence. Explain which additional observations would justify stronger wording.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery; Chapter 1 — Frame a bounded finding from the completed observation.

V011-C01-DISCUSSION-006 — Consider setup exports, status logs, native data, transition timing, and potential reconstruction. Discuss whether a state can be established retrospectively and what must remain qualified if it cannot. Preserve the original record. A responsible outcome separates usable observations from unsupported amplitude or sensitivity claims instead of accepting or rejecting the entire record without analysis.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

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V011-C01-DISCUSSION-007 — Distinguish continued function after the event from knowledge of the earlier state. Discuss which faults the check could reveal and which historical ambiguities it cannot resolve. Define a useful closing test and a report statement that acknowledges its time and scope. Avoid treating the check as either universal assurance or wholly irrelevant.

Review: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Treat configuration changes as changes in the measurement law.

V011-C01-DISCUSSION-008 — Examine command timing, acceptance, settling, and automatic behavior. Discuss whether the trace itself can discriminate the states and what additional records are needed. Consider the risks of averaging through the disagreement. The discussion should produce a documented resolution or a bounded limitation attached to affected data.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law.

V011-C01-DISCUSSION-009 — Identify the event class, threshold or sensitivity conditions, frequency and time coverage, and exclusions. Discuss which omitted conditions would matter to the client's decision. Draft a negative finding that preserves practical meaning while directing any justified follow-up to an actual gap. Avoid both unsupported certainty and empty general caution.

Review: Chapter 1 — Frame a bounded finding from the completed observation; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-DISCUSSION-010 — Distinguish complete evidence preservation from proportionate presentation. Discuss which tests materially affect alternatives, coverage, or confidence in the finding. Explain how the final report can link to a reviewable record without concealing unfavorable outcomes. The decision must remain consistent with authorized retention and disclosure.

Review: Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Mission Authority and Collection Boundaries.

V011-C01-DISCUSSION-011 — Consider changed coupling, polarization, path sensitivity, intermittent behavior, and the actual observation opportunity. Identify a suitable return or reference comparison. The discussion should separate a useful location-dependent observation from a definitive source location and specify what evidence would narrow the alternatives.

Review: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

V011-C01-DISCUSSION-012 — Compare a known scalar correction with clipping, magnitude-only retention, missing samples, or inadequate rejection before decimation. Discuss which transformations can be reconstructed and which require missing information. The conclusion should guide preservation and reporting, including when a corrected number would give a false impression of recovery.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.7. Show why a clipping flag defeats an ordinary gain inverse; Chapter 1 — Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase.

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V011-C01-DISCUSSION-013 — State the detection criterion and configured chain. Discuss external components and instrument-generated alternatives, then propose discriminating observations. Examine how authority, state identity, and valid comparison conditions constrain the next step. The discussion should produce a testable question instead of assigning ownership or intent from the display.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery; Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

V011-C01-DISCUSSION-014 — Compare usable time and frequency coverage, estimator, detector, gain, blockers, and sensitivity. Discuss what a matched follow-up would establish. Only after those conditions are reconciled should the discussion assess the residual evidence for change. Preserve the possibility that the original and later records answer different questions.

Review: Chapter 1 — Frame a bounded finding from the completed observation.

V011-C01-DISCUSSION-015 — Discuss planned decision points, controlled deviations, specialist escalation, and the evidence needed to assess validity afterward. Consider a case in which a rigid menu sequence misses a consequential state change. A strong discussion keeps judgment reviewable through reasons and records without pretending that a checklist eliminates technical interpretation.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-DISCUSSION-016 — Begin with the chapter's warning that a configuration string does not alone establish location or ownership. Discuss controlled state changes, physical correlation, timing, and competing mechanisms. Specify which inference each observation supports. The discussion should avoid both automatic acceptance and an unsupported assertion that identifiers can never be useful.

Review: Chapter 1 — Observation, Classification, Attribution, and Content Recovery.

V011-C01-DISCUSSION-017 — Compare the intended estimator, gains, losses, noise, validity, timing, and calibration applicability. Discuss whether separate corrections or a state-aware model can support the combination. Identify what must be retained for reconstruction. The final position should explain the conditions of a valid combination and when separate results are necessary.

Review: Chapter 1 — Treat configuration changes as changes in the measurement law; Chapter 1 — Equation 2C. Average after each interval has its own valid correction.

V011-C01-DISCUSSION-018 — Use concrete examples to examine the interaction rather than choosing a slogan. A capable receiver can be poorly configured, while a controlled system can still lack necessary sensitivity or coverage. Discuss how the objective determines required capability and how records and checks establish that it was available during the observation.

Review: Chapter 1 — Receiver as a Measurement System; Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Evidence Record and Closing Verification.

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V011-C01-DISCUSSION-019 — Identify retained observations, model parameters, assumptions, and the predicted domain. Discuss how to label extrapolation and what evidence would test it. A useful conclusion preserves the model's analytical value without presenting unobserved intervals or configurations as measured coverage.

Review: Chapter 1 — Keep the evidence chain reversible to its declared inputs; Chapter 1 — Application 1A.10. Separate a valid corrected level from an unobserved transition interval.

V011-C01-DISCUSSION-020 — Discuss the authorized scope, the operational stop rule, preservation of the incident record, and the process for any valid extension. Keep technical interest separate from authority. The discussion should identify what can be reported about the incomplete acquisition and what additional permission or redesign would be required for further collection.

Review: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Operational Decision Discipline.

V011-C01-DISCUSSION-021 — Propose a record containing the original indication, ordered path, gain and loss signs, relevant states, and destination plane. Discuss a forward arithmetic check and the limits of the scalar model. The conclusion should make it possible to identify double counting or unsupported conversion without requiring the reviewer to infer missing settings.

Review: Chapter 1 — Equation 2. Corrected input power; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C01-DISCUSSION-022 — Discuss illustration, communication, context, and the limits of a screen image. Consider whether the screenshot documents a display state that the native file omits, while retaining the need for data lineage and actual configuration. A proportionate package uses each representation for its supported purpose and avoids treating visual appearance as complete technical proof.

Review: Chapter 1 — Reference Planes and Configuration Identity; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

V011-C01-DISCUSSION-023 — Connect the required depth to the decision and evidence. Discuss whether the tested configuration dependence supports a bounded artifact finding, what alternatives remain, and what would justify naming a particular circuit. The conclusion should not demand unlimited investigation, but it must distinguish a useful diagnostic result from complete mechanism identification.

Review: Chapter 1 — Frame a bounded finding from the completed observation; Chapter 1 — Hypothetical Case Adjudication: Receiver-System Boundaries, Mission Authority, and Evidence Formation.

V011-C01-DISCUSSION-024 — Identify the observed mechanism, operating domain, record quality, and failed alternatives. Discuss how to present the lesson as a hypothesis or bounded procedure requiring validation in the new setting. Propose a training exercise that tests transfer rather than encouraging uncritical repetition of an anecdote.

Review: Chapter 1 — Operational Decision Discipline.

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V011-C01-DISCUSSION-025 — Construct a coherent argument from authority and measurement definition to valid state, retained inputs, corrections, challenges, and conclusion. Identify the most important open alternative and the next observation that could address it. The discussion should demonstrate that explicit limits improve the decision value of the finding without substituting repeated generic caution for technical evidence.

Review: Chapter 1 — Mission Authority and Collection Boundaries; Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 1 — Evidence Record and Closing Verification; Chapter 1 — Frame a bounded finding from the completed observation.

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Chapter Glossary

ACQUISITION INTERVAL: The declared span of physical time during which observations are eligible to contribute to a measurement. Its usable portion may exclude transitions, failed captures, or invalid states; a file's existence alone does not establish continuous valid coverage.

ACTUAL STATE: The receiver configuration supported by status and observation evidence for a particular record interval. It may differ from the commanded state because of rejection, settling, automatic control, or other changes that affect the measurement.

ADAPTIVE CONTROL: A mechanism that changes a receiver or processing state in response to input or operating conditions. Its effect must be retained in configuration identity when it alters gain, validity, timing, or another part of the measurement law.

ARTIFACT: A feature introduced by the measurement apparatus or processing that can resemble a component of the environment. The term identifies an explanatory possibility or supported finding; it does not by itself identify every responsible circuit or coupling path.

ATTRIBUTION: An evidence-supported connection between an observed component and a physical emitter or system. It requires more than detection or a waveform-family label and must retain the assumptions and alternative explanations relevant to that connection.

BANDWIDTH: The frequency extent associated with an admitted path or reported measurement. Its precise definition must accompany the result because a nominal setting does not by itself identify the energy, filtering, or estimator represented by the indication.

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CALIBRATION APPLICABILITY: The conditions under which existing calibration information supports a particular measurement result. A changed path, gain state, detector, software process, or reference plane can require reassessment even when the instrument still carries a valid certificate.

CLOSING VERIFICATION: A check after an important observation that assesses specified functions of the measurement chain at the time of the check. Its assurance is limited to the states and conditions exercised; the check alone does not establish uninterrupted validity throughout the preceding acquisition.

COLLECTION BOUNDARY: The authorized limits on what an engagement may acquire and how that information may be retained or disclosed. In receiver work these limits are implemented through frequency, time, mode, channel, recording, and handling choices.

COMMANDED STATE: The configuration requested by an operator, script, or controller. It records intended operation but does not alone prove that the receiver accepted the request, settled, or maintained that state throughout the associated acquisition.

CONFIGURATION IDENTITY: Complete hardware, firmware, software, option, accessory, and setting state required to reproduce a receiver observation.

CONFIGURATION TRANSITION: A change between receiver states that can include transient, relocking, or settling behavior. Records affected by the transition must be distinguished from intervals governed by an established valid configuration.

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CONTENT RECOVERY: Reconstruction of information carried by a signal rather than mere detection or classification of its waveform.

CORRECTION CHAIN: The ordered, documented transformations that convert an original indication into a result at a declared reference plane. Retaining each term, sign, state, and applicability permits reconstruction and exposes omitted or double-counted contributions.

DECISION CRITERION: The stated condition under which an observation or numerical estimate supports an intended action or conclusion. It includes relevant validity and uncertainty requirements and must not be inferred merely from the appearance of a display.

DETECTION: A finding that energy or a structured component met a stated decision rule under declared observation conditions. It does not automatically establish waveform class, emitter identity, carried content, or intent.

DISPLAY INDICATION: The value or feature presented by an instrument or software interface before its physical meaning is fully established. Interpretation requires the relevant plane, state, estimator, scale, and applicable corrections.

ESTIMATOR: The specified mathematical operation that converts retained observations into a reported quantity. A detector bucket, integrated channel, fitted tone, or timing estimate can answer different questions despite similar display labels.

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EVIDENCE RECORD: The retained observations and contextual information needed to review a measurement and its interpretation. It includes consequential settings, native data, timing, corrections, challenges, unsuccessful tests, and limits on what was examined.

EXTERNAL GAIN: Signal gain contributed by a component outside the receiver indication's reference boundary. In the stated scalar backward level correction it is subtracted, provided its value and operating state apply to the observed path.

FREQUENCY INTERVAL: The declared frequency scope over which components can contribute to an observation or reported estimate. Excluded or unobserved portions remain outside a negative finding unless separate evidence establishes their coverage.

INDEPENDENT COMPARISON: A comparison that changes relevant sources of measurement error while retaining the capability required to observe the component of interest. Separate instruments do not establish independence when shared clocks, input paths, or processing can produce a common result.

INPUT PATH: The physical route by which energy reaches the selected receiver input, including consequential antennas, cables, adapters, filters, switches, and other components. Changing the route can change both desired transfer and artifact mechanisms.

INSTALLED PATH: The measurement path in its actual operating geometry and connections. Cable routing, antenna position, polarization, accessories, and coupling conditions can distinguish it from an isolated component characterization.

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INTERNAL CONTRIBUTION: Noise or artifacts generated within the declared measurement system rather than simply arriving at its chosen external input. Equation 1 retains this contribution so that observed output is not automatically equated with an environmental source.

MEASURAND: Quantity intended to be measured, stated with its reference plane, state, bandwidth, and conditions.

MEASUREMENT CHAIN: The connected physical and computational transformations that carry an input to a reported result. Its relevant boundaries include gain, loss, filtering, conversion, detection, sampling, timing, and analysis.

MEASUREMENT DEFINITION: The stated quantity or proposition together with its reference plane, frequency and time intervals, receiver state, estimator, and intended decision.

MINIMIZATION: Technical and procedural limitation of collection, retention, and disclosure to information necessary for an authorized purpose.

NATIVE RECORD: Data retained in the acquisition system's original useful representation, together with sufficient configuration information to interpret them. The term does not guarantee correctness; it identifies inputs that can support reconstruction before later transformations discard information.

NEGATIVE FINDING: A bounded statement that no event meeting a defined criterion was observed under demonstrated valid coverage and capability. Its meaning must preserve the tested event class, sensitivity, intervals, and exclusions.

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OBSERVATION: A recorded result of an examination under a particular measurement state. Its interpretation may support additional propositions, but the observed feature and those model-dependent or source-dependent inferences remain distinguishable.

OPERATING DOMAIN: The stated range of conditions within which a measurement model or approximation is intended to apply. A local linear description, for example, requires a defined state and limits that address relevant overload or adaptive behavior.

PASSIVE PATH LOSS: The attenuation assigned to the relevant passive part of a measurement path under the stated conditions. The scalar backward correction adds this loss to the downstream indication when estimating the upstream power.

PROCESSING LINEAGE: The documented sequence connecting retained input data with derived outputs. It identifies software, settings, corrections, selections, and transformations so that a result can be reconstructed and its irreversible steps recognized.

REFERENCE CHECK: An observation of a known or controlled input used to test specified functions of a measurement chain. Its conclusion must remain limited to the capability and conditions actually exercised.

REFERENCE PLANE: Declared physical or mathematical location to which amplitude, phase, impedance, or timing is referred.

SIGNAL CLASSIFICATION: The association of an observed component with a waveform family, modulation, timing behavior, or service type. The classification describes characteristics and is separate from attribution to a particular emitter or owner.

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STATE INTERVAL: A declared portion of a record during which the relevant receiver configuration and its calibration remain applicable.

TIME BASIS: The declared reference and event definition used to assign times to observations. It includes the meaning of a timestamp and, where relevant, synchronization sources, clock state, and uncertainty needed for comparison.

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References and Works Cited

United States Navy. Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles. NAVEDTRA 14189. September 1998. Pages 2-10 through 2-14. Reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388-8392; title and edition at compilation page 8345.

Annotation. The cited historical passages support receiver functions, superheterodyne intermediate-frequency architecture, and detection. The complete configuration and evidence boundary is the author's synthesis developed through Chapters 2-16. This historical training source does not certify a modern instrument or establish a legal conclusion. The original proposition-level footnote remains in the chapter. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver’s actual topology. Ideal mixer identities do not establish that a real component is free of compression, leakage, spurs or path-dependent calibration errors. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

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Joint Committee for Guides in Metrology. International vocabulary of metrology: Basic and general concepts and associated terms. VIM3 online edition, entries 2.48, 2.49 and 2.53. https://jcgm.bipm.org/vim/en/2.48.html; https://jcgm.bipm.org/vim/en/2.49.html; https://jcgm.bipm.org/vim/en/2.53.html. Read November 2, 2026. These entries support the distinctions among a measurement model, its evaluating function and a correction; they do not certify the chapter's constructed receiver configurations.

Annotation. This institutional vocabulary establishes conventional relationships among measurands, measurement results, calibration, uncertainty and traceability. Its role is terminological rather than an instrument-specific proof: the survey must still state the actual measurement model, reference plane and uncertainty evidence. A correct definition cannot compensate for an uncalibrated observation or justify conflating detection, classification and transmitter attribution. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

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Taylor, Barry N., and Chris E. Kuyatt. Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results. NIST Technical Note 1297, 1994 edition, September 1994. Appendix A, A.1–A.5. https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The official online text and cover were read for the measurement-process and uncertainty framework. Model 14B develops its exact-affine and local-approximation distinction; the Chapter 1 numerical cases are independent synthetic examples.

Annotation. This metrological guidance concerns the evaluation and reporting of measurement uncertainty, including propagation through a measurement model. Covariance, shared calibration terms, nonlinear transformations and declared coverage factors require attention when evidence from multiple receiver channels is combined. An uncertainty budget is meaningful only for a specified measurand and operating condition; it does not itself certify the authenticity of the underlying acquisition. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

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Chapter 2. Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal

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2.1 Thermal Noise as a Bandwidth-Dependent Quantity

Receiver sensitivity begins with noise power available from a source at a stated physical temperature and bandwidth. The familiar $k\ T\ B$ relation is a model for available thermal noise from a matched source, not a universal description of every noise observed at an instrument input. Antenna temperature can differ from ambient temperature, especially when the antenna views sky, ground, a hot structure, or a lossy network. Preselection, mismatch, cable loss, and external gain alter the noise delivered to the receiver before its internal noise is added.[1]

Noise must be related to the actual detector and effective bandwidth. A 1 kHz resolution filter and a 1 MHz digitized channel do not integrate the same noise even if both are centered on the same frequency. Window equivalent noise bandwidth, filter shape, detector law, averaging, and post-detection filtering affect the displayed level. Comparing noise readings requires matching these conditions or converting them through a documented model.

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1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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2.2 Power, bandwidth, and the reference plane

The input of a noise calculation is a physical port, not a trace on a screen. At a matched real impedance, available source noise and noise delivered to the receiver coincide. Away from that condition, the source can offer one available power while the receiver accepts another. A quoted cable insertion loss, measured between matched ports, therefore cannot automatically repair a measurement made between a strongly reactive antenna and a receiver whose input match changes with attenuation. The distinction should be settled before temperatures, decibels, or correction files are combined.

Choose a source plane, an output plane, and an observation band. The source plane may be an antenna terminal, the input connector of a remote preamplifier, or the receiver connector after a cable. Each choice answers a different question. Moving the source plane forward past a lossy cable makes the reported receiver noise figure smaller because the cable is no longer included; it does not improve the original antenna-to-output measurement. A useful report names the plane in words and on the path drawing, then attaches every gain, loss, and temperature to a component between the two planes.

Bandwidth is equally physical. A channel filter weights the noise density over frequency, whereas a narrow tone experiences the response at its own frequency. The equivalent noise bandwidth is the width of a rectangular filter that passes the same noise power under the stated normalization. If the density and gain are flat over that band, the integration reduces to their product with bandwidth. If they vary appreciably, a single center-frequency

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gain or noise temperature is insufficient. The weighted integration developed in Model 11B illustrates the required discipline; its particular phase-noise spectrum is not a substitute for the thermal-noise spectrum here.

A narrower analysis channel can reduce integrated noise while also rejecting part of a modulated or short-duration signal. The signal-to-noise improvement is then smaller than the bandwidth ratio alone suggests. For a tone retained at the channel center, reducing the effective bandwidth by ten reduces white-noise power by ten. For a burst whose energy spreads outside the new channel, the retained signal must be measured or calculated as well. Reporting only the lower noise trace hides this loss of useful signal. Detector averaging, trace averaging, and longer observation may alter variability without producing the same physical filtering.

An input-referred noise value is obtained by dividing a measured output noise power by the appropriate signal power gain. This operation is a reporting transformation; the receiver has not physically moved its noise generators to the input. It remains valid only for the gain that connects the selected input signal to that output. A gain correction derived from another attenuator state, another sideband, or another point in a compressed response can produce a plausible input number with no valid measurement interpretation. Retaining both the raw output result and the gain used in the conversion makes that failure detectable.

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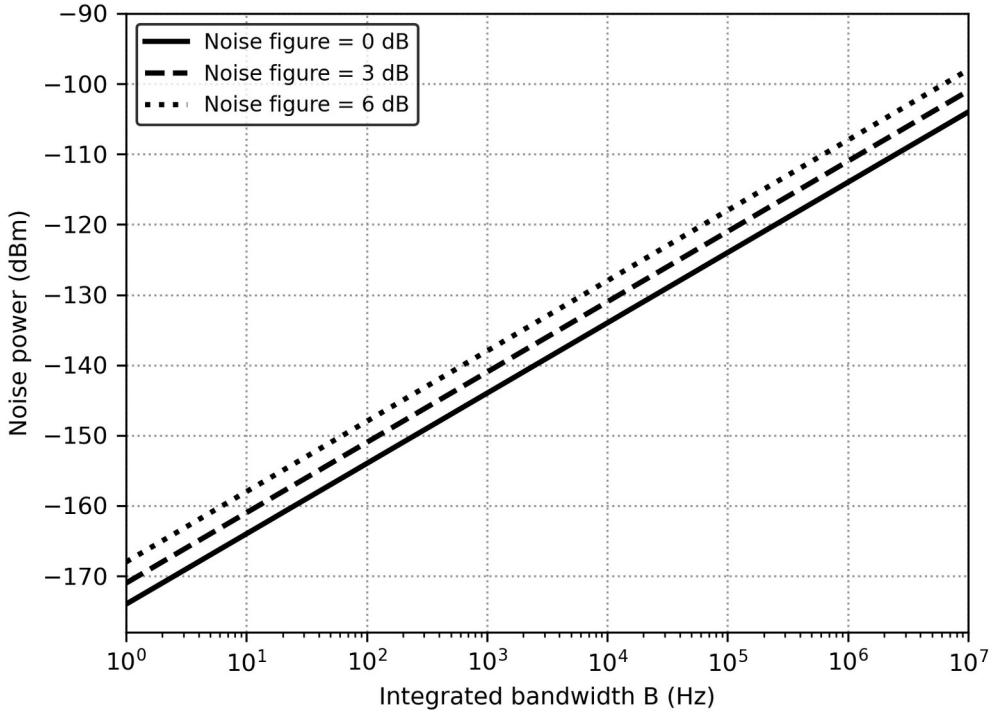

At 290 K, nominal thermal-noise density ≈ −174 dBm/Hz

$$P_N\,(\mathrm{dBm}) \approx -174 + 10\log_{10}(B/1\,\mathrm{Hz}) + NF$$

Assumes thermal-noise-limited input and equivalent rectangular noise bandwidth.

Figure 5. Thermal noise versus measurement bandwidth.

Cross-volume technical interface. S001-V007(Electronics Foundations for TSCM Practitioners) supplies deeper device-level treatment of passive and active noise mechanisms, whileS001-V008(RF Theory Propagation and Spectrum Behaviour) supplies the external propagation setting andS001-

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V016(EMI EMC Shielding Grounding Bonding and Power Integrity) the conductive and radiative interference setting. For this receiver analysis, keep available source power, equivalent input noise temperature, reference temperature, measurement bandwidth, cascade gain, and uncertainty explicitly separate. Neither a device noise figure nor a displayed noise floor alone identifies the environmental origin of a signal.

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2.3 Noise Figure and Noise Temperature

Noise factor compares the input signal-to-noise ratio with the output signal-to-noise ratio under specified source conditions. Expressed in decibels, noise figure is convenient but can conceal whether a lossy cable, filter, preamplifier, mixer, or receiver dominates the system. Equivalent noise temperature offers another representation and is especially useful for cascades and low-noise front ends. Both require a declared reference temperature and impedance.

In 1944, H. T. Friis framed receiver noise as a property of a network that could be related to the properties of its components. His paper extended the discussion beyond high-gain receivers and included interstage mismatch and measurement. That network perspective motivates the chain analysis developed here. Model 2B states its narrower working assumptions explicitly: a selected equivalent channel, matched scalar power gains, declared temperatures, zero cross-power between the admitted noise contributions, and a fixed receiver state. The practical question is which stage contributes noise referred to the chosen input and which gain suppresses later contributions. A total gain figure alone cannot answer it.[2]

A preamplifier improves system sensitivity only when its gain is sufficient to suppress later receiver noise and its own noise, mismatch, compression, and out-of-band response remain acceptable. Placing a low-noise amplifier

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2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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after a long lossy cable cannot recover the signal-to-noise ratio lost before it. Conversely, an amplifier at the antenna can worsen a survey by overloading on strong legitimate transmitters or by generating intermodulation. The sensitivity plan is therefore inseparable from dynamic range and preselection.

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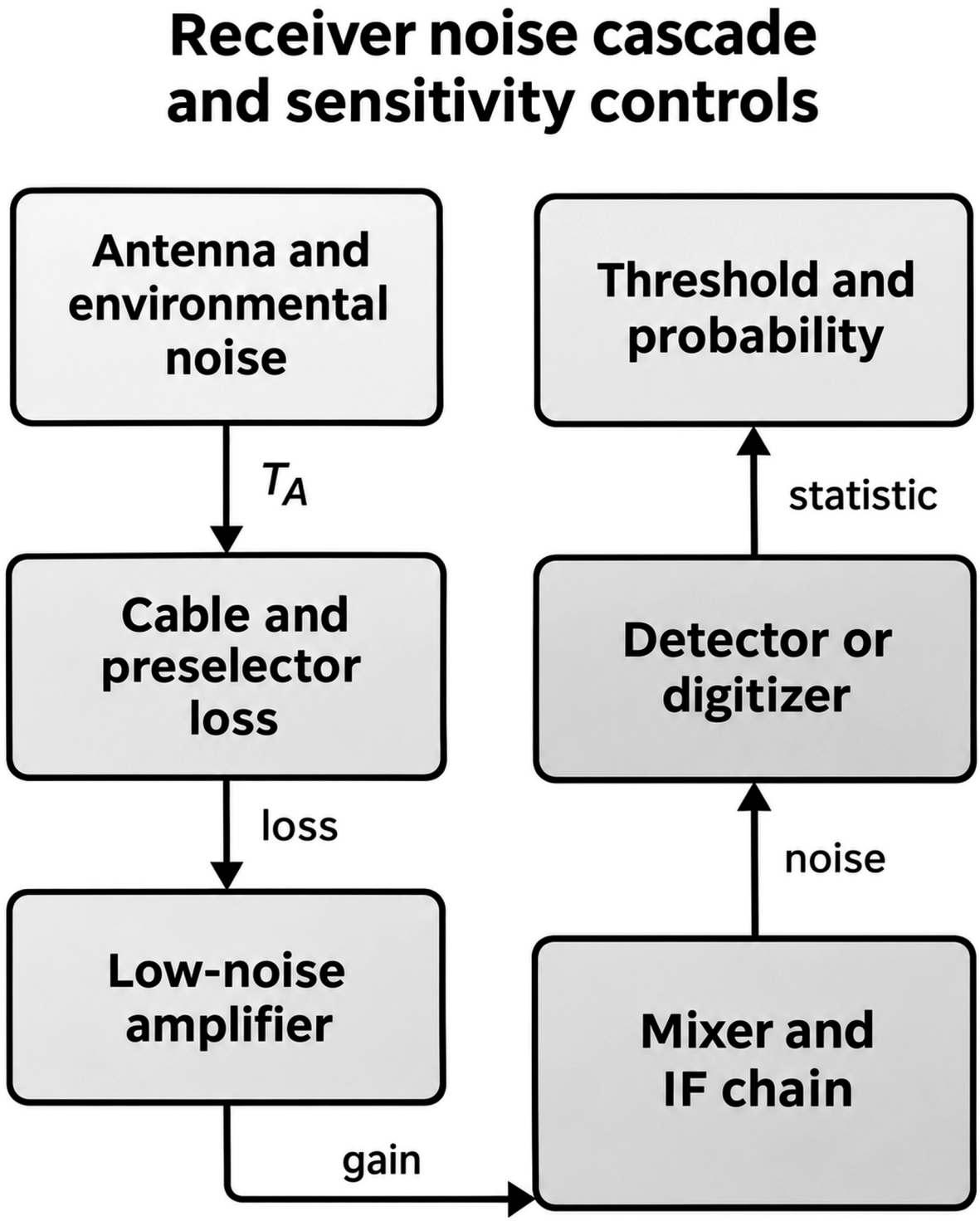

Figure 6. Receiver noise cascade and sensitivity.

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2.4 Sensitivity Specifications and Decision Thresholds

Minimum discernible signal, noise floor, sensitivity, usable sensitivity, and minimum detectable signal are not interchangeable specifications. A manufacturer may define sensitivity for a particular modulation, bandwidth, error rate, audio signal-to-noise ratio, detector, or probability of detection. A spectrum analyzer displayed average noise level often includes normalization and detector conventions that differ from communications-receiver sensitivity. The test must reproduce the definition or state that a different measurand was used.

A defensive search also needs a decision threshold. Detection can be based on amplitude above a local baseline, matched filtering, coherent integration, correlation with a state change, persistence across sensors, or another statistic. The threshold should be selected with a false-alarm objective and validated against noise-only data. A lower threshold increases apparent sensitivity but can flood the survey with random peaks and receiver products. The report states both the threshold and the evidence supporting its operating characteristics.

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2.5 Define sensitivity as a reproducible decision

A sensitivity claim should start with the event that counts as a successful observation. Examples include resolving a continuous tone within a declared frequency error, detecting a burst of specified duration, or recovering a waveform at a stated quality. These events require different observation intervals and processing. A mean noise power provides a scale for a decision statistic, but it supplies neither the distribution of that statistic nor the number of opportunities for a false alarm. Searching many frequencies or many time windows creates more opportunities than evaluating one preselected channel.

For a bounded calculation, one may stipulate a required output signal-to-noise ratio and solve for the corresponding input signal power. That is the use of Equation 4L below. The stipulated ratio must come from a separately justified detector requirement or a controlled empirical characterization. It is not legitimate to attach an arbitrary probability of detection to a ten-decibel ratio. A threshold estimated from the same records used to advertise performance can also look better than it is. Keep a distinct set of challenge records, including noise-only intervals and weak reference events, to test the chosen rule.

The detection record should retain the native samples or equivalent unaveraged measurement data, the decision statistic, the threshold, the event duration, and the receiver state. For a scanning receiver, also retain when the channel was actually observed. A failed detection while the receiver was tuned elsewhere is a coverage failure, whereas a failed detection during a valid dwell can inform a sensitivity estimate. These

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failures should not be pooled without stating the population. Chapter 15 develops the timing and capture consequences; the noise budget here establishes only the amplitude environment during a valid observation.

A useful sensitivity verification changes one declared quantity at a time. First establish a quiet baseline at fixed gain and bandwidth. Then reduce a known desired reference through the decision region. Finally repeat with a bounded interferer or an alternate gain state. If sensitivity deteriorates only in the interferer condition, a laboratory noise figure has not become numerically wrong; it has become insufficient to describe the new state. The next analysis must test compression, gain control, intermodulation, reciprocal mixing, or spectral overlap. Chapter 11 supplies the mechanisms needed to distinguish those possibilities.

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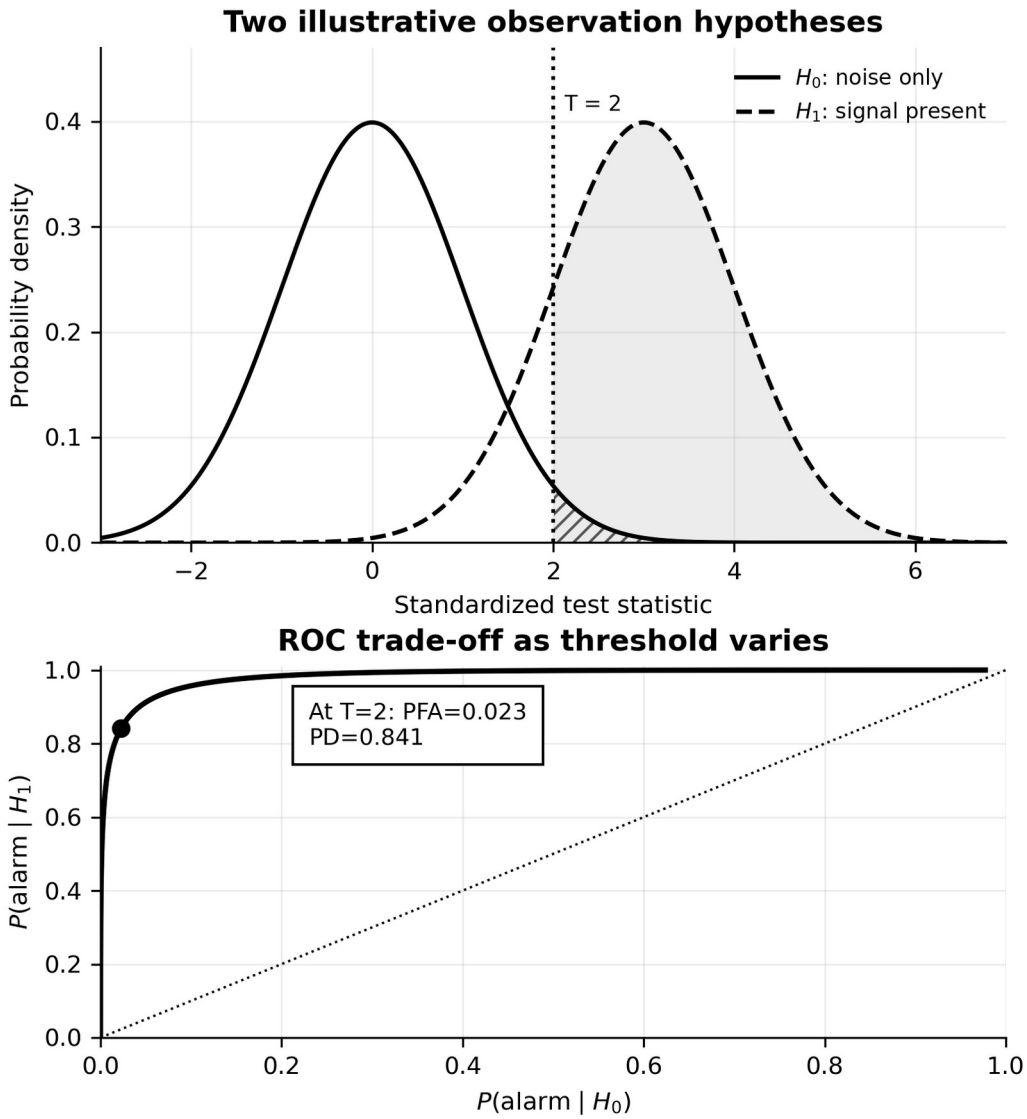

TECHNICAL INTERPRETATION

Raising a fixed threshold suppresses false alarms but can also miss weak emissions. Detection probability requires a declared statistical model.

Figure 7. Detection thresholds and statistical errors.

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2.6 Y-Factor and Comparative Noise Measurements

Noise figure can be measured by applying two known source noise temperatures and observing the output power ratio. The method depends on source calibration, excess-noise ratio, receiver linearity, bandwidth stability, gain stability, and correct switching state. The receiver must remain below compression for both source states, and automatic gain control must be disabled or characterized. Loss and mismatch between the noise source and the receiver reference plane require correction.

Comparative measurements are often more practical in field work. A terminated input, shielded source, alternate antenna, preamplifier bypass, or known reference signal can reveal whether the observed noise is external, conducted, internally generated, or overload-related. These tests do not by themselves produce a traceable noise figure, but they can discriminate mechanisms. The configuration and timing of each comparison must be retained.

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2.7 Uncertainty and Environmental Noise

Receiver sensitivity can be dominated by the environment rather than the instrument. Urban radio noise, switching power supplies, lighting, digital electronics, power-line carriers, broadcast transmitters, and building systems raise the effective noise temperature and can vary with time and operating state. A low laboratory noise figure does not imply the same detection limit at an occupied site. Spatial, temporal, polarization, and operational baselines are needed.

Uncertainty includes source calibration, gain and loss corrections, bandwidth, detector statistics, mismatch, repeatability, temperature, and limited sample duration. Noise estimates are random variables; short measurements fluctuate. The variance of an average depends on the sample covariance and averaging rule, as developed in Chapters 8 and 14. Correlated or duplicated samples do not supply their nominal independent sample count, and changing receiver or source states can change the measurand being averaged. A sensitivity statement should therefore include its bandwidth, detector, probability or confidence convention, and environmental state.

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2.8 Operational Sensitivity Verification

A complete receiver system is verified with calibrated coherent and noise-like references introduced at the selected field or terminal plane. Measurements are repeated with the antennas, cables, filters, preamplifiers, gain states, and detector modes that will be used during the survey. The verification determines detection probability or level uncertainty under a bounded strong-signal environment rather than treating a quiet laboratory specification as an operational guarantee.

Reference signals are controlled so that they do not contaminate unrelated bands or create an undocumented test emitter. Their identity is marked in native data, and the injection or radiation geometry is described. A closing verification tests the sensitivity-related functions actually exercised by the reference, in the state and at the time of the check. It does not alone establish uninterrupted validity during the preceding engagement or verify antenna and accessory paths bypassed by the injection.

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2.9 Quantitative Model for Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal

Equation 1. Available thermal-noise power

$$P_{\mathrm{n}} = k\,T\,B$$

Available thermal-noise power P_{n} in watts equals Boltzmann constant k, source noise temperature T in kelvins, and equivalent noise bandwidth B in hertz for a matched thermal source. The relation does not include receiver-added noise, mismatch, nonthermal interference, or detector corrections.

Equation 2. Cascaded noise factor

$$F_{\mathrm{total}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$$

The Friis cascade relation uses linear noise factors F and available power gains G referred to compatible planes. It assumes linear operation and correctly characterized interstage networks. Loss before the first gain stage should be included as a noisy stage.

Equations 3 and 4 belong to the matched noise-cascade family developed in Model 2B and Applications 2B.1–2B.10. Use linear power gains and linear noise factors in Equation 4. Refer a passive loss to its physical temperature before converting the total input-equivalent temperature to noise figure.

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Table 1. Chapter 2 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Thermal-noise model	Source temperature, impedance, bandwidth, and antenna view	Establishes the physical noise reference	Urban interference and active electronics are not thermal noise
Noise figure or temperature	Reference temperature, source calibration, gain state, and linearity	Allocates receiver-added noise	Automatic gain or compression invalidates the simple test
Sensitivity criterion	Modulation, bandwidth, detector, probability, SNR, BER, or SINAD	Defines what detectable means	Catalog figures using different criteria cannot be compared directly
Environmental baseline	Time, location, polarization, operating state, and repeated samples	Separates site noise from receiver noise	A quiet laboratory result does not predict occupied-site performance

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2.10 Hypothetical Applied Calculation: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal

At 290 K and 10 kHz equivalent noise bandwidth, $k\ T\ B$ is approximately $4.00 \times 10^{-17}\ \mathrm{W}$, or -134.0 dBm. A receiver with 7 dB noise figure has an input-referred noise near -127.0 dBm before required detection margin, mismatch, and environmental interference. Reducing the bandwidth to 1 kHz improves the thermal-noise term by 10 dB if the signal remains fully represented.

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2.11 Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal

A remote probe shows a 9 dB rise in apparent noise when connected through a 25 m coaxial cable. Replacing the antenna with a matched termination leaves the rise unchanged, but bypassing an inline preamplifier removes it. The preamplifier is then found to oscillate intermittently when powered through the long bias line. The observation is documented as front-end instability, not elevated environmental noise.

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2.12 Measuring-Receiver Scope and System Noise Floor

CISPR 16-1-1:2019 specifies measuring-apparatus characteristics for radio-disturbance work from 9 kHz to 18 GHz and applies to EMI receivers and spectrum analyzers. It is a basic EMC measurement standard, not a universal TSCM attribution method. A receiver satisfying the apparatus standard can still be misconfigured, overloaded, connected to an uncalibrated external chain, or used outside the scope of a particular result.[3]

3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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2.13 Worked Example 2A.1. Thermal Noise-Floor Screening

Engineering question. Estimate the room-temperature receiver noise floor for bandwidth $B = 10\ \text{kHz}$ and system noise figure $\text{NF} = 5.0\ \text{dB}$.

Variables and units. The -174 dBm/Hz term is the conventional room-temperature thermal-noise density approximation; B is bandwidth in hertz; NF is noise figure in decibels; P_{n} is in dBm.

$$P_{\text{n,dBm}} \approx -174 + 10\log_{10}\left(\frac{B}{1\ \text{Hz}}\right) + \text{NF}$$

Calculation. $10\ \log_{10}(10{,}000) = 40.0\ \text{dB}$. Therefore $P_{\text{n}} = -174 + 40 + 5 = -129\ \text{dBm}$.

Dimensional check. The bandwidth ratio inside the logarithm is dimensionless relative to 1 Hz. Decibel terms combine consistently.

Uncertainty and valid range. The value is a screening estimate. Actual temperature, gain distribution, mismatch, filter noise bandwidth, detector, external preamplifier, cable loss, interference, and calibration uncertainty are omitted.

Practical meaning. A signal below -129 dBm may still be detectable through narrower bandwidth, coherent processing, or averaging. A signal above it is not automatically valid if overload or spurious response is present.

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2.14 Model 2B: a matched, fixed-state noise cascade

Model 2B expands the chapter's three-stage Equation 4 into an explicit reference-plane model shared with Chapters 3, 13, and 14. Its purpose is to predict how source noise and independently added stage noise reach one output, then invert or constrain that same relation. It is a small-signal model of one configuration. The sixteen local display groups, Equations 4A through 4P, are parts of this single family. The ten applications use constructed values to expose different design and measurement decisions. They are not performance data from a receiver, installation, or calibration laboratory.

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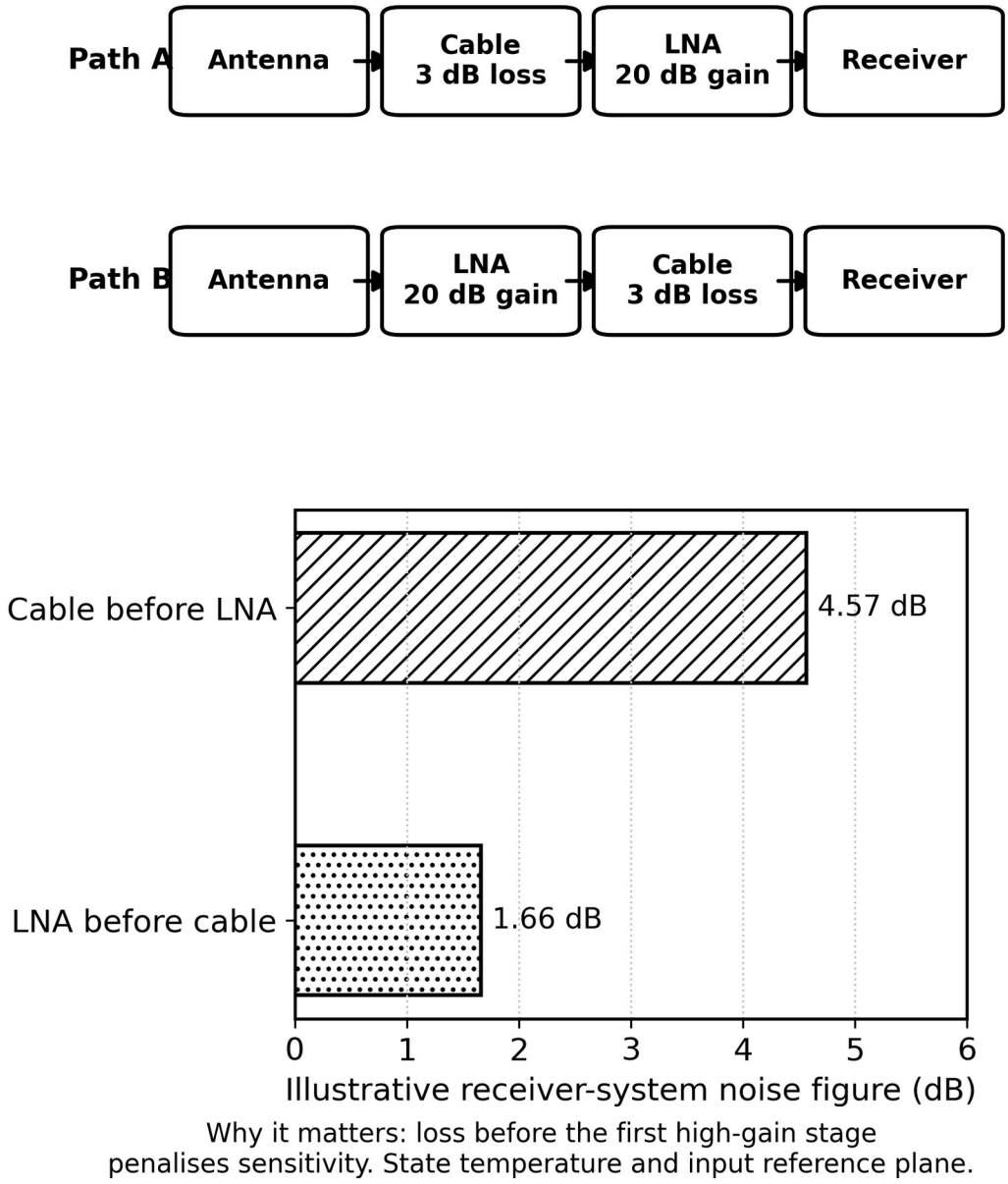

Figure 8. Gain-stage order and receiver noise figure.

Assume a positive integer n of linear, time-invariant stages in the selected equivalent channel coordinates. All interfaces, the source, and the load are matched to a common real reference impedance R_0; the applications use 50 ohms. Stage i has positive finite power gain g_i and finite nonnegative

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equivalent input noise temperature $T_{\mathrm{e},i}$, both approximately constant over one effective noise bandwidth B greater than zero. The source has effective noise temperature T_{s}. Source noise and the noises added by separate stages have zero cross-power, so their powers add. The classical thermal-noise approximation applies over the selected band.

The scalar quantities exclude unmodeled image paths, feedback between mismatched stages, gain changes, compression, and signal-generated noise. A frequency-converting receiver is not literally time invariant at the RF waveform level. It may be represented here by an empirically established scalar power and noise law in the selected channel only when its effective gain and noise temperature apply to the actual sideband architecture, input environment, and operating state. Analog Devices' cascade analysis explicitly shows why a mixer's nominal single- or double-sideband noise figure cannot be inserted blindly into an otherwise scalar chain. The present derivation uses the matched linear-block case and keeps that boundary visible.[4]

Equation 4A. Cumulative power gain

$$G_0 = 1$$
$$G_j = \prod_{i=1}^{j} g_i, \; j = 1, \ldots, n$$

G_j is the power gain from the cascade input to the output of stage j. The empty product G_0 equals one. Define N_i as the noise power in the common

4 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers” (June 14, 2013), “Baseline Case: Cascade of Linear Circuit Blocks” and “Noise Temperature,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and synthetic cases are stated in Model 2B.

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observation band at that stage output. By definition, the noise added by stage i at its output is $k\ B\ g_i\ T_{\mathrm{e},i}$, where k is Boltzmann's constant in joules per kelvin. The preceding noise is multiplied by g_i. These two contributions give the recurrence in Equation 4B. Every term is a power in watts; gain is dimensionless.

Equation 4B. Noise propagation through one stage

$$N_0 = kBT_s$$
$$N_i = g_i N_{i-1} + kBg_i T_{e,i}$$

Divide the stage recurrence by G_i. The earlier contribution becomes $\frac{N_{i-1}}{G_{i-1}}$, while the new contribution becomes $\frac{k\ B\ T_{\mathrm{e},i}}{G_{i-1}}$. Repeating this step back to the source gives the sum in Equation 4C. This derivation makes the ordering explicit: the input-referred importance of a later noise source is reduced by all preceding gain, and increased by preceding loss. A component's own output gain is absent from its input-equivalent contribution because that gain has already been included in the definition of $T_{\mathrm{e},i}$.

Equation 4C. Cascade temperature and integrated output noise

$$T_e = \sum_{i=1}^{n} \frac{T_{e,i}}{G_{i-1}}$$
$$N_{out} = kBG_n\left(T_s + T_e\right)$$

The sum T_{e} is the equivalent input noise temperature of the complete cascade at its selected first plane. It is not the physical temperature of the enclosure. A stage can have a physical temperature near ambient while its equivalent noise temperature is much smaller or larger. Temperature is a convenient power-density scale in this model. The source term T_{s} remains

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separate because changing the antenna environment should not silently change the defined receiver contribution.

Equation 4D. Noise factor at the reference temperature

$$F_0 = 1 + \frac{T_e}{T_0}$$
$$NF_0 = 10 \log_{10}(F_0), T_0 = 290\,K$$

Equation 4D defines F_0 relative to T_0 equal to 290 K, and expresses it logarithmically as NF_0. With source noise $k\ B\ T_s$ and a positive desired signal power that experiences G_n, direct division of input and output signal-to-noise ratios gives Equation 4E. When T_e is positive, the result equals F_0 if and only if T_s equals T_0. If T_e is zero, both ratios equal one for every positive T_s. For a cold source, receiver noise causes a larger relative degradation; for a very noisy source, the same receiver noise contributes little to the total. At T_s equal to zero, input signal-to-noise ratio is unbounded in the classical idealization, so Equation 4E is stated only for positive T_s.

Equation 4E. Signal-to-noise degradation for the actual source

$$\frac{SNR_{¿}}{SNR_{out}} = 1 + \frac{T_e}{T_s}, T_s > 0$$

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2.15 Derive passive loss from thermal equilibrium

Consider a matched dissipative attenuator with linear power loss L at uniform physical temperature T_{p}. Its power gain is $\frac{1}{L}$. Place it between matched terminations at the same temperature T_{p}. Thermal equilibrium requires the output available noise to remain $k\ B\ T_{\mathrm{p}}$. The source contributes only $\frac{k\ B\ T_{\mathrm{p}}}{L}$ after transmission, so the attenuator must contribute $k\ B\ T_{\mathrm{p}}\left(1-\frac{1}{L}\right)$ at its output. Dividing that added power by the gain gives Equation 4F. This argument does not assign thermal emission to power that was merely reflected by an arbitrary mismatch.

Equation 4F. Noise temperature of a matched dissipative loss

$$g_{loss}=\frac{1}{L}, T_{e,loss}=(L-1)T_p, L\geq 1$$

At T_{p} equal to T_0, the passive noise factor equals L, and the noise figure in decibels equals the insertion loss in decibels. At another physical temperature, that equality no longer follows. Placing this loss ahead of a following chain with temperature $T_{\mathrm{e,c}}$ gives Equation 4G. The first term is the attenuator's own contribution; the second is the following chain referred backward through the loss. Both are at the original input plane. Keysight's noise-measurement guide treats loss before and after a device separately and includes the physical temperature of the lossy connection in its compensation.[5]

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5 H. T. Friis, “Noise Figures of Radio Receivers,” Proceedings of the IRE 32, no. 7 (July 1944): 419–22, https://doi.org/10.1109/JRPROC.1944.232049. The publisher’s abstract was read for the historical network, component, mismatch, and measurement framing. The full paper

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Equation 4G. Loss followed by a characterized chain

$$T_{e,total} = (L-1)T_p + L\,T_{e,c}$$

A warm cable is consequently more than a level correction in a noise measurement. A level correction restores the reported signal to an earlier plane, but the cable's thermal contribution and the amplified importance of downstream receiver noise still enter the uncertainty and sensitivity. If several passive sections have different temperatures, use separate stages. Replacing all of them with one total loss at an arbitrary room temperature discards the ordering and the thermal information needed by the recurrence.

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was not accessed; Model 2B supplies its own stated derivation and working conventions.

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2.16 Invert the same model with two source temperatures

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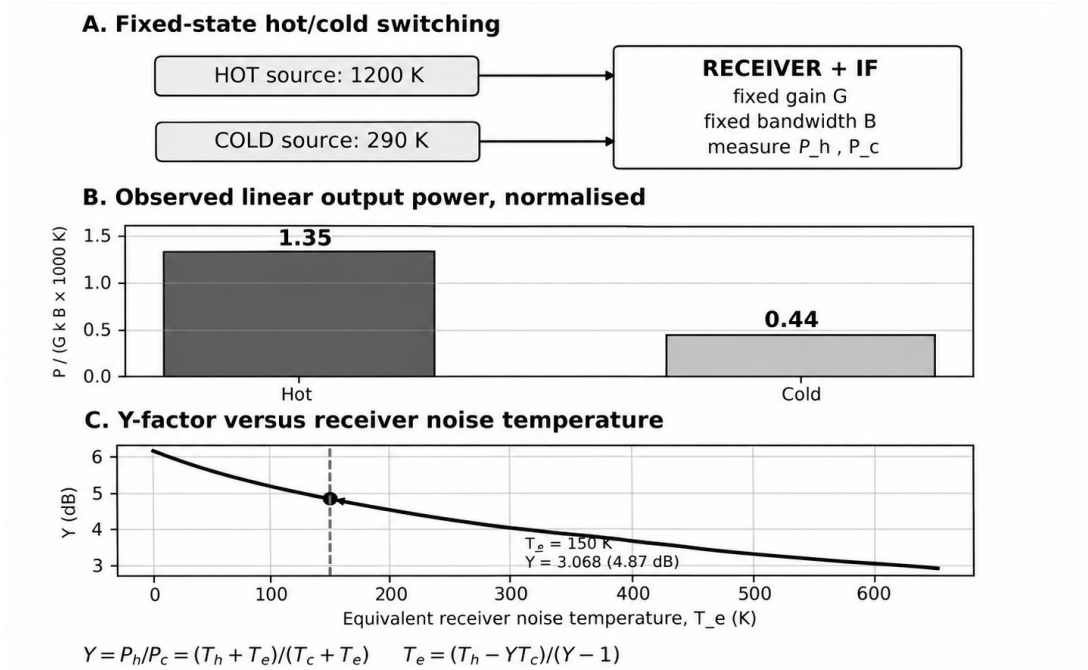

Figure 9. Hot/cold Y-factor noise measurement.

Let T_{h} and T_{c} be known hot and cold source temperatures at the chosen receiver input, with T_{h} greater than T_{c} and T_{c} at least zero. Require $T_{\mathrm{c}}+T_{\mathrm{e}}$ greater than zero so the cold output power and the finite ratio are defined. Hold gain, bandwidth, matching, and receiver noise temperature fixed during both observations. The ratio of the two linear output powers is Y. The common $k\ B\ G_n$ cancels, giving Equation 4H. This cancellation is the attraction of the method, and also its vulnerability: a quantity cancels only if it is actually common to both measurements. The measurement arrangement and inversion are illustrated in Figure 9.

Equation 4H. Hot-to-cold output power ratio

$$Y=\frac{N_h}{N_c}=\frac{T_h+T_e}{T_c+T_e}$$

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Equation 4I. Recovered input noise temperature and its domain

$$T_e = \frac{T_h - Y T_c}{Y - 1}$$

$$1 < Y \leq \frac{T_h}{T_c} \left(T_c > 0 \right)$$

For positive T_c and finite nonnegative T_e, Y lies above one and no higher than $\frac{T_h}{T_c}$. A measured value outside that range should trigger investigation of the source values, gain state, compression, offsets, or statistical uncertainty. It should not be forced into a physical result by clipping a negative temperature to zero. When T_c is zero, the upper-ratio statement is replaced by the direct formula; the cold output must still be positive for a finite measured ratio. As Y approaches one, the inversion becomes sensitive to small errors because its denominator becomes small.

A noise-source excess-noise-ratio calibration supplies a relation between its on and off temperatures and the reference temperature. In the convention used here, linear ENR is $\frac{\left(T_h - T_c\right)}{T_0}$. Read the actual source certificate and the instrument's convention before using it. The cold state need not equal 290 K, and loss between the calibrated source plane and the receiver changes both effective temperatures. A control measurement should establish that the receiver remains linear in the hot state as well as the cold state. More averaging cannot correct a systematic change of gain between them.

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2.17 Turn the cascade into bounded design requirements

For two stages, Equation 4C reduces to $T_{\mathrm{e},1}$ plus $\frac{T_{\mathrm{e},2}}{g_1}$. If the allowed total temperature is T_{target}, solving for first-stage gain gives Equation 4J when T_{target} exceeds $T_{\mathrm{e},1}$ and $T_{\mathrm{e},2}$ is positive. If T_{target} equals $T_{\mathrm{e},1}$, no finite gain can satisfy the limit while the second stage adds positive noise. If the limit is smaller, the first stage alone makes the requirement impossible. These boundary cases are as useful as the numeric answer because they distinguish a gain shortage from a fundamentally unsuitable first stage.

Equation 4J. Minimum first-stage gain for a temperature limit

$$g_1 \geq \frac{T_{e,2}}{T_{target} - T_{e,1}}, T_{target} > T_{e,1}$$

Solving Equation 4G for allowed preceding loss gives Equation 4K when its denominator is positive. A feasible passive loss must also satisfy L at least one. If the computed upper bound is below one, even a lossless connection cannot meet the requested temperature. The bound includes only noise. Filter rejection, source matching, stability, and strong-signal loading remain separate requirements, which Chapter 3 applies before choosing a physical implementation.

Equation 4K. Maximum allowed preceding loss

$$1 \leq L \leq \frac{T_{target} + T_p}{T_p + T_{e,c}}$$

Equation 4L. Input signal power for a stipulated output ratio

$$P_{req} = \gamma k B \left(T_s + T_e\right)$$
$$\gamma > 0, T_s + T_e > 0$$

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In Equation 4L, γ is a positive required linear output signal-to-noise ratio, $T_s + T_e$ is positive, and the desired signal is wholly retained by the observation channel with gain G_n. The positive-noise condition excludes the noiseless endpoint where a zero-signal ratio would be undefined. The input requirement is obtained by dividing the required output signal power by that same gain, which cancels. Increasing gain after the noise has already been added therefore does not improve this input requirement. It may improve the use of a later digitizer's range, provided the additional stage stays linear, but that is a different constraint from recovering signal-to-noise ratio.

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2.18 Application 2B.1: assemble a four-stage noise budget

Take a 1.5 dB preselector at 290 K, a low-noise amplifier with 20 dB gain and 1.2 dB noise figure, a 3 dB cable at 290 K, and a receiver with 30 dB gain and 600 K input noise temperature. The source is 290 K and the effective noise bandwidth is 10 kHz. Convert decibels before forming products or sums. The preselector loss is 1.41254, the amplifier gain is 100, and the cable loss is 1.99526. The total power gain is 35,481.34, or 45.5 dB.

The preselector contributes $(1.41254-1)290$ equal to 119.64 K. The amplifier's own temperature is $290(10^{0.12}-1)$ equal to 92.29 K, which becomes 130.37 K when referred backward through the preselector. The cable contributes 4.08 K at the original input because preceding gain suppresses its contribution. The receiver contributes 600 divided by the gain through the first three stages, or 16.91 K. The sum is 270.99 K, giving a cascade noise figure of 2.866 dB.

Table 2B.1. Constructed input-equivalent contributions in Application 2B.1

Stage	Own temperature, K	Preceding power gain	Input contribution, K
Preselector	119.64	1.00000	119.64
Amplifier	92.29	0.707946	130.37
Cable	288.63	70.7946	4.08
Receiver	600.00	35.4813	16.91

The input-equivalent integrated noise is k times 10,000 times $(290+270.99)$, or 7.7453×10^{-17} W, equal to −131.11 dBm. Multiplication by the total gain produces −85.61 dBm at the output. If a separately established decision rule requires 10 dB output signal-to-noise ratio for a wholly retained signal, Equation 4L gives an input requirement of −121.11 dBm. This is the requirement for the declared quiet, linear state. The two largest

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contributions identify the preselector and first amplifier as productive places to investigate before increasing downstream gain.

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2.19 Application 2B.2: move an amplifier across a cable

Compare two orders containing the same 20 dB gain, 1 dB noise-figure amplifier, the same 6 dB cable at 290 K, and the same 30 dB gain, 8 dB noise-figure receiver. The amplifier temperature is 75.09 K; the cable temperature is 864.51 K; and the receiver temperature is 1,539.78 K. Both orders have total gain of 44 dB, so a signal-only gain budget cannot distinguish them.

With the amplifier first, the three input-equivalent contributions are 75.09 K, $\frac{864.51\ \mathrm{K}}{100} \approx 8.65\ \mathrm{K}$, and 1,539.78 divided by 25.1189 equal to 61.30 K. Their sum is 145.03 K, or 1.761 dB noise figure. With the cable first, its 864.51 K is unsuppressed. The amplifier contributes 75.09 times 3.98107 equal to 298.93 K, while the receiver still contributes 61.30 K. The sum becomes 1,224.74 K, or 7.179 dB noise figure.

The 5.418 dB noise-figure difference arises entirely from ordering; total signal gain is unchanged. Remote amplification is therefore attractive under the model, but its feasibility depends on the remote amplifier's admitted blocker power, bias delivery, stability, and physical environment. A remote unit that compresses or oscillates cannot be credited with the calculated improvement. Chapter 13 uses this comparison to connect a component decision to acceptance of the installed path.

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2.20 Application 2B.3: distinguish loss from temperature

A matched 2 dB attenuator has L equal to 1.58489 and gain 0.630957. At 290 K its input-equivalent noise temperature is 169.62 K, and its noise figure is exactly 2 dB under the reference convention. If the same loss occurs at 330 K, Equation 4F gives 193.01 K and Equation 4D gives 2.216 dB. The extra 0.216 dB is not a change in the stipulated insertion loss; it is the consequence of greater thermal emission.

With a 290 K source, the output noise temperature is $\frac{(290+169.62)}{1.58489}$ equal to 290 K in the first case. This is the equilibrium check used in the derivation. For the warm attenuator, the corresponding output is $\frac{(290+193.01)}{1.58489}$ equal to 304.76 K. A signal still suffers 2 dB loss in both cases. Treating every 2 dB loss as a 2 dB noise figure would miss the difference. If the attenuator's actual loss also changes with temperature, that measured change is an additional input, not something already included in these values.

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2.21 Application 2B.4: change the source environment

Let a fixed receiver have T_e equal to 150 K and a 10 kHz effective bandwidth. Its 290 K reference noise figure is 1.811 dB regardless of which source is connected. With a 40 K effective source, however, the actual signal-to-noise degradation is $1+\frac{150}{40}$ equal to 4.75, or 6.767 dB. The input-equivalent integrated noise is −135.81 dBm. With a 5,000 K source, the degradation is only 1.03, or 0.128 dB, but the integrated noise is much higher, at −121.48 dBm.

Now imagine replacing the receiver with one whose T_e is 50 K while retaining all other assumptions. The cold-source noise falls in the ratio $\frac{190}{90}$, an improvement of 3.245 dB. The noisy-source case improves only in the ratio $\frac{5{,}150}{5{,}050}$, or 0.085 dB. This comparison explains why a lower receiver noise figure can be valuable in one observation and practically irrelevant in another. The 5,000 K value here is a constructed effective thermal-noise representation. A discrete interferer or time-varying impulsive environment should not be folded into that temperature without a justified observation model.

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2.22 Application 2B.5: solve for the gain that is useful

Suppose a first stage has $T_{e,1}$ equal to 80 K and the following receiver has $T_{e,2}$ equal to 1,200 K. The target cascade temperature is no more than 120 K. Equation 4J requires g_1 at least $\frac{1{,}200}{(120-80)}$, or 30, equal to 14.771 dB. At this gain, the later contribution is exactly 40 K. At 20 dB gain it is 12 K, so the total is 92 K. The calculation provides a lower gain requirement, not a preference for the largest gain available.

The asymptotic limit is 80 K as gain grows without bound. A 70 K target is impossible with this first stage, and an 80 K target would require infinite gain while the later noise remains positive. In practice, a designer would next compare the feasible gain range against maximum admitted signal power and downstream headroom. If the noise requirement demands more gain than the strong-signal condition permits, the architecture needs a lower-noise later stage, more selective admission, or another substantive change. Adjusting a displayed reference level alone cannot resolve the conflict.

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2.23 Application 2B.6: allocate loss to a preselector

A following receiver chain has 90 K input noise temperature. A proposed matched preselector operates at 300 K, and the complete input temperature must remain no greater than 180 K. Equation 4K gives L no greater than $\frac{(180+300)}{(300+90)}$, equal to 1.23077, or 0.902 dB. This is the allowed dissipative loss under the stated noise budget. It does not specify the filter's rejection at a blocker frequency.

A candidate with 0.8 dB loss gives $(10^{0.08}-1)300$ plus $10^{0.08}$ times 90, equal to 168.88 K, and meets the temperature target. A candidate with 1.2 dB loss gives 214.12 K and does not. The lower-loss candidate may still fail because it admits too much blocker power, while the higher-loss candidate may produce the only valid measurement in a strong-signal environment. That decision requires a joint assessment: report the noise penalty and test whether the desired signal remains detectable in the usable state. Calling either filter better solely from one of its specifications would omit half of the design problem.

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2.24 Application 2B.7: place attenuation before the vulnerable stage

Use a 20 dB gain, 1 dB noise-figure amplifier followed by a 30 dB gain, 8 dB noise-figure receiver. A constructed blocker arrives at −5 dBm. For this example only, the first amplifier's independently established linear operating envelope ends at −20 dBm input for that blocker condition. Compare a 20 dB attenuator at 290 K placed before the amplifier with the same attenuator placed after it. Both paths have 30 dB total small-signal gain.

With input attenuation, the amplifier sees −25 dBm, giving 5 dB margin to the stipulated envelope. The cascade input temperature is 28,710 plus 7,508.84 plus 1,539.78, or 37,758.61 K; its noise figure is 21.179 dB. With attenuation after the amplifier, the formal small-signal temperature would be 75.09 plus 287.10 plus 1,539.78, or 1,901.96 K, giving 8.784 dB noise figure. However, the amplifier still sees −5 dBm, which exceeds its stated envelope by 15 dB. That second noise result is inapplicable in the declared blocker state.

The example prevents an attractive arithmetic result from overriding a violated assumption. Input attenuation buys validity at a substantial noise cost. Selective rejection before the first amplifier may offer a better compromise when the desired and blocker frequencies permit it, but that requires a measured filter response at both frequencies. Neither the example's −20 dBm envelope nor its 5 dB margin is a general equipment rating. Actual limits and protection requirements come from the particular device and the complete incident waveform.

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2.25 Application 2B.8: recover noise temperature from two powers

Take known source temperatures T_{h} equal to 9,000 K and T_{c} equal to 290 K, a receiver temperature of 500 K, power gain of 100,000, and bandwidth of 1 MHz. The model predicts hot output power k times 10^6 times 10^5 times 9,500, or $1.31162 \times 10^{-8}\ \mathrm{W}$, equal to −48.822 dBm. The cold output is $1.09071 \times 10^{-9}\ \mathrm{W}$, equal to −59.623 dBm. Their linear ratio is 12.025316, which is 10.801 dB.

Substituting that ratio in Equation 4I gives $\frac{(9{,}000 - 12.025316 \times 290)}{(12.025316 - 1)}$, recovering 500 K. The corresponding reference noise figure is 4.352 dB. Linear ENR is $\frac{(9{,}000 - 290)}{290}$ equal to 30.0345, or 14.776 dB. Notice that subtracting the two output readings in decibels gives the logarithm of Y, not Y itself. The inversion must use 12.025316. The recovered value is a consistency check on this constructed case; a real result would also require calibrated source temperatures, stable matching, receiver linearity, and a complete uncertainty statement.

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2.26 Application 2B.9: expose a change hidden by a ratio

Equation 4M. Observed ratio when hot and cold gains differ

$$Y_{obs} = r_g \frac{T_h + T_e}{T_c + T_e}$$

$$r_g = \frac{G_h}{G_c}$$

Retain the source temperatures and true receiver temperature from Application 2B.8, but let the hot-state power gain be 1 percent larger than the cold-state gain. Equation 4M gives observed Y equal to 1.01×12.025316, or 12.145570. If the analyst incorrectly assumes equal gain, Equation 4I returns 491.48 K, an error of −8.52 K. The inferred noise figure becomes 4.305 dB, about 0.047 dB lower than its true constructed value.

The direction follows from the inversion: a larger hot-to-cold ratio appears to indicate a quieter receiver. Repeating the same biased sequence can make this wrong answer highly repeatable. A bracketed cold-hot-cold sequence can reveal drift, while a separate gain monitor may identify its cause, but neither is an automatic correction unless the gain at the relevant times is known. Automatic gain control, a changed attenuator, source switching transients, or temperature settling could create state differences. Record the state and timing before deciding which explanation applies.

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2.27 Application 2B.10: propagate the local calibration uncertainty

Use the inversion at T_{h} equal to 9,000 K, T_{c} equal to 290 K, and Y equal to 12.025316. Assume standard uncertainties of 180 K, 1 K, and 0.05, respectively, with zero covariances for this constructed case. Differentiating the same inversion gives Equations 4N and 4O. These derivatives are sensitivity coefficients for the uncertainty law already stated in Equation 27 of Chapter 14; they do not define an additional noise model.

Equation 4N. Temperature sensitivity coefficients

$$\frac{\partial T_e}{\partial T_h} = \frac{1}{Y-1}$$
$$\frac{\partial T_e}{\partial T_c} = \frac{-Y}{Y-1}$$

Equation 4O. Power-ratio sensitivity coefficient

$$\frac{\partial T_e}{\partial Y} = \frac{T_c - T_h}{(Y-1)^2}$$

The coefficients are 0.0907003, −1.0907003, and −71.6533 K per unit Y. Multiplying by the respective standard uncertainties and squaring gives contributions of 266.54, 1.19, and 12.84 square kelvin. Their sum is 280.57 square kelvin, and its square root is 16.75 K. The hot-source calibration dominates this particular budget. Reducing the random uncertainty of Y alone would therefore yield only a limited improvement; better source characterization would address the largest contribution.

Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty

$$\frac{\partial NF_0}{\partial T_e} = \frac{10}{\ln(10)(T_0 + T_e)}$$

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Equation 4P converts the result locally to 0.0921 dB standard uncertainty in noise figure. Multiplying by an illustrative coverage factor of two gives 33.50 K or 0.184 dB expanded uncertainty. This multiplication does not establish 95 percent coverage without a distribution and degrees-of-freedom justification. The calculation is also local: when uncertainty is large enough to approach Y equal to one, the nonlinear inversion requires a more suitable propagation analysis. Correlated source-calibration inputs must enter Equation 27 through their covariance or through explicit common input quantities.

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2.28 From a calculated temperature to a defended result

The applications deliberately keep the same governing law while changing the engineering question. They identify the dominant stage, compare ordering, account for physical temperature, distinguish source environment from receiver definition, allocate gain and loss, reject an overloaded state, and examine a calibration inversion. This continuity is useful during a review because every result can be traced to a declared input, a reference plane, and a violated or satisfied assumption. It also makes disagreement productive: a reviewer can challenge the source temperature, gain, bandwidth, or state without treating the entire receiver as an unexplained black box.

A measured noise temperature still needs a measurement record. Retain hot and cold output powers in linear units, their time order, effective bandwidth, receiver gain state, source serial and calibration values, connection loss and temperature, and the exact input plane. Add the observations that support linearity and stability. NIST's noise-temperature uncertainty treatment includes explicit linearity checks and distinguishes repeated power observations from repeated system calibrations. That distinction prevents a large number of nearly identical readings from being mistaken for evidence that calibration, reconnection, or mismatch uncertainty has disappeared.[6]

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6 International Electrotechnical Commission, CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus, 5th ed. (May 22, 2019), official publication scope, https://webstore.iec.ch/en/publication/60774, checked November 1, 2026. The public scope identifies the 9 kHz–18 GHz apparatus range and EMI receivers and

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2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure

Noise figure and an equivalent input temperature are useful summaries only when the selected reference plane, frequency interval and receiver state are fixed. A receiving system exposed to shaped interference, impulsive noise or frequency-selective gain cannot be represented faithfully by one scalar white-noise level over an arbitrary bandwidth. The relevant quantity becomes a spectral-density function S_n(f), expressed in watts per hertz at the specified plane, and a measurement weighting H(f). The integrated contribution is N = integral S_n(f)|H(f)| squared df, where H includes the known receiver and estimator response. Under flat-density assumptions this reduces to the familiar density multiplied by equivalent noise bandwidth. Outside that domain, substituting the centre-frequency noise into a broad integration can understate a narrow interferer or overstate an attenuated region. The engineer should therefore preserve both the spectral shape and the weighting used for the actual decision statistic, not merely a picture of a noise floor.

The distinction matters particularly when detection operates across several correlated bins. Write a vector of observed complex spectral coefficients z with noise covariance C = E[(z - E[z])(z - E[z]) conjugate-transposed]. For a known template s under a specified zero-mean complex-Gaussian approximation, an appropriately whitened linear statistic uses C inverse times s; this does not claim that the site noise is generally Gaussian or

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spectrum analyzers. No access to or clause-by-clause compliance review of the complete standard is claimed.

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stationary. Strong narrowband interference can make C ill conditioned, and estimation from the same candidate-rich data used to test the threshold can create selection bias. Calibrated regularisation must be declared before evaluating the held-out challenge set. A diagonal approximation discards cross-bin and cross-channel structure; it is not justified simply because adjacent frequency labels are displayed separately.

A numerical teaching case shows why covariance matters. Two unbiased measurements each have variance 4 square units and correlation coefficient 0.8. Their simple average has variance [4 + 4 + 2(0.8)(4)]/4 = 3.6 square units, not 2 square units as the independence assumption would suggest. Its standard deviation is approximately 1.897 rather than 1.414 units. The point is not that averaging is useless, but that repeated correlated measurements provide less independent evidence than their count suggests. In a receiver this correlation can arise from shared analogue noise, overlapping FFT windows, common oscillator phase noise, duplicated buffers or an interferer admitted to multiple channels. An estimate of covariance itself has uncertainty and requires representative calibration records.

For an operational sensitivity statement, retain separate observations of threshold behaviour under noise-only conditions and of successful detection under known, deliberately weak reference inputs. Define the signal family, bandwidth, duration, receiver states, observation opportunity and decision threshold before reporting numerical probabilities. A mean noise level cannot determine a detection probability without a distribution or independently tested operating characteristic for the chosen statistic. A nominal 10 dB margin may be a legitimate stated design requirement, but it is not a universal conversion into a probability of intercept. If the desired

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emission can arrive during receiver blind time, operational capture further depends on the event-time model, which must not be concealed inside the amplifier noise figure.

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2.30 Advanced technical expansion. Coloured-noise covariance and operational detection limits

The familiar thermal model kTB is useful only after the reference plane, source temperature, equivalent noise bandwidth and system state have been defined. Real installed paths present frequency-selective gain, correlated conversion products, interference with temporal structure and noise whose distribution is poorly approximated by a stationary Gaussian process. An experimentally meaningful development starts with a sampled covariance matrix R, whose element R[i,j] represents the expected cross-product between the ith and jth complex noise samples after removal of their estimated mean. If R is diagonal, ideal independent-noise formulas are available. If off-diagonal terms are consequential, the variance of a coherent sum changes and the nominal sample count cannot be equated with the number of independent observations. For a weighted estimator $z = w^H x$, with complex weight vector w and input covariance R, noise variance is $w^H R w$. This compact expression prevents an apparently precise average from inheriting a variance formula whose independence assumptions have not been demonstrated.

A concrete laboratory example illustrates the danger. Suppose four synchronous channels each have noise variance 1 in a consistent arbitrary power unit and equal pairwise correlation coefficient 0.25, with a valid positive-semidefinite covariance matrix. The mean of all four channels has variance $[1 + (4 - 1) \times 0.25]/4 = 0.4375$, rather than the independent-noise value of 0.25. Its standard deviation is approximately 0.6614 instead of 0.5000. Parallel recording still improves that estimator relative to one

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channel, but the gain is weaker than independence would predict. Shared oscillator noise, a common front-end noise wave or a digital artefact copied into all streams may cause such correlation. The numerical values are invented solely to compare two models; a real receiver needs its own covariance estimate and uncertainty assessment, including the possibility that the covariance changes across frequency and time.

Detection thresholds should be attached to a named statistic, rather than a generic noise figure. An energy detector evaluates a squared-magnitude statistic; a coherent detector evaluates correlation with a specified complex reference; a pulse detector may depend on leading-edge shape or a time-frequency template. Their distributions under the no-event hypothesis differ. Thresholding millions of spectral bins and successive time windows introduces multiple opportunities for false alarms, often with dependencies because FFT windows overlap and adjacent bins share leakage. A single-bin false-alarm rate cannot be transplanted unaltered into a whole-survey false-alarm claim. A credible test freezes the analysis code and threshold before evaluating a held-out noise-only population and separate weak-event population. The test records the search area, background interference conditions, excluded states and numbers of independent experimental trials, rather than treating every correlated FFT cell as a separate confirmation.

Noise-temperature calibration also requires a state-valid inverse. In a hot-cold experiment, the ratio of measured output noise powers cancels receiver gain only when gain, effective bandwidth and detector operation are genuinely common to the two states. A temperature inversion that yields a physically inadmissible negative receiver contribution must trigger

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examination of source calibration, compression, mismatch and switching transients. It must not be repaired by replacing the result with zero. When a calibration source and the receiver share temperature or frequency-reference uncertainties, covariance can matter as much as repeatability. Applying a root-sum-square rule without shared-input terms produces false confidence. A documented uncertainty budget therefore identifies the sensitivity coefficient for every quantity and the empirical basis of every significant covariance, following the general propagation approach described in NIST Technical Note 1297.

Operational sensitivity is ultimately a property of a declared event and opportunity to observe it. A low-noise amplifier may reduce internal noise yet amplify a nearby cellular transmitter enough to drive the next stage into compression. A narrowed channel may lower integrated noise while discarding much of a short chirp. A dwell detector may correctly identify a reference burst when tuned to its frequency but miss the same burst during a scan elsewhere. Separate probability of observation from conditional probability of detection, and keep both apart from false-alarm probability. An acceptance programme should sweep signal level, burst duration, modulation and blocker state while preserving the realised receiver settings and raw samples. The resulting operating envelope is more useful to a demanding examiner than a single unqualified sensitivity figure.

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2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth

A receiver system advertised with a minus-170-dBm input-referred noise floor in one hertz must declare whether the figure is a physical input-equivalent noise spectral density, a displayed average-noise-level normalisation, a minimum detectable signal, or an estimate from repeated measurements. These concepts can have the same units on a screenshot only because the display obscures the original normalisation. Under a matched 290 K thermal source, the available noise spectral density is approximately minus 173.98 dBm/Hz. A total input-equivalent density of minus 170 dBm/Hz is about four decibels higher, corresponding to an idealised four-decibel noise figure for the specified receiver state. It is plausible for a qualified low-noise signal chain. It is not a plausible guarantee for every frequency from baseband to forty gigahertz, regardless of preceding antenna loss, source temperature or strong-signal exposure.

To turn a density into an integrated noise power, define the equivalent noise bandwidth rather than merely selecting a number labelled RBW. For white noise with constant input-referred density N_0 over a channel having effective noise bandwidth B_{eq}, the admitted mean power is $N_0 B_{eq}$. In decibels, its level is $N_0[\text{dBm/Hz}]+10\log10(B_{eq}/1\ \text{Hz})$. For a source density of −170 dBm/Hz and $B_{eq}=30$ Hz, the result is approximately −155.23 dBm. If the FFT window has an equivalent noise bandwidth different from its bin spacing, use the actual B_{eq}. A successful narrowband matched-filter experiment can sometimes detect a known waveform with a signal-energy statistic whose threshold is below the integrated noise power. It must report

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processing gain, duration, false-alarm criterion and signal model, rather than silently relabel the threshold as thermal-noise power.

The forty-gigahertz architecture makes frequency dependence unavoidable. Each antenna, low-noise preamplifier, preselector, frequency converter and digitiser has different gain, noise and linearity characteristics. A system-level noise map should therefore give an input reference plane and calibration interval for every frequency slice, together with detector mode, effective bandwidth and usable gain range. A spur or desensitisation event can raise an operational detection threshold without altering the quiet matched-source noise figure. Four hours of valid monitoring requires repeated calibration challenge data or a measured stability basis, because the original low-noise acceptance result is not necessarily transferable across changing thermal, gain or blocker conditions. The report should publish typical, worst qualified and unqualified regions separately; a single global minimum figure may be true somewhere while misleading elsewhere.

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Chapter Summary

Sensitivity is a defined probability and bandwidth problem, not a single instrument label. Thermal noise, cascade noise, environmental interference, dynamic range, and detector statistics must be controlled together.

Build the noise budget at a declared source plane and observation band. Distinguish available from delivered power and retain the matching assumptions. Equivalent noise bandwidth expresses integrated weighting; a quieter narrow channel is useful only if it also retains the required signal.

Model 2B carries gain and added noise through a fixed-state cascade. Earlier gain reduces later input-equivalent noise, while preceding dissipative loss both attenuates and emits according to its temperature. Reference noise factor uses 290 K; actual SNR degradation also depends on the actual source temperature.

Hot-cold inversion requires applicable source states, gain, bandwidth and linearity. Check the admissible ratio and uncertainty, especially near a ratio of one. Repetition does not remove unchanged bias or create independent data. Operational sensitivity additionally needs detector and false-alarm evidence for the defined event. Preserve installed-path verification, strong-signal validity and actual acquisition coverage; a missed dwell is a coverage limitation.

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Chapter 2 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C02-MCQ-001. At a declared input plane, what condition permits the available thermal-noise power kTB to equal the power delivered to the receiver?

A. The source and receiver have the same physical temperature, regardless of impedance.

B. The source and receiver are matched at the declared real reference impedance.

C. The output detector averages power for a sufficiently long interval.

D. The receiver has enough gain to make its input mismatch negligible.

Answer: B. Matching establishes the available-to-delivered power equivalence used in the model. Equal temperature, high gain, and averaging do not establish that equivalence. Review: Power, bandwidth, and the reference plane; Equation 3. Source: Equation 3. Available thermal-noise power (p. 659)

Why the selected alternative fits: The source and receiver are matched at the declared real reference impedance.

Distinguishing consideration: compare this with option A, “The source and receiver have the same physical temperature, regardless of impedance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 3. Available thermal-noise power; Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Equation 3. Available thermal-noise power; Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-002. An antenna viewing a hot structure is connected to a receiver at 290 K. Which temperature belongs in the source term of the noise model?

A. The effective source noise temperature for the antenna environment and selected band.

B. The receiver enclosure temperature because the receiver sets the reference plane.

C. The equivalent input noise temperature of the receiver alone.

D. 290 K because noise figure is conventionally referred to that temperature.

Answer: A. The source term describes noise offered by the source. The reference temperature and receiver-added equivalent temperature have different roles.

Review: Thermal Noise as a Bandwidth-Dependent Quantity; Equation 4C. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why the selected alternative fits: The effective source noise temperature for the antenna environment and selected band.

Distinguishing consideration: compare this with option B, “The receiver enclosure temperature because the receiver sets the reference plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Thermal Noise as a Bandwidth-Dependent Quantity.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Thermal Noise as a Bandwidth-Dependent Quantity.

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V011-C02-MCQ-003. A report moves its input reference plane from the antenna terminal to the receiver connector after a lossy cable. What follows?

A. The cable thermal contribution vanishes physically because it lies before the new plane.

B. The original and revised noise figures can be compared without stating their planes.

C. The reported receiver noise figure can decrease because the cable is excluded, while antenna-to-output performance is unchanged.

D. The antenna-to-output signal-to-noise ratio improves by the removed cable loss.

Answer: C. Changing the reporting boundary changes the included network. It does not change the installed path or recover its lost signal-to-noise ratio. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why the selected alternative fits: The reported receiver noise figure can decrease because the cable is excluded, while antenna-to-output performance is unchanged.

Distinguishing consideration: compare this with option A, “The cable thermal contribution vanishes physically because it lies before the new plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-004. Which is the correct interpretation of equivalent noise bandwidth under a declared filter normalization?

A. The receiver sampling rate divided by the number of displayed trace points in every mode.

B. The width of a rectangular filter that passes the same noise power for the stated noise-density model.

C. The largest occupied signal bandwidth that can be detected with a fixed threshold.

D. The frequency interval between the filter half-power points in every filter design.

Answer: B. Equivalent noise bandwidth is defined by integrated weighting. It need not equal a half-power width, display spacing, or signal bandwidth. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why the selected alternative fits: The width of a rectangular filter that passes the same noise power for the stated noise-density model.

Distinguishing consideration: compare this with option A, “The receiver sampling rate divided by the number of displayed trace points in every mode”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-005. The noise density and gain vary appreciably across the observation band. What is the defensible next calculation?

A. Multiply center-frequency noise density by the nominal bandwidth without further qualification.

B. Average the gain values in decibels and substitute that average into kTB.

C. Integrate the frequency-dependent noise density through the actual power response.

D. Use the largest gain in the band for both the desired tone and every noise contribution.

Answer: C. A weighted integral retains the frequency dependence. A single center value is justified only when the flatness approximation is adequate. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why the selected alternative fits: Integrate the frequency-dependent noise density through the actual power response.

Distinguishing consideration: compare this with option A, “Multiply center-frequency noise density by the nominal bandwidth without further qualification”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-006. The equivalent bandwidth is reduced from 10 kHz to 1 kHz while a centered continuous tone remains fully retained. What happens to flat integrated white-noise power?

A. It decreases by 10 dB.

B. It decreases by 20 dB.

C. It decreases by 1 dB because the bandwidth ratio is ten.

D. It remains fixed because the source temperature is fixed.

Answer: A. Noise power is proportional to bandwidth, so 10 log10(1/10) equals -10 dB. This statement depends on retaining the tone. Review: Equation 3; Power, bandwidth, and the reference plane. Source: Equation 3. Available thermal-noise power (p. 659)

Why the selected alternative fits: It decreases by 10 dB.

Distinguishing consideration: compare this with option B, “It decreases by 20 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 3. Available thermal-noise power; Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Equation 3. Available thermal-noise power; Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-007. The same bandwidth reduction removes part of a short burst spectrum. Which statement is justified?

A. The signal-to-noise ratio necessarily improves by 10 dB because white noise has decreased by 10 dB.

B. The burst peak amplitude alone establishes that all relevant energy remains in the channel.

C. The rejected signal energy can be restored by subtracting the measured noise-floor change.

D. Signal retention must be evaluated before claiming the full bandwidth-ratio improvement in signal-to-noise ratio.

Answer: D. The ratio depends on both retained signal and admitted noise. A smaller noise reading does not establish an equal improvement for a spectrally extended signal. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why the selected alternative fits: Signal retention must be evaluated before claiming the full bandwidth-ratio improvement in signal-to-noise ratio.

Distinguishing consideration: compare this with option A, “The signal-to-noise ratio necessarily improves by 10 dB because white noise has decreased by 10 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-008. What operation defines an input-referred noise value from a measured output noise power in the stated scalar model?

A. Divide by the voltage gain regardless of impedance or the quantity measured.

B. Subtract the receiver noise figure in linear units from output watts.

C. Divide by a gain from any calibrated attenuator state at the same center frequency.

D. Divide by the signal power gain connecting the selected input and output planes in that state.

Answer: D. The conversion uses the appropriate power gain and matched configuration. It is a reporting transformation, not a physical relocation of noise generators. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why the selected alternative fits: Divide by the signal power gain connecting the selected input and output planes in that state.

Distinguishing consideration: compare this with option A, “Divide by the voltage gain regardless of impedance or the quantity measured”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-009. Why can a matched-port cable insertion-loss certificate be insufficient for correcting an antenna-connected receiver result?

A. Cable loss ceases to depend on frequency whenever an antenna is connected.

B. A reactive antenna and state-dependent receiver match can require a model beyond matched scalar loss.

C. The certificate determines the antenna noise temperature without another measurement.

D. Matched-port insertion loss is always a voltage ratio and cannot describe power.

Answer: B. The original measurement conditions matter. Reflection and interaction between actual impedances are outside a simple matched dissipative-loss substitution. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why the selected alternative fits: A reactive antenna and state-dependent receiver match can require a model beyond matched scalar loss.

Distinguishing consideration: compare this with option A, “Cable loss ceases to depend on frequency whenever an antenna is connected”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-010. Which statement correctly distinguishes source temperature from cascade equivalent input noise temperature?

A. Source temperature describes noise supplied to the cascade, while equivalent input temperature represents noise added by the included chain.

B. Both must equal the enclosure temperature when all gains are constant.

C. Source temperature is omitted whenever noise figure is stated at 290 K.

D. Equivalent input temperature includes every external interferer by definition.

Answer: A. Equation 4C keeps the source and added receiver contributions separate. That separation allows the source environment to change without redefining receiver noise. Review: Equation 4C. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why the selected alternative fits: Source temperature describes noise supplied to the cascade, while equivalent input temperature represents noise added by the included chain.

Distinguishing consideration: compare this with option B, “Both must equal the enclosure temperature when all gains are constant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-MCQ-011. In Equation 4A, what does G_0 = 1 accomplish?

A. It normalizes every later stage gain to the first stage noise figure.

B. It sets the source noise temperature to one kelvin.

C. It supplies the empty preceding-gain product for the first stage contribution.

D. It assumes the first physical stage has unity power gain.

Answer: C. The first added-noise contribution is divided by unity because no stages precede it. G_0 is an indexing convention, not a hardware requirement. Review: Equations 4A and 4C. Source: Equation 4A. Cumulative power gain (p. 667)

Why the selected alternative fits: It supplies the empty preceding-gain product for the first stage contribution.

Distinguishing consideration: compare this with option A, “It normalizes every later stage gain to the first stage noise figure”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4A. Cumulative power gain; Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4A. Cumulative power gain; Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-MCQ-012. For a stage with power gain g_i and equivalent input noise temperature $T_{e,i}$, what is the stage-added output noise in bandwidth B?

A. $k B g_i T_{e,i}$.

B. $\frac{k B T_{e,i}}{g_i}$.

C. $\frac{k B \left(T_{e,i}+T_s\right)}{G_{i-1}}$ alone.

D. $\frac{k B T_s}{g_i}$.

Answer: A. Equivalent input temperature is converted to the stage output by the stage power gain. Noise already entering the stage is handled by the other recurrence term. Review: Equation 4B. Source: Equation 4B. Noise propagation through one stage (p. 668)

Why the selected alternative fits: option A contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 2 — Equation 4B. Noise propagation through one stage.

Review: Chapter 2 — Equation 4B. Noise propagation through one stage.

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V011-C02-MCQ-013. Why is a later stage temperature $T_{e,i}$ divided by G_{i-1} when referred to the cascade input?

A. Each preceding stage must have a noise figure of zero decibels.

B. The later stage gain removes the thermal noise it generates.

C. The source temperature is assumed equal to the later stage temperature.

D. All preceding stages amplify the input signal before that stage adds its own noise.

Answer: D. Referring the new output noise back through the cascade cancels the stage own gain and leaves the product of preceding gains. Review: Derivation of Equation 4C. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why the selected alternative fits: All preceding stages amplify the input signal before that stage adds its own noise.

Distinguishing consideration: compare this with option A, “Each preceding stage must have a noise figure of zero decibels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-MCQ-014. Two stages have power gains 10 and 20. What is their cumulative power gain?

A. 30, or approximately 14.77 dB.

B. 2, or approximately 3.01 dB.

C. 200, or approximately 23.01 dB.

D. 200, or approximately 46.02 dB.

Answer: C. Linear power gains multiply: 10 times 20 equals 200. The decibel conversion is 10 log10(200). Review: Equation 4A. Source: Equation 4A. Cumulative power gain (p. 667)

Why the selected alternative fits: 200, or approximately 23.01 dB.

Distinguishing consideration: compare this with option A, “30, or approximately 14.77 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4A. Cumulative power gain.

Review: Chapter 2 — Equation 4A. Cumulative power gain.

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V011-C02-MCQ-015. A two-stage chain has $T_{e,1}$ = 80 K, $T_{e,2}$ = 1200 K, and g_1 = 100. What is its equivalent input noise temperature?

A. 1280 K.

B. 12.8 K.

C. 92 K.

D. 120080 K.

Answer: C. Equation 4C gives 80 + 1200/100 = 92 K. The later stage is referred through the first-stage gain. Review: Equation 4C; Application 2B.5. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why the selected alternative fits: 92 K.

Distinguishing consideration: compare this with option A, "1280 K"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Application 2B.5: solve for the gain that is useful.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Application 2B.5: solve for the gain that is useful.

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V011-C02-MCQ-016. Two chains have equal total small-signal gain but different ordering of a cable and low-noise amplifier. Which conclusion follows?

A. The first-stage noise can be suppressed by increasing gain only after the final stage.

B. Their equivalent input noise temperatures can differ because preceding gain weights each added-noise contribution.

C. Their noise figures must match because output signal powers match.

D. The cable contribution is unchanged at the original input plane in both arrangements.

Answer: B. Total gain does not identify where noise is added. The recurrence retains ordering even when total signal gain is the same. Review: Equation 4C; Application 2B.2. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why the selected alternative fits: Their equivalent input noise temperatures can differ because preceding gain weights each added-noise contribution.

Distinguishing consideration: compare this with option A, “The first-stage noise can be suppressed by increasing gain only after the final stage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Application 2B.2: move an amplifier across a cable.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Application 2B.2: move an amplifier across a cable.

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V011-C02-MCQ-017. Which condition permits simple addition of source and stage noise powers in Model 2B?

A. All stage output voltages have the same phase.

B. The receiver averages long enough to make any correlation physically disappear.

C. The admitted noise contributions have zero cross-power.

D. Every noise contribution has the same instantaneous waveform.

Answer: C. Zero cross-power removes cross terms from the power sum. Correlated contributions require their covariance or cross-spectrum to be retained. Review: Model 2B assumptions. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: The admitted noise contributions have zero cross-power.

Distinguishing consideration: compare this with option A, “All stage output voltages have the same phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-MCQ-018. A receiver changes gain midway through a record. What must be established before applying one fixed-state noise law to the whole record?

A. Only the mean of the two gain settings in decibels.

B. A valid model for the state intervals and any justified combination of their results.

C. That both gain settings use the same nominal center frequency.

D. Only that the final output file has a continuous timestamp field.

Answer: B. The fixed-state model does not automatically describe a mixture of states. Frequency and timestamps alone do not supply the missing gain/noise law.

Review: Model 2B assumptions; Uncertainty and Environmental Noise. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: A valid model for the state intervals and any justified combination of their results.

Distinguishing consideration: compare this with option A, “Only the mean of the two gain settings in decibels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Uncertainty and Environmental Noise.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Uncertainty and Environmental Noise.

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V011-C02-MCQ-019. Why must a mixer noise figure be checked before inserting it into an otherwise scalar cascade?

A. Noise figure becomes independent of the input environment after a frequency conversion.

B. Its sideband architecture and image contributions may differ from the selected equivalent-channel model.

C. A frequency conversion guarantees equal single-sideband and double-sideband noise figures.

D. All mixers have zero power gain and therefore cannot be modeled at all.

Answer: B. The chapter permits an empirically established selected-channel law but excludes unmodeled image contributions and blind use of nominal sideband figures. Review: Model 2B scope; Analog Devices source note. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: Its sideband architecture and image contributions may differ from the selected equivalent-channel model.

Distinguishing consideration: compare this with option A, “Noise figure becomes independent of the input environment after a frequency conversion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-MCQ-020. Which physical situation is outside the declared scalar model even if its output can be assigned an average power?

A. A matched stage with a positive finite power gain below unity.

B. A source temperature different from 290 K but within the classical approximation.

C. A finite nonnegative equivalent input noise temperature for every stage.

D. Feedback between mismatched stages that materially changes the response.

Answer: D. The model excludes unmodeled mismatch feedback. Matched attenuation, nonreference source temperatures, and finite stage temperatures are explicitly accommodated. Review: Model 2B assumptions. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: Feedback between mismatched stages that materially changes the response.

Distinguishing consideration: compare this with option A, “A matched stage with a positive finite power gain below unity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-MCQ-021. A matched dissipative attenuator has linear loss L = 2 and physical temperature T_p = 290 K. What is its equivalent input noise temperature?

A. 145 K.

B. 580 K.

C. 290 K.

D. 0 K.

Answer: C. Equation 4F gives $(L-1)T_p$ = 290 K. The output-added temperature contribution is different because it includes the one-half transmission gain. Review: Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why the selected alternative fits: 290 K.

Distinguishing consideration: compare this with option A, “145 K”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-MCQ-022. For that same L = 2 attenuator, what is its own added output noise expressed as temperature times $k\,B$?

A. 290 K times $k\,B$.

B. 145 K times $k\,B$.

C. 580 K times $k\,B$.

D. 0 K times $k\,B$.

Answer: B. The output-added term is $k\,B\,T_p\left(1-\frac{1}{L}\right)$, which is $k\,B$ times 145 K.

Input-equivalent temperature is obtained by dividing by the gain. Review: Derivation of Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why the selected alternative fits: 145 K times.

Distinguishing consideration: compare this with option A, “290 K times”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-MCQ-023. A matched attenuator and both connected terminations are all at T_p. What output available thermal-noise power is required by equilibrium?

A. $\frac{kBT_p}{L}$ because the attenuator only removes noise.

B. kBT_p, independent of its dissipative loss within this model.

C. Zero because equal-temperature components exchange no instantaneous noise power.

D. kBT_pL because loss increases the output source noise.

Answer: B. Attenuator thermal emission complements the attenuated source noise. Their sum remains the equilibrium available noise power. Review: Derivation of Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why the selected alternative fits: independent of its dissipative loss within this model.

Distinguishing consideration: compare this with option A, “because the attenuator only removes noise”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-MCQ-024. When does the noise figure in decibels of a matched genuinely dissipative attenuator with linear loss L greater than 1 equal its insertion loss in decibels?

A. Only when its linear loss equals one.

B. Whenever its output noise is below the receiver-added noise.

C. When its physical temperature equals the noise-factor reference temperature.

D. Whenever its source and load impedances are equal, regardless of temperature.

Answer: C. For L greater than 1, $F_0 = 1 + \frac{(L-1)T_p}{T_0}$ equals L when $T_p = T_0$.

Matching alone is insufficient. The excluded lossless case $L = 1$ has $F_0 = L = 1$ independently of T_p in this model. Review: Equations 4D and 4F. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why the selected alternative fits: When its physical temperature equals the noise-factor reference temperature.

Distinguishing consideration: compare this with option A, “Only when its linear loss equals one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-MCQ-025. Why must arbitrary reflection loss not be assigned the equivalent temperature $(L-1)T_p$ without further modeling?

A. The equilibrium derivation applies to dissipation and its thermal emission, not merely reflected power.

B. Reflection loss always has the same noise figure as a matched resistor at 290 K.

C. Reflected signal power increases the physical temperature of every downstream stage equally.

D. The passive-loss relation applies only to amplifiers with gain greater than one.

Answer: A. The derivation balances transmitted source noise and emission from a dissipative element. A mismatch can change delivered power without the assumed dissipation. Review: Derive passive loss from thermal equilibrium. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

Why the selected alternative fits: The equilibrium derivation applies to dissipation and its thermal emission, not merely reflected power.

Distinguishing consideration: compare this with option B, “Reflection loss always has the same noise figure as a matched resistor at 290 K”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Derive passive loss from thermal equilibrium.

Review: Chapter 2 — Derive passive loss from thermal equilibrium.

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V011-C02-MCQ-026. A matched loss L = 1.5 at 300 K precedes a chain with $T_{e,c}$ = 100 K. What is the combined input-equivalent temperature?

A. 200 K.

B. 250 K.

C. 100 K.

D. 300 K.

Answer: D. Equation 4G gives (1.5 - 1) times 300 + 1.5 times 100 = 150 + 150 = 300 K.

Review: Equation 4G. Source: Equation 4G. Loss followed by a characterized chain (p. 671)

Why the selected alternative fits: 300 K.

Distinguishing consideration: compare this with option A, “200 K”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

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V011-C02-MCQ-027. For that loss-before-chain calculation, which term accounts for the downstream chain referred back through the loss?

A. $LT_{e,c}$.

B. $\frac{T_p}{L}$.

C. $\frac{T_{e,c}}{L}$.

D. $(L-1)T_p$ alone.

Answer: A. The loss reduces the signal reaching the downstream chain, so the chain noise becomes more important when referred to the original input. Review:

Equation 4G. Source: Equation 4G. Loss followed by a characterized chain (p. 671)

Why the selected alternative fits: option A contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

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V011-C02-MCQ-028. Several passive sections have different physical temperatures. What preserves the required thermal information?

A. Ignore the cooler sections because only the warmest contributes thermal noise.

B. Use the receiver reference temperature for every passive section regardless of its state.

C. Combine their losses in decibels and assign the first section temperature to all of them.

D. Represent the sections separately with their own loss, temperature, and position.

Answer: D. Separate stages retain temperature and ordering. A single total loss at an arbitrary temperature can discard information required by the recurrence.

Review: Equation 4G discussion. Source: Equation 4G. Loss followed by a characterized chain (p. 671)

Why the selected alternative fits: Represent the sections separately with their own loss, temperature, and position.

Distinguishing consideration: compare this with option A, “Ignore the cooler sections because only the warmest contributes thermal noise”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

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V011-C02-MCQ-029. In Application 2B.3 a 2 dB attenuator warms from 290 K to 330 K. Which quantity stays 2 dB under the stipulated constant-loss model?

A. Its equivalent input noise temperature.

B. Its output thermal-noise level with a fixed 290 K source.

C. Its signal insertion loss.

D. Its noise figure referred to 290 K.

Answer: C. The stipulated loss stays fixed while thermal emission rises. Noise figure changes from 2 dB to about 2.216 dB and output noise also changes. Review: Application 2B.3. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

Why the selected alternative fits: Its signal insertion loss.

Distinguishing consideration: compare this with option A, “Its equivalent input noise temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.3: distinguish loss from temperature.

Review: Chapter 2 — Application 2B.3: distinguish loss from temperature.

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V011-C02-MCQ-030. Why does a scalar signal-level correction for a warm cable not complete a noise measurement correction?

A. The cable physical temperature is relevant only to connector mechanical tolerances.

B. Cable thermal emission and the reweighted downstream receiver noise must also be included.

C. A signal-level correction necessarily removes all thermal noise from the retained record.

D. Cable loss affects source and receiver noise identically at the original input plane.

Answer: B. Restoring a reported signal level to an earlier plane does not undo the cable contribution to the noise budget or its uncertainty. Review: Equation 4G discussion. Source: Equation 4G. Loss followed by a characterized chain (p. 671)

Why the selected alternative fits: Cable thermal emission and the reweighted downstream receiver noise must also be included.

Distinguishing consideration: compare this with option A, “The cable physical temperature is relevant only to connector mechanical tolerances”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

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V011-C02-MCQ-031. For T_e = 290 K and T_0 = 290 K, what are the reference noise factor and noise figure?

A. 2 and approximately 3.01 dB.

B. 290 and approximately 24.62 dB.

C. 2 and approximately 6.02 dB.

D. 1 and 0 dB.

Answer: A. $F_0 = 1 + \frac{T_e}{T_0}$ = 2; noise figure uses 10 log10 of this power-ratio factor.

Review: Equation 4D. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why the selected alternative fits: 2 and approximately 3.01 dB.

Distinguishing consideration: compare this with option B, “290 and approximately 24.62 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

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V011-C02-MCQ-032. A receiver has T_e = 150 K and a source has T_s = 40 K. What is the actual SNR degradation ratio?

A. 4.75.

B. 0.267.

C. 3.75.

D. 1.517.

Answer: A. Equation 4E gives 1 + 150/40 = 4.75. The reference factor at 290 K is a different quantity. Review: Equation 4E; Application 2B.4. Source: Equation 4E. Signal-to-noise degradation for the actual source (p. 669)

Why the selected alternative fits: 4.75.

Distinguishing consideration: compare this with option B, “0.267”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source; Chapter 2 — Application 2B.4: change the source environment.

Review: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source; Chapter 2 — Application 2B.4: change the source environment.

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V011-C02-MCQ-033. The same T_e = 150 K receiver is connected to a source at T_s = 5000 K. What is the actual SNR degradation ratio?

A. 33.33.

B. 0.03.

C. 1.517.

D. 1.03.

Answer: D. The ratio is 1 + 150/5000 = 1.03. Receiver-added noise is a small fraction of the much larger source contribution. Review: Equation 4E; Application 2B.4.

Source: Equation 4E. Signal-to-noise degradation for the actual source (p. 669)

Why the selected alternative fits: 1.03.

Distinguishing consideration: compare this with option A, “33.33”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source; Chapter 2 — Application 2B.4: change the source environment.

Review: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source; Chapter 2 — Application 2B.4: change the source environment.

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V011-C02-MCQ-034. Under which stated condition does the actual SNR degradation ratio equal the reference noise factor F_0?

A. The output noise is dominated by the first amplifier in every case.

B. The total receiver gain equals its noise factor.

C. The actual source noise temperature T_s equals T_0.

D. The signal power equals the available source noise power.

Answer: C. Equations 4D and 4E have the same denominator only when $T_s = T_0$, apart from the trivial zero-added-noise case. Review: Equations 4D and 4E. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why the selected alternative fits: The actual source noise temperature equals.

Distinguishing consideration: compare this with option A, "The output noise is dominated by the first amplifier in every case"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

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V011-C02-MCQ-035. Why is Equation 4E explicitly restricted to positive T_s?

A. Power gain ceases to be dimensionless at zero source temperature.

B. A receiver with $T_s = 0$ must have negative equivalent input noise temperature.

C. At $T_s = 0$ the classical input SNR is unbounded, so the stated finite-ratio comparison is not defined.

D. The output noise must be zero whenever the source temperature is zero.

Answer: C. Receiver-added noise may remain at $T_s = 0$, but the particular input-to-output SNR ratio needs a positive source-noise denominator. Review: Equation 4E domain. Source: Equation 4E. Signal-to-noise degradation for the actual source (p. 669)

Why the selected alternative fits: At the classical input SNR is unbounded, so the stated finite-ratio comparison is not defined.

Distinguishing consideration: compare this with option A, “Power gain ceases to be dimensionless at zero source temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

Review: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

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V011-C02-MCQ-036. What does a reported equivalent input noise temperature of 80 K imply about an amplifier enclosure?

A. The enclosure must be held at exactly 80 K during every use.

B. The enclosure temperature must be below the source noise temperature.

C. No direct equality with enclosure physical temperature is implied.

D. The amplifier cannot be operating at room temperature.

Answer: C. Equivalent temperature is a noise-power-density representation of an active network, not a thermometer reading of the enclosure. Review: Equation 4C discussion. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why the selected alternative fits: No direct equality with enclosure physical temperature is implied.

Distinguishing consideration: compare this with option A, “The enclosure must be held at exactly 80 K during every use”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-MCQ-037. A cold-source system changes receiver T_e from 150 K to 50 K with T_s = 40 K and unchanged signal gain and bandwidth. What is the reduction in input-referred total noise?

A. 10 log10(150/50), approximately 4.771 dB.

B. 10 log10(290/40), approximately 8.603 dB.

C. Exactly 10 dB because receiver T_e decreases by 100 K.

D. 10 log10(190/90), approximately 3.245 dB.

Answer: D. Total input-referred noise includes the source term. The relevant old/new ratio is (40 + 150)/(40 + 50). Review: Application 2B.4. Source: §2.21 Application 2B.4: change the source environment (p. 681)

Why the selected alternative fits: 10 log10(190/90), approximately 3.245 dB.

Distinguishing consideration: compare this with option A, “10 log10(150/50), approximately 4.771 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.4: change the source environment.

Review: Chapter 2 — Application 2B.4: change the source environment.

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V011-C02-MCQ-038. Why does the same receiver-temperature improvement produce much less benefit with a 5000 K source?

A. Thermal noise stops depending on bandwidth in a noisy environment.

B. The unchanged source contribution dominates the total input-referred noise.

C. The receiver power gain must fall in proportion to source temperature.

D. The receiver reference noise figure becomes undefined above 290 K source temperature.

Answer: B. Changing T_e has limited impact when T_s is much larger. The reference receiver noise figure can remain valid while its operational importance decreases. Review: Application 2B.4. Source: §2.21 Application 2B.4: change the source environment (p. 681)

Why the selected alternative fits: The unchanged source contribution dominates the total input-referred noise.

Distinguishing consideration: compare this with option A, “Thermal noise stops depending on bandwidth in a noisy environment”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.4: change the source environment.

Review: Chapter 2 — Application 2B.4: change the source environment.

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V011-C02-MCQ-039. A receiver noise figure is 7 dB at T_0 = 290 K. Which expression converts it to equivalent input temperature?

A. 290 times ($10^{\frac{7}{10}}$ - 1) kelvins.

B. 290 times ($10^{\frac{7}{20}}$ - 1) kelvins.

C. 290 times 7 kelvins.

D. 290 divided by 7 kelvins.

Answer: A. First convert the decibel noise figure to linear noise factor, then apply T_e = T_0(F_0 - 1). Review: Equation 4D. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why the selected alternative fits: 290 times (- 1) kelvins.

Distinguishing consideration: compare this with option B, “290 times (- 1) kelvins”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

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V011-C02-MCQ-040. A very noisy environment raises the system detection limit without a change in the receiver hardware state. Which description is most accurate?

A. The reference temperature T_0 must be replaced by the measured noise temperature in its defining convention.

B. The environmental contribution can be removed solely by increasing output gain.

C. The receiver noise figure must rise by exactly the environmental noise increase.

D. The source/environment contribution can rise while the receiver reference noise figure remains the same.

Answer: D. Reference noise figure describes added receiver noise under its stated convention. Operational total noise also includes the source environment. Review: Uncertainty and Environmental Noise; Equations 4C and 4D. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why the selected alternative fits: The source/environment contribution can rise while the receiver reference noise figure remains the same.

Distinguishing consideration: compare this with option A, “The reference temperature must be replaced by the measured noise temperature in its defining convention”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Uncertainty and Environmental Noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Uncertainty and Environmental Noise.

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V011-C02-MCQ-041. Which condition is essential for the simple hot-cold Y-factor inversion?

A. The receiver must operate at a different attenuation setting for each source state.

B. The gain, effective bandwidth, and receiver noise law are the same in both source states.

C. The hot and cold source temperatures must be symmetric about 290 K.

D. The hot output power must be at the receiver compression threshold.

Answer: B. The ratio cancels the common gain-bandwidth factor. State-dependent gain or compression prevents that cancellation. Review: Equations 4H and 4I. Source: Equation 4H. Hot-to-cold output power ratio (p. 673)

Why the selected alternative fits: The gain, effective bandwidth, and receiver noise law are the same in both source states.

Distinguishing consideration: compare this with option A, “The receiver must operate at a different attenuation setting for each source state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-MCQ-042. With T_h = 9000 K, T_c = 290 K, and T_e = 500 K, what is Y in the fixed-state model?

A. 9500/790, approximately 12.0253.

B. 8710/500, or 17.42.

C. 9000/290, approximately 31.0345.

D. 790/9500, approximately 0.08316.

Answer: A. Y includes receiver-added noise in both states: $\frac{T_h+T_e}{T_c+T_e}$. Review: Equation 4H; Application 2B.8. Source: Equation 4H. Hot-to-cold output power ratio (p. 673)

Why the selected alternative fits: 9500/790, approximately 12.0253.

Distinguishing consideration: compare this with option B, “8710/500, or 17.42”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Application 2B.8: recover noise temperature from two powers.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Application 2B.8: recover noise temperature from two powers.

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V011-C02-MCQ-043. For $T_h > T_c > 0$ and finite nonnegative T_e, which domain follows for Y?

A. Y can take any positive value without testing the assumptions.

B. $Y \geq \frac{T_h}{T_c}$ with no upper bound.

C. $1 < Y \leq \frac{T_h}{T_c}$.

D. 0 < Y < 1.

Answer: C. Adding the same nonnegative T_e moves the temperature ratio toward one. T_e = 0 gives the upper boundary; finite T_e leaves Y greater than one. Review: Equation 4I domain. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why the selected alternative fits: option C contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-MCQ-044. Measured Y exceeds $\frac{T_h}{T_c}$ for positive T_c. What is the appropriate response?

A. Increase T_c numerically until the result enters the expected range without documenting a correction.

B. Treat the excess as proof of a receiver with negative added-noise power in this model.

C. Investigate calibration, gain state, mismatch, bandwidth, or data errors before accepting the inversion.

D. Clip the inferred negative temperature to zero and report the clipped value as the measurement.

Answer: C. The observation violates the model domain for nonnegative T_e. It is a diagnostic signal, not permission to hide the inconsistency. Review: Equation 4I domain. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why the selected alternative fits: Investigate calibration, gain state, mismatch, bandwidth, or data errors before accepting the inversion.

Distinguishing consideration: compare this with option A, “Increase numerically until the result enters the expected range without documenting a correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-MCQ-045. Why does the inversion become ill-conditioned as Y approaches one?

A. The reference impedance approaches zero whenever Y is near one.

B. The cold source temperature necessarily becomes negative.

C. The output detector becomes exactly noiseless at Y = 1.

D. The small denominator $Y - 1$ amplifies changes in the ratio and source-temperature inputs.

Answer: D. Equation 4I divides by $Y - 1$, and its derivatives grow. Small input uncertainty can produce a large or strongly nonlinear temperature uncertainty.

Review: Equations 4I, 4N, and 4O. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why the selected alternative fits: The small denominator amplifies changes in the ratio and source-temperature inputs.

Distinguishing consideration: compare this with option A, “The reference impedance approaches zero whenever Y is near one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient.

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V011-C02-MCQ-046. Which is the chapter convention for the linear excess-noise ratio?

A. ENR = $\frac{T_h - T_c}{T_0}$, subject to the actual source certificate convention.

B. ENR = $Y - 1$ independent of the receiver noise temperature.

C. ENR = $\frac{T_e}{T_0}$ because the receiver creates the source excess noise.

D. ENR = $\frac{T_h}{T_c}$ for every calibration certificate.

Answer: A. The chapter declares a temperature-difference convention and warns that certificate definitions must be read rather than assumed. Review: Y-factor discussion following Equation 4I. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why the selected alternative fits: ENR = subject to the actual source certificate convention.

Distinguishing consideration: compare this with option B, “ENR = independent of the receiver noise temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Invert the same model with two source temperatures.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Invert the same model with two source temperatures.

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V011-C02-MCQ-047. Why must T_c not automatically be set to 290 K in every Y-factor reduction?

A. The calibrated or actual cold-state temperature and certificate convention may differ from the reference temperature.

B. A hot-cold ratio eliminates all dependence on the cold source temperature.

C. Noise factor cannot be defined if the cold source differs from 290 K.

D. The Y-factor equation requires T_c to be zero.

Answer: A. T_0 sets the reporting convention, whereas T_c is a source input to the measurement equation. Review: Y-factor discussion; Equations 4D and 4I. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why the selected alternative fits: The calibrated or actual cold-state temperature and certificate convention may differ from the reference temperature.

Distinguishing consideration: compare this with option B, “A hot-cold ratio eliminates all dependence on the cold source temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Invert the same model with two source temperatures.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Invert the same model with two source temperatures.

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V011-C02-MCQ-048. If hot-state gain is 1% larger than cold-state gain and all else is unchanged, how does the observed hot/cold ratio change?

A. It is unchanged because ratios cancel all gain differences.

B. It increases by exactly 1 dB.

C. It is multiplied by 1.01.

D. It is divided by 1.01.

Answer: C. Only a common gain cancels. A hot/cold gain ratio of 1.01 directly multiplies the physical noise-power ratio. Review: Application 2B.9. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

Why the selected alternative fits: It is multiplied by 1.01.

Distinguishing consideration: compare this with option A, “It is unchanged because ratios cancel all gain differences”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-MCQ-049. In Application 2B.9, ignoring that 1% hot-state gain increase yields T_e approximately 491.48 K instead of 500 K. How should the error be characterized?

A. A rounding difference that disappears when powers are expressed in dBm.

B. An improvement in the receiver physical sensitivity caused by the calibration cycle.

C. Independent zero-mean random noise guaranteed to average to zero.

D. A state-dependent bias that repetition alone does not remove.

Answer: D. The equal-gain model interprets the elevated ratio as lower receiver-added noise. Repeating the same biased procedure retains the bias. Review: Application 2B.9. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

Why the selected alternative fits: A state-dependent bias that repetition alone does not remove.

Distinguishing consideration: compare this with option A, “A rounding difference that disappears when powers are expressed in dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-MCQ-050. What can a cold-hot-cold sequence establish without an independent gain model?

A. It proves equal hot and cold gain because the first and last source labels match.

B. It guarantees the hot state was below compression.

C. It can reveal drift or inconsistency, but does not automatically supply a valid correction for every state-dependent gain change.

D. It removes all mismatch differences by averaging the cold readings.

Answer: C. Bracketing measurements provide evidence about temporal behavior. A correction still requires a justified model and relevant controls. Review: Application 2B.9. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

Why the selected alternative fits: It can reveal drift or inconsistency, but does not automatically supply a valid correction for every state-dependent gain change.

Distinguishing consideration: compare this with option A, “It proves equal hot and cold gain because the first and last source labels match”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-MCQ-051. For a two-stage chain, what condition permits a finite first-stage gain to satisfy $T_e \leq T_{target}$ when $T_{e,2}$ is positive?

A. T_{target} must be no greater than $T_{e,1}$.

B. The source temperature must be below T_{target}.

C. T_{target} must exceed $T_{e,1}$.

D. The final stage gain must equal T_{target} in decibels.

Answer: C. $T_e = T_{e,1} + \frac{T_{e,2}}{g_1}$ approaches $T_{e,1}$ from above. A positive finite downstream contribution requires a target above that limit. Review: Equation 4J.

Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why the selected alternative fits: must exceed.

Distinguishing consideration: compare this with option A, “must be no greater than”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

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V011-C02-MCQ-052. For $T_{e,1}$ = 80 K, $T_{e,2}$ = 1200 K, and T_{target} = 120 K, what is the minimum first-stage power gain?

A. 15, approximately 11.761 dB.

B. 10, exactly 10 dB.

C. 120, approximately 20.792 dB.

D. 30, approximately 14.771 dB.

Answer: D. The inequality gives g_1 >= 1200/(120 - 80) = 30. Review: Equation 4J; Application 2B.5. Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why the selected alternative fits: 30, approximately 14.771 dB.

Distinguishing consideration: compare this with option A, “15, approximately 11.761 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit; Chapter 2 — Application 2B.5: solve for the gain that is useful.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit; Chapter 2 — Application 2B.5: solve for the gain that is useful.

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V011-C02-MCQ-053. What happens if the target is changed to 80 K in that same two-stage chain while $T_{e,2}$ remains positive?

A. A unity first-stage gain is sufficient.

B. A 3 dB gain increase makes the target exact.

C. The final-stage gain alone can make the equivalent temperature zero.

D. No finite first-stage gain reaches the target exactly.

Answer: D. The later contribution tends to zero only as first-stage gain tends to infinity. A finite gain leaves T_e above 80 K. Review: Equation 4J domain. Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why the selected alternative fits: No finite first-stage gain reaches the target exactly.

Distinguishing consideration: compare this with option A, “A unity first-stage gain is sufficient”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

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V011-C02-MCQ-054. For a chain with $T_{e,c}$ = 90 K, a preceding passive section at 300 K, and T_{target} = 180 K, what is the maximum permitted linear loss?

A. 390/480, approximately 0.8125.

B. 480/390, approximately 1.23077.

C. 180/90, or 2.

D. 300/180, approximately 1.66667.

Answer: B. Equation 4K gives L <= (T_{target}+T_p)/(T_p+$T_{e,c}$). The passive domain also requires L >= 1. Review: Equation 4K; Application 2B.6. Source: Equation 4K. Maximum allowed preceding loss (p. 675)

Why the selected alternative fits: 480/390, approximately 1.23077.

Distinguishing consideration: compare this with option A, “390/480, approximately 0.8125”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4K. Maximum allowed preceding loss; Chapter 2 — Application 2B.6: allocate loss to a preselector.

Review: Chapter 2 — Equation 4K. Maximum allowed preceding loss; Chapter 2 — Application 2B.6: allocate loss to a preselector.

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V011-C02-MCQ-055. If the calculated upper bound on passive loss is below one, what does the design inequality imply?

A. Choose a passive element with negative insertion loss and keep calling it a loss.

B. Even the lossless preceding path cannot meet the stated target with that following chain.

C. The physical temperature should be omitted from the calculation.

D. Any sufficiently narrow detector bandwidth changes the derived temperature bound to one.

Answer: B. A matched passive loss must have L >= 1. A smaller upper bound leaves the feasible interval empty. Review: Equation 4K domain. Source: Equation 4K. Maximum allowed preceding loss (p. 675)

Why the selected alternative fits: Even the lossless preceding path cannot meet the stated target with that following chain.

Distinguishing consideration: compare this with option A, “Choose a passive element with negative insertion loss and keep calling it a loss”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

Review: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

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V011-C02-MCQ-056. Why is the noise-optimal ordering not automatically the operationally valid ordering under a strong blocker?

A. The first active stage can overload even when the linear noise calculation looks favorable.

B. The cascade temperature formula already includes every intermodulation product.

C. An attenuator placed after an overloaded amplifier restores the earlier linear response.

D. Equal total small-signal gain guarantees equal blocker stress at every internal stage.

Answer: A. Noise and linearity must be checked at their relevant internal planes. A low formal temperature does not validate a compressed configuration. Review: Application 2B.7. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why the selected alternative fits: The first active stage can overload even when the linear noise calculation looks favorable.

Distinguishing consideration: compare this with option B, “The cascade temperature formula already includes every intermodulation product”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

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V011-C02-MCQ-057. In Application 2B.7 a -5 dBm blocker precedes 20 dB attenuation placed before the amplifier. What blocker level reaches the amplifier?

A. +15 dBm.

B. -25 dBm.

C. -20 dBm.

D. -5 dBm.

Answer: B. The input attenuation reduces the blocker level by 20 dB, giving -25 dBm at the amplifier input. Review: Application 2B.7. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why the selected alternative fits: -25 dBm.

Distinguishing consideration: compare this with option A, “+15 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

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V011-C02-MCQ-058. If the amplifier input linear-envelope limit is -20 dBm in that stipulated case, what margin does the -25 dBm blocker provide?

A. 5 dB below the stated limit.

B. 15 dB above the stated limit.

C. 20 dB below the stated limit.

D. 25 dB above the stated limit.

Answer: A. The difference between -20 dBm and -25 dBm is 5 dB. This is a stipulated envelope margin, not a general instrument specification. Review: Application 2B.7.

Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why the selected alternative fits: 5 dB below the stated limit.

Distinguishing consideration: compare this with option B, “15 dB above the stated limit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

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V011-C02-MCQ-059. The same 20 dB attenuation is moved after the amplifier. What is the key validity result for the -5 dBm blocker?

A. The lower formal noise figure proves that the blocker cannot generate distortion.

B. The amplifier sees -25 dBm because total chain loss is unchanged.

C. The amplifier input exceeds the stipulated -20 dBm envelope by 15 dB, invalidating the simple linear prediction.

D. The amplifier input is safe because the final output power is reduced.

Answer: C. Post-amplifier attenuation cannot protect the earlier amplifier input. The formal noise result belongs to a state whose linearity assumption has failed. Review: Application 2B.7. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why the selected alternative fits: The amplifier input exceeds the stipulated -20 dBm envelope by 15 dB, invalidating the simple linear prediction.

Distinguishing consideration: compare this with option A, “The lower formal noise figure proves that the blocker cannot generate distortion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

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V011-C02-MCQ-060. In Application 2B.6, why does meeting the 180 K noise target not settle the preselector choice?

A. A passive section meeting the noise target must reject every out-of-band signal.

B. Blocker rejection and linearity require a separate performance assessment.

C. The source reference plane can be omitted once the numerical target is satisfied.

D. Noise temperature already specifies the full frequency-selective rejection curve.

Answer: B. A noise constraint is only one design criterion. The preselector must also provide the required rejection without invalidating other assumptions. Review: Application 2B.6. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

Why the selected alternative fits: Blocker rejection and linearity require a separate performance assessment.

Distinguishing consideration: compare this with option A, “A passive section meeting the noise target must reject every out-of-band signal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.6: allocate loss to a preselector.

Review: Chapter 2 — Application 2B.6: allocate loss to a preselector.

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V011-C02-MCQ-061. What additional input is required to turn the input-referred noise budget into the bounded signal requirement in Equation 4L?

A. An arbitrary probability of detection assigned to any convenient SNR.

B. A separately justified required output SNR γ for the declared detector and event.

C. The maximum trace level in one noise-only record.

D. Only the receiver total gain, regardless of noise or detector behavior.

Answer: B. Gamma is a stipulated detector requirement, not a probability derived from mean noise power alone. Review: Equation 4L; Define sensitivity as a reproducible decision. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why the selected alternative fits: A separately justified required output SNR for the declared detector and event.

Distinguishing consideration: compare this with option A, “An arbitrary probability of detection assigned to any convenient SNR”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-MCQ-062. Within Equation 4L, why does total gain cancel from the required input signal power?

A. The source and receiver temperatures are required to be equal.

B. Output gain physically removes receiver noise from the chain.

C. The retained desired signal and admitted total noise share the same valid scalar gain to the output.

D. The detector threshold is assumed independent of its measured quantity.

Answer: C. Both output signal and noise include G_n. The cancellation depends on the stated common gain and signal-retention assumptions. Review: Equation 4L.

Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why the selected alternative fits: The retained desired signal and admitted total noise share the same valid scalar gain to the output.

Distinguishing consideration: compare this with option A, “The source and receiver temperatures are required to be equal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C02-MCQ-063. For T_s+T_e = 600 K, B = 10 kHz, and γ = 10, using k = 1.380649×10^{-23} J/K, what required input power follows?

A. 8.283894×10^{-17} W, approximately -130.82 dBm.

B. 6.0×10^{7} W because γ, temperature, and bandwidth multiply directly.

C. 8.283894×10^{-15} W, approximately -110.82 dBm.

D. 8.283894×10^{-16} W, approximately -120.82 dBm.

Answer: D. Multiply k, 600 K, 10000 Hz, and γ 10. Conversion to dBm uses 10 log10(P/0.001 W). Review: Equation 4L. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why the selected alternative fits: W, approximately -120.82 dBm.

Distinguishing consideration: compare this with option A, “W, approximately -130.82 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C02-MCQ-064. A designer adds an ideal stage with 20 dB power gain and negligible added noise after the final noisy stage, while keeping all prior behavior valid. What happens to the required input power in Equation 4L?

A. It becomes independent of bandwidth.

B. It remains the same when that added gain contributes negligible additional noise and both signal and noise are amplified equally.

C. It improves by 20 dB because the displayed signal is higher.

D. It worsens by 20 dB because the output noise is higher.

Answer: B. Post-chain equal amplification changes output levels, not their SNR. Any real added-stage noise must be included if nonnegligible. Review: Equation 4L discussion. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why the selected alternative fits: It remains the same when that added gain contributes negligible additional noise and both signal and noise are amplified equally.

Distinguishing consideration: compare this with option A, “It becomes independent of bandwidth”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C02-MCQ-065. Which statement about mean noise power and probability of detection is correct?

A. A 10 dB SNR always implies the same probability of detection for every waveform.

B. A threshold above mean noise guarantees zero false alarms.

C. A lower noise figure uniquely determines the scan capture probability.

D. Mean noise power alone does not supply the decision-statistic distribution or probability of detection.

Answer: D. Detection performance also depends on waveform, duration, statistic, threshold, and sampling or observation opportunities. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why the selected alternative fits: Mean noise power alone does not supply the decision-statistic distribution or probability of detection.

Distinguishing consideration: compare this with option A, “A 10 dB SNR always implies the same probability of detection for every waveform”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-MCQ-066. Why must a search across many bins or time windows account for more than a single-channel false-alarm objective?

A. All bins become independent whenever the trace is displayed on a logarithmic scale.

B. The search creates multiple opportunities for noise to cross the decision threshold.

C. The number of searched windows replaces the need for noise-only validation.

D. Each additional bin physically raises receiver equivalent input temperature.

Answer: B. Multiplicity changes the search-level interpretation of threshold crossings. Dependence between opportunities also matters to the chosen validation method. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why the selected alternative fits: The search creates multiple opportunities for noise to cross the decision threshold.

Distinguishing consideration: compare this with option A, “All bins become independent whenever the trace is displayed on a logarithmic scale”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-MCQ-067. A threshold was tuned using a particular set of weak signals and noise records. Which next step best tests its advertised performance?

A. Lower the threshold until all tuning signals are detected and infer zero missed detections generally.

B. Evaluate it on distinct held-out noise-only and weak-reference records under declared conditions.

C. Replace every false alarm in the tuning set with a higher estimated noise temperature.

D. Report the best observed performance on the tuning set without identifying its use.

Answer: B. Separate challenge records help expose selection optimism. They do not remove the need to state the tested population and operating conditions. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why the selected alternative fits: Evaluate it on distinct held-out noise-only and weak-reference records under declared conditions.

Distinguishing consideration: compare this with option A, “Lower the threshold until all tuning signals are detected and infer zero missed detections generally”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-MCQ-068. A burst occurs while a scanning receiver is tuned elsewhere. What failure category is supported?

A. A demonstrated noise-limited sensitivity failure during a valid dwell.

B. A measured degradation in receiver noise figure.

C. A verified false alarm caused by the burst.

D. A coverage failure for that event.

Answer: D. The event was not observed in the relevant channel. It cannot be pooled unqualified with failed detections during valid observation intervals. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why the selected alternative fits: A coverage failure for that event.

Distinguishing consideration: compare this with option A, “A demonstrated noise-limited sensitivity failure during a valid dwell”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-MCQ-069. Two manufacturers give sensitivity figures using different modulation and quality criteria. What comparison is defensible?

A. Reproduce a common declared criterion or explicitly retain the different measurands and conditions.

B. Subtract the two values in dBm and call the result a universal detection advantage.

C. Choose the figure measured in the narrower bandwidth without considering the signal.

D. Convert both figures to watts and assume their quality criteria then coincide.

Answer: A. Unit conversion does not reconcile different definitions. Modulation, bandwidth, detector, and success criterion belong to the comparison. Review: Sensitivity Specifications and Decision Thresholds. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

Why the selected alternative fits: Reproduce a common declared criterion or explicitly retain the different measurands and conditions.

Distinguishing consideration: compare this with option B, “Subtract the two values in dBm and call the result a universal detection advantage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

Review: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

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V011-C02-MCQ-070. An analyzer's displayed average noise level is compared directly with communications-receiver usable sensitivity. What is the main missing step?

A. Treat displayed noise level as the same quantity as a specified error-rate signal level.

B. Normalize both quoted levels to the same noise bandwidth and treat that alone as establishing a common success criterion.

C. Refer both quoted levels to a 290 K source and treat the resulting numbers as interchangeable.

D. Reconcile detector, normalization, bandwidth, and success-criterion conventions.

Answer: D. These specifications can refer to different quantities and operations. Their names do not establish comparability. Review: Sensitivity Specifications and Decision Thresholds. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

Why the selected alternative fits: Reconcile detector, normalization, bandwidth, and success-criterion conventions.

Distinguishing consideration: compare this with option A, "Treat displayed noise level as the same quantity as a specified error-rate signal level"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

Review: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

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V011-C02-MCQ-071. For $T_e = \frac{T_h - Y\,T_c}{Y - 1}$, what is the partial derivative with respect to T_h when other inputs are held fixed?

A. $\frac{T_h}{Y - 1}$.

B. $\frac{Y}{Y - 1}$.

C. $\frac{1}{Y - 1}$.

D. $-\frac{1}{(Y - 1)^2}$.

Answer: C. The numerator is linear in T_h and the denominator is constant with respect to that input. Review: Equation 4N. Source: Equation 4N. Temperature sensitivity coefficients (p. 687)

Why the selected alternative fits: option C contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

Review: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

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V011-C02-MCQ-072. In Equation 4N, what is the sensitivity to T_c?

A. $-\frac{1}{Y}$.

B. $\frac{T_h - T_c}{(Y-1)^2}$.

C. $-\frac{Y}{Y-1}$.

D. $\frac{1}{Y-1}$.

Answer: C. Differentiating the numerator with respect to T_c gives -Y while the denominator is unchanged. Review: Equation 4N. Source: Equation 4N. Temperature sensitivity coefficients (p. 687)

Why the selected alternative fits: option C contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

Review: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

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V011-C02-MCQ-073. What is the corresponding partial derivative with respect to Y?

A. $\frac{T_c - T_h}{(Y-1)^2}$.

B. $\frac{T_h + T_c}{Y-1}$.

C. $\frac{T_c}{(Y-1)^2}$.

D. $\frac{T_h - T_c}{Y-1}$.

Answer: A. The quotient rule gives the negative temperature contrast over the squared denominator. This derivative drives strong sensitivity near Y = 1. Review: Equation 4O. Source: Equation 4O. Power-ratio sensitivity coefficient (p. 687)

Why the selected alternative fits: option A contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient.

Review: Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient.

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V011-C02-MCQ-074. Why must covariance terms be retained when relevant in uncertainty propagation?

A. Repeatability variance replaces all source-calibration uncertainty.

B. Covariance vanishes whenever source temperatures are expressed in kelvins.

C. Correlated inputs can increase or decrease the propagated variance depending on the sensitivities and covariance signs.

D. Covariance is always positive and can only increase uncertainty.

Answer: C. The full propagation law includes cross terms. Treating correlated inputs as independent changes the calculated result. Review: Application 2B.10; Equation 27 in Chapter 14. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

Why the selected alternative fits: Correlated inputs can increase or decrease the propagated variance depending on the sensitivities and covariance signs.

Distinguishing consideration: compare this with option A, “Repeatability variance replaces all source-calibration uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

Review: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

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V011-C02-MCQ-075. In Application 2B.10, zero covariance is stipulated among inputs giving variance contributions approximately 266.54, 1.19, and 12.84 K squared. What is the combined standard uncertainty?

A. The sum of their square roots, approximately 21.00 K.

B. Their arithmetic mean, approximately 93.52 K.

C. Their sum, approximately 280.57 K.

D. The square root of their sum, approximately 16.75 K.

Answer: D. For the stipulated zero covariance, add variances and take the square root. Variance and standard uncertainty have different units. Review: Application 2B.10. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

Why the selected alternative fits: The square root of their sum, approximately 16.75 K.

Distinguishing consideration: compare this with option A, “The sum of their square roots, approximately 21.00 K”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

Review: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

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V011-C02-MCQ-076. Which input dominates the variance in that example?

A. The measured Y input.

B. The cold-source temperature input.

C. The declared reference impedance input, which is the largest listed contribution.

D. The hot-source temperature calibration input.

Answer: D. The hot-temperature term contributes about 266.54 of 280.57 K squared. The impedance is not among the propagated inputs in that constructed calculation. Review: Application 2B.10. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

Why the selected alternative fits: The hot-source temperature calibration input.

Distinguishing consideration: compare this with option A, “The measured Y input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

Review: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

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V011-C02-MCQ-077. For $NF_0 = 10\log_{10}\left(1+\frac{T_e}{T_0}\right)$, what local sensitivity converts a small temperature uncertainty to noise-figure uncertainty?

A. $\frac{10}{\ln(10)T_e}$ decibels per kelvin in every case.

B. $\frac{T_0}{T_e}$ kelvins per decibel.

C. $\frac{20}{\ln(10)(T_0 - T_e)}$ decibels per kelvin.

D. $\frac{10}{\ln(10)(T_0 + T_e)}$ decibels per kelvin.

Answer: D. Differentiating the logarithm gives the stated sensitivity. The denominator includes both reference and equivalent input temperatures. Review: Equation 4P. Source: Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty (p. 687)

Why the selected alternative fits: decibels per kelvin.

Distinguishing consideration: compare this with option A, “decibels per kelvin in every case”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

Review: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

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V011-C02-MCQ-078. A reported expanded uncertainty is k = 2 times the standard uncertainty. Which conclusion is justified from that multiplier alone?

A. The stated expansion factor is two; a 95% coverage claim needs distributional and degrees-of-freedom support.

B. The calibration result is valid in every receiver gain state.

C. All systematic effects have been removed.

D. Coverage is exactly 95% for every possible distribution.

Answer: A. A coverage factor is not by itself a complete probability statement or a statement of configuration applicability. Review: Equation 4P; Application 2B.10.

Source: Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty (p. 687)

Why the selected alternative fits: The stated expansion factor is two; a 95% coverage claim needs distributional and degrees-of-freedom support.

Distinguishing consideration: compare this with option B, “The calibration result is valid in every receiver gain state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

Review: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

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V011-C02-MCQ-079. Why can first-order uncertainty propagation be inadequate near Y = 1?

A. The source temperature units cease to be kelvins.

B. The inverse relation becomes strongly nonlinear over the plausible input range.

C. The hot and cold powers are guaranteed to be uncorrelated there.

D. The receiver gain automatically becomes zero.

Answer: B. A local linearization may poorly represent an asymmetric or broad output distribution near the singular denominator. Review: Equation 4I; Equations 4N-4P; Application 2B.10. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why the selected alternative fits: The inverse relation becomes strongly nonlinear over the plausible input range.

Distinguishing consideration: compare this with option A, “The source temperature units cease to be kelvins”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2....

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

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V011-C02-MCQ-080. A noise average contains duplicated or strongly correlated samples. What is the valid conclusion about its uncertainty?

A. Every sample in the file contributes one independent observation by definition.

B. Duplicating the record halves every systematic uncertainty.

C. Averaging in decibels makes all samples independent.

D. The nominal sample count does not establish the corresponding independent-sample precision.

Answer: D. Precision depends on covariance and the averaging rule. File length alone does not determine independent information. Review: Uncertainty and Environmental Noise. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

Why the selected alternative fits: The nominal sample count does not establish the corresponding independent-sample precision.

Distinguishing consideration: compare this with option A, “Every sample in the file contributes one independent observation by definition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Uncertainty and Environmental Noise.

Review: Chapter 2 — Uncertainty and Environmental Noise.

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V011-C02-MCQ-081. A low-noise amplifier improves the quiet baseline but generates intermodulation in the site environment. What should govern its use?

A. The highest total gain regardless of internally generated products.

B. The lowest calculated noise figure alone.

C. The quiet baseline measured with a terminated input alone.

D. Both the noise benefit and validity under the bounded strong-signal environment.

Answer: D. An operational configuration must remain valid in the relevant environment. Noise figure alone does not characterize strong-signal behavior.

Review: Noise Figure and Noise Temperature. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

Why the selected alternative fits: Both the noise benefit and validity under the bounded strong-signal environment.

Distinguishing consideration: compare this with option A, “The highest total gain regardless of internally generated products”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Noise Figure and Noise Temperature.

Review: Chapter 2 — Noise Figure and Noise Temperature.

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V011-C02-MCQ-082. A 9 dB apparent noise rise remains with a matched termination but vanishes when an inline preamplifier is bypassed. What does this comparison support first?

A. Investigating the preamplifier or its associated path as a contributor.

B. Certifying a traceable 9 dB preamplifier noise figure from the comparison alone.

C. Assigning the full 9 dB rise to antenna temperature without further tests.

D. Concluding that all excess noise is radiated by the external environment.

Answer: A. The comparison localizes a mechanism for further testing. In the chapter case, intermittent oscillation was then found; the initial comparison is not a complete calibrated noise-figure measurement. Review: Hypothetical Case Adjudication. Source: §2.11 Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal (p. 662)

Why the selected alternative fits: Investigating the preamplifier or its associated path as a contributor.

Distinguishing consideration: compare this with option B, “Certifying a traceable 9 dB preamplifier noise figure from the comparison alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

Review: Chapter 2 — Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

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V011-C02-MCQ-083. Why does replacing an antenna by a matched termination not by itself establish a traceable receiver noise figure?

A. The receiver noise figure must equal the difference between the two displayed traces.

B. Traceable noise figure is defined only for antennas.

C. A matched termination cannot generate thermal noise.

D. The comparison lacks the complete calibrated source, state, correction, and uncertainty model required for that result.

Answer: D. Comparative observations can discriminate mechanisms without satisfying all conditions for a metrological noise-figure result. Review: Y-Factor and Comparative Noise Measurements. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

Why the selected alternative fits: The comparison lacks the complete calibrated source, state, correction, and uncertainty model required for that result.

Distinguishing consideration: compare this with option A, “The receiver noise figure must equal the difference between the two displayed traces”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Y-Factor and Comparative Noise Measurements.

Review: Chapter 2 — Y-Factor and Comparative Noise Measurements.

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V011-C02-MCQ-084. A receiver meets a measuring-apparatus standard within its stated scope. Which conclusion still requires separate evidence?

A. That a specified apparatus characteristic can be tested under the applicable method.

B. That EMI receivers and spectrum analyzers can be within the apparatus scope.

C. That the installed receiver chain and configuration support a particular operational finding.

D. That the apparatus standard has an identified publication scope.

Answer: C. Apparatus conformity does not establish configuration validity, external-chain calibration, absence of overload, or source attribution for a separate result.

Review: Measuring-Receiver Scope and System Noise Floor. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

Why the selected alternative fits: That the installed receiver chain and configuration support a particular operational finding.

Distinguishing consideration: compare this with option A, “That a specified apparatus characteristic can be tested under the applicable method”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

Review: Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

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V011-C02-MCQ-085. What is the stated public frequency scope of CISPR 16-1-1:2019 cited in the chapter?

A. 9 kHz to 18 GHz for the identified radio-disturbance measuring-apparatus scope.

B. 9 MHz to 18 MHz for audio sensitivity tests.

C. 9 kHz to 180 GHz for every receiver application.

D. DC to 18 GHz for all TSCM attribution methods.

Answer: A. The chapter cites the official publication scope and explicitly does not claim full-standard access or universal attribution coverage. Review: Measuring-Receiver Scope and System Noise Floor; footnote 4. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

Why the selected alternative fits: 9 kHz to 18 GHz for the identified radio-disturbance measuring-apparatus scope.

Distinguishing consideration: compare this with option B, “9 MHz to 18 MHz for audio sensitivity tests”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Measuring-Receiver Scope and System Noise Floor; Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

Review: Chapter 2 — Measuring-Receiver Scope and System Noise Floor; Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

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V011-C02-MCQ-086. What is the proper first interpretation when sensitivity worsens only after a bounded interferer is introduced?

A. The receiver laboratory noise figure must be replaced by the interferer level in dBm.

B. The interferer has proven a change in ambient physical temperature.

C. All subsequent records should be averaged with the quiet records as one unchanged measurand.

D. The original noise budget may remain valid for its quiet state but is insufficient to explain the interferer condition.

Answer: D. The changed condition calls for tests of compression, gain control, intermodulation, reciprocal mixing, or overlap. It does not identify one mechanism by itself. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why the selected alternative fits: The original noise budget may remain valid for its quiet state but is insufficient to explain the interferer condition.

Distinguishing consideration: compare this with option A, “The receiver laboratory noise figure must be replaced by the interferer level in dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-MCQ-087. Which verification best represents the actual field configuration?

A. Use a catalog noise figure without checking the selected detector mode.

B. Increase gain until a reference is visible and treat visibility as full calibration.

C. Test only the receiver connector while omitting all accessories, then assume their effects are negligible.

D. Introduce a controlled calibrated reference at the selected plane with the installed path and intended states exercised.

Answer: D. The source plane, path, gain, detector, and strong-signal conditions must correspond to the intended claim. Review: Operational Sensitivity Verification.

Source: §2.8 Operational Sensitivity Verification (p. 658)

Why the selected alternative fits: Introduce a controlled calibrated reference at the selected plane with the installed path and intended states exercised.

Distinguishing consideration: compare this with option A, “Use a catalog noise figure without checking the selected detector mode”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Operational Sensitivity Verification.

Review: Chapter 2 — Operational Sensitivity Verification.

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V011-C02-MCQ-088. How should injected reference events be handled in retained acquisition data?

A. Remove their identity so analysts cannot distinguish test events from unknown observations.

B. Mark their identity and describe the injection or radiation geometry.

C. Assume every signal in the tested band during the engagement is the reference.

D. Treat their timing as irrelevant once their nominal power is known.

Answer: B. Reference identification prevents contamination of the evidential interpretation and supports repeatable geometry and timing. Review: Operational Sensitivity Verification. Source: §2.8 Operational Sensitivity Verification (p. 658)

Why the selected alternative fits: Mark their identity and describe the injection or radiation geometry.

Distinguishing consideration: compare this with option A, “Remove their identity so analysts cannot distinguish test events from unknown observations”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Operational Sensitivity Verification.

Review: Chapter 2 — Operational Sensitivity Verification.

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V011-C02-MCQ-089. What does a successful closing sensitivity check establish on its own?

A. Validity of every untested antenna path and software export mode.

B. Absence of all prior overload events that left no persistent change.

C. The specified tested functions and state met the check at its own time and conditions.

D. Uninterrupted validity of every earlier acquisition interval.

Answer: C. A later check is time- and scope-bounded. It cannot alone prove the absence of transient earlier faults or validate functions it did not exercise. Review: Operational Sensitivity Verification; temporal qualification. Source: §2.8 Operational Sensitivity Verification (p. 658)

Why the selected alternative fits: The specified tested functions and state met the check at its own time and conditions.

Distinguishing consideration: compare this with option A, “Validity of every untested antenna path and software export mode”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Operational Sensitivity Verification.

Review: Chapter 2 — Operational Sensitivity Verification.

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V011-C02-MCQ-090. Why should site baselines include spatial, temporal, polarization, and operating-state information?

A. They remove the need to state receiver bandwidth and detector.

B. Environmental contributions can vary along those dimensions and alter operational sensitivity.

C. They guarantee that the receiver contribution dominates total noise.

D. Those dimensions uniquely identify every emitter without other evidence.

Answer: B. The environment is part of the observed noise context. Baseline coverage helps distinguish variations without treating a quiet laboratory value as a field guarantee. Review: Uncertainty and Environmental Noise. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

Why the selected alternative fits: Environmental contributions can vary along those dimensions and alter operational sensitivity.

Distinguishing consideration: compare this with option A, “They remove the need to state receiver bandwidth and detector”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Uncertainty and Environmental Noise.

Review: Chapter 2 — Uncertainty and Environmental Noise.

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V011-C02-MCQ-091. In Application 2B.1, the four input-referred stage contributions are 119.64, 130.37, 4.08, and 16.91 K. Which interpretation follows?

A. The preselector and amplifier contributions dominate the stipulated cascade temperature.

B. The final receiver contributes 600 K at the original input plane without gain weighting.

C. The temperatures must be multiplied because the corresponding gains multiply.

D. The smallest contribution determines the total noise figure.

Answer: A. Added-noise contributions sum after referral to the common input. The first two total about 250 K of the approximately 271 K total. Review: Application 2B.1. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

Why the selected alternative fits: The preselector and amplifier contributions dominate the stipulated cascade temperature.

Distinguishing consideration: compare this with option B, “The final receiver contributes 600 K at the original input plane without gain weighting”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.1: assemble a four-stage noise budget.

Review: Chapter 2 — Application 2B.1: assemble a four-stage noise budget.

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V011-C02-MCQ-092. The same application gives input-referred total noise -131.11 dBm and cumulative gain 45.5 dB. What output noise follows in the linear model?

A. -85.61 dBm.

B. -131.11 dBm because input referral makes output gain irrelevant.

C. -2.881 dBm.

D. -176.61 dBm.

Answer: A. Output noise equals input-referred noise plus power gain in decibels: -131.11 + 45.5 = -85.61 dBm. Review: Application 2B.1. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

Why the selected alternative fits: -85.61 dBm.

Distinguishing consideration: compare this with option B, "-131.11 dBm because input referral makes output gain irrelevant"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 2 — Application 2B.1: assemble a four-stage noise budget.

Review: Chapter 2 — Application 2B.1: assemble a four-stage noise budget.

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V011-C02-MCQ-093. If the required SNR is 10 dB and that input-referred total noise is -131.11 dBm, what is the bounded required input signal?

A. -121.11 dBm.

B. -131.11 dBm.

C. -85.61 dBm.

D. -141.11 dBm.

Answer: A. A required signal-to-noise power ratio of ten adds 10 dB to the input-referred noise. Detector justification is a separate condition. Review: Equation 4L; Application 2B.1. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why the selected alternative fits: -121.11 dBm.

Distinguishing consideration: compare this with option B, “-131.11 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Application 2B.1: assemble a four-stage noise budget.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Application 2B.1: assemble a four-stage noise budget.

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V011-C02-MCQ-094. In Application 2B.2, amplifier-first and cable-first noise figures are about 1.761 and 7.179 dB. What is their difference?

A. 5.418 dB, despite equal total gain in the stipulated arrangements.

B. 4.077 dB because the figures should be divided as linear numbers.

C. 0 dB because both chains have the same gain.

D. 8.940 dB because noise figures must be added across alternative systems.

Answer: A. Alternative noise figures compare by subtraction in decibels when referred to the same boundary and conditions. Review: Application 2B.2. Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

Why the selected alternative fits: 5.418 dB, despite equal total gain in the stipulated arrangements.

Distinguishing consideration: compare this with option B, “4.077 dB because the figures should be divided as linear numbers”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.2: move an amplifier across a cable.

Review: Chapter 2 — Application 2B.2: move an amplifier across a cable.

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V011-C02-MCQ-095. For hot and cold output powers expressed in dBm, which operation obtains the linear Y-factor?

A. Add the two dBm numbers, then divide by twenty.

B. Divide the two signed dBm numbers directly.

C. Subtract cold dBm from hot dBm, then take ten to that difference divided by ten.

D. Subtract the two powers in watts and call the result dimensionless.

Answer: C. The dBm difference is the decibel power ratio. A linear ratio requires conversion from that logarithmic difference. Review: Equation 4H; Application 2B.8.

Source: Equation 4H. Hot-to-cold output power ratio (p. 673)

Why the selected alternative fits: Subtract cold dBm from hot dBm, then take ten to that difference divided by ten.

Distinguishing consideration: compare this with option A, “Add the two dBm numbers, then divide by twenty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Application 2B.8: recover noise temperature from two powers.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Application 2B.8: recover noise temperature from two powers.

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V011-C02-MCQ-096. The hot-cold power difference is 10.801 dB. Which linear ratio is consistent?

A. Approximately 3.468.

B. Approximately 12.025.

C. Exactly 10.801.

D. Approximately 0.08316.

Answer: B. Power-ratio conversion uses $10^{\frac{10.801}{10}}$. Using division by twenty would compute an amplitude ratio instead. Review: Application 2B.8. Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)

Why the selected alternative fits: Approximately 12.025.

Distinguishing consideration: compare this with option A, “Approximately 3.468”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.8: recover noise temperature from two powers.

Review: Chapter 2 — Application 2B.8: recover noise temperature from two powers.

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V011-C02-MCQ-097. In a Y-factor experiment, why is hot-state compression especially hazardous to the simple inversion?

A. The hot output no longer follows the same proportional gain law as the cold output.

B. Compression guarantees that the cold source temperature is wrong.

C. The ratio automatically compensates compression because both observations use the same detector.

D. The source temperature difference becomes physically zero.

Answer: A. Compression changes the response law. The cancellation of common gain is not valid merely because hardware and detector labels are unchanged.
Review: Y-Factor and Comparative Noise Measurements. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)
Why the selected alternative fits: The hot output no longer follows the same proportional gain law as the cold output.
Distinguishing consideration: compare this with option B, “Compression guarantees that the cold source temperature is wrong”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 2 — Y-Factor and Comparative Noise Measurements.
Review: Chapter 2 — Y-Factor and Comparative Noise Measurements.

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V011-C02-MCQ-098. Which statement best describes the ten Applications 2B.1 through 2B.10?

A. Constructed cases that expose distinct decisions under explicitly stated assumptions.

B. Independent experimental proof that all practical cascades are matched and scalar.

C. Calibration certificates for every receiver using a 50-ohm connector.

D. Measured performance records from one identified field installation.

Answer: A. The chapter explicitly labels the values as synthetic demonstrations. They teach use and limits of the model without asserting instrument performance. Review: Model 2B introduction. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: Constructed cases that expose distinct decisions under explicitly stated assumptions.

Distinguishing consideration: compare this with option B, “Independent experimental proof that all practical cascades are matched and scalar”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-MCQ-099. Which record most directly permits an independent reviewer to reproduce an input-referral calculation?

A. Only the final input-referred value rounded to a whole decibel.

B. The raw output noise, selected planes, applicable state-specific signal power gain, bandwidth, and corrections.

C. Only the receiver model name and nominal maximum gain.

D. Only the apparent trace height relative to its screen grid.

Answer: B. The transformation must be reconstructable from its measured quantity and applicable conversion law. A final number or equipment label does not supply those inputs. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why the selected alternative fits: The raw output noise, selected planes, applicable state-specific signal power gain, bandwidth, and corrections.

Distinguishing consideration: compare this with option A, “Only the final input-referred value rounded to a whole decibel”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-MCQ-100. A calculation predicts a low noise floor, but the desired modulation is partly outside the filter and the receiver changes gain during bursts. What is the strongest defensible conclusion?

A. The source temperature alone can absorb both effects without changing the measurand.

B. The fixed-state, fully retained-signal prediction needs revision before it can support the burst sensitivity claim.

C. Adding the two nominal gain settings restores the missing modulation components.

D. The lower calculated floor proves improved burst detection regardless of the two changes.

Answer: B. Both signal retention and fixed-state response are explicit conditions. A result outside those conditions cannot inherit the claimed sensitivity unchanged.

Review: Model 2B assumptions; Equation 4L; Power, bandwidth, and the reference plane. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: The fixed-state, fully retained-signal prediction needs revision before it can support the burst sensitivity claim.

Distinguishing consideration: compare this with option A, “The source temperature alone can absorb both effects without changing the measurand”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Power, bandwidth, and the reference plane.

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Fill-in-the-Blank Questions

V011-C02-FIB-001. The kTB expression describes available thermal-noise power; equality with delivered power requires the stated port _____ condition.

Answer: matching. The matched real-impedance model identifies available and delivered power at the chosen plane. A mismatch needs its own delivery model.
Review: Equation 3; Power, bandwidth, and the reference plane. Source: Equation 3. Available thermal-noise power (p. 659)
Why this term is required: “matching” completes the stated technical proposition.
Question context: The kTB expression describes available thermal-noise power; equality with delivered power requires the stated port _____ condition
Basis and qualification: Chapter 2 — Equation 3. Available thermal-noise power; Chapter 2 — Power, bandwidth, and the reference plane.
Review: Chapter 2 — Equation 3. Available thermal-noise power; Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-FIB-002. In kTB, the unit of Boltzmann constant k is joules per _____.

Answer: kelvin. Multiplying J/K by K and Hz, where Hz is inverse seconds, gives watts. Review: Equation 3. Source: Equation 3. Available thermal-noise power (p. 659) Why this term is required: “kelvin” completes the stated technical proposition. Question context: In kTB, the unit of Boltzmann constant k is joules per _____ Basis and qualification: Chapter 2 — Equation 3. Available thermal-noise power. Review: Chapter 2 — Equation 3. Available thermal-noise power.

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V011-C02-FIB-003. In Model 2B the source term T_s remains separate from the receiver contribution _____.

Answer: T_e. Their sum sets the input-referred total noise, but the two terms represent different origins and can change independently. Review: Equation 4C.

Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why this term is required: "Their sum sets the input-referred total noise, but the two terms represent different origins and…" completes the stated technical proposition.

Question context: In Model 2B the source term remains separate from the receiver contribution _____

Basis and qualification: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-FIB-004. Antenna noise temperature describes the source environment and need not equal the receiver enclosure _____ temperature.

Answer: physical. The antenna can view sky, ground, or hot structures, while equivalent receiver noise temperature is also distinct from a physical thermometer reading. Review: Thermal Noise as a Bandwidth-Dependent Quantity. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

Why this term is required: “physical” completes the stated technical proposition.

Question context: Antenna noise temperature describes the source environment and need not equal the receiver enclosure _____ temperature

Basis and qualification: Chapter 2 — Thermal Noise as a Bandwidth-Dependent Quantity.

Review: Chapter 2 — Thermal Noise as a Bandwidth-Dependent Quantity.

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V011-C02-FIB-005. A power correction becomes interpretable only after the input and output reference _____ are identified.

Answer: planes. Each gain, loss, and noise contribution must be located between the declared boundaries. Moving a boundary changes the network being described.
Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
Why this term is required: “planes” completes the stated technical proposition.
Question context: A power correction becomes interpretable only after the input and output reference _____ are identified
Basis and qualification: Chapter 2 — Power, bandwidth, and the reference plane.
Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-FIB-006. The rectangular-filter width giving the same integrated white-noise passage under the stated normalization is the equivalent noise _____.

Answer: bandwidth. The definition concerns integrated power weighting. It does not generally reduce to a filter half-power width. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
Why this term is required: “bandwidth” completes the stated technical proposition.
Question context: The rectangular-filter width giving the same integrated white-noise passage under the stated normalization is the equivalent noise _____
Basis and qualification: Chapter 2 — Power, bandwidth, and the reference plane.
Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-FIB-007. If noise density and gain vary materially with frequency, replace a center-value product by a weighted _____.

Answer: integral. Integrating the density through the actual power response retains the frequency dependence that a flat approximation discards. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why this term is required: “integral” completes the stated technical proposition.

Question context: If noise density and gain vary materially with frequency, replace a center-value product by a weighted _____

Basis and qualification: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-FIB-008. Reducing white-noise bandwidth from 20 kHz to 5 kHz changes integrated noise power by approximately _____ dB.

Answer: -6.02. The ratio is 5/20 = 0.25, and 10 log10(0.25) is approximately -6.02 dB. Signal retention is a separate question. Review: Equation 3. Source: Equation 3. Available thermal-noise power (p. 659)

Why this term is required: "-6.02" completes the stated technical proposition.

Question context: Reducing white-noise bandwidth from 20 kHz to 5 kHz changes integrated noise power by approximately _____ dB

Basis and qualification: Chapter 2 — Equation 3. Available thermal-noise power.

Review: Chapter 2 — Equation 3. Available thermal-noise power.

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V011-C02-FIB-009. A burst sensitivity claim after narrowing the channel must account for the fraction of desired signal _____ by that channel.

Answer: retained. Noise reduction alone does not establish the SNR improvement if useful signal energy is also rejected. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

Why this term is required: “retained” completes the stated technical proposition.

Question context: A burst sensitivity claim after narrowing the channel must account for the fraction of desired signal _____ by that channel

Basis and qualification: Chapter 2 — Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-FIB-010. To refer output noise to the selected input, divide by the applicable signal _____ gain.

Answer: power. A voltage ratio is not interchangeable with a power gain without the necessary impedance and quantity conversion. Review: Power, bandwidth, and the reference plane. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
Why this term is required: “power” completes the stated technical proposition.
Question context: To refer output noise to the selected input, divide by the applicable signal _____ gain
Basis and qualification: Chapter 2 — Power, bandwidth, and the reference plane.
Review: Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-FIB-011. The empty preceding-gain product in Equation 4A is G_0 = _____.

Answer: 1. No physical stage precedes the cascade input. This convention gives the first noise contribution its correct weight. Review: Equation 4A. Source: Equation 4A. Cumulative power gain (p. 667)

Why this term is required: "1" completes the stated technical proposition.

Question context: The empty preceding-gain product in Equation 4A is = _____

Basis and qualification: Chapter 2 — Equation 4A. Cumulative power gain.

Review: Chapter 2 — Equation 4A. Cumulative power gain.

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V011-C02-FIB-012. For three stages, the cumulative power gain is G_3 = _____.

Answer: $g_1 g_2 g_3$. Linear power gains multiply in order. Their decibel representations add. Review: Equation 4A. Source: Equation 4A. Cumulative power gain (p. 667)

Why this term is required: "Linear power gains multiply in order" completes the stated technical proposition.

Question context: For three stages, the cumulative power gain is = _____

Basis and qualification: Chapter 2 — Equation 4A. Cumulative power gain.

Review: Chapter 2 — Equation 4A. Cumulative power gain.

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V011-C02-FIB-013. A 13 dB power gain corresponds to a linear gain of approximately _____.

Answer: 19.95. The conversion is $10^{\frac{13}{10}}$, approximately 19.9526. The 20-log amplitude conversion would be inappropriate here. Review: Equation 4A conventions. Source: Equation 4A. Cumulative power gain (p. 667)

Why this term is required: “19.95” completes the stated technical proposition.

Question context: A 13 dB power gain corresponds to a linear gain of approximately _____

Basis and qualification: Chapter 2 — Equation 4A. Cumulative power gain.

Review: Chapter 2 — Equation 4A. Cumulative power gain.

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V011-C02-FIB-014. The stage recurrence is $N_i = g_i N_{i-1} +$ _____.

Answer: $k B g_i T_{e,i}$. The first term transmits incoming noise; the second is the stage own output-added noise. Both terms are powers in watts. Review: Equation 4B.

Source: Equation 4B. Noise propagation through one stage (p. 668)

Why this term is required: "The first term transmits incoming noise; the second is the stage own output-added noise" completes the stated technical proposition.

Question context: The stage recurrence is = + _____

Basis and qualification: Chapter 2 — Equation 4B. Noise propagation through one stage.

Review: Chapter 2 — Equation 4B. Noise propagation through one stage.

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V011-C02-FIB-015. Dividing the recurrence by G_i makes the new stage contribution $k\,B\,T_{e,i}$ divided by _____.

Answer: G_{i-1}. The stage own gain cancels against its contribution to cumulative gain, leaving only preceding gain. Review: Derivation of Equation 4C. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why this term is required: "The stage own gain cancels against its contribution to cumulative gain, leaving only preceding gain" completes the stated technical proposition.

Question context: Dividing the recurrence by makes the new stage contribution divided by _____

Basis and qualification: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-FIB-016. For a one-stage chain, the cascade equivalent input temperature equals _____.

Answer: $T_{e,1}$. Its only noise contribution is divided by G_0 = 1. Changing its output gain does not suppress that input-equivalent contribution. Review: Equation 4C.

Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why this term is required: "Its only noise contribution is divided by = 1" completes the stated technical proposition.

Question context: For a one-stage chain, the cascade equivalent input temperature equals _____

Basis and qualification: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-FIB-017. For $T_{e,1}$ = 50 K, $T_{e,2}$ = 900 K, and g_1 = 30, the two-stage T_e is _____ K.

Answer: 80. The second stage contributes 900/30 = 30 K at the original input, which adds to the first-stage 50 K. Review: Equation 4C. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why this term is required: "80" completes the stated technical proposition.

Question context: For = 50 K, = 900 K, and = 30, the two-stage is _____ K

Basis and qualification: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-FIB-018. A third stage with $T_{e,3}$ = 2000 K follows gains g_1 = 20 and g_2 = 5. Its input-referred contribution is _____ K.

Answer: 20. The preceding gain is 20 times 5 = 100, so the contribution is 2000/100.

Review: Equation 4C. Source: Equation 4C. Cascade temperature and integrated output noise (p. 668)

Why this term is required: “20” completes the stated technical proposition.

Question context: A third stage with = 2000 K follows gains = 20 and = 5. Its input-referred contribution is _____ K

Basis and qualification: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-FIB-019. Simple power addition in Model 2B assumes zero _____ between the admitted source and stage noise contributions.

Answer: cross-power. If contributions are correlated, cross terms can affect output power and the scalar independent-addition derivation is incomplete. Review: Model 2B assumptions. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
Why this term is required: “cross-power” completes the stated technical proposition.
Question context: Simple power addition in Model 2B assumes zero _____ between the admitted source and stage noise contributions
Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.
Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-FIB-020. A noise law for one receiver configuration is a _____-state model.

Answer: fixed. Gain changes, compression, and unmodeled state dependence are outside the stated law unless a new valid model is supplied. Review: Model 2B introduction and assumptions. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “fixed” completes the stated technical proposition.

Question context: A noise law for one receiver configuration is a _____-state model

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-FIB-021. The conventional reference temperature used in Equation 4D is T_0 = _____ K.

Answer: 290. This is the reporting convention for the reference factor. It is not a claim that every actual source or component is at that temperature. Review: Equation 4D. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why this term is required: “290” completes the stated technical proposition.

Question context: The conventional reference temperature used in Equation 4D is = _____ K

Basis and qualification: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

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V011-C02-FIB-022. The reference noise factor is F_0 = 1 + _____.

Answer: $\frac{T_e}{T_0}$. The receiver-added equivalent temperature is scaled by the declared reference temperature. Review: Equation 4D. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why this term is required: "The receiver-added equivalent temperature is scaled by the declared reference temperature" completes the stated technical proposition.

Question context: The reference noise factor is = 1 + _____

Basis and qualification: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

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V011-C02-FIB-023. Noise figure is NF_0 = _____ log10(F_0).

Answer: 10. Noise factor is a power-related ratio. The multiplier twenty would apply to an appropriate amplitude-ratio representation, not this definition. Review:

Equation 4D. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why this term is required: “10” completes the stated technical proposition.

Question context: Noise figure is = _____ log10()

Basis and qualification: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

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V011-C02-FIB-024. A noise factor of 4 corresponds to a noise figure of approximately _____ dB.

Answer: 6.02. 10 log10(4) is approximately 6.0206 dB. Review: Equation 4D. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why this term is required: “6.02” completes the stated technical proposition.

Question context: A noise factor of 4 corresponds to a noise figure of approximately _____ dB

Basis and qualification: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

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V011-C02-FIB-025. At T_0 = 290 K, a noise factor of 1.5 corresponds to T_e = _____ K.

Answer: 145. Rearranging $F_0 = 1 + \frac{T_e}{T_0}$ gives T_e = 290 times 0.5. Review: Equation 4D. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why this term is required: "145" completes the stated technical proposition.

Question context: At = 290 K, a noise factor of 1.5 corresponds to = _____ K

Basis and qualification: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature.

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V011-C02-FIB-026. For positive source temperature, the actual SNR degradation is 1 + _____.

Answer: $\frac{T_e}{T_s}$. The actual source temperature belongs in this ratio. The reference factor instead uses T_0. Review: Equation 4E. Source: Equation 4E. Signal-to-noise degradation for the actual source (p. 669)

Why this term is required: "The actual source temperature belongs in this ratio" completes the stated technical proposition.

Question context: For positive source temperature, the actual SNR degradation is 1 + _____

Basis and qualification: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

Review: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

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V011-C02-FIB-027. With T_e = 100 K and T_s = 25 K, the actual SNR degradation ratio is _____.

Answer: 5. The ratio is 1 + 100/25. The same receiver has a smaller reference factor when referred to 290 K. Review: Equation 4E. Source: Equation 4E. Signal-to-noise degradation for the actual source (p. 669)

Why this term is required: "5" completes the stated technical proposition.

Question context: With = 100 K and = 25 K, the actual SNR degradation ratio is _____

Basis and qualification: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

Review: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

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V011-C02-FIB-028. With T_e = 100 K and T_s = 1000 K, that ratio is

_____.

Answer: 1.1. The larger source contribution makes the same receiver-added temperature less significant as a fraction of total noise. Review: Equation 4E. Source: Equation 4E. Signal-to-noise degradation for the actual source (p. 669)

Why this term is required: "1.1" completes the stated technical proposition.

Question context: With = 100 K and = 1000 K, that ratio is _____

Basis and qualification: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

Review: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

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V011-C02-FIB-029. For nonzero T_e, the actual SNR degradation equals F_0 when T_s = _____.

Answer: T_0. The defining ratios then use the same temperature denominator.

Review: Equations 4D and 4E. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why this term is required: "The defining ratios then use the same temperature denominator" completes the stated technical proposition.

Question context: For nonzero the actual SNR degradation equals when = _____

Basis and qualification: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

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V011-C02-FIB-030. The stated finite SNR-ratio comparison excludes $T_s = 0$ because the idealized input SNR is _____.

Answer: unbounded. Receiver-added noise can remain finite, but the input SNR denominator vanishes in the classical zero-source-noise idealization. Review: Equation 4E domain. Source: Equation 4E. Signal-to-noise degradation for the actual source (p. 669)

Why this term is required: “unbounded” completes the stated technical proposition.

Question context: The stated finite SNR-ratio comparison excludes because the idealized input SNR is _____

Basis and qualification: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

Review: Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

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V011-C02-FIB-031. For a matched passive dissipative loss L, the signal power gain is _____.

Answer: $\frac{1}{L}$. The loss variable is at least one. Its reciprocal is the fraction of matched signal power transmitted. Review: Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why this term is required: "The loss variable is at least one" completes the stated technical proposition.

Question context: For a matched passive dissipative loss L, the signal power gain is _____

Basis and qualification: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-FIB-032. Its equivalent input temperature is $T_{e,loss}$ = _____.

Answer: $(L-1)T_p$. This expression follows from thermal equilibrium at the physical temperature T_p, then referral of the added output noise through the gain.

Review: Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why this term is required: "This expression follows from thermal equilibrium at the physical temperature then referral of the…" completes the stated technical proposition.

Question context: Its equivalent input temperature is = _____

Basis and qualification: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-FIB-033. For L = 1.25 and T_p = 320 K, $T_{e,loss}$ =

_____ K.

Answer: 80. The equivalent input temperature is 0.25 times 320 K. Review: Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why this term is required: “80” completes the stated technical proposition.

Question context: For L = 1.25 and = 320 K, = _____ K

Basis and qualification: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-FIB-034. The same L = 1.25 attenuator has a power gain of _____.

Answer: 0.8. Gain is the reciprocal of loss. Its own output-added temperature equivalent is 0.8 times 80 K = 64 K. Review: Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why this term is required: “0.8” completes the stated technical proposition.

Question context: The same L = 1.25 attenuator has a power gain of _____

Basis and qualification: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-FIB-035. At equilibrium with matched source and load at T_p, the attenuator output available noise remains _____.

Answer: $k B T_p$. The attenuated source noise and attenuator thermal emission sum to the equilibrium value. Review: Derivation of Equation 4F. Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why this term is required: "The attenuated source noise and attenuator thermal emission sum to the equilibrium value" completes the stated technical proposition.

Question context: At equilibrium with matched source and load at the attenuator output available noise remains _____

Basis and qualification: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-FIB-036. The attenuator own output-added noise is kBT_p times _____.

Answer: $1-\frac{1}{L}$. The transmitted source noise at equilibrium is $\frac{kBT_p}{L}$. The added component supplies the remaining fraction. Review: Derivation of Equation 4F.

Source: Equation 4F. Noise temperature of a matched dissipative loss (p. 670)

Why this term is required: "The transmitted source noise at equilibrium is The added component supplies the remaining fraction" completes the stated technical proposition.

Question context: The attenuator own output-added noise is times _____

Basis and qualification: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-FIB-037. For a matched genuinely dissipative passive attenuator with linear loss L greater than 1, equality of noise figure and insertion loss in decibels requires T_p = _____.

Answer: T_0. With L greater than 1, only then does 1 + $\frac{(L-1)T_p}{T_0}$ reduce to L. In the excluded lossless case $L=1$, equality holds independently of T_p in this model.

Review: Equations 4D and 4F. Source: Equation 4D. Noise factor at the reference temperature (p. 669)

Why this term is required: "With L greater than 1, only then does 1 + reduce to L" completes the stated technical proposition.

Question context: For a matched genuinely dissipative passive attenuator with linear loss L greater than 1, equality of noise figure and insertion loss in decibels requires = _____

Basis and qualification: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

Review: Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss.

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V011-C02-FIB-038. A mismatch that merely reflects power cannot automatically be treated as matched thermal _____.

Answer: dissipation. The passive-noise derivation concerns dissipative loss and associated thermal emission, not arbitrary reflection. Review: Derive passive loss from thermal equilibrium. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

Why this term is required: “dissipation” completes the stated technical proposition.

Question context: A mismatch that merely reflects power cannot automatically be treated as matched thermal _____

Basis and qualification: Chapter 2 — Derive passive loss from thermal equilibrium.

Review: Chapter 2 — Derive passive loss from thermal equilibrium.

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V011-C02-FIB-039. For loss before a following chain, Equation 4G is $T_{e,total}$ = $(L-1)T_p$ + _____.

Answer: $LT_{e,c}$. Downstream added noise is referred backward through the preceding attenuation and therefore multiplied by L. Review: Equation 4G. Source: Equation 4G. Loss followed by a characterized chain (p. 671)

Why this term is required: "Downstream added noise is referred backward through the preceding attenuation and therefore…" completes the stated technical proposition.

Question context: For loss before a following chain, Equation 4G is = + _____

Basis and qualification: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

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V011-C02-FIB-040. For L = 2, T_p = 300 K, and $T_{e,c}$ = 75 K, the combined $T_{e,total}$ is _____ K.

Answer: 450. The loss contributes 300 K, and the following chain contributes 2 times 75 K = 150 K. Review: Equation 4G. Source: Equation 4G. Loss followed by a characterized chain (p. 671)

Why this term is required: “450” completes the stated technical proposition.

Question context: For L = 2, = 300 K, and = 75 K, the combined is _____ K

Basis and qualification: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain.

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V011-C02-FIB-041. A two-stage target $T_e \leq T_{target}$ with $T_{e,2} > 0$ requires g_1 >= _____.

Answer: $\frac{T_{e,2}}{T_{target} - T_{e,1}}$. The denominator must be positive for a finite feasible gain.

This inequality is derived directly from the cascade temperature. Review: Equation 4J. Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why this term is required: "The denominator must be positive for a finite feasible gain" completes the stated technical proposition.

Question context: A two-stage target with requires >= _____

Basis and qualification: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

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V011-C02-FIB-042. With $T_{e,1}$ = 60 K, $T_{e,2}$ = 1000 K, and T_{target} = 100 K, minimum g_1 is _____.

Answer: 25. The available temperature allowance for the second-stage contribution is 40 K, so g_1 must be at least 1000/40. Review: Equation 4J. Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why this term is required: "25" completes the stated technical proposition.

Question context: With = 60 K, = 1000 K, and = 100 K, minimum is _____

Basis and qualification: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

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V011-C02-FIB-043. For positive $T_{e,2}$, the limiting cascade temperature as g_1 grows without bound is _____.

Answer: $T_{e,1}$. Preceding gain suppresses the downstream term, but it cannot remove the first stage own input-equivalent noise. Review: Equation 4J discussion.

Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why this term is required: "Preceding gain suppresses the downstream term, but it cannot remove the first stage own…" completes the stated technical proposition.

Question context: For positive the limiting cascade temperature as grows without bound is _____

Basis and qualification: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

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V011-C02-FIB-044. If T_{target} is below $T_{e,1}$ under those assumptions, the gain design is _____.

Answer: infeasible. No positive finite gain can make the nonnegative downstream contribution lower the first-stage temperature. Review: Equation 4J domain. Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why this term is required: “infeasible” completes the stated technical proposition.

Question context: If is below under those assumptions, the gain design is _____

Basis and qualification: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit.

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V011-C02-FIB-045. The maximum allowed loss before a chain is (T_{target}+T_p) divided by _____.

Answer: T_p+$T_{e,c}$. This bound follows by collecting the terms proportional to L in Equation 4G. Review: Equation 4K. Source: Equation 4K. Maximum allowed preceding loss (p. 675)

Why this term is required: "This bound follows by collecting the terms proportional to L in Equation 4G" completes the stated technical proposition.

Question context: The maximum allowed loss before a chain is () divided by _____

Basis and qualification: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

Review: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

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V011-C02-FIB-046. The physically allowed loss interval starts at L = _____.

Answer: 1. A matched passive dissipative section cannot have signal power gain above unity in this loss model. Review: Equation 4K domain. Source: Equation 4K. Maximum allowed preceding loss (p. 675)

Why this term is required: “1” completes the stated technical proposition.

Question context: The physically allowed loss interval starts at L = _____

Basis and qualification: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

Review: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

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V011-C02-FIB-047. For T_{target} = 200 K, T_p = 300 K, and $T_{e,c}$ = 100 K, the maximum L is _____.

Answer: 1.25. The upper bound is (200 + 300)/(300 + 100) = 1.25, provided the other model conditions hold. Review: Equation 4K. Source: Equation 4K. Maximum allowed preceding loss (p. 675)

Why this term is required: "1.25" completes the stated technical proposition.

Question context: For = 200 K, = 300 K, and = 100 K, the maximum L is _____

Basis and qualification: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

Review: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

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V011-C02-FIB-048. That linear loss limit corresponds to approximately _____ dB.

Answer: 0.969. 10 log10(1.25) is approximately 0.9691 dB. Review: Equation 4K.

Source: Equation 4K. Maximum allowed preceding loss (p. 675)

Why this term is required: “0.969” completes the stated technical proposition.

Question context: That linear loss limit corresponds to approximately _____ dB

Basis and qualification: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

Review: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

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V011-C02-FIB-049. An output attenuator cannot protect an amplifier that has already exceeded its input _____ envelope.

Answer: linear. Internal signal levels must be checked at the stage where overload can occur. Downstream attenuation cannot reverse earlier distortion. Review: Application 2B.7. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why this term is required: “linear” completes the stated technical proposition.

Question context: An output attenuator cannot protect an amplifier that has already exceeded its input _____ envelope

Basis and qualification: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

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V011-C02-FIB-050. The Application 2B.7 blocker is -5 dBm. A 20 dB attenuator before the amplifier places it at _____ dBm at that input.

Answer: -25. Subtract the input loss from the blocker power in dBm. Its location before the amplifier is essential to this result. Review: Application 2B.7. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why this term is required: "-25" completes the stated technical proposition.

Question context: The Application 2B.7 blocker is -5 dBm. A 20 dB attenuator before the amplifier places it at _____ dBm at that input

Basis and qualification: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

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V011-C02-FIB-051. The Y-factor is the hot output noise power divided by the _____ output noise power.

Answer: cold. Both powers must represent the same effective receiver state, bandwidth, and detection law for the simple ratio model. Review: Equation 4H.

Source: Equation 4H. Hot-to-cold output power ratio (p. 673)

Why this term is required: “cold” completes the stated technical proposition.

Question context: The Y-factor is the hot output noise power divided by the _____ output noise power

Basis and qualification: Chapter 2 — Equation 4H. Hot-to-cold output power ratio.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio.

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V011-C02-FIB-052. Under the common-state law, Y = (T_h+T_e) divided by _____.

Answer: T_c+T_e. The receiver-added contribution appears in both source states and cannot be omitted from the cold denominator. Review: Equation 4H. Source: Equation 4H. Hot-to-cold output power ratio (p. 673)

Why this term is required: "The receiver-added contribution appears in both source states and cannot be omitted from the cold…" completes the stated technical proposition.

Question context: Under the common-state law, Y = () divided by _____

Basis and qualification: Chapter 2 — Equation 4H. Hot-to-cold output power ratio.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio.

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V011-C02-FIB-053. The temperature obtained by inversion is T_e = (T_h - YTc) divided by _____.

Answer: $Y - 1$. This denominator explains the poor conditioning when the two output powers become nearly equal. Review: Equation 4I. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why this term is required: "This denominator explains the poor conditioning when the two output powers become nearly equal" completes the stated technical proposition.

Question context: The temperature obtained by inversion is = (- YTc) divided by _____

Basis and qualification: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-FIB-054. For T_h = 3000 K, T_c = 300 K, and Y = 6, the inferred T_e is _____ K.

Answer: 240. The numerator is 3000 - 1800 = 1200 K; division by 5 gives 240 K.

Review: Equation 4I. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why this term is required: “240” completes the stated technical proposition.

Question context: For = 3000 K, = 300 K, and Y = 6, the inferred is _____ K

Basis and qualification: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-FIB-055. For positive T_c and nonnegative finite T_e, the upper Y boundary is _____.

Answer: $\frac{T_h}{T_c}$. The upper bound occurs at T_e = 0. Adding receiver noise moves the ratio toward one. Review: Equation 4I domain. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why this term is required: "The upper bound occurs at = 0" completes the stated technical proposition.

Question context: For positive and nonnegative finite the upper Y boundary is _____

Basis and qualification: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-FIB-056. The finite-T_e lower boundary is strict: Y must be greater than _____.

Answer: 1. With T_h greater than T_c, equal finite added noise cannot make the ratio exactly one, though it can approach it. Review: Equation 4I domain. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why this term is required: “1” completes the stated technical proposition.

Question context: The finite- lower boundary is strict: Y must be greater than _____

Basis and qualification: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-FIB-057. A computed negative T_e under the nonnegative-temperature model is a reason to investigate the measurement and model, not automatically to _____ the value to zero.

Answer: clip. Clipping conceals an inconsistency and does not correct calibration, state, mismatch, or data errors. Review: Equation 4I domain. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why this term is required: “clip” completes the stated technical proposition.

Question context: A computed negative under the nonnegative-temperature model is a reason to investigate the measurement and model, not automatically to _____ the value to zero

Basis and qualification: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-FIB-058. The chapter excess-noise-ratio convention uses the difference T_h - T_c divided by _____.

Answer: T_0. The actual source certificate must still be read because conventions and cold-state definitions can differ. Review: Y-factor discussion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why this term is required: "The actual source certificate must still be read because conventions and cold-state definitions can…" completes the stated technical proposition.

Question context: The chapter excess-noise-ratio convention uses the difference - divided by _____

Basis and qualification: Chapter 2 — Invert the same model with two source temperatures.

Review: Chapter 2 — Invert the same model with two source temperatures.

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V011-C02-FIB-059. If T_h - T_c = 5800 K and T_0 = 290 K, the linear ENR is _____.

Answer: 20. The ratio is 5800/290. Its decibel value is approximately 13.01 dB.

Review: Y-factor discussion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why this term is required: “20” completes the stated technical proposition.

Question context: If - = 5800 K and = 290 K, the linear ENR is _____

Basis and qualification: Chapter 2 — Invert the same model with two source temperatures.

Review: Chapter 2 — Invert the same model with two source temperatures.

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V011-C02-FIB-060. In a Y-factor test, automatic gain control must be disabled or _____.

Answer: characterized. A source-state-dependent gain change invalidates cancellation unless its effect is modeled and corrected with justified evidence.

Review: Y-Factor and Comparative Noise Measurements. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

Why this term is required: “characterized” completes the stated technical proposition.

Question context: In a Y-factor test, automatic gain control must be disabled or _____

Basis and qualification: Chapter 2 — Y-Factor and Comparative Noise Measurements.

Review: Chapter 2 — Y-Factor and Comparative Noise Measurements.

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V011-C02-FIB-061. If hot gain divided by cold gain is r_g, the observed ratio is r_g times the equal-state _____.

Answer: Y-factor. The multiplicative gain error changes the ratio before inversion. Equal hardware names do not establish equal realized gains. Review: Application 2B.9. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

Why this term is required: "Y-factor" completes the stated technical proposition.

Question context: If hot gain divided by cold gain is the observed ratio is times the equal-state _____

Basis and qualification: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-FIB-062. For true Y = 8 and hot/cold gain ratio 1.02, the observed Y is _____.

Answer: 8.16. The state gain ratio multiplies the noise-power ratio: 1.02 times 8.

Review: Application 2B.9 mechanism. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

Why this term is required: "8.16" completes the stated technical proposition.

Question context: For true Y = 8 and hot/cold gain ratio 1.02, the observed Y is _____

Basis and qualification: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-FIB-063. Repeating an unchanged hot-state gain error reduces random scatter but does not by itself remove the resulting _____.

Answer: bias. Precision around the wrong expectation is not evidence that the equal-gain model has become valid. Review: Application 2B.9. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

Why this term is required: “bias” completes the stated technical proposition.

Question context: Repeating an unchanged hot-state gain error reduces random scatter but does not by itself remove the resulting _____

Basis and qualification: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-FIB-064. A cold-hot-cold sequence can reveal temporal _____, but does not automatically identify every correction.

Answer: drift. The bracketing observations show change only through the functions and conditions actually observed; a corrective gain model needs additional justification. Review: Application 2B.9. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

Why this term is required: “drift” completes the stated technical proposition.

Question context: A cold-hot-cold sequence can reveal temporal _____, but does not automatically identify every correction

Basis and qualification: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-FIB-065. To compute Y from two dBm readings, first take their _____, then convert the resulting decibel ratio to linear form.

Answer: difference. Subtract cold dBm from hot dBm and apply 10 to that value divided by ten. Direct division of signed dBm readings is invalid. Review: Equation 4H. Source: Equation 4H. Hot-to-cold output power ratio (p. 673)

Why this term is required: “difference” completes the stated technical proposition.

Question context: To compute Y from two dBm readings, first take their _____, then convert the resulting decibel ratio to linear form

Basis and qualification: Chapter 2 — Equation 4H. Hot-to-cold output power ratio.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio.

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V011-C02-FIB-066. The partial derivative of T_e with respect to T_h is

_____.

Answer: $\frac{1}{Y-1}$. This sensitivity is dimensionless because both the output and that input are temperatures. Review: Equation 4N. Source: Equation 4N. Temperature sensitivity coefficients (p. 687)

Why this term is required: "This sensitivity is dimensionless because both the output and that input are temperatures" completes the stated technical proposition.

Question context: The partial derivative of with respect to is _____

Basis and qualification: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

Review: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

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V011-C02-FIB-067. The partial derivative of T_e with respect to T_c is

_____.

Answer: $-\frac{Y}{Y-1}$. Its negative sign matters when correlated input uncertainties are propagated. Review: Equation 4N. Source: Equation 4N. Temperature sensitivity coefficients (p. 687)

Why this term is required: "Its negative sign matters when correlated input uncertainties are propagated" completes the stated technical proposition.

Question context: The partial derivative of with respect to is _____

Basis and qualification: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

Review: Chapter 2 — Equation 4N. Temperature sensitivity coefficients.

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V011-C02-FIB-068. The partial derivative with respect to Y is (T_c - T_h) divided by _____.

Answer: $(Y-1)^2$. Because Y is dimensionless, this sensitivity has units of kelvins. It grows strongly near Y = 1. Review: Equation 4O. Source: Equation 4O. Power-ratio sensitivity coefficient (p. 687)

Why this term is required: "Because Y is dimensionless, this sensitivity has units of kelvins" completes the stated technical proposition.

Question context: The partial derivative with respect to Y is (-) divided by _____

Basis and qualification: Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient.

Review: Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient.

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V011-C02-FIB-069. The square of a standard uncertainty in kelvins has units of _____.

Answer: kelvins squared. Variance terms are added in common squared units before taking the square root to obtain standard uncertainty. Review: Application 2B.10; Equation 27 in Chapter 14. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

Why this term is required: "kelvins squared" completes the stated technical proposition.

Question context: The square of a standard uncertainty in kelvins has units of _____

Basis and qualification: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

Review: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

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V011-C02-FIB-070. When inputs are correlated, the propagation law includes cross terms containing their _____.

Answer: covariances. Zero covariance is an assumption in the worked example, not a universal property of source and ratio estimates. Review: Application 2B.10; Equation 27 in Chapter 14. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

Why this term is required: "covariances" completes the stated technical proposition.

Question context: When inputs are correlated, the propagation law includes cross terms containing their _____

Basis and qualification: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

Review: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

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V011-C02-FIB-071. With independent variance contributions 9, 16, and 0 K squared, the combined standard uncertainty is _____ K.

Answer: 5. The square root of 9 + 16 is 5 K. Adding standard deviations would not implement the stated independent-input propagation. Review: Application 2B.10; Equation 27 in Chapter 14. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

Why this term is required: “5” completes the stated technical proposition.

Question context: With independent variance contributions 9, 16, and 0 K squared, the combined standard uncertainty is _____ K

Basis and qualification: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

Review: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

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V011-C02-FIB-072. For a local conversion from T_e uncertainty to NF uncertainty, the denominator of the sensitivity is ln(10) times _____.

Answer: T_0+T_e. The derivative is 10 divided by that denominator and has units of decibels per kelvin. Review: Equation 4P. Source: Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty (p. 687)

Why this term is required: "The derivative is 10 divided by that denominator and has units of decibels per kelvin" completes the stated technical proposition.

Question context: For a local conversion from uncertainty to NF uncertainty, the denominator of the sensitivity is ln(10) times _____

Basis and qualification: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

Review: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

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V011-C02-FIB-073. In Application 2B.10, u(T_e) is approximately 16.75 K; multiplying by coverage factor 2 gives expanded uncertainty _____ K.

Answer: 33.5. This is the arithmetic expansion. Its coverage probability still requires the stated distribution and degrees-of-freedom reasoning. Review: Equation 4P; Application 2B.10. Source: Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty (p. 687)

Why this term is required: "33.5" completes the stated technical proposition.

Question context: In Application 2B.10, u() is approximately 16.75 K; multiplying by coverage factor 2 gives expanded uncertainty _____ K

Basis and qualification: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

Review: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

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V011-C02-FIB-074. A factor-of-two expanded uncertainty does not alone establish an exact _____ percent coverage probability.

Answer: 95. The multiplier does not specify the output distribution or effective degrees of freedom. Review: Equation 4P. Source: Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty (p. 687)

Why this term is required: “95” completes the stated technical proposition.

Question context: A factor-of-two expanded uncertainty does not alone establish an exact _____ percent coverage probability

Basis and qualification: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

Review: Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

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V011-C02-FIB-075. Near the Y = 1 boundary, a first-order propagation may fail because the inverse measurement relation is strongly _____.

Answer: nonlinear. A local derivative may not represent the full plausible range or asymmetry of the inferred temperature. Review: Equation 4I; Equations 4N-4P; Application 2B.10. Source: Equation 4I. Recovered input noise temperature and its domain (p. 674)

Why this term is required: “nonlinear” completes the stated technical proposition.

Question context: Near the Y = 1 boundary, a first-order propagation may fail because the inverse measurement relation is strongly _____

Basis and qualification: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2 —....

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

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V011-C02-FIB-076. The precision of an average depends on its covariance structure and averaging rule, not only the nominal _____ count.

Answer: sample. Duplicated and correlated data do not provide as many independent observations as their file length suggests. Review: Uncertainty and Environmental Noise. Source: §2.7 Uncertainty and Environmental Noise (p. 657)
Why this term is required: “sample” completes the stated technical proposition.
Question context: The precision of an average depends on its covariance structure and averaging rule, not only the nominal _____ count
Basis and qualification: Chapter 2 — Uncertainty and Environmental Noise.
Review: Chapter 2 — Uncertainty and Environmental Noise.

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V011-C02-FIB-077. The output-SNR requirement in Equation 4L is represented by the positive ratio _____.

Answer: γ . Its value must come from a separately justified detector requirement or bounded empirical characterization. Review: Equation 4L. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why this term is required: "Its value must come from a separately justified detector requirement or bounded empirical..." completes the stated technical proposition.

Question context: The output-SNR requirement in Equation 4L is represented by the positive ratio _____

Basis and qualification: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C02-FIB-078. The bounded required input power is $\gamma\ k\ B$ times _____.

Answer: T_s+T_e. The input-referred noise includes source and receiver contributions. The desired signal must be fully retained under the declared law.

Review: Equation 4L. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why this term is required: "The input-referred noise includes source and receiver contributions" completes the stated technical proposition.

Question context: The bounded required input power is times _____

Basis and qualification: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C02-FIB-079. If γ doubles with the other Equation 4L quantities fixed, required signal power increases by approximately _____ dB.

Answer: 3.01. Power doubles, so its decibel change is 10 log10(2). Review: Equation 4L. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why this term is required: "3.01" completes the stated technical proposition.

Question context: If doubles with the other Equation 4L quantities fixed, required signal power increases by approximately _____ dB

Basis and qualification: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C02-FIB-080. If effective bandwidth falls by a factor of five with full signal retention and unchanged γ, required power decreases by approximately _____ dB.

Answer: 6.99. The power ratio is one fifth, or -6.9897 dB. The question asks the magnitude of the decrease. Review: Equation 4L. Source: Equation 4L. Input signal power for a stipulated output ratio (p. 675)

Why this term is required: “6.99” completes the stated technical proposition.

Question context: If effective bandwidth falls by a factor of five with full signal retention and unchanged required power decreases by approximately _____ dB

Basis and qualification: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C02-FIB-081. A mean noise power is insufficient to derive detection probability because the distribution of the decision _____ is also needed.

Answer: statistic. Detector law, event conditions, threshold, and observation opportunities affect the operating characteristics. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
Why this term is required: “statistic” completes the stated technical proposition.
Question context: A mean noise power is insufficient to derive detection probability because the distribution of the decision _____ is also needed
Basis and qualification: Chapter 2 — Define sensitivity as a reproducible decision.
Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-FIB-082. A threshold validation set distinct from the tuning set is commonly called a _____-out set.

Answer: held. Independent challenge records help test whether apparent tuning performance generalizes to the declared operating population. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why this term is required: “held” completes the stated technical proposition.

Question context: A threshold validation set distinct from the tuning set is commonly called a _____-out set

Basis and qualification: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-FIB-083. Searching many channels or windows creates multiple opportunities for a false _____.

Answer: alarm. A search-level claim must account for the opportunities and their dependence, rather than transferring one preselected-channel result unqualified.
Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
Why this term is required: “alarm” completes the stated technical proposition.
Question context: Searching many channels or windows creates multiple opportunities for a false _____
Basis and qualification: Chapter 2 — Define sensitivity as a reproducible decision.
Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-FIB-084. A signal occurring while the receiver is tuned elsewhere is a _____ failure, rather than a noise-limited miss during a valid dwell.

Answer: coverage. The relevant channel was not observed then. That event belongs to a different failure population. Review: Define sensitivity as a reproducible decision. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why this term is required: “coverage” completes the stated technical proposition.

Question context: A signal occurring while the receiver is tuned elsewhere is a _____ failure, rather than a noise-limited miss during a valid dwell

Basis and qualification: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-FIB-085. To distinguish those failure populations, a scanning receiver record must retain when each channel was actually _____.

Answer: observed. Nominal scan settings alone do not show the valid time intervals available for a particular event. Review: Define sensitivity as a reproducible decision.

Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why this term is required: “observed” completes the stated technical proposition.

Question context: To distinguish those failure populations, a scanning receiver record must retain when each channel was actually _____

Basis and qualification: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-FIB-086. Sensitivity defined at a specified error rate cannot be compared directly with another figure unless their success _____ are reconciled.

Answer: criteria. Unit conversion alone cannot make different modulation, detector, quality, and bandwidth definitions identical. Review: Sensitivity Specifications and Decision Thresholds. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

Why this term is required: “criteria” completes the stated technical proposition.

Question context: Sensitivity defined at a specified error rate cannot be compared directly with another figure unless their success _____ are reconciled

Basis and qualification: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

Review: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

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V011-C02-FIB-087. A lower laboratory receiver noise figure can be insufficient to describe an occupied site because the _____ contribution may dominate.

Answer: environmental. External noise and interferers can vary with location, time, polarization, and operating state. Review: Uncertainty and Environmental Noise.

Source: §2.7 Uncertainty and Environmental Noise (p. 657)

Why this term is required: “environmental” completes the stated technical proposition.

Question context: A lower laboratory receiver noise figure can be insufficient to describe an occupied site because the _____ contribution may dominate

Basis and qualification: Chapter 2 — Uncertainty and Environmental Noise.

Review: Chapter 2 — Uncertainty and Environmental Noise.

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V011-C02-FIB-088. In the chapter preamplifier case, the mechanism finally identified was intermittent _____.

Answer: oscillation. The terminated-input and bypass comparisons helped localize the problem, but the mechanism was established through the subsequent investigation. Review: Hypothetical Case Adjudication. Source: §2.11 Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal (p. 662)

Why this term is required: “oscillation” completes the stated technical proposition.

Question context: In the chapter preamplifier case, the mechanism finally identified was intermittent _____

Basis and qualification: Chapter 2 — Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

Review: Chapter 2 — Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

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V011-C02-FIB-089. A comparative termination test can discriminate mechanisms without by itself yielding a metrologically _____ noise-figure result.

Answer: traceable. A traceable result requires the applicable calibration chain and uncertainty evidence, not merely a file or equipment provenance record. Review: Y-Factor and Comparative Noise Measurements. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

Why this term is required: “traceable” completes the stated technical proposition.

Question context: A comparative termination test can discriminate mechanisms without by itself yielding a metrologically _____ noise-figure result

Basis and qualification: Chapter 2 — Y-Factor and Comparative Noise Measurements.

Review: Chapter 2 — Y-Factor and Comparative Noise Measurements.

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V011-C02-FIB-090. When a bounded interferer alone degrades sensitivity, possible mechanisms include compression, gain control, intermodulation, reciprocal mixing, and spectral _____.

Answer: overlap. The observation calls for discriminating tests; it does not uniquely identify one mechanism. Review: Define sensitivity as a reproducible decision.

Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

Why this term is required: “overlap” completes the stated technical proposition.

Question context: When a bounded interferer alone degrades sensitivity, possible mechanisms include compression, gain control, intermodulation, reciprocal mixing, and spectral _____

Basis and qualification: Chapter 2 — Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

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V011-C02-FIB-091. Verification references should be introduced at the declared field or terminal _____ and through the intended installed path.

Answer: plane. Testing only a downstream point can bypass functions included in a broader operational claim. Review: Operational Sensitivity Verification. Source: §2.8 Operational Sensitivity Verification (p. 658)

Why this term is required: “plane” completes the stated technical proposition.

Question context: Verification references should be introduced at the declared field or terminal _____ and through the intended installed path

Basis and qualification: Chapter 2 — Operational Sensitivity Verification.

Review: Chapter 2 — Operational Sensitivity Verification.

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V011-C02-FIB-092. A reference signal identity should be marked in _____ data so it is not mistaken for an unrelated observation.

Answer: native. Retained event identity, geometry, and timing connect the test input to the resulting record. Review: Operational Sensitivity Verification. Source: §2.8 Operational Sensitivity Verification (p. 658)

Why this term is required: “native” completes the stated technical proposition.

Question context: A reference signal identity should be marked in _____ data so it is not mistaken for an unrelated observation

Basis and qualification: Chapter 2 — Operational Sensitivity Verification.

Review: Chapter 2 — Operational Sensitivity Verification.

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V011-C02-FIB-093. A successful closing check alone cannot establish _____ validity throughout an earlier acquisition.

Answer: uninterrupted. The check assesses exercised functions at its own time and conditions; transient earlier failures may leave no later persistent evidence. Review: Operational Sensitivity Verification; temporal qualification. Source: §2.8 Operational Sensitivity Verification (p. 658)

Why this term is required: “uninterrupted” completes the stated technical proposition.

Question context: A successful closing check alone cannot establish _____ validity throughout an earlier acquisition

Basis and qualification: Chapter 2 — Operational Sensitivity Verification.

Review: Chapter 2 — Operational Sensitivity Verification.

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V011-C02-FIB-094. The cited CISPR 16-1-1:2019 public scope begins at _____ kHz.

Answer: 9. The chapter cites the official measuring-apparatus scope, which extends to 18 GHz, while retaining the stated access limitation. Review: Measuring-Receiver Scope and System Noise Floor. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

Why this term is required: “9” completes the stated technical proposition.

Question context: The cited CISPR 16-1-1:2019 public scope begins at _____ kHz

Basis and qualification: Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

Review: Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

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V011-C02-FIB-095. The public scope of that cited edition extends to _____ GHz.

Answer: 18. This apparatus scope does not convert conformity into proof of a separate operational attribution or installed-chain claim. Review: Measuring-Receiver Scope and System Noise Floor. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

Why this term is required: “18” completes the stated technical proposition.

Question context: The public scope of that cited edition extends to _____ GHz

Basis and qualification: Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

Review: Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

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V011-C02-FIB-096. At 290 K and 10 kHz, the chapter kTB screening value is approximately _____ dBm before receiver noise figure.

Answer: -134. The available thermal noise is about 4.00×10^{-17} W. The value is a room-temperature approximation under the declared conditions. Review: Hypothetical Applied Calculation. Source: §2.10 Hypothetical Applied Calculation: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal (p. 661)
Why this term is required: "-134" completes the stated technical proposition.
Question context: At 290 K and 10 kHz, the chapter kTB screening value is approximately _____ dBm before receiver noise figure
Basis and qualification: Chapter 2 — Hypothetical Applied Calculation: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.
Review: Chapter 2 — Hypothetical Applied Calculation: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

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V011-C02-FIB-097. Adding a 7 dB receiver noise figure to that -134 dBm room-temperature estimate gives approximately _____ dBm input-referred noise.

Answer: -127. This screening calculation omits additional detection margin, mismatch, and environmental interference. Review: Hypothetical Applied Calculation. Source: §2.10 Hypothetical Applied Calculation: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal (p. 661)

Why this term is required: "-127" completes the stated technical proposition.

Question context: Adding a 7 dB receiver noise figure to that -134 dBm room-temperature estimate gives approximately _____ dBm input-referred noise

Basis and qualification: Chapter 2 — Hypothetical Applied Calculation: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

Review: Chapter 2 — Hypothetical Applied Calculation: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

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V011-C02-FIB-098. Using the -174 dBm/Hz approximation with 10 kHz bandwidth and 5 dB noise figure gives _____ dBm.

Answer: -129. The bandwidth term is 40 dB, so -174 + 40 + 5 = -129 dBm. Review: Worked Example 2A.1. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

Why this term is required: "-129" completes the stated technical proposition.

Question context: Using the -174 dBm/Hz approximation with 10 kHz bandwidth and 5 dB noise figure gives _____ dBm

Basis and qualification: Chapter 2 — Worked Example 2A.1. Thermal Noise-Floor Screening.

Review: Chapter 2 — Worked Example 2A.1. Thermal Noise-Floor Screening.

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V011-C02-FIB-099. The sixteen local equation groups 4A through 4P belong to one matched noise-cascade _____, rather than sixteen new principal models.

Answer: family. They propagate, invert, constrain, and quantify uncertainty within the same explicitly bounded scalar model. Review: Model 2B introduction. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “family” completes the stated technical proposition.

Question context: The sixteen local equation groups 4A through 4P belong to one matched noise-cascade _____, rather than sixteen new principal models

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-FIB-100. Applications 2B.1 through 2B.10 use constructed values and do not claim measured _____ from a receiver or installation.

Answer: performance. Their purpose is to demonstrate distinct engineering decisions and failure limits under stated assumptions. Review: Model 2B introduction. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “performance” completes the stated technical proposition.

Question context: Applications 2B.1 through 2B.10 use constructed values and do not claim measured _____ from a receiver or installation

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C02-ESSAY-001. Derive the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes, dimensions, and independence assumption explicit. Explain why the own-stage gain does not appear in its final input-equivalent contribution.

- Opening: Present a thesis that answers this precise question: Derive the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes, dimensions, and independence assumption explicit. Identify which evidence would falsify the proposed conclusion Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Core terminology and scope: Define recurrence, making, planes in the question's particular technical setting; explain how independence, assumption, appear differ if that distinction would change the analysis of "Derive the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes, dimensions, and independence assumption explicit" Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Problem statement and purpose: Frame the actual measurement or decision in the question. A complete answer defines = 1 and as the product of gains through stage i Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,… to the claimed result, following "Noise-colour models, covariance and decision

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performance beyond a scalar noise figure"; name the intermediate states and measurable outputs Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,…. Explain that is already an input-equivalent quantity for its own stage, so its own gain cancels Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Power, bandwidth, and the reference plane" that resolves the question about the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,…; derive the relevant result with units and stated validity conditions Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,…. State the common matched real impedance, fixed state, band-flatness approximation, and zero-cross-power assumptions Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Worked application or illustrative case: Build a worked example of "the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,…",

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addressing this associated condition: Explain why the own-stage gain does not appear in its final input-equivalent contribution. A complete answer defines = 1 and as the product of gains through stage i Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,…”. Using “Power, bandwidth, and the reference plane”, specify a discriminator and the result expected under each explanation Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,…, including the effect of missing measurements and inconsistent operating conditions Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)
- Scholarly synthesis and implications: Explain what the result about the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes,… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Closing: Conclude by answering “Derive the arbitrary-stage equivalent input noise-temperature sum from the one-stage recurrence, making the reference planes, dimensions, and

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independence assumption explicit" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

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V011-C02-ESSAY-002. Develop the passive-loss noise-temperature relation from thermal equilibrium. Contrast dissipative attenuation with a mismatch that only changes delivered power.

- Opening: Present a thesis that answers this precise question: Develop the passive-loss noise-temperature relation from thermal equilibrium. Contrast dissipative attenuation with a mismatch that only changes delivered power. Identify which evidence would falsify the proposed conclusion Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)
- Core terminology and scope: Define relation, thermal, equilibrium in the question's particular technical setting; explain how Contrast, dissipative, delivered differ if that distinction would change the analysis of "Develop the passive-loss noise-temperature relation from thermal equilibrium. Contrast dissipative attenuation with a mismatch that only changes delivered power" Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Set the source and matched terminations to the attenuator physical temperature The source contributes at the output Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the passive-loss noise-temperature relation from thermal equilibrium to the claimed result, following "Thermal Noise as a Bandwidth-Dependent Quantity"; name the intermediate states and measurable outputs Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the passive-loss noise-temperature relation from thermal equilibrium. Full credit requires separating available power, delivered power, physical temperature, and equivalent input temperature Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)
- Analytical framework: Identify the equation, calibration or evidential decision test in “From a calculated temperature to a defended result” that resolves the question about the passive-loss noise-temperature relation from thermal equilibrium; derive the relevant result with units and stated validity conditions Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the passive-loss noise-temperature relation from thermal equilibrium. Review: Derive passive loss from thermal equilibrium; Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)
- Worked application or illustrative case: Build a worked example of “the passive-loss noise-temperature relation from thermal equilibrium”, addressing this associated condition: Contrast dissipative attenuation with a mismatch that only changes delivered power. Set the source and matched terminations to the attenuator physical temperature The source contributes at the output Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the passive-loss noise-temperature

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relation from thermal equilibrium". Using "From a calculated temperature to a defended result", specify a discriminator and the result expected under each explanation Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the passive-loss noise-temperature relation from thermal equilibrium, including the effect of missing measurements and inconsistent operating conditions Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)
- Scholarly synthesis and implications: Explain what the result about the passive-loss noise-temperature relation from thermal equilibrium authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)
- Closing: Conclude by answering "Develop the passive-loss noise-temperature relation from thermal equilibrium. Contrast dissipative attenuation with a mismatch that only changes delivered power" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

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V011-C02-ESSAY-003. Compare two matched chains using a 15 dB amplifier with T_e = 70 K, a 4 dB cable at 300 K, and a following receiver with T_e = 900 K. Calculate amplifier-first and cable-first equivalent input temperatures, then explain what additional evidence is needed to choose an operational configuration.

- Opening: Present a thesis that answers this precise question: Compare two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K. Identify which evidence would falsify the proposed conclusion Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Core terminology and scope: Define matched, chains, following in the question's particular technical setting; explain how Calculate, temperatures, additional differ if that distinction would change the analysis of "Compare two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K" Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use = = 31.6228 and L = = 2.51189 Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K to the claimed result, following "Application 2B.1: assemble a four-stage noise budget"; name the intermediate states and measurable outputs Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K. The cable equivalent temperature is about 453.57 K Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 2B.6: allocate loss to a preselector” that resolves the question about two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K; derive the relevant result with units and stated validity conditions Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Evidence and method: Specify the native observations, control records and calculations that would resolve two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K. Amplifier-first is 70 + 453.57/31.6228 + 2.51189 times 900/31.6228, approximately 155.83 K Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Worked application or illustrative case: Build a worked example of “two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K”, addressing this associated condition: Calculate amplifier-first and cable-first equivalent input temperatures, then explain what additional.... Use = = 31.6228 and L = = 2.51189 Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K”. Using “Application 2B.6: allocate loss to a preselector”, specify a discriminator and the result expected under each explanation Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K, including the effect of missing measurements and inconsistent operating conditions Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Scholarly synthesis and implications: Explain what the result about two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Closing: Conclude by answering “Compare two matched chains using a 15 dB amplifier with = 70 K, a 4 dB cable at 300 K, and a following receiver with = 900 K” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

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V011-C02-ESSAY-004. Explain why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference temperature. Use a receiver with T_e = 100 K and compare sources at 20 K and 2000 K.

- Opening: Present a thesis that answers this precise question: Explain why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference temperature. Identify which evidence would falsify the proposed conclusion Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Core terminology and scope: Define figure, degradation, quantities in the question's particular technical setting; explain how source, temperature, sources differ if that distinction would change the analysis of "Explain why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference temperature" Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compute = 1 + 100/290, approximately 1.34483, and approximately 1.287 dB Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference... to the claimed result, following "Application 2B.3: distinguish loss from

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temperature"; name the intermediate states and measurable outputs Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference.... For the 20 K source, actual degradation is 6, or about 7.782 dB Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 2B.7: place attenuation before the vulnerable stage" that resolves the question about why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference...; derive the relevant result with units and stated validity conditions Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference.... For the 2000 K source it is 1.05, or about 0.212 dB Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Worked application or illustrative case: Build a worked example of "why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference...", addressing this associated condition: Use a receiver with = 100 K and compare sources at 20 K and 2000 K. Compute = 1 + 100/290,

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approximately 1.34483, and approximately 1.287 dB Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference…”. Using “Application 2B.7: place attenuation before the vulnerable stage”, specify a discriminator and the result expected under each explanation Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference…, including the effect of missing measurements and inconsistent operating conditions Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)
- Scholarly synthesis and implications: Explain what the result about why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Closing: Conclude by answering “Explain why a receiver reference noise figure and actual SNR degradation are different quantities when the source is not at the reference temperature” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.21 Application 2B.4: change the source environment (p. 681)

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V011-C02-ESSAY-005. A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power. Derive the resulting SNR change and explain why the noise-trace reduction alone would overstate the improvement.

- Opening: Present a thesis that answers this precise question: A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power. Identify which evidence would falsify the proposed conclusion Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Core terminology and scope: Define reduces, retains, resulting in the question's particular technical setting; explain how reduction, overstate, improvement differ if that distinction would change the analysis of "A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power" Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Let original desired signal and white-noise powers be S and N Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power to the claimed result, following "Thermal Noise as a Bandwidth-Dependent Quantity"; name the intermediate states and measurable outputs Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power. The new values are 0.5S and 0.25N, so new SNR is twice the old SNR, an improvement of about 3.01 dB Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 2B.4: change the source environment” that resolves the question about A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power; derive the relevant result with units and stated validity conditions Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power. Noise alone falls by about 6.02 dB Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Worked application or illustrative case: Build a worked example of “A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power”, addressing this associated condition: Derive the resulting SNR change and explain why the noise-trace reduction alone would overstate the.... Let original desired signal and white-noise powers be S and N Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A filter change reduces equivalent noise

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bandwidth by four but retains only half of the desired signal power". Using "Application 2B.4: change the source environment", specify a discriminator and the result expected under each explanation Source: §2.21 Application 2B.4: change the source environment (p. 681)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power, including the effect of missing measurements and inconsistent operating conditions Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)
- Scholarly synthesis and implications: Explain what the result about A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Closing: Conclude by answering "A filter change reduces equivalent noise bandwidth by four but retains only half of the desired signal power" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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V011-C02-ESSAY-006. Derive the hot-cold inversion and its admissible Y domain for $T_h > T_c > 0$ and finite nonnegative receiver equivalent temperature. Explain how an out-of-domain result should be handled.

- Opening: Present a thesis that answers this precise question: Derive the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature. Explain how an out-of-domain result should be handled. Identify which evidence would falsify the proposed conclusion Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Core terminology and scope: Define inversion, admissible, domain in the question's particular technical setting; explain how nonnegative, equivalent, temperature differ if that distinction would change the analysis of "Derive the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature. Explain how an out-of-domain result should be handled" Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start with common output factor multiplying and Divide to obtain Y, rearrange YTc + YTe = and solve = Since hot temperature exceeds cold temperature, Y is greater than one Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature to the claimed result, following "From a calculated temperature to a defended result"; name the

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intermediate states and measurable outputs Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature. Treat values outside the domain as evidence requiring investigation of source inputs, gain, compression, bandwidth, mismatch, and record processing Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 2B.9: expose a change hidden by a ratio” that resolves the question about the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature; derive the relevant result with units and stated validity conditions Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature. Do not award a valid result to a silently clipped negative temperature Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Worked application or illustrative case: Build a worked example of “the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature”, addressing this associated condition: Explain how an out-of-domain result should be handled. Start with common output factor multiplying and Divide to

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obtain Y, rearrange YTc + YTe = and solve = Since hot temperature exceeds cold temperature, Y is greater than... Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature”. Using “Application 2B.9: expose a change hidden by a ratio”, specify a discriminator and the result expected under each explanation Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature, including the effect of missing measurements and inconsistent operating conditions Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Scholarly synthesis and implications: Explain what the result about the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Closing: Conclude by answering “Derive the hot-cold inversion and its admissible Y domain for and finite nonnegative receiver equivalent temperature. Explain how an out-of-domain result should be handled” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §2.16 Invert the same model with two source temperatures (p. 672)

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V011-C02-ESSAY-007. Design a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source. Define what must be held fixed, what should be measured, and how the result would be challenged.

- Opening: Present a thesis that answers this precise question: Design a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source. Identify which evidence would falsify the proposed conclusion Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Core terminology and scope: Define Design, drift, automatic in the question's particular technical setting; explain how Define, held, challenged differ if that distinction would change the analysis of "Design a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source" Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Problem statement and purpose: Frame the actual measurement or decision in the question. A strong answer identifies the selected reference plane, calibrated hot and cold source conditions, common effective bandwidth, detector law, and loss/mismatch corrections Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source to the claimed result, following "From a calculated temperature to a

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defended result"; name the intermediate states and measurable outputs Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source. Disable automatic gain control if valid or characterize its actual state dependence Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Invert the same model with two source temperatures" that resolves the question about a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source; derive the relevant result with units and stated validity conditions Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source. Establish linearity in both source states, retain native powers and state records, and interleave or bracket cold and hot measurements to reveal drift Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Worked application or illustrative case: Build a worked example of "a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source",

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addressing this associated condition: Define what must be held fixed, what should be measured, and how the result would be challenged. A strong answer identifies the selected reference plane, calibrated hot and cold source conditions, common effective... Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source”. Using “Invert the same model with two source temperatures”, specify a discriminator and the result expected under each explanation Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source, including the effect of missing measurements and inconsistent operating conditions Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)
- Scholarly synthesis and implications: Explain what the result about a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic gain control can react to the hot source authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Closing: Conclude by answering “Design a Y-factor measurement sequence for a receiver whose gain may drift and whose automatic

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gain control can react to the hot source" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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V011-C02-ESSAY-008. Quantify the bias from a hot/cold gain ratio of 1.02 when T_h = 6000 K, T_c = 300 K, and the true T_e = 400 K. Interpret the sign of the result obtained by incorrectly assuming equal gains.

- Opening: Present a thesis that answers this precise question: Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K. Interpret the sign of the result obtained by incorrectly assuming equal.... Identify which evidence would falsify the proposed conclusion Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Core terminology and scope: Define Quantify, Interpret, obtained in the question's particular technical setting; explain how incorrectly, assuming, gains differ if that distinction would change the analysis of "Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K. Interpret the sign of the result obtained by incorrectly assuming equal..." Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The true Y is 6400/700, approximately 9.142857 Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K to the claimed result, following "Application 2B.8: recover noise temperature from two powers"; name the intermediate states and measurable outputs Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K. The observed ratio is 1.02 times this, approximately 9.325714 Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Invert the same model with two source temperatures” that resolves the question about Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K; derive the relevant result with units and stated validity conditions Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K. Substituting it into the equal-gain inversion gives approximately 384.63 K, about 15.37 K below the true value Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Worked application or illustrative case: Build a worked example of “Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K”, addressing this associated condition: Interpret the sign of the result obtained by incorrectly assuming equal gains. The true Y is 6400/700, approximately 9.142857 Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K”. Using “Invert the same model with two source temperatures”, specify a discriminator and the result expected under each explanation Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K, including the effect of missing measurements and inconsistent operating conditions Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Scholarly synthesis and implications: Explain what the result about Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Closing: Conclude by answering “Quantify the bias from a hot/cold gain ratio of 1.02 when = 6000 K, = 300 K, and the true = 400 K. Interpret the sign of the result obtained by incorrectly assuming equal…” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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V011-C02-ESSAY-009. Derive the first-stage gain requirement for a two-stage noise target. Discuss the three cases in which T_{target} is above, equal to, or below the first-stage equivalent temperature.

- Opening: Present a thesis that answers this precise question: Derive the first-stage gain requirement for a two-stage noise target. Discuss the three cases in which is above, equal to, or below the first-stage equivalent temperature. Identify which evidence would falsify the proposed conclusion Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Core terminology and scope: Define requirement, target, cases in the question's particular technical setting; explain how equal, equivalent, temperature differ if that distinction would change the analysis of "Derive the first-stage gain requirement for a two-stage noise target. Discuss the three cases in which is above, equal to, or below the first-stage equivalent temperature" Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Starting from with positive and positive finite rearrange to >= when the target exceeds the first-stage temperature Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the first-stage gain requirement for a two-stage noise target to the claimed result, following "Turn the cascade into bounded design requirements"; name the intermediate states and measurable outputs Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the first-stage gain requirement for a two-stage noise target. At equality, no finite gain eliminates the positive second-stage contribution; the target is only a limit as gain grows without bound Source: §2.17 Turn the cascade into bounded design requirements (p. 675)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 2B: a matched, fixed-state noise cascade” that resolves the question about the first-stage gain requirement for a two-stage noise target; derive the relevant result with units and stated validity conditions Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the first-stage gain requirement for a two-stage noise target. Below the first-stage temperature, there is no feasible gain Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Worked application or illustrative case: Build a worked example of “the first-stage gain requirement for a two-stage noise target”, addressing this associated condition: Discuss the three cases in which is above, equal to, or below the first-stage equivalent temperature. Starting from with positive and positive finite rearrange to >= when the target exceeds the first-stage temperature Source: §2.17 Turn the cascade into bounded design requirements (p. 675)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the first-stage gain requirement for a

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two-stage noise target". Using "Model 2B: a matched, fixed-state noise cascade", specify a discriminator and the result expected under each explanation Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the first-stage gain requirement for a two-stage noise target, including the effect of missing measurements and inconsistent operating conditions Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)
- Scholarly synthesis and implications: Explain what the result about the first-stage gain requirement for a two-stage noise target authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Closing: Conclude by answering "Derive the first-stage gain requirement for a two-stage noise target. Discuss the three cases in which is above, equal to, or below the first-stage equivalent temperature" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

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V011-C02-ESSAY-010. A following chain has $T_{e,c}$ = 80 K. A preceding matched filter is at 320 K and the total target is 160 K. Derive the permitted loss bound and assess a filter with 0.7 dB loss.

- Opening: Present a thesis that answers this precise question: A following chain has = 80 K. A preceding matched filter is at 320 K and the total target is 160 K. Derive the permitted loss bound and assess a filter with 0.7 dB loss. Identify which evidence would falsify the proposed conclusion Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Core terminology and scope: Define following, preceding, matched in the question's particular technical setting; explain how target, permitted, bound differ if that distinction would change the analysis of "A following chain has = 80 K. A preceding matched filter is at 320 K and the total target is 160 K. Derive the permitted loss bound and assess a filter with 0.7 dB loss" Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Equation 4K gives Lmax = (160 + 320)/(320 + 80) = 1.2, about 0.792 dB Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A following chain has = 80 K to the claimed result, following "Derive passive loss from thermal equilibrium"; name the intermediate states and measurable outputs Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A following chain has = 80 K. A 0.7 dB loss has L approximately 1.17490, giving = (L - 1)320 + L times 80, approximately 149.96 K, so it meets the stipulated noise target Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 2B.3: distinguish loss from temperature” that resolves the question about A following chain has = 80 K; derive the relevant result with units and stated validity conditions Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A following chain has = 80 K. Identify the common reference plane and physical filter temperature Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Worked application or illustrative case: Build a worked example of “A following chain has = 80 K”, addressing this associated condition: A preceding matched filter is at 320 K and the total target is 160 K. Equation 4K gives Lmax = (160 + 320)/(320 + 80) = 1.2, about 0.792 dB Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A following chain has = 80 K”. Using “Application 2B.3: distinguish loss from temperature”, specify a discriminator and the result expected under each explanation Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A following chain has = 80 K, including the effect of missing measurements and inconsistent operating conditions Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Scholarly synthesis and implications: Explain what the result about A following chain has = 80 K authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Closing: Conclude by answering “A following chain has = 80 K. A preceding matched filter is at 320 K and the total target is 160 K. Derive the permitted loss bound and assess a filter with 0.7 dB loss” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

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V011-C02-ESSAY-011. Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable configuration. Develop a decision that considers both the noise budget and internal blocker levels.

- Opening: Present a thesis that answers this precise question: Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable configuration. Identify which evidence would falsify the proposed conclusion Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Core terminology and scope: Define structure, calculated, figure in the question's particular technical setting; explain how belong, budget, internal differ if that distinction would change the analysis of "Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable configuration" Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Track the blocker to the amplifier input for attenuation placed before versus after it Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable… to the claimed result, following "Application 2B.2: move an amplifier across a

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cable"; name the intermediate states and measurable outputs Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable.... In the constructed case, -5 dBm reduced by 20 dB reaches -25 dBm before the amplifier, which is 5 dB below the stipulated -20 dBm envelope Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 2B.1: assemble a four-stage noise budget" that resolves the question about Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable...; derive the relevant result with units and stated validity conditions Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable.... With attenuation after the amplifier, the amplifier still sees -5 dBm, 15 dB above that envelope Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Worked application or illustrative case: Build a worked example of "Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable...", addressing this associated condition: Develop a decision that

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considers both the noise budget and internal blocker levels. Track the blocker to the amplifier input for attenuation placed before versus after it Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable…”. Using “Application 2B.1: assemble a four-stage noise budget”, specify a discriminator and the result expected under each explanation Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable…, including the effect of missing measurements and inconsistent operating conditions Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Scholarly synthesis and implications: Explain what the result about Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Closing: Conclude by answering “Using the structure of Application 2B.7, explain how a formally lower calculated noise figure can belong to an unusable configuration” using only the demonstrated

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evidence; state the remaining decisive verification step Source: §2.24

Application 2B.7: place attenuation before the vulnerable stage (p. 684)

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V011-C02-ESSAY-012. Construct an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs. Explain which quantities must be known before reporting a combined standard uncertainty.

- Opening: Present a thesis that answers this precise question: Construct an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs. Identify which evidence would falsify the proposed conclusion Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Core terminology and scope: Define Construct, inversion, correlated in the question's particular technical setting; explain how quantities, reporting, combined differ if that distinction would change the analysis of "Construct an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs" Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify input estimates and Y, their standard uncertainties, and the full relevant covariance matrix Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs to the claimed result, following "From a calculated temperature to a defended result";

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name the intermediate states and measurable outputs Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs. Derive sensitivities and Form the sum of sensitivity-weighted variances and twice the cross-sensitivity covariance terms Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 2B.9: expose a change hidden by a ratio” that resolves the question about an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs; derive the relevant result with units and stated validity conditions Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs. State what calibration or measurement evidence supports the covariances Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Worked application or illustrative case: Build a worked example of “an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs”, addressing this associated condition: Explain which quantities must be known

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before reporting a combined standard uncertainty. Identify input estimates and Y, their standard uncertainties, and the full relevant covariance matrix Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs”. Using “Application 2B.9: expose a change hidden by a ratio”, specify a discriminator and the result expected under each explanation Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs, including the effect of missing measurements and inconsistent operating conditions Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Scholarly synthesis and implications: Explain what the result about an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Closing: Conclude by answering “Construct an uncertainty model for the hot-cold temperature inversion that includes correlated source-temperature inputs” using only the demonstrated evidence; state

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the remaining decisive verification step Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

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V011-C02-ESSAY-013. For T_h = 3000 K, T_c = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature inversion. Convert the result locally to noise-figure uncertainty at T_0 = 290 K.

- Opening: Present a thesis that answers this precise question: For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature inversion. Identify which evidence would falsify the proposed conclusion Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Core terminology and scope: Define propagate, standard, uncertainties in the question's particular technical setting; explain how inversion, Convert, locally differ if that distinction would change the analysis of "For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature inversion" Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain why the conditions associated with For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature… determine the proper scope of the answer Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature… to the claimed result,

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following “Application 2B.1: assemble a four-stage noise budget”; name the intermediate states and measurable outputs Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature.... Sensitivities are 0.2, -1.2, and -108 K per unit Y Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Noise-colour models, covariance and decision performance beyond a scalar noise figure” that resolves the question about For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature...; derive the relevant result with units and stated validity conditions Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature.... With zero covariance, variance is + + = 42.1056 K squared Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Worked application or illustrative case: Build a worked example of “For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature...”,

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addressing this associated condition: Convert the result locally to noise-figure uncertainty at = 290 K. Sensitivities are 0.2, -1.2, and -108 K per unit Y Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature…”. Using “Noise-colour models, covariance and decision performance beyond a scalar noise figure”, specify a discriminator and the result expected under each explanation Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature…, including the effect of missing measurements and inconsistent operating conditions Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)
- Scholarly synthesis and implications: Explain what the result about For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Closing: Conclude by answering “For = 3000 K, = 300 K, and Y = 6, propagate independent standard uncertainties 30 K, 1 K, and 0.02 through the temperature inversion” using only the demonstrated

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evidence; state the remaining decisive verification step Source: §2.27

Application 2B.10: propagate the local calibration uncertainty (p. 687)

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V011-C02-ESSAY-014. Explain what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed output. Propose a principled analysis route.

- Opening: Present a thesis that answers this precise question: Explain what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed output. Propose a principled…. Identify which evidence would falsify the proposed conclusion Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Core terminology and scope: Define fails, checking, distribution in the question's particular technical setting; explain how inputs, transformed, route differ if that distinction would change the analysis of "Explain what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed output. Propose a principled…" Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The inverse contains in the denominator, so derivative magnitudes grow and the transformation can become strongly nonlinear over the input uncertainty range Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed… to the claimed result, following "Noise-floor specification for a 1 Hz reference and a 30 Hz

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analysis bandwidth"; name the intermediate states and measurable outputs Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed.... A symmetric input range can yield a broad or asymmetric output range, possibly encountering an inadmissible domain Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Model 2B: a matched, fixed-state noise cascade" that resolves the question about what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed...; derive the relevant result with units and stated validity conditions Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Evidence and method: Specify the native observations, control records and calculations that would resolve what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed.... A principled route starts with credible input distributions and dependence Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Worked application or illustrative case: Build a worked example of "what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed...",

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addressing this associated condition: Propose a principled analysis route. The inverse contains in the denominator, so derivative magnitudes grow and the transformation can become strongly nonlinear over the input uncertainty range Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed…". Using "Model 2B: a matched, fixed-state noise cascade", specify a discriminator and the result expected under each explanation Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed…, including the effect of missing measurements and inconsistent operating conditions Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Scholarly synthesis and implications: Explain what the result about what fails when a first-order uncertainty estimate is used near Y = 1 without checking the distribution of inputs and transformed… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Closing: Conclude by answering "Explain what fails when a first-order uncertainty estimate is used near Y = 1 without checking the

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distribution of inputs and transformed output. Propose a principled…" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-C02-ESSAY-015. Formulate a sensitivity claim for detecting short bursts with a scanning receiver. Explain how you would keep coverage and amplitude sensitivity distinct in the experiment and report.

- Opening: Present a thesis that answers this precise question: Formulate a sensitivity claim for detecting short bursts with a scanning receiver. Explain how you would keep coverage and amplitude sensitivity distinct in the experiment.... Identify which evidence would falsify the proposed conclusion Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Core terminology and scope: Define claim, detecting, bursts in the question's particular technical setting; explain how scanning, distinct, experiment differ if that distinction would change the analysis of "Formulate a sensitivity claim for detecting short bursts with a scanning receiver. Explain how you would keep coverage and amplitude sensitivity distinct in the experiment..." Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the burst waveform, duration, frequency range, required event success, and valid detector state Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Formulate a sensitivity claim for detecting short bursts with a scanning receiver to the claimed result, following "Sensitivity Specifications and Decision Thresholds"; name the intermediate states and measurable outputs Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Formulate a sensitivity claim for detecting short bursts with a scanning receiver. Retain actual dwell intervals, settling exclusions, native data, decision statistic, threshold, and relevant configuration Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Operational Sensitivity Verification” that resolves the question about Formulate a sensitivity claim for detecting short bursts with a scanning receiver; derive the relevant result with units and stated validity conditions Source: §2.8 Operational Sensitivity Verification (p. 658)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Formulate a sensitivity claim for detecting short bursts with a scanning receiver. Classify a burst outside valid channel observation as a coverage failure; use observed valid dwells for the specified amplitude-sensitivity population Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Worked application or illustrative case: Build a worked example of “Formulate a sensitivity claim for detecting short bursts with a scanning receiver”, addressing this associated condition: Explain how you would keep coverage and amplitude sensitivity distinct in the experiment and report. Define the burst waveform, duration, frequency range, required event success, and valid detector state Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Formulate a sensitivity claim for detecting short bursts with a scanning receiver”. Using “Operational Sensitivity Verification”, specify a discriminator and the result expected under each explanation Source: §2.8 Operational Sensitivity Verification (p. 658)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Formulate a sensitivity claim for detecting short bursts with a scanning receiver, including the effect of missing measurements and inconsistent operating conditions Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)
- Scholarly synthesis and implications: Explain what the result about Formulate a sensitivity claim for detecting short bursts with a scanning receiver authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Closing: Conclude by answering “Formulate a sensitivity claim for detecting short bursts with a scanning receiver. Explain how you would keep coverage and amplitude sensitivity distinct in the experiment…” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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V011-C02-ESSAY-016. Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB margin. Specify what evidence would be needed to support a numerical detection probability.

- Opening: Present a thesis that answers this precise question: Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB margin. Identify which evidence would falsify the proposed conclusion Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Core terminology and scope: Define converts, floor, claimed in the question's particular technical setting; explain how arbitrary, margin, Specify differ if that distinction would change the analysis of "Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB margin" Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the unsupported link between a mean power scale and a detector operating characteristic Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB… to the claimed result, following "Sensitivity Specifications and Decision Thresholds"; name the intermediate states and measurable outputs Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB.... Require the event waveform and duration, statistic and its distribution or empirical behavior, threshold, false-alarm objective, search opportunities, observation coverage, and... Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth" that resolves the question about Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB...; derive the relevant result with units and stated validity conditions Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB.... A ten-decibel SNR can be an explicit stipulated requirement in Equation 4L, but its probability interpretation needs a separate justified basis Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Worked application or illustrative case: Build a worked example of "Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB...", addressing this associated condition: Specify what evidence would

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be needed to support a numerical detection probability. Identify the unsupported link between a mean power scale and a detector operating characteristic Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB…”. Using “Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth”, specify a discriminator and the result expected under each explanation Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB…, including the effect of missing measurements and inconsistent operating conditions Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Scholarly synthesis and implications: Explain what the result about Critique a report that converts a measured noise floor into a claimed 99% probability of detection by adding an arbitrary 10 dB… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Closing: Conclude by answering “Critique a report that converts a measured noise floor into a claimed 99% probability of detection by

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adding an arbitrary 10 dB margin" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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V011-C02-ESSAY-017. Compare narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result. Explain why their benefits cannot be described by one bandwidth ratio in every case.

- Opening: Present a thesis that answers this precise question: Compare narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result. Identify which evidence would falsify the proposed conclusion Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Core terminology and scope: Define narrowband, trace, longer in the question's particular technical setting; explain how ways, benefits, described differ if that distinction would change the analysis of "Compare narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result" Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start with physical integration of noise through a channel response and the signal-retention requirement Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result to the claimed result, following "Sensitivity Specifications and Decision

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Thresholds"; name the intermediate states and measurable outputs Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result. Then distinguish averaging of a decision statistic or displayed trace from a change in admitted physical bandwidth Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Thermal Noise as a Bandwidth-Dependent Quantity" that resolves the question about narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result; derive the relevant result with units and stated validity conditions Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)
- Evidence and method: Specify the native observations, control records and calculations that would resolve narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result. Averaging can change estimator variability, while correlation determines effective information; it does not necessarily lower the same mean noise power Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Worked application or illustrative case: Build a worked example of "narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result",

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addressing this associated condition: Explain why their benefits cannot be described by one bandwidth ratio in every case. Start with physical integration of noise through a channel response and the signal-retention requirement Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result”. Using “Thermal Noise as a Bandwidth-Dependent Quantity”, specify a discriminator and the result expected under each explanation Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result, including the effect of missing measurements and inconsistent operating conditions Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Scholarly synthesis and implications: Explain what the result about narrowband filtering, trace averaging, detector averaging, and longer observation as ways of changing a displayed noise result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Closing: Conclude by answering “Compare narrowband filtering, trace averaging, detector averaging, and longer observation as ways

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of changing a displayed noise result" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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V011-C02-ESSAY-018. Develop a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and quality criteria.

- Opening: Present a thesis that answers this precise question: Develop a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and quality criteria. Identify which evidence would falsify the proposed conclusion Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Core terminology and scope: Define comparing, specifications, bandwidths in the question's particular technical setting; explain how formats, quality, criteria differ if that distinction would change the analysis of "Develop a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and quality criteria" Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Read each specification definition and applicable state rather than treating the dBm figures as interchangeable Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and… to the claimed result, following "Uncertainty and Environmental Noise"; name the

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intermediate states and measurable outputs Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and…. Identify whether a common signal, bandwidth, detector, duration, reference plane, and success criterion can be tested on both devices Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Define sensitivity as a reproducible decision" that resolves the question about a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and…; derive the relevant result with units and stated validity conditions Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and…. Include external path loss, gain, mismatch, environmental conditions, and relevant uncertainty Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Worked application or illustrative case: Build a worked example of "a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and…", addressing this associated condition: Read each specification

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definition and applicable state rather than treating the dBm figures as.... Read each specification definition and applicable state rather than treating the dBm figures as interchangeable Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and...". Using "Define sensitivity as a reproducible decision", specify a discriminator and the result expected under each explanation Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and..., including the effect of missing measurements and inconsistent operating conditions Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)
- Scholarly synthesis and implications: Explain what the result about a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and... authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)
- Closing: Conclude by answering "Develop a reproducible plan for comparing two receiver sensitivity specifications that use different bandwidths, modulation formats, and quality criteria" using only the

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demonstrated evidence; state the remaining decisive verification step Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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V011-C02-ESSAY-019. A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed. Design a sequence of tests that can distinguish amplifier-added noise, oscillation, overload, and path coupling.

- Opening: Present a thesis that answers this precise question: A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed. Identify which evidence would falsify the proposed conclusion Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Core terminology and scope: Define survives, replacement, termination in the question's particular technical setting; explain how disappears, bypassed, oscillation differ if that distinction would change the analysis of "A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed" Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the initial comparisons to localize a candidate subsystem without prematurely claiming a calibrated noise figure Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed to the claimed result, following "Application 2B.7: place attenuation before the vulnerable stage"; name the intermediate states and measurable

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outputs Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed. Retain matched load conditions, gain settings, supply and bias state, cable arrangement, timing, and output spectra or native data Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Y-Factor and Comparative Noise Measurements” that resolves the question about A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed; derive the relevant result with units and stated validity conditions Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed. Change one relevant mechanism at a time, such as supply stability, input attenuation, output loading, bounded blocker level, or physical coupling, while maintaining comparable observation… Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)
- Worked application or illustrative case: Build a worked example of “A field noise rise survives antenna replacement with a matched

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termination and disappears when an inline amplifier is bypassed", addressing this associated condition: Design a sequence of tests that can distinguish amplifier-added noise, oscillation, overload, and path.... Use the initial comparisons to localize a candidate subsystem without prematurely claiming a calibrated noise... Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed". Using "Y-Factor and Comparative Noise Measurements", specify a discriminator and the result expected under each explanation Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed, including the effect of missing measurements and inconsistent operating conditions Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Scholarly synthesis and implications: Explain what the result about A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

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- Closing: Conclude by answering “A field noise rise survives antenna replacement with a matched termination and disappears when an inline amplifier is bypassed” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

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V011-C02-ESSAY-020. Explain how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration applicability.

- Opening: Present a thesis that answers this precise question: Explain how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration applicability. Identify which evidence would falsify the proposed conclusion Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Core terminology and scope: Define documented, analyst, reconstruct in the question's particular technical setting; explain how test, calibration, applicability differ if that distinction would change the analysis of "Explain how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration applicability" Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Provide the raw output quantity, units, integration or detector operation, equivalent bandwidth, input and output planes, and the exact signal power gain used Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration… to the claimed result, following "Model 2B: a matched, fixed-state noise cascade"; name

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the intermediate states and measurable outputs Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration.... Identify path components, source conditions, gain/attenuator state, sideband architecture where relevant, and any correction files or interpolation Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 2B.9: expose a change hidden by a ratio" that resolves the question about how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration...; derive the relevant result with units and stated validity conditions Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration.... State the validity envelope, uncertainty inputs, and evidence for linearity Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Worked application or illustrative case: Build a worked example of "how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration...", addressing this associated condition: Provide the raw output

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quantity, units, integration or detector operation, equivalent bandwidth, input and.... Provide the raw output quantity, units, integration or detector operation, equivalent bandwidth, input and... Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration...". Using "Application 2B.9: expose a change hidden by a ratio", specify a discriminator and the result expected under each explanation Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration..., including the effect of missing measurements and inconsistent operating conditions Source: §2.3 Noise Figure and Noise Temperature (p. 649)
- Scholarly synthesis and implications: Explain what the result about how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration... authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Closing: Conclude by answering "Explain how an input-referred noise result should be documented so that another analyst can reconstruct it and test the calibration applicability" using only the

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demonstrated evidence; state the remaining decisive verification step Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-C02-ESSAY-021. Analyze why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site. Distinguish environmental noise dominance from nonlinear receiver behavior.

- Opening: Present a thesis that answers this precise question: Analyze why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site. Distinguish environmental noise dominance from nonlinear…. Identify which evidence would falsify the proposed conclusion Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Core terminology and scope: Define excellent, noisy, occupied in the question's particular technical setting; explain how site, environmental, nonlinear differ if that distinction would change the analysis of "Analyze why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site. Distinguish environmental noise dominance from nonlinear…" Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use to explain genuine source-noise dominance: lowering produces little benefit when is much larger Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site to the claimed result, following "Y-Factor and Comparative Noise Measurements"; name the intermediate states

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and measurable outputs Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site. Separately discuss how strong legitimate signals can cause gain control, compression, intermodulation, reciprocal mixing, or overlap, which may require a model beyond the quiet scalar noise... Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Noise-colour models, covariance and decision performance beyond a scalar noise figure” that resolves the question about why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site; derive the relevant result with units and stated validity conditions Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site. Propose spatial, temporal, polarization, and operating-state baselines plus bounded interferer tests Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Worked application or illustrative case: Build a worked example of “why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site”, addressing this associated

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condition: Distinguish environmental noise dominance from nonlinear receiver behavior. Use to explain genuine source-noise dominance: lowering produces little benefit when is much larger Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site”. Using “Noise-colour models, covariance and decision performance beyond a scalar noise figure”, specify a discriminator and the result expected under each explanation Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site, including the effect of missing measurements and inconsistent operating conditions Source: §2.21 Application 2B.4: change the source environment (p. 681)
- Scholarly synthesis and implications: Explain what the result about why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Closing: Conclude by answering “Analyze why a receiver with an excellent quiet-laboratory noise figure can underperform at a noisy occupied site. Distinguish environmental noise dominance from nonlinear…” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §2.7 Uncertainty and Environmental Noise (p. 657)

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V011-C02-ESSAY-022. Explain the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference.

- Opening: Present a thesis that answers this precise question: Explain the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference. Identify which evidence would falsify the proposed conclusion Source: §2.8 Operational Sensitivity Verification (p. 658)
- Core terminology and scope: Define closing, design, complementary in the question's particular technical setting; explain how functions, bypassed, injected differ if that distinction would change the analysis of "Explain the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference" Source: §2.8 Operational Sensitivity Verification (p. 658)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the injection plane and list the antenna, cable, filter, gain, detector, recording, and software functions actually exercised Source: §2.8 Operational Sensitivity Verification (p. 658)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference to the claimed result, following "Noise Figure and Noise Temperature"; name the intermediate states and measurable outputs Source: §2.3 Noise Figure and Noise Temperature (p. 649)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference. State that a successful check supports those functions only in its tested state and at its time Source: §2.3 Noise Figure and Noise Temperature (p. 649)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Define sensitivity as a reproducible decision” that resolves the question about the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference; derive the relevant result with units and stated validity conditions Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference. It does not alone prove uninterrupted validity during preceding acquisition or verify an antenna path that was bypassed Source: §2.8 Operational Sensitivity Verification (p. 658)
- Worked application or illustrative case: Build a worked example of “the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference”, addressing this associated condition: Identify the injection plane and list the antenna, cable, filter, gain, detector, recording, and software.... Identify the injection plane and list the antenna, cable, filter, gain,

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detector, recording, and software... Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference”. Using “Define sensitivity as a reproducible decision”, specify a discriminator and the result expected under each explanation Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference, including the effect of missing measurements and inconsistent operating conditions Source: §2.2 Power, bandwidth, and the reference plane (p. 645)
- Scholarly synthesis and implications: Explain what the result about the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.8 Operational Sensitivity Verification (p. 658)
- Closing: Conclude by answering “Explain the limits of a closing sensitivity check and design complementary checks for functions bypassed by an injected reference” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.8 Operational Sensitivity Verification (p. 658)

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V011-C02-ESSAY-023. Discuss the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR 16-1-1:2019 as the example.

- Opening: Present a thesis that answers this precise question: Discuss the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR 16-1-1:2019 as the example. Identify which evidence would falsify the proposed conclusion Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)
- Core terminology and scope: Define evidential, standard, investigation in the question's particular technical setting; explain how treatment, CISPR, example differ if that distinction would change the analysis of "Discuss the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR 16-1-1:2019 as the example" Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the cited public apparatus scope, 9 kHz to 18 GHz for relevant EMI receivers Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR… to the claimed result, following "From a calculated temperature to a defended

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result"; name the intermediate states and measurable outputs Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR…. Explain how a conformity claim, if separately established, can support specified apparatus characteristics while leaving the actual installed chain, state, calibration, overload, Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 2B.10: propagate the local calibration uncertainty" that resolves the question about the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR…; derive the relevant result with units and stated validity conditions Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR…. Do not treat an EMC apparatus standard as a universal attribution method Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)
- Worked application or illustrative case: Build a worked example of "the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR…",

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addressing this associated condition: Identify the cited public apparatus scope, 9 kHz to 18 GHz for relevant EMI receivers. Identify the cited public apparatus scope, 9 kHz to 18 GHz for relevant EMI receivers Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR…”. Using “Application 2B.10: propagate the local calibration uncertainty”, specify a discriminator and the result expected under each explanation Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR…, including the effect of missing measurements and inconsistent operating conditions Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Scholarly synthesis and implications: Explain what the result about the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)
- Closing: Conclude by answering “Discuss the evidential role of a measuring-apparatus standard in a receiver-system investigation, using the chapter treatment of CISPR 16-1-1:2019 as the example”

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using only the demonstrated evidence; state the remaining decisive verification step Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

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V011-C02-ESSAY-024. Evaluate the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many independent samples had been acquired.

- Opening: Present a thesis that answers this precise question: Evaluate the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many independent samples had been acquired. Identify which evidence would falsify the proposed conclusion Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Core terminology and scope: Define claim, improves, precision in the question's particular technical setting; explain how exactly, twice, acquired differ if that distinction would change the analysis of "Evaluate the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many independent samples had been acquired" Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Duplicated observations carry the same noise realization, so the nominal file length overstates independent information Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many… to the claimed result, following "Noise-colour models, covariance and decision performance beyond a scalar noise figure"; name the intermediate

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states and measurable outputs Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many.... Explain that variance of an average includes covariance terms; perfect duplicates do not create a second independent experiment Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)
- Analytical framework: Identify the equation, calibration or evidential decision test in “From a calculated temperature to a defended result” that resolves the question about the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many...; derive the relevant result with units and stated validity conditions Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many.... Also distinguish sample correlation within a genuine longer acquisition from changes in gain or source state that alter the measurand Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Worked application or illustrative case: Build a worked example of “the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many...”,

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addressing this associated condition: Duplicated observations carry the same noise realization, so the nominal file length overstates independent.... Duplicated observations carry the same noise realization, so the nominal file length overstates independent... Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many...". Using "From a calculated temperature to a defended result", specify a discriminator and the result expected under each explanation Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many..., including the effect of missing measurements and inconsistent operating conditions Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
- Scholarly synthesis and implications: Explain what the result about the claim that duplicating a noise record and averaging all its samples improves the precision exactly as if twice as many... authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.7 Uncertainty and Environmental Noise (p. 657)
- Closing: Conclude by answering "Evaluate the claim that duplicating a noise record and averaging all its samples improves the precision

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exactly as if twice as many independent samples had been acquired" using only the demonstrated evidence; state the remaining decisive verification step Source: §2.7 Uncertainty and Environmental Noise (p. 657)

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V011-C02-ESSAY-025. Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a reproducible detection claim. Identify the order in which the evidence should constrain the design.

- Opening: Present a thesis that answers this precise question: Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a reproducible detection claim. Identify which evidence would falsify the proposed conclusion Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Core terminology and scope: Define argument, meet, target in the question's particular technical setting; explain how reproducible, constrain, design differ if that distinction would change the analysis of "Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a reproducible detection claim" Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the event and reference plane first, then calculate a noise budget with valid matched-state assumptions and signal retention Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a… to the claimed result,

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following “Define sensitivity as a reproducible decision”; name the intermediate states and measurable outputs Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a.... Use gain and loss bounds to identify feasible chains, but check internal blocker levels, preselector rejection, stability, and detector validity before selecting a noise-optimal arrangement Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Turn the cascade into bounded design requirements” that resolves the question about Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a...; derive the relevant result with units and stated validity conditions Source: §2.17 Turn the cascade into bounded design requirements (p. 675)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a.... Characterize the required decision ratio or detector operating characteristics on controlled data and validate on distinct challenge records Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

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- Worked application or illustrative case: Build a worked example of “Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a…”, addressing this associated condition: Identify the order in which the evidence should constrain the design. Define the event and reference plane first, then calculate a noise budget with valid matched-state assumptions and signal retention Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a…”. Using “Turn the cascade into bounded design requirements”, specify a discriminator and the result expected under each explanation Source: §2.17 Turn the cascade into bounded design requirements (p. 675)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a…, including the effect of missing measurements and inconsistent operating conditions Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Scholarly synthesis and implications: Explain what the result about Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- Closing: Conclude by answering “Prepare a design-review argument for a receiver chain that must meet a noise target, tolerate a bounded blocker, and support a reproducible detection claim” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C02-DISCUSSION-001. Should a receiver team always place a low-noise amplifier at the antenna rather than after the cable? Develop the conditions under which each arrangement could be defensible.

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a receiver team always place a low-noise amplifier at the antenna rather than after the cable? Develop the conditions under which each arrangement could be defensible.” Put this particular dispute to the panel: Should a receiver team always place a low-noise amplifier at the antenna rather than after the cable? Develop the conditions under which each arrangement could be defensible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position.
  Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 02. Student A, terminology and scope: Agree the operational meanings of place, amplifier, cable and conditions, arrangement, defensible in “Should a receiver team always place a low-noise amplifier at the antenna rather than after the cable? Develop the conditions under which each arrangement could be defensible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the

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outcome and request a specific example from the stated receiver scenario. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Noise Figure and Noise Temperature”. Then require internal blocker levels, amplifier linearity and stability, remote power and cable conditions, and the actual source environment Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Noise Figure and Noise Temperature”. Then require internal blocker levels, amplifier linearity and stability, remote power and cable conditions, and the actual source environment Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask participants to compute or explain the ordering effect in Equation 4C before discussing operations Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask

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which setting or observation would discriminate between them without changing the measurand. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable. A defensible conclusion can prefer amplifier-first for a valid noise-limited case yet choose another architecture when strong-signal or installation constraints dominate Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver

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state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable. A defensible conclusion can prefer amplifier-first for a valid noise-limited case yet choose another architecture when strong-signal or installation constraints dominate Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.19 Application 2B.2: move an amplifier across a cable (p. 679)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable and Develop the conditions under which each arrangement could be defensible; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains

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within authorised laboratory and field boundaries. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a receiver team always place a low-noise amplifier at the antenna rather than after the cable”, addressing “Develop the conditions under which each arrangement could be defensible”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a receiver team always place a low-noise amplifier at the antenna rather than after the cable? Develop the conditions under which each arrangement could be defensible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a receiver team always place a low-noise amplifier at the antenna rather than after the cable? Develop the conditions under which each arrangement could be defensible.”. Allocate the next measurement and documentary action to named

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student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-C02-DISCUSSION-002. A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Which parts of the statement can be retained and which require correction?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Which parts of the statement can be retained and which require correction?” Put this particular dispute to the panel: A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Which parts of the statement can be retained and…. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, says, restores and sensitivity, parts, statement in “A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Which parts of the statement can be retained and…”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 2B.1: assemble a four-stage noise budget”. A valid correction can refer a measured signal to an earlier plane; it does not remove cable thermal emission, downstream noise reweighting, or information lost in an invalid state Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 2B.1: assemble a four-stage noise budget”. A valid correction can refer a measured signal to an earlier plane; it does not remove cable thermal emission, downstream noise reweighting, or information lost in an invalid state Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate the reported signal-level transformation from the physical noise budget Put two specific questions to Student D about the stated competing

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options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Ask what source-plane and calibration evidence is needed and whether the desired signal was retained Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible

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instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.18 Application 2B.1: assemble a four-stage noise budget (p. 677)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Ask what source-plane and calibration evidence is needed and whether the desired signal was retained Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity and Which parts of the statement can be retained and which require correction; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity”, addressing “Which parts of the statement can be retained and which require correction”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Which parts of the statement can be retained and…”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reviewer says that a cable loss correction restores the original signal and therefore restores the original sensitivity. Which parts of the statement can be retained and which require correction”. Allocate the next measurement and documentary action to named student roles, and require each

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participant to distinguish accepted evidence from an unsupported assertion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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V011-C02-DISCUSSION-003. Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold antenna. How would you reconcile the disagreement?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold antenna. How would you reconcile the disagreement?” Put this particular dispute to the panel: Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold antenna. How would you reconcile the disagreement. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 02. Student A, terminology and scope: Agree the operational meanings of disagree, compares, degradation and cold, reconcile, disagreement in “Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold antenna. How would you reconcile the disagreement”; state which definitions materially change the competing positions Ask Student B which definition would most

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materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Use Equations 4D and 4E to show that both numbers can be correct for different definitions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Use Equations 4D and 4E to show that both numbers can be correct for different definitions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Have each engineer identify the denominator temperature in the quantity being quoted Put two specific questions to Student D about the stated competing

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options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…. Then compare total input-referred noise and the event detection requirement Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…, formulate an instrumental artifact or

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confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold.... Then compare total input-referred noise and the event detection requirement Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold... and How would you reconcile the disagreement; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the

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proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold…”, addressing “How would you reconcile the disagreement”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold antenna. How would you reconcile the disagreement”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two engineers disagree because one compares reference noise figure and the other compares actual SNR degradation for a cold antenna. How would

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you reconcile the disagreement". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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V011-C02-DISCUSSION-004. A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. What should the team optimize?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. What should the team optimize?” Put this particular dispute to the panel: A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. What should the team optimize. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 02. Student A, terminology and scope: Agree the operational meanings of smaller, trace, loses and leading, edge, bursts in “A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. What should the team optimize”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Thermal Noise as a Bandwidth-Dependent Quantity”. Discuss retained burst energy and timing, filter response, effective noise bandwidth, detector behavior, and actual observation coverage Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A smaller bandwidth produces

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a cleaner-looking trace but loses the leading edge of short bursts; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Thermal Noise as a Bandwidth-Dependent Quantity”. Discuss retained burst energy and timing, filter response, effective noise bandwidth, detector behavior, and actual observation coverage Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require an event definition before choosing a visual criterion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. The appropriate tradeoff depends on the stated success event and false-alarm objective Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. The appropriate tradeoff depends on the stated success event and false-alarm objective Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts and What should the team optimize; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts”, addressing “What should the team optimize”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. What should the team optimize”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A smaller bandwidth produces a cleaner-looking trace but loses the leading edge of short bursts. What should the team optimize”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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V011-C02-DISCUSSION-005. A laboratory obtains a negative equivalent input temperature from its hot-cold inversion. One analyst proposes clipping it to zero because negative added noise is outside the model. How should the review proceed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A laboratory obtains a negative equivalent input temperature from its hot-cold inversion. One analyst proposes clipping it to zero because negative added noise is outside the model. How should the review proceed?” Put this particular dispute to the panel: A laboratory obtains a negative equivalent input temperature from its hot-cold inversion. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 02. Student A, terminology and scope: Agree the operational meanings of inversion, analyst, clipping and added, outside, review in “A laboratory obtains a negative equivalent input temperature from its hot-cold inversion”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A laboratory obtains a negative equivalent input temperature from its hot-cold inversion; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Invert the same model with two source temperatures”. Enumerate plausible source calibration, gain-state, compression, bandwidth, mismatch, ratio-processing, and uncertainty explanations Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A laboratory obtains a negative equivalent input temperature from its hot-cold inversion; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Invert the same model with two source temperatures”. Enumerate plausible source calibration, gain-state, compression, bandwidth, mismatch, ratio-processing, and uncertainty explanations Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the admissible Y domain to establish why the result is inconsistent with the selected model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A laboratory obtains a negative equivalent input temperature from its hot-cold inversion: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A laboratory obtains a negative equivalent input temperature from its hot-cold inversion; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A laboratory obtains a negative equivalent input temperature from its hot-cold inversion: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A laboratory obtains a negative equivalent input temperature from its hot-cold inversion, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A laboratory obtains a negative equivalent input temperature from

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its hot-cold inversion: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A laboratory obtains a negative equivalent input temperature from its hot-cold inversion. Clipping cannot resolve the inconsistency and may conceal its size Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A laboratory obtains a negative equivalent input temperature from its hot-cold inversion, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A laboratory obtains a negative equivalent input temperature from its hot-cold inversion. Clipping cannot resolve the inconsistency and may conceal its size Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A laboratory obtains a negative equivalent input temperature from its hot-cold inversion and One analyst proposes clipping it to zero because negative added noise is outside the model; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A laboratory obtains a negative equivalent input temperature from its hot-cold inversion”, addressing “One analyst proposes clipping it to zero because negative added noise is outside the model”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A laboratory obtains a negative equivalent input temperature from its hot-cold inversion”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A laboratory obtains a negative equivalent input temperature from its hot-cold inversion. One analyst proposes clipping it to zero because negative added noise is outside the model. How should the review proceed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-C02-DISCUSSION-006. The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Is the precision of the Y-factor result persuasive?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Is the precision of the Y-factor result persuasive?” Put this particular dispute to the panel: The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Is the precision of the Y-factor result persuasive. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 02. Student A, terminology and scope: Agree the operational meanings of stable, repeatable, source and states, precision, persuasive in “The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Is the precision of the Y-factor result persuasive”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Repeated application of the same state-dependent ratio can produce a tightly clustered biased inferred temperature Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Repeated application of the same state-dependent ratio can produce a tightly clustered biased inferred temperature Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate precision from model validity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The hot-source output is stable and repeatable, but the receiver gain

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is 1% different between source states: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Ask how the gain difference is known, whether it is stable, and what uncertainty accompanies any correction Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what

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evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Ask how the gain difference is known, whether it is stable, and what uncertainty accompanies any correction Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states and Is the precision of the Y-factor result persuasive; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.16 Invert the same model with two source temperatures (p. 672)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states”, addressing “Is the precision of the Y-factor result persuasive”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Is the precision of the Y-factor result persuasive”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The hot-source output is stable and repeatable, but the receiver gain is 1% different between source states. Is the precision of the Y-factor result persuasive”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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V011-C02-DISCUSSION-007. Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels?” Put this particular dispute to the panel: Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 02. Student A, terminology and scope: Agree the operational meanings of accept, automatic, final and traces, displayed, labels in “Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Invert the same model with two source temperatures”. Participants should ask whether actual hot/cold gain and noise law were characterized, whether the source states remained linear, and how transitions or settling were excluded Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Invert the same model with two source temperatures”. Participants should ask whether actual hot/cold gain and noise law were characterized, whether the source states remained linear, and how transitions or settling were excluded Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The labels are insufficient by themselves Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels. An enabled control is not automatically disqualifying if a valid characterized model exists, but unobserved state changes undermine the simple cancellation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels, formulate an instrumental artifact or confounding alternative, then identify the control measurement that

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would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels. An enabled control is not automatically disqualifying if a valid characterized model exists, but unobserved state changes undermine the simple cancellation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels and Participants should ask whether actual hot/cold gain and noise law were characterized, whether the source…; exclude protections irrelevant to the scenario Question

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Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels”, addressing “Participants should ask whether actual hot/cold gain and noise law were characterized, whether the source…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Would you accept a hot-cold measurement with automatic gain control enabled if the final traces have equal displayed gain labels”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Would you accept a hot-cold measurement with automatic gain control enabled

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if the final traces have equal displayed gain labels". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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V011-C02-DISCUSSION-008. An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation. Which convention should govern the reduction?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation. Which convention should govern the reduction?” Put this particular dispute to the panel: An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation. Which convention should govern the reduction. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 02. Student A, terminology and scope: Agree the operational meanings of supplier, certificate, differs and simplified, govern, reduction in “An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation. Which convention should govern the reduction”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 2B.10: propagate the local calibration uncertainty”. The chapter declares one explicit temperature-difference convention but does not override the calibration source definition Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 2B.10: propagate the local calibration uncertainty”. The chapter declares one explicit temperature-difference convention but does not override the calibration source definition Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Read the certificate and connect its defined quantities to the measurement equation Put

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two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which

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datum should be collected first and what uncertainty remains if it is missing. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation. Discuss how to map between conventions, retain the reference temperature separately, and propagate uncertainty Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter

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simplified calculation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.27 Application 2B.10: propagate the local calibration uncertainty (p. 687)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation. Discuss how to map between conventions, retain the reference temperature separately, and propagate uncertainty Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation and Which convention should govern the reduction; exclude protections irrelevant to the scenario Question

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Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation”, addressing “Which convention should govern the reduction”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An instrument supplier gives ENR in a certificate whose cold-state convention differs from the chapter simplified calculation. Which convention should govern the reduction”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An instrument supplier gives ENR in a certificate whose cold-state convention differs from

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the chapter simplified calculation. Which convention should govern the reduction”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-C02-DISCUSSION-009. A design meets the required cascade temperature only if first-stage gain is made extremely large. What engineering questions should follow the inequality calculation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A design meets the required cascade temperature only if first-stage gain is made extremely large. What engineering questions should follow the inequality calculation?” Put this particular dispute to the panel: A design meets the required cascade temperature only if first-stage gain is made extremely large. What engineering questions should follow the inequality calculation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- 02. Student A, terminology and scope: Agree the operational meanings of meets, cascade, large and engineering, questions, inequality in “A design meets the required cascade temperature only if first-stage gain is made extremely large. What engineering questions should follow the inequality calculation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A design meets the required cascade temperature only if first-stage gain is made extremely large; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Turn the cascade into bounded design requirements”. Discuss blocker stress, compression, stability, band flatness, gain-state control, and uncertainty in the first-stage temperature Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A design meets the required cascade temperature only if first-stage gain is made extremely large; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Turn the cascade into bounded design requirements”. Discuss blocker stress, compression, stability, band flatness, gain-state control, and uncertainty in the first-stage temperature Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The mathematical bound identifies a noise requirement, not a complete feasible implementation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask

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which setting or observation would discriminate between them without changing the measurand. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A design meets the required cascade temperature only if first-stage gain is made extremely large: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A design meets the required cascade temperature only if first-stage gain is made extremely large; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A design meets the required cascade temperature only if first-stage gain is made extremely large: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A design meets the required cascade temperature only if first-stage gain is made extremely large, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A design meets the required cascade temperature only if first-stage

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gain is made extremely large: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A design meets the required cascade temperature only if first-stage gain is made extremely large. If the target is too close to the design may have little useful margin Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A design meets the required cascade temperature only if first-stage gain is made extremely large, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A design meets the required cascade temperature only if first-stage gain is made extremely large. If the target is too close to the design may have little useful margin Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A design meets the required cascade temperature only if first-stage gain is made extremely large and What engineering questions should follow the inequality calculation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A design meets the required cascade temperature only if first-stage gain is made extremely large”, addressing “What engineering questions should follow the inequality calculation”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A design meets the required cascade temperature only if first-stage gain is made extremely large. What engineering questions should follow the inequality calculation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A design meets the required cascade temperature only if first-stage gain is made extremely large. What engineering questions should follow the inequality calculation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

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V011-C02-DISCUSSION-010. A passive-filter noise-loss bound is below one. Should the team search for a better passive filter or revise another part of the design?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A passive-filter noise-loss bound is below one. Should the team search for a better passive filter or revise another part of the design?” Put this particular dispute to the panel: A passive-filter noise-loss bound is below one. Should the team search for a better passive filter or revise another part of the design. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 02. Student A, terminology and scope: Agree the operational meanings of bound, search, better and passive, revise, design in “A passive-filter noise-loss bound is below one. Should the team search for a better passive filter or revise another part of the design”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A passive-filter noise-loss bound is below one; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Turn the cascade into bounded design requirements”. Review the following chain temperature, target, physical temperature inputs, and correctness of the chosen reference plane Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A passive-filter noise-loss bound is below one; explain what each record can establish State

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what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Turn the cascade into bounded design requirements”. Review the following chain temperature, target, physical temperature inputs, and correctness of the chosen reference plane Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Recognize that the stated passive feasible interval is empty, even for a lossless preceding section Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A passive-filter noise-loss bound is below one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A passive-filter noise-loss bound is below one; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A passive-filter noise-loss bound is below one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A passive-filter noise-loss bound is below one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A passive-filter noise-loss bound is below one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A passive-filter noise-loss bound is below

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one. A different architecture or revised justified requirement may be needed Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A passive-filter noise-loss bound is below one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A passive-filter noise-loss bound is below one. A different architecture or revised justified requirement may be needed Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A passive-filter noise-loss bound is below one and Should the team search for a better passive filter or revise another part of the design; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A passive-filter noise-loss bound is below one”, addressing “Should the team search for a better passive filter or revise another part of the design”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A passive-filter noise-loss bound is below one.

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Should the team search for a better passive filter or revise another part of the design", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A passive-filter noise-loss bound is below one. Should the team search for a better passive filter or revise another part of the design". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

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V011-C02-DISCUSSION-011. A temperature uncertainty budget is dominated by the hot-source calibration term. Is taking many more output samples the most effective improvement?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A temperature uncertainty budget is dominated by the hot-source calibration term. Is taking many more output samples the most effective improvement?” Put this particular dispute to the panel: A temperature uncertainty budget is dominated by the hot-source calibration term. Is taking many more output samples the most effective improvement. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 02. Student A, terminology and scope: Agree the operational meanings of budget, dominated, term and taking, effective, improvement in “A temperature uncertainty budget is dominated by the hot-source calibration term. Is taking many more output samples the most effective improvement”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A temperature uncertainty budget is dominated by the hot-source calibration term; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Uncertainty and Environmental Noise”. More output samples can reduce a genuinely independent random ratio component but may have little effect on a dominant calibration input Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A temperature uncertainty budget is dominated by the hot-source calibration term; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Uncertainty and Environmental Noise”. More output samples can reduce a genuinely independent random ratio component but may have little effect on a dominant calibration input Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the sensitivity-weighted variance contributions to separate source calibration uncertainty from ratio repeatability Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A temperature uncertainty budget is dominated by the hot-source calibration term: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A temperature uncertainty budget is dominated by the hot-source calibration term; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.16 Invert the same model with two source temperatures (p. 672)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A temperature uncertainty budget is dominated by the hot-source calibration term: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A temperature uncertainty budget is dominated by the hot-source calibration term, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A temperature uncertainty budget is dominated by the hot-source

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calibration term: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A temperature uncertainty budget is dominated by the hot-source calibration term. Discuss better source characterization, source contrast, covariance evidence, and whether the first-order model is adequate Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A temperature uncertainty budget is dominated by the hot-source calibration term, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A temperature uncertainty budget is dominated by the hot-source calibration term. Discuss better source characterization, source contrast, covariance evidence, and whether the first-order model is adequate Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A temperature uncertainty budget is dominated by the hot-source calibration term and Is taking many more output samples the most effective improvement; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A temperature uncertainty budget is dominated by the hot-source calibration term”, addressing “Is taking many more output samples the most effective improvement”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A temperature uncertainty budget is dominated by the hot-source calibration term. Is taking many more output samples the most effective improvement”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A temperature uncertainty budget is dominated by the hot-source calibration term. Is taking many more output samples the most effective improvement”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-C02-DISCUSSION-012. Should every expanded uncertainty using coverage factor two be described as a 95% interval in a field report?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should every expanded uncertainty using coverage factor two be described as a 95% interval in a field report?” Put this particular dispute to the panel: Should every expanded uncertainty using coverage factor two be described as a 95% interval in a field report. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 02. Student A, terminology and scope: Agree the operational meanings of expanded, coverage, factor and described, field, report in “Should every expanded uncertainty using coverage factor two be described as a 95% interval in a field report”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 2B.6: allocate loss to a preselector”. The multiplication by two is transparent arithmetic, but it does not itself specify coverage Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether every expanded uncertainty using coverage factor two be described as a 95%

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interval in a field report; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 2B.6: allocate loss to a preselector”. The multiplication by two is transparent arithmetic, but it does not itself specify coverage Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require the distributional approximation, degrees-of-freedom treatment, and uncertainty model supporting the coverage statement Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether every expanded uncertainty using coverage factor two be described as a 95%

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interval in a field report: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report. Discuss how to report the factor and assumptions when the probability interpretation is limited Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report. Discuss how to report the factor and assumptions when the probability interpretation is limited Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether every expanded uncertainty using coverage factor two be described as a 95% interval in a field report and Require the distributional approximation, degrees-of-freedom treatment, and uncertainty model supporting the…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether every expanded uncertainty

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using coverage factor two be described as a 95% interval in a field report", addressing "Require the distributional approximation, degrees-of-freedom treatment, and uncertainty model supporting the…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Should every expanded uncertainty using coverage factor two be described as a 95% interval in a field report", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Should every expanded uncertainty using coverage factor two be described as a 95% interval in a field report". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-C02-DISCUSSION-013. A very noisy source makes the actual receiver SNR degradation close to one. Does that imply excellent operational sensitivity?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A very noisy source makes the actual receiver SNR degradation close to one. Does that imply excellent operational sensitivity?” Put this particular dispute to the panel: A very noisy source makes the actual receiver SNR degradation close to one. Does that imply excellent operational sensitivity. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 02. Student A, terminology and scope: Agree the operational meanings of noisy, makes, degradation and close, imply, excellent in “A very noisy source makes the actual receiver SNR degradation close to one. Does that imply excellent operational sensitivity”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A very noisy source makes the actual receiver SNR degradation close to one; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define sensitivity as a reproducible decision”. A dominant source can make receiver-added noise relatively unimportant while leaving the absolute required signal much larger Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A very noisy source makes the actual receiver SNR degradation close to one; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define sensitivity as a reproducible decision”. A dominant source can make receiver-added noise relatively unimportant while leaving the absolute required signal much larger Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Contrast relative degradation with total input-referred noise Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A very noisy source makes the actual receiver

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SNR degradation close to one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A very noisy source makes the actual receiver SNR degradation close to one; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A very noisy source makes the actual receiver SNR degradation close to one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A very noisy source makes the actual receiver SNR degradation close to one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A very noisy source makes the actual receiver SNR degradation close to one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A very noisy source makes the actual

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receiver SNR degradation close to one. Use and Equation 4L to connect the distinction to an event requirement Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A very noisy source makes the actual receiver SNR degradation close to one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A very noisy source makes the actual receiver SNR degradation close to one. Use and Equation 4L to connect the distinction to an event requirement Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or

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uncertainty term that limits confidence. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A very noisy source makes the actual receiver SNR degradation close to one and Does that imply excellent operational sensitivity; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A very noisy source makes the actual receiver SNR degradation close to one”, addressing “Does that imply excellent operational sensitivity”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A very noisy source makes the actual receiver SNR degradation close to one. Does that imply excellent operational sensitivity”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A very noisy source makes the actual receiver SNR degradation close to one. Does that imply excellent operational sensitivity”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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V011-C02-DISCUSSION-014. A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal. What would make the ranking meaningful?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal. What would make the ranking meaningful?” Put this particular dispute to the panel: A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal. What would make the ranking meaningful. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 02. Student A, terminology and scope: Agree the operational meanings of narrowband, specification, wideband and modulated, make, meaningful in “A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal. What would make the ranking meaningful”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the

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outcome and request a specific example from the stated receiver scenario. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Power, bandwidth, and the reference plane”. If the devices serve different tasks, an unqualified scalar ranking may be inappropriate Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Power, bandwidth, and the reference plane”. If the devices serve different tasks, an unqualified scalar ranking may be inappropriate Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The team must define the intended application and a common success criterion, waveform, bandwidth, observation interval, detector, and reference plane Put two specific questions to Student D about the stated

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competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which

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datum should be collected first and what uncertainty remains if it is missing. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal. Ask what measurements can be reproduced and what differences must remain explicit Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A sensitivity comparison ranks a receiver with

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a narrowband tone specification above one specified for a wideband modulated signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal. Ask what measurements can be reproduced and what differences must remain explicit Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal and What would make the ranking meaningful;

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exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal”, addressing “What would make the ranking meaningful”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A sensitivity comparison ranks a receiver with a narrowband tone specification above one specified for a wideband modulated signal. What would make the ranking meaningful”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A sensitivity comparison ranks a receiver with a

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narrowband tone specification above one specified for a wideband modulated signal. What would make the ranking meaningful”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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V011-C02-DISCUSSION-015. A survey threshold was tuned until every weak reference in the development set was detected. What evidence should the final performance report require?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A survey threshold was tuned until every weak reference in the development set was detected. What evidence should the final performance report require?” Put this particular dispute to the panel: A survey threshold was tuned until every weak reference in the development set was detected. What evidence should the final performance report require. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 02. Student A, terminology and scope: Agree the operational meanings of threshold, tuned, development and detected, final, performance in “A survey threshold was tuned until every weak reference in the development set was detected. What evidence should the final performance report require”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A survey threshold was tuned until every weak reference in the development set was detected; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Noise-colour models, covariance and decision performance beyond a scalar noise figure”. Successful tuning records demonstrate fit to those records; they do not alone establish performance for the declared population Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A survey threshold was tuned until every weak reference in the development set was detected; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Noise-colour models, covariance and decision performance beyond a scalar noise figure”. Successful tuning records demonstrate fit to those records; they do not alone establish performance for the declared population Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss noise-only false alarms, distinct held-out weak events, event selection, receiver state, search opportunities, and uncertainty in the observed

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performance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A survey threshold was tuned until every weak reference in the development set was detected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A survey threshold was tuned until every weak reference in the development set was detected; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A survey threshold was tuned until every weak reference in the development set was detected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A survey threshold was tuned until every weak reference in the development set was detected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving A survey threshold was tuned until every weak reference in the development set was detected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A survey threshold was tuned until every weak reference in the development set was detected. Ask whether the threshold and processing were frozen before the challenge set was evaluated and how exclusions were documented Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A survey threshold was tuned until every weak reference in the development set was detected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver

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state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A survey threshold was tuned until every weak reference in the development set was detected. Ask whether the threshold and processing were frozen before the challenge set was evaluated and how exclusions were documented Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A survey threshold was tuned until every weak reference in the development set was detected and What evidence should the final performance report require; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within

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authorised laboratory and field boundaries. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A survey threshold was tuned until every weak reference in the development set was detected”, addressing “What evidence should the final performance report require”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A survey threshold was tuned until every weak reference in the development set was detected. What evidence should the final performance report require”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A survey threshold was tuned until every weak reference in the development set was detected. What evidence should the final performance report require”. Allocate the next measurement and documentary action to named student roles, and require each

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participant to distinguish accepted evidence from an unsupported assertion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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V011-C02-DISCUSSION-016. Should missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve?” Put this particular dispute to the panel: Should missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 02. Student A, terminology and scope: Agree the operational meanings of missed, bursts, tuned and included, sensitivity, curve in “Should missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Operational Sensitivity Verification”. Both may be useful if their populations are stated Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve; explain what each record can establish State what the existing

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record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Operational Sensitivity Verification”. Both may be useful if their populations are stated Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Participants should distinguish the curve conditional on a valid observation interval from an overall operational detection measure Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether missed bursts while the receiver is

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tuned elsewhere be included in a sensitivity curve: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to

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identify an alternative that could survive the proposed test. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve. Pooling them without qualification obscures whether failure arose from amplitude sensitivity or coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve. Pooling them without qualification obscures whether failure arose from amplitude sensitivity or coverage Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve and Participants should distinguish the curve conditional on a valid observation interval from an overall…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve”, addressing “Participants should distinguish the curve conditional on a valid observation interval from an overall…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should missed bursts while the receiver is tuned elsewhere be included in a sensitivity curve”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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V011-C02-DISCUSSION-017. Two noise records use the same sample count, but one contains repeated buffers. What should an independent reviewer infer about their precision?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two noise records use the same sample count, but one contains repeated buffers. What should an independent reviewer infer about their precision?” Put this particular dispute to the panel: Two noise records use the same sample count, but one contains repeated buffers. What should an independent reviewer infer about their precision. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 02. Student A, terminology and scope: Agree the operational meanings of contains, repeated, buffers and reviewer, infer, precision in “Two noise records use the same sample count, but one contains repeated buffers. What should an independent reviewer infer about their precision”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two noise records use the same sample count, but one contains repeated buffers; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Discuss continuity evidence, duplicate detection, the estimator and covariance, and whether repeated buffers represent acquisition failure or deliberate resampling Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two noise records use the same sample count, but one contains repeated buffers; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Discuss continuity evidence, duplicate detection, the estimator and covariance, and whether repeated buffers represent acquisition failure or deliberate resampling Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Nominal count alone cannot establish equal information Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two noise records use the same sample count, but one contains repeated buffers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two noise records use the same sample count, but one contains repeated buffers; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two noise records use the same sample count, but one contains repeated buffers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two noise records use the same sample count, but one contains repeated buffers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving Two noise records use the same sample count, but one contains repeated buffers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two noise records use the same sample count, but one contains repeated buffers. The repeated data cannot be credited as independent observations Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two noise records use the same sample count, but one contains repeated buffers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two noise records use the same sample count, but one contains repeated buffers. The repeated data cannot be credited as independent observations Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two noise records use the same sample count, but one contains repeated buffers and What should an independent reviewer infer about their precision; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.8 Operational Sensitivity Verification (p. 658)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two noise records use the same sample count, but one contains repeated buffers”, addressing “What should an independent reviewer infer about their precision”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two noise records use the same sample count, but one contains repeated buffers. What should an independent reviewer infer about their precision”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two noise records use the same sample count, but one contains repeated buffers. What should an independent reviewer infer about their precision”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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V011-C02-DISCUSSION-018. A matched-termination comparison reduces the site noise trace. Can the difference be reported as antenna temperature immediately?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A matched-termination comparison reduces the site noise trace. Can the difference be reported as antenna temperature immediately?” Put this particular dispute to the panel: A matched-termination comparison reduces the site noise trace. Can the difference be reported as antenna temperature immediately. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 02. Student A, terminology and scope: Agree the operational meanings of reduces, site, trace and difference, reported, immediately in “A matched-termination comparison reduces the site noise trace. Can the difference be reported as antenna temperature immediately”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A matched-termination comparison reduces the site noise trace; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Discuss what assumptions permit an equivalent source temperature and whether nonthermal interference fits the chosen representation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A matched-termination

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comparison reduces the site noise trace; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Discuss what assumptions permit an equivalent source temperature and whether nonthermal interference fits the chosen representation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The comparison suggests an external or path-dependent contribution Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A matched-termination comparison reduces the site noise trace: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A matched-termination comparison reduces the site noise trace; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A matched-termination comparison reduces the site noise trace: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A matched-termination comparison reduces the site noise trace, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A matched-termination comparison reduces the site noise trace: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A matched-termination comparison reduces the site noise trace. A calibrated quantitative result requires more than subtracting two displayed numbers Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A matched-termination comparison reduces the site noise trace, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A matched-termination comparison reduces the site noise trace. A calibrated quantitative result requires more than subtracting two displayed numbers Respond point by point to

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Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A matched-termination comparison reduces the site noise trace and Can the difference be reported as antenna temperature immediately; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A matched-termination comparison reduces the site noise trace”, addressing “Can the difference be reported as antenna temperature immediately”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that

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remains unresolved. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A matched-termination comparison reduces the site noise trace. Can the difference be reported as antenna temperature immediately”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A matched-termination comparison reduces the site noise trace. Can the difference be reported as antenna temperature immediately”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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V011-C02-DISCUSSION-019. A preamplifier bypass test changes both gain and noise floor. How can the comparison still discriminate mechanisms without overstating its metrological result?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A preamplifier bypass test changes both gain and noise floor. How can the comparison still discriminate mechanisms without overstating its metrological result?” Put this particular dispute to the panel: A preamplifier bypass test changes both gain and noise floor. How can the comparison still discriminate mechanisms without overstating its metrological result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 02. Student A, terminology and scope: Agree the operational meanings of bypass, floor, discriminate and mechanisms, overstating, metrological in “A preamplifier bypass test changes both gain and noise floor. How can the comparison still discriminate mechanisms without overstating its metrological result”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A preamplifier bypass test changes both gain and noise floor; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Worked Example 2A.1. Thermal Noise-Floor Screening”. Use controlled changes to test predictions for noise, instability, and overload while maintaining sufficient observation capability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A preamplifier bypass test changes both gain and noise floor; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Worked Example 2A.1. Thermal Noise-Floor Screening”. Use controlled changes to test predictions for noise, instability, and overload while maintaining sufficient observation capability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require raw observations, the actual bypass path, source conditions, state-specific gains, detector operation, and linearity evidence Put two specific questions to Student D about the stated competing options

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and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A preamplifier bypass test changes both gain and noise floor: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A preamplifier bypass test changes both gain and noise floor; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A preamplifier bypass test changes both gain and noise floor: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A preamplifier bypass test changes both gain and noise floor, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A preamplifier bypass test changes both gain and noise floor:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A preamplifier bypass test changes both gain and noise floor. A qualitative discriminating test may be useful even when it does not produce a traceable noise figure Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A preamplifier bypass test changes both gain and noise floor, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A preamplifier bypass test changes both gain and noise floor. A qualitative discriminating test may be useful even when it does not produce a traceable noise figure Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A preamplifier bypass test changes both gain and noise floor and How can the comparison still discriminate mechanisms without overstating its metrological result; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A preamplifier bypass test changes both gain and noise floor”, addressing “How can the comparison still

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discriminate mechanisms without overstating its metrological result"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A preamplifier bypass test changes both gain and noise floor. How can the comparison still discriminate mechanisms without overstating its metrological result", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A preamplifier bypass test changes both gain and noise floor. How can the comparison still discriminate mechanisms without overstating its metrological result". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

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V011-C02-DISCUSSION-020. A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier. What does the apparatus status contribute to the final operational claim?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier. What does the apparatus status contribute to the final operational claim?” Put this particular dispute to the panel: A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier. What does the apparatus status contribute to the…. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

- 02. Student A, terminology and scope: Agree the operational meanings of satisfying, specification, apparatus and status, contribute, final in “A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier. What does the apparatus status contribute to the…”; state which definitions materially change the competing

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positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. It does not validate the accessories, the installed reference plane, the chosen state, or source attribution Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. It does not validate the accessories, the installed reference plane, the chosen state, or source attribution Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It may support identified apparatus characteristics within the standard and evidence actually available Put two specific questions to Student D

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about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier. Ask participants to map each part of the claimed result to its supporting evidence and identify the extra checks needed Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier, formulate an instrumental artifact or

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confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier. Ask participants to map each part of the claimed result to its supporting evidence and identify the extra checks needed Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier and What does the apparatus status contribute to the final operational claim; exclude protections irrelevant to the scenario Question Student F about the custody and

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reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier”, addressing “What does the apparatus status contribute to the final operational claim”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized cable, antenna, and amplifier. What does the apparatus status contribute to the…”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A receiver satisfying an EMI measuring-apparatus specification is used with an uncharacterized

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cable, antenna, and amplifier. What does the apparatus status contribute to the final operational claim”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.12 Measuring-Receiver Scope and System Noise Floor (p. 663)

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V011-C02-DISCUSSION-021. The final receiver connector passes a closing injected-reference check. A reviewer says the antenna path was therefore valid for the whole engagement. How should the team respond?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The final receiver connector passes a closing injected-reference check. A reviewer says the antenna path was therefore valid for the whole engagement. How should the team respond?” Put this particular dispute to the panel: The final receiver connector passes a closing injected-reference check. A reviewer says the antenna path was therefore valid for the whole engagement. How should the team…. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 02. Student A, terminology and scope: Agree the operational meanings of passes, closing, reviewer and says, engagement, respond in “The final receiver connector passes a closing injected-reference check. A reviewer says the antenna path was therefore valid for the whole engagement. How should the team…”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the

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outcome and request a specific example from the stated receiver scenario. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The final receiver connector passes a closing injected-reference check; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Operational Sensitivity Verification”. A downstream injection can bypass the antenna and upstream path, and a later successful response cannot alone exclude earlier transient faults Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The final receiver connector passes a closing injected-reference check; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Operational Sensitivity Verification”. A downstream injection can bypass the antenna and upstream path, and a later successful response cannot alone exclude earlier transient faults Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Map the injection point and the functions exercised Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The final receiver connector passes a closing injected-reference check: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The final receiver connector passes a closing injected-reference check; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The final receiver connector passes a closing injected-reference check: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The final receiver connector passes a closing injected-reference check, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The final receiver connector passes a closing injected-reference check: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The final receiver connector passes a closing injected-reference check. Propose complementary checks and temporal state evidence appropriate to the actual claim Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The final receiver connector passes a closing injected-reference check, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The final receiver connector passes a closing injected-reference check. Propose complementary checks and temporal state evidence appropriate to the actual claim Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The final receiver connector passes a closing injected-reference check and A reviewer says the antenna path was therefore valid for the whole engagement; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.6 Y-Factor and Comparative Noise Measurements (p. 656)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The final receiver connector passes a closing injected-reference check”, addressing “A reviewer says the antenna path was therefore valid for the whole engagement”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The final receiver connector passes a closing injected-reference check. A reviewer says the antenna path was therefore valid for the whole engagement. How should the team…”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The final receiver connector passes a closing injected-reference check. A reviewer says the antenna path was therefore valid for the whole engagement. How should the team respond”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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V011-C02-DISCUSSION-022. An environmental noise rise appears only when building equipment operates. Should the receiver model absorb it into one higher source temperature?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An environmental noise rise appears only when building equipment operates. Should the receiver model absorb it into one higher source temperature?” Put this particular dispute to the panel: An environmental noise rise appears only when building equipment operates. Should the receiver model absorb it into one higher source temperature. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 02. Student A, terminology and scope: Agree the operational meanings of rise, building, equipment and operates, absorb, higher in “An environmental noise rise appears only when building equipment operates. Should the receiver model absorb it into one higher source temperature”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An environmental noise rise appears only when building equipment operates; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Thermal Noise as a Bandwidth-Dependent Quantity”. Discuss controlled equipment-state comparisons, spectra, polarization, timing, and bounded interferer tests Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An environmental noise rise appears only when building equipment operates; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Thermal Noise as a Bandwidth-Dependent Quantity”. Discuss controlled equipment-state comparisons, spectra, polarization, timing, and bounded interferer tests Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. An equivalent temperature may be a useful defined power-density representation under a declared band and statistic Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An environmental noise rise appears only when building equipment operates: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An environmental noise rise appears only when building equipment operates; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An environmental noise rise appears only when building equipment operates: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An environmental noise rise appears only when building equipment operates, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An environmental noise rise appears only when building equipment operates: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An environmental noise rise appears only when building equipment operates. The adopted model should match the intended prediction and retain its limitations rather than treating every observed contribution as equilibrium thermal noise Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An environmental noise rise appears only when building equipment operates, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.1 Thermal Noise as a Bandwidth-Dependent Quantity (p. 644)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An environmental noise rise appears only when building equipment operates. The adopted model should match the intended prediction and retain its limitations rather than treating every observed contribution as equilibrium thermal noise Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.7 Uncertainty and Environmental Noise (p. 657)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An environmental noise rise appears only when building equipment operates and Should the receiver model absorb it into one higher source temperature; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An environmental noise rise appears only when building equipment operates”, addressing “Should the receiver model absorb it into one higher source temperature”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An environmental noise rise appears only when building equipment operates. Should the receiver model absorb it into one higher source temperature”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An environmental noise rise appears only when building equipment operates. Should the receiver model absorb it into one higher source temperature”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

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V011-C02-DISCUSSION-023. A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. What should happen before using that number?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. What should happen before using that number?” Put this particular dispute to the panel: A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. What should happen before using that number. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 02. Student A, terminology and scope: Agree the operational meanings of mixer, sheet, figure and planned, represents, number in “A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. What should happen before using that number”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Noise-colour models, covariance and decision performance beyond a scalar noise figure”. The chapter permits a scalar equivalent-channel law only when empirically justified for the selected architecture Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Noise-colour models, covariance and decision performance beyond a scalar noise figure”. The chapter permits a scalar equivalent-channel law only when empirically justified for the selected architecture Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine the actual sideband and image paths, input environment, conversion gain definition, and calibration conditions Put two specific questions to

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Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. A nominal figure cannot be inserted blindly just because it is expressed in decibels Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible

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instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. A nominal figure cannot be inserted blindly just because it is expressed in decibels Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel and What should happen before using that number; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.13 Worked Example 2A.1. Thermal Noise-Floor Screening (p. 664)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel”, addressing “What should happen before using that number”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. What should happen before using that number”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A mixer data sheet gives a double-sideband noise figure, while the planned chain model represents one selected channel. What should happen before using that number”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence

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from an unsupported assertion. Source: §2.3 Noise Figure and Noise Temperature (p. 649)

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V011-C02-DISCUSSION-024. The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Is the analysis reproducible enough for the intended claim?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Is the analysis reproducible enough for the intended claim?” Put this particular dispute to the panel: The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Is the analysis reproducible enough for the intended…. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 02. Student A, terminology and scope: Agree the operational meanings of lost, retains, final and reproducible, intended, claim in “The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Is the analysis reproducible enough for the intended…”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. A retained final value and nominal gain may permit arithmetic reversal but cannot necessarily recover the original observation or validate the gain applicability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. A retained final value and nominal gain may permit arithmetic reversal but cannot necessarily recover the original observation or validate the gain applicability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask whether the original detector operation, bandwidth, reference plane, actual state, corrections, and uncertainty can still be established Put two

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specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Discuss the narrow conclusions still supportable and which missing evidence prevents stronger claims Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement

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accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Discuss the narrow conclusions still supportable and which missing evidence prevents stronger claims Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.25 Application 2B.8: recover noise temperature from two powers (p. 685)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number and Is the analysis reproducible enough for the intended claim; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains

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within authorised laboratory and field boundaries. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number”, addressing “Is the analysis reproducible enough for the intended claim”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Is the analysis reproducible enough for the intended…”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The raw output power record is lost, but a spreadsheet retains the final input-referred noise value and a gain number. Is the analysis reproducible enough for the intended claim”. Allocate the next measurement and documentary action to

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named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.2 Power, bandwidth, and the reference plane (p. 645)

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V011-C02-DISCUSSION-025. What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding rather than a favorable noise-floor number?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding rather than a favorable noise-floor number?” Put this particular dispute to the panel: What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding rather than a favorable noise-floor number. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 02. Student A, terminology and scope: Agree the operational meanings of successful, objective, reproducible and defensive, finding, favorable in “What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding rather than a favorable noise-floor number”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define sensitivity as a reproducible decision”. Include state and uncertainty evidence, held-out challenges, and bounded closing checks Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define sensitivity as a reproducible decision”. Include state and uncertainty evidence, held-out challenges, and bounded closing checks Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The discussion should connect a defined authorized event Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would

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discriminate between them without changing the measurand. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 08. Student D, answer to Student E: Design a discriminating experiment involving What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…. A useful outcome is an explicit tested operating domain with remaining limits, not a single catalog-like number detached from its event and environment Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement

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accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.5 Define sensitivity as a reproducible decision (p. 653)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding.... A useful outcome is an explicit tested operating domain with remaining limits, not a single catalog-like number detached from its event and environment Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding... and The discussion should connect a defined authorized event; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains

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within authorised laboratory and field boundaries. Source: §2.4 Sensitivity Specifications and Decision Thresholds (p. 652)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding…”, addressing “The discussion should connect a defined authorized event”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.8 Operational Sensitivity Verification (p. 658)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding rather than a favorable noise-floor number”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should count as successful operational sensitivity verification when the objective is a reproducible defensive finding rather than a favorable noise-floor number”. Allocate the next measurement and documentary action to named student roles,

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and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.8 Operational Sensitivity Verification (p. 658)

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Chapter 2 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C02-ESSAY-001 — A complete answer defines G_0 = 1 and G_i as the product of gains through stage i, writes $N_i = g_i N_{i-1} + k B g_i T_{e,i}$, and divides by G_i. It then telescopes to $\frac{N_{out}}{G_n} = k B [T_s + \sum_{i=1}^{n} \frac{T_{e,i}}{G_{i-1}}]$. Each gain is a dimensionless power ratio, temperature is in kelvins, B is in hertz, and all noise terms are in watts. Explain that $T_{e,i}$ is already an input-equivalent quantity for its own stage, so its own gain cancels. State the common matched real impedance, fixed state, band-flatness approximation, and zero-cross-power assumptions. Do not extend the sum silently to correlated contributions or mismatched feedback. Review: Model 2B assumptions; Equations 4A-4C.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Equation 4A. Cumulative power gain; Chapter 2 — Equation 4B. Noise propagation through one stage; Chapter 2 — Equation 4C. Cascade temperature and integrated output noise.

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V011-C02-ESSAY-002 — Set the source and matched terminations to the attenuator physical temperature T_p. The source contributes $\frac{kBT_p}{L}$ at the output, while equilibrium requires total output noise kBT_p. The attenuator must therefore add $kBT_p\left(1-\frac{1}{L}\right)$. Divide by power gain $\frac{1}{L}$ to obtain $T_{e,loss}$ = $(L-1)T_p$. Explain why the signal still loses power even though equilibrium output noise remains kBT_p. A reflection can redirect power without the assumed dissipation and emission, so applying the relation to arbitrary mismatch requires another model. Full credit requires separating available power, delivered power, physical temperature, and equivalent input temperature. Review: Derive passive loss from thermal equilibrium; Equation 4F.

Review: Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss; Chapter 2 — Derive passive loss from thermal equilibrium.

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V011-C02-ESSAY-003 — Use g_A = $10^{1.5}$ = 31.6228 and L = $10^{0.4}$ = 2.51189. The cable equivalent temperature is about 453.57 K. Amplifier-first T_e is 70 + 453.57/31.6228 + 2.51189 times 900/31.6228, approximately 155.83 K. Cable-first T_e is 453.57 + 2.51189 times 70 + 2.51189 times 900/31.6228, approximately 700.89 K. State the common input plane and note that total signal gain is the same. The lower noise result favors the first arrangement only within the assumed linear matched state. Discuss blocker levels, compression, stability, cable power delivery, and applicable source environment before making an operational recommendation. Review: Equations 4C, 4F, and 4G; Applications 2B.2 and 2B.7.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Equation 4F. Noise temperature of a matched dissipative loss; Chapter 2 — Equation 4G. Loss followed by a characterized chain; Chapter 2 — Application 2B.2: move an amplifier across a cable; Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

V011-C02-ESSAY-004 — Compute F_0 = 1 + 100/290, approximately 1.34483, and NF_0 approximately 1.287 dB. For the 20 K source, actual degradation is 6, or about 7.782 dB. For the 2000 K source it is 1.05, or about 0.212 dB. The same receiver contribution has very different relative effects because the source-noise denominator changes. Also compare total noise temperatures, 120 K and 2100 K: the case with small relative degradation can still have far greater total noise. Distinguish this result from the undefined finite-ratio comparison at $T_s=0$ and retain the fixed receiver-state assumption. Review: Equations 4C-4E; Application 2B.4.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source; Chapter 2 — Application 2B.4: change the source environment.

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V011-C02-ESSAY-005 — Let original desired signal and white-noise powers be S and N. The new values are 0.5S and 0.25N, so new SNR is twice the old SNR, an improvement of about 3.01 dB. Noise alone falls by about 6.02 dB. State that this calculation assumes unchanged receiver-added density, valid common gain, and a retained signal-power fraction of one half under the actual event definition. Explain how a burst waveform, filter transient, or modulation spectrum could require a more detailed retention calculation. Averaging changes and bandwidth changes must not be conflated without an explicit estimator model. Review: Power, bandwidth, and the reference plane; Equation 4L.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Power, bandwidth, and the reference plane.

V011-C02-ESSAY-006 — Start with common output factor $k B G_n$ multiplying T_h+T_e and T_c+T_e. Divide to obtain Y, rearrange YTc + YTe = T_h+T_e, and solve T_e = $\frac{T_h - Y T_c}{Y - 1}$. Since hot temperature exceeds cold temperature, Y is greater than one; with nonnegative T_e, Y cannot exceed $\frac{T_h}{T_c}$. Equality at the upper boundary means T_e = 0. Treat values outside the domain as evidence requiring investigation of source inputs, gain, compression, bandwidth, mismatch, and record processing. Do not award a valid result to a silently clipped negative temperature. State that $T_c = 0$ needs a separately expressed upper-domain discussion. Review: Equations 4H and 4I.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

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V011-C02-ESSAY-007 — A strong answer identifies the selected reference plane, calibrated hot and cold source conditions, common effective bandwidth, detector law, and loss/mismatch corrections. Disable automatic gain control if valid or characterize its actual state dependence. Establish linearity in both source states, retain native powers and state records, and interleave or bracket cold and hot measurements to reveal drift. Use an independent gain observation or justified drift model before applying a correction. Distinguish a diagnostic sequence from proof that all changes have been corrected. Reserve challenge measurements to test repeatability and assumptions, then propagate relevant calibration, ratio, and covariance inputs. Review: Y-Factor and Comparative Noise Measurements; Application 2B.9.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio; Chapter 2 — Y-Factor and Comparative Noise Measurements.

V011-C02-ESSAY-008 — The true Y is 6400/700, approximately 9.142857. The observed ratio is 1.02 times this, approximately 9.325714. Substituting it into the equal-gain inversion gives T_e approximately 384.63 K, about 15.37 K below the true value. The increased hot gain raises the measured ratio, which the wrong model interprets as a smaller receiver contribution. Repetition can reduce random scatter while retaining this bias. Explain why averaging dBm values, changing displayed units, or merely bracketing source states does not automatically remove the effect. A valid correction needs evidence for the gain ratio and its uncertainty. Review: Equations 4H and 4I; Application 2B.9.

Review: Chapter 2 — Equation 4H. Hot-to-cold output power ratio; Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-ESSAY-009 — Starting from $T_e = T_{e,1} + \frac{T_{e,2}}{g_1}$ with positive $T_{e,2}$ and positive finite g_1, rearrange to g_1 >= $\frac{T_{e,2}}{T_{target} - T_{e,1}}$ when the target exceeds the first-stage temperature. At equality, no finite gain eliminates the positive second-stage contribution; the target is only a limit as gain grows without bound. Below the first-stage temperature, there is no feasible gain. Discuss why a gain satisfying the noise inequality still requires a blocker and stability check. State separately the degenerate $T_{e,2}$ = 0 case rather than applying the positive-noise derivation indiscriminately. Review: Equation 4J; Application 2B.5.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit; Chapter 2 — Application 2B.5: solve for the gain that is useful.

V011-C02-ESSAY-010 — Equation 4K gives Lmax = (160 + 320)/(320 + 80) = 1.2, about 0.792 dB. A 0.7 dB loss has L approximately 1.17490, giving $T_{e,total}$ = (L - 1)320 + L times 80, approximately 149.96 K, so it meets the stipulated noise target. Identify the common reference plane and physical filter temperature. A complete answer does not equate this pass with adequate blocker rejection, linearity, or mismatch performance. Discuss the separate rejection specification and the possibility that temperature or loss uncertainty could affect the available margin. Review: Equations 4G and 4K; Application 2B.6.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain; Chapter 2 — Equation 4K. Maximum allowed preceding loss; Chapter 2 — Application 2B.6: allocate loss to a preselector.

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V011-C02-ESSAY-011 — Track the blocker to the amplifier input for attenuation placed before versus after it. In the constructed case, -5 dBm reduced by 20 dB reaches -25 dBm before the amplifier, which is 5 dB below the stipulated -20 dBm envelope. With attenuation after the amplifier, the amplifier still sees -5 dBm, 15 dB above that envelope. The lower formal noise temperature in the latter order does not validate its failed linearity assumption. A sound decision specifies the necessary sensitivity, permissible signal environment, and measured linearity margin, then selects or redesigns the configuration. Avoid treating a downstream output limit as protection for an upstream stage. Review: Application 2B.7.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

V011-C02-ESSAY-012 — Identify input estimates T_h, T_c, and Y, their standard uncertainties, and the full relevant covariance matrix. Derive sensitivities $\frac{1}{Y-1}$, $-\frac{Y}{Y-1}$, and $\frac{T_c - T_h}{(Y-1)^2}$. Form the sum of sensitivity-weighted variances and twice the cross-sensitivity covariance terms. State what calibration or measurement evidence supports the covariances. Check the domain and adequacy of a first-order approximation, especially near Y = 1. Distinguish random ratio variability from uncorrected state-dependent gain bias; merely including a small repeatability term does not validate an incorrect measurement equation. Review: Equations 4N and 4O; Application 2B.10; Equation 27 in Chapter 14.

Review: Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

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V011-C02-ESSAY-013 — The inferred T_e is 240 K. Sensitivities are 0.2, -1.2, and -108 K per unit Y. With zero covariance, variance is $(0.2 \times 30)^2$ + $(-1.2 \times 1)^2$ + $(-108 \times 0.02)^2$ = 42.1056 K squared. The standard uncertainty is approximately 6.489 K. The NF sensitivity is 10/[ln(10) times 530], about 0.008194 dB/K, giving u(NF) approximately 0.0532 dB. State the local-linearization assumption and distinguish standard uncertainty from an expanded interval or a claimed coverage probability. Review: Equation 4I; Equations 4N-4P; Equation 27 in Chapter 14.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty; Chapter 14 — Equation 27. Combined standard uncertainty.

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V011-C02-ESSAY-014 — The inverse contains $Y - 1$ in the denominator, so derivative magnitudes grow and the transformation can become strongly nonlinear over the input uncertainty range. A symmetric input range can yield a broad or asymmetric output range, possibly encountering an inadmissible domain. A principled route starts with credible input distributions and dependence, explores the nonlinear transformation, and reports how invalid-domain realizations or model mismatch are handled without clipping them into apparent success. Discuss whether the measurement design should increase hot-cold contrast or reduce uncertainty. Do not claim that more decimal places or an arbitrary coverage multiplier repairs poor conditioning. Review: Equation 4I domain; Equations 4N-4P.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

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V011-C02-ESSAY-015 — Define the burst waveform, duration, frequency range, required event success, and valid detector state. Retain actual dwell intervals, settling exclusions, native data, decision statistic, threshold, and relevant configuration. Classify a burst outside valid channel observation as a coverage failure; use observed valid dwells for the specified amplitude-sensitivity population. Test weak references and noise-only intervals under declared environmental and interferer conditions, with distinct challenge records. Explain how overall event detection can depend on both opportunities to observe and performance during those opportunities, without assigning a universal probability from mean noise power alone. Review: Define sensitivity as a reproducible decision; Chapter 15 connection.

Review: Chapter 2 — Define sensitivity as a reproducible decision; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-C02-ESSAY-016 — Identify the unsupported link between a mean power scale and a detector operating characteristic. Require the event waveform and duration, statistic and its distribution or empirical behavior, threshold, false-alarm objective, search opportunities, observation coverage, and receiver/environment state. A ten-decibel SNR can be an explicit stipulated requirement in Equation 4L, but its probability interpretation needs a separate justified basis. Propose held-out noise-only and weak-reference trials with a defined population and uncertainty treatment. Explain how threshold tuning on the same data used for performance reporting can produce optimistic estimates. Review: Sensitivity Specifications and Decision Thresholds; Equation 4L.

Review: Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio; Chapter 2 — Sensitivity Specifications and Decision Thresholds.

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V011-C02-ESSAY-017 — Start with physical integration of noise through a channel response and the signal-retention requirement. Then distinguish averaging of a decision statistic or displayed trace from a change in admitted physical bandwidth. Averaging can change estimator variability, while correlation determines effective information; it does not necessarily lower the same mean noise power. Longer observation can improve a suitable estimator but also change event coverage or require stationarity assumptions. A strong answer names the measured quantity and operation for each case and avoids treating visually smoother traces as proof of an equal improvement in detection probability. Review: Power, bandwidth, and the reference plane; Uncertainty and Environmental Noise.

Review: Chapter 2 — Power, bandwidth, and the reference plane; Chapter 2 — Uncertainty and Environmental Noise.

V011-C02-ESSAY-018 — Read each specification definition and applicable state rather than treating the dBm figures as interchangeable. Identify whether a common signal, bandwidth, detector, duration, reference plane, and success criterion can be tested on both devices. Include external path loss, gain, mismatch, environmental conditions, and relevant uncertainty. If a common test is not meaningful, report the original measurands separately and explain what limited comparison remains. Do not infer a universal performance difference by unit conversion alone. The plan should preserve raw observations and state records so another reviewer can distinguish measured differences from changed definitions. Review: Sensitivity Specifications and Decision Thresholds.

Review: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

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V011-C02-ESSAY-019 — Use the initial comparisons to localize a candidate subsystem without prematurely claiming a calibrated noise figure. Retain matched load conditions, gain settings, supply and bias state, cable arrangement, timing, and output spectra or native data. Change one relevant mechanism at a time, such as supply stability, input attenuation, output loading, bounded blocker level, or physical coupling, while maintaining comparable observation capability. Seek evidence predicted by each mechanism and record tests that do not discriminate. Confirm any diagnosed mechanism with an appropriately bounded challenge; do not convert a bypass difference alone into environmental temperature or a traceable amplifier noise factor. Review: Y-Factor and Comparative Noise Measurements; Hypothetical Case Adjudication.

Review: Chapter 2 — Y-Factor and Comparative Noise Measurements; Chapter 2 — Hypothetical Case Adjudication: Sensitivity, Thermal Noise, Noise Figure, and Minimum Detectable Signal.

V011-C02-ESSAY-020 — Provide the raw output quantity, units, integration or detector operation, equivalent bandwidth, input and output planes, and the exact signal power gain used. Identify path components, source conditions, gain/attenuator state, sideband architecture where relevant, and any correction files or interpolation. State the validity envelope, uncertainty inputs, and evidence for linearity. Retain distinct states rather than applying a gain from another configuration. Explain that input referral changes the reporting plane and does not move physical noise sources or recover information lost through compression. Review: Power, bandwidth, and the reference plane; Model 2B scope.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-ESSAY-021 — Use T_s+T_e to explain genuine source-noise dominance: lowering T_e produces little benefit when T_s is much larger. Separately discuss how strong legitimate signals can cause gain control, compression, intermodulation, reciprocal mixing, or overlap, which may require a model beyond the quiet scalar noise budget. Propose spatial, temporal, polarization, and operating-state baselines plus bounded interferer tests. Do not absorb every nonthermal interferer into an arbitrary temperature without defining what the resulting model represents. The final interpretation should identify which evidence distinguishes an external contribution from changed receiver behavior. Review: Uncertainty and Environmental Noise; Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision; Chapter 2 — Uncertainty and Environmental Noise.

V011-C02-ESSAY-022 — Identify the injection plane and list the antenna, cable, filter, gain, detector, recording, and software functions actually exercised. State that a successful check supports those functions only in its tested state and at its time. It does not alone prove uninterrupted validity during preceding acquisition or verify an antenna path that was bypassed. Add complementary field or terminal checks appropriate to the omitted functions, retain temporal state evidence, and define how transient overload or configuration disturbances would be detected or bounded. Avoid claiming universal continuity from a single successful end-of-engagement response. Review: Operational Sensitivity Verification; temporal and path-scope qualification.

Review: Chapter 2 — Operational Sensitivity Verification.

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V011-C02-ESSAY-023 — Identify the cited public apparatus scope, 9 kHz to 18 GHz for relevant EMI receivers and spectrum analyzers, and preserve the access limitation: public scope review is not full-standard access or clause-by-clause compliance certification. Explain how a conformity claim, if separately established, can support specified apparatus characteristics while leaving the actual installed chain, state, calibration, overload, and operational interpretation to be demonstrated. Do not treat an EMC apparatus standard as a universal attribution method. Distinguish source-supported scope statements from the author derived scalar noise model and synthetic applications. Review: Measuring-Receiver Scope and System Noise Floor; footnote 4.

Review: Chapter 2 — Measuring-Receiver Scope and System Noise Floor; Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

V011-C02-ESSAY-024 — Duplicated observations carry the same noise realization, so the nominal file length overstates independent information. Explain that variance of an average includes covariance terms; perfect duplicates do not create a second independent experiment. Also distinguish sample correlation within a genuine longer acquisition from changes in gain or source state that alter the measurand. A rigorous answer states the averaging rule, estimates or justifies dependence, and retains the original time/state lineage. Repetition of a systematically biased hot-cold procedure also does not remove its state-dependent bias. Review: Uncertainty and Environmental Noise; Application 2B.9.

Review: Chapter 2 — Uncertainty and Environmental Noise; Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

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V011-C02-ESSAY-025 — Define the event and reference plane first, then calculate a noise budget with valid matched-state assumptions and signal retention. Use gain and loss bounds to identify feasible chains, but check internal blocker levels, preselector rejection, stability, and detector validity before selecting a noise-optimal arrangement. Characterize the required decision ratio or detector operating characteristics on controlled data and validate on distinct challenge records. Include source environment and observation coverage, then propagate relevant calibration and statistical uncertainty. A sound review presents the feasible operating envelope and unresolved limits rather than treating a low calculated noise figure as the entire acceptance case. Review: Model 2B; Applications 2B.1-2B.10; Operational Sensitivity Verification.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Operational Sensitivity Verification; Chapter 2 — Application 2B.1: assemble a four-stage noise budget; Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

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Discussion Guidance

V011-C02-DISCUSSION-001 — Ask participants to compute or explain the ordering effect in Equation 4C before discussing operations. Then require internal blocker levels, amplifier linearity and stability, remote power and cable conditions, and the actual source environment. A defensible conclusion can prefer amplifier-first for a valid noise-limited case yet choose another architecture when strong-signal or installation constraints dominate. Reject arguments based only on total gain or the lowest formal noise figure. Review: Applications 2B.2 and 2B.7.

Review: Chapter 2 — Application 2B.2: move an amplifier across a cable; Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

V011-C02-DISCUSSION-002 — Separate the reported signal-level transformation from the physical noise budget. A valid correction can refer a measured signal to an earlier plane; it does not remove cable thermal emission, downstream noise reweighting, or information lost in an invalid state. Ask what source-plane and calibration evidence is needed and whether the desired signal was retained. The discussion should produce a precise corrected claim rather than simply rejecting all cable corrections. Review: Power, bandwidth, and the reference plane; Equation 4G.

Review: Chapter 2 — Equation 4G. Loss followed by a characterized chain; Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-DISCUSSION-003 — Have each engineer identify the denominator temperature in the quantity being quoted. Use Equations 4D and 4E to show that both numbers can be correct for different definitions. Then compare total input-referred noise and the event detection requirement. A productive resolution reports the receiver convention and source conditions together without redefining T_0 to force agreement. Review: Equations 4C-4E.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Equation 4D. Noise factor at the reference temperature; Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source.

V011-C02-DISCUSSION-004 — Require an event definition before choosing a visual criterion. Discuss retained burst energy and timing, filter response, effective noise bandwidth, detector behavior, and actual observation coverage. The appropriate tradeoff depends on the stated success event and false-alarm objective. The discussion should end with a measurable comparison, such as held-out burst detection under matched conditions, rather than treating trace smoothness as the objective. Review: Power, bandwidth, and the reference plane; Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision; Chapter 2 — Power, bandwidth, and the reference plane.

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V011-C02-DISCUSSION-005 — Use the admissible Y domain to establish why the result is inconsistent with the selected model. Enumerate plausible source calibration, gain-state, compression, bandwidth, mismatch, ratio-processing, and uncertainty explanations. Clipping cannot resolve the inconsistency and may conceal its size. A defensible review preserves the observation, investigates the equation inputs, and states whether a valid result can be produced after a justified correction. Review: Equation 4I domain.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain.

V011-C02-DISCUSSION-006 — Separate precision from model validity. Repeated application of the same state-dependent ratio can produce a tightly clustered biased inferred temperature. Ask how the gain difference is known, whether it is stable, and what uncertainty accompanies any correction. Discuss the role and limits of bracketing measurements and independent gain checks. Do not equate small repeatability scatter with negligible total uncertainty. Review: Application 2B.9.

Review: Chapter 2 — Application 2B.9: expose a change hidden by a ratio.

V011-C02-DISCUSSION-007 — The labels are insufficient by themselves. Participants should ask whether actual hot/cold gain and noise law were characterized, whether the source states remained linear, and how transitions or settling were excluded. An enabled control is not automatically disqualifying if a valid characterized model exists, but unobserved state changes undermine the simple cancellation. Frame the acceptance decision around evidence for the law actually used. Review: Y-Factor and Comparative Noise Measurements.

Review: Chapter 2 — Y-Factor and Comparative Noise Measurements.

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V011-C02-DISCUSSION-008 — Read the certificate and connect its defined quantities to the measurement equation. The chapter declares one explicit temperature-difference convention but does not override the calibration source definition. Discuss how to map between conventions, retain the reference temperature separately, and propagate uncertainty. Blindly setting T_c to 290 K or treating ENR as the measured receiver Y-factor should be challenged. Review: Y-factor discussion following Equation 4I.

Review: Chapter 2 — Equation 4I. Recovered input noise temperature and its domain; Chapter 2 — Invert the same model with two source temperatures.

V011-C02-DISCUSSION-009 — The mathematical bound identifies a noise requirement, not a complete feasible implementation. Discuss blocker stress, compression, stability, band flatness, gain-state control, and uncertainty in the first-stage temperature. If the target is too close to $T_{e,1}$, the design may have little useful margin. Consider changing the first device, path loss, preselection, or detector requirement rather than assuming arbitrarily high gain is available and valid. Review: Equation 4J; Applications 2B.5 and 2B.7.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit; Chapter 2 — Application 2B.5: solve for the gain that is useful; Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage.

V011-C02-DISCUSSION-010 — Recognize that the stated passive feasible interval is empty, even for a lossless preceding section. Review the following chain temperature, target, physical temperature inputs, and correctness of the chosen reference plane. A different architecture or revised justified requirement may be needed. A passive element cannot be assigned L below one merely to make the inequality pass. Review: Equation 4K domain.

Review: Chapter 2 — Equation 4K. Maximum allowed preceding loss.

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V011-C02-DISCUSSION-011 — Use the sensitivity-weighted variance contributions to separate source calibration uncertainty from ratio repeatability. More output samples can reduce a genuinely independent random ratio component but may have little effect on a dominant calibration input. Discuss better source characterization, source contrast, covariance evidence, and whether the first-order model is adequate. Do not assume every budget component averages down with sample count. Review: Application 2B.10.

Review: Chapter 2 — Application 2B.10: propagate the local calibration uncertainty.

V011-C02-DISCUSSION-012 — Require the distributional approximation, degrees-of-freedom treatment, and uncertainty model supporting the coverage statement. The multiplication by two is transparent arithmetic, but it does not itself specify coverage. Discuss how to report the factor and assumptions when the probability interpretation is limited. Near an ill-conditioned inversion, a nonlinear or asymmetric result may require a different interval description. Review: Equations 4N-4P.

Review: Chapter 2 — Equation 4N. Temperature sensitivity coefficients; Chapter 2 — Equation 4O. Power-ratio sensitivity coefficient; Chapter 2 — Equation 4P. Local conversion from temperature uncertainty to noise-figure uncertainty.

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V011-C02-DISCUSSION-013 — Contrast relative degradation with total input-referred noise. A dominant source can make receiver-added noise relatively unimportant while leaving the absolute required signal much larger. Use T_s+T_e and Equation 4L to connect the distinction to an event requirement. Discuss whether reducing receiver T_e, changing observation conditions, or improving selectivity would address the actual limitation. Review: Equations 4C, 4E, and 4L.

Review: Chapter 2 — Equation 4C. Cascade temperature and integrated output noise; Chapter 2 — Equation 4E. Signal-to-noise degradation for the actual source; Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

V011-C02-DISCUSSION-014 — The team must define the intended application and a common success criterion, waveform, bandwidth, observation interval, detector, and reference plane. If the devices serve different tasks, an unqualified scalar ranking may be inappropriate. Ask what measurements can be reproduced and what differences must remain explicit. Converting both catalog numbers to the same power unit does not solve a measurand mismatch. Review: Sensitivity Specifications and Decision Thresholds.

Review: Chapter 2 — Sensitivity Specifications and Decision Thresholds.

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V011-C02-DISCUSSION-015 — Discuss noise-only false alarms, distinct held-out weak events, event selection, receiver state, search opportunities, and uncertainty in the observed performance. Successful tuning records demonstrate fit to those records; they do not alone establish performance for the declared population. Ask whether the threshold and processing were frozen before the challenge set was evaluated and how exclusions were documented. Review: Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision.

V011-C02-DISCUSSION-016 — Participants should distinguish the curve conditional on a valid observation interval from an overall operational detection measure. Both may be useful if their populations are stated. Pooling them without qualification obscures whether failure arose from amplitude sensitivity or coverage. Require actual channel timing and settling records before classification, and discuss how a deployment-level report can present both measures. Review: Define sensitivity as a reproducible decision; Chapter 15 connection.

Review: Chapter 2 — Define sensitivity as a reproducible decision; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-C02-DISCUSSION-017 — Nominal count alone cannot establish equal information. Discuss continuity evidence, duplicate detection, the estimator and covariance, and whether repeated buffers represent acquisition failure or deliberate resampling. The repeated data cannot be credited as independent observations. Also ask whether apparently continuous timestamps correspond to real acquired samples or only software-generated record positions. Review: Uncertainty and Environmental Noise.

Review: Chapter 2 — Uncertainty and Environmental Noise.

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V011-C02-DISCUSSION-018 — The comparison suggests an external or path-dependent contribution, but the interpretation needs the antenna/termination states, gains, impedance behavior, effective bandwidth, receiver-added noise, and possible overload effects. Discuss what assumptions permit an equivalent source temperature and whether nonthermal interference fits the chosen representation. A calibrated quantitative result requires more than subtracting two displayed numbers. Review: Y-Factor and Comparative Noise Measurements; Uncertainty and Environmental Noise.

Review: Chapter 2 — Y-Factor and Comparative Noise Measurements; Chapter 2 — Uncertainty and Environmental Noise.

V011-C02-DISCUSSION-019 — Require raw observations, the actual bypass path, source conditions, state-specific gains, detector operation, and linearity evidence. Use controlled changes to test predictions for noise, instability, and overload while maintaining sufficient observation capability. A qualitative discriminating test may be useful even when it does not produce a traceable noise figure. State that narrower evidential role explicitly. Review: Y-Factor and Comparative Noise Measurements.

Review: Chapter 2 — Y-Factor and Comparative Noise Measurements.

V011-C02-DISCUSSION-020 — It may support identified apparatus characteristics within the standard and evidence actually available. It does not validate the accessories, the installed reference plane, the chosen state, or source attribution. Ask participants to map each part of the claimed result to its supporting evidence and identify the extra checks needed. Preserve the difference between public scope review and a documented conformity assessment. Review: Measuring-Receiver Scope and System Noise Floor.

Review: Chapter 2 — Measuring-Receiver Scope and System Noise Floor.

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V011-C02-DISCUSSION-021 — Map the injection point and the functions exercised. A downstream injection can bypass the antenna and upstream path, and a later successful response cannot alone exclude earlier transient faults. Propose complementary checks and temporal state evidence appropriate to the actual claim. The corrected conclusion should state what was tested, when, and what remains unsupported. Review: Operational Sensitivity Verification; closing-check scope qualification.

Review: Chapter 2 — Operational Sensitivity Verification.

V011-C02-DISCUSSION-022 — An equivalent temperature may be a useful defined power-density representation under a declared band and statistic, but it must not conceal structured interference, time variation, or receiver nonlinearity. Discuss controlled equipment-state comparisons, spectra, polarization, timing, and bounded interferer tests. The adopted model should match the intended prediction and retain its limitations rather than treating every observed contribution as equilibrium thermal noise. Review: Uncertainty and Environmental Noise.

Review: Chapter 2 — Uncertainty and Environmental Noise.

V011-C02-DISCUSSION-023 — Examine the actual sideband and image paths, input environment, conversion gain definition, and calibration conditions. The chapter permits a scalar equivalent-channel law only when empirically justified for the selected architecture. A nominal figure cannot be inserted blindly just because it is expressed in decibels. Identify which manufacturer source or measurement would supply the missing applicability evidence. Review: Model 2B scope; Analog Devices source note.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-C02-DISCUSSION-024 — Ask whether the original detector operation, bandwidth, reference plane, actual state, corrections, and uncertainty can still be established. A retained final value and nominal gain may permit arithmetic reversal but cannot necessarily recover the original observation or validate the gain applicability. Discuss the narrow conclusions still supportable and which missing evidence prevents stronger claims. Avoid treating a reversible scalar formula as proof that all original information was preserved. Review: Power, bandwidth, and the reference plane.

Review: Chapter 2 — Power, bandwidth, and the reference plane.

V011-C02-DISCUSSION-025 — The discussion should connect a defined authorized event, valid reference plane and installed chain, controlled reference identity, strong-signal envelope, actual observation opportunities, and a validated decision criterion. Include state and uncertainty evidence, held-out challenges, and bounded closing checks. A useful outcome is an explicit tested operating domain with remaining limits, not a single catalog-like number detached from its event and environment. Review: Operational Sensitivity Verification; Define sensitivity as a reproducible decision.

Review: Chapter 2 — Define sensitivity as a reproducible decision; Chapter 2 — Operational Sensitivity Verification.

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Chapter Glossary

AVAILABLE NOISE POWER: Noise power that a source can supply under the specified matching condition. In the chapter's classical thermal model it is kBT_s, where k is the Boltzmann constant in joules per kelvin, B is equivalent noise bandwidth in hertz, and T_s is source noise temperature in kelvins. It is a source quantity at a declared plane and differs from the power actually accepted by a mismatched receiver.

CASCADE NOISE TEMPERATURE: Equivalent input noise temperature of an ordered chain, found by referring each added stage contribution through the gain preceding it.

COLD-SOURCE TEMPERATURE: Effective source noise temperature in the lower-temperature state of a hot/cold measurement at the stated input plane.

COMBINED STANDARD UNCERTAINTY: The standard uncertainty obtained by propagating the relevant input uncertainties and covariances through the stated measurement model. In the local Y-factor calculation it is the square root of the sensitivity-weighted variance sum, including any applicable cross terms. It is distinct from an expanded uncertainty and does not itself specify a chosen coverage probability.

COVERAGE FAILURE: Failure to observe an event because the relevant channel or interval was not validly acquired, such as a burst occurring while a scanning receiver was tuned elsewhere. It is distinct from a failure to detect an event during a valid dwell. Actual observation and settling records are needed to assign the failure category.

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CUMULATIVE POWER GAIN: The product G_j of the linear power gains from the selected input through stage j. It describes signal power transfer between those planes in the stated fixed-state model. G_0 is defined as one, allowing the first stage noise contribution to be handled by the same recurrence as later stages.

DECISION STATISTIC: The quantity computed from an observation and compared with a criterion to decide whether a specified event has been detected. Examples in the chapter include amplitude, correlation, or coherent-integration results. Its distribution, duration, receiver state, and processing affect detection and false-alarm behavior; mean noise power alone does not specify those properties.

DELIVERED NOISE POWER: Noise power accepted by the receiving port under the actual source and load conditions. It equals available noise power in the stated matched real-impedance model. A matched-port insertion-loss value alone does not establish delivered power for a reactive antenna and a state-dependent receiver input match.

DETECTION THRESHOLD: The declared boundary applied to a decision statistic for a defined detection event. Its selection should reflect a false-alarm objective and be tested with suitable noise-only and weak-reference observations. Lowering it can increase detected weak events while also increasing unwanted crossings; the threshold is not interchangeable with a receiver noise-floor number.

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DISSIPATIVE ATTENUATION: Signal power reduction caused by a passive element that dissipates energy under the stated matched conditions. Its physical temperature determines its thermal emission. For loss L at temperature T_p, Model 2B assigns gain $\frac{1}{L}$ and equivalent input temperature $(L-1)T_p$; arbitrary reflected power is not automatically covered by this relation.

ENVIRONMENTAL BASELINE: A set of observations describing the site contribution under stated spatial, temporal, polarization, and operating conditions. It helps identify variation relevant to operational sensitivity and possible external noise mechanisms. A baseline is bounded by its coverage and receiver validity; it does not make a quiet laboratory noise figure a guarantee for every occupied-site state.

EQUIVALENT NOISE BANDWIDTH: Bandwidth of an ideal rectangular filter passing the same noise power as the actual filter or processing window.

EXCESS-NOISE RATIO: Calibrated noise-source quantity whose temperature and reference convention must be read explicitly; Model 2B uses the on-minus-off temperature divided by 290 K.

HELD-OUT DETECTION TEST: Evaluation of a fixed detection rule on challenge records distinct from those used to select its threshold or processing. The chapter calls for both noise-only intervals and weak reference events under declared conditions. The separation helps reveal optimistic tuning results, while the tested event population and uncertainty still limit the conclusion.

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HOT-COLD GAIN RATIO: Power gain in the hot source state divided by power gain in the cold state; a value other than unity invalidates the equal-gain Y-factor inversion.

HOT-SOURCE TEMPERATURE: The calibrated or otherwise justified effective noise temperature T_h of the higher-noise source state in a hot-cold measurement. It must exceed T_c for the chapter inversion. Its applicability is tied to the reference plane, connection corrections, and source convention; it is not inferred solely from the receiver output being larger.

HOT-STATE COMPRESSION: Nonlinear response caused when the higher-noise source state drives part of the receiver beyond the applicable proportional gain range. It breaks the common linear law used to cancel gain in the hot-cold ratio. A stable output reading does not exclude this effect; both source states require an appropriate linearity check.

INPUT REFERRAL: A reporting transformation that expresses an output quantity at a declared input plane using the applicable transfer law. For noise power in the valid scalar model, divide by the state-specific signal power gain. The operation does not move noise generators physically or restore information lost through an invalid nonlinear state.

INVERSION CONDITIONING: The sensitivity of an inferred quantity to changes in the measured inputs of an inverse relation. The Y-factor temperature inversion is poorly conditioned near $Y = 1$ because its denominator approaches zero. Small ratio or calibration uncertainties can then produce large, asymmetric changes that a local linear uncertainty approximation may not adequately describe.

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MINIMUM DETECTABLE SIGNAL: Input signal level meeting a stated detection criterion under specified conditions.

MINIMUM PRECEDING GAIN: The least first-stage power gain that meets a specified two-stage equivalent-temperature target under the stated positive downstream-noise assumptions. Equation 4J gives $\frac{T_{e,2}}{T_{target} - T_{e,1}}$ when T_{target} exceeds $T_{e,1}$. This is a noise constraint; it does not establish that the required gain is available, stable, or valid under the blocker environment.

NOISE FACTOR: Ratio of input signal-to-noise ratio to output signal-to-noise ratio under the declared source temperature and matching convention, expressed in linear units. Model 2B uses a 290 K reference source; degradation for a different actual source temperature is a separate quantity.

NOISE FIGURE: The logarithmic expression of noise factor, $NF_0 = 10 \log_{10}(F_0)$, in decibels at the declared reference temperature and conditions. Its numerical convenience does not remove the need to identify the included network and state. It differs from actual SNR degradation when the source temperature differs from the reference temperature, except in the zero-added-noise case.

NOISE-LIMITED SENSITIVITY: A bounded input-signal requirement derived when the admitted source and receiver noise are the relevant limiting contributions and the detector requirement is separately justified. Equation 4L uses $\gamma k B(T_s + T_e)$ with full desired-signal retention. Compression, structured interference, coverage failures, or another detector law can require a different operational analysis.

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NOISE-ONLY VALIDATION: Evaluation of the chosen detection rule on records intended to represent the stated no-target condition. It supports assessment of false-alarm behavior for the tested state and population. The record must still account for receiver artifacts, environmental structure, processing, and search opportunities; a quiet mean level alone is not a complete validation.

NOISE TEMPERATURE: Equivalent temperature used to represent available noise power or device-added noise.

OUTPUT-ADDED NOISE: Noise attributed to a stage and expressed at that stage output, excluding the incoming noise it transmits. For stage i in Model 2B the value is $k B g_i T_{e,i}$. Referring this contribution to another plane requires the corresponding signal power gain, rather than treating the stage equivalent input temperature as an output temperature directly.

PASSIVE-LOSS ALLOWANCE: The permitted interval of matched dissipative loss before a characterized chain under a specified total noise-temperature target. Equation 4K combines the requirement $L \geq 1$ with an upper bound determined by target, physical path temperature, and downstream equivalent temperature. An upper bound below one means the stipulated passive design has no feasible solution.

PRECEDING GAIN: The cumulative power gain before the stage whose added noise is being referred to the cascade input. The contribution $T_{e,i}$ is divided by G_{i-1}, because the input signal has experienced those earlier stages before that noise is added. Preceding loss increases, rather than suppresses, the downstream input-equivalent contribution.

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RECEIVER-ADDED NOISE: The noise contribution produced by the included receiver chain beyond the admitted source contribution. Model 2B represents it at the input by T_e and at the output by $k B G_n T_e$. This representation depends on the selected path, gain state, bandwidth, and model domain; it is not an arbitrary label for every observed interferer.

REFERENCE NOISE TEMPERATURE: Temperature used to define a noise-factor convention, equal to 290 K in Model 2B and distinct from actual source or component temperature.

SEARCH MULTIPLICITY: The presence of multiple opportunities for a decision statistic to cross a threshold during a search over frequencies, windows, or other tested conditions. It affects how a single-channel false-alarm objective relates to a whole-search claim. The number and dependence of those opportunities must be considered in the chosen validation or probability model.

SENSITIVITY FAILURE: Failure to detect the defined event during an acquisition interval that validly observed the relevant channel under the stated conditions. It can inform a sensitivity estimate only within that specified population and detector rule. Events missed because the receiver was not observing belong to a separate coverage category unless a broader operational measure is explicitly defined.

SIGNAL RETENTION: The fraction or representation of the desired signal preserved by the selected channel and processing for the intended measurement or detection event. Reducing equivalent noise bandwidth can reject desired modulation or burst energy as well as noise. A claimed sensitivity improvement must evaluate the retained signal, rather than relying only on the reduced noise trace.

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SOURCE NOISE TEMPERATURE: The temperature-scale representation T_s of noise supplied at the cascade input under the declared band and model. It can reflect the antenna view or an applied calibrated source and need not equal ambient temperature. Model 2B keeps it separate from the equivalent temperature representing receiver-added noise.

SOURCE SWITCHING: The controlled transition between the hot and cold input-source states of a comparative noise measurement. The record must identify the realized state, timing, settling, and any associated change in gain, bandwidth, mismatch, or noise law. Switching labels alone do not establish the common-state conditions needed for the simple Y-factor inversion.

TEMPERATURE CONTRAST: The difference $T_h - T_c$ between the effective hot and cold source temperatures in the declared hot-cold measurement convention. It enters the source excess-noise ratio and influences the measured power contrast. Its calibration and uncertainty must be retained; a large nominal contrast alone does not establish receiver linearity or correct source-plane delivery.

THERMAL EQUILIBRIUM: The condition used in the passive-loss derivation in which the matched source, attenuator, and connected terminations share the physical temperature T_p. The attenuator output available noise remains $k B T_p$ because thermal emission complements the transmitted source noise. Equal equilibrium noise does not mean that a desired signal passes without attenuation.

Y-FACTOR: Ratio of measured output powers for two known input noise temperatures.

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Y-FACTOR ADMISSIBLE DOMAIN: The set of output-noise ratios compatible with the stated hot-cold model and its input constraints. For $T_h > T_c > 0$ and finite nonnegative T_e, it is $1 < Y \leq \frac{T_h}{T_c}$. An observed ratio outside that interval calls for investigation of the inputs and model rather than silent clipping of the inferred temperature.

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References and Works Cited

Analog Devices. System Noise-Figure Analysis for Modern Radio Receivers. June 14, 2013. Sections Baseline Case: Cascade of Linear Circuit Blocks, A Heterodyne Receiver, Noise Temperature, and Y-Factor. https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html

Annotation. Supports the distinction between matched linear blocks, selected-channel mixer applicability, equivalent temperature, and hot-cold measurement. The chapter supplies its own bounded derivation and constructed applications. The cited work treats receiver noise as a gain- and bandwidth-dependent measurement problem, including equivalent input noise or cascaded stages. Input and output reference planes, source temperature, impedance match, receiver gain and effective detector bandwidth must all be stated. Noise-figure figures from a particular test setup do not establish minimum detectable signals or calibrated sensitivity in every field installation. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

Friis, H. T. Noise Figures of Radio Receivers. Proceedings of the IRE 32, no. 7 (July 1944): 419-422. https://doi.org/10.1109/JRPROC.1944.232049

Annotation. The publisher abstract was read for historical network, component, mismatch, and measurement framing. Full-paper access is not claimed. The cited work treats receiver noise as a gain- and bandwidth-dependent measurement problem, including equivalent input

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noise or cascaded stages. Input and output reference planes, source temperature, impedance match, receiver gain and effective detector bandwidth must all be stated. Noise-figure figures from a particular test setup do not establish minimum detectable signals or calibrated sensitivity in every field installation. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

International Electrotechnical Commission. CISPR 16-1-1:2019. Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus. Fifth edition. May 22, 2019. Official publication scope. https://webstore.iec.ch/en/publication/60774

Annotation. The public scope was checked November 1, 2026. It supports the stated 9 kHz to 18 GHz apparatus scope; full-standard access or clause-by-clause compliance certification is not claimed. The reference concerns apparatus and practices for electromagnetic interference measurements, with detector modes and equipment characteristics set by its identified scope. Quasi-peak, peak and average detection cannot be freely substituted when interpreting short or intermittent disturbances. A scope statement or product manual must not be mistaken for proof of compliance with every clause or correct operation under field conditions. The cited work is a methodological

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reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

Keysight Technologies. Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide. Part N9069-90001, edition 1. March 2016. Pages 10-11 and 73-81, especially Using Loss Compensation and Setting Temperature of Loss. https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf

Annotation. The identified edition supports the stated loss-compensation and temperature controls, without extending the claim to every current analyzer. The cited work treats receiver noise as a gain- and bandwidth-dependent measurement problem, including equivalent input noise or cascaded stages. Input and output reference planes, source temperature, impedance match, receiver gain and effective detector bandwidth must all be stated. Noise-figure figures from a particular test setup do not establish minimum detectable signals or calibrated sensitivity in every field installation. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Randa, James P. Uncertainties in NIST Noise-Temperature Measurements. NIST Technical Note 1502. March 1998. Sections 3.9-3.10, pages 16-17. https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf

Annotation. Supports noise-temperature uncertainty considerations. Historical radiometer thresholds are not adopted as acceptance limits for the chapter constructed receiver. The cited work treats receiver noise as a gain- and bandwidth-dependent measurement problem, including equivalent input noise or cascaded stages. Input and output reference planes, source temperature, impedance match, receiver gain and effective detector bandwidth must all be stated. Noise-figure figures from a particular test setup do not establish minimum detectable signals or calibrated sensitivity in every field installation. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

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Chapter 3. RF Front Ends, Preselection, Gain Distribution, and Input Protection

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3.1 Front-End Purpose and Architecture

The RF front end determines which energy reaches the vulnerable gain and conversion stages. It can include switching, duplexing, limiters, electrostatic protection, attenuators, high-pass or low-pass sections, tunable preselectors, fixed band-pass filters, tracking filters, notch filters, amplifiers, and calibration injection paths. These components establish the receiver's practical input range and often determine whether a weak signal is observable in the presence of strong legitimate transmitters.[7]

Wide instantaneous coverage is not always advantageous. A direct-sampling receiver connected to an unfiltered broadband antenna may accept energy far outside the displayed span. Strong AM, FM, television, cellular, radar, or nearby digital transmitters can drive the input network or converter nonlinearly even when they are invisible on the selected screen. A front-end diagram and out-of-band survey are therefore part of weak-signal work.

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7 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers,” June 14, 2013, “Baseline Case: Cascade of Linear Circuit Blocks,” “A Heterodyne Receiver,” “Noise Temperature,” and “Y-Factor,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html. The scalar derivation and numerical cases here are original and explicitly exclude unmodeled image contributions.

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3.2 Find the first stage that can lose validity

Front-end design is easiest to reason about when the desired signal and every significant interferer are followed separately through the actual order of components. A filter near the receiver output may make the final display clean while leaving an earlier amplifier exposed to a large signal. Once that amplifier has compressed or generated an in-band product, later filtering cannot reconstruct the undistorted weak signal. The relevant question is therefore where an unwanted signal is rejected relative to the first component that it can drive outside its valid operating state.

Draw each path from the external connector to the digitizer or detector. Mark a desired-signal transfer at its own frequency, blocker transfers at their frequencies, and the total loading presented to each stage. Do not use the desired-frequency gain for a blocker located across a filter skirt. For several blockers, the total mean power matters to some mechanisms, while instantaneous voltage and relative phase can matter to others. The cubic model in Chapter 11 provides a bounded intermodulation calculation; a scalar gain budget by itself does not predict those products or a protection device's transient response.

A practical architecture can have more than one low-noise operating state. The R&S ESW manual, for example, places its standard preamplifier after preselection and describes an optional low-noise amplifier ahead of it. The manual also distinguishes the sensitivity benefit from the reduction in large-signal immunity. This is a concrete illustration of why an instrument's preamplifier indicator is insufficient configuration information: the location

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of the active stage and the filters preceding it determine which signals it admits.[8]

For an unknown environment, begin with a state whose exposure is understood and then test whether more gain is useful. That does not imply a universal attenuator setting. The appropriate state follows the instrument's ratings, the anticipated signal environment, and the required observation. Once a quieter state is selected, record the change as a new measurement configuration. Measurements from different states may later be compared at a common reference plane, but their noise, overload behavior, and time coverage remain distinct.

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8 Keysight Technologies, Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide, part N9069-90001, edition 1 (March 2016), 10–11, 73–81, especially “Using Loss Compensation” and “Setting Temperature of Loss,” https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf. This identified edition supports the stated measurement controls, not a claim about every current analyzer.

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3.3 Preselection and Filter State

Preselection limits the spectral energy admitted to later stages. Tracking filters follow the tuned frequency, while switched filter banks cover defined bands. The important characteristics include insertion loss, passband ripple, rejection, transition width, return loss, group delay, tuning repeatability, power handling, and switching transient. A filter that improves overload immunity can also remove a broadband transient, distort modulation, or introduce temperature-dependent loss.

Filter state must be documented rather than inferred from a displayed center frequency. Some receivers select prefilters automatically, and a boundary crossing can change gain, noise, phase, or calibration. External filters and notches must be identified by serial number and measured response when amplitude accuracy matters. Comparing observations made through different filters requires separate correction and uncertainty.

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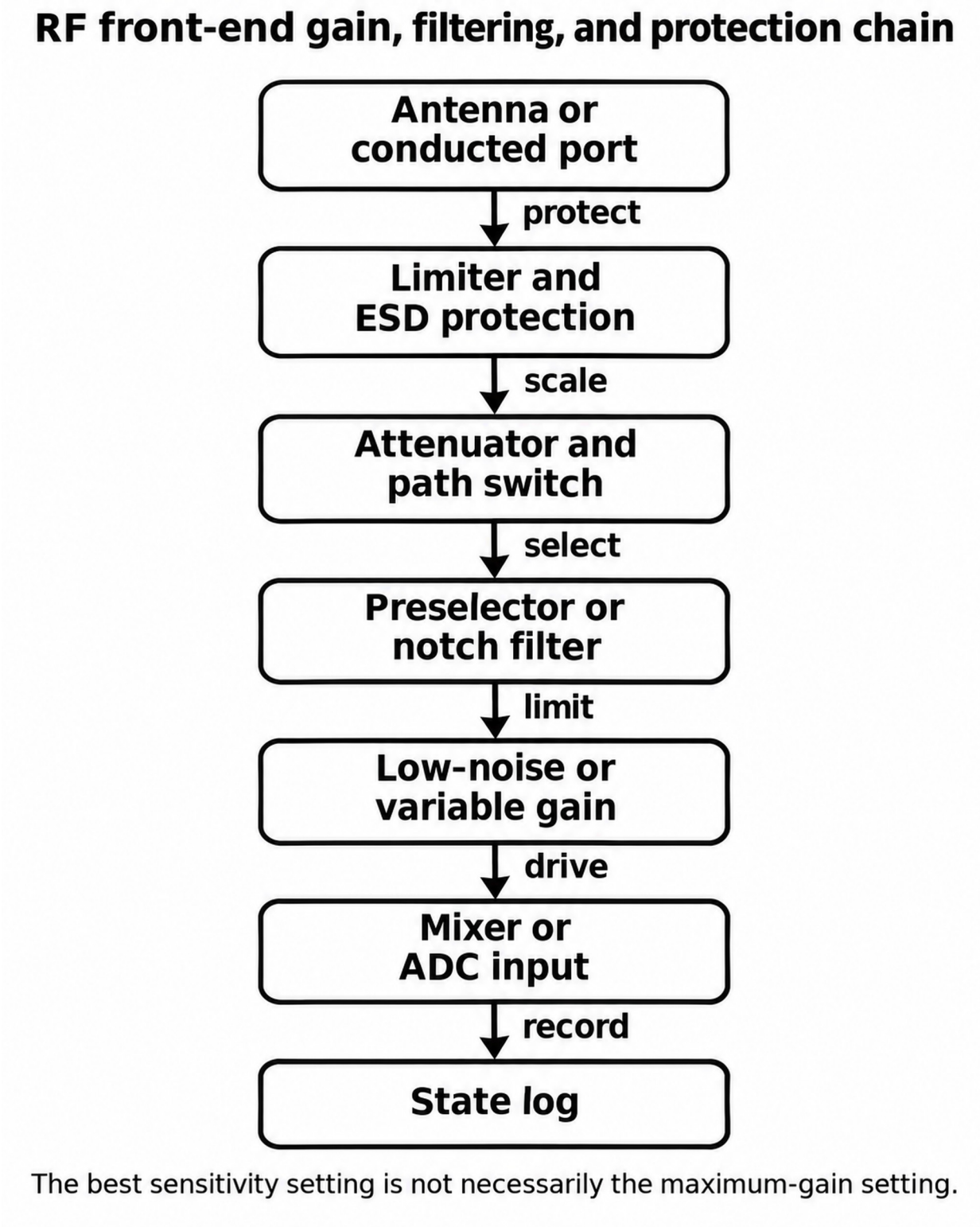

Figure 10. RF front-end gain, filtering and protection.

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3.4 Use preselection as a measured transfer function

A preselector trades desired-band insertion loss against unwanted-band admission. Application 2B.6 quantifies one side of that trade: loss ahead of the first amplifier raises the complete input-equivalent temperature. The other side requires the filter response at each blocker frequency. A filter that costs 1 dB at the desired frequency but suppresses a dominant remote blocker can make a previously invalid observation usable. A filter with the same insertion loss and inadequate blocker rejection supplies only the noise penalty. Both statements depend on its placement ahead of the vulnerable stage.

Characterize the passband as well as its center. A narrow desired waveform near the center can be retained while a wider waveform extending into the skirt suffers amplitude and phase distortion. Switching among preselector bands can also change the response abruptly at a boundary. A calibration at the center of one band cannot establish continuity across that transition. Record band identifiers and actual settings, then place reference checks at frequencies that challenge the boundary and the regions where the response changes rapidly.

The desired and blocker corrections should be separate columns in the path record. Suppose a filter is known to have modest loss at the desired frequency and substantial rejection at the blocker frequency. The desired-signal correction restores the reported level at the original plane, while the blocker transfer estimates the power reaching the next active component. Applying the rejection value as a desired-signal correction would create an impossible sensitivity improvement. Applying the desired insertion loss to

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the blocker would conceal the intended protection. Neither correction is a generic property independent of frequency.

A strong-signal challenge should confirm the predicted mechanism with the desired reference still present. Record the desired amplitude, phase or modulation quality, the local noise, and any new spectral products before and after changing the preselector. A lower displayed baseline alone is ambiguous: the filter may have rejected environmental noise, suppressed reciprocal mixing, reduced gain, or removed part of the desired waveform. Remeasuring the desired transfer separates these interpretations. The signed-frequency and admitted-power conventions of Model 11B are especially useful when the challenge involves reciprocal mixing.

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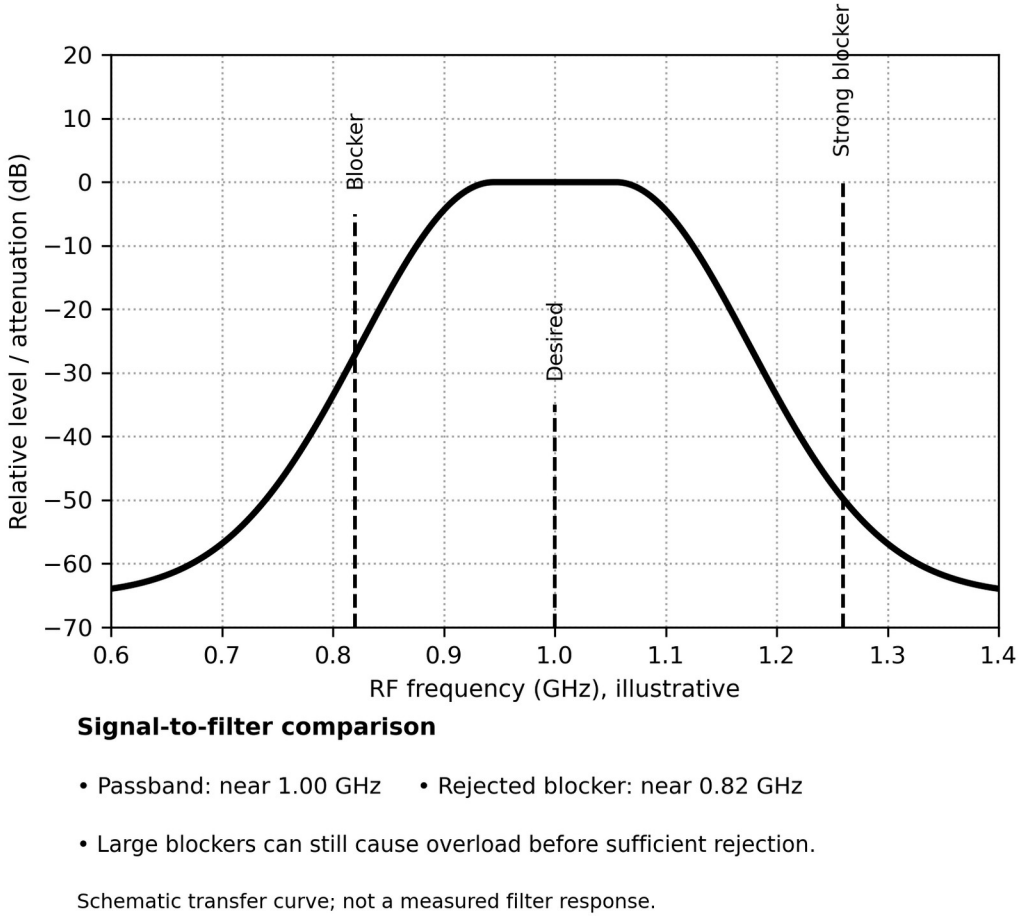

Figure 11. Preselector rejection and out-of-band blocking.

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3.5 Gain Distribution and Attenuation

Gain should be distributed so that the system remains above later-stage noise without sacrificing headroom at early stages. Input attenuation protects the front end and provides a powerful linearity challenge. Preamplification can improve noise performance but reduces input intercept margin. Variable-gain amplifiers, RF attenuators, IF gain, digital scaling, and detector normalization may interact, especially under automatic control.

A useful survey records at least two gain states. A genuine external signal should change predictably after correction for the altered gain or attenuation. A component that does not follow the expected change can be generated after the switched element, clipped by a later stage, or affected by control loops. Step-attenuator accuracy, repeatability, contact condition, and frequency response should be included when the result depends on a small level difference.

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3.6 Choose gain from a feasible interval

Model 2B supplies a minimum gain needed to suppress later receiver noise. A separate large-signal analysis supplies an upper gain compatible with downstream loading. The useful choice lies in the overlap. Application 2B.5 shows the diminishing return clearly: after later noise is already small compared with first-stage noise, more gain gives little improvement in input sensitivity. It still raises every admitted signal at the next stage. A gain plan should therefore state both the noise target and the limiting signal condition, rather than treating low displayed noise as the only objective.

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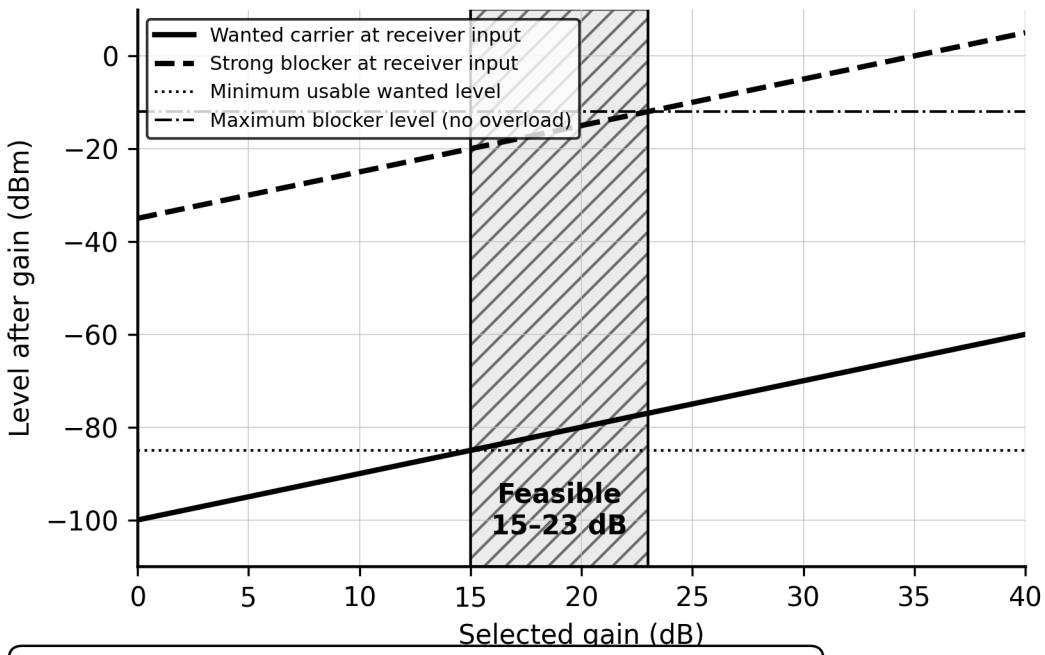

Gain constraints referred to the same measurement plane:
Wanted signal: $-100 + G \geq -85 \Rightarrow G \geq 15$ dB
Blocker: $-35 + G \leq -12 \Rightarrow G \leq 23$ dB

Practical check: gain alone cannot improve an inadequate input SNR.
Also test preselector loss, intermodulation, ADC headroom, and state changes.

Figure 12. Usable gain, noise and overload limits.

The location of an attenuator determines what it protects. Application 2B.7 places the same nominal attenuation before and after an amplifier. Equal total signal gain does not mean equal noise or equal protection. Attenuation after the amplifier may preserve a good formal small-signal noise figure

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while leaving that amplifier overloaded. Conversely, attenuation before it can restore linear operation at a high sensitivity cost. The corrected display may continue to show the same desired signal level because the instrument accounts for its attenuator; that correction says nothing about the physical noise penalty.

Gain control adds a time dimension. If automatic gain control responds to an intermittent blocker, the weak desired signal can change even while its source remains constant. A sample record should retain the gain state or a sufficiently resolved gain-control trace when quantitative amplitude is needed. If the state cannot be reconstructed, amplitude comparisons spanning the transition require qualification. A calibration performed at one settled gain does not automatically describe the trajectory between states, and an average gain value cannot undo clipping or missing samples during that trajectory.

A later digitizer introduces another constraint: analog signal and noise must use its range adequately without approaching overload. Increasing analog gain can reduce the input-referred significance of converter noise, but it cannot improve an already established analog signal-to-noise ratio. The sampling and digitizer treatment in Chapter 10 must be applied at its actual input plane. Chapter 9 supplies the relevant FFT normalization when a spectrum is derived from those samples. An apparently quiet digitized trace can instead indicate insufficient analog gain, heavy digital averaging, or clipping followed by scaling. Preserve raw samples and state metadata before interpreting the display.

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3.7 Input Protection and Recovery

Limiters and protection devices can prevent damage from high-power pulses, transmitter leakage, electrostatic discharge, and accidental connection. Their recovery time, leakage, capacitance, insertion loss, harmonic generation, and power history matter. A limiter that has survived an overload event may remain functional at low frequency while introducing distortion or loss at higher frequency. Gas devices, PIN limiters, transient suppressors, and relay contacts have different signatures.

Protection is not a substitute for exposure analysis. The practitioner estimates expected continuous and peak power, duty factor, antenna gain, near-field coupling, and switching transients before connecting the receiver. Directional couplers, external attenuators, power sensors, or sacrificial front ends may be necessary. Following a suspected overload, the receiver is checked with known references at several levels and frequencies before evidence is accepted.

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3.8 Measure protection in the small-signal and recovery states

A protection element participates in the signal path even when it is not limiting. Its insertion loss, return loss, and reactive loading can change the desired transfer and the noise budget. In a PIN-diode limiter, stored carriers change the diode's RF resistance during a large signal, and removal of those carriers affects the return to low insertion loss. MACOM's receiver-protection explanation describes both this charge behavior and the role of the external current path. The diode geometry also affects capacitance. These mechanisms justify measuring the complete mounted protection network rather than assigning it an ideal on/off state.[9]

Protection has at least three distinct consequences to characterize: the signal that leaks through during the large event, the survival of the protected hardware, and the recovery of a valid weak-signal measurement afterward. A device can survive while the useful channel remains desensitized. A short leading transient can reach a downstream component even when the later leakage is limited. A catalog recovery time must be interpreted with its test conditions and the required recovery criterion; the time to return near nominal insertion loss is not necessarily the time to recover calibrated phase or a detector's baseline.

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9 James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. Its historical radiometer thresholds are not adopted as acceptance limits for the present constructed receiver.

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The ADL8201 data sheet illustrates the separation of these quantities. Its tables distinguish insertion loss, leakage, compression, intermodulation, and recovery from pulse-width and duty-cycle dependent survivability data. Those are specifications of that device under stated conditions, not transferable limits for another receiver or for an arbitrary assembly. An acceptance plan should carry the same separation into its own measured quantities, with the actual instrument and accessory limits governing the applied challenge.[10]

To evaluate recovery, retain a weak desired reference while applying a bounded, independently controlled strong-signal event. Observe the reference before, during, and after the event. Define recovery by the measurement need, such as return of amplitude within a stated tolerance and restoration of the baseline variance. Record the event waveform, repetition, timing, and gain state. Repeating only a continuous-wave sweep will not expose a recovery interval after a pulse, and observing only the end of a long record can miss the period in which nearby events would have been undetectable.

Interpret an apparent recovery delay carefully. The protection network, amplifier bias, automatic gain control, digital filter, detector averaging, and trigger logic can each introduce persistence. A shorter detector time constant may reveal the analog recovery more clearly but also changes the

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10 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf; MACOM, “Designing with Diodes: Protecting Sensitive Components” (September 2, 2022), receiver-protector operation and recovery discussion, https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting. These are identified examples of preselection, gain placement, and protection, not a universal front-end architecture or an instrument-independent limit.

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measurement noise. A bypass comparison can help only when it is permitted by the hardware configuration and the remaining path remains within its ratings. The resulting evidence should identify which part of the path was actually isolated. Do not assign a delayed trace to a limiter merely because a limiter is present.

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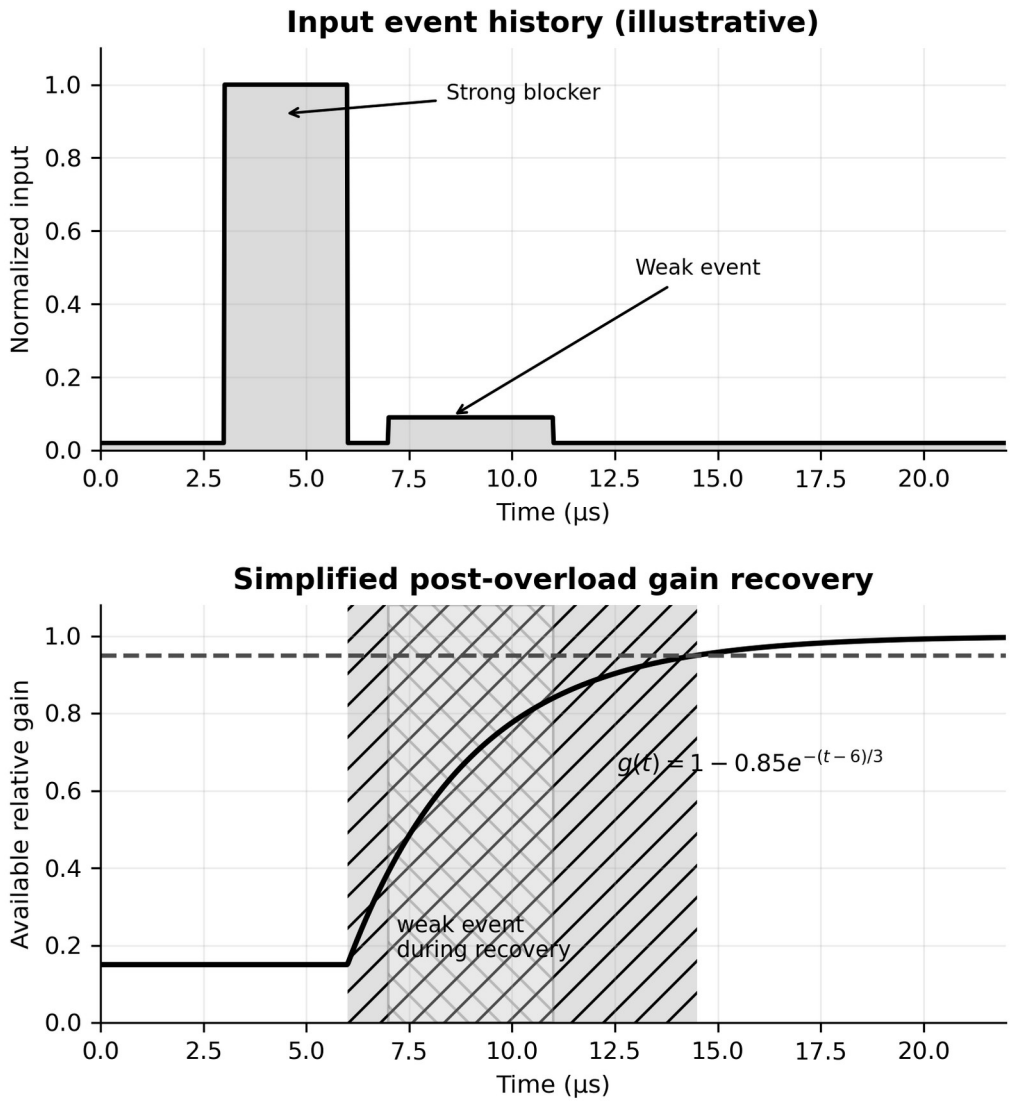

TECHNICAL INTERPRETATION

A strong blocker may disappear before the gain state has recovered.
A weak event during recovery can be attenuated or entirely missed.

Figure 13. Limiter overload and recovery time.

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3.9 Front-End Characterization and Field Decisions

Characterization includes insertion gain or loss, passband shape, return loss, compression, intermodulation, noise contribution, switching repeatability, and leakage between paths. A vector network analyzer can measure small-signal response, but large-signal and pulsed behavior require appropriate sources, couplers, power sensors, and protection. Temperature and bias state should be controlled where active devices are involved.

Field choices are driven by the environment. In a strong broadcast area, a narrow preselector and moderate input attenuation may produce better sensitivity to the signal of interest than maximum preamplifier gain. Near a pulsed radar, peak-power protection and time-domain blanking may be necessary. Indoors, multiple antennas and polarization changes can reduce a dominant local signal without changing the receiver. The selected front-end state and its rationale belong in the survey record.

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3.10 An acceptance sequence that separates competing failures

A defensible front-end acceptance begins with the sources and combining path. Two generators joined through a poorly isolated combiner can interact and create products before the receiver. Measure or otherwise bound the desired and blocker levels at the intended receiver plane, verify the combining components at the applied levels, and retain a check of source spectral purity. If a new line appears, a source-path control is needed before attributing it to receiver intermodulation. The same principle applies to broadband noise: the blocker source may carry noise at the desired channel.

Next establish the quiet small-signal response at the frequencies and levels that will be used. Retain desired gain, noise baseline, and relevant phase or modulation quality. Introduce the blocker in controlled steps while keeping the desired source fixed, then remove it and confirm return. Repeat in the alternative preselector or attenuator state that the mechanism predicts should matter. The sequence is informative because the predictions differ: compression changes desired transfer, reciprocal mixing raises admitted noise, and a discrete intermodulation mechanism produces particular frequencies. More than one mechanism can occur simultaneously.

Table 3A. Evidence to retain during a constructed front-end challenge

Question	Observable	Controlled change	Interpretive limit
Does desired transfer change?	Desired amplitude and quality	Blocker level with fixed desired source	A gain-control response can mimic compression
Does admitted noise rise?	Linear integrated channel noise	Blocker offset and preselection	Source noise must be bounded

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Question	Observable	Controlled change	Interpretive limit
Does a discrete product appear?	Product frequency and level	Tone frequencies and input attenuation	Combiner or source products remain alternatives
When is validity restored?	Desired response versus time	Bounded strong-event duration	Detector settling can mask analog recovery
Is the path stable afterward?	Closing reference and baseline	Return to original state	One frequency does not verify every band

For each change, retain a comparison at a common input plane and a record in the physical output units. The corrected comparison answers whether the external signal estimate changed; the raw comparison helps show whether the receiver actually changed gain or noise. If both cannot be reconstructed, a later analyst may be unable to distinguish an intentional attenuator correction from an unexplained level shift. Retaining the instrument settings as text or machine-readable metadata is more reliable than relying on a screen image whose annotations may be incomplete.

An unresolved challenge is still a useful result. If increasing attenuation suppresses both an apparent product and the desired reference below the measurement floor, the observation does not establish the product's origin. If two states produce different noise but also different bandwidths, repeat with matched bandwidth or account for the difference explicitly. State which competing explanations remain. This disciplined endpoint prevents a plausible front-end story from becoming a stronger claim than the test supports, and it supplies the artifact review in Chapter 16 with evidence that can be reexamined.

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3.11 Verification and Maintenance Controls

Front-end verification is repeated after cable changes, filter substitution, overload events, firmware updates, battery replacement, and transport between sites. Reference sweeps and two-tone tests are compared with accepted baselines using serialized accessories and controlled torque. Differences that exceed uncertainty are investigated before the path is returned to service.

Maintenance records distinguish ordinary wear from hidden configuration changes. Attenuator contacts, relay isolation, filter tuning, bias current, limiter leakage, connector damage, and thermal drift can alter performance gradually. The receiver system is released with known limitations and a documented frequency and level range rather than a blanket statement that it passed.

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3.12 Quantitative Model for RF Front Ends, Preselection, Gain Distribution, and Input Protection

Equation 3. Linear cascaded gain

$$G_{\text{total}} = G_1 \times G_2 \times \cdots \times G_n$$

Total available power gain in linear units is the product of stage gains when reference impedances and mismatch conventions are compatible. In decibels, gains and losses add algebraically. The relation does not establish headroom or linearity.

Equation 4. Input power after front-end correction

$$P_{\text{stage,dBm}} = P_{\text{input,dBm}} - L_{\text{filter,dB}} - A_{\text{att,dB}} + G_{\text{LNA,dB}}$$

Power entering the next stage equals input power minus filter loss and switched attenuation plus amplifier gain. Each term is frequency, temperature, and state dependent, and the result must be compared with compression and damage limits.

Equations 5 and 6 reuse the scalar gain chain of Model 2B. Its ten applications and the gain-interval discussion in this chapter show why a noise calculation must be paired with a separately justified upper signal-level limit. A positive power gain is dimensionless in Equation 5; the signed corrections in Equation 6 are numerical values in decibels.

Table 2. Chapter 3 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Preselector	Passband, rejection, insertion loss, switch state, and group delay	Reduces out-of-band energy before vulnerable stages	May suppress broadband or frequency-agile signals

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Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Input attenuation	Actual step loss, flatness, repeatability, and placement	Provides headroom and a linearity challenge	Uncorrected traces cannot be compared directly
Preamplifier	Gain, noise figure, intercept, compression, bias, and stability	Can improve sensitivity when placed before loss	Can oscillate or generate intermodulation in strong environments
Protection network	Peak rating, recovery, insertion loss, leakage, and post-event check	Reduces damage risk	May create distortion or remain degraded after an overload

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3.13 Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection

A front end contains a 2.1 dB filter loss, 10.0 dB attenuation, and a preamplifier with 17.5 dB gain. A -62.0 dBm antenna-terminal signal reaches the mixer at -56.6 dBm. If the mixer's input compression begins near -25 dBm, the nominal headroom is 31.6 dB, but strong out-of-band signals must be included in the total power and intermodulation assessment.

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3.14 Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection

A suspected 1.2 GHz emitter appears only with the broadband input selected. Switching to a measured 1.0-1.4 GHz preselector removes the component, even though the filter passes the displayed frequency with less than 2 dB loss. A two-tone test reproduces the component from strong signals at lower frequencies. These observations support a receiver-product hypothesis. Assigning the product specifically to the receiver front end still requires bounding source and combiner products at the receiver plane and verifying the desired-reference transfer through both input states, as discussed in Model 11A.

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3.15 Additional analytical treatment: the input plane as a coupled nonlinear system

A receiver-front-end arrangement should not be characterised merely by adding the nominal gains printed beside its component symbols. Its function is to preserve a specified property of incident electromagnetic energy in the presence of competing energy, mismatched interfaces, component memory and uncertain physical conditions. That statement begins at a declared electrical reference plane, for example the coaxial connector at the enclosure boundary. Antenna-terminal power may differ from power incident upon that connector because the preceding cable and protection assembly has both dissipative and reflected loss. The expression for a scalar input power budget is justified only when the quantities are compatible, the impedances are specified and the components are operating within the linear regime. Otherwise the description must use incident and reflected waves or another verified nonlinear model. A device's gain in a catalogue is not a sufficient identification of the device's measurement state.

The correct primitive observation is the time-dependent voltage or travelling-wave combination at the receiver's measurement plane, together with its spectral content and uncertainty. A strong distant transmitter may contribute power far outside the narrow frequency range currently displayed on the analyser. Before preselection, that power can load an input limiter, protection switch, preamplifier or mixer. Thus an apparently empty displayed span can coexist with a crowded physical front end. An operator seeking a faint emission must define the complete incident frequency range relevant to overload, not merely the display's centre frequency and

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resolution bandwidth. The scope of that range should follow from filter rejection, active-device frequency response and the credible environmental source distribution. Where total incident power cannot be measured, the resulting limitation belongs in the conclusion.

A simple representation introduces x(t), the voltage waveform at a declared input reference plane; s, the hardware configuration state; T, the component temperature state; and H[s,T]{x(t)}, the transformation from that waveform to the analogue converter input. A measurement y(t) may be expressed as y(t)=H[s,T]{x(t)}+n(t) when an additive-noise approximation is valid. Here n(t) is the effective noise after the modelled transfer, not automatically a stationary Gaussian process. If H depends on previous inputs because of limiting, bias recovery, thermal drift or gain feedback, a time-invariant transfer function is insufficient. In practice one measures local responses to controlled small signals while varying blocker amplitude and time history. A defensible investigation does not infer linearity from a quiet display. It directly tests the range of inputs for which the local approximation remains acceptable.

Input protection must be analysed through three observations with different acceptance criteria. The first is survival: no irreversible damage from the stipulated maximum exposure. The second is leakage: the voltage or power allowed to reach a vulnerable downstream node while the protection element is operating. The third is recovery: the elapsed time until the protected chain again meets a predefined weak-signal measurement specification. Meeting the first criterion does not establish the other two. A limiter may preserve an amplifier from damage but retain trapped charge, alter its impedance or provoke a downstream automatic gain reduction long

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after the triggering pulse has ended. The report must declare its recovery criterion in observable terms, for example whether a low-power reference has returned to its initial amplitude within a stated tolerance and whether its variance has returned to a validated range.

A field acceptance test should therefore bracket all consequential state changes with a repeatable control. Begin with an authorised reference at a known plane and measure gain, noise and response time before exposure. Apply the bounded challenge waveform through a calibrated combining network, record the actual delivered level and monitor the receiving chain without exceeding component limits. Remove the challenge, restore the identical reference settings and record the return to the prior validated state. Repeat with the preselector and attenuator alternatives required by the operating plan. If the observed change follows a cable or amplifier substitution rather than the suspected external source, that differential result provides evidence about the chain, not necessarily about the nature of the outside environment. It also provides a stronger safeguard against attributing receiver-generated products to third-party apparatus.

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3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings

The phrase maximum input level is ambiguous unless the duration, frequency distribution, impedance, state and acceptance criterion are supplied. Continuous single-tone power may be constrained by amplifier compression or heating; pulsed energy may be constrained by a transient voltage rating, protective recovery or peak current; a strong out-of-band signal may exceed the tolerance of a broadband input switch even when a following preselector is capable of excellent rejection. Moreover, two strong tones can create third-order products inside an input amplifier while the desired frequency itself receives only modest incident energy. Maximum safe exposure, maximum linear input and maximum signal level for accurate amplitude estimation are consequently three different boundaries. They cannot be substituted for one another in a technical survey report.

Define P_B as the sum of powers of all blockers reaching the vulnerable device plane, P_D as the power of a desired test tone at that same plane, G as the linear power gain, and P_{1dB} as the measured output power at which gain has compressed by 1 dB under the stated stimulus. A first-order screening calculation may compare P_B+P_D to an extrapolated small-signal output, but the relation is not a complete guarantee when blockers differ in frequency, crest factor or phase. For uncorrelated continuous powers, sum in milliwatts before converting back to dBm. For coincident coherent voltages or strongly peaked waveforms, evaluate the envelope or another appropriate peak criterion. The amount of headroom should be the difference between a justified operating threshold and the worst relevant input at the same node, after all path corrections. It is not the difference

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between a receiver's input terminal rating and a displayed peak that has already undergone filtering.

Preselection is effective only if it acts before the susceptible stage. A selective filter positioned after a nonlinear amplifier cannot remove intermodulation products already created by that amplifier when those products fall within the desired passband. The filter may still protect a later converter but does not retroactively protect the earlier stage. Similarly a digital filter following an ADC cannot repair clipping that occurred at its analogue input. In a mixed architecture the correct order may deliberately sacrifice some small-signal noise performance to prevent irreversible overload. The gain and loss budgets must be evaluated simultaneously, because filtering loss can worsen minimum detectable level while blocker rejection can restore validity over a much larger operating region.

The filter itself should be treated as an imperfect and potentially history-dependent component. A passive tuned filter has measured insertion loss, return loss, stopband leakage, group delay and temperature dependence. A switched filter bank introduces finite switching time, transient leakage and possible contact-related intermodulation. A tracking filter depends on a tuning law which can be offset from the instrument's indicated frequency. A filter chosen solely for narrow nominal bandwidth may deform a pulsed event, because the waveform's spectral sidebands extend beyond its carrier. For short-burst measurement the acceptance criterion must include amplitude and temporal shape, not simply the survival of a monochromatic tone at the centre frequency.

An informative blocker challenge holds the desired reference fixed while varying one blocker parameter at a time. The operator records attenuation,

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input and output power at declared planes, measured filter state, detector configuration, ambient temperature and the receiver's instantaneous gain-control state. Three questions are answered independently. Does the desired reference remain detectable? Does its measured amplitude or spectral shape remain within stated tolerance? Does the purported unknown emission change in a manner consistent with an internally generated artifact? Failure of one test does not necessarily establish the physical identity of the event. A spectral component that disappears when the blocker is attenuated may be a mixing product, a blocker-dependent gain artifact or a genuine weak signal rendered undetectable by the changed noise floor. Further controls are required to distinguish those explanations.

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3.17 Noise, mismatch and gain-order dependencies

The ideal Friis cascade equation applies to properly specified available-power gains and noise factors under its source and impedance assumptions. Let F_i denote the linear noise factor of stage i and G_i the linear available gain of stage i. For three stages, $F_{total} = F_1+(F_2-1)/G_1+(F_3-1)/(G_1 G_2)$. The familiar result that the first stage dominates follows only while G_1 is high enough and the first stage is operating normally. A preamplifier driven into compression does not preserve that calculation's small-signal validity. Likewise noise figure is not an estimate of environmental interference. The antenna may deliver externally generated noise or multiple transmitters far above the nominal thermal reference, and the operator should not confuse a favourable catalogue noise factor with quiet operating conditions.

Loss before the first amplifier matters disproportionately because it attenuates the signal before gain is available. For a passive matched attenuator with linear loss L at the standard reference temperature, its noise factor equals L under the conventional assumptions. At a different physical temperature, the device's equivalent input noise temperature changes and should be handled explicitly if uncertainty warrants. A filter with two decibels of loss can substantially alter the noise budget, but its rejection of strong out-of-band signals may prevent a much greater loss of useful dynamic range. Good front-end design therefore seeks the feasible region in which input-referred noise, blocker tolerance and protected-stage survival are all acceptable. Maximum gain is rarely an adequate optimisation objective.

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Mismatch is another reason a scalar level correction can be misleading. At a two-port connection the incident and reflected travelling waves depend upon source and load reflection coefficients. The power actually delivered to a device differs from a source's available power when the port match is imperfect, and changes in a preselector or cable can alter this ratio. A calibrated sensor that measures power at one connector may not establish the available power presented by an antenna with a different source impedance. Measurements intended for rigorous comparison should record reflection or return-loss information at relevant states, retain the fixture configuration and avoid comparing values reported to different power conventions. An input pad can improve match while adding loss, so a gain correction must not be mistaken for restoration of the signal-to-noise ratio or the physical available power.

A practical uncertainty ledger distinguishes correction uncertainty from repeatability. For a simple corrected reading, $P_{input,dBm} = P_{display,dBm} - L_{gain,dB} + L_{cable,dB} + L_{filter,dB}$, where the chosen signs depend on the actual direction of the calibration reference planes. This expression assumes the receiver gain is defined as output minus input, while cable and filter losses are positive attenuation magnitudes. If those correction quantities are independent, their standard uncertainties may be combined in quadrature. If they share a calibration source, reference attenuator or frequency-dependent model, covariance terms are required. Treating shared errors as independent can create an unrealistically narrow uncertainty interval. Receiver gain and filter loss may even move in the same direction with temperature. The quality of the uncertainty budget rests upon identifying those dependencies before performing arithmetic.

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3.18 Protective switching, recovery and transient exclusion intervals

A receiver should retain a state-transition record when protection relays, limiters, tunable filters and gain-control loops are operated in the course of a survey. The record should identify the command time, the observed hardware transition time if available, and any period for which the output cannot meet the relevant measurement acceptance criterion. These times need not coincide. A host timestamp may correspond to the delivery of a software command while the electromechanical switch continues moving; an ADC may continue sampling the transition; a detector may average across states. If the instrument silently retains samples during this interval, a later analyst may mistake switching transient energy for an event from the external environment. Exclusion intervals should be justified by laboratory measurements, not invented after an unexplained detection.

Protection components can exhibit distinct recovery laws. A fast RF switch may settle quickly in isolation yet leave a gain-control loop recovering slowly. A limiter may recover promptly for a small challenge but exhibit delayed return after a stronger or longer pulse. A charge-storage device can behave differently when two pulses arrive in close succession. Consequently recovery time should be specified over a bounded operating envelope, including challenge amplitude, pulse width, duty cycle, temperature and the defined tolerance for the weak reference signal. An unqualified single recovery-time number risks implying that every operating history has the same effect.

The experimental record should include both positive and negative controls. A positive control deliberately exercises the protection function with a signal

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known to exceed the chosen intervention threshold while remaining within the apparatus' safe operating limits. A negative control repeats the test with a lower-level stimulus that should not cause intervention. A reference receiver, where properly isolated, may distinguish an actual external pulse from an internal switching transient. Yet a shared power supply, reference clock or test combiner can contaminate both instruments, so apparent agreement must still be challenged. Whenever possible use a different input path or independent monitor with separately characterised limitations.

A reversible data record preserves the raw trace, the timing of each state transition, the calibration terms and the reason for excluding a segment from quantitative analysis. The derived record may mark a portion invalid without deleting it, subject to lawful retention and minimisation constraints. This avoids the twin mistakes of falsely treating corrupted samples as trustworthy measurements and silently removing data that a future reviewer may need to understand an apparent anomaly. A robust report identifies the measurement state in which each conclusion was reached and refuses to bridge an unobserved transition by speculation.

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3.19 Ten worked front-end engineering examples, with stated assumptions

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3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget

Suppose a matched front end receives a -67.0 dBm reference tone at the specified input plane. An input filter has 2.3 dB insertion loss at that frequency, a selected attenuator has 6.0 dB attenuation and a preamplifier provides 18.2 dB gain. All parts are assumed linear at the applied power. The estimated power at the amplifier output is -67.0-2.3-6.0+18.2 = -57.1 dBm. If the following converter has a maximum calibrated linear input of -25.0 dBm, nominal headroom relative to this reference tone is 32.1 dB. That result does not mean an additional +32.1 dB of arbitrary environmental interference can be tolerated: signals outside the displayed band may reach the amplifier, and large multi-tone or pulsed inputs may create distortion at lower total power. The correct acceptance statement identifies the particular -67 dBm tone and the stipulated matched, linear state. A blocker test is required before extending it to an RF survey environment.

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3.19.2 Example 3.C2. Converting two blockers to a single equivalent power

Two uncorrelated continuous blockers arrive at a particular vulnerable amplifier input with powers of -18.0 dBm and -21.0 dBm. Converting to milliwatts gives 10^(-18/10)=0.01585 mW and 10^(-21/10)=0.007943 mW. The sum is 0.02379 mW, equivalent to 10 log10(0.02379)=-16.24 dBm. Adding the two values as if dBm were ordinary linear numbers would be physically meaningless. If the device's tested maximum linear input for this stimulus family is -14.0 dBm, the simple power margin is 2.24 dB. That margin is small enough that measurement uncertainty, another unobserved blocker, modulation crest factor or phase coherence might change the conclusion. This calculation concerns incoherent average powers and does not establish the peak voltage of a phase-related multi-tone waveform.

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3.19.3 Example 3.C3. Why filter placement changes intermodulation validity

A broadband amplifier precedes a bandpass filter. At its input two equal unwanted tones are each -22 dBm, and a small-signal input third-order intercept of +8 dBm has been measured under a specified equal-tone test. Under the conventional weak-distortion approximation, the third-order product from one fundamental is $P_{IM3} = 3 P_{tone} - 2 IIP3 = 3(-22)-2(8)=-82$ dBm referred to that amplifier input. Suppose the following bandpass filter passes the resulting product at the frequency under examination. Its attenuation of the two original blocker tones cannot remove the product already generated. If a suitable preselector were moved before the amplifier and suppressed each original blocker by 15 dB, the same approximation predicts $P_{IM3} = 3(-37)-16=-127$ dBm at the amplifier input reference. The 45 dB predicted product difference illustrates why component order matters. It remains conditional on constant IIP3, equal-tone validity and the source-combining network not creating its own products.

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3.19.4 Example 3.C4. Input attenuation as an overload intervention

Assume an otherwise linear receiver shows a faint spectral component at -96 dBm displayed, while its wideband input is illuminated by an unmeasured powerful transmission. The operator inserts a calibrated 10.0 dB input pad. A genuine weak signal that follows the ordinary linear gain path should be reduced by approximately 10 dB before any software correction, provided the added attenuation does not move it below the noise or alter the detector decision. A receiver-generated third-order product produced after the pad may decrease by approximately 30 dB under the usual two-tone weak-distortion model. A change larger than the desired tone's change is therefore a diagnostic clue, not proof. The operator must compare raw levels, noise and corrected input-referred values, and should repeat with more than one attenuation state. If the purported component disappears entirely, the correct initial finding is that it is state-dependent and unresolved, not that a particular external transmitter has been disproved.

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3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor

Take a passive matched filter whose insertion loss is 2.0 dB at the measurement frequency and whose physical temperature is close to the conventional noise reference. Its linear loss is L=10^(2/10)=1.585, so its approximate noise factor is 1.585. Follow it with an amplifier of 15 dB gain and 1.5 dB noise figure. The amplifier's linear noise factor is 10^(1.5/10)=1.413 and its gain is 31.623. Referred to the filter input, the two-stage cascade is F_total=L+(F_amp-1)/G_filter, where G_filter=1/L=0.631. Hence F_total=1.585+0.413/0.631=2.239, equivalent to a 3.50 dB noise figure. This result is consistent with a filter loss adding approximately 2 dB to the amplifier noise figure under the stated matched, reference-temperature conditions. It is not a substitute for a noise measurement when the filter's temperature or mismatch differs appreciably.

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3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier

Consider a reference chain with a 20 dB low-noise amplifier and a 10 dB attenuation pad, both well matched. Its net small-signal gain is 10 dB regardless of the pad's position. Yet the consequences differ. With the pad before the amplifier, an input blocker of -5 dBm reaches the amplifier near -15 dBm. With the pad after the amplifier, the same blocker reaches its input at -5 dBm and may overload it even though the final output level is nominally identical. Moreover, the preceding pad increases the input-referred noise factor of the system, whereas a pad after a sufficiently high-gain low-noise amplifier ordinarily contributes less to the overall noise factor. This example illustrates a trade-off, not a universal preference for one ordering. In a high-blocker environment the lower-noise configuration may be physically invalid unless preselection or another protective measure is introduced.

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3.19.7 Example 3.C7. A conservative frequency-dependent correction

A reference source delivers -80.0 dBm at an antenna-port test fixture. The cable loss measured at the target frequency is 3.1 dB and an input filter contributes 1.7 dB, both expressed as positive loss. The receiver input therefore receives an estimated -84.8 dBm, ignoring mismatch. Suppose the displayed receiver result, corrected for its internal calibrated gain, is -84.5 dBm. The 0.3 dB disagreement is not automatically significant. If the standard uncertainties of source level, cable loss, filter loss and corrected receiver level are respectively 0.2, 0.15, 0.12 and 0.25 dB and are genuinely uncorrelated, their root-sum-square is sqrt(0.2^2+0.15^2+0.12^2+0.25^2)=0.374 dB. A 0.3 dB discrepancy is smaller than that combined standard uncertainty. Shared source and receiver calibration would require a covariance-aware treatment and could change the inference.

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3.19.8 Example 3.C8. Recovery time after a protective intervention

A calibrated low-level reference remains present while a lawful laboratory pulse activates an input protection element. Before the challenge, the corrected reference amplitude is -70.0 dBm and a short-window measurement variability has been characterised. The acceptance criterion is restoration within +/-0.5 dB of the baseline for at least five consecutive 1 ms analysis windows, without a renewed overload indication. After the pulse, the first windows fall at -73.0, -71.5, -70.6, -70.3, -70.2, -70.1 and -70.1, -70.0 dBm. The first qualifying five-window sequence begins with the fourth value, because the third differs by 0.6 dB. With nonoverlapping 1 ms windows and known alignment, the candidate recovery interval begins with the fourth window and is confirmed only after the eighth observed window. The actual recovery interval is bounded by the timing resolution and window origin; the numbers do not establish phase or waveform-shape recovery. An independent noise-variance test remains necessary if that too is required by the measurement.

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3.19.9 Example 3.C9. A mismatch screening calculation

Suppose an interface has an effective magnitude of reflection coefficient |Gamma|=0.20 relative to the declared reference impedance. The reflected power fraction is |Gamma|^2=0.04, or 4 percent, while the nonreflected fraction in the simplified single-interface model is 0.96. The corresponding mismatch-only loss is -10 log10(0.96)=0.177 dB. That result does not predict the entire mismatch error of a source connected through a two-port network, because the source reflection coefficient, electrical phase, standing-wave relationships and frequency-dependent transfer also matter. It provides a limited screening result: even an apparently modest return loss can introduce a correction whose significance depends on the required amplitude uncertainty. A careful investigator retains the complex scattering parameters or a validated mismatch uncertainty model rather than applying one universal 0.177 dB correction.

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3.19.10 Example 3.C10. Selecting a feasible gain interval

A nominal desired signal arrives at -100 dBm and the following converter's calibrated minimum useful level is -78 dBm. The necessary net gain for this nominal desired signal is at least 22 dB. Independently, a worst-stipulated blocker arrives at -12 dBm and the first vulnerable downstream component must see no more than -20 dBm to remain within its validated linear range. That condition requires net gain of at most -8 dB along the blocker's path. If the architecture provides the same gain to both frequencies before any selectivity, no single scalar gain meets both bounds. The appropriate design response is to change the front-end topology, provide frequency-selective attenuation, obtain more intrinsic dynamic range, or alter the observation arrangement. Pretending that the 22 dB desired-signal gain can coexist with the -8 dB blocker constraint would conceal an empty feasible interval. Any new filter must be tested for both desired insertion loss and blocker rejection.

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3.20 Laboratory decision protocol and defensible reporting

A complete front-end report should include a configuration schematic identifying the input and output planes, a state table for each switchable signal path, the serial or traceable identifier of each consequential component, a calibrated small-signal transfer measurement, and a separate challenge record for nonlinear and time-dependent behaviour. A useful state table has fields for filter path, gain stage, attenuation, limiter state, detector mode, reference clock, temperature, measured noise baseline, and the beginning and end of each observation interval. Values inherited from a previous survey are not silently reused after cable substitution, thermal excursion or overload. The report also identifies any interval in which input conditions exceeded the validated apparatus envelope, including intervals inferred from status flags rather than continuously measured incident power.

Before a component is attributed to an unknown external emitter, the laboratory should ask whether a different combination of filter state, input attenuation, reference antenna and independent receiver gives a consistent input-referred result. Agreement should not be manufactured by correcting away actual discrepancies. When two arrangements share the same input switch, reference clock or power source, their errors may be correlated; a claim of independent corroboration must account for that commonality. A negative challenge may show only that an internal artifact hypothesis has not been reproduced under the tested conditions, not that every possible internal cause has been excluded. Conversely a reproduced artifact under controlled injection can support a much narrower and more useful

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conclusion: the particular measured feature is consistent with a documented front-end failure mode.

The end product is a bounded finding with four separate elements: the observation itself, the verified measurement state, the controls that failed or supported alternative explanations, and the uncertainty that limits inference. That formulation is more robust than a confident description built solely around a colourful spectral display. It remains readable to a technically qualified independent examiner and supplies a path for reanalysis if later information about the source, calibration or lawful scope becomes available. Every illustrative calculation in this extension is hypothetical. It is not evidence of measured performance of the reader's instruments; the appropriate field limits must be established on the actual hardware and configuration.

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3.21 Multitone loading, receiver-generated emissions and the distinction between power and voltage stress

One of the most persistent errors in field receiver selection is the assumption that a small number on the display reflects a correspondingly small voltage at every preceding analogue component. In a multi-emitter environment, the highest instantaneous stress may be created by signals that the chosen tuning and display configuration deliberately exclude. A first-stage switch designed to cover an octave may receive the combined energy of broadcast, communication and industrial emissions even when the selected channel is only a few kilohertz wide. An electrical model of loading must therefore specify whether its limit is expressed in total average power, peak envelope power, peak voltage, current, junction temperature, intermodulation distortion or a recovery-dependent validity criterion. Those limits describe different physical mechanisms, and a single catalogue rating cannot be safely treated as a bound on all of them.

To distinguish the mechanisms, consider a two-tone source whose tones have equal powers P_1 and P_2 and phases ϕ_1 and ϕ_2. The average power into a matched linear resistor is additive when averaging over a suitable observation interval, but the instantaneous voltage is the algebraic sum of the waveforms. At some instants the two voltage components reinforce. When several tones have related phases, the peak-to-average ratio can rise substantially above that of one sinusoid. For modulated signals, peak envelope power may vary with symbol sequences and with the distribution of occupied subcarriers. Consequently an amplifier chosen on the basis of average-input headroom may saturate briefly on rare peaks and produce error bursts in the digital record. An acceptance test should include

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the relevant peak statistics, preferably using a separately verified source waveform rather than assuming that two nominally equal average powers create an identical envelope under every phase relation.

Third-order intercept values deserve similarly careful treatment. The familiar extrapolation for an input-referred third-order product from equal tones is a useful local model while the amplifier is weakly nonlinear and the products are significantly below the fundamentals. It is not an independent physical guarantee of dynamic range under arbitrary modulation, wide separation, temperature, or saturation. The extrapolated line would falsely suggest increasing product growth without limit if extended through compression. A real receiver can exhibit additional memory terms, bias variations, filter selectivity and gain-control responses. The investigator therefore needs a measured distortion-versus-level curve over the actual operating region, and should recognise that adjacent-channel regrowth may differ from the ideal products of a narrow two-tone experiment.

Second-order responses have different frequency geometry. Their sums and differences may fall into the desired band even when neither fundamental lies near it. Harmonics can likewise enter through imperfect image rejection or a later mixing mechanism. A sufficiently wide frequency survey of the physical front end is therefore needed to formulate competing internal-artifact hypotheses. This does not authorise unrestricted collection of unrelated communication content. Suitable laboratory substitutes, controlled known sources and aggregate power monitors can establish the chain's susceptibility while respecting the authorised purpose. A test result should state exactly which source family, level interval and hardware

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configuration produced the measured product, rather than suggest that all possible interferers have been excluded.

The combining apparatus itself must be challenged. Two signal generators joined through inadequate isolation can mix in the output stages of one another or within a damaged combiner, creating a product before the receiver under test. If that upstream product is not independently measured or bounded, its appearance at the receiver cannot prove the receiver generated it. A high-quality test uses suitable isolation, independently characterised path levels and a reference monitor connected at a carefully specified plane. The reference monitor has its own finite dynamic range, so it too must be tested for internal products under the challenge conditions. This is an unusually important source of false certainty: an investigation may otherwise demonstrate only that two nonideal test instruments interact, not that the field receiver is intrinsically defective.

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3.22 Front-end noise spectroscopy as an instrument-state test

A receiver's displayed noise floor is a property of its entire measurement configuration, including the source impedance, analogue transfer function, detection and estimator bandwidth, gain-control state, averaging, digitiser scale and any digital correction. A calibrated noise factor is normally defined relative to a specified input noise temperature under particular reference conditions. It is not an instrument's universal minimum observable signal. An electrically quiet terminated input, for example, provides information about internally generated noise but may not represent the environmental noise arriving from an antenna. A low-noise preamplifier can improve a chain's input-referred noise figure while simultaneously increasing susceptibility to a strong ambient transmission. The resulting sensitivity must be evaluated as a conditional detection problem, not as a fixed property printed on the instrument panel.

An appropriate baseline measurement begins with a characterised source at the intended reference plane. A matched termination of known temperature can establish an internal reference state; a known calibrated noise source permits comparison across states; and an independent low-level test tone or modulated waveform can connect the noise statistics to an actual decision threshold. The relevant noise quantity should be computed in the equivalent noise bandwidth of the estimator, not inferred by multiplying arbitrary displayed bin spacing by a spectrum marker. For a filter whose magnitude response is H(f), an effective noise bandwidth can be expressed as the integral of |H(f)| squared across frequency divided by the square of an appropriate peak gain, with the exact formula depending upon the gain

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convention. This bandwidth may differ from the nominal resolution-bandwidth label and can change across filter families or software revisions.

Noise measurements also require attention to drift and dependence. Thermal changes can alter gain and noise factor gradually, while intermittent blocker loading can create abrupt changes or long recovery tails. A single pre-survey noise figure does not show that the same distribution prevailed throughout a day-long capture. Retain state-tagged baseline samples at chosen intervals, record ambient temperature where meaningful, and compare changes against the predicted calibration and uncertainty model. Where a data record shows large spectral occupancy variations, the investigator must distinguish changes in background energy from changes in receiver gain. Using a digital correction to hold the displayed noise floor constant can disguise a real loss of sensitivity if the underlying analogue signal has become compressed or if a gain-control stage has reduced both desired signal and interferer.

The relationship between bandwidth and the noise power is a useful check. Under a thermal white-noise approximation at a specified reference temperature, noise power is proportional to bandwidth. Doubling the equivalent bandwidth increases expected noise power by approximately 3.01 dB. If two otherwise identical settings differ by 10 in equivalent noise bandwidth, the expected integrated noise-power difference is approximately 10 dB. This does not imply that the ratio of probability-of-detection thresholds is precisely 10 dB, because the threshold also depends upon noise distribution, false-alarm constraints, temporal integration and waveform structure. It does expose contradictions in a purportedly

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calibrated noise record: a noise-floor comparison across different bandwidth settings is invalid if the bandwidth dependence has not been accounted for.

A high quality evaluation does not simply produce a single lowest-noise number. It maps the feasible region: input-referred noise versus blocker level, gain state, frequency, temperature and detector algorithm. The measured result can be represented as a multidimensional acceptance surface with clearly defined interpolation limits. If no observations exist near a high-power corner, that corner should remain unqualified rather than populated by a confident extrapolation. A defensible conclusion may show that a narrow preselector state delivers lower detection threshold under a specified blocker while the broadband state performs better in a quiet laboratory. This is not contradiction; it is configuration-dependent performance, and the report should preserve that distinction.

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3.23 Switching architectures and state-machine validity

The physical implementation of preselection determines what it can and cannot guarantee. A tracking filter tuned with the receiver's local oscillator may offer strong rejection of remote interferers but can introduce tuning error, settling delay and amplitude ripple. A switched filter bank may offer rapid operation across selected ranges but presents transitions at band edges, finite relay or semiconductor isolation, and different loss characteristics in each branch. A fixed multi-band network may be robust but less selective in a highly occupied environment. There is no universally correct topology because the objective may be to characterise a narrow transmission, detect a very short broadband pulse, or monitor many noncontiguous services with unequal probabilities of occurrence.

An instrument whose preselector state changes automatically has a time-dependent measurement operator. The state transition may be commanded in software, applied by hardware after an uncertain delay and confirmed only when an internal control signal settles. The software's recorded timestamp may refer to the command rather than the actual RF path. A rapid-frequency scanner might therefore attribute energy received during a transition to the next channel even though the analogue filter had not reached that state. This failure may generate a convincing event list whose frequencies appear exact to the nearest programmed tuning step. A validity window should be derived from test observations of the complete switching path and extended by appropriate timing uncertainty. The interval must be excluded or separately marked in the analysis, without silently deleting raw source records where lawful preservation is required.

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A state-machine acceptance test can deliberately command rapid transitions while a fixed, authorised test tone remains present. The signal's apparent frequency, amplitude and event time are compared with a simultaneously recorded independent reference. The test repeats with a tone near each filter transition, because the most consequential errors frequently occur at the edges rather than in the centre of a nominal passband. It also tests absent-signal cases. A receiver that produces a spurious peak during a relay movement may otherwise be mistaken for a detector that faithfully caught a rare short burst. The tested conditions should include temperature excursions, supply variation within rated limits and repeated operations sufficient to reveal intermittent switch contact behaviour.

A practical design may use two measurement paths. The main receiver scans or switches preselectors to achieve acceptable sensitivity and blocker rejection; an independently characterised auxiliary receiver monitors an appropriate wider band to detect events that occur during the main path's blind intervals. This can improve situational awareness, but it does not create perfect coverage by definition. The auxiliary path may have poorer dynamic range, different time stamping or a shared antenna front end that fails under the same blocker. Its detections can be valuable triggers for a subsequent controlled measurement, yet an event visible only on the auxiliary path must be reported with that path's own calibration and limitations. The system must not borrow precision or attribution capabilities from the main receiver when those observations were never actually made.

A recording system should preserve machine-readable state information, preferably aligned to the hardware's own acquisition counter rather than to an operating-system wall clock alone. It should identify the filter path, relay

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state, gain, attenuation, limiters, ADC validity flag, clock discipline and any estimated missing-sample intervals. This record provides a basis for reconstructing which measurements were lawful and technically qualified at each instant. It also permits later investigators to challenge a classification decision without changing the original observations. State identity is part of the measurement, not an optional engineering diary.

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3.24 Low-level event survival under analogue filtering

Preselection is sometimes proposed as though narrow passband transmission and high stopband rejection were sufficient to preserve every legitimate event. That is inadequate for short transients. A burst's energy is spread over a bandwidth related to its duration and modulation; rapidly changing waveforms contain sidebands which may be outside a narrow preselector. A filter can preserve an apparent carrier frequency while attenuating the edges, extending the pulse in time, changing phase and creating ringing. A detector that reports the resulting duration may therefore be reporting the instrument's impulse response rather than the original source's emission interval. The needed acceptance criterion must specify the allowable changes in amplitude, delay, envelope or correlation statistic for the relevant waveform class.

An elementary linear model represents the output y(t) as the convolution of the input x(t) with a measured impulse response h(t). The convolution model is justified only if the filter behaves approximately linearly and time invariantly over the observation interval. In practice a highly selective tracking filter may be changing its centre frequency while the burst arrives, so a single fixed h(t) may be invalid. A state-indexed family of responses, with explicit transition intervals, is more defensible. If a receiver measures only the magnitude of a transformed waveform, phase information necessary for an exact inverse may already be absent. Similarly, if the filter has practically zero transmission over some spectral region, recovering that portion of an arbitrary unknown waveform may be ill posed. A reconstructed sharper pulse is not a restored original unless its assumptions and uncertainty are independently established.

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A useful test programme applies laboratory signals that deliberately exercise the boundaries of the intended interpretation. These may include a narrow continuous reference, a gated carrier, a chirp, a pulse train with changing duty cycle and an amplitude-modulated event with steep edges. Compare the output with an independently calibrated wideband reference at the same input plane. For each case retain insertion loss at relevant spectral components, apparent event duration, group-delay behaviour, trigger response and any ringing or post-pulse persistence. Vary the event start time relative to filter state changes. The resulting dataset can support a statement such as: within the tested duration and bandwidth region, a particular preselector state preserves the selected timing statistic within a bounded error. It should not support an unconditional claim that every possible unknown pulse is preserved.

A narrow-band measurement can remain valuable even if it does not preserve waveform shape. For example, detecting persistent energy near a suspected carrier may require neither time-domain fidelity nor phase coherence, provided the limited conclusion is explicit. But an investigator seeking to compare brief onset transients between devices must use a measurement chain and sampling arrangement capable of preserving those features. Choosing the receiver mode from the forensic question is therefore more important than choosing the smallest displayed resolution bandwidth. The same hardware may be fit for an occupancy claim and unfit for individual-emitter timing inference.

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3.25 Power-sensitive failure modes and fault isolation

A receiver may exhibit nonlinear products whose incidence depends on power-supply loading rather than on the nominal signal-path architecture. A high-level external pulse can change amplifier bias current, heat a protective device or disturb a shared supply rail. The resulting transient may leak into multiple nominally independent RF channels. If those channels share the same DC/DC converter or bias-control arrangement, coincident features do not constitute independent observations of one external emitter. A forensic test should vary one source of stress at a time, monitor relevant bias and supply states where permissible, and compare against a truly separate measurement path. A common power disturbance is an alternative hypothesis that must be considered whenever correlation appears unexpectedly perfect across many channels.

Mechanical and electromagnetic coupling also interact. A shielded enclosure is not a perfect abstraction if cable shields conduct current on their exterior surfaces, if panel seams create slot apertures, or if a connector is contaminated or incompletely tightened. An RF field may couple directly into a local oscillator or digital clock network and create a response that differs from ordinary antenna reception. An instrument whose antenna connector is terminated can still show a spectral feature from internal or enclosure coupling. A different terminated-input response is a useful challenge but not a universal proof, because the termination itself may change grounding or impedance. Multiple controls should be chosen to discriminate a physical coupling mechanism rather than to make the apparent event simply disappear.

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Conducted interference through mains supplies, network ports or peripheral cables may produce products which track external activity but are not radiation received by the intended antenna. The study should record whether changing an isolation arrangement altered only the suspected coupling path or also changed the receiver's reference and grounding. For example, removing a network cable might stop a periodic component while also terminating the data stream that produced the spectrum. That observation suggests a relationship, but does not settle whether the original feature was a genuine external RF emission, a digital harmonic, or a gain artifact driven by supply noise. The conclusion should be proportionate to the specificity of the control.

In an operational survey, the safest correction is often to improve the physical receiving chain rather than to perform increasingly elaborate software removal of unexplained peaks. Controlled input attenuation, validated preselection, sound connectors, independently measured shielding and proper reference-plane calibration can prevent misleading artifacts at the source. A software algorithm may flag likely spur families, but cannot repair analogue measurements whose provenance or linearity is unknown. Data-processing sophistication does not remove the need for elementary electrical checks. The audit trail should show which interventions altered the physical chain and which merely reinterpreted its records.

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3.26 A graded laboratory qualification matrix

Qualification should be tied to the intended measurement claim and should not consist of one undifferentiated pass or fail mark. A minimal receiver chain intended for approximate occupancy might require repeatable frequency coverage, a validated detection threshold and documented blind intervals. A chain intended for precise amplitude comparison additionally requires calibrated gain, impedance treatment and uncertainty over the relevant signal and blocker conditions. A chain intended for pulse timing requires an independently demonstrated impulse response, clock relation and trigger latency. A chain intended for direction finding needs antenna and phase-response controls outside the ordinary single-port receiver specification. Passing the first level does not imply passage at the higher levels.

One can express this as a set of measurement capability statements. Each statement has a measurand, the physical input reference plane, a frequency and level domain, applicable configuration states, a method for traceable testing and a bound on the resulting uncertainty. The statement should include exclusion conditions. A measurement may be valid for narrowband sinusoids under a low-blocker environment but unqualified for short unknown pulses in a congested spectrum. Such a statement is more useful than an inflated general capability claim because it allows the investigator to choose hardware for the actual question and to report explicitly when the apparatus operated outside its demonstrated envelope.

An especially revealing experiment combines a strong blocker with a desired weak event whose timing is unknown to the operator conducting the test.

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Randomise the event occurrence within the observation interval and retain all test trials, including those in which the detector reports nothing. If an operator retrospectively selects only successful examples, the apparent probability of detection will be overstated. Likewise a display that indicates a low noise floor after a long averaging interval may conceal brief desensitisation during blocker pulses. Independent monitoring and a time-resolved gain-state record are needed to distinguish absence of the event from receiver blindness. The analysis should report both event-detection performance and the fraction of time for which the receiver met its calibrated operating conditions.

The qualification matrix should be maintainable over the instrument's lifetime. After service, firmware updates, filter substitution, mechanical damage or major configuration changes, the affected capability statements should be revalidated. This does not require rerunning every conceivable test after a minor change, but it does require a documented technical argument identifying which measurements are sensitive to the alteration. A change to a display palette normally does not alter analogue gain, although it may affect an analyst's visual detection strategy. A firmware change to the preselector state machine or the digital detector can alter the measurement law and should be treated much more seriously. The change-control record must describe what actually changed rather than rely on an unqualified software version label.

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3.27 Evidence interpretation when the reference chain fails

A failure to qualify one interval should not force an examiner to discard all observations from the survey. Instead, segment the evidence according to what remained verifiable. In one interval the chain may support accurate received power; in another the receiver may have been overloaded but still show the temporal occurrence of a large event; in a third the acquisition clock may be invalid, making event ordering uncertain. These are different limitations. The report should preserve the observed data and explicitly identify which analyses remain supportable. A general declaration that the measurement is 'bad' may conceal valuable bounded information; a general declaration that it is 'good' may wrongly elevate a narrow observation into source attribution.

When an instrument displays a new spectral feature shortly after a high-power event, the investigator should consider protection recovery, oscillator pulling, gain-control persistence, bias shift, switching transients, cable nonlinearity and external propagation alternatives. Each hypothesis predicts different responses to controlled changes. Repeating the measurement with a separately characterised receiver can challenge internal-artifact hypotheses, but the two receivers should not share an unexamined vulnerable front end. Similarly, a second antenna may be affected by the same illumination geometry and common-mode cable paths. The most effective verification is not simply adding more instruments. It is designing an experiment whose outcomes discriminate among competing physical explanations.

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The case record should avoid retrospective certainty. An unexpected peak observed only once in a congested environment might be important, but if receiver state was unknown and the event was not independently captured, it may remain unclassified. The justified conclusion can identify its frequency region, apparent duration, display and configuration context, and the possible internal explanations that were not excluded. That statement preserves the opportunity for later analysis without claiming more than the evidence supports. In a legally sensitive context, the report also specifies the scope of authority, data minimisation measures and the custody of any retained technical samples. It must not convert the presence of RF energy into an allegation about a particular person, device or communication.

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3.28 Impedance-aware transfer functions, scattering parameters and network uncertainty

A front-end assembly that appears to be a simple series of components is, electrically, a network whose behaviour depends upon what drives it and what terminates it. The insertion loss of an RF filter measured between nominally matched ports is a property of that test configuration. If its source is later replaced by an antenna with a different complex impedance, the transducer transfer can change because of multiple reflections. The effect may be small in a well-matched laboratory, yet substantial near a filter resonance or in a cable system with strong standing waves. A technically persuasive record distinguishes the available power of the source, incident wave power at an interface, power delivered to the load and displayed power after digital correction. The numbers may all be expressed in decibels while referring to different physical quantities.

A two-port network can be represented by scattering parameters S11, S21, S12 and S22 at a chosen real reference impedance. S11 and S22 describe input and output reflection, S21 forward wave transmission and S12 reverse coupling, under their specified termination convention. For a linear passive network in its calibrated frequency region, a complex S21 measurement preserves phase information and can expose sharp group-delay changes concealed by a magnitude-only trace. For a network of multiple components, cascade computation may be performed using suitable chain parameters, provided singularities and measurement uncertainty are treated properly. The result should be checked against a direct measurement of the assembled chain, because connector repeatability,

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cable routing and reference-plane definition can introduce effects absent from individually tested modules.

Source and load reflection coefficients can create a mismatch factor that varies with electrical length. Rotating or moving a coaxial cable changes the phase of reflected waves at the same time that the external antenna geometry may change. It is therefore possible for an apparently stable input field to produce different receiver measurements after a seemingly innocuous cable replacement. This complicates inference from small amplitude changes. A practical response is to retain a confidence interval derived from measured reflection magnitudes and credible phase variation, or to characterise the complete installed transfer. Where phase cannot be measured, the report should avoid converting a worst-case mismatch envelope into a fictitious precise correction. An uncertainty bound with honest assumptions is more useful than a single apparently exact decimal.

The operator should also consider whether a nominally passive network remains linear under all relevant stresses. Connector interfaces, protection diodes, ferrite cores and ageing contacts can show power-dependent behaviour. A small-signal S-parameter measurement may be excellent while a high-level two-tone experiment exposes intermodulation. Both results can be true. Network characterisation must therefore be indexed by input level and stimulus where the investigation requires nonlinear validity. A one-time bench sweep is not enough to establish behaviour during a pulsed overload, just as a high-power survival test does not establish sensitive small-signal accuracy. The test purpose determines the applicable representation.

An instructive uncertainty analysis separates frequency calibration, magnitude calibration, phase error, mismatch, drift and repeatability. These

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sources can be correlated because the same calibration kit, network analyser reference, connector set and environmental state may influence several measured terms. A seemingly elaborate model can still be wrong if shared uncertainty is treated as independent. The final uncertainty budget should state which components are type-A observations of repeatability, which are type-B estimates based on calibration or specifications, and which correlations have been retained. It should also identify model inadequacy, such as unknown nonlinear behaviour, that cannot be reduced to a small Gaussian correction without experimental justification.

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3.29 Thermal modelling and the time scales of front-end stability

An RF receiver front end undergoes changes on several time scales. A protective diode responds to a strong pulse over a very short interval; gain-control electronics can recover more slowly; an amplifier's die temperature and bias state can evolve over seconds or minutes; the enclosure and antenna feed may respond to environmental changes over many minutes. These mechanisms interact. A long-term drift record that samples one receiver marker every quarter-hour may completely miss short desensitisation intervals. Conversely a high-rate capture of a pulse may not establish the thermal equilibrium required for a reliable gain or noise figure calibration. A complete stability specification must identify the relevant timescale for each claimed parameter.

A simple thermal screening model may treat a component with effective thermal capacitance C_{th} and thermal resistance R_{th}, yielding a time constant $\tau = R_{th} C_{th}$ for a first-order approximation. If a constant incremental dissipation ΔP begins at $t=0$, a corresponding temperature rise under that model is $\Delta T(t) = \Delta P R_{th}(1-\exp(-t/\tau))$. The model is useful as a hypothesis, not a complete account of a package with multiple thermal nodes, forced airflow and nonlinear dissipation. The acceptance test should measure the quantity of interest directly. For example, gain drift may be evaluated against observed temperature rather than inferred solely from a junction model whose parameters were never measured. The report should note whether thermal behaviour was stationary, cyclic, hysteretic or dependent on prior high-power events.

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Thermal effects can also alter the interpretation of a calibration performed at a reference frequency. A filter's centre frequency may shift; a coaxial cable's electrical length may change; a preamplifier's gain and noise factor may drift; and a limiter's intervention threshold may vary. The interactions matter most when a narrow measurement margin is reported. Suppose a receiver declares an emission only 0.5 dB above an acceptance threshold while unmeasured thermal gain drift could plausibly exceed that amount. The evidence does not justify an unqualified deterministic result. The decision should either include the thermal uncertainty or be repeated under a controlled state. If a programme requires field operation across seasons, the test plan should include cold start, warm-up, sustained use and return-to-baseline behaviour rather than extrapolate from a single comfortable laboratory temperature.

A useful approach records both ambient and internal indicators but does not assume they are interchangeable. Air temperature near an antenna does not equal the junction temperature of an enclosed amplifier; a thermistor on a printed circuit board may respond more slowly than the vulnerable device. Calibration metadata should identify each sensor location and uncertainty. Where a gain-temperature coefficient is fitted, its validity interval and hysteresis should be checked in both directions. A linear correction derived during warming may not remove the effect during cooling if mechanical expansion, moisture or bias behaviour is path dependent. In a forensic chronology the time of the temperature observation itself may matter, especially when calibration data are recorded by a host clock different from the receiver's acquisition clock.

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Environmental chamber qualification cannot by itself guarantee actual field behaviour. Vibration, humidity, conducted interference, supply transients and load impedance may interact with thermal effects in ways the chamber did not exercise. A conservative release statement specifies the tested envelope and the change-control actions that require recalibration. Transport, repair and component substitution should trigger targeted checks selected by a technical risk assessment. The goal is to retain evidence that the apparatus remained within the conditions under which its measurements were validated, not to produce an ornamental certificate that is unrelated to the reported observations.

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3.30 Calibration-fixture integrity and traceability of source amplitude

Many apparently precise receiver tests are limited by the apparatus used to inject reference signals. A signal generator's displayed output setting may be calibrated at its connector under specified conditions, yet the power delivered to a receiver after an attenuator, coupler, switch and combination network is different. The test should identify the final injection reference plane, measure or characterise the intervening loss, and document uncertainty. A variable pad may exhibit frequency-dependent step error and imperfect repeatability; a directional coupler may have limited directivity; a source may exhibit harmonics or spurious components; and a power sensor may not respond to a pulsed waveform in the same manner as to a continuous sinusoid. Such differences must be resolved before a detector's apparent behaviour can be attributed to the receiver under test.

A strong blocker test is particularly susceptible to interaction between the source and receiver. If the input device reflects a large fraction of incident power, the generator may see a changing load and alter its output. An isolator or attenuator can reduce sensitivity to that load, but adds a new calibration term and may itself impose power or frequency limits. A combiner with insufficient port isolation can cause one generator to feed energy into another. Its nonlinear response may generate test artefacts at frequencies precisely where the investigator is searching for receiver intermodulation. The reference monitoring point should be sufficiently close to the receiver input to detect such upstream products, while the monitoring apparatus is separately qualified for its own large-signal behaviour.

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The test should also distinguish power delivered from power inferred from a measurement made elsewhere. A bidirectional coupler may permit estimation of forward and reflected waves, but the inference depends upon calibration, directivity and the impedance reference. A termination at the end of a test cable does not necessarily recreate the complex load presented by a powered receiver across all frequencies. Where a high-risk overload test is involved, use a safe, rated arrangement with suitable attenuation and protection; do not energise a receiver beyond its limits simply to discover where it fails. Many susceptibility characteristics can be studied with bounded signals and a model validated at safer operating points, while explicit uncertainty remains for untested exposures.

Calibration records should be designed for later examination rather than convenient operation alone. An entry needs the identifier of the reference source, its calibration interval and status, the applied frequency and power, the transfer correction to the measurement plane, the instrumentation and software version, the measured environment, the operator and the reason for any change. A screen capture of the source setting is weak evidence if it does not identify the intervening network. When the field report relies upon a corrected value, it should retain the original observed reading, the correction applied, its sign and units, and the uncertainty. The conversion should be reversible at the level of the recorded quantities, even if the physical measurement itself cannot be repeated.

Reproducibility must be tested by someone who can use the record without relying on unstated operator memories. A second qualified examiner should be able to reconstruct the source-level budget, challenge major assumptions and identify the exact hardware state used in the original

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observation. An apparently identical replacement accessory may not be equivalent if its measured loss, match or nonlinear response differs. Maintaining serialized component records is therefore not clerical excess; it is a necessary defence against the gradual substitution of an imaginary chain for the one that actually produced the evidence.

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3.31 Intermodulation maps and the topology of false spectral components

Receiver-generated products form patterns that can be predicted from the frequencies of strong signals under specific nonlinear models. For a memoryless third-order nonlinearity excited by two sinusoidal components at f1 and f2, third-order terms include 2 f1-f2 and 2 f2-f1, alongside harmonics and fundamental contributions. If an apparent weak feature lies near one of those combinations, a plausible internal-product hypothesis exists. A technician should test that hypothesis by varying one source level while holding the other controlled, selecting a different preselector state, or observing the input on an independently characterised path. Matching a frequency expression alone is insufficient. The environment may contain genuine emitters at coincident frequencies, and the receiver can have other mechanisms that produce similar spectral geometry.

The change of product amplitude with source level is potentially diagnostic. In the ideal weak-distortion regime, the third-order product grows approximately three decibels for each one decibel increase in a single equal-tone drive scale, while the fundamental grows approximately one decibel. This slope should not be assumed in compression or across a changing filter response. Practical measurements should use enough levels to demonstrate a local trend, with the source combining network and reference monitor checked for their own products. A single pair of traces at two levels may be confounded by detector averaging, gain-control intervention or a noise threshold. The report should distinguish an empirically observed slope from a textbook model fitted without sufficient evidence.

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Other mixing mechanisms complicate attribution. A local oscillator harmonic can interact with a blocker, generating an apparent frequency determined by integer combinations of the oscillator and input frequencies. Clock harmonics and digital switching noise can couple into analogue stages. A power supply may introduce periodic modulation of amplifier gain, generating sidebands about genuine signals. A connector may produce passive intermodulation under strong illumination while behaving almost linearly in a quiet bench test. These products may move when the receiver retunes or when cable geometry changes, and such movement can be informative. But an apparent retuning relation should be checked against the instrument's actual frequency-conversion scheme and state-machine timing, not inferred from a simplified block diagram.

An effective intermodulation map contains the strong-signal candidates, their frequency intervals, uncertainty, measured powers at a common plane, relevant integer combinations and the predicted dependence on gain or attenuation. It need not expose protected communication content. Spectral power and occupancy summaries are often sufficient to test the hypothesis. The investigator should record which combinations have been eliminated by independent controls and which remain plausible. If the source environment contains many high-level signals, a full enumeration of all hypothetical products may be impossible. In that case the report should state the search method, the tested subset and any limitations rather than assert that no internal spur could exist.

The map can also reveal why removing a component from the display is not proof that it was internal. A changed gain state may suppress both a genuine weak emitter and an internal product. A preselector may reject the

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genuine external signal if the displayed centre frequency does not correspond to the actual incoming RF frequency because of aliasing or an image response. The appropriate experimental question is whether the same input-referred physical signal survives a set of controlled receiver configurations that impose different internal failure mechanisms. A successful conclusion is conditional upon those tests and the independence of the alternative measurement paths.

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3.32 Statistical validity of gain-state comparisons

It is tempting to accept a faint spectral peak when it appears repeatedly after a front-end change, but repeated observations are not necessarily independent. A gain-control loop may preserve memory across adjacent sweeps, a temperature gradient may last for hours, and multiple FFT windows may overlap heavily. A detection probability or confidence interval computed as though all displayed points were independent can be drastically overstated. The experiment should define the unit of an independent trial in terms of physical reset, source randomisation or sufficiently separated state histories. If the receiver is subject to a persistent blocker, repeating a trace with the same conditions may add less information than an independent instrument-state challenge.

The analysis should distinguish exploration from confirmation. During an initial survey the operator may try different preselector settings, attenuation values and detector thresholds to discover a stable-looking feature. That exploratory process is legitimate but changes the meaning of a subsequent significance claim. A confirmatory test should predefine the chosen measurement state, the source and detector acceptance criteria, and the error rate to be controlled. If the operator selects only the most favourable trace from many trials, the apparent false-alarm performance no longer describes the full search. The case record needs enough detail to show how many alternative configurations were tried and which decisions were made after seeing the data.

A practical controlled sequence is to randomise the order of acceptable front-end states while retaining a stable authorised reference and a

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separately monitored blocker. If the apparent component persists across states as predicted by an external-source model, that supports the hypothesis. If it follows the input-gain cube or a state transition, an internal mechanism becomes more plausible. In either case the conclusion remains bounded by the source and detector models. A field study cannot typically randomise unknown external transmitters, so the laboratory result is a susceptibility study rather than proof of what happened during every unobserved field interval.

The measurement report should make uncertainty visible without turning a complex statistical analysis into opaque authority. Provide the detection rule, the number and nature of trials, the state sequence, the observed effects, the estimated uncertainty and the principal competing hypotheses. State whether the comparison was decided beforehand or selected retrospectively. This is especially important when a finding could affect legal rights or security decisions. The precision of the displayed spectrum cannot compensate for an analysis that selected its answer from the data and then presented it as an independent test.

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3.33 Extended controlled case studies for complex receiving environments

The following studies are designed as experimental reasoning exercises, not as accounts of actual surveillance events. Each begins with a declared engineering question, a physically plausible input arrangement and a limited set of observations. The calculations use conventional linear or small-signal approximations only where their hypotheses are stated. The investigator's principal task is to decide which conclusion is warranted and which further measurement would discriminate competing explanations. An attractive numerical result is not sufficient by itself to identify an emitter, establish lawful collection or certify an instrument's calibration. Every procedure presumes authorised test sources, suitable RF protection and safe access to the apparatus.

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3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim

An authorised laboratory survey monitors a weak reference at a fixed radio frequency, while a separate source transmits controlled high-power pulses at another frequency. The receiver's display is configured for a narrow spectral interval and shows the weak reference clearly during quiet periods. During each strong pulse the reference disappears, even though its independent generator level remains unchanged. The first hypothesis might be that the weak transmitter stopped radiating. A more plausible set of alternatives includes gain compression, input protection activity, automatic gain reduction, converter clipping or a trigger state that stopped valid recording. To test these explanations, the operator retains the weak generator's independent monitor, records the receiver's gain and overload flags where available, and repeats with calibrated input attenuation and preselection.

Suppose the weak reference enters the vulnerable amplifier at -90 dBm in quiet conditions, and a blocker momentarily enters at -8 dBm. The difference is 82 dB. This does not itself establish that the amplifier is overloaded, because its measured compression and frequency response are not yet known, but it gives a scale for the engineering challenge. If a preselector suppresses the blocker by 40 dB while incurring 2 dB loss for the weak reference, the relevant levels at the preamplifier become about -48 dBm and -92 dBm. The improved operating state may restore validity even though the reference has suffered insertion loss. That observation would support a blocker-dependent receiver limitation, not the assertion that the outside environment lacked emissions during the original blind period. The

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final report should identify a measured loss of observation opportunity and avoid using those intervals in a negative-survey coverage calculation.

The independent reference source is crucial because the receiver alone cannot distinguish an absent signal from an inability to observe it. Repetition with different pulse intervals and amplitudes can estimate the onset and recovery of the impairment. If the receiver reports the weak reference only after a 12 ms delay following the pulse, the documented invalid interval must include the time between the pulse and recovery under the stipulated criterion. The experiment does not prove identical recovery in another frequency, temperature or duty-cycle condition. Its conclusion is limited to the tested chain, and its accuracy depends on whether the challenge and reference power levels were actually characterised at the vulnerable input plane.

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3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency

A front end is exposed to two controlled tones at frequencies f1=900 MHz and f2=950 MHz, and a small feature appears at 850 MHz. The frequency is consistent with 2f1-f2=2(900)-950=850 MHz, a conventional third-order intermodulation product. If the receiver has a measured input third-order intercept IIP3 of +5 dBm, and both tones are -25 dBm at its vulnerable amplifier input, the ideal weak-distortion approximation predicts the product near 3(-25)-2(5)=-85 dBm input-referred. Such agreement is a diagnostic clue, not a proof of its origin. The two generators might themselves mix through a nonideal combiner, and a real third external source could operate near 850 MHz. The operator therefore measures or bounds upstream products independently and varies source level systematically.

A 5 dB equal reduction of the two tones would predict, within the weak-distortion model, a 15 dB reduction of the receiver-generated product. If the observed component falls by only 5 dB, several explanations remain. It might be a genuine 850 MHz source, the receiver's gain state might have changed, the source combiner might dominate the product or the measurement might approach the noise floor. The experiment should record both raw and corrected levels and retain enough points to estimate a local slope with uncertainty. Because the two tones are known laboratory sources, this diagnostic can be performed without recovering communications content. It should be repeated with an independent RF arrangement if the finding is consequential.

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The defensible report language is conditional: the observed feature lies at a predicted combination frequency and responds, within measurement uncertainty, consistently or inconsistently with a particular nonlinearity model. A source-identity claim requires additional evidence not contained in the frequency arithmetic. It is especially important to state whether the IIP3 figure came from a test of the actual assembled chain or merely from an individual component. An upstream limiter, cable junction or input switch can change the effective nonlinearity and make a component-level extrapolation misleading. The test should also verify that the preselector in use was physically located before the nonlinearity the operator intended to suppress.

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3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain

A receiving system is initially calibrated with a 12 dB input amplifier and a measured noise figure of 3.5 dB under a quiet matched-source test. The operator replaces it with a nominal 24 dB amplifier of the same noise figure, expecting a substantially better minimum detectable signal. A correctly designed noise-budget analysis shows that increasing first-stage gain mainly reduces the input-referred contribution of later stages; it cannot indefinitely reduce the first amplifier's own noise factor or external antenna noise. The additional 12 dB gain also increases the level delivered to downstream mixers and converters for every input component in the amplifier's passband, including unwanted blockers. A display that becomes brighter after the replacement does not establish a 12 dB improvement in physical sensitivity.

To assess the change, hold the desired test input and decision criterion fixed. Measure output noise and signal-to-noise ratio in matched equivalent noise bandwidths, verify converter clipping and track the receiver gain state. Introduce a measured blocker at increasing levels and record when amplitude, phase or detection behaviour becomes invalid. The result may show that the original amplifier had already made later-stage noise negligible; the replacement then provides almost no intrinsic sensitivity advantage while substantially reducing downstream headroom. Alternatively, a long lossy feeder may leave significant later-stage noise, and the additional gain may help under an adequately filtered environment. The conclusion cannot be decided from gain labels alone.

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A scientifically useful comparison would show the improvement in measured signal-to-noise ratio at the stated input plane, not only the change in output magnitude. If the new configuration permits lower converter input attenuation without overload, that consequence should also be recorded. The report must preserve the preamplifier's identifier, frequency response, bias state, operating temperature, insertion connector arrangement and calibration date. A negative survey performed under the higher gain state should not be called more thorough merely because the display's nominal noise floor is lower. The system's time-varying validity and blocker susceptibility determine whether it actually observed the weak events more reliably.

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3.33.4 Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration

A switched filter bank has a nominal band that extends from 700 to 900 MHz. A centre-frequency test at 800 MHz shows 1.5 dB insertion loss and apparently excellent matching. An unknown burst is suspected near 895 MHz. If the filter's real passband has a steep transition, the insertion loss and group delay at 895 MHz may differ substantially from the centre-band values. A 1.5 dB correction applied across the entire nominal band can therefore overstate or understate the true input-referred level. The proper test measures the actual assembled transfer as a function of frequency with sufficient resolution near the edge, taking account of both amplitude and phase where transient characterisation matters.

Suppose a laboratory sweep shows 2.0 dB loss at 880 MHz, 4.5 dB at 890 MHz and 10.0 dB at 898 MHz under the same switch state. These observations establish that the original centre-band correction is unsuitable near the boundary. They do not show that every burst at 895 MHz will simply be attenuated by a scalar intermediate value, because its modulation sidebands may see a strongly varying response. If the pulse is short, the distorted spectral weighting can alter the apparent pulse width and trigger time. A controlled chirp or gated carrier covering the same spectral region should be compared against an independent wideband reference to determine which measurements survive the filtering.

The report should distinguish an occupancy claim from a waveform-shape claim. The filter might be adequate to indicate energy near the edge while failing to preserve fast timing or phase. A calibrated amplitude correction is

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valid only within an interval where the transfer can be adequately approximated. An interpolation between sparse points may be defensible for a smooth response with validated uncertainty, but not across a sharp unmeasured resonance or state transition. The survey's frequency-coverage statement should use the measured acceptance bandwidth for the claimed detection threshold, not the aesthetically convenient nominal band endpoints.

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3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading

An SDR input chain operates with automatic gain control, and a low-power authorised reference is transmitted continuously at constant level. The receiver's waterfall shows a sudden 9 dB reduction in that component at the moment a separate high-power test burst begins. A casual interpretation might describe propagation fading of the weak source. Yet the detector's output is a function of both the external signal and its internal gain setting. If gain control changes by 9 dB at the same moment, a raw output amplitude reduction is exactly what one would expect even when the incident reference is unchanged. Applying a gain correction can restore an input-referred estimate if the gain-state calibration is valid and no stage has saturated. It cannot restore samples that were clipped, dropped or altered by nonlinear recovery.

The operator should record the timing and commanded gain state with sufficient resolution to bracket the burst. The controls include an independently monitored reference source, a fixed-gain test configuration where safe, and an alternative attenuation state that changes the blocker loading. If the receiver's gain register updates several milliseconds after the physical gain has started to move, reconstructing the original waveform from register values alone may introduce time-dependent amplitude errors. A field determination of short-burst amplitude is then unqualified even though an averaged marker may appear plausible. The correct report should state the number of affected samples or a bounded interval of uncertainty, not silently smooth the transition away.

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Repeated observations should distinguish feedback memory from external source behaviour. An AGC loop that responds strongly to one pulse may remain partially attenuated through the next weak event. Two identical weak events separated by different recovery intervals can therefore appear to have different strengths. The relevant state variable is not merely instantaneous gain but the preceding input and control history. A calibrated static correction fails if the response is hysteretic or time varying. The investigator may still report event existence or approximate timing if those aspects are independently supported, but should not present invalid amplitudes as physical changes in the source.

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3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor

During a lawful equipment survey, a feeder is moved around the edge of a metal instrument cabinet while the antenna and receiver remain in their nominal positions. A persistent peak changes by 6 dB and the displayed noise floor changes in a narrower frequency band. Such behaviour may indicate common-mode coupling on the cable screen, changes in connector impedance, movement of the cable into a different electromagnetic field, or altered phase relationships in a mismatched network. It does not establish that the suspected emitter moved. An investigator should avoid making the cable's contribution disappear merely through repeated physical adjustments until the display looks favourable. Each tested configuration is itself an observation whose significance must be interpreted.

A suitable experiment compares the original and rerouted states using known reference injections and, where safely feasible, a separately characterised receiving antenna that does not share the same cable path. The operator records source levels, geometry, cable bend and strain, connector condition, common-mode suppression, and return-loss changes. If a ferrite suppression arrangement reduces the peak without changing the reference tone's differential-mode transfer, that supports a common-mode coupling hypothesis, although it remains important to ensure the ferrite did not alter other aspects of the network. A different result following connector retightening suggests another mechanism and may call for a detailed examination of nonlinear contact behaviour under controlled power.

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The report should not claim a quantitative field-strength change solely from the raw receiver display. The relevant antenna transfer and cable current path may have changed, so the measurand is no longer identical. If the original scene must be preserved for evidential reasons, intrusive rearrangement may be inappropriate until it is documented and authorised. The proper distinction is between non-invasive observation, controlled challenge and physical alteration of the measurement environment. A technically modest statement of this distinction can be more informative than an elaborate but unsupported source-location estimate.

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3.33.7 Case study 3.D7. Protection recovery confused with absence of radio activity

A receiver's protective limiter is challenged by a bounded 100 microsecond RF pulse from an authorised laboratory generator. The limiter prevents damage, but the monitored low-level test carrier remains depressed for several milliseconds afterward. Suppose the acceptance criterion requires the carrier to recover to within 1 dB of its prechallenge level and its short-window variance to return within an established tolerance. The observed amplitude first meets the 1 dB condition at 4 ms but does not meet the variance condition until 9 ms. The recovered measurement state therefore cannot be declared at 4 ms under the combined criterion. The invalid interval extends at least to the later condition, with additional time uncertainty associated with the window lengths and hardware timestamps.

If the source pulse recurs every 6 ms, the receiver may never recover fully between events. A spectrum display could nevertheless report a stable lower noise floor after averaging, concealing the persistent desensitisation. The test should vary repetition interval and pulse energy within safe bounds to identify whether recovery is monotonic or history dependent. It should also record the condition of the receiver after the challenge. A device that survives may have changed its noise factor or input match, requiring a closing calibration before earlier data can be interpreted confidently.

The forensic implication concerns blind time. A negative finding during the recovering state has less evidential weight because the receiver's detection capability was not qualified. The operator should not retrospectively assume that the source of interest was silent. A separately calibrated auxiliary path

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might preserve evidence during part of the interval, but its own overload susceptibility and reference-plane integrity must be demonstrated. The report should state what was observed and which intervals were technically invalid. That approach supports responsible engineering practice without making an untestable claim about emissions that may have occurred while the primary path was compromised.

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3.33.8 Case study 3.D8. Temperature-dependent drift and the risk of overcorrection

A bench measurement at 20 degrees Celsius establishes a front-end gain of 15.0 dB. During field operation the enclosure temperature rises to 40 degrees and a later measurement indicates 14.3 dB. An operator might propose a linear correction of +0.7 dB to every field record made at 40 degrees. That proposal is justified only if the underlying gain-versus-temperature relationship is sufficiently well characterised, the temperature sensor represents the relevant device state, and other conditions remained constant. If the receiver was simultaneously exposed to higher blocker power, the gain change may partly reflect compression rather than an ordinary thermal coefficient. Correcting all observations by the full 0.7 dB could conceal rather than remove the error.

A more rigorous study fits gain across multiple stable temperature states while monitoring source power, frequency, attenuation and load impedance. It repeats during cooling to test hysteresis and records the time needed for the hardware to reach a stable condition. A gain coefficient derived from only two points should be treated as provisional, with uncertainty reflecting both measurement error and possible curvature. If the relationship is approximately linear over the validated interval, a model $G(T)=G_{ref}+k(T-T_{ref})$ may be used, where k is the measured gain coefficient in dB per degree and T is the relevant device temperature. Outside that interval, extrapolation should be explicitly qualified.

The final report should preserve the raw gain data, the chosen regression, residuals and reference plane. It should also identify intervals of insufficient

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temperature information. A measurement campaign may benefit from periodic internal references rather than relying on one environmental thermometer. The objective is not to produce an unnaturally smooth corrected power trace. It is to distinguish real source changes from instrument drift while showing how much uncertainty remains after correction. The correct response to unresolved drift may be a wider uncertainty interval or a restricted operating claim.

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3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change

A receiver's analogue hardware is unchanged, but a firmware update replaces its digital decimation filter and alters the nominal sample rate. The system continues to report the same input frequency range and nearly the same average noise floor. A brief laboratory burst that previously triggered reliably is now detected only intermittently. The first question is not whether the firmware is defective, but which part of the measurement law changed. The new filter may have a different impulse response, equivalent noise bandwidth, phase delay or transient acceptance behaviour. The trigger may also use a fixed threshold whose relationship to the filtered noise and signal has changed. An average noise-floor comparison cannot settle these possibilities.

A controlled verification preserves the same independently monitored input waveform and uses both firmware versions under a documented, reversible configuration where permitted. The operator compares retained raw samples, filter response, event timing and detection probability over predeclared trials. If a common raw data set can be processed by both versions, that isolates some software effects from analogue acquisition variability, though not every firmware change is necessarily replayable. A separate acquisition comparison may still be required. Event timing must be referred to sample apertures or a calibrated time reference, not to file-system creation times, if submillisecond conclusions are intended.

The forensic report should make clear that a change in processing algorithm can change the class of events the receiver can detect. Version identity and

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executable provenance thus belong in the measurement record. A detector may remain correct for a stipulated narrowband signal but become less reliable for pulses at a passband boundary. A claim that the instrument was 'calibrated' before the firmware change does not automatically validate the new processing state. That principle applies equally to FPGA channelisation, digital automatic-gain processing and receiver software libraries.

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3.33.10 Case study 3.D10. A bounded negative survey statement and its necessary controls

An authorised technical-security survey covers a specified building for six hours using two calibrated receiving systems. The instruments alternate among several frequency ranges, and the operator finds no qualifying emissions under the chosen detection criteria. The strongest defensible result is not that the building contained no transmission devices. Each receiver had limited frequency coverage, finite dwell times, antenna pattern nulls and possible periods of overload or maintenance. A precise coverage record should identify which ranges were observed at which times, the relevant detection thresholds, the antenna geometries, and the proportion of time that each configuration met its acceptance conditions.

Suppose a particular 20 MHz subband was actively monitored for a total of 72 minutes out of the six-hour campaign, and all observations during those 72 minutes passed internal validity checks. The gross temporal coverage fraction is 72/360=0.20. That fraction alone does not equal probability of detecting an unknown emitter, because event timing, duty cycle, reception conditions and the detector's conditional performance also matter. It demonstrates why the words 'six-hour survey of the band' can be misleading if they imply continuous observation. A claim that no qualifying event was detected during the 72 valid minutes is narrower and better supported. If independent receivers shared a front-end splitter, the coverage record must also examine their common failure paths before counting them as independent confirmation.

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A rigorous closeout compares pre- and post-survey reference measurements and records any change in equipment state. It preserves the instrument settings and calibration evidence necessary for review, within the governing lawful authority and data minimisation requirements. The operator should distinguish signal non-detection from transmitter nonexistence, and laboratory susceptibility tests from observations of the actual site. The final report can provide useful reassurance about the measurements conducted without promising an impossible proof of absence across every frequency, location and time. Such disciplined restraint is not a weakness; it is the scientific condition under which a negative technical finding remains defensible.

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3.34 Synthesis: what the completed front-end record can establish

The foregoing cases show that front-end fidelity is not represented by one noise-figure value, one gain budget or one overload specification. Validity is a multidimensional property of source frequency, amplitude, waveform, time history, temperature, impedance and instrument state. A defensible receiver record begins with its intended measurand, identifies the relevant reference planes, preserves source and instrument controls, and records every condition that can change the measurement law. Its calculations are necessary, but they become evidentially useful only when their assumptions have been challenged in the actual hardware configuration.

A properly designed investigation may end with an unresolved RF feature. The failure to identify an emitter does not erase the value of the observation or the success of a controlled test. Conversely an elegant spectral plot, a precise frequency display or a successful source-model fit cannot eliminate unmeasured front-end behaviour. For each detected component, the examiner should preserve the original evidence, state which alternative hypotheses were tested, describe any receiver states that invalidated observation, and identify which conclusions remain conditional. That is the standard by which front-end calculations should be judged before they are incorporated into a larger forensic narrative.

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3.35 Metrological qualification of system-level front-end conclusions

An engineering calculation becomes a defensible measurement claim only after the investigator specifies what was measured and the relationship between the measured quantity and the desired conclusion. This distinction may be formalised using a measurement equation with an explicit configuration vector theta. Let z denote the digitised observation, x the signal or physical quantity of interest at a declared reference plane, and theta the collection of measurable state variables: filter selection, gains, losses, converter scale, impedance conditions, timing corrections and temperature-sensitive coefficients. A simple model has the form z=f(x,theta) +epsilon, where epsilon denotes effects represented as observational noise rather than deterministic transformation. Even if the processing software can invert f, that inverse may be valid only over a bounded domain. If compression or clipping makes f many-to-one, distinct input waveforms can produce indistinguishable outputs and the reconstruction problem is not uniquely solvable. The report must distinguish a mathematically calculated inverse from an experimentally validated one.

A measurement model should be designed to withstand deliberate falsification. Consider the hypothesis that a newly observed narrow component is an external emitter. The corresponding alternative hypotheses might include a local-oscillator product, a blocker-driven intermodulation term, a switching transient, a clock harmonic or common-mode coupling through a cable. Each hypothesis should predict at least one discriminating observation under a permissible control. Altering a preselector while holding the desired reference fixed tests whether the feature depends on strong out-of-band loading. Introducing input

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attenuation can test the local slope of a presumed nonlinear product. A separate receiver and physically distinct antenna arrangement can challenge a receiver-specific artifact. None of these tests is infallible. A good experimental programme records the conditions under which two hypotheses cannot be separated, rather than choosing the explanation that happens to be most convenient for the narrative.

The correct uncertainty framework follows the chosen measurand rather than an inherited instrument worksheet. For a corrected amplitude at an antenna port, uncertainty terms can include receiver amplitude error, feeder and filter loss, mismatch, thermal drift, gain-state ambiguity, source fluctuation and repeatability. For a pulse timing claim, additional terms include clock relation, acquisition aperture, filter group delay, detector latency and state-transition validity. For a source-location claim, antenna geometry, propagation model and polarisation contribute. These uncertainties can be correlated. A single expanded uncertainty number copied between amplitude, timing and location findings would be scientifically indefensible even if it carries an impressive number of decimal places. Where a dominant model defect cannot be assigned a credible distribution, the result should be reported as unqualified or bounded by explicit scenarios instead of being forced into a deceptively narrow numerical interval.

The lawfulness of the investigation is a separate axis of validity. Technical capacity to receive or store information does not supply authority to collect communications content. A defensive survey can often test receiver susceptibility and spectral occupancy by means of independent laboratory sources, narrow technical extracts or aggregate measurements. The

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operator should establish authorisation, necessary retention and access restrictions before configuring the receiving chain. This also improves scientific clarity: a narrowly defined collection plan avoids indiscriminate recording whose purpose and relevant measurement parameters cannot later be explained. A well-controlled technical record states both the physics supporting its conclusions and the governance constraints defining what was legitimately observed.

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3.36 Release-gate checklist for a qualified receiver input chain

At release, the practitioner should be able to answer ten questions from the evidence record rather than from institutional habit. First, are the antenna and conducted input reference planes unequivocally identified? Second, are the relevant frequency- and level-dependent transfer corrections measured in the installed configuration? Third, have the actual blocker conditions been compared with measured linearity and protection limits? Fourth, has the noise and detection behaviour been demonstrated at the estimator bandwidth and under the intended gain state? Fifth, have the preselector and gain-control transitions been time-aligned and their invalid windows identified? Sixth, have limiter leakage, survival and recovery been differentiated? Seventh, have physically distinct controls been used to challenge plausible receiver-generated products? Eighth, have all calibration sources and fixtures been characterised sufficiently to exclude test-setup artifacts? Ninth, have the uncertainty and sensitivity of the chosen detection criterion been reported with the relevant correlations? Tenth, can an independent examiner reproduce the findings and identify the intervals in which no reliable observation was possible?

A negative response to any of these questions does not necessarily invalidate all data. It restricts the class of permissible conclusions. An input chain might be fit to detect strong persistent carriers yet unfit to resolve fast transients or weak events beneath a time-varying blocker. Another arrangement might preserve coherent phase at modest levels while lacking sufficient protection near a powerful transmitter. The key editorial requirement is to present the qualified operating envelope without conflating these independent capabilities. A reviewer should be able to read

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the state table and understand why a particular observation was retained, excluded or subjected to a lower-confidence interpretation. Such specificity prevents an impressive instrument specification from being substituted for a demonstrated measurement capability.

The closing verification should deliberately return to the original reference configuration. After a survey, the operator measures the same weak test reference, filter transfer or noise marker used at acceptance, with adequate control of environmental and source changes. A meaningful discrepancy triggers investigation before the earlier records are treated as stable throughout the campaign. If the closing check cannot be performed, the limitation remains explicit. The audit trail should preserve the original and closing values, the comparison calculation and the relevant uncertainty, rather than merely state that the receiver passed. This is particularly important where an overload event or mechanical disturbance may have changed the instrument without producing an obvious software alarm.

A front-end design will never remove every possible ambiguity. Its scientific value rests on making the known ambiguities testable, reducing the relevant ones by careful topology and calibration, and reporting the remainder honestly. The strongest conclusion is therefore not always a categorical attribution. Often it is a precise statement about a measured signal under a documented receiver state, with the alternative origins that have been challenged and those that remain unexcluded. In a complex technical surveillance countermeasures investigation, that bounded statement can withstand more rigorous examination than an unqualified claim of certainty. The distinction between observed electromagnetic energy, receiver-internal

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transformations and attributed external apparatus should remain visible at every stage of the evidential record.

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3.37 A research agenda for independent replication

Independent replication should test the scientific proposition rather than reproduce only its apparent final numerical answer. Suppose one laboratory finds that a weak reference remains detectable with an input preselector engaged and becomes unreliable when the filter is bypassed. Another laboratory should not simply build a visually similar rack and expect identical results. It must identify the essential variables of the claim: desired-signal level, blocker spectrum, preselector transfer, amplifier operating range, detector decision rule, calibration planes, timing and uncertainty. A different instrument can reproduce the same phenomenon while producing different raw voltages and baseline noise because the transfer functions differ. The appropriate comparison is therefore based on corrected physical quantities and state-dependent validity, not on matching a screen capture.

Replications should include a deliberate failure condition. An experiment that tests only the successful configuration cannot show whether the model has discriminatory power. For example, a front-end claimed to reject internally generated third-order products should be challenged with source tones whose combination frequency falls within the desired passband and then with a source combination that falls outside. The operator should vary the amplifier input loading while monitoring the combining network independently. The failure condition helps establish whether the instrument's response follows the hypothesised mechanism, and it may reveal a different unexpected cause. A result that does not match the original study is not automatically wrong; it may expose an unstated assumption or an untested hardware dependency.

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A robust replication archive retains instrument configuration, relevant firmware and software identities, calculation scripts, source-level measurements, calibration records, ambient conditions and a map of hardware connections. For transient experiments it also records acquisition clocks, trigger definitions, timing alignment and any sample gaps. The archive should distinguish original recordings from analyses that rescale, interpolate, correct or otherwise transform them. Where lawful retention requirements limit raw signal storage, a record of controlled reference experiments and technical metadata can support some validation without indiscriminate collection of communications content. The purpose of retaining these materials is to make the inference independently challengeable, not to accumulate files whose provenance or authority cannot be established.

Finally, the chapter's scope should remain linked to the wider Volume 11 architecture. The noise model interacts with Chapter 2, frequency conversion with Chapter 4, timing with Chapter 12, integrated reference planes with Chapter 13, uncertainty with Chapter 14 and evidential challenge with Chapter 16. Cross-references should direct a reader to those specialised treatments rather than duplicate entire derivations in several chapters. The front-end chapter owns the practical question of whether incident energy can pass through the earliest receiving stages without unacceptable loss, distortion or loss of observability. Its contribution is to explain how that question can be tested, calculated and reported under the conditions actually encountered.

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3.38 Independent challenge of recovered input-referred amplitude

A software-generated input-referred amplitude is not automatically a physical measurement made at the declared input plane. Its validity depends on every correction between the digitised record and that plane. A receiver may export a floating-point magnitude after applying a factory gain table, a selected input pad correction, preselector loss, detector scaling and a nominal impedance convention. If one part of the chain changed silently, the output can remain numerically precise while describing a different physical state. The examiner should therefore maintain an explicit correction ledger whose entries specify the direction of the transformation, the frequency and time interval, the uncertainty, and the evidence establishing that the correction applied during the event. For a corrected power in decibel units, the algebra is simple; the difficult part is proving the corrections correspond to the hardware state that actually produced the samples.

An independent calibration challenge can inject a series of known authorised reference levels, not merely one convenient midscale tone. Tests should bracket the intended weak-signal decision threshold and extend towards the validated upper edge of linear performance. A frequency sweep should include the centre and boundaries of each intended preselector path. A temporal test should include short bursts and repeated pulses with intervals chosen to reveal gain-control memory and protection recovery. Each result is compared with the predicted input-referred value and a stated acceptance tolerance. When the challenge reveals a consistent correction bias, a new calibration model may be justified over its tested interval. When it reveals state-dependent discontinuities, fitting one global offset is

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inappropriate. The result is a family of qualified states rather than an attractive universal scale factor.

An instructive laboratory counterexample involves a receiver whose software adds a fixed 20 dB gain correction while the input amplifier has in fact switched from 20 dB to 10 dB because of a blocker-triggered control action. A raw observed level of -50 dBm at the subsequent measurement stage would be corrected to -70 dBm under the erroneous 20 dB assumption, whereas a linear 10 dB gain state would imply -60 dBm at the input. The resulting 10 dB mistake is not reduced by averaging thousands of FFT frames. Averaging can reduce statistical variation around the wrong value while leaving the systematic state error intact. A proper record identifies the gain epoch and invalidates corrections whose state cannot be established. This is why calibration and configuration provenance must be tied to the sample index or another reliable acquisition-time reference, rather than inferred from a later screen capture.

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3.39 Uncertainty-aware interpretation of instrument agreement

Two calibrated instruments displaying nearly identical amplitudes do not necessarily provide two independent measurements of the external electromagnetic field. If they share a receiving antenna, a splitter, a lossy connector and the same environmental coupling path, those shared elements can introduce a common error. A comparison may establish agreement downstream of the splitter while saying little about the antenna's effective transfer or the physical source geometry. To assess independence, the investigator should trace which components and calibration standards the systems share. Correlation should be treated as a property to be examined, not assumed absent because the instruments bear different serial numbers.

Suppose two receivers measure a controlled reference as -79.8 and -80.1 dBm after their individual calibration corrections. The absolute difference is 0.3 dB. That number is not a valid statistical agreement test until each receiver's uncertainty and their covariance are known. If the independent parts of each measurement have 0.2 dB standard uncertainty and both share a common 0.5 dB antenna-path uncertainty, the difference can appear unusually precise because the shared term cancels in a direct comparison. Conversely their agreement does not remove the 0.5 dB uncertainty affecting the common input-referred estimate. A complete analysis should distinguish the uncertainty of a difference from the uncertainty of the absolute quantity. This distinction is essential when apparent agreement is used to support a source attribution rather than a simple instrument-consistency claim.

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A useful independent challenge may substitute a separately located calibrated antenna or introduce a reference directly at the receiver input. These tests answer different questions. A direct injection isolates the downstream receiver chain but bypasses the real antenna and its environment; a separate antenna tests more of the field-to-receiver path but introduces differences in pattern, polarisation and propagation. Neither arrangement alone identifies the source. Together they can help bound systematic uncertainty and separate alternative explanations. The final report should identify the exact corroborative proposition supported by each comparison. It should not convert two similar traces into a general proof of independent external origin.

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3.40 Closing doctrine on magnitude, event time and source attribution

Front-end qualification supports a hierarchy of findings. At the lowest level, a recorder may show a reproducible nonzero output under a documented configuration. A stronger finding establishes that the output corresponds to electromagnetic energy incident at a specified input plane, with receiver-generated products and corrupted states adequately challenged. Stronger still is a quantitative estimate of amplitude, frequency or temporal properties with uncertainties traceable to accepted calibration. Distinguishing an external source class, identifying a specific device or assigning responsibility to a person requires additional evidence outside the scalar input-chain model. Each inferential step must be independently supported; it cannot be supplied merely by increasing the numerical precision of the preceding step.

A front end's proper role is to preserve the information needed for the stated lawful and technical purpose, while exposing the circumstances under which information may have been transformed or lost. Protective filtering can improve selectivity but remove useful spectral sidebands. Gain can improve converter utilisation but reduce blocker tolerance. A limiter can prevent damage but create an unobservable recovery interval. A cable arrangement can deliver a weak desired signal but also collect unintended common-mode interference. Those trade-offs are intrinsic physical characteristics, not software defects that can always be corrected retrospectively. The responsible measurement report retains both the benefits and the limitations in view.

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Accordingly the acceptance test should end with an explicit decision: which input ranges and waveform classes have been demonstrated, which alternative hardware states remain untested, and which observations can support the intended conclusion. An unresolved anomaly should remain unresolved until a discriminating experiment is performed. The strongest technical publication does not promise that every unknown RF event will be detected. It establishes a transparent method for determining when the receiver can be trusted, when it cannot, and what can still be said about evidence collected near the boundary of its demonstrated performance.

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3.41 Blocker-dependent front-end state machines and hidden recovery intervals

A broadband receiver confronted by time-varying strong transmissions is better modelled as a state machine with memory than as a single linear transfer element. Define state Q as quiet calibrated operation, state C as compressed or limited operation, state R as measurable recovery, and state U as unknown or unvalidated behaviour. The transition Q to C may be caused by peak voltage, total admitted power, a protective limiter or automatic control; the return through R can be delayed by stored charge, amplifier bias restoration, local-oscillator settling, filter memory or detector smoothing. A component appearing only during R is not necessarily a newly active external source. A receiver can generate a transient spectral product while it is recovering from a completely unrelated blocker. The useful experimental control is therefore a weak, continuous reference retained across the blocker event, with event times and gain states available at sufficient resolution.

A calibration record based exclusively upon steady continuous-wave stimuli does not establish how the front end behaves during a microsecond pulse followed by weak activity. Measurements of limiter survival, residual leakage and restoration of weak-signal validity answer different questions. For an illustrative linear recovery model, let fractional amplitude error be $e(t) = e_0 \exp[-(t - t_0)/\tau]$ for t at or after the end t_0 of a particular strong event. If e_0 equals 0.4, tau equals 1.5 milliseconds, and a calibrated amplitude condition requires $|e|$ no greater than 0.01, then the minimum model recovery time is 1.5 ms multiplied by ln(40), approximately 5.53 ms. This

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result is conditional on the exponential law and one amplitude criterion; phase, detector noise and gain-state restoration may require longer and cannot be inferred from the same constant. A real limiter must be challenged experimentally rather than assigned the constructed time constant.

A useful front-end acceptance experiment varies blocker amplitude, blocker duration and repetition rate separately while keeping the weak reference nominally fixed. Record actual protection path, preselector selection, gain state, thermal conditions, limiter event flags, output waveform and native receiver samples. An independent monitor should establish the stimulus at the declared plane, particularly because source and combiner products can be mistaken for receiver-generated intermodulation. Repeat with the blocker moved beyond the selected preselector, without changing the weak reference, so that the predicted suppression can be tested at the physically relevant stage. The interpretation must separate insufficient sensitivity, reduced observation opportunity, amplitude distortion and a genuine discrete product; these outcomes cannot be exchanged merely because they all reduce confidence in a displayed weak line.

The final report should use a validity mask over the acquisition timeline. A time interval in which the receiver is protected but temporarily blind to the stipulated weak event is not part of demonstrated observation coverage. A persistent artifact that survives the strong pulse for several milliseconds should not be treated as evidence that the pulse source itself persisted. Conversely, a late weak emission appearing after recovery may be real even though the earlier stage was overloaded. State histories and explicit restoration tests make those propositions distinguishable. This approach

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extends the ordinary noise-and-gain budget into a practical account of transient susceptibility, which is essential when the purpose of the survey is to find rare, weak emissions rather than simply measure continuous carriers.

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3.42 Advanced technical expansion. Multitone stress and the limits of protective front-end linearity

The front end must be analysed as an ordered physical network whose small-signal gain and large-signal response are different kinds of evidence. For each stage j, calculate or measure the level of every intended signal and important blocker at that stage's actual input, incorporating the individual frequency response of upstream filters and the state of switched attenuators. A decibel sum is legitimate for a signal traversing a demonstrated linear scalar path; it cannot predict the intermodulation waveform created when an amplifier experiences several strong components. Even a clean output filter cannot remove an in-band product already generated upstream. The correct exposure record therefore includes more than the displayed band. It includes the frequencies and levels admitted to the first nonlinear element and any protection device that encounters the environment before the first amplifier.

A stylised two-tone test makes the distinction concrete. Let the input contain sinusoidal components at 940 and 947 MHz, with amplitudes sufficiently small for the first stage to be described locally by $y(t) = a_1x(t) + a_3x(t)^3$, where a_1 is a linear voltage coefficient and a_3 is a cubic coefficient in compatible units. Third-order terms may appear near 933 MHz and 954 MHz, because the algebraic combinations $2f_1-f_2$ and $2f_2-f_1$ are inside or near a receiving band even when both original components appear remote. Their exact levels depend on amplitudes, device coefficients, impedance, frequency response and phase, so no universal product level follows from frequency arithmetic. The operator should measure the purity of the combined

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sources before attributing products to the receiver; an inadequately isolated generator combiner can create identical frequencies before the receiver is even connected.

A protective limiter has at least four separately testable behaviours: low-level insertion loss, leakage during a specified incident pulse, survival under its stated energy and repetition conditions, and recovery to a declared small-signal measurement tolerance. Survival does not imply immediate recovery. A receiver may remain within damage limits while a PIN limiter, amplifier bias or gain-control loop temporarily renders weak-event measurements invalid. A useful test overlays a calibrated low-level reference on a bounded strong event, records the actual response at sufficient temporal resolution and measures recovery to independently selected amplitude and phase criteria. An observed 2 ms amplitude recovery and 7 ms phase recovery would create different validity windows for different measurands. Those figures would be measured results only if actual instrument records existed; in manuscript examples they must be explicitly hypothetical.

The gain-selection problem is therefore constrained from both sides. A noise budget yields a minimum useful gain to suppress later-stage contributions; a blocker and headroom budget yields a maximum gain compatible with linear operation at vulnerable stages. If the lower bound exceeds the upper bound, the design has no acceptable gain setting under the declared assumptions. Choosing an arithmetic compromise does not create physical feasibility. Instead, improve preselection, relocate amplification, reduce preceding loss, revise the tolerated blocker environment or adopt an architecture with different noise and compression limits. Record which trade

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was chosen, because later attenuation corrections may restore a reported signal level but cannot restore information distorted during a previous overloaded state.

A complete acceptance record incorporates temperature, connection state, limiter history and mechanical disturbance, particularly for equipment transported between sites. The same connector may exhibit changing contact resistance or passive intermodulation under bending or vibration. An artefact that disappears when the cable is moved could reflect the installed path rather than a transmitter's actual state. Test the mechanical condition deliberately, retain before-and-after reference observations and avoid assuming that a network-analyser sweep at low power validates high-level transient behaviour. The report should distinguish the demonstrated operating envelope from the untested combinations of pulse width, duty factor, frequency and temperature.

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Chapter Summary

Preselection, gain, attenuation, and protection determine both sensitivity and credibility. Front-end state must be chosen for the actual environment and challenged whenever a weak component could be an overload product.

Follow the desired signal and each blocker through the actual component order. The first vulnerable stage can lose validity before a downstream filter or narrow display acts. Keep desired-frequency loss separate from blocker rejection, and apply scalar budgets only within their impedance, frequency and state assumptions.

Choose preselection and gain together. A noise-derived minimum and downstream-loading maximum define a feasible gain interval; an empty interval requires a design change. Verify that the desired waveform survives the filter. Equal corrected amplitudes across settings do not imply equal sensitivity or unchanged physical loading.

Separate protection loss, leakage, survival and recovery. Use an observable-specific recovery criterion and a weak reference to identify impaired intervals; surviving hardware can still be unable to make the intended measurement. Record gain transitions, source and combiner controls, common-plane corrections and raw outputs. Challenges and closing checks support the operating conditions they actually exercise, with remaining limitations explicit.

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Chapter 3 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C03-MCQ-001. A narrow final filter removes a strong blocker from the displayed span, but the blocker entered an earlier amplifier. What establishes whether that amplifier was protected?

A. The blocker level and rejection before the amplifier, compared with its valid operating range.

B. The final filter bandwidth being narrower than the displayed span.

C. The final trace being free of the blocker after filtering.

D. The amplitude correction assigned to the final filter.

Answer: A. Protection requires sufficient rejection before the first vulnerable component. A later filter does not undo earlier compression or generated in-band products. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: The blocker level and rejection before the amplifier, compared with its valid operating range.

Distinguishing consideration: compare this with option B, “The final filter bandwidth being narrower than the displayed span”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-002. An unfiltered direct-sampling receiver shows only a narrow display span. Which conclusion about converter exposure is justified?

A. Display decimation removes out-of-span energy before the converter.

B. Signals outside the display may still load the analog path or converter.

C. Only frequencies inside the display contribute to converter overload.

D. A clean display establishes that all analog stages remained linear.

Answer: B. Displayed selection and physical admission are different boundaries. The front-end response and actual converter input determine exposure. Review: Front-End Purpose and Architecture. Source: §3.1 Front-End Purpose and Architecture (p. 1248)

Why the selected alternative fits: Signals outside the display may still load the analog path or converter.

Distinguishing consideration: compare this with option A, “Display decimation removes out-of-span energy before the converter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Front-End Purpose and Architecture.

Review: Chapter 3 — Front-End Purpose and Architecture.

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V011-C03-MCQ-003. Two otherwise identical chains place the same blocker-rejecting filter before or after the first amplifier. What is the principal reason their behavior can differ?

A. A filter after an amplifier always has zero insertion loss.

B. Scalar gain multiplication ceases to apply whenever components are reordered.

C. Only the first arrangement reduces the blocker presented to that amplifier.

D. The final desired-signal correction necessarily has opposite sign in the two chains.

Answer: C. Equal final small-signal gain can coexist with different internal loading. Component order changes the first vulnerable stage exposure. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: Only the first arrangement reduces the blocker presented to that amplifier.

Distinguishing consideration: compare this with option A, “A filter after an amplifier always has zero insertion loss”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-004. A desired signal is in a filter passband and a blocker lies on its skirt. Which gain budget is appropriate?

A. The center-frequency gain applied equally to both signals.

B. The blocker rejection applied as the desired-signal loss correction.

C. Separate frequency-specific transfers for desired signal and blocker.

D. One average filter loss weighted only by the displayed desired trace.

Answer: C. A filter has frequency-dependent transfer. A single desired-band gain cannot represent a blocker at a different frequency. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: Separate frequency-specific transfers for desired signal and blocker.

Distinguishing consideration: compare this with option A, “The center-frequency gain applied equally to both signals”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-005. What cannot be established from the scalar gain relations in Equations 5 and 6 alone?

A. A predicted stage level under a stipulated linear transfer.

B. The product of compatible linear stage power gains.

C. The sum of signed gains and losses in decibels.

D. The magnitude and frequency of a nonlinear intermodulation product.

Answer: D. The scalar relations describe linear transfer. Nonlinear products need a justified nonlinear model and valid source and state assumptions. Review:

Equations 5 and 6. Source: Equation 5. Linear cascaded gain (p. 1269)

Why the selected alternative fits: The magnitude and frequency of a nonlinear intermodulation product.

Distinguishing consideration: compare this with option A, “A predicted stage level under a stipulated linear transfer”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-MCQ-006. Several blockers have a known total mean input power. Why can that information be insufficient for a peak-sensitive failure mechanism?

A. Peak loading is always equal to the largest individual mean power.

B. Relative phase and instantaneous voltage can change peaks without being specified by the mean alone.

C. A gain correction determines the relative phase of all blockers.

D. Mean power can never be used in a receiver loading assessment.

Answer: B. Mean and instantaneous loading address different mechanisms. A peak-sensitive analysis needs waveform or phase information appropriate to that mechanism. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: Relative phase and instantaneous voltage can change peaks without being specified by the mean alone.

Distinguishing consideration: compare this with option A, “Peak loading is always equal to the largest individual mean power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-007. The preamplifier indicator is on in the chapter's instrument example. Which additional fact is essential to interpreting strong-signal exposure?

A. Only the nominal gain of the final detector normalization.

B. Which active stage is enabled and whether preselection precedes it.

C. Only the final displayed noise level with the antenna disconnected.

D. Whether the display annotation uses the same name in every application.

Answer: B. The cited architecture has distinct amplifier placements. The state label alone does not identify the filtering before the active stage. Review: Front-End Purpose and Architecture; source note 9. Source: §3.1 Front-End Purpose and Architecture (p. 1248)

Why the selected alternative fits: Which active stage is enabled and whether preselection precedes it.

Distinguishing consideration: compare this with option A, "Only the nominal gain of the final detector normalization"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-008. What starting policy does the chapter justify for an unknown RF environment?

A. Infer a safe starting state from the final display span alone.

B. Always start with the maximum preamplifier gain because it minimizes receiver noise.

C. Always use a fixed attenuation value independently of receiver ratings.

D. Choose a state with understood exposure using actual ratings and anticipated signals, then test whether more gain is useful.

Answer: D. The required state depends on the actual path, environment and objective. Neither maximum gain nor a universal attenuation value establishes validity. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: Choose a state with understood exposure using actual ratings and anticipated signals, then test whether more gain is useful.

Distinguishing consideration: compare this with option A, “Infer a safe starting state from the final display span alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-009. A survey changes from a protected state to a quieter high-gain state. How should the observations be retained?

A. As identified configuration intervals with their own noise, overload and coverage behavior.

B. As interchangeable records whenever the corrected desired level agrees.

C. As one calibration interval because the same external connector was used.

D. As one state after replacing both gain settings by their arithmetic average.

Answer: A. A common reporting plane does not erase changes in internal state or time coverage. The actual state intervals must remain identifiable. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: As identified configuration intervals with their own noise, overload and coverage behavior.

Distinguishing consideration: compare this with option B, “As interchangeable records whenever the corrected desired level agrees”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-010. Where should desired and blocker levels be established for a front-end acceptance challenge?

A. Only at the final detector after automatic amplitude normalization.

B. At whichever connector has the lowest reflected-power indication, without a transfer record.

C. At the intended receiver reference plane after the actual combining and accessory path.

D. Only at each generator front-panel indication.

Answer: C. Generator settings do not include all intervening losses, interaction and mismatch. The claimed receiver exposure belongs to its declared input plane.

Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: At the intended receiver reference plane after the actual combining and accessory path.

Distinguishing consideration: compare this with option A, “Only at the final detector after automatic amplitude normalization”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-011. Compatible linear stage power gains are 10, 0.5 and 20. What is the total gain under Equation 5?

A. 30.5, equivalent to about 14.84 dB.

B. 200, equivalent to about 23.01 dB.

C. 100, equivalent to 20 dB.

D. 0.01, equivalent to -20 dB.

Answer: C. Multiply the dimensionless power gains: $10 \times 0.5 \times 20 = 100$. Ten times the base-ten logarithm gives 20 dB. Review: Equation 5. Source: Equation 5. Linear cascaded gain (p. 1269)

Why the selected alternative fits: 100, equivalent to 20 dB.

Distinguishing consideration: compare this with option A, “30.5, equivalent to about 14.84 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 5. Linear cascaded gain.

Review: Chapter 3 — Equation 5. Linear cascaded gain.

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V011-C03-MCQ-012. A -62.0 dBm input passes through 2.1 dB filter loss, 10.0 dB attenuation and 17.5 dB amplifier gain. What stage input follows?

A. -91.6 dBm.

B. -56.6 dBm.

C. -35.4 dBm.

D. -80.6 dBm.

Answer: B. Apply Equation 6 with losses subtracted and gain added: -62.0 minus 2.1 minus 10.0 plus 17.5 equals -56.6 dBm. Review: Equation 6; Hypothetical Applied Calculation. Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: -56.6 dBm.

Distinguishing consideration: compare this with option A, “-91.6 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-MCQ-013. For the preceding constructed -56.6 dBm stage level and a specified -25.0 dBm compression onset, what is the nominal headroom for that signal alone?

A. 31.6 dB.

B. 81.6 dB.

C. 25.0 dB.

D. -31.6 dB.

Answer: A. Subtract the operating level from the stated limit: -25.0 minus -56.6 equals 31.6 dB. This does not incorporate additional blockers or peak behavior.

Review: Hypothetical Applied Calculation. Source: §3.13 Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection (p. 1271)

Why the selected alternative fits: 31.6 dB.

Distinguishing consideration: compare this with option B, “81.6 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

Review: Chapter 3 — Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-MCQ-014. Which use of decibels is consistent with Equation 6?

A. Multiply the numerical values of stage gains expressed in dB.

B. Interpret a 10 dB attenuator setting as an absolute output power of 10 dBm.

C. Add all absolute signal powers in dBm directly to obtain their combined power.

D. Add signed gains and losses in dB to an absolute input level in dBm.

Answer: D. A decibel transfer is a logarithmic ratio, whereas dBm is an absolute level referenced to one milliwatt. Their roles in the level budget differ. Review: Equations 5 and 6. Source: Equation 5. Linear cascaded gain (p. 1269)

Why the selected alternative fits: Add signed gains and losses in dB to an absolute input level in dBm.

Distinguishing consideration: compare this with option A, “Multiply the numerical values of stage gains expressed in dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-MCQ-015. What condition accompanies the product of available stage power gains in Equation 5?

A. A requirement that all stages have identical physical temperature.

B. An assumption that every stage has unit voltage gain.

C. Compatible reference impedances and mismatch conventions across the chain.

D. A guarantee that the product remains valid through compression.

Answer: C. The gain definitions and interface conventions must support the multiplication. The formula does not itself establish matching, linearity or headroom. Review: Equation 5. Source: Equation 5. Linear cascaded gain (p. 1269)

Why the selected alternative fits: Compatible reference impedances and mismatch conventions across the chain.

Distinguishing consideration: compare this with option A, “A requirement that all stages have identical physical temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 5. Linear cascaded gain.

Review: Chapter 3 — Equation 5. Linear cascaded gain.

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V011-C03-MCQ-016. Filter loss and switched attenuation are recorded as positive loss magnitudes. How do they enter Equation 6?

A. Their arithmetic average is subtracted regardless of component count.

B. Both are added because each is recorded as a positive number.

C. Filter loss is added while attenuation is subtracted.

D. Both are subtracted from the input level before adding amplifier gain.

Answer: D. A positive loss magnitude corresponds to a negative change in the transmitted power level. The sign follows the transfer, not the printed sign of the magnitude. Review: Equation 6. Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: Both are subtracted from the input level before adding amplifier gain.

Distinguishing consideration: compare this with option A, “Their arithmetic average is subtracted regardless of component count”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-MCQ-017. A -15 dBm blocker encounters 35 dB filter rejection, 6 dB attenuation and 20 dB gain before a mixer. Assuming those transfers remain valid at its frequency, what level reaches the mixer?

A. 24 dBm.

B. -76 dBm.

C. -2 dBm.

D. -36 dBm.

Answer: D. The blocker budget is -15 minus 35 minus 6 plus 20 equals -36 dBm. Its frequency-specific rejection is essential. Review: Equation 6; Use preselection as a measured transfer function. Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: -36 dBm.

Distinguishing consideration: compare this with option A, “24 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-018. In the same chain, a -95 dBm desired signal experiences only 1 dB filter loss, the same 6 dB attenuation and 20 dB gain. What is its predicted mixer input?

A. -82 dBm.

B. -122 dBm.

C. -68 dBm.

D. -116 dBm.

Answer: A. The desired-frequency budget is -95 minus 1 minus 6 plus 20 equals -82 dBm. The blocker rejection does not belong in this correction. Review: Equation 6.

Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: -82 dBm.

Distinguishing consideration: compare this with option B, “-122 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-MCQ-019. The two preceding constructed inputs differ by 80 dB before the filter. Its blocker rejection is 35 dB and desired loss is 1 dB; later transfers are equal. What separation remains?

A. 44 dB.

B. 114 dB.

C. 46 dB.

D. 80 dB.

Answer: C. The filter changes the separation by 35 minus 1 equals 34 dB. The remaining blocker-to-desired separation is 80 minus 34 equals 46 dB. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: 46 dB.

Distinguishing consideration: compare this with option A, “44 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-020. The desired path has a net gain of 13 dB and its measured stage level is -82 dBm. What input-plane estimate follows under the valid linear correction?

A. -69 dBm.

B. -82 dBm.

C. -95 dBm.

D. -106.6 dBm.

Answer: C. Refer the output indication backward by subtracting the path gain: -82 minus 13 equals -95 dBm. This correction does not repair a nonlinear acquisition.

Review: Equation 6; An acceptance sequence that separates competing failures.

Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: -95 dBm.

Distinguishing consideration: compare this with option A, “-69 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-021. Two candidate preselectors have equal desired-band insertion loss. Only one supplies substantial rejection of the dominant blocker before the vulnerable stage. What distinguishes their likely usefulness?

A. The filter with weaker rejection must always have the lower receiver noise temperature.

B. Their order matters only after the final detector.

C. The filter with substantial blocker rejection may restore valid operation; equal desired loss does not imply equal blocker protection.

D. They must produce equal operational sensitivity because their desired losses match.

Answer: C. Desired-band loss and blocker admission are different transfers. The noise cost can be similar while the validity benefit differs substantially. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: The filter with substantial blocker rejection may restore valid operation; equal desired loss does not imply equal blocker protection.

Distinguishing consideration: compare this with option A, “The filter with weaker rejection must always have the lower receiver noise temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-022. An amplifier generates an in-band product before a narrow downstream filter. Which outcome is physically plausible?

A. The filter reconstructs the original weak waveform by removing the blocker.

B. The filter rejects the original blocker while passing the already generated in-band product.

C. The product disappears whenever the original blocker is absent from the display.

D. The filter converts the nonlinear product back into source noise.

Answer: B. Filtering acts on the spectrum at its own input. It cannot identify and reverse an upstream nonlinear history merely because its final passband is narrow.

Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: The filter rejects the original blocker while passing the already generated in-band product.

Distinguishing consideration: compare this with option A, “The filter reconstructs the original weak waveform by removing the blocker”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-023. A center-frequency calibration is satisfactory, but a desired modulation occupies a much wider passband. What remains to be established?

A. Only the same center-frequency gain at one additional power level.

B. Amplitude and phase transfer across the occupied signal bandwidth.

C. That the noise floor decreases when the display span is reduced.

D. Only the filter label and its nominal center frequency.

Answer: B. A wide waveform samples ripple and phase behavior away from the center. A scalar center correction does not establish waveform preservation.

Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why the selected alternative fits: Amplitude and phase transfer across the occupied signal bandwidth.

Distinguishing consideration: compare this with option A, “Only the same center-frequency gain at one additional power level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-MCQ-024. Which preselector characteristic is especially relevant to relative timing distortion across a desired waveform bandwidth?

A. The stopband rejection measured at one remote blocker frequency.

B. The center-frequency insertion loss alone.

C. The displayed attenuation correction alone.

D. Group delay as a function of frequency.

Answer: D. Frequency-dependent phase delay can alter waveform timing even when center amplitude appears correct. The complete passband response must match the measurement need. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why the selected alternative fits: Group delay as a function of frequency.

Distinguishing consideration: compare this with option A, “The stopband rejection measured at one remote blocker frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-MCQ-025. A receiver automatically changes preselector bands at a frequency boundary. What does a calibration at the center of only one band fail to establish?

A. The arithmetic sign of every passive loss in the chain.

B. Continuity and accuracy of response across the switched boundary.

C. Whether an amplifier power gain is dimensionless.

D. The center-frequency response at the calibration state already measured.

Answer: B. The switch can change gain, noise, phase and calibration. Boundary checks must exercise the actual adjoining states. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: Continuity and accuracy of response across the switched boundary.

Distinguishing consideration: compare this with option A, “The arithmetic sign of every passive loss in the chain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-026. An external notch filter is substituted during an amplitude survey. Which record supports a defensible comparison?

A. A statement that both filters are passive and therefore interchangeable.

B. Its identity, actual response and state-dependent correction and uncertainty.

C. Only the nominal notch frequency printed on its case.

D. The receiver calibration certificate without identifying the added filter.

Answer: B. The accessory changes the measurement path. Its serial identity and measured transfer connect the physical substitution to the reported amplitude.

Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why the selected alternative fits: Its identity, actual response and state-dependent correction and uncertainty.

Distinguishing consideration: compare this with option A, “A statement that both filters are passive and therefore interchangeable”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-MCQ-027. The baseline falls when preselection is enabled. Which interpretation is justified before the desired transfer is remeasured?

A. The desired signal-to-noise ratio must have improved by the same amount.

B. Several mechanisms remain possible, including noise rejection, changed gain, reduced reciprocal mixing or desired-signal loss.

C. The receiver's intrinsic noise figure must have improved by the entire displayed change.

D. The earlier trace must have been a receiver-generated artifact.

Answer: B. A lower baseline alone does not identify the transfer or error mechanism. The desired reference and relevant state controls separate the alternatives. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: Several mechanisms remain possible, including noise rejection, changed gain, reduced reciprocal mixing or desired-signal loss.

Distinguishing consideration: compare this with option A, "The desired signal-to-noise ratio must have improved by the same amount"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-028. A strong-signal challenge compares two preselector states. Why retain the same weak desired reference in both?

A. To test whether the changed state preserves the desired measurement while changing blocker admission.

B. To remove the need to measure blocker levels at the receiver plane.

C. To guarantee that both preselector states have identical thermal noise.

D. To make the final filter reverse any earlier clipping.

Answer: A. The reference exposes altered desired transfer or lost sensitivity that might otherwise make disappearance of a suspect component misleading. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: To test whether the changed state preserves the desired measurement while changing blocker admission.

Distinguishing consideration: compare this with option B, “To remove the need to measure blocker levels at the receiver plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-029. A report applies 35 dB blocker rejection as the correction for a desired signal that experiences only 1 dB filter loss. What is the central error?

A. It underestimates the desired input level by 34 dB.

B. It uses transfer at the wrong frequency and overstates the inferred desired input level by 34 dB.

C. It changes only the uncertainty, leaving the corrected value valid.

D. It correctly compensates all signals because the filter is passive.

Answer: B. The desired-plane correction must use the desired-frequency loss. The extra 34 dB is a wrong-frequency correction, not a physical sensitivity improvement. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: It uses transfer at the wrong frequency and overstates the inferred desired input level by 34 dB.

Distinguishing consideration: compare this with option A, “It underestimates the desired input level by 34 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-MCQ-030. A filter loss calibration was made at a temperature different from the field state. What follows when temperature dependence is consequential?

A. Treat all passive filters as temperature independent.

B. Apply the blocker rejection instead of the desired passband loss.

C. Average the calibration temperature and field temperature and declare the response exact.

D. Use an applicable correction or quantify the residual uncertainty for the actual state.

Answer: D. The gain budget terms are state dependent. A calibration must be applicable to the state or accompanied by a justified treatment of the difference.

Review: Equation 6; Preselection and Filter State. Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: Use an applicable correction or quantify the residual uncertainty for the actual state.

Distinguishing consideration: compare this with option A, “Treat all passive filters as temperature independent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Preselection and Filter State.

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V011-C03-MCQ-031. Two mutually uncorrelated blockers each deliver -20 dBm at a stage. What is their combined mean power, assuming powers add at that plane?

A. -20 dBm.

B. 0 dBm.

C. Approximately -16.99 dBm.

D. -40 dBm.

Answer: C. Each supplies 0.01 mW, so the total is 0.02 mW. Ten times its base-ten logarithm is -16.99 dBm; absolute dBm values are not directly added. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: Approximately -16.99 dBm.

Distinguishing consideration: compare this with option A, “-20 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-032. A constructed loading budget contains 1 mW and 3 mW of additive mean blocker power. What total level follows?

A. 4 mW, approximately 12.04 dBm.

B. 2 mW, approximately 3.01 dBm.

C. 3 mW, approximately 4.77 dBm.

D. 4 mW, approximately 6.02 dBm.

Answer: D. Linear powers sum to 4 mW. A power ratio uses ten times the base-ten logarithm, producing approximately 6.02 dBm. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: 4 mW, approximately 6.02 dBm.

Distinguishing consideration: compare this with option A, “4 mW, approximately 12.04 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-033. Two equal mean-power signals can have different relative phase histories. Which assessment should avoid treating their combined mean as a complete peak specification?

A. A mechanism governed by instantaneous input voltage or envelope peaks.

B. A thermal calculation explicitly averaged over times long compared with the relative phase variation.

C. A calculation explicitly limited to additive long-term mean powers.

D. A correction of a single known small-signal passband loss.

Answer: A. Peak-sensitive loading depends on time-domain superposition. A mean-power sum can be correct while lacking the peak information needed for a different mechanism. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: A mechanism governed by instantaneous input voltage or envelope peaks.

Distinguishing consideration: compare this with option B, “A thermal calculation explicitly averaged over times long compared with the relative phase variation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-034. A preselector retains one narrow desired channel but excludes other frequencies visited by a frequency-agile event. What limits a negative observation?

A. Only the admitted frequencies and their valid observation times were covered.

B. A low in-band noise floor guarantees coverage of the entire agile trajectory.

C. A scalar loss correction restores samples from excluded frequencies.

D. The preselector rejection establishes absence at every excluded frequency.

Answer: A. Spectral exclusion can improve immunity while reducing event coverage. A correction cannot restore signal information that was never admitted.

Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why the selected alternative fits: Only the admitted frequencies and their valid observation times were covered.

Distinguishing consideration: compare this with option B, “A low in-band noise floor guarantees coverage of the entire agile trajectory”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-MCQ-035. When is a notch filter potentially useful in the chapter's front-end strategy?

A. When measured rejection of a dominant unwanted band occurs before the vulnerable stage while the desired response remains acceptable.

B. When its nominal notch frequency alone proves the desired waveform is unaffected.

C. Only when placed after every active stage.

D. Whenever it produces the lowest displayed baseline regardless of desired transfer.

Answer: A. The relevant benefit is reduced harmful admission with retained desired capability. Actual response and placement determine that trade. Review: Front-End Characterization and Field Decisions. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

Why the selected alternative fits: When measured rejection of a dominant unwanted band occurs before the vulnerable stage while the desired response remains acceptable.

Distinguishing consideration: compare this with option B, "When its nominal notch frequency alone proves the desired waveform is unaffected"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Front-End Characterization and Field Decisions.

Review: Chapter 3 — Front-End Characterization and Field Decisions.

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V011-C03-MCQ-036. A preselector precedes an amplifier and strongly rejects a blocker. Why must the filter's own power-handling and state limits still be considered?

A. Strong rejection guarantees zero stored energy and zero heating.

B. All receiver limits are determined only by the last digitizer.

C. Passive components cannot be characterized by a transfer function.

D. The filter itself can be the first component to leave the assumed valid transfer regime.

Answer: D. The first-vulnerable-stage analysis applies to every exposed component. A downstream amplifier can be protected while an upstream accessory is outside its conditions. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: The filter itself can be the first component to leave the assumed valid transfer regime.

Distinguishing consideration: compare this with option A, "Strong rejection guarantees zero stored energy and zero heating"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-MCQ-037. A constructed gain plan requires a linear power gain of at least 16 for noise performance and no more than 25 for downstream loading. Which choice is inside the feasible interval?

A. 40.

B. 12.

C. 30.

D. 20.

Answer: D. Both independently justified bounds must hold: 16 no greater than gain no greater than 25. A choice of 20 satisfies the overlap. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why the selected alternative fits: 20.

Distinguishing consideration: compare this with option A, “40”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-038. The required minimum gain for noise is 25, but the maximum permitted gain for loading is 10, both in linear power units. What is the justified conclusion?

A. No gain setting satisfies both stated bounds; alter the architecture or requirement and re-evaluate.

B. Use 10 and claim that downstream amplification restores the original noise target.

C. Use 25 because noise requirements always override loading limits.

D. Use the arithmetic mean, 17.5, because it compromises between the limits.

Answer: A. An empty intersection is infeasible under the stipulated model. Averaging incompatible bounds does not satisfy either requirement. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why the selected alternative fits: No gain setting satisfies both stated bounds; alter the architecture or requirement and re-evaluate.

Distinguishing consideration: compare this with option B, “Use 10 and claim that downstream amplification restores the original noise target”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-039. A blocker is -40 dBm at the input of an adjustable linear amplifier. A separately justified downstream limit is -20 dBm, with no other transfer. What is the maximum amplifier gain under that limit?

A. -20 dB.

B. 60 dB.

C. 20 dB.

D. 40 dB.

Answer: C. The output is -40 dBm plus gain in dB. Requiring it not exceed -20 dBm bounds gain at 20 dB. Actual peaks and other blockers remain part of a full loading analysis. Review: Equation 6; Choose gain from a feasible interval. Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: 20 dB.

Distinguishing consideration: compare this with option A, “-20 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-040. A noise calculation requires a minimum linear gain of 25, while loading permits at most 20 dB. Which interval is consistent in decibels?

A. Approximately 13.98 dB through 20 dB.

B. 0.04 dB through 20 dB.

C. Approximately 27.96 dB through 20 dB.

D. 25 dB through 20 dB.

Answer: A. Convert the power ratio with ten times $\log_{10}$: 25 corresponds to 13.979 dB. Mixing linear gain and dB can falsely make a feasible interval appear empty.
Review: Choose gain from a feasible interval; Model 2B. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
Why the selected alternative fits: Approximately 13.98 dB through 20 dB.
Distinguishing consideration: compare this with option B, “0.04 dB through 20 dB”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.
Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-041. Under the matched two-stage model, the first stage contributes 80 K, the second 2000 K, and the target is 100 K. Downstream loading separately limits first-stage gain to 15 dB. Which conclusion is correct?

A. The noise target requires at least 20 dB, so the stated design has no feasible gain overlap.

B. A gain of 15 dB satisfies the target because 80 K is below 100 K.

C. A gain of 17.5 dB satisfies both constraints by averaging their limits.

D. Later digital scaling can make 15 dB satisfy the analog noise bound.

Answer: A. The later contribution may be at most 20 K, requiring power gain $\frac{2000}{20}=100$, or 20 dB. The independently stated 15 dB ceiling prevents that choice.

Review: Choose gain from a feasible interval; Equation 4J. Source: Equation 4J. Minimum first-stage gain for a temperature limit (p. 675)

Why the selected alternative fits: The noise target requires at least 20 dB, so the stated design has no feasible gain overlap.

Distinguishing consideration: compare this with option B, “A gain of 15 dB satisfies the target because 80 K is below 100 K”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-042. Increasing attenuation before an overloaded amplifier restores its linear response. What trade remains to be assessed?

A. Whether a corrected signal display must fall by exactly the attenuation amount.

B. The accompanying sensitivity and noise penalty at the original input plane.

C. Whether attenuation after the final detector can provide the same upstream protection.

D. Whether the original compressed samples can now be repaired by the new setting.

Answer: B. Pre-amplifier loss can restore validity while raising input-equivalent noise. A useful choice must satisfy the intended weak-signal observation as well as loading. Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

Why the selected alternative fits: The accompanying sensitivity and noise penalty at the original input plane.

Distinguishing consideration: compare this with option A, “Whether a corrected signal display must fall by exactly the attenuation amount”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-MCQ-043. An attenuator is moved from before an amplifier to immediately after it, preserving nominal total signal gain. What protection inference is justified?

A. The amplifier loses the protection previously supplied by that attenuation at its input.

B. The amplifier exposure is unchanged because total chain gain is unchanged.

C. The amplifier input compression limit rises by the attenuation setting.

D. The after-amplifier attenuator reverses products created inside the amplifier.

Answer: A. A downstream attenuator changes what reaches later stages; it does not reduce what enters the preceding amplifier. Equal final gain conceals this internal difference. Review: Choose gain from a feasible interval; Application 2B.7. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why the selected alternative fits: The amplifier loses the protection previously supplied by that attenuation at its input.

Distinguishing consideration: compare this with option B, “The amplifier exposure is unchanged because total chain gain is unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-044. The corrected desired level remains constant when input attenuation is increased. What does that establish about sensitivity?

A. It does not establish unchanged sensitivity; the corrected noise and detection criterion must also be evaluated.

B. It proves that the attenuator is physically noiseless.

C. It establishes identical input-equivalent noise because both signal estimates agree.

D. It establishes that every upstream and downstream component is linear.

Answer: A. Amplitude correction can keep the external-signal estimate constant while physical loss worsens the noise budget. The signal estimate and sensitivity are different quantities. Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

Why the selected alternative fits: It does not establish unchanged sensitivity; the corrected noise and detection criterion must also be evaluated.

Distinguishing consideration: compare this with option B, “It proves that the attenuator is physically noiseless”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-MCQ-045. A receiver clips before a final digital scaling operation. What does reducing only the digital scale accomplish for those clipped samples?

A. It lowers their displayed magnitude but cannot restore the missing analog information.

B. It reconstructs the clipped sample peaks from the scale factor.

C. It increases the physical input range of the preceding amplifier.

D. It makes an earlier gain calibration valid through the clipped interval.

Answer: A. Scaling retained data is not a reversal of saturation. The acquisition must remain within the relevant analog and converter ranges. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why the selected alternative fits: It lowers their displayed magnitude but cannot restore the missing analog information.

Distinguishing consideration: compare this with option B, “It reconstructs the clipped sample peaks from the scale factor”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-046. A constant weak source appears to vary whenever an intermittent blocker arrives and automatic gain control is active. What is a justified explanation to test?

A. The blocker can drive gain-state changes that alter the weak-source indication.

B. The weak transmitter must have changed its emitted power synchronously.

C. AGC guarantees that every corrected transient amplitude is exact.

D. A receiver gain change cannot affect a source that is physically constant.

Answer: A. The observed amplitude depends on both source and receiver state. Gain-control telemetry or an equivalent state reconstruction is needed to separate them. Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

Why the selected alternative fits: The blocker can drive gain-state changes that alter the weak-source indication.

Distinguishing consideration: compare this with option B, “The weak transmitter must have changed its emitted power synchronously”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-MCQ-047. Why is an average gain value insufficient to reconstruct an interval that includes clipping and missing samples?

A. Average gain always equals the smallest instantaneous gain.

B. A single average necessarily determines the timing of every state transition.

C. An arithmetic average is forbidden even for a separately justified linear estimator.

D. It does not identify the time-dependent transfer or restore information discarded during invalid states.

Answer: D. Gain history and irreversible loss cannot be inferred from one mean. A valid estimator must account for the states and information that actually remain.

Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why the selected alternative fits: It does not identify the time-dependent transfer or restore information discarded during invalid states.

Distinguishing consideration: compare this with option A, “Average gain always equals the smallest instantaneous gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-048. When analog signal and noise underuse a later digitizer range, what can additional valid analog gain improve?

A. The number of analog samples that existed before a recording gap.

B. The analog SNR lost before that gain stage, regardless of added noise.

C. The input-referred importance of converter noise, while leaving the established analog SNR unchanged if added noise is negligible.

D. The frequency rejection of an earlier absent preselector.

Answer: C. More gain can make converter noise less consequential relative to the admitted analog signal and noise. It cannot reverse an earlier analog SNR loss.

Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why the selected alternative fits: The input-referred importance of converter noise, while leaving the established analog SNR unchanged if added noise is negligible.

Distinguishing consideration: compare this with option A, “The number of analog samples that existed before a recording gap”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-049. A quiet digital trace is observed after heavy processing. Which additional evidence is needed before interpreting it as a valid low-noise analog observation?

A. Only the nominal ADC bit count without its actual input level.

B. Raw samples and gain or overload state sufficient to exclude clipping, underuse and processing-induced suppression.

C. Only the final digital scale multiplier.

D. Only the displayed baseline after the heaviest available averaging.

Answer: B. Several invalid or differently processed acquisitions can produce a quiet display. The retained raw data and state record constrain that interpretation.

Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why the selected alternative fits: Raw samples and gain or overload state sufficient to exclude clipping, underuse and processing-induced suppression.

Distinguishing consideration: compare this with option A, “Only the nominal ADC bit count without its actual input level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-MCQ-050. A challenge relies on a small difference between two attenuator settings. Which physical characteristics most directly affect that comparison?

A. Actual step loss, frequency response, repeatability and contact condition.

B. Only the number of selectable attenuation states.

C. Only the final filter center frequency.

D. Only the displayed correction rounded to the nearest decibel.

Answer: A. The test depends on the realized difference in transfer, not merely the commanded labels. Small systematic step errors can imitate or hide the expected change. Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

Why the selected alternative fits: Actual step loss, frequency response, repeatability and contact condition.

Distinguishing consideration: compare this with option B, “Only the number of selectable attenuation states”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-MCQ-051. A component does not follow the expected raw change when a known attenuator is switched. What is the correct first interpretation?

A. The attenuator correction has proved all later stages linear.

B. Its origin or validity may involve a stage after the attenuator, clipping or control-loop behavior, which requires further tests.

C. It is conclusively internal regardless of source and combiner behavior.

D. It is conclusively an external emitter because the input source remains connected.

Answer: B. The differential response constrains mechanisms but is not a unique attribution by itself. Realized transfer and competing receiver behavior must be checked. Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

Why the selected alternative fits: Its origin or validity may involve a stage after the attenuator, clipping or control-loop behavior, which requires further tests.

Distinguishing consideration: compare this with option A, “The attenuator correction has proved all later stages linear”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-MCQ-052. A valid external CW signal is measured in two fixed states differing only by 6 dB input attenuation. What raw and correctly input-referred behavior is expected?

A. Both raw and corrected levels must rise by 6 dB.

B. Raw signal level falls by 6 dB; the corrected input estimate remains approximately constant within uncertainty.

C. Both levels remain constant even without applying any state correction.

D. Raw signal level remains constant; the corrected input estimate falls by 6 dB.

Answer: B. The physical attenuator changes the transmitted signal. An applicable input-plane correction removes that known transfer from the estimate, without removing its noise consequences. Review: Gain Distribution and Attenuation; Equation 6. Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: Raw signal level falls by 6 dB; the corrected input estimate remains approximately constant within uncertainty.

Distinguishing consideration: compare this with option A, “Both raw and corrected levels must rise by 6 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-MCQ-053. A line generated after a switched attenuator may respond differently from an external reference. Why is that useful but insufficient for final attribution?

A. It distinguishes path hypotheses, but clipping, control changes and upstream source products can complicate the response.

B. Every internal line necessarily has exactly zero response to every attenuator state.

C. A single two-state comparison fixes the physical origin without a source control.

D. An external signal can never coexist with a receiver product at the same frequency.

Answer: A. State responses must be interpreted under their actual transfer and validity conditions. A plausible mechanism remains a hypothesis until discriminating alternatives are bounded. Review: Gain Distribution and Attenuation; An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: It distinguishes path hypotheses, but clipping, control changes and upstream source products can complicate the response.

Distinguishing consideration: compare this with option B, “Every internal line necessarily has exactly zero response to every attenuator state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures; Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — An acceptance sequence that separates competing failures; Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-MCQ-054. Two preselector states show different noise levels but also use different effective bandwidths. What comparison is justified?

A. Treat the entire difference as a receiver noise-figure change.

B. Use the lower trace as proof of superior weak-signal detection in every case.

C. Subtract the center frequencies to obtain the bandwidth correction.

D. Match bandwidth or account explicitly for its effect before attributing the difference to the preselector mechanism.

Answer: D. Integrated noise depends on admitted bandwidth. A changed bandwidth is a competing explanation, and desired-signal retention must also remain adequate. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: Match bandwidth or account explicitly for its effect before attributing the difference to the preselector mechanism.

Distinguishing consideration: compare this with option A, “Treat the entire difference as a receiver noise-figure change”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-055. A test changes preselector, amplifier gain and detector averaging at once. What is its principal attribution weakness?

A. A correct final amplitude removes the need to identify the altered states.

B. The effect can always be assigned to whichever setting changed by the largest numerical amount.

C. Every simultaneous change necessarily corrupts all retained raw data.

D. Several altered mechanisms can explain the result, so the test does not isolate the proposed cause.

Answer: D. A useful challenge predicts how a controlled change affects competing mechanisms. Multiple uncontrolled changes weaken that discrimination. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: Several altered mechanisms can explain the result, so the test does not isolate the proposed cause.

Distinguishing consideration: compare this with option A, “A correct final amplitude removes the need to identify the altered states”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-056. A report states that the receiver has 12 dB of headroom. What information makes that statement interpretable?

A. Only the receiver's absolute damage rating.

B. Only the final chain gain in decibels.

C. Only the difference between the displayed noise floor and the top of the screen.

D. The operating quantity and plane, the particular limiting criterion, and the applicable state and signal conditions.

Answer: D. Headroom is relative to a specified limit. Compression, converter clipping and damage thresholds are different quantities and cannot be substituted silently. Review: Chapter Glossary: Headroom; Equation 6. Source: Equation 6. Input power after front-end correction (p. 1269)

Why the selected alternative fits: The operating quantity and plane, the particular limiting criterion, and the applicable state and signal conditions.

Distinguishing consideration: compare this with option A, "Only the receiver's absolute damage rating"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — HEADROOM (glossary).

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — HEADROOM (glossary).

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V011-C03-MCQ-057. A short pulse has modest average power but a large peak. Which conclusion follows for protection planning?

A. A peak rating for one pulse width covers every duty cycle.

B. Both peak and average exposure must be compared with limits having appropriate waveform and duration conditions.

C. The final display detector necessarily measures the largest incident peak.

D. The average power alone guarantees survival whenever it is below a CW rating.

Answer: B. Protection and heating depend on waveform conditions. Neither a mean nor an unqualified peak number supplies every relevant exposure condition.

Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: Both peak and average exposure must be compared with limits having appropriate waveform and duration conditions.

Distinguishing consideration: compare this with option A, “A peak rating for one pulse width covers every duty cycle”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-058. Why does an idle protection limiter still belong in a small-signal calibration and noise budget?

A. Its survival rating determines its exact small-signal phase response.

B. It necessarily has zero transfer effect until its damage threshold is crossed.

C. Its insertion loss, mismatch and reactive loading can change the desired transfer before limiting begins.

D. A limiter is outside the receiver boundary whenever it is passive.

Answer: C. Protection hardware remains a physical part of the signal path. Its small-signal state must be characterized instead of represented as an ideal transparent switch. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Its insertion loss, mismatch and reactive loading can change the desired transfer before limiting begins.

Distinguishing consideration: compare this with option A, “Its survival rating determines its exact small-signal phase response”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-059. In the PIN-limiter mechanism described by the cited manufacturer, what happens when a large RF signal increases carriers in the intrinsic region?

A. The desired weak-signal phase is guaranteed unchanged during limiting.

B. The RF resistance necessarily increases without changing mismatch.

C. The RF resistance decreases and the circuit can present a stronger limiting mismatch.

D. The carrier population is irrelevant to the RF conduction state.

Answer: C. The cited mechanism relates stored carriers to lowered RF resistance. It explains why the mounted protection network cannot be treated as an ideal on/off element. Review: Measure protection in the small-signal and recovery states; source note 10. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: The RF resistance decreases and the circuit can present a stronger limiting mismatch.

Distinguishing consideration: compare this with option A, “The desired weak-signal phase is guaranteed unchanged during limiting”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-060. Why can a PIN-limiter recovery depend on the external current-return path?

A. The return path makes every detector recover at the same instant as the diode.

B. The return path removes the need to characterize the mounted network.

C. The external path fixes the desired source frequency independently of the input.

D. Carrier removal after the event depends partly on the path through which stored charge can leave.

Answer: D. The cited device explanation connects carrier removal with the external circuit. Recovery of the entire measured chain can still include additional mechanisms. Review: Measure protection in the small-signal and recovery states; source note 10. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Carrier removal after the event depends partly on the path through which stored charge can leave.

Distinguishing consideration: compare this with option A, “The return path makes every detector recover at the same instant as the diode”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-061. Why characterize a complete mounted protection network rather than only a bare diode specification?

A. Mounting, reactive loading and the surrounding current path can affect small-signal transfer and recovery.

B. Circuit parasitics disappear whenever the receiver uses a 50-ohm nominal interface.

C. The mounted network necessarily has exactly the same response at every frequency.

D. A bare diode specification has no possible relevance to any design decision.

Answer: A. A component rating applies under its stated conditions. The installed network adds interfaces and circuit behavior that must be included in the actual signal path. Review: Measure protection in the small-signal and recovery states.

Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Mounting, reactive loading and the surrounding current path can affect small-signal transfer and recovery.

Distinguishing consideration: compare this with option B, “Circuit parasitics disappear whenever the receiver uses a 50-ohm nominal interface”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-062. Which set contains three distinct protection consequences identified in the chapter?

A. During-event leakage, hardware survival, and subsequent recovery of a valid weak-signal measurement.

B. Detector bandwidth alone, independent of the event and protected hardware.

C. Nominal gain, corrected gain, and displayed gain as three independent survival guarantees.

D. Center frequency, display center, and tuned frequency as three equivalent recovery measures.

Answer: A. A device may survive while the useful channel remains disturbed, and leakage during the event is a separate exposure quantity. Each needs its own criterion. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: During-event leakage, hardware survival, and subsequent recovery of a valid weak-signal measurement.

Distinguishing consideration: compare this with option B, “Detector bandwidth alone, independent of the event and protected hardware”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-063. A limiter bounds the later portion of a pulse. What may still reach a downstream component?

A. A leading transient before the limiter reaches its limiting state.

B. No RF energy, because eventual limiting guarantees zero earlier leakage.

C. A waveform determined entirely by the final detector averaging setting.

D. Only thermal noise at the enclosure temperature.

Answer: A. The beginning of an event and its steady limited portion can have different transfer. Protection planning must address the leading response as well as later leakage. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: A leading transient before the limiter reaches its limiting state.

Distinguishing consideration: compare this with option B, “No RF energy, because eventual limiting guarantees zero earlier leakage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-064. A catalog gives recovery time to nearly nominal insertion loss. Why may that be insufficient for coherent phase measurement?

A. Insertion loss and phase must recover at identical times in every network.

B. A phase measurement depends only on the limiter survival rating.

C. A shorter catalog recovery value always implies lower measurement uncertainty.

D. Amplitude recovery under that criterion does not automatically establish calibrated phase recovery.

Answer: D. Recovery is defined by an observable and tolerance. The criterion must match the intended amplitude, phase, modulation or baseline requirement. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Amplitude recovery under that criterion does not automatically establish calibrated phase recovery.

Distinguishing consideration: compare this with option A, “Insertion loss and phase must recover at identical times in every network”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-065. Which practice is consistent with the ADL8201 data-sheet example used in the chapter?

A. Treat a typical recovery entry as proof of a complete receiver detector response.

B. Keep the identified device, frequency, pulse width, duty cycle and temperature conditions attached to its survival data.

C. Apply one listed pulse survival rating to every receiver accessory.

D. Use a single device number as a universal permissible test exposure.

Answer: B. The cited tables separate operational performance and conditional survivability. The chapter does not transfer those limits to an arbitrary assembly.

Review: Measure protection in the small-signal and recovery states; source note 11.

Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Keep the identified device, frequency, pulse width, duty cycle and temperature conditions attached to its survival data.

Distinguishing consideration: compare this with option A, “Treat a typical recovery entry as proof of a complete receiver detector response”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-066. What is the appropriate interpretation of an absolute maximum stress rating in a component data sheet?

A. It replaces all pulse-width and duty-cycle conditions elsewhere in the data sheet.

B. It defines the calibrated small-signal range for every waveform.

C. It is not a guarantee of valid continuous measurement operation at that stress.

D. It establishes the complete receiver damage margin without considering accessories.

Answer: C. A stress limit and an operating specification have different purposes. The specified functional conditions and the installed path govern the measurement.
Review: Source note 11; Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: It is not a guarantee of valid continuous measurement operation at that stress.
Distinguishing consideration: compare this with option A, “It replaces all pulse-width and duty-cycle conditions elsewhere in the data sheet”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 3 — Input Protection and Recovery; Chapter 3 — Measure protection in the small-signal and recovery states.
Review: Chapter 3 — Input Protection and Recovery; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-067. A constructed rectangular pulse has 20 dBm on-state power and 1 percent duty factor, with negligible off-state power. What average power follows?

A. 0 dBm.

B. -20 dBm.

C. 2 dBm.

D. 20 dBm.

Answer: A. Twenty dBm is 100 mW. Multiplying by 0.01 gives 1 mW, or 0 dBm. The 20 dBm peak condition still matters to peak-sensitive protection. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: 0 dBm.

Distinguishing consideration: compare this with option B, “-20 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-068. Constructed pulses last 5 microseconds and recur every 1 millisecond without overlap. What duty factor follows?

A. 0.05 percent.

B. 20 percent.

C. 0.5 percent.

D. 5 percent.

Answer: C. Divide 5 microseconds by 1000 microseconds: 0.005, or 0.5 percent. Pulse duration and repetition must use compatible units. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: 0.5 percent.

Distinguishing consideration: compare this with option A, “0.05 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-069. A protected chain survives a pulse but remains outside its weak-signal acceptance tolerance for 20 microseconds. A desired event arrives 10 microseconds after the pulse ends. What is justified?

A. Hardware survival does not establish valid observation of that desired event during recovery.

B. Survival guarantees the desired event was measured with normal sensitivity.

C. The delayed event can be reconstructed from the limiter's peak-power rating.

D. A later successful closing check establishes the earlier event's amplitude.

Answer: A. Recovery creates a time-dependent validity limit. A check after recovery cannot supply information that was unavailable during the disturbed interval.

Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Hardware survival does not establish valid observation of that desired event during recovery.

Distinguishing consideration: compare this with option B, "Survival guarantees the desired event was measured with normal sensitivity"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-070. Which record best supports a recovery measurement after a bounded strong-signal event?

A. A weak desired reference observed before, during and after the event, with event timing and receiver state retained.

B. Only the last sample after the trace appears quiet.

C. Only the data-sheet recovery value of one component.

D. Only a continuous-wave insertion-loss sweep made before the event.

Answer: A. The time-resolved reference reveals both disruption and return under the actual measurement criterion. State and event records support attribution.

Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: A weak desired reference observed before, during and after the event, with event timing and receiver state retained.

Distinguishing consideration: compare this with option B, “Only the last sample after the trace appears quiet”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-071. Why does a satisfactory continuous-wave gain sweep not establish pulsed recovery performance?

A. A pulsed event always has less peak exposure than a CW signal of the same mean power.

B. Recovery is fixed solely by the displayed frequency span.

C. It may never exercise or observe the post-pulse transient state that defines recovery.

D. Continuous-wave gain is unrelated to every possible small-signal measurement.

Answer: C. Steady-state response and time-dependent recovery test different conditions. The pulse waveform and observation interval must actually exercise the latter. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: It may never exercise or observe the post-pulse transient state that defines recovery.

Distinguishing consideration: compare this with option A, “A pulsed event always has less peak exposure than a CW signal of the same mean power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-072. A long acquisition is reviewed only at its final settled endpoint. What can that review miss?

A. Every possible calibration error in the final sample by definition.

B. The need for a clock only when no pulse was present.

C. An earlier invalid interval during which nearby weak events were distorted or undetectable.

D. The final settled amplitude that was actually measured.

Answer: C. A valid endpoint does not describe the entire trajectory. Recovery requires observations over the interval relevant to subsequent events. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: An earlier invalid interval during which nearby weak events were distorted or undetectable.

Distinguishing consideration: compare this with option A, “Every possible calibration error in the final sample by definition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-073. A slow trace return follows a pulse in a chain containing a limiter, AGC and detector averaging. What can be concluded from the trace alone?

A. The limiter alone caused the delay because it is present.

B. The data sheet recovery time is necessarily false.

C. The analog amplifier must be damaged permanently.

D. The measured chain has persistence, but the responsible subsystem has not yet been isolated.

Answer: D. Multiple stages can retain memory. A controlled change or independent observable is required to assign the measured delay to one mechanism. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: The measured chain has persistence, but the responsible subsystem has not yet been isolated.

Distinguishing consideration: compare this with option A, “The limiter alone caused the delay because it is present”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-074. Reducing detector averaging time makes a recovery edge appear faster. Which accompanying effect must be evaluated?

A. A guaranteed equal reduction in physical limiter carrier lifetime.

B. The changed measurement variability and temporal response of the detector itself.

C. A guaranteed increase in the protected amplifier's damage threshold.

D. Removal of every gain-state transition from the acquisition.

Answer: B. Detector dynamics can mask analog recovery. Altering them changes the observation system, including noise, and must be recorded. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: The changed measurement variability and temporal response of the detector itself.

Distinguishing consideration: compare this with option A, "A guaranteed equal reduction in physical limiter carrier lifetime"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-075. When can a bypass comparison help attribute a protection-related delay?

A. When the configuration permits it, the remaining path stays within its ratings, and the isolated change is actually documented.

B. Whenever the bypass produces a numerically higher gain, without a reference comparison.

C. Whenever removal of protection makes the trace cleaner, regardless of downstream exposure.

D. Only when all other settings are also changed to maximize sensitivity.

Answer: A. A bypass is informative only under valid, controlled conditions. Otherwise it changes exposure or confounds the mechanism being isolated. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: When the configuration permits it, the remaining path stays within its ratings, and the isolated change is actually documented.

Distinguishing consideration: compare this with option B, “Whenever the bypass produces a numerically higher gain, without a reference comparison”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-076. After a suspected overload, which check best reflects the chapter's verification principle?

A. A single low-frequency tone that proves every band remains unchanged.

B. The absence of visible mechanical damage as evidence of calibrated transfer.

C. A front-panel self-test alone that replaces external path verification in all cases.

D. Known references at several relevant levels and frequencies, compared with applicable accepted baselines.

Answer: D. Hidden loss, distortion and recovery defects can depend on level and frequency. The check must exercise the range relevant to the subsequent measurement. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: Known references at several relevant levels and frequencies, compared with applicable accepted baselines.

Distinguishing consideration: compare this with option A, "A single low-frequency tone that proves every band remains unchanged"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-077. A limiter still passes a low-frequency reference after an event. What remains unproved?

A. Its low-frequency response at the conditions just checked.

B. Whether low-frequency and high-frequency signals use the same units.

C. The existence of the retained low-frequency reference record.

D. Its required loss, distortion and response at untested higher frequencies and levels.

Answer: D. A local successful test has local scope. It cannot verify every spectral and loading condition of the installed path. Review: Input Protection and Recovery.

Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: Its required loss, distortion and response at untested higher frequencies and levels.

Distinguishing consideration: compare this with option A, “Its low-frequency response at the conditions just checked”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-078. What governs the magnitude of a proposed strong-signal challenge to an installed receiver?

A. The amount of attenuation shown only after the vulnerable component.

B. A favorable survival number from an unrelated limiter data sheet.

C. The highest level the available generator can produce.

D. The actual receiver and accessory limits under the intended waveform and configuration.

Answer: D. A constructed example is not an equipment rating. The complete exposed path and specified conditions govern a valid challenge. Review: Input Protection and Recovery; source note 11. Source: §3.7 Input Protection and Recovery (p. 1260)

Why the selected alternative fits: The actual receiver and accessory limits under the intended waveform and configuration.

Distinguishing consideration: compare this with option A, “The amount of attenuation shown only after the vulnerable component”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Input Protection and Recovery; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Input Protection and Recovery; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-079. A protection network prevents permanent damage but significantly raises the weak-signal noise floor. How should its acceptance be judged?

A. Only by its peak-power rating, without a noise or transfer measurement.

B. As necessarily defective because protection can never change small-signal loss.

C. Against both survival and the declared operational measurement requirement, as separate criteria.

D. As fully acceptable for every weak-signal task because the hardware survived.

Answer: C. Protection success and usable measurement performance are distinct. The intended observation determines whether the surviving path is fit for use.

Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Against both survival and the declared operational measurement requirement, as separate criteria.

Distinguishing consideration: compare this with option A, “Only by its peak-power rating, without a noise or transfer measurement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-MCQ-080. A front-end response drifts after repeated high-power events while nominal settings remain fixed. What should the investigation include?

A. Only the average corrected signal level after discarding event timing.

B. Only a replacement final display scale.

C. Power history, temperature, bias and protection state alongside the measured transfer.

D. Only the commanded frequency because an unchanged setting establishes unchanged hardware.

Answer: C. Physical state can change without a new menu setting. The chapter identifies history, thermal behavior and bias as possible contributors to gradual or persistent response change. Review: Input Protection and Recovery; Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why the selected alternative fits: Power history, temperature, bias and protection state alongside the measured transfer.

Distinguishing consideration: compare this with option A, “Only the average corrected signal level after discarding event timing”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Verification and Maintenance Controls; Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Verification and Maintenance Controls; Chapter 3 — Input Protection and Recovery.

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V011-C03-MCQ-081. Two generators joined through a combiner produce a new line when both are enabled. What must be bounded before assigning the line to receiver intermodulation?

A. Only the desired-frequency display correction.

B. Source harmonics and noise, generator interaction, combiner behavior and actual levels at the receiver plane.

C. Only the receiver gain setting, because a passive combiner cannot affect attribution.

D. Only the nominal frequency difference between the generators.

Answer: B. The source and combining path can generate or convey the same apparent product. A receiver attribution needs controls that exclude those alternatives. Review: An acceptance sequence that separates competing failures.

Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: Source harmonics and noise, generator interaction, combiner behavior and actual levels at the receiver plane.

Distinguishing consideration: compare this with option A, “Only the desired-frequency display correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-082. A blocker source carries broadband noise inside the desired channel. What can that contamination imitate?

A. A proof that the receiver's equivalent noise temperature is independent of input state.

B. A receiver-related noise rise attributed to the blocker condition.

C. Only a calibration-date error, without any change in measured noise.

D. Only a change in the desired transmitter clock frequency.

Answer: B. The observed channel noise can originate upstream of the receiver. Source spectral purity and delivered noise must be bounded when interpreting the challenge. Review: An acceptance sequence that separates competing failures.

Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: A receiver-related noise rise attributed to the blocker condition.

Distinguishing consideration: compare this with option A, "A proof that the receiver's equivalent noise temperature is independent of input state"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-083. Two blocker sources deliver the same carrier level but different close-in noise at the desired offset. What follows for a comparison of receiver desensitization?

A. Any difference in desired-channel noise must be receiver reciprocal mixing.

B. Equal carrier levels imply equal complete waveforms at the input plane.

C. The source with lower noise requires no measurement of its actual transfer path.

D. Equal carrier levels alone do not establish equivalent noise exposure or isolate the receiver mechanism.

Answer: D. A carrier amplitude is only one property of the applied environment. Different source noise can change the observed outcome before receiver-generated effects are considered. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: Equal carrier levels alone do not establish equivalent noise exposure or isolate the receiver mechanism.

Distinguishing consideration: compare this with option A, “Any difference in desired-channel noise must be receiver reciprocal mixing”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-084. A controlled blocker sweep keeps the weak desired source fixed. Which observation is most directly associated with changed desired transfer?

A. A source-plane carrier reading unchanged by design.

B. A reproducible change in the desired amplitude or modulation quality under the blocker condition.

C. A new line at an unrelated frequency without measuring the desired response.

D. A nominal filter-state name without any retained signal record.

Answer: B. The chapter separates desired-transfer change, admitted-noise rise and discrete products. Compression and gain control can both affect the desired response, so attribution still needs controls. Review: Table 3A. Source: Table 3A. Evidence to retain during a constructed front-end challenge (p. 1266)

Why the selected alternative fits: A reproducible change in the desired amplitude or modulation quality under the blocker condition.

Distinguishing consideration: compare this with option A, “A source-plane carrier reading unchanged by design”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge.

Review: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge.

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V011-C03-MCQ-085. The blocker is removed and the desired reference returns to its accepted baseline. What is the proper scope of that result?

A. It establishes all receiver bands and accessory paths even if only one was exercised.

B. It supports return of the tested observable in the checked state and interval, without proving uninterrupted validity during the prior exposure.

C. It proves that no earlier desired event was distorted.

D. It removes the need to retain the during-event record.

Answer: B. A return check is evidence about the functions and time actually tested. Its successful endpoint does not reconstruct the preceding measurement history.

Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: It supports return of the tested observable in the checked state and interval, without proving uninterrupted validity during the prior exposure.

Distinguishing consideration: compare this with option A, “It establishes all receiver bands and accessory paths even if only one was exercised”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-086. A two-tone challenge is intended to test a discrete-product hypothesis. Which controlled change is particularly informative?

A. Changing only the plot reference level while leaving the physical inputs identical.

B. Averaging more traces after discarding the tone settings.

C. Changing every gain and filter state simultaneously without a reference.

D. Changing tone frequencies and checking whether the suspect component follows the predicted product frequency.

Answer: D. A mechanism makes a frequency prediction that can be challenged. Source-path products must still be excluded because they may follow similar combinations. Review: Table 3A; Hypothetical Case Adjudication. Source: Table 3A. Evidence to retain during a constructed front-end challenge (p. 1266)

Why the selected alternative fits: Changing tone frequencies and checking whether the suspect component follows the predicted product frequency.

Distinguishing consideration: compare this with option A, “Changing only the plot reference level while leaving the physical inputs identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge; Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

Review: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge; Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-MCQ-087. An apparent product follows an expected attenuation dependence in one comparison. Why retain source controls?

A. Attenuation dependence is irrelevant to every nonlinear model.

B. A calibrated attenuator removes the need to identify its location.

C. A product generated outside the receiver cannot enter its passband.

D. Source or combiner products and state changes can mimic part of the expected response.

Answer: D. A predicted slope is supportive within its model, not a unique physical-origin label. Controls must test credible alternative generation paths. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: Source or combiner products and state changes can mimic part of the expected response.

Distinguishing consideration: compare this with option A, “Attenuation dependence is irrelevant to every nonlinear model”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-088. Why retain both a common-input-plane comparison and the raw physical output indications?

A. Corrected output alone preserves every analog state transition.

B. Raw output alone always identifies the correct external reference plane.

C. The former compares external estimates; the latter exposes the actual gain or noise change used to produce them.

D. They are duplicate records with identical meaning in every state.

Answer: C. Corrections can hide deliberate or unexplained changes in raw level. Retaining both forms makes the transfer and its application reviewable. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: The former compares external estimates; the latter exposes the actual gain or noise change used to produce them.

Distinguishing consideration: compare this with option A, “Corrected output alone preserves every analog state transition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-089. Which configuration record is generally stronger than a screen image alone for reproducing a front-end comparison?

A. The nominal model name without installed options or path state.

B. A retained setup or machine-readable state record that identifies the actual path, gain, filter and timing conditions.

C. A single statement that the instrument used its normal mode.

D. A cropped spectrum with its settings annotations removed.

Answer: B. Screen annotations can omit consequential settings. A state record connects the observed trace to the configuration that produced it. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: A retained setup or machine-readable state record that identifies the actual path, gain, filter and timing conditions.

Distinguishing consideration: compare this with option A, “The nominal model name without installed options or path state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-090. Table 3A calls for linear integrated channel noise during a blocker challenge. Why keep the quantity and processing definition explicit?

A. All noise detectors produce identical values once the center frequency matches.

B. The desired source frequency alone fixes the noise estimator.

C. Different detector and averaging operations can produce different displayed statistics from the same underlying noise.

D. A decibel trace average is automatically the same estimator as mean linear power.

Answer: C. The test compares a declared observable. Changing processing can imitate a physical noise change unless the estimator and conditions remain compatible. Review: Table 3A. Source: Table 3A. Evidence to retain during a constructed front-end challenge (p. 1266)

Why the selected alternative fits: Different detector and averaging operations can produce different displayed statistics from the same underlying noise.

Distinguishing consideration: compare this with option A, “All noise detectors produce identical values once the center frequency matches”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge.

Review: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge.

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V011-C03-MCQ-091. Improving generator isolation removes a suspect line while the delivered fundamental tones are restored to the same levels. Which interpretation is most supported?

A. The receiver's nonlinear coefficient must have changed solely because isolation was added upstream.

B. Receiver attribution no longer requires checking the actual source-plane spectrum.

C. Generation or interaction in the source/combiner path remains a strong explanation for the original line.

D. The original line is proved to have come from an external transmitter unrelated to the test.

Answer: C. The controlled change specifically challenges source interaction. Preserving delivered fundamentals makes that comparison more discriminating, while the full path evidence still determines the claim. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: Generation or interaction in the source/combiner path remains a strong explanation for the original line.

Distinguishing consideration: compare this with option A, "The receiver's nonlinear coefficient must have changed solely because isolation was added upstream"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-092. Added attenuation suppresses both the suspect component and the desired reference below the measurement floor. What conclusion is warranted?

A. The suspect component is conclusively external because the desired reference disappeared.

B. The comparison is inconclusive about origin because observation capability was also lost.

C. The suspect component is conclusively internal because it disappeared.

D. The receiver's noise floor must have remained physically unchanged.

Answer: B. Disappearance is not a discriminating result when both hypotheses become unobservable. A redesigned challenge must retain sufficient desired-reference capability. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: The comparison is inconclusive about origin because observation capability was also lost.

Distinguishing consideration: compare this with option A, "The suspect component is conclusively external because the desired reference disappeared"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-MCQ-093. Which event calls for renewed front-end verification under the chapter's maintenance controls?

A. Only expiration of a calendar interval, regardless of intervening configuration events.

B. Only visible permanent damage to the enclosure.

C. Only a measured conversion-gain change, treating unchanged gain as sufficient evidence of unchanged noise, linearity and recovery.

D. A consequential cable, filter, firmware, battery, transport or overload change affecting the measurement path.

Answer: D. The controls are tied to changes that may alter actual transfer, state or stability. A scheduled interval alone does not capture every consequential event.

Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why the selected alternative fits: A consequential cable, filter, firmware, battery, transport or overload change affecting the measurement path.

Distinguishing consideration: compare this with option A, "Only expiration of a calendar interval, regardless of intervening configuration events"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-MCQ-094. Why retain serialized accessories and controlled connector assembly conditions when comparing reference sweeps?

A. To guarantee exactly zero measurement uncertainty.

B. To replace all frequency and level information in the reference record.

C. To reduce ambiguity between a receiver change and a changed external connection or accessory response.

D. To make mismatch corrections unnecessary at every frequency.

Answer: C. The installed path includes accessories and connectors. Their identity and assembly conditions help make repeated comparisons physically comparable.

Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why the selected alternative fits: To reduce ambiguity between a receiver change and a changed external connection or accessory response.

Distinguishing consideration: compare this with option A, “To guarantee exactly zero measurement uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-MCQ-095. A repeat reference sweep differs from its accepted baseline by more than the stated comparison uncertainty. What is the appropriate action?

A. Apply the baseline gain unchanged because the nominal instrument model is the same.

B. Average the discrepant sweep with the baseline and declare the result exact.

C. Investigate the difference and applicable state before returning the path to the intended measurement service.

D. Discard the new result whenever the equipment still powers on.

Answer: C. A consequential difference can indicate changed transfer, setup or uncertainty assumptions. It requires a resolved explanation or a bounded limitation.

Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why the selected alternative fits: Investigate the difference and applicable state before returning the path to the intended measurement service.

Distinguishing consideration: compare this with option A, “Apply the baseline gain unchanged because the nominal instrument model is the same”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-MCQ-096. Which release statement is most defensible after a front-end verification?

A. A claim that one two-tone test excludes every future artifact mechanism.

B. A statement that hardware survival alone establishes calibrated measurement accuracy.

C. A blanket pass statement that implies all possible frequencies and waveforms were tested.

D. A statement of verified frequency, level, state and known limitations supported by retained results.

Answer: D. The release scope should follow the actual tested envelope. It must not convert finite tests into a universal claim. Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why the selected alternative fits: A statement of verified frequency, level, state and known limitations supported by retained results.

Distinguishing consideration: compare this with option A, “A claim that one two-tone test excludes every future artifact mechanism”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-MCQ-097. The chapter's hypothetical 1.2 GHz component disappears with a preselector that passes that frequency, and a two-tone test reproduces it. What is the strongest immediately justified description?

A. Proof that only the receiver's first amplifier could have generated the line.

B. Evidence supporting a product hypothesis, with source/combiner products and desired-transfer preservation still to be bounded for receiver-specific attribution.

C. Proof that a hostile 1.2 GHz transmitter was removed by the preselector.

D. Proof that every component passing the preselector is an external signal.

Answer: B. The observations are discriminating but do not by themselves identify every physical generation path. The chapter retains the source-path and reference-transfer qualifications. Review: Hypothetical Case Adjudication. Source: §3.14 Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection (p. 1272)

Why the selected alternative fits: Evidence supporting a product hypothesis, with source/combiner products and desired-transfer preservation still to be bounded for receiver-specific attribution.

Distinguishing consideration: compare this with option A, "Proof that only the receiver's first amplifier could have generated the line"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

Review: Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-MCQ-098. Changing antenna polarization reduces a dominant local blocker. What additional check supports a claimed weak-signal benefit?

A. Treat the lower blocker level as a complete receiver calibration.

B. Establish how the same change affects the desired signal and the resulting measurement capability.

C. Apply the original antenna correction without regard to orientation.

D. Assume the desired transfer is unchanged because only the blocker was noticed.

Answer: B. An antenna change can alter both desired and unwanted coupling. The useful comparison must retain the intended observation rather than infer benefit from blocker reduction alone. Review: Front-End Characterization and Field Decisions. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

Why the selected alternative fits: Establish how the same change affects the desired signal and the resulting measurement capability.

Distinguishing consideration: compare this with option A, “Treat the lower blocker level as a complete receiver calibration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Front-End Characterization and Field Decisions.

Review: Chapter 3 — Front-End Characterization and Field Decisions.

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V011-C03-MCQ-099. A measured filter response is applied to another switched state with a different path. Which conclusion is correct?

A. The correction becomes exact if more observations are averaged.

B. A matching filter name establishes identical gain, phase and uncertainty.

C. The correction needs demonstrated applicability to that state; the same center frequency is insufficient.

D. The response is interchangeable whenever both paths use passive components.

Answer: C. Calibration belongs to a physical path and state. A similar label or additional averaging does not establish the missing transfer relationship. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why the selected alternative fits: The correction needs demonstrated applicability to that state; the same center frequency is insufficient.

Distinguishing consideration: compare this with option A, “The correction becomes exact if more observations are averaged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-MCQ-100. Which front-end decision best integrates the chapter's reasoning?

A. Select a state that meets the declared noise and loading constraints, preserves the desired waveform, and passes a controlled challenge with recorded limits.

B. Maximize total gain while treating all blocker limits as output-display properties.

C. Choose the highest survival rating and infer calibrated weak-signal recovery from it.

D. Choose the state with the lowest displayed baseline without testing desired transfer.

Answer: A. A useful state simultaneously addresses sensitivity, validity, protection and retained evidence. Each scalar result remains bounded by the actual path and test conditions. Review: Choose gain from a feasible interval; An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why the selected alternative fits: Select a state that meets the declared noise and loading constraints, preserves the desired waveform, and passes a controlled challenge with recorded limits.

Distinguishing consideration: compare this with option B, "Maximize total gain while treating all blocker limits as output-display properties"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 3 — An acceptance sequence that separates competing failures; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — An acceptance sequence that separates competing failures; Chapter 3 — Choose gain from a feasible interval.

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Fill-in-the-Blank Questions

V011-C03-FIB-001. The location that first determines whether a blocker invalidates the chain is the first vulnerable _____ it reaches.

Answer: stage. Follow the blocker through the component order. Rejection after a vulnerable component does not reduce the exposure that component has already experienced. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why this term is required: “stage” completes the stated technical proposition.

Question context: The location that first determines whether a blocker invalidates the chain is the first vulnerable _____ it reaches

Basis and qualification: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-FIB-002. A receiver can admit strong energy outside its displayed frequency _____.

Answer: span. The selected display is a processing view, while the analog front end may admit a wider spectrum. Exposure must be established from the actual input architecture. Review: Front-End Purpose and Architecture. Source: §3.1 Front-End Purpose and Architecture (p. 1248)

Why this term is required: “span” completes the stated technical proposition.

Question context: A receiver can admit strong energy outside its displayed frequency _____

Basis and qualification: Chapter 3 — Front-End Purpose and Architecture.

Review: Chapter 3 — Front-End Purpose and Architecture.

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V011-C03-FIB-003. A filter placed after a compressed amplifier cannot reconstruct the original undistorted _____ signal.

Answer: weak desired. Compression changes the transfer before the filter. Removing a later visible blocker does not undo that earlier information loss. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why this term is required: “weak desired” completes the stated technical proposition.

Question context: A filter placed after a compressed amplifier cannot reconstruct the original undistorted _____ signal

Basis and qualification: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-FIB-004. In a path budget, the blocker transfer must be evaluated at the blocker's own _____.

Answer: frequency. Filter rejection and amplifier gain can vary strongly with frequency. The desired-channel correction is not a substitute for the blocker-frequency response. Review: Use preselection as a measured transfer function.

Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why this term is required: "frequency" completes the stated technical proposition.

Question context: In a path budget, the blocker transfer must be evaluated at the blocker's own _____

Basis and qualification: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-FIB-005. For matched compatible stages with power gains 8, 0.25, and 50, the total linear power gain is _____.

Answer: 100. Equation 5 multiplies the three dimensionless power ratios: $8 \times 0.25 \times 50 = 100$, corresponding to 20 dB. Review: Equation 5. Source: Equation 5. Linear cascaded gain (p. 1269)

Why this term is required: “100” completes the stated technical proposition.

Question context: For matched compatible stages with power gains 8, 0.25, and 50, the total linear power gain is _____

Basis and qualification: Chapter 3 — Equation 5. Linear cascaded gain.

Review: Chapter 3 — Equation 5. Linear cascaded gain.

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V011-C03-FIB-006. A 0.25 linear power gain is approximately _____ dB.

Answer: -6.02. Use ten times the base-ten logarithm of 0.25. A power loss is represented by a negative gain in decibels, or a positive loss subtracted in Equation 6. Review: Equations 5 and 6. Source: Equation 5. Linear cascaded gain (p. 1269)

Why this term is required: "-6.02" completes the stated technical proposition.

Question context: A 0.25 linear power gain is approximately _____ dB

Basis and qualification: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-FIB-007. In Equation 6, a positive stated filter loss is _____ from the input level.

Answer: subtracted. The loss reduces power reaching the next plane. The convention must distinguish a positive loss magnitude from an already signed negative gain. Review: Equation 6. Source: Equation 6. Input power after front-end correction (p. 1269)

Why this term is required: “subtracted” completes the stated technical proposition.

Question context: In Equation 6, a positive stated filter loss is _____ from the input level

Basis and qualification: Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-FIB-008. For an input of -70 dBm, filter loss 1.5 dB, attenuation 6 dB, and gain 18 dB, the next-stage input is _____ dBm.

Answer: -59.5. Apply the signed budget: $-70-1.5-6+18=-59.5$. This prediction still requires small-signal validity and applicable frequency-specific values. Review: Equation 6. Source: Equation 6. Input power after front-end correction (p. 1269)

Why this term is required: "-59.5" completes the stated technical proposition.

Question context: For an input of -70 dBm, filter loss 1.5 dB, attenuation 6 dB, and gain 18 dB, the next-stage input is _____ dBm

Basis and qualification: Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-FIB-009. If the stated linear operating limit is -22 dBm and the predicted operating level is -59.5 dBm, nominal headroom is _____ dB.

Answer: 37.5. Subtract the operating level from the upper limit: $-22-(-59.5)=37.5$. This single-signal margin does not include unbudgeted blockers. Review: Hypothetical Applied Calculation; Equation 6. Source: Equation 6. Input power after front-end correction (p. 1269)

Why this term is required: "37.5" completes the stated technical proposition.

Question context: If the stated linear operating limit is -22 dBm and the predicted operating level is -59.5 dBm, nominal headroom is _____ dB

Basis and qualification: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Hypothetical Applied Calculation: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-FIB-010. Equation 5 establishes scalar gain but does not by itself establish headroom or _____.

Answer: linearity. A product of small-signal gains contains no nonlinear response law or stage-limit test. Each relevant internal plane needs a separate validity assessment. Review: Equation 5 interpretation. Source: Equation 5. Linear cascaded gain (p. 1269)

Why this term is required: “linearity” completes the stated technical proposition.

Question context: Equation 5 establishes scalar gain but does not by itself establish headroom or _____

Basis and qualification: Chapter 3 — Equation 5. Linear cascaded gain.

Review: Chapter 3 — Equation 5. Linear cascaded gain.

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V011-C03-FIB-011. For distinct blockers whose mean powers add without a cross term, two equal -30 dBm powers total approximately _____ dBm.

Answer: -26.99. Each is 0.001 mW, so the total is 0.002 mW. Adding the two logarithmic numbers directly would give the wrong physical power. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why this term is required: "-26.99" completes the stated technical proposition.

Question context: For distinct blockers whose mean powers add without a cross term, two equal -30 dBm powers total approximately _____ dBm

Basis and qualification: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-FIB-012. Aggregate mean power does not by itself specify the largest instantaneous _____ presented by multiple coherent components.

Answer: voltage. Peak voltage also depends on relative phase and waveform timing. A mean-power budget is not a complete peak-loading or pulse-protection model. Review: Find the first stage that can lose validity. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why this term is required: “voltage” completes the stated technical proposition.

Question context: Aggregate mean power does not by itself specify the largest instantaneous _____ presented by multiple coherent components

Basis and qualification: Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity.

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V011-C03-FIB-013. A front-end state with an amplifier before preselection can expose that amplifier to more out-of-band _____ than a state with the same amplifier after adequate rejection.

Answer: energy. Placement changes the spectrum admitted to the active component. The same preamplifier indicator does not establish the same physical architecture. Review: Front-End Purpose and Architecture; source note 9. Source: §3.1 Front-End Purpose and Architecture (p. 1248)

Why this term is required: “energy” completes the stated technical proposition.

Question context: A front-end state with an amplifier before preselection can expose that amplifier to more out-of-band _____ than a state with the same amplifier after adequate rejection

Basis and qualification: Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

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V011-C03-FIB-014. An instrument-specific architecture claim must retain its model, manual edition, and applicable _____ context.

Answer: firmware. The cited manual describes a particular implementation. A later firmware, option set, or different instrument can change the relevant state or behavior. Review: Source note 9. Source: §3.1 Front-End Purpose and Architecture (p. 1248)

Why this term is required: “firmware” completes the stated technical proposition.

Question context: An instrument-specific architecture claim must retain its model, manual edition, and applicable _____ context

Basis and qualification: Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

Review: Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

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V011-C03-FIB-015. A tracking filter follows the receiver tuning _____ rather than remaining fixed across all observations.

Answer: frequency. Its selected state changes with tuning. That behavior can improve rejection but creates state-dependent amplitude and phase response that must be documented. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why this term is required: “frequency” completes the stated technical proposition.

Question context: A tracking filter follows the receiver tuning _____ rather than remaining fixed across all observations

Basis and qualification: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-FIB-016. Variation of transmission magnitude within the useful passband is passband _____.

Answer: ripple. A center-frequency calibration does not remove frequency-dependent variation across a wider desired waveform. The retained spectrum must be assessed over its occupied band. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why this term is required: “ripple” completes the stated technical proposition.

Question context: Variation of transmission magnitude within the useful passband is passband _____

Basis and qualification: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-FIB-017. The frequency interval over which a filter changes from its passband to its rejected region is the transition _____.

Answer: width. Signals in this interval can see rapidly changing amplitude and phase. Center-frequency correction alone is particularly weak near the skirt. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why this term is required: “width” completes the stated technical proposition.

Question context: The frequency interval over which a filter changes from its passband to its rejected region is the transition _____

Basis and qualification: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-FIB-018. Filter phase response can distort a modulated waveform even when center-frequency insertion _____ appears acceptable.

Answer: loss. Magnitude at one frequency does not describe phase differences across the signal spectrum. Group-delay behavior matters when preserving waveform shape or timing. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)
Why this term is required: “loss” completes the stated technical proposition.
Question context: Filter phase response can distort a modulated waveform even when center-frequency insertion _____ appears acceptable
Basis and qualification: Chapter 3 — Use preselection as a measured transfer function.
Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-FIB-019. A switched filter-bank boundary can produce a discontinuity in gain, noise, phase, or _____.

Answer: calibration. Crossing a boundary changes a physical state. The new band needs applicable response evidence, not an assumed continuation of the previous band. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why this term is required: “calibration” completes the stated technical proposition.

Question context: A switched filter-bank boundary can produce a discontinuity in gain, noise, phase, or _____

Basis and qualification: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-FIB-020. A response check only at the center of one filter band cannot establish continuity across the band _____.

Answer: boundary. Reference checks should challenge the transition and nearby frequencies. Smooth tuning values do not establish smooth physical transfer through a switched network. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)
Why this term is required: “boundary” completes the stated technical proposition.
Question context: A response check only at the center of one filter band cannot establish continuity across the band _____
Basis and qualification: Chapter 3 — Use preselection as a measured transfer function.
Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-FIB-021. A 1 dB loss at the desired frequency and 28 dB rejection at a blocker frequency must be entered as _____ transfer corrections.

Answer: separate frequency-specific. The desired correction refers the measured desired level to its input plane; the rejection estimates blocker loading. Interchanging them changes the physical question. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why this term is required: “separate frequency-specific” completes the stated technical proposition.

Question context: A 1 dB loss at the desired frequency and 28 dB rejection at a blocker frequency must be entered as _____ transfer corrections

Basis and qualification: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-FIB-022. For a -12 dBm blocker, 28 dB rejection, 4 dB attenuation, and 15 dB amplifier gain, the next-stage blocker level is _____ dBm.

Answer: -29. The blocker-frequency budget is $-12-28-4+15=-29$ dBm. Desired-band insertion loss is not used for this calculation. Review: Equation 6.

Source: Equation 6. Input power after front-end correction (p. 1269)

Why this term is required: "-29" completes the stated technical proposition.

Question context: For a -12 dBm blocker, 28 dB rejection, 4 dB attenuation, and 15 dB amplifier gain, the next-stage blocker level is _____ dBm

Basis and qualification: Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-FIB-023. For a -88 dBm desired signal through 1 dB loss, 4 dB attenuation, and 15 dB gain, the next-stage desired level is _____ dBm.

Answer: -78. The desired-frequency budget is $-88-1-4+15=-78$ dBm. The 28 dB blocker rejection from the separate case does not correct this signal. Review: Equation 6. Source: Equation 6. Input power after front-end correction (p. 1269)

Why this term is required: "-78" completes the stated technical proposition.

Question context: For a -88 dBm desired signal through 1 dB loss, 4 dB attenuation, and 15 dB gain, the next-stage desired level is _____ dBm

Basis and qualification: Chapter 3 — Equation 6. Input power after front-end correction.

Review: Chapter 3 — Equation 6. Input power after front-end correction.

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V011-C03-FIB-024. A lower displayed baseline after inserting a preselector is ambiguous unless the desired-signal _____ is also checked.

Answer: transfer. The baseline can fall through less admitted noise, altered gain, or signal rejection. Retaining a desired reference helps discriminate those mechanisms. Review: Use preselection as a measured transfer function. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why this term is required: “transfer” completes the stated technical proposition.

Question context: A lower displayed baseline after inserting a preselector is ambiguous unless the desired-signal _____ is also checked

Basis and qualification: Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-FIB-025. A filter can improve validity by rejecting a blocker while still increasing input-equivalent receiver _____ through its preceding loss.

Answer: noise. Blocker rejection and small-signal noise are different effects. An acceptable state can trade a noise penalty for restoration of a valid linear observation. Review: Use preselection as a measured transfer function; Application 2B.6. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

Why this term is required: “noise” completes the stated technical proposition.

Question context: A filter can improve validity by rejecting a blocker while still increasing input-equivalent receiver _____ through its preceding loss

Basis and qualification: Chapter 2 — Application 2B.6: allocate loss to a preselector; Chapter 3 — Use preselection as a measured transfer function.

Review: Chapter 2 — Application 2B.6: allocate loss to a preselector; Chapter 3 — Use preselection as a measured transfer function.

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V011-C03-FIB-026. A notch intended for a blocker can also remove desired spectral content when the desired waveform _____ that rejected band.

Answer: overlaps. The filter does not distinguish desired from unwanted sources at the same admitted frequency. Signal retention must be tested for the actual waveform. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why this term is required: “overlaps” completes the stated technical proposition.

Question context: A notch intended for a blocker can also remove desired spectral content when the desired waveform _____ that rejected band

Basis and qualification: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-FIB-027. An external filter used for accurate amplitude work should have an identified unit and measured _____, not only a generic product label.

Answer: response. Unit identity ties the correction to the installed hardware. The response must apply to the frequency, state, temperature, and level conditions used. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why this term is required: “response” completes the stated technical proposition.

Question context: An external filter used for accurate amplitude work should have an identified unit and measured _____, not only a generic product label

Basis and qualification: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-FIB-028. A preselector loss correction valid at one temperature may require revision when temperature changes its _____.

Answer: transfer response. Temperature dependence can change the physical gain or loss. A stored correction must be applicable to the new condition or carry the relevant uncertainty. Review: Preselection and Filter State. Source: §3.3 Preselection and Filter State (p. 1251)

Why this term is required: “transfer response” completes the stated technical proposition.

Question context: A preselector loss correction valid at one temperature may require revision when temperature changes its _____

Basis and qualification: Chapter 3 — Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-FIB-029. The minimum useful first-stage gain follows the noise requirement, whereas an upper gain limit follows downstream signal _____.

Answer: loading. The chosen state must satisfy both bounds. A low predicted input noise does not certify that the next stage remains within its linear range. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “loading” completes the stated technical proposition.

Question context: The minimum useful first-stage gain follows the noise requirement, whereas an upper gain limit follows downstream signal _____

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-030. If noise requires at least 12 dB gain and loading permits at most 19 dB, the feasible gain interval is _____ dB.

Answer: 12 to 19 inclusive. The intersection of the lower and upper constraints is nonempty. A selected hardware state must lie inside that interval and satisfy the other model assumptions. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “12 to 19 inclusive” completes the stated technical proposition.

Question context: If noise requires at least 12 dB gain and loading permits at most 19 dB, the feasible gain interval is _____ dB

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-031. If the minimum required gain is 22 dB and the maximum permitted gain is 17 dB, the feasible interval is _____.

Answer: empty. No gain setting satisfies both conditions. One must change the architecture, rejection, downstream range, or justified target rather than select a compromise that violates a bound. Review: Choose gain from a feasible interval.

Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “empty” completes the stated technical proposition.

Question context: If the minimum required gain is 22 dB and the maximum permitted gain is 17 dB, the feasible interval is _____

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-032. For a two-stage model with first-stage equivalent temperature 60 K, downstream 900 K, and a 90 K target, minimum linear first-stage gain is _____.

Answer: 30. The downstream contribution must be at most 30 K, so gain must be at least $\frac{900}{30}=30$. The corresponding power gain is about 14.77 dB. Review: Model 2B; Choose gain from a feasible interval. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “30” completes the stated technical proposition.

Question context: For a two-stage model with first-stage equivalent temperature 60 K, downstream 900 K, and a 90 K target, minimum linear first-stage gain is _____

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-033. If a blocker at -38 dBm must remain no greater than -18 dBm after an amplifier, maximum amplifier gain is _____ dB in the stipulated scalar model.

Answer: 20. The output constraint is -38 + gain no greater than -18. This bound is separate from the amplifier's own input-linearity and peak-power constraints.
Review: Equation 6; Choose gain from a feasible interval. Source: Equation 6. Input power after front-end correction (p. 1269)
Why this term is required: "20" completes the stated technical proposition.
Question context: If a blocker at -38 dBm must remain no greater than -18 dBm after an amplifier, maximum amplifier gain is _____ dB in the stipulated scalar model
Basis and qualification: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Choose gain from a feasible interval.
Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-034. Once downstream noise is small, extra gain gives diminishing input-sensitivity benefit while continuing to raise downstream _____ levels.

Answer: signal and blocker. The first-stage noise establishes an asymptotic limit, but later loading continues to grow. The useful operating point is constrained by both effects. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “signal and blocker” completes the stated technical proposition.

Question context: Once downstream noise is small, extra gain gives diminishing input-sensitivity benefit while continuing to raise downstream _____ levels

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-035. An attenuator after an overloaded amplifier does not reduce the _____ that already reached that amplifier.

Answer: input exposure. The element only changes later levels. Equal end-to-end gain between two arrangements does not imply equal internal validity. Review: Gain Distribution and Attenuation; Application 2B.7. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

Why this term is required: “input exposure” completes the stated technical proposition.

Question context: An attenuator after an overloaded amplifier does not reduce the _____ that already reached that amplifier

Basis and qualification: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage; Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage; Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-FIB-036. A corrected display can retain the same desired level after input attenuation while the physical input-referred noise _____.

Answer: increases. The correction changes the reported plane. It does not reverse passive loss or eliminate downstream noise when referred through the added attenuation. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “increases” completes the stated technical proposition.

Question context: A corrected display can retain the same desired level after input attenuation while the physical input-referred noise _____

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-037. If a raw desired output falls by 8 dB after a verified 8 dB attenuation increase, the corrected input estimate should ideally remain _____.

Answer: unchanged. Under a valid linear fixed-state model, adding back the applicable loss returns the same input level. This agreement alone does not certify every internal stage. Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

Why this term is required: “unchanged” completes the stated technical proposition.

Question context: If a raw desired output falls by 8 dB after a verified 8 dB attenuation increase, the corrected input estimate should ideally remain _____

Basis and qualification: Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-FIB-038. A line that fails to follow a switched attenuation prediction may arise from a downstream source, clipping, or a gain-control _____, so one mechanism is not established by that test alone.

Answer: response. Several mechanisms can cause anomalous scaling. The challenge must retain desired-reference behavior and complementary controls to discriminate them. Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

Why this term is required: “response” completes the stated technical proposition.

Question context: A line that fails to follow a switched attenuation prediction may arise from a downstream source, clipping, or a gain-control _____, so one mechanism is not established by that test alone

Basis and qualification: Chapter 3 — Gain Distribution and Attenuation.

Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-FIB-039. When an amplitude comparison depends on a small attenuator step, contact condition and step _____ become relevant uncertainty inputs.

Answer: repeatability. A nominal setting is not an exact physical transfer. Repeated switching can expose state variation that matters to the inferred level difference.
Review: Gain Distribution and Attenuation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)
Why this term is required: “repeatability” completes the stated technical proposition.
Question context: When an amplitude comparison depends on a small attenuator step, contact condition and step _____ become relevant uncertainty inputs
Basis and qualification: Chapter 3 — Gain Distribution and Attenuation.
Review: Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-FIB-040. Automatic gain control adds a _____ dimension to the gain model.

Answer: time. A state that varies during a burst or blocker event cannot be represented by one settled gain unless that approximation is justified for the quantity being estimated. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “time” completes the stated technical proposition.

Question context: Automatic gain control adds a _____ dimension to the gain model

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-041. For a quantitative record spanning gain transitions, retain the gain state or a sufficiently resolved gain-control _____.

Answer: trace. The metadata must locate the changes relative to the samples. A single configuration value may not describe the trajectory actually experienced.
Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)
Why this term is required: “trace” completes the stated technical proposition.
Question context: For a quantitative record spanning gain transitions, retain the gain state or a sufficiently resolved gain-control _____
Basis and qualification: Chapter 3 — Choose gain from a feasible interval.
Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-042. An average gain value cannot recover samples lost through _____ during a gain transition.

Answer: clipping. Clipping is a nonlinear many-to-one transformation. Multiplying the resulting samples by a correction cannot reconstruct the original amplitudes.

Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “clipping” completes the stated technical proposition.

Question context: An average gain value cannot recover samples lost through _____ during a gain transition

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-043. Increasing analog gain can reduce the input-referred significance of converter noise, but cannot improve an already established analog signal-to-noise _____.

Answer: ratio. Common linear amplification scales signal and existing analog noise together. Any benefit concerns additional downstream converter noise under valid range conditions. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “ratio” completes the stated technical proposition.

Question context: Increasing analog gain can reduce the input-referred significance of converter noise, but cannot improve an already established analog signal-to-noise _____

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-044. The digitizer range must be evaluated at the digitizer's actual input _____, not merely the external antenna terminal.

Answer: plane. The analog stages transform the signal and noise before conversion. Internal level budgeting is necessary to assess quantization significance and overload. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: "plane" completes the stated technical proposition.

Question context: The digitizer range must be evaluated at the digitizer's actual input _____, not merely the external antenna terminal

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-045. Heavy digital averaging may make a trace look quiet without establishing an adequate analog _____ distribution.

Answer: gain. Display variance and physical analog range use are different quantities. Raw samples and state metadata are needed to distinguish the mechanisms. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “gain” completes the stated technical proposition.

Question context: Heavy digital averaging may make a trace look quiet without establishing an adequate analog _____ distribution

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-046. A protection network affects the signal path even in its nonlimiting, _____-signal state.

Answer: small. Insertion loss, return loss, and reactive loading persist when no large event is present. The protector belongs in the ordinary transfer and noise budget. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “small” completes the stated technical proposition.

Question context: A protection network affects the signal path even in its nonlimiting, _____-signal state

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-047. In the chapter's PIN-limiter explanation, stored carriers alter the diode's RF _____.

Answer: resistance. The cited mechanism connects large-signal charge storage to reduced RF resistance. The mounted circuit and external current path also affect behavior. Review: Measure protection in the small-signal and recovery states; source note 10. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: "resistance" completes the stated technical proposition.

Question context: In the chapter's PIN-limiter explanation, stored carriers alter the diode's RF _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-048. Removal or recombination of stored carriers contributes to the return toward low insertion _____ after a large event.

Answer: loss. The recovery mechanism has memory. A limiter is not an instantaneous ideal switch whose pre-event transfer necessarily returns at the event's trailing edge. Review: Measure protection in the small-signal and recovery states; source note 10. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: "loss" completes the stated technical proposition.

Question context: Removal or recombination of stored carriers contributes to the return toward low insertion _____ after a large event

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-049. Limiter diode geometry can change capacitance and therefore the mounted network's reactive _____.

Answer: loading. The RF response includes parasitic reactance as well as the large-signal resistance change. Device identity alone does not establish the assembled network response. Review: Measure protection in the small-signal and recovery states; source note 10. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: "loading" completes the stated technical proposition.

Question context: Limiter diode geometry can change capacitance and therefore the mounted network's reactive _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-050. The three separate protection outcomes emphasized in the chapter are leakage, hardware survival, and weak-signal _____.

Answer: recovery. A protected device can remain undamaged while its transfer or noise baseline is still unsuitable for the intended observation. Each outcome needs its own observable. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
Why this term is required: “recovery” completes the stated technical proposition.
Question context: The three separate protection outcomes emphasized in the chapter are leakage, hardware survival, and weak-signal _____
Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.
Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-051. A brief transient passing the protector before its later limited state is established is leading-edge _____.

Answer: leakage. The downstream path may experience a short exposure larger than the later leakage level. A steady limited-power measurement can miss this event. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “leakage” completes the stated technical proposition.

Question context: A brief transient passing the protector before its later limited state is established is leading-edge _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-052. A catalog recovery value must be interpreted with its stated test conditions and recovery _____.

Answer: criterion. Return of insertion loss, calibrated phase, noise variance, and detector output can occur at different times. The applicable observable must match the intended measurement. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “criterion” completes the stated technical proposition.

Question context: A catalog recovery value must be interpreted with its stated test conditions and recovery _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-053. Survival of a protection component does not establish immediate restoration of calibrated weak-signal _____.

Answer: performance. Hardware integrity and measurement validity are distinct. A surviving network can remain desensitized, have changed loss, or be temporarily disturbed. Review: Measure protection in the small-signal and recovery states.

Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “performance” completes the stated technical proposition.

Question context: Survival of a protection component does not establish immediate restoration of calibrated weak-signal _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-054. For rectangular pulses of constant peak power and negligible off-state power, duty factor equals pulse width divided by pulse _____.

Answer: period. The ratio is dimensionless and determines mean power in this stipulated waveform. Different pulse shapes or off-state power need their own integration. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why this term is required: “period” completes the stated technical proposition.

Question context: For rectangular pulses of constant peak power and negligible off-state power, duty factor equals pulse width divided by pulse _____

Basis and qualification: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-FIB-055. Rectangular 8 microsecond pulses repeated every 400 microseconds have duty factor _____ percent.

Answer: 2. The ratio is $\frac{8}{400}=0.02$. Keep width and period in the same time unit before converting the fraction to percent. Review: Input Protection and Recovery.

Source: §3.7 Input Protection and Recovery (p. 1260)

Why this term is required: “2” completes the stated technical proposition.

Question context: Rectangular 8 microsecond pulses repeated every 400 microseconds have duty factor _____ percent

Basis and qualification: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-FIB-056. With 10 mW peak power, 2 percent duty factor, and zero off-state power, mean power is _____ mW.

Answer: 0.2. Mean power is peak power multiplied by duty factor: 10×0.02. The peak exposure remains 10 mW despite the lower mean. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why this term is required: “0.2” completes the stated technical proposition.

Question context: With 10 mW peak power, 2 percent duty factor, and zero off-state power, mean power is _____ mW

Basis and qualification: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-FIB-057. A rectangular pulse train with peak power 30 dBm and duty factor 0.001 has mean power _____ dBm when off-state power is zero.

Answer: 0. The duty-factor correction is $10\log_{10}(0.001) = -30$ dB. Add that correction to the 30 dBm peak; the peak rating still needs a separate check. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why this term is required: “0” completes the stated technical proposition.

Question context: A rectangular pulse train with peak power 30 dBm and duty factor 0.001 has mean power _____ dBm when off-state power is zero

Basis and qualification: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-FIB-058. A pulse survival specification conditioned on pulse width cannot be transferred unqualified to a different pulse _____.

Answer: duration. Thermal and charge-storage effects depend on the event history. A matching peak-power number alone does not establish equivalent stress. Review: Source note 11; Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “duration” completes the stated technical proposition.

Question context: A pulse survival specification conditioned on pulse width cannot be transferred unqualified to a different pulse _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-059. Absolute maximum ratings must not be treated as guaranteed calibrated operating _____.

Answer: performance. Stress limits and specified measurement behavior serve different purposes. The actual operating conditions and the relevant performance table must be retained. Review: Source note 11. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1262)

Why this term is required: “performance” completes the stated technical proposition.

Question context: Absolute maximum ratings must not be treated as guaranteed calibrated operating _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-060. A component data sheet does not automatically establish the limits of a complete mounted receiver _____.

Answer: assembly. Layout, connected components, bias, thermal conditions, and the downstream load can change the system response. Assembly-level evidence is needed for an assembly-level claim. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “assembly” completes the stated technical proposition.

Question context: A component data sheet does not automatically establish the limits of a complete mounted receiver _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-061. To observe the useful channel throughout a protection challenge, retain a weak desired _____ before, during, and after the event.

Answer: reference. A reference provides an observable transfer through the disturbance. A record of the blocker alone cannot establish when weak-signal measurement becomes valid again. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “reference” completes the stated technical proposition.

Question context: To observe the useful channel throughout a protection challenge, retain a weak desired _____ before, during, and after the event

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-062. If the desired amplitude criterion is met at 40 microseconds but the required baseline-variance criterion only at 70 microseconds, joint recovery is no earlier than _____ microseconds.

Answer: 70. Both declared conditions must hold. Accepting the earlier time would silently discard the variance requirement. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “70” completes the stated technical proposition.

Question context: If the desired amplitude criterion is met at 40 microseconds but the required baseline-variance criterion only at 70 microseconds, joint recovery is no earlier than _____ microseconds

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-063. A continuous-wave sweep alone cannot reveal the full _____ interval following a pulse.

Answer: recovery. The transient history is absent from a settled sweep. A timed record through the strong event is necessary to characterize post-event validity.

Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “recovery” completes the stated technical proposition.

Question context: A continuous-wave sweep alone cannot reveal the full _____ interval following a pulse

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-064. Observing only the end of a long acquisition can miss early post-event intervals during which weak events were _____.

Answer: undetectable. A final recovered state does not characterize every earlier time. Time-resolved desired-reference and baseline observations are needed.

Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “undetectable” completes the stated technical proposition.

Question context: Observing only the end of a long acquisition can miss early post-event intervals during which weak events were _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-065. A delayed trace can arise from detector averaging even after the analog path has _____.

Answer: recovered. The displayed quantity can retain temporal memory in downstream processing. Apparent recovery must be attributed to the measured path and processing state. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “recovered” completes the stated technical proposition.

Question context: A delayed trace can arise from detector averaging even after the analog path has _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-066. Reducing a detector time constant changes both temporal response and measurement _____.

Answer: variability. Less averaging may expose faster analog recovery while increasing output scatter. A fair interpretation records the changed estimator conditions. Review: Measure protection in the small-signal and recovery states.

Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “variability” completes the stated technical proposition.

Question context: Reducing a detector time constant changes both temporal response and measurement _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-067. A limiter-bypass comparison is informative only if the configuration permits it and the remaining path stays within its _____.

Answer: ratings. Removing protection changes exposure. The comparison must have a bounded valid operating condition and identify exactly which component was isolated. Review: Measure protection in the small-signal and recovery states.

Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “ratings” completes the stated technical proposition.

Question context: A limiter-bypass comparison is informative only if the configuration permits it and the remaining path stays within its _____

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-068. Apparent recovery persistence can originate in amplifier bias, gain control, digital filtering, or trigger _____ as well as protection.

Answer: logic. Several subsystems have memory or acquisition dead time. The mere presence of a limiter does not locate the cause of the delay. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “logic” completes the stated technical proposition.

Question context: Apparent recovery persistence can originate in amplifier bias, gain control, digital filtering, or trigger _____ as well as protection

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-069. Post-overload checks at one low frequency do not automatically verify transfer at _____ frequencies.

Answer: higher or untested. A damaged or altered path can retain one response while changing another. Checks should cover the frequencies, levels, and observables relevant to the intended release. Review: Input Protection and Recovery. Source: §3.7 Input Protection and Recovery (p. 1260)

Why this term is required: “higher or untested” completes the stated technical proposition.

Question context: Post-overload checks at one low frequency do not automatically verify transfer at _____ frequencies

Basis and qualification: Chapter 3 — Input Protection and Recovery.

Review: Chapter 3 — Input Protection and Recovery.

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V011-C03-FIB-070. A vector network analyzer normally characterizes the chosen small-signal response; large-signal or pulsed claims require additional appropriate _____ and observations.

Answer: stimuli. The instrument name does not make every nonlinear or transient property part of a small-signal sweep. The applied stimulus must exercise the behavior being claimed. Review: Front-End Characterization and Field Decisions.

Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

Why this term is required: “stimuli” completes the stated technical proposition.

Question context: A vector network analyzer normally characterizes the chosen small-signal response; large-signal or pulsed claims require additional appropriate _____ and observations

Basis and qualification: Chapter 3 — Front-End Characterization and Field Decisions.

Review: Chapter 3 — Front-End Characterization and Field Decisions.

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V011-C03-FIB-071. For active front-end characterization, temperature and _____ state can affect the measured response.

Answer: bias. Active device gain, noise, linearity, and recovery can depend on operating conditions. The state belongs in both the characterization record and its applicability limits. Review: Front-End Characterization and Field Decisions. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

Why this term is required: “bias” completes the stated technical proposition.

Question context: For active front-end characterization, temperature and _____ state can affect the measured response

Basis and qualification: Chapter 3 — Front-End Characterization and Field Decisions.

Review: Chapter 3 — Front-End Characterization and Field Decisions.

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V011-C03-FIB-072. Before assigning a two-tone product to the receiver, check whether the sources interact through insufficient combiner _____.

Answer: isolation. Generator interaction can create the same line before the receiver. A source-path control is needed to bound that alternative. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “isolation” completes the stated technical proposition.

Question context: Before assigning a two-tone product to the receiver, check whether the sources interact through insufficient combiner _____

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-073. The desired and blocker levels in a challenge must be established at the intended receiver _____ plane.

Answer: input. Generator settings alone omit intervening combiner, cable, mismatch, and attenuation effects. The defined plane makes the applied exposure reconstructable. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “input” completes the stated technical proposition.

Question context: The desired and blocker levels in a challenge must be established at the intended receiver _____ plane

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-074. Blocker-source broadband noise at the desired channel can mimic a receiver-generated noise _____.

Answer: rise. The desired-channel observation may already be contaminated at the input. Source spectral purity must be bounded before assigning the rise to reciprocal mixing or another receiver mechanism. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “rise” completes the stated technical proposition.

Question context: Blocker-source broadband noise at the desired channel can mimic a receiver-generated noise _____

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-075. A quiet baseline should precede the blocker challenge, with the desired source held _____ during controlled blocker changes.

Answer: fixed. Holding the desired stimulus fixed makes changes in its measured transfer informative. Unrecorded desired-source drift would create an alternative explanation. Review: An acceptance sequence that separates competing failures.

Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “fixed” completes the stated technical proposition.

Question context: A quiet baseline should precede the blocker challenge, with the desired source held _____ during controlled blocker changes

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-076. Removing the blocker and returning to the original state provides a _____ check of the observed path.

Answer: return. The comparison can reveal persistence or drift at the check time. It does not by itself prove that every intervening sample was valid. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “return” completes the stated technical proposition.

Question context: Removing the blocker and returning to the original state provides a _____ check of the observed path

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-077. Compression can change desired transfer, whereas reciprocal mixing can raise admitted _____ around the desired channel.

Answer: noise. The mechanisms have different predicted observables. A useful challenge records both desired response and noise so it can test those predictions.
Review: An acceptance sequence that separates competing failures; Table 3A.

Source: Table 3A. Evidence to retain during a constructed front-end challenge (p. 1266)

Why this term is required: “noise” completes the stated technical proposition.
Question context: Compression can change desired transfer, whereas reciprocal mixing can raise admitted _____ around the desired channel
Basis and qualification: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge; Chapter 3 — An acceptance sequence that separates competing failures.
Review: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge; Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-078. A discrete intermodulation hypothesis should predict product _____ as well as level behavior.

Answer: frequencies. Frequency relationships can help discriminate a nonlinear mechanism, but sources and combining paths can generate related products too. Input-plane controls remain necessary. Review: An acceptance sequence that separates competing failures; Model 11A connection. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

Why this term is required: “frequencies” completes the stated technical proposition.

Question context: A discrete intermodulation hypothesis should predict product _____ as well as level behavior

Basis and qualification: Chapter 11 — Model 11A for cubic intermodulation and intercept metrics; Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 11 — Model 11A for cubic intermodulation and intercept metrics; Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-079. Because gain control can mimic a change in desired transfer, compression attribution requires state evidence or an appropriate _____ control.

Answer: fixed-gain. A falling desired output is not uniquely compression. A known fixed gain or a characterized gain-control trajectory helps distinguish the response law. Review: Table 3A. Source: Table 3A. Evidence to retain during a constructed front-end challenge (p. 1266)

Why this term is required: “fixed-gain” completes the stated technical proposition.

Question context: Because gain control can mimic a change in desired transfer, compression attribution requires state evidence or an appropriate _____ control

Basis and qualification: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge.

Review: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge.

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V011-C03-FIB-080. More than one front-end failure mechanism can occur _____ during a strong-signal challenge.

Answer: simultaneously. A discrete product does not exclude noise rise or desired-signal compression. The retained observables should permit multiple supported effects to be reported. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “simultaneously” completes the stated technical proposition.

Question context: More than one front-end failure mechanism can occur _____ during a strong-signal challenge

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-081. Input-corrected comparisons should be retained alongside measurements in physical _____ units.

Answer: output. The corrected quantity estimates the common external plane; the raw output helps reconstruct the actual gain, loading, and noise changes. One view cannot replace the other. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “output” completes the stated technical proposition.

Question context: Input-corrected comparisons should be retained alongside measurements in physical _____ units

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-082. A screen image can omit state information, so settings should also be retained as text or machine-readable _____.

Answer: metadata. Reconstruction requires exact filter, attenuation, gain, bandwidth, detector, and timing information where relevant. The visible annotations may be incomplete. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “metadata” completes the stated technical proposition.

Question context: A screen image can omit state information, so settings should also be retained as text or machine-readable _____

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-083. If both the suspect line and desired reference fall below the floor after attenuation, the test is _____ about the line's origin.

Answer: inconclusive. Loss of observation capability prevents the proposed discrimination. The disappearance alone does not show whether the line originated before or inside the receiver. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: "inconclusive" completes the stated technical proposition.

Question context: If both the suspect line and desired reference fall below the floor after attenuation, the test is _____ about the line's origin

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-084. Noise traces from states with different bandwidths need matched bandwidth or an explicit bandwidth _____ before comparison.

Answer: accounting model. Integrated noise depends on admitted bandwidth. A difference cannot be attributed wholly to the front-end state when processing bandwidth changed too. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “accounting model” completes the stated technical proposition.

Question context: Noise traces from states with different bandwidths need matched bandwidth or an explicit bandwidth _____ before comparison

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-085. An unresolved test should retain competing _____ instead of converting a plausible mechanism into an established conclusion.

Answer: explanations. The result remains useful when its limits are stated. It can guide a more discriminating challenge and later artifact review. Review: An acceptance sequence that separates competing failures. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

Why this term is required: “explanations” completes the stated technical proposition.

Question context: An unresolved test should retain competing _____ instead of converting a plausible mechanism into an established conclusion

Basis and qualification: Chapter 3 — An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-FIB-086. A front-end release should state a documented frequency and level _____ rather than a universal pass.

Answer: range. Verification applies to the tested configuration and conditions. Declared limits prevent a bounded acceptance result from being extended to unsupported operating states. Review: Verification and Maintenance Controls.

Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why this term is required: “range” completes the stated technical proposition.

Question context: A front-end release should state a documented frequency and level _____ rather than a universal pass

Basis and qualification: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-FIB-087. A substituted filter or cable changes the measurement path and therefore calls for renewed _____.

Answer: verification. The prior path response may no longer apply. Applicable corrections and uncertainty must follow the installed components and their current state. Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why this term is required: “verification” completes the stated technical proposition.

Question context: A substituted filter or cable changes the measurement path and therefore calls for renewed _____

Basis and qualification: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-FIB-088. Serialized accessories and controlled connector torque help make reference sweeps _____.

Answer: reproducible. The mechanical and component configuration can affect loss and mismatch. Recording these conditions supports meaningful comparison with an accepted baseline. Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why this term is required: “reproducible” completes the stated technical proposition.

Question context: Serialized accessories and controlled connector torque help make reference sweeps _____

Basis and qualification: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-FIB-089. A difference from an accepted baseline that exceeds the applicable uncertainty should be _____ before returning the path to its claimed service.

Answer: investigated. The result may reflect a physical fault, configuration change, or correction problem. Merely repeating the old pass label does not resolve the difference. Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why this term is required: “investigated” completes the stated technical proposition.

Question context: A difference from an accepted baseline that exceeds the applicable uncertainty should be _____ before returning the path to its claimed service

Basis and qualification: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-FIB-090. Attenuator contacts, relay isolation, filter tuning, and bias current can change gradually, so maintenance must track performance _____.

Answer: drift. A binary damaged/not-damaged classification can miss slow response changes. Relevant baseline comparisons reveal changes before a broad failure is obvious. Review: Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why this term is required: “drift” completes the stated technical proposition.

Question context: Attenuator contacts, relay isolation, filter tuning, and bias current can change gradually, so maintenance must track performance _____

Basis and qualification: Chapter 3 — Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-FIB-091. In the chapter's 1.2 GHz case, removal by a filter that passes 1.2 GHz is evidence for a product hypothesis only after desired-reference _____ is verified.

Answer: transfer. A passband label or nominal loss does not establish the actual installed signal retention. Source and combiner products also need to be bounded before locating the generation site. Review: Hypothetical Case Adjudication. Source: §3.14 Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection (p. 1272)

Why this term is required: "transfer" completes the stated technical proposition.

Question context: In the chapter's 1.2 GHz case, removal by a filter that passes 1.2 GHz is evidence for a product hypothesis only after desired-reference _____ is verified

Basis and qualification: Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

Review: Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-FIB-092. Reproducing the suspect frequency with two strong tones supports a nonlinear mechanism, but does not alone locate it inside the _____.

Answer: receiver. The generators or combining path can create a product before the input plane. A controlled source-path observation is needed for receiver-specific attribution. Review: Hypothetical Case Adjudication; Model 11A connection. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

Why this term is required: “receiver” completes the stated technical proposition.

Question context: Reproducing the suspect frequency with two strong tones supports a nonlinear mechanism, but does not alone locate it inside the _____

Basis and qualification: Chapter 11 — Model 11A for cubic intermodulation and intercept metrics; Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

Review: Chapter 11 — Model 11A for cubic intermodulation and intercept metrics; Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-FIB-093. Changing antenna polarization can reduce a dominant local interferer, but can also change desired-signal _____.

Answer: coupling. The field-to-terminal transfer is part of the comparison. A useful operational change must retain sufficient desired observation capability and record the new geometry. Review: Front-End Characterization and Field Decisions. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

Why this term is required: “coupling” completes the stated technical proposition.

Question context: Changing antenna polarization can reduce a dominant local interferer, but can also change desired-signal _____

Basis and qualification: Chapter 3 — Front-End Characterization and Field Decisions.

Review: Chapter 3 — Front-End Characterization and Field Decisions.

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V011-C03-FIB-094. A strong broadcast environment may favor moderate attenuation and selective filtering over maximum preamplifier _____ when the latter state is nonlinear.

Answer: gain. Useful sensitivity depends on valid measurement behavior in the actual environment. An excellent quiet-state noise result does not override strong-signal failure. Review: Front-End Characterization and Field Decisions. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

Why this term is required: “gain” completes the stated technical proposition.

Question context: A strong broadcast environment may favor moderate attenuation and selective filtering over maximum preamplifier _____ when the latter state is nonlinear

Basis and qualification: Chapter 3 — Front-End Characterization and Field Decisions.

Review: Chapter 3 — Front-End Characterization and Field Decisions.

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V011-C03-FIB-095. An injected closing reference assesses only the functions actually _____ by its path and settings at the check time.

Answer: exercised. A downstream injection can bypass the antenna or earlier filters. Wider functional coverage needs complementary checks, and a final check cannot establish uninterrupted earlier validity. Review: Verification and Maintenance Controls; Chapter 1 closing-verification qualification. Source: §3.11 Verification and Maintenance Controls (p. 1268)

Why this term is required: “exercised” completes the stated technical proposition.

Question context: An injected closing reference assesses only the functions actually _____ by its path and settings at the check time

Basis and qualification: Chapter 3 — Verification and Maintenance Controls; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 3 — Verification and Maintenance Controls; Chapter 1 — Evidence Record and Closing Verification.

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V011-C03-FIB-096. If a later attenuation change restores linearity, data acquired during the earlier invalid state cannot be repaired merely by a scalar gain _____.

Answer: correction. A valid correction re-expresses a valid measurement. It cannot recover signal information lost through clipping, compression, missing samples, or unobserved state changes. Review: Choose gain from a feasible interval. Source: §3.6 Choose gain from a feasible interval (p. 1257)

Why this term is required: “correction” completes the stated technical proposition.

Question context: If a later attenuation change restores linearity, data acquired during the earlier invalid state cannot be repaired merely by a scalar gain _____

Basis and qualification: Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-FIB-097. Gain and loss values from different reference-impedance conventions cannot be multiplied without reconciling _____ effects.

Answer: mismatch. Equation 5 assumes compatible power-gain conventions. Available, delivered, and transducer power quantities may differ when ports are not matched. Review: Equation 5 interpretation. Source: Equation 5. Linear cascaded gain (p. 1269)

Why this term is required: “mismatch” completes the stated technical proposition.

Question context: Gain and loss values from different reference-impedance conventions cannot be multiplied without reconciling _____ effects

Basis and qualification: Chapter 3 — Equation 5. Linear cascaded gain.

Review: Chapter 3 — Equation 5. Linear cascaded gain.

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V011-C03-FIB-098. The cited limiter data sheet's recovery and survivability tables are conditional evidence for that identified _____, not universal receiver limits.

Answer: device. The component, revision, operating conditions, and test definition bound the source claim. A synthetic case must not silently inherit a commercial rating. Review: Source note 11. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1262)

Why this term is required: "device" completes the stated technical proposition.

Question context: The cited limiter data sheet's recovery and survivability tables are conditional evidence for that identified _____, not universal receiver limits

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-099. A defensible recovery report states the strong-event waveform, time origin, required observables, tolerances, and receiver _____.

Answer: state. These inputs make the recovered interval interpretable. A single time number without the measurement criterion cannot establish suitability for another event or application. Review: Measure protection in the small-signal and recovery states. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
Why this term is required: “state” completes the stated technical proposition.
Question context: A defensible recovery report states the strong-event waveform, time origin, required observables, tolerances, and receiver _____
Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states.
Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-FIB-100. The chapter's gain equations should be combined with independent noise, exposure, and recovery evidence to define an operational _____.

Answer: envelope. Each relation answers a bounded question. The release envelope is the intersection of supported conditions, rather than a universal claim derived from one favorable number. Review: Quantitative Model; Verification and Maintenance Controls. Source: §3.11 Verification and Maintenance Controls (p. 1268)
Why this term is required: "envelope" completes the stated technical proposition.
Question context: The chapter's gain equations should be combined with independent noise, exposure, and recovery evidence to define an operational _____
Basis and qualification: Chapter 3 — Verification and Maintenance Controls; Chapter 3 — Quantitative Model for RF Front Ends, Preselection, Gain Distribution, and Input Protection.
Review: Chapter 3 — Verification and Maintenance Controls; Chapter 3 — Quantitative Model for RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C03-ESSAY-001. Derive the relation between the linear cascaded-power-gain budget and the signed decibel budget. Specify the conditions under which the same budget can be used for a desired signal and for a blocker.

- Opening: Present a thesis that answers this precise question: Derive the relation between the linear cascaded-power-gain budget and the signed decibel budget. Specify the conditions under which the same budget can be used for a desired.... Identify which evidence would falsify the proposed conclusion Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)
- Core terminology and scope: Define relation, budget, signed in the question's particular technical setting; explain how decibel, Specify, used differ if that distinction would change the analysis of "Derive the relation between the linear cascaded-power-gain budget and the signed decibel budget. Specify the conditions under which the same budget can be used for a desired..." Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin with output power equal to input power multiplied by each stage power gain in the valid scalar chain Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the relation between the linear cascaded-power-gain budget and the signed decibel budget to the claimed result, following "Example 3.C1. Filter,

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attenuator and amplifier power budget"; name the intermediate states and measurable outputs Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the relation between the linear cascaded-power-gain budget and the signed decibel budget. Taking ten times the base-ten logarithm converts the product to a sum Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Find the first stage that can lose validity" that resolves the question about the relation between the linear cascaded-power-gain budget and the signed decibel budget; derive the relevant result with units and stated validity conditions Source: §3.2 Find the first stage that can lose validity (p. 1249)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the relation between the linear cascaded-power-gain budget and the signed decibel budget. A passive loss written as a positive decibel magnitude enters with a minus sign; a positive amplifier gain enters with a plus sign Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)
- Worked application or illustrative case: Build a worked example of "the relation between the linear cascaded-power-gain budget and the signed decibel budget", addressing this associated condition: Specify the conditions under which the same budget can be used for

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a desired signal and for a blocker. Begin with output power equal to input power multiplied by each stage power gain in the valid scalar chain Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the relation between the linear cascaded-power-gain budget and the signed decibel budget”. Using “Find the first stage that can lose validity”, specify a discriminator and the result expected under each explanation Source: §3.2 Find the first stage that can lose validity (p. 1249)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the relation between the linear cascaded-power-gain budget and the signed decibel budget, including the effect of missing measurements and inconsistent operating conditions Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)
- Scholarly synthesis and implications: Explain what the result about the relation between the linear cascaded-power-gain budget and the signed decibel budget authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)
- Closing: Conclude by answering “Derive the relation between the linear cascaded-power-gain budget and the signed decibel budget. Specify the conditions under which the same budget can be used for a desired…” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

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V011-C03-ESSAY-002. A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer. The desired input is -92 dBm and sees 1.2 dB filter loss. A blocker at -8 dBm sees 34 dB filter rejection. Calculate both mixer-input levels and evaluate a stipulated -24 dBm maximum blocker level. Explain which conclusions remain unsupported.

- Opening: Present a thesis that answers this precise question: A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer. Identify which evidence would falsify the proposed conclusion Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Core terminology and scope: Define precede, sees, Calculate in the question's particular technical setting; explain how maximum, conclusions, unsupported differ if that distinction would change the analysis of "A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer" Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The desired level is dBm Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer to the claimed result, following "Example 3.C6. Comparing attenuation ahead of and after an amplifier"; name the intermediate states and measurable outputs Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer. The blocker level is dBm, giving 7 dB nominal margin below the stipulated mixer limit Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 3.C10. Selecting a feasible gain interval” that resolves the question about A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer; derive the relevant result with units and stated validity conditions Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer. Keep the two filter transfers separate and identify the mixer input as the final plane Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Worked application or illustrative case: Build a worked example of “A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer”, addressing this associated condition: The desired input is -92 dBm and sees 1.2 dB filter loss. The desired level is dBm Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer”. Using “Example 3.C10. Selecting a feasible gain interval”, specify a discriminator and the result

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expected under each explanation Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer, including the effect of missing measurements and inconsistent operating conditions Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)
- Scholarly synthesis and implications: Explain what the result about A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Closing: Conclude by answering “A filter, 5 dB attenuator, and 16 dB amplifier precede a mixer” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)

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V011-C03-ESSAY-003. Two equal distinct blockers each deliver -18 dBm at a receiver stage. Their mean powers add without a cross term. Calculate aggregate mean power, then explain why this result is insufficient to certify peak-voltage immunity.

- Opening: Present a thesis that answers this precise question: Two equal distinct blockers each deliver -18 dBm at a receiver stage. Identify which evidence would falsify the proposed conclusion Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)
- Core terminology and scope: Define deliver, Calculate, aggregate in the question's particular technical setting; explain how insufficient, certify, immunity differ if that distinction would change the analysis of "Two equal distinct blockers each deliver -18 dBm at a receiver stage" Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Each blocker has approximately 0.015849 mW mean power Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Two equal distinct blockers each deliver -18 dBm at a receiver stage to the claimed result, following "Find the first stage that can lose validity"; name the intermediate states and measurable outputs Source: §3.2 Find the first stage that can lose validity (p. 1249)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Two

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equal distinct blockers each deliver -18 dBm at a receiver stage. Their sum is approximately 0.031698 mW, or -14.99 dBm Source: §3.2 Find the first stage that can lose validity (p. 1249)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 3.C1. Filter, attenuator and amplifier power budget” that resolves the question about Two equal distinct blockers each deliver -18 dBm at a receiver stage; derive the relevant result with units and stated validity conditions Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Two equal distinct blockers each deliver -18 dBm at a receiver stage. The increase relative to either individual blocker is about 3.01 dB Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)
- Worked application or illustrative case: Build a worked example of “Two equal distinct blockers each deliver -18 dBm at a receiver stage”, addressing this associated condition: Their mean powers add without a cross term. Each blocker has approximately 0.015849 mW mean power Source: §3.2 Find the first stage that can lose validity (p. 1249)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Two equal distinct blockers each deliver -18 dBm at a receiver stage”. Using “Example 3.C1. Filter, attenuator and amplifier power budget”, specify a discriminator and the result expected under each explanation Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Two equal distinct blockers each deliver -18 dBm at a receiver stage, including the effect of missing measurements and inconsistent operating conditions Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Scholarly synthesis and implications: Explain what the result about Two equal distinct blockers each deliver -18 dBm at a receiver stage authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)
- Closing: Conclude by answering “Two equal distinct blockers each deliver -18 dBm at a receiver stage” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)

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V011-C03-ESSAY-004. A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K. The target is at most 115 K. A -42 dBm admitted blocker must reach the next stage at no more than -23 dBm. Derive the feasible first-stage gain interval and assess available settings of 10, 15, and 20 dB.

- Opening: Present a thesis that answers this precise question: A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K. Identify which evidence would falsify the proposed conclusion Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Core terminology and scope: Define downstream, target, admitted in the question's particular technical setting; explain how reach, feasible, settings differ if that distinction would change the analysis of "A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K" Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The downstream temperature allowance is 40 K, so the first-stage linear power gain must be at least approximately 14.77 dB Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K to the claimed result, following "Choose gain from a feasible interval"; name the

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intermediate states and measurable outputs Source: §3.6 Choose gain from a feasible interval (p. 1257)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K. The blocker condition permits no more than 19 dB gain Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 3.C5. Passive filter loss and the first-stage noise factor” that resolves the question about A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K; derive the relevant result with units and stated validity conditions Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K. The feasible interval is therefore approximately 14.77 to 19 dB, under the stated model Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Worked application or illustrative case: Build a worked example of “A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K”, addressing this associated condition: The target is at most 115 K. The downstream temperature allowance is 40 K, so the first-stage linear power gain

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must be at least approximately 14.77 dB Source: §3.6 Choose gain from a feasible interval (p. 1257)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K”. Using “Example 3.C5. Passive filter loss and the first-stage noise factor”, specify a discriminator and the result expected under each explanation Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K, including the effect of missing measurements and inconsistent operating conditions Source: §3.33.8 Case study 3.D8. Temperature-dependent drift and the risk of overcorrection (p. 1342)
- Scholarly synthesis and implications: Explain what the result about A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Closing: Conclude by answering “A two-stage receiver has first-stage equivalent input temperature 75 K and downstream equivalent temperature 1200 K” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

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V011-C03-ESSAY-005. A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB. Develop a design response that preserves the two requirements instead of selecting a gain halfway between them.

- Opening: Present a thesis that answers this precise question: A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB. Identify which evidence would falsify the proposed conclusion Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Core terminology and scope: Define needs, downstream, design in the question's particular technical setting; explain how requirements, selecting, halfway differ if that distinction would change the analysis of "A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB" Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Show that the intersection is empty: a 21 dB compromise violates both original bounds Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB to the claimed result, following "Choose gain from a feasible interval"; name the

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intermediate states and measurable outputs Source: §3.6 Choose gain from a feasible interval (p. 1257)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB. Identify the mechanism behind each bound before proposing changes Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Use preselection as a measured transfer function” that resolves the question about A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB; derive the relevant result with units and stated validity conditions Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB. Better blocker rejection before the limiting path can relax the loading bound if the desired transfer and preceding-loss noise penalty remain acceptable Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Worked application or illustrative case: Build a worked example of “A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB”, addressing this associated condition: Develop a design response that preserves

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the two requirements instead of selecting a gain halfway.... Show that the intersection is empty: a 21 dB compromise violates both original bounds Source: §3.6 Choose gain from a feasible interval (p. 1257)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB”. Using “Use preselection as a measured transfer function”, specify a discriminator and the result expected under each explanation Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB, including the effect of missing measurements and inconsistent operating conditions Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Scholarly synthesis and implications: Explain what the result about A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Closing: Conclude by answering “A noise requirement needs at least 24 dB first-stage gain, but a downstream loading constraint permits at most 18 dB” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

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V011-C03-ESSAY-006. Compare a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker. The amplifier's stipulated maximum valid input level is -15 dBm. Both arrangements have the same net small-signal gain. Determine what the shared end-to-end number conceals.

- Opening: Present a thesis that answers this precise question: Compare a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker. Identify which evidence would falsify the proposed conclusion Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Core terminology and scope: Define attenuator, placed, maximum in the question's particular technical setting; explain how arrangements, shared, conceals differ if that distinction would change the analysis of "Compare a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker" Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Problem statement and purpose: Frame the actual measurement or decision in the question. With attenuation before the amplifier, its input blocker is -19 dBm, 4 dB below the stated validity limit Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker to the claimed result, following "Choose gain from a feasible interval"; name the intermediate states and measurable outputs Source: §3.6 Choose gain from a feasible interval (p. 1257)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker. The final small-signal prediction is +1 dBm Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 3.C1. Filter, attenuator and amplifier power budget” that resolves the question about a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker; derive the relevant result with units and stated validity conditions Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker. With attenuation after the amplifier, the amplifier sees -7 dBm, 8 dB above its stated valid input limit; the same +1 dBm end-to-end prediction is therefore not justified by the small-signal... Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Worked application or illustrative case: Build a worked example of “a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker”, addressing this associated condition: The amplifier’s stipulated maximum valid input level is -15 dBm. With attenuation before the amplifier, its input blocker is -19 dBm, 4 dB below the stated validity limit Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a 12 dB attenuator placed before and

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after a 20 dB amplifier for a -7 dBm blocker". Using "Example 3.C1. Filter, attenuator and amplifier power budget", specify a discriminator and the result expected under each explanation Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker, including the effect of missing measurements and inconsistent operating conditions Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)
- Scholarly synthesis and implications: Explain what the result about a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Closing: Conclude by answering "Compare a 12 dB attenuator placed before and after a 20 dB amplifier for a -7 dBm blocker" using only the demonstrated evidence; state the remaining decisive verification step Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

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V011-C03-ESSAY-007. Design a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest. Address amplitude, phase, noise, and state reproducibility.

- Opening: Present a thesis that answers this precise question: Design a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest. Address amplitude, phase, noise, and state.... Identify which evidence would falsify the proposed conclusion Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Core terminology and scope: Define Design, boundary, characterization in the question's particular technical setting; explain how switches, preselector, reproducibility differ if that distinction would change the analysis of "Design a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest. Address amplitude, phase, noise, and state..." Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the actual band identifiers and switching rule, then use reference frequencies on both sides of the boundary and within the region where response changes rapidly Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest to the claimed result, following "An acceptance sequence that separates competing failures"; name

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the intermediate states and measurable outputs Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest. Keep the desired reference plane, source level, processing bandwidth, and detector convention controlled Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Preselection and Filter State” that resolves the question about a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest; derive the relevant result with units and stated validity conditions Source: §3.3 Preselection and Filter State (p. 1251)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest. Retain raw response and corrected response, relevant phase or modulation quality, noise, and the realized filter state Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Worked application or illustrative case: Build a worked example of “a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest”, addressing this associated condition: Address amplitude, phase, noise, and state

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reproducibility. Identify the actual band identifiers and switching rule, then use reference frequencies on both sides of the boundary and within the region where response changes… Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest”. Using “Preselection and Filter State”, specify a discriminator and the result expected under each explanation Source: §3.3 Preselection and Filter State (p. 1251)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest, including the effect of missing measurements and inconsistent operating conditions Source: §3.23 Switching architectures and state-machine validity (p. 1302)
- Scholarly synthesis and implications: Explain what the result about a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Closing: Conclude by answering “Design a filter-bank boundary characterization for a receiver that switches preselector states near a frequency of interest. Address amplitude, phase, noise, and state…” using only the demonstrated evidence; state the remaining

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decisive verification step Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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V011-C03-ESSAY-008. A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power. Under unchanged valid detection processing, calculate the SNR change and explain the additional work needed for a burst-detection claim.

- Opening: Present a thesis that answers this precise question: A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power. Identify which evidence would falsify the proposed conclusion Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Core terminology and scope: Define lowers, integrated, removes in the question's particular technical setting; explain how unchanged, calculate, work differ if that distinction would change the analysis of "A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power" Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The desired-to-noise ratio improves by 2 dB because desired power changes by -4 dB while noise changes by -6 dB Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power to the claimed result, following "Case study 3.D3. The misleading improvement from additional preamplifier gain"; name the intermediate states and measurable

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outputs Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power. Equivalently, divide the desired retention factor by the noise retention factor Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 3.C5. Passive filter loss and the first-stage noise factor” that resolves the question about A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power; derive the relevant result with units and stated validity conditions Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power. This arithmetic assumes the quantities are comparable integrated powers at a common plane and that the detector law remains applicable Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Worked application or illustrative case: Build a worked example of “A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power”, addressing this

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associated condition: Under unchanged valid detection processing, calculate the SNR change and explain the additional work.... The desired-to-noise ratio improves by 2 dB because desired power changes by -4 dB while noise changes by -6 dB Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power”. Using “Example 3.C5. Passive filter loss and the first-stage noise factor”, specify a discriminator and the result expected under each explanation Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power, including the effect of missing measurements and inconsistent operating conditions Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)
- Scholarly synthesis and implications: Explain what the result about A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired waveform power authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Closing: Conclude by answering “A narrow preselector lowers integrated channel noise by 6 dB but removes 4 dB of the desired

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waveform power" using only the demonstrated evidence; state the remaining decisive verification step Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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V011-C03-ESSAY-009. Develop a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent blocker. Explain why a mean gain correction is inadequate.

- Opening: Present a thesis that answers this precise question: Develop a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent blocker. Explain why a mean gain…. Identify which evidence would falsify the proposed conclusion Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)
- Core terminology and scope: Define structure, distinguishes, intermittent in the question's particular technical setting; explain how blocker, mean, inadequate differ if that distinction would change the analysis of "Develop a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent blocker. Explain why a mean gain…" Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain native samples or physical detector output with acquisition timing Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent… to the claimed result, following "3. Front-end noise spectroscopy as an instrument-state

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test"; name the intermediate states and measurable outputs Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent.... Align the state trajectory with the affected data and characterize the transfer for the states and transitions used Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)
- Analytical framework: Identify the equation, calibration or evidential decision test in "3. Independent challenge of recovered input-referred amplitude" that resolves the question about a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent...; derive the relevant result with units and stated validity conditions Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent.... Compare a permitted fixed-gain challenge or an independently characterized control response to discriminate source change from automatic gain action Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)
- Worked application or illustrative case: Build a worked example of "a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent...",

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addressing this associated condition: Explain why a mean gain correction is inadequate. Retain native samples or physical detector output with acquisition timing Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent…”. Using “3. Independent challenge of recovered input-referred amplitude”, specify a discriminator and the result expected under each explanation Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent…, including the effect of missing measurements and inconsistent operating conditions Source: §3.5 Gain Distribution and Attenuation (p. 1256)
- Scholarly synthesis and implications: Explain what the result about a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)
- Closing: Conclude by answering “Develop a record structure that distinguishes a real external amplitude change from receiver gain-control response during an intermittent blocker. Explain why a

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mean gain…" using only the demonstrated evidence; state the remaining decisive verification step Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

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V011-C03-ESSAY-010. Explain how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload. Distinguish the analog SNR from input-referred converter noise.

- Opening: Present a thesis that answers this precise question: Explain how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload. Distinguish the analog SNR from…. Identify which evidence would falsify the proposed conclusion Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Core terminology and scope: Define digitizer, leaves, converter in the question's particular technical setting; explain how significant, approaches, overload differ if that distinction would change the analysis of "Explain how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload. Distinguish the analog SNR from…" Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Map the desired signal, admitted noise, and strongest relevant event to the actual converter input Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload to the claimed result, following "Find the first stage that can lose validity"; name the

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intermediate states and measurable outputs Source: §3.2 Find the first stage that can lose validity (p. 1249)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload. In the valid linear region, common analog gain does not improve the SNR already present before that gain Source: §3.2 Find the first stage that can lose validity (p. 1249)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose gain from a feasible interval” that resolves the question about how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload; derive the relevant result with units and stated validity conditions Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload. It can reduce the converter-added contribution when referred back to the external input Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Worked application or illustrative case: Build a worked example of “how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload”,

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addressing this associated condition: Distinguish the analog SNR from input-referred converter noise. Map the desired signal, admitted noise, and strongest relevant event to the actual converter input Source: §3.2 Find the first stage that can lose validity (p. 1249)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload”. Using “Choose gain from a feasible interval”, specify a discriminator and the result expected under each explanation Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload, including the effect of missing measurements and inconsistent operating conditions Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)
- Scholarly synthesis and implications: Explain what the result about how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Closing: Conclude by answering “Explain how to choose analog gain before a digitizer when low gain leaves converter noise significant and high gain approaches overload. Distinguish the analog SNR from…” using only the demonstrated evidence; state the remaining

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decisive verification step Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

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V011-C03-ESSAY-011. A receiver protection network survives a pulse test. Define three distinct acceptance questions that remain, and design observables appropriate to each.

- Opening: Present a thesis that answers this precise question: A receiver protection network survives a pulse test. Define three distinct acceptance questions that remain, and design observables appropriate to each. Identify which evidence would falsify the proposed conclusion Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Core terminology and scope: Define protection, survives, distinct in the question's particular technical setting; explain how questions, design, observables differ if that distinction would change the analysis of "A receiver protection network survives a pulse test. Define three distinct acceptance questions that remain, and design observables appropriate to each" Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Problem statement and purpose: Frame the actual measurement or decision in the question. First quantify what reaches the downstream path during the event, including any leading transient and later leakage under the actual source and load conditions Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A receiver protection network survives a pulse test to the claimed result, following "Blocker-dependent front-end state machines and hidden recovery intervals"; name the intermediate states and measurable

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outputs Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A receiver protection network survives a pulse test. Second establish hardware survival using the applicable conditioned limits and post-event functional evidence; absence of obvious damage is not every performance test Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Analytical framework: Identify the equation, calibration or evidential decision test in “An acceptance sequence that separates competing failures” that resolves the question about A receiver protection network survives a pulse test; derive the relevant result with units and stated validity conditions Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A receiver protection network survives a pulse test. Third measure recovery of the desired weak-signal observables, such as amplitude, phase, modulation quality, and baseline variance within stated tolerances Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Worked application or illustrative case: Build a worked example of “A receiver protection network survives a pulse test”, addressing this associated condition: Define three distinct acceptance questions that remain, and design observables appropriate to each. First quantify what reaches the downstream path during the event,

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including any leading transient and later leakage under the actual source and load conditions Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A receiver protection network survives a pulse test”. Using “An acceptance sequence that separates competing failures”, specify a discriminator and the result expected under each explanation Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A receiver protection network survives a pulse test, including the effect of missing measurements and inconsistent operating conditions Source: §3.7 Input Protection and Recovery (p. 1260)
- Scholarly synthesis and implications: Explain what the result about A receiver protection network survives a pulse test authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Closing: Conclude by answering “A receiver protection network survives a pulse test. Define three distinct acceptance questions that remain, and design observables appropriate to each” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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V011-C03-ESSAY-012. For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate duty factor and mean power. Explain why the resulting mean is not sufficient for protection acceptance.

- Opening: Present a thesis that answers this precise question: For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate duty factor and mean power. Identify which evidence would falsify the proposed conclusion Source: §3.7 Input Protection and Recovery (p. 1260)
- Core terminology and scope: Define rectangular, pulses, microsecond in the question's particular technical setting; explain how period, calculate, duty differ if that distinction would change the analysis of "For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate duty factor and mean power" Source: §3.7 Input Protection and Recovery (p. 1260)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The duty factor is or 2 percent Source: §3.7 Input Protection and Recovery (p. 1260)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate… to the claimed result, following "Measure protection in the small-signal and recovery states"; name the intermediate states and measurable

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outputs Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate…. Mean power is mW, which is 0 dBm; peak power is approximately 16.99 dBm Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Blocker-dependent front-end state machines and hidden recovery intervals” that resolves the question about For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate…; derive the relevant result with units and stated validity conditions Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate…. The mean may inform some thermal questions, but it does not replace the peak, pulse-width, repetition, leading-edge leakage, or recovery conditions relevant to the device and assembly Source: §3.7 Input Protection and Recovery (p. 1260)
- Worked application or illustrative case: Build a worked example of “For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate…”,

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addressing this associated condition: Explain why the resulting mean is not sufficient for protection acceptance. The duty factor is or 2 percent Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate…”. Using “Blocker-dependent front-end state machines and hidden recovery intervals”, specify a discriminator and the result expected under each explanation Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate…, including the effect of missing measurements and inconsistent operating conditions Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)
- Scholarly synthesis and implications: Explain what the result about For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with zero off-state power, calculate… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.7 Input Protection and Recovery (p. 1260)
- Closing: Conclude by answering “For rectangular pulses of 50 mW peak power, 6 microsecond width, and 300 microsecond period with

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zero off-state power, calculate duty factor and mean power" using only the demonstrated evidence; state the remaining decisive verification step Source: §3.7 Input Protection and Recovery (p. 1260)

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V011-C03-ESSAY-013. Construct an observable-specific recovery criterion for a weak modulated reference. The amplitude is within tolerance after 35 microseconds, phase after 60 microseconds, and baseline variance after 85 microseconds. What interval can support a claim requiring all three?

- Opening: Present a thesis that answers this precise question: Construct an observable-specific recovery criterion for a weak modulated reference. Identify which evidence would falsify the proposed conclusion Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)
- Core terminology and scope: Define Construct, modulated, tolerance in the question's particular technical setting; explain how microseconds, baseline, requiring differ if that distinction would change the analysis of "Construct an observable-specific recovery criterion for a weak modulated reference" Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)
- Problem statement and purpose: Frame the actual measurement or decision in the question. If all three criteria are required and remain satisfied thereafter under the declared observation rule, recovery is no earlier than 85 microseconds after the defined event time origin Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an observable-specific recovery criterion for a weak modulated reference to the claimed result, following "Blocker-dependent front-end state machines and hidden recovery intervals"; name the intermediate

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states and measurable outputs Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an observable-specific recovery criterion for a weak modulated reference. State whether the origin is the event leading edge or trailing edge, how persistence within tolerance is judged, and how time resolution affects the reported boundary Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration” that resolves the question about an observable-specific recovery criterion for a weak modulated reference; derive the relevant result with units and stated validity conditions Source: §3.33.4 Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration (p. 1334)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an observable-specific recovery criterion for a weak modulated reference. The 35 microsecond amplitude crossing alone cannot establish phase or variance recovery Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)
- Worked application or illustrative case: Build a worked example of “an observable-specific recovery criterion for a weak modulated reference”, addressing this associated condition: The amplitude is within tolerance after 35 microseconds, phase after 60

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microseconds, and baseline.... If all three criteria are required and remain satisfied thereafter under the declared observation rule, recovery is no earlier than 85 microseconds after the defined... Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an observable-specific recovery criterion for a weak modulated reference”. Using “Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration”, specify a discriminator and the result expected under each explanation Source: §3.33.4 Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration (p. 1334)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an observable-specific recovery criterion for a weak modulated reference, including the effect of missing measurements and inconsistent operating conditions Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)
- Scholarly synthesis and implications: Explain what the result about an observable-specific recovery criterion for a weak modulated reference authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)
- Closing: Conclude by answering “Construct an observable-specific recovery criterion for a weak modulated reference” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

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V011-C03-ESSAY-014. A measured recovery delay decreases when detector averaging is shortened. Develop a mechanism-discrimination argument that neither blames the limiter automatically nor assumes the analog path is instantly recovered.

- Opening: Present a thesis that answers this precise question: A measured recovery delay decreases when detector averaging is shortened. Identify which evidence would falsify the proposed conclusion Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Core terminology and scope: Define decreases, argument, limiter in the question's particular technical setting; explain how automatically, assumes, recovered differ if that distinction would change the analysis of "A measured recovery delay decreases when detector averaging is shortened" Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the complete path from the protection network through amplifiers, gain control, digital filtering, detector, and trigger logic Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A measured recovery delay decreases when detector averaging is shortened to the claimed result, following "Case study 3.D1. Intermittent high-power illumination and a false absence claim"; name the

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intermediate states and measurable outputs Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A measured recovery delay decreases when detector averaging is shortened. Shorter detector averaging changes the observation response and its noise variability; the difference supports a processing contribution but does not uniquely quantify every analog delay Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Blocker-dependent front-end state machines and hidden recovery intervals” that resolves the question about A measured recovery delay decreases when detector averaging is shortened; derive the relevant result with units and stated validity conditions Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A measured recovery delay decreases when detector averaging is shortened. Retain a weak reference and compare time-resolved amplitude or phase with appropriate raw observations under controlled event conditions Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Worked application or illustrative case: Build a worked example of “A measured recovery delay decreases when detector averaging is shortened”, addressing this associated condition: Develop a

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mechanism-discrimination argument that neither blames the limiter automatically nor assumes.... Identify the complete path from the protection network through amplifiers, gain control, digital filtering, detector, and trigger logic Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A measured recovery delay decreases when detector averaging is shortened”. Using “Blocker-dependent front-end state machines and hidden recovery intervals”, specify a discriminator and the result expected under each explanation Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A measured recovery delay decreases when detector averaging is shortened, including the effect of missing measurements and inconsistent operating conditions Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)
- Scholarly synthesis and implications: Explain what the result about A measured recovery delay decreases when detector averaging is shortened authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Closing: Conclude by answering “A measured recovery delay decreases when detector averaging is shortened” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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V011-C03-ESSAY-015. Explain why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge. Connect the required observations to the charge-storage mechanism described in the chapter.

- Opening: Present a thesis that answers this precise question: Explain why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge. Identify which evidence would falsify the proposed conclusion Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Core terminology and scope: Define needs, characterization, timed in the question's particular technical setting; explain how Connect, mechanism, described differ if that distinction would change the analysis of "Explain why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge" Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Problem statement and purpose: Frame the actual measurement or decision in the question. In the nonlimiting state, insertion loss, return loss, and reactive loading affect desired transfer and the noise budget Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge to the claimed result, following "Front-End Characterization and Field Decisions"; name the intermediate

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states and measurable outputs Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge. During a large event, stored carriers alter RF resistance; the external current path and device geometry influence the mounted response Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Preselection and Filter State” that resolves the question about why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge; derive the relevant result with units and stated validity conditions Source: §3.3 Preselection and Filter State (p. 1251)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge. Removal or recombination of carriers contributes to the return toward the low-loss state Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Worked application or illustrative case: Build a worked example of “why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge”, addressing this associated condition: Connect the required observations to the charge-storage mechanism described in the chapter. In the

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nonlimiting state, insertion loss, return loss, and reactive loading affect desired transfer and the noise budget Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge”. Using “Preselection and Filter State”, specify a discriminator and the result expected under each explanation Source: §3.3 Preselection and Filter State (p. 1251)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge, including the effect of missing measurements and inconsistent operating conditions Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Scholarly synthesis and implications: Explain what the result about why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Closing: Conclude by answering “Explain why a mounted PIN-limiter network needs both small-signal characterization and a timed large-event challenge” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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V011-C03-ESSAY-016. Design a source-path control for a two-generator test that produces a new line in the receiver output. Explain what must be bounded before assigning that line to receiver intermodulation.

- Opening: Present a thesis that answers this precise question: Design a source-path control for a two-generator test that produces a new line in the receiver output. Explain what must be bounded before assigning that line to receiver…. Identify which evidence would falsify the proposed conclusion Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Core terminology and scope: Define Design, produces, line in the question's particular technical setting; explain how bounded, assigning, intermodulation differ if that distinction would change the analysis of "Design a source-path control for a two-generator test that produces a new line in the receiver output. Explain what must be bounded before assigning that line to receiver…" Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Establish both generator outputs and their harmonics, spurs, and relevant noise at the intended receiver input plane through the actual cables and combiner Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a source-path control for a two-generator test that produces a new line in the receiver output to the claimed result, following "3. Calibration-fixture integrity and traceability of source amplitude"; name the

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intermediate states and measurable outputs Source: §3.30 Calibration-fixture integrity and traceability of source amplitude (p. 1319)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a source-path control for a two-generator test that produces a new line in the receiver output. Assess combiner isolation and linearity at the applied levels because generator interaction or passive/nonlinear combining elements can create the line before the receiver Source: §3.30 Calibration-fixture integrity and traceability of source amplitude (p. 1319)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Case study 3.D3. The misleading improvement from additional preamplifier gain” that resolves the question about a source-path control for a two-generator test that produces a new line in the receiver output; derive the relevant result with units and stated validity conditions Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a source-path control for a two-generator test that produces a new line in the receiver output. Use suitable independent observations, isolation changes, or controlled source-path substitutions that preserve known applied levels Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Worked application or illustrative case: Build a worked example of “a source-path control for a two-generator test that produces a new

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line in the receiver output", addressing this associated condition: Explain what must be bounded before assigning that line to receiver intermodulation. Establish both generator outputs and their harmonics, spurs, and relevant noise at the intended receiver input plane through the actual cables and combiner Source: §3.30 Calibration-fixture integrity and traceability of source amplitude (p. 1319)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "a source-path control for a two-generator test that produces a new line in the receiver output". Using "Case study 3.D3. The misleading improvement from additional preamplifier gain", specify a discriminator and the result expected under each explanation Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a source-path control for a two-generator test that produces a new line in the receiver output, including the effect of missing measurements and inconsistent operating conditions Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)
- Scholarly synthesis and implications: Explain what the result about a source-path control for a two-generator test that produces a new line in the receiver output authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Closing: Conclude by answering "Design a source-path control for a two-generator test that produces a new line in the receiver output.

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Explain what must be bounded before assigning that line to receiver…" using only the demonstrated evidence; state the remaining decisive verification step Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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V011-C03-ESSAY-017. A receiver channel noise floor rises when a strong offset source is introduced. Formulate a test that separates noise carried by the source from reciprocal mixing and gain-state changes.

- Opening: Present a thesis that answers this precise question: A receiver channel noise floor rises when a strong offset source is introduced. Formulate a test that separates noise carried by the source from reciprocal mixing and…. Identify which evidence would falsify the proposed conclusion Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Core terminology and scope: Define rises, introduced, separates in the question's particular technical setting; explain how carried, reciprocal, mixing differ if that distinction would change the analysis of "A receiver channel noise floor rises when a strong offset source is introduced. Formulate a test that separates noise carried by the source from reciprocal mixing and…" Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Characterize or bound source spectral purity at the desired channel and the levels delivered through the actual combining path Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A receiver channel noise floor rises when a strong offset source is introduced to the claimed result, following "Use preselection as a measured transfer

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function"; name the intermediate states and measurable outputs Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A receiver channel noise floor rises when a strong offset source is introduced. Keep desired reference, effective bandwidth, detector operation, and reference plane controlled Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Analytical framework: Identify the equation, calibration or evidential decision test in "3. Front-end noise spectroscopy as an instrument-state test" that resolves the question about A receiver channel noise floor rises when a strong offset source is introduced; derive the relevant result with units and stated validity conditions Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A receiver channel noise floor rises when a strong offset source is introduced. Record gain-state changes and desired transfer while varying blocker level, offset, or preselection in ways predicted to affect the candidate mechanisms Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Worked application or illustrative case: Build a worked example of "A receiver channel noise floor rises when a strong offset source is introduced", addressing this associated condition: Formulate a test that separates noise carried by the source from reciprocal mixing and gain-state changes. Characterize or bound source spectral

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purity at the desired channel and the levels delivered through the actual combining path Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A receiver channel noise floor rises when a strong offset source is introduced”. Using “3. Front-end noise spectroscopy as an instrument-state test”, specify a discriminator and the result expected under each explanation Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A receiver channel noise floor rises when a strong offset source is introduced, including the effect of missing measurements and inconsistent operating conditions Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)
- Scholarly synthesis and implications: Explain what the result about A receiver channel noise floor rises when a strong offset source is introduced authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Closing: Conclude by answering “A receiver channel noise floor rises when a strong offset source is introduced. Formulate a test that separates noise carried by the source from reciprocal mixing and…” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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V011-C03-ESSAY-018. Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast environment. State the ordering and purpose of the measurements.

- Opening: Present a thesis that answers this precise question: Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast environment. State the ordering and purpose of the.... Identify which evidence would falsify the proposed conclusion Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Core terminology and scope: Define intended, broadcast, environment in the question's particular technical setting; explain how ordering, purpose, measurements differ if that distinction would change the analysis of "Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast environment. State the ordering and purpose of the..." Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin by establishing source and combining-path validity, actual applied levels, and the operating ratings Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast... to the claimed

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result, following “Blocker-dependent front-end state machines and hidden recovery intervals”; name the intermediate states and measurable outputs Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast…. Measure the quiet desired transfer and noise in the selected state, including the intended waveform bandwidth and relevant phase or quality Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Measure protection in the small-signal and recovery states” that resolves the question about Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast…; derive the relevant result with units and stated validity conditions Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast…. Introduce a bounded blocker in controlled increments with the desired source fixed, recording transfer, channel noise, discrete products, and state telemetry Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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- Worked application or illustrative case: Build a worked example of “Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast…”, addressing this associated condition: State the ordering and purpose of the measurements. Begin by establishing source and combining-path validity, actual applied levels, and the operating ratings Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast…”. Using “Measure protection in the small-signal and recovery states”, specify a discriminator and the result expected under each explanation Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast…, including the effect of missing measurements and inconsistent operating conditions Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)
- Scholarly synthesis and implications: Explain what the result about Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- Closing: Conclude by answering “Prepare an acceptance sequence for a new front-end state that is intended to retain a weak reference in a strong broadcast environment. State the ordering and purpose of the…” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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V011-C03-ESSAY-019. An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor. Critique a report that calls this conclusive evidence of receiver-generated intermodulation, and propose a discriminating follow-up.

- Opening: Present a thesis that answers this precise question: An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor. Identify which evidence would falsify the proposed conclusion Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Core terminology and scope: Define increase, removes, suspect in the question's particular technical setting; explain how line, calls, discriminating differ if that distinction would change the analysis of "An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor" Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The comparison lost the ability to observe both quantities, so disappearance is consistent with several origins Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor to the claimed result, following "Case study 3.D2. A two-tone product that coincides with a suspected frequency"; name the intermediate states and

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measurable outputs Source: §3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency (p. 1330)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor. The attenuation change does not by itself establish the suspect line's scaling law Source: §3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency (p. 1330)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Gain Distribution and Attenuation" that resolves the question about An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor; derive the relevant result with units and stated validity conditions Source: §3.5 Gain Distribution and Attenuation (p. 1256)
- Evidence and method: Specify the native observations, control records and calculations that would resolve An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor. Preserve the measured floor, raw levels, and corrections and state the unresolved alternatives Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Worked application or illustrative case: Build a worked example of "An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor", addressing this associated condition: Critique a report that calls this conclusive evidence of receiver-generated intermodulation, and propose.... The

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comparison lost the ability to observe both quantities, so disappearance is consistent with several origins Source: §3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency (p. 1330)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor”. Using “Gain Distribution and Attenuation”, specify a discriminator and the result expected under each explanation Source: §3.5 Gain Distribution and Attenuation (p. 1256)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor, including the effect of missing measurements and inconsistent operating conditions Source: §3.33.8 Case study 3.D8. Temperature-dependent drift and the risk of overcorrection (p. 1342)
- Scholarly synthesis and implications: Explain what the result about An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Closing: Conclude by answering “An 8 dB attenuation increase removes both a suspect line and the weak desired reference below the measurement floor” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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V011-C03-ESSAY-020. A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector. Two lower-frequency tones reproduce a line at 1.2 GHz. Develop the strongest bounded conclusion and identify the remaining attribution checks.

- Opening: Present a thesis that answers this precise question: A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector. Identify which evidence would falsify the proposed conclusion Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Core terminology and scope: Define suspected, emitter, absent in the question's particular technical setting; explain how reproduce, strongest, remaining differ if that distinction would change the analysis of "A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector" Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The combined observations support a nonlinear product hypothesis because rejection of lower-frequency inputs can remove a line while the preselector nominally passes the displayed frequency Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector to the claimed result, following "Use preselection as a measured transfer function"; name the

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intermediate states and measurable outputs Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector. Verify the actual desired-reference transfer at 1.2 GHz through both installed states so the disappearance is not explained by lost observation capability Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Case study 3.D2. A two-tone product that coincides with a suspected frequency” that resolves the question about A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector; derive the relevant result with units and stated validity conditions Source: §3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency (p. 1330)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector. Establish the relevant lower-frequency levels and rejection, and bound source and combiner products at the receiver input plane Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Worked application or illustrative case: Build a worked example of “A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector”, addressing

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this associated condition: Two lower-frequency tones reproduce a line at 1.2 GHz. The combined observations support a nonlinear product hypothesis because rejection of lower-frequency inputs can remove a line while the preselector nominally passes the... Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector”. Using “Case study 3.D2. A two-tone product that coincides with a suspected frequency”, specify a discriminator and the result expected under each explanation Source: §3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency (p. 1330)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector, including the effect of missing measurements and inconsistent operating conditions Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)
- Scholarly synthesis and implications: Explain what the result about A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to 1.4 GHz preselector authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Closing: Conclude by answering “A suspected 1.2 GHz emitter is present in a broadband state and absent through a measured 1.0 to

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1.4 GHz preselector" using only the demonstrated evidence; state the remaining decisive verification step Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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V011-C03-ESSAY-021. Develop a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter. Explain what the earlier acceptance record can and cannot establish.

- Opening: Present a thesis that answers this precise question: Develop a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter. Explain what the earlier acceptance record…. Identify which evidence would falsify the proposed conclusion Source: §3.11 Verification and Maintenance Controls (p. 1268)
- Core terminology and scope: Define maintenance, release, fitted in the question's particular technical setting; explain how replacement, earlier, acceptance differ if that distinction would change the analysis of "Develop a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter. Explain what the earlier acceptance record…" Source: §3.11 Verification and Maintenance Controls (p. 1268)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the new serialized components, connection conditions, relevant torque, filter state, and firmware or configuration Source: §3.11 Verification and Maintenance Controls (p. 1268)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter to the claimed result, following "Preselection and Filter State"; name the intermediate

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states and measurable outputs Source: §3.3 Preselection and Filter State (p. 1251)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter. Compare applicable reference sweeps and bounded multi-tone or recovery checks with accepted baselines over the frequencies and levels required for use Source: §3.3 Preselection and Filter State (p. 1251)
- Analytical framework: Identify the equation, calibration or evidential decision test in “3. Release-gate checklist for a qualified receiver input chain” that resolves the question about a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter; derive the relevant result with units and stated validity conditions Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter. Retain corrections, uncertainty, and any evidence of drift in contacts, tuning, bias, leakage, or isolation Source: §3.11 Verification and Maintenance Controls (p. 1268)
- Worked application or illustrative case: Build a worked example of “a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter”, addressing this associated condition: Explain what the earlier acceptance record

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can and cannot establish. Identify the new serialized components, connection conditions, relevant torque, filter state, and firmware or configuration Source: §3.3 Preselection and Filter State (p. 1251)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter”. Using “3. Release-gate checklist for a qualified receiver input chain”, specify a discriminator and the result expected under each explanation Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter, including the effect of missing measurements and inconsistent operating conditions Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Scholarly synthesis and implications: Explain what the result about a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.11 Verification and Maintenance Controls (p. 1268)
- Closing: Conclude by answering “Develop a maintenance and release record after a receiver is transported, recabled, and fitted with a replacement external filter. Explain what the earlier acceptance record…” using only the demonstrated evidence; state

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the remaining decisive verification step Source: §3.11 Verification and Maintenance Controls (p. 1268)

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V011-C03-ESSAY-022. Explain how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change. Give a numerical example with a verified 10 dB attenuation step.

- Opening: Present a thesis that answers this precise question: Explain how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change. Identify which evidence would falsify the proposed conclusion Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)
- Core terminology and scope: Define corrected, jointly, intentional in the question's particular technical setting; explain how unexplained, verified, step differ if that distinction would change the analysis of "Explain how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change" Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Suppose a valid raw desired output is -50 dBm before the step and -60 dBm afterward, with all other applicable gains unchanged Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change to the claimed

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result, following “Example 3.C4. Input attenuation as an overload intervention”; name the intermediate states and measurable outputs Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change. The added 10 dB input loss explains the raw decrease; adding back the appropriate state-specific correction gives the same external estimate Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 3.C6. Comparing attenuation ahead of and after an amplifier” that resolves the question about how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change; derive the relevant result with units and stated validity conditions Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change. The raw record shows the physical output change while the corrected record supports a common-plane comparison Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

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- Worked application or illustrative case: Build a worked example of “how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change”, addressing this associated condition: Give a numerical example with a verified 10 dB attenuation step. Suppose a valid raw desired output is -50 dBm before the step and -60 dBm afterward, with all other applicable gains unchanged Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change”. Using “Example 3.C6. Comparing attenuation ahead of and after an amplifier”, specify a discriminator and the result expected under each explanation Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change, including the effect of missing measurements and inconsistent operating conditions Source: §3.19.1 Example 3.C1. Filter, attenuator and amplifier power budget (p. 1284)
- Scholarly synthesis and implications: Explain what the result about how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change authorises the investigator or engineer to claim, and what

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stronger proposition remains unsupported Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- Closing: Conclude by answering “Explain how raw output and corrected input-plane records jointly distinguish intentional gain correction from an unexplained level change” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

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V011-C03-ESSAY-023. Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver. Identify the source and system evidence required for a defensible limit.

- Opening: Present a thesis that answers this precise question: Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver. Identify which evidence would falsify the proposed conclusion Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Core terminology and scope: Define proposal, apply, published in the question's particular technical setting; explain how limiter, rating, assembled differ if that distinction would change the analysis of "Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver" Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Read the actual device and revision, conditioned pulse width and duty factor, frequency and temperature range, and distinction between specifications and absolute maximum ratings Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver to the claimed result, following "3. Frequency-selective headroom and the failure of

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scalar 'maximum input' ratings"; name the intermediate states and measurable outputs Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver. Identify the installed topology, mounting, current path, thermal environment, and downstream components Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Blocker-dependent front-end state machines and hidden recovery intervals" that resolves the question about Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver; derive the relevant result with units and stated validity conditions Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver. Establish how leading and later leakage reach the protected circuitry and whether the desired measurement recovers within the required interval Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Worked application or illustrative case: Build a worked example of "Critique a proposal to apply a published limiter's pulse-survival

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number as the allowable input rating for an assembled receiver", addressing this associated condition: Identify the source and system evidence required for a defensible limit. Read the actual device and revision, conditioned pulse width and duty factor, frequency and temperature range, and distinction between... Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver". Using "Blocker-dependent front-end state machines and hidden recovery intervals", specify a discriminator and the result expected under each explanation Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver, including the effect of missing measurements and inconsistent operating conditions Source: §3.33.8 Case study 3.D8. Temperature-dependent drift and the risk of overcorrection (p. 1342)
- Scholarly synthesis and implications: Explain what the result about Critique a proposal to apply a published limiter's pulse-survival number as the allowable input rating for an assembled receiver authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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- Closing: Conclude by answering “Critique a proposal to apply a published limiter’s pulse-survival number as the allowable input rating for an assembled receiver” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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V011-C03-ESSAY-024. A closing injected reference at the receiver connector produces its expected amplitude. Formulate a precise verification statement and design complementary checks for functions that the injection did not exercise.

- Opening: Present a thesis that answers this precise question: A closing injected reference at the receiver connector produces its expected amplitude. Identify which evidence would falsify the proposed conclusion Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Core terminology and scope: Define closing, injected, precise in the question's particular technical setting; explain how complementary, functions, exercise differ if that distinction would change the analysis of "A closing injected reference at the receiver connector produces its expected amplitude" Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the injection plane, frequency, level, waveform, receiver state, output observation, and time Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A closing injected reference at the receiver connector produces its expected amplitude to the claimed result, following "Blocker-dependent front-end state machines and hidden recovery intervals"; name the intermediate states and measurable outputs Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A closing injected reference at the receiver connector produces its expected amplitude. The check supports the exercised transfer or function under those conditions at that time Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Analytical framework: Identify the equation, calibration or evidential decision test in “3. Additional analytical treatment: the input plane as a coupled nonlinear system” that resolves the question about A closing injected reference at the receiver connector produces its expected amplitude; derive the relevant result with units and stated validity conditions Source: §3.15 Additional analytical treatment: the input plane as a coupled nonlinear system (p. 1273)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A closing injected reference at the receiver connector produces its expected amplitude. It may bypass the antenna, an external preselector, or upstream cabling, and it does not by itself establish uninterrupted validity during prior acquisition Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Worked application or illustrative case: Build a worked example of “A closing injected reference at the receiver connector produces its expected amplitude”, addressing this associated condition: Formulate a precise verification statement and design complementary checks for functions that the.... State the injection plane, frequency, level, waveform, receiver state, output

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observation, and time Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A closing injected reference at the receiver connector produces its expected amplitude”. Using “3. Additional analytical treatment: the input plane as a coupled nonlinear system”, specify a discriminator and the result expected under each explanation Source: §3.15 Additional analytical treatment: the input plane as a coupled nonlinear system (p. 1273)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A closing injected reference at the receiver connector produces its expected amplitude, including the effect of missing measurements and inconsistent operating conditions Source: §3.26 A graded laboratory qualification matrix (p. 1309)
- Scholarly synthesis and implications: Explain what the result about A closing injected reference at the receiver connector produces its expected amplitude authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Closing: Conclude by answering “A closing injected reference at the receiver connector produces its expected amplitude” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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V011-C03-ESSAY-025. Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed operational state. Explain how a technically favorable calculation could still fail the review.

- Opening: Present a thesis that answers this precise question: Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed operational state. Identify which evidence would falsify the proposed conclusion Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Core terminology and scope: Define requirements, review, argument in the question's particular technical setting; explain how proposed, technically, favorable differ if that distinction would change the analysis of "Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed operational state" Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the intended observation, reference plane, desired waveform, and bounded interferer environment Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed... to the claimed result, following "An acceptance sequence that separates competing

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failures"; name the intermediate states and measurable outputs Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed.... Use frequency-specific gains to track desired and blocker levels through the actual order, then combine the noise-derived minimum gain with the downstream loading maximum Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Use preselection as a measured transfer function" that resolves the question about Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed...; derive the relevant result with units and stated validity conditions Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed.... Check signal retention, state reproducibility, and the relevant protection and recovery behavior Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Worked application or illustrative case: Build a worked example of "Integrate the chapter's gain, preselection, protection, and record requirements into a review argument for one proposed...",

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addressing this associated condition: Explain how a technically favorable calculation could still fail the review. Define the intended observation, reference plane, desired waveform, and bounded interferer environment Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Integrate the chapter’s gain, preselection, protection, and record requirements into a review argument for one proposed…”. Using “Use preselection as a measured transfer function”, specify a discriminator and the result expected under each explanation Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Integrate the chapter’s gain, preselection, protection, and record requirements into a review argument for one proposed…, including the effect of missing measurements and inconsistent operating conditions Source: §3.2 Find the first stage that can lose validity (p. 1249)
- Scholarly synthesis and implications: Explain what the result about Integrate the chapter’s gain, preselection, protection, and record requirements into a review argument for one proposed… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Closing: Conclude by answering “Integrate the chapter’s gain, preselection, protection, and record requirements into a review argument for one proposed operational state” using only the

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demonstrated evidence; state the remaining decisive verification step Source: §3.6 Choose gain from a feasible interval (p. 1257)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C03-DISCUSSION-001. A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. How should the team test that proposition?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. How should the team test that proposition?” Put this particular dispute to the panel: A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. How should the team test that proposition. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 02. Student A, terminology and scope: Agree the operational meanings of clean, narrow, proves and exposed, energy, proposition in “A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. How should the team test that proposition”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.24 Low-level event survival under analogue filtering (p. 1305)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. Low-level event survival under analogue filtering”. Identify the first vulnerable stage and the rejection preceding it Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.24 Low-level event survival under analogue filtering (p. 1305)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. Low-level event survival under analogue filtering”. Identify the first vulnerable stage and the rejection preceding it Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.24 Low-level event survival under analogue filtering (p. 1305)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask for the actual analog path and admitted spectrum before discussing the displayed trace Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.24 Low-level event survival under analogue filtering (p. 1305)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. Consider the possibility of a wideband converter or amplifier followed by a narrow display filter Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible

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instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.24 Low-level event survival under analogue filtering (p. 1305)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. Consider the possibility of a wideband converter or amplifier followed by a narrow display filter Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy and How should the team test that proposition; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy”, addressing “How should the team test that proposition”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. How should the team test that proposition”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A colleague argues that a clean narrow display proves the receiver has not been exposed to strong out-of-band energy. How should the team test that proposition”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an

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unsupported assertion. Source: §3.2 Find the first stage that can lose validity (p. 1249)

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V011-C03-DISCUSSION-002. Should a low-noise amplifier always precede the preselector? Discuss a quiet laboratory case and a strong-broadcast site using the same receiver.

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a low-noise amplifier always precede the preselector? Discuss a quiet laboratory case and a strong-broadcast site using the same receiver.” Put this particular dispute to the panel: Should a low-noise amplifier always precede the preselector? Discuss a quiet laboratory case and a strong-broadcast site using the same receiver. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 02. Student A, terminology and scope: Agree the operational meanings of amplifier, precede, preselector and quiet, laboratory, site in “Should a low-noise amplifier always precede the preselector? Discuss a quiet laboratory case and a strong-broadcast site using the same receiver”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a low-noise amplifier always precede the preselector; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 3.C6. Comparing attenuation ahead of and after an amplifier”. Require a desired-signal requirement and an internal blocker budget Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a low-noise amplifier always precede the preselector; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 3.C6. Comparing attenuation ahead of and after an amplifier”. Require a desired-signal requirement and an internal blocker budget Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare the preceding-loss noise penalty with the spectrum admitted to the amplifier in each order Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a low-noise amplifier always precede the preselector: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a low-noise amplifier always precede the preselector; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a low-noise amplifier

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always precede the preselector: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a low-noise amplifier always precede the preselector, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a low-noise amplifier always precede the preselector: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a low-noise amplifier always precede the preselector. The quiet case may favor early gain, while the strong-signal case can require rejection before that gain Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a low-noise amplifier always precede the preselector, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a low-noise amplifier always precede the preselector. The quiet case may favor early gain, while the strong-signal case can require rejection before that gain Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a low-noise amplifier always precede the preselector and Discuss a quiet laboratory case and a strong-broadcast site using the same receiver; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a low-noise amplifier always precede the preselector”, addressing “Discuss a quiet laboratory case and a strong-broadcast site using the same receiver”; specify

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the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a low-noise amplifier always precede the preselector? Discuss a quiet laboratory case and a strong-broadcast site using the same receiver”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a low-noise amplifier always precede the preselector? Discuss a quiet laboratory case and a strong-broadcast site using the same receiver.”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

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V011-C03-DISCUSSION-003. A team selects a preselector because it lowers the noise trace most. What other evidence should decide whether that state improves the intended observation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team selects a preselector because it lowers the noise trace most. What other evidence should decide whether that state improves the intended observation?” Put this particular dispute to the panel: A team selects a preselector because it lowers the noise trace most. What other evidence should decide whether that state improves the intended observation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 02. Student A, terminology and scope: Agree the operational meanings of selects, preselector, lowers and trace, improves, intended in “A team selects a preselector because it lowers the noise trace most. What other evidence should decide whether that state improves the intended observation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team selects a preselector because it lowers the noise trace most; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “An acceptance sequence that separates competing failures”. Compare retained amplitude, phase or modulation quality, noise, and strong-signal validity at a common plane Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team selects a preselector because it lowers the noise trace most; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.31 Intermodulation maps and the topology of false spectral components (p. 1322)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “An acceptance sequence that separates competing failures”. Compare retained amplitude, phase or modulation quality, noise, and strong-signal validity at a common plane Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require the desired waveform, occupied bandwidth, and success criterion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation

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would discriminate between them without changing the measurand. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A team selects a preselector because it lowers the noise trace most: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team selects a preselector because it lowers the noise trace most; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.31 Intermodulation maps and the topology of false spectral components (p. 1322)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team selects a preselector because it lowers the noise trace most: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team selects a preselector because it lowers the noise trace most, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team selects a preselector because it lowers the noise trace most:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team selects a preselector because it lowers the noise trace most. A lower trace can result from reduced gain or rejected desired energy Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.31 Intermodulation maps and the topology of false spectral components (p. 1322)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team selects a preselector because it lowers the noise trace most, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team selects a preselector because it lowers the noise trace most. A lower trace can result from reduced gain or rejected desired energy Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.31 Intermodulation maps and the topology of false spectral components (p. 1322)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team selects a preselector because it lowers the noise trace most and What other evidence should decide whether that state improves the intended observation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team selects a preselector because it lowers the noise trace most”, addressing “What other evidence

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should decide whether that state improves the intended observation"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A team selects a preselector because it lowers the noise trace most. What other evidence should decide whether that state improves the intended observation", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A team selects a preselector because it lowers the noise trace most. What other evidence should decide whether that state improves the intended observation". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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V011-C03-DISCUSSION-004. A single filter correction is proposed for every frequency in a sweep. Under what conditions could that simplification be defensible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A single filter correction is proposed for every frequency in a sweep. Under what conditions could that simplification be defensible?” Put this particular dispute to the panel: A single filter correction is proposed for every frequency in a sweep. Under what conditions could that simplification be defensible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.3 Preselection and Filter State (p. 1251)

- 02. Student A, terminology and scope: Agree the operational meanings of single, correction, proposed and sweep, conditions, defensible in “A single filter correction is proposed for every frequency in a sweep. Under what conditions could that simplification be defensible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.3 Preselection and Filter State (p. 1251)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A single filter correction is proposed for every frequency in a sweep; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Use preselection as a measured transfer function”. A flat approximation can be justified within a bounded tolerance; it is not established by one center-frequency measurement Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A single filter correction is

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proposed for every frequency in a sweep; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.33.4 Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration (p. 1334)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Use preselection as a measured transfer function”. A flat approximation can be justified within a bounded tolerance; it is not established by one center-frequency measurement Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Have participants identify the permitted amplitude error, measured passband variation, temperature and state range, and the spectrum of the desired signal Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.3 Preselection and Filter State (p. 1251)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A single filter correction is proposed for every frequency in a sweep: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.3 Preselection and Filter State (p. 1251)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A single filter correction is proposed for every frequency in a sweep; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.33.4 Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration (p. 1334)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A single filter correction is proposed for every frequency in a sweep: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.3 Preselection and Filter State (p. 1251)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A single filter correction is proposed for every frequency in a sweep, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A single filter correction is proposed for every frequency in a sweep: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.3 Preselection and Filter State (p. 1251)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A single filter correction is proposed for every frequency in a sweep. Filter skirts, switched boundaries, and notches require particular scrutiny Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.33.4 Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration (p. 1334)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A single filter correction is proposed for every frequency in a sweep, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A single filter correction is proposed for every frequency in a sweep. Filter skirts, switched boundaries, and notches require particular scrutiny Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.33.4 Case study 3.D4. Frequency-edge losses hidden by a centre-band calibration (p. 1334)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A single filter correction is proposed for every frequency in a sweep and Under what conditions could that simplification be defensible; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A single filter correction is proposed for every frequency in a sweep”, addressing “Under what conditions could that simplification be defensible”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the

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narrow agreement and the specific contested proposition that remains unresolved. Source: §3.3 Preselection and Filter State (p. 1251)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A single filter correction is proposed for every frequency in a sweep. Under what conditions could that simplification be defensible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A single filter correction is proposed for every frequency in a sweep. Under what conditions could that simplification be defensible”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.3 Preselection and Filter State (p. 1251)

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V011-C03-DISCUSSION-005. A corrected weak-signal level is unchanged after adding input attenuation. One reviewer says the two states therefore have equal sensitivity. How should the statement be revised?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A corrected weak-signal level is unchanged after adding input attenuation. One reviewer says the two states therefore have equal sensitivity. How should the statement be revised?” Put this particular dispute to the panel: A corrected weak-signal level is unchanged after adding input attenuation. One reviewer says the two states therefore have equal sensitivity. How should the statement be…. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 02. Student A, terminology and scope: Agree the operational meanings of unchanged, adding, reviewer and says, statement, revised in “A corrected weak-signal level is unchanged after adding input attenuation. One reviewer says the two states therefore have equal sensitivity. How should the statement be…”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A corrected weak-signal level is unchanged after adding input attenuation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. A graded laboratory qualification matrix”. Input loss can increase input-referred receiver noise even when the display compensates the desired amplitude exactly Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A corrected weak-signal level is unchanged after adding input attenuation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. A graded laboratory qualification matrix”. Input loss can increase input-referred receiver noise even when the display compensates the desired amplitude exactly Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish the valid common-plane signal estimate from the physical noise and detection capability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask

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which setting or observation would discriminate between them without changing the measurand. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A corrected weak-signal level is unchanged after adding input attenuation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A corrected weak-signal level is unchanged after adding input attenuation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A corrected weak-signal level is unchanged after adding input attenuation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A corrected weak-signal level is unchanged after adding input attenuation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A corrected weak-signal level is unchanged after adding input attenuation: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A corrected weak-signal level is unchanged after adding input attenuation. Request corresponding raw and corrected noise, bandwidth, detector condition, and linearity evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A corrected weak-signal level is unchanged after adding input attenuation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A corrected weak-signal level is unchanged after adding input attenuation. Request corresponding raw and corrected noise, bandwidth, detector condition, and linearity evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A corrected weak-signal level is unchanged after adding input attenuation and One reviewer says the two states therefore have equal sensitivity; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A corrected weak-signal level is unchanged after adding input attenuation”, addressing “One reviewer says the two states therefore have equal sensitivity”;

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specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A corrected weak-signal level is unchanged after adding input attenuation. One reviewer says the two states therefore have equal sensitivity. How should the statement be…”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A corrected weak-signal level is unchanged after adding input attenuation. One reviewer says the two states therefore have equal sensitivity. How should the statement be revised”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

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V011-C03-DISCUSSION-006. When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more filtering first?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more filtering first?” Put this particular dispute to the panel: When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more filtering first. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 02. Student A, terminology and scope: Agree the operational meanings of minimum, exceeds, maximum and noise, target, filtering in “When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more filtering first”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.6 Choose gain from a feasible interval (p. 1257)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Gain Distribution and Attenuation”. Discuss whether extra rejection occurs before the limiting stage and how its insertion loss changes the noise bound Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Gain Distribution and Attenuation”. Discuss whether extra rejection occurs before the limiting stage and how its insertion loss changes the noise bound Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The choice depends on the intended observation and the mechanisms behind the bounds Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 08. Student D, answer to Student E: Design a discriminating experiment involving When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…. Consider a lower-noise later stage or greater downstream range as alternatives Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty

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statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more.... Consider a lower-noise later stage or greater downstream range as alternatives Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more... and The choice depends on the intended observation and the mechanisms behind the bounds; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within

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authorised laboratory and field boundaries. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more…”, addressing “The choice depends on the intended observation and the mechanisms behind the bounds”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more filtering first”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When the noise-derived minimum gain exceeds the loading-derived maximum, should the team relax the noise target or add more filtering first”. Allocate the next measurement and documentary

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action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

Source: §3.6 Choose gain from a feasible interval (p. 1257)

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V011-C03-DISCUSSION-007. Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains stable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains stable?” Put this particular dispute to the panel: Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains stable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 02. Student A, terminology and scope: Agree the operational meanings of challenge, sufficient, prove and suspect, corrected, stable in “Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains stable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. Statistical validity of gain-state comparisons”. Ask which element was switched, where a possible artifact could originate, and whether the desired reference and gain state behaved as expected Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.35 Metrological qualification of system-level front-end conclusions (p. 1349)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. Statistical validity of gain-state comparisons”. Ask which element was switched, where a possible artifact could originate, and whether the desired reference and gain state behaved as expected Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Stable scaling is compatible with an external input under the tested conditions, but may also occur for internal behavior that scales similarly or is masked by correction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.35 Metrological qualification of system-level front-end conclusions (p. 1349)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is an attenuation challenge sufficient to prove that a suspect

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component is an external signal if its corrected level remains…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…. Combine amplitude scaling with frequency, source-path, and configuration controls appropriate to the hypothesis Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.35 Metrological qualification of system-level front-end conclusions (p. 1349)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what

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evidence would reverse the conclusion. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains.... Combine amplitude scaling with frequency, source-path, and configuration controls appropriate to the hypothesis Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.35 Metrological qualification of system-level front-end conclusions (p. 1349)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains... and Stable scaling is compatible with an external input under the tested conditions, but may also occur for...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains…”, addressing “Stable scaling is compatible with an external input under the tested conditions, but may also occur for…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains stable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Is an attenuation challenge sufficient to prove that a suspect component is an external signal if its corrected level remains stable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

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V011-C03-DISCUSSION-008. Should automatic gain control be disabled for every front-end measurement?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should automatic gain control be disabled for every front-end measurement?” Put this particular dispute to the panel: Should automatic gain control be disabled for every front-end measurement. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 02. Student A, terminology and scope: Agree the operational meanings of automatic, gain, control and disabled, every, front-end in “Should automatic gain control be disabled for every front-end measurement”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether automatic gain control be disabled for every front-end measurement; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. Protective switching, recovery and transient exclusion intervals”. Disabling control can simplify the first question, while the second may require measuring its real response Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether automatic gain control be disabled for every front-end measurement; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. Protective switching, recovery and transient exclusion intervals”. Disabling control can simplify the first question, while the second may require measuring its real response Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish characterization of a fixed component transfer from evaluation of the operational closed-loop receiver Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether automatic gain control be disabled for every front-end measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether automatic gain control be disabled for every front-end measurement; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether automatic gain control be disabled for every front-end measurement: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether automatic gain control be disabled for every front-end measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether automatic gain control be disabled for every front-end measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether automatic gain control be disabled for every front-end measurement. In either case, retain the state and timing and label the quantity correctly Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether automatic gain control be disabled for every front-end measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether automatic gain control be disabled for every front-end measurement. In either case, retain the state and timing and label the quantity correctly Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether automatic gain control be disabled for every front-end measurement and Distinguish characterization of a fixed component transfer from evaluation of the operational closed-loop…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether automatic gain control be disabled for every front-end measurement”, addressing “Distinguish characterization of a fixed component transfer from evaluation of

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the operational closed-loop…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should automatic gain control be disabled for every front-end measurement”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should automatic gain control be disabled for every front-end measurement”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

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V011-C03-DISCUSSION-009. A digitized trace becomes smoother after software scaling and averaging. What evidence would establish that analog gain was actually improved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A digitized trace becomes smoother after software scaling and averaging. What evidence would establish that analog gain was actually improved?” Put this particular dispute to the panel: A digitized trace becomes smoother after software scaling and averaging. What evidence would establish that analog gain was actually improved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 02. Student A, terminology and scope: Agree the operational meanings of digitized, trace, scaling and averaging, analog, actually in “A digitized trace becomes smoother after software scaling and averaging. What evidence would establish that analog gain was actually improved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A digitized trace becomes smoother after software scaling and averaging; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D3. The misleading improvement from additional preamplifier gain”. Software scaling changes units and averaging changes estimator behavior; neither alone changes analog SNR or reverses clipping Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A digitized trace becomes smoother after software scaling and averaging; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D3. The misleading improvement from additional preamplifier gain”. Software scaling changes units and averaging changes estimator behavior; neither alone changes analog SNR or reverses clipping Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask for native samples, analog gain states, converter range use, and corresponding input-referred converter contribution Put two

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specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A digitized trace becomes smoother after software scaling and averaging: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A digitized trace becomes smoother after software scaling and averaging; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A digitized trace becomes smoother after software scaling and averaging: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A digitized trace becomes smoother after software scaling and averaging, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving A digitized trace becomes smoother after software scaling and averaging: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A digitized trace becomes smoother after software scaling and averaging. A useful comparison holds the waveform and processing definition fixed while assessing the physical analog state and its valid range Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A digitized trace becomes smoother after software scaling and averaging, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample

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coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A digitized trace becomes smoother after software scaling and averaging. A useful comparison holds the waveform and processing definition fixed while assessing the physical analog state and its valid range Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A digitized trace becomes smoother after software scaling and averaging and What evidence would establish that analog gain was actually improved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A digitized trace becomes smoother after software scaling and averaging”, addressing “What evidence would establish that analog gain was actually improved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A digitized trace becomes smoother after software scaling and averaging. What evidence would establish that analog gain was actually improved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A digitized trace becomes smoother after software scaling and averaging. What evidence would establish that analog gain was actually improved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

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V011-C03-DISCUSSION-010. An installed limiter has survived every field event so far. Is it reasonable to omit it from the noise and amplitude correction model?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An installed limiter has survived every field event so far. Is it reasonable to omit it from the noise and amplitude correction model?” Put this particular dispute to the panel: An installed limiter has survived every field event so far. Is it reasonable to omit it from the noise and amplitude correction model. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 02. Student A, terminology and scope: Agree the operational meanings of installed, limiter, survived and field, event, omit in “An installed limiter has survived every field event so far. Is it reasonable to omit it from the noise and amplitude correction model”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An installed limiter has survived every field event so far; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.7 Input Protection and Recovery (p. 1260)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Input Protection and Recovery”. Ask what measured small-signal response is available and whether it varies with frequency, temperature, or prior events Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.7 Input Protection and Recovery (p. 1260)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An installed limiter has

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survived every field event so far; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Input Protection and Recovery”. Ask what measured small-signal response is available and whether it varies with frequency, temperature, or prior events Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.7 Input Protection and Recovery (p. 1260)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Survival history concerns one aspect of protection, while ordinary insertion loss, return loss, and reactive loading remain in the signal path Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An installed limiter has survived every field event so far: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An installed limiter has survived every field event so far; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An installed limiter has survived every field event so far: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings,

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controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An installed limiter has survived every field event so far, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.7 Input Protection and Recovery (p. 1260)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An installed limiter has survived every field event so far: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An installed limiter has survived every field event so far. A negligible contribution can be justified within the measurement uncertainty, but it should not be inferred solely from lack of damage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An installed limiter has survived every field event so far, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.7 Input Protection and Recovery (p. 1260)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An installed limiter has survived every field event so far. A negligible contribution can be justified within the measurement uncertainty, but it should not be inferred solely from lack of damage Respond point by point to Student J. Distinguish a

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verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.9 Front-End Characterization and Field Decisions (p. 1265)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An installed limiter has survived every field event so far and Is it reasonable to omit it from the noise and amplitude correction model; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.3 Preselection and Filter State (p. 1251)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An installed limiter has survived every field event so far”, addressing “Is it reasonable to omit it from the noise and amplitude correction model”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An installed limiter has survived every field event so far. Is it reasonable to omit it from the noise and amplitude correction model”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An installed limiter has survived every field event so far. Is it reasonable to omit it from the noise and amplitude correction model”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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V011-C03-DISCUSSION-011. Two teams quote different recovery times for the same receiver. One uses amplitude tolerance and the other uses baseline variance. Must one be wrong?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two teams quote different recovery times for the same receiver. One uses amplitude tolerance and the other uses baseline variance. Must one be wrong?” Put this particular dispute to the panel: Two teams quote different recovery times for the same receiver. One uses amplitude tolerance and the other uses baseline variance. Must one be wrong. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 02. Student A, terminology and scope: Agree the operational meanings of recovery, times, tolerance and baseline, variance, wrong in “Two teams quote different recovery times for the same receiver. One uses amplitude tolerance and the other uses baseline variance. Must one be wrong”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two teams quote different recovery times for the same receiver; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D5. A gain-control transition that resembles transmitter fading”. Reconcile the event waveform, time origin, state, detector response, tolerance, and persistence rule before comparing numbers Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two teams quote different recovery times for the same receiver; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D5. A gain-control transition that resembles transmitter fading”. Reconcile the event waveform, time origin, state, detector response, tolerance, and persistence rule before comparing numbers Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. They may be reporting different observables Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two teams quote different recovery times for the same receiver: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two teams quote different recovery times for the same receiver; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two teams quote different recovery times for the same receiver: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two teams quote different recovery times for the same receiver, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two teams quote different recovery times for the same receiver:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two teams quote different recovery times for the same receiver. A receiver can meet amplitude tolerance while still having excessive variance or phase error Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two teams quote different recovery times for the same receiver, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two teams quote different recovery times for the same receiver. A receiver can meet amplitude tolerance while still having excessive variance or phase error Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two teams quote different recovery times for the same receiver and One uses amplitude tolerance and the other uses baseline variance; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two teams quote different recovery times

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for the same receiver", addressing "One uses amplitude tolerance and the other uses baseline variance"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Two teams quote different recovery times for the same receiver. One uses amplitude tolerance and the other uses baseline variance. Must one be wrong", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Two teams quote different recovery times for the same receiver. One uses amplitude tolerance and the other uses baseline variance. Must one be wrong". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

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V011-C03-DISCUSSION-012. How should a team respond when a post-event trace looks normal but the event itself was not recorded?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a team respond when a post-event trace looks normal but the event itself was not recorded?” Put this particular dispute to the panel: How should a team respond when a post-event trace looks normal but the event itself was not recorded. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 02. Student A, terminology and scope: Agree the operational meanings of respond, post-event, trace and looks, event, recorded in “How should a team respond when a post-event trace looks normal but the event itself was not recorded”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a team respond when a post-event trace looks normal but the event itself was not recorded; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D1. Intermittent high-power illumination and a false absence claim”. Discuss what contemporaneous state, overload, timing, or reference evidence exists and which intervals can still support the intended result Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of how should a team respond when a post-event trace looks normal but the event itself was not recorded; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D1. Intermittent high-power illumination and a false absence claim”. Discuss what contemporaneous state, overload, timing, or reference evidence exists and which intervals can still support the intended result Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A normal later state supports the observed functions at that time; it does not establish event leakage, temporary desensitization, or the duration of unusable intervals Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a team respond when a post-event trace looks normal but the event itself was not recorded: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team respond when a post-event trace looks normal but the event itself was not recorded; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a team respond when a post-event trace looks normal but the event itself was not recorded: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a team respond when a post-event trace looks normal but the event itself was not recorded, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving how should a team respond when a post-event trace looks normal but the event itself was not recorded: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a team respond when a post-event trace looks normal but the event itself was not recorded. Future characterization should retain the event and weak reference through recovery Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a team respond when a post-event trace looks normal but the event itself was not recorded, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual

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receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a team respond when a post-event trace looks normal but the event itself was not recorded. Future characterization should retain the event and weak reference through recovery Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a team respond when a post-event trace looks normal but the event itself was not recorded and A normal later state supports the observed functions at that time; it does not establish event leakage,...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and

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field boundaries. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a team respond when a post-event trace looks normal but the event itself was not recorded”, addressing “A normal later state supports the observed functions at that time; it does not establish event leakage,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a team respond when a post-event trace looks normal but the event itself was not recorded”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a team respond when a post-event trace looks normal but the event itself was not recorded”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence

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from an unsupported assertion. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

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V011-C03-DISCUSSION-013. A proposed pulse test has low mean power but high peak power. Which quantities should govern whether its results are applicable to an operating environment?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A proposed pulse test has low mean power but high peak power. Which quantities should govern whether its results are applicable to an operating environment?” Put this particular dispute to the panel: A proposed pulse test has low mean power but high peak power. Which quantities should govern whether its results are applicable to an operating environment. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.7 Input Protection and Recovery (p. 1260)

- 02. Student A, terminology and scope: Agree the operational meanings of proposed, quantities, govern and applicable, operating, environment in “A proposed pulse test has low mean power but high peak power. Which quantities should govern whether its results are applicable to an operating environment”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §3.7 Input Protection and Recovery (p. 1260)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A proposed pulse test has low mean power but high peak power; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D1. Intermittent high-power illumination and a false absence claim”. Compare them with the conditional instrument and accessory limits and with the measurement’s required recovery interval Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A proposed pulse test has low mean power but high peak power; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D1. Intermittent high-power illumination and a false absence claim”. Compare them with the conditional instrument and accessory limits and with the measurement’s required recovery interval Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require the actual peak, duration, repetition, waveform, frequency, coupling, and source/load conditions Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.7 Input Protection and Recovery (p. 1260)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A proposed pulse test has low mean power but high peak power: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.7 Input Protection and Recovery (p. 1260)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A proposed pulse test has low mean power but high peak power; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.2 Find the first stage that can lose validity (p. 1249)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A proposed pulse test has low mean power but high peak power: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.7 Input Protection and Recovery (p. 1260)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A proposed pulse test has low mean power but high peak power, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A proposed pulse test has low mean power but high peak power: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.7 Input Protection and Recovery (p. 1260)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A proposed pulse test has low mean power but high peak power. Low average power does not remove peak stress or leading-edge leakage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A proposed pulse test has low mean power but high peak power, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A proposed pulse test has low mean power but high peak power. Low average power does not remove peak stress or leading-edge leakage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A proposed pulse test has low mean power but high peak power and Which quantities should govern whether its results are applicable to an operating environment; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.24 Low-level event survival under analogue filtering (p. 1305)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A proposed pulse test has low mean power but high peak power”, addressing “Which quantities should govern whether its results are applicable to an operating environment”; specify the exact measurement or evidential gap on

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which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.7 Input Protection and Recovery (p. 1260)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A proposed pulse test has low mean power but high peak power. Which quantities should govern whether its results are applicable to an operating environment”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A proposed pulse test has low mean power but high peak power. Which quantities should govern whether its results are applicable to an operating environment”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.7 Input Protection and Recovery (p. 1260)

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V011-C03-DISCUSSION-014. A limiter-bypass comparison shortens recovery. What additional evidence is needed before publishing the difference as the limiter's recovery time?

- 01. Moderator, opening proposition: Introduce the exact dispute, "A limiter-bypass comparison shortens recovery. What additional evidence is needed before publishing the difference as the limiter's recovery time?" Put this particular dispute to the panel: A limiter-bypass comparison shortens recovery. What additional evidence is needed before publishing the difference as the limiter's recovery time. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 02. Student A, terminology and scope: Agree the operational meanings of shortens, recovery, additional and difference, limiter, time in "A limiter-bypass comparison shortens recovery. What additional evidence is needed before publishing the difference as the limiter's recovery time"; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A limiter-bypass comparison shortens recovery; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. Protective switching, recovery and transient exclusion intervals”. Compare applied event levels, downstream gain, matching, processing, and detector variability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A limiter-bypass comparison shortens recovery; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.7 Input Protection and Recovery (p. 1260)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. Protective switching, recovery and transient exclusion intervals”. Compare applied event levels, downstream gain, matching, processing, and detector variability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Establish that the permitted bypass changed only the claimed subsystem in a meaningful way and that the remaining path stayed within ratings Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A limiter-bypass comparison shortens recovery: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A limiter-bypass comparison shortens recovery; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.7 Input Protection and Recovery (p. 1260)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A limiter-bypass comparison

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shortens recovery: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A limiter-bypass comparison shortens recovery, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A limiter-bypass comparison shortens recovery: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A limiter-bypass comparison shortens recovery. The difference can include interactions with amplifier bias or gain control Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.7 Input Protection and Recovery (p. 1260)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A limiter-bypass comparison shortens recovery, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.18 Protective switching, recovery and transient exclusion intervals (p. 1281)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A limiter-bypass comparison shortens recovery.

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The difference can include interactions with amplifier bias or gain control Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.7 Input Protection and Recovery (p. 1260)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A limiter-bypass comparison shortens recovery and What additional evidence is needed before publishing the difference as the limiter's recovery time; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about "A limiter-bypass comparison shortens recovery", addressing "What additional evidence is needed before publishing the difference as the limiter's recovery time"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the

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narrow agreement and the specific contested proposition that remains unresolved. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A limiter-bypass comparison shortens recovery. What additional evidence is needed before publishing the difference as the limiter’s recovery time”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A limiter-bypass comparison shortens recovery. What additional evidence is needed before publishing the difference as the limiter’s recovery time”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

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V011-C03-DISCUSSION-015. A new intermodulation line appears only when two sources are connected through a combiner. Which part of the setup should be investigated first?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A new intermodulation line appears only when two sources are connected through a combiner. Which part of the setup should be investigated first?” Put this particular dispute to the panel: A new intermodulation line appears only when two sources are connected through a combiner. Which part of the setup should be investigated first. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 02. Student A, terminology and scope: Agree the operational meanings of line, appears, sources and combiner, setup, investigated in “A new intermodulation line appears only when two sources are connected through a combiner. Which part of the setup should be investigated first”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A new intermodulation line appears only when two sources are connected through a combiner; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D6. A cable movement that changes the apparent noise floor”. Discuss isolation, linearity, source harmonics, phase noise, and the floor of the independent input-plane observation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A new intermodulation line appears only when two sources are connected through a combiner; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D6. A cable movement that changes the apparent noise floor”. Discuss isolation, linearity, source harmonics, phase noise, and the floor of the independent input-plane observation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Begin with the applied source and combining path because contamination there can enter the receiver as an ordinary signal Put two specific

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questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A new intermodulation line appears only when two sources are connected through a combiner: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A new intermodulation line appears only when two sources are connected through a combiner; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.11 Verification and Maintenance Controls (p. 1268)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A new intermodulation line appears only when two sources are connected through a combiner: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A new intermodulation line appears only when two sources are connected through a combiner, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving A new intermodulation line appears only when two sources are connected through a combiner: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A new intermodulation line appears only when two sources are connected through a combiner. Then use controlled receiver-state changes to locate any additional generation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A new intermodulation line appears only when two sources are connected through a combiner, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A new intermodulation line appears only when two sources are connected through a combiner. Then use controlled receiver-state changes to locate any additional generation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A new intermodulation line appears only when two sources are connected through a combiner and Which part of the setup should be investigated first; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency (p. 1330)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A new intermodulation line appears only when two sources are connected through a combiner”, addressing “Which part of the setup should be investigated first”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A new intermodulation line appears only when two sources are connected through a combiner. Which part of the setup should be investigated first”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A new intermodulation line appears only when two sources are connected through a combiner. Which part of the setup should be investigated first”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

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V011-C03-DISCUSSION-016. How can a team compare two preselector states fairly when they also change effective measurement bandwidth?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How can a team compare two preselector states fairly when they also change effective measurement bandwidth?” Put this particular dispute to the panel: How can a team compare two preselector states fairly when they also change effective measurement bandwidth. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 02. Student A, terminology and scope: Agree the operational meanings of preselector, states, fairly and they, effective, bandwidth in “How can a team compare two preselector states fairly when they also change effective measurement bandwidth”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how can a team compare two preselector states fairly when they also change effective measurement bandwidth; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Use preselection as a measured transfer function”. Use matched processing bandwidth where feasible or a justified model that accounts for noise integration and desired-signal retention Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how can a team compare two preselector states fairly when they also change effective

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measurement bandwidth; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Use preselection as a measured transfer function”. Use matched processing bandwidth where feasible or a justified model that accounts for noise integration and desired-signal retention Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify which bandwidth is physical admission and which belongs to later processing Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how can a team compare two preselector states fairly when they also change effective measurement bandwidth: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how can a team compare two preselector states fairly when they also change effective measurement bandwidth; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how can a team compare two preselector states fairly when they also change effective

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measurement bandwidth: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how can a team compare two preselector states fairly when they also change effective measurement bandwidth, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how can a team compare two preselector states fairly when they also change effective measurement bandwidth: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how can a team compare two preselector states fairly when they also change effective measurement bandwidth. Preserve each state's gain and calibration Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how can a team compare two preselector states fairly when they also change effective measurement bandwidth, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how can a team compare two preselector states fairly when they also change effective measurement bandwidth. Preserve each state's gain and calibration Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how can a team compare two preselector states fairly when they also change effective measurement bandwidth and Identify which bandwidth is physical admission and which belongs to later processing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about "how can a team compare two preselector states fairly when they also change effective measurement

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bandwidth", addressing "Identify which bandwidth is physical admission and which belongs to later processing"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "How can a team compare two preselector states fairly when they also change effective measurement bandwidth", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "How can a team compare two preselector states fairly when they also change effective measurement bandwidth". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

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V011-C03-DISCUSSION-017. Is an inconclusive attenuation challenge a failed measurement or a useful result?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is an inconclusive attenuation challenge a failed measurement or a useful result?” Put this particular dispute to the panel: Is an inconclusive attenuation challenge a failed measurement or a useful result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 02. Student A, terminology and scope: Agree the operational meanings of inconclusive, attenuation, challenge and failed, useful, measurement in “Is an inconclusive attenuation challenge a failed measurement or a useful result”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is an inconclusive attenuation challenge a failed measurement or a useful result; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D6. A cable movement that changes the apparent noise floor”. Examples include both lines falling below the floor, unrecorded gain changes, or source contamination that cannot be bounded Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is an inconclusive attenuation

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challenge a failed measurement or a useful result; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D6. A cable movement that changes the apparent noise floor”. Examples include both lines falling below the floor, unrecorded gain changes, or source contamination that cannot be bounded Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It can be a useful bounded result if the reason for nondiscrimination is retained Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Is an inconclusive attenuation challenge a failed measurement or a useful result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is an inconclusive attenuation challenge a failed measurement or a useful result; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is an inconclusive attenuation challenge a failed measurement or a useful result: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is an inconclusive attenuation challenge a failed measurement or a useful result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is an inconclusive attenuation challenge a failed measurement or a useful result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is an inconclusive attenuation challenge a failed measurement or a useful result. Ask what follow-up would separate the remaining mechanisms and whether the existing record still supports a narrower claim Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is an inconclusive attenuation challenge a failed measurement or a useful result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is an inconclusive attenuation challenge a failed measurement or a useful result. Ask what follow-up would separate the remaining mechanisms and whether the existing record still supports a narrower claim Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is an inconclusive attenuation challenge a failed measurement or a useful result and It can be a useful bounded result if the reason for nondiscrimination is retained; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is an inconclusive attenuation challenge a failed measurement or a useful result”, addressing “It can be a useful bounded result if the reason for nondiscrimination is

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retained"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Is an inconclusive attenuation challenge a failed measurement or a useful result", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Is an inconclusive attenuation challenge a failed measurement or a useful result". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

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V011-C03-DISCUSSION-018. A source manual describes an optional amplifier ahead of preselection. How should that fact be used in a general textbook without implying every receiver shares the architecture?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A source manual describes an optional amplifier ahead of preselection. How should that fact be used in a general textbook without implying every receiver shares the architecture?” Put this particular dispute to the panel: A source manual describes an optional amplifier ahead of preselection. How should that fact be used in a general textbook without implying every receiver shares the…. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 02. Student A, terminology and scope: Agree the operational meanings of manual, optional, ahead and fact, general, textbook in “A source manual describes an optional amplifier ahead of preselection. How should that fact be used in a general textbook without implying every receiver shares the…”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A source manual describes an optional amplifier ahead of preselection; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 3.C6. Comparing attenuation ahead of and after an amplifier”. Use the example to illustrate why component order matters, then state the general reasoning separately Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A source manual describes an optional amplifier ahead of preselection; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.17 Noise, mismatch and gain-order dependencies (p. 1279)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 3.C6. Comparing attenuation ahead of and after an amplifier”. Use the example to illustrate why component order matters, then state the general reasoning separately Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain the manufacturer, model, option, manual edition, and applicable firmware context Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask

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which setting or observation would discriminate between them without changing the measurand. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A source manual describes an optional amplifier ahead of preselection: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A source manual describes an optional amplifier ahead of preselection; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.17 Noise, mismatch and gain-order dependencies (p. 1279)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A source manual describes an optional amplifier ahead of preselection: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A source manual describes an optional amplifier ahead of preselection, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A source manual describes an optional amplifier ahead of

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preselection: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A source manual describes an optional amplifier ahead of preselection. The same indicator name can correspond to different physical paths Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.17 Noise, mismatch and gain-order dependencies (p. 1279)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A source manual describes an optional amplifier ahead of preselection, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.19.6 Example 3.C6. Comparing attenuation ahead of and after an amplifier (p. 1289)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A source manual describes an optional amplifier ahead of preselection. The same indicator name can correspond to different physical paths Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.17 Noise, mismatch and gain-order dependencies (p. 1279)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A source manual describes an optional amplifier ahead of preselection and How should that fact be used in a general textbook without implying every receiver shares the…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A source manual describes an optional amplifier ahead of preselection”, addressing “How should that fact

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be used in a general textbook without implying every receiver shares the…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A source manual describes an optional amplifier ahead of preselection. How should that fact be used in a general textbook without implying every receiver shares the…", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A source manual describes an optional amplifier ahead of preselection. How should that fact be used in a general textbook without implying every receiver shares the architecture". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.2 Find the first stage that can lose validity (p. 1249)

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V011-C03-DISCUSSION-019. Should a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance?

- 01. Moderator, opening proposition: Introduce the exact dispute, "Should a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance?" Put this particular dispute to the panel: Should a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 02. Student A, terminology and scope: Agree the operational meanings of absolute, maximum, rating and appear, table, guaranteed in "Should a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance"; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in "Measure protection in the small-signal and recovery states". Stress ratings do not certify gain accuracy, noise, distortion, or recovery at the boundary Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in "Measure protection in the small-signal and recovery states". Stress ratings do not certify gain accuracy, noise, distortion, or recovery at the boundary Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It may appear if the quantities are clearly separated and their purposes and conditions are explicit Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance. Discuss how assembly limits and accessory constraints can be more restrictive Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a component's absolute maximum rating appear in the same acceptance table as guaranteed

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measurement performance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance. Discuss how assembly limits and accessory constraints can be more restrictive Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a component's absolute maximum rating appear in the same acceptance table as guaranteed measurement performance and It may appear if the quantities are clearly separated and their purposes and conditions are explicit;

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exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a component’s absolute maximum rating appear in the same acceptance table as guaranteed measurement performance”, addressing “It may appear if the quantities are clearly separated and their purposes and conditions are explicit”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a component’s absolute maximum rating appear in the same acceptance table as guaranteed measurement performance”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a

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component’s absolute maximum rating appear in the same acceptance table as guaranteed measurement performance”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.16 Frequency-selective headroom and the failure of scalar 'maximum input' ratings (p. 1276)

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V011-C03-DISCUSSION-020. A maintenance technician replaces a cable with the same model and length. What evidence would justify retaining the prior correction unchanged?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A maintenance technician replaces a cable with the same model and length. What evidence would justify retaining the prior correction unchanged?” Put this particular dispute to the panel: A maintenance technician replaces a cable with the same model and length. What evidence would justify retaining the prior correction unchanged. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 02. Student A, terminology and scope: Agree the operational meanings of maintenance, replaces, length and retaining, prior, unchanged in “A maintenance technician replaces a cable with the same model and length. What evidence would justify retaining the prior correction unchanged”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.11 Verification and Maintenance Controls (p. 1268)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A maintenance technician replaces a cable with the same model and length; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D9. Weak-event detection after a digital-filter change”. Compare the serialized replacement’s applicable response, connection conditions, frequency range, and uncertainty against the prior correction Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A maintenance technician replaces a cable with the same model and length; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D9. Weak-event detection after a digital-filter change”. Compare the serialized replacement’s applicable response, connection conditions, frequency range, and uncertainty against the prior correction Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The model label and nominal length provide context but do not establish identical installed loss and mismatch Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A maintenance technician replaces a cable with the same model and length: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A maintenance technician replaces a cable with the same model and length; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A maintenance technician replaces a cable with the same model and length: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A maintenance technician replaces a cable with the same model and length, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A maintenance technician replaces a cable with the same model and

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length: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A maintenance technician replaces a cable with the same model and length. A difference small relative to the required tolerance may justify retention with documented evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A maintenance technician replaces a cable with the same model and length, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A maintenance technician replaces a cable with the same model and length. A difference small relative to the required tolerance may justify retention with documented evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A maintenance technician replaces a cable with the same model and length and What evidence would justify retaining the prior correction unchanged; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.17 Noise, mismatch and gain-order dependencies (p. 1279)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A maintenance technician replaces a cable with the same model and length”, addressing “What evidence would

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justify retaining the prior correction unchanged"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A maintenance technician replaces a cable with the same model and length. What evidence would justify retaining the prior correction unchanged", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A maintenance technician replaces a cable with the same model and length. What evidence would justify retaining the prior correction unchanged". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.11 Verification and Maintenance Controls (p. 1268)

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V011-C03-DISCUSSION-021. A weak component vanishes after changing antenna polarization. How should the team distinguish operational interference reduction from an attribution claim?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A weak component vanishes after changing antenna polarization. How should the team distinguish operational interference reduction from an attribution claim?” Put this particular dispute to the panel: A weak component vanishes after changing antenna polarization. How should the team distinguish operational interference reduction from an attribution claim. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 02. Student A, terminology and scope: Agree the operational meanings of vanishes, polarization, interference and reduction, attribution, claim in “A weak component vanishes after changing antenna polarization. How should the team distinguish operational interference reduction from an attribution claim”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A weak component vanishes after changing antenna polarization; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D6. A cable movement that changes the apparent noise floor”. Retain geometry, timing, desired-reference capability, and receiver state Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A weak component vanishes after changing antenna polarization; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D6. A cable movement that changes the apparent noise floor”. Retain geometry, timing, desired-reference capability, and receiver state Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Polarization changes coupling for desired and unwanted fields and can also alter multipath Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which

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setting or observation would discriminate between them without changing the measurand. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A weak component vanishes after changing antenna polarization: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A weak component vanishes after changing antenna polarization; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A weak component vanishes after changing antenna polarization: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A weak component vanishes after changing antenna polarization, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A weak component vanishes after changing antenna polarization:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A weak component vanishes after changing antenna polarization. The change may improve a practical observation while leaving the component's origin unresolved Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A weak component vanishes after changing antenna polarization, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.6 Case study 3.D6. A cable movement that changes the apparent noise floor (p. 1338)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A weak component vanishes after changing antenna polarization. The change may improve a practical observation while leaving the component's origin unresolved Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A weak component vanishes after changing antenna polarization and How should the team distinguish operational interference reduction from an attribution claim; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about "A weak component vanishes after changing antenna polarization", addressing "How should the team

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distinguish operational interference reduction from an attribution claim”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A weak component vanishes after changing antenna polarization. How should the team distinguish operational interference reduction from an attribution claim”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A weak component vanishes after changing antenna polarization. How should the team distinguish operational interference reduction from an attribution claim”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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V011-C03-DISCUSSION-022. Would you accept a front-end release statement that says only all tests passed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Would you accept a front-end release statement that says only all tests passed?” Put this particular dispute to the panel: Would you accept a front-end release statement that says only all tests passed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 02. Student A, terminology and scope: Agree the operational meanings of accept, release, statement and says, tests, passed in “Would you accept a front-end release statement that says only all tests passed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Would

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you accept a front-end release statement that says only all tests passed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.10 Case study 3.D10. A bounded negative survey statement and its necessary controls (p. 1346)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D10. A bounded negative survey statement and its necessary controls”. A concise pass statement can summarize a referenced bounded record, but cannot replace it Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.10 Case study 3.D10. A bounded negative survey statement and its necessary controls (p. 1346)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Would you accept a front-end release statement that says only all tests passed; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D10. A bounded negative survey statement and its necessary controls”. A concise pass statement can summarize a referenced bounded record, but cannot replace it Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.10 Case study 3.D10. A bounded negative survey statement and its necessary controls (p. 1346)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require the actual configuration, applicable frequencies and levels, waveform and timing conditions, observables, tolerances, uncertainty, and identified limitations Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.11 Verification and Maintenance Controls (p. 1268)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Would you accept a front-end release statement that says only all tests passed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Would you accept a front-end release statement that says only all tests passed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Would you accept a front-end release statement that says only all tests passed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Would you accept a front-end release statement that says only all tests passed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.10 Case study 3.D10. A bounded negative survey statement and its necessary controls (p. 1346)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Would you accept a front-end release statement that says only all tests passed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.11 Verification and Maintenance Controls (p. 1268)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Would you accept a front-end release statement that says only all tests passed. Ask whether protection, recovery, and source-path controls were included when relevant Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Would you accept a front-end release statement that says only all tests passed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.10 Case study 3.D10. A bounded negative survey statement and its necessary controls (p. 1346)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Would you accept a front-end release statement that says only all tests passed. Ask whether protection, recovery,

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and source-path controls were included when relevant Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.26 A graded laboratory qualification matrix (p. 1309)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Would you accept a front-end release statement that says only all tests passed and Require the actual configuration, applicable frequencies and levels, waveform and timing conditions,…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Would you accept a front-end release statement that says only all tests passed”, addressing “Require the actual configuration, applicable frequencies and levels, waveform and timing conditions,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another

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speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.11 Verification and Maintenance Controls (p. 1268)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Would you accept a front-end release statement that says only all tests passed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Would you accept a front-end release statement that says only all tests passed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.11 Verification and Maintenance Controls (p. 1268)

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V011-C03-DISCUSSION-023. A team wants to retain only input-corrected results because they are easier to compare. What interpretive capability would be lost?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team wants to retain only input-corrected results because they are easier to compare. What interpretive capability would be lost?” Put this particular dispute to the panel: A team wants to retain only input-corrected results because they are easier to compare. What interpretive capability would be lost. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 02. Student A, terminology and scope: Agree the operational meanings of wants, retain, results and interpretive, capability, lost in “A team wants to retain only input-corrected results because they are easier to compare. What interpretive capability would be lost”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team wants to retain only input-corrected results because they are easier to compare; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “An acceptance sequence that separates competing failures”. Corrected values can conceal a changed attenuator state or a normalization error if the underlying data and state are absent Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A team wants to retain only input-corrected results because they are easier to compare; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “An acceptance sequence that separates competing failures”. Corrected values can conceal a changed attenuator state or a normalization error if the underlying data and state are absent Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Raw output reveals actual range use, gain changes, and noise behavior before correction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A team wants to retain only input-corrected results because they are easier to compare: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team wants to retain only input-corrected results because they are easier to compare; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team wants to retain only input-corrected results because they are easier to compare: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team wants to retain only input-corrected results because they are easier to compare, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team wants to retain only input-corrected results because they are

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easier to compare: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team wants to retain only input-corrected results because they are easier to compare. Retaining both allows an independent reviewer to reconstruct the transformation and assess validity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team wants to retain only input-corrected results because they are easier to compare, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §3.10 An acceptance sequence that separates competing failures (p. 1266)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team wants to retain only input-corrected results because they are easier to compare. Retaining both allows an independent reviewer to reconstruct the transformation and assess validity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.38 Independent challenge of recovered input-referred amplitude (p. 1357)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team wants to retain only input-corrected results because they are easier to compare and What interpretive capability would be lost; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.17 Noise, mismatch and gain-order dependencies (p. 1279)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team wants to retain only input-corrected results because they are easier to compare”, addressing “What interpretive capability would be lost”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team wants to retain only input-corrected results because they are easier to compare. What interpretive capability would be lost”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team wants to retain only input-corrected results because they are easier to compare. What interpretive capability would be lost”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

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V011-C03-DISCUSSION-024. Can a successful closing reference ever support a conclusion about earlier acquisition?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a successful closing reference ever support a conclusion about earlier acquisition?” Put this particular dispute to the panel: Can a successful closing reference ever support a conclusion about earlier acquisition. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

- 02. Student A, terminology and scope: Agree the operational meanings of successful, closing, support and conclusion, earlier, acquisition in “Can a successful closing reference ever support a conclusion about earlier acquisition”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a successful closing reference ever support a conclusion about earlier acquisition; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. Evidence interpretation when the reference chain fails”. Its direct observation remains time- and function-bounded Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a successful closing reference ever support a conclusion about earlier acquisition;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.37 A research agenda for independent replication (p. 1355)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. Evidence interpretation when the reference chain fails”. Its direct observation remains time- and function-bounded Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It can contribute to a broader argument together with contemporaneous state records, bracketing, known failure behavior, and relevant monitoring Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a successful closing reference ever support a conclusion about earlier acquisition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a successful closing reference ever support a conclusion about earlier acquisition; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.37 A research agenda for independent replication (p. 1355)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a successful closing reference ever support a conclusion about earlier acquisition: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a successful closing reference ever support a conclusion about earlier acquisition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a successful closing reference ever support a conclusion about earlier acquisition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a successful closing reference ever support a conclusion about earlier acquisition. Require the team to state which inference connects the later check to the earlier interval and what evidence supports that inference Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.37 A research agenda for independent replication (p. 1355)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a successful closing reference ever support a conclusion about earlier acquisition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a successful closing reference ever support a conclusion about earlier acquisition. Require the team to state which inference connects the later check to the earlier interval and what evidence supports that inference Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.37 A research agenda for independent replication (p. 1355)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a successful closing reference ever support a conclusion about earlier acquisition and It can contribute to a broader argument together with contemporaneous state records, bracketing, known…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a successful closing reference ever

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support a conclusion about earlier acquisition", addressing "It can contribute to a broader argument together with contemporaneous state records, bracketing, known…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Can a successful closing reference ever support a conclusion about earlier acquisition", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Can a successful closing reference ever support a conclusion about earlier acquisition". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.36 Release-gate checklist for a qualified receiver input chain (p. 1352)

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V011-C03-DISCUSSION-025. Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most reproducible operational result?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most reproducible operational result?” Put this particular dispute to the panel: Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most reproducible operational result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 02. Student A, terminology and scope: Agree the operational meanings of choice, best, largest and quoted, dynamic, reproducible in “Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most reproducible operational result”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. Laboratory decision protocol and defensible reporting”. A reproducible operational result still needs technical validity; reproducible overload is not success Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. Laboratory decision protocol and defensible reporting”. A reproducible operational result still needs technical validity; reproducible overload is not success Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask participants to define the intended event and then map each quoted metric to its own conditions Put two specific questions to Student D about the

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stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is

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missing. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…. Combine noise, internal loading, desired transfer, recovery, and source controls to determine the supported operating envelope Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

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- 14. Student J, Socratic challenge to Student I: For the precise observation involving Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.20 Laboratory decision protocol and defensible reporting (p. 1294)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…. Combine noise, internal loading, desired transfer, recovery, and source controls to determine the supported operating envelope Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.22 Front-end noise spectroscopy as an instrument-state test (p. 1299)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Which should decide a difficult front-end

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choice: the best laboratory noise figure, the largest quoted dynamic range, or the most… and Ask participants to define the intended event and then map each quoted metric to its own conditions; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most…”, addressing “Ask participants to define the intended event and then map each quoted metric to its own conditions”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic

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range, or the most reproducible operational result", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Which should decide a difficult front-end choice: the best laboratory noise figure, the largest quoted dynamic range, or the most reproducible operational result". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

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Chapter 3 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C03-ESSAY-001 — Begin with output power equal to input power multiplied by each stage power gain in the valid scalar chain. Taking ten times the base-ten logarithm converts the product to a sum. A passive loss written as a positive decibel magnitude enters with a minus sign; a positive amplifier gain enters with a plus sign. Define both reference planes and compatible impedance and mismatch conventions. The desired and blocker calculations can share the component order but generally require different frequency-specific transfer values. State the fixed-state and small-signal assumptions, and explain why a successful gain calculation supplies neither a compression model nor a pulse-survival rating. Full credit requires distinguishing a logarithmic power level in dBm from a gain or loss in dB. Review: Equations 5 and 6; Find the first stage that can lose validity.

Review: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Find the first stage that can lose validity.

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V011-C03-ESSAY-002 — The desired level is $-92-1.2-5+16=-82.2$ dBm. The blocker level is $-8-34-5+16=-31$ dBm, giving 7 dB nominal margin below the stipulated mixer limit. Keep the two filter transfers separate and identify the mixer input as the final plane. The amplifier input blocker is -47 dBm, which must independently meet that amplifier's applicable input envelope. The calculation does not establish aggregate loading from other signals, peak-voltage stress, stability, or actual filter response at temperature. If the chain remains linear and corrections apply, subtract the net desired gain of 9.8 dB from the mixer desired level to recover -92 dBm. Do not use the 34 dB blocker rejection as the desired correction. Review: Equation 6; Use preselection as a measured transfer function.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Use preselection as a measured transfer function.

V011-C03-ESSAY-003 — Each blocker has approximately 0.015849 mW mean power. Their sum is approximately 0.031698 mW, or -14.99 dBm. The increase relative to either individual blocker is about 3.01 dB. State the observation interval and cross-term assumption that make this mean-power addition appropriate. Instantaneous voltage depends on the component waveforms, impedance, timing, and relative phase; crest behavior cannot be inferred solely from the mean-power sum. A scalar gain budget also omits nonlinear products and protection dynamics. A complete acceptance argument therefore compares the appropriate aggregate mean, peak, and individual-tone conditions with the actual stage limits, using compatible quantities rather than treating one dBm number as every type of stress. Review: Find the first stage that can lose validity; Equation 6.

Review: Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Find the first stage that can lose validity.

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V011-C03-ESSAY-004 — The downstream temperature allowance is 40 K, so the first-stage linear power gain must be at least $\frac{1200}{40}=30$, approximately 14.77 dB. The blocker condition permits no more than 19 dB gain. The feasible interval is therefore approximately 14.77 to 19 dB, under the stated model. Of the available settings, 15 dB lies inside it; 10 dB fails the noise target and 20 dB exceeds the downstream blocker bound. At 15 dB the gain is approximately 31.6228, giving total equivalent temperature about 112.95 K and a blocker level of -27 dBm. The latter has 4 dB margin to the stipulated limit. Check the first amplifier's own exposure, stability, source matching, signal retention, and uncertainty before treating this scalar feasible choice as an accepted configuration. Review: Choose gain from a feasible interval; Model 2B Equation 4J; Equation 6.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 2 — Equation 4J. Minimum first-stage gain for a temperature limit; Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-ESSAY-005 — Show that the intersection is empty: a 21 dB compromise violates both original bounds. Identify the mechanism behind each bound before proposing changes. Better blocker rejection before the limiting path can relax the loading bound if the desired transfer and preceding-loss noise penalty remain acceptable. A lower-noise downstream stage, lower first-stage equivalent temperature, or a different gain distribution can relax the noise constraint. Greater downstream linear range may change the loading bound but cannot repair an earlier overloaded stage. A revised sensitivity target requires an application-based justification rather than an arbitrary numerical relaxation. Recompute the interval and validate the selected physical state, including frequency response and relevant uncertainty. The result should be a supported new design or an explicit infeasibility finding. Review: Choose gain from a feasible interval; Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 3 — Choose gain from a feasible interval.

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V011-C03-ESSAY-006 — With attenuation before the amplifier, its input blocker is -19 dBm, 4 dB below the stated validity limit. The final small-signal prediction is +1 dBm. With attenuation after the amplifier, the amplifier sees -7 dBm, 8 dB above its stated valid input limit; the same +1 dBm end-to-end prediction is therefore not justified by the small-signal model. Do not report that invalid prediction as measured performance. Explain that attenuation placement also changes input-referred noise through the cascade relation. The valid arrangement still needs a check that the amplifier output and downstream components tolerate the resulting level and that the attenuator's own rating applies. Equal nominal net gain describes neither equal noise nor equal internal validity. Review: Gain Distribution and Attenuation; Application 2B.7; Equation 6.

Review: Chapter 2 — Application 2B.7: place attenuation before the vulnerable stage; Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-ESSAY-007 — Identify the actual band identifiers and switching rule, then use reference frequencies on both sides of the boundary and within the region where response changes rapidly. Keep the desired reference plane, source level, processing bandwidth, and detector convention controlled. Retain raw response and corrected response, relevant phase or modulation quality, noise, and the realized filter state. Repeat tuning across the boundary in both directions to reveal hysteresis or state-selection differences where relevant. A center-frequency calibration from one band cannot establish continuity. Associate each correction with its own state and uncertainty, and distinguish a physical response change from a correction-table discontinuity. Test the occupied bandwidth of the intended waveform, not only a single tone at the nominal tuning frequency. Review: Preselection and Filter State; Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 3 — Preselection and Filter State.

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V011-C03-ESSAY-008 — The desired-to-noise ratio improves by 2 dB because desired power changes by -4 dB while noise changes by -6 dB. Equivalently, divide the desired retention factor by the noise retention factor. This arithmetic assumes the quantities are comparable integrated powers at a common plane and that the detector law remains applicable. It does not establish preservation of waveform phase, burst onset, group delay, or enough observation time. A burst claim needs the actual signal spectrum, temporal filter response, success criterion, and relevant false-alarm condition. Retain desired-reference measurements before and after the filter and account for any changed processing bandwidth. Do not report the full 6 dB baseline reduction as a 6 dB sensitivity improvement. Review: Use preselection as a measured transfer function; Chapter 2 signal-retention relation.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 2 — Equation 4L. Input signal power for a stipulated output ratio.

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V011-C03-ESSAY-009 — Retain native samples or physical detector output with acquisition timing, gain-state telemetry or a sufficiently resolved gain-control trace, filter and attenuator states, and the fixed desired-reference identity. Align the state trajectory with the affected data and characterize the transfer for the states and transitions used. Compare a permitted fixed-gain challenge or an independently characterized control response to discriminate source change from automatic gain action. A mean gain can conceal short compression, clipped samples, settling, or gaps; those losses are not invertible by one scalar correction. State which intervals remain quantitatively usable, which have qualified amplitude, and which cannot support the intended claim. A calibration at one settled gain does not establish the transition law. Review: Choose gain from a feasible interval; Gain Distribution and Attenuation.

Review: Chapter 3 — Choose gain from a feasible interval; Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-ESSAY-010 — Map the desired signal, admitted noise, and strongest relevant event to the actual converter input. In the valid linear region, common analog gain does not improve the SNR already present before that gain. It can reduce the converter-added contribution when referred back to the external input. The useful gain is bounded above by converter range and earlier-stage linearity, and below by the acceptable downstream contribution. Preserve the relevant waveform peaks rather than budgeting only mean power. Keep raw sample scaling and the gain state so later FFT normalization is interpretable. Explain why a digitally rescaled or heavily averaged quiet trace does not prove appropriate range use, and why clipped samples cannot be restored by gain metadata. Review: Choose gain from a feasible interval; Chapter 10 digitizer connection; Chapter 9 normalization connection.

Review: Chapter 3 — Choose gain from a feasible interval; Chapter 10 — Quantization, Clipping, and Converter Performance; Chapter 10 — Quantization margin and channel bandwidth; Chapter 9 — Windowed DFT normalization: line amplitude, noise density, and finite-record energy.

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V011-C03-ESSAY-011 — First quantify what reaches the downstream path during the event, including any leading transient and later leakage under the actual source and load conditions. Second establish hardware survival using the applicable conditioned limits and post-event functional evidence; absence of obvious damage is not every performance test. Third measure recovery of the desired weak-signal observables, such as amplitude, phase, modulation quality, and baseline variance within stated tolerances. Retain a weak reference throughout a bounded event and record timing, waveform, duty factor, gain state, and processing. Explain that each criterion can pass at a different time or stress level. Device data-sheet values are conditional evidence for that device and cannot be transferred as receiver-assembly ratings. Review: Measure protection in the small-signal and recovery states; source note 11.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-ESSAY-012 — The duty factor is $\frac{6}{300}=0.02$, or 2 percent. Mean power is $50\times0.02=1$ mW, which is 0 dBm; peak power is approximately 16.99 dBm. The mean may inform some thermal questions, but it does not replace the peak, pulse-width, repetition, leading-edge leakage, or recovery conditions relevant to the device and assembly. State the rectangular-waveform and zero-off-state assumptions explicitly. A different pulse shape requires time integration. Apply the actual component and accessory ratings to the proposed challenge and retain the waveform delivered at the receiver plane. Do not infer a universal safe pulse test merely because the average power is modest. Review: Input Protection and Recovery; Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Input Protection and Recovery.

V011-C03-ESSAY-013 — If all three criteria are required and remain satisfied thereafter under the declared observation rule, recovery is no earlier than 85 microseconds after the defined event time origin. State whether the origin is the event leading edge or trailing edge, how persistence within tolerance is judged, and how time resolution affects the reported boundary. The 35 microsecond amplitude crossing alone cannot establish phase or variance recovery. Retain the pre-event baseline, reference waveform, event history, receiver state, detector averaging, and trigger behavior. Distinguish observed system recovery from the physical recovery of a particular limiter. The data may support several narrower recovery times as long as each is labeled by its observable and conditions. Review: Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-ESSAY-014 — Identify the complete path from the protection network through amplifiers, gain control, digital filtering, detector, and trigger logic. Shorter detector averaging changes the observation response and its noise variability; the difference supports a processing contribution but does not uniquely quantify every analog delay. Retain a weak reference and compare time-resolved amplitude or phase with appropriate raw observations under controlled event conditions. If a bypass or alternate detector is allowed, keep all remaining hardware within ratings and state exactly which subsystem was isolated. Define recovery using the intended measurement tolerance and account for changed estimator variability. A strong answer produces bounded attribution and preserves unresolved contributions rather than converting a trace-duration difference into a device-specific recovery specification. Review: Measure protection in the small-signal and recovery states; Table 3A.

Review: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-ESSAY-015 — In the nonlimiting state, insertion loss, return loss, and reactive loading affect desired transfer and the noise budget. During a large event, stored carriers alter RF resistance; the external current path and device geometry influence the mounted response. Removal or recombination of carriers contributes to the return toward the low-loss state. These mechanisms justify observing leakage and recovery over time as well as measuring a settled small-signal sweep. Do not derive a universal numerical recovery law from the qualitative explanation. State the circuit, bias where applicable, source and load conditions, event waveform, and required observable. Cite the identified MACOM explanation for the mechanism while distinguishing original acceptance reasoning from a manufacturer rating. Review: Measure protection in the small-signal and recovery states; source note 10.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-ESSAY-016 — Establish both generator outputs and their harmonics, spurs, and relevant noise at the intended receiver input plane through the actual cables and combiner. Assess combiner isolation and linearity at the applied levels because generator interaction or passive/nonlinear combining elements can create the line before the receiver. Use suitable independent observations, isolation changes, or controlled source-path substitutions that preserve known applied levels. Retain a desired reference and vary tone frequencies or attenuation to test the predicted product behavior. A product-frequency relationship is evidence for a mechanism but not a unique generation location. State the measurement floor of the source control and the residual bound on pre-existing products rather than treating a nondetection as zero contamination. Review: An acceptance sequence that separates competing failures; Model 11A connection.

Review: Chapter 11 — Model 11A for cubic intermodulation and intercept metrics; Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-ESSAY-017 — Characterize or bound source spectral purity at the desired channel and the levels delivered through the actual combining path. Keep desired reference, effective bandwidth, detector operation, and reference plane controlled. Record gain-state changes and desired transfer while varying blocker level, offset, or preselection in ways predicted to affect the candidate mechanisms. A source with significant in-band noise can create the observed rise directly; a receiver mixing interpretation requires that alternative to be bounded. An automatic gain response can change raw and corrected noise differently. Retain linear integrated channel power and raw output alongside the input-referred result. Explain that several mechanisms can coexist and that the result may remain an upper bound or unresolved attribution. Review: An acceptance sequence that separates competing failures; Table 3A; Model 11B connection.

Review: Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge; Chapter 11 — Model 11B for reciprocal mixing and admitted noise; Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-ESSAY-018 — Begin by establishing source and combining-path validity, actual applied levels, and the operating ratings. Measure the quiet desired transfer and noise in the selected state, including the intended waveform bandwidth and relevant phase or quality. Introduce a bounded blocker in controlled increments with the desired source fixed, recording transfer, channel noise, discrete products, and state telemetry. Remove the blocker and observe return, then repeat an alternative filter or attenuation state chosen to discriminate the suspected mechanism. Keep raw and common-plane corrected records and identify uncertainty and source controls. Release only the frequency, level, waveform, and state range supported by the observations. The sequence should be informative about failure mechanisms rather than merely produce a pass/fail label. Review: An acceptance sequence that separates competing failures; Verification and Maintenance Controls.

Review: Chapter 3 — An acceptance sequence that separates competing failures; Chapter 3 — Verification and Maintenance Controls.

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V011-C03-ESSAY-019 — The comparison lost the ability to observe both quantities, so disappearance is consistent with several origins. The attenuation change does not by itself establish the suspect line's scaling law. Preserve the measured floor, raw levels, and corrections and state the unresolved alternatives. A follow-up might retain a stronger bounded desired reference, adjust valid downstream gain without overloading earlier stages, use narrower appropriate measurement bandwidth while accounting for signal retention, or test source frequency relationships. Each change needs its own validity assessment. Source and combiner products must still be bounded for receiver-specific attribution. Do not infer a numerical slope from a censored observation reported only as below the floor. Review: An acceptance sequence that separates competing failures; Assessment 3A.8.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-ESSAY-020 — The combined observations support a nonlinear product hypothesis because rejection of lower-frequency inputs can remove a line while the preselector nominally passes the displayed frequency. Verify the actual desired-reference transfer at 1.2 GHz through both installed states so the disappearance is not explained by lost observation capability. Establish the relevant lower-frequency levels and rejection, and bound source and combiner products at the receiver input plane. Test the predicted product-frequency and level relationships without exceeding valid test conditions. Receiver-front-end attribution requires evidence locating the generation, not only reproduction of the output frequency. Distinguish the observed component, the supported product mechanism, and any claim about an external source's identity or intent. Review: Hypothetical Case Adjudication; Model 11A connection.

Review: Chapter 11 — Model 11A for cubic intermodulation and intercept metrics; Chapter 3 — Hypothetical Case Adjudication: RF Front Ends, Preselection, Gain Distribution, and Input Protection.

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V011-C03-ESSAY-021 — Identify the new serialized components, connection conditions, relevant torque, filter state, and firmware or configuration. Compare applicable reference sweeps and bounded multi-tone or recovery checks with accepted baselines over the frequencies and levels required for use. Retain corrections, uncertainty, and any evidence of drift in contacts, tuning, bias, leakage, or isolation. The old record documents the prior configuration; it does not automatically validate the replacement path. Investigate differences exceeding the relevant uncertainty and distinguish ordinary wear from changed configuration. A release statement should define the supported state and operating range, name limitations, and link to the actual measurements. A generic passed label omits the conditions needed for later interpretation. Review: Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-ESSAY-022 — Suppose a valid raw desired output is -50 dBm before the step and -60 dBm afterward, with all other applicable gains unchanged. The added 10 dB input loss explains the raw decrease; adding back the appropriate state-specific correction gives the same external estimate. The raw record shows the physical output change while the corrected record supports a common-plane comparison. If only the corrected value remains, one may not reconstruct actual range use, noise, or overload; if only raw values remain, the external comparison lacks its transfer model. Retain the step's measured frequency response and repeatability, other state changes, bandwidth, detector, and timing. Equal corrected signal estimates do not establish equal sensitivity because the input attenuation changes the physical noise budget. Review: Gain Distribution and Attenuation; An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures; Chapter 3 — Gain Distribution and Attenuation.

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V011-C03-ESSAY-023 — Read the actual device and revision, conditioned pulse width and duty factor, frequency and temperature range, and distinction between specifications and absolute maximum ratings. Identify the installed topology, mounting, current path, thermal environment, and downstream components. Establish how leading and later leakage reach the protected circuitry and whether the desired measurement recovers within the required interval. The component value can inform a design but does not certify the assembled receiver or its accessories. Use the real instrument and accessory limits to bound any challenge, and preserve the data-sheet applicability rather than invent a universal multiplier. A useful conclusion separates component survival evidence, system exposure analysis, and validated weak-signal performance. Review: Measure protection in the small-signal and recovery states; source note 11.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-ESSAY-024 — State the injection plane, frequency, level, waveform, receiver state, output observation, and time. The check supports the exercised transfer or function under those conditions at that time. It may bypass the antenna, an external preselector, or upstream cabling, and it does not by itself establish uninterrupted validity during prior acquisition. Complement it with appropriate field or upstream terminal references, multiple relevant frequencies and levels, state records, and checks of recording/export functions when those are part of the intended claim. Temporal monitoring or bracketing can add evidence but should retain its own scope. The final statement should identify what was observed and which earlier or unexercised functions remain unsupported. Review: Verification and Maintenance Controls; Chapter 1 closing-verification qualification.

Review: Chapter 3 — Verification and Maintenance Controls; Chapter 1 — Evidence Record and Closing Verification.

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V011-C03-ESSAY-025 — Define the intended observation, reference plane, desired waveform, and bounded interferer environment. Use frequency-specific gains to track desired and blocker levels through the actual order, then combine the noise-derived minimum gain with the downstream loading maximum. Check signal retention, state reproducibility, and the relevant protection and recovery behavior. Support each assumption with applicable source or measured evidence and retain source-path controls for artifact attribution. Raw output and corrected input records must allow reconstruction. A favorable scalar budget can still fail if a stage is nonlinear, a waveform is filtered away, gain history is unknown, source products are unbounded, or recovery misses the required interval. Release the supported envelope and document unresolved limits rather than averaging conflicting criteria into a universal score. Review: Chapter 3 synthesis; Equations 5 and 6; Table 3A.

Review: Chapter 3 — Equation 5. Linear cascaded gain; Chapter 3 — Equation 6. Input power after front-end correction; Chapter 3 — Table 3A. Evidence to retain during a constructed front-end challenge.

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Discussion Guidance

V011-C03-DISCUSSION-001 — Ask for the actual analog path and admitted spectrum before discussing the displayed trace. Identify the first vulnerable stage and the rejection preceding it. Consider the possibility of a wideband converter or amplifier followed by a narrow display filter. The discussion should produce an exposure survey and a bounded desired-reference challenge, not merely a wider screenshot. A clean display can be retained as an observation while the claim about internal validity remains unproved. Review: Front-End Purpose and Architecture; Find the first stage that can lose validity.

Review: Chapter 3 — Find the first stage that can lose validity; Chapter 3 — Front-End Purpose and Architecture.

V011-C03-DISCUSSION-002 — Compare the preceding-loss noise penalty with the spectrum admitted to the amplifier in each order. Require a desired-signal requirement and an internal blocker budget. The quiet case may favor early gain, while the strong-signal case can require rejection before that gain. Avoid a universal ranking based only on noise figure. Retain the exact physical state and model-specific option architecture when an instrument example is used. Review: Front-End Purpose and Architecture; Use preselection as a measured transfer function; source note 9.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

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V011-C03-DISCUSSION-003 — Require the desired waveform, occupied bandwidth, and success criterion. Compare retained amplitude, phase or modulation quality, noise, and strong-signal validity at a common plane. A lower trace can result from reduced gain or rejected desired energy. The useful endpoint is a demonstrated improvement or necessary validity restoration for the defined event, with the accompanying loss and uncertainty documented. Review: Use preselection as a measured transfer function.

Review: Chapter 3 — Use preselection as a measured transfer function.

V011-C03-DISCUSSION-004 — Have participants identify the permitted amplitude error, measured passband variation, temperature and state range, and the spectrum of the desired signal. A flat approximation can be justified within a bounded tolerance; it is not established by one center-frequency measurement. Filter skirts, switched boundaries, and notches require particular scrutiny. The team should state a validity interval and uncertainty for the simplification or retain a frequency-dependent correction. Review: Preselection and Filter State.

Review: Chapter 3 — Preselection and Filter State.

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V011-C03-DISCUSSION-005 — Distinguish the valid common-plane signal estimate from the physical noise and detection capability. Input loss can increase input-referred receiver noise even when the display compensates the desired amplitude exactly. Request corresponding raw and corrected noise, bandwidth, detector condition, and linearity evidence. The revision should preserve the useful agreement of the signal estimates without converting it into an unsupported equality of sensitivity. Review: Gain Distribution and Attenuation; Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval; Chapter 3 — Gain Distribution and Attenuation.

V011-C03-DISCUSSION-006 — The choice depends on the intended observation and the mechanisms behind the bounds. Discuss whether extra rejection occurs before the limiting stage and how its insertion loss changes the noise bound. Consider a lower-noise later stage or greater downstream range as alternatives. Require recomputation after each proposed change. A target may be revised only with an application-based rationale; no numerical compromise satisfies an empty interval. Review: Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-DISCUSSION-007 — Stable scaling is compatible with an external input under the tested conditions, but may also occur for internal behavior that scales similarly or is masked by correction. Ask which element was switched, where a possible artifact could originate, and whether the desired reference and gain state behaved as expected. Combine amplitude scaling with frequency, source-path, and configuration controls appropriate to the hypothesis. The conclusion should match the discriminatory power of the actual test. Review: Gain Distribution and Attenuation; An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures; Chapter 3 — Gain Distribution and Attenuation.

V011-C03-DISCUSSION-008 — Distinguish characterization of a fixed component transfer from evaluation of the operational closed-loop receiver. Disabling control can simplify the first question, while the second may require measuring its real response. In either case, retain the state and timing and label the quantity correctly. Discuss exposure limits and loss of dynamic range under a fixed setting. A control that remains enabled needs a characterized trajectory before quantitative amplitude correction is assumed. Review: Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

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V011-C03-DISCUSSION-009 — Ask for native samples, analog gain states, converter range use, and corresponding input-referred converter contribution. Software scaling changes units and averaging changes estimator behavior; neither alone changes analog SNR or reverses clipping. A useful comparison holds the waveform and processing definition fixed while assessing the physical analog state and its valid range. Separate a visual improvement from a measurement-performance result. Review: Choose gain from a feasible interval.

Review: Chapter 3 — Choose gain from a feasible interval.

V011-C03-DISCUSSION-010 — Survival history concerns one aspect of protection, while ordinary insertion loss, return loss, and reactive loading remain in the signal path. Ask what measured small-signal response is available and whether it varies with frequency, temperature, or prior events. A negligible contribution can be justified within the measurement uncertainty, but it should not be inferred solely from lack of damage. Keep the assembly conditions explicit. Review: Input Protection and Recovery; Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Input Protection and Recovery.

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V011-C03-DISCUSSION-011 — They may be reporting different observables. Reconcile the event waveform, time origin, state, detector response, tolerance, and persistence rule before comparing numbers. A receiver can meet amplitude tolerance while still having excessive variance or phase error. A productive outcome reports observable-specific times and the joint time needed by the intended task. Avoid forcing one catalog-like number onto different measurement requirements. Review: Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

V011-C03-DISCUSSION-012 — A normal later state supports the observed functions at that time; it does not establish event leakage, temporary desensitization, or the duration of unusable intervals. Discuss what contemporaneous state, overload, timing, or reference evidence exists and which intervals can still support the intended result. Future characterization should retain the event and weak reference through recovery. Do not reconstruct an unobserved recovery history from the final trace alone. Review: Measure protection in the small-signal and recovery states; Verification and Maintenance Controls.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Verification and Maintenance Controls.

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V011-C03-DISCUSSION-013 — Require the actual peak, duration, repetition, waveform, frequency, coupling, and source/load conditions. Compare them with the conditional instrument and accessory limits and with the measurement's required recovery interval. Low average power does not remove peak stress or leading-edge leakage. Conversely, matching peak power alone does not reproduce thermal or charge history. The discussion should yield a bounded representativeness argument, not a universal safe-test rule. Review: Input Protection and Recovery; source note 11.

Review: Chapter 3 — Input Protection and Recovery; Chapter 3 — Measure protection in the small-signal and recovery states.

V011-C03-DISCUSSION-014 — Establish that the permitted bypass changed only the claimed subsystem in a meaningful way and that the remaining path stayed within ratings. Compare applied event levels, downstream gain, matching, processing, and detector variability. The difference can include interactions with amplifier bias or gain control. Report the measured system comparison and its scope; isolate a device-specific time only when the measurement model and controls support that attribution. Review: Measure protection in the small-signal and recovery states.

Review: Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-C03-DISCUSSION-015 — Begin with the applied source and combining path because contamination there can enter the receiver as an ordinary signal. Discuss isolation, linearity, source harmonics, phase noise, and the floor of the independent input-plane observation. Then use controlled receiver-state changes to locate any additional generation. The ordering avoids treating a plausible product-frequency relationship as proof of its location. Review: An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

V011-C03-DISCUSSION-016 — Identify which bandwidth is physical admission and which belongs to later processing. Use matched processing bandwidth where feasible or a justified model that accounts for noise integration and desired-signal retention. Preserve each state's gain and calibration. A raw noise difference cannot be assigned entirely to rejection when bandwidth changed too. The comparison should state the common measurand and retain any irreducible difference in capability. Review: An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-DISCUSSION-017 — It can be a useful bounded result if the reason for nondiscrimination is retained. Examples include both lines falling below the floor, unrecorded gain changes, or source contamination that cannot be bounded. Ask what follow-up would separate the remaining mechanisms and whether the existing record still supports a narrower claim. Avoid rewarding a confident attribution when the test removed its own observation capability. Review: An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

V011-C03-DISCUSSION-018 — Retain the manufacturer, model, option, manual edition, and applicable firmware context. Use the example to illustrate why component order matters, then state the general reasoning separately. The same indicator name can correspond to different physical paths. Participants should distinguish accurate source attribution from a universal design assertion and identify what evidence is needed for the instrument actually being used. Review: Front-End Purpose and Architecture; source note 9.

Review: Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Front-End Purpose and Architecture; Chapter 3 — Find the first stage that can lose validity.

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V011-C03-DISCUSSION-019 — It may appear if the quantities are clearly separated and their purposes and conditions are explicit. Stress ratings do not certify gain accuracy, noise, distortion, or recovery at the boundary. Discuss how assembly limits and accessory constraints can be more restrictive. An acceptance table should preserve the distinctions between operation, survival, and the desired measurement criterion rather than imply they are interchangeable thresholds. Review: Measure protection in the small-signal and recovery states; source note 11.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Measure protection in the small-signal and recovery states.

V011-C03-DISCUSSION-020 — The model label and nominal length provide context but do not establish identical installed loss and mismatch. Compare the serialized replacement's applicable response, connection conditions, frequency range, and uncertainty against the prior correction. A difference small relative to the required tolerance may justify retention with documented evidence. Otherwise update the correction and verify affected observations. The decision should follow the measurement need, not the purchase description alone. Review: Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

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V011-C03-DISCUSSION-021 — Polarization changes coupling for desired and unwanted fields and can also alter multipath. Retain geometry, timing, desired-reference capability, and receiver state. The change may improve a practical observation while leaving the component's origin unresolved. Discuss complementary spatial, frequency, and input-path controls needed for a stronger interpretation. Do not treat a single polarization response as unique identification. Review: Front-End Characterization and Field Decisions.

Review: Chapter 3 — Front-End Characterization and Field Decisions.

V011-C03-DISCUSSION-022 — Require the actual configuration, applicable frequencies and levels, waveform and timing conditions, observables, tolerances, uncertainty, and identified limitations. A concise pass statement can summarize a referenced bounded record, but cannot replace it. Ask whether protection, recovery, and source-path controls were included when relevant. The discussion should end with a release statement that can be compared with a future intended use. Review: Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls.

V011-C03-DISCUSSION-023 — Raw output reveals actual range use, gain changes, and noise behavior before correction. Corrected values can conceal a changed attenuator state or a normalization error if the underlying data and state are absent. Retaining both allows an independent reviewer to reconstruct the transformation and assess validity. Discuss storage and metadata choices in terms of that evidential need, with native samples or physical output quantities appropriate to the task. Review: An acceptance sequence that separates competing failures.

Review: Chapter 3 — An acceptance sequence that separates competing failures.

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V011-C03-DISCUSSION-024 — It can contribute to a broader argument together with contemporaneous state records, bracketing, known failure behavior, and relevant monitoring. Its direct observation remains time- and function-bounded. Require the team to state which inference connects the later check to the earlier interval and what evidence supports that inference. A final response alone cannot establish uninterrupted validity or exercise an upstream path it bypasses. Review: Verification and Maintenance Controls; Chapter 1 closing-verification qualification.

Review: Chapter 3 — Verification and Maintenance Controls; Chapter 1 — Evidence Record and Closing Verification.

V011-C03-DISCUSSION-025 — Ask participants to define the intended event and then map each quoted metric to its own conditions. A reproducible operational result still needs technical validity; reproducible overload is not success. Combine noise, internal loading, desired transfer, recovery, and source controls to determine the supported operating envelope. Different states can be preferable for different environments. The final argument should identify the governing limitations rather than select one universal headline metric. Review: Chapter 3 synthesis; Choose gain from a feasible interval; Verification and Maintenance Controls.

Review: Chapter 3 — Verification and Maintenance Controls; Chapter 3 — Choose gain from a feasible interval.

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Chapter Glossary

AGGREGATE INPUT POWER: The combined power presented by all relevant admitted components at a specified stage input. Mean powers can be summed when the applicable cross-power terms vanish under the defined averaging or ensemble convention. The aggregate mean does not by itself establish peak voltage, crest behavior, or the nonlinear products generated by several strong signals.

BLOCKER-SOURCE NOISE: Noise carried by the applied interfering source into the desired observation channel or another relevant admitted region. It can produce a measured noise rise without requiring the proposed receiver mechanism. A reciprocal-mixing interpretation therefore needs this contribution bounded or accounted for under the same source, frequency, and path conditions.

BLOCKER TRANSFER: Frequency-specific gain or loss connecting an external interfering signal to a vulnerable receiver stage.

CARRIER STORAGE: Retention of excess charge carriers in a semiconductor after they are introduced by a large event or bias condition. In the chapter's PIN-limiter explanation, stored charge changes RF resistance and its removal contributes to recovery. This qualitative mechanism does not supply a universal numerical recovery time for an arbitrary mounted network.

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COMBINER ISOLATION: The degree to which a combining network prevents energy from one input port from reaching another under specified conditions. In a two-source challenge, inadequate isolation can let generators interact and produce artifacts before the receiver. Isolation must be considered with the combiner's linearity and actual applied levels; it is not the same as insertion loss.

DOWNSTREAM LOADING: The signal, noise, and interference presented to a later stage after the gains and losses preceding it. It is evaluated at that stage's own plane and frequencies, not inferred from the final corrected display. Additional early gain can reduce a later noise contribution while simultaneously increasing this loading and reducing the later stage's valid margin.

FILTER-BANK BOUNDARY: A tuning region where a receiver changes between discrete preselector or filter paths. The transition can change gain, phase, noise, or correction applicability even if the displayed frequency changes smoothly. Reference observations on both sides, together with actual band identifiers, are needed to assess continuity and the validity of comparisons across the boundary.

FILTER TUNING REPEATABILITY: The consistency of a tunable or switched filter's realized response when commanded to return to a specified state. It includes the response relevant to the intended amplitude, phase, or rejection measurement, not merely agreement of the displayed tuning value. Boundary crossings, temperature, and switching history can require explicit comparison.

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FLAT LEAKAGE: The leakage level during the comparatively settled limiting portion of a specified large-signal event, as distinguished from an initial leading transient. The term does not imply identical behavior for every pulse width, frequency, source impedance, or load. It must be tied to the applicable test definition and does not alone establish survival or recovery.

GAIN ALLOCATION: Choice and placement of gain that satisfies a noise requirement while preserving the valid signal range of later stages.

GAIN-FEASIBILITY INTERVAL: The overlap between a lower gain bound required by a noise objective and an upper gain bound permitted by downstream loading, under declared models and conditions. An empty overlap means no gain choice satisfies both requirements. A nonempty interval identifies candidate settings but does not independently establish stability, mismatch behavior, or transient validity.

GAIN-STATE TELEMETRY: A retained record of actual receiver gain settings or gain-control behavior associated with acquisition time. Its temporal resolution must be sufficient for the amplitude interpretation being made. A final setting or average gain does not describe brief transitions, and telemetry cannot restore information lost by clipping or samples that were never acquired.

GROUP DELAY: A description of how a transfer function’s phase changes with frequency, representing delay for a sufficiently narrow group of spectral components under the applicable linear model. Variation across a modulated signal can distort its relative timing even when center-frequency insertion loss is acceptable. The actual filter state and frequency interval must accompany a useful group-delay claim.

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HEADROOM: Difference between operating level and a specified compression, overload, clipping, or damage limit.

INPUT INTERCEPT POINT: Extrapolated input level at which selected nonlinear products would equal the fundamental output under a defined test.

INPUT-REFERRED CONVERTER NOISE: The converter-added noise contribution expressed at an earlier selected input plane through the applicable analog signal power gain. Increasing valid analog gain can reduce this referred contribution while leaving the analog signal-to-noise ratio already present unchanged. The conversion requires the actual state and does not justify exceeding converter or upstream-stage range.

LEADING-EDGE LEAKAGE: The early portion of a strong event that reaches the protected downstream path before the later limiting response is established. Its peak and duration can differ from the subsequent leakage. A measurement of only the settled limited level may therefore underdescribe the actual exposure of the protected component.

LIMITER CURRENT-RETURN PATH: The external circuit path through which current associated with a limiter's large-signal operation can flow. Its implementation influences the mounted protection response alongside the device itself. Characterizing only the isolated component can omit this circuit dependence, particularly when interpreting leakage, stored charge, and return to small-signal transfer.

LIMITER LEAKAGE: Signal power or transient energy that reaches the downstream path while a protection limiter is responding to a strong input.

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NOTCH FILTER: A filter designed to reject a selected frequency region while retaining other regions. In a front end it can reduce a dominant interferer before a vulnerable component, but it also removes any desired signal content occupying the notch. Its installed response, placement, and power handling determine whether it improves the intended observation.

PASSBAND PHASE DISTORTION: A change in the relative phases of a signal's admitted spectral components that alters the intended waveform or modulation representation through the passband. Center-frequency magnitude alone does not reveal it. Its significance depends on the signal spectrum, measurement objective, and applicable phase or group-delay response of the installed filter state.

PASSBAND RIPPLE: Variation of transmission magnitude within a filter's declared useful passband, expressed under a specified normalization and frequency interval. A correction measured only at the center cannot establish the amplitude of a wide waveform across the ripple. The relevant tolerance follows the intended level or modulation measurement, rather than a passband label alone.

PEAK INPUT POWER: The largest input power under the stated waveform and time-resolution convention at a specified plane. It is distinct from average power and must be related to the applicable pulse or continuous-wave rating. For pulsed exposure, duration, repetition, source and load conditions, and leading transients can matter alongside the peak value.

PRESELECTION: Filtering placed before vulnerable gain or conversion stages to limit admitted spectrum.

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PROTECTION RECOVERY CRITERION: Declared observable and tolerance used to decide when a valid weak-signal measurement has returned after a strong event.

PROTECTION SURVIVABILITY: The ability of specified hardware to remain within the stated survival criterion after a defined exposure. The criterion and waveform conditions must be retained; survival is distinct from accurate transfer during the event and from prompt recovery afterward. Component survivability data do not automatically establish the survivability or measurement capability of a complete receiver assembly.

PULSE DUTY FACTOR: The fraction of a stated interval during which a defined pulse condition is present. For a periodic rectangular pulse it is pulse width divided by repetition period. Multiplying constant peak power by this fraction gives mean power only when the stipulated waveform and off-state assumptions apply; the peak exposure remains a separate quantity.

RECOVERY ATTRIBUTION: The assignment of an observed post-event delay or disturbance to a particular subsystem or mechanism using discriminating evidence. Protection, amplifier bias, gain control, digital filtering, detector averaging, and trigger behavior can all contribute. A delay observed in the final display is a system observation until the relevant path contributions have been separated.

RECOVERY BASELINE: The pre-event reference behavior against which post-event return is evaluated, including the desired response and any required noise or variability measure. It must belong to the same relevant state and processing definition. A later quiet trace cannot substitute for an unrecorded baseline when the recovery criterion depends on a quantitative change.

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RECOVERY TIME: Time required for a protection or gain stage to return to specified behavior after a strong event.

RELEASE ENVELOPE: The documented range of configuration, frequency, level, waveform, environmental, and timing conditions for which a receiver path's stated acceptance criteria are supported. It connects the tests to permitted interpretation and records limitations. A blanket pass without this envelope cannot establish applicability to a changed front-end state or exposure.

RETURN LOSS: A logarithmic measure of reflection at a stated port and reference impedance, conventionally expressed as a positive decibel value for a passive mismatch. It characterizes port matching rather than through-path insertion loss. Changes in input match can alter delivered power and source interaction, so a matched-port transmission correction may not describe every installed antenna condition.

SMALL-SIGNAL PROTECTION LOSS: The ordinary signal attenuation introduced by a protection network when it is not in its limiting state. It affects the desired transfer and, when dissipative and preceding gain, the input-equivalent noise budget. Survival of large events does not establish that this loss is negligible, stable, or unchanged after an event.

SMALL-SIGNAL VALIDITY: Operating condition in which the linear gain and added-noise law used by the measurement model remain applicable.

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SOURCE-PATH CONTROL: A measurement or controlled comparison that bounds signals and artifacts already present in the sources, cables, and combining network before the receiver input. It is needed when receiver-generated intermodulation or noise is being claimed. Its measurement floor and applicability must be retained because an undetected contribution is bounded, not necessarily absent.

SOURCE SPECTRAL PURITY: The extent and distribution of a test source's unwanted spectral components under the applied operating conditions, including harmonics, spurs, and relevant broadband noise. It must be assessed at the receiver plane through the actual path when artifact attribution depends on it. A source's nominal carrier level does not characterize these unwanted contributions.

STEP-ATTENUATOR REPEATABILITY: The consistency of the realized insertion loss when an attenuator returns to the same nominal setting under stated frequency and connection conditions. Contact behavior and switching history can produce variation distinct from nominal step accuracy. Repeated-state evidence matters when a small level difference is used to infer linearity or external-signal scaling.

STOPBAND REJECTION: Attenuation supplied by a filter over a declared unwanted-frequency region relative to the stated transfer reference. In a blocker budget it must apply at the blocker frequency and before the vulnerable stage. A desired-frequency insertion-loss value does not establish rejection, and a rejection specification does not establish desired-signal retention.

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TRACKING FILTER: Tunable filter whose passband follows the receiver tuning frequency.

TRANSITION WIDTH: Frequency interval connecting specified passband and stopband boundaries of a filter. The boundary criteria must be stated because different level definitions give different widths. Signals occupying this region can experience rapidly changing magnitude and phase; a tuning frequency by itself does not show whether a broadband desired waveform remains inside the usable response.

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References and Works Cited

Rohde & Schwarz. R&S ESW EMI Test Receiver User Manual. Document 1177.6298.02, version 18. 2025. Sections 9.7.1.2 and 9.7.1.3, pages 193–194. Firmware 3.20 and higher. https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf

Annotation. An identified instrument example of preselection and amplifier placement, including the distinction between a standard preamplifier and an optional low-noise path. The architecture and conditions belong to the cited instrument and edition; they do not prescribe a universal receiver layout. The reference concerns apparatus and practices for electromagnetic interference measurements, with detector modes and equipment characteristics set by its identified scope. Quasi-peak, peak and average detection cannot be freely substituted when interpreting short or intermittent disturbances. A scope statement or product manual must not be mistaken for proof of compliance with every clause or correct operation under field conditions. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

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MACOM. Designing with Diodes: Protecting Sensitive Components. September 2, 2022. Receiver-protector operation and recovery discussion. https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting

Annotation. Supports the qualitative explanation of PIN-limiter charge storage, RF resistance, external current path, and return toward the nonlimiting state. The chapter does not infer an instrument-independent numerical recovery law from that explanation. The component or engineering reference concerns protection against excessive RF drive and the nonlinear behaviour inherent in an input limiter. Front-end loss, limiting threshold, recovery time and spectral products should be checked against the actual arrangement before characterising a faint signal. A protection device that prevents damage does not guarantee accurate level measurement or freedom from in-band artefacts. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

Analog Devices. ADL8201: DC to 30 GHz, RF Limiter. Data sheet, revision 0. January 2026. Tables 1–6, pages 3–5. https://www.analog.com/media/en/technical-documentation/data-sheets/adl8201.pdf

Annotation. Illustrates the separate conditions for small-signal performance, leakage, recovery, survivability, and absolute maximum ratings. Device-specific numerical limits are not transferred to the

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constructed assessment cases or to an unspecified assembled receiver. The component or engineering reference concerns protection against excessive RF drive and the nonlinear behaviour inherent in an input limiter. Front-end loss, limiting threshold, recovery time and spectral products should be checked against the actual arrangement before characterising a faint signal. A protection device that prevents damage does not guarantee accurate level measurement or freedom from in-band artefacts. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Chapter 4. Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses

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4.1 Frequency Conversion as Multiplication

A mixer combines an RF input with a local oscillator and produces components related to sums, differences, harmonics, and device nonlinearity. In an ideal multiplication model, the desired first-order products are easy to predict. Practical mixers also exhibit port leakage, conversion loss, impedance sensitivity, intermodulation, direct feedthrough, and products involving harmonic indices. The selected intermediate frequency is therefore one member of a larger product set.[1]

Frequency conversion can occur in active or passive devices, switching mixers, sampling mixers, image-reject structures, quadrature converters, and digital downconverters. Each architecture changes spur behavior, noise, dynamic range, and calibration. A receiver block diagram should identify the number of conversions, high-side or low-side injection, tunable ranges, fixed intermediate frequencies, and filter locations. Without that information, a displayed frequency may be assigned to the wrong external source.

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1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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4.2 Model 4A: a declared conversion map

A conversion calculation has two jobs: identify the frequency that a selected path will deliver, and preserve the amplitude and phase convention used to describe that delivery. The familiar absolute-difference expression performs only the first job for a real, first-order difference product. It does not state the loaded voltage gain, distinguish opposite complex-frequency signs, or identify the particular hardware mechanism that generated an observed peak. Model 4A supplies those missing conventions before using the retained Equations 7 and 8 in a challenge test.

Use positive RF and LO frequencies, a peak RF voltage A, and a nonnegative voltage scale g. The real multiplier is defined to multiply the RF voltage by twice g times a unit-amplitude LO cosine. The factor two makes the selected difference-product peak equal to $g\,A$. It is a normalization for this model. A physical mixer may have conversion loss or gain, and its source and load impedances, LO drive, and operating level determine the measured value. Analog Devices explicitly distinguishes an ideal multiplier from a switching mixer and explains why their scaling must be specified.[2]

In the equations, f_{RF} and f_{LO} are in hertz, t is in seconds, and the phases θ_{RF} and θ_{LO} are in radians. A and the selected voltage phasors are in volts; g is dimensionless. R_{RF} and R_{IF} are the positive loaded resistances in ohms, and P_{RF} and P_{IF} are powers in watts. The sign ε records conversion orientation

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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and is either plus or minus one away from zero difference. A decibel gain or finite power ratio additionally requires positive input and selected-output powers.

Equation 7A. RF and normalized real LO

$$x_{RF}(t)=A\cos\left(2\pi f_{RF}t+\theta_{RF}\right)$$
$$l_R(t)=2g\cos\left(2\pi f_{LO}t+\theta_{LO}\right)$$

Equation 7B. The two real multiplier products

$$y(t)=gA\cos\left(2\pi(f_{RF}-f_{LO})t+\theta_{RF}-\theta_{LO}\right)$$
$$+gA\cos\left(2\pi(f_{RF}+f_{LO})t+\theta_{RF}+\theta_{LO}\right)$$

The product identity follows by adding the cosine of the sum angle to the cosine of the difference angle. The sum term is removed only if the selected path rejects it. The remaining signed difference can be negative. Rewriting a negative-frequency cosine at positive frequency changes the sign of its phase, so high-side injection reverses the orientation of a small RF frequency change and conjugates the associated positive-frequency phasor. Taking an absolute value too early erases this information. At exact equality of RF and LO, the output contains a DC term; its power and phase conventions need separate treatment, so the present tone examples keep the difference nonzero.

Equation 7C. Selected difference and orientation

$$\Delta f=f_{RF}-f_{LO},\varepsilon=sgn(\Delta f),\Delta f\neq 0$$
$$f_{IF}=|\Delta f|,\theta_{IF}=\varepsilon(\theta_{RF}-\theta_{LO})$$

Voltage gain and power gain coincide numerically only after the impedance convention has been settled. With a loaded RF resistance and loaded IF resistance, both real and positive, average sinusoidal power is peak voltage squared divided by twice resistance. The selected product therefore has the

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power-gain expression in Equation 7D. This is a comparison between declared loaded planes. It is not automatically the available-power conversion gain that a data sheet quotes, and it does not justify replacing either impedance with a nominal value when a mismatched path is under test.

Equation 7D. Loaded selected-product power gain

$$P_{RF}=\frac{A^2}{2R_{RF}},\ P_{IF}=\frac{g^2A^2}{2R_{IF}}$$
$$G_P=\frac{P_{IF}}{P_{RF}}=g^2\frac{R_{RF}}{R_{IF}},\ A,g>0$$

An analytic complex representation keeps the sign of frequency. Let the RF analytic signal be a finite-band complex envelope translated to a carrier sufficiently high that its admitted band remains at positive physical frequency. Multiplication by a complex LO translates that band without folding. If the calculation starts with the real waveform, the conjugate band must be rejected and the factor-of-two normalization retained. The resulting sign convention must agree with the I/Q channel order and complex-exponential convention used in Chapter 10. A reversal of Q changes apparent frequency orientation even when every displayed magnitude looks reasonable.

Equation 7E. Complex conversion without frequency folding

$$x_a(t)=u(t)\exp\left(j2\pi f_{RF}t\right)$$
$$y_a(t)=gu(t)\exp\left(j\left(2\pi(f_{RF}-f_{LO})t-\theta_{LO}\right)\right)$$

For first-order real difference conversion, reflecting the desired RF frequency about the LO gives the conventional image. That reflected frequency is relevant only if it is physically positive and can reach the mixer through the actual RF path. A predicted negative value does not identify a

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second positive RF tone in the same simple architecture. At finite bandwidth, the whole admitted IF interval maps to two RF intervals. Preselection or a verified image-reject path is what separates them; the label on an IF spectrum alone cannot do so.

Equation 7F. Conventional image and RF interval mapping

$$f_{image} = 2 f_{LO} - f_{RF} > 0$$
$$f_{IF} \in [a, b], 0 < a \leq b$$
$$RF\ set: [f_{LO} - b, f_{LO} - a] \cup [f_{LO} + a, f_{LO} + b]$$
$$Retain\ only\ positive\ admitted\ RF\ frequencies.$$

Two external inputs that arrive at the same IF can be coherent. Their selected IF voltages then add before power is formed, with the high-side phase convention already applied. Depending on phase, the result can exceed or fall below the desired-only response. Power addition is valid when the measurement establishes zero cross power over its averaging operation. Merely calling one tone the image does not make it statistically independent. This distinction becomes especially visible in a controlled test where both generators share a reference.

Equation 7G. Coherent collision and the zero-cross-power condition

$$|a_d + a_i|^2 = |a_d|^2 + |a_i|^2 + 2\Re\left(a_d a_i^*\right)$$
$$\langle P \rangle = \frac{\left\langle |a_d|^2 \right\rangle + \left\langle |a_i|^2 \right\rangle}{2 R_{IF}} \text{ if } \Re\langle a_d a_i^* \rangle = 0$$

Equation 8 is best used as a bounded hypothesis generator. Choose integer indices and a finite search order from the known architecture, then calculate signed candidate frequencies before applying the real-output absolute value. A matching number is cheap to obtain if enough parent signals and integer combinations are admitted. Stronger evidence comes from a predeclared perturbation: change one parent or the LO by a known

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increment and predict the movement of each candidate. Away from a zero crossing, the signed movement follows the corresponding integer coefficient. Near a crossing, the absolute-frequency trace has a cusp, so a single constant slope no longer describes both sides.

Equation 7H. Bounded integer product search

$$F_{mn}=mf_{RF}+nf_{LO},f_{mn}=|F_{mn}|$$
$$m,n\in\mathbb{Z},1\leq|m|+|n|\leq K,K\in\mathbb{Z}_{¿0}$$

Equation 7I. Retuning a signed and an absolute product

$$\Delta F_{mn}=n\Delta f_{LO}$$
$$\Delta f_{mn}=|F_{mn}+n\Delta f_{LO}|-|F_{mn}|$$
$$\frac{df_{mn}}{df_{LO}}=n\,sgn(F_{mn}),F_{mn}\neq 0$$

Several conversion stages can reverse orientation more than once. Track a local signed derivative through each selected path. For a real first-order difference stage away from zero IF, the derivative is plus one for low-side injection and minus one for high-side injection. Multiplying these signs gives the orientation of the final selected output relative to a small original RF change, provided no stage switches path or crosses zero. A dual-conversion receiver may therefore have the same final IF in two settings while presenting opposite spectral orientation.

Equation 7J. Orientation through selected real difference stages

$$f_i=|f_{i-1}-f_{LO,i}|,\varepsilon_i=sgn(f_{i-1}-f_{LO,i})$$
$$\frac{df_q}{df_0}=\prod_{i=1}^{q}\varepsilon_i\quad\text{on fixed nonzero branches}$$

All ten applications below are constructed examples. Their numbers test the stated conversion map; they do not specify a commercial receiver, predict an unmeasured mixer spur amplitude, or establish an external source

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identity. The same discipline applies when a frequency plan is supplied by a manufacturer: confirm the active band-switch and correction state for the actual observation rather than treating a generic block diagram as the live configuration.

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4.3 Worked applications with hypothetical inputs

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4.4 Application 4A.1: Locate a low-side image

A desired tone is at 145.1 MHz and the LO is at 134.4 MHz. Subtracting gives a positive 10.7 MHz IF. Reflecting the desired tone about the LO gives 123.7 MHz, also 10.7 MHz from the LO. The desired and image inputs are separated by 21.4 MHz. This separation is a frequency-plan result; it says nothing about the rejection actually supplied by the front end.

The practical test uses separate calibrated injections at those two RF frequencies while holding the IF path and gain state fixed. A difference in output level can then be attributed to the two path responses under those conditions. If the generator level, preselector, or automatic attenuation changes between injections, the comparison no longer measures image rejection alone. The image frequency belongs in the challenge record even if no environmental signal is presently known there.

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4.5 Application 4A.2: Track high-side spectral inversion

Tune a 900 MHz input with a 970 MHz LO. The signed difference is −70 MHz and the real IF is 70 MHz. With RF phase 30 degrees and LO phase 10 degrees, the negative-frequency difference term has phase 20 degrees; expressed at positive 70 MHz, it has phase −20 degrees. The conventional image is 1,040 MHz. Increasing the desired RF tone by 1 MHz lowers the real IF to 69 MHz.

This example explains why a frequency axis cannot be calibrated from its center alone. A 70 MHz tone is compatible with either injection side, but a small known frequency step reveals orientation. In a complex recording, retain the signed frequency and I/Q convention as well. Conjugating a stored record to make its spectrum look familiar is a processing operation that must be recorded, especially if later phase or delay comparisons use that record.

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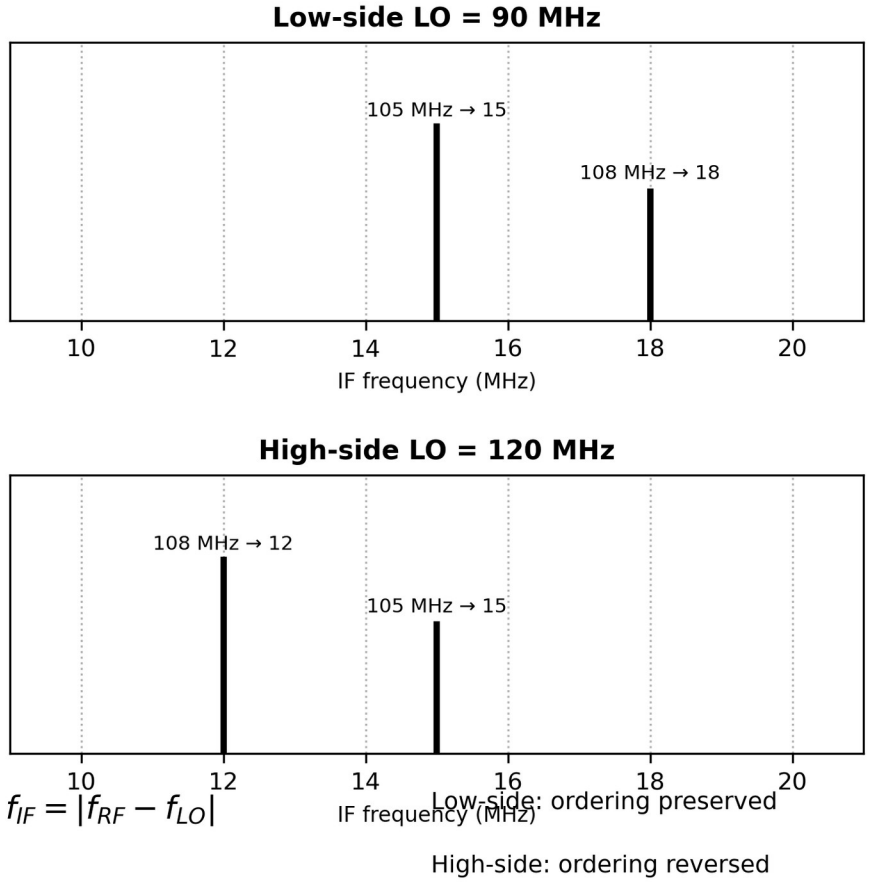

Figure 14. Spectral inversion and local-oscillator injection.

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4.6 Application 4A.3: Separate loaded voltage gain from power gain

Let the loaded RF peak be 0.2 V across 50 Ω, the selected-product voltage scale be 3, and the IF load be 200 Ω. The IF peak is 0.6 V. The input power is 0.4000 mW and the output power is 0.9000 mW. Their ratio is 2.25, or 3.5218 dB, although the voltage ratio is 3.

The corresponding levels are -3.9794 dBm and -0.4576 dBm. Applying twenty times the logarithm of 3 as a power gain would overstate the result because the output resistance is four times larger. The calculation is useful for checking a simulation or a loaded-voltage calibration. An available-power measurement requires its own source and load conditions and should not inherit these numbers without that conversion.

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4.7 Application 4A.4: Expose the multiplier normalization

Multiply a 1 V peak RF cosine by a unit-amplitude LO cosine with no leading factor two. Either selected product has peak 0.5 V. At equal 50 Ω resistances, the power ratio is one quarter, or -6.0206 dB. Reintroducing the model's factor two returns a 1 V selected-product peak and unity power ratio.

The apparent 6.0206 dB disagreement between those results is entirely a normalization difference. It is resolved by writing the multiplier equation, not by changing an RF calibration file. A digital downconverter may likewise use a scale factor that differs from a real mixer convention. Track that factor through the sampling and arithmetic models before reporting physical watts. The normalized mathematical multiplier is not a passive circuit whose energy balance has been established.

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4.8 Application 4A.5: Allocate image rejection ahead of equal conversion

Suppose the desired input is −90 dBm and an image-frequency input is −30 dBm. The preselector loses 3 dB at the desired frequency and 70 dB at the image; both selected conversion paths then have −6 dB gain. The desired output is −99 dBm, while the image output is −106 dBm. The desired signal is only 7 dB above the image despite the apparently large 70 dB rejection figure.

To obtain a 10 dB desired-over-image margin with the other assumptions unchanged, the image path needs at least 73 dB loss. The calculation compares the external level difference with the differential path loss. It also assumes the strong image input has not compressed a preceding component or changed gain. If it does, the linear subtraction is no longer the relevant acceptance result; the blocker tests in Chapter 11 must be applied to that state.

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4.9 Application 4A.6: Combine coherent desired and image fields

Let the selected desired IF peak be 1 mV and the image contribution 0.25 mV at the same frequency. Relative phases of 0, 90, and 180 degrees give powers 1.5625, 1.0625, and 0.5625 times the desired-only power. Those ratios are 1.9382, 0.2633, and -2.4988 dB, respectively.

The zero-cross-power sum is 1.0625 times the desired-only power. It happens to equal the coherent 90-degree result, but the reason is different: the coherent cross term vanishes at that phase, whereas an incoherent average requires a justified averaging relationship. A single power reading therefore cannot distinguish those mechanisms. Varying relative phase in a controlled injection can expose the collision; assuming independent powers would conceal the possible cancellation.

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4.10 Application 4A.7: Keep opposite complex-frequency bins distinct

A complex converter with a 10 MHz LO receives a tone at 10.01 MHz or, in a separate trial, at 9.99 MHz. Their baseband frequencies are +10 kHz and −10 kHz. At 50,000 complex samples per second with a 100-point DFT, the ordinary array indices are 20 and 80. Under the signed-bin convention they are +20 and −20.

A real magnitude display at 10 kHz could show either input, while the correctly ordered complex record distinguishes them. This is a useful end-to-end acceptance stimulus because it simultaneously tests tuning sign, I/Q order, and frequency-axis labeling. The discrete frequencies still belong to sampling equivalence classes, so the analog admitted band in Chapter 10 remains part of the claim. Complex representation does not eliminate aliases outside that band.

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4.11 Application 4A.8: Test the movement of a candidate harmonic product

An RF parent at 103 MHz and an LO at 100 MHz give the candidate $2f_{\mathrm{RF}} - 2f_{\mathrm{LO}}$ at 6 MHz. Raising the LO by 0.1 MHz moves that candidate to 5.8 MHz, a slope of −2 Hz per hertz of LO change. The first-order difference instead moves from 3 to 2.9 MHz, with slope −1. The two hypotheses make different, testable movement predictions.

Before retuning, specify the IF band in which both observations remain measurable and the tolerance allowed for frequency estimation. A measured slope near −2 supports this candidate relationship, but it still does not identify the nonlinear device or rule out another clock-derived combination with the same slope. A second independent parent change, a level-dependence test, or a path bypass can discriminate further. Products that disappear into the filter during the first change remain unresolved by that observation.

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4.12 Application 4A.9: Track inversion through two real conversions

The first conversion again uses 900 MHz RF and 970 MHz LO, giving a real 70 MHz IF with reversed orientation. A second LO at 60 MHz produces a 10 MHz output without another reversal. A second LO at 80 MHz also produces 10 MHz, but adds a second reversal. Increasing the original RF by 1 MHz consequently gives 9 MHz in the first arrangement and 11 MHz in the second.

The final center frequency is identical in both arrangements, so a center-tone verification misses the difference. A two-tone or small frequency-step check establishes the final axis orientation. The recorded configuration should retain both LO choices, including any automatic change at a band boundary. If a later analysis compares phase or modulation sidebands across that boundary, it must use the appropriate orientation for each segment.

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4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals

A real converter uses a 100 MHz LO and admits positive IF frequencies from 9.9 through 10.1 MHz. The corresponding upper RF interval is 109.9 through 110.1 MHz, and the lower interval is 89.9 through 90.1 MHz. Both intervals therefore belong in the external-source search and preselector verification. A single image center frequency would leave their edges unexamined.

Here the admitted interval is an ideal set used to make the mapping exact. A real filter has a transition response and a measurement threshold, so its useful admission boundary must be defined from the intended decision. For amplitude calibration, the acceptable flatness may determine the band; for a spurious-response challenge, a much weaker skirt response may still matter. Use the same frequency map with the measured weighting rather than pretending that the labeled bandwidth is a perfect rectangle.

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4.14 Local-Oscillator Purity and Leakage

The local oscillator determines tuning accuracy and contributes phase noise, harmonics, subharmonics, reference spurs, and modulation. Leakage from the LO to the RF input or antenna can radiate outside the receiver, couple into nearby systems, or be detected by another instrument. Reverse isolation depends on mixer type, switching, preselection, input termination, and gain state. A receiver used in a sensitive area may therefore be both a sensor and an unintended emitter.

LO leakage tests compare terminated and connected inputs, change tuning while observing with an independent receiver, and vary preselection or isolation. The test should separate radiation from the receiver enclosure, cable common-mode current, and re-radiation through the antenna. A detected LO component identifies receiver activity but does not by itself expose the complete tuning plan or prove that the instrument is malfunctioning.

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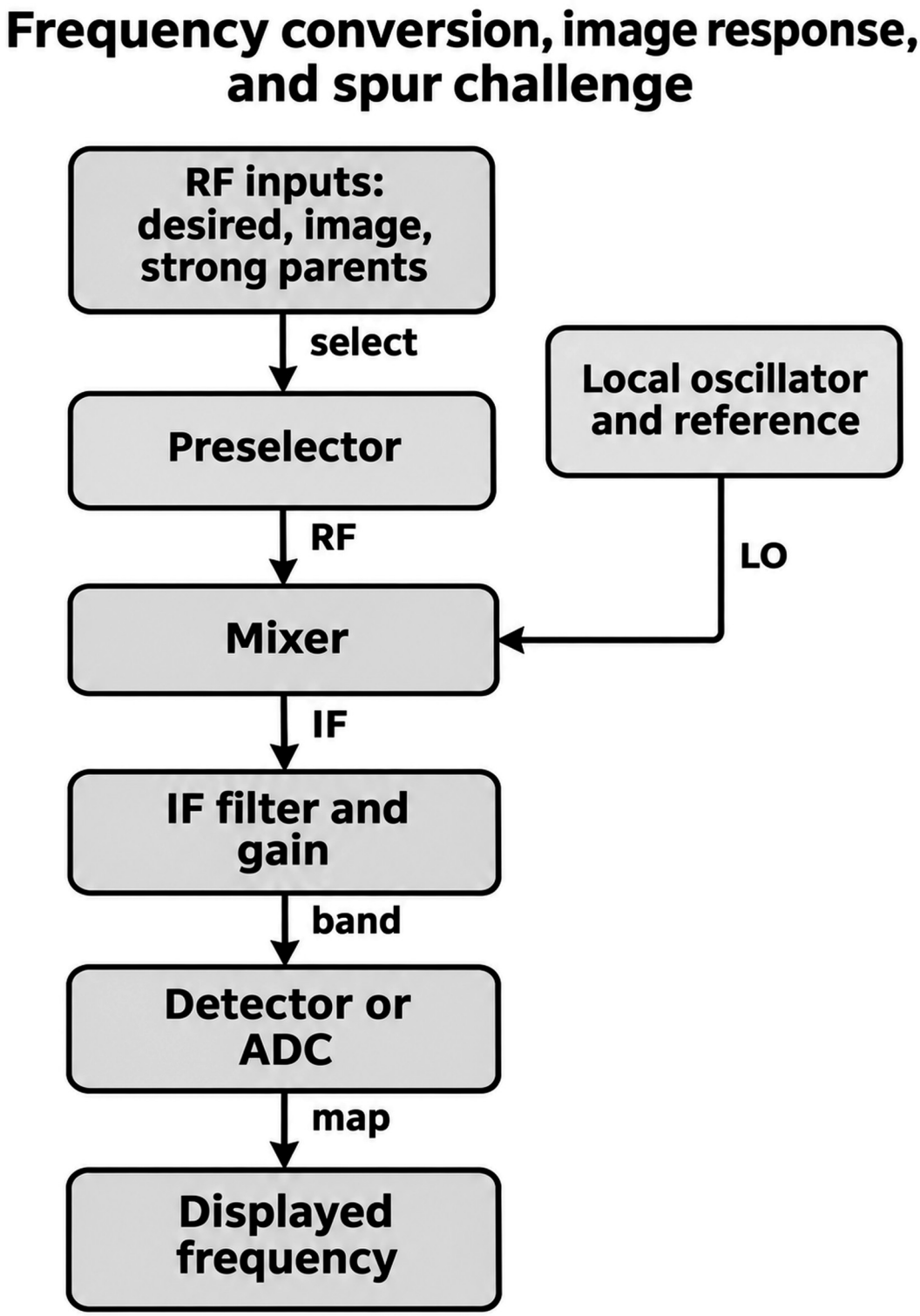

Figure 15. Frequency conversion and image responses.

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4.15 Image Responses and Image Rejection

An image frequency is an unwanted RF input that produces the same intermediate frequency as the desired input. Image location depends on the injection scheme and IF. Preselection and image-reject mixing suppress the response, but rejection varies with frequency, alignment, amplitude, temperature, and quadrature balance. Direct-conversion receivers avoid a conventional first IF image but introduce other challenges, including DC offset, even-order distortion, LO leakage, and I/Q imbalance.

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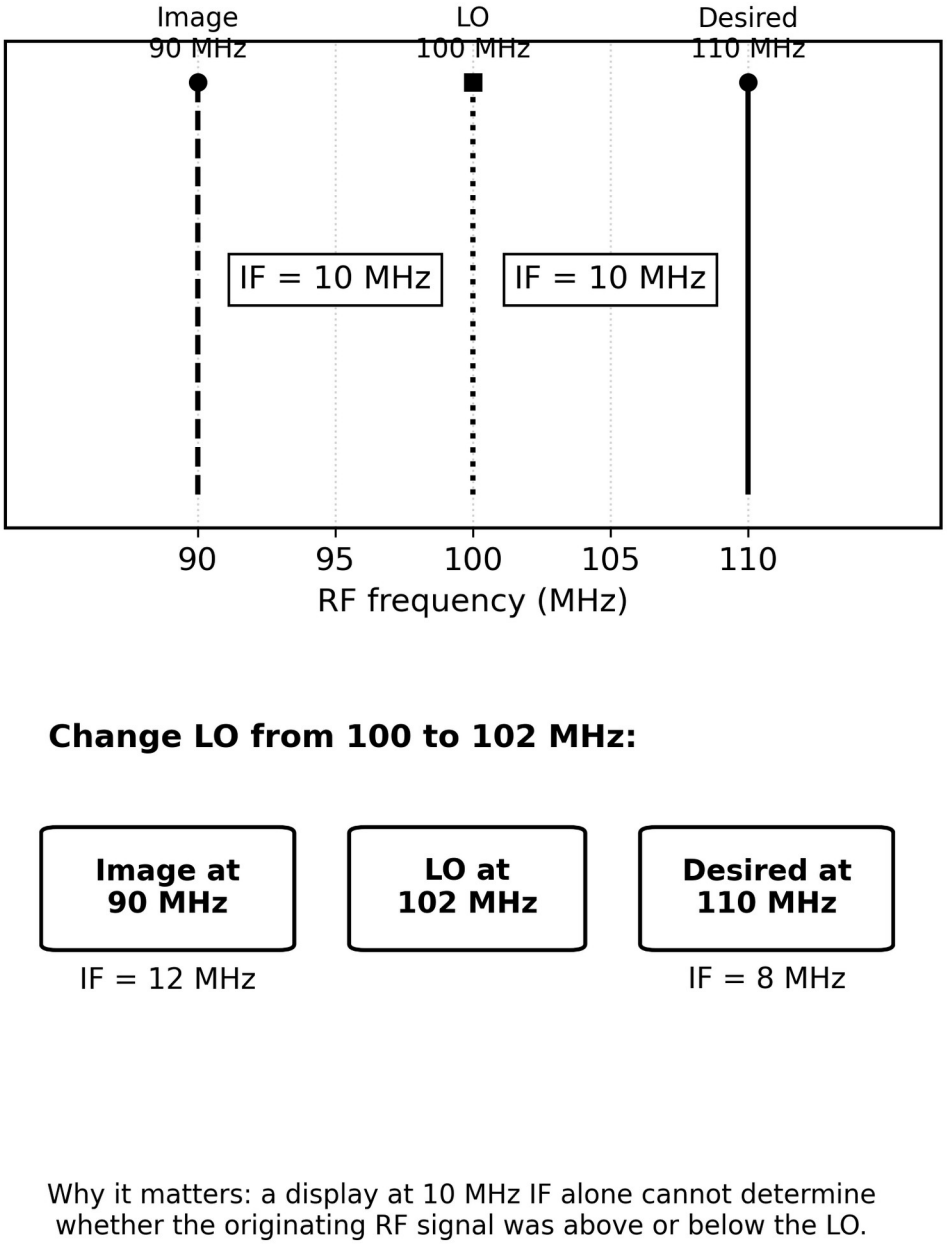

Figure 16. Image-response folding and oscillator retuning.

Image testing injects equal calibrated signals at the desired and predicted image frequencies and compares the indicated outputs under identical settings. The source path must not itself generate harmonics or leak through switches. Strong images can also arise from overloaded front ends

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or filter bypass paths. A signal seen at one displayed frequency is not attributed until image and alias possibilities have been challenged.

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4.16 Spur Tables and Product Search

Spurious responses can be organized with product indices m and n, where an output occurs near $|mf_{\mathrm{RF}} \pm nf_{\mathrm{LO}}|$ or from combinations of multiple input signals. Real receivers add harmonics of references, synthesizer dividers, clocks, ADC sample rates, digital numerically controlled oscillators, and power converters. Spur tables should therefore combine analog and digital architecture rather than listing only mixer products.

A practical search begins with measured strong signals and known internal clocks. Candidate products are calculated and compared with the observation. The test then changes one parent frequency, input level, attenuation, LO plan, sample rate, or reference clock. A true product moves or changes according to the generating relationship. This challenge is more persuasive than a numerical coincidence between one observed peak and one predicted formula.

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4.17 Conversion Gain, Loss, and Calibration

Conversion gain or loss is measured between declared RF and IF reference planes with specified LO drive, source and load impedance, frequency, temperature, and signal level. Mixers can compress on total input power or on LO disturbance. Filters and amplifiers around the mixer contribute to the measured result, so de-embedding is needed if the mixer alone is the measurand.

Calibration of a tunable receiver may contain frequency-dependent corrections for preselection, mixing, IF gain, detector, and digitizer response. Those corrections can become invalid after repair, firmware change, alignment, or option change. Independent verification at several points across each band is preferable to assuming a single correction. Spur-free performance also requires tests at several input levels because some products grow faster than the desired response.

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4.18 From a product map to a discriminating test

Start a conversion challenge by recording the complete active plan: antenna or injection port, preselector, attenuation, amplifier state, every known LO and IF, selected bandwidth, detector or sample path, and frequency-reference state. Mark the external reference plane and the point at which the output is measured. A direct-sampling mode, an alternate first IF, and an image-reject mode are different configurations even if the front-panel center frequency is unchanged. Confirm the path with a known tone before applying a strong parent or image stimulus.

For each candidate response, write a predicted change that could be observed without destroying the measurement. An image challenge changes the injected RF frequency while preserving its input level. A spur movement challenge changes one parent frequency. A level challenge changes a known parent while keeping the desired reference measurable. A leakage challenge compares a terminated input with controlled coupling paths and, where appropriate, an independent receiver. The useful result is the relationship between controlled change and response, not the largest collection of screenshots.

Stimulus purity is part of the experiment. A generator harmonic can enter through the desired path and imitate receiver image response. Two combined sources can intermodulate in a passive junction or in one source output before reaching the receiver. Attenuation and isolation between sources, a terminated-path check, and an independently measured source spectrum constrain these alternatives. If the stimulus cannot be verified at

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the required level, report a bound or an unresolved result rather than assigning all observed output to the receiver.

Keep movement and amplitude evidence separate until the observations justify joining them. A frequency relationship can be accurate even when compression makes the amplitude response invalid. Conversely, a stable calibrated amplitude can belong to an image whose external frequency was misidentified. A conversion-state boundary may change both path loss and orientation. Repeat a small known frequency step and a level reference on each side of the boundary, then compare each environmental observation only with the applicable state.

A response that survives these tests still requires an appropriate external claim. The tests may establish that energy entered through an RF path, that it is compatible with one source frequency, or that a particular internal product is favored. They do not by themselves locate an emitter or identify an operator. Chapter 16 turns these bounded conversion results into an artifact-discrimination record with explicit competing explanations and unresolved outcomes.

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4.19 Conversion-State Challenge Protocol

Receiver conversion states are challenged across adjacent bands, high-side and low-side injection, alternate IF paths, and direct-sampling modes where available. The test matrix includes known desired signals, predicted images, selected harmonic products, terminated-input residuals, and strong out-of-band parents. Results are captured at more than one input level so that response slope can distinguish linear transfer from nonlinear generation.

A conversion-state change is treated as a configuration event. Native setup files, correction tables, synthesizer lock state, and band-switch boundaries are preserved. When a signal appears only in one conversion plan, the report explains whether the evidence supports an external source, an image, an LO-related product, or an unresolved mechanism.

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4.20 Quantitative Model for Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses

Equation 1. First intermediate-frequency relation

$$f_{\mathrm{IF}} = \left| f_{\mathrm{RF}} - f_{\mathrm{LO}} \right|$$

For a first-order difference conversion, the intermediate frequency equals the absolute difference between RF and local-oscillator frequencies. Sum conversion and higher-order products must also be considered in a practical receiver.

Equation 2. General mixer-product family

$$f_{\mathrm{spur}} = \left| m f_{\mathrm{RF}} \pm n f_{\mathrm{LO}} \right|$$

A candidate spur can occur at integer harmonic indices m and n. The expression is a search aid, not proof that a product exists. Device nonlinearity, filtering, port isolation, and input amplitude determine observable products.

Model 4A and Applications 4A.1–4A.10 retain the sign of the selected conversion before forming the magnitude in Equation 7. Its integer product lattice supplies Equation 8’s candidate locations. Product order and receiver measurements are needed to decide which candidates have appreciable amplitude.

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Table 1. Chapter 4 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
LO plan	Frequency, injection side, tuning range, step, reference, and phase noise	Maps display frequency to physical conversion	Undocumented conversion stages create ambiguous attribution
Image response	Predicted image, injected level, desired response, and rejection	Tests an alternate external frequency producing the same IF	Overload or leakage can imitate a poor image response
Spurious product	Parent frequencies, indices, input levels, attenuation, and movement test	Explains internally generated peaks	A numerical frequency match alone is weak evidence
Conversion calibration	RF and IF planes, LO drive, gain or loss, impedance, and temperature	Supports corrected amplitude across bands	Repairs and firmware changes can invalidate stored correction

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4.21 Hypothetical Applied Calculation: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses

A superheterodyne receiver uses a 70 MHz first IF and high-side injection. Tuning 900 MHz places the LO at 970 MHz. An input at 1.040 GHz also converts to 70 MHz and is the first image. A 1.040 GHz test signal should therefore be included before attributing a displayed 900 MHz component.

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4.22 Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses

A recurring peak is displayed at 312.5 MHz on several antennas. Changing the receiver reference clock from its internal 10 MHz source to a verified external reference shifts the peak by the exact fractional clock change, while a second receiver shows no external signal. The clock-dependent movement supports testing a clock-related mechanism. Equation 23I also shows how clock calibration can move the displayed frequency of a fixed external tone. Distinguishing an internal spur from that relabeling requires the actual LO and sample-clock mapping, an independent physical-frequency reference, and a comparison receiver with characterized sensitivity and coverage. The stated observations leave that classification open.

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4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas

A mixer is a time-varying system whose outputs cannot be interpreted solely by naming a nominal intermediate frequency. For a real product mixer fed by sinusoids at f_{RF} and f_{LO}, the first-order output contains components at $|f_{RF} - f_{LO}|$ and $f_{RF} + f_{LO}$. In practical receiving chains harmonics of the oscillator, input and other local clocks can yield additional combinations $m f_{RF}$ plus or minus $n f_{LO}$, with integer orders m and n determined by the nonlinear mechanism and effective filtering. The frequency relation predicts where an artefact might occur; it does not determine its amplitude without the circuit's conversion response and drive conditions. Importantly, a receiver's software frequency label may use a chosen sign convention for complex sampling that differs from the spectrum of real intermediate-frequency voltage. Record the convention explicitly before interpreting a spectral mirror as an independent radiating source.

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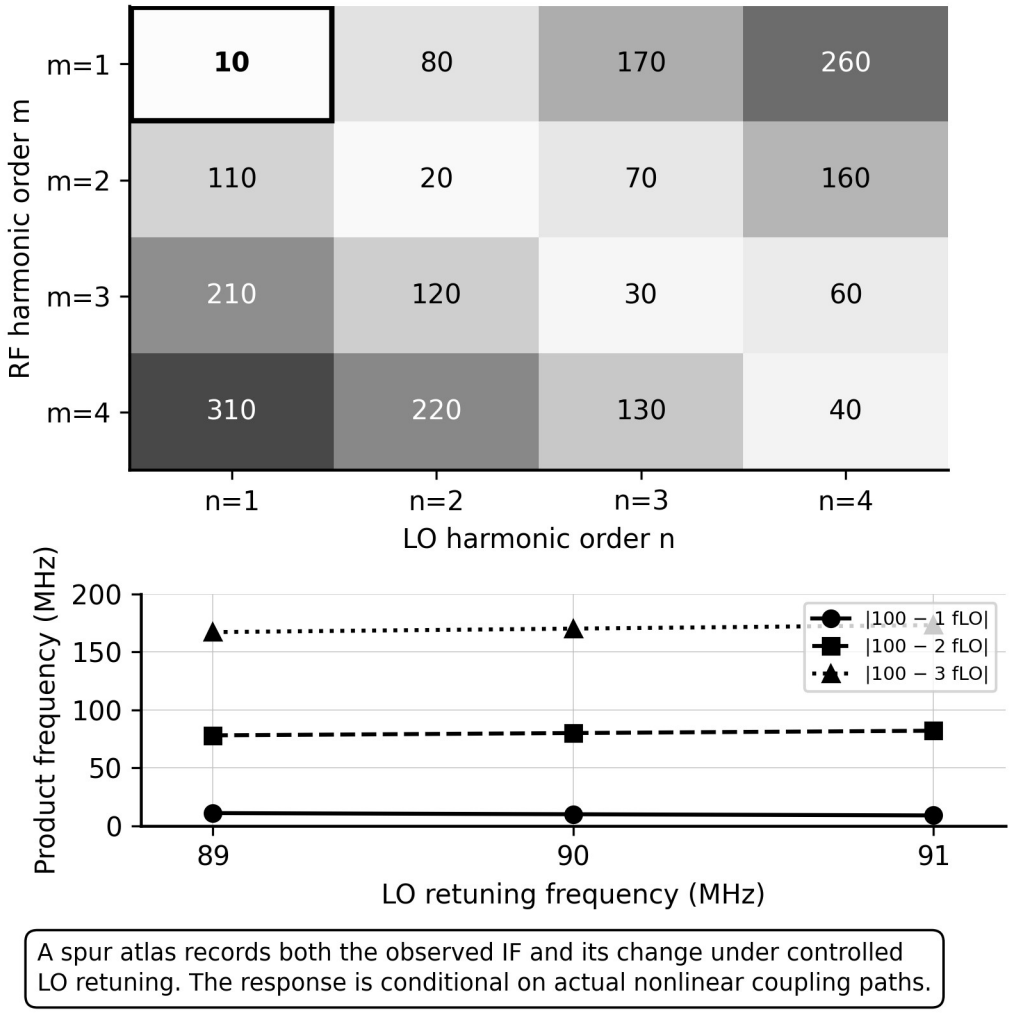

Figure 17. Mixer harmonic products and spur lattice.

An instrument-specific spur atlas should be built with input-port terminations and calibrated reference sources, at several local oscillator settings and gain states. Index each candidate feature by physical output frequency, displayed frequency, local oscillator frequency, source settings

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and known aliases. Predict the differential slope of a candidate under a controlled oscillator shift: a first-order desired conversion may shift in a documented direction, whereas a locally generated fixed clock harmonic can remain at a fixed physical output or move according to a different order. A change in displayed position is not evidence of external motion unless the software frequency mapping and its state are established. Coupled oscillators, leakage into the antenna path and synthesiser fractional spurs can defeat a simplistic one-frequency challenge, so alternative controls are indispensable.

For a purely numerical illustration, a 120 MHz real input mixed with a 100 MHz oscillator generates first-order terms at 20 MHz and 220 MHz. If the IF chain passes 20 MHz, a different real input at 80 MHz can also yield 20 MHz before preselection, creating the familiar image ambiguity. A calibrated RF filter that passes 120 MHz while strongly rejecting 80 MHz can discriminate these two source possibilities, provided its actual transfer and the mixer's operating state are known. A software frequency-label convention cannot by itself eliminate the ambiguity. The laboratory should repeat the comparison with a known reference injected at each potential RF input and record the physical IF output, rather than assuming that an ideal sideband diagram describes the installed hardware.

Reciprocal mixing complicates the atlas because a strong blocker and oscillator phase-noise sidebands can produce a raised background in the desired IF channel without a stable discrete new line. The relevant calculation integrates the blocker's converted noise contribution through the channel response and the oscillator noise spectrum under a clearly stated normalization. A single phase-noise value at one offset is not

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sufficient for arbitrary channel shapes. Separately document synthesiser lock transitions, fractional-divider configuration and reference-source changes. The result is a falsifiable catalogue of observed and predicted instrument products, not a universal guarantee that an unlisted spectral component must have arrived from the environment.

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4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels

Consider a receiver with two translation stages. For each stage the algebraic image of an input frequency depends upon whether the local oscillator is above or below the selected radio-frequency component, and upon the sideband that the subsequent filter retains. A positive absolute frequency on an instrument screen can conceal a reversal of spectral orientation, since a waveform described through complex analytic coordinates retains a sign convention that a magnitude display discards. Define the first local oscillator f_{L1}, the second oscillator f_{L2} and the signed offsets f_1 and f_2. Under an expressly chosen complex mixing convention, a desired first translation can be written $f_1 = f_{RF} - f_{L1}$ and the next $f_2 = f_1 - f_{L2}$. The recorded frequency must also include the choice of analytic sideband and the final sampling convention. Substituting magnitudes at every step destroys signs and can lead an analyst to assign two physically different RF frequencies to the same displayed line. Forensic frequency inference therefore calls for an ordered mapping table, not a single arithmetic subtraction.

A mixer does not operate as a perfect multiplication by one pure sinusoid. Practical switching waveforms contain harmonics, local-oscillator paths can leak to the input or output, and finite isolation admits coupling that depends upon termination and bias state. An observed product may be approximated by $f_p = |m f_{RF} + n f_{LO}|$ for specified signed integers m and n, but a catalogue of possible integer combinations does not prove that any particular product is generated with observable amplitude. The relevant

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nonlinear order, conversion gain, excitation level, port impedance, mixing direction and filtering determine whether the product is physically plausible. A spur atlas should therefore contain a predicted frequency, a predicted level or bounded level if known, an instrument state, a reference-plane statement, and a discriminating test. Merely finding integers that explain a frequency is vulnerable to post hoc pattern matching when many candidate carriers and oscillators are present.

The analyst should distinguish three responses to a controlled change in first-oscillator frequency. A genuine external input at a fixed RF frequency follows the selected frequency-translation law; a product involving the local oscillator may move at an integer multiple of the commanded change; and a digitally generated display marker may remain fixed in bin coordinates while its indicated physical frequency shifts with the software frequency origin. This experimental distinction fails when the receiver retunes the preselector or changes intermediate-frequency plans automatically at the same time. Retain actual synthesizer readback, not merely the requested tuning command. If a local oscillator is fractional-N synthesised, a change in its fractional division sequence may also alter the spur distribution without materially changing its nominal centre frequency. Harmonic arithmetic is a map of hypotheses rather than an independent validation of the synthesiser's spectral purity.

For an illustrative acceptance exercise, take an RF candidate at 2,410 MHz and a first oscillator at 2,300 MHz, with selected difference IF 110 MHz. A separate RF input at 2,190 MHz can produce the same 110 MHz magnitude as an image through the corresponding difference term. A first-stage preselector with only 3 dB rejection of the image frequency cannot by itself

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establish a single-valued inverse from IF to RF. If its measured rejection is 65 dB at 2,190 MHz and the actual interferer powers are bounded, the image hypothesis may be weakened quantitatively, but it is not eliminated by naming the filter alone. A second RF source placed at the predicted image frequency can challenge the architecture in a controlled setting. The test must also establish its own source harmonics, combiner isolation and output calibration to avoid attributing a generator product to the receiver.

Image-reject and quadrature mixers add a complex-balance problem. With ideal in-phase and quadrature paths a selected sideband cancels at one combination, but amplitude mismatch and phase error leave a residual. A small calibration error might be negligible at a weak input yet devastating when a strong image lies tens of decibels above the desired component. Define separate amplitude balance, phase balance, frequency dependence, temperature and LO drive as measurement inputs. A quoted image-rejection ratio measured at one frequency and one gain setting is not a certificate covering every input band or dynamic state. It should be measured using an independent reference that challenges both spectral sides over the proposed operating interval. In particular, correction algorithms should not fit and certify themselves on the same dataset.

Conversion loss is itself a calibrated measurement, not just a number that can be copied from a component catalogue. A two-port small-signal ratio may omit image-side noise, mismatch and pumped nonlinear source dependence. If an apparent receiver noise figure is computed from a mixer whose data sheet uses a double-sideband convention, the model and measured quantity must be reconciled before the value enters a selected-channel single-sideband cascade. Similarly, when a conversion product

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appears at a frequency predicted by multiple nonlinear pathways, an amplitude-versus-input-level sweep may discriminate second-order, third-order and other mechanisms only within a range where the slopes are observed consistently. Amplifier compression, interstage filtering and source impurity can invalidate a simple integer-slope expectation.

The engineering chapter should culminate in a reproducible frequency-plan examination: declare the oscillator frequencies and phase conventions; trace desired and image paths through every stage; compute candidate spur combinations within a justified order range; measure relevant rejection and transfer states; vary one source frequency or amplitude at a time; document actual LO state and lock quality; and preserve both accepted and rejected explanations. The resulting map permits the reviewer to ask a precise question about each suspicious line rather than accepting the most elegant arithmetic coincidence as proof of its origin.

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4.25 Additional study: switching mixers as periodically time-varying multiport networks

A frequency mixer is frequently introduced as a multiplier, but this elementary representation neglects how a physical switching network couples three ports and the terminations attached to them. The multiplication model is useful because it correctly predicts translations of a deliberately small signal under a specified sinusoidal local oscillator. It is not, without further qualification, an adequate model of the energy distribution in a diode ring, an active Gilbert cell, or a converter exposed to several strong signals. An advanced treatment must distinguish a mathematical multiplication operator from a periodically time-varying network, whose operating point and internal junction impedances are functions of both local-oscillator phase and applied radio-frequency voltage. This distinction matters for forensic receivers because a spectral feature may be an image, a harmonic mixing product, leakage from another port, or a genuine input signal that has been translated into the same output passband.

Consider a symmetric idealised polarity-reversing switch, with switching function $s(t)$ that is $+1$ during the positive half of a local-oscillator cycle and -1 during the negative half. Its Fourier series contains odd harmonics: $s(t) = (4/\pi)[\cos(\omega_{LO} t) - \cos(3\omega_{LO} t)/3 + \cos(5\omega_{LO} t)/5 - \ldots]$, for a suitable choice of phase origin and Fourier convention. A small signal $v_{RF}(t)$ multiplied by $s(t)$ produces translated components near odd multiples of the switching frequency, not solely near the fundamental. With a single input $v_{RF}(t) = A \cos(\omega_{RF} t + \varphi)$, the fundamental term generates output tones proportional to $2A/\pi$ at angular frequencies $|\omega_{RF} \pm \omega_{LO}|$. The actual port

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loading, filter response and available power set the realised conversion loss. The coefficient 2/π describes a waveform-amplitude result under the stipulated ideal switch convention; it must not be applied as a universal measured conversion factor at a nominal fifty-ohm connector. A diode ring's commutation quality, balanced transformers, lead parasitics and output termination can all alter the ratio. This is one reason an input-to-output calibration must specify the local-oscillator drive and the third-port load in addition to its centre frequency.

There are at least three distinct levels at which the ideal switch model can fail. First, a local oscillator that does not completely commutate the switching elements creates intervals of intermediate conduction, modifying desired conversion loss, isolation and higher-order content. Secondly, finite transformer balance permits an LO-derived voltage at the RF or IF port even when the desired small-signal transfer is acceptable. Thirdly, large RF inputs influence the conduction state and generate terms beyond the linear periodically switched response. The third effect is not always visible as ordinary one-decibel compression. A converter may produce an unwanted mixing component that compromises an adjacent weak-signal channel while the desired tone remains close to its normal level. The relevant acceptance envelope therefore includes in-band distortion, spurious response and phase integrity at the levels and modulation conditions of interest; it cannot be replaced by a single compression-number comparison.

A useful engineering representation is to assign a measured complex transfer coefficient $H_k(f_{RF}, P_{RF}, P_{LO}, Z_{RF}, Z_{IF}, T)$ to each allowed mixing order k. The arguments identify RF frequency, RF level, LO drive, loaded RF and IF impedances, and physical temperature. The output near

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frequency $f_{RF} + k f_{LO}$ is then modelled by the input complex amplitude multiplied by H_k, provided small-signal superposition remains valid in the chosen operating domain. Unlike a simple product-frequency table, this representation records amplitude and phase as well as frequency location. It also makes clear why an observed line at the predicted frequency is insufficient proof of a particular mechanism: a source harmonic or signal-generator intermodulation product can enter through an entirely different route. The coefficient is an experimentally characterised property of a particular complete state, not a presumed number from an ideal circuit diagram.

The test fixture has an evidential role. A two-tone measurement that combines generators through an inadequately isolated passive combiner can generate third-order products in the generators themselves. A spectrum analyser attached to the IF output may additionally overload on LO feedthrough, rendering the observed distortion a property of the instrument used to characterise the mixer. The remedy is to verify source spectral purity at the actual mixer input, to characterise the combining path and terminating impedances, and to use enough independently measured attenuation or filtering to keep the observing receiver in its accepted state. The measurement plan should specify where each frequency component is measured, how levels are referred through the fixture, and which artefact mechanisms remain unexcluded. Independent signal-source and observation controls should be repeated after a component is declared anomalous, not merely performed once at the beginning of a test campaign.

A converter's apparent image selectivity requires the same discipline. In a real scalar downconverter, two RF frequencies symmetrically located about

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the LO can produce the same positive difference frequency. RF preselection may remove one of those possibilities, but only when its transfer and actual switching state are demonstrated at the image frequency. In a complex I/Q converter, the two spectral signs can be distinguished if quadrature phase and amplitude match the applied correction model. At high frequencies or over broad instantaneous spans, the ratio between the desired complex response and the conjugate leakage response becomes a function of frequency. A single image-rejection number measured at the centre of a band cannot certify every channel in a wide receiver. A defensible acceptance test therefore sweeps both desired and image input families across the full working frequency interval and independently measures the phase response of the complex channel.

The state of the source must be included in the validity claim. A local oscillator synthesiser can change phase-noise density, output level or fractional-N spur structure between tuning states, even if the displayed LO frequency is exact. The mixer may also experience LO pulling through coupling from a strong RF source. These behaviours are relevant to a technical-surveillance examination where an intermittent external event and a spur produced by the instrument may coincide for only one synthesiser configuration. A useful counterfactual test changes LO frequency by a known increment while maintaining the same RF input environment and repeats it with a separately synthesised reference. An external RF signal and a converter-order product generally predict different shifts in output frequency. The comparison becomes persuasive only after confirming that the LO change did not also alter hidden preselection, gain, acquisition bandwidth or receiver saturation.

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The relation between measurement and inference should be written as an explicit proposition. An observation may establish that an IF component moved by a measured frequency increment when LO frequency changed. It may support the bounded interpretation that a known mixing order explains the movement. It cannot, without additional evidence, establish that the RF input was absent, that the component originated entirely inside the receiver, or that every other product sharing the same frequency was excluded. Forensic strength comes from discriminating experiments that alter a relevant causal mechanism while retaining observation capability. This chapter's new treatment extends the existing signed-frequency maps by requiring measured amplitude, phase, load and state-dependent coefficients for any numerical claim about a physical converter.

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4.26 Experimental protocol: comparing passive and active conversion

The comparison begins with two separately qualified paths operated at common RF, LO and IF reference planes. In the passive path, measure loss and port isolation while varying LO drive over a specified range without exceeding any rating. In the active path, measure conversion gain, bias dependence and its corresponding noise and compression behaviour. Do not compare a passive mixer's conversion loss with an active mixer's voltage gain without first reconciling load impedance, delivered versus available power, and output noise. A fixed IF amplitude can conceal a large difference in input sensitivity when the active path contributes more noise. Conversely, an active converter with useful gain may place downstream filters or analogue-to-digital converters closer to overload, even when its nominal RF input limit has not been reached.

Take a matrix of RF test frequencies, LO frequencies, levels and temperatures. At each matrix point record the desired converted tone, the corresponding unwanted image response, LO-to-IF and LO-to-RF feedthrough, the noise floor in a declared equivalent bandwidth, and evidence of clipping or gain changes. A differential comparison between the two topologies is meaningful only on the intersection of their valid operating ranges. If one mixer requires a drive level or bias that cannot be maintained over the full band, that part of the matrix should be labelled inapplicable rather than filled by extrapolation. If output correction files are interpolated between measured reference points, the interpolation method and uncertainty become inputs to the comparison.

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For a constructed numerical illustration, let a passive mixer have an RF input of −65 dBm and calibrated conversion loss of 7.2 dB at a specified LO drive. Its expected desired IF output is −72.2 dBm before downstream gain. An active mixer with 9.5 dB conversion gain at the same input instead predicts −55.5 dBm. The difference of 16.7 dB in output level is not an equal improvement in sensitivity: the comparison needs each path's noise contribution, linearity, dynamic range and load conditions. If the active mixer's gain becomes 7.5 dB under a different blocker state, the uncorrected output changes to −57.5 dBm even when the input source remains constant. A display that applies the old 9.5 dB correction could then overstate or understate the input depending on its convention. This example is hypothetical; it is not evidence about a manufacturer component.

A second constructed test assigns desired and image transfer levels of −6 dB and −46 dB respectively at one frequency, resulting in 40 dB image rejection for equal injected inputs. At another frequency the corresponding levels are −8 dB and −33 dB, yielding 25 dB rejection. The apparent 15 dB deterioration could originate in the RF preselector, quadrature error, conversion response or the measurement fixture. The proper test retains a vector transfer measurement and repeats the image injection with independent source and receiver paths. A catalogue value of 40 dB at one reference frequency cannot be applied without qualification to a survey at the second frequency.

A third test probes an IF line suspected to be a harmonic translation. Suppose the nominal RF frequency is 915 MHz and the LO is 900 MHz. The first-order difference is 15 MHz. If the LO is increased to 901 MHz while the

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same RF source is held fixed, the difference falls to 14 MHz. A line that instead rises by 3 MHz is incompatible with this simple first-order difference model, although it might satisfy a different converter order or arise from an internal synthesis product. The examiner should log the measured movement, not assert a frequency-order attribution from the output alone. The final decision is a comparison of predicted trajectories across several independent LO changes, with each relevant source, image and receiver response calibrated.

The production outcome of this protocol is a converter acceptance surface, not a single recommended mixer type. It identifies the subset of frequency, signal level, blocker condition, temperature and LO state for which a chosen transfer coefficient and uncertainty are supported. Outside that subset, the study retains uncertainty about the conversion law. The model is falsifiable because a held-out test condition can be applied after the acceptance surface is frozen; disagreement is then recorded as evidence of model inadequacy or previously uncharacterised state dependence, rather than repaired silently by editing the coefficient table.

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4.27 Advanced technical expansion. Harmonic-mixing lattices and an inverse interpretation of observed spurs

A frequency converter cannot be adequately understood by writing only fIF = |fRF - fLO|. The observed output may contain an entire lattice of frequencies generated by harmonics of the RF input and local oscillator, nonlinear interactions between multiple RF tones, leakage paths and later aliasing. An analytical search begins with signed frequencies f = m fRF + n fLO for bounded integers m and n, augmented by multitone terms when the RF input contains several sources. The index set must be physically restricted by a characterised nonlinear device model and by filtering; the mere mathematical existence of a combination frequency does not establish that the device generates it at an observable amplitude. This distinction matters when a spectrum analyser displays a weak line near an expected intermediate frequency. A plausible arithmetic relationship is a hypothesis for a conversion artefact, not evidence that the hypothetical nonlinear term was present.

Consider a receiver tuned with an illustrative local oscillator at 1,020 MHz and an intermediate frequency of 20 MHz. A desired 1,000 MHz signal produces a 20 MHz difference, but a 1,040 MHz signal produces the same magnitude when a real rather than quadrature conversion discards the frequency sign. A measured preselector attenuation at the image frequency is therefore part of the interpretation, not a menu preference. If the image undergoes 46 dB rejection and the desired path undergoes 2 dB insertion loss, the different front-end transfers must be applied to their respective source frequencies. These numbers are hypothetical. Their importance lies

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in the independent requirement to demonstrate that the image was sufficiently rejected during the actual observation, including mismatch and dynamic front-end state, before an IF line can be assigned to one of the two RF origins.

Complex mixing retains a sign convention that can distinguish upper and lower sidebands, but practical quadrature channels suffer relative gain and phase errors. For small mismatch, an image-suppression ratio can be predicted by an explicitly calibrated complex I/Q transformation rather than by assuming equal channels. Suppose one channel has a 1% relative amplitude mismatch and a quadrature phase error of two degrees. A small-error approximation gives an image amplitude fraction on the order of one half the magnitude of the complex mismatch, and an image power suppression near 34 dB; the numerical value depends on the convention and exact nonlinear ratio adopted. It must therefore be checked against a precisely defined complex measurement law before use as a numerical acceptance claim. More importantly, correction derived from one LO frequency or temperature may be invalid when the channel phase imbalance varies across IF bandwidth or gain state.

Mixer conversion loss and noise cannot be separated from the sideband architecture. A single-sideband noise figure and a double-sideband noise figure describe different treatment of image-frequency noise; inserting one into an otherwise matched cascade without defining the admitted image path can give a formally coherent but physically incorrect input noise result. Gain compression, LO-drive variation and intermodulation further restrict the simple scalar model. In a controlled bench experiment, vary the LO drive, individual RF input powers and input preselection independently,

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while observing both the wanted conversion and potential spur frequencies. A valid inference must distinguish a spur that scales with RF power from an LO leak, a source-generated harmonic and an alias created downstream in the digitiser.

An inverse-spur investigation should preserve several candidate source combinations rather than selecting the first that solves a frequency equation. Build a table of each observed output, permitted integer order, hypothetical input frequency, predicted behaviour when LO frequency changes, and the actual evidence obtained from controlled retuning. If a spur moves by twice the LO-frequency change, it suggests a different conversion order from a component that moves once, but the observation alone may still be compatible with another integer combination or a shared clock. Compare the observed slopes against the predicted signed lattice while maintaining a time-coherent record of the LO and converter settings. This turns an otherwise anecdotal observation into a falsifiable engineering claim.

The complete experiment must also control the sources. A two-generator test may create products in a combiner; a spectrum analyser used to inspect the receiver output may itself introduce overload; and an uncalibrated reference clock may make frequency relationships appear inconsistent. Preserve generator purity records, calibrated power at the DUT plane, output analyser attenuation, frequency-reference state and raw sweep files. The acceptance conclusion should be framed by what was actually challenged: a particular converter and LO configuration under stated source levels, not an assertion that every image and spur in a future environment has been excluded.

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Chapter Summary

Frequency conversion produces a family of desired and undesired responses. LO plan, images, spur tables, movement tests, and level scaling are essential before a displayed frequency is assigned to an external emitter.

Model 4A retains signed RF-minus-LO frequency, selected-product amplitude and phase before real-frequency folding. Loaded power conversion also depends on the two resistances. Complex conversion preserves orientation only under consistent analytic-band, I/Q, normalization and sampling conventions.

An image is an admitted positive RF frequency reflected about the LO. Map complete IF intervals and their transfers, not only center frequencies. Colliding desired and image phasors combine before power is formed unless a zero-cross-power average is justified. Spur tables identify candidate locations, not guaranteed amplitudes.

Use predeclared LO or parent-frequency changes to test movement, treating zero-crossing cusps piecewise. Conversion-branch signs determine final orientation. Verify stimulus purity and preserve actual filters, gain, clock state, references and native records. Keep frequency movement separate from amplitude validity under compression. A supported product relationship or admitted RF interval does not alone establish an emitter’s identity, location or purpose.

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Chapter 4 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C04-MCQ-001. A model predicts a 12 MHz mixer output but gives no loaded resistance or multiplier scale. Which claim remains unsupported by that prediction?

A. The need to identify which output product the path selects.

B. The distinction between the parent RF and LO frequencies.

C. The selected output power or conversion gain.

D. The candidate frequency under the declared frequency map.

Answer: C. A frequency relation alone does not specify voltage normalization, load power, or an actual device transfer. Those require additional declared quantities.

Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: The selected output power or conversion gain.

Distinguishing consideration: compare this with option A, “The need to identify which output product the path selects”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-MCQ-002. Two positive external RF frequencies produce the same real IF in a declared first-order difference converter. What evidence is needed to decide which supplied an observation?

A. Admitted-path information and a discriminating RF or image challenge.

B. More decimal places in the same IF magnitude.

C. An assumption that the frequency nearest the receiver display is the desired source.

D. A conversion-loss correction applied equally to both candidates.

Answer: A. The real absolute-difference map can admit two RF inputs. A magnitude label cannot distinguish them without path rejection or additional observations.

Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: Admitted-path information and a discriminating RF or image challenge.

Distinguishing consideration: compare this with option B, “More decimal places in the same IF magnitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-003. A receiver changes its first IF automatically at a band boundary. Which configuration record is needed for reconstruction?

A. The active conversion stages, LO choices, IF path and filter state for each segment.

B. Only the first LO frequency, assuming later stages are unchanged whenever the final IF label is unchanged.

C. One nominal conversion-gain value for the complete instrument.

D. Only the final center-frequency label if the displayed bandwidth is unchanged.

Answer: A. A state change can alter both loss and orientation. The active plan, rather than a generic block diagram, controls the frequency mapping. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: The active conversion stages, LO choices, IF path and filter state for each segment.

Distinguishing consideration: compare this with option B, “Only the first LO frequency, assuming later stages are unchanged whenever the final IF label is unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-MCQ-004. In Model 4A, why does rejecting the sum product require an explicit path condition?

A. The LO phase makes the sum product vanish for every RF phase.

B. A negative difference frequency necessarily cancels the sum product.

C. The multiplier creates both products; their mathematical generation does not select one physically.

D. The difference product is generated only after the sum product is removed.

Answer: C. The product identity contains sum and difference terms. An actual filter or selected processing path must establish which reaches the reported output.

Review: Equations 7A and 7B. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: The multiplier creates both products; their mathematical generation does not select one physically.

Distinguishing consideration: compare this with option A, “The LO phase makes the sum product vanish for every RF phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products.

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products.

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V011-C04-MCQ-005. An ideal real multiplier combines 1000 MHz RF with 925 MHz LO. Which pair lists the positive first-order difference and sum frequencies?

A. 925 MHz and 1000 MHz.

B. 1075 MHz and 1925 MHz.

C. 75 MHz and 1925 MHz.

D. 75 MHz and 1850 MHz.

Answer: C. The difference is 1000 minus 925, and the sum is 1000 plus 925. Which product is retained remains a separate path choice. Review: Equation 7B. Source: Equation 7B. The two real multiplier products (p. 1925)

Why the selected alternative fits: 75 MHz and 1925 MHz.

Distinguishing consideration: compare this with option A, “925 MHz and 1000 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7B. The two real multiplier products.

Review: Chapter 4 — Equation 7B. The two real multiplier products.

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V011-C04-MCQ-006. Under the normalized real multiplier, RF peak voltage is 0.08 V and the nonnegative voltage scale is 2. What is the peak of the selected nonzero difference product?

A. 0.32 V.

B. 0.08 V.

C. 0.04 V.

D. 0.16 V.

Answer: D. The leading factor two in the LO multiplier makes either selected product peak equal to $g\,A$. Here that is 2 times 0.08 V. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: 0.16 V.

Distinguishing consideration: compare this with option A, “0.32 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-007. A 0.12 V peak RF cosine is multiplied by a unit LO cosine with no leading factor two. What is either separated product peak?

A. 0.0144 V.

B. 0.12 V.

C. 0.24 V.

D. 0.06 V.

Answer: D. The cosine product identity contributes a factor of one half to each term. This is the unnormalized mathematical multiplier, not a device conversion-loss specification. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: 0.06 V.

Distinguishing consideration: compare this with option A, “0.0144 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-008. A simulation retains both real multiplier products and reports their total mean output power as the selected IF power. What must be corrected?

A. Replace the signed frequency difference with the sum frequency everywhere.

B. Count each product twice to compensate for the cosine identity.

C. Set RF and IF loads equal regardless of their modeled values.

D. Apply the declared product selection before assigning the selected IF power.

Answer: D. Model 4A defines selected-product power after the unwanted term is rejected. Power integrated over both separated products answers a different question. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: Apply the declared product selection before assigning the selected IF power.

Distinguishing consideration: compare this with option A, “Replace the signed frequency difference with the sum frequency everywhere”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-009. For 320 MHz RF and 300 MHz LO, what is the local orientation of the nonzero real difference IF with respect to a small RF increase?

A. Positive: the IF increases by the same small increment.

B. Negative: the IF decreases by the same small increment.

C. Indeterminate even when the same nonzero branch is retained.

D. Zero: the LO is fixed, so the IF is fixed.

Answer: A. RF exceeds LO, so the signed difference is positive and the local derivative of its magnitude with respect to RF is plus one. Review: Equation 7C.

Source: Equation 7C. Selected difference and orientation (p. 1925)

Why the selected alternative fits: Positive: the IF increases by the same small increment.

Distinguishing consideration: compare this with option B, “Negative: the IF decreases by the same small increment”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-MCQ-010. For 320 MHz RF and 350 MHz LO, which description of the selected real difference is correct?

A. The real IF is 670 MHz because the difference is negative.

B. The signed difference and real IF are both -30 MHz.

C. The signed difference is -30 MHz, the real IF is 30 MHz, and a small RF increase lowers that IF.

D. The signed difference is 30 MHz and a small RF increase raises the IF.

Answer: C. High-side injection retains a negative signed difference before a real display forms its magnitude. Its local RF orientation is reversed. Review: Equation 7C; Application 4A.2. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why the selected alternative fits: The signed difference is -30 MHz, the real IF is 30 MHz, and a small RF increase lowers that IF.

Distinguishing consideration: compare this with option A, “The real IF is 670 MHz because the difference is negative”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Application 4A.2: Track high-side spectral inversion.

Review: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Application 4A.2: Track high-side spectral inversion.

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V011-C04-MCQ-011. A high-side conversion has RF phase 40 degrees and LO phase 15 degrees. What phase describes its selected real IF at positive frequency?

A. 55 degrees.

B. -25 degrees.

C. 25 degrees.

D. -55 degrees.

Answer: B. The signed difference term has phase 25 degrees. Rewriting its negative-frequency cosine at positive frequency negates that phase. Review: Equation 7C. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why the selected alternative fits: -25 degrees.

Distinguishing consideration: compare this with option A, “55 degrees”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-MCQ-012. A low-side conversion has RF phase -15 degrees and LO phase 25 degrees. What is the selected positive-IF phase under Model 4A?

A. 40 degrees.

B. -10 degrees.

C. 10 degrees.

D. -40 degrees.

Answer: D. Low-side conversion has positive orientation, so the RF-minus-LO phase remains -15 minus 25 degrees. Review: Equation 7C. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why the selected alternative fits: -40 degrees.

Distinguishing consideration: compare this with option A, “40 degrees”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-MCQ-013. The RF and LO frequencies become exactly equal in a proposed tone example. Why does the chapter exclude this point from its nonzero-IF examples?

A. Choosing either orientation sign at equality preserves the same nonzero-frequency phase convention.

B. Its selected DC power is still the peak squared divided by twice the load, independently of relative phase.

C. The selected term becomes DC and requires separate phase and average-power treatment.

D. The positive- and negative-frequency descriptions supply two independent DC tones whose powers must be added.

Answer: C. The cosine at zero frequency is a constant whose value depends on phase. The nonzero sinusoidal power convention cannot be transferred mechanically to it. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: The selected term becomes DC and requires separate phase and average-power treatment.

Distinguishing consideration: compare this with option A, “Choosing either orientation sign at equality preserves the same nonzero-frequency phase convention”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-MCQ-014. A calculation sets the selected voltage scale to zero and then requests a finite decibel power gain. What should the reviewer state?

A. The RF-to-IF resistance ratio alone determines a finite logarithmic result.

B. The output must equal the input because the LO scale was removed.

C. Zero output is outside the stated positive-power domain for a finite logarithmic gain.

D. The finite power gain is necessarily 0 dB.

Answer: C. A power ratio can be zero, but its logarithm is not finite. Equation 7D explicitly restricts the finite gain case to positive input and selected output powers.

Review: Equation 7D. Source: Equation 7D. Loaded selected-product power gain (p. 1926)

Why the selected alternative fits: Zero output is outside the stated positive-power domain for a finite logarithmic gain.

Distinguishing consideration: compare this with option A, “The RF-to-IF resistance ratio alone determines a finite logarithmic result”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7D. Loaded selected-product power gain.

Review: Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-MCQ-015. Which unit specification can be inserted directly into the phase argument $2\pi f t+\theta$ exactly as written, without additional conversion factors?

A. Frequency in hertz, time in seconds and phase in radians.

B. Frequency in megahertz, time in seconds and phase in radians.

C. Frequency in hertz, time in seconds and phase in degrees.

D. The quantity f as angular frequency in radians per second, time in seconds and phase in radians.

Answer: A. Frequency times time is a cycle count, multiplied by two pi to form radians. An additive phase must use that angular convention. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: Frequency in hertz, time in seconds and phase in radians.

Distinguishing consideration: compare this with option B, “Frequency in megahertz, time in seconds and phase in radians”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-MCQ-016. A physical analog multiplier is written as output voltage equal to the product of two input voltages. What additional scale is needed for dimensional consistency?

A. Treat the two physical voltage inputs as dimensionless without specifying how their volt values were normalized.

B. Only a dimensionless load-resistance ratio, assumed sufficient to convert the voltage product back to volts.

C. Only a unit-amplitude cosine notation, with no statement of how the physical LO voltage enters the transfer.

D. A declared voltage normalization or equivalent gain constant with the necessary units.

Answer: D. The chapter distinguishes its normalized mathematical multiplier from a physical voltage multiplier. The physical transfer must retain its dimensional scale.

Review: Model 4A; MT-080 multiplier-scaling discussion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: A declared voltage normalization or equivalent gain constant with the necessary units.

Distinguishing consideration: compare this with option A, “Treat the two physical voltage inputs as dimensionless without specifying how their volt values were normalized”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-MCQ-017. An ideal polarity-switching mixer and the chapter's cosine multiplier give different selected amplitudes. What is the first comparison to make?

A. Compare only their LO frequencies and assume that this fixes the selected amplitude.

B. Compare their LO waveforms and normalization before treating the difference as a calibration error.

C. Assume every ideal mixer has the same conversion loss.

D. Equate their peak LO amplitudes and assume that this alone makes the selected amplitudes equal.

Answer: B. A square-wave sign switch contains a harmonic series, while the normalized cosine multiplier is a different operation. The declared model controls the scale. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: Compare their LO waveforms and normalization before treating the difference as a calibration error.

Distinguishing consideration: compare this with option A, "Compare only their LO frequencies and assume that this fixes the selected amplitude"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-MCQ-018. A real mixer's LO drive changes while its nominal LO frequency stays fixed. Which conclusion is justified?

A. Only the displayed frequency can change; amplitude cannot.

B. Conversion gain and other operating properties may change and need an applicable state measurement.

C. The ideal multiplier normalization determines the actual gain without further evidence.

D. All conversion properties remain fixed because frequency is unchanged.

Answer: B. The actual conversion transfer depends on LO drive, loading and operating level. A frequency map does not freeze those physical conditions. Review: Conversion Gain, Loss, and Calibration. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

Why the selected alternative fits: Conversion gain and other operating properties may change and need an applicable state measurement.

Distinguishing consideration: compare this with option A, "Only the displayed frequency can change; amplitude cannot"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Conversion Gain, Loss, and Calibration.

Review: Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-MCQ-019. A predicted harmonic product falls exactly on an observed line. Which additional claim does that coincidence fail to establish?

A. That the enumerated arithmetic combination has that candidate frequency.

B. That the candidate belongs to the selected finite search list.

C. That a movement challenge can be designed for the chosen coefficient pair.

D. That the receiver generates the line with a particular amplitude or at a particular internal component.

Answer: D. A product lattice supplies locations. Physical generation, strength and location require evidence beyond the arithmetic match. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: That the receiver generates the line with a particular amplitude or at a particular internal component.

Distinguishing consideration: compare this with option A, “That the enumerated arithmetic combination has that candidate frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-020. Model 4A declares a nonnegative voltage scale. An equivalent hardware description uses a negative real scale. What extra convention must be handled before comparison?

A. Negate the selected power ratio along with the voltage coefficient.

B. The sign can be represented as an additional phase reversal, which must be retained explicitly.

C. Conjugate the entire output frequency coordinate instead of retaining an additional phase shift.

D. Use only the scale magnitude and discard its sign because the power gain is unchanged.

Answer: B. A sign on a sinusoidal voltage corresponds to a phase change. Power is not negative merely because a voltage coefficient is negative; the chapter keeps this choice outside g. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: The sign can be represented as an additional phase reversal, which must be retained explicitly.

Distinguishing consideration: compare this with option A, “Negate the selected power ratio along with the voltage coefficient”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-MCQ-021. A loaded RF sine wave has peak 0.10 V across 50 ohms. What is its average input power?

A. 0.20 mW.

B. 1.00 mW.

C. 0.05 mW.

D. 0.10 mW.

Answer: D. Square the peak voltage and divide by twice the resistance: 0.01 divided by 100 watts gives 0.0001 W. Review: Equations 7A-7D; Applications 4A.3 and 4A.4.

Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: 0.10 mW.

Distinguishing consideration: compare this with option A, “0.20 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-022. For RF peak 0.10 V across 50 ohms, scale 2 and IF load 200 ohms, what is the selected loaded power gain?

A. Unity, or 0 dB.

B. Two, or about 3.01 dB.

C. Four, or about 6.02 dB.

D. One quarter, or about -6.02 dB.

Answer: A. The voltage doubles, but the load resistance is four times larger. The ratio is 2 squared times 50 divided by 200, equal to one. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: Unity, or 0 dB.

Distinguishing consideration: compare this with option B, “Two, or about 3.01 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-023. The voltage scale is 0.5, the RF load is 50 ohms and the IF load is 200 ohms. What is the selected power-gain ratio?

A. 0.25.

B. 1.0.

C. 0.5.

D. 0.0625.

Answer: D. The loaded ratio is 0.5 squared times 50 divided by 200. Both the squared voltage reduction and the resistance ratio contribute. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: 0.0625.

Distinguishing consideration: compare this with option A, “0.25”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-024. A unity voltage scale connects declared loaded planes of 75 ohms and 300 ohms. What is the selected power gain in decibels?

A. Approximately -3.01 dB.

B. 0 dB.

C. Approximately 6.02 dB.

D. Approximately -6.02 dB.

Answer: D. The power ratio is 75 divided by 300, or one quarter, despite equal loaded peak voltages. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: Approximately -6.02 dB.

Distinguishing consideration: compare this with option A, “Approximately -3.01 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-025. At equal positive real RF and IF loads, a selected voltage scale of 3 corresponds to which power gain?

A. One third, or approximately -4.77 dB.

B. 9, or approximately 9.54 dB.

C. 3, or approximately 4.77 dB.

D. 6, or approximately 7.78 dB.

Answer: B. With equal loads, power gain is the squared voltage ratio. Twenty times $\log_{10}$ of 3 and ten times $\log_{10}$ of 9 are equivalent here. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: 9, or approximately 9.54 dB.

Distinguishing consideration: compare this with option A, “One third, or approximately -4.77 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-026. A target loaded power gain is 4, with RF resistance 50 ohms and IF resistance 200 ohms. What nonnegative voltage scale is required by Equation 7D?

A. 1.

B. 4.

C. 2.

D. 8.

Answer: B. The resistance ratio is one quarter, so g^2 must be 16 to make the power ratio four. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: 4.

Distinguishing consideration: compare this with option A, “1”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-027. An RF peak of 0.40 V is applied across a declared 50-ohm loaded plane. What average power enters the model?

A. 8.0 mW.

B. 0.8 mW.

C. 3.2 mW.

D. 1.6 mW.

Answer: D. The squared peak is 0.16 V squared; dividing by 100 ohms gives 0.0016 W. Peak and RMS voltage conventions must not be mixed. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: 1.6 mW.

Distinguishing consideration: compare this with option A, “8.0 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-028. With equal loads, removing the leading factor two from a normalized cosine multiplier changes selected power by what factor?

A. It is unchanged.

B. It becomes one quarter of its former value.

C. It becomes one half of its former value.

D. It doubles.

Answer: B. Selected voltage is halved; power at the same resistance is therefore reduced by the square of one half. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: It becomes one quarter of its former value.
Distinguishing consideration: compare this with option A, “It is unchanged”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….
Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-029. The normalized scale decreases from 2 to 1 with input and loads fixed. What selected-power change follows while the model remains valid?

A. An increase of approximately 6.02 dB.

B. A decrease of approximately 6.02 dB.

C. No change because both scales are positive.

D. A decrease of approximately 3.01 dB.

Answer: B. The selected voltage halves, so power becomes one quarter. This is a scalar transfer result, not an overload assessment. Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why the selected alternative fits: A decrease of approximately 6.02 dB.

Distinguishing consideration: compare this with option A, “An increase of approximately 6.02 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-030. A loaded-voltage calculation is compared with an available-power conversion-gain data-sheet value. What must be reconciled?

A. Only equality of nominal impedance labels, assumed to establish matching at both physical planes.

B. Reference planes, source and load conditions, and the distinction between loaded and available power.

C. Only replacement of ten-times-log power scaling by twenty-times-log voltage scaling.

D. Only conversion frequency and injection side, since nominal impedance labels are assumed to establish matched available power.

Answer: B. The two power conventions are not automatically the same. A nominal impedance label cannot replace the actual matching and measurement definition.
Review: Equations 7A-7D; Applications 4A.3 and 4A.4. Source: Equation 7A. RF and normalized real LO (p. 1925)
Why the selected alternative fits: Reference planes, source and load conditions, and the distinction between loaded and available power.
Distinguishing consideration: compare this with option A, “Only equality of nominal impedance labels, assumed to establish matching at both physical planes”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….
Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-MCQ-031. An LO at 200 MHz converts a desired 215 MHz input to a real 15 MHz IF. What is the conventional first-order image candidate?

A. 185 MHz.

B. 15 MHz.

C. 400 MHz.

D. 230 MHz.

Answer: A. Reflect the desired frequency about the LO: twice 200 minus 215 gives 185 MHz. It is observable only if the actual RF path admits it. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: 185 MHz.

Distinguishing consideration: compare this with option B, “15 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-032. A desired 200 MHz input uses a 230 MHz LO. What positive image candidate also yields the same real difference IF?

A. 30 MHz.

B. 260 MHz.

C. 430 MHz.

D. 170 MHz.

Answer: B. The desired is 30 MHz below the LO; its conventional image is 30 MHz above it. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: 260 MHz.

Distinguishing consideration: compare this with option A, “30 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-033. A real difference converter uses 100 MHz LO for a desired 250 MHz input. The reflection formula gives -50 MHz. What follows in the chapter's positive physical-RF domain?

A. Every other mixer or sampling response has been excluded.

B. A 50 MHz input must be the conventional reflected image.

C. The desired 250 MHz input cannot produce a real difference output.

D. There is no second positive RF image from that particular first-order reflection.

Answer: D. A negative reflected frequency is outside the stipulated positive-RF domain. This does not eliminate other product families or sampling mechanisms. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: There is no second positive RF image from that particular first-order reflection.

Distinguishing consideration: compare this with option A, "Every other mixer or sampling response has been excluded"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-034. A desired frequency coincides exactly with the LO. How should a proposed ordinary image-rejection calculation be treated?

A. The usual separated-image injection pair can be retained unchanged even though both frequencies now coincide.

B. The two real-frequency branches remain independent inputs whose DC powers can always be added.

C. The nonzero sinusoidal power rule applies directly to the DC term without regard to relative phase.

D. The zero-IF coincidence requires its own DC and quadrature analysis; the separated nonzero-image example does not apply directly.

Answer: D. The conventional two-branch tone picture degenerates at zero difference. The chapter keeps that boundary separate from its nonzero-IF examples. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: The zero-IF coincidence requires its own DC and quadrature analysis; the separated nonzero-image example does not apply directly.

Distinguishing consideration: compare this with option A, “The usual separated-image injection pair can be retained unchanged even though both frequencies now coincide”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-035. A 10 MHz LO feeds a real difference path admitting IF from 2 through 3 MHz. Which RF intervals are mapped to that path?

A. 7 through 8 MHz and 12 through 13 MHz.

B. 8 through 12 MHz only.

C. 7 through 13 MHz as one unbroken interval.

D. 2 through 3 MHz and 10 through 13 MHz.

Answer: A. Subtract the IF interval from the LO with reversed endpoint order for the lower branch, then add it for the upper branch. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: 7 through 8 MHz and 12 through 13 MHz.
Distinguishing consideration: compare this with option B, “8 through 12 MHz only”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....
Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-036. A 2 MHz LO feeds a real path admitting positive IF from 1 through 4 MHz. After restricting physical RF to positive values, which RF set remains?

A. Only 1 through 4 MHz because the IF filter defines the RF band directly.

B. The whole interval from -2 through 6 MHz.

C. Only 3 through 6 MHz because the lower interval has one negative endpoint.

D. Frequencies greater than zero through 1 MHz, together with 3 through 6 MHz.

Answer: D. The algebraic lower interval is -2 through 1 MHz. Intersect it with positive RF rather than discarding its positive portion or retaining negative physical frequencies. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: Frequencies greater than zero through 1 MHz, together with 3 through 6 MHz.

Distinguishing consideration: compare this with option A, “Only 1 through 4 MHz because the IF filter defines the RF band directly”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-037. With LO fixed and a low-side desired RF increased by 1 MHz, how does its conventional reflected image candidate move?

A. It remains fixed.

B. It increases by 2 MHz.

C. It increases by 1 MHz.

D. It decreases by 1 MHz.

Answer: D. The image is twice the fixed LO minus desired RF, so its derivative with respect to the desired frequency is minus one. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: It decreases by 1 MHz.

Distinguishing consideration: compare this with option A, “It remains fixed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-038. For a conventional positive first-order image, what is the desired-to-image frequency separation?

A. The sum of desired RF and IF.

B. Twice the LO frequency.

C. Twice the nonzero real IF.

D. Exactly the real IF.

Answer: C. The desired and image lie on opposite sides of the LO at the same IF distance. The separation follows geometry, not a rejection specification. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: Twice the nonzero real IF.

Distinguishing consideration: compare this with option A, “The sum of desired RF and IF”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-039. Desired input is -100 dBm and image input is -50 dBm. Desired-path loss is 2 dB; both conversion paths have 6 dB loss. What image-path loss is needed for at least 10 dB desired-over-image output margin in the valid linear model?

A. At least 50 dB.

B. At least 12 dB.

C. At least 58 dB.

D. At least 62 dB.

Answer: D. The desired output is -108 dBm. The image output is -56 dBm minus its preselection loss; requiring it to be at most -118 dBm gives 62 dB. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: At least 62 dB.

Distinguishing consideration: compare this with option A, “At least 50 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-040. An image input is 55 dB stronger than the desired input. Desired-path loss is 3 dB, image-path loss is 68 dB, and conversion gains are equal. What desired-over-image output margin results?

A. 10 dB.

B. 65 dB.

C. -10 dB.

D. 13 dB.

Answer: A. Differential path loss is 68 minus 3, or 65 dB. Subtract the 55 dB external level disadvantage to obtain a 10 dB output margin. Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why the selected alternative fits: 10 dB.

Distinguishing consideration: compare this with option B, “65 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-041. Equal calibrated desired and image injections produce outputs differing by 43 dB in the same valid state. What does this comparison support?

A. Proof that any environmental line at the displayed frequency is the desired input.

B. A 43 dB relative response at those two frequencies and specified conditions.

C. Proof that no image energy can reach an earlier vulnerable component.

D. A universal 43 dB rejection at every frequency and input level.

Answer: B. The measured ratio is conditional on the injected frequencies, levels and receiver state. It does not establish a universal rejection envelope. Review: Image Responses and Image Rejection. Source: §4.15 Image Responses and Image Rejection (p. 1944)

Why the selected alternative fits: A 43 dB relative response at those two frequencies and specified conditions.

Distinguishing consideration: compare this with option A, “Proof that any environmental line at the displayed frequency is the desired input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Image Responses and Image Rejection.

Review: Chapter 4 — Image Responses and Image Rejection.

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V011-C04-MCQ-042. An image-rejection comparison changes automatic attenuation between desired and image injections. What is the main problem?

A. The comparison includes a state-dependent transfer change and no longer isolates image response without reconstruction.

B. Normalizing both outputs to the same noise bandwidth automatically removes the attenuation-state difference.

C. Only the injected-level difference matters because an attenuator does not change the image-frequency map.

D. Averaging the two output levels isolates image rejection regardless of which attenuation state was used.

Answer: A. The intended comparison holds the IF path and relevant state fixed. A changed transfer must be measured and accounted for, or the test redesigned.

Review: Application 4A.1; Image Responses and Image Rejection. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

Why the selected alternative fits: The comparison includes a state-dependent transfer change and no longer isolates image response without reconstruction.

Distinguishing consideration: compare this with option B, “Normalizing both outputs to the same noise bandwidth automatically removes the attenuation-state difference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Image Responses and Image Rejection.

Review: Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Image Responses and Image Rejection.

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V011-C04-MCQ-043. A positive image candidate is rejected by the measured RF path. Which statement is appropriate?

A. The measured rejection applies to every alternate conversion state with the same center-frequency label.

B. The candidate must be removed from the frequency map because the current filter suppresses its response.

C. The measured attenuation establishes absence of image contribution independently of the possible image input level.

D. The frequency map still identifies a candidate, while the measured path limits its observable contribution.

Answer: D. Candidate location and admission are distinct. A valid map need not produce an observable response when the physical path suppresses that input.
Review: Equation 7F; Applications 4A.1, 4A.5 and 4A.10. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)
Why the selected alternative fits: The frequency map still identifies a candidate, while the measured path limits its observable contribution.
Distinguishing consideration: compare this with option A, “The measured rejection applies to every alternate conversion state with the same center-frequency label”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion;....
Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-044. Why should an image challenge include RF interval edges when the intended IF passband has finite width?

A. An image exists only at the mathematical center of each interval.

B. Checking the LO center automatically measures all filter skirts.

C. Both admitted RF intervals have width and their edge responses can differ from their center responses.

D. The RF interval endpoints are independent of the IF endpoints.

Answer: C. The entire IF interval maps through both branches. A center-frequency check does not establish rejection or amplitude response across its edges. Review: Application 4A.10. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

Why the selected alternative fits: Both admitted RF intervals have width and their edge responses can differ from their center responses.

Distinguishing consideration: compare this with option A, “An image exists only at the mathematical center of each interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

Review: Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-MCQ-045. A quadrature image-reject path has finite amplitude and phase imbalance. What should be expected?

A. Residual image response can remain and needs measurement under the relevant conditions.

B. The mathematical label image-reject guarantees zero image response.

C. Only conversion gain can change; rejection cannot.

D. The ordinary RF-to-LO difference ceases to describe any candidate frequency.

Answer: A. Cancellation depends on the implemented balance. Architecture alone is not a measured rejection specification. Review: Image Responses and Image Rejection. Source: §4.15 Image Responses and Image Rejection (p. 1944)

Why the selected alternative fits: Residual image response can remain and needs measurement under the relevant conditions.

Distinguishing consideration: compare this with option B, “The mathematical label image-reject guarantees zero image response”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Image Responses and Image Rejection.

Review: Chapter 4 — Image Responses and Image Rejection.

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V011-C04-MCQ-046. A direct-conversion mode avoids a conventional nonzero first IF. Which further checks remain relevant?

A. Only the positive-frequency baseband response, because the quadrature side is automatically redundant.

B. Only a center-tone amplitude check, because removal of a nonzero IF establishes complete conversion validity.

C. DC offset, even-order response, LO leakage and I/Q imbalance.

D. Only the analog low-pass cutoff, without testing the quadrature transfer or DC behavior.

Answer: C. Moving the desired band to zero IF changes the artifact set. It does not eliminate the need to characterize the actual conversion and quadrature path.

Review: Image Responses and Image Rejection. Source: §4.15 Image Responses and Image Rejection (p. 1944)

Why the selected alternative fits: DC offset, even-order response, LO leakage and I/Q imbalance.

Distinguishing consideration: compare this with option A, “Only the positive-frequency baseband response, because the quadrature side is automatically redundant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Image Responses and Image Rejection.

Review: Chapter 4 — Image Responses and Image Rejection.

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V011-C04-MCQ-047. No image line is visible during a quiet environmental observation. What does this say about receiver image rejection?

A. The quiet output floor can be used as an image-response denominator with an assumed input level.

B. It supplies the same differential transfer information as equal calibrated desired and image injections.

C. A previously quoted image-rejection figure can be transferred to the current state without a stimulus check.

D. It does not quantify rejection unless a suitable image-frequency stimulus or bound is present.

Answer: D. Image response is conditional on energy entering at the relevant RF frequency. Absence of a line can reflect absence of stimulus. Review: Image Responses and Image Rejection. Source: §4.15 Image Responses and Image Rejection (p. 1944)

Why the selected alternative fits: It does not quantify rejection unless a suitable image-frequency stimulus or bound is present.

Distinguishing consideration: compare this with option A, “The quiet output floor can be used as an image-response denominator with an assumed input level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Image Responses and Image Rejection.

Review: Chapter 4 — Image Responses and Image Rejection.

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V011-C04-MCQ-048. An injected image-frequency generator also produces a harmonic in the desired RF passband. What is required before attributing the IF response to an image path?

A. Correct only the generator fundamental level and assign every remaining IF component to image transfer.

B. Assume the receiver preselector removes the harmonic even though it lies in the desired RF passband.

C. Average the IF power longer and assume this removes the source harmonic's contribution.

D. Bound the harmonic and other stimulus-path contributions at the receiver input plane.

Answer: D. Source contamination can enter through the ordinary desired path. The actual stimulus spectrum must support the intended image-response interpretation. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: Bound the harmonic and other stimulus-path contributions at the receiver input plane.

Distinguishing consideration: compare this with option A, "Correct only the generator fundamental level and assign every remaining IF component to image transfer"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-MCQ-049. A correctly calibrated IF amplitude is associated with an unchallenged image alternative. Which claim remains uncertain?

A. Whether the declared correction was numerically applied.

B. Whether a power unit can be stated at the IF plane.

C. The external RF frequency assigned to the observation.

D. Whether the measured IF amplitude was recorded.

Answer: C. Amplitude calibration and source-frequency attribution are separate obligations. Correct amplitude does not select one of two admitted RF origins.

Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: The external RF frequency assigned to the observation.

Distinguishing consideration: compare this with option A, “Whether the declared correction was numerically applied”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-MCQ-050. Which condition is sufficient for adding desired and image mean powers at one IF under the stated averaging operation?

A. The image input is weaker than the desired input.

B. The relative source phase is unknown at the beginning of the observation.

C. The generators share a frequency reference but no phase-resolved record was retained.

D. The real part of their averaged cross product is zero.

Answer: D. The cross term controls whether the mean of squared summed voltage equals the sum of the individual mean squares. Naming or relative size does not remove it. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: The real part of their averaged cross product is zero.

Distinguishing consideration: compare this with option A, “The image input is weaker than the desired input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-051. The selected image phasor is 0.4 times the desired phasor magnitude and is in phase with it. What is the total power relative to desired-only power?

A. 1.40.

B. 1.16.

C. 0.36.

D. 1.96.

Answer: D. The voltage magnitudes add to 1.4 times the desired magnitude, whose square is 1.96. Incoherent power addition would give a different result. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: 1.96.

Distinguishing consideration: compare this with option A, “1.40”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-052. The same 0.4-amplitude image is exactly opposite in phase to the desired contribution. What power ratio results?

A. 0.60.

B. 0.36.

C. 1.16.

D. 1.96.

Answer: B. The net amplitude is 1 minus 0.4, or 0.6. Squaring gives 0.36, so a coherent contaminant can reduce the observed power. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: 0.36.

Distinguishing consideration: compare this with option A, “0.60”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-053. A 0.4-amplitude image is in quadrature with the desired IF phasor. What is the total-to-desired power ratio?

A. 1.16.

B. 1.40.

C. 1.96.

D. 0.36.

Answer: A. The coherent cross term is zero at a 90-degree relative phase, leaving one plus 0.4 squared. This does not establish statistical independence. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: 1.16.

Distinguishing consideration: compare this with option B, “1.40”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-054. Equal-magnitude desired and image IF phasors are exactly opposite in phase in the ideal model. What is the resulting selected output?

A. Four times the desired-only power.

B. Twice the desired-only power.

C. Zero net phasor, so no finite logarithmic level follows from the ideal zero power.

D. The desired-only power because an image cannot cancel a desired term.

Answer: C. Coherent voltages cancel exactly under these ideal conditions. Finite noise or imbalance in an experiment requires its own treatment. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: Zero net phasor, so no finite logarithmic level follows from the ideal zero power.

Distinguishing consideration: compare this with option A, “Four times the desired-only power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-055. An image has amplitude ratio 0.3 with arbitrary relative phase. What bounds the total-to-desired power ratio?

A. 0.70 through 1.30.

B. 0.49 through 1.69.

C. Exactly 1.09.

D. 0.09 through 1.00.

Answer: B. The extremal net amplitudes are 1 minus 0.3 and 1 plus 0.3. Their squares bound the phase-dependent power. Review: Equation 7G; Application 4A.6.

Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: 0.49 through 1.69.

Distinguishing consideration: compare this with option A, “0.70 through 1.30”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-056. Relative phase was not recorded during a short desired-plus-image observation. Is adding their separately measured powers automatically justified?

A. Yes; weak images are always statistically independent.

B. No; the relevant cross-power condition must be established for the actual averaging operation.

C. No; powers can never add for signals at one IF.

D. Yes; unrecorded phase is equivalent to uniformly random phase.

Answer: B. Lack of a phase record is a lack of information, not a probability model. Power addition can be valid, but needs an applicable cross-power condition. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: No; the relevant cross-power condition must be established for the actual averaging operation.

Distinguishing consideration: compare this with option A, “Yes; weak images are always statistically independent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-057. A coherent 90-degree collision and a zero-cross-power average give the same total power. What additional observation can distinguish their mechanisms?

A. Applying the same gain correction to both powers.

B. Controlled phase variation or an appropriate phase-resolved record.

C. Another decimal place in the same scalar power reading alone.

D. Use a longer scalar average without establishing how relative phase changes during it.

Answer: B. One scalar mean can be consistent with different cross-term mechanisms. Controlled phase response provides information absent from that scalar. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: Controlled phase variation or an appropriate phase-resolved record.

Distinguishing consideration: compare this with option A, “Applying the same gain correction to both powers”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-058. Two test generators share a reference and feed desired and image inputs. Which assumption deserves explicit checking?

A. That their selected IF contributions have zero cross power over the measurement.

B. That accurate common referencing alone makes the two selected phases statistically independent.

C. That equal frequency accuracy forces a fixed quadrature relationship at the IF.

D. That equal nominal source powers determine the relative selected IF phase.

Answer: A. A shared reference can support stable coherence. Its presence does not establish a particular phase or justify automatically adding powers. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: That their selected IF contributions have zero cross power over the measurement.

Distinguishing consideration: compare this with option B, “That accurate common referencing alone makes the two selected phases statistically independent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-059. Desired and image RF phases are known, with one input on the high-side branch. What must precede their IF phasor addition?

A. Discard both phases because the output frequencies are equal.

B. Add the two powers first and then assign their common phase.

C. Map each RF phase into the declared positive-IF phase convention, including high-side conjugation.

D. Add the RF phases directly without considering conversion orientation.

Answer: C. The phasors must be expressed in the same IF convention before addition. A branch sign changes the positive-frequency phase. Review: Equations 7C and 7G. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why the selected alternative fits: Map each RF phase into the declared positive-IF phase convention, including high-side conjugation.

Distinguishing consideration: compare this with option A, “Discard both phases because the output frequencies are equal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-MCQ-060. A reviewer adds selected desired and image voltage magnitudes, squares the result, and calls it the average for arbitrary phase. What was silently assumed?

A. Constructive phase alignment of the two contributions.

B. Zero cross power under the averaging operation.

C. A uniformly distributed relative phase over the observation.

D. A fixed quadrature phase relationship between the two contributions.

Answer: A. Adding magnitudes selects the constructive extreme. It does not represent an arbitrary relative phase or a general incoherent average. Review: Equation 7G; Application 4A.6. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why the selected alternative fits: Constructive phase alignment of the two contributions.

Distinguishing consideration: compare this with option B, “Zero cross power under the averaging operation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-MCQ-061. An analytic complex signal at 20 MHz is mixed with a complex 21 MHz LO under the chapter's convention. Where is the translated carrier?

A. -1 MHz.

B. +1 MHz only.

C. 41 MHz only.

D. Both +1 MHz and -1 MHz necessarily remain because every complex multiplier duplicates the real cosine products.

Answer: A. Complex translation retains the signed RF-minus-LO frequency rather than folding negative values to a real magnitude. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: -1 MHz.

Distinguishing consideration: compare this with option B, "+1 MHz only"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-062. At 100000 complex samples per second and DFT length 200, a +20 kHz baseband tone occupies which ordinary array index?

A. 40.

B. 160.

C. 20.

D. 100.

Answer: A. Bin spacing is 500 Hz, so 20000 Hz corresponds to index 40 within the stated ordinary DFT convention. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: 40.

Distinguishing consideration: compare this with option B, “160”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-063. With the same sample rate and DFT length, which ordinary array index represents -20 kHz?

A. 200.

B. 40.

C. 160.

D. -160.

Answer: C. The signed index is -40. Adding the length 200 gives ordinary array index 160; this preserves the sign information before display labeling. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: 160.

Distinguishing consideration: compare this with option A, “200”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-064. Only the sign of the Q samples is reversed in a stored complex record. What operation has been performed?

A. Removal of all sampling aliases.

B. Complex conjugation, reversing signed spectral orientation and phase.

C. A change only to the absolute RF reference frequency.

D. A pure positive real gain with no phase effect.

Answer: B. Changing I plus jQ to I minus jQ conjugates the record. Magnitude plots can hide the resulting orientation change. Review: Equation 7E; Application 4A.7.

Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: Complex conjugation, reversing signed spectral orientation and phase.

Distinguishing consideration: compare this with option A, “Removal of all sampling aliases”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-065. A real RF waveform is used to obtain a single analytic complex translated band. What must the derivation retain?

A. The conjugate-band rejection and the appropriate factor-of-two normalization.

B. Both conjugate bands with no distinction in normalization.

C. An assumption that the real input already contains only one complex-frequency band.

D. An unconditional absolute value of every translated frequency.

Answer: A. A real waveform has conjugate spectral structure. Obtaining the selected analytic band requires an explicit selection and scale. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: The conjugate-band rejection and the appropriate factor-of-two normalization.

Distinguishing consideration: compare this with option B, “Both conjugate bands with no distinction in normalization”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-066. Why does the analytic RF-envelope example require the admitted band to remain at positive physical frequency?

A. It guarantees that the envelope bandwidth is less than half any later sample rate.

B. It removes the need for conjugate-band selection when the starting waveform is real.

C. It keeps the declared analytic carrier-and-envelope representation consistent with the selected physical band.

D. It establishes physical image rejection independently of the implemented quadrature balance.

Answer: C. The condition belongs to the continuous-time analytic representation. Sampling, gain and oscillator phase still need their own conventions. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: It keeps the declared analytic carrier-and-envelope representation consistent with the selected physical band.

Distinguishing consideration: compare this with option A, “It guarantees that the envelope bandwidth is less than half any later sample rate”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-067. A complex baseband display distinguishes positive and negative offsets. What ambiguity can still remain in a sampled receiver?

A. Different admitted analog frequencies can alias into the same discrete frequency class.

B. A mandatory folding of every negative baseband bin onto a positive one within the retained complex record.

C. An unavoidable ambiguity between opposite signed bins even when I/Q order and the full complex record are known.

D. A frequency-origin ambiguity from FFT shift that cannot be resolved by retained indexing metadata.

Answer: A. Complex representation avoids real-frequency folding inside its selected convention; it does not remove sampling equivalence or the need to know the admitted analog band. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: Different admitted analog frequencies can alias into the same discrete frequency class.

Distinguishing consideration: compare this with option B, “A mandatory folding of every negative baseband bin onto a positive one within the retained complex record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-068. Which end-to-end test best checks whether an I/Q frequency axis has the intended orientation?

A. Compare only total integrated power before and after conjugation.

B. Inject separately known tones above and below the LO and verify their signed output locations.

C. Check only one tone exactly at the center frequency.

D. Compare integrated noise powers at one positive baseband offset without a known RF ordering.

Answer: B. Opposite known offsets exercise the sign convention and channel ordering. A center tone or magnitude total cannot establish orientation. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: Inject separately known tones above and below the LO and verify their signed output locations.

Distinguishing consideration: compare this with option A, “Compare only total integrated power before and after conjugation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-069. An analyst conjugates a capture to match a familiar display convention. What should the analysis record retain?

A. Only an amplitude correction, assuming the changed phase convention is recoverable from a magnitude spectrum alone.

B. Only the revised magnitude plot because conjugation cannot affect interpretation.

C. The conjugation as an explicit processing step and the resulting frequency/phase convention.

D. A changed physical LO value used to represent the software conjugation as if it were an acquisition retune.

Answer: C. The operation is reversible but changes orientation and phase. Reproducible processing needs its identity and convention. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: The conjugation as an explicit processing step and the resulting frequency/phase convention.

Distinguishing consideration: compare this with option A, “Only an amplitude correction, assuming the changed phase convention is recoverable from a magnitude spectrum…”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-070. A finite analytic RF band lies entirely above its carrier's chosen LO in one state and below it in another. What should a complex converter do under the same convention?

A. Translate it to the corresponding positive or negative baseband interval without absolute-value folding.

B. Discard the below-LO interval even when it is admitted and within the complex passband.

C. Treat the change of offset sign as a change in sample rate and rescale the frequency axis accordingly.

D. Reflect both intervals onto positive frequency automatically.

Answer: A. Complex translation preserves signed frequency. Whether the translated band is retained depends on the selected path and passband. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why the selected alternative fits: Translate it to the corresponding positive or negative baseband interval without absolute-value folding.

Distinguishing consideration: compare this with option B, "Discard the below-LO interval even when it is admitted and within the complex passband"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-MCQ-071. For RF 101 MHz and LO 100 MHz, consider the signed candidate twice RF minus twice LO. Raising LO by 0.2 MHz produces which positive output?

A. 2.2 MHz.

B. 1.8 MHz.

C. 2.4 MHz.

D. 1.6 MHz.

Answer: D. The original candidate is 2 MHz and the LO coefficient is -2. The signed change is -0.4 MHz, leaving 1.6 MHz on the same positive branch. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: 1.6 MHz.

Distinguishing consideration: compare this with option A, “2.2 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-072. For RF 97 MHz and LO 100 MHz, the first-order signed difference is negative. Raising LO by 1 MHz changes the real difference IF how?

A. It stays at 3 MHz.

B. It falls from 3 to 2 MHz.

C. It rises from 3 to 4 MHz.

D. It becomes a negative real-display frequency.

Answer: C. The signed difference moves from -3 to -4 MHz. Taking magnitudes increases the real IF by 1 MHz. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: It rises from 3 to 4 MHz.

Distinguishing consideration: compare this with option A, “It stays at 3 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-073. A signed candidate starts at +0.1 MHz with LO coefficient -1. An LO increase of 0.2 MHz leaves the same 0.1 MHz absolute output. What happened?

A. The source frequency necessarily stayed at the displayed IF.

B. The signed candidate crossed zero; equal endpoint magnitudes do not imply zero LO dependence.

C. The candidate must have LO coefficient zero.

D. The receiver necessarily rejected both observations.

Answer: B. The signed value moves to -0.1 MHz. The absolute map has a cusp, so a single constant derivative cannot describe the crossing. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: The signed candidate crossed zero; equal endpoint magnitudes do not imply zero LO dependence.

Distinguishing consideration: compare this with option A, “The source frequency necessarily stayed at the displayed IF”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-074. A candidate uses RF coefficient 3 and LO coefficient -2. What is its total integer order under the chapter's bounded search?

A. 1.

B. 5.

C. -5.

D. 6.

Answer: B. The search order is the sum of the absolute coefficient values, three plus two, rather than their algebraic sum or product. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: 5.

Distinguishing consideration: compare this with option A, "1"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-075. A search is explicitly limited to total order 4. May a coefficient pair 3 and -2 appear in its reported enumerated results?

A. No; that pair has order 5 and lies outside the declared bound.

B. Yes; opposite signs reduce its order to 1.

C. No; negative coefficients are excluded from all mixer-product searches.

D. Yes; only the larger coefficient determines order.

Answer: A. Both signs are allowed, but the finite bound applies to the sum of absolute indices. Expanding the search must be declared. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: No; that pair has order 5 and lies outside the declared bound.

Distinguishing consideration: compare this with option B, “Yes; opposite signs reduce its order to 1”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-076. Pairs of coefficients related by changing both signs predict the same absolute output frequency. What does this imply for a real-spectrum candidate list?

A. One pair must be discarded because negative signed frequencies are physically forbidden in the calculation.

B. Every duplicate magnitude proves two independent generated tones.

C. The output amplitude is twice the value predicted by either pair alone.

D. Duplicate magnitudes need not identify distinct observable mechanisms.

Answer: D. Absolute-value mapping loses the global sign. Candidate bookkeeping must not count equivalent arithmetic descriptions as independent evidence. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: Duplicate magnitudes need not identify distinct observable mechanisms.

Distinguishing consideration: compare this with option A, “One pair must be discarded because negative signed frequencies are physically forbidden in the calculation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-077. A bounded search includes RF coefficient zero and LO coefficient one. What does that arithmetic candidate establish?

A. A possible LO-frequency location, without proving a leakage path or amplitude.

B. That LO-to-RF isolation has been measured.

C. That pure LO leakage is the only physical mechanism capable of placing energy at that frequency.

D. That an external RF emitter exists exactly at the LO.

Answer: A. A zero RF coefficient can represent a clock or LO-related location. Observing and locating its physical coupling remains an experimental task. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: A possible LO-frequency location, without proving a leakage path or amplitude.

Distinguishing consideration: compare this with option B, “That LO-to-RF isolation has been measured”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-078. A very large set of integer combinations is searched after seeing an unexplained line. What strengthens a selected candidate beyond a numerical coincidence?

A. Select the lowest-order arithmetic match and treat that alone as physical identification.

B. Reporting the best frequency match without its search scope.

C. Increasing the search order until many candidates match.

D. A predeclared independent perturbation with a testable movement prediction.

Answer: D. A predicted response to a controlled change can discriminate hypotheses. Broad retrospective arithmetic matching alone supplies weak attribution. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: A predeclared independent perturbation with a testable movement prediction.

Distinguishing consideration: compare this with option A, “Select the lowest-order arithmetic match and treat that alone as physical identification”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-079. An LO movement test pushes a candidate outside the retained IF filter before its new frequency can be measured. What is the warranted conclusion?

A. The movement remains unresolved by that observation unless the changed admission is accounted for.

B. The line must have been external rather than receiver-generated.

C. The candidate has been confirmed at the predicted frequency despite no measurement.

D. The candidate relationship is disproved because the line disappeared.

Answer: A. The planned observable must remain within a measurable path. Disappearance through filtering can fit several mechanisms. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: The movement remains unresolved by that observation unless the changed admission is accounted for.

Distinguishing consideration: compare this with option B, “The line must have been external rather than receiver-generated”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-080. Away from zero and with LO fixed, what sets the local real-output slope with respect to a small RF-parent change for a chosen integer candidate?

A. The sum of the absolute coefficient values, regardless of sign.

B. Its LO coefficient alone.

C. Its RF coefficient multiplied by the sign of the signed candidate frequency.

D. Its RF coefficient divided by its LO coefficient, independently of the signed-frequency branch.

Answer: C. Differentiate the signed candidate with respect to RF, then apply the local derivative of absolute value. The branch condition is essential. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: Its RF coefficient multiplied by the sign of the signed candidate frequency.

Distinguishing consideration: compare this with option A, “The sum of the absolute coefficient values, regardless of sign”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-081. A spectral label moves when the receiver clock calibration is changed, but the actual external tone may be fixed. What additional evidence is needed?

A. A conversion-loss correction at the original IF.

B. Only a demonstration that the indicated shift is proportional to the nominal clock correction.

C. An independent physical-frequency reference and the actual LO/sample-clock mapping.

D. An assumption that every clock-dependent movement proves an internally generated spur.

Answer: C. Clock calibration can relabel a fixed physical input. The chapter's hypothetical case keeps internal generation and relabeling as competing explanations. Review: Hypothetical Case Adjudication; From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: An independent physical-frequency reference and the actual LO/sample-clock mapping.

Distinguishing consideration: compare this with option A, "A conversion-loss correction at the original IF"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test; Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

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V011-C04-MCQ-082. Why is the derivative of absolute candidate frequency not assigned one fixed value through a zero-frequency crossing?

A. The RF and LO coefficients must be interchanged whenever the signed product changes sign.

B. A monotonic LO change requires the displayed product frequency to remain monotonic through zero.

C. The absolute-value function changes branch at zero.

D. The signed product relation necessarily stops being linear even when its parent frequencies change linearly.

Answer: C. The signed relation remains linear in the stipulated frequency increment, but its absolute representation has a cusp. Review: Equations 7H and 7I; Application 4A.8. Source: Equation 7H. Bounded integer product search (p. 1928)

Why the selected alternative fits: The absolute-value function changes branch at zero.

Distinguishing consideration: compare this with option A, “The RF and LO coefficients must be interchanged whenever the signed product changes sign”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-MCQ-083. A 750 MHz RF passes first through an 800 MHz LO and then a 40 MHz LO, retaining real difference outputs. What is the final local RF orientation?

A. Zero.

B. Positive.

C. Negative.

D. Undefined despite both selected differences remaining nonzero.

Answer: C. The first IF is 50 MHz with a negative sign; the second IF is 10 MHz with a positive sign. Their product is negative. Review: Equation 7J; Application 4A.9. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why the selected alternative fits: Negative.

Distinguishing consideration: compare this with option A, “Zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-MCQ-084. The same 750 MHz RF and 800 MHz first LO instead use a 60 MHz second LO. What is the final local RF orientation?

A. Negative.

B. Zero.

C. Positive.

D. Determined only by the 10 MHz center frequency.

Answer: C. The first 50 MHz IF is inverted, and the 60 MHz second LO adds a second inversion. The two signs multiply to plus one. Review: Equation 7J; Application 4A.9.

Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why the selected alternative fits: Positive.

Distinguishing consideration: compare this with option A, “Negative”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-MCQ-085. In those two arrangements, an original RF increase of 0.5 MHz gives which final IF pair, ordered as second LO 40 MHz then 60 MHz?

A. 10 MHz and 10 MHz.

B. 10.5 MHz and 9.5 MHz.

C. 9.5 MHz and 10.5 MHz.

D. 9.5 MHz and 9.5 MHz.

Answer: C. The first IF falls to 49.5 MHz. Its distances from 40 and 60 MHz are respectively 9.5 and 10.5 MHz. Review: Equation 7J; Application 4A.9. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why the selected alternative fits: 9.5 MHz and 10.5 MHz.

Distinguishing consideration: compare this with option A, “10 MHz and 10 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-MCQ-086. Three fixed nonzero difference stages have orientation signs negative, positive and negative. What is their composite local RF orientation?

A. Negative.

B. The sum of the signs, equal to negative one.

C. Positive.

D. Zero.

Answer: C. Cascade orientation multiplies the three local derivatives. Two reversals restore positive orientation. Review: Equation 7J; Application 4A.9. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why the selected alternative fits: Positive.

Distinguishing consideration: compare this with option A, “Negative”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-MCQ-087. A proposed RF perturbation crosses zero IF in one stage of a cascade. How should the constant orientation-product calculation be used?

A. Restrict it to separate fixed branches and evaluate the crossing explicitly.

B. Apply the original product unchanged across the whole perturbation.

C. Use the final IF magnitude alone to assign one orientation to every earlier stage.

D. Average the local signs over the whole excursion and use that average as one exact transfer slope.

Answer: A. The stated derivative product is local to fixed nonzero branches. A crossing changes the applicable sign and can change path admission. Review: Equation 7J; Application 4A.9. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why the selected alternative fits: Restrict it to separate fixed branches and evaluate the crossing explicitly.

Distinguishing consideration: compare this with option B, “Apply the original product unchanged across the whole perturbation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-MCQ-088. Two dual-conversion plans share the same final center IF but have opposite orientation products. A center-tone check reports equal frequencies and equal corrected amplitudes. What does it still miss?

A. Whether the two measured center-frequency values coincide under the tested settings.

B. Whether the measured center-tone amplitudes agree in those tested states.

C. Whether an output response is present at the tested center in each state.

D. The direction in which nearby original RF frequencies map around that center.

Answer: D. Center agreement is compatible with opposite sideband ordering. A frequency step or ordered two-tone stimulus tests the missing local mapping.

Review: Equation 7J; Application 4A.9. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why the selected alternative fits: The direction in which nearby original RF frequencies map around that center.

Distinguishing consideration: compare this with option A, “Whether the two measured center-frequency values coincide under the tested settings”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-MCQ-089. Which stimulus most directly verifies spectral orientation across a conversion-state boundary?

A. One center tone measured only before the boundary.

B. A conversion-gain comparison using equal RF powers only at the two state centers.

C. A known small RF frequency step or ordered pair of nearby tones in each state.

D. A constant power reading with no known RF frequency.

Answer: C. The known RF ordering must be compared with the output ordering on each side. A single center point cannot establish the sign. Review: Equation 7J; Application 4A.9. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why the selected alternative fits: A known small RF frequency step or ordered pair of nearby tones in each state.

Distinguishing consideration: compare this with option A, “One center tone measured only before the boundary”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-MCQ-090. What should be rechecked when an automatic band change can alter both conversion loss and orientation?

A. Only a DC continuity check at the unchanged RF port.

B. A level reference and a known frequency-step response in each applicable state.

C. Only a matched noise-bandwidth check without a calibrated RF stimulus.

D. Only the final center-frequency label.

Answer: B. Gain and orientation are different aspects of the transfer. The state-specific checks establish both rather than assuming continuity. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: A level reference and a known frequency-step response in each applicable state.

Distinguishing consideration: compare this with option A, “Only a DC continuity check at the unchanged RF port”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-MCQ-091. An independent receiver detects a component that follows the examined receiver's tuning with its input terminated. What is supported initially?

A. An LO- or clock-related emission hypothesis that still needs coupling-path and frequency-plan checks.

B. A complete reconstruction of every internal conversion stage.

C. Proof that the examined receiver is defective.

D. A radiated frequency necessarily equal to the RF frequency shown on the examined receiver's display.

Answer: A. Tuning-dependent radiation can reveal receiver activity, but does not by itself identify the exact path, full plan or malfunction. Review: Local-Oscillator Purity and Leakage. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

Why the selected alternative fits: An LO- or clock-related emission hypothesis that still needs coupling-path and frequency-plan checks.

Distinguishing consideration: compare this with option B, "A complete reconstruction of every internal conversion stage"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

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V011-C04-MCQ-092. A leakage signal changes when the antenna cable is replaced by a termination. Which alternatives should the test distinguish?

A. Antenna reradiation, cable common-mode coupling and enclosure radiation.

B. Only the IF output level after applying the existing gain correction.

C. Only the leakage level at one tuning frequency with the same antenna connection.

D. Only the first-order image frequency computed from the final IF.

Answer: A. Several physical paths can radiate LO energy. A controlled path comparison is needed before attributing the observed field to one route. Review: Local-Oscillator Purity and Leakage. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

Why the selected alternative fits: Antenna reradiation, cable common-mode coupling and enclosure radiation.

Distinguishing consideration: compare this with option B, “Only the IF output level after applying the existing gain correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

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V011-C04-MCQ-093. Two comparison receivers share the same external clock and show the same weak line. Why is independence still unresolved?

A. A shared line necessarily proves a physical external transmitter.

B. The shared clock can supply a common coupling or spur mechanism.

C. That use of two front ends eliminates any clock-related mechanism common to their measurements.

D. That agreement establishes independence as soon as the two receivers use different antennas.

Answer: B. A nominally separate instrument may share a relevant error source. The comparison must change or bound that dependency. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: The shared clock can supply a common coupling or spur mechanism.

Distinguishing consideration: compare this with option A, “A shared line necessarily proves a physical external transmitter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-MCQ-094. A mixer calibration is repeated with different LO drive, temperature and termination. Which interpretation is appropriate?

A. It must equal the previous calibration because RF and IF frequencies match.

B. It characterizes a different operating condition whose applicability must be established.

C. It measures only a frequency offset and cannot affect amplitude.

D. It can be substituted without documenting the changed conditions.

Answer: B. The chapter defines conversion gain through specified planes and operating conditions. Those changes can alter the measured transfer. Review: Conversion Gain, Loss, and Calibration. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

Why the selected alternative fits: It characterizes a different operating condition whose applicability must be established.

Distinguishing consideration: compare this with option A, “It must equal the previous calibration because RF and IF frequencies match”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Conversion Gain, Loss, and Calibration.

Review: Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-MCQ-095. A measured RF-to-IF path includes a preselector and IF amplifier, but the intended measurand is the mixer alone. What is needed?

A. Substitute a published mixer loss as if it were directly measured in the assembled path.

B. Applicable de-embedding or separate characterization of the surrounding path.

C. Subtract only nominal cable loss, assuming the preselector and IF amplifier contributions cancel.

D. Assign all measured gain to the mixer by definition.

Answer: B. The included filters and amplifiers contribute to the measured result. Their effects must be separated if the claim is specific to the mixer. Review: Conversion Gain, Loss, and Calibration. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

Why the selected alternative fits: Applicable de-embedding or separate characterization of the surrounding path.

Distinguishing consideration: compare this with option A, “Substitute a published mixer loss as if it were directly measured in the assembled path”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Conversion Gain, Loss, and Calibration.

Review: Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-MCQ-096. A firmware update changes automatic conversion-state selection. What is the appropriate treatment of old frequency-dependent correction tables?

A. Transfer the correction from whichever old state is nearest in tuning frequency without checking its mapping.

B. Apply the old correction whenever the center-frequency label matches, without checking the active conversion state.

C. Treat correction-table identity as proof of current physical response.

D. Verify their applicability to the new active states before using them for the intended result.

Answer: D. State selection and processing changes can alter the relationship between the stored correction and actual path. Preserve both provenance and new verification evidence. Review: Conversion Gain, Loss, and Calibration; Conversion-State Challenge Protocol. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

Why the selected alternative fits: Verify their applicability to the new active states before using them for the intended result.

Distinguishing consideration: compare this with option A, “Transfer the correction from whichever old state is nearest in tuning frequency without checking its mapping”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Conversion Gain, Loss, and Calibration; Chapter 4 — Conversion-State Challenge Protocol.

Review: Chapter 4 — Conversion Gain, Loss, and Calibration; Chapter 4 — Conversion-State Challenge Protocol.

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V011-C04-MCQ-097. An observed product grows faster with input level than the desired response. What further evidence helps identify its mechanism?

A. The line must be ignored because linear calibration is unavailable.

B. Its frequency relationship, controlled parent perturbations and source-path controls.

C. The growth alone proves one particular physical component.

D. A higher-order label can be assigned solely from one pair of amplitudes.

Answer: B. Level dependence can support a nonlinear hypothesis but is not a complete mechanism identifier. Frequency and path evidence constrain alternatives. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: Its frequency relationship, controlled parent perturbations and source-path controls.

Distinguishing consideration: compare this with option A, “The line must be ignored because linear calibration is unavailable”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-MCQ-098. A candidate line follows the predicted retuning law while the receiver is compressed. Which separation is necessary?

A. Compression makes every measured frequency necessarily meaningless.

B. The line's power must equal the ideal multiplier prediction.

C. Frequency-movement evidence may remain useful while the amplitude-transfer interpretation is invalid.

D. Correct movement proves all amplitude calculations are linear.

Answer: C. Movement and amplitude are different observations with different validity requirements. The chapter advises keeping them separate until evidence supports combining them. Review: From a product map to a discriminating test.

Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: Frequency-movement evidence may remain useful while the amplitude-transfer interpretation is invalid.

Distinguishing consideration: compare this with option A, "Compression makes every measured frequency necessarily meaningless"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-MCQ-099. A clock-dependent peak is absent on a comparison receiver whose sensitivity at that frequency is unknown. What conclusion remains unsupported?

A. That the peak cannot be an external signal.

B. That the two instruments produced different reported observations.

C. That a better-characterized comparison could discriminate hypotheses.

D. That the first receiver's label changed under the clock intervention.

Answer: A. A nondetection requires adequate coverage and sensitivity to exclude an external alternative. The clock intervention can also change frequency labeling.

Review: Hypothetical Case Adjudication. Source: §4.22 Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses (p. 1955)

Why the selected alternative fits: That the peak cannot be an external signal.

Distinguishing consideration: compare this with option B, "That the two instruments produced different reported observations"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

Review: Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

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V011-C04-MCQ-100. After valid conversion challenges, a line is consistent with one admitted RF input but no location or device linkage is available. What is the strongest supported report?

A. A unique physical emitter location inferred from one IF magnitude.

B. A bounded RF-path and frequency interpretation, with unresolved emitter identity and location stated.

C. A claim that all receiver artifacts have been excluded universally.

D. A confirmed operator identity inferred from the mixer equation.

Answer: B. Conversion tests support the quantities and alternatives they actually exercise. They do not supply spatial or identity evidence absent from the observations. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: A bounded RF-path and frequency interpretation, with unresolved emitter identity and location stated.

Distinguishing consideration: compare this with option A, “A unique physical emitter location inferred from one IF magnitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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Fill-in-the-Blank Questions

V011-C04-FIB-001. A mixer frequency relation identifies a candidate location but does not by itself specify the selected output _____.

Answer: amplitude or power. The amplitude result needs a multiplier scale, declared reference planes and loading, plus evidence that the physical path remains in the applicable state. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “amplitude or power” completes the stated technical proposition.

Question context: A mixer frequency relation identifies a candidate location but does not by itself specify the selected output _____

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-FIB-002. The numerical scale assigned to an ideal multiplication operation is its multiplier _____.

Answer: normalization. This fixes how the input voltage maps to each product. A change of normalization can explain a gain difference without implying that a physical calibration changed. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “normalization” completes the stated technical proposition.

Question context: The numerical scale assigned to an ideal multiplication operation is its multiplier _____

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-FIB-003. The chapter places a factor of _____ before the scale and LO cosine so that each selected product peak equals the scale times RF peak.

Answer: two. The cosine product identity contributes one half to each component. The declared leading factor cancels that one half; it is an explicit model convention.

Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “two” completes the stated technical proposition.

Question context: The chapter places a factor of _____ before the scale and LO cosine so that each selected product peak equals the scale times RF peak

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-004. A real cosine multiplier creates first-order products at the frequency sum and frequency _____.

Answer: difference. The selected path must then establish which component is retained. The mathematical identity alone does not implement filtering. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “difference” completes the stated technical proposition.

Question context: A real cosine multiplier creates first-order products at the frequency sum and frequency _____

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-005. With time in seconds, the chapter expresses RF and LO frequency in _____ before multiplication by two pi.

Answer: hertz. A hertz-second product is a cycle count. Multiplication by two pi supplies the radian angle used by the cosine or complex exponential. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “hertz” completes the stated technical proposition.

Question context: With time in seconds, the chapter expresses RF and LO frequency in _____ before multiplication by two pi

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-FIB-006. The additive RF and LO phases in the model are expressed in _____.

Answer: radians. A phase in degrees must be converted before insertion in an equation written with radian arguments. Numerical examples may report degrees if that reporting convention is explicit. Review: Model 4A: a declared conversion map.

Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “radians” completes the stated technical proposition.

Question context: The additive RF and LO phases in the model are expressed in _____

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-FIB-007. The normalized voltage scale is a _____ quantity, because it relates voltages at declared loaded planes.

Answer: dimensionless. The physical voltage units stay with the RF amplitude and selected phasor. A physical multiplier using two voltage inputs needs a separate dimensional normalization. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “dimensionless” completes the stated technical proposition.

Question context: The normalized voltage scale is a _____ quantity, because it relates voltages at declared loaded planes

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-FIB-008. The amplitude A in Model 4A is a _____ voltage, not an RMS voltage.

Answer: peak. For a nonzero sinusoidal tone the RMS value is the peak divided by the square root of two. Confusing these conventions changes power by a factor of two. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “peak” completes the stated technical proposition.

Question context: The amplitude A in Model 4A is a _____ voltage, not an RMS voltage

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-009. The loaded-power formula assumes RF and IF resistances are real and _____.

Answer: positive. Its elementary average-power expression is not a general complex-impedance mismatch model. Declared loading is part of the calculation's scope. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: "positive" completes the stated technical proposition.

Question context: The loaded-power formula assumes RF and IF resistances are real and _____

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-010. A finite logarithmic conversion gain requires both input and selected output power to be _____.

Answer: positive. At zero output the linear power ratio can be zero, but its logarithm is not finite. The chapter states this domain before quoting decibel gains.

Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “positive” completes the stated technical proposition.

Question context: A finite logarithmic conversion gain requires both input and selected output power to be _____

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-011. An RF at 260 MHz and LO at 240 MHz produce a nonzero real first-order difference IF of _____ MHz.

Answer: 20. Subtracting RF minus LO gives positive 20 MHz. The same fixed branch has positive local RF orientation. Review: Equation 7C. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: “20” completes the stated technical proposition.

Question context: An RF at 260 MHz and LO at 240 MHz produce a nonzero real first-order difference IF of _____ MHz

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-FIB-012. An RF at 260 MHz and LO at 280 MHz have a signed difference of _____ MHz.

Answer: -20. The real IF is the magnitude 20 MHz, but the signed value must be retained for orientation and phase interpretation. Review: Equation 7C. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: "-20" completes the stated technical proposition.

Question context: An RF at 260 MHz and LO at 280 MHz have a signed difference of _____ MHz

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-FIB-013. For 260 MHz RF and a 280 MHz LO, raising RF by 0.5 MHz with LO fixed changes the real difference IF to _____ MHz.

Answer: 19.5. The signed difference moves from -20 to -19.5 MHz. Its magnitude decreases because the path remains on the high-side branch. Review: Equation 7C.

Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: “19.5” completes the stated technical proposition.

Question context: For 260 MHz RF and a 280 MHz LO, raising RF by 0.5 MHz with LO fixed changes the real difference IF to _____ MHz

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-FIB-014. For 260 MHz RF, lowering a 240 MHz LO to 239 MHz changes the selected real difference IF to _____ MHz.

Answer: 21. The RF-minus-LO difference becomes 21 MHz. This is a change of LO with RF fixed, distinct from the RF-perturbation orientation convention. Review: Equation 7I. Source: Equation 7I. Retuning a signed and an absolute product (p. 1928)

Why this term is required: “21” completes the stated technical proposition.

Question context: For 260 MHz RF, lowering a 240 MHz LO to 239 MHz changes the selected real difference IF to _____ MHz

Basis and qualification: Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-015. A high-side difference has RF phase 12 degrees and LO phase -8 degrees. Its positive-IF phase is _____ degrees.

Answer: -20. The signed difference phase is 20 degrees. Conjugating the negative-frequency real cosine representation gives the negative of that phase. Review: Equation 7C. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: "-20" completes the stated technical proposition.

Question context: A high-side difference has RF phase 12 degrees and LO phase -8 degrees. Its positive-IF phase is _____ degrees

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-FIB-016. A low-side difference has RF phase 23 degrees and LO phase 7 degrees. Its selected positive-IF phase is _____ degrees.

Answer: 16. The difference phase is 23 minus 7 degrees. Positive conversion orientation leaves that phase sign unchanged. Review: Equation 7C. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: “16” completes the stated technical proposition.

Question context: A low-side difference has RF phase 23 degrees and LO phase 7 degrees. Its selected positive-IF phase is _____ degrees

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-FIB-017. At exact equality of RF and LO, the selected difference component becomes _____, so the nonzero sinusoidal convention requires separate treatment.

Answer: DC. Its constant value depends on the phase difference. Do not insert zero difference into the nonzero-tone power and orientation examples without revisiting those definitions. Review: Model 4A: a declared conversion map. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “DC” completes the stated technical proposition.

Question context: At exact equality of RF and LO, the selected difference component becomes _____, so the nonzero sinusoidal convention requires separate treatment

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-FIB-018. Taking an absolute value before recording the signed frequency can erase conversion _____.

Answer: orientation. Both a positive and a negative signed difference map to the same real IF magnitude. Their response to a small RF step and their positive-frequency phase conventions differ. Review: Equation 7C. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: “orientation” completes the stated technical proposition.

Question context: Taking an absolute value before recording the signed frequency can erase conversion _____

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-FIB-019. Rewriting a negative-frequency real cosine at positive frequency corresponds to _____ its associated complex phasor.

Answer: conjugating. The phase sign reverses while the real waveform remains the same. This convention must be applied before comparing or adding IF phasors.

Review: Equations 7B and 7C. Source: Equation 7B. The two real multiplier products (p. 1925)

Why this term is required: “conjugating” completes the stated technical proposition.

Question context: Rewriting a negative-frequency real cosine at positive frequency corresponds to _____ its associated complex phasor

Basis and qualification: Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation.

Review: Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-FIB-020. The local derivative rule is valid while the selected conversion remains on one fixed nonzero _____.

Answer: branch. A zero crossing changes the sign of the absolute-value derivative. A band or path switch can also invalidate a single local mapping across the whole interval. Review: Equations 7C and 7J. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: “branch” completes the stated technical proposition.

Question context: The local derivative rule is valid while the selected conversion remains on one fixed nonzero _____

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7J. Orientation through selected real difference stages.

Review: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7J. Orientation through selected real difference stages.

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V011-C04-FIB-021. RF peak 0.06 V and normalized scale 2.5 give selected product peak _____ V.

Answer: 0.15. Multiply the declared scale by RF peak. The result is a loaded voltage prediction; power still needs the selected output load. Review: Equations 7A-7D.

Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “0.15” completes the stated technical proposition.

Question context: RF peak 0.06 V and normalized scale 2.5 give selected product peak _____ V

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-022. A 0.30 V peak RF cosine multiplied by an unscaled unit LO cosine gives either separated product peak _____ V.

Answer: 0.15. Without the chapter's leading factor two, each product receives half the RF peak. This distinction is mathematical normalization, not a universal device loss. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: "0.15" completes the stated technical proposition.
Question context: A 0.30 V peak RF cosine multiplied by an unscaled unit LO cosine gives either separated product peak _____ V
Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....
Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-023. A 0.20 V peak RF sine wave across 100 ohms has average power _____ mW.

Answer: 0.20. Peak voltage squared is 0.04 V squared. Divide by twice 100 ohms to obtain 0.0002 W, then express it in milliwatts. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “0.20” completes the stated technical proposition.

Question context: A 0.20 V peak RF sine wave across 100 ohms has average power _____ mW

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded….

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-024. A 0.20 V peak RF input with scale 2 produces a 0.40 V peak selected output across 400 ohms. Its average power is _____ mW.

Answer: 0.20. The squared voltage is 0.16 and twice the output resistance is 800 ohms, giving 0.0002 W. Voltage doubles while the resistance quadruples, leaving equal powers. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “0.20” completes the stated technical proposition.
Question context: A 0.20 V peak RF input with scale 2 produces a 0.40 V peak selected output across 400 ohms. Its average power is _____ mW
Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....
Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-025. With scale 2, RF resistance 100 ohms and IF resistance 50 ohms, the loaded selected power-gain ratio is _____.

Answer: 8. The ratio is the square of 2 multiplied by $\frac{100}{50}$. Equal voltage and power gains cannot be assumed when the loads differ. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “8” completes the stated technical proposition.

Question context: With scale 2, RF resistance 100 ohms and IF resistance 50 ohms, the loaded selected power-gain ratio is _____

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-026. With scale 0.25, RF resistance 200 ohms and IF resistance 50 ohms, the loaded selected power-gain ratio is _____.

Answer: 0.25. The squared voltage ratio is 0.0625 and the resistance ratio is 4. Their product is 0.25, corresponding to approximately -6.02 dB. Review: Equations 7A-7D.

Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “0.25” completes the stated technical proposition.

Question context: With scale 0.25, RF resistance 200 ohms and IF resistance 50 ohms, the loaded selected power-gain ratio is _____

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-027. For a nonzero sinusoid, peak voltage divided by the square root of two gives its _____ voltage.

Answer: RMS. The chapter's average-power formula uses peak squared divided by twice resistance. Using RMS squared divided by resistance is equivalent if the convention is kept consistent. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: "RMS" completes the stated technical proposition.

Question context: For a nonzero sinusoid, peak voltage divided by the square root of two gives its _____ voltage

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-028. Power accepted at a declared loaded plane must be distinguished from source _____ power.

Answer: available. An available-power specification invokes source and matching conditions. A loaded-voltage calculation does not automatically supply those conditions. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “available” completes the stated technical proposition.

Question context: Power accepted at a declared loaded plane must be distinguished from source _____ power

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-029. Before comparing a loaded mixer calculation with a data-sheet conversion value, reconcile the reference planes and source/load _____ conventions.

Answer: impedance and matching. A nominal 50-ohm label does not establish the actual delivered or available power under arbitrary mismatch. The measurement definition must match the claimed gain. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “impedance and matching” completes the stated technical proposition.

Question context: Before comparing a loaded mixer calculation with a data-sheet conversion value, reconcile the reference planes and source/load _____ conventions

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-030. A linear power ratio is converted to decibels with ten times its base-ten _____.

Answer: logarithm. Twenty times the logarithm of a voltage ratio gives the same power-gain value only when the relevant impedance relationship has been accounted for. Review: Equations 7A-7D. Source: Equation 7A. RF and normalized real LO (p. 1925)

Why this term is required: “logarithm” completes the stated technical proposition.

Question context: A linear power ratio is converted to decibels with ten times its base-ten _____

Basis and qualification: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded....

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7D. Loaded selected-product power gain.

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V011-C04-FIB-031. For 140 MHz desired RF and 130 MHz LO, the conventional image candidate is _____ MHz.

Answer: 120. The reflection about the LO is twice 130 minus 140. Both desired and candidate lie 10 MHz from the LO, on opposite sides. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: “120” completes the stated technical proposition.

Question context: For 140 MHz desired RF and 130 MHz LO, the conventional image candidate is _____ MHz

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-032. For 140 MHz desired RF and 155 MHz LO, the conventional positive image candidate is _____ MHz.

Answer: 170. The desired is 15 MHz below the LO, so the reflected candidate is 15 MHz above it. Actual admission remains a measured path condition. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)
Why this term is required: “170” completes the stated technical proposition.
Question context: For 140 MHz desired RF and 155 MHz LO, the conventional positive image candidate is _____ MHz
Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.
Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-033. For 360 MHz desired RF and 150 MHz LO, the reflection formula gives -60 MHz. The number of additional positive first-order reflected RF candidates is _____.

Answer: zero. Negative physical RF is outside the stated domain. Do not replace -60 MHz with +60 MHz and call it the same conventional reflected candidate. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: “zero” completes the stated technical proposition.

Question context: For 360 MHz desired RF and 150 MHz LO, the reflection formula gives -60 MHz. The number of additional positive first-order reflected RF candidates is _____

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-034. When both first-order reflected RF frequencies are positive, their separation is _____ times the real IF.

Answer: two. Each lies one IF distance from the LO on opposite sides. This geometric separation does not state how strongly either path is admitted. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)
Why this term is required: “two” completes the stated technical proposition.
Question context: When both first-order reflected RF frequencies are positive, their separation is _____ times the real IF
Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.
Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-035. For 40 MHz LO and admitted positive IF 3 through 5 MHz, the lower RF interval is _____ MHz.

Answer: 35 through 37. Subtract the upper IF endpoint to obtain the lower RF endpoint, then subtract the lower IF endpoint for the upper endpoint. The subtraction reverses interval order. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: “35 through 37” completes the stated technical proposition.

Question context: For 40 MHz LO and admitted positive IF 3 through 5 MHz, the lower RF interval is _____ MHz

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-036. For the same 40 MHz LO and 3 through 5 MHz IF interval, the upper RF interval is _____ MHz.

Answer: 43 through 45. Adding the two IF endpoints to the LO gives the upper interval. Both branches need consideration before excluding possible external input frequencies. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: “43 through 45” completes the stated technical proposition.

Question context: For the same 40 MHz LO and 3 through 5 MHz IF interval, the upper RF interval is _____ MHz

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-037. A labeled real filter bandwidth should be replaced, where consequential, by its measured frequency-dependent _____ when applying the interval map.

Answer: response or weighting. The chapter's ideal interval makes the geometry exact. A physical filter has transition skirts, and the useful admission threshold depends on the intended measurement. Review: Application 4A.10. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
Why this term is required: "response or weighting" completes the stated technical proposition.
Question context: A labeled real filter bandwidth should be replaced, where consequential, by its measured frequency-dependent _____ when applying the interval map
Basis and qualification: Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.
Review: Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-FIB-038. After forming algebraic RF intervals, the stated model retains only _____ physical RF frequencies admitted by the path.

Answer: positive. An interval can straddle zero. Intersect it with the positive domain; neither retaining negative physical frequencies nor discarding the positive portion is correct. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: “positive” completes the stated technical proposition.

Question context: After forming algebraic RF intervals, the stated model retains only _____ physical RF frequencies admitted by the path

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-039. To prevent an image from loading a vulnerable mixer, sufficient rejection must occur _____ that mixer.

Answer: before. A later IF filter cannot distinguish desired and image inputs once they have been converted to the same selected IF, and it cannot undo earlier overload. Review: Image Responses and Image Rejection. Source: §4.15 Image Responses and Image Rejection (p. 1944)

Why this term is required: “before” completes the stated technical proposition.

Question context: To prevent an image from loading a vulnerable mixer, sufficient rejection must occur _____ that mixer

Basis and qualification: Chapter 4 — Image Responses and Image Rejection.

Review: Chapter 4 — Image Responses and Image Rejection.

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V011-C04-FIB-040. A relative image-response measurement compares calibrated desired and image injections while holding the relevant receiver _____ fixed.

Answer: state. Changing preselection, gain, automatic attenuation or the IF path changes the comparison. Any necessary change requires measurement and explicit reconstruction. Review: Application 4A.1. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

Why this term is required: “state” completes the stated technical proposition.

Question context: A relative image-response measurement compares calibrated desired and image injections while holding the relevant receiver _____ fixed

Basis and qualification: Chapter 4 — Application 4A.1: Locate a low-side image.

Review: Chapter 4 — Application 4A.1: Locate a low-side image.

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V011-C04-FIB-041. An image is 30 dB stronger at the input, desired-path loss is 1 dB and equal conversions are assumed. For 12 dB desired-over-image output margin, image-path loss must be at least _____ dB.

Answer: 43. Differential path loss must overcome the 30 dB input disadvantage and provide 12 dB margin. Adding the 1 dB desired loss gives 43 dB image loss. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)
Why this term is required: “43” completes the stated technical proposition.
Question context: An image is 30 dB stronger at the input, desired-path loss is 1 dB and equal conversions are assumed. For 12 dB desired-over-image output margin, image-path loss must be at least _____ dB
Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.
Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-042. A desired input of -80 dBm experiences 2 dB preselection loss and 5 dB conversion loss. Its selected output is _____ dBm.

Answer: -87. Subtract both applicable loss magnitudes from the input level. The calculation assumes the path remains in its stated linear state. Review: Equation 7F.

Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: "-87" completes the stated technical proposition.

Question context: A desired input of -80 dBm experiences 2 dB preselection loss and 5 dB conversion loss. Its selected output is _____ dBm

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-043. An image input of -40 dBm experiences 60 dB preselection loss and 5 dB conversion loss. Its selected output is _____ dBm.

Answer: -105. The total loss is 65 dB. Compared with the separate -87 dBm desired output, the image is 18 dB lower under the same linear assumptions. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: "-105" completes the stated technical proposition.

Question context: An image input of -40 dBm experiences 60 dB preselection loss and 5 dB conversion loss. Its selected output is _____ dBm

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-044. Equal calibrated desired and image injections produce selected outputs differing by 28 dB. Their measured relative rejection at those conditions is _____ dB.

Answer: 28. Equal input powers make the output ratio the relative path response. Preserve frequencies, state, level, uncertainty and stimulus purity; the result is not a universal rejection claim. Review: Image Responses and Image Rejection. Source: §4.15 Image Responses and Image Rejection (p. 1944)

Why this term is required: “28” completes the stated technical proposition.

Question context: Equal calibrated desired and image injections produce selected outputs differing by 28 dB. Their measured relative rejection at those conditions is _____ dB

Basis and qualification: Chapter 4 — Image Responses and Image Rejection.

Review: Chapter 4 — Image Responses and Image Rejection.

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V011-C04-FIB-045. With desired RF fixed, raising LO by 1 MHz moves the reflection-formula image candidate by _____ MHz.

Answer: 2. The image expression contains twice the LO frequency minus the fixed RF frequency. This is movement of the candidate input location, not a claim about environmental emitter motion. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: “2” completes the stated technical proposition.

Question context: With desired RF fixed, raising LO by 1 MHz moves the reflection-formula image candidate by _____ MHz

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-046. A frequency-plan image separation supplies no numerical _____ specification by itself.

Answer: rejection. Rejection depends on the admitted RF transfer and any image-canceling structure. Location arithmetic and measured response are separate parts of the analysis. Review: Equation 7F. Source: Equation 7F. Conventional image and RF interval mapping (p. 1927)

Why this term is required: “rejection” completes the stated technical proposition.

Question context: A frequency-plan image separation supplies no numerical _____ specification by itself

Basis and qualification: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-FIB-047. When desired and image contributions are coherent at one IF, add their complex _____ before forming power.

Answer: voltages or phasors. The magnitude square of their sum includes a phase-dependent cross term. Adding only powers would discard possible constructive or destructive interference. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “voltages or phasors” completes the stated technical proposition.

Question context: When desired and image contributions are coherent at one IF, add their complex _____ before forming power

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-048. The sum-of-powers formula is valid when the real part of the averaged cross product is _____.

Answer: zero. This is a condition on the actual averaging or ensemble operation. Different labels, separate cables or unequal amplitudes do not establish it. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “zero” completes the stated technical proposition.

Question context: The sum-of-powers formula is valid when the real part of the averaged cross product is _____

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-049. An in-phase image with 0.2 times the desired IF amplitude yields total-to-desired power ratio _____.

Answer: 1.44. The net amplitude is 1.2 times the desired amplitude, and its square is 1.44. The incoherent sum would instead be 1.04. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: "1.44" completes the stated technical proposition.

Question context: An in-phase image with 0.2 times the desired IF amplitude yields total-to-desired power ratio _____

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-050. An image with 0.2 times the desired IF amplitude in opposite phase yields total-to-desired power ratio _____.

Answer: 0.64. The net amplitude becomes 0.8 times the desired amplitude. The result demonstrates that coherent contamination can lower an observed level.

Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “0.64” completes the stated technical proposition.

Question context: An image with 0.2 times the desired IF amplitude in opposite phase yields total-to-desired power ratio _____

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-051. An image with 0.2 times the desired IF amplitude in quadrature yields total-to-desired power ratio _____.

Answer: 1.04. The cross term vanishes at 90 degrees, leaving one plus 0.2 squared. This particular coherent result does not prove a random-phase average. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “1.04” completes the stated technical proposition.

Question context: An image with 0.2 times the desired IF amplitude in quadrature yields total-to-desired power ratio _____

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-052. Two equal IF phasors in phase yield _____ times the power of either alone.

Answer: four. The amplitude doubles and the common-load power is proportional to squared amplitude. It is not merely the sum of the two individual powers. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “four” completes the stated technical proposition.

Question context: Two equal IF phasors in phase yield _____ times the power of either alone

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-053. Two equal IF phasors in exact phase opposition produce a net phasor of _____.

Answer: zero. That is an ideal coherent cancellation. A real observation will have its own residual, noise and uncertainty, so the exact ideal result must not be treated as a guaranteed measurement floor. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “zero” completes the stated technical proposition.

Question context: Two equal IF phasors in exact phase opposition produce a net phasor of _____

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-054. For an image-to-desired amplitude ratio 0.5, arbitrary relative phase gives power-ratio bounds _____ through _____.

Answer: 0.25; 2.25. The minimum and maximum amplitudes are 0.5 and 1.5 times desired. Squaring yields the bounds; 1.25 is the zero-cross-power sum, not the whole possible range. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “0” completes the stated technical proposition.

Question context: For an image-to-desired amplitude ratio 0.5, arbitrary relative phase gives power-ratio bounds _____ through _____

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-055. A vanishing averaged cross term is sufficient for power addition, but it does not necessarily establish full statistical _____.

Answer: independence. The cross-power condition concerns the relevant second-order quantity. Stronger distributional statements need their own evidence. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “independence” completes the stated technical proposition.

Question context: A vanishing averaged cross term is sufficient for power addition, but it does not necessarily establish full statistical _____

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-056. Before coherent addition, a high-side input's phase must be mapped into the same positive-IF _____ as the desired contribution.

Answer: convention. The high-side mapping reverses the phase sign of the negative-frequency real term. Combining unconverted RF phases can predict the wrong interference. Review: Equations 7C and 7G. Source: Equation 7C. Selected difference and orientation (p. 1925)

Why this term is required: "convention" completes the stated technical proposition.

Question context: Before coherent addition, a high-side input's phase must be mapped into the same positive-IF _____ as the desired contribution

Basis and qualification: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-057. An unrecorded relative phase is missing information, not proof of a _____ phase distribution.

Answer: uniform random. Averaging away the cross term requires a justified mechanism and observation interval. Uncertainty about phase is not itself such a physical condition. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “uniform random” completes the stated technical proposition.

Question context: An unrecorded relative phase is missing information, not proof of a _____ phase distribution

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-058. A cross-power claim must identify the measurement's averaging _____ or ensemble.

Answer: operation. The relevant cross term can depend on integration time, coherence and changes of state. A condition established for one operation need not hold for another. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: "operation" completes the stated technical proposition.

Question context: A cross-power claim must identify the measurement's averaging _____ or ensemble

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-059. A common frequency reference can make two generator contributions _____ enough that their phase relationship matters at the IF.

Answer: coherent. Sharing a reference does not prescribe a particular phase, but it removes any justification for automatically treating the powers as independent solely because there are two sources. Review: Equation 7G. Source: Equation 7G. Coherent collision and the zero-cross-power condition (p. 1927)

Why this term is required: “coherent” completes the stated technical proposition.

Question context: A common frequency reference can make two generator contributions _____ enough that their phase relationship matters at the IF

Basis and qualification: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-FIB-060. If the strong image drives a preceding stage beyond its valid state, the simple linear image-margin calculation needs its _____ reestablished.

Answer: applicability. Frequency reflection can still identify a candidate while the assumed gain and interference amplitudes fail. Validate the strong-signal state separately. Review: Application 4A.5. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

Why this term is required: “applicability” completes the stated technical proposition.

Question context: If the strong image drives a preceding stage beyond its valid state, the simple linear image-margin calculation needs its _____ reestablished

Basis and qualification: Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion.

Review: Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion.

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V011-C04-FIB-061. An analytic input carrier at 12.003 MHz and complex LO at 12 MHz translate to _____ kHz.

Answer: +3. Complex translation retains RF minus LO with sign. The positive offset is distinct from a corresponding below-LO input. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: "+3" completes the stated technical proposition.

Question context: An analytic input carrier at 12.003 MHz and complex LO at 12 MHz translate to _____ kHz

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-062. An analytic input carrier at 11.997 MHz with the same 12 MHz complex LO translates to _____ kHz.

Answer: -3. The negative complex frequency is retained rather than folded to +3 kHz. I/Q ordering and the exponential convention must agree. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: "-3" completes the stated technical proposition.

Question context: An analytic input carrier at 11.997 MHz with the same 12 MHz complex LO translates to _____ kHz

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-063. At 24000 complex samples per second and a 96-point DFT, the bin spacing is _____ Hz.

Answer: 250. Divide sample rate by transform length. This arithmetic uses the complex sample rate and ordinary DFT indexing convention. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: “250” completes the stated technical proposition.

Question context: At 24000 complex samples per second and a 96-point DFT, the bin spacing is _____ Hz

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-064. At 24000 complex samples per second with a 96-point DFT, a +3 kHz tone has ordinary array index _____.

Answer: 12. Three thousand divided by 250 gives 12. This is below the positive Nyquist boundary and requires no index wrap. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: “12” completes the stated technical proposition.

Question context: At 24000 complex samples per second with a 96-point DFT, a +3 kHz tone has ordinary array index _____

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-065. At 24000 complex samples per second with a 96-point DFT, a -3 kHz tone has ordinary array index _____.

Answer: 84. Its signed index is -12. Adding 96 maps it to ordinary array index 84 while retaining the associated negative-frequency interpretation. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: “84” completes the stated technical proposition.

Question context: At 24000 complex samples per second with a 96-point DFT, a -3 kHz tone has ordinary array index _____

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-066. Changing I plus jQ to I minus jQ performs complex _____.

Answer: conjugation. The operation reverses spectral orientation and phase. It should remain visible in processing lineage even if the magnitude spectrum appears familiar. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: “conjugation” completes the stated technical proposition.

Question context: Changing I plus jQ to I minus jQ performs complex _____

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-067. Starting from real RF, construction of one translated analytic band requires rejection of the _____ band.

Answer: conjugate. A real waveform contains conjugate spectral components. The selected complex representation must specify how the unwanted band is removed.
Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)
Why this term is required: “conjugate” completes the stated technical proposition.
Question context: Starting from real RF, construction of one translated analytic band requires rejection of the _____ band
Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.
Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-068. The conversion from real input to the selected analytic-band convention must retain the appropriate factor-of-_____ normalization.

Answer: two. Selecting one half of a real waveform's conjugate spectral representation changes the amplitude convention. It must be tracked before assigning physical power. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: "two" completes the stated technical proposition.

Question context: The conversion from real input to the selected analytic-band convention must retain the appropriate factor-of-_____ normalization

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-069. A signed complex spectrum does not remove sampling equivalence; interpretation still needs the admitted analog _____.

Answer: band. Different analog inputs can map to the same discrete-frequency class. Complex processing and analog admission solve different parts of the source-attribution problem. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: “band” completes the stated technical proposition.

Question context: A signed complex spectrum does not remove sampling equivalence; interpretation still needs the admitted analog _____

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-070. The conversion record should state I/Q order, exponential sign and the signed DFT-bin _____.

Answer: convention. Without these, a positive displayed offset can be mistaken for its negative counterpart or an index wrap. End-to-end known-offset tests establish the implemented mapping. Review: Equation 7E; Application 4A.7. Source: Equation 7E. Complex conversion without frequency folding (p. 1926)

Why this term is required: “convention” completes the stated technical proposition.

Question context: The conversion record should state I/Q order, exponential sign and the signed DFT-bin _____

Basis and qualification: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-FIB-071. A candidate twice 104 MHz RF minus three times 70 MHz LO has signed frequency _____ MHz.

Answer: -2. The signed arithmetic is 208 minus 210. The corresponding real magnitude is 2 MHz, but the negative sign matters for a movement prediction.

Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: "-2" completes the stated technical proposition.

Question context: A candidate twice 104 MHz RF minus three times 70 MHz LO has signed frequency _____ MHz

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-072. For the candidate twice 104 MHz RF minus three times 70 MHz LO, increasing LO by 0.1 MHz with RF fixed changes the absolute output to _____ MHz.

Answer: 2.3. The LO coefficient is -3, so the signed value decreases by 0.3 MHz to -2.3 MHz. Its magnitude increases. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: “2.3” completes the stated technical proposition.

Question context: For the candidate twice 104 MHz RF minus three times 70 MHz LO, increasing LO by 0.1 MHz with RF fixed changes the absolute output to _____ MHz

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-073. For twice 104 MHz RF minus three times 70 MHz LO, the local absolute-output slope with respect to LO on that negative signed branch is _____ hertz per hertz.

Answer: +3. Multiply the LO coefficient -3 by the signed-frequency sign -1. The result holds only while the same nonzero branch remains selected. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)
Why this term is required: “+3” completes the stated technical proposition.
Question context: For twice 104 MHz RF minus three times 70 MHz LO, the local absolute-output slope with respect to LO on that negative signed branch is _____ hertz per hertz
Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.
Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-074. For the candidate twice RF minus three times LO, with LO held at 70 MHz, raising the 104 MHz RF parent by 0.5 MHz changes the absolute output to _____ MHz.

Answer: 1. The RF coefficient 2 produces a +1 MHz signed shift from -2 to -1 MHz. A parent-frequency change probes a different derivative from an LO change. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)
Why this term is required: “1” completes the stated technical proposition.
Question context: For the candidate twice RF minus three times LO, with LO held at 70 MHz, raising the 104 MHz RF parent by 0.5 MHz changes the absolute output to _____ MHz
Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.
Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-075. The coefficient pair 2 and -3 has bounded-search order _____.

Answer: 5. Order is the sum of absolute coefficient values. It is not their algebraic difference or the magnitude of the resulting output frequency. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: “5” completes the stated technical proposition.

Question context: The coefficient pair 2 and -3 has bounded-search order _____

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-076. A declared maximum order 4 search _____ the pair 2 and -3.

Answer: excludes. The candidate lies outside the reported finite hypothesis set. Extending the bound is possible, but should be declared rather than silently applied after seeing a match. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: “excludes” completes the stated technical proposition.

Question context: A declared maximum order 4 search _____ the pair 2 and -3

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-077. The integer product search is explicitly _____ so that its hypothesis scope can be reported and tested.

Answer: bounded. Allowing arbitrary order and arbitrary parent signals can produce many coincidences. The architecture and a declared finite search constrain the interpretation. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: “bounded” completes the stated technical proposition.

Question context: The integer product search is explicitly _____ so that its hypothesis scope can be reported and tested

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-078. Changing both integer coefficients' signs preserves the real output _____ even though it reverses the signed candidate.

Answer: magnitude. The absolute-frequency representation cannot distinguish those global-sign partners by location alone. They should not count as independent evidence for separate mechanisms. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: "magnitude" completes the stated technical proposition.

Question context: Changing both integer coefficients' signs preserves the real output _____ even though it reverses the signed candidate

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-079. A signed candidate starts at +0.2 MHz with LO coefficient -2. Raising LO by 0.2 MHz leaves absolute output _____ MHz.

Answer: 0.2. The signed shift is -0.4 MHz, so the candidate ends at -0.2 MHz. Equal endpoint magnitudes conceal a zero crossing rather than proving zero dependence.

Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: “0.2” completes the stated technical proposition.

Question context: A signed candidate starts at +0.2 MHz with LO coefficient -2. Raising LO by 0.2 MHz leaves absolute output _____ MHz

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-080. At a zero crossing, the absolute-frequency trajectory has a _____ rather than one constant derivative through the crossing.

Answer: cusp. Evaluate the signed relation and then its magnitude, or handle each branch separately. Extrapolating a single slope across zero gives the wrong movement. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: “cusp” completes the stated technical proposition.

Question context: At a zero crossing, the absolute-frequency trajectory has a _____ rather than one constant derivative through the crossing

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-081. For 600 MHz RF, a 660 MHz first LO and a 50 MHz second LO, the final real difference IF is 10 MHz and composite orientation is _____.

Answer: negative. The first stage reverses orientation at 60 MHz; the second has positive orientation because 60 exceeds 50. Their sign product is negative. Review: Equation 7J. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why this term is required: “negative” completes the stated technical proposition.

Question context: For 600 MHz RF, a 660 MHz first LO and a 50 MHz second LO, the final real difference IF is 10 MHz and composite orientation is _____

Basis and qualification: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

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V011-C04-FIB-082. For 600 MHz RF, a 660 MHz first LO and a 70 MHz second LO, the final real difference IF is 10 MHz and composite orientation is _____.

Answer: positive. The second stage now reverses as well. Two reversals preserve the local ordering of original RF offsets at the final IF. Review: Equation 7J. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why this term is required: “positive” completes the stated technical proposition.

Question context: For 600 MHz RF, a 660 MHz first LO and a 70 MHz second LO, the final real difference IF is 10 MHz and composite orientation is _____

Basis and qualification: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

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V011-C04-FIB-083. For 600 MHz RF, a 660 MHz first LO and a 50 MHz second LO, raising the original RF by 2 MHz changes the final real difference IF to _____ MHz.

Answer: 8. The first IF falls from 60 to 58 MHz. The distance from the 50 MHz second LO is 8 MHz, consistent with negative composite orientation. Review: Equation 7J. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why this term is required: “8” completes the stated technical proposition.

Question context: For 600 MHz RF, a 660 MHz first LO and a 50 MHz second LO, raising the original RF by 2 MHz changes the final real difference IF to _____ MHz

Basis and qualification: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

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V011-C04-FIB-084. For 600 MHz RF, a 660 MHz first LO and a 70 MHz second LO, raising the original RF by 2 MHz changes the final real difference IF to _____ MHz.

Answer: 12. The first IF again becomes 58 MHz, but its distance below 70 MHz becomes 12 MHz. The extra reversal changes the direction of the final offset.
Review: Equation 7J. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)
Why this term is required: “12” completes the stated technical proposition.
Question context: For 600 MHz RF, a 660 MHz first LO and a 70 MHz second LO, raising the original RF by 2 MHz changes the final real difference IF to _____ MHz
Basis and qualification: Chapter 4 — Equation 7J. Orientation through selected real difference stages.
Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

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V011-C04-FIB-085. Three orientation reversals on fixed nonzero branches produce an overall _____ orientation.

Answer: negative. Multiplying three minus-one derivatives gives minus one. Counting center-frequency values alone would not reveal that sideband ordering.

Review: Equation 7J. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why this term is required: “negative” completes the stated technical proposition.

Question context: Three orientation reversals on fixed nonzero branches produce an overall _____ orientation

Basis and qualification: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

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V011-C04-FIB-086. Two orientation reversals on fixed nonzero branches produce an overall _____ orientation.

Answer: positive. The local derivatives multiply. This restores frequency ordering, but does not by itself establish unwanted-product rejection or gain calibration.

Review: Equation 7J. Source: Equation 7J. Orientation through selected real difference stages (p. 1928)

Why this term is required: “positive” completes the stated technical proposition.

Question context: Two orientation reversals on fixed nonzero branches produce an overall _____ orientation

Basis and qualification: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

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V011-C04-FIB-087. A change of selected IF or injection side is recorded as a conversion-state _____ rather than treated as unchanged configuration.

Answer: event. The event can alter both amplitude response and orientation. Preserve its timing and state identity so each record segment uses the correct model. Review: Conversion-State Challenge Protocol. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

Why this term is required: “event” completes the stated technical proposition.

Question context: A change of selected IF or injection side is recorded as a conversion-state _____ rather than treated as unchanged configuration

Basis and qualification: Chapter 4 — Conversion-State Challenge Protocol.

Review: Chapter 4 — Conversion-State Challenge Protocol.

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V011-C04-FIB-088. The LO-only movement formula holds the RF parent _____ during the perturbation.

Answer: fixed. If a shared reference moves both RF and LO, both coefficient-weighted changes contribute. The controlled variable and dependencies must be stated. Review: Equations 7H and 7I. Source: Equation 7H. Bounded integer product search (p. 1928)

Why this term is required: “fixed” completes the stated technical proposition.

Question context: The LO-only movement formula holds the RF parent _____ during the perturbation

Basis and qualification: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-FIB-089. A retuned candidate must remain within a measurable IF _____ if its movement is to be observed directly.

Answer: passband. Disappearance at a filter boundary is not a measured new frequency. Plan an excursion and estimator that retain the predicted candidate when feasible. Review: Application 4A.8. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

Why this term is required: “passband” completes the stated technical proposition.

Question context: A retuned candidate must remain within a measurable IF _____ if its movement is to be observed directly

Basis and qualification: Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

Review: Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-FIB-090. Frequency-movement evidence and amplitude-transfer evidence have separate _____ requirements.

Answer: validity. A nonlinear state may preserve a candidate frequency relationship while invalidating scalar gain. Conversely, accurate amplitude can still be assigned to the wrong external RF branch. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why this term is required: “validity” completes the stated technical proposition.

Question context: Frequency-movement evidence and amplitude-transfer evidence have separate _____ requirements

Basis and qualification: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-FIB-091. The suppression of unwanted coupling from one mixer port to another is port _____.

Answer: isolation. It depends on the physical mixer and operating state. A frequency-product formula does not provide a measured leakage level. Review: Local-Oscillator Purity and Leakage. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

Why this term is required: “isolation” completes the stated technical proposition.

Question context: The suppression of unwanted coupling from one mixer port to another is port _____

Basis and qualification: Chapter 4 — Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

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V011-C04-FIB-092. A leakage test should distinguish antenna reradiation, enclosure radiation and cable _____ coupling.

Answer: common-mode. The observed field can change when the external cable or termination changes. The experiment should identify which physical route was actually altered. Review: Local-Oscillator Purity and Leakage. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

Why this term is required: “common-mode” completes the stated technical proposition.

Question context: A leakage test should distinguish antenna reradiation, enclosure radiation and cable _____ coupling

Basis and qualification: Chapter 4 — Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

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V011-C04-FIB-093. A terminated RF input does not automatically exclude radiation from the receiver _____.

Answer: enclosure. Termination challenges the antenna-input path. Internal circuitry can still couple to an enclosure or cable, so broader leakage claims need corresponding observations. Review: Local-Oscillator Purity and Leakage. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

Why this term is required: “enclosure” completes the stated technical proposition.

Question context: A terminated RF input does not automatically exclude radiation from the receiver _____

Basis and qualification: Chapter 4 — Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

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V011-C04-FIB-094. A generator _____ falling in the desired RF path can imitate an image-test response.

Answer: harmonic. Verify or bound the stimulus spectrum at the receiver plane. A clean fundamental setting on the generator does not prove that only that frequency was delivered. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why this term is required: “harmonic” completes the stated technical proposition.

Question context: A generator _____ falling in the desired RF path can imitate an image-test response

Basis and qualification: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-FIB-095. Two sources can generate a false candidate before the receiver through interaction in the _____ path.

Answer: combining. Isolation, component linearity and independent source-path observations constrain this alternative. A receiver-product label needs more than the output line's frequency match. Review: From a product map to a discriminating test. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why this term is required: "combining" completes the stated technical proposition.

Question context: Two sources can generate a false candidate before the receiver through interaction in the _____ path

Basis and qualification: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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V011-C04-FIB-096. Separating surrounding filter and amplifier transfer from a mixer-only measurand is called _____.

Answer: de-embedding. The path measurement includes all those elements. The intended mixer result requires applicable individual characterization and separation with stated uncertainty. Review: Conversion Gain, Loss, and Calibration. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

Why this term is required: “de-embedding” completes the stated technical proposition.

Question context: Separating surrounding filter and amplifier transfer from a mixer-only measurand is called _____

Basis and qualification: Chapter 4 — Conversion Gain, Loss, and Calibration.

Review: Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-FIB-097. Conversion gain is conditioned on LO _____ as well as frequency, reference planes, loading, level and temperature.

Answer: drive. Two measurements at the same RF and LO frequencies can differ if the LO excitation changes the mixer's operating state. Review: Conversion Gain, Loss, and Calibration. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)
Why this term is required: "drive" completes the stated technical proposition.
Question context: Conversion gain is conditioned on LO _____ as well as frequency, reference planes, loading, level and temperature
Basis and qualification: Chapter 4 — Conversion Gain, Loss, and Calibration.
Review: Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-FIB-098. After firmware changes alter automatic path selection, stored correction tables require _____ checks before reuse.

Answer: applicability. The file's identity and historical validity do not establish that the current path realizes the same transfer. Preserve the version and verify relevant states. Review: Conversion-State Challenge Protocol. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

Why this term is required: "applicability" completes the stated technical proposition.

Question context: After firmware changes alter automatic path selection, stored correction tables require _____ checks before reuse

Basis and qualification: Chapter 4 — Conversion-State Challenge Protocol.

Review: Chapter 4 — Conversion-State Challenge Protocol.

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V011-C04-FIB-099. To distinguish a clock-related internal spur from relabeling of a fixed external tone, use an independent physical-frequency _____ and the actual clock/LO map.

Answer: reference. A displayed frequency can change when the receiver's time or frequency scale changes. The chapter's case therefore leaves generation mechanism open without this additional evidence. Review: Hypothetical Case Adjudication. Source: §4.22 Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses (p. 1955)

Why this term is required: "reference" completes the stated technical proposition.

Question context: To distinguish a clock-related internal spur from relabeling of a fixed external tone, use an independent physical-frequency _____ and the actual clock/LO map

Basis and qualification: Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

Review: Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

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V011-C04-FIB-100. Conversion tests can support a bounded frequency-path interpretation, but emitter identity needs additional _____ evidence.

Answer: linkage. The mathematical map does not locate an emitter or identify its operator. The report should separate the supported conversion result from those unresolved external claims. Review: From a product map to a discriminating test.

Source: §4.18 From a product map to a discriminating test (p. 1949)

Why this term is required: “linkage” completes the stated technical proposition.

Question context: Conversion tests can support a bounded frequency-path interpretation, but emitter identity needs additional _____ evidence

Basis and qualification: Chapter 4 — From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C04-ESSAY-001. Derive the two output tones of the normalized real multiplier in Model 4A. Explain which additional condition is needed before the difference term can be treated as the selected output.

- Opening: Present a thesis that answers this precise question: Derive the two output tones of the normalized real multiplier in Model 4A. Explain which additional condition is needed before the difference term can be treated as the.... Identify which evidence would falsify the proposed conclusion Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Core terminology and scope: Define tones, normalized, multiplier in the question's particular technical setting; explain how condition, term, treated differ if that distinction would change the analysis of "Derive the two output tones of the normalized real multiplier in Model 4A. Explain which additional condition is needed before the difference term can be treated as the..." Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Write the RF as a peak-amplitude cosine and the real LO multiplier as twice the nonnegative voltage scale times a unit cosine Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the two output tones of the normalized real multiplier in Model 4A to the claimed result, following "Application 4A.4: Expose the multiplier normalization"; name the intermediate states and measurable outputs Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the two output tones of the normalized real multiplier in Model 4A. Apply the cosine product identity to obtain a difference-frequency term and a sum-frequency term Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.3: Separate loaded voltage gain from power gain” that resolves the question about the two output tones of the normalized real multiplier in Model 4A; derive the relevant result with units and stated validity conditions Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the two output tones of the normalized real multiplier in Model 4A. The derivation predicts both terms; it does not remove the sum term Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Worked application or illustrative case: Build a worked example of “the two output tones of the normalized real multiplier in Model 4A”, addressing this associated condition: Explain which additional condition is needed before the difference term can be treated as the selected.... Write the RF as a peak-amplitude cosine and the real LO multiplier as twice the nonnegative voltage scale times a unit cosine Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the two output tones of the normalized

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real multiplier in Model 4A". Using "Application 4A.3: Separate loaded voltage gain from power gain", specify a discriminator and the result expected under each explanation Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the two output tones of the normalized real multiplier in Model 4A, including the effect of missing measurements and inconsistent operating conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Scholarly synthesis and implications: Explain what the result about the two output tones of the normalized real multiplier in Model 4A authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Closing: Conclude by answering "Derive the two output tones of the normalized real multiplier in Model 4A. Explain which additional condition is needed before the difference term can be treated as the…" using only the demonstrated evidence; state the remaining decisive verification step Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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V011-C04-ESSAY-002. A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees. Calculate the signed and real IF, the positive-frequency IF phase, the conventional image, and the response to a 0.4 MHz RF increase. State the conditions behind those results.

- Opening: Present a thesis that answers this precise question: A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees. Identify which evidence would falsify the proposed conclusion Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Core terminology and scope: Define degrees, converted, Calculate in the question's particular technical setting; explain how conventional, image, increase differ if that distinction would change the analysis of "A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees" Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The signed difference is -23 MHz, so the selected real IF is 23 MHz Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees to the claimed result, following "Application 4A.1: Locate a low-side image"; name the intermediate states and

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measurable outputs Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees. The signed difference phase is -55 degrees; rewriting the negative-frequency cosine at positive frequency gives +55 degrees Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.9: Track inversion through two real conversions” that resolves the question about A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees; derive the relevant result with units and stated validity conditions Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees. Reflection about the LO gives an image candidate at 478 MHz, provided that positive RF frequency reaches the mixer Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Worked application or illustrative case: Build a worked example of “A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees”, addressing this associated condition: Calculate the signed and real IF, the positive-frequency IF phase, the conventional image, and the.... The signed difference is -23 MHz, so

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the selected real IF is 23 MHz Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees”. Using “Application 4A.9: Track inversion through two real conversions”, specify a discriminator and the result expected under each explanation Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees, including the effect of missing measurements and inconsistent operating conditions Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Scholarly synthesis and implications: Explain what the result about A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Closing: Conclude by answering “A 432 MHz RF tone with phase -20 degrees is converted by a 455 MHz LO with phase 35 degrees” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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V011-C04-ESSAY-003. For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale $g=2$, and a 300-ohm IF load, calculate both powers and the selected-product power gain. Explain the error in treating the squared voltage ratio alone as the power ratio.

- Opening: Present a thesis that answers this precise question: For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the selected-product power gain. Identify which evidence would falsify the proposed conclusion Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Core terminology and scope: Define loaded, ohms, load in the question's particular technical setting; explain how calculate, treating, squared differ if that distinction would change the analysis of "For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the selected-product power gain" Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The selected IF peak is 0.36 V Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the… to the claimed result, following "Model 4A: a declared conversion map"; name the

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intermediate states and measurable outputs Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the.... The RF power is or 0.216 mW Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.4: Expose the multiplier normalization” that resolves the question about For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the...; derive the relevant result with units and stated validity conditions Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the.... The IF power is also 0.216 mW Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Worked application or illustrative case: Build a worked example of “For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the...”, addressing this associated condition: Explain the error in treating the squared voltage ratio alone as the power ratio. The selected IF peak is 0.36 V Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the…”. Using “Application 4A.4: Expose the multiplier normalization”, specify a discriminator and the result expected under each explanation Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the…, including the effect of missing measurements and inconsistent operating conditions Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)
- Scholarly synthesis and implications: Explain what the result about For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Closing: Conclude by answering “For a loaded RF peak voltage of 0.18 V across 75 ohms, voltage scale and a 300-ohm IF load, calculate both powers and the selected-product power gain” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

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V011-C04-ESSAY-004. Compare an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone. Use equal 50-ohm loaded planes for the real sinusoidal powers and explain why the normalization difference is not evidence of a calibration defect.

- Opening: Present a thesis that answers this precise question: Compare an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone. Identify which evidence would falsify the proposed conclusion Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Core terminology and scope: Define unscaled, cosine, multiplier in the question's particular technical setting; explain how loaded, sinusoidal, defect differ if that distinction would change the analysis of "Compare an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone" Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Problem statement and purpose: Frame the actual measurement or decision in the question. An unscaled unit cosine LO gives a selected real product with 0.2 V peak Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone to the claimed result, following "Model 4A: a declared conversion map"; name the

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intermediate states and measurable outputs Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone. The RF power is 1.6 mW and the selected IF power is 0.4 mW, so the ratio is one quarter, approximately -6.02 dB Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.3: Separate loaded voltage gain from power gain” that resolves the question about an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone; derive the relevant result with units and stated validity conditions Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone. With the leading factor two and the selected peak is 0.4 V and the loaded selected-product ratio is unity Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Worked application or illustrative case: Build a worked example of “an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone”, addressing this associated condition: Use equal 50-ohm loaded

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planes for the real sinusoidal powers and explain why the normalization.... An unscaled unit cosine LO gives a selected real product with 0.2 V peak Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone”. Using “Application 4A.3: Separate loaded voltage gain from power gain”, specify a discriminator and the result expected under each explanation Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone, including the effect of missing measurements and inconsistent operating conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Scholarly synthesis and implications: Explain what the result about an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)
- Closing: Conclude by answering “Compare an unscaled real cosine multiplier, the normalized real multiplier, and analytic complex conversion for a 0.4 V peak RF tone” using only the demonstrated

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evidence; state the remaining decisive verification step Source: §4.7

Application 4A.4: Expose the multiplier normalization (p. 1935)

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V011-C04-ESSAY-005. The desired RF input is -96 dBm and an image input is -34 dBm. Desired-path preselection loss is 2.5 dB. Selected conversion gains are -7 dB for the desired path and -8 dB for the image path. Find the minimum image-frequency preselection loss needed for a 12 dB desired-over-image output margin.

- Opening: Present a thesis that answers this precise question: The desired RF input is -96 dBm and an image input is -34 dBm. Identify which evidence would falsify the proposed conclusion Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Core terminology and scope: Define image, preselection, conversion in the question's particular technical setting; explain how gains, minimum, margin differ if that distinction would change the analysis of "The desired RF input is -96 dBm and an image input is -34 dBm" Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The desired output is dBm Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting The desired RF input is -96 dBm and an image input is -34 dBm to the claimed result, following "4. Experimental protocol: comparing passive and active conversion"; name the intermediate states and measurable outputs Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for The desired RF input is -96 dBm and an image input is -34 dBm. A 12 dB margin requires the image output to be no greater than -117.5 dBm Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Image Responses and Image Rejection” that resolves the question about The desired RF input is -96 dBm and an image input is -34 dBm; derive the relevant result with units and stated validity conditions Source: §4.15 Image Responses and Image Rejection (p. 1944)
- Evidence and method: Specify the native observations, control records and calculations that would resolve The desired RF input is -96 dBm and an image input is -34 dBm. If the image preselection loss is L dB, its output is dBm Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Worked application or illustrative case: Build a worked example of “The desired RF input is -96 dBm and an image input is -34 dBm”, addressing this associated condition: Desired-path preselection loss is 2.5 dB. The desired output is dBm Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “The desired RF input is -96 dBm and an image input is -34 dBm”. Using “Image Responses and Image Rejection”, specify a discriminator and the result expected under each explanation Source: §4.15 Image Responses and Image Rejection (p. 1944)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to The desired RF input is -96 dBm and an image input is -34 dBm, including the effect of missing measurements and inconsistent operating conditions Source: §4.18 From a product map to a discriminating test (p. 1949)
- Scholarly synthesis and implications: Explain what the result about The desired RF input is -96 dBm and an image input is -34 dBm authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Closing: Conclude by answering “The desired RF input is -96 dBm and an image input is -34 dBm” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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V011-C04-ESSAY-006. A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz. Derive both RF intervals and their orientation. Then explain how the mapping changes when the lower interval crosses zero physical RF frequency.

- Opening: Present a thesis that answers this precise question: A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz. Identify which evidence would falsify the proposed conclusion Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Core terminology and scope: Define converter, admits, orientation in the question's particular technical setting; explain how mapping, lower, crosses differ if that distinction would change the analysis of "A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz" Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The upper RF interval is 65 through 68 MHz, and the lower interval is 52 through 55 MHz Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz to the claimed result, following "Application 4A.9: Track inversion through two real conversions"; name the intermediate states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz. Increasing RF within the upper interval increases IF; increasing RF within the lower interval decreases IF Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.2: Track high-side spectral inversion” that resolves the question about A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz; derive the relevant result with units and stated validity conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz. The reversal of interval endpoints follows directly from subtracting the IF endpoints from the LO Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Worked application or illustrative case: Build a worked example of “A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz”, addressing this associated condition: Derive both RF intervals and their orientation. The upper RF interval is 65 through 68 MHz, and the lower interval is 52 through 55 MHz Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz”. Using “Application 4A.2: Track high-side spectral inversion”, specify a discriminator and the result expected under each explanation Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz, including the effect of missing measurements and inconsistent operating conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Scholarly synthesis and implications: Explain what the result about A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Closing: Conclude by answering “A real difference converter uses a 60 MHz LO and admits IF frequencies from 5 through 8 MHz” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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V011-C04-ESSAY-007. At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV. Across a 50-ohm load, calculate powers for relative phases of 0, 90, and 180 degrees. Explain what a single measured power cannot establish.

- Opening: Present a thesis that answers this precise question: At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV. Identify which evidence would falsify the proposed conclusion Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Core terminology and scope: Define phasor, contribution, load in the question's particular technical setting; explain how calculate, phases, degrees differ if that distinction would change the analysis of "At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV" Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The desired-only power is 40 nW Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV to the claimed result, following "Application 4A.2: Track high-side spectral inversion"; name the intermediate states and measurable outputs Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV. The image-to-desired peak ratio is 0.3, so the normalized powers are 1.69 at zero phase, 1.09 at 90 degrees, and 0.49 at 180 degrees Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.5: Allocate image rejection ahead of equal conversion” that resolves the question about At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV; derive the relevant result with units and stated validity conditions Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Evidence and method: Specify the native observations, control records and calculations that would resolve At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV. The corresponding powers are 67.6, 43.6, and 19.6 nW Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Worked application or illustrative case: Build a worked example of “At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV”, addressing this associated condition: Across a 50-ohm load, calculate powers for relative phases of 0, 90, and 180 degrees. The desired-only power is 40 nW Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV”. Using “Application 4A.5: Allocate image rejection ahead of equal conversion”, specify a discriminator and the result expected under each explanation Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV, including the effect of missing measurements and inconsistent operating conditions Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Scholarly synthesis and implications: Explain what the result about At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Closing: Conclude by answering “At one selected IF, the desired peak phasor has magnitude 2 mV and an image contribution has magnitude 0.6 mV” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

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V011-C04-ESSAY-008. Derive the condition under which the two powers in a desired/image collision may be added. Distinguish a fixed 90-degree relative phase from a justified incoherent average even when they produce the same measured power.

- Opening: Present a thesis that answers this precise question: Derive the condition under which the two powers in a desired/image collision may be added. Identify which evidence would falsify the proposed conclusion Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Core terminology and scope: Define added, degree, justified in the question's particular technical setting; explain how incoherent, average, produce differ if that distinction would change the analysis of "Derive the condition under which the two powers in a desired/image collision may be added" Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Expand the squared magnitude of the sum of the two selected IF phasors Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the condition under which the two powers in a desired/image collision may be added to the claimed result, following "Model 4A: a declared conversion map"; name the intermediate states and measurable outputs Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the condition under which the two powers in a desired/image collision may be added. The result contains the two squared magnitudes and twice the real part of their cross product Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.5: Allocate image rejection ahead of equal conversion” that resolves the question about the condition under which the two powers in a desired/image collision may be added; derive the relevant result with units and stated validity conditions Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the condition under which the two powers in a desired/image collision may be added. After applying the declared averaging operation, power addition requires that the averaged real cross term vanish Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Worked application or illustrative case: Build a worked example of “the condition under which the two powers in a desired/image collision may be added”, addressing this associated condition: Distinguish a fixed 90-degree relative phase from a justified incoherent average even when they produce.... Expand the squared magnitude of the sum of the two selected IF phasors Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the condition under which the two powers in a desired/image collision may be added”. Using “Application 4A.5: Allocate image rejection ahead of equal conversion”, specify a discriminator and the result expected under each explanation Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the condition under which the two powers in a desired/image collision may be added, including the effect of missing measurements and inconsistent operating conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Scholarly synthesis and implications: Explain what the result about the condition under which the two powers in a desired/image collision may be added authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Closing: Conclude by answering “Derive the condition under which the two powers in a desired/image collision may be added” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

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V011-C04-ESSAY-009. A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT. In separate trials the RF is 25.0125 MHz and 24.9875 MHz. Determine signed baseband frequencies and ordinary DFT array indices, and design an orientation check.

- Opening: Present a thesis that answers this precise question: A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT. Identify which evidence would falsify the proposed conclusion Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)
- Core terminology and scope: Define trials, baseband, ordinary in the question's particular technical setting; explain how array, design, orientation differ if that distinction would change the analysis of "A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT" Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The signed baseband frequencies are +12.5 kHz and -12.5 kHz Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT to the claimed result, following "Application 4A.9: Track inversion through two real conversions"; name the intermediate states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT. The bin spacing is 500 Hz, so the signed bin numbers are +25 and -25 Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.10: Map an admitted IF interval back to both RF intervals” that resolves the question about A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT; derive the relevant result with units and stated validity conditions Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT. Under ordinary zero-based array indexing, those correspond to indices 25 and 135 Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)
- Worked application or illustrative case: Build a worked example of “A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT”, addressing this associated condition: In separate trials the RF is 25.0125 MHz and 24.9875 MHz. The signed baseband frequencies are +12.5 kHz and -12.5 kHz Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT”. Using “Application 4A.10: Map an admitted IF interval back to both RF intervals”, specify a discriminator and the result expected under each explanation Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT, including the effect of missing measurements and inconsistent operating conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Scholarly synthesis and implications: Explain what the result about A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)
- Closing: Conclude by answering “A complex converter uses a 25 MHz LO, an 80,000-complex-samples-per-second rate, and a 160-point DFT” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

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V011-C04-ESSAY-010. Explain the positive-frequency admission assumption in the analytic RF representation of Model 4A. Assess a proposed complex envelope occupying offsets from -4 through +4 MHz when its carrier is only 3 MHz.

- Opening: Present a thesis that answers this precise question: Explain the positive-frequency admission assumption in the analytic RF representation of Model 4A. Identify which evidence would falsify the proposed conclusion Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Core terminology and scope: Define admission, assumption, representation in the question's particular technical setting; explain how proposed, envelope, offsets differ if that distinction would change the analysis of "Explain the positive-frequency admission assumption in the analytic RF representation of Model 4A" Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Translating those envelope offsets to a 3 MHz carrier produces nominal support from -1 through +7 MHz, so the stated band is not wholly at positive physical RF frequency Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the positive-frequency admission assumption in the analytic RF representation of Model 4A to the claimed result, following "Application 4A.9: Track inversion through two real conversions"; name the intermediate

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states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the positive-frequency admission assumption in the analytic RF representation of Model 4A. It therefore violates the particular analytic-band assumption used to connect this envelope directly to the real RF waveform Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 4A: a declared conversion map” that resolves the question about the positive-frequency admission assumption in the analytic RF representation of Model 4A; derive the relevant result with units and stated validity conditions Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the positive-frequency admission assumption in the analytic RF representation of Model 4A. One cannot simply label the entire translated band the positive-frequency analytic RF signal Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Worked application or illustrative case: Build a worked example of “the positive-frequency admission assumption in the analytic RF representation of Model 4A”, addressing this associated condition: Assess a proposed complex envelope occupying offsets from -4 through +4 MHz when its carrier is only 3.... Translating those

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envelope offsets to a 3 MHz carrier produces nominal support from -1 through +7 MHz, so the stated band is not wholly at positive… Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the positive-frequency admission assumption in the analytic RF representation of Model 4A”. Using “Model 4A: a declared conversion map”, specify a discriminator and the result expected under each explanation Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the positive-frequency admission assumption in the analytic RF representation of Model 4A, including the effect of missing measurements and inconsistent operating conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Scholarly synthesis and implications: Explain what the result about the positive-frequency admission assumption in the analytic RF representation of Model 4A authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Closing: Conclude by answering “Explain the positive-frequency admission assumption in the analytic RF representation of Model 4A” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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V011-C04-ESSAY-011. An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product $3f_{RF} - 2f_{LO}$. Determine its order and predict separate responses to a 0.25 MHz LO increase and a 0.1 MHz RF increase. Explain what matching both movements would establish.

- Opening: Present a thesis that answers this precise question: An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate responses to a 0.25 MHz LO increase and a 0.1 MHz RF.... Identify which evidence would falsify the proposed conclusion Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Core terminology and scope: Define parent, candidate, predict in the question's particular technical setting; explain how responses, increase, matching differ if that distinction would change the analysis of "An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate responses to a 0.25 MHz LO increase and a 0.1 MHz RF..." Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The candidate starts at 6 MHz and has total harmonic order 5, so a search bounded below order 5 must exclude it Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product

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Determine its order and predict separate… to the claimed result, following “Application 4A.9: Track inversion through two real conversions”; name the intermediate states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate…. Raising the LO by 0.25 MHz changes the signed product by -0.5 MHz, giving a real output at 5.5 MHz Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.2: Track high-side spectral inversion” that resolves the question about An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate…; derive the relevant result with units and stated validity conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Evidence and method: Specify the native observations, control records and calculations that would resolve An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate…. Restoring the LO and raising the RF by 0.1 MHz changes the product by +0.3 MHz, giving 6.3 MHz Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- Worked application or illustrative case: Build a worked example of “An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate…”, addressing this associated condition: Explain what matching both movements would establish. The candidate starts at 6 MHz and has total harmonic order 5, so a search bounded below order 5 must exclude it Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate…”. Using “Application 4A.2: Track high-side spectral inversion”, specify a discriminator and the result expected under each explanation Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate…, including the effect of missing measurements and inconsistent operating conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Scholarly synthesis and implications: Explain what the result about An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate… authorises the investigator or engineer to claim, and

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what stronger proposition remains unsupported Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- Closing: Conclude by answering “An RF parent at 82 MHz and an LO at 120 MHz produce the candidate signed product Determine its order and predict separate responses to a 0.25 MHz LO increase and a 0.1 MHz RF…” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-ESSAY-012. A candidate has signed frequency +0.15 MHz and LO coefficient $n = -2$. The LO is then increased by 0.10 MHz. Calculate the final real frequency and explain why extrapolating one absolute-frequency slope across the whole change fails.

- Opening: Present a thesis that answers this precise question: A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz. Identify which evidence would falsify the proposed conclusion Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Core terminology and scope: Define candidate, Calculate, final in the question's particular technical setting; explain how extrapolating, slope, fails differ if that distinction would change the analysis of "A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz" Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The signed change is -0.20 MHz, so the final signed frequency is -0.05 MHz and the real frequency is 0.05 MHz Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz to the claimed result, following "Application 4A.9: Track inversion through two real conversions"; name the

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intermediate states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz. The endpoint change in the real frequency is therefore -0.10 MHz Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.2: Track high-side spectral inversion” that resolves the question about A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz; derive the relevant result with units and stated validity conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz. Before the crossing, the local real-frequency slope with respect to LO is -2; after it, the slope is +2 Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Worked application or illustrative case: Build a worked example of “A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz”, addressing this associated condition: Calculate the final real frequency and explain why extrapolating one absolute-frequency slope across the.... The signed change is -0.20 MHz, so the final signed frequency is -0.05 MHz and

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the real frequency is 0.05 MHz Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz”. Using “Application 4A.2: Track high-side spectral inversion”, specify a discriminator and the result expected under each explanation Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz, including the effect of missing measurements and inconsistent operating conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Scholarly synthesis and implications: Explain what the result about A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Closing: Conclude by answering “A candidate has signed frequency +0.15 MHz and LO coefficient The LO is then increased by 0.10 MHz” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-ESSAY-013. For an RF parent of 41 MHz, an LO of 40 MHz, and a search order $K=3$, identify the candidate real product frequencies in the interval greater than zero through 5 MHz. Explain what changes when K is extended to 4 and how to prevent a post hoc frequency match from becoming an unsupported physical conclusion.

- Opening: Present a thesis that answers this precise question: For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval greater than zero through 5 MHz. Identify which evidence would falsify the proposed conclusion Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Core terminology and scope: Define greater, extended, prevent in the question's particular technical setting; explain how post, match, unsupported differ if that distinction would change the analysis of "For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval greater than zero through 5 MHz" Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Problem statement and purpose: Frame the actual measurement or decision in the question. At order no greater than 3, the difference pair with coefficients +1 and -1 gives 1 MHz; reversing both signs gives the same real frequency Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the

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candidate real product frequencies in the interval… to the claimed result, following “Application 4A.9: Track inversion through two real conversions”; name the intermediate states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval…. No other nonzero integer combination inside that order bound falls in the stated interval Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.10: Map an admitted IF interval back to both RF intervals” that resolves the question about For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval…; derive the relevant result with units and stated validity conditions Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval…. At order 4, the pair +2 and -2 adds a 2 MHz candidate, again with a redundant globally negated representation Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- Worked application or illustrative case: Build a worked example of "For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval…", addressing this associated condition: Explain what changes when K is extended to 4 and how to prevent a post hoc frequency match from becoming…. At order no greater than 3, the difference pair with coefficients +1 and -1 gives 1 MHz; reversing both… Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Alternative explanations and failure modes: Construct two plausible technical explanations for "For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval…". Using "Application 4A.10: Map an admitted IF interval back to both RF intervals", specify a discriminator and the result expected under each explanation Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval…, including the effect of missing measurements and inconsistent operating conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Scholarly synthesis and implications: Explain what the result about For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- Closing: Conclude by answering “For an RF parent of 41 MHz, an LO of 40 MHz, and a search order identify the candidate real product frequencies in the interval greater than zero through 5 MHz” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-ESSAY-014. A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz. Find its center outputs and final RF orientation. Compare a third LO of 8 MHz, including the effect of a 0.5 MHz RF increase.

- Opening: Present a thesis that answers this precise question: A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz. Identify which evidence would falsify the proposed conclusion Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Core terminology and scope: Define outputs, final, orientation in the question's particular technical setting; explain how including, effect, increase differ if that distinction would change the analysis of "A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz" Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The first two real outputs are 50 and 10 MHz, with local orientations negative and positive Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz to the claimed result, following "Application 4A.1: Locate a low-side image"; name the intermediate states and measurable outputs Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz. A 12 MHz third LO gives 2 MHz with a negative third orientation, so the product of signs is positive Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.2: Track high-side spectral inversion” that resolves the question about A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz; derive the relevant result with units and stated validity conditions Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz. Raising the original RF to 1,200.5 MHz gives successive outputs 49.5, 9.5, and 2.5 MHz Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Worked application or illustrative case: Build a worked example of “A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz”, addressing this associated condition: Find its center outputs and final RF orientation. The first two real outputs are 50 and 10 MHz, with local orientations negative and positive Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz”. Using “Application 4A.2: Track high-side spectral inversion”, specify a discriminator and the result expected under each explanation Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz, including the effect of missing measurements and inconsistent operating conditions Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Scholarly synthesis and implications: Explain what the result about A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Closing: Conclude by answering “A three-stage real difference chain has RF 1,200 MHz, first LO 1,250 MHz, second LO 40 MHz, and third LO 12 MHz” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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V011-C04-ESSAY-015. Design a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table. Explain why a center-tone level check alone is insufficient.

- Opening: Present a thesis that answers this precise question: Design a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table. Explain why a center-tone level check.... Identify which evidence would falsify the proposed conclusion Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Core terminology and scope: Define Design, verification, injection in the question's particular technical setting; explain how table, check, insufficient differ if that distinction would change the analysis of "Design a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table. Explain why a center-tone level check..." Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Treat the boundary as a change in physical conversion state Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table to the claimed result, following "Application 4A.9: Track inversion through two real conversions"; name the intermediate states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table. Record the selected RF path, every available LO and IF, preselection, attenuation, gain, sample path, correction identity, and lock state on both sides Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 4A: a declared conversion map” that resolves the question about a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table; derive the relevant result with units and stated validity conditions Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table. Apply a known tone or ordered tone pair with a small frequency separation that remains within each selected path, and establish the sign and scale of the frequency map Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Worked application or illustrative case: Build a worked example of “a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table”, addressing this associated condition: Explain why a center-tone level check alone is insufficient. Treat the boundary as a change in

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physical conversion state Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table”. Using “Model 4A: a declared conversion map”, specify a discriminator and the result expected under each explanation Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table, including the effect of missing measurements and inconsistent operating conditions Source: §4.18 From a product map to a discriminating test (p. 1949)
- Scholarly synthesis and implications: Explain what the result about a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Closing: Conclude by answering “Design a verification across a receiver band boundary that may change both the LO injection side and the conversion correction table. Explain why a center-tone level check…” using only the demonstrated evidence; state the remaining

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decisive verification step Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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V011-C04-ESSAY-016. A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output. An image-frequency injection is actually -57 dBm at that plane and produces -109 dBm output. Calculate the differential path rejection and explain why the raw 43 dB output difference is not the complete result.

- Opening: Present a thesis that answers this precise question: A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output. Identify which evidence would falsify the proposed conclusion Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Core terminology and scope: Define injection, actually, produces in the question's particular technical setting; explain how Calculate, differential, rejection differ if that distinction would change the analysis of "A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output" Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The desired transfer is -6 dB and the image transfer is -52 dB Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output to the claimed result, following "4. Experimental protocol: comparing passive and active conversion"; name the

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intermediate states and measurable outputs Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output. Their difference is 46 dB, so the measured path rejection under these conditions is 46 dB Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Image Responses and Image Rejection” that resolves the question about A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output; derive the relevant result with units and stated validity conditions Source: §4.15 Image Responses and Image Rejection (p. 1944)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output. The raw output separation is only 43 dB because the image input was 3 dB stronger Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Worked application or illustrative case: Build a worked example of “A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output”, addressing this associated condition: An image-frequency injection is actually -57 dBm at that plane and produces -109 dBm output. The desired transfer is -6 dB and the

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image transfer is -52 dB Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output”. Using “Image Responses and Image Rejection”, specify a discriminator and the result expected under each explanation Source: §4.15 Image Responses and Image Rejection (p. 1944)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output, including the effect of missing measurements and inconsistent operating conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Scholarly synthesis and implications: Explain what the result about A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Closing: Conclude by answering “A desired-frequency injection is actually -60 dBm at the RF plane and produces -66 dBm output” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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V011-C04-ESSAY-017. A desired RF frequency of 150 MHz is converted with a 100 MHz LO. During an image test at 50 MHz, the generator delivers -30 dBm at 50 MHz and a third harmonic of -80 dBm at 150 MHz. The desired-path conversion gain is -6 dB and the measured output is -86 dBm at 50 MHz IF. Assess the attribution and propose a stronger test.

- Opening: Present a thesis that answers this precise question: A desired RF frequency of 150 MHz is converted with a 100 MHz LO. Identify which evidence would falsify the proposed conclusion Source: §4.18 From a product map to a discriminating test (p. 1949)
- Core terminology and scope: Define converted, generator, delivers in the question's particular technical setting; explain how harmonic, attribution, stronger differ if that distinction would change the analysis of "A desired RF frequency of 150 MHz is converted with a 100 MHz LO" Source: §4.18 From a product map to a discriminating test (p. 1949)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Both 150 MHz and the conventional image at 50 MHz reach the same 50 MHz real IF Source: §4.18 From a product map to a discriminating test (p. 1949)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A desired RF frequency of 150 MHz is converted with a 100 MHz LO to the claimed result, following "Application 4A.2: Track high-side spectral inversion"; name the intermediate states and measurable outputs Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A

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desired RF frequency of 150 MHz is converted with a 100 MHz LO. The generator harmonic already present at the desired RF frequency would alone predict -86 dBm through the stated desired path Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.1: Locate a low-side image” that resolves the question about A desired RF frequency of 150 MHz is converted with a 100 MHz LO; derive the relevant result with units and stated validity conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A desired RF frequency of 150 MHz is converted with a 100 MHz LO. Thus the observation does not establish a measurable image response from the 50 MHz fundamental Source: §4.18 From a product map to a discriminating test (p. 1949)
- Worked application or illustrative case: Build a worked example of “A desired RF frequency of 150 MHz is converted with a 100 MHz LO”, addressing this associated condition: During an image test at 50 MHz, the generator delivers -30 dBm at 50 MHz and a third harmonic of -80 dBm.... Both 150 MHz and the conventional image at 50 MHz reach the same 50 MHz real IF Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A desired RF frequency of 150 MHz is converted with a 100 MHz LO”. Using “Application 4A.1: Locate a low-

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side image", specify a discriminator and the result expected under each explanation Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A desired RF frequency of 150 MHz is converted with a 100 MHz LO, including the effect of missing measurements and inconsistent operating conditions Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Scholarly synthesis and implications: Explain what the result about A desired RF frequency of 150 MHz is converted with a 100 MHz LO authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.18 From a product map to a discriminating test (p. 1949)
- Closing: Conclude by answering "A desired RF frequency of 150 MHz is converted with a 100 MHz LO" using only the demonstrated evidence; state the remaining decisive verification step Source: §4.18 From a product map to a discriminating test (p. 1949)

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V011-C04-ESSAY-018. Two generators at 30 and 40 MHz are combined before a receiver. A component at 50 MHz appears, and a 60 MHz LO maps it to 10 MHz IF. Formulate a test that distinguishes a product already present before the receiver from one generated within its receiving chain.

- Opening: Present a thesis that answers this precise question: Two generators at 30 and 40 MHz are combined before a receiver. Identify which evidence would falsify the proposed conclusion Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Core terminology and scope: Define generators, combined, appears in the question's particular technical setting; explain how maps, present, receiving differ if that distinction would change the analysis of "Two generators at 30 and 40 MHz are combined before a receiver" Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The arithmetic relation twice 40 minus 30 equals 50 MHz supplies a plausible multi-parent product, but the final 10 MHz IF does not identify where it arose Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Two generators at 30 and 40 MHz are combined before a receiver to the claimed result, following "Application 4A.9: Track inversion through two real conversions"; name the intermediate states and measurable outputs Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Two generators at 30 and 40 MHz are combined before a receiver. First establish the actual spectrum at the receiver input plane with sufficient measurement capability Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.1: Locate a low-side image” that resolves the question about Two generators at 30 and 40 MHz are combined before a receiver; derive the relevant result with units and stated validity conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Two generators at 30 and 40 MHz are combined before a receiver. Compare individual-source, combined-source, and appropriately isolated or filtered-source conditions while retaining known delivered parent levels Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Worked application or illustrative case: Build a worked example of “Two generators at 30 and 40 MHz are combined before a receiver”, addressing this associated condition: A component at 50 MHz appears, and a 60 MHz LO maps it to 10 MHz IF. The arithmetic relation twice 40 minus 30 equals 50 MHz supplies a plausible multi-parent product, but the final 10 MHz IF does not identify where it

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arose Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Two generators at 30 and 40 MHz are combined before a receiver”. Using “Application 4A.1: Locate a low-side image”, specify a discriminator and the result expected under each explanation Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Two generators at 30 and 40 MHz are combined before a receiver, including the effect of missing measurements and inconsistent operating conditions Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Scholarly synthesis and implications: Explain what the result about Two generators at 30 and 40 MHz are combined before a receiver authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Closing: Conclude by answering “Two generators at 30 and 40 MHz are combined before a receiver” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-ESSAY-019. Develop an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and re-radiation through the connected antenna. State what tuning-dependent detection alone cannot prove.

- Opening: Present a thesis that answers this precise question: Develop an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and re-radiation through the connected antenna. Identify which evidence would falsify the proposed conclusion Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)
- Core terminology and scope: Define characterization, distinguishes, radiation in the question's particular technical setting; explain how enclosure, coupling, prove differ if that distinction would change the analysis of "Develop an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and re-radiation through the connected antenna" Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use an independent observation path with documented frequency coverage, sensitivity, geometry, and its own artifact controls Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and… to the claimed result, following "Conversion-State Challenge Protocol"; name the

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intermediate states and measurable outputs Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and…. Compare a properly terminated RF input with controlled antenna and cable configurations, changing one coupling path at a time where feasible Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Analytical framework: Identify the equation, calibration or evidential decision test in "From a product map to a discriminating test" that resolves the question about an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and…; derive the relevant result with units and stated validity conditions Source: §4.18 From a product map to a discriminating test (p. 1949)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and…. Track known tuning changes and the resulting candidate LO-related frequencies, while retaining receiver gain, preselection, termination, and lock state Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)
- Worked application or illustrative case: Build a worked example of "an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and…",

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addressing this associated condition: State what tuning-dependent detection alone cannot prove. Use an independent observation path with documented frequency coverage, sensitivity, geometry, and its own artifact controls Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and…”. Using “From a product map to a discriminating test”, specify a discriminator and the result expected under each explanation Source: §4.18 From a product map to a discriminating test (p. 1949)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and…, including the effect of missing measurements and inconsistent operating conditions Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)
- Scholarly synthesis and implications: Explain what the result about an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)
- Closing: Conclude by answering “Develop an LO-leakage characterization that distinguishes radiation from the receiver enclosure, cable common-mode coupling, and re-radiation through the connected antenna” using only the demonstrated evidence;

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state the remaining decisive verification step Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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V011-C04-ESSAY-020. A fixed-frequency component is displayed at 312.5 MHz. A processing change increases the frequency-axis scale by 100 parts per million, producing a 31.25 kHz indicated shift. Explain why this result alone cannot classify the component as an internally generated clock spur.

- Opening: Present a thesis that answers this precise question: A fixed-frequency component is displayed at 312.5 MHz. Identify which evidence would falsify the proposed conclusion Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Core terminology and scope: Define increases, million, producing in the question's particular technical setting; explain how indicated, shift, internally differ if that distinction would change the analysis of "A fixed-frequency component is displayed at 312.5 MHz" Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Multiplying 312.5 MHz by 100 parts per million gives 31.25 kHz, so a purely numerical scale change can produce the stated indication even if the physical input frequency is unchanged Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A fixed-frequency component is displayed at 312.5 MHz to the claimed result, following "Application 4A.2: Track high-side spectral inversion"; name the intermediate states and measurable outputs Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A fixed-frequency component is displayed at 312.5 MHz. The change is compatible with relabeling; a hardware clock or LO change may also alter physical conversion, and its direction and magnitude must come from the actual mapping Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.7: Keep opposite complex-frequency bins distinct” that resolves the question about A fixed-frequency component is displayed at 312.5 MHz; derive the relevant result with units and stated validity conditions Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A fixed-frequency component is displayed at 312.5 MHz. Retain the native sample rate, LO plan, reference state, and the software scale used in each record Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Worked application or illustrative case: Build a worked example of “A fixed-frequency component is displayed at 312.5 MHz”, addressing this associated condition: A processing change increases the frequency-axis scale by 100 parts per million, producing a 31.25 kHz.... Multiplying 312.5 MHz by 100 parts per million gives 31.25 kHz, so a purely numerical scale change can produce the stated

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indication even if the physical input frequency... Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A fixed-frequency component is displayed at 312.5 MHz”. Using “Application 4A.7: Keep opposite complex-frequency bins distinct”, specify a discriminator and the result expected under each explanation Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A fixed-frequency component is displayed at 312.5 MHz, including the effect of missing measurements and inconsistent operating conditions Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Scholarly synthesis and implications: Explain what the result about A fixed-frequency component is displayed at 312.5 MHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Closing: Conclude by answering “A fixed-frequency component is displayed at 312.5 MHz” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-ESSAY-021. A valid linear RF-to-IF path has measured gain -12 dB. It contains 2 dB input-filter loss, an unknown mixer conversion gain, 8 dB following amplifier gain, and 3 dB IF-filter loss. Determine the mixer gain under compatible power conventions, then explain the limits of this de-embedding.

- Opening: Present a thesis that answers this precise question: A valid linear RF-to-IF path has measured gain -12 dB. Identify which evidence would falsify the proposed conclusion Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)
- Core terminology and scope: Define contains, unknown, following in the question's particular technical setting; explain how compatible, conventions, limits differ if that distinction would change the analysis of "A valid linear RF-to-IF path has measured gain -12 dB" Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The known surrounding gains sum to +3 dB: The mixer gain must therefore be -15 dB, corresponding to 15 dB conversion loss under the same power and reference-plane conventions Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A valid linear RF-to-IF path has measured gain -12 dB to the claimed result, following "4. Experimental protocol: comparing passive and active conversion"; name the intermediate states and measurable outputs Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A valid linear RF-to-IF path has measured gain -12 dB. The subtraction is meaningful only if all quantities apply to the same frequencies, loading, LO drive, temperature, level, and selected conversion state Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 4A: a declared conversion map” that resolves the question about A valid linear RF-to-IF path has measured gain -12 dB; derive the relevant result with units and stated validity conditions Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A valid linear RF-to-IF path has measured gain -12 dB. If interface mismatch changes when components are connected, isolated scalar gain values may not describe the installed cascade Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)
- Worked application or illustrative case: Build a worked example of “A valid linear RF-to-IF path has measured gain -12 dB”, addressing this associated condition: It contains 2 dB input-filter loss, an unknown mixer conversion gain, 8 dB following amplifier gain, and.... The known surrounding gains sum to +3 dB: The mixer gain must therefore be -15 dB, corresponding to 15 dB conversion loss under the same power and reference-plane... Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A valid linear RF-to-IF path has measured gain -12 dB”. Using “Model 4A: a declared conversion map”, specify a discriminator and the result expected under each explanation Source: §4.2 Model 4A: a declared conversion map (p. 1924)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A valid linear RF-to-IF path has measured gain -12 dB, including the effect of missing measurements and inconsistent operating conditions Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Scholarly synthesis and implications: Explain what the result about A valid linear RF-to-IF path has measured gain -12 dB authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)
- Closing: Conclude by answering “A valid linear RF-to-IF path has measured gain -12 dB” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

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V011-C04-ESSAY-022. A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has phase 10 degrees. The selected IF peak magnitudes are 1 mV and 0.5 mV. Calculate their positive-frequency phases and combined power relative to the desired-only power.

- Opening: Present a thesis that answers this precise question: A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has phase 10 degrees. Identify which evidence would falsify the proposed conclusion Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Core terminology and scope: Define degrees, image, magnitudes in the question's particular technical setting; explain how Calculate, phases, combined differ if that distinction would change the analysis of "A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has phase 10 degrees" Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The desired tone lies above the LO, so its selected positive-frequency phase is degrees Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has… to the

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claimed result, following “Application 4A.6: Combine coherent desired and image fields”; name the intermediate states and measurable outputs Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has…. The image lies below the LO; its signed difference phase is degrees, which becomes -40 degrees at positive 10 MHz IF Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.1: Locate a low-side image” that resolves the question about A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has…; derive the relevant result with units and stated validity conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has…. The relative selected phase is therefore -60 degrees Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Worked application or illustrative case: Build a worked example of “A coherent desired tone at 110 MHz has RF phase 30 degrees, an

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image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has…", addressing this associated condition: The selected IF peak magnitudes are 1 mV and 0.5 mV. The desired tone lies above the LO, so its selected positive-frequency phase is degrees Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has…". Using "Application 4A.1: Locate a low-side image", specify a discriminator and the result expected under each explanation Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has…, including the effect of missing measurements and inconsistent operating conditions Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Scholarly synthesis and implications: Explain what the result about A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Closing: Conclude by answering "A coherent desired tone at 110 MHz has RF phase 30 degrees, an image at 90 MHz has RF phase 50 degrees, and the LO at 100 MHz has phase 10 degrees" using only

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the demonstrated evidence; state the remaining decisive verification step Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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V011-C04-ESSAY-023. A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during the test. Separate the conclusions that remain supported from those that require a new measurement.

- Opening: Present a thesis that answers this precise question: A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during the test. Identify which evidence would falsify the proposed conclusion Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Core terminology and scope: Define suspect, movement, simultaneously in the question's particular technical setting; explain how compresses, conclusions, supported differ if that distinction would change the analysis of "A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during the test" Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The measured frequency trajectory may remain evidence for the proposed coefficient relationship if frequency estimation and path selection are still valid Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during… to the

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claimed result, following “From a product map to a discriminating test”; name the intermediate states and measurable outputs Source: §4.18 From a product map to a discriminating test (p. 1949)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during.... It does not make the amplitude response a valid linear conversion measurement Source: §4.18 From a product map to a discriminating test (p. 1949)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.5: Allocate image rejection ahead of equal conversion” that resolves the question about A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during...; derive the relevant result with units and stated validity conditions Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during.... Reference compression shows that the state used for at least part of the observation has lost the intended weak-signal transfer, so rejection or gain inferred by linear subtraction is... Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- Worked application or illustrative case: Build a worked example of “A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during…”, addressing this associated condition: Separate the conclusions that remain supported from those that require a new measurement. The measured frequency trajectory may remain evidence for the proposed coefficient relationship if frequency estimation… Source: §4.18 From a product map to a discriminating test (p. 1949)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during…”. Using “Application 4A.5: Allocate image rejection ahead of equal conversion”, specify a discriminator and the result expected under each explanation Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during…, including the effect of missing measurements and inconsistent operating conditions Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)
- Scholarly synthesis and implications: Explain what the result about A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- Closing: Conclude by answering “A suspect line follows the predicted -2 Hz-per-hertz LO movement, but a simultaneously retained weak reference compresses during the test” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-ESSAY-024. A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz. Explain how a preselector review should use both RF intervals and why amplitude-calibration admission may differ from spurious-response admission.

- Opening: Present a thesis that answers this precise question: A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz. Identify which evidence would falsify the proposed conclusion Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Core terminology and scope: Define converter, preselector, review in the question's particular technical setting; explain how intervals, admission, differ differ if that distinction would change the analysis of "A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz" Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The two nominal RF intervals are 68 through 70 MHz and 100 through 102 MHz Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz to the claimed result, following "Application 4A.2: Track high-side spectral inversion"; name the intermediate states and measurable outputs Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz. Their centers alone do not cover the image-band edges Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.9: Track inversion through two real conversions” that resolves the question about A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz; derive the relevant result with units and stated validity conditions Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz. Measure or obtain applicable transfer across both intervals and relevant filter transitions, while retaining the selected receiver state Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Worked application or illustrative case: Build a worked example of “A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz”, addressing this associated condition: Explain how a preselector review should use both RF intervals and why amplitude-calibration admission.... The two nominal RF intervals are 68 through 70 MHz and 100 through 102 MHz Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A real converter uses an 85 MHz LO and

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a nominal IF interval of 15 through 17 MHz". Using "Application 4A.9: Track inversion through two real conversions", specify a discriminator and the result expected under each explanation Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz, including the effect of missing measurements and inconsistent operating conditions Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Scholarly synthesis and implications: Explain what the result about A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Closing: Conclude by answering "A real converter uses an 85 MHz LO and a nominal IF interval of 15 through 17 MHz" using only the demonstrated evidence; state the remaining decisive verification step Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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V011-C04-ESSAY-025. Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image, harmonic-product, and clock-movement challenges. Distinguish that claim from identification or location of an emitter.

- Opening: Present a thesis that answers this precise question: Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image, harmonic-product, and clock-movement challenges. Identify which evidence would falsify the proposed conclusion Source: §4.18 From a product map to a discriminating test (p. 1949)
- Core terminology and scope: Define Specify, release, challenges in the question's particular technical setting; explain how identification, location, emitter differ if that distinction would change the analysis of "Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image, harmonic-product, and clock-movement challenges" Source: §4.18 From a product map to a discriminating test (p. 1949)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain the complete active conversion plan, input and output planes, source and clock states, filters, gain, detector or sampling path, correction identity, and native observations Source: §4.18 From a product map to a discriminating test (p. 1949)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,... to the claimed result,

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following “Application 4A.1: Locate a low-side image”; name the intermediate states and measurable outputs Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,…. For each tested explanation, record the predicted response, controlled perturbation, observed movement or level change, remaining observation capability, and applicable uncertainty or bound Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.8: Test the movement of a candidate harmonic product” that resolves the question about Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,…; derive the relevant result with units and stated validity conditions Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,…. Desired and image injections establish the tested frequency map only under their actual transfer conditions; spur movements constrain relationships but do not automatically locate generation Source: §4.18 From a product map to a discriminating test (p. 1949)

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- Worked application or illustrative case: Build a worked example of “Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,...”, addressing this associated condition: Distinguish that claim from identification or location of an emitter. Retain the complete active conversion plan, input and output planes, source and clock states, filters, gain, detector or sampling path, correction identity,... Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,...”. Using “Application 4A.8: Test the movement of a candidate harmonic product”, specify a discriminator and the result expected under each explanation Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,..., including the effect of missing measurements and inconsistent operating conditions Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)
- Scholarly synthesis and implications: Explain what the result about Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image,... authorises the investigator or engineer to claim, and what stronger proposition

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remains unsupported Source: §4.18 From a product map to a discriminating test (p. 1949)

- Closing: Conclude by answering “Specify the evidence needed to release a conversion result for an external-frequency claim after desired, image, harmonic-product, and clock-movement challenges” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.18 From a product map to a discriminating test (p. 1949)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C04-DISCUSSION-001. Two conversion plans give the same final center IF. May a team reuse one frequency-axis interpretation for both plans?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two conversion plans give the same final center IF. May a team reuse one frequency-axis interpretation for both plans?” Put this particular dispute to the panel: Two conversion plans give the same final center IF. May a team reuse one frequency-axis interpretation for both plans. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 02. Student A, terminology and scope: Agree the operational meanings of conversion, plans, final and center, reuse, interpretation in “Two conversion plans give the same final center IF. May a team reuse one frequency-axis interpretation for both plans”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two conversion plans give the same final center IF; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.2: Track high-side spectral inversion”. Use a known frequency step or ordered tone pair to distinguish equal center values with opposite final orientation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two conversion plans give the

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same final center IF; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.2: Track high-side spectral inversion”. Use a known frequency step or ordered tone pair to distinguish equal center values with opposite final orientation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask the team to trace each selected stage and multiply its local orientation signs on the applicable nonzero branches Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two conversion plans give the same final center IF: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two conversion plans give the same final center IF; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two conversion plans give the same final center IF: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two conversion plans give the same final center IF, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two conversion plans give the same final center IF: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two conversion plans give the same final center IF. The discussion should produce state-specific axis and phase conventions, including any I/Q conjugation, rather than an assumption based on the matching center Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two conversion plans give the same final center IF, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two conversion plans give the same final center IF. The discussion should produce state-specific axis and phase conventions, including any I/Q conjugation, rather than an

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assumption based on the matching center Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two conversion plans give the same final center IF and May a team reuse one frequency-axis interpretation for both plans; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two conversion plans give the same final center IF”, addressing “May a team reuse one frequency-axis interpretation for both plans”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two conversion plans give the same final center IF. May a team reuse one frequency-axis interpretation for both plans”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two conversion plans give the same final center IF. May a team reuse one frequency-axis interpretation for both plans”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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V011-C04-DISCUSSION-002. A receiver is frequency-locked to a reliable reference. Does that establish its conversion-amplitude accuracy?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A receiver is frequency-locked to a reliable reference. Does that establish its conversion-amplitude accuracy?” Put this particular dispute to the panel: A receiver is frequency-locked to a reliable reference. Does that establish its conversion-amplitude accuracy. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 02. Student A, terminology and scope: Agree the operational meanings of receiver, frequency-locked, reliable and reference, conversion-amplitude, accuracy in “A receiver is frequency-locked to a reliable reference. Does that establish its conversion-amplitude accuracy”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A receiver is frequency-locked to a reliable reference; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “4. Experimental protocol: comparing passive and active conversion”. A locked oscillator can coexist with wrong amplitude normalization or an altered physical path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver is frequency-locked to a reliable reference; explain what each record can establish State what the existing record establishes, what it does not establish, and

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which further measurement would change your opinion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “4. Experimental protocol: comparing passive and active conversion”. A locked oscillator can coexist with wrong amplitude normalization or an altered physical path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate frequency-reference agreement from loaded gain, LO drive, impedance, filter response, detector scaling, and correction applicability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A receiver is frequency-locked to a reliable

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reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver is frequency-locked to a reliable reference; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A receiver is frequency-locked to a reliable reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A receiver is frequency-locked to a reliable reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A receiver is frequency-locked to a reliable reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A receiver is frequency-locked to a reliable reference. Require a declared amplitude measurand and an applicable calibrated level reference Explain the relevant statistical

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or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A receiver is frequency-locked to a reliable reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A receiver is frequency-locked to a reliable reference. Require a declared amplitude measurand and an applicable calibrated level reference Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A receiver is frequency-locked to a reliable reference and Does that establish its conversion-amplitude accuracy; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A receiver is frequency-locked to a reliable reference”, addressing “Does that establish its conversion-amplitude accuracy”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A receiver is frequency-locked to a reliable reference. Does that establish its conversion-amplitude accuracy”, specifying the next test, responsible measurement record and limit

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of the conclusion Summarise the strongest evidence for and against the resolution of “A receiver is frequency-locked to a reliable reference. Does that establish its conversion-amplitude accuracy”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

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V011-C04-DISCUSSION-003. A simulation and a real-multiplier calculation disagree by 6.02 dB. Should the calibration table be changed immediately?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A simulation and a real-multiplier calculation disagree by 6.02 dB. Should the calibration table be changed immediately?” Put this particular dispute to the panel: A simulation and a real-multiplier calculation disagree by 6.02 dB. Should the calibration table be changed immediately. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

- 02. Student A, terminology and scope: Agree the operational meanings of simulation, calculation, disagree and calibration, table, immediately in “A simulation and a real-multiplier calculation disagree by 6.02 dB. Should the calibration table be changed immediately”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A simulation and a real-multiplier calculation disagree by 6.02 dB; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 4A: a declared conversion map”. The factor-two normalization alone can create this power difference Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A simulation and a real-multiplier calculation disagree by 6.02 dB; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 4A: a declared conversion map”. The factor-two normalization alone can create this power difference Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. First compare the real LO multiplier, analytic-signal convention, selected product, peak-versus-RMS definition, and impedance ratio Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A simulation and a real-multiplier calculation

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disagree by 6.02 dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A simulation and a real-multiplier calculation disagree by 6.02 dB; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A simulation and a real-multiplier calculation disagree by 6.02 dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A simulation and a real-multiplier calculation disagree by 6.02 dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A simulation and a real-multiplier calculation disagree by 6.02 dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A simulation and a real-multiplier calculation disagree by 6.02 dB. Determine whether the disagreement is mathematical scaling or a measured physical transfer error before changing corrections Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A simulation and a real-multiplier calculation disagree by 6.02 dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A simulation and a real-multiplier calculation disagree by 6.02 dB. Determine whether the disagreement is mathematical scaling or a measured physical transfer error before

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changing corrections Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A simulation and a real-multiplier calculation disagree by 6.02 dB and Should the calibration table be changed immediately; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A simulation and a real-multiplier calculation disagree by 6.02 dB”, addressing “Should the calibration table be changed immediately”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A simulation and a real-multiplier calculation disagree by 6.02 dB. Should the calibration table be changed immediately”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A simulation and a real-multiplier calculation disagree by 6.02 dB. Should the calibration table be changed immediately”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.7 Application 4A.4: Expose the multiplier normalization (p. 1935)

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V011-C04-DISCUSSION-004. The conventional image formula produces a negative value. Should the report convert it to a positive RF image by taking its absolute value?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The conventional image formula produces a negative value. Should the report convert it to a positive RF image by taking its absolute value?” Put this particular dispute to the panel: The conventional image formula produces a negative value. Should the report convert it to a positive RF image by taking its absolute value. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 02. Student A, terminology and scope: Agree the operational meanings of conventional, image, formula and convert, taking, absolute in “The conventional image formula produces a negative value. Should the report convert it to a positive RF image by taking its absolute value”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The conventional image formula produces a negative value; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Image Responses and Image Rejection”. A negative reflected value is not a second positive input in that simple map Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The conventional image formula produces a negative value; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Image Responses and Image Rejection”. A negative reflected value is not a second positive input in that simple map Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Return to the stated first-order real-difference architecture and its domain of positive physical RF inputs Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The conventional image formula produces a

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negative value: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The conventional image formula produces a negative value; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The conventional image formula produces a negative value: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The conventional image formula produces a negative value, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The conventional image formula produces a negative value: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The conventional image formula produces a negative value. Taking another absolute value would create an unsupported candidate Explain the relevant statistical or calibration

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uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The conventional image formula produces a negative value, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The conventional image formula produces a negative value. Taking another absolute value would create an unsupported candidate Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The conventional image formula produces a negative value and Should the report convert it to a positive RF image by taking its absolute value; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The conventional image formula produces a negative value”, addressing “Should the report convert it to a positive RF image by taking its absolute value”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The conventional image formula produces a negative value. Should the report convert it to a positive RF image by taking its absolute value”, specifying the next test, responsible

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measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The conventional image formula produces a negative value. Should the report convert it to a positive RF image by taking its absolute value”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

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V011-C04-DISCUSSION-005. Would a larger first IF always improve image performance?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Would a larger first IF always improve image performance?” Put this particular dispute to the panel: Would a larger first IF always improve image performance. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 02. Student A, terminology and scope: Agree the operational meanings of larger, first, always and improve, image, performance in “Would a larger first IF always improve image performance”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Would a larger first IF always improve image performance; require both to

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name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. Actual rejection also depends on preselection, image-reject balance, alternate paths, levels, and conversion architecture Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Would a larger first IF always improve image performance; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. Actual rejection also depends on preselection, image-reject balance, alternate paths, levels, and conversion architecture Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The conventional desired/image separation is twice the IF for a valid positive image, so changing IF changes the frequency-separation challenge Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Would a larger first IF always improve image performance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to

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both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Would a larger first IF always improve image performance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Would a larger first IF always improve image performance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.15 Image Responses and Image Rejection (p. 1944)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Would a larger first IF always improve image performance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Would a larger first IF always improve image performance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Would a larger first IF always improve image performance. Discuss which measured transfer evidence is needed for the proposed plan rather than ranking receivers by separation alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question

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cannot be settled by visual appearance or a single unqualified reading. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Would a larger first IF always improve image performance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Would a larger first IF always improve image performance. Discuss which measured transfer evidence is needed for the proposed plan rather than ranking receivers by separation alone Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Would a larger first IF always improve image performance and The conventional desired/image separation is twice the IF for a valid positive image, so changing IF changes…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Would a larger first IF always improve image performance”, addressing “The conventional desired/image separation is twice the IF for a valid positive image, so changing IF changes…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.15 Image Responses and Image Rejection (p. 1944)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Would a larger first IF always improve image performance”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Would a larger first IF always improve image performance”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

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V011-C04-DISCUSSION-006. During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. Can the output difference still be called image rejection?

- 01. Moderator, opening proposition: Introduce the exact dispute, “During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. Can the output difference still be called image rejection?” Put this particular dispute to the panel: During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. Can the output difference still be called image rejection. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 02. Student A, terminology and scope: Agree the operational meanings of image, automatically, attenuation and frequencies, called, rejection in “During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. Can the output difference still be called image rejection”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.5: Allocate image rejection ahead of equal conversion”. Determine whether the intended measurand is the complete operational receiver behavior or differential rejection at a fixed conversion state Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.5: Allocate image rejection ahead of equal conversion”. Determine whether the intended measurand is the complete operational receiver behavior or differential rejection at a fixed conversion state Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The comparison now includes a state change Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 08. Student D, answer to Student E: Design a discriminating experiment involving During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. For the latter, hold or explicitly characterize the settings and their corrections Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. For the latter, hold or explicitly characterize the settings and their corrections Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies and Can the output difference still be called image rejection; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies”, addressing “Can the output difference still be called image rejection”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. Can the output difference still be called image rejection”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “During equal-input image tests, the receiver automatically changes attenuation between the two RF frequencies. Can the output difference still be called image rejection”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

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V011-C04-DISCUSSION-007. If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption?

- 01. Moderator, opening proposition: Introduce the exact dispute, “If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption?” Put this particular dispute to the panel: If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 02. Student A, terminology and scope: Agree the operational meanings of image, inputs, unknown and adding, powers, assumption in “If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. Use the observation interval, source relationship, and measured coherence to justify any averaging law Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of If the relative phase of desired

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and image inputs is unknown, is adding their powers the most neutral assumption; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. Use the observation interval, source relationship, and measured coherence to justify any averaging law Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Unknown phase does not establish a zero averaged cross term Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would

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lead the panel to retain, qualify or reject the conclusion. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption. Where phase remains unspecified, report phase-dependent possibilities or bounds appropriate to the question Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption. Where phase remains unspecified, report phase-dependent possibilities or bounds appropriate to the question Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption and Unknown phase does not establish a zero averaged cross term; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “If the relative phase of desired and image

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inputs is unknown, is adding their powers the most neutral assumption", addressing "Unknown phase does not establish a zero averaged cross term"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "If the relative phase of desired and image inputs is unknown, is adding their powers the most neutral assumption". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

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V011-C04-DISCUSSION-008. A desired tone disappears when a coherent image stimulus is added. Does the result show that the receiver stopped admitting the desired RF input?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A desired tone disappears when a coherent image stimulus is added. Does the result show that the receiver stopped admitting the desired RF input?” Put this particular dispute to the panel: A desired tone disappears when a coherent image stimulus is added. Does the result show that the receiver stopped admitting the desired RF input. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 02. Student A, terminology and scope: Agree the operational meanings of desired, disappears, coherent and image, stimulus, added in “A desired tone disappears when a coherent image stimulus is added. Does the result show that the receiver stopped admitting the desired RF input”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A desired tone disappears when a coherent image stimulus is added; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.6: Combine coherent desired and image fields”. Change the relative phase or use separate calibrated injections while holding the receiver state fixed Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A desired tone disappears when a coherent image stimulus is added; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.6: Combine coherent desired and image fields”. Change the relative phase or use separate calibrated injections while holding the receiver state fixed Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider destructive combination of the selected IF phasors before concluding that the desired path vanished Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A desired tone disappears when a coherent image stimulus is added: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A desired tone disappears when a coherent image stimulus is added; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A desired tone disappears when a coherent image stimulus is added: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A desired tone disappears when a coherent image stimulus is added, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A desired tone disappears when a coherent image stimulus is added: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A desired tone disappears when a coherent image stimulus is added. Also test compression and source interaction Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A desired tone disappears when a coherent image stimulus is added, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A desired tone disappears when a coherent image stimulus is added. Also test compression and source interaction Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the

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missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A desired tone disappears when a coherent image stimulus is added and Does the result show that the receiver stopped admitting the desired RF input; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A desired tone disappears when a coherent image stimulus is added”, addressing “Does the result show that the receiver stopped admitting the desired RF input”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A desired tone disappears when a coherent image stimulus is added. Does the result show that the receiver stopped admitting the desired RF input”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A desired tone disappears when a coherent image stimulus is added. Does the result show that the receiver stopped admitting the desired RF input”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

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V011-C04-DISCUSSION-009. A complex baseband record contains a negative-frequency peak. Should it be described as a negative physical RF frequency?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A complex baseband record contains a negative-frequency peak. Should it be described as a negative physical RF frequency?” Put this particular dispute to the panel: A complex baseband record contains a negative-frequency peak. Should it be described as a negative physical RF frequency. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 02. Student A, terminology and scope: Agree the operational meanings of baseband, contains, peak and described, negative, physical in “A complex baseband record contains a negative-frequency peak. Should it be described as a negative physical RF frequency”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A complex baseband record contains a negative-frequency peak; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 4A: a declared conversion map”. Reconstruct the physical RF interval using the actual translation map and admitted band Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A complex baseband record contains a negative-frequency peak; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 4A: a declared conversion map”. Reconstruct the physical RF interval using the actual translation map and admitted band Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The sign is a coordinate relative to the declared LO and complex convention Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A complex baseband record contains a negative-frequency peak: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A complex baseband record contains a negative-frequency peak; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A complex baseband record contains a negative-frequency peak: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A complex baseband record contains a negative-frequency peak, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A complex baseband record contains a negative-frequency peak: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A complex baseband record contains a negative-frequency peak. Negative baseband can represent a positive RF input below the LO Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A complex baseband record contains a negative-frequency peak, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A complex baseband record contains a negative-frequency peak. Negative baseband can represent a positive RF input below the LO Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A complex baseband record contains a negative-frequency peak and Should it be described as a negative physical RF frequency; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A complex baseband record contains a negative-frequency peak”, addressing “Should it be described as a negative physical RF frequency”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A complex baseband record contains a negative-frequency peak. Should it be described as a negative physical RF frequency”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A complex baseband record contains a negative-frequency peak. Should it be described as a negative physical RF frequency”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

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V011-C04-DISCUSSION-010. An analyst conjugates an I/Q record so that its spectrum looks familiar. Is this merely a display choice?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An analyst conjugates an I/Q record so that its spectrum looks familiar. Is this merely a display choice?” Put this particular dispute to the panel: An analyst conjugates an I/Q record so that its spectrum looks familiar. Is this merely a display choice. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, spectrum, familiar and merely, display, choice in “An analyst conjugates an I/Q record so that its spectrum looks familiar. Is this merely a display choice”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An analyst conjugates an I/Q record so that its spectrum looks familiar; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.2: Track high-side spectral inversion”. It may be a valid documented transformation, but it must remain in the processing lineage, especially for sideband, phase, delay, or modulation comparisons Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst conjugates an I/Q record so that its spectrum looks familiar; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.2: Track high-side spectral inversion”. It may be a valid documented transformation, but it must remain in the processing lineage, especially for sideband, phase, delay, or modulation comparisons Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Conjugation reverses complex-frequency sign and changes phase relationships Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An analyst conjugates an I/Q record so that its spectrum looks familiar: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst conjugates an I/Q record so that its spectrum looks familiar; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An analyst conjugates an I/Q record so that its spectrum looks familiar: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An analyst conjugates an I/Q record so that its spectrum looks familiar, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An analyst conjugates an I/Q record so that its spectrum looks familiar: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An analyst conjugates an I/Q record so that its spectrum looks familiar. Require a known-tone orientation check and retain the original record Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An analyst conjugates an I/Q record so that its spectrum looks familiar, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An analyst conjugates an I/Q record so that its spectrum looks familiar. Require a known-tone orientation check and retain the original record Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.10 Application 4A.7: Keep opposite complex-frequency bins distinct (p. 1938)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An analyst conjugates an I/Q record so that its spectrum looks familiar and Is this merely a display choice; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An analyst conjugates an I/Q record so that its spectrum looks familiar”, addressing “Is this merely a display choice”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond

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to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An analyst conjugates an I/Q record so that its spectrum looks familiar. Is this merely a display choice”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An analyst conjugates an I/Q record so that its spectrum looks familiar. Is this merely a display choice”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

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V011-C04-DISCUSSION-011. A large automated spur search finds several exact matches to one observed frequency. Which candidate should be accepted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A large automated spur search finds several exact matches to one observed frequency. Which candidate should be accepted?” Put this particular dispute to the panel: A large automated spur search finds several exact matches to one observed frequency. Which candidate should be accepted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 02. Student A, terminology and scope: Agree the operational meanings of large, automated, search and finds, matches, candidate in “A large automated spur search finds several exact matches to one observed frequency. Which candidate should be accepted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A large automated spur search finds several exact matches to one observed frequency; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Spur Tables and Product Search”. Record the parent set, search order, tolerances, and any search expansion after observing the peak Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A large automated spur search finds several exact matches to one observed frequency; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Spur Tables and Product Search”. Record the parent set, search order, tolerances, and any search expansion after observing the peak Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No candidate earns acceptance solely from arithmetic agreement Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A large automated spur search finds several exact matches to one observed frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A large automated spur search finds several exact matches to one observed frequency; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A large automated spur search finds several exact matches to one observed frequency: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A large automated spur search finds several exact matches to one observed frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A large automated spur search finds several exact matches to one observed frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A large automated spur search finds several exact matches to one observed frequency. Compare predeclared movement predictions, level behavior, path controls, and continued observability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A large automated spur search finds several exact matches to one observed frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A large automated spur search finds several

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exact matches to one observed frequency. Compare predeclared movement predictions, level behavior, path controls, and continued observability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A large automated spur search finds several exact matches to one observed frequency and Which candidate should be accepted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A large automated spur search finds several exact matches to one observed frequency”, addressing “Which candidate should be accepted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A large automated spur search finds several exact matches to one observed frequency. Which candidate should be accepted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A large automated spur search finds several exact matches to one observed frequency. Which candidate should be accepted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-DISCUSSION-012. A measured LO slope matches one product coefficient exactly. Has the generating component been identified?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A measured LO slope matches one product coefficient exactly. Has the generating component been identified?” Put this particular dispute to the panel: A measured LO slope matches one product coefficient exactly. Has the generating component been identified. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 02. Student A, terminology and scope: Agree the operational meanings of slope, matches, coefficient and exactly, generating, identified in “A measured LO slope matches one product coefficient exactly. Has the generating component been identified”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A measured LO slope matches one product coefficient exactly; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Spur Tables and Product Search”. Different paths or clock combinations can have the same coefficient, and a source-generated signal may be converted by the receiver Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A measured LO slope matches one product coefficient exactly; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Spur Tables and Product Search”. Different paths or clock combinations can have the same coefficient, and a source-generated signal may be converted by the receiver Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A slope can support a frequency relationship without locating the nonlinear element Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A measured LO slope matches one product

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coefficient exactly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A measured LO slope matches one product coefficient exactly; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A measured LO slope matches one product coefficient exactly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A measured LO slope matches one product coefficient exactly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A measured LO slope matches one product coefficient exactly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A measured LO slope matches one product coefficient exactly. Ask which independent parent perturbation or physical-path control would distinguish the remaining hypotheses Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A measured LO slope matches one product coefficient exactly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A measured LO slope matches one product coefficient exactly. Ask which independent parent perturbation or physical-path control would distinguish the remaining hypotheses Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A measured LO slope matches one product coefficient exactly and Has the generating component been identified; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A measured LO slope matches one product coefficient exactly”, addressing “Has the generating component been identified”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A measured LO slope matches one product coefficient exactly. Has the generating component been identified”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A measured LO slope matches one product coefficient exactly. Has the generating component been identified”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-DISCUSSION-013. A predicted spur disappears after retuning. Is that a failed hypothesis?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A predicted spur disappears after retuning. Is that a failed hypothesis?” Put this particular dispute to the panel: A predicted spur disappears after retuning. Is that a failed hypothesis. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 02. Student A, terminology and scope: Agree the operational meanings of predicted, spur, disappears and retuning, failed, hypothesis in “A predicted spur disappears after retuning. Is that a failed hypothesis”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A

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predicted spur disappears after retuning; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.8: Test the movement of a candidate harmonic product”. If the test removed observation capability, disappearance is inconclusive about generation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A predicted spur disappears after retuning; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.16 Spur Tables and Product Search (p. 1947)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.8: Test the movement of a candidate harmonic product”. If the test removed observation capability, disappearance is inconclusive about generation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check whether the predicted trajectory remained within the selected IF path, detector range, and measurement floor Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A predicted spur disappears after retuning: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A predicted spur disappears after retuning; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A predicted spur disappears after retuning: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A predicted spur disappears after retuning, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A predicted spur disappears after retuning: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A predicted spur disappears after retuning. Replan a smaller perturbation or an observation band that covers both predicted positions, with a retained reference Explain the relevant statistical or calibration uncertainty, the range of defensible

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claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A predicted spur disappears after retuning, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A predicted spur disappears after retuning. Replan a smaller perturbation or an observation band that covers both predicted positions, with a retained reference Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.16 Spur Tables and Product Search (p. 1947)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A predicted spur disappears after retuning and Is that a failed hypothesis; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A predicted spur disappears after retuning”, addressing “Is that a failed hypothesis”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A predicted spur disappears after retuning. Is that a failed hypothesis”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A predicted

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spur disappears after retuning. Is that a failed hypothesis”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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V011-C04-DISCUSSION-014. Should movement tests always avoid a zero-frequency crossing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should movement tests always avoid a zero-frequency crossing?” Put this particular dispute to the panel: Should movement tests always avoid a zero-frequency crossing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 02. Student A, terminology and scope: Agree the operational meanings of movement, tests, always and avoid, zero-frequency, crossing in “Should movement tests always avoid a zero-frequency crossing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of

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whether movement tests always avoid a zero-frequency crossing; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a product map to a discriminating test”. Either design must state the piecewise prediction and verify observability near DC Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether movement tests always avoid a zero-frequency crossing; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a product map to a discriminating test”. Either design must state the piecewise prediction and verify observability near DC Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Avoiding a crossing can simplify a local-slope test, but a deliberately observed cusp can itself discriminate a signed product map Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether movement tests always avoid a zero-frequency crossing: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion

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Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether movement tests always avoid a zero-frequency crossing; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether movement tests always avoid a zero-frequency crossing: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether movement tests always avoid a zero-frequency crossing, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether movement tests always avoid a zero-frequency crossing: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether movement tests always avoid a zero-frequency crossing. A single straight-line slope should not be

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fitted across both branches without justification Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether movement tests always avoid a zero-frequency crossing, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether movement tests always avoid a zero-frequency crossing. A single straight-line slope should not be fitted across both branches without justification Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.23 Signed-frequency conversion maps and the forensic construction of a spur atlas (p. 1956)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether movement tests always avoid a zero-frequency crossing and Avoiding a crossing can simplify a local-slope test, but a deliberately observed cusp can itself discriminate…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether movement tests always avoid a zero-frequency crossing”, addressing “Avoiding a crossing can simplify a local-slope test, but a deliberately observed cusp can itself discriminate…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should movement tests always avoid a zero-frequency crossing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should movement tests always avoid a zero-frequency crossing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

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V011-C04-DISCUSSION-015. Can multiplying conversion orientation signs validate a receiver's entire frequency plan?

- 01. Moderator, opening proposition: Introduce the exact dispute, "Can multiplying conversion orientation signs validate a receiver's entire frequency plan?" Put this particular dispute to the panel: Can multiplying conversion orientation signs validate a receiver's entire frequency plan. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 02. Student A, terminology and scope: Agree the operational meanings of multiplying, conversion, orientation and signs, validate, entire in "Can multiplying conversion orientation signs validate a receiver's entire frequency plan"; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can multiplying conversion orientation signs validate a receiver's entire frequency plan; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in "Model 4A: a declared conversion map". It does not establish that the intended path was actually selected, that unwanted products are rejected, or that the mapping remains valid across a band switch Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can multiplying conversion orientation signs validate a receiver's entire frequency plan; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 4A: a declared conversion map”. It does not establish that the intended path was actually selected, that unwanted products are rejected, or that the mapping remains valid across a band switch Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The product gives a local derivative only while each selected branch and state remains fixed and nonzero Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can multiplying conversion orientation signs validate a receiver's entire frequency plan: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can multiplying conversion orientation signs validate a receiver's entire frequency plan; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can multiplying conversion orientation signs validate a receiver's entire frequency plan: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can multiplying conversion orientation signs validate a receiver's entire frequency plan, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can multiplying conversion orientation signs validate a receiver's entire frequency plan: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can multiplying conversion orientation signs validate a receiver's entire frequency plan. Combine the sign calculation with known-tone checks and actual state records Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can multiplying conversion orientation signs validate a receiver's entire frequency plan, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can multiplying conversion orientation signs validate a receiver's entire frequency plan. Combine the sign

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calculation with known-tone checks and actual state records Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can multiplying conversion orientation signs validate a receiver's entire frequency plan and The product gives a local derivative only while each selected branch and state remains fixed and nonzero; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about "Can multiplying conversion orientation signs validate a receiver's entire frequency plan", addressing "The product gives a local derivative only while each selected branch and state remains fixed and nonzero"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another

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speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can multiplying conversion orientation signs validate a receiver’s entire frequency plan”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can multiplying conversion orientation signs validate a receiver’s entire frequency plan”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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V011-C04-DISCUSSION-016. An independent receiver detects an LO-related component near the instrument. Does that prove malfunction?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An independent receiver detects an LO-related component near the instrument. Does that prove malfunction?” Put this particular dispute to the panel: An independent receiver detects an LO-related component near the instrument. Does that prove malfunction. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 02. Student A, terminology and scope: Agree the operational meanings of independent, receiver, component and near, instrument, prove in “An independent receiver detects an LO-related component near the instrument. Does that prove malfunction”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An independent receiver detects an LO-related component near the instrument; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Conversion-State Challenge Protocol”. Retain the emitting receiver state, coupling geometry, reference relationship, and independent observer limitations Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An independent receiver detects an LO-related component near the instrument; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Conversion-State Challenge Protocol”. Retain the emitting receiver state, coupling geometry, reference relationship, and independent observer limitations Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate observation of leakage from an applicable acceptance criterion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An independent receiver detects an LO-related

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component near the instrument: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An independent receiver detects an LO-related component near the instrument; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An independent receiver detects an LO-related component near the instrument: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative

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that could survive the proposed test. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An independent receiver detects an LO-related component near the instrument, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An independent receiver detects an LO-related component near the instrument: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An independent receiver detects an LO-

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related component near the instrument. LO-related energy can indicate activity without revealing the full tuning plan or establishing a fault Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An independent receiver detects an LO-related component near the instrument, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An independent receiver detects an LO-related component near the instrument. LO-related energy can indicate activity without revealing the full tuning plan or establishing a fault Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence.

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Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An independent receiver detects an LO-related component near the instrument and Does that prove malfunction; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An independent receiver detects an LO-related component near the instrument”, addressing “Does that prove malfunction”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An independent receiver detects an LO-related component near the instrument. Does that prove malfunction”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An independent receiver detects an LO-related component near the instrument. Does that prove malfunction”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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V011-C04-DISCUSSION-017. A detected LO component becomes stronger when an antenna cable is attached. Has antenna re-radiation been isolated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A detected LO component becomes stronger when an antenna cable is attached. Has antenna re-radiation been isolated?” Put this particular dispute to the panel: A detected LO component becomes stronger when an antenna cable is attached. Has antenna re-radiation been isolated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 02. Student A, terminology and scope: Agree the operational meanings of detected, stronger, antenna and cable, attached, isolated in “A detected LO component becomes stronger when an antenna cable is attached. Has antenna re-radiation been isolated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A detected LO component becomes stronger when an antenna cable is attached; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Conversion-State Challenge Protocol”. Plan controlled substitutions and geometry changes that distinguish those paths while retaining the receiver state Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A detected LO component becomes stronger when an antenna cable is attached; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Conversion-State Challenge Protocol”. Plan controlled substitutions and geometry changes that distinguish those paths while retaining the receiver state Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The cable can also change common-mode coupling, termination, enclosure currents, and the observing antenna transfer Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A detected LO component becomes stronger when an antenna cable is attached: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A detected LO component becomes stronger when an antenna cable is attached; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A detected LO component becomes stronger when an antenna cable is attached: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A detected LO component becomes stronger when an antenna cable is attached, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A detected LO component becomes stronger when an antenna cable is attached: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A detected LO component becomes stronger when an antenna cable is attached. Stronger detection is useful evidence of a configuration effect, but it does not uniquely identify one radiation mechanism Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A detected LO component becomes stronger when an antenna cable is attached, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A detected LO component becomes stronger when an antenna cable is attached. Stronger detection is useful

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evidence of a configuration effect, but it does not uniquely identify one radiation mechanism Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.24 A multiconversion receiver must be audited as a frequency-sign system, not merely as a chain of nominal intermediate-frequency labels (p. 1960)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A detected LO component becomes stronger when an antenna cable is attached and Has antenna re-radiation been isolated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A detected LO component becomes stronger when an antenna cable is attached”, addressing “Has antenna re-radiation been isolated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by

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another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A detected LO component becomes stronger when an antenna cable is attached. Has antenna re-radiation been isolated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A detected LO component becomes stronger when an antenna cable is attached. Has antenna re-radiation been isolated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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V011-C04-DISCUSSION-018. A suspect line shifts when the frequency reference is changed. How should a team choose between internal generation and relabeling of a fixed external tone?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A suspect line shifts when the frequency reference is changed. How should a team choose between internal generation and relabeling of a fixed external tone?” Put this particular dispute to the panel: A suspect line shifts when the frequency reference is changed. How should a team choose between internal generation and relabeling of a fixed external tone. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 02. Student A, terminology and scope: Agree the operational meanings of suspect, line, shifts and internal, generation, external in “A suspect line shifts when the frequency reference is changed. How should a team choose between internal generation and relabeling of a fixed external tone”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A suspect line shifts when the frequency reference is changed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. Use an independent physical-frequency observation or calibrated injected tone to constrain the mapping Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A suspect line shifts when the frequency reference is changed; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. Use an independent physical-frequency observation or calibrated injected tone to constrain the mapping Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reconstruct how the reference change affects actual LOs, sample timing, and software frequency scale Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A suspect line shifts when the frequency reference is changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A suspect line shifts when the frequency reference is changed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A suspect line shifts when the frequency reference is changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A suspect line shifts when the frequency reference is changed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A suspect line shifts when the frequency reference is changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A suspect line shifts when the frequency reference is changed. A proportional shift is compatible with more than one explanation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A suspect line shifts when the frequency reference is changed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A suspect line shifts when the frequency reference is changed. A proportional shift is compatible with more than one explanation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.5 Application 4A.2: Track high-side spectral inversion (p. 1932)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A suspect line shifts when the frequency reference is changed and How should a team choose between internal generation and relabeling of a fixed external tone; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A suspect line shifts when the frequency reference is changed”, addressing “How should a team choose between internal generation and relabeling of a fixed external tone”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A suspect line shifts when the frequency reference is changed. How should a team choose between internal generation and relabeling of a fixed external tone”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A suspect line shifts when the frequency reference is changed. How should a team choose between internal generation and relabeling of a fixed external tone”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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V011-C04-DISCUSSION-019. The comparison receiver shows no corresponding signal. How much weight should that carry in a spur investigation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The comparison receiver shows no corresponding signal. How much weight should that carry in a spur investigation?” Put this particular dispute to the panel: The comparison receiver shows no corresponding signal. How much weight should that carry in a spur investigation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 02. Student A, terminology and scope: Agree the operational meanings of shows, corresponding, weight and carry, spur, investigation in “The comparison receiver shows no corresponding signal. How much weight should that carry in a spur investigation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The comparison receiver shows no corresponding signal; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.1 Frequency Conversion as Multiplication (p. 1923)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frequency Conversion as Multiplication”. A less capable or differently timed observation cannot exclude an external component seen by the first receiver Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.1 Frequency Conversion as Multiplication (p. 1923)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The comparison receiver shows no corresponding signal; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frequency Conversion as Multiplication”. A less capable or differently timed observation cannot exclude an external component seen by the first receiver Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.1 Frequency Conversion as Multiplication (p. 1923)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require comparable frequency coverage, time coverage, antenna or injection transfer, bandwidth, detection criterion, and sensitivity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The comparison receiver shows no corresponding signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The comparison receiver shows no corresponding signal; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The comparison receiver shows no corresponding signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The comparison receiver shows no corresponding signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.1 Frequency Conversion as Multiplication (p. 1923)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The comparison receiver shows no corresponding signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The comparison receiver shows no

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corresponding signal. A characterized nondetection can provide a useful bound Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The comparison receiver shows no corresponding signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.1 Frequency Conversion as Multiplication (p. 1923)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The comparison receiver shows no corresponding signal. A characterized nondetection can provide a useful bound Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.15 Image Responses and Image Rejection (p. 1944)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The comparison receiver shows no corresponding signal and How much weight should that carry in a spur investigation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.16 Spur Tables and Product Search (p. 1947)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The comparison receiver shows no corresponding signal”, addressing “How much weight should that carry in a spur investigation”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The comparison receiver shows no corresponding signal. How much weight should that carry in a spur

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investigation", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "The comparison receiver shows no corresponding signal. How much weight should that carry in a spur investigation". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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V011-C04-DISCUSSION-020. A firmware update leaves the center-frequency display unchanged. Is that sufficient reason to retain all old conversion corrections?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A firmware update leaves the center-frequency display unchanged. Is that sufficient reason to retain all old conversion corrections?” Put this particular dispute to the panel: A firmware update leaves the center-frequency display unchanged. Is that sufficient reason to retain all old conversion corrections. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 02. Student A, terminology and scope: Agree the operational meanings of firmware, update, leaves and unchanged, sufficient, reason in “A firmware update leaves the center-frequency display unchanged. Is that sufficient reason to retain all old conversion corrections”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A firmware update leaves the center-frequency display unchanged; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Conversion Gain, Loss, and Calibration”. Review the actual configuration and applicable release information, then verify relevant level and orientation behavior across the used bands Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A firmware update leaves the

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center-frequency display unchanged; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Conversion Gain, Loss, and Calibration”. Review the actual configuration and applicable release information, then verify relevant level and orientation behavior across the used bands Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The display label does not show whether an LO plan, filter selection, detector path, or correction algorithm changed Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A firmware update leaves the center-frequency display unchanged: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A firmware update leaves the center-frequency display unchanged; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A firmware update leaves the center-frequency display unchanged: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a

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rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A firmware update leaves the center-frequency display unchanged, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A firmware update leaves the center-frequency display unchanged: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A firmware update leaves the center-frequency display unchanged. Retain a correction only with evidence of continued applicability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A firmware update leaves the center-frequency display unchanged, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A firmware update leaves the center-frequency display unchanged. Retain a correction only with evidence of continued applicability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A firmware update leaves the center-frequency display unchanged and Is that sufficient reason to retain all old conversion corrections; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A firmware update leaves the center-frequency display unchanged”, addressing “Is that sufficient reason to retain all old conversion corrections”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A firmware update leaves the center-frequency display unchanged. Is that sufficient reason to retain all old conversion corrections”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A firmware update leaves the center-frequency display unchanged. Is that sufficient reason to retain all old conversion corrections”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.12 Application 4A.9: Track inversion through two real conversions (p. 1940)

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V011-C04-DISCUSSION-021. A generator meets its published harmonic specification. Must source purity still be checked during an image test?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A generator meets its published harmonic specification. Must source purity still be checked during an image test?” Put this particular dispute to the panel: A generator meets its published harmonic specification. Must source purity still be checked during an image test. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 02. Student A, terminology and scope: Agree the operational meanings of generator, meets, published and harmonic, purity, checked in “A generator meets its published harmonic specification. Must source purity still be checked during an image test”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A generator meets its published harmonic specification; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. A small harmonic may dominate a very weak image response Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A generator meets its published harmonic specification; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.1: Locate a low-side image”. A small harmonic may dominate a very weak image response Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Relate the specified residual to the required rejection measurement, actual frequency and level, connected filters and combining path, and the receiver’s desired-path sensitivity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A generator meets its published harmonic

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specification: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A generator meets its published harmonic specification; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A generator meets its published harmonic specification: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A generator meets its published harmonic specification, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A generator meets its published harmonic specification: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A generator meets its published harmonic

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specification. The relevant question is whether source contamination is bounded adequately at the receiver plane under the test conditions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A generator meets its published harmonic specification, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A generator meets its published harmonic specification. The relevant question is whether source contamination is bounded adequately at the receiver plane under the test conditions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the

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missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A generator meets its published harmonic specification and Must source purity still be checked during an image test; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A generator meets its published harmonic specification”, addressing “Must source purity still be checked during an image test”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A generator meets its published harmonic specification. Must source purity still be checked during an image test”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A generator meets its published harmonic specification. Must source purity still be checked during an image test”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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V011-C04-DISCUSSION-022. A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. When is that defensible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. When is that defensible?” Put this particular dispute to the panel: A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. When is that defensible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 02. Student A, terminology and scope: Agree the operational meanings of subtracts, isolated, gains and obtain, mixer, defensible in “A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. When is that defensible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “4. Experimental protocol: comparing passive and active conversion”. Discuss whether mismatch or interaction makes the isolated component values inapplicable to the installed path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “4. Experimental protocol: comparing passive and active conversion”. Discuss whether mismatch or interaction makes the isolated component values inapplicable to the installed path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require compatible power conventions, reference planes, actual loading, frequency, LO drive, level, and state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team subtracts isolated filter and amplifier gains from a complete

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receiver measurement to obtain mixer loss: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. If the complete path is the actual measurand, de-embedding may answer a different question Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. If the complete path is the actual measurand, de-embedding may answer a different question Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.14 Local-Oscillator Purity and Leakage (p. 1942)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss and When is that defensible; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss”, addressing “When is that defensible”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. When is that defensible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team subtracts isolated filter and amplifier gains from a complete receiver measurement to obtain mixer loss. When is that defensible”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

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V011-C04-DISCUSSION-023. A line grows faster than the desired signal during an input-level challenge. Does that establish receiver-generated nonlinearity?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A line grows faster than the desired signal during an input-level challenge. Does that establish receiver-generated nonlinearity?” Put this particular dispute to the panel: A line grows faster than the desired signal during an input-level challenge. Does that establish receiver-generated nonlinearity. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 02. Student A, terminology and scope: Agree the operational meanings of line, grows, desired and signal, challenge, nonlinearity in “A line grows faster than the desired signal during an input-level challenge. Does that establish receiver-generated nonlinearity”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A line grows faster than the desired signal during an input-level challenge; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Image Responses and Image Rejection”. Retain desired-reference validity and actual delivered parent levels while characterizing the source path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A line grows faster than the desired signal during an input-level challenge; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Image Responses and Image Rejection”. Retain desired-reference validity and actual delivered parent levels while characterizing the source path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The behavior supports investigation of nonlinear generation, but source outputs, combiners, connectors, and earlier equipment may generate the same product before the receiver Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A line grows faster than the desired signal during an input-level challenge: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A line grows faster than the desired signal during an input-level challenge; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A line grows faster than the desired signal during an input-level challenge: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A line grows faster than the desired signal during an input-level challenge, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A line grows faster than the desired signal during an input-level challenge: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A line grows faster than the desired signal during an input-level challenge. Frequency relationships and path controls help locate generation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A line grows faster than the desired signal during an input-level challenge, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A line grows faster than the desired signal during an input-level challenge. Frequency relationships and path controls help locate generation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A line grows faster than the desired signal during an input-level challenge and Does that establish receiver-generated nonlinearity; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A line grows faster than the desired signal during an input-level challenge”, addressing “Does that establish receiver-generated nonlinearity”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A line grows faster than the desired signal during an input-level challenge. Does that establish receiver-generated nonlinearity”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A line grows faster than the desired signal during an input-level challenge. Does that establish receiver-generated nonlinearity”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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V011-C04-DISCUSSION-024. After a conversion challenge, the receiver returns to the original indicated level and frequency. Does that validate every earlier observation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “After a conversion challenge, the receiver returns to the original indicated level and frequency. Does that validate every earlier observation?” Put this particular dispute to the panel: After a conversion challenge, the receiver returns to the original indicated level and frequency. Does that validate every earlier observation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 02. Student A, terminology and scope: Agree the operational meanings of challenge, returns, original and indicated, validate, earlier in “After a conversion challenge, the receiver returns to the original indicated level and frequency. Does that validate every earlier observation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of After a conversion challenge, the receiver returns to the original indicated level and frequency; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Conversion-State Challenge Protocol”. It can reveal persistent change or support a broader stability argument, but it cannot alone prove uninterrupted earlier validity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of After a conversion challenge, the receiver returns to the original indicated level and frequency; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Conversion-State Challenge Protocol”. It can reveal persistent change or support a broader stability argument, but it cannot alone prove uninterrupted earlier validity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A return check assesses the functions exercised at that later time Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving After a conversion challenge, the receiver returns to the original indicated level and frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of After a conversion challenge, the receiver returns to the original indicated level and frequency; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving After a conversion challenge, the receiver returns to the original indicated level and frequency: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving After a conversion challenge, the receiver returns to the original indicated level and frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving After a conversion challenge, the receiver returns to the original indicated level and frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for After a conversion challenge, the receiver returns to the original indicated level and frequency. Review contemporaneous lock, gain, state, and reference records to identify any compressed or transitional intervals Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving After a conversion challenge, the receiver returns to the original indicated level and frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for After a conversion challenge, the receiver

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returns to the original indicated level and frequency. Review contemporaneous lock, gain, state, and reference records to identify any compressed or transitional intervals Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about After a conversion challenge, the receiver returns to the original indicated level and frequency and Does that validate every earlier observation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.17 Conversion Gain, Loss, and Calibration (p. 1948)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “After a conversion challenge, the receiver returns to the original indicated level and frequency”, addressing “Does that validate every earlier observation”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.18 From a product map to a discriminating test (p. 1949)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “After a conversion challenge, the receiver returns to the original indicated level and frequency. Does that validate every earlier observation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “After a conversion challenge, the receiver returns to the original indicated level and frequency. Does that validate every earlier observation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.18 From a product map to a discriminating test (p. 1949)

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V011-C04-DISCUSSION-025. What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data?” Put this particular dispute to the panel: What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 02. Student A, terminology and scope: Agree the operational meanings of desired, image, tests and leave, explanations, compatible in “What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.5: Allocate image rejection ahead of equal conversion”. Identify a specific next perturbation or independent reference that would separate their predictions while preserving observation capability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is the most useful result

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when desired, image, and clock tests leave two explanations compatible with the data; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.5: Allocate image rejection ahead of equal conversion”. Identify a specific next perturbation or independent reference that would separate their predictions while preserving observation capability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the observed component, the tested conversion states, the surviving explanations, and the limits that prevented discrimination Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What is the most useful result

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when desired, image, and clock tests leave two explanations compatible with the data: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data. A bounded unresolved result is more reproducible than an unsupported external attribution Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data. A bounded unresolved result is more reproducible than an unsupported external attribution Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.4 Application 4A.1: Locate a low-side image (p. 1931)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data and State the observed component, the tested conversion states, the surviving explanations, and the limits that…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.9 Application 4A.6: Combine coherent desired and image fields (p. 1937)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data”, addressing “State the observed component, the tested conversion states, the surviving explanations, and the limits that…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What is the most useful result when desired, image, and clock tests leave two explanations compatible with the data”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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Chapter 4 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C04-ESSAY-001 — Write the RF as a peak-amplitude cosine and the real LO multiplier as twice the nonnegative voltage scale times a unit cosine. Apply the cosine product identity to obtain a difference-frequency term and a sum-frequency term, each with peak voltage $g\,A$. Their phase arguments respectively contain the RF phase minus and plus the LO phase. The derivation predicts both terms; it does not remove the sum term. The actual selected path must reject the unwanted product adequately for the intended observation. Retain the signed difference until the real positive-frequency representation is formed. If the RF is below the LO, negate the difference phase when rewriting the cosine at positive frequency. State the nonzero-difference restriction, frequencies in hertz, phases in radians, peak voltage convention, and dimensionless multiplier scale. A physical mixer additionally needs measured conversion behavior, loading, LO drive, and operating-state evidence; the normalization does not establish its loss or spur amplitudes. Review: Model 4A Equations 7A–7C; source notes 12 and 13.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7B. The two real multiplier products; Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Frequency Conversion as Multiplication; Chapter 4 — Model 4A: a declared conversion map.

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V011-C04-ESSAY-002 — The signed difference is -23 MHz, so the selected real IF is 23 MHz. The signed difference phase is -55 degrees; rewriting the negative-frequency cosine at positive frequency gives +55 degrees. Reflection about the LO gives an image candidate at 478 MHz, provided that positive RF frequency reaches the mixer. Raising the RF to 432.4 MHz changes the signed difference to -22.6 MHz and the real IF to 22.6 MHz. Thus the local RF-to-IF orientation is negative. All phases use the same time origin and the declared real cosine convention. The calculation assumes fixed LO, unchanged selected path, and no zero crossing. It predicts frequency and phase orientation, not the actual rejection of the image or a calibrated output level. A useful verification therefore includes the known RF step and separate desired/image injections with recorded physical levels. Review: Equations 7C and 7F; Applications 4A.1 and 4A.2.

Review: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.2: Track high-side spectral inversion.

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V011-C04-ESSAY-003 — The selected IF peak is 0.36 V. The RF power is $\frac{0.18^2}{2 \times 75}$, or 0.216 mW. The IF power is $\frac{0.36^2}{2 \times 300}$, also 0.216 mW. The loaded power gain is therefore unity, or 0 dB. Equivalently, Equation 7D gives g^2 multiplied by the resistance ratio: $4 \times \frac{75}{300} = 1$. Using the squared voltage ratio alone would report a factor of 4, or approximately 6.02 dB, because it silently assumes equal resistances. The quantities are loaded sinusoidal powers at two declared planes; they do not automatically equal an available-power conversion specification. A physical measurement must establish those actual loads and the applicable small-signal state. Uncertain or complex impedances require an appropriate circuit or power-wave treatment rather than substitution into this positive-real-resistance example. Review: Equation 7D; Application 4A.3.

Review: Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Application 4A.3: Separate loaded voltage gain from power gain.

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V011-C04-ESSAY-004 — An unscaled unit cosine LO gives a selected real product with 0.2 V peak. The RF power is 1.6 mW and the selected IF power is 0.4 mW, so the ratio is one quarter, approximately -6.02 dB. With the leading factor two and $g=1$, the selected peak is 0.4 V and the loaded selected-product ratio is unity. In the analytic representation, a unit-magnitude complex LO translates the analytic amplitude without the real product identity splitting it into two terms. If starting from the real signal, one must retain the intended positive-frequency band and the corresponding factor-of-two convention. Do not equate the squared magnitude of an analytic signal directly with the real average power without its power convention. The three statements can be consistent because they describe different declared operations. They do not establish a passive physical circuit or justify changing an RF calibration table. Review: Equations 7A, 7D and 7E; Application 4A.4.

Review: Chapter 4 — Equation 7A. RF and normalized real LO; Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.4: Expose the multiplier normalization.

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V011-C04-ESSAY-005 — The desired output is $-96-2.5-7=-105.5$ dBm. A 12 dB margin requires the image output to be no greater than -117.5 dBm. If the image preselection loss is L dB, its output is $-34-L-8=-42-L$ dBm. The required inequality therefore gives L at least 75.5 dB. Use the two actual conversion gains separately; the equal-conversion simplification in Application 4A.5 is not assumed here. The large external level difference consumes most of the rejection. State that the scalar budget requires linear transfer, applicable frequency-dependent losses, and no gain-state change or preceding overload caused by the image. The result is a design requirement under those assumptions, not evidence that a real filter supplies it. A calibrated injection must test both desired retention and image suppression at the actual state and level. Review: Equation 7F; Application 4A.5; Conversion Gain, Loss, and Calibration.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-ESSAY-006 — The upper RF interval is 65 through 68 MHz, and the lower interval is 52 through 55 MHz. Increasing RF within the upper interval increases IF; increasing RF within the lower interval decreases IF. The reversal of interval endpoints follows directly from subtracting the IF endpoints from the LO. The admitted RF set is the union of both intervals intersected with the physically positive RF domain and the actual front-end admission. For example, with a 4 MHz LO and IF interval 3 through 6 MHz, the algebraic lower interval is -2 through 1 MHz. Its positive part is greater than zero through 1 MHz, while the upper interval is 7 through 10 MHz. Negative algebraic frequencies must not be reported as additional positive RF inputs. Real filter skirts require an explicit response or threshold convention rather than a perfect rectangular admission assumption. Review: Equation 7F; Application 4A.10.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals.

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V011-C04-ESSAY-007 — The desired-only power is 40 nW. The image-to-desired peak ratio is 0.3, so the normalized powers are 1.69 at zero phase, 1.09 at 90 degrees, and 0.49 at 180 degrees. The corresponding powers are 67.6, 43.6, and 19.6 nW. Add the complex selected IF voltages before forming power; both phasors must already use the positive-frequency orientation convention. The zero-cross-power sum also gives 43.6 nW, but agreement with the coherent quadrature result does not identify the mechanism. One scalar power cannot reveal the relative phase history, separate the two RF contributions, or demonstrate statistical independence. A controlled relative-phase change can expose constructive and destructive interference. The load, time origin, observation interval, and coherent-source conditions belong in the result, and real compression would invalidate this linear phasor calculation. Review: Equation 7G; Application 4A.6.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-ESSAY-008 — Expand the squared magnitude of the sum of the two selected IF phasors. The result contains the two squared magnitudes and twice the real part of their cross product. After applying the declared averaging operation, power addition requires that the averaged real cross term vanish. Statistical independence with suitable zero-mean phase behavior can justify that condition in a particular model, but the label image does not do so. A fixed 90-degree phase relation makes the real cross term zero deterministically, without making the sources independent. Unknown phase is also not equivalent to a uniform phase distribution. State the integration or ensemble convention and any shared frequency-reference relationship. A sound answer explains why equal observed sums can hide different phase sensitivities and why an injection test that varies phase provides information absent from one average-power reading. Review: Equation 7G; Application 4A.6.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-ESSAY-009 — The signed baseband frequencies are +12.5 kHz and -12.5 kHz. The bin spacing is 500 Hz, so the signed bin numbers are +25 and -25. Under ordinary zero-based array indexing, those correspond to indices 25 and 135. The test should retain the known RF ordering, LO frequency, complex-exponential convention, I/Q order, sampling rate, and any FFT-shift operation. Reversing the sign of Q conjugates the complex record and exchanges the two signed-frequency interpretations. A real magnitude plot at 12.5 kHz would not distinguish the trials. Retain the analog admitted band because sampled frequencies remain equivalent modulo the sample rate; a correct signed bin does not exclude an out-of-band alias. The acceptance observation is that both known tones appear with the predicted opposite signs in the actual saved and processed data. Review: Equation 7E; Application 4A.7; Chapter 10 sampling connection.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct; Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation; Chapter 10 — Sampling application 7 Complex coordinates retain a sign.

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V011-C04-ESSAY-010 — Translating those envelope offsets to a 3 MHz carrier produces nominal support from -1 through +7 MHz, so the stated band is not wholly at positive physical RF frequency. It therefore violates the particular analytic-band assumption used to connect this envelope directly to the real RF waveform. One cannot simply label the entire translated band the positive-frequency analytic RF signal. A valid setup may choose a carrier above 4 MHz with a suitable physical band, restrict the admitted envelope support, or explicitly reformulate the analytic representation for the actual signal. The complex translation operation itself still has an algebraic meaning, but its identification with the physical real-input band requires the stated representation conditions. If starting from a real signal, account for its conjugate spectral band and the factor-of-two construction before assigning loaded power. The issue is representation and admission, not a newly discovered mixer spur. Review: Equation 7E and its analytic-signal assumptions.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding.

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V011-C04-ESSAY-011 — The candidate starts at 6 MHz and has total harmonic order 5, so a search bounded below order 5 must exclude it. Raising the LO by 0.25 MHz changes the signed product by -0.5 MHz, giving a real output at 5.5 MHz. Restoring the LO and raising the RF by 0.1 MHz changes the product by +0.3 MHz, giving 6.3 MHz. Neither perturbation crosses zero. These independent predictions test the coefficient pair more strongly than one frequency coincidence. Before changing either parent, define the IF region, measurable level, frequency-estimation tolerance, and fixed receiver state. Agreement supports that frequency relationship under the tested conditions; it does not identify the physical nonlinear element, prove that the candidate is the only possible parent combination, or determine conversion amplitude. Source-generated products and other clock combinations remain relevant alternatives. Review: Equations 7H and 7I; Application 4A.8.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-ESSAY-012 — The signed change is -0.20 MHz, so the final signed frequency is -0.05 MHz and the real frequency is 0.05 MHz. The endpoint change in the real frequency is therefore -0.10 MHz. Before the crossing, the local real-frequency slope with respect to LO is -2; after it, the slope is +2. The zero occurs after a +0.075 MHz LO change. Extrapolating the initial slope across the full step would ignore the absolute-value cusp. Preserve the signed candidate trajectory and evaluate the absolute values at each state. A test near DC must also establish that both portions remain observable through the selected path and processing. Disappearance around the crossing may reflect filtering or a DC exclusion, so it cannot automatically reject the product hypothesis. Phase and sinusoidal-power conventions at the exact DC point need separate treatment. Review: Equation 7I; Equation 7C nonzero-difference restriction.

Review: Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Equation 7C. Selected difference and orientation.

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V011-C04-ESSAY-013 — At order no greater than 3, the difference pair with coefficients +1 and -1 gives 1 MHz; reversing both signs gives the same real frequency. No other nonzero integer combination inside that order bound falls in the stated interval. At order 4, the pair +2 and -2 adds a 2 MHz candidate, again with a redundant globally negated representation. The zero pair is excluded by the model. A useful answer distinguishes coefficient pairs from distinct absolute-frequency locations and records the order bound before examining the result. Increasing the search order expands arithmetic possibilities without demonstrating a generating mechanism or amplitude. For a suspected 2 MHz product, an LO perturbation predicts a local slope of -2 on the positive signed branch, whereas the 1 MHz difference predicts -1. These movements, source controls, and maintained observability provide a discriminating test. Review: Equations 7H and 7I; Spur Tables and Product Search.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Spur Tables and Product Search.

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V011-C04-ESSAY-014 — The first two real outputs are 50 and 10 MHz, with local orientations negative and positive. A 12 MHz third LO gives 2 MHz with a negative third orientation, so the product of signs is positive. Raising the original RF to 1,200.5 MHz gives successive outputs 49.5, 9.5, and 2.5 MHz. With an 8 MHz third LO, the center output is also 2 MHz but the third orientation is positive, giving a negative overall orientation. The same RF increase then produces 49.5, 9.5, and 1.5 MHz. A center-only check cannot distinguish the final axes. State that each selected stage remains on a fixed nonzero branch and that filtering continues to select the intended product. This calculation validates a local map; it does not establish spur rejection or amplitude calibration through the three physical stages. Review: Equation 7J; Application 4A.9.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

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V011-C04-ESSAY-015 — Treat the boundary as a change in physical conversion state. Record the selected RF path, every available LO and IF, preselection, attenuation, gain, sample path, correction identity, and lock state on both sides. Apply a known tone or ordered tone pair with a small frequency separation that remains within each selected path, and establish the sign and scale of the frequency map. Separately measure a calibrated level reference at the declared input plane to test the applicable amplitude correction. A correct center amplitude can coexist with reversed spectral orientation, and a correct frequency step can coexist with an erroneous gain table. Repeat transitions in both directions if state history may matter, retain native data and setup files, and identify the interval belonging to each state. The acceptance record should state what frequency and level behavior was actually tested and preserve unresolved transient or boundary regions. Review: Application 4A.9; From a product map to a discriminating test; Conversion-State Challenge Protocol.

Review: Chapter 4 — Application 4A.9: Track inversion through two real conversions; Chapter 4 — From a product map to a discriminating test; Chapter 4 — Conversion-State Challenge Protocol.

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V011-C04-ESSAY-016 — The desired transfer is -6 dB and the image transfer is -52 dB. Their difference is 46 dB, so the measured path rejection under these conditions is 46 dB. The raw output separation is only 43 dB because the image input was 3 dB stronger. Refer both outputs to their actual calibrated RF-plane levels before comparing transfer. This is equivalent to equalizing the stimulus levels analytically only while the paths remain linear and in the same state. Automatic gain, preselector, or attenuation changes between trials would add configuration differences that must be controlled or separately modeled. Retain source purity, frequency-specific cable corrections, measurement floor, and applicable uncertainty. The result concerns the tested pair of frequencies and levels; it is not a universal image-rejection rating over all tuning states or strong-signal exposures. Review: Image Responses and Image Rejection; Application 4A.1.

Review: Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Image Responses and Image Rejection.

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V011-C04-ESSAY-017 — Both 150 MHz and the conventional image at 50 MHz reach the same 50 MHz real IF. The generator harmonic already present at the desired RF frequency would alone predict -86 dBm through the stated desired path. Thus the observation does not establish a measurable image response from the 50 MHz fundamental. It is compatible with source contamination even if the receiver rejects the true image strongly. Characterize or suppress the generator harmonic at the actual receiver plane, for example with an applicable source filter and an independent spectral check whose floor is adequate. Preserve the 50 MHz delivered level and receiver state while improving purity. If contributions remain coherent at one IF, naive subtraction of powers may be invalid; use a bounded result or a controlled phase-sensitive comparison. The source nameplate or fundamental setting cannot replace this input-plane control. Review: Image Responses and Image Rejection; Stimulus purity in From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 4 — Image Responses and Image Rejection.

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V011-C04-ESSAY-018 — The arithmetic relation twice 40 minus 30 equals 50 MHz supplies a plausible multi-parent product, but the final 10 MHz IF does not identify where it arose. First establish the actual spectrum at the receiver input plane with sufficient measurement capability, considering generator reverse coupling, combining-network nonlinearity, and source output interaction. Compare individual-source, combined-source, and appropriately isolated or filtered-source conditions while retaining known delivered parent levels. Then use bounded receiver-state or attenuation changes with a desired reference still measurable to test additional internal generation. Frequency movement with a parent can support the product relation regardless of its location, so location needs the path controls. A nondetection in the source-path observation supplies a bound set by that measurement, not proof of zero contamination. Keep any unresolved combination of upstream and receiver-generated contributions explicit. Review: Spur Tables and Product Search; From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 4 — Spur Tables and Product Search.

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V011-C04-ESSAY-019 — Use an independent observation path with documented frequency coverage, sensitivity, geometry, and its own artifact controls. Compare a properly terminated RF input with controlled antenna and cable configurations, changing one coupling path at a time where feasible. Track known tuning changes and the resulting candidate LO-related frequencies, while retaining receiver gain, preselection, termination, and lock state. Spatial or coupling changes can help separate enclosure radiation from cable and antenna paths, but they also alter the observation transfer and therefore require calibrated or bounded comparison. Tuning-dependent detection supports a relationship with receiver activity; it does not reveal every hidden conversion stage, establish the dominant radiation path, or prove malfunction without an applicable performance criterion. Report the measured emission or coupling under the actual state and geometry, with alternative paths and observation limits retained. Review: Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

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V011-C04-ESSAY-020 — Multiplying 312.5 MHz by 100 parts per million gives 31.25 kHz, so a purely numerical scale change can produce the stated indication even if the physical input frequency is unchanged. The change is compatible with relabeling; a hardware clock or LO change may also alter physical conversion, and its direction and magnitude must come from the actual mapping. Retain the native sample rate, LO plan, reference state, and the software scale used in each record. Compare against an independent physical-frequency reference or a calibrated injected tone to separate axis changes from movement of the entering signal. A second receiver must have characterized sensitivity and coverage before its nondetection becomes informative. Matching a clock-related fractional change supports a testable hypothesis but does not by itself locate generation inside the first receiver or establish an external source identity. Review: Hypothetical Case Adjudication; Chapter 10 Equation 23I connection.

Review: Chapter 12 — Equation 23I. Actual sample-clock time and frequency scaling; Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

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V011-C04-ESSAY-021 — The known surrounding gains sum to +3 dB: $-2+8-3$. The mixer gain must therefore be -15 dB, corresponding to 15 dB conversion loss under the same power and reference-plane conventions. The subtraction is meaningful only if all quantities apply to the same frequencies, loading, LO drive, temperature, level, and selected conversion state. If interface mismatch changes when components are connected, isolated scalar gain values may not describe the installed cascade. Likewise, compression or LO disturbance defeats the assumed linear transfer. State whether the intended measurand is the complete receiver path or the mixer alone; removing surrounding elements is unnecessary and potentially misleading when the full path is the quantity of interest. Retain correction provenance and associated uncertainty without claiming that mathematical subtraction alone supplies an independently measured mixer characteristic. Review: Conversion Gain, Loss, and Calibration; Equation 7D.

Review: Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-ESSAY-022 — The desired tone lies above the LO, so its selected positive-frequency phase is $30-10=20$ degrees. The image lies below the LO; its signed difference phase is $50-10=40$ degrees, which becomes -40 degrees at positive 10 MHz IF. The relative selected phase is therefore -60 degrees. The normalized combined power is $1+0.25+2\times 0.5\times \cos(60°)$, or 1.75. Using the original RF phase difference of 20 degrees would be wrong because it ignores high-side phase conjugation. Both RF phases and the LO phase must refer to a common time origin, and the tones must retain the stated coherent relationship over the observation. The result is a loaded linear phasor comparison at the common IF plane, not an independent-power sum or a prediction of real image-path attenuation. Review: Equations 7C and 7G; Applications 4A.2 and 4A.6.

Review: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.2: Track high-side spectral inversion; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

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V011-C04-ESSAY-023 — The measured frequency trajectory may remain evidence for the proposed coefficient relationship if frequency estimation and path selection are still valid. It does not make the amplitude response a valid linear conversion measurement. Reference compression shows that the state used for at least part of the observation has lost the intended weak-signal transfer, so rejection or gain inferred by linear subtraction is unsupported there. Retain the original frequency and amplitude data with that limitation rather than discarding useful frequency evidence or declaring full acceptance. Repeat at bounded parent levels, improved rejection, or a suitable gain state while keeping the predicted product and desired reference observable. Source controls remain necessary because an upstream product can share the same movement. The eventual report should distinguish a supported frequency hypothesis, a failed amplitude-validity condition, and any unresolved generation location. Review: Application 4A.8; From a product map to a discriminating test.

Review: Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product; Chapter 4 — From a product map to a discriminating test.

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V011-C04-ESSAY-024 — The two nominal RF intervals are 68 through 70 MHz and 100 through 102 MHz. Their centers alone do not cover the image-band edges. Measure or obtain applicable transfer across both intervals and relevant filter transitions, while retaining the selected receiver state. For amplitude work, the useful interval may be limited by a specified flatness or correction uncertainty. For a spur challenge, a much weaker response in a filter skirt may still pass enough of a strong input to matter. These are different decision thresholds applied to the same physical frequency-dependent transfer. The ideal interval map locates candidate inputs, whereas the measured weighting determines their influence. A sound review states its response threshold, desired waveform bandwidth, input-level bounds, and correction applicability rather than treating the nominal IF label as a perfectly rectangular exclusion of every other RF frequency. Review: Equation 7F; Application 4A.10; Image Responses and Image Rejection.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping; Chapter 4 — Application 4A.10: Map an admitted IF interval back to both RF intervals; Chapter 4 — Image Responses and Image Rejection.

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V011-C04-ESSAY-025 — Retain the complete active conversion plan, input and output planes, source and clock states, filters, gain, detector or sampling path, correction identity, and native observations. For each tested explanation, record the predicted response, controlled perturbation, observed movement or level change, remaining observation capability, and applicable uncertainty or bound. Desired and image injections establish the tested frequency map only under their actual transfer conditions; spur movements constrain relationships but do not automatically locate generation. Clock comparisons must distinguish physical movement from axis relabeling. State which alternatives were excluded within the tested domain, which remain compatible, and any intervals invalidated by compression or state transitions. The strongest justified result may be a bounded external-frequency interpretation or an unresolved conversion artifact. Neither establishes emitter position, operator identity, or intent without separate evidence appropriate to those claims. Review: From a product map to a discriminating test; Conversion-State Challenge Protocol; Chapter 16 connection.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 4 — Conversion-State Challenge Protocol; Chapter 16 — Localize an artifact by changing the stage that could create it; Chapter 16 — Write findings that preserve the strength and limit of each test.

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Discussion Guidance

V011-C04-DISCUSSION-001 — Ask the team to trace each selected stage and multiply its local orientation signs on the applicable nonzero branches. Use a known frequency step or ordered tone pair to distinguish equal center values with opposite final orientation. The discussion should produce state-specific axis and phase conventions, including any I/Q conjugation, rather than an assumption based on the matching center. Amplitude calibration is a separate check. Review: Equation 7J; Application 4A.9.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages; Chapter 4 — Application 4A.9: Track inversion through two real conversions.

V011-C04-DISCUSSION-002 — Separate frequency-reference agreement from loaded gain, LO drive, impedance, filter response, detector scaling, and correction applicability. A locked oscillator can coexist with wrong amplitude normalization or an altered physical path. Require a declared amplitude measurand and an applicable calibrated level reference. The useful outcome is a list of distinct observations supporting frequency and level claims, not an expanded meaning of lock. Review: Equation 7D; Conversion Gain, Loss, and Calibration.

Review: Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Conversion Gain, Loss, and Calibration.

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V011-C04-DISCUSSION-003 — First compare the real LO multiplier, analytic-signal convention, selected product, peak-versus-RMS definition, and impedance ratio. The factor-two normalization alone can create this power difference. Determine whether the disagreement is mathematical scaling or a measured physical transfer error before changing corrections. A consistent normalization does not certify a real mixer, and a real measurement discrepancy should not be hidden by renaming the convention. Review: Application 4A.4; Equation 7E.

Review: Chapter 4 — Application 4A.4: Expose the multiplier normalization; Chapter 4 — Equation 7E. Complex conversion without frequency folding.

V011-C04-DISCUSSION-004 — Return to the stated first-order real-difference architecture and its domain of positive physical RF inputs. A negative reflected value is not a second positive input in that simple map. Taking another absolute value would create an unsupported candidate. Other harmonic or multistage responses may still exist, but they require their own architecture and coefficient analysis. Preserve the domain limitation rather than claiming universal image immunity. Review: Equation 7F.

Review: Chapter 4 — Equation 7F. Conventional image and RF interval mapping.

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V011-C04-DISCUSSION-005 — The conventional desired/image separation is twice the IF for a valid positive image, so changing IF changes the frequency-separation challenge. Actual rejection also depends on preselection, image-reject balance, alternate paths, levels, and conversion architecture. Discuss which measured transfer evidence is needed for the proposed plan rather than ranking receivers by separation alone. Retain any changes in usable bandwidth, gain, or downstream conditions as separate design considerations. Review: Applications 4A.1 and 4A.5; Image Responses and Image Rejection.

Review: Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Application 4A.5: Allocate image rejection ahead of equal conversion; Chapter 4 — Image Responses and Image Rejection.

V011-C04-DISCUSSION-006 — The comparison now includes a state change. Determine whether the intended measurand is the complete operational receiver behavior or differential rejection at a fixed conversion state. For the latter, hold or explicitly characterize the settings and their corrections. For the former, report the automatic states as part of the result. Equal generator settings alone do not establish equal physical input levels or isolate image-path rejection. Review: Image Responses and Image Rejection; Application 4A.1.

Review: Chapter 4 — Application 4A.1: Locate a low-side image; Chapter 4 — Image Responses and Image Rejection.

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V011-C04-DISCUSSION-007 — Unknown phase does not establish a zero averaged cross term. Use the observation interval, source relationship, and measured coherence to justify any averaging law. Where phase remains unspecified, report phase-dependent possibilities or bounds appropriate to the question. Participants should distinguish lack of knowledge from a chosen random-phase model and explain how a controlled phase change could add evidence. Review: Equation 7G; Application 4A.6.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition; Chapter 4 — Application 4A.6: Combine coherent desired and image fields.

V011-C04-DISCUSSION-008 — Consider destructive combination of the selected IF phasors before concluding that the desired path vanished. Change the relative phase or use separate calibrated injections while holding the receiver state fixed. Also test compression and source interaction. The result may show cancellation at the observation plane even while both inputs are admitted. A nondetection at one phase cannot establish absence of either physical input. Review: Equation 7G.

Review: Chapter 4 — Equation 7G. Coherent collision and the zero-cross-power condition.

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V011-C04-DISCUSSION-009 — The sign is a coordinate relative to the declared LO and complex convention. Reconstruct the physical RF interval using the actual translation map and admitted band. Negative baseband can represent a positive RF input below the LO. Retain sampling equivalence and I/Q order, because the signed bin alone does not identify a unique physical source outside the verified analog band. Review: Equation 7E; Application 4A.7.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

V011-C04-DISCUSSION-010 — Conjugation reverses complex-frequency sign and changes phase relationships. It may be a valid documented transformation, but it must remain in the processing lineage, especially for sideband, phase, delay, or modulation comparisons. Require a known-tone orientation check and retain the original record. A magnitude plot can conceal the operation while downstream interpretation changes. Review: Equation 7E; Applications 4A.2 and 4A.7.

Review: Chapter 4 — Equation 7E. Complex conversion without frequency folding; Chapter 4 — Application 4A.2: Track high-side spectral inversion; Chapter 4 — Application 4A.7: Keep opposite complex-frequency bins distinct.

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V011-C04-DISCUSSION-011 — No candidate earns acceptance solely from arithmetic agreement. Record the parent set, search order, tolerances, and any search expansion after observing the peak. Compare predeclared movement predictions, level behavior, path controls, and continued observability. The discussion should rank testable hypotheses and preserve ambiguity when different mechanisms share predictions, rather than choosing the most familiar formula. Review: Equations 7H and 7I; Spur Tables and Product Search.

Review: Chapter 4 — Equation 7H. Bounded integer product search; Chapter 4 — Equation 7I. Retuning a signed and an absolute product; Chapter 4 — Spur Tables and Product Search.

V011-C04-DISCUSSION-012 — A slope can support a frequency relationship without locating the nonlinear element. Different paths or clock combinations can have the same coefficient, and a source-generated signal may be converted by the receiver. Ask which independent parent perturbation or physical-path control would distinguish the remaining hypotheses. The report should name the relationship actually tested and avoid converting it into a component diagnosis. Review: Application 4A.8.

Review: Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product.

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V011-C04-DISCUSSION-013 — Check whether the predicted trajectory remained within the selected IF path, detector range, and measurement floor. If the test removed observation capability, disappearance is inconclusive about generation. Replan a smaller perturbation or an observation band that covers both predicted positions, with a retained reference. An informative negative result requires a stated capability to see the response if the hypothesis were true. Review: Application 4A.8; From a product map to a discriminating test.

Review: Chapter 4 — Application 4A.8: Test the movement of a candidate harmonic product; Chapter 4 — From a product map to a discriminating test.

V011-C04-DISCUSSION-014 — Avoiding a crossing can simplify a local-slope test, but a deliberately observed cusp can itself discriminate a signed product map. Either design must state the piecewise prediction and verify observability near DC. A single straight-line slope should not be fitted across both branches without justification. Discuss the separate phase and power conventions at exact zero and any instrument DC exclusions. Review: Equations 7C and 7I.

Review: Chapter 4 — Equation 7C. Selected difference and orientation; Chapter 4 — Equation 7I. Retuning a signed and an absolute product.

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V011-C04-DISCUSSION-015 — The product gives a local derivative only while each selected branch and state remains fixed and nonzero. It does not establish that the intended path was actually selected, that unwanted products are rejected, or that the mapping remains valid across a band switch. Combine the sign calculation with known-tone checks and actual state records. The result should be scoped to the verified interval. Review: Equation 7J.

Review: Chapter 4 — Equation 7J. Orientation through selected real difference stages.

V011-C04-DISCUSSION-016 — Separate observation of leakage from an applicable acceptance criterion. Retain the emitting receiver state, coupling geometry, reference relationship, and independent observer limitations. LO-related energy can indicate activity without revealing the full tuning plan or establishing a fault. A malfunction conclusion requires evidence that the observed behavior violates a relevant condition or impairs the intended measurement. Review: Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

V011-C04-DISCUSSION-017 — The cable can also change common-mode coupling, termination, enclosure currents, and the observing antenna transfer. Plan controlled substitutions and geometry changes that distinguish those paths while retaining the receiver state. Stronger detection is useful evidence of a configuration effect, but it does not uniquely identify one radiation mechanism. Report any remaining coupled contributions explicitly. Review: Local-Oscillator Purity and Leakage.

Review: Chapter 4 — Local-Oscillator Purity and Leakage.

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V011-C04-DISCUSSION-018 — Reconstruct how the reference change affects actual LOs, sample timing, and software frequency scale. Use an independent physical-frequency observation or calibrated injected tone to constrain the mapping. A proportional shift is compatible with more than one explanation. The discussion should produce a discriminating measurement with stated sensitivity and state control, not a classification based on the word clock. Review: Hypothetical Case Adjudication; Chapter 10 Equation 23I connection.

Review: Chapter 12 — Equation 23I. Actual sample-clock time and frequency scaling; Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

V011-C04-DISCUSSION-019 — Require comparable frequency coverage, time coverage, antenna or injection transfer, bandwidth, detection criterion, and sensitivity. A less capable or differently timed observation cannot exclude an external component seen by the first receiver. A characterized nondetection can provide a useful bound. Preserve that bound separately from the first receiver’s clock or conversion evidence. Review: Hypothetical Case Adjudication.

Review: Chapter 4 — Hypothetical Case Adjudication: Mixers, Local Oscillators, Frequency Conversion, Images, and Spurious Responses.

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V011-C04-DISCUSSION-020 — The display label does not show whether an LO plan, filter selection, detector path, or correction algorithm changed. Review the actual configuration and applicable release information, then verify relevant level and orientation behavior across the used bands. Retain a correction only with evidence of continued applicability. The discussion should connect verification scope to the intended measurement rather than requiring unrelated blanket testing. Review: Conversion Gain, Loss, and Calibration; Conversion-State Challenge Protocol.

Review: Chapter 4 — Conversion Gain, Loss, and Calibration; Chapter 4 — Conversion-State Challenge Protocol.

V011-C04-DISCUSSION-021 — Relate the specified residual to the required rejection measurement, actual frequency and level, connected filters and combining path, and the receiver's desired-path sensitivity. A small harmonic may dominate a very weak image response. The relevant question is whether source contamination is bounded adequately at the receiver plane under the test conditions. A specification can contribute evidence but should not be assumed to cover an altered assembly or a deeper measurement floor. Review: Image Responses and Image Rejection; Stimulus purity in From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 4 — Image Responses and Image Rejection.

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V011-C04-DISCUSSION-022 — Require compatible power conventions, reference planes, actual loading, frequency, LO drive, level, and state. Discuss whether mismatch or interaction makes the isolated component values inapplicable to the installed path. If the complete path is the actual measurand, de-embedding may answer a different question. A defensible calculation retains uncertainty and clearly distinguishes inferred mixer behavior from an independent mixer measurement. Review: Conversion Gain, Loss, and Calibration; Equation 7D.

Review: Chapter 4 — Equation 7D. Loaded selected-product power gain; Chapter 4 — Conversion Gain, Loss, and Calibration.

V011-C04-DISCUSSION-023 — The behavior supports investigation of nonlinear generation, but source outputs, combiners, connectors, and earlier equipment may generate the same product before the receiver. Retain desired-reference validity and actual delivered parent levels while characterizing the source path. Frequency relationships and path controls help locate generation. Do not extrapolate a small-range slope through compression or assume one mechanism from an unqualified rate of growth. Review: Spur Tables and Product Search; From a product map to a discriminating test.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 4 — Spur Tables and Product Search.

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V011-C04-DISCUSSION-024 — A return check assesses the functions exercised at that later time. It can reveal persistent change or support a broader stability argument, but it cannot alone prove uninterrupted earlier validity. Review contemporaneous lock, gain, state, and reference records to identify any compressed or transitional intervals. Preserve useful earlier data with bounded interpretation instead of transferring the final successful check backward without evidence. Review: From a product map to a discriminating test; Chapter 1 closing-verification qualification.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 1 — Evidence Record and Closing Verification.

V011-C04-DISCUSSION-025 — State the observed component, the tested conversion states, the surviving explanations, and the limits that prevented discrimination. Identify a specific next perturbation or independent reference that would separate their predictions while preserving observation capability. A bounded unresolved result is more reproducible than an unsupported external attribution. The discussion should end with an evidence record and a decisive next test, without claiming emitter identity or location. Review: From a product map to a discriminating test; Chapter 16 connection.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 16 — Localize an artifact by changing the stage that could create it; Chapter 16 — Write findings that preserve the strength and limit of each test.

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Chapter Glossary

ABSOLUTE-FREQUENCY CUSP: The change of slope produced when a signed conversion product passes through zero and its displayed frequency is represented by an absolute value. The signed trajectory can remain linear while the nonnegative trajectory has two branches. Endpoint changes must be calculated from the absolute values or the appropriate piecewise map; one local slope cannot be extended across the crossing.

ADMITTED RF BAND: The physical RF-frequency region that can influence a selected receiver path under its actual filter and switching state. It may extend beyond the displayed span, and weak skirt transmission can matter for a strong input. A nominal bandwidth label does not define a perfect exclusion boundary. Conversion claims therefore combine the frequency map with an applicable measured transfer or stated admission threshold.

ANALYTIC SIGNAL: A complex representation of a real signal that retains its positive-frequency content with the corresponding amplitude convention and removes the redundant negative-frequency conjugate content. In Model 4A the admitted translated envelope must remain at positive physical RF frequency. Its complex magnitude and the real waveform’s average loaded power require their declared normalization; they must not be interchanged without that convention.

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AVAILABLE SOURCE POWER: The power a source could supply under its specified matching condition, distinguished from the power actually delivered to a particular connected load. A mixer specification stated using available input power cannot automatically be substituted for the chapter's ratio of loaded sinusoidal powers at positive real resistances. The source, load, matching, and selected output conventions must be reconciled before comparing the quantities.

CANDIDATE SPUR LATTICE: A bounded set of integer parent-frequency combinations used to test possible product locations without predicting their amplitudes.

CASCADED CONVERSION BRANCH: A particular sequence of selected sum or difference choices and sign regions through a receiver's conversion stages. The chapter's first-order real-difference orientation rule applies to a fixed sequence of nonzero branches, multiplying their local signs. A different LO choice can give the same final center IF with a different orientation. State changes therefore require an updated branch record and verification.

COHERENT IMAGE COLLISION: Combination of desired and image contributions at the same selected IF with a retained phase relationship. Their IF phasors add before power is formed, so the observed power can increase or decrease relative to the desired-only result. The high-side phase transformation must already be applied. One power reading cannot separate the contributions or establish that their powers add independently.

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COMPLEX ENVELOPE: The complex amplitude-and-phase function that describes a signal relative to a chosen carrier in an analytic representation. Multiplying that envelope by the carrier exponential locates its spectrum around the carrier. Carrier choice, envelope bandwidth, and admitted physical RF band must be consistent. The envelope is a representation of the waveform, not proof that an image or an alias has been rejected by the receiver.

COMPLEX LOCAL OSCILLATOR: A rotating complex multiplier used to translate an analytic band without the absolute-frequency folding of a real difference display. The chapter uses a negative complex-exponential frequency convention for downconversion and retains the LO phase. The sign of that convention must agree with I/Q ordering and subsequent frequency-axis labeling. A mathematical unit-magnitude rotation does not state a physical mixer's conversion loss.

CONJUGATE-BAND REJECTION: Selection that removes the unwanted conjugate spectral band when constructing or processing the intended analytic complex signal from a real input. It is part of the representation and filtering required by the stated conversion convention. The associated factor-of-two amplitude normalization must be tracked. Merely naming an output I/Q does not demonstrate adequate rejection, correct channel ordering, or freedom from sampling aliases.

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CONJUGATE SYMMETRY: The paired relationship between positive- and negative-frequency components of a real waveform: the coefficients at opposite frequencies are complex conjugates. This redundancy explains why a real magnitude observation cannot by itself distinguish the two sides of a conversion LO. An analytic representation removes the redundant band under an explicit normalization; a correctly retained complex record can then preserve signed-frequency information.

CONVERSION LOSS: Ratio of available input power at one mixer port to desired output power at the selected product port.

CONVERSION ORIENTATION: The sign with which a local RF-frequency change maps into the selected real or complex output-frequency coordinate.

CONVERSION-STATE BOUNDARY: A transition between receiver configurations that may change an LO plan, selected IF, injection side, preselector, or correction path. Both amplitude transfer and frequency orientation can change across it. Retaining state identity and timing allows observations to be interpreted with the applicable map. Verification should exercise relevant frequencies on each side and distinguish settled states from uncharacterized transition intervals.

CROSS-POWER TERM: The interference contribution that appears when power is formed from the sum of two selected IF fields. Its value depends on their relative phase and on the averaging operation. Adding the individual mean powers is justified only when the relevant averaged real cross term vanishes. An unknown phase is not sufficient evidence for that condition, and a fixed quadrature relationship is distinct from statistical independence.

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DIFFERENCE PRODUCT: A mixer output component whose signed frequency is formed by subtracting one parent frequency from another under the selected conversion relation. For Model 4A the signed first-order value is RF minus LO; its real positive-frequency representation also depends on the sign of that difference. The component is distinct from the sum product, and selecting it requires a suitable actual signal path.

FREQUENCY-AXIS CALIBRATION: Establishing the relationship between known frequency values and a receiver or processing system's frequency indications under specified conditions. The relationship includes scale, offset, and orientation where relevant, together with applicable uncertainty. A center-tone agreement does not establish the direction of a frequency increment, and a reference or software-scale change can move labels without proving that a physical external tone moved.

HARMONIC PRODUCT ORDER: The declared integer-search measure equal to the sum of the absolute parent coefficients in the chapter's bounded product lattice. It limits which candidate combinations are enumerated. This bookkeeping order does not itself identify the physical nonlinearity, establish that every candidate is generated, or predict amplitude. A search report should retain the bound and any later expansion that increases the number of possible matches.

IMAGE FREQUENCY: Unwanted input frequency that produces the same selected intermediate frequency as the desired input.

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IMAGE REJECTION: Suppression of the response to an unwanted RF input that reaches the same selected IF as the desired input, evaluated under declared frequency, level, and receiver-state conditions. A differential path measurement refers outputs to the actual calibrated input levels and controls source contamination. Rejection can vary with tuning, alignment, temperature, quadrature balance, and overload; a single tested pair does not establish a universal receiver value.

INJECTION SIDE: Whether the local oscillator lies above or below the desired RF frequency for a selected conversion.

INTERMEDIATE FREQUENCY: A frequency coordinate at an internal selected conversion output used for subsequent filtering, amplification, detection, or sampling. A receiver can contain several IFs, and the same final IF can arise through different conversion plans. Its magnitude alone does not identify the external RF input, the injection side, the phase orientation, or which unwanted response may have reached the selected path.

I/Q ORDERING: The assignment and sign convention by which the in-phase and quadrature channels form a complex sample sequence. Reversing the sign of the quadrature channel conjugates that sequence and reverses its signed-frequency interpretation. A magnitude display may conceal the change. Known tones on both sides of the LO provide an end-to-end check of the saved data and frequency-axis convention.

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LOADED CONVERSION POWER GAIN: The ratio of selected IF power to RF power at the two declared loaded planes in Model 4A. For positive real loaded resistances, it equals the squared voltage scale multiplied by RF resistance divided by IF resistance. It therefore differs from the squared voltage ratio when the loads differ. This defined ratio is not automatically an available-power data-sheet gain.

LOCAL CONVERSION SLOPE: The derivative describing a small change in selected output-frequency coordinate with respect to a specified parent frequency on a fixed conversion branch. In the integer lattice its magnitude and sign depend on the relevant coefficient and, for a real absolute-frequency output, the sign of the current product. It is conditional on unchanged path selection and does not apply across an unmodeled switch or cusp.

LOCAL-OSCILLATOR LEAKAGE: Unintended appearance of oscillator energy at mixer ports, cables, enclosure, or antenna.

LO DRIVE: The actual local-oscillator excitation applied to a mixer under a stated waveform, level, frequency, and port condition. It influences physical conversion behavior and cannot be replaced by the dimensionless normalization of an ideal multiplier. A conversion measurement must retain the applicable drive and any disturbance caused by strong input signals. The correct LO frequency alone does not establish the intended conversion gain.

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MIXER DE-EMBEDDING: Removal or accounting of surrounding filter, amplifier, cable, and interface effects so that an inferred result refers to the mixer itself at declared planes. Scalar gain subtraction requires compatible power conventions and applicable linear installed-path values; mismatch and interaction can require a more complete treatment. De-embedding changes the measurand and must not be confused with directly measuring the complete receiver transfer.

MULTIPLIER NORMALIZATION: The declared numerical scale of an ideal mixing operation that determines selected-product voltage and power.

PARENT-FREQUENCY PERTURBATION: A controlled change in one frequency used to test a candidate conversion relationship while other relevant parents and receiver states are held fixed or accounted for. The signed movement follows that parent’s integer coefficient in the stated lattice. The absolute movement may change branch at zero. A useful test predeclares the expected response and keeps the candidate within a measurable region.

PEAK-TO-RMS CONVERSION: The relation between the peak amplitude of a nonzero-frequency sinusoid and its root-mean-square amplitude: RMS equals peak divided by the square root of two. It gives average power equal to peak voltage squared divided by twice the positive real load resistance. The rule does not apply unchanged to DC, arbitrary pulsed waveforms, or an analytic-signal magnitude without its own power convention.

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PHASE CONJUGATION: Reversal of a complex phasor's phase sign. In the chapter's real conversion map, rewriting a negative-frequency difference cosine at positive frequency conjugates its associated phasor. Conjugating a saved I/Q record also reverses signed-frequency orientation. The operation must be retained in the interpretation and processing history whenever phase, sideband, timing, or modulation comparisons depend on the original convention.

PORT ISOLATION: Suppression of unwanted transfer between identified mixer or receiver ports under specified frequencies, terminations, and operating states. Finite LO-to-RF isolation can contribute leakage into an input cable or antenna, while other coupling paths may involve the enclosure. Isolation belongs to the installed configuration and relevant direction; it should not be inferred solely from mixer type or the absence of one displayed line.

RF INTERVAL MAPPING: The relationship between an admitted IF interval and the RF intervals that can reach it through the stated conversion. A real first-order difference path generally has a lower and an upper interval around the LO, restricted to positive physically admitted RF frequencies. Mapping the complete interval exposes edge and skirt responses that a single image-center calculation omits.

SELECTED CONVERSION PRODUCT: The particular output component admitted by the chosen mixer, filter, and processing path for the intended measurement. A multiplier can generate several mathematical or physical candidates, so a frequency formula must be tied to this selection. Changing an IF path or filter state can change which product is observed even when the front-panel tuning label remains the same.

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SIGNED DIFFERENCE FREQUENCY: The algebraic RF-minus-LO frequency retained before any conversion to a nonnegative real-frequency display.

SOURCE HARMONIC CONTAMINATION: An unwanted harmonic already present in a test source or its delivery path that enters the receiver as an ordinary RF input. During an image test, such a harmonic can fall in the desired path and imitate response to the intended image-frequency fundamental. Bounding the contamination at the actual receiver plane is necessary before assigning the measured IF output to receiver image rejection.

SPURIOUS RESPONSE: Receiver output caused by an unwanted internal or external frequency-conversion mechanism.

SUM PRODUCT: The first-order real-multiplier component at the sum of the positive RF and LO frequencies. In the normalized ideal cosine model it has the same peak scale as the difference product before output selection, with the sum of their phases. It is not absent merely because a receiver intends to use the difference IF. Actual filtering and path response determine whether it influences the observation.

ZERO-DIFFERENCE BOUNDARY: The conversion condition at which RF and LO frequencies coincide in the selected first-order difference model. The real difference output then includes a DC term, so the nonzero sinusoidal phase and power conventions used for the chapter’s tone examples cannot be transferred unchanged. Crossing the boundary also changes the sign of the real-frequency orientation and requires piecewise interpretation.

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References and Works Cited

Kester, Walt. MT-080: Mixers and Modulators. Revision 0. Analog Devices, October 2008. Pages 1–2 and 5, including the multiplier discussion and Image Response. https://www.analog.com/media/en/training-seminars/tutorials/mt-080.pdf

Annotation. Supports mixer terminology, dimensional scaling, and conventional image locations. The printed sine-product identities on page 5, Equations 1 and 1a, have incorrect sum-term signs; those signs are not adopted. Model 4A develops its own cosine-product derivation, loading conventions, and constructed cases. Neither its normalization nor its candidate product lattice supplies a commercial mixer loss or spur-amplitude specification. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver’s actual topology. Ideal mixer identities do not establish that a real component is free of compression, leakage, spurs or path-dependent calibration errors. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

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Chapter 5. Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors

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5.1 Intermediate Frequency as a Controlled Band

An intermediate-frequency chain places the selected information into a band where stable gain, filtering, detection, and digitization can be implemented. A receiver may use several IFs, with each conversion trading image rejection, filter realizability, tuning range, dynamic range, and spur behavior. Fixed crystal, ceramic, surface-acoustic-wave, cavity, lumped, digital, or hybrid filters may be used. The IF is therefore a designed measurement environment, not merely a numerical difference between the RF and local oscillator.[1]

The practitioner identifies the center frequency, filter family, selectable bandwidths, shape factor, group delay, gain distribution, limiter state, detector takeoff, and calibration injection points. In a wideband survey receiver, one IF path may feed the displayed spectrum while another feeds audio or a demodulator. Results from those paths can differ because of bandwidth, AGC, detector, and scaling. The record states which path produced each observation.

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1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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5.2 Filter Shape, Selectivity, and Time Response

Selectivity depends on more than nominal bandwidth. Passband ripple changes amplitude accuracy, skirt response determines adjacent-signal rejection, group-delay variation distorts modulation and pulses, and finite impulse response creates settling and ringing. A narrow filter can reveal a weak continuous component near a strong carrier while suppressing a short burst whose energy is spread in time. Conversely, a wide filter can preserve pulse shape while admitting more noise and interference.

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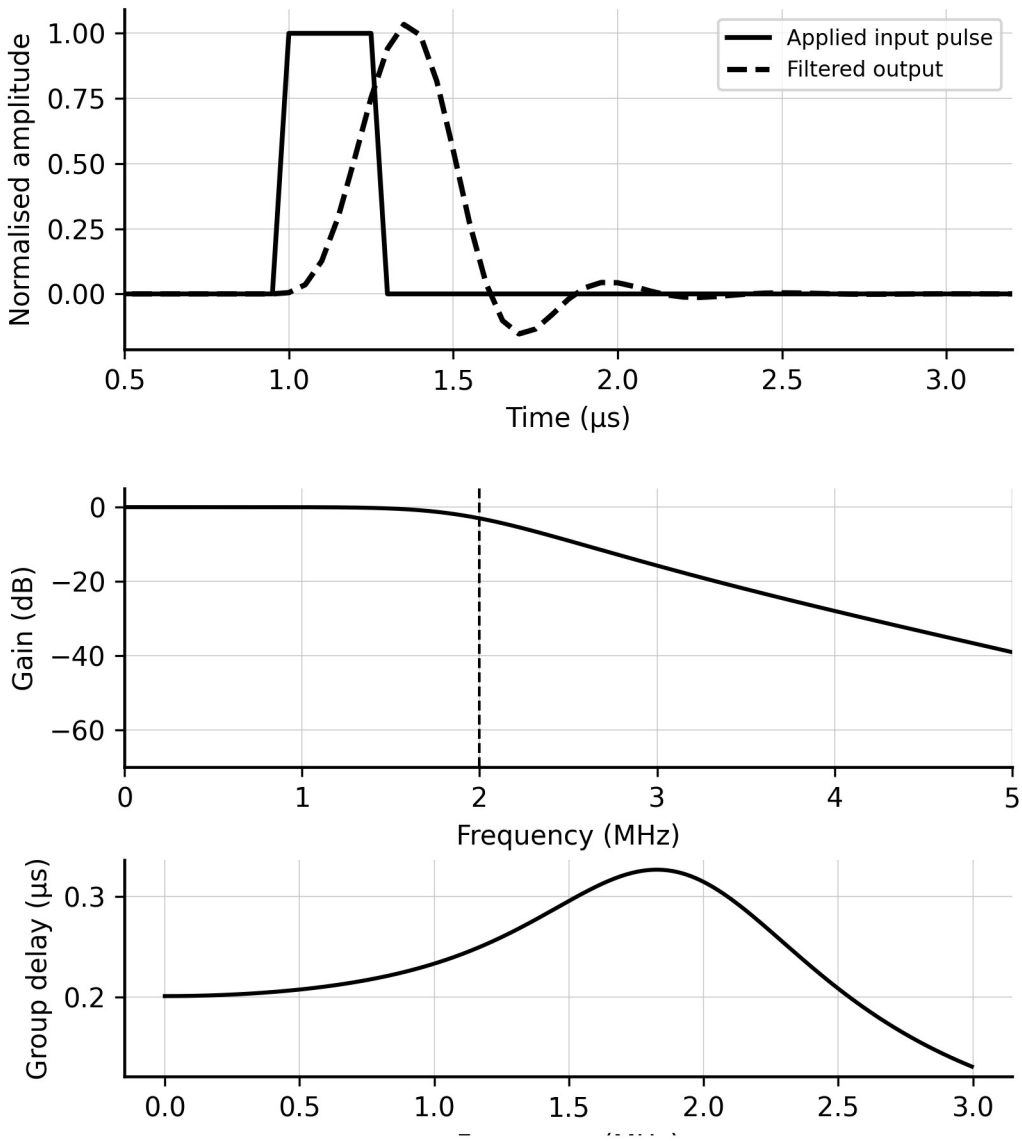

Figure 18. IF-filter response and pulse distortion.

Filter bandwidth should be selected from the signal's occupied spectrum and the question being answered. Measuring total channel power, modulation deviation, close-in spurs, pulse rise time, or frequency stability requires different filters. A receiver's labeled bandwidth may refer to -3 dB

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width, -6 dB width, noise bandwidth, or a digital design parameter. Verification uses a swept or stepped source and, when timing matters, an impulse or modulated test.

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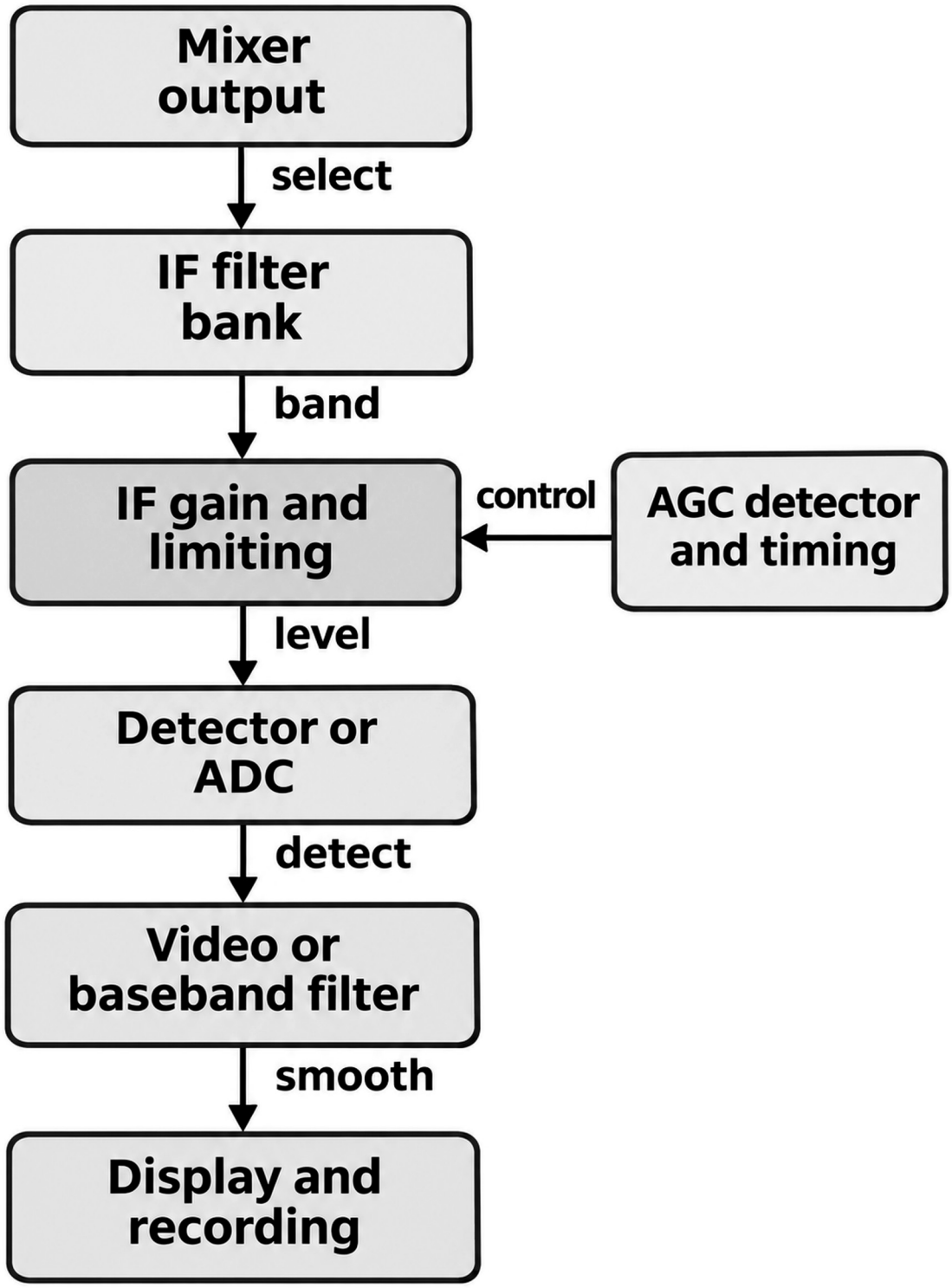

Figure 19. Intermediate-frequency gain and detector paths.

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5.3 Choose an IF path for the quantity being measured

An IF path has both a frequency response and a time response. A narrow channel can improve the separation of continuous tones while delaying or reducing the peak of a short event. The same filter can preserve total energy over a long record yet produce a misleading instantaneous peak. Decide whether the measurand is a tone amplitude, integrated channel power, modulation waveform, onset time, or burst peak before selecting the path. That choice determines which part of its response requires calibration.

The loaded-Q expression in Equation 9 describes one bandwidth ratio. Two paths with the same center and -3 dB width can have different skirts, passband ripple, delay, and ringing. Reuse the weighted noise and spectrum conventions in Chapters 2, 9, and 11 when noise power or spectral density is the quantity of interest. For a transient, preserve the impulse or step response and the sample history needed by the filter. A scalar Q does not supply either of those missing records.

Group delay is a local frequency-domain descriptor obtained from the slope of unwrapped transfer phase. It is meaningful over frequencies where the transfer is measurable and the phase reference is coherent. It does not imply that every waveform traverses the filter as an unchanged delayed copy. That stronger claim requires sufficiently flat amplitude and linear phase across the waveform band. Near a deep notch, phase estimates can be unstable, so a dramatic apparent delay may mostly reflect an ill-conditioned measurement.

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5.4 Model 5A: an identified one-pole gain-control response

Equation 10 is developed here as a local control-state model. It describes a real voltage approaching a constant target with a positive time constant from a known initial value. The model does not infer the entire detector, feedback topology, or overload recovery from that one response. The AD8367 data sheet provides a concrete example of this distinction: it identifies a single-pole response for small level changes and separately discusses integrating action, slew limits, and overdrive behavior. The numerical applications below are independent synthetic cases, not specifications for that device.[2]

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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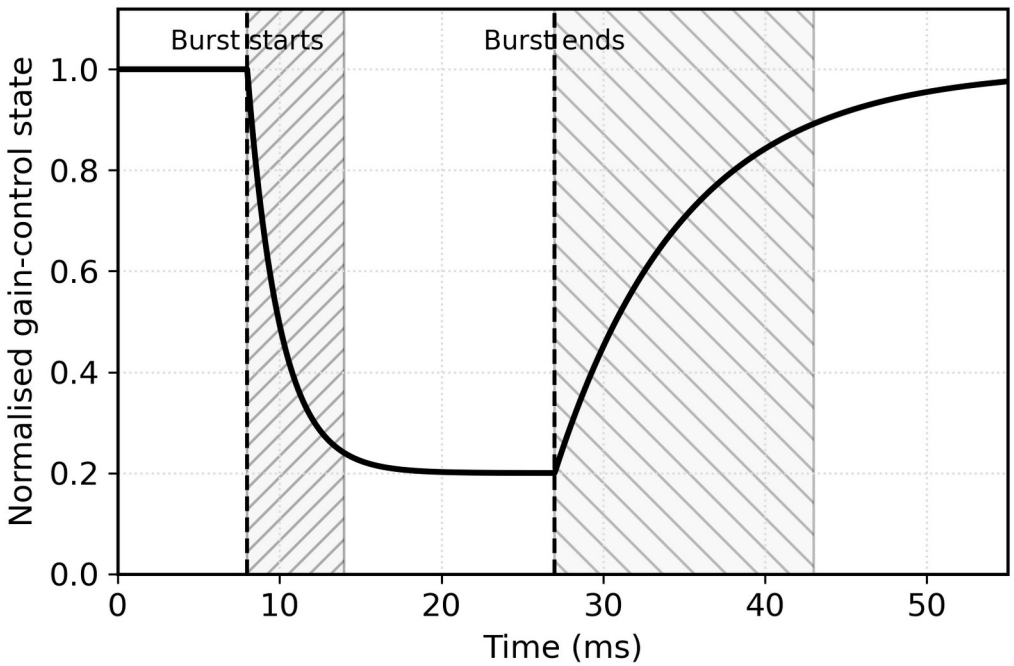

Why it matters: a short burst and the gain-control transient may not support the same amplitude calibration.

Figure 20. AGC attack, release and burst recovery.

Equation 10A. Identified control-state equation

$$\frac{dv}{dt}=\frac{v_\infty - v}{\tau}, \tau>0, v(0)=v_0$$

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The state v, its initial value v_0, target v_∞ and reference v_{ref} are control voltages in volts. Time t and time constant τ use the same time unit. Gain d and its reference d_{ref} are in decibels, and the signed local slope s is in decibels per volt. The voltage residual e is v minus v_∞; the gain-error magnitude E_d is the absolute slope times its magnitude. These distinct units determine which positive tolerance is inserted into the settling calculation.

Equation 10B. Control voltage and residual

$$v(t) = v_\infty + (v_0 - v_\infty)\exp\left(\frac{-t}{\tau}\right)$$

$$e(t) = v(t) - v_\infty = (v_0 - v_\infty)\exp\left(\frac{-t}{\tau}\right)$$

Subtracting the constant target converts the equation into exponential decay of the residual. The solution preserves its sign and moves monotonically between the initial state and target. This property gives a useful validity check: a measured overshoot, sign reversal, delayed start, or sustained oscillation cannot be explained by the same uninterrupted one-pole segment. Such behavior may be real and important, but it requires an additional state, a changed target, or a different identified model.

Control voltage becomes RF gain only through an explicit calibration. In this chapter the local relation is linear in decibels, with a signed slope and a reference voltage. All points between the initial and final states must remain within the range where that relation applies. A negative slope means rising control voltage reduces gain. A positive slope requires the opposite control direction for the same leveling objective. A mislabeled polarity can turn a plausible exponential voltage trace into a completely wrong amplitude correction.

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Equation 10C. Local control-to-gain law

$$d(v)=d_{ref}+s(v-v_{ref}),v\in[v_{min},v_{max}]$$

Equation 10D. Output level and gain-error magnitude

$$P_{out,dBm}=P_{\text{in,dBm}}+d(v)$$
$$E_d(t)=|s||v_0-v_\infty|\exp\left(\frac{-t}{\tau}\right)=E_0\exp\left(\frac{-t}{\tau}\right)$$

For a fixed RF input in the calibrated small-signal path, adding the gain in decibels to input power in dBm gives output power in dBm. This does not turn an envelope detector voltage into power without its own law. It also does not mean that averaging gain in decibels is equivalent to averaging output power. If the gain changes during a record, the correct operation depends on whether the desired result is a time-resolved input waveform, an average physical power, or a control-state summary.

A settling requirement must specify its error units and a positive tolerance. For an initial error larger than that tolerance, solving the exponential inequality gives the logarithmic settling time. If the initial error is already acceptable, the earliest time is zero. Exact zero error is not reached at finite time from a nonzero residual in this model. For gain tolerance, use the absolute gain slope to convert the initial voltage residual into a gain-error magnitude. A zero slope makes this inversion uninformative rather than infinitely fast.

Equation 10E. Settling time for a positive error tolerance

$$t_\varepsilon=0\,if\;0\le E_0\le\varepsilon$$
$$t_\varepsilon=\tau\ln\left(\frac{E_0}{\varepsilon}\right)if\;E_0>\varepsilon>0$$

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Two same-sign residual observations can identify a candidate time constant when their magnitude decreases. Taking their ratio eliminates the unknown initial amplitude, and taking its logarithm isolates the elapsed-time difference divided by the time constant. The fit should then be challenged at additional times and levels. Two points always support an exponential interpolation under favorable signs; they do not establish that the actual loop has only one relevant state.

Equation 10F. Two-point identification of the local time constant

$$\tau = \frac{t_2 - t_1}{\ln\left(\left|\frac{e_1}{e_2}\right|\right)}$$
$$t_2 > t_1, e_1 e_2 > 0, \mid e_1 \mid > \mid e_2 \mid$$

A burst or a sequence of levels rarely leaves the control at equilibrium before the next change. Carry the actual terminal state into the next interval. Separate attack and release constants can be used if both have been identified and the switch condition is declared. A hang interval is a separate state that holds or modifies the target; it cannot be represented simply by calling the previous time constant slow. Retuning, a detector bandwidth change, or a new gain range can likewise invalidate the previous segment parameters.

Equation 10G. Carry state across a target change

$$v(t) = v_{\infty,j} + \left(v(t_j) - v_{\infty,j}\right)\exp\left(\frac{-(t - t_j)}{\tau_j}\right)$$
$$t_j \le t \le t_{j+1}, \tau_j > 0; carry\ v(t_{j+1})\ forward$$

For recorded control samples, the exact discrete recurrence follows directly by evaluating the continuous solution one sample interval later. Its coefficient lies strictly between zero and one for positive interval and time

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constant. Forward Euler gives another coefficient that can become negative or exceed unity in magnitude. A large simulated oscillation can therefore be a numerical error even when the physical one-pole model is stable. Prefer the exact recurrence for this model and record any different numerical implementation that is actually being assessed.

Equation 10H. Exact sampled-state recurrence

$$v_{k+1}=a\,v_k+(1-a)\,v_\infty$$
$$a=\exp\left(\frac{-\Delta t}{\tau}\right),\Delta t>0,0<a<1$$

Equation 10I. Forward-Euler residual and its validity range

$$e_{k+1}=(1-\frac{\Delta t}{\tau})e_k$$
$$stable:0<\frac{\Delta t}{\tau}<2$$
$$nonalternating\,residual:0<\frac{\Delta t}{\tau}\leq 1$$

Uncertainty in the initial state contracts by the same positive exponential factor when the target and time constant are fixed. An initial interval therefore maps to another interval without needing a statistical distribution. A negative gain slope reverses the order of the corresponding gain endpoints, although their width remains the absolute slope times the control-state width. Uncertainty in the target or time constant is an additional contribution and must not be hidden inside this initial-state calculation.

Equation 10J. Propagation of an initial-state interval

$$v_0\in[l,u],a(t)=\exp\left(\frac{-t}{\tau}\right)$$
$$v(t)\in[v_\infty+a(t)(l-v_\infty),v_\infty+a(t)(u-v_\infty)]$$

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5.5 Worked applications with hypothetical inputs

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5.6 Application 5A.1: Read a voltage step and its 95 percent settling time

A control voltage starts at 0.2 V and approaches 0.8 V with a 0.4 ms time constant. At 0.8 ms, two time constants have elapsed, so the residual is $\exp(-2)$ of its initial value. The control has reached 0.718799 V, completing 86.466 percent of the step. The 95 percent settling time is 1.198293 ms.

The voltage result alone does not give an RF amplitude correction. It becomes useful for gain only after the control-to-gain relation and the applicable operating interval have been verified. A measured control value beyond 0.8 V during this segment would contradict the stated monotone model. The response record should retain that discrepancy rather than silently replacing the observed trace with the fitted exponential.

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5.7 Application 5A.2: Set a gain-error settling requirement

An initial voltage residual has magnitude 0.3 V. With a gain slope of −50 dB/V, its initial gain error is 15 dB. The requirement is an error no larger than 0.1 dB, and the time constant is 2 ms. Equation 10E gives $2\ \mathrm{ms}\ \ln\backslash(150\backslash)$, or 10.021271 ms. A generic instruction to wait three time constants would leave about 0.747 dB error and would not meet this requirement.

The result is tied to the declared slope and gain tolerance. A different gain range can have another slope, and a detector-based indication may add settling of its own. The acceptance test should compare the gain error directly, or use a control-voltage correction whose calibration uncertainty is small enough for the 0.1 dB decision. Crossing a nominal voltage threshold is insufficient if the RF path remains in recovery.

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5.8 Application 5A.3: Convert a control state into an output level

The local gain is 30 dB at 0.1 V and decreases by 40 dB per volt. Starting at 0.1 V, the control approaches 0.5 V with a 0.5 ms time constant. At 0.3 ms it is 0.280475 V, giving 22.780986 dB gain. A fixed −60 dBm input therefore produces -37.219014 dBm at that instant. The final output is −46 dBm.

Using the final gain throughout the record would understate the early output and overcorrect an input-referred trace. A time-resolved correction requires synchronized control and RF observations, including their relative delay. If control telemetry is sampled much more slowly than the burst, the exponential may provide an interpolation only after its model has been validated for that burst regime. It does not recreate unobserved saturation behavior.

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5.9 Application 5A.4: Check the required control polarity after a level step

A 12 dB input increase must be balanced by a 12 dB gain decrease. At −50 dB/V, the target voltage therefore rises by 0.24 V, from 0.30 to 0.54 V. One 1 ms time constant later the control is 0.451709 V. Gain has changed by -7.585447 dB, leaving an output increase of 4.414553 dB.

The residual is a transient consequence of the stated response, not evidence that the steady-state target is wrong. Its sign also checks the control polarity: a falling control voltage with this negative slope would increase gain and worsen the initial output rise. If the input changes again before settling, use the carried state from Application 5A.6. Do not restart the calculation from the old equilibrium simply because a new trigger occurred.

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5.10 Application 5A.5: Identify a time constant from two signed residuals

Residuals relative to the same target are +0.12 V at 0.5 ms and +0.04 V at 1.6 ms. Their ratio is three over an elapsed 1.1 ms, giving a time constant 1.001263 ms. Extrapolating the first residual backward gives an initial error of 0.197722 V. Both residuals have the same sign and decrease in magnitude, as the one-pole hypothesis requires.

Now measure additional points before using that fitted constant in an acceptance decision. A residual floor can indicate a wrong target or a detector offset; an early straight ramp can indicate slew limiting; different slopes in a semilogarithmic residual plot can indicate more than one time constant. These observations change the model choice. They should not be discarded as inconvenient outliers merely because two selected points fit well.

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5.11 Application 5A.6: Carry state across two target intervals

Begin at 0.2 V, approach 0.8 V for 0.4 ms with a 0.5 ms time constant, then approach 0.3 V for another 0.6 ms with the same constant. The first interval ends at 0.530403 V. Using that actual value as the second initial condition gives 0.369396 V at the end of the sequence.

The second response is a decay from the carried value toward 0.3 V. Starting it at 0.8 V would incorrectly assume that the first interval had fully settled. This distinction matters in repeated bursts, where a reproducible periodic control trajectory can differ substantially from either steady-state target. A valid burst-level correction must therefore retain enough preceding history to determine the state at the beginning of the burst.

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5.12 Application 5A.7: Use separately identified attack and release constants

Use a 0.2 ms attack constant for a change from 0.1 toward 0.7 V lasting 0.5 ms. Then use a separately identified 2 ms release constant while returning toward 0.1 V for 1 ms. The end-of-attack state is 0.650749 V, and the end-of-release state is 0.434046 V. The slower release preserves appreciable control displacement after the strong interval has ended.

This piecewise calculation does not include a hang timer. If the measured receiver holds its control for a fixed duration before releasing, add that observed interval explicitly and define which event starts the timer. A later weak signal can otherwise be mistaken for a sensitivity failure when it is being measured during intentional gain hold. Fixed-gain and automatic-gain observations should remain separately labeled in the evidence record.

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5.13 Application 5A.8: Compare burst duration with control settling

A 0.3 ms burst changes the control target from 0.2 to 1 V, but the time constant is 3 ms. Only 9.516 percent of the step occurs during the burst; its final control voltage is 0.276130 V. Reaching 95 percent would require 8.987197 ms, far longer than the burst.

A steady-state gain reading cannot characterize this short event. The model predicts only the identified control trajectory, while the initial RF peak may encounter a separate overload limit before the gain changes appreciably. Record both the control response and the signal-path behavior. If the burst is shorter than the detector or telemetry response as well, the displayed control history may not reveal the actual peak condition at all.

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5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation

For a 1 ms time constant sampled every 2.5 ms, the exact residual multiplier is 0.08208500. Forward Euler instead uses −1.5. From an initial 0.4 V residual, five exact steps leave 0.000001491 V. Five Euler steps give -3.0375 V, with alternating sign and growing magnitude.

The second sequence is an unstable approximation to a stable differential equation. It is not a prediction that the physical control voltage reaches those values, and it may lie well outside the calibrated control range. This example is a software verification case: compare the implemented recurrence with the exact sampled solution before interpreting a simulated oscillation as a receiver defect. If the actual controller is discrete rather than a sampled continuous loop, identify its own governing recurrence instead.

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5.15 Application 5A.10: Propagate an initial-state interval

The initial voltage is known only to lie between 0.2 and 0.3 V. With a fixed 0.6 V target, 0.4 ms time constant, and 0.8 ms elapsed time, the possible state lies between 0.545866 and 0.559399 V. Its width is 0.013534 V. A −20 dB/V gain slope maps this to a 0.270671 dB gain interval.

The larger voltage corresponds to the smaller gain, so the endpoint order reverses when the gain interval is written. The width calculation remains positive. These are deterministic initial-state bounds; they do not include uncertainty in the target, time constant, slope, or timing alignment. A complete gain-correction uncertainty budget adds those contributions under the measurement model in Chapter 14, rather than treating this one interval as the entire error budget.

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5.16 Automatic Gain Control and Hidden State

Automatic gain control maintains a useful output range by changing gain in response to detected signal level. Attack, decay, hang time, detector law, threshold, gain range, and control location determine how the receiver responds to bursts and multiple signals. AGC can mask fading, compression, and true amplitude differences. A strong signal outside the displayed channel can reduce gain for a weak signal through a shared control path.

For quantitative work, AGC should be disabled or its state recorded and calibrated. If it cannot be disabled, the practitioner captures gain-control voltage or reported gain, uses reference signals around the event, and tests with alternate input levels. Audio volume and digital display normalization are not substitutes for an RF gain record. A component that changes when AGC is held may have been a control artifact rather than a change in the environment.

An integrating automatic-gain-control loop has a memory that the displayed amplitude alone cannot reveal. In a representative controller, the unsaturated command may be written as $u_c(t) = K_p e(t) + z(t)$, with $e(t)$ the setpoint error, K_p the proportional coefficient and $z(t)$ the integral state; the physical gain actuator can deliver only $u(t) = \mathrm{clamp}[u_c(t), u_{min}, u_{max}]$. When u_c attempts to exceed a limit while the integral state continues to accumulate, the controller can display a prolonged recovery after the original overload or input-step condition has ended. This mechanism is termed integrator windup. Its manifestation depends upon the detector bandwidth, loop polarity, integration constant, actuator bounds, anti-windup design and internal signal routing. A published square-law-detector

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AGC example demonstrates integration onto a control capacitor; it does not establish that an unidentified receiver implements clamping, back-calculation or any particular recovery topology.

The appropriate forensic challenge is a state-conditioned step-and-recovery experiment, not an assumption drawn from a smooth trace. With the permitted signal source and loading fixed, vary the incoming amplitude across the suspected control limit, retain input and output envelope records, record the control voltage or digital gain word where available, and measure recovery against elapsed time and preceding overload duration. Repeat at more than one starting state. If the hardware design permits examination of the controller, conditional integration or clamping may suspend integration while an output limit is active; back-calculation instead uses the difference between requested and saturated commands to unwind the integral state. These are alternative general control methods, not proof of their presence in any specific commercial or field receiver. A reported change in observed signal strength must remain qualified until control-loop dynamics have been separated from an actual change at the antenna reference plane.

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5.17 Logarithmic Amplifiers, Detectors, and Scaling

Logarithmic amplifiers compress a wide input range into a manageable output, making them useful for spectrum displays, pulse measurements, and direction-finding amplitude comparison. Their slope, intercept, ripple, temperature coefficient, video bandwidth, recovery, and pulse response determine accuracy. At low levels, noise and offsets dominate; near the upper range, compression and detector saturation can create apparent plateaus or altered pulse width.

Detectors may respond to peak, sample, average, root-mean-square, quasi-peak, envelope, phase, or digital power estimates. The appropriate detector depends on waveform and measurement objective. A peak detector reports rare excursions differently from an averaging detector. Root-mean-square detection is meaningful only within its crest-factor and bandwidth limits. The trace label, detector, dwell, averaging count, and video filtering should accompany the result.

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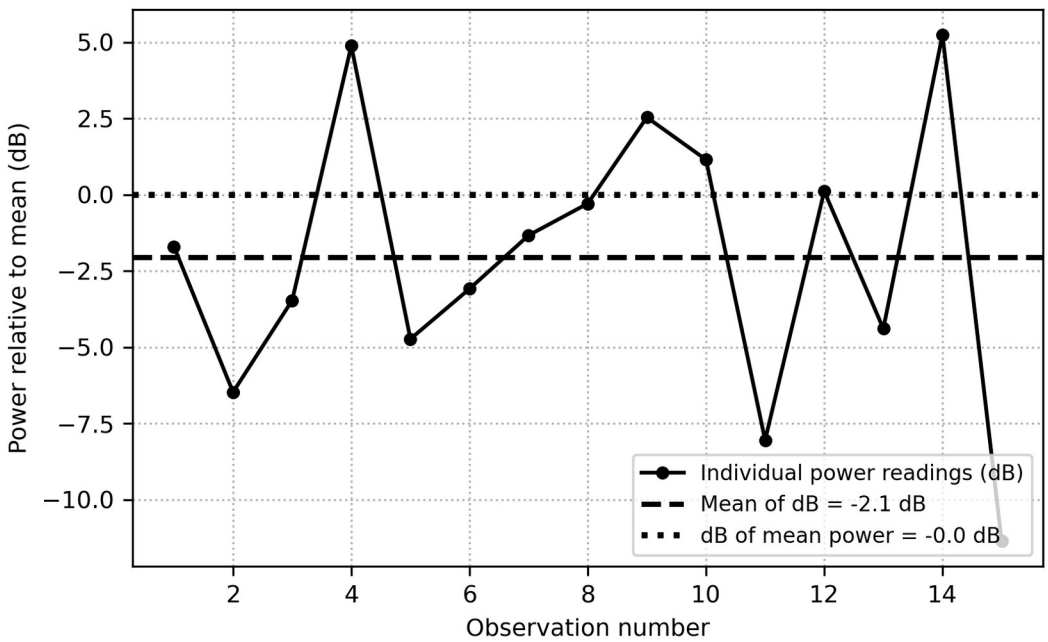

$$\text{mean}[10\log_{10}(P_i)] \neq 10\log_{10}(\text{mean}[P_i])$$

Example is synthetic positive power samples. Specify the detector and averaging domain.

Figure 21. Linear-power versus logarithmic averaging.

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5.18 IF Alignment, Calibration, and Failure Localization

Analog IF chains can drift through component aging, mechanical adjustment, temperature, supply state, or repair. Alignment affects center frequency, symmetry, gain, image rejection, detector linearity, and demodulation. Digital filters reduce some drift but depend on sample clocks, coefficients, scaling, and firmware. A calibration file can conceal a degraded analog path until a direct response measurement is made.

Failure localization compares responses before and after each IF stage where access is authorized. Injected signals, noise, swept frequency, pulses, and modulation exercise different properties. An apparently deaf receiver can result from a mistuned filter, failed switch, AGC fault, detector offset, reference-clock error, or software scaling. The closing test covers several bandwidths and levels so that one successful center-frequency tone does not mask residual defects.

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5.19 Verify the detector and control path as part of the IF result

A detector defines an operation on a waveform, not merely a preferred display style. A peak trace can retain a rare excursion; a sample trace can miss it; a power average estimates mean squared amplitude under its stated selection; an average of logarithmic levels estimates something else. Reuse the finite-record averaging treatment in Chapter 8 to keep these operations separate. The accepted detector must also remain within its bandwidth, level, crest-factor, and recovery limits for the actual waveform.

A useful IF verification sequence first fixes gain and disables avoidable automatic changes. Measure several continuous tones through the passband and skirts, then a calibrated noise input under the declared effective bandwidth. Next apply a pulse or burst whose duration and timing can be changed independently. Observe the path before and after detection where accessible. Finally enable the intended gain-control mode and repeat the stimuli that exercise attack, release, shared-channel loading, and recovery. Each step tests a different part of the measurement chain.

Separate amplitude normalization from physical recovery. A flat displayed output after a strong input may mean successful leveling, a limiter plateau, clipping, a saturated log detector, or software normalization. A weak reference carried through the same interval helps distinguish these alternatives if it remains measurable. Verify that its amplitude and phase return to the accepted range after the disturbance. A control voltage that has settled does not prove that every preceding stage has recovered.

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Where two IF paths serve different outputs, compare them only after accounting for their filters and detectors. Audio, a spectrum trace, and stored I/Q data may be drawn from different points. A narrow audio path can hide an interferer that still drives a wider AGC detector. A wide digitizer path can preserve an event whose displayed trace is averaged away. Label each derived product with its source path and state so that these differences become interpretable observations rather than apparent contradictions.

Acceptance ends with a retained set of responses tied to the exact configuration. Include filter and gain boundaries, a short-event case, and a recovery case in addition to the center-frequency tone. After repair or software change, repeat the cases whose assumptions could have changed. Where a proprietary control algorithm cannot be reconstructed, preserve its observed input/output behavior and configuration limits instead of claiming that the simple one-pole fit describes its internal implementation.

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5.20 IF Acceptance and Regression Tests

Acceptance uses a matrix of center frequencies, bandwidths, gain states, detectors, levels, and transient waveforms. Each result is compared with declared specifications or an approved baseline using the same reference planes and correction method. Automatic filter selection and shared AGC paths are exercised at their boundaries, because many intermittent failures occur only when the receiver changes mode.

Regression testing preserves characteristic traces for representative continuous, pulsed, and modulated references. After alignment or repair, those traces are repeated before the receiver is released. A passing narrowband amplitude point is not allowed to conceal degraded skirt response, group delay, transient recovery, or detector scaling.

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5.21 Quantitative Model for Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors

Equation 1. Loaded quality factor

$$Q_{\mathrm{L}} = \frac{f_0}{B_{3\mathrm{dB}}}$$

Loaded quality factor Q_{L} is center frequency f_0 divided by the -3 dB bandwidth $B_{3\mathrm{dB}}$ for a resonance whose response supports that approximation. Filter shape, coupling, multiple poles, and digital definitions may require a different descriptor.

Equation 2. First-order AGC response

$$v_c(t) = v_{\mathrm{final}} + \left(v_{\mathrm{initial}} - v_{\mathrm{final}}\right)\exp\left(\frac{-t}{\tau_{\mathrm{AGC}}}\right)$$

A simple first-order model describes gain-control voltage v_c moving toward a new value with time constant τ_{AGC}. Practical AGC can have separate attack and decay constants, thresholds, hang states, and nonlinear gain mapping.

Equation 9 is a response descriptor for a specified resonance, not a complete filter design or settling law. Equation 10 is the identified control-voltage response developed in Model 5A and its ten applications. Its voltage-to-gain map and attack, decay, clamp, and local-validity limits must accompany any prediction of usable signal recovery.

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Table 1. Chapter 5 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
IF filter	Center, bandwidth definition, shape factor, ripple, group delay, and settling	Determines selectivity and time response	Nominal bandwidth alone does not describe pulse or modulation fidelity
AGC state	Control point, gain value, attack, decay, hang, threshold, and shared paths	Explains hidden amplitude normalization	A strong off-channel signal can suppress a weak channel
Detector	Peak, sample, average, RMS, quasi-peak, envelope, or digital estimator	Defines the statistic shown or recorded	Different detectors cannot be compared without waveform context
Alignment and calibration	Stage response, switching, center frequency, gain, scaling, and temperature	Separates hardware drift from software correction	A center-frequency tone can miss skirt or dynamic defects

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5.22 Hypothetical Applied Calculation: Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors

An IF filter is centered at 10.7 MHz and has a measured -3 dB bandwidth of 180 kHz. Its simple loaded quality factor is about 59.4. A second filter labeled 180 kHz but with steeper skirts and greater group-delay variation may produce the same Q value while giving different adjacent-channel rejection and modulation fidelity.

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5.23 Hypothetical Case Adjudication: Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors

A burst appears 6 dB lower when the receiver is set to a narrow bandwidth, even though the signal spectrum fits inside the nominal filter. Time-domain capture shows that the burst is shorter than the filter settling time and the peak detector samples before the response reaches steady state. The discrepancy is attributed to IF transient response, not propagation loss.

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5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics

An intermediate-frequency chain is not defined completely by its nominal centre frequency and 3 dB passband width. Filter amplitude and phase response, group-delay variation, limiting, logarithmic-amplifier dynamics and the selected detector each impose a distinct transformation upon short events. A narrow IF filter can extend a brief incident pulse into a longer ringing envelope; a quasi-peak detector weights pulse recurrence differently from a peak or root-mean-square detector; and video filtering can smooth the display while losing temporal detail. The observer should therefore distinguish event duration at the RF input from the duration of the particular IF or displayed response. An apparently long pulse need not indicate a long RF transmission, especially where detector memory is substantial compared with the source event.

One controlled test uses a precisely timed reference pulse with duration T_p and independently monitored amplitude. Record the analogue IF output if accessible, the detector output, the digitised trace and the exported display under fixed source and gain conditions. Repeat across pulse width and repetition interval, including a spacing long enough for the detector to return to baseline. For a first-order envelope response with time constant tau, a rectangular pulse of amplitude A produces at its end $A[1 - \exp(-T_p/\tau)]$ when initial state is zero. With $\tau = 2$ ms and $T_p = 0.2$ ms, the end value is about 0.09516A, not A. That example shows why calibrating a detector with a long continuous source and using the same amplitude interpretation for a short transient can give a severe systematic

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underestimate. It is not a prediction of any named commercial IF instrument, whose response must be measured.

Detection statistics require a stated averaging law. A peak over an interval, a mean of linear power, a root-mean-square envelope and a mean of logarithmic labels are not the same physical quantity; changing the number of displayed points can change the effective observation. A 10 dB difference in mean power means a factor of ten in the corresponding linear powers, but that rule does not turn a mean of dBm values into a mean power. When comparing receiver modes, preserve a native trace at sufficient rate to recompute the declared statistic and distinguish detector latency from sample timestamp. A calibration adjusted to align two display modes at one constant-wave level does not establish agreement for another modulation or pulse recurrence distribution.

The forensic question should direct the detector choice. A rare transient investigation benefits from capture modes that retain its temporal envelope and actual observation intervals; an interference compliance measurement may require a precisely specified weighting detector whose result intentionally embodies recurrence. Those instruments can disagree without either being defective because they estimate different quantities. The report must identify detector mode, weighting and dwell, cite the relevant apparatus specification only within its applicable scope, and avoid treating a weighted quasi-peak indication as a reconstructed waveform amplitude. The boundary between acquisition and representation remains visible when raw IF evidence is retained wherever lawful and technically feasible.

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5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators

An intermediate-frequency chain is commonly specified by centre frequency, nominal bandwidth, gain and perhaps selectivity. These quantities are insufficient when the intended observation is a short burst or a waveform with appreciable occupied bandwidth. The complete linear filter contributes a complex transfer H(f), whose amplitude affects energy passage and whose phase changes temporal structure. Under a stable linear time-invariant approximation, the output waveform is the convolution of the input with the impulse response. When gain control, logarithmic compression or threshold decisions follow the filter, the receiver no longer reduces to one linear convolution. The ordering of filtering, detection and smoothing must therefore be specified explicitly. A detected pulse width can increase because the filter rings after the excitation ceases, even though the external RF emission was brief.

A useful example is a first-order IF low-pass response to a positive envelope step. Define y(t) as the normalised detected envelope, tau as the known filter time constant, and assume a settled zero initial state. The response is y(t) = 1 - exp(-t/tau) for nonnegative t. The time to cross threshold fraction alpha, with zero less than alpha less than one, is t_alpha = -tau ln(1-alpha). With tau = 2 ms, a 90 per cent threshold occurs after about 4.605 ms. A 3 ms physical pulse cannot bring the idealised step response to 90 per cent, regardless of how clean its steady-state spectral measurement might appear. At the pulse end the filter stores state, which then decays; a later threshold crossing or persistence on a waterfall can be a processing

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consequence. The model is deliberately elementary, but it demonstrates why steady-state filter bandwidth does not establish the response to every temporal event.

Logarithmic detectors introduce a further conceptual trap. An ideal logarithmic output is proportional to a logarithm of an admissible positive input quantity. It does not follow that the mean of displayed decibels equals the decibel of mean input power. For a signal with two equal-duration states at 1 and 100 arbitrary linear power units, the mean power is 50.5 units whereas the mean of the individual power levels in decibels corresponds to a geometric mean of 10 units. The discrepancy is 10 log10(50.5/10), approximately 7.03 dB. This is not a numerical defect of a logarithmic display; it is a difference between estimands. A detector operated in average-of-log mode and one operated in log-of-average mode may therefore produce different trace values from the same fluctuating input even before considering overload, video filtering or peak-hold logic.

A receiver with automatic gain control should be represented by a control state g(t) that is driven by one or more filtered statistics of the admitted signal. The displayed output depends on both current input and past input through that state. Attack and release constants are not always equal, and a nominal single time constant may apply only to a specific stimulus range. A short strong interferer can depress the gain seen by a weak target long after the interferer has gone. The resulting blank interval must not be interpreted as evidence that the weak transmitter was inactive. To determine which interval is truly observed, measure the weak reference waveform through the entire disturbance and define a recovery criterion tied to the actual required measurement, such as amplitude accuracy within

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0.5 dB and stable detector variance. The detector's own smoothing must be characterised separately, otherwise one recovery mechanism masks another.

IF group delay merits independent measurement when coherent phase or timing is important. Define group delay tau_g(f) as the negative frequency derivative of transfer phase divided by 2 pi when phase is expressed in radians against frequency in hertz. If group delay varies materially across the signal band, different spectral components of a pulse can arrive at different times, changing its shape without introducing a corresponding change at the source. A narrow continuous tone may still have a well-defined gain and phase at its centre. This is why a one-tone calibration cannot certify a wideband time-of-arrival measurement. Controlled multitone or swept vector measurements, with phase unwrapping and reference-plane corrections, are needed to establish timing distortion within a stated frequency region.

Quasi-peak and other weighted detectors deserve treatment as specified decision operations rather than cosmetic display modes. Their prescribed time constants and weighting laws are designed for particular measurement purposes and are not interchangeable with simple instantaneous peak or RMS detection. A spectrum analyser's video bandwidth changes a smoothing process after a selected RF resolution filter, while the resolution filter governs admitted spectral energy and temporal response before detection. Lowering VBW may make a trace visually calmer without improving the receiver's ability to preserve a rare short event. If the detector's output does not capture a transient because the integration is too slow, no later display magnification can reconstruct the missing peak. A

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controlled acceptance procedure should therefore inject pulses spanning a range of durations and repetition intervals, measure each detector mode's transfer to a declared statistic, and report which event classes were actually represented.

The analytical conclusion is that an IF chain produces a measurement only after its time-domain and statistical transfer is declared. Acceptance must include frequency response, group delay, gain compression, overload recovery, detector law, noise distribution and timing of setting changes. Where some of these cannot be determined, the released claim should narrow to the properties actually tested rather than treating one calibrated amplitude marker as assurance for every time-dependent measurement.

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5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity

Intermediate-frequency filtering is often treated as a bandwidth setting, yet any practical linear filter has an impulse response that determines what it remembers of the past. Two filters with an identical nominal three-decibel bandwidth can differ substantially in phase response, group delay, overshoot, settling time and response to a brief pulse. The quantity displayed by a detector downstream is therefore not simply the instantaneous power entering the filter. It is the consequence of convolution with a physical or digital impulse response, sometimes followed by a nonlinear detector and an adaptive control system. For transient evidence the observation time must be associated with the entire relevant processing chain. An event ending before an IF detector settles can remain visible after it has physically disappeared; conversely, a short weak event can be suppressed by earlier states that persist into its interval.

Represent the small-signal filter by a causal impulse response $h(t)$. For an input $x(t)$, output $y(t)$ equals the convolution integral of $h(\tau)x(t-\tau)$ over nonnegative delay τ when the fixed-state linear approximation is valid. Frequency response $H(f)$ is the Fourier transform of $h(t)$. The magnitude $|H(f)|$ characterises amplitude selection, while its phase determines the delay experienced by different spectral components. Group delay is $\tau_g(f) = -(1/2\pi)\, d \arg H(f)/df$, with the phase unwrapped under a declared transform convention. This derivative must not be taken blindly across discontinuous phase wrappers or near a transmission zero where phase is poorly determined. The group-delay curve is a property of the signal path at a

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particular gain, loading, temperature and calibration state, not an inherent attribute of a displayed bandwidth label.

For a first-order low-pass prototype $H(s) = 1/(1+s\tau)$, the impulse response is $h(t) = \exp(-t/\tau)/\tau$ for t at least zero, with τ positive in seconds. The step response is $1-\exp(-t/\tau)$. The −3 dB frequency is $f_c = 1/(2\pi\tau)$, while the time to reach 95 percent of a unit step is $t_{95} = -\tau \ln(0.05)$, approximately 2.996τ. Thus bandwidth and settling are connected for this prototype. A real IF response with multiple poles, zeros, equalisation or switched bandwidth states can violate any simple one-pole extrapolation. In particular, deliberately shaped filters may trade frequency selectivity for a longer impulse tail. A nominally narrow detector sometimes appears more sensitive on a stationary tone while having lower probability of registering an isolated burst of equal total energy.

Group delay affects coherent reconstruction as well as absolute timing. If two frequency components separated by Δf pass through a filter whose group delay differs by Δτ, their relative phase changes by approximately $2\pi\Delta f\,\Delta\tau$ beyond the intended ideal-delay relationship, provided the local approximation is valid. For broadband pulses, the time-domain consequence depends on the entire phase function, not one scalar delay measured at the centre. Pulse broadening, post-cursor ringing and pre-cursor effects in noncausal offline processing should be distinguished. A causal physical IF chain cannot produce a response before an input reaches it, but a zero-phase offline filter that operates on samples before and after an event can display apparent pre-ringing. This is not retrocausal RF energy; it is a property of the reconstruction algorithm and must be labelled as such in the provenance record.

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Intermediate-frequency gain control adds a hidden dynamical state. Suppose a detector estimates an envelope a(t) and a controller adjusts log gain g(t). A simplified first-order law is $dg/dt = (g_{target}(a) - g)/\tau_s$, where τ_s is an attack or release constant selected by the current transition. The target can be nonlinear and can saturate at gain limits. An output sample then depends on both the present input and the gain state inherited from earlier strong inputs. Merely recording the displayed gain setting may be inadequate when the controller is still settling. A forensic interpretation of an intermittent weak transmission therefore needs a model of the gain-state trajectory, preferably measured or logged at sufficient time resolution. Where state telemetry does not exist, controlled weak-reference tests can bound the recovery interval, but they do not reconstruct an unobserved signal that was suppressed during that interval.

Separate IF filter persistence from detector persistence experimentally. Drive the input with a source whose amplitude step is substantially faster than both candidate dynamics, and observe an independent broadband reference before the filtering or detection path. Measure the complex IF output where possible, then compare it with rectified or logarithmic outputs under the same actual configuration. If the complex IF decays while the displayed envelope remains high, the detector or post-detection filter contributes additional memory. If gain telemetry changes while both outputs respond, the control loop must be treated as another state variable. These tests should be conducted at more than one input level because detector and gain-control time constants may be signal dependent; one result at the reference calibration level does not necessarily cover near-threshold events.

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The comparison of detector statistics requires a defined measurement population. A positive-peak detector selects the maximum over an interval; its expected value increases with the number of noise opportunities even if mean noise power is unchanged. An RMS detector instead estimates the square root of a mean of squared values over a declared band and time. A sample detector can preserve the instantaneous trace at selected points but can miss a narrow excursion between them. An average detector's behaviour depends on whether the averaging is performed in linear voltage, linear power, logarithmic amplitude or a derived trace quantity. Those operations are not interchangeable, and a report should never describe a smooth trace as evidence that a signal was absent unless its event criterion and the detector's capture properties are established.

A hypothetical filter example uses $\tau = 0.40$ ms. Its one-pole cutoff frequency is 397.887 Hz, and 95 percent step settling occurs at 1.1983 ms. A 0.10 ms pulse ends well before the filter settles; treating its peak filtered output as the original peak amplitude would produce a biased result. Specifically, during a unit rectangular pulse the first-order response rises to $1-\exp(-0.10/0.40)$, approximately 0.2212 of the steady-state amplitude. The output then decays with the same time constant after the pulse ends. These numbers are consequences of the stipulated idealised filter. They are not a general pulse correction for a spectrum analyser with an unspecified IF topology or a nonlinear detector.

A second synthetic example uses a narrow pulse seen immediately after a strong interfering burst. Suppose the AGC gain is 12 dB below its quiet target at the end of the blocker and returns exponentially in the logarithmic gain coordinate with release constant 4 ms. At 2 ms after the blocker, the

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remaining gain deficit is 12 exp(−0.5) = 7.278 dB, assuming the simplified law applies. At 8 ms the residual deficit is 12 exp(−2) = 1.624 dB. A weak source whose unattenuated level is fixed may therefore appear to rise by more than 5.6 dB across those observation times. An analyst who interprets the later amplitude increase as evidence of transmitter activation has omitted a testable receiver-state explanation. The physically correct inference requires an actual gain-state record or a controlled measurement that supports the assumed response law.

A third example concerns an IF path with group delay changing from 3 μs to 8 μs across a 2 MHz occupied waveform. The variation is 5 μs, comparable to ten cycles of the 2 MHz spectral separation used for illustration. The product $\Delta f\,\Delta\tau$ equals ten and corresponds to a relative phase change of 20π radians, which reduces to zero modulo 2π for these endpoints but does not make the intervening phase function flat. This illustrates why endpoints alone are insufficient: an integer multiple of 2π can conceal substantial differential phase and time spreading between frequencies. A useful acceptance test samples the continuous unwrapped phase response across the occupied band and evaluates the recovered waveform's distortion, rather than inferring fidelity from two equal endpoint phases.

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5.27 Calibration and negative-survey validity for dynamic IF paths

For amplitude measurements, the calibration matrix should include input level, filter setting, gain state, detector mode, modulation or burst class, and observation duration. Each row should specify a measurand and reference plane. A steady continuous-wave amplitude result cannot automatically validate a microsecond burst because the detector may not reach the same state. A short impulsive reference that fails to cross the display threshold may indicate insufficient dwell, filtering loss or control-state suppression. It is not equivalent to the absence of an input pulse. The acceptance report must make this distinction visible by listing successful and unsuccessful trials with their actual timing and decision criteria.

For timing measurements, mark at least three event times: stimulus onset at the source reference plane, waveform change at the selected IF observation plane, and decision or display update. Let t_{src}, t_{IF} and t_{dec} denote those times, all in seconds. The differences $t_{IF}-t_{src}$ and $t_{dec}-t_{IF}$ may have separate calibration and uncertainty distributions. Summing their central values is legitimate only when the intended event definitions align and the latency is sufficiently stationary over the tested state. When the IF and decision paths share a clock, correlated clock errors must be retained in the variance of the combined latency. A timestamp assigned by a computer after file buffering may be precise to nanoseconds in its software representation while being milliseconds from the physical sampling event.

A defensible negative finding must specify the event class that the measurement could have registered. A continuous unmodulated signal

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above the qualified threshold may be excluded over a set of frequency-time intervals without establishing the same coverage for short chirps or short low-duty-cycle bursts. To test that difference, construct a blind reference schedule with randomised pulse start times relative to the sweep or monitoring cycle, varying pulse duration and amplitude. Preserve both the source truth and the receiver observation. The accepted event class should then be limited to the conditions where the detection rule has been independently shown to work. A model fit to a deliberately convenient subset does not justify statements about untested classes.

The acceptance record should also distinguish filter stability from calibration stability. A filter may maintain amplitude response yet exhibit temperature-dependent group delay, which matters for coherent phase or event timing. A detector may maintain its quiet baseline while drifting in its peak response after a strong pulse. A digital correction might reduce one of those errors while increasing noise or changing the temporal shape of an event. It is therefore necessary to retain the original complex or appropriately unaveraged IF record, the correction algorithm's version, the actual hardware state and any failure indicators. A derived scalar result does not carry every property of the original physical waveform.

A fourth hypothetical calculation illustrates a timing bound. Let a pulse's true onset be within ±10 μs of a source reference mark, with independently bounded IF-path latency between 25 and 40 μs and detection decision latency between 60 and 100 μs. The earliest possible decision after the source mark is 10 μs early plus 25 plus 60 = 75 μs; the latest is 10 μs late plus 40 plus 100 = 150 μs. The decision timestamp therefore falls in a constructed 75–150 μs interval relative to the marked time under those bounds. Treating

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112.5 μs as an exact correction would introduce a precision that the stated physical information does not establish. If the intervals are dependent, the endpoints must be constrained jointly; assuming independent uniform distributions solely to produce a standard deviation is not justified.

A fifth synthetic example concerns two detector modes with identical mean noise power but different peak-selection opportunities. If N independent noise-bin powers are exponentially distributed with common mean μ, the maximum has cumulative distribution $P(M \leq m) = [1-\exp(-m/\mu)]^N$ for $m \geq 0$. At $m=5\mu$ and $N=1$, exceedance probability is $\exp(-5)$, approximately 0.006738; at $N=100$, it is $1-[1-\exp(-5)]^{100}$, approximately 0.4916. This is not a change in physical thermal noise. It is the consequence of taking a maximum over more independent trials. Real detector samples may be correlated, so the independence hypothesis must be tested or replaced by a calibrated effective model. The example illustrates the difference between a displayed peak and the physical noise process producing the observation.

The output of the IF module should be a declared validity map. Its dimensions are amplitude, event duration, frequency, temperature, gain-control history, filter state and detector mode. Each validated cell includes the procedure, measured response, uncertainty, failure flags and tested hypothesis. Cells outside the tested map remain unqualified. This is more scientifically useful than a single nominal IF bandwidth because it identifies precisely when a receiver can support a conclusion about signal amplitude, timing or non-detection.

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5.28 Advanced technical expansion. Filter memory, log detection and hidden IF-state changes

An intermediate-frequency chain should be modelled as a dynamic system rather than a sequence of gain labels. A linear IF filter has an impulse response h(t), and its output is the convolution of h(t) with the admitted input under fixed-state conditions. A narrow spectral passband necessarily entails an impulse response extending over a nonzero interval; the detailed duration and ringing depend on the filter poles, zeros and phase characteristic, not merely the nominal resolution bandwidth. For a sudden burst whose duration is short compared with the filter settling time, the output peak may substantially underestimate the level a continuous-wave test would predict. The recorded response can persist after the physical RF burst ends. Neither effect implies that the transmitter's original pulse was necessarily weak or prolonged. The physical origin and observable consequence of filter memory must be separated.

A first-order illustrative envelope detector obeys tau dy/dt + y = u(t), where u(t) represents a nonnegative envelope estimate, y(t) is the detector state and tau is a positive time constant in seconds. If a unit step begins from zero, the response is y(t) = 1 - exp(-t/tau). At t = tau, the reading reaches approximately 0.632 of its final value; at three tau it reaches approximately 0.950. A two-millisecond event measured by a detector with tau = 5 ms reaches only 1 - exp(-0.4), or approximately 0.330 of its settled amplitude before the event ends. These results are for the stated mathematical detector, not a calibrated claim about every logarithmic or quasi-peak

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circuit. Changing the detector mode or the video filter alters the estimator and therefore the meaning of the displayed burst level.

Logarithmic amplification introduces another layer. A cascaded limiting or logarithmic detector may provide a useful approximate output proportional to the logarithm of input amplitude within a specified range, while individual stages saturate or change response near their transitions. The relevant error is not simply the departure of a calibration curve from a straight line. Temperature, pulse duration, modulation and detection bandwidth can cause the effective response to depend on the recent signal history. In an acceptance trial, calibrate several levels with a settled continuous wave, then repeat with finite bursts and varying duty factor while retaining the actual waveform at a suitable reference plane. If the same peak input produces a different reported output solely because its preceding quiet interval differs, a memory-dependent transfer must replace a static amplitude correction.

Automatic gain control should be identified as a closed-loop dynamical subsystem. Let g(t) denote effective small-signal gain and q(t) an internal envelope estimate that drives the control. Their coupled dynamics may be nonlinear, with a fast attack, slower release, discrete attenuation steps and clipping at gain limits. A weak reference present throughout a strong blocker illustrates gain pumping: during the blocker, the loop reduces gain; after the blocker disappears, the weak reference remains suppressed until control recovers. A trace with no observed weak event may therefore reflect temporary instrument desensitisation rather than absence of the emitter. Effective measurement coverage should exclude those intervals unless a validated state-dependent sensitivity model is available. A scalar average

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gain applied after the fact cannot reconstruct the omitted weak-signal samples.

Group-delay distortion is particularly consequential for wideband modulation. If phase transfer phi(f) varies with frequency, group delay tau_g(f) is minus its angular-frequency derivative. Constant group delay over the occupied signal band preserves relative timing up to an overall delay, whereas varying group delay distorts complex envelopes and pulse shape. A detector showing the correct integrated power may still conceal a demodulation failure due to differential phase distortion. Perform a swept vector or appropriate multitone measurement across the occupied band, compare against a stable phase reference and evaluate the response after any automatic IF state changes. Report both amplitude and phase deviations, because a single scalar passband-loss figure cannot quantify coherent waveform fidelity.

The validation procedure should separate five states: settled quiet response, signal attack, high-level control action, release, and regained measurement validity. Introduce a weak, independently observed reference and a bounded interferer with precisely recorded onset and duration; acquire an unsmoothed IF or complex-baseband record concurrently with the displayed detector output. Vary the filter, video bandwidth and gain control separately. A response change following one intervention is evidence of a candidate mechanism, not proof if the intervention also changes the admitted reference. In the released report retain measured recovery tolerances, state-transition times, the corresponding accepted sample ranges and the limitations of the mathematical model. A static noise-floor screenshot is no substitute for this time-resolved characterisation.

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Chapter Summary

The IF chain shapes both spectrum and time. Filter response, AGC state, detector law, scaling, and alignment must be visible in the evidence record whenever amplitude, bandwidth, timing, or modulation is interpreted.

Choose the IF path for the intended amplitude, power, modulation or timing quantity. Nominal bandwidth and loaded Q omit ripple, skirts, phase and ringing. Verify the applicable transfer and retain the detector takeoff and acquisition configuration.

Model 5A describes a local voltage approaching a fixed target with a positive time constant. Its residual keeps its sign; RF gain follows only through a calibrated signed map. Declare error units and tolerance, carry the actual state through target changes, and distinguish attack, release and hang. Challenge fitted parameters and separate numerical artifacts from physical dynamics.

Peak, sampled, RMS-power and logarithmic detectors perform different operations within stated bandwidth, level and recovery limits. Shared control can respond outside the displayed channel. Align calibrated telemetry with the native record; it cannot recreate clipped data. Verify fixed gain before automatic operation with representative stimuli. A settled voltage or later passing check does not establish recovery of every function or uninterrupted earlier validity.

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Chapter 5 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C05-MCQ-001. Two receivers report the same intermediate frequency but have different filters, detector takeoffs and gain control. What does the common IF establish by itself?

A. A shared frequency coordinate, without establishing equivalent measurement transfer.

B. Equivalent detector statistics because the carrier frequency is identical.

C. The same admitted noise power independently of filter shape.

D. The same transient response whenever their center-frequency gains agree.

Answer: A. An IF is a designed signal path as well as a frequency. Filtering, control and detection determine which quantity its output represents. Review: Intermediate Frequency as a Controlled Band. Source: §5.1 Intermediate Frequency as a Controlled Band (p. 2513)

Why the selected alternative fits: A shared frequency coordinate, without establishing equivalent measurement transfer.

Distinguishing consideration: compare this with option B, “Equivalent detector statistics because the carrier frequency is identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Intermediate Frequency as a Controlled Band.

Review: Chapter 5 — Intermediate Frequency as a Controlled Band.

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V011-C05-MCQ-002. A receiver records a burst in stored I/Q data but shows little change on its audio output. Which explanation must be examined before calling either record erroneous?

A. The two outputs may use different IF bandwidths, detectors and control paths.

B. A missing audio response proves the digitizer created the RF event.

C. The narrower path must always have the larger instantaneous burst peak.

D. Any common RF input forces identical time-domain envelopes at all outputs.

Answer: A. The outputs are different observations unless their transfer and state have been reconciled. A narrow or averaged path can suppress a feature retained elsewhere. Review: Intermediate Frequency as a Controlled Band; Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: The two outputs may use different IF bandwidths, detectors and control paths.

Distinguishing consideration: compare this with option B, “A missing audio response proves the digitizer created the RF event”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Intermediate Frequency as a Controlled Band.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Intermediate Frequency as a Controlled Band.

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V011-C05-MCQ-003. Two filters have equal center frequency and equal minus-3 dB width. Which additional property is still unconstrained by their equal loaded-Q ratios?

A. Their skirt attenuation, phase response and transient ringing.

B. The particular minus-3 dB width stipulated in the comparison.

C. The numerical ratio of center frequency to the stated width.

D. The center frequency used to form that ratio.

Answer: A. Loaded Q retains only one bandwidth ratio. Many response shapes can share it while differing in adjacent-signal rejection and waveform fidelity. Review: Equation 9; Choose an IF path for the quantity being measured. Source: Equation 9. Loaded quality factor (p. 2544)

Why the selected alternative fits: Their skirt attenuation, phase response and transient ringing.

Distinguishing consideration: compare this with option B, “The particular minus-3 dB width stipulated in the comparison”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 9. Loaded quality factor; Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Equation 9. Loaded quality factor; Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-MCQ-004. A resonance is centered at 10.7 MHz with a measured minus-3 dB width of 200 kHz. Under Equation 9, what is its loaded quality factor?

A. 53.5.

B. 53500.

C. 0.0535.

D. 18.7.

Answer: A. Express both frequencies in the same unit: 10.7 divided by 0.200 equals 53.5. The dimensionless result is a response descriptor, not a complete filter model.

Review: Equation 9. Source: Equation 9. Loaded quality factor (p. 2544)

Why the selected alternative fits: 53.5.

Distinguishing consideration: compare this with option B, “53500”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 9. Loaded quality factor.

Review: Chapter 5 — Equation 9. Loaded quality factor.

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V011-C05-MCQ-005. For the same resonance convention, a center frequency of 21.4 MHz and loaded Q of 100 imply which minus-3 dB bandwidth?

A. 2.14 MHz.

B. 4.673 kHz.

C. 214 kHz.

D. 21.4 kHz.

Answer: C. Rearrange the ratio as bandwidth equal to center frequency divided by Q. The result is 0.214 MHz, or 214 kHz. Review: Equation 9. Source: Equation 9. Loaded quality factor (p. 2544)

Why the selected alternative fits: 214 kHz.

Distinguishing consideration: compare this with option A, “2.14 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 9. Loaded quality factor.

Review: Chapter 5 — Equation 9. Loaded quality factor.

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V011-C05-MCQ-006. A filter shape factor is explicitly defined as its minus-60 dB width divided by its minus-6 dB width. Those widths are 360 kHz and 120 kHz. What value follows?

A. 240 kHz.

B. 3.

C. 480 kHz.

D. 0.333.

Answer: B. The stated definition is a dimensionless ratio of widths at two specified attenuation levels. It cannot be exchanged with a difference or an inverse ratio.

Review: Chapter Glossary: Shape factor; Filter Shape, Selectivity, and Time Response.

Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

Why the selected alternative fits: 3.

Distinguishing consideration: compare this with option A, “240 kHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Filter Shape, Selectivity, and Time Response; Chapter 5 — SHAPE FACTOR (glossary).

Review: Chapter 5 — Filter Shape, Selectivity, and Time Response; Chapter 5 — SHAPE FACTOR (glossary).

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V011-C05-MCQ-007. Two front-panel settings are both labeled 100 kHz, but one denotes minus-3 dB width and the other equivalent noise bandwidth. What is required before comparing measured noise power?

A. Establish the actual weighting or effective noise bandwidth of each path.

B. Compare only passband center gain and ignore frequency weighting.

C. Replace both definitions with loaded Q without measuring their shapes.

D. Use the identical displayed number as proof of equal integrated noise.

Answer: A. Equal labels with different definitions need not admit equal noise. The relevant integration uses the actual power response or a compatible effective bandwidth. Review: Filter Shape, Selectivity, and Time Response; Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why the selected alternative fits: Establish the actual weighting or effective noise bandwidth of each path.

Distinguishing consideration: compare this with option B, “Compare only passband center gain and ignore frequency weighting”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Choose an IF path for the quantity being measured; Chapter 5 — Filter Shape, Selectivity, and Time Response.

Review: Chapter 5 — Choose an IF path for the quantity being measured; Chapter 5 — Filter Shape, Selectivity, and Time Response.

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V011-C05-MCQ-008. The intended measurand changes from separation of two continuous tones to the peak of a short burst. Which decision must be revisited?

A. Only the final display offset, since a tone calibration characterizes any burst.

B. Only the carrier-frequency label, because filter response affects no peak.

C. The selected IF response and its calibration for the new temporal quantity.

D. Only the observation length, with no need to test the impulse response.

Answer: C. A narrow path useful for tone separation can smear or attenuate a short peak. The measurement objective determines which response properties must be known. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why the selected alternative fits: The selected IF response and its calibration for the new temporal quantity.

Distinguishing consideration: compare this with option A, “Only the final display offset, since a tone calibration characterizes any burst”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-MCQ-009. A filter preserves the measured energy of a burst over a sufficiently long, appropriately calibrated record but reduces its instantaneous peak. Which interpretation is sound?

A. Energy agreement does not establish instantaneous peak fidelity.

B. Equal integrated energy forces the waveform to be an unchanged delayed copy.

C. The original peak can always be recovered from total energy alone.

D. Any reduced peak proves that all burst energy was lost.

Answer: A. Temporal spreading can change a maximum while preserving an integrated quantity. Energy and peak are different measurands, and one scalar cannot reconstruct the waveform. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why the selected alternative fits: Energy agreement does not establish instantaneous peak fidelity.

Distinguishing consideration: compare this with option B, “Equal integrated energy forces the waveform to be an unchanged delayed copy”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-MCQ-010. Group delay is evaluated from transfer phase expressed in radians. Which derivative has the stated units and convention?

A. The negative phase derivative with respect to frequency in hertz with no factor conversion.

B. The positive derivative of transfer magnitude with respect to frequency.

C. Phase divided by center frequency for every possible phase intercept.

D. The negative phase derivative with respect to angular frequency.

Answer: D. Angular frequency in radians per second gives a delay in seconds. A derivative against hertz requires the corresponding two-pi conversion and is not numerically interchangeable. Review: Chapter Glossary: Group delay; Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why the selected alternative fits: The negative phase derivative with respect to angular frequency.

Distinguishing consideration: compare this with option A, “The negative phase derivative with respect to frequency in hertz with no factor conversion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Choose an IF path for the quantity being measured; Chapter 5 — GROUP DELAY (glossary).

Review: Chapter 5 — Choose an IF path for the quantity being measured; Chapter 5 — GROUP DELAY (glossary).

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V011-C05-MCQ-011. Over a measurable coherent passband, unwrapped phase has slope minus 4 microseconds when differentiated with respect to angular frequency. What is the group delay?

A. Zero because the phase slope is negative.

B. Positive 4 microseconds.

C. Negative 4 microseconds.

D. Positive 4 times two pi microseconds.

Answer: B. The definition contains a minus sign. A negative phase slope with angular frequency therefore gives positive group delay of the same magnitude.
Review: Chapter Glossary: Group delay. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)
Why the selected alternative fits: Positive 4 microseconds.
Distinguishing consideration: compare this with option A, “Zero because the phase slope is negative”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 5 — GROUP DELAY (glossary).
Review: Chapter 5 — GROUP DELAY (glossary).

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V011-C05-MCQ-012. A group-delay calculation differentiates principal phase values across a jump from positive pi to negative pi. What must be checked first?

A. Whether the magnitude response can replace the missing phase convention.

B. Phase unwrapping and a coherent reference before estimating the local slope.

C. Whether the jump can simply be interpreted as an impulse delay in the filter.

D. Whether averaging the two wrapped angles automatically reconstructs the branch.

Answer: B. A representation wrap is not a physical discontinuity of an otherwise smooth transfer phase. Differentiation must use a consistent branch supported by the measurement. Review: Choose an IF path for the quantity being measured.

Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why the selected alternative fits: Phase unwrapping and a coherent reference before estimating the local slope.

Distinguishing consideration: compare this with option A, “Whether the magnitude response can replace the missing phase convention”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-MCQ-013. An enormous apparent group delay occurs at a deep notch where the transfer is near the measurement floor. What is the strongest immediate interpretation?

A. The notch phase is always more precise because its transmitted amplitude is smaller.

B. The phase-derived estimate may be ill-conditioned and needs a capability check.

C. The notch proves that every waveform experiences that same large delay.

D. A large numerical derivative establishes correspondingly large stored energy without other evidence.

Answer: B. Phase becomes poorly determined when the measured transfer approaches noise or residuals. A dramatic derivative alone is not a reliable physical-delay claim. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why the selected alternative fits: The phase-derived estimate may be ill-conditioned and needs a capability check.

Distinguishing consideration: compare this with option A, “The notch phase is always more precise because its transmitted amplitude is smaller”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-MCQ-014. Which combination supports treating a band-limited waveform as an approximately unchanged delayed copy through the selected IF path?

A. Sufficiently flat amplitude and approximately linear phase over its occupied band.

B. Only a single measured group-delay value at the center frequency.

C. Only equality of the input and output carrier frequencies.

D. Only a high loaded Q independent of the waveform bandwidth.

Answer: A. Constant amplitude scaling and linear phase across the waveform band support undistorted delay. A local derivative at one frequency cannot establish the full-band condition. Review: Choose an IF path for the quantity being measured.

Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why the selected alternative fits: Sufficiently flat amplitude and approximately linear phase over its occupied band.

Distinguishing consideration: compare this with option B, “Only a single measured group-delay value at the center frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-MCQ-015. A burst falls 6 dB when a narrower IF setting is selected; a time capture shows that the peak is sampled before the filter settles. What should be corrected before inferring a propagation change?

A. The RF source location, because a bandwidth change cannot alter a peak.

B. Only the steady-state center-frequency gain, assumed sufficient for every burst.

C. The path-dependent transient and detection interpretation.

D. The gain-control polarity, regardless of whether AGC was enabled.

Answer: C. The observation is compatible with the receiver path changing the measured peak. A timing-sensitive calibration or a suitable path is needed before assigning the difference to propagation. Review: Hypothetical Case Adjudication; Filter Shape, Selectivity, and Time Response. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

Why the selected alternative fits: The path-dependent transient and detection interpretation.

Distinguishing consideration: compare this with option A, “The RF source location, because a bandwidth change cannot alter a peak”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Filter Shape, Selectivity, and Time Response; Chapter 5 — Hypothetical Case Adjudication: Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors.

Review: Chapter 5 — Filter Shape, Selectivity, and Time Response; Chapter 5 — Hypothetical Case Adjudication: Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors.

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V011-C05-MCQ-016. In Model 5A, the control state is in volts and the time constant is in milliseconds. Which form of the exponent is dimensionally valid?

A. Negative control volts divided by the time constant.

B. Negative elapsed seconds divided directly by a numerical millisecond value without conversion.

C. Negative elapsed time in milliseconds divided by the time constant in milliseconds.

D. Negative elapsed time multiplied by the time constant.

Answer: C. The exponential argument must be dimensionless. Matching time units is essential even when all displayed numbers look plausible. Review: Equations 10A and 10B. Source: Equation 10A. Identified control-state equation (p. 2520)

Why the selected alternative fits: Negative elapsed time in milliseconds divided by the time constant in milliseconds.

Distinguishing consideration: compare this with option A, “Negative control volts divided by the time constant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-MCQ-017. The initial control voltage equals the constant target in the stipulated one-pole model. What follows?

A. The time constant becomes negative.

B. The voltage must first overshoot before reaching equilibrium.

C. The state must decay toward zero volts regardless of the target.

D. The residual is zero for the entire segment.

Answer: D. The homogeneous residual starts at zero and remains zero. The equilibrium is the specified target, not necessarily zero voltage. Review: Equations 10A and 10B. Source: Equation 10A. Identified control-state equation (p. 2520)

Why the selected alternative fits: The residual is zero for the entire segment.

Distinguishing consideration: compare this with option A, “The time constant becomes negative”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-MCQ-018. A control voltage starts at 0.9 V and approaches 0.3 V with a 2 ms time constant. What is its value after 2 ms?

A. Exactly 0.3 V.

B. Approximately 0.22073 V.

C. Approximately 0.67927 V.

D. Approximately 0.52073 V.

Answer: D. One time constant leaves the initial 0.6 V residual multiplied by exp of minus one. Add the remaining 0.22073 V to the 0.3 V target. Review: Equation 10B; Application 5A.1. Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: Approximately 0.52073 V.

Distinguishing consideration: compare this with option A, “Exactly 0.3 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

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V011-C05-MCQ-019. For a nonzero initial step in Model 5A, what fraction of the total voltage change has occurred after one time constant?

A. Approximately 63.21 percent.

B. Approximately 95 percent.

C. Approximately 36.79 percent.

D. Exactly 100 percent.

Answer: A. The residual fraction is exp of minus one, approximately 0.3679. The completed fraction is one minus that value. Review: Equation 10B; Application 5A.1.

Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: Approximately 63.21 percent.

Distinguishing consideration: compare this with option B, “Approximately 95 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

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V011-C05-MCQ-020. An observed control voltage crosses its fixed target and then returns while the fitted model assumes one uninterrupted positive-time-constant segment. What does this indicate?

A. The observation proves that the RF input was clipped.

B. Changing only the sign of the gain slope makes the voltage crossing consistent.

C. Ordinary first-order settling necessarily overshoots once.

D. The stipulated one-pole segment is insufficient for that observation.

Answer: D. The exponential residual preserves its sign. Overshoot requires a changed target, additional dynamics, measurement error or another explanation; it does not uniquely identify clipping. Review: Equation 10B and its monotonicity discussion. Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: The stipulated one-pole segment is insufficient for that observation.

Distinguishing consideration: compare this with option A, “The observation proves that the RF input was clipped”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-MCQ-021. A fitted time constant is negative for a supposedly relaxing segment. Can it be inserted unchanged into Model 5A as an ordinary settling time?

A. No; it violates the stated positive-time-constant model and requires investigation.

B. Yes; a negative gain slope requires a negative time constant.

C. Yes; only the absolute value of elapsed time matters.

D. Yes; changing the voltage reference automatically changes its sign.

Answer: A. The gain-map polarity and the time constant are different quantities. A negative fitted constant describes residual growth under this equation, not the stipulated stable relaxation. Review: Equations 10A, 10C and 10F. Source: Equation 10A. Identified control-state equation (p. 2520)

Why the selected alternative fits: No; it violates the stated positive-time-constant model and requires investigation.

Distinguishing consideration: compare this with option B, “Yes; a negative gain slope requires a negative time constant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-MCQ-022. A small-change voltage trace fits Model 5A closely. Which additional claim remains unestablished?

A. The fitted local response over the actual tested interval.

B. The units assigned to the recorded control voltage.

C. The full internal detector topology and recovery from large overdrive.

D. The residual predicted by that fitted equation at a tested sample time.

Answer: C. An input/output fit is local evidence. Integrating control, slew, clamps and additional stages can behave differently outside the tested range. Review: Model 5A introduction; source note 15. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why the selected alternative fits: The full internal detector topology and recovery from large overdrive.

Distinguishing consideration: compare this with option A, “The fitted local response over the actual tested interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — Model 5A: an identified one-pole gain-control response.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — Model 5A: an identified one-pole gain-control response.

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V011-C05-MCQ-023. A voltage trajectory stays between its endpoints, but both endpoints lie outside the calibrated gain-map range. What can the analyst infer about RF gain from the trajectory alone?

A. The endpoint gains can be assumed equal because the state is bounded.

B. No calibrated gain prediction follows merely from the monotone voltage fit.

C. The local gain slope must become zero outside the calibrated interval.

D. Monotonicity automatically extends the gain calibration to all voltages.

Answer: B. The state model and the voltage-to-gain calibration have separate applicability limits. A well-behaved state trajectory does not validate an extrapolated gain law. Review: Equation 10C and its operating interval. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: No calibrated gain prediction follows merely from the monotone voltage fit.

Distinguishing consideration: compare this with option A, “The endpoint gains can be assumed equal because the state is bounded”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-MCQ-024. During a fitted segment the receiver changes its control target in response to a new input level. What is required for subsequent prediction?

A. Reset the state to the previous target whether or not it was reached.

B. Start a new applicable segment using the actual state at the target change.

C. Set the residual to zero at every trigger.

D. Keep the original constant target for the whole record because the time constant is unchanged.

Answer: B. The constant-target solution applies within a segment. A target change preserves the actual state while changing the equilibrium and possibly the identified parameters. Review: Equation 10G; Application 5A.6. Source: Equation 10G. Carry state across a target change (p. 2523)

Why the selected alternative fits: Start a new applicable segment using the actual state at the target change.

Distinguishing consideration: compare this with option A, “Reset the state to the previous target whether or not it was reached”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

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V011-C05-MCQ-025. A calibrated gain slope is minus 25 dB/V. A control-voltage increase of 0.16 V produces which gain change within that local range?

A. Plus 4 dB.

B. Plus 25.16 dB.

C. Minus 0.0064 dB.

D. Minus 4 dB.

Answer: D. Multiply the signed slope by the voltage change. The negative sign means a rising control voltage reduces gain. Review: Equation 10C. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: Minus 4 dB.

Distinguishing consideration: compare this with option A, “Plus 4 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-MCQ-026. A local gain slope is positive 30 dB/V. What target-voltage change is needed for a 9 dB gain reduction?

A. Minus 3.33 V.

B. Minus 0.30 V.

C. Plus 270 V.

D. Plus 0.30 V.

Answer: B. The required gain change is minus 9 dB. Dividing by the positive slope gives minus 0.30 V, subject to the calibrated control range. Review: Equation 10C; control-polarity discussion. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: Minus 0.30 V.

Distinguishing consideration: compare this with option A, “Minus 3.33 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-MCQ-027. Gain is 24 dB at 0.20 V with slope minus 40 dB/V. At 0.35 V, a fixed minus-70 dBm input remains in the valid path. What is the output level?

A. Minus 40 dBm.

B. Minus 46 dBm.

C. Minus 76 dBm.

D. Minus 52 dBm.

Answer: D. The voltage displacement is 0.15 V, so gain falls by 6 dB to 18 dB. Add that gain to minus 70 dBm. Review: Equations 10C and 10D. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: Minus 52 dBm.

Distinguishing consideration: compare this with option A, “Minus 40 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude.

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V011-C05-MCQ-028. Gain is 25 dB at 0.10 V with slope minus 50 dB/V. Control starts at 0.10 V and approaches 0.50 V with a 2 ms time constant. For fixed minus-65 dBm input, what is output after 2 ms?

A. Exactly minus 60 dBm.

B. Exactly minus 40 dBm.

C. Approximately minus 52.6424 dBm.

D. Approximately minus 47.3576 dBm.

Answer: C. After one time constant the voltage has moved by 0.4 times 0.6321206 V. Gain is 12.3576 dB, giving minus 52.6424 dBm output; the final 5 dB gain has not yet been reached. Review: Equations 10B through 10D; Application 5A.3. Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: Approximately minus 52.6424 dBm.

Distinguishing consideration: compare this with option A, “Exactly minus 60 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Application 5A.3:….

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Application 5A.3: Convert a control state into an output level.

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V011-C05-MCQ-029. A detector reports 0.6 V while a separate AGC telemetry channel also reports 0.6 V. May those voltages be assigned the same RF-power meaning?

A. Only if the separate detector and control-to-gain laws justify that interpretation.

B. Yes; equal voltages always denote equal powers in the same receiver.

C. No detector voltage can ever support a calibrated power result.

D. Yes; the gain slope in dB/V is automatically the detector power slope.

Answer: A. Control voltage and detected output are different physical quantities. Each requires its own calibrated relationship and operating conditions. Review: Equations 10C and 10D; Logarithmic Amplifiers, Detectors, and Scaling. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: Only if the separate detector and control-to-gain laws justify that interpretation.

Distinguishing consideration: compare this with option B, “Yes; equal voltages always denote equal powers in the same receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

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V011-C05-MCQ-030. At fixed input power, equal-duration valid gain states are 0 dB and 20 dB. What is the mean linear output power relative to the input?

A. 20 times, because the numerical dB values can be averaged as powers.

B. 100 times, because the larger gain controls every average.

C. 50.5 times, equivalent to approximately 17.03 dB.

D. 10 times, because the arithmetic mean gain is 10 dB.

Answer: C. The two power gains are 1 and 100. Average those linear quantities to get 50.5, then convert to decibels if desired. Review: Equation 10D discussion; Verify the detector and control path as part of the IF result. Source: Equation 10D. Output level and gain-error magnitude (p. 2522)

Why the selected alternative fits: 50.5 times, equivalent to approximately 17.03 dB. Distinguishing consideration: compare this with option A, “20 times, because the numerical dB values can be averaged as powers”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Verify the detector and control path as part of the IF result. Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-031. Initial gain-error magnitude is 10 dB, tolerance is 0.1 dB, and the time constant is 0.5 ms. What is the earliest settling time under Model 5A?

A. Exactly 1.5 ms.

B. Approximately 0.05 ms.

C. Approximately 2.3026 ms.

D. Approximately 0.2303 ms.

Answer: C. The error ratio is 100. Multiplying its natural logarithm by 0.5 ms gives 2.302585 ms; a generic three-time-constant wait would not meet this tolerance.

Review: Equation 10E; Application 5A.2. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why the selected alternative fits: Approximately 2.3026 ms.

Distinguishing consideration: compare this with option A, “Exactly 1.5 ms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement.

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V011-C05-MCQ-032. An initial gain-error magnitude of 0.05 dB is already within a 0.1 dB tolerance. What earliest acceptance time does Equation 10E assign within its stipulated model?

A. Zero.

B. Exactly one time constant.

C. A negative time from the logarithmic branch.

D. An infinite time because the residual is nonzero.

Answer: A. The piecewise rule assigns zero whenever the initial error is no greater than the positive tolerance. The logarithmic branch is only for a larger initial error.

Review: Equation 10E. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why the selected alternative fits: Zero.

Distinguishing consideration: compare this with option B, “Exactly one time constant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-MCQ-033. Starting from a nonzero residual, a requirement demands exactly zero error under the uninterrupted exponential model. What finite settling time follows?

A. Zero because exactness removes the tolerance calculation.

B. Three time constants for every initial residual.

C. None; exact zero is approached asymptotically.

D. One time constant because that is the defined decay interval.

Answer: C. The exponential remains positive at every finite time. A positive practical tolerance or a separately justified deadband is needed for finite acceptance. Review: Equation 10E and its zero-error qualification. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why the selected alternative fits: None; exact zero is approached asymptotically.

Distinguishing consideration: compare this with option A, “Zero because exactness removes the tolerance calculation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-MCQ-034. The local gain-map slope is zero. What does a gain-based settling test reveal about control-voltage settling in that interval?

A. It cannot identify the voltage residual from gain changes under that map.

B. It proves that every earlier RF stage has recovered.

C. It forces the physical time constant to zero.

D. It proves that the voltage reaches its target instantaneously.

Answer: A. Zero slope makes gain insensitive to control voltage locally. That lack of sensitivity is an uninformative inversion, not evidence of instantaneous state or chain recovery. Review: Equations 10C through 10E. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: It cannot identify the voltage residual from gain changes under that map.

Distinguishing consideration: compare this with option B, “It proves that every earlier RF stage has recovered”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-MCQ-035. An initial voltage error is 0.4 V and the slope magnitude is 25 dB/V. After three time constants, which gain-error magnitude remains?

A. Approximately 0.498 dB.

B. Approximately 0.020 dB.

C. Approximately 9.502 dB.

D. Exactly 0.1 dB.

Answer: A. The initial gain error is 10 dB. Multiply by exp of minus three to obtain approximately 0.49787 dB; the completed portion is not the remaining error.

Review: Equations 10D and 10E; Application 5A.2. Source: Equation 10D. Output level and gain-error magnitude (p. 2522)

Why the selected alternative fits: Approximately 0.498 dB.

Distinguishing consideration: compare this with option B, “Approximately 0.020 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement.

Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement.

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V011-C05-MCQ-036. For the same initial error above both tolerances, the permitted residual is tightened by a factor of ten. How much additional settling time is required?

A. Exactly ten additional time constants.

B. Ten times the original settling time in every case.

C. No extra time because the decay rate is unchanged.

D. The time constant multiplied by the natural logarithm of ten.

Answer: D. Subtract the two logarithmic settling expressions. The initial error cancels, leaving the time constant times the logarithm of the tolerance ratio.

Review: Equation 10E. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why the selected alternative fits: The time constant multiplied by the natural logarithm of ten.

Distinguishing consideration: compare this with option A, “Exactly ten additional time constants”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-MCQ-037. What multiple of the time constant completes 95 percent of a nonzero voltage step in the one-pole model?

A. Exactly 5.

B. Approximately 0.0513.

C. Exactly 0.95.

D. Approximately 2.996.

Answer: D. Five percent residual means exp of minus time over time constant equals 0.05. The required ratio is the natural logarithm of 20. Review: Equation 10B; Application 5A.1. Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: Approximately 2.996.

Distinguishing consideration: compare this with option A, “Exactly 5”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

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V011-C05-MCQ-038. A settling calculation divides an initial error of 0.3 V by a tolerance of 0.1 dB inside a logarithm. What is wrong?

A. Voltage errors can never be converted into gain errors.

B. The numerator and denominator are different quantities and must first be expressed in compatible error units.

C. The logarithm must always be base ten because gain is in decibels.

D. A signed slope must be replaced by a signed time constant.

Answer: B. The logarithm requires a dimensionless ratio of like errors. Use the absolute calibrated gain slope to convert voltage-error magnitude to decibels when appropriate. Review: Equations 10D and 10E. Source: Equation 10D. Output level and gain-error magnitude (p. 2522)

Why the selected alternative fits: The numerator and denominator are different quantities and must first be expressed in compatible error units.

Distinguishing consideration: compare this with option A, “Voltage errors can never be converted into gain errors”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-MCQ-039. A permitted gain error is 2 dB and the valid slope is minus 40 dB/V. What voltage-error magnitude corresponds to that tolerance?

A. 0.05 V.

B. 20 V.

C. 80 V.

D. Minus 0.05 V.

Answer: A. Divide the nonnegative gain-error tolerance by the slope magnitude. Error magnitude remains positive despite the negative gain-map polarity. Review: Equations 10C through 10E. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: 0.05 V.

Distinguishing consideration: compare this with option B, “20 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-MCQ-040. The positive time constant is known only to lie between 1 ms and 2 ms; the initial error and target are fixed. Which endpoint sets the conservative wait for a smaller positive tolerance?

A. 2 ms, because the larger time constant gives slower residual decay.

B. Their arithmetic mean without any additional assumption.

C. 1 ms, because smaller time constants always produce larger residuals.

D. Neither endpoint because the gain slope changes sign with the time constant.

Answer: A. The settling expression is proportional to the time constant when the error ratio exceeds one. A bound must retain the slower admissible case. Review: Equation 10E; uncertainty qualification following Equation 10J. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why the selected alternative fits: 2 ms, because the larger time constant gives slower residual decay.

Distinguishing consideration: compare this with option B, “Their arithmetic mean without any additional assumption”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-MCQ-041. Two voltage steps have the same time constant but different magnitudes. Under the same one-pole model, which settling comparison is correct?

A. Both percentage and absolute-tolerance settling times are necessarily identical.

B. The larger step always has a proportionally larger percentage-settling time.

C. A percentage requirement has units of volts and cannot be used.

D. The time to complete the same percentage is equal, but a common absolute-error tolerance can give different times.

Answer: D. Fractional residual depends only on normalized time. An absolute tolerance introduces the initial magnitude through the logarithmic error ratio.

Review: Equations 10B and 10E. Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: The time to complete the same percentage is equal, but a common absolute-error tolerance can give different times.

Distinguishing consideration: compare this with option A, “Both percentage and absolute-tolerance settling times are necessarily identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-MCQ-042. A 12 dB input increase requires an eventual 12 dB gain reduction. With a valid one-pole response, what output increase remains after one time constant?

A. Exactly 12 dB.

B. Approximately 7.585 dB.

C. Exactly 0 dB.

D. Approximately 4.415 dB.

Answer: D. The residual correction is 12 times exp of minus one dB. The gain has completed about 7.585 dB of the required reduction, leaving about 4.415 dB.

Review: Application 5A.4. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

Why the selected alternative fits: Approximately 4.415 dB.

Distinguishing consideration: compare this with option A, “Exactly 12 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

Review: Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

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V011-C05-MCQ-043. An input increases by 8 dB and the local control slope is minus 20 dB/V. What target-voltage change would restore the previous output level if the path stays valid?

A. A rise of 2.5 V.

B. No voltage change because only input power changed.

C. A rise of 0.4 V.

D. A fall of 0.4 V.

Answer: C. Restoring the output requires minus 8 dB of gain change. Dividing by minus 20 dB/V gives plus 0.4 V, provided the new target is within the valid range. Review: Equation 10C; Application 5A.4. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: A rise of 0.4 V.

Distinguishing consideration: compare this with option A, “A rise of 2.5 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

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V011-C05-MCQ-044. The gain calibration is valid only from 0.1 V through 0.7 V, while a proposed settling segment runs from 0.2 V toward 0.9 V. What must be limited or re-established?

A. The gain prediction once the control leaves the calibrated interval.

B. Only the initial gain, because a valid starting point validates every later point.

C. Only the time unit, because calibration range cannot affect gain.

D. Nothing, provided the exponential is mathematically monotone.

Answer: A. The state equation may still produce numbers, but the stipulated voltage-to-gain law does not justify gain beyond its interval. Extend calibration or restrict the claim. Review: Equation 10C. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: The gain prediction once the control leaves the calibrated interval.

Distinguishing consideration: compare this with option B, “Only the initial gain, because a valid starting point validates every later point”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-MCQ-045. Control telemetry reaches its accepted gain-error tolerance after an overload. What still needs separate verification before accepting the entire signal path?

A. Only whether the time constant was positive in the fitted control equation.

B. The relevant RF and detector response, including any stages with independent recovery.

C. Only whether the final target voltage equals its stored setting.

D. Nothing else, because a settled control voltage proves all stages linear.

Answer: B. Control-state settling is one observable. Earlier amplifiers, limiters or detectors can remain disturbed even when telemetry appears settled. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: The relevant RF and detector response, including any stages with independent recovery.

Distinguishing consideration: compare this with option A, “Only whether the time constant was positive in the fitted control equation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-046. Residuals relative to one fixed target are minus 0.20 V and minus 0.05 V, separated by 2 ms. What positive time constant does Equation 10F infer?

A. Exactly 0.5 ms.

B. Minus 1.443 ms.

C. Approximately 1.443 ms.

D. Approximately 2.773 ms.

Answer: C. The ratio of the signed residuals is four, so the natural logarithm is positive. Divide 2 ms by that logarithm; the common negative sign is allowed.

Review: Equation 10F; Application 5A.5. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why the selected alternative fits: Approximately 1.443 ms.

Distinguishing consideration: compare this with option A, “Exactly 0.5 ms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

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V011-C05-MCQ-047. Two nonzero residuals about the same fixed target have opposite signs. Can they identify an uninterrupted positive-time-constant segment through Equation 10F?

A. Yes; taking absolute values always makes the physical model valid.

B. No; the stipulated exponential cannot reverse residual sign.

C. Yes; a negative gain slope requires a residual sign reversal.

D. Yes; the time constant is simply the elapsed time divided by two.

Answer: B. Absolute values would conceal a model contradiction. Investigate target changes, overshoot, measurement error or additional dynamics before fitting.

Review: Equations 10B and 10F. Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: No; the stipulated exponential cannot reverse residual sign.

Distinguishing consideration: compare this with option A, “Yes; taking absolute values always makes the physical model valid”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-MCQ-048. Two equal nonzero residual magnitudes of the same sign are observed at different times about a fixed target. What follows for an exact finite positive one-pole fit?

A. The time constant equals the time separation.

B. The time constant is zero.

C. No such decaying fit follows; the logarithmic denominator is zero.

D. The residual has necessarily reached equilibrium.

Answer: C. A finite positive time constant causes strict magnitude decrease from a nonzero residual. Equal values may reflect a floor, hold state or insufficient resolution, but not the exact stipulated decay. Review: Equation 10F. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why the selected alternative fits: No such decaying fit follows; the logarithmic denominator is zero.

Distinguishing consideration: compare this with option A, “The time constant equals the time separation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-MCQ-049. Same-sign residual magnitudes grow between two observations about the claimed fixed target. Which conclusion is justified?

A. They fail the decreasing-magnitude condition for the stated relaxation model.

B. They validate an ordinary positive settling time after taking an absolute logarithm.

C. They prove that the target voltage is physically zero.

D. They show that the gain slope must be negative.

Answer: A. Taking an absolute logarithm would hide the direction of change. Growth requires a different state description, target or error explanation. Review: Equation 10F and its identification conditions. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why the selected alternative fits: They fail the decreasing-magnitude condition for the stated relaxation model.

Distinguishing consideration: compare this with option B, “They validate an ordinary positive settling time after taking an absolute logarithm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-MCQ-050. Two residual measurements produce a plausible positive time constant. What is the next substantive validation step?

A. Declare the complete internal AGC topology uniquely identified.

B. Challenge the fitted response at additional times and relevant levels or states.

C. Use the same constant through all clamps, hang intervals and overloads.

D. Discard any later point that departs from the two-point fit.

Answer: B. Two favorable points can interpolate an exponential without proving model adequacy. Additional observations can expose target errors, slew, multiple time constants or state changes. Review: Equation 10F; Application 5A.5. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why the selected alternative fits: Challenge the fitted response at additional times and relevant levels or states.

Distinguishing consideration: compare this with option A, “Declare the complete internal AGC topology uniquely identified”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

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V011-C05-MCQ-051. A residual trace appears to stop decaying at a small nonzero floor. Which possibility should be checked before assigning a very long time constant?

A. A proof that the final output power is exactly zero.

B. A necessary sign change in the calibrated gain slope.

C. An incorrect target estimate or a detector offset contributing to the residual.

D. A requirement that every first-order response has a nonzero residual floor.

Answer: C. Residuals are defined relative to the target. A target error or offset can create a floor even when the underlying state has settled. Review: Application 5A.5.

Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

Why the selected alternative fits: An incorrect target estimate or a detector offset contributing to the residual.

Distinguishing consideration: compare this with option A, “A proof that the final output power is exactly zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

Review: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

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V011-C05-MCQ-052. A semilogarithmic plot of measured residual magnitude shows two distinct slopes over the retained interval. What should be reconsidered?

A. Whether changing the final gain offset can always make both slopes identical.

B. Whether one time constant adequately describes the whole interval.

C. Whether the time axis should be ignored because only residual sign matters.

D. Whether any two-slope response must be attributed to RF fading alone.

Answer: B. A single exponential gives one slope when its target is correct. Multiple slopes can reveal additional dynamics, changing state or measurement effects that need evaluation. Review: Equation 10F; Application 5A.5. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why the selected alternative fits: Whether one time constant adequately describes the whole interval.

Distinguishing consideration: compare this with option A, “Whether changing the final gain offset can always make both slopes identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

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V011-C05-MCQ-053. An overdriven control response begins with an approximately constant voltage slope and later approaches its target exponentially. What is the best model treatment?

A. Infer that the later positive time constant also proves the early ramp exponential.

B. Replace the signed gain slope with the voltage slew rate because they have the same units.

C. Force one exponential through both regions and discard the early deviation.

D. Distinguish the possible slew-limited segment from the later local exponential segment.

Answer: D. A voltage rate has units of volts per time, whereas the gain map has units of decibels per volt. Large-change slew and local small-change response are separate mechanisms. Review: Model 5A introduction; Application 5A.5; source note 15. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why the selected alternative fits: Distinguish the possible slew-limited segment from the later local exponential segment.

Distinguishing consideration: compare this with option A, “Infer that the later positive time constant also proves the early ramp exponential”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals; Chapter 5 — Model 5A: an identified one-pole gain-control….

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals; Chapter 5 — Model 5A: an identified one-pole gain-control response.

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V011-C05-MCQ-054. Residual observations have a fixed dimensionless ratio, and their time separation is entered in milliseconds. In what unit does Equation 10F return the time constant?

A. Seconds automatically, regardless of the entered unit.

B. Milliseconds.

C. Volts per millisecond.

D. A dimensionless value.

Answer: B. The logarithm of the residual ratio is dimensionless, so the numerator supplies the time unit. No implicit factor of one thousand is introduced. Review: Equation 10F. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why the selected alternative fits: Milliseconds.

Distinguishing consideration: compare this with option A, “Seconds automatically, regardless of the entered unit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-MCQ-055. Control starts at 0 V and approaches 1 V for a duration equal to the time constant times $\ln(2)$. It then approaches 0 V for the same duration and time constant. What is the final state?

A. 0.50 V.

B. 0.25 V.

C. 0.75 V.

D. 0 V.

Answer: B. Each interval leaves half of its starting residual. The first ends at 0.5 V; the second halves that carried value to 0.25 V. Review: Equation 10G; Application 5A.6. Source: Equation 10G. Carry state across a target change (p. 2523)

Why the selected alternative fits: 0.25 V.

Distinguishing consideration: compare this with option A, “0.50 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

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V011-C05-MCQ-056. A second burst begins before the control has reached the first burst's target. Which starting condition should its model use?

A. The actual control state at the second burst's start.

B. The first target, because a target change resets the physical state.

C. Zero residual at each trigger, independent of history.

D. The arithmetic mean of the two targets without a dynamic calculation.

Answer: A. The state is continuous under the stipulated finite-rate model. Discarding its unresolved residual misrepresents the second interval. Review: Equation 10G; Application 5A.6. Source: Equation 10G. Carry state across a target change (p. 2523)

Why the selected alternative fits: The actual control state at the second burst's start.

Distinguishing consideration: compare this with option B, "The first target, because a target change resets the physical state"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

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V011-C05-MCQ-057. Control rises from 0.2 V toward 0.6 V for 0.5 ms with a 0.25 ms attack constant, then releases toward 0.2 V for 1 ms with a 2 ms release constant. What final value follows?

A. Approximately 0.44261 V.

B. Approximately 0.40978 V.

C. Approximately 0.24681 V.

D. Exactly 0.2 V.

Answer: B. The attack ends at 0.545866 V. Carry that state into release and multiply its 0.345866 V displacement by exp of minus 0.5, then add 0.2 V. Review: Equation 10G; Application 5A.7. Source: Equation 10G. Carry state across a target change (p. 2523)

Why the selected alternative fits: Approximately 0.40978 V.

Distinguishing consideration: compare this with option A, “Approximately 0.44261 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

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V011-C05-MCQ-058. A receiver holds its gain-control state for a fixed time after a strong burst before beginning exponential release. How should this be represented?

A. As the same release exponential merely renamed with a larger time constant.

B. As an explicit hang state with its trigger and duration, followed by the applicable release segment.

C. As proof that the physical time constant is negative during the hold.

D. As an instantaneous reset to the pre-burst target.

Answer: B. A hold interval and a slow exponential have different trajectories. The timing rule and carried state must be declared. Review: Equation 10G discussion; Application 5A.7. Source: Equation 10G. Carry state across a target change (p. 2523)

Why the selected alternative fits: As an explicit hang state with its trigger and duration, followed by the applicable release segment.

Distinguishing consideration: compare this with option A, “As the same release exponential merely renamed with a larger time constant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

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V011-C05-MCQ-059. A burst lasts 0.5 ms while the identified time constant is 5 ms. What fraction of the target control step occurs during the burst?

A. Exactly 50 percent.

B. Approximately 9.516 percent.

C. Approximately 90.484 percent.

D. Approximately 99.995 percent.

Answer: B. The elapsed time is one tenth of a time constant. The completed fraction is one minus exp of minus 0.1, not the remaining fraction. Review: Equation 10B; Application 5A.8. Source: Equation 10B. Control voltage and residual (p. 2521)

Why the selected alternative fits: Approximately 9.516 percent.

Distinguishing consideration: compare this with option A, “Exactly 50 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.8: Compare burst duration with control settling.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.8: Compare burst duration with control settling.

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V011-C05-MCQ-060. Identical repeated bursts settle into a reproducible periodic control trajectory that never reaches either target. What record is needed to correct the next burst's gain?

A. Only the final control sample after the complete acquisition.

B. Enough preceding state history or a validated periodic-state estimate to determine its actual initial condition.

C. Only the burst repetition frequency, with no amplitude or duration information.

D. Only the target associated with the new burst, treating it as already attained.

Answer: B. Reproducibility does not mean equilibrium. The unresolved residual from earlier intervals determines the next trajectory. Review: Equation 10G; Application 5A.6. Source: Equation 10G. Carry state across a target change (p. 2523)

Why the selected alternative fits: Enough preceding state history or a validated periodic-state estimate to determine its actual initial condition.

Distinguishing consideration: compare this with option A, "Only the final control sample after the complete acquisition"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

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V011-C05-MCQ-061. For a 2 ms time constant and 1 ms sample interval, what is the exact sampled residual multiplier?

A. Exactly 0.5.

B. Exactly minus 0.5.

C. Approximately 1.64872.

D. Approximately 0.60653.

Answer: D. The exact coefficient is exp of minus interval divided by time constant, here exp of minus 0.5. The value 0.5 belongs to the Euler approximation. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why the selected alternative fits: Approximately 0.60653.

Distinguishing consideration: compare this with option A, “Exactly 0.5”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-MCQ-062. An exact sampled coefficient is 0.8 for a 1 ms interval. What positive time constant is consistent with that coefficient?

A. Minus 4.4814 ms.

B. Approximately 0.2231 ms.

C. Approximately 4.4814 ms.

D. Exactly 5 ms.

Answer: C. Take the natural logarithm of 0.8 and solve time constant equal to minus 1 ms divided by that logarithm. The five-millisecond value would come from an Euler relation. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why the selected alternative fits: Approximately 4.4814 ms.

Distinguishing consideration: compare this with option A, “Minus 4.4814 ms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-MCQ-063. In the exact recurrence, current state is 0.2 V, target is 0.8 V and the coefficient is 0.25. What is the next state?

A. 0.65 V.

B. 0.95 V.

C. 0.20 V.

D. 0.35 V.

Answer: A. Weight the current state by 0.25 and the target by 0.75: 0.05 plus 0.60 equals 0.65 V. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why the selected alternative fits: 0.65 V.

Distinguishing consideration: compare this with option B, “0.95 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-MCQ-064. Why does the exact sampled recurrence preserve the monotone segment for positive sample interval and time constant?

A. Its coefficient is independent of the sample interval.

B. Its coefficient is always zero, so every update reaches the target exactly.

C. Its coefficient lies strictly between zero and one, making the update a convex combination of current state and target.

D. Its coefficient is always negative, producing physical alternating convergence.

Answer: C. The positive exponential coefficient contracts the residual without changing its sign. This is the sampled form of the continuous solution. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why the selected alternative fits: Its coefficient lies strictly between zero and one, making the update a convex combination of current state and target.

Distinguishing consideration: compare this with option A, “Its coefficient is independent of the sample interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-MCQ-065. Forward Euler uses a sample interval equal to one quarter of the time constant. What is its residual multiplier?

A. 1.25.

B. 0.75.

C. Approximately 0.7788.

D. Minus 0.75.

Answer: B. Euler subtracts the interval-to-time-constant ratio from one. The exponential value approximately 0.7788 is the exact coefficient, which is close but different. Review: Equations 10H and 10I. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why the selected alternative fits: 0.75.

Distinguishing consideration: compare this with option A, “1.25”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-MCQ-066. Forward Euler uses a sample interval 1.5 times the time constant. What behavior does its residual recurrence predict?

A. Alternating growth with multiplier minus 1.5.

B. An exact physical one-pole trajectory at the sample times.

C. Monotone decay with multiplier positive 0.5.

D. Alternating decay with multiplier minus 0.5.

Answer: D. The Euler coefficient is one minus 1.5. Its magnitude is less than one, but its negative sign creates alternation absent from the stipulated continuous relaxation. Review: Equation 10I. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why the selected alternative fits: Alternating decay with multiplier minus 0.5.

Distinguishing consideration: compare this with option A, “Alternating growth with multiplier minus 1.5”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-MCQ-067. At an Euler interval exactly twice the time constant, what happens to a nonzero residual?

A. It reaches zero after one step.

B. It necessarily grows in magnitude on every step.

C. It alternates with unchanged magnitude, so it does not asymptotically decay.

D. It follows the exact exponential coefficient exp of minus two.

Answer: C. The Euler coefficient is minus one at this boundary. The strict stability interval excludes equality at two. Review: Equation 10I. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why the selected alternative fits: It alternates with unchanged magnitude, so it does not asymptotically decay.

Distinguishing consideration: compare this with option A, “It reaches zero after one step”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-MCQ-068. A simulation with an Euler interval 2.5 times the time constant produces alternating, increasing residuals. What should be checked before diagnosing physical instability?

A. The numerical update, whose multiplier is minus 1.5 and is unstable for this step.

B. Whether the continuous time constant should be made negative to match the simulation.

C. Only the logarithmic detector intercept, regardless of the simulated variable.

D. Only the RF generator phase, since the numerical scheme cannot cause growth.

Answer: A. The stated continuous one-pole system is stable for positive time constant. Euler is outside its stability interval and can manufacture the observed divergence. Review: Equation 10I; Application 5A.9. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why the selected alternative fits: The numerical update, whose multiplier is minus 1.5 and is unstable for this step.

Distinguishing consideration: compare this with option B, “Whether the continuous time constant should be made negative to match the simulation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range; Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range; Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

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V011-C05-MCQ-069. Euler is used with interval equal to the time constant and predicts zero residual after one step. What is the corresponding exact residual fraction?

A. One, because a full time constant prevents decay.

B. Zero, because Euler is exact at that step size.

C. Minus one, because the exact solution changes sign.

D. Exp of minus one, approximately 0.3679.

Answer: D. Euler's coefficient is zero at this step, but the exact coefficient remains positive. Numerical finite-step extinction must not be mistaken for physical exact settling. Review: Equations 10H and 10I. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why the selected alternative fits: Exp of minus one, approximately 0.3679.

Distinguishing consideration: compare this with option A, "One, because a full time constant prevents decay"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-MCQ-070. The actual receiver implements a discrete controller rather than a sampled version of the continuous one-pole loop. What must govern its prediction?

A. Only the analog control-voltage units, which uniquely determine its dynamics.

B. Forward Euler with any chosen interval, irrespective of implemented logic.

C. The exponential recurrence automatically, because all digital controllers are exact samples of one pole.

D. Its own identified recurrence and state rules.

Answer: D. The exact recurrence is exact for the stipulated continuous model. A physically discrete controller can contain different updates, delays, quantization and mode transitions. Review: Application 5A.9. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

Why the selected alternative fits: Its own identified recurrence and state rules.

Distinguishing consideration: compare this with option A, “Only the analog control-voltage units, which uniquely determine its dynamics”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

Review: Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

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V011-C05-MCQ-071. An initial state lies in 0.1 through 0.3 V. With fixed target 0.7 V and exponential factor 0.25, what state interval follows?

A. 0.10 through 0.70 V.

B. 0.55 through 0.60 V.

C. 0.025 through 0.075 V.

D. 0.60 through 0.65 V.

Answer: B. Apply target plus one quarter of each initial displacement. Positivity of the coefficient preserves the voltage endpoint order. Review: Equation 10J; Application 5A.10. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why the selected alternative fits: 0.55 through 0.60 V.

Distinguishing consideration: compare this with option A, “0.10 through 0.70 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-MCQ-072. The initial-state interval width is 0.2 V and the exact exponential factor is 0.25. What width remains when target and time constant are fixed?

A. 0.15 V.

B. 0.05 V.

C. 0.8 V.

D. 0.25 V.

Answer: B. The affine map multiplies the initial width by its positive coefficient. This is contraction of the initial-state contribution only. Review: Equation 10J. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why the selected alternative fits: 0.05 V.

Distinguishing consideration: compare this with option A, “0.15 V”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-MCQ-073. A propagated voltage interval has width 0.05 V and the local gain slope is minus 40 dB/V. What is the corresponding gain-interval width?

A. Minus 2 dB.

B. 0.00125 dB.

C. 2 dB.

D. 40.05 dB.

Answer: C. Multiply voltage width by the absolute slope. A width is nonnegative even though the gain mapping reverses order. Review: Equations 10C and 10J.

Source: Equation 10C. Local control-to-gain law (p. 2522)

Why the selected alternative fits: 2 dB.

Distinguishing consideration: compare this with option A, “Minus 2 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-MCQ-074. A calibrated local gain slope is negative. When mapping an ordered voltage interval into an ordered gain interval, which endpoint supplies the minimum gain?

A. The smaller voltage endpoint.

B. The arithmetic midpoint regardless of the slope.

C. Both endpoints because interval propagation removes polarity.

D. The larger voltage endpoint.

Answer: D. A negative affine slope reverses order. Applying endpoint values without sorting would label the gain bounds incorrectly. Review: Equation 10J; Application 5A.10. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why the selected alternative fits: The larger voltage endpoint.

Distinguishing consideration: compare this with option A, “The smaller voltage endpoint”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-MCQ-075. Equation 10J propagates uncertainty only in the initial state while holding target and time constant fixed. What additional claim is unsupported?

A. That the resulting interval is the entire uncertainty budget for a gain correction.

B. That positive exponential weighting preserves voltage endpoint order.

C. That the initial-state contribution contracts by the stated exponential factor.

D. That the declared fixed-target model maps each included initial state.

Answer: A. Target, time constant, slope, timing and measurement effects can contribute separately. A partial deterministic bound must not be reported as a complete uncertainty result. Review: Equation 10J; Application 5A.10. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why the selected alternative fits: That the resulting interval is the entire uncertainty budget for a gain correction.

Distinguishing consideration: compare this with option B, “That positive exponential weighting preserves voltage endpoint order”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-MCQ-076. The initial voltage lies between 0.1 and 0.3 V, target is 0.6 V, slope magnitude is 20 dB/V, and time constant is 2 ms. What wait ensures the whole initial-state interval has gain error at most 0.1 dB?

A. Approximately 8.7641 ms using the midpoint.

B. Exactly 6 ms.

C. Approximately 9.2103 ms.

D. Approximately 4.6052 ms.

Answer: C. The largest initial voltage error is 0.5 V, giving 10 dB. Use 2 ms times ln of 100; choosing the midpoint would not cover the entire interval. Review: Equations 10E and 10J. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why the selected alternative fits: Approximately 9.2103 ms.

Distinguishing consideration: compare this with option A, “Approximately 8.7641 ms using the midpoint”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-MCQ-077. Initial-state uncertainty has nearly decayed away, but the target voltage remains uncertain. What can still limit a late-time gain correction?

A. Nothing, because contraction of initial uncertainty removes every parameter uncertainty.

B. Uncertainty in the limiting target and its calibrated gain mapping.

C. Only the discarded initial-state sign.

D. A mandatory return to the initial voltage after enough time constants.

Answer: B. As the state approaches its target, uncertainty in that target does not disappear. The initial-state contraction result must not be extended to fixed but uncertain parameters. Review: Equation 10J and its stated exclusions. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why the selected alternative fits: Uncertainty in the limiting target and its calibrated gain mapping.

Distinguishing consideration: compare this with option A, “Nothing, because contraction of initial uncertainty removes every parameter uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-MCQ-078. A gain correction uses calibrated control telemetry that is delayed relative to the RF samples during a fast transient. What is the main remaining problem?

A. Only the final settled gain matters for every sample in the record.

B. A fixed telemetry delay can never affect input-referred amplitude.

C. Calibration of the static gain map automatically removes all timing error.

D. The correction may apply a valid gain value to the wrong signal time.

Answer: D. A time-varying correction needs synchronized observations or an applicable delay correction. Static calibration alone does not establish temporal alignment. Review: Application 5A.3. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

Why the selected alternative fits: The correction may apply a valid gain value to the wrong signal time.

Distinguishing consideration: compare this with option A, “Only the final settled gain matters for every sample in the record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Application 5A.3: Convert a control state into an output level.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level.

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V011-C05-MCQ-079. A strong signal outside a narrow displayed channel reduces a weak in-channel response. Which receiver mechanism is explicitly plausible in the chapter?

A. A narrower display necessarily disables all automatic gain changes.

B. Every out-of-display signal is physically excluded before all control detectors.

C. The weak source must have changed power because the displayed frequency is unchanged.

D. A wider shared detector controls gain used by the weak channel.

Answer: D. Display bandwidth and control-detector admission may differ. A shared path can let off-channel energy change the gain applied to the desired channel.

Review: Automatic Gain Control and Hidden State. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

Why the selected alternative fits: A wider shared detector controls gain used by the weak channel.

Distinguishing consideration: compare this with option A, “A narrower display necessarily disables all automatic gain changes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Automatic Gain Control and Hidden State.

Review: Chapter 5 — Automatic Gain Control and Hidden State.

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V011-C05-MCQ-080. AGC cannot be disabled during a quantitative observation. Which retained record best supports later amplitude interpretation?

A. Only the audio-volume setting.

B. Only the final settled gain, assumed constant throughout the event.

C. Only a normalized trace with its original gain history removed.

D. Calibrated, time-aligned gain state together with applicable signal-path and reference observations.

Answer: D. The control's changing effect must be reconstructible within its tested range. Display normalization and audio volume do not supply an RF gain history.

Review: Automatic Gain Control and Hidden State; Application 5A.3. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

Why the selected alternative fits: Calibrated, time-aligned gain state together with applicable signal-path and reference observations.

Distinguishing consideration: compare this with option A, "Only the audio-volume setting"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 5 — Application 5A.3: Convert a control state into an output level; Chapter 5 — Automatic Gain Control and Hidden State.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level; Chapter 5 — Automatic Gain Control and Hidden State.

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V011-C05-MCQ-081. A detector is labeled RMS, but the waveform exceeds its stated crest-factor or bandwidth conditions. Which claim is unjustified?

A. That the operating conditions need to be retained in the record.

B. That the waveform may need a separately validated measurement path.

C. That the RMS label alone guarantees correct mean-square response for that waveform.

D. That detector recovery can affect a transient result.

Answer: C. An estimator name does not remove its physical limits. Waveform-dependent capability must be established for the actual peak and spectral content.

Review: Logarithmic Amplifiers, Detectors, and Scaling; source note 15. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

Why the selected alternative fits: That the RMS label alone guarantees correct mean-square response for that waveform.

Distinguishing consideration: compare this with option A, “That the operating conditions need to be retained in the record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling; Chapter 5 — Model 5A: an identified one-pole gain-control response.

Review: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling; Chapter 5 — Model 5A: an identified one-pole gain-control response.

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V011-C05-MCQ-082. A rare short excursion appears in a peak trace but not in a sparsely sampled display trace. What does this difference establish initially?

A. The peak trace must contain a false RF signal.

B. Different detector or selection operations can produce different observations of the same waveform.

C. Both traces necessarily estimate the same mean-square quantity.

D. The sample trace proves that the excursion never occurred.

Answer: B. A peak operation can retain an excursion missed by sample selection. Detector law, dwell and timing must be reconciled before comparing the reported quantities. Review: Verify the detector and control path as part of the IF result.

Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: Different detector or selection operations can produce different observations of the same waveform.

Distinguishing consideration: compare this with option A, “The peak trace must contain a false RF signal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-083. Two equal-duration power levels are 0 dBm and 20 dBm. Their logarithmic average is 10 dBm. Which physical mean-power statement is correct?

A. The mean is 20 mW because the dBm values add.

B. The mean is 10 mW because averaging dBm is averaging power.

C. The mean is 50.5 mW, approximately 17.03 dBm.

D. The mean is 100 mW because the larger level determines every average.

Answer: C. Convert the two powers to 1 mW and 100 mW before equal-duration averaging. The mean of logarithms is a different operation. Review: Verify the detector and control path as part of the IF result; Chapter 8 averaging connection.

Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: The mean is 50.5 mW, approximately 17.03 dBm.

Distinguishing consideration: compare this with option A, “The mean is 20 mW because the dBm values add”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

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V011-C05-MCQ-084. A displayed output remains flat as the input increases. What can the trace alone distinguish?

A. It does not uniquely distinguish successful leveling, limiting, clipping, detector saturation or software normalization.

B. It proves that only AGC is active.

C. It proves that a log amplifier has a perfectly calibrated intercept.

D. It proves that the receiver remains linear.

Answer: A. Several different mechanisms can create a plateau. Additional state records and a suitable reference are needed to establish valid transfer. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: It does not uniquely distinguish successful leveling, limiting, clipping, detector saturation or software normalization.

Distinguishing consideration: compare this with option B, “It proves that only AGC is active”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-085. A logarithmic detector is used close to its low-level floor. Which effects deserve particular attention?

A. Only high-power thermal damage, regardless of the weak input.

B. An assumption that logarithmic compression removes additive offsets.

C. A guarantee that its calibrated high-level slope extends indefinitely downward.

D. Noise and offsets that can dominate the indicated response.

Answer: D. The useful logarithmic law has a finite operating range. At low levels, residual noise and offsets can determine the indication and invalidate simple extrapolation. Review: Logarithmic Amplifiers, Detectors, and Scaling. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

Why the selected alternative fits: Noise and offsets that can dominate the indicated response.

Distinguishing consideration: compare this with option A, “Only high-power thermal damage, regardless of the weak input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

Review: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

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V011-C05-MCQ-086. Video bandwidth is reduced after detection while the IF filter is unchanged. Which interpretation is appropriate?

A. The displayed smoothing and temporal response can change without an identical change to RF/IF admission.

B. The operation changes only visual styling and cannot alter a measured peak.

C. All upstream overload exposure is reduced by the video-bandwidth ratio.

D. The IF selectivity necessarily narrows by exactly the same factor.

Answer: A. Post-detection filtering acts on a different quantity and stage. Its smoothing can change displayed peaks and timing without protecting earlier components. Review: Chapter Glossary: Video bandwidth; Logarithmic Amplifiers, Detectors, and Scaling. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

Why the selected alternative fits: The displayed smoothing and temporal response can change without an identical change to RF/IF admission.

Distinguishing consideration: compare this with option B, “The operation changes only visual styling and cannot alter a measured peak”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling; Chapter 5 — VIDEO BANDWIDTH (glossary).

Review: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling; Chapter 5 — VIDEO BANDWIDTH (glossary).

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V011-C05-MCQ-087. A noise measurement uses an averaging detector and a selectable IF filter. Which information is needed to interpret the reported mean power?

A. Only a loaded-Q ratio without the noise weighting convention.

B. Only the nominal filter label and a claim that all averaging is equivalent.

C. The detector operation, actual effective bandwidth, gain state and acquisition conditions.

D. Only the peak value seen at any instant during the record.

Answer: C. Noise power depends on frequency weighting and the statistic applied. Detector selection and averaging history are part of the measurement definition. Review: Filter Shape, Selectivity, and Time Response; Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: The detector operation, actual effective bandwidth, gain state and acquisition conditions.

Distinguishing consideration: compare this with option A, “Only a loaded-Q ratio without the noise weighting convention”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Filter Shape, Selectivity, and Time Response.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Filter Shape, Selectivity, and Time Response.

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V011-C05-MCQ-088. RF samples clip during a burst, but complete calibrated AGC telemetry is retained. Can gain correction reconstruct the lost waveform peaks uniquely?

A. Yes; the one-pole model supplies the original RF waveform as well as control state.

B. Yes; the final target voltage determines every clipped sample.

C. No; a gain record does not restore information lost through clipping.

D. Yes; dividing by the instantaneous gain reverses any saturation.

Answer: C. The state model predicts control, not missing signal values.

Noninvertible clipping can map many input peaks to the same recorded value.

Review: Application 5A.3; Verify the detector and control path as part of the IF result.

Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

Why the selected alternative fits: No; a gain record does not restore information lost through clipping.

Distinguishing consideration: compare this with option A, “Yes; the one-pole model supplies the original RF waveform as well as control state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Application 5A.3: Convert a control state into an output level; Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level; Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-089. Two paths produce the same flat final output after a strong pulse, but one uses a limiter and the other a valid leveling loop. What distinguishes them for amplitude work?

A. Their measured transfer and retention of recoverable signal information, not the plateau alone.

B. Equal output level establishes identical input-referred amplitudes.

C. A limiter label always guarantees more faithful amplitude than calibrated gain control.

D. A stable plateau proves that neither path experienced recovery.

Answer: A. Similar scalar outputs can arise from different operations. A reference and state-dependent transfer test determine which amplitude claims remain supported. Review: Verify the detector and control path as part of the IF result.

Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: Their measured transfer and retention of recoverable signal information, not the plateau alone.

Distinguishing consideration: compare this with option B, “Equal output level establishes identical input-referred amplitudes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-090. A weak reference is carried through the same disturbed interval as the signal of interest. What condition is essential for that reference to assess continuing path validity?

A. Its absence is treated as successful verification regardless of the floor.

B. It is assumed unaffected simply because its input level is small.

C. It remains measurable with sufficient sensitivity and a known applicable transfer criterion.

D. Its last post-event sample is substituted for the entire event history.

Answer: C. An obscured or clipped reference cannot establish an uninterrupted valid transfer. Its own observability and acceptance condition must be retained.

Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: It remains measurable with sufficient sensitivity and a known applicable transfer criterion.

Distinguishing consideration: compare this with option A, “Its absence is treated as successful verification regardless of the floor”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-091. Why does the chapter's IF verification sequence first fix gain and disable avoidable automatic changes?

A. To prove that automatic gain control can never be used for measurements.

B. To remove the need to test detectors and bandwidths afterward.

C. To make every receiver stage physically linear at any input level.

D. To characterize the selected path without conflating its transfer with changing control state.

Answer: D. Holding state supports attribution of the measured response. The intended automatic mode is then tested separately with stimuli that exercise its dynamics. Review: Verify the detector and control path as part of the IF result.

Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: To characterize the selected path without conflating its transfer with changing control state.

Distinguishing consideration: compare this with option A, "To prove that automatic gain control can never be used for measurements"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-092. A repaired IF path passes a center-frequency tone amplitude test. Which further property remains unverified by that result alone?

A. The particular tested tone level at the stated center and configuration.

B. Whether an output indication was present in that test.

C. The identity of the applied test frequency in the retained setup record.

D. Skirt response, group-delay variation and transient recovery.

Answer: D. One scalar point cannot characterize a frequency- and time-dependent path. The chapter calls for representative passband, boundary and transient checks.

Review: IF Acceptance and Regression Tests. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

Why the selected alternative fits: Skirt response, group-delay variation and transient recovery.

Distinguishing consideration: compare this with option A, “The particular tested tone level at the stated center and configuration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-MCQ-093. A calibrated noise input is added after passband tone tests. What distinct property does it help exercise?

A. The receiver's entire control topology uniquely from one mean value.

B. Integrated path weighting and detector response under the declared effective bandwidth.

C. Every possible pulse rise time without any transient stimulus.

D. Only the center-frequency phase, independent of the noise spectrum.

Answer: B. Noise excites a frequency-weighted power observation different from a tone point. Its usefulness depends on the known spectrum and detector convention. Review: Verify the detector and control path as part of the IF result.

Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: Integrated path weighting and detector response under the declared effective bandwidth.

Distinguishing consideration: compare this with option A, "The receiver's entire control topology uniquely from one mean value"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-094. An audio path and a spectrum path give different amplitude histories for one event. What should a reproducible record identify?

A. A single average of both traces without retaining their separate origins.

B. Only one common receiver model number, assumed to define both paths.

C. Only the final displayed units, since matching units imply matching transfer.

D. Which IF takeoff, filter, detector and gain state produced each history.

Answer: D. Derived products can represent different filtered and controlled observations. Path identity makes the difference interpretable and supports valid comparison. Review: Verify the detector and control path as part of the IF result.

Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: Which IF takeoff, filter, detector and gain state produced each history.

Distinguishing consideration: compare this with option A, “A single average of both traces without retaining their separate origins”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-095. An IF filter is implemented digitally. Which change can still alter its physical or indicated response?

A. Only an analog mechanical adjustment inside the filter.

B. A change to sample clock, coefficients, scaling or firmware.

C. None; digital implementation establishes permanent calibration.

D. Only the RF antenna polarization, independent of the processing state.

Answer: B. Digital implementation reduces some analog drift but remains dependent on numerical and timing configuration. Its current transfer still needs applicable verification. Review: IF Alignment, Calibration, and Failure Localization.

Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

Why the selected alternative fits: A change to sample clock, coefficients, scaling or firmware.

Distinguishing consideration: compare this with option A, “Only an analog mechanical adjustment inside the filter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

Review: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

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V011-C05-MCQ-096. A stored amplitude-correction file produces an apparently correct center-tone level while the uncorrected analog response has degraded. What is the appropriate inference?

A. A numerical correction necessarily restores lost bandwidth and transient information.

B. The correction file proves that all analog stages remain unchanged.

C. The corrected point does not by itself establish unchanged physical path response.

D. An unchanged filename establishes the calibration's present applicability.

Answer: C. A correction can conceal one manifestation of drift while skirts, delay or dynamic range worsen. Direct response and applicability checks remain necessary. Review: IF Alignment, Calibration, and Failure Localization. Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

Why the selected alternative fits: The corrected point does not by itself establish unchanged physical path response.

Distinguishing consideration: compare this with option A, "A numerical correction necessarily restores lost bandwidth and transient information"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

Review: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

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V011-C05-MCQ-097. Firmware changes automatic IF selection at a bandwidth boundary. Which regression is most directly relevant?

A. Repeat only one unchanged center-tone setting far from the boundary.

B. Assume all old correction tables remain applicable because the RF connector is unchanged.

C. Repeat applicable level, response and transient cases on both sides of the changed boundary.

D. Test only the final display normalization without the active filter states.

Answer: C. Boundary behavior can alter path, gain and dynamics. The repeated cases should exercise the assumptions affected by the actual change. Review: IF Acceptance and Regression Tests. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

Why the selected alternative fits: Repeat applicable level, response and transient cases on both sides of the changed boundary.

Distinguishing consideration: compare this with option A, “Repeat only one unchanged center-tone setting far from the boundary”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-MCQ-098. A proprietary control algorithm cannot be reconstructed from available documentation. What is an honest characterization outcome?

A. A claim that a fitted one-pole curve proves the hidden internal implementation.

B. An assumption that unknown control states can be removed by changing display units.

C. A universal recovery guarantee based on one small level step.

D. A retained input/output response and configuration-limited model with its tested scope stated.

Answer: D. An empirical model can be useful without an internal-circuit claim. Its limits and the observed configuration must remain explicit. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: A retained input/output response and configuration-limited model with its tested scope stated.

Distinguishing consideration: compare this with option A, “A claim that a fitted one-pole curve proves the hidden internal implementation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-MCQ-099. A closing reference test passes after the event and after the chain has returned to its normal state. What does that check establish by itself?

A. All unexercised filter and gain combinations were also valid.

B. Every earlier transient sample was necessarily acquired in the same valid state.

C. Any preceding clipping can now be corrected from the passing final value.

D. The exercised functions met that check at its time, without proving uninterrupted validity during the earlier event.

Answer: D. A later check supplies temporally scoped evidence. Contemporaneous state and reference records are needed for claims about an earlier interval. Review: IF Acceptance and Regression Tests; Chapter 1 closing-verification qualification.

Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

Why the selected alternative fits: The exercised functions met that check at its time, without proving uninterrupted validity during the earlier event.

Distinguishing consideration: compare this with option A, “All unexercised filter and gain combinations were also valid”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — IF Acceptance and Regression Tests; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 5 — IF Acceptance and Regression Tests; Chapter 1 — Evidence Record and Closing Verification.

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V011-C05-MCQ-100. An IF path passes the declared tone, noise, burst and recovery cases in specified configurations. What is the strongest warranted release statement?

A. The path met those stated criteria in the tested domain, with remaining configuration and waveform limits retained.

B. No future calibration or regression can be needed because all detector types are equivalent.

C. The simple fitted control equation is proven to describe every internal stage.

D. Every possible input waveform and hidden receiver state has been validated.

Answer: A. Acceptance is tied to measurands, criteria, configurations and stimulus coverage. It supports a bounded capability statement rather than an unlimited physical model. Review: IF Acceptance and Regression Tests; Table 5. Source: Table 5. Chapter 5 receiver controls and interpretation limits (p. 2545)

Why the selected alternative fits: The path met those stated criteria in the tested domain, with remaining configuration and waveform limits retained.

Distinguishing consideration: compare this with option B, “No future calibration or regression can be needed because all detector types are equivalent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Table 5. Chapter 5 receiver controls and interpretation limits; Chapter 5 — IF Acceptance and Regression Tests.

Review: Chapter 5 — Table 5. Chapter 5 receiver controls and interpretation limits; Chapter 5 — IF Acceptance and Regression Tests.

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Fill-in-the-Blank Questions

V011-C05-FIB-001. An IF chain is a designed measurement _____, not merely the difference between two oscillator frequencies.

Answer: environment. Its filtering, gain, detection and sampling determine what quantity the output can represent. The numerical IF alone omits those operations.
Review: Intermediate Frequency as a Controlled Band. Source: §5.1 Intermediate Frequency as a Controlled Band (p. 2513)
Why this term is required: “environment” completes the stated technical proposition.
Question context: An IF chain is a designed measurement _____, not merely the difference between two oscillator frequencies
Basis and qualification: Chapter 5 — Intermediate Frequency as a Controlled Band.
Review: Chapter 5 — Intermediate Frequency as a Controlled Band.

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V011-C05-FIB-002. When audio and I/Q outputs come from different takeoffs, each observation should identify its source _____ and state.

Answer: path. Bandwidth and control may differ between outputs. Retaining the actual path makes their different responses interpretable. Review: Intermediate Frequency as a Controlled Band; Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “path” completes the stated technical proposition.

Question context: When audio and I/Q outputs come from different takeoffs, each observation should identify its source _____ and state

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Intermediate Frequency as a Controlled Band.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Intermediate Frequency as a Controlled Band.

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V011-C05-FIB-003. In Equation 9, loaded Q is center frequency divided by the bandwidth measured at _____ dB relative to the stated reference response.

Answer: minus 3. This is the particular bandwidth convention used in that ratio. Noise bandwidth or a width at another attenuation is not automatically interchangeable. Review: Equation 9. Source: Equation 9. Loaded quality factor (p. 2544)

Why this term is required: “minus 3” completes the stated technical proposition.

Question context: In Equation 9, loaded Q is center frequency divided by the bandwidth measured at _____ dB relative to the stated reference response

Basis and qualification: Chapter 5 — Equation 9. Loaded quality factor.

Review: Chapter 5 — Equation 9. Loaded quality factor.

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V011-C05-FIB-004. A resonance centered at 25 MHz with a 500 kHz minus-3 dB width has loaded Q equal to _____.

Answer: 50. Use 25 MHz divided by 0.5 MHz. The units cancel, leaving the dimensionless response ratio. Review: Equation 9. Source: Equation 9. Loaded quality factor (p. 2544)

Why this term is required: “50” completes the stated technical proposition.

Question context: A resonance centered at 25 MHz with a 500 kHz minus-3 dB width has loaded Q equal to _____

Basis and qualification: Chapter 5 — Equation 9. Loaded quality factor.

Review: Chapter 5 — Equation 9. Loaded quality factor.

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V011-C05-FIB-005. A 30 MHz resonance with loaded Q of 150 has minus-3 dB bandwidth _____ kHz.

Answer: 200. Divide 30 MHz by 150 to obtain 0.2 MHz. This rearrangement retains the stated resonance and bandwidth convention. Review: Equation 9. Source: Equation 9. Loaded quality factor (p. 2544)

Why this term is required: “200” completes the stated technical proposition.

Question context: A 30 MHz resonance with loaded Q of 150 has minus-3 dB bandwidth _____ kHz

Basis and qualification: Chapter 5 — Equation 9. Loaded quality factor.

Review: Chapter 5 — Equation 9. Loaded quality factor.

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V011-C05-FIB-006. Equal loaded-Q ratios do not establish equal filter skirts, passband ripple or group _____.

Answer: delay. Q encodes only a center-to-width ratio. Phase response and full transfer shape require additional observations. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why this term is required: “delay” completes the stated technical proposition.

Question context: Equal loaded-Q ratios do not establish equal filter skirts, passband ripple or group _____

Basis and qualification: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-FIB-007. A shape-factor report must identify the two attenuation _____ used to define its bandwidth ratio.

Answer: levels. Without those levels, the numerical ratio is ambiguous. A ratio at minus 60 and minus 6 dB is different from one using minus 40 and minus 3 dB.

Review: Chapter Glossary: Shape factor. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

Why this term is required: “levels” completes the stated technical proposition.

Question context: A shape-factor report must identify the two attenuation _____ used to define its bandwidth ratio

Basis and qualification: Chapter 5 — SHAPE FACTOR (glossary).

Review: Chapter 5 — SHAPE FACTOR (glossary).

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V011-C05-FIB-008. For a broadband noise-power comparison, the useful filter descriptor is its effective noise _____ or the corresponding full weighting.

Answer: bandwidth. Noise integration depends on the power transfer across frequency, not solely on a labeled passband width. Review: Filter Shape, Selectivity, and Time Response. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
Why this term is required: “bandwidth” completes the stated technical proposition.
Question context: For a broadband noise-power comparison, the useful filter descriptor is its effective noise _____ or the corresponding full weighting
Basis and qualification: Chapter 5 — Filter Shape, Selectivity, and Time Response.
Review: Chapter 5 — Filter Shape, Selectivity, and Time Response.

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V011-C05-FIB-009. A timing-sensitive IF calibration can use an impulse or step response to expose settling and _____.

Answer: ringing. A center-frequency tone cannot reveal the complete transient response. Retain the relevant input waveform and observation timing. Review: Filter Shape, Selectivity, and Time Response. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

Why this term is required: “ringing” completes the stated technical proposition.

Question context: A timing-sensitive IF calibration can use an impulse or step response to expose settling and _____

Basis and qualification: Chapter 5 — Filter Shape, Selectivity, and Time Response.

Review: Chapter 5 — Filter Shape, Selectivity, and Time Response.

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V011-C05-FIB-010. Agreement in a burst's integrated energy does not by itself establish fidelity of its instantaneous _____.

Answer: peak. Temporal spreading can preserve an integral while reducing a maximum. The intended measurand determines the calibration required. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why this term is required: "peak" completes the stated technical proposition.

Question context: Agreement in a burst's integrated energy does not by itself establish fidelity of its instantaneous _____

Basis and qualification: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-FIB-011. Group delay is the _____ derivative of transfer phase with respect to angular frequency.

Answer: negative. The minus sign makes a conventional linear phase lag correspond to positive delay. Use radians and compatible angular-frequency units.
Review: Chapter Glossary: Group delay. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)
Why this term is required: “negative” completes the stated technical proposition.
Question context: Group delay is the _____ derivative of transfer phase with respect to angular frequency
Basis and qualification: Chapter 5 — GROUP DELAY (glossary).
Review: Chapter 5 — GROUP DELAY (glossary).

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V011-C05-FIB-012. If transfer phase is differentiated with respect to frequency in hertz, the group-delay conversion includes division by _____.

Answer: two pi. The standard definition uses angular frequency. Its derivative differs from the hertz-frequency derivative by the factor relating those coordinates. Review: Choose an IF path for the quantity being measured; Chapter Glossary: Group delay. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518) Why this term is required: “two pi” completes the stated technical proposition. Question context: If transfer phase is differentiated with respect to frequency in hertz, the group-delay conversion includes division by _____
Basis and qualification: Chapter 5 — Choose an IF path for the quantity being measured; Chapter 5 — GROUP DELAY (glossary).
Review: Chapter 5 — Choose an IF path for the quantity being measured; Chapter 5 — GROUP DELAY (glossary).

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V011-C05-FIB-013. Before differentiating phase through representation wraps, construct an appropriately _____ phase record.

Answer: unwrapped. A principal-value jump need not be a physical transfer discontinuity. The branch and coherent reference must support the derivative.

Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why this term is required: “unwrapped” completes the stated technical proposition.

Question context: Before differentiating phase through representation wraps, construct an appropriately _____ phase record

Basis and qualification: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-FIB-014. A phase-derived group-delay estimate needs transfer amplitude sufficiently _____ for the phase measurement to be meaningful.

Answer: measurable. Near the measurement floor, phase can become unstable and its derivative can amplify that instability. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why this term is required: “measurable” completes the stated technical proposition.

Question context: A phase-derived group-delay estimate needs transfer amplitude sufficiently _____ for the phase measurement to be meaningful

Basis and qualification: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-FIB-015. An approximately unchanged delayed waveform requires flat amplitude and approximately _____ phase over its occupied band.

Answer: linear. A local group-delay value at one frequency is insufficient. The response must meet the relevant amplitude and phase conditions throughout the waveform band. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why this term is required: “linear” completes the stated technical proposition.

Question context: An approximately unchanged delayed waveform requires flat amplitude and approximately _____ phase over its occupied band

Basis and qualification: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-FIB-016. A dramatic apparent delay at a deep notch may reflect an _____-conditioned phase measurement.

Answer: ill. The low transmitted amplitude can make phase sensitive to noise and residuals. A large number alone does not establish a reliable physical delay. Review: Choose an IF path for the quantity being measured. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

Why this term is required: “ill” completes the stated technical proposition.

Question context: A dramatic apparent delay at a deep notch may reflect an _____-conditioned phase measurement

Basis and qualification: Chapter 5 — Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-FIB-017. The state, initial value and target in Model 5A are control voltages expressed in _____.

Answer: volts. They are not automatically RF amplitudes or power levels. The separate gain calibration gives their relevance to the signal path. Review: Equation 10A and its variable definitions. Source: Equation 10A. Identified control-state equation (p. 2520)

Why this term is required: “volts” completes the stated technical proposition.

Question context: The state, initial value and target in Model 5A are control voltages expressed in _____

Basis and qualification: Chapter 5 — Equation 10A. Identified control-state equation.

Review: Chapter 5 — Equation 10A. Identified control-state equation.

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V011-C05-FIB-018. The local signed gain-map slope has units of _____ per volt.

Answer: decibels. Multiplying that slope by a control-voltage displacement yields a gain change in decibels. Its sign determines control polarity. Review: Equation 10C.

Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “decibels” completes the stated technical proposition.

Question context: The local signed gain-map slope has units of _____ per volt

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-FIB-019. Elapsed time and time constant must use the _____ time unit inside the exponential ratio.

Answer: same. The exponent is dimensionless. Convert seconds, milliseconds or microseconds consistently before substitution. Review: Equation 10B. Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “same” completes the stated technical proposition.

Question context: Elapsed time and time constant must use the _____ time unit inside the exponential ratio

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-020. The stipulated relaxation model requires its time constant to be strictly _____.

Answer: positive. This gives decaying rather than growing residual magnitude for positive elapsed time. The time-constant sign is separate from gain-map polarity.

Review: Equation 10A. Source: Equation 10A. Identified control-state equation (p. 2520)

Why this term is required: “positive” completes the stated technical proposition.

Question context: The stipulated relaxation model requires its time constant to be strictly _____

Basis and qualification: Chapter 5 — Equation 10A. Identified control-state equation.

Review: Chapter 5 — Equation 10A. Identified control-state equation.

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V011-C05-FIB-021. The signed residual is control voltage minus the constant _____.

Answer: target. Subtracting the target converts the state equation into exponential residual decay. A wrong target can distort the inferred decay. Review: Equation 10B.

Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “target” completes the stated technical proposition.

Question context: The signed residual is control voltage minus the constant _____

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-022. If the initial residual is zero, it stays _____ throughout the unchanged model segment.

Answer: zero. The system is already at the specified equilibrium. This does not imply that unrelated receiver stages are in a valid state. Review: Equations 10A and 10B. Source: Equation 10A. Identified control-state equation (p. 2520)

Why this term is required: “zero” completes the stated technical proposition.

Question context: If the initial residual is zero, it stays _____ throughout the unchanged model segment

Basis and qualification: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-023. A nonzero residual under one uninterrupted positive-time-constant segment preserves its _____.

Answer: sign. The exponential multiplier is positive. A target crossing therefore requires another explanation beyond the stipulated segment. Review: Equation 10B.

Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “sign” completes the stated technical proposition.

Question context: A nonzero residual under one uninterrupted positive-time-constant segment preserves its _____

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-024. Equation 10B assumes that the target is _____ during the modeled segment.

Answer: constant. A changed target requires a new applicable segment and state carryover, rather than continued use of the original equilibrium. Review: Equations 10B and 10G. Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “constant” completes the stated technical proposition.

Question context: Equation 10B assumes that the target is _____ during the modeled segment

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10G. Carry state across a target change.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10G. Carry state across a target change.

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V011-C05-FIB-025. Measured overshoot contradicts the _____ voltage approach predicted by the stated one-pole segment.

Answer: monotone. The state remains between its initial value and fixed target. Overshoot can indicate additional dynamics, target changes or measurement effects. Review: Equation 10B discussion. Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “monotone” completes the stated technical proposition.

Question context: Measured overshoot contradicts the _____ voltage approach predicted by the stated one-pole segment

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-026. After two time constants, the remaining residual is approximately _____ percent of its initial value.

Answer: 13.53. The residual multiplier is exp of minus two, approximately 0.135335. The completed fraction is instead approximately 86.47 percent. Review: Equation 10B; Application 5A.1. Source: Equation 10B. Control voltage and residual (p. 2521)
Why this term is required: “13.53” completes the stated technical proposition.
Question context: After two time constants, the remaining residual is approximately _____ percent of its initial value
Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.
Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

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V011-C05-FIB-027. Control starts at 0.1 V and approaches 0.9 V. After a duration equal to the time constant times $\ln(4)$, the state is _____ V.

Answer: 0.7. The remaining residual fraction is one quarter. Add one quarter of minus 0.8 V to the 0.9 V target. Review: Equation 10B. Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “0.7” completes the stated technical proposition.

Question context: Control starts at 0.1 V and approaches 0.9 V. After a duration equal to the time constant times the state is _____ V

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-028. Control starts at 0.8 V and approaches 0.2 V. After a duration equal to the time constant times $\ln(2)$, the state is _____ V.

Answer: 0.5. The initial positive residual of 0.6 V is halved to 0.3 V, which is then added to the target. Review: Equation 10B. Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “0.5” completes the stated technical proposition.

Question context: Control starts at 0.8 V and approaches 0.2 V. After a duration equal to the time constant times the state is _____ V

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-029. For initial state and target both equal to 0.4 V, the state after any finite positive duration is _____ V.

Answer: 0.4. The residual is identically zero. The time constant controls perturbation decay but does not move an exact equilibrium. Review: Equation 10B.

Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “0.4” completes the stated technical proposition.

Question context: For initial state and target both equal to 0.4 V, the state after any finite positive duration is _____ V

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-FIB-030. A slope of minus 30 dB/V and a control rise of 0.2 V give a gain change of _____ dB.

Answer: minus 6. Multiply the signed quantities. Taking only the slope magnitude would reverse the physical interpretation. Review: Equation 10C. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “minus 6” completes the stated technical proposition.

Question context: A slope of minus 30 dB/V and a control rise of 0.2 V give a gain change of _____ dB

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-FIB-031. Gain is 20 dB at 0.2 V with slope positive 25 dB/V. At 0.4 V, gain is _____ dB.

Answer: 25. The voltage displacement is 0.2 V and the gain increase is 5 dB. Add that change to the reference gain. Review: Equation 10C. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “25” completes the stated technical proposition.

Question context: Gain is 20 dB at 0.2 V with slope positive 25 dB/V. At 0.4 V, gain is _____ dB

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-FIB-032. A fixed input of minus 80 dBm through valid gain of 25 dB gives output _____ dBm.

Answer: minus 55. Power level in dBm plus power gain in dB gives output level in dBm within the applicable transfer model. Review: Equation 10D. Source: Equation 10D. Output level and gain-error magnitude (p. 2522)

Why this term is required: “minus 55” completes the stated technical proposition.

Question context: A fixed input of minus 80 dBm through valid gain of 25 dB gives output _____ dBm

Basis and qualification: Chapter 5 — Equation 10D. Output level and gain-error magnitude.

Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude.

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V011-C05-FIB-033. To restore an unchanged output after a 10 dB input increase, the required gain change is _____ dB.

Answer: minus 10. The input-level and gain changes add in decibels. Their sum must be zero for the same output, subject to available gain range. Review: Equation 10D; Application 5A.4. Source: Equation 10D. Output level and gain-error magnitude (p. 2522)

Why this term is required: “minus 10” completes the stated technical proposition.

Question context: To restore an unchanged output after a 10 dB input increase, the required gain change is _____ dB

Basis and qualification: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

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V011-C05-FIB-034. With a minus-50 dB/V slope, a 10 dB gain reduction requires a target-voltage change of _____ V.

Answer: plus 0.2. Divide minus 10 dB by minus 50 dB/V. The positive displacement must still lie in the calibrated control range. Review: Equation 10C; Application 5A.4.

Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “plus 0” completes the stated technical proposition.

Question context: With a minus-50 dB/V slope, a 10 dB gain reduction requires a target-voltage change of _____ V

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

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V011-C05-FIB-035. With a positive 40 dB/V slope, an 8 dB gain reduction requires a target-voltage change of _____ V.

Answer: minus 0.2. A positive slope requires a falling control voltage for gain reduction. The polarity differs from the negative-slope example. Review: Equation 10C. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “minus 0” completes the stated technical proposition.

Question context: With a positive 40 dB/V slope, an 8 dB gain reduction requires a target-voltage change of _____ V

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-FIB-036. Initial voltage-error magnitude is 0.25 V and the slope magnitude is 32 dB/V. Initial gain-error magnitude is _____ dB.

Answer: 8. Multiply the two magnitudes. This puts the initial error in the same units as a gain-error tolerance. Review: Equation 10D. Source: Equation 10D. Output level and gain-error magnitude (p. 2522)

Why this term is required: “8” completes the stated technical proposition.

Question context: Initial voltage-error magnitude is 0.25 V and the slope magnitude is 32 dB/V. Initial gain-error magnitude is _____ dB

Basis and qualification: Chapter 5 — Equation 10D. Output level and gain-error magnitude.

Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude.

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V011-C05-FIB-037. For initial gain error 8 dB, tolerance 0.2 dB and time constant 0.75 ms, the settling time is approximately _____ ms.

Answer: 2.7667. The ratio is 40, and 0.75 times ln 40 equals approximately 2.76666 ms. The logarithm is natural because the decay law is exponential. Review: Equation 10E. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why this term is required: “2.7667” completes the stated technical proposition.

Question context: For initial gain error 8 dB, tolerance 0.2 dB and time constant 0.75 ms, the settling time is approximately _____ ms

Basis and qualification: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-FIB-038. When initial error is already no greater than the positive tolerance, the earliest model acceptance time is _____.

Answer: zero. The piecewise definition avoids using a negative logarithmic time. Actual measurement acceptance still needs applicable model and calibration evidence. Review: Equation 10E. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why this term is required: “zero” completes the stated technical proposition.

Question context: When initial error is already no greater than the positive tolerance, the earliest model acceptance time is _____

Basis and qualification: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-FIB-039. Starting from nonzero error, exact zero residual is reached only as time tends to _____ in the ideal exponential model.

Answer: infinity. No finite positive time makes the exponential zero. A finite practical settling requirement therefore uses a positive tolerance. Review: Equation 10E qualification. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why this term is required: “infinity” completes the stated technical proposition.

Question context: Starting from nonzero error, exact zero residual is reached only as time tends to _____ in the ideal exponential model

Basis and qualification: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-FIB-040. The error ratio inside the settling logarithm must be _____.

Answer: dimensionless. Use numerator and denominator of the same quantity and unit, such as two gain-error magnitudes in decibels or two voltage-error magnitudes in volts. Review: Equation 10E. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why this term is required: “dimensionless” completes the stated technical proposition.

Question context: The error ratio inside the settling logarithm must be _____

Basis and qualification: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-FIB-041. A time constant of 0.6 ms gives a 95-percent voltage-step completion time of approximately _____ ms.

Answer: 1.7974. Multiply 0.6 ms by $\ln(20)$. The remaining fraction is five percent, so this is distinct from one time constant. Review: Equation 10B; Application 5A.1.

Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “1.7974” completes the stated technical proposition.

Question context: A time constant of 0.6 ms gives a 95-percent voltage-step completion time of approximately _____ ms

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.1: Read a voltage step and its 95 percent settling time.

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V011-C05-FIB-042. Waiting three time constants leaves approximately _____ percent of a nonzero initial residual.

Answer: 4.979. Exp of minus three is approximately 0.049787. Whether this is adequate depends on the initial error and required absolute tolerance. Review: Equation 10E; Application 5A.2. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why this term is required: “4.979” completes the stated technical proposition.

Question context: Waiting three time constants leaves approximately _____ percent of a nonzero initial residual

Basis and qualification: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement.

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V011-C05-FIB-043. Tightening a positive tolerance by a factor of ten adds approximately _____ time constants for one fixed initial error above both tolerances.

Answer: 2.3026. The additional normalized time is $\ln(10)$. It is an additive increase, not an automatic tenfold increase in the total wait. Review: Equation 10E. Source: Equation 10E. Settling time for a positive error tolerance (p. 2522)

Why this term is required: "2.3026" completes the stated technical proposition.

Question context: Tightening a positive tolerance by a factor of ten adds approximately _____ time constants for one fixed initial error above both tolerances

Basis and qualification: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-FIB-044. A 0.15 dB gain tolerance with slope magnitude 30 dB/V corresponds to a voltage-error tolerance of _____ V.

Answer: 0.005. Divide 0.15 by 30. The applicable calibration uncertainty must be considered before using this voltage threshold as an acceptance rule. Review: Equations 10C through 10E. Source: Equation 10C. Local control-to-gain law (p. 2522)
Why this term is required: “0.005” completes the stated technical proposition.
Question context: A 0.15 dB gain tolerance with slope magnitude 30 dB/V corresponds to a voltage-error tolerance of _____ V
Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.
Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance.

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V011-C05-FIB-045. A zero local gain slope makes inversion from observed gain to control voltage _____.

Answer: uninformative. Gain has no local sensitivity to that voltage under the stated map. It does not prove that the physical state settles instantly. Review: Equation 10C and zero-slope qualification. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “uninformative” completes the stated technical proposition.

Question context: A zero local gain slope makes inversion from observed gain to control voltage _____

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law.

Review: Chapter 5 — Equation 10C. Local control-to-gain law.

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V011-C05-FIB-046. Residuals of plus 0.16 V and plus 0.04 V separated by 1.4 ms give a time constant of approximately _____ ms.

Answer: 1.0099. The ratio is four, so divide 1.4 ms by $\ln(4)$. Additional data are needed to assess whether the fitted one-pole model is adequate. Review: Equation 10F. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)
Why this term is required: "1.0099" completes the stated technical proposition.
Question context: Residuals of plus 0.16 V and plus 0.04 V separated by 1.4 ms give a time constant of approximately _____ ms
Basis and qualification: Chapter 5 — Equation 10F. Two-point identification of the local time constant.
Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-FIB-047. Residuals of minus 0.18 V and minus 0.06 V separated by 0.8 ms give a time constant of approximately _____ ms.

Answer: 0.7282. The signed ratio is positive three. Divide 0.8 ms by $\ln(3)$; same-sign negative residuals satisfy the sign condition. Review: Equation 10F. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why this term is required: “0.7282” completes the stated technical proposition.

Question context: Residuals of minus 0.18 V and minus 0.06 V separated by 0.8 ms give a time constant of approximately _____ ms

Basis and qualification: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-FIB-048. Two nonzero residuals used in Equation 10F must have the _____ sign.

Answer: same. The uninterrupted exponential preserves residual sign. Taking absolute values of a genuine sign reversal would hide a model violation. Review: Equation 10F. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why this term is required: “same” completes the stated technical proposition.

Question context: Two nonzero residuals used in Equation 10F must have the _____ sign

Basis and qualification: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-FIB-049. For a positive fitted time constant, the later residual magnitude must be _____ than the earlier one.

Answer: smaller. The ratio of earlier to later same-sign residuals must exceed one, giving a positive logarithm for positive elapsed time. Review: Equation 10F. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why this term is required: “smaller” completes the stated technical proposition.

Question context: For a positive fitted time constant, the later residual magnitude must be _____ than the earlier one

Basis and qualification: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-FIB-050. The two residuals in a time-constant identification must refer to the _____ target.

Answer: same. Subtracting different targets would not produce two samples of the same homogeneous decay. Target changes require a segmented analysis. Review: Equation 10F. Source: Equation 10F. Two-point identification of the local time constant (p. 2523)

Why this term is required: “same” completes the stated technical proposition.

Question context: The two residuals in a time-constant identification must refer to the _____ target

Basis and qualification: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-FIB-051. A two-point exponential interpolation should be challenged using _____ observations before it is accepted as an adequate model.

Answer: additional. More times and relevant levels can expose wrong targets, floors, slew or multiple dynamics that two points cannot distinguish. Review: Application 5A.5. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

Why this term is required: “additional” completes the stated technical proposition.

Question context: A two-point exponential interpolation should be challenged using _____ observations before it is accepted as an adequate model

Basis and qualification: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

Review: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

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V011-C05-FIB-052. A small residual floor may arise from an incorrect target or a detector _____.

Answer: offset. A constant offset changes the apparent late residual. It should not automatically be interpreted as an extremely slow physical time constant. Review: Application 5A.5. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

Why this term is required: “offset” completes the stated technical proposition.

Question context: A small residual floor may arise from an incorrect target or a detector _____

Basis and qualification: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

Review: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

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V011-C05-FIB-053. An early approximately linear voltage ramp can indicate a _____ limit instead of ordinary small-change exponential response.

Answer: slew. A rate limit can dominate a large excursion even when a later local segment is well described by a pole. The regimes should be separated. Review: Application 5A.5; source note 15. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

Why this term is required: “slew” completes the stated technical proposition.

Question context: An early approximately linear voltage ramp can indicate a _____ limit instead of ordinary small-change exponential response

Basis and qualification: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals; Chapter 5 — Model 5A: an identified one-pole gain-control response.

Review: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals; Chapter 5 — Model 5A: an identified one-pole gain-control response.

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V011-C05-FIB-054. For an ideal one-pole decay, the slope of ln residual magnitude against time is minus one divided by the _____.

Answer: time constant. This follows by taking the logarithm of the positive residual magnitude. It assumes a correct fixed target and nonzero residual. Review: Equations 10B and 10F. Source: Equation 10B. Control voltage and residual (p. 2521)
Why this term is required: “time constant” completes the stated technical proposition.
Question context: For an ideal one-pole decay, the slope of ln residual magnitude against time is minus one divided by the _____
Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10F. Two-point identification of the local time constant.
Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10F. Two-point identification of the local time constant.

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V011-C05-FIB-055. At a target change, the next segment starts from the actual _____ state of the preceding segment.

Answer: terminal. Resetting to the old target would discard an unresolved residual. The physical state is carried forward under the stipulated finite-rate model. Review: Equation 10G. Source: Equation 10G. Carry state across a target change (p. 2523)

Why this term is required: “terminal” completes the stated technical proposition.

Question context: At a target change, the next segment starts from the actual _____ state of the preceding segment

Basis and qualification: Chapter 5 — Equation 10G. Carry state across a target change.

Review: Chapter 5 — Equation 10G. Carry state across a target change.

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V011-C05-FIB-056. Starting at 0.2 V toward target 1.0 V with exponential factor 0.5, the first segment ends at _____ V.

Answer: 0.6. The remaining displacement is half of minus 0.8 V. Add that minus 0.4 V residual to the 1.0 V target. Review: Equation 10G. Source: Equation 10G. Carry state across a target change (p. 2523)

Why this term is required: “0.6” completes the stated technical proposition.

Question context: Starting at 0.2 V toward target 1.0 V with exponential factor 0.5, the first segment ends at _____ V

Basis and qualification: Chapter 5 — Equation 10G. Carry state across a target change.

Review: Chapter 5 — Equation 10G. Carry state across a target change.

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V011-C05-FIB-057. Carry that 0.6 V state into a segment with target 0.4 V and exponential factor 0.25. The new terminal state is _____ V.

Answer: 0.45. One quarter of the initial 0.2 V displacement is 0.05 V, which remains above the new target. Review: Equation 10G. Source: Equation 10G. Carry state across a target change (p. 2523)

Why this term is required: “0.45” completes the stated technical proposition.

Question context: Carry that 0.6 V state into a segment with target 0.4 V and exponential factor 0.25. The new terminal state is _____ V

Basis and qualification: Chapter 5 — Equation 10G. Carry state across a target change.

Review: Chapter 5 — Equation 10G. Carry state across a target change.

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V011-C05-FIB-058. Unequal attack and release behavior can use _____ identified positive time constants for the two applicable segments.

Answer: separately. One constant should not be transferred to the other regime merely for convenience. The switch condition and carried state must also be retained. Review: Application 5A.7. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

Why this term is required: “separately” completes the stated technical proposition.

Question context: Unequal attack and release behavior can use _____ identified positive time constants for the two applicable segments

Basis and qualification: Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

Review: Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

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V011-C05-FIB-059. A fixed hold before release is represented as an explicit _____ state.

Answer: hang. A hold and a slow exponential are different trajectories. State which event begins the timer and what quantity is held. Review: Equation 10G discussion; Application 5A.7. Source: Equation 10G. Carry state across a target change (p. 2523)
Why this term is required: “hang” completes the stated technical proposition.
Question context: A fixed hold before release is represented as an explicit _____ state
Basis and qualification: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.
Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

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V011-C05-FIB-060. A burst lasting 0.2 time constants completes approximately _____ percent of its target control step.

Answer: 18.13. One minus exp of minus 0.2 is approximately 0.181269. A steady-state gain value therefore does not describe most of that control trajectory. Review: Equation 10B; Application 5A.8. Source: Equation 10B. Control voltage and residual (p. 2521)

Why this term is required: “18.13” completes the stated technical proposition.

Question context: A burst lasting 0.2 time constants completes approximately _____ percent of its target control step

Basis and qualification: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.8: Compare burst duration with control settling.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Application 5A.8: Compare burst duration with control settling.

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V011-C05-FIB-061. A time-resolved gain correction needs control telemetry _____ with the RF observations.

Answer: synchronized or time-aligned. Otherwise a valid calibration can be applied to the wrong instant. Retain or correct the relative delay and its applicable uncertainty. Review: Application 5A.3. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

Why this term is required: “synchronized or time-aligned” completes the stated technical proposition.

Question context: A time-resolved gain correction needs control telemetry _____ with the RF observations

Basis and qualification: Chapter 5 — Application 5A.3: Convert a control state into an output level.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level.

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V011-C05-FIB-062. Applying the final gain to an entire unsettled record discards the control's _____ history.

Answer: time or state. The early gain can differ materially from the final value. A fixed end-state correction cannot reproduce the changing input/output transfer.

Review: Application 5A.3. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

Why this term is required: "time or state" completes the stated technical proposition.

Question context: Applying the final gain to an entire unsettled record discards the control's _____ history

Basis and qualification: Chapter 5 — Application 5A.3: Convert a control state into an output level.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level.

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V011-C05-FIB-063. The exact sampled coefficient is the exponential of the _____ sample-interval-to-time-constant ratio.

Answer: negative. Both interval and time constant are positive, so the coefficient is between zero and one. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why this term is required: “negative” completes the stated technical proposition.

Question context: The exact sampled coefficient is the exponential of the _____ sample-interval-to-time-constant ratio

Basis and qualification: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-FIB-064. For a sample interval equal to the time constant times $\ln(3)$, the exact residual multiplier is _____.

Answer: one third. Substitution gives exp of minus $\ln(3)$. The result is exact for the stipulated continuous one-pole model. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why this term is required: “one third” completes the stated technical proposition.

Question context: For a sample interval equal to the time constant times the exact residual multiplier is _____

Basis and qualification: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-FIB-065. With current state 0.3 V, target 0.9 V and exact coefficient one third, the next state is _____ V.

Answer: 0.7. The weights give 0.1 V from the current state plus 0.6 V from the target. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why this term is required: “0.7” completes the stated technical proposition.

Question context: With current state 0.3 V, target 0.9 V and exact coefficient one third, the next state is _____ V

Basis and qualification: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-FIB-066. For a positive interval and time constant, the exact coefficient lies strictly between _____ and _____.

Answer: zero; one. These bounds make the update a convex combination and preserve the residual sign. The endpoints are limiting cases, not finite positive-interval values. Review: Equation 10H. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why this term is required: “zero; one” completes the stated technical proposition.

Question context: For a positive interval and time constant, the exact coefficient lies strictly between _____ and _____

Basis and qualification: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence.

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V011-C05-FIB-067. An Euler interval equal to 0.4 time constants gives residual multiplier _____.

Answer: 0.6. Forward Euler uses one minus the normalized interval. It is an approximation to the exact exponential coefficient. Review: Equation 10I. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why this term is required: “0.6” completes the stated technical proposition.

Question context: An Euler interval equal to 0.4 time constants gives residual multiplier _____

Basis and qualification: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-FIB-068. An Euler interval equal to 1.2 time constants gives residual multiplier _____.

Answer: minus 0.2. The magnitude is less than one, so the sequence decays, but the negative sign makes it alternate across the target. Review: Equation 10I. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why this term is required: “minus 0” completes the stated technical proposition.

Question context: An Euler interval equal to 1.2 time constants gives residual multiplier _____

Basis and qualification: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-FIB-069. At an Euler interval of exactly two time constants, residual magnitude remains _____ while its sign alternates.

Answer: constant. The multiplier is minus one. This boundary does not provide asymptotic decay and is excluded from the strict stability interval. Review: Equation 10I. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why this term is required: “constant” completes the stated technical proposition.

Question context: At an Euler interval of exactly two time constants, residual magnitude remains _____ while its sign alternates

Basis and qualification: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-FIB-070. Forward-Euler asymptotic stability requires a positive normalized interval strictly less than _____.

Answer: two. The residual multiplier must have magnitude below one. Equality at two leaves undamped alternation. Review: Equation 10I. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why this term is required: “two” completes the stated technical proposition.

Question context: Forward-Euler asymptotic stability requires a positive normalized interval strictly less than _____

Basis and qualification: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-FIB-071. A nonalternating Euler residual requires the positive normalized interval to be no greater than _____.

Answer: one. At one the approximation sets the residual to zero in a single step; below one its multiplier is positive. This condition is stricter than stability alone.

Review: Equation 10I. Source: Equation 10I. Forward-Euler residual and its validity range (p. 2524)

Why this term is required: “one” completes the stated technical proposition.

Question context: A nonalternating Euler residual requires the positive normalized interval to be no greater than _____

Basis and qualification: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-FIB-072. A negative Euler residual multiplier can create simulated target _____ absent from the physical one-pole trajectory.

Answer: crossings or alternation. The exact continuous residual keeps its sign. Numerical oscillation must be distinguished from measured loop behavior. Review: Equations 10H and 10I. Source: Equation 10H. Exact sampled-state recurrence (p. 2524)

Why this term is required: “crossings or alternation” completes the stated technical proposition.

Question context: A negative Euler residual multiplier can create simulated target _____ absent from the physical one-pole trajectory

Basis and qualification: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

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V011-C05-FIB-073. An unstable numerical approximation does not by itself establish an unstable physical _____.

Answer: loop or system. The chapter's large-step Euler example diverges despite a stable positive-time-constant differential equation. Check the implementation before assigning a receiver fault. Review: Application 5A.9. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

Why this term is required: "loop or system" completes the stated technical proposition.

Question context: An unstable numerical approximation does not by itself establish an unstable physical _____

Basis and qualification: Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

Review: Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

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V011-C05-FIB-074. A physically discrete controller requires its own governing _____ rather than automatic adoption of the sampled continuous law.

Answer: recurrence. Delays, quantization and switching can change its dynamics. Exactness of Equation 10H is conditional on the model from which it was derived. Review: Application 5A.9. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

Why this term is required: “recurrence” completes the stated technical proposition.

Question context: A physically discrete controller requires its own governing _____ rather than automatic adoption of the sampled continuous law

Basis and qualification: Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

Review: Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

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V011-C05-FIB-075. Because the exponential coefficient is positive, initial-state interval propagation preserves voltage endpoint _____.

Answer: order. Each endpoint undergoes the same increasing affine transformation. A subsequent negative gain slope can reverse gain order. Review: Equation 10J. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)
Why this term is required: “order” completes the stated technical proposition.
Question context: Because the exponential coefficient is positive, initial-state interval propagation preserves voltage endpoint _____
Basis and qualification: Chapter 5 — Equation 10J. Propagation of an initial-state interval.
Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-FIB-076. Initial voltage 0.2 through 0.4 V, target 0.8 V and factor 0.5 give the state interval _____ through _____ V.

Answer: 0.5; 0.6. Half the lower and upper initial displacements remain, giving 0.8 minus 0.3 and 0.8 minus 0.2 V. Review: Equation 10J. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why this term is required: “0” completes the stated technical proposition.

Question context: Initial voltage 0.2 through 0.4 V, target 0.8 V and factor 0.5 give the state interval _____ through _____ V

Basis and qualification: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-FIB-077. The propagated interval 0.5 through 0.6 V has width _____ V.

Answer: 0.1. Subtract the lower bound from the upper bound. This is a deterministic state width, not a standard deviation. Review: Equation 10J. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why this term is required: “0.1” completes the stated technical proposition.

Question context: The propagated interval 0.5 through 0.6 V has width _____ V

Basis and qualification: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-FIB-078. Gain is 30 dB at 0.2 V with slope minus 20 dB/V. Mapping voltage 0.5 through 0.6 V gives ordered gain bounds _____ through _____ dB.

Answer: 22; 24. The larger voltage gives 22 dB and the smaller gives 24 dB. Reorder the mapped endpoints when writing the gain interval. Review: Equations 10C and 10J. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “22; 24” completes the stated technical proposition.

Question context: Gain is 30 dB at 0.2 V with slope minus 20 dB/V. Mapping voltage 0.5 through 0.6 V gives ordered gain bounds _____ through _____ dB

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-FIB-079. A 0.1 V state interval under a slope magnitude of 20 dB/V has gain width _____ dB.

Answer: 2. Multiply the nonnegative width by the absolute slope. This agrees with the interval from 22 through 24 dB in the preceding case. Review: Equations 10C and 10J. Source: Equation 10C. Local control-to-gain law (p. 2522)

Why this term is required: “2” completes the stated technical proposition.

Question context: A 0.1 V state interval under a slope magnitude of 20 dB/V has gain width _____ dB

Basis and qualification: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-FIB-080. The initial-state interval in Equation 10J does not automatically include uncertainty in the target or time _____.

Answer: constant. Those parameters were held fixed in that propagation. They need additional treatment in the full measurement model. Review: Equation 10J qualification. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)
Why this term is required: “constant” completes the stated technical proposition.
Question context: The initial-state interval in Equation 10J does not automatically include uncertainty in the target or time _____
Basis and qualification: Chapter 5 — Equation 10J. Propagation of an initial-state interval.
Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-FIB-081. With a negative gain slope, the upper voltage bound corresponds to the _____ gain bound.

Answer: lower. The decreasing affine map reverses order. Keeping the original voltage order would mislabel minimum and maximum gain. Review: Application 5A.10. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

Why this term is required: “lower” completes the stated technical proposition.

Question context: With a negative gain slope, the upper voltage bound corresponds to the _____ gain bound

Basis and qualification: Chapter 5 — Application 5A.10: Propagate an initial-state interval.

Review: Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-FIB-082. Deterministic interval propagation does not require assigning a probability _____ to the initial state.

Answer: distribution. It carries all included values through the stated map. A probabilistic uncertainty claim would need additional assumptions and interpretation. Review: Equation 10J; Application 5A.10. Source: Equation 10J. Propagation of an initial-state interval (p. 2524)

Why this term is required: “distribution” completes the stated technical proposition.

Question context: Deterministic interval propagation does not require assigning a probability _____ to the initial state

Basis and qualification: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-FIB-083. A strong off-channel signal can suppress a desired weak signal through a _____ AGC path.

Answer: shared. The controlling detector may admit a wider band than the displayed channel. Display absence does not prove absence from the control input.

Review: Automatic Gain Control and Hidden State. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

Why this term is required: “shared” completes the stated technical proposition.

Question context: A strong off-channel signal can suppress a desired weak signal through a _____ AGC path

Basis and qualification: Chapter 5 — Automatic Gain Control and Hidden State.

Review: Chapter 5 — Automatic Gain Control and Hidden State.

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V011-C05-FIB-084. RMS detection must remain within applicable bandwidth and _____-factor limits for the actual waveform.

Answer: crest. High peaks relative to RMS level can violate physical detector conditions even when the average input seems acceptable. Review: Logarithmic Amplifiers, Detectors, and Scaling. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

Why this term is required: “crest” completes the stated technical proposition.

Question context: RMS detection must remain within applicable bandwidth and _____-factor limits for the actual waveform

Basis and qualification: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

Review: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

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V011-C05-FIB-085. Video bandwidth describes filtering after _____ or in the display path.

Answer: detection. Its smoothing can alter trace timing and peaks without an identical change to earlier RF or IF admission. Review: Chapter Glossary: Video bandwidth. Source: §8.1.6 Video bandwidth, smoothing, and averaging (p. 4381)

Why this term is required: “detection” completes the stated technical proposition.

Question context: Video bandwidth describes filtering after _____ or in the display path

Basis and qualification: Chapter 5 — VIDEO BANDWIDTH (glossary).

Review: Chapter 5 — VIDEO BANDWIDTH (glossary).

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V011-C05-FIB-086. To compute physical mean power from changing dB levels, convert to _____ power before averaging.

Answer: linear. A mean of logarithms represents a different quantity. The temporal weights and applicable detector selection must also be defined. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “linear” completes the stated technical proposition.

Question context: To compute physical mean power from changing dB levels, convert to _____ power before averaging

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-FIB-087. Equal-duration levels of 10 mW and 100 mW have physical mean power _____ mW.

Answer: 55. The arithmetic mean is taken in the linear power domain. Its logarithmic level is approximately 17.40 dBm, not the 15 dBm mean of the two dBm levels. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “55” completes the stated technical proposition.

Question context: Equal-duration levels of 10 mW and 100 mW have physical mean power _____ mW

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-FIB-088. Equal-duration levels of 0 dBm and 10 dBm have mean power 5.5 mW, corresponding to approximately _____ dBm.

Answer: 7.404. Ten times the base-ten logarithm of 5.5 gives 7.4036 dBm. Averaging the two logarithmic levels would instead give 5 dBm. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “7.404” completes the stated technical proposition.

Question context: Equal-duration levels of 0 dBm and 10 dBm have mean power 5.5 mW, corresponding to approximately _____ dBm

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-FIB-089. A peak detector can retain a rare _____ that an averaging operation weights only briefly.

Answer: excursion. Peak and mean operations answer different questions about the waveform. Their results need not agree even when both are functioning properly. Review: Logarithmic Amplifiers, Detectors, and Scaling. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

Why this term is required: “excursion” completes the stated technical proposition.

Question context: A peak detector can retain a rare _____ that an averaging operation weights only briefly

Basis and qualification: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

Review: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

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V011-C05-FIB-090. A sample trace can _____ a short event when its selection times do not capture the excursion.

Answer: miss. Absence in that trace is not proof of absence from the physical waveform. Dwell, selection and timing are relevant. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “miss” completes the stated technical proposition.

Question context: A sample trace can _____ a short event when its selection times do not capture the excursion

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-FIB-091. At the low end of a log detector's range, noise and _____ can dominate the response.

Answer: offsets. A high-level calibrated slope does not justify unlimited downward extrapolation. The actual floor and operating range must be known. Review: Logarithmic Amplifiers, Detectors, and Scaling. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

Why this term is required: "offsets" completes the stated technical proposition.

Question context: At the low end of a log detector's range, noise and _____ can dominate the response

Basis and qualification: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

Review: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

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V011-C05-FIB-092. A flat output at high input can arise from AGC, limiting, clipping, log-detector _____ or software normalization.

Answer: saturation. The plateau alone does not distinguish those mechanisms. A known reference and controlled path observations help identify valid transfer.

Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “saturation” completes the stated technical proposition.

Question context: A flat output at high input can arise from AGC, limiting, clipping, log-detector _____ or software normalization

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-FIB-093. Calibrated gain telemetry cannot recreate signal information lost through _____.

Answer: clipping. The control-state record and the RF waveform are different observations. Noninvertible saturation destroys distinctions that a gain correction cannot restore. Review: Application 5A.3. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

Why this term is required: “clipping” completes the stated technical proposition.

Question context: Calibrated gain telemetry cannot recreate signal information lost through _____

Basis and qualification: Chapter 5 — Application 5A.3: Convert a control state into an output level.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level.

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V011-C05-FIB-094. The chapter's verification sequence begins with _____ gain before testing the intended automatic-control dynamics.

Answer: fixed. Holding avoidable state changes supports interpretation of tones, noise and bursts. Automatic mode is then tested under its own conditions. Review: Verify the detector and control path as part of the IF result. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: "fixed" completes the stated technical proposition.

Question context: The chapter's verification sequence begins with _____ gain before testing the intended automatic-control dynamics

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-FIB-095. Digital IF response can depend on sample clocks, coefficients, scaling and _____.

Answer: firmware. Digital implementation does not make its physical frequency mapping or numerical transfer permanently invariant. Review: IF Alignment, Calibration, and Failure Localization. Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

Why this term is required: “firmware” completes the stated technical proposition.

Question context: Digital IF response can depend on sample clocks, coefficients, scaling and _____

Basis and qualification: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

Review: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

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V011-C05-FIB-096. Regression tests should exercise automatic filter and gain _____ because behavior can change when a mode switches.

Answer: boundaries. A passing point far from a transition does not validate switching, carried state or the new path. Test the conditions affected by the change. Review: IF Acceptance and Regression Tests. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

Why this term is required: “boundaries” completes the stated technical proposition.

Question context: Regression tests should exercise automatic filter and gain _____ because behavior can change when a mode switches

Basis and qualification: Chapter 5 — IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-FIB-097. Authorized observations before and after an IF stage can help _____ a response defect.

Answer: localize. Different stimuli exercise frequency response, detection and dynamics. The observation planes and injected path must be retained. Review: IF Alignment, Calibration, and Failure Localization. Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

Why this term is required: “localize” completes the stated technical proposition.

Question context: Authorized observations before and after an IF stage can help _____ a response defect

Basis and qualification: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

Review: Chapter 5 — IF Alignment, Calibration, and Failure Localization.

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V011-C05-FIB-098. A passing center-frequency tone cannot by itself validate filter skirts, group delay or transient _____.

Answer: recovery. The path has more degrees of behavior than one amplitude point can test. Representative spectral and temporal cases are needed. Review: IF Acceptance and Regression Tests. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

Why this term is required: “recovery” completes the stated technical proposition.

Question context: A passing center-frequency tone cannot by itself validate filter skirts, group delay or transient _____

Basis and qualification: Chapter 5 — IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-FIB-099. A closing check assesses the functions it exercises at the _____ of that check.

Answer: time. It cannot alone establish uninterrupted validity during an earlier acquisition, especially across overload or state changes. Review: IF Acceptance and Regression Tests; Chapter 1 closing-verification qualification. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

Why this term is required: “time” completes the stated technical proposition.

Question context: A closing check assesses the functions it exercises at the _____ of that check

Basis and qualification: Chapter 5 — IF Acceptance and Regression Tests; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 5 — IF Acceptance and Regression Tests; Chapter 1 — Evidence Record and Closing Verification.

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V011-C05-FIB-100. A release statement should retain the tested configurations, waveform domain, criteria and unresolved _____.

Answer: limits. Bounded capability is the defensible outcome of a finite acceptance matrix. A local fit does not establish every hidden state or possible waveform.

Review: IF Acceptance and Regression Tests. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

Why this term is required: “limits” completes the stated technical proposition.

Question context: A release statement should retain the tested configurations, waveform domain, criteria and unresolved _____

Basis and qualification: Chapter 5 — IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Acceptance and Regression Tests.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C05-ESSAY-001. Derive the constant-target solution of Model 5A from its state equation. Explain which measured behaviors would contradict one uninterrupted segment and which physical claims the solution does not establish.

- Opening: Present a thesis that answers this precise question: Derive the constant-target solution of Model 5A from its state equation. Identify which evidence would falsify the proposed conclusion Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Core terminology and scope: Define solution, equation, contradict in the question's particular technical setting; explain how uninterrupted, segment, claims differ if that distinction would change the analysis of "Derive the constant-target solution of Model 5A from its state equation" Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the residual as the control voltage minus the fixed target Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the constant-target solution of Model 5A from its state equation to the claimed result, following "Application 5A.5: Identify a time constant from two signed residuals"; name the intermediate states and measurable outputs Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the constant-target solution of Model 5A from its state equation. Its derivative is minus the residual divided by the positive time constant Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation” that resolves the question about the constant-target solution of Model 5A from its state equation; derive the relevant result with units and stated validity conditions Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the constant-target solution of Model 5A from its state equation. Integration gives where is the initial residual; adding the target gives the voltage solution in Equation 10B Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Worked application or illustrative case: Build a worked example of “the constant-target solution of Model 5A from its state equation”, addressing this associated condition: Explain which measured behaviors would contradict one uninterrupted segment and which physical claims.... Define the residual as the control voltage minus the fixed target Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the constant-target solution of Model 5A from its state equation”. Using “Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation”, specify a discriminator and the result expected under each explanation Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the constant-target solution of Model 5A from its state equation, including the effect of missing measurements and inconsistent operating conditions Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Scholarly synthesis and implications: Explain what the result about the constant-target solution of Model 5A from its state equation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Closing: Conclude by answering “Derive the constant-target solution of Model 5A from its state equation” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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V011-C05-ESSAY-002. A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz. Calculate loaded Q and the explicitly defined ratio of minus-60 dB to minus-3 dB width. Explain why those values cannot alone validate a burst-peak measurement.

- Opening: Present a thesis that answers this precise question: A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz. Identify which evidence would falsify the proposed conclusion Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
- Core terminology and scope: Define centered, width, Calculate in the question's particular technical setting; explain how loaded, explicitly, validate differ if that distinction would change the analysis of "A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz" Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use consistent frequency units to obtain Q equal to 10.7 divided by 0.180, approximately 59.44 Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz to the claimed result, following "Choose an IF path for the quantity being measured"; name the intermediate states and measurable outputs Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz. The stated width ratio is 720 divided by 180, or 4 Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Intermediate-frequency detector memory, settling and comparable measurement statistics” that resolves the question about A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz; derive the relevant result with units and stated validity conditions Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz. Label its two attenuation levels explicitly; do not silently compare it with a shape factor defined using minus-6 dB width Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
- Worked application or illustrative case: Build a worked example of “A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz”, addressing this associated condition: Calculate loaded Q and the explicitly defined ratio of minus-60 dB to minus-3 dB width. Use consistent frequency units to obtain Q equal to 10.7 divided by 0.180, approximately 59.44 Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz”. Using “Intermediate-frequency detector memory, settling and comparable measurement statistics”, specify a discriminator and the result expected under each explanation Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz, including the effect of missing measurements and inconsistent operating conditions Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Scholarly synthesis and implications: Explain what the result about A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
- Closing: Conclude by answering “A filter is centered at 10.7 MHz, with minus-3 dB width 180 kHz and minus-60 dB width 720 kHz” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

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V011-C05-ESSAY-003. Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant. Gain is 32 dB at 0.15 V with slope minus 35 dB/V, valid from 0.10 through 0.80 V. For fixed minus-72 dBm input, calculate voltage, gain and output at 1.2 ms, the final output, and the wait for gain error no larger than 0.2 dB.

- Opening: Present a thesis that answers this precise question: Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant. Identify which evidence would falsify the proposed conclusion Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Core terminology and scope: Define starts, approaches, slope in the question's particular technical setting; explain how calculate, wait, larger differ if that distinction would change the analysis of "Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant" Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The elapsed ratio is 1.5, so the remaining voltage residual is minus 0.6 times exp of minus 1.5 V Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant to the claimed result, following "Application 5A.3: Convert a control state into an output level"; name the intermediate states and measurable outputs Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant. Explain which changes in Gain is 32 dB at 0.15 V with slope minus 35 dB/V, valid from 0.10 through 0.80 V would invalidate an unqualified comparison Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.10: Propagate an initial-state interval” that resolves the question about Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant; derive the relevant result with units and stated validity conditions Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant. Subtract the reference voltage and apply the signed slope to obtain 15.68573 dB gain; output is minus 56.31427 dBm Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Worked application or illustrative case: Build a worked example of “Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant”, addressing this associated condition: Gain is 32 dB at 0.15 V with slope minus 35 dB/V, valid from 0.10 through 0.80 V. The elapsed ratio is 1.5, so the remaining voltage residual is minus 0.6 times exp of minus 1.5 V Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant”. Using “Application 5A.10: Propagate an initial-state interval”, specify a discriminator and the result expected under each explanation Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant, including the effect of missing measurements and inconsistent operating conditions Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Scholarly synthesis and implications: Explain what the result about Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Closing: Conclude by answering “Control starts at 0.15 V and approaches 0.75 V with a 0.8 ms time constant” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

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V011-C05-ESSAY-004. A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V. The initial control is 0.2 V, the new target remains in range, and the identified time constant is 1.2 ms. Find the target, the control at 0.6 ms, and the remaining output rise. Explain the control-polarity check.

- Opening: Present a thesis that answers this precise question: A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V. Identify which evidence would falsify the proposed conclusion Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Core terminology and scope: Define step, slope, target in the question's particular technical setting; explain how identified, remaining, rise differ if that distinction would change the analysis of "A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V" Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Restoring the previous output requires a gain change of minus 15 dB Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V to the claimed result, following "Application 5A.10: Propagate an initial-state interval"; name the intermediate states and measurable outputs Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V. Dividing by minus 30 dB/V gives a positive 0.5 V target change, so the target is 0.7 V Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.2: Set a gain-error settling requirement” that resolves the question about A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V; derive the relevant result with units and stated validity conditions Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V. At half a time constant the state is 0.3967347 V Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Worked application or illustrative case: Build a worked example of “A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V”, addressing this associated condition: The initial control is 0.2 V, the new target remains in range, and the identified time constant is 1.2 ms. Restoring the previous output requires a gain change of minus 15 dB Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A 15 dB input step must be leveled by a

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gain map with slope minus 30 dB/V". Using "Application 5A.2: Set a gain-error settling requirement", specify a discriminator and the result expected under each explanation Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V, including the effect of missing measurements and inconsistent operating conditions Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Scholarly synthesis and implications: Explain what the result about A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Closing: Conclude by answering "A 15 dB input step must be leveled by a gain map with slope minus 30 dB/V" using only the demonstrated evidence; state the remaining decisive verification step Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

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V011-C05-ESSAY-005. Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms. Identify the time constant and initial residual, and predict the residual at 2.1 ms. Explain how an additional measured point should be used.

- Opening: Present a thesis that answers this precise question: Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms. Identify which evidence would falsify the proposed conclusion Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Core terminology and scope: Define Residuals, target, initial in the question's particular technical setting; explain how predict, point, used differ if that distinction would change the analysis of "Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms" Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The two residuals have the same sign and decrease in magnitude Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms to the claimed result, following "Application 5A.10: Propagate an initial-state interval"; name the intermediate states and measurable outputs Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms. Their ratio is five over a 1.2 ms separation, giving a time constant of 1.2 divided by or 0.7456019 ms Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation” that resolves the question about Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms; derive the relevant result with units and stated validity conditions Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms. Extrapolating the first residual backward gives approximately minus 0.2243023 V at the time origin Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Worked application or illustrative case: Build a worked example of “Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms”, addressing this associated condition: Identify the time constant and initial residual, and predict the residual at 2.1 ms. The two residuals have the same sign and decrease in magnitude Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms”. Using “Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation”, specify a discriminator and the result expected under each explanation Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms, including the effect of missing measurements and inconsistent operating conditions Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Scholarly synthesis and implications: Explain what the result about Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Closing: Conclude by answering “Residuals about one fixed target are minus 0.15 V at 0.3 ms and minus 0.03 V at 1.5 ms” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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V011-C05-ESSAY-006. Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant. Calculate both terminal states and quantify the error in restarting the second segment at 0.9 V.

- Opening: Present a thesis that answers this precise question: Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant. Identify which evidence would falsify the proposed conclusion Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Core terminology and scope: Define Begin, approach, Calculate in the question's particular technical setting; explain how terminal, quantify, segment differ if that distinction would change the analysis of "Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant" Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The first segment leaves the initial minus 0.8 V residual multiplied by exp of minus two thirds Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant to the claimed result, following "Application 5A.10: Propagate an initial-state

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interval"; name the intermediate states and measurable outputs Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant. Its terminal state is approximately 0.4892663 V Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 5A.5: Identify a time constant from two signed residuals" that resolves the question about Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant; derive the relevant result with units and stated validity conditions Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant. Use that value as the second initial state: the remaining displacement from 0.3 V is 0.1892663 V times exp of minus 0.8 divided by 1.5 Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Worked application or illustrative case: Build a worked example of "Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant", addressing this associated condition: Calculate both

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terminal states and quantify the error in restarting the second segment at 0.9 V. The first segment leaves the initial minus 0.8 V residual multiplied by exp of minus two thirds Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant”. Using “Application 5A.5: Identify a time constant from two signed residuals”, specify a discriminator and the result expected under each explanation Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant, including the effect of missing measurements and inconsistent operating conditions Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Scholarly synthesis and implications: Explain what the result about Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Closing: Conclude by answering “Begin at 0.1 V, approach 0.9 V for 0.4 ms with a 0.6 ms time constant, then approach 0.3 V for 0.8 ms with a 1.5 ms time constant” using only the demonstrated evidence;

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state the remaining decisive verification step Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

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V011-C05-ESSAY-007. Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant. It then holds its attained value for 0.4 ms, followed by release toward 0.2 V for 0.8 ms with a 1.6 ms constant. Find the final state and compare the result obtained by ignoring the hold.

- Opening: Present a thesis that answers this precise question: Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant. Identify which evidence would falsify the proposed conclusion Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Core terminology and scope: Define holds, attained, followed in the question's particular technical setting; explain how release, obtained, ignoring differ if that distinction would change the analysis of "Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant" Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Attack ends at approximately 0.6661219 V, calculated from a 1.5-time-constant segment Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant to the claimed result, following "Application 5A.6: Carry state across two target intervals"; name the intermediate states and measurable outputs Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant. The explicitly stipulated hold retains that state for 0.4 ms Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.5: Identify a time constant from two signed residuals” that resolves the question about Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant; derive the relevant result with units and stated validity conditions Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant. Release then lasts only 0.8 ms, half its own time constant, giving final state approximately 0.4827172 V Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Worked application or illustrative case: Build a worked example of “Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant”, addressing this associated condition: It then holds its attained value for 0.4 ms, followed by release toward 0.2 V for 0.8 ms with a 1.6 ms.... Attack ends at approximately 0.6661219 V, calculated from a 1.5-time-constant segment Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant”. Using “Application 5A.5: Identify a time constant from two signed residuals”, specify a discriminator and the result expected under each explanation Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant, including the effect of missing measurements and inconsistent operating conditions Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Scholarly synthesis and implications: Explain what the result about Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Closing: Conclude by answering “Control starts at 0.2 V and attacks toward 0.8 V for 0.3 ms with a 0.2 ms constant” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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V011-C05-ESSAY-008. A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms. The local slope is minus 40 dB/V and the input has risen by 28 dB. Calculate step completion, terminal voltage, gain change, remaining output rise and 95-percent settling time. State the main physical limitation of the calculation.

- Opening: Present a thesis that answers this precise question: A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms. Identify which evidence would falsify the proposed conclusion Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Core terminology and scope: Define Calculate, terminal, remaining in the question's particular technical setting; explain how rise, main, limitation differ if that distinction would change the analysis of "A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms" Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The elapsed ratio is 0.0625, so step completion is one minus exp of minus 0.0625, approximately 6.05869 percent Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms to the claimed result, following "Application 5A.8: Compare burst duration with control settling"; name the intermediate states

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and measurable outputs Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms. The voltage reaches approximately 0.2424109 V Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.4: Check the required control polarity after a level step” that resolves the question about A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms; derive the relevant result with units and stated validity conditions Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms. Its 0.0424109 V increase changes gain by minus 1.69643 dB, leaving an output rise of approximately 26.30357 dB under the valid small-signal model Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Worked application or illustrative case: Build a worked example of “A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms”, addressing this associated condition: The local slope is minus 40 dB/V and the input has risen by 28 dB. The elapsed ratio is 0.0625, so step completion is one minus exp of

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minus 0.0625, approximately 6.05869 percent Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms”. Using “Application 5A.4: Check the required control polarity after a level step”, specify a discriminator and the result expected under each explanation Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms, including the effect of missing measurements and inconsistent operating conditions Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Scholarly synthesis and implications: Explain what the result about A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Closing: Conclude by answering “A 0.25 ms burst changes the control target from 0.2 to 0.9 V, but the time constant is 4 ms” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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V011-C05-ESSAY-009. For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler. Starting with a 0.6 V residual, calculate the residual after five steps and classify both sequences.

- Opening: Present a thesis that answers this precise question: For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler. Starting with a 0.6 V residual, calculate the residual after five steps and…. Identify which evidence would falsify the proposed conclusion Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Core terminology and scope: Define recurrence, Euler, Starting in the question's particular technical setting; explain how calculate, steps, sequences differ if that distinction would change the analysis of "For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler. Starting with a 0.6 V residual, calculate the residual after five steps and…" Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The normalized interval is 1.5 Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler to the claimed result, following "Application 5A.5: Identify a time constant from two signed residuals"; name the

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intermediate states and measurable outputs Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler. The exact residual coefficient is exp of minus 1.5, approximately 0.2231302; after five steps the residual is 0.6 times exp of minus 7.5, approximately 0.000331851 V Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.1: Read a voltage step and its 95 percent settling time” that resolves the question about For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler; derive the relevant result with units and stated validity conditions Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler. Its sign stays positive and its magnitude decays monotonically Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Worked application or illustrative case: Build a worked example of “For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler”, addressing this associated condition: Starting with a 0.6 V residual, calculate the residual after

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five steps and classify both sequences. The normalized interval is 1.5 Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler”. Using “Application 5A.1: Read a voltage step and its 95 percent settling time”, specify a discriminator and the result expected under each explanation Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler, including the effect of missing measurements and inconsistent operating conditions Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Scholarly synthesis and implications: Explain what the result about For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)
- Closing: Conclude by answering “For a 0.8 ms time constant sampled every 1.2 ms, compare the exact recurrence with forward Euler. Starting with a 0.6 V residual, calculate the residual after five steps and…” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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V011-C05-ESSAY-010. The initial voltage lies between 0.15 and 0.25 V. The fixed target is 0.65 V, time constant 0.5 ms, and elapsed time 1 ms. Gain is 30 dB at 0.15 V with slope minus 40 dB/V. Find the state and gain intervals, and determine the wait needed for every included state to lie within 0.2 dB of final gain.

- Opening: Present a thesis that answers this precise question: The initial voltage lies between 0.15 and 0.25 V. Identify which evidence would falsify the proposed conclusion Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Core terminology and scope: Define initial, target, elapsed in the question's particular technical setting; explain how slope, wait, included differ if that distinction would change the analysis of "The initial voltage lies between 0.15 and 0.25 V" Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The exponential factor is exp of minus two Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting The initial voltage lies between 0.15 and 0.25 V to the claimed result, following "Application 5A.2: Set a gain-error settling requirement"; name the intermediate states and measurable outputs Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for The initial voltage lies between 0.15 and 0.25 V. Mapping the initial

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endpoints gives approximately 0.5823324 through 0.5958659 V Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.3: Convert a control state into an output level” that resolves the question about The initial voltage lies between 0.15 and 0.25 V; derive the relevant result with units and stated validity conditions Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Evidence and method: Specify the native observations, control records and calculations that would resolve The initial voltage lies between 0.15 and 0.25 V. The negative slope reverses endpoint order in gain, giving approximately 12.16536 through 12.70671 dB; its width is 0.541341 dB Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Worked application or illustrative case: Build a worked example of “The initial voltage lies between 0.15 and 0.25 V”, addressing this associated condition: The fixed target is 0.65 V, time constant 0.5 ms, and elapsed time 1 ms. The exponential factor is exp of minus two Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “The initial voltage lies between 0.15 and 0.25 V”. Using “Application 5A.3: Convert a control state into an output level”, specify a discriminator and the result expected under each explanation Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to The initial voltage lies between 0.15 and 0.25 V, including the effect of missing measurements and inconsistent operating conditions Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Scholarly synthesis and implications: Explain what the result about The initial voltage lies between 0.15 and 0.25 V authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Closing: Conclude by answering “The initial voltage lies between 0.15 and 0.25 V” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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V011-C05-ESSAY-011. A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively. Calculate mean output power in logarithmic form and compare it with adding the time-averaged dB gain. Explain the correct order for input-referred waveform correction.

- Opening: Present a thesis that answers this precise question: A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively. Identify which evidence would falsify the proposed conclusion Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Core terminology and scope: Define lasting, respectively, Calculate in the question's particular technical setting; explain how logarithmic, form, adding differ if that distinction would change the analysis of "A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively" Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The linear power gains are 1, 10 and 100 Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively to the claimed result, following "Application 5A.10: Propagate an initial-state interval"; name the intermediate states and measurable outputs Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively. With the stated durations, mean power gain is the weighted sum 1 plus 20 plus 100 divided by 4, or 30.25 Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Detector dynamics and intermediate-frequency filters as temporally extended measurement operators” that resolves the question about A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively; derive the relevant result with units and stated validity conditions Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively. Its logarithmic equivalent is approximately 14.80725 dB, so mean output is minus 45.19275 dBm Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Worked application or illustrative case: Build a worked example of “A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively”, addressing this associated condition: Calculate mean output power in logarithmic form and compare it with adding the time-averaged dB gain. The

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linear power gains are 1, 10 and 100 Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively”. Using “Detector dynamics and intermediate-frequency filters as temporally extended measurement operators”, specify a discriminator and the result expected under each explanation Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively, including the effect of missing measurements and inconsistent operating conditions Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)
- Scholarly synthesis and implications: Explain what the result about A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Closing: Conclude by answering “A fixed minus-60 dBm input is observed through valid gain states of 0, 10 and 20 dB lasting 1, 2 and 1 ms respectively” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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V011-C05-ESSAY-012. Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians. Calculate the corresponding constant group delay. The amplitude response varies by plus or minus 1 dB across that band. Assess a claim that every waveform in the band emerges as an unchanged delayed copy.

- Opening: Present a thesis that answers this precise question: Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians. Identify which evidence would falsify the proposed conclusion Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Core terminology and scope: Define decreases, linearly, Calculate in the question's particular technical setting; explain how varies, delayed, copy differ if that distinction would change the analysis of "Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians" Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Convert the frequency span to angular-frequency span by multiplying 200000 Hz by two pi Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians to the claimed result, following "5. Additional study: IF filters as dynamical systems and the meaning of transient measurement validity"; name the intermediate states and

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measurable outputs Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians. The negative phase slope divided by that span gives positive group delay approximately 3 microseconds Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.10: Propagate an initial-state interval” that resolves the question about Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians; derive the relevant result with units and stated validity conditions Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians. State that the finite-difference calculation represents a constant slope only because linear phase has been stipulated Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Worked application or illustrative case: Build a worked example of “Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians”, addressing this associated condition: Calculate the corresponding constant group delay. Convert the frequency span to angular-frequency span by

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multiplying 200000 Hz by two pi Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians”. Using “Application 5A.10: Propagate an initial-state interval”, specify a discriminator and the result expected under each explanation Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians, including the effect of missing measurements and inconsistent operating conditions Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Scholarly synthesis and implications: Explain what the result about Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Closing: Conclude by answering “Across a measurable 200 kHz band, coherent unwrapped phase decreases linearly by 3.769911 radians” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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V011-C05-ESSAY-013. Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the positive time constant lies between 0.8 and 1.2 ms. Find a wait covering all these possibilities for a 0.2 dB gain-error tolerance. State what uncertainty this result still excludes.

- Opening: Present a thesis that answers this precise question: Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the positive time constant lies between 0.8 and 1.2 ms. Identify which evidence would falsify the proposed conclusion Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Core terminology and scope: Define Initial, target, slope in the question's particular technical setting; explain how wait, tolerance, excludes differ if that distinction would change the analysis of "Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the positive time constant lies between 0.8 and 1.2 ms" Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The farthest initial endpoint is 0.1 V, with 0.5 V error, giving a maximum initial gain error of 25 dB Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the… to the claimed result,

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following “Application 5A.10: Propagate an initial-state interval”; name the intermediate states and measurable outputs Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the…. The slowest admissible decay uses 1.2 ms Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.4: Check the required control polarity after a level step” that resolves the question about Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the…; derive the relevant result with units and stated validity conditions Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the…. The conservative wait is therefore 1.2 times ln of 125 ms, approximately 5.79398 ms Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Worked application or illustrative case: Build a worked example of “Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the…”, addressing this associated condition: Find a wait covering all these

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possibilities for a 0.2 dB gain-error tolerance. The farthest initial endpoint is 0.1 V, with 0.5 V error, giving a maximum initial gain error of 25 dB Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the…”. Using “Application 5A.4: Check the required control polarity after a level step”, specify a discriminator and the result expected under each explanation Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the…, including the effect of missing measurements and inconsistent operating conditions Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Scholarly synthesis and implications: Explain what the result about Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Closing: Conclude by answering “Initial control voltage is bounded by 0.1 through 0.3 V, the fixed target is 0.6 V, the slope magnitude is 50 dB/V, and the positive time constant lies between 0.8 and 1.2 ms”

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using only the demonstrated evidence; state the remaining decisive verification step Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

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V011-C05-ESSAY-014. A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms. At physical time 1 ms, correction software mistakenly uses the gain from 0.8 ms because telemetry is delayed. Calculate the gain mismatch and input-level bias for a valid fixed input and output observation.

- Opening: Present a thesis that answers this precise question: A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms. Identify which evidence would falsify the proposed conclusion Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Core terminology and scope: Define trajectory, plus, divided in the question's particular technical setting; explain how telemetry, delayed, Calculate differ if that distinction would change the analysis of "A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms" Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Actual gain at 1 ms is 5 plus 20 times exp of minus one, approximately 12.35759 dB Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms to the claimed result, following "Application 5A.10: Propagate an initial-state interval"; name the intermediate states and measurable outputs Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms. The stale value from 0.8 ms is approximately 13.98658 dB Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.4: Check the required control polarity after a level step” that resolves the question about A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms; derive the relevant result with units and stated validity conditions Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms. Subtracting that stale, larger gain from the actual output underestimates the input level by approximately 1.62899 dB Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Worked application or illustrative case: Build a worked example of “A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms”, addressing this associated condition: At physical time 1 ms, correction software mistakenly uses the gain from 0.8 ms because telemetry is.... Actual gain at 1 ms is 5 plus 20 times exp of minus one, approximately 12.35759 dB Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms”. Using “Application 5A.4: Check the required control polarity after a level step”, specify a discriminator and the result expected under each explanation Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms, including the effect of missing measurements and inconsistent operating conditions Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)
- Scholarly synthesis and implications: Explain what the result about A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Closing: Conclude by answering “A calibrated gain trajectory is 5 dB plus 20 dB times exp of negative time divided by 1 ms” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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V011-C05-ESSAY-015. Design an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak. Explain which measurements can be shared and which must remain distinct.

- Opening: Present a thesis that answers this precise question: Design an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak. Identify which evidence would falsify the proposed conclusion Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Core terminology and scope: Define Design, characterization, measurands in the question's particular technical setting; explain how integrated, shared, distinct differ if that distinction would change the analysis of "Design an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak" Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin with the actual path identity, reference planes, gain state and filter configuration Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak to the claimed result, following "Filter Shape, Selectivity, and Time Response"; name

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the intermediate states and measurable outputs Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak. A swept or stepped calibrated tone can characterize passband amplitude and skirts and provides useful common response evidence Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
- Analytical framework: Identify the equation, calibration or evidential decision test in “5. Calibration and negative-survey validity for dynamic IF paths” that resolves the question about an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak; derive the relevant result with units and stated validity conditions Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak. Tone amplitude needs the applicable frequency and level correction Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Worked application or illustrative case: Build a worked example of “an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak”, addressing this associated condition: Explain which measurements

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can be shared and which must remain distinct. Begin with the actual path identity, reference planes, gain state and filter configuration Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak”. Using “5. Calibration and negative-survey validity for dynamic IF paths”, specify a discriminator and the result expected under each explanation Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak, including the effect of missing measurements and inconsistent operating conditions Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Scholarly synthesis and implications: Explain what the result about an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Closing: Conclude by answering “Design an IF-path characterization for three measurands: continuous-tone amplitude, integrated channel power and short-burst peak” using only the demonstrated

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evidence; state the remaining decisive verification step Source: §5.3

Choose an IF path for the quantity being measured (p. 2518)

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V011-C05-ESSAY-016. A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain. Explain how a piecewise gain correction should be constructed and which continuity assumptions must be checked.

- Opening: Present a thesis that answers this precise question: A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain. Identify which evidence would falsify the proposed conclusion Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Core terminology and scope: Define slope, piecewise, constructed in the question's particular technical setting; explain how continuity, assumptions, checked differ if that distinction would change the analysis of "A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain" Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain the actual transition time, range identity and control state Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain to the claimed result, following "Application 5A.2: Set a gain-error settling requirement"; name the intermediate states and measurable outputs Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain. Apply the calibrated gain law belonging to each range over its valid voltage and signal interval; do not continue the old slope merely because the telemetry voltage is continuous Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.1: Read a voltage step and its 95 percent settling time” that resolves the question about A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain; derive the relevant result with units and stated validity conditions Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain. A range switch can produce an actual gain step, so continuity of RF gain is a measurement question rather than an automatic constraint Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Worked application or illustrative case: Build a worked example of “A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain”, addressing this associated condition: Explain how a piecewise gain correction

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should be constructed and which continuity assumptions must be.... Retain the actual transition time, range identity and control state Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain”. Using “Application 5A.1: Read a voltage step and its 95 percent settling time”, specify a discriminator and the result expected under each explanation Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain, including the effect of missing measurements and inconsistent operating conditions Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Scholarly synthesis and implications: Explain what the result about A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Closing: Conclude by answering “A receiver changes gain range midway through an event, giving a new control-voltage slope and reference gain” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

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V011-C05-ESSAY-017. A weak desired tone falls when a strong signal is added outside the displayed channel. Develop a test that distinguishes shared-AGC suppression from actual weak-source fading and from early-stage overload.

- Opening: Present a thesis that answers this precise question: A weak desired tone falls when a strong signal is added outside the displayed channel. Identify which evidence would falsify the proposed conclusion Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Core terminology and scope: Define falls, added, outside in the question's particular technical setting; explain how suppression, fading, overload differ if that distinction would change the analysis of "A weak desired tone falls when a strong signal is added outside the displayed channel" Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Maintain a known weak reference at the declared input plane and document the strong signal's delivered level and spectrum Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A weak desired tone falls when a strong signal is added outside the displayed channel to the claimed result, following "Application 5A.8: Compare burst duration with control settling"; name the intermediate states

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and measurable outputs Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A weak desired tone falls when a strong signal is added outside the displayed channel. Record control state and the path feeding the control detector, which may be wider than the displayed channel Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Verify the detector and control path as part of the IF result” that resolves the question about A weak desired tone falls when a strong signal is added outside the displayed channel; derive the relevant result with units and stated validity conditions Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A weak desired tone falls when a strong signal is added outside the displayed channel. Compare fixed-gain and intended automatic-gain operation while controlling other settings Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Worked application or illustrative case: Build a worked example of “A weak desired tone falls when a strong signal is added outside the displayed channel”, addressing this associated condition: Develop a test that distinguishes shared-AGC suppression from actual weak-source fading and from.... Maintain a known weak reference at the declared input plane and document the strong signal’s delivered

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level and spectrum Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A weak desired tone falls when a strong signal is added outside the displayed channel”. Using “Verify the detector and control path as part of the IF result”, specify a discriminator and the result expected under each explanation Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A weak desired tone falls when a strong signal is added outside the displayed channel, including the effect of missing measurements and inconsistent operating conditions Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Scholarly synthesis and implications: Explain what the result about A weak desired tone falls when a strong signal is added outside the displayed channel authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Closing: Conclude by answering “A weak desired tone falls when a strong signal is added outside the displayed channel” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

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V011-C05-ESSAY-018. Explain why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any instrument malfunction. Specify what a meaningful comparison must retain.

- Opening: Present a thesis that answers this precise question: Explain why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any instrument malfunction. Identify which evidence would falsify the proposed conclusion Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Core terminology and scope: Define observations, waveform, differ in the question's particular technical setting; explain how instrument, Specify, meaningful differ if that distinction would change the analysis of "Explain why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any instrument malfunction" Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Each detector applies a different operation and often a different temporal selection Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any… to the claimed result, following "Logarithmic Amplifiers, Detectors, and Scaling"; name the

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intermediate states and measurable outputs Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any.... A peak can retain a rare excursion; a sample can miss it; a mean-square operation weights power over its stated interval; a mean of logarithmic levels gives another statistic Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Intermediate-frequency detector memory, settling and comparable measurement statistics" that resolves the question about why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any...; derive the relevant result with units and stated validity conditions Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any.... Burst duty, dwell, sample selection, averaging count and video filtering affect the comparison Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Worked application or illustrative case: Build a worked example of "why peak, sample, RMS power and average-logarithmic

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observations of a burst-and-noise waveform can all differ without any…", addressing this associated condition: Specify what a meaningful comparison must retain. Each detector applies a different operation and often a different temporal selection Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any…". Using "Intermediate-frequency detector memory, settling and comparable measurement statistics", specify a discriminator and the result expected under each explanation Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any…, including the effect of missing measurements and inconsistent operating conditions Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)
- Scholarly synthesis and implications: Explain what the result about why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- Closing: Conclude by answering “Explain why peak, sample, RMS power and average-logarithmic observations of a burst-and-noise waveform can all differ without any instrument malfunction” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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V011-C05-ESSAY-019. A proprietary AGC loop fits one exponential at a small input step. Evaluate the claim that this identifies the complete loop and predicts every future strong-burst recovery.

- Opening: Present a thesis that answers this precise question: A proprietary AGC loop fits one exponential at a small input step. Evaluate the claim that this identifies the complete loop and predicts every future strong-burst recovery. Identify which evidence would falsify the proposed conclusion Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Core terminology and scope: Define proprietary, loop, fits in the question's particular technical setting; explain how exponential, predicts, future differ if that distinction would change the analysis of "A proprietary AGC loop fits one exponential at a small input step. Evaluate the claim that this identifies the complete loop and predicts every future strong-burst recovery" Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Problem statement and purpose: Frame the actual measurement or decision in the question. A local fit identifies an observed response under the tested target, initial state, gain range, detector conditions and level excursion Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A proprietary AGC loop fits one exponential at a small input step to the claimed result, following "Automatic Gain Control and Hidden State"; name the

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intermediate states and measurable outputs Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A proprietary AGC loop fits one exponential at a small input step. It does not uniquely determine the internal architecture Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.10: Propagate an initial-state interval” that resolves the question about A proprietary AGC loop fits one exponential at a small input step; derive the relevant result with units and stated validity conditions Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A proprietary AGC loop fits one exponential at a small input step. Different systems can share one small-signal response while differing in integrating action, limits, hang rules, delays, windup and overdrive behavior Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Worked application or illustrative case: Build a worked example of “A proprietary AGC loop fits one exponential at a small input step”, addressing this associated condition: Evaluate the claim that this identifies the complete loop and predicts every future strong-burst recovery. A local fit identifies an observed response under the tested target, initial state, gain range, detector conditions and level excursion Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A proprietary AGC loop fits one exponential at a small input step”. Using “Application 5A.10: Propagate an initial-state interval”, specify a discriminator and the result expected under each explanation Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A proprietary AGC loop fits one exponential at a small input step, including the effect of missing measurements and inconsistent operating conditions Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Scholarly synthesis and implications: Explain what the result about A proprietary AGC loop fits one exponential at a small input step authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Closing: Conclude by answering “A proprietary AGC loop fits one exponential at a small input step. Evaluate the claim that this identifies the complete loop and predicts every future strong-burst recovery” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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V011-C05-ESSAY-020. After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated. Explain the possible interpretations and a controlled localization sequence.

- Opening: Present a thesis that answers this precise question: After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated. Explain the possible interpretations and a controlled.... Identify which evidence would falsify the proposed conclusion Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Core terminology and scope: Define flat, settled, attenuated in the question's particular technical setting; explain how possible, interpretations, localization differ if that distinction would change the analysis of "After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated. Explain the possible interpretations and a controlled..." Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Problem statement and purpose: Frame the actual measurement or decision in the question. A settled control state does not establish that every signal-path stage has recovered Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated to the claimed result, following "Automatic Gain Control and Hidden State"; name the intermediate

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states and measurable outputs Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated. A limiter, amplifier, detector or digital normalization step can retain a different disturbance; the reference measurement itself can also be bandwidth- or floor-limited Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Analytical framework: Identify the equation, calibration or evidential decision test in “IF Alignment, Calibration, and Failure Localization” that resolves the question about After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated; derive the relevant result with units and stated validity conditions Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)
- Evidence and method: Specify the native observations, control records and calculations that would resolve After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated. First establish that the weak reference is observable and that its injection point exercises the intended stages Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Worked application or illustrative case: Build a worked example of “After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated”, addressing this associated condition: Explain the possible interpretations and a controlled localization sequence. A settled control state does not

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establish that every signal-path stage has recovered Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated”. Using “IF Alignment, Calibration, and Failure Localization”, specify a discriminator and the result expected under each explanation Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated, including the effect of missing measurements and inconsistent operating conditions Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)
- Scholarly synthesis and implications: Explain what the result about After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Closing: Conclude by answering “After a strong pulse, the display is flat and the AGC voltage has settled, but a weak reference remains attenuated. Explain the possible interpretations and a controlled…” using only the demonstrated evidence; state the remaining decisive

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verification step Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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V011-C05-ESSAY-021. The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example. Explain how it can still be used responsibly in the chapter without treating corrected arithmetic as a verified device specification.

- Opening: Present a thesis that answers this precise question: The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example. Identify which evidence would falsify the proposed conclusion Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Core terminology and scope: Define cited, AD8367, printed in the question's particular technical setting; explain how treating, verified, specification differ if that distinction would change the analysis of "The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example" Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the exact revision and inspected pages, then separate the supported qualitative discussion from the disputed printed numerical expressions Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example to the claimed result, following "Application 5A.5: Identify a time constant from two signed

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residuals"; name the intermediate states and measurable outputs Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example. The source supports a local single-pole response for small changes, integrating control, gain polarity and distinct large-change current-limited behavior Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 5A.4: Check the required control polarity after a level step" that resolves the question about The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example; derive the relevant result with units and stated validity conditions Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Evidence and method: Specify the native observations, control records and calculations that would resolve The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example. Page 13's printed Equation 4 has an intercept-sign conflict with its explanatory text, and the page 16 capacitance, slew and bandwidth example is internally inconsistent Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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- Worked application or illustrative case: Build a worked example of “The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example”, addressing this associated condition: Explain how it can still be used responsibly in the chapter without treating corrected arithmetic as a.... Identify the exact revision and inspected pages, then separate the supported qualitative discussion from the... Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example”. Using “Application 5A.4: Check the required control polarity after a level step”, specify a discriminator and the result expected under each explanation Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example, including the effect of missing measurements and inconsistent operating conditions Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)
- Scholarly synthesis and implications: Explain what the result about The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example authorises the investigator or engineer to claim, and what

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stronger proposition remains unsupported Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- Closing: Conclude by answering “The cited AD8367 Revision A source contains numerical inconsistencies in its printed RSSI relation and one large-change example” using only the demonstrated evidence; state the remaining decisive verification step Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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V011-C05-ESSAY-022. A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label. Design the relevant regression and record requirements.

- Opening: Present a thesis that answers this precise question: A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label. Design the relevant regression and record.... Identify which evidence would falsify the proposed conclusion Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Core terminology and scope: Define update, interpretation, preserving in the question's particular technical setting; explain how Design, regression, requirements differ if that distinction would change the analysis of "A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label. Design the relevant regression and record..." Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain the old and new firmware, coefficients, sample-rate interpretation, scaling, filter selection and correction identities Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label to the claimed result, following "IF Alignment, Calibration, and Failure Localization";

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name the intermediate states and measurable outputs Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label. A common center label does not establish unchanged physical frequency weighting, gain or time response Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)
- Analytical framework: Identify the equation, calibration or evidential decision test in “IF Acceptance and Regression Tests” that resolves the question about A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label; derive the relevant result with units and stated validity conditions Source: §5.20 IF Acceptance and Regression Tests (p. 2543)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label. Apply known tones across the passband and skirts, a calibrated noise case with an appropriate effective bandwidth, and representative bursts or modulation that exercise delay and settling Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Worked application or illustrative case: Build a worked example of “A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency

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label", addressing this associated condition: Design the relevant regression and record requirements. Retain the old and new firmware, coefficients, sample-rate interpretation, scaling, filter selection and correction identities Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label". Using "IF Acceptance and Regression Tests", specify a discriminator and the result expected under each explanation Source: §5.20 IF Acceptance and Regression Tests (p. 2543)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label, including the effect of missing measurements and inconsistent operating conditions Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)
- Scholarly synthesis and implications: Explain what the result about A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Closing: Conclude by answering "A digital IF update changes coefficients and sample-clock interpretation while preserving the displayed center-frequency label. Design the relevant regression

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and record…" using only the demonstrated evidence; state the remaining decisive verification step Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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V011-C05-ESSAY-023. Develop an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level. Keep it tied to the chapter's measurement model.

- Opening: Present a thesis that answers this precise question: Develop an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level. Keep it tied to the chapter's measurement model. Identify which evidence would falsify the proposed conclusion Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Core terminology and scope: Define validity, checklist, converting in the question's particular technical setting; explain how recorded, burst, tied differ if that distinction would change the analysis of "Develop an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level. Keep it tied to the chapter's measurement model" Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the local gain reference, signed slope, calibrated voltage interval and applicable RF levels Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level to the claimed result, following "Application 5A.3: Convert a control state into an output level"; name

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the intermediate states and measurable outputs Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level. Include control-voltage measurement uncertainty, reference-gain and slope uncertainty, and the relative timing of telemetry and RF observations Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 5A.8: Compare burst duration with control settling” that resolves the question about an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level; derive the relevant result with units and stated validity conditions Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level. If a dynamic fit is used between samples, include uncertainty and adequacy of its target, time constant, initial state and segmentation Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Worked application or illustrative case: Build a worked example of “an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level”, addressing this

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associated condition: Keep it tied to the chapter's measurement model. Identify the local gain reference, signed slope, calibrated voltage interval and applicable RF levels Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level". Using "Application 5A.8: Compare burst duration with control settling", specify a discriminator and the result expected under each explanation Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level, including the effect of missing measurements and inconsistent operating conditions Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)
- Scholarly synthesis and implications: Explain what the result about an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)
- Closing: Conclude by answering "Develop an uncertainty and validity checklist for converting recorded control voltage into an input-referred burst level. Keep it tied to the chapter's measurement

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model" using only the demonstrated evidence; state the remaining decisive verification step Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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V011-C05-ESSAY-024. Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining dynamic defect. Distinguish the meaning of closing verification.

- Opening: Present a thesis that answers this precise question: Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining dynamic defect. Distinguish the meaning of…. Identify which evidence would falsify the proposed conclusion Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Core terminology and scope: Define repair, prevent, concealing in the question's particular technical setting; explain how defect, meaning, closing differ if that distinction would change the analysis of "Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining dynamic defect. Distinguish the meaning of…" Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Record exact configuration, reference planes, stimuli, correction method, environmental conditions relevant to the response and the acceptance criteria Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining… to the claimed result, following "IF Acceptance and Regression Tests"; name the

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intermediate states and measurable outputs Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining.... Include several passband and skirt frequencies, applicable bandwidth and gain boundaries, a calibrated noise case, a short event and a recovery case Source: §5.20 IF Acceptance and Regression Tests (p. 2543)
- Analytical framework: Identify the equation, calibration or evidential decision test in "5. Calibration and negative-survey validity for dynamic IF paths" that resolves the question about Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining...; derive the relevant result with units and stated validity conditions Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining.... Use fixed gain to characterize the path and the intended automatic mode to exercise attack, release, hang and shared-channel loading Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Worked application or illustrative case: Build a worked example of "Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining...",

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addressing this associated condition: Distinguish the meaning of closing verification. Record exact configuration, reference planes, stimuli, correction method, environmental conditions relevant to the response and the acceptance criteria Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining…”. Using “5. Calibration and negative-survey validity for dynamic IF paths”, specify a discriminator and the result expected under each explanation Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining…, including the effect of missing measurements and inconsistent operating conditions Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)
- Scholarly synthesis and implications: Explain what the result about Specify an IF acceptance record after repair that would prevent one successful center-tone check from concealing a remaining… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)
- Closing: Conclude by answering “Specify an IF acceptance record after repair that would prevent one successful center-tone check

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from concealing a remaining dynamic defect. Distinguish the meaning of…" using only the demonstrated evidence; state the remaining decisive verification step Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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V011-C05-ESSAY-025. A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio. AGC telemetry moves during the event. Formulate a defensible adjudication and next measurement.

- Opening: Present a thesis that answers this precise question: A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio. Identify which evidence would falsify the proposed conclusion Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Core terminology and scope: Define clearly, visible, wider in the question's particular technical setting; explain how absent, telemetry, moves differ if that distinction would change the analysis of "A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio" Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Treat the three outputs as different paths until their filter, takeoff, detector, averaging and gain states are reconciled Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio to the claimed result, following "Verify the detector and control path as part of the IF result"; name the

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intermediate states and measurable outputs Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio. The narrow trace may reduce a short peak through settling or selection, while the wider I/Q path can retain it and the audio path can exclude it Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose an IF path for the quantity being measured” that resolves the question about A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio; derive the relevant result with units and stated validity conditions Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio. Moving telemetry adds a time-dependent gain factor; a final settled gain cannot correct the whole event Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Worked application or illustrative case: Build a worked example of “A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio”, addressing this

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associated condition: AGC telemetry moves during the event. Treat the three outputs as different paths until their filter, takeoff, detector, averaging and gain states are reconciled Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio”. Using “Choose an IF path for the quantity being measured”, specify a discriminator and the result expected under each explanation Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio, including the effect of missing measurements and inconsistent operating conditions Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)
- Scholarly synthesis and implications: Explain what the result about A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)
- Closing: Conclude by answering “A short event is 6 dB lower on a narrow spectrum trace, clearly visible in a wider I/Q record, and absent in audio” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C05-DISCUSSION-001. Should a team choose the narrowest IF filter whenever the displayed noise floor improves?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a team choose the narrowest IF filter whenever the displayed noise floor improves?” Put this particular dispute to the panel: Should a team choose the narrowest IF filter whenever the displayed noise floor improves. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 02. Student A, terminology and scope: Agree the operational meanings of narrowest, filter, displayed and noise, floor, improves in “Should a team choose the narrowest IF filter whenever the displayed noise floor improves”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a team choose the narrowest IF filter whenever the displayed noise floor improves; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Filter Shape, Selectivity, and Time Response”. A narrower response can reduce admitted noise while changing settling and the signal itself Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a team choose the narrowest IF filter whenever the displayed noise floor improves; explain what each record can establish State what the existing

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record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Filter Shape, Selectivity, and Time Response”. A narrower response can reduce admitted noise while changing settling and the signal itself Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask what quantity the observation must preserve: tone separation, channel power, modulation, onset time or peak Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a team choose the narrowest IF filter whenever the displayed noise floor improves: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a team choose the narrowest IF filter whenever the displayed noise floor improves; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a team choose the narrowest IF filter whenever the displayed noise floor improves: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a team choose the narrowest IF filter whenever the displayed noise floor improves, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a team choose the narrowest IF filter whenever the displayed noise floor improves: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a team choose the narrowest IF filter whenever the displayed noise floor improves. Require a measured transfer or a representative stimulus for the intended quantity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a team choose the narrowest IF filter whenever the displayed noise floor improves, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a team choose the narrowest IF filter whenever the displayed noise floor improves. Require a measured transfer or a representative stimulus for the intended quantity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a team choose the narrowest IF filter whenever the displayed noise floor improves and Ask what quantity the observation must preserve: tone separation, channel power, modulation, onset time or…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a team choose the narrowest IF filter whenever the displayed noise floor improves”, addressing “Ask

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what quantity the observation must preserve: tone separation, channel power, modulation, onset time or…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Should a team choose the narrowest IF filter whenever the displayed noise floor improves", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Should a team choose the narrowest IF filter whenever the displayed noise floor improves". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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V011-C05-DISCUSSION-002. Two filters share the same loaded Q. Is either one a sufficient substitute in an existing burst-measurement procedure?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two filters share the same loaded Q. Is either one a sufficient substitute in an existing burst-measurement procedure?” Put this particular dispute to the panel: Two filters share the same loaded Q. Is either one a sufficient substitute in an existing burst-measurement procedure. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 02. Student A, terminology and scope: Agree the operational meanings of share, loaded, sufficient and substitute, existing, procedure in “Two filters share the same loaded Q. Is either one a sufficient substitute in an existing burst-measurement procedure”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two filters share the same loaded Q; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Filter Shape, Selectivity, and Time Response”. Determine whether the existing procedure depends on properties absent from Q Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two filters share the same loaded Q; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.26

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Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Filter Shape, Selectivity, and Time Response”. Determine whether the existing procedure depends on properties absent from Q Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate the common center-to-width ratio from skirts, ripple, phase and impulse response Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two filters share the same loaded Q: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two filters share the same loaded Q; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two filters share the same loaded Q: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two filters share the same loaded Q, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two filters share the same loaded Q: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two filters share the same loaded Q. A substitution needs evidence for those properties and for detector timing under the same waveform Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the

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question cannot be settled by visual appearance or a single unqualified reading. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two filters share the same loaded Q, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two filters share the same loaded Q. A substitution needs evidence for those properties and for detector timing under the same waveform Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two filters share the same loaded Q and Is either one a sufficient substitute in an existing burst-measurement procedure; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two filters share the same loaded Q”, addressing “Is either one a sufficient substitute in an existing burst-measurement procedure”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two filters share the same loaded Q. Is either one a sufficient substitute in an existing burst-measurement procedure”, specifying the next test, responsible measurement

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record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two filters share the same loaded Q. Is either one a sufficient substitute in an existing burst-measurement procedure”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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V011-C05-DISCUSSION-003. Does a large measured group delay at a deep notch justify reporting a long physical transit time?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Does a large measured group delay at a deep notch justify reporting a long physical transit time?” Put this particular dispute to the panel: Does a large measured group delay at a deep notch justify reporting a long physical transit time. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 02. Student A, terminology and scope: Agree the operational meanings of large, group, delay and notch, reporting, long in “Does a large measured group delay at a deep notch justify reporting a long physical transit time”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Does a large measured group delay at a deep notch justify reporting a long physical transit time; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Choose an IF path for the quantity being measured”. Near a notch, uncertainty can dominate the phase slope Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does a large measured group delay at a deep notch justify reporting a long physical transit time; explain what each record can establish State what the existing

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record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Choose an IF path for the quantity being measured”. Near a notch, uncertainty can dominate the phase slope Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine transfer magnitude, measurement floor, phase coherence and unwrapping before accepting the derivative Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Does a large measured group delay at a deep

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notch justify reporting a long physical transit time: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does a large measured group delay at a deep notch justify reporting a long physical transit time; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Does a large measured group delay at a deep notch justify reporting a long physical transit time: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable,

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expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Does a large measured group delay at a deep notch justify reporting a long physical transit time, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Does a large measured group delay at a deep notch justify reporting a long physical transit time: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Does a large measured group delay at a deep notch justify reporting a long physical transit time. Even a valid local group delay does not establish unchanged transmission of an arbitrary pulse Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Does a large measured group delay at a deep notch justify reporting a long physical transit time, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Does a large measured group delay at a deep notch justify reporting a long physical transit time. Even a valid local group delay does not establish unchanged transmission of an arbitrary pulse Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Does a large measured group delay at a deep notch justify reporting a long physical transit time and Examine transfer magnitude, measurement floor, phase coherence and unwrapping before accepting the derivative; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Does a large measured group delay at a

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deep notch justify reporting a long physical transit time", addressing "Examine transfer magnitude, measurement floor, phase coherence and unwrapping before accepting the derivative"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Does a large measured group delay at a deep notch justify reporting a long physical transit time", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Does a large measured group delay at a deep notch justify reporting a long physical transit time". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

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V011-C05-DISCUSSION-004. A familiar rule says to wait three time constants before taking a measurement. When is that adequate?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A familiar rule says to wait three time constants before taking a measurement. When is that adequate?” Put this particular dispute to the panel: A familiar rule says to wait three time constants before taking a measurement. When is that adequate. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 02. Student A, terminology and scope: Agree the operational meanings of familiar, says, wait and constants, taking, adequate in “A familiar rule says to wait three time constants before taking a measurement. When is that adequate”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A familiar rule says to wait three time constants before taking a measurement; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. A large initial gain error can leave an unacceptable result after three time constants Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A familiar rule says to wait three time constants before taking a measurement; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. A large initial gain error can leave an unacceptable result after three time constants Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Translate the rule into the remaining fraction, approximately 4.98 percent, and compare that residual with the actual error tolerance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A familiar rule says to wait three time constants before taking a measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A familiar rule says to wait three time constants before taking a measurement; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A familiar rule says to wait three time constants before taking a measurement: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A familiar rule says to wait three time constants before taking a measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A familiar rule says to wait three time constants before taking a measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A familiar rule says to wait three time constants before taking a measurement. Require compatible units, calibrated slope and an applicable model Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A familiar rule says to wait three time constants before taking a measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A familiar rule says to wait three time constants before taking a measurement. Require compatible units, calibrated slope and an applicable model Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A familiar rule says to wait three time constants before taking a measurement and When is that adequate; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A familiar rule says to wait three time constants before taking a measurement”, addressing “When is that adequate”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A familiar rule says to wait three time constants before taking a measurement. When is that adequate”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A familiar rule says to wait three time constants before taking a measurement. When is that adequate”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

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V011-C05-DISCUSSION-005. Should an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good?” Put this particular dispute to the panel: Should an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 02. Student A, terminology and scope: Agree the operational meanings of observed, voltage, overshoot and removed, outlier, good in “Should an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. Overshoot is inconsistent with the uninterrupted monotone model, so it is evidence that deserves investigation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether an observed voltage

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overshoot be removed as an outlier because the one-pole fit is otherwise good; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. Overshoot is inconsistent with the uninterrupted monotone model, so it is evidence that deserves investigation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask whether the target, state, acquisition or model changed Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether an observed voltage overshoot be removed as an outlier because the one-pole fit is

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otherwise good: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good. Establish measurement uncertainty and repeatability before deciding whether the point is erroneous Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good. Establish measurement uncertainty and repeatability before deciding whether the point is erroneous Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good and Ask whether the target, state, acquisition or model changed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good”, addressing “Ask whether the target, state, acquisition or model changed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should an observed voltage overshoot be removed as an outlier because the one-pole fit is otherwise good”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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V011-C05-DISCUSSION-006. May two-point identification be called a validation of the complete AGC loop?

- 01. Moderator, opening proposition: Introduce the exact dispute, “May two-point identification be called a validation of the complete AGC loop?” Put this particular dispute to the panel: May two-point identification be called a validation of the complete AGC loop. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 02. Student A, terminology and scope: Agree the operational meanings of two-point, identification, called and validation, complete, loop in “May two-point identification be called a validation of the complete AGC loop”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of May

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two-point identification be called a validation of the complete AGC loop; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 5A: an identified one-pole gain-control response”. Favorable signs and decreasing residuals allow a positive time constant, but additional times, levels and states can reveal other dynamics Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of May two-point identification be called a validation of the complete AGC loop; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 5A: an identified one-pole gain-control response”. Favorable signs and decreasing residuals allow a positive time constant, but additional times, levels and states can reveal other dynamics Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate interpolation from model adequacy and internal identification Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving May two-point identification be called a validation of the complete AGC loop: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of May two-point identification be called a validation of the complete AGC loop; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving May two-point identification be called a validation of the complete AGC loop: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving May two-point identification be called a validation of the complete AGC loop, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving May two-point identification be called a validation of the complete AGC loop: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for May two-point identification be called a validation of the complete AGC loop. The team should identify the exact response supported by the two points and propose an independent challenge Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving May two-point identification be called a validation of the complete AGC loop, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for May two-point identification be called a validation of the complete AGC loop. The team should identify the exact response supported by the two points and propose an independent challenge Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about May two-point identification be called a validation of the complete AGC loop and Separate interpolation from model adequacy and internal identification; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “May two-point identification be called a

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validation of the complete AGC loop", addressing "Separate interpolation from model adequacy and internal identification"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "May two-point identification be called a validation of the complete AGC loop", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "May two-point identification be called a validation of the complete AGC loop". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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V011-C05-DISCUSSION-007. A residual trace has a late floor. Should the team fit a second very slow pole immediately?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A residual trace has a late floor. Should the team fit a second very slow pole immediately?” Put this particular dispute to the panel: A residual trace has a late floor. Should the team fit a second very slow pole immediately. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 02. Student A, terminology and scope: Agree the operational meanings of residual, trace, floor and slow, pole, immediately in “A residual trace has a late floor. Should the team fit a second very slow pole immediately”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A residual trace has a late floor; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 5A: an identified one-pole gain-control response”. Examine whether the apparent floor is stable under changed references or input levels Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A residual trace has a late floor; explain what each record can establish State what the existing record establishes, what it does not establish, and which further

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measurement would change your opinion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 5A: an identified one-pole gain-control response”. Examine whether the apparent floor is stable under changed references or input levels Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider target error, detector offset, resolution and hold behavior before increasing model complexity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A residual trace has a late floor: specify the

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altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A residual trace has a late floor; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A residual trace has a late floor: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A residual trace has a late floor, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A residual trace has a late floor: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A residual trace has a late floor. A second pole is a hypothesis that needs discriminating evidence, not a mandatory interpretation of every departure from zero Explain the

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relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A residual trace has a late floor, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A residual trace has a late floor. A second pole is a hypothesis that needs discriminating evidence, not a mandatory interpretation of every departure from zero Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A residual trace has a late floor and Should the team fit a second very slow pole immediately; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A residual trace has a late floor”, addressing “Should the team fit a second very slow pole immediately”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A residual trace has a late floor. Should the team fit a second very slow pole immediately”, specifying the next

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test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A residual trace has a late floor. Should the team fit a second very slow pole immediately”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

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V011-C05-DISCUSSION-008. A control voltage rises during a strong input. Does that prove the receiver is reducing gain?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A control voltage rises during a strong input. Does that prove the receiver is reducing gain?” Put this particular dispute to the panel: A control voltage rises during a strong input. Does that prove the receiver is reducing gain. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 02. Student A, terminology and scope: Agree the operational meanings of control, voltage, rises and strong, prove, reducing in “A control voltage rises during a strong input. Does that prove the receiver is reducing gain”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A control voltage rises during a strong input; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.2: Set a gain-error settling requirement”. A rising voltage reduces gain only for the appropriate negative slope; another circuit or mode can have the opposite polarity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A control voltage rises during a strong input; explain what each record can establish State what the existing record establishes, what it does not establish, and which

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further measurement would change your opinion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.2: Set a gain-error settling requirement”. A rising voltage reduces gain only for the appropriate negative slope; another circuit or mode can have the opposite polarity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require the signed local gain map and active gain range Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A control voltage rises during a strong input: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A control voltage rises during a strong input; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A control voltage rises during a strong input: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A control voltage rises during a strong input, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A control voltage rises during a strong input: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A control voltage rises during a strong input. Check the reference gain, valid voltage interval and RF response Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be

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settled by visual appearance or a single unqualified reading. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A control voltage rises during a strong input, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A control voltage rises during a strong input. Check the reference gain, valid voltage interval and RF response Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A control voltage rises during a strong input and Does that prove the receiver is reducing gain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A control voltage rises during a strong input”, addressing “Does that prove the receiver is reducing gain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A control voltage rises during a strong input. Does that prove the receiver is reducing gain”, specifying the next test, responsible measurement record and limit of the conclusion

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Summarise the strongest evidence for and against the resolution of "A control voltage rises during a strong input. Does that prove the receiver is reducing gain". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

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V011-C05-DISCUSSION-009. May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly?

- 01. Moderator, opening proposition: Introduce the exact dispute, “May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly?” Put this particular dispute to the panel: May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 02. Student A, terminology and scope: Agree the operational meanings of burst, calculation, restart and equilibrium, pattern, repeats in “May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Carry the actual prior terminal state or establish the periodic initial state from sufficient history Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats

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regularly; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Carry the actual prior terminal state or establish the periodic initial state from sufficient history Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Regular repetition can produce a periodic trajectory that never reaches equilibrium Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly. Compare burst spacing with attack, hold and release behavior Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly. Compare burst spacing with attack, hold and release behavior Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly and Regular repetition can produce a periodic trajectory that never reaches equilibrium; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly”, addressing “Regular repetition can produce a periodic trajectory

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that never reaches equilibrium"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "May each burst calculation restart from the pre-burst equilibrium if the burst pattern repeats regularly". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

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V011-C05-DISCUSSION-010. Can a hang interval be represented adequately by increasing the release time constant?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a hang interval be represented adequately by increasing the release time constant?” Put this particular dispute to the panel: Can a hang interval be represented adequately by increasing the release time constant. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 02. Student A, terminology and scope: Agree the operational meanings of hang, represented, adequately and increasing, release, constant in “Can a hang interval be represented adequately by increasing the release time constant”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a hang interval be represented adequately by increasing the release time constant; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.6: Carry state across two target intervals”. The distinction can change a later weak-signal response Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a hang interval be represented adequately by increasing the release time constant; explain what each record can establish State what the existing

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record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.6: Carry state across two target intervals”. The distinction can change a later weak-signal response Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare the trajectories: a specified hold remains at its carried value before release, whereas a slow exponential moves immediately Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a hang interval be represented adequately by increasing the release time constant: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a hang interval be represented adequately by increasing the release time constant; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a hang interval be represented adequately by increasing the release time constant: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a hang interval be represented adequately by increasing the release time constant, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a hang interval be represented adequately by increasing the release time constant: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a hang interval be represented adequately by increasing the release time constant. Define the timer trigger, retrigger rule and held quantity, then test them Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a hang interval be represented adequately by increasing the release time constant, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a hang interval be represented adequately by increasing the release time constant. Define the timer trigger, retrigger rule and held quantity, then test them Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a hang interval be represented adequately by increasing the release time constant and Compare the trajectories: a specified hold remains at its carried value before release, whereas a slow…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a hang interval be represented adequately by increasing the release time constant”, addressing

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"Compare the trajectories: a specified hold remains at its carried value before release, whereas a slow…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Can a hang interval be represented adequately by increasing the release time constant", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Can a hang interval be represented adequately by increasing the release time constant". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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V011-C05-DISCUSSION-011. A simulated one-pole controller oscillates while the measured control voltage does not. What should be checked first?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A simulated one-pole controller oscillates while the measured control voltage does not. What should be checked first?” Put this particular dispute to the panel: A simulated one-pole controller oscillates while the measured control voltage does not. What should be checked first. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 02. Student A, terminology and scope: Agree the operational meanings of simulated, one-pole, oscillates and control, voltage, checked in “A simulated one-pole controller oscillates while the measured control voltage does not. What should be checked first”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A simulated one-pole controller oscillates while the measured control voltage does not; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. Forward Euler can alternate or diverge even when the stipulated continuous system is stable Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A simulated one-pole

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controller oscillates while the measured control voltage does not; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. Forward Euler can alternate or diverge even when the stipulated continuous system is stable Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Inspect the numerical recurrence and sample interval Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A simulated one-pole controller oscillates while the measured control voltage does not: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A simulated one-pole controller oscillates while the measured control voltage does not; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A simulated one-pole controller oscillates while the measured control voltage does not: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A simulated one-pole controller oscillates while the measured control voltage does not, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A simulated one-pole controller oscillates while the measured control voltage does not: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A simulated one-pole controller oscillates while the measured control voltage does not. Compare with the exact sampled solution and distinguish stability from accuracy Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A simulated one-pole controller oscillates while the measured control voltage does not, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A simulated one-pole controller oscillates while the measured control voltage does not. Compare with the exact sampled solution and distinguish stability from accuracy Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A simulated one-pole controller oscillates while the measured control voltage does not and What should be checked first; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A simulated one-pole controller oscillates while the measured control voltage does not”, addressing “What should be checked first”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A simulated one-pole controller oscillates while the measured control voltage does not. What should be checked first”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A simulated one-pole controller oscillates while the measured control voltage does not. What should be checked first”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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V011-C05-DISCUSSION-012. If Euler is stable at the chosen step size, is that enough to trust a calculated settling time?

- 01. Moderator, opening proposition: Introduce the exact dispute, “If Euler is stable at the chosen step size, is that enough to trust a calculated settling time?” Put this particular dispute to the panel: If Euler is stable at the chosen step size, is that enough to trust a calculated settling time. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 02. Student A, terminology and scope: Agree the operational meanings of Euler, chosen, step and size, trust, calculated in “If Euler is stable at the chosen step size, is that enough to trust a calculated settling time”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of If Euler is stable at the chosen step size, is that enough to trust a calculated settling time; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. Compare residual values and acceptance crossings with the exact recurrence for this model Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of If Euler is stable at the chosen step size, is that enough to trust a calculated settling time; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.1: Read a voltage step and its 95 percent settling time”. Compare residual values and acceptance crossings with the exact recurrence for this model Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A stable alternating approximation can still misrepresent a monotone physical response Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving If Euler is stable at the chosen step size, is that enough to trust a calculated settling time: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of If Euler is stable at the chosen step size, is that enough to trust a calculated settling time; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving If Euler is stable at the chosen step size, is that enough to trust a calculated settling time: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving If Euler is stable at the chosen step size, is that enough to trust a calculated settling time, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving If Euler is stable at the chosen step size, is that enough to trust a calculated settling time: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for If Euler is stable at the chosen step size, is that enough to trust a calculated settling time. State numerical error where it matters to the tolerance Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving If Euler is stable at the chosen step size, is that enough to trust a calculated settling time, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for If Euler is stable at the chosen step size, is that enough to trust a calculated settling time. State numerical error where it matters to the tolerance Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about If Euler is stable at the chosen step size, is that enough to trust a calculated settling time and A stable alternating approximation can still misrepresent a monotone physical response; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “If Euler is stable at the chosen step size, is that enough to trust a calculated settling time”, addressing “A stable alternating approximation can still misrepresent a monotone

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physical response"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "If Euler is stable at the chosen step size, is that enough to trust a calculated settling time", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "If Euler is stable at the chosen step size, is that enough to trust a calculated settling time". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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V011-C05-DISCUSSION-013. An initial-state interval contracts to a very narrow range. Has the gain-correction uncertainty become negligible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An initial-state interval contracts to a very narrow range. Has the gain-correction uncertainty become negligible?” Put this particular dispute to the panel: An initial-state interval contracts to a very narrow range. Has the gain-correction uncertainty become negligible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 02. Student A, terminology and scope: Agree the operational meanings of interval, very, narrow and range, uncertainty, negligible in “An initial-state interval contracts to a very narrow range. Has the gain-correction uncertainty become negligible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An initial-state interval contracts to a very narrow range; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.2: Set a gain-error settling requirement”. Target, time constant, slope, gain reference and timing can still contribute Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An initial-state interval contracts to a very narrow range; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.2: Set a gain-error settling requirement”. Target, time constant, slope, gain reference and timing can still contribute Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify which quantities were fixed during that propagation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An initial-state interval contracts to a very narrow range: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An initial-state interval contracts to a very narrow range; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An initial-state interval contracts to a very narrow range: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An initial-state interval contracts to a very narrow range, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An initial-state interval contracts to a very narrow range: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An initial-state interval contracts to a very

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narrow range. Contraction removes only sensitivity to the uncertain initial state under the stated model Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An initial-state interval contracts to a very narrow range, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.7 Application 5A.2: Set a gain-error settling requirement (p. 2527)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An initial-state interval contracts to a very narrow range. Contraction removes only sensitivity to the uncertain initial state under the stated model Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or

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uncertainty term that limits confidence. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An initial-state interval contracts to a very narrow range and Has the gain-correction uncertainty become negligible; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.10 Application 5A.5: Identify a time constant from two signed residuals (p. 2530)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An initial-state interval contracts to a very narrow range”, addressing “Has the gain-correction uncertainty become negligible”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An initial-state interval contracts to a very narrow range. Has the gain-correction uncertainty become negligible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An initial-state interval contracts to a very narrow range. Has the gain-correction uncertainty become negligible”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

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V011-C05-DISCUSSION-014. Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation?” Put this particular dispute to the panel: Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 02. Student A, terminology and scope: Agree the operational meanings of calibrated, telemetry, replace and weak, overload, investigation in “Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.3: Convert a control state into an output level”. An RF reference can expose independent compression or recovery in the actual exercised path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a calibrated gain telemetry channel replace a weak RF reference during an overload

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investigation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.3: Convert a control state into an output level”. An RF reference can expose independent compression or recovery in the actual exercised path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Telemetry assesses one control state and its calibrated relationship Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation. Neither is automatically sufficient alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation. Neither is automatically sufficient alone Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation and Telemetry assesses one control state and its calibrated relationship; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation”, addressing “Telemetry assesses one control state and its calibrated

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relationship"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Can a calibrated gain telemetry channel replace a weak RF reference during an overload investigation". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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V011-C05-DISCUSSION-015. A blocker lies outside the displayed span. May it be excluded from the explanation for gain suppression?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A blocker lies outside the displayed span. May it be excluded from the explanation for gain suppression?” Put this particular dispute to the panel: A blocker lies outside the displayed span. May it be excluded from the explanation for gain suppression. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 02. Student A, terminology and scope: Agree the operational meanings of lies, outside, span and excluded, explanation, suppression in “A blocker lies outside the displayed span. May it be excluded from the explanation for gain suppression”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A blocker lies outside the displayed span; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. A wider shared path can drive AGC Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A blocker lies outside the displayed span; explain what each record can establish State what the existing record establishes, what it does not establish, and which

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further measurement would change your opinion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. A wider shared path can drive AGC Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Trace the signal admission to the control detector and vulnerable stages rather than using the display limits as a physical filter specification Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A blocker lies outside the displayed span: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A blocker lies outside the displayed span; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A blocker lies outside the displayed span: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A blocker lies outside the displayed span, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A blocker lies outside the displayed span: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A blocker lies outside the displayed span. Use a controlled blocker and retained weak reference to distinguish gain control from overload or source changes Explain the relevant statistical or calibration uncertainty, the range of defensible claims,

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and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A blocker lies outside the displayed span, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A blocker lies outside the displayed span. Use a controlled blocker and retained weak reference to distinguish gain control from overload or source changes Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A blocker lies outside the displayed span and May it be excluded from the explanation for gain suppression; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A blocker lies outside the displayed span”, addressing “May it be excluded from the explanation for gain suppression”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A blocker lies outside the displayed span. May it be excluded from the explanation for gain suppression”, specifying the next test, responsible measurement record and limit

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of the conclusion Summarise the strongest evidence for and against the resolution of “A blocker lies outside the displayed span. May it be excluded from the explanation for gain suppression”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

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V011-C05-DISCUSSION-016. Should a quieter RMS trace be preferred over a peak trace for every burst measurement?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a quieter RMS trace be preferred over a peak trace for every burst measurement?” Put this particular dispute to the panel: Should a quieter RMS trace be preferred over a peak trace for every burst measurement. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 02. Student A, terminology and scope: Agree the operational meanings of quieter, trace, preferred and peak, every, burst in “Should a quieter RMS trace be preferred over a peak trace for every burst measurement”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a quieter RMS trace be preferred over a peak trace for every burst measurement; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Logarithmic Amplifiers, Detectors, and Scaling”. The traces perform different operations, and each has waveform-dependent bandwidth, crest-factor and recovery limits Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a quieter RMS trace be preferred over a peak trace for every burst measurement;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Logarithmic Amplifiers, Detectors, and Scaling”. The traces perform different operations, and each has waveform-dependent bandwidth, crest-factor and recovery limits Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Define whether the intended result is a rare maximum, average power or another quantity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a quieter RMS trace be preferred over a peak trace for every burst measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a quieter RMS trace be preferred over a peak trace for every burst measurement; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a quieter RMS trace be preferred over a peak trace for every burst measurement: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a quieter RMS trace be preferred over a peak trace for every burst measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a quieter RMS trace be preferred over a peak trace for every burst measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a quieter RMS trace be preferred over a peak trace for every burst measurement. A quieter appearance does not make an estimator appropriate Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a quieter RMS trace be preferred over a peak trace for every burst measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a quieter RMS trace be preferred over a peak trace for every burst measurement. A quieter appearance does not make an estimator appropriate Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a quieter RMS trace be preferred over a peak trace for every burst measurement and Define whether the intended result is a rare maximum, average power or another quantity; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a quieter RMS trace be preferred over a peak trace for every burst measurement”, addressing “Define whether the intended result is a rare maximum, average power or

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another quantity"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Should a quieter RMS trace be preferred over a peak trace for every burst measurement", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Should a quieter RMS trace be preferred over a peak trace for every burst measurement". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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V011-C05-DISCUSSION-017. Does matching dBm labeling make two averaged traces directly comparable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Does matching dBm labeling make two averaged traces directly comparable?” Put this particular dispute to the panel: Does matching dBm labeling make two averaged traces directly comparable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 02. Student A, terminology and scope: Agree the operational meanings of matching, labeling, make and averaged, traces, comparable in “Does matching dBm labeling make two averaged traces directly comparable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Does matching dBm labeling make two averaged traces directly comparable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. Matching units can conceal different operations and time weights Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does matching dBm labeling make two averaged traces directly comparable; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. Matching units can conceal different operations and time weights Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify whether each trace averages linear power, logarithmic levels, selected samples or another detector output Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Does matching dBm labeling make two averaged traces directly comparable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does matching dBm labeling make two averaged traces directly comparable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Does matching dBm labeling make two averaged traces directly comparable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Does matching dBm labeling make two averaged traces directly comparable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Does matching dBm labeling make two averaged traces directly comparable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Does matching dBm labeling make two averaged traces directly comparable. Reconstruct a common intended statistic only when the retained data and calibration permit it Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Does matching dBm labeling make two averaged traces directly comparable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Does matching dBm labeling make two

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averaged traces directly comparable. Reconstruct a common intended statistic only when the retained data and calibration permit it Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Does matching dBm labeling make two averaged traces directly comparable and Identify whether each trace averages linear power, logarithmic levels, selected samples or another detector…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Does matching dBm labeling make two averaged traces directly comparable”, addressing “Identify whether each trace averages linear power, logarithmic levels, selected samples or another detector…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Does matching dBm labeling make two averaged traces directly comparable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Does matching dBm labeling make two averaged traces directly comparable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

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V011-C05-DISCUSSION-018. A flat output is described as successful AGC. What would make that conclusion persuasive?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A flat output is described as successful AGC. What would make that conclusion persuasive?” Put this particular dispute to the panel: A flat output is described as successful AGC. What would make that conclusion persuasive. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 02. Student A, terminology and scope: Agree the operational meanings of flat, described, successful and make, conclusion, persuasive in “A flat output is described as successful AGC. What would make that conclusion persuasive”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A flat output is described as successful AGC; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Automatic Gain Control and Hidden State”. Consider limiting, clipping, log-detector saturation and software normalization as alternative plateau mechanisms Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A flat output is described as successful AGC; explain what each record can establish State what the existing record establishes, what it does not establish, and which

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further measurement would change your opinion. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Automatic Gain Control and Hidden State”. Consider limiting, clipping, log-detector saturation and software normalization as alternative plateau mechanisms Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require control-state evidence, a calibrated gain relationship and a reference demonstrating valid signal transfer under the same conditions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A flat output is described as successful AGC: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A flat output is described as successful AGC; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A flat output is described as successful AGC: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A flat output is described as successful AGC, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A flat output is described as successful AGC: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A flat output is described as successful AGC. The team should define an observable prediction that separates them, including recovery and weak-signal response, rather than accepting flatness alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A flat output is described as successful AGC, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A flat output is described as successful AGC. The team should define an observable prediction that separates them, including recovery and weak-signal response, rather than accepting flatness alone Respond point by point to Student J. Distinguish a

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verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A flat output is described as successful AGC and What would make that conclusion persuasive; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A flat output is described as successful AGC”, addressing “What would make that conclusion persuasive”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A flat output is described as successful AGC. What would make that conclusion persuasive”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A flat output is described as successful AGC. What would make that conclusion persuasive”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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V011-C05-DISCUSSION-019. A digital filter update preserves the center-frequency label and corrected tone level. Is regression still needed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A digital filter update preserves the center-frequency label and corrected tone level. Is regression still needed?” Put this particular dispute to the panel: A digital filter update preserves the center-frequency label and corrected tone level. Is regression still needed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- 02. Student A, terminology and scope: Agree the operational meanings of digital, update, preserves and label, corrected, regression in “A digital filter update preserves the center-frequency label and corrected tone level. Is regression still needed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A digital filter update preserves the center-frequency label and corrected tone level; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. Center agreement can coexist with altered skirts, delay or transient behavior Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A digital filter update preserves the center-frequency label and corrected tone level;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. Center agreement can coexist with altered skirts, delay or transient behavior Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine coefficient, clock, scaling, detector and automatic-selection changes Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A digital filter update preserves the center-frequency label and corrected tone level: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A digital filter update preserves the center-frequency label and corrected tone level; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A digital filter update preserves the center-frequency label and corrected tone level: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A digital filter update preserves the center-frequency label and corrected tone level, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A digital filter update preserves the center-frequency label and corrected tone level: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A digital filter update preserves the center-frequency label and corrected tone level. Repeat the cases whose assumptions could have changed and verify correction applicability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A digital filter update preserves the center-frequency label and corrected tone level, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A digital filter update preserves the center-frequency label and corrected tone level. Repeat the cases whose

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assumptions could have changed and verify correction applicability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.18 IF Alignment, Calibration, and Failure Localization (p. 2540)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A digital filter update preserves the center-frequency label and corrected tone level and Is regression still needed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A digital filter update preserves the center-frequency label and corrected tone level”, addressing “Is regression still needed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A digital filter update preserves the center-frequency label and corrected tone level. Is regression still needed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A digital filter update preserves the center-frequency label and corrected tone level. Is regression still needed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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V011-C05-DISCUSSION-020. A manual contains a numerical inconsistency but useful qualitative circuit discussion. Should the whole source be discarded?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A manual contains a numerical inconsistency but useful qualitative circuit discussion. Should the whole source be discarded?” Put this particular dispute to the panel: A manual contains a numerical inconsistency but useful qualitative circuit discussion. Should the whole source be discarded. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 02. Student A, terminology and scope: Agree the operational meanings of manual, contains, numerical and circuit, discussion, discarded in “A manual contains a numerical inconsistency but useful qualitative circuit discussion. Should the whole source be discarded”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A manual contains a numerical inconsistency but useful qualitative circuit discussion; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “5. Calibration and negative-survey validity for dynamic IF paths”. Derive synthetic teaching cases independently and do not promote a guessed correction to a verified device specification Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A manual contains a numerical inconsistency but useful qualitative circuit discussion; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “5. Calibration and negative-survey validity for dynamic IF paths”. Derive synthetic teaching cases independently and do not promote a guessed correction to a verified device specification Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish the specific inconsistent expressions from the supported material, retaining exact edition and page scope Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A manual contains a numerical inconsistency but useful qualitative circuit discussion: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A manual contains a numerical inconsistency but useful qualitative circuit discussion; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A manual contains a numerical inconsistency but useful qualitative circuit discussion: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A manual contains a numerical inconsistency but useful qualitative circuit discussion, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A manual contains a numerical inconsistency but useful qualitative

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circuit discussion: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A manual contains a numerical inconsistency but useful qualitative circuit discussion. Document the qualification and seek clarification or measurement for equipment-specific use Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A manual contains a numerical inconsistency but useful qualitative circuit discussion, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A manual contains a numerical inconsistency but useful qualitative circuit discussion. Document the qualification and seek clarification or measurement for equipment-specific use Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A manual contains a numerical inconsistency but useful qualitative circuit discussion and Should the whole source be discarded; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A manual contains a numerical inconsistency but useful qualitative circuit discussion”, addressing “Should the whole source be discarded”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A manual contains a numerical inconsistency but useful qualitative circuit discussion. Should the whole source be discarded”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A manual contains a numerical inconsistency but useful qualitative circuit discussion. Should the whole source be discarded”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

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V011-C05-DISCUSSION-021. A repaired receiver passes only the procedure's usual center-tone test. What should determine whether more checks are necessary?

- 01. Moderator, opening proposition: Introduce the exact dispute, "A repaired receiver passes only the procedure's usual center-tone test. What should determine whether more checks are necessary?" Put this particular dispute to the panel: A repaired receiver passes only the procedure's usual center-tone test. What should determine whether more checks are necessary. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- 02. Student A, terminology and scope: Agree the operational meanings of repaired, passes, procedure and usual, checks, necessary in "A repaired receiver passes only the procedure's usual center-tone test. What should determine whether more checks are necessary"; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A repaired receiver passes only the procedure's usual center-tone test; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.1 Intermediate Frequency as a Controlled Band (p. 2513)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in "Intermediate Frequency as a Controlled Band". Skirts, delay, gain boundaries, detection and recovery may require representative additional cases Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.1 Intermediate Frequency as a Controlled Band (p. 2513)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A repaired receiver passes only the procedure's usual center-tone test; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Intermediate Frequency as a Controlled Band”. Skirts, delay, gain boundaries, detection and recovery may require representative additional cases Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.1 Intermediate Frequency as a Controlled Band (p. 2513)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Relate the repair to the path properties and measurement claims that could have changed Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A repaired receiver passes only the procedure's usual center-tone test: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A repaired receiver passes only the procedure's usual center-tone test; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A repaired receiver passes only the procedure's usual center-tone test: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a

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rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A repaired receiver passes only the procedure's usual center-tone test, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.1 Intermediate Frequency as a Controlled Band (p. 2513)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A repaired receiver passes only the procedure's usual center-tone test: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A repaired receiver passes only the procedure's usual center-tone test. Use declared criteria or an applicable baseline rather than expanding testing without a concrete purpose Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A repaired receiver passes only the procedure's usual center-tone test, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.1 Intermediate Frequency as a Controlled Band (p. 2513)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A repaired receiver passes only the procedure's usual center-tone test. Use declared criteria or an applicable baseline rather than expanding testing without a concrete purpose Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A repaired receiver passes only the procedure's usual center-tone test and What should determine whether more checks are necessary; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about "A repaired receiver passes only the procedure's usual center-tone test", addressing "What should determine whether more checks are necessary"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A repaired receiver passes only the procedure’s usual center-tone test. What should determine whether more checks are necessary”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A repaired receiver passes only the procedure’s usual center-tone test. What should determine whether more checks are necessary”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.20 IF Acceptance and Regression Tests (p. 2543)

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V011-C05-DISCUSSION-022. A later closing check passes after a burst that may have overloaded the path. May it validate the burst retrospectively?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A later closing check passes after a burst that may have overloaded the path. May it validate the burst retrospectively?” Put this particular dispute to the panel: A later closing check passes after a burst that may have overloaded the path. May it validate the burst retrospectively. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 02. Student A, terminology and scope: Agree the operational meanings of closing, check, passes and overloaded, validate, retrospectively in “A later closing check passes after a burst that may have overloaded the path. May it validate the burst retrospectively”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A later closing check passes after a burst that may have overloaded the path; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “5. Calibration and negative-survey validity for dynamic IF paths”. The check assesses the functions exercised at its own time; it can reveal persistent change but does not establish uninterrupted earlier transfer Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A later closing check passes after a burst that may have overloaded the path; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “5. Calibration and negative-survey validity for dynamic IF paths”. The check assesses the functions exercised at its own time; it can reveal persistent change but does not establish uninterrupted earlier transfer Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Keep the time scope explicit Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A later closing check passes after a burst that may have overloaded the path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A later closing check passes after a burst that may have overloaded the path; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A later closing check passes after a burst that may have overloaded the path: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A later closing check passes after a burst that may have overloaded the path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A later closing check passes after a burst that may have overloaded the path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A later closing check passes after a burst that may have overloaded the path. Contemporaneous references, clipping indicators and state records are needed for the burst interval Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A later closing check passes after a burst that may have overloaded the path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A later closing check passes after a burst that may have overloaded the path. Contemporaneous references, clipping indicators and state records are needed for the burst interval Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A later closing check passes after a burst that may have overloaded the path and May it validate the burst retrospectively; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.9 Application 5A.4: Check the required control polarity after a level step (p. 2529)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A later closing check passes after a burst that may have overloaded the path”, addressing “May it validate the burst retrospectively”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and

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I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A later closing check passes after a burst that may have overloaded the path. May it validate the burst retrospectively”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A later closing check passes after a burst that may have overloaded the path. May it validate the burst retrospectively”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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V011-C05-DISCUSSION-023. May the final gain value be applied to a record if the control telemetry is too slow to resolve the event?

- 01. Moderator, opening proposition: Introduce the exact dispute, “May the final gain value be applied to a record if the control telemetry is too slow to resolve the event?” Put this particular dispute to the panel: May the final gain value be applied to a record if the control telemetry is too slow to resolve the event. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 02. Student A, terminology and scope: Agree the operational meanings of final, applied, control and telemetry, slow, resolve in “May the final gain value be applied to a record if the control telemetry is too slow to resolve the event”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of May the final gain value be applied to a record if the control telemetry is too slow to resolve the event; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Without that evidence, the final value does not describe an unsettled burst Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of May the final gain value be applied to a record if the control telemetry is too slow to resolve the

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event; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Without that evidence, the final value does not describe an unsettled burst Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask whether a validated dynamic model and known initial state support interpolation for this regime Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving May the final gain value be applied to a record if the control telemetry is too slow to resolve the event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of May the final gain value be applied to a record if the control telemetry is too slow to resolve the event; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving May the final gain value be applied to a record if the control telemetry is too slow to resolve the event: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving May the final gain value be applied to a record if the control telemetry is too slow to resolve the event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving May the final gain value be applied to a record if the control telemetry is too slow to resolve the event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for May the final gain value be applied to a record if the control telemetry is too slow to resolve the event. Even a valid control interpolation cannot recreate clipped RF peaks Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving May the final gain value be applied to a record if the control telemetry is too slow to resolve the event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for May the final gain value be applied to a record if the control telemetry is too slow to resolve the event. Even a valid control interpolation cannot recreate clipped RF peaks Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about May the final gain value be applied to a record if the control telemetry is too slow to resolve the event and Ask whether a validated dynamic model and known initial state support interpolation for this regime; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.15 Application 5A.10: Propagate an initial-state interval (p. 2535)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “May the final gain value be applied to a record if the control telemetry is too slow to resolve the event”,

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addressing “Ask whether a validated dynamic model and known initial state support interpolation for this regime”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “May the final gain value be applied to a record if the control telemetry is too slow to resolve the event”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “May the final gain value be applied to a record if the control telemetry is too slow to resolve the event”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.8 Application 5A.3: Convert a control state into an output level (p. 2528)

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V011-C05-DISCUSSION-024. When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity?” Put this particular dispute to the panel: When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 02. Student A, terminology and scope: Agree the operational meanings of audio, trace, stored and disagree, highest, apparent in “When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “5. Calibration and negative-survey validity for dynamic IF paths”. The outputs may represent different quantities, and sensitivity to one waveform does not validate another measurement Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “5. Calibration and negative-survey validity for dynamic IF paths”. The outputs may represent different quantities, and sensitivity to one waveform does not validate another measurement Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reconcile path origin, filter, detector, state and acquisition timing first Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 08. Student D, answer to Student E: Design a discriminating experiment involving When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity. Choose the observation suited to the intended claim, retaining the others as complementary evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage

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and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity. Choose the observation suited to the intended claim, retaining the others as complementary evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity and Reconcile path origin, filter, detector, state and acquisition timing first; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field

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boundaries. Source: §5.25 Detector dynamics and intermediate-frequency filters as temporally extended measurement operators (p. 2550)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity”, addressing “Reconcile path origin, filter, detector, state and acquisition timing first”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When audio, a spectrum trace and stored I/Q disagree, should the team select the output with the highest apparent sensitivity”. Allocate the next measurement and documentary action to named student roles, and

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require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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V011-C05-DISCUSSION-025. What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved?” Put this particular dispute to the panel: What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 02. Student A, terminology and scope: Agree the operational meanings of report, support, leave and recovery, mechanism, unresolved in “What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Retain the event interval, references and competing explanations, and propose a specific additional observable or controlled perturbation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Retain the event interval, references and competing explanations, and propose a specific additional observable or controlled perturbation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the tested model, configuration, level and time domain separately from the

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unresolved recovery behavior Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 08. Student D, answer to Student E: Design a discriminating experiment involving What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is

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missing. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved. A bounded result is useful when its limits are explicit Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should a team report when its IF tests

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support a local control model but leave the strong-event recovery mechanism unresolved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved. A bounded result is useful when its limits are explicit Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved and State the tested model, configuration,

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level and time domain separately from the unresolved recovery behavior; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved”, addressing “State the tested model, configuration, level and time domain separately from the unresolved recovery behavior”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the

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strongest evidence for and against the resolution of “What should a team report when its IF tests support a local control model but leave the strong-event recovery mechanism unresolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

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Chapter 5 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C05-ESSAY-001 — Define the residual as the control voltage minus the fixed target. Its derivative is minus the residual divided by the positive time constant. Integration gives $e(t)=e_0\exp(\frac{-t}{\tau})$, where e_0 is the initial residual; adding the target gives the voltage solution in Equation 10B. Retain voltage units for the state and matched time units in the dimensionless exponent. Since the exponential is positive and decreases from one, the residual keeps its sign and the voltage moves monotonically between the initial state and target. Overshoot, a delayed start, persistent oscillation or a sign reversal therefore cannot be explained by the same uninterrupted segment. They may indicate additional dynamics, a changed target, a hold state or measurement error; the equation alone does not select among those explanations. A voltage fit also does not supply RF gain without the calibrated signed local map. It neither identifies the full feedback topology nor validates clipping, slew or recovery outside its fitted domain. A sound answer separates the mathematical consequence from the empirical evidence needed to apply it. Review: Equations 10A–10C; Model 5A introduction.

Review: Chapter 5 — Equation 10A. Identified control-state equation; Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Model 5A: an identified one-pole gain-control response.

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V011-C05-ESSAY-002 — Use consistent frequency units to obtain Q equal to 10.7 divided by 0.180, approximately 59.44. The stated width ratio is 720 divided by 180, or 4. Label its two attenuation levels explicitly; do not silently compare it with a shape factor defined using minus-6 dB width. These two scalars still omit passband ripple, the detailed skirts, transfer phase, group-delay variation and impulse response. A burst can be shorter than the path's settling time even when its nominal occupied spectrum seems to fit. The measured peak also depends on detector operation and the instant at which it is sampled. Establish the actual burst waveform, path response and observation timing, then verify peak transfer with an applicable calibrated transient. A continuous center-frequency gain correction is not enough. Equal loaded Q or equal width ratio in another filter does not guarantee equivalent temporal response or noise weighting. The report should retain the bandwidth definitions and the peak-specific verification separately. Review: Equation 9; Filter Shape, Selectivity, and Time Response; Hypothetical Case Adjudication.

Review: Chapter 5 — Equation 9. Loaded quality factor; Chapter 5 — Filter Shape, Selectivity, and Time Response; Chapter 5 — Hypothetical Case Adjudication: Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors.

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V011-C05-ESSAY-003 — The elapsed ratio is 1.5, so the remaining voltage residual is minus 0.6 times exp of minus 1.5 V. The state is 0.6161219 V. Subtract the reference voltage and apply the signed slope to obtain 15.68573 dB gain; output is minus 56.31427 dBm. At the 0.75 V target, gain is 11 dB and output is minus 61 dBm. The initial gain-error magnitude relative to that target is 35 times 0.6, or 21 dB. The settling expression is 0.8 times ln of 105 ms, giving 3.72317 ms. The whole monotone voltage trajectory lies inside the stated calibration range, but the calculation additionally assumes fixed RF input and a valid signal path. It does not establish that an earlier stage avoids compression. The final gain must not be applied to all earlier samples; a time-resolved correction needs the calibrated control state aligned to the RF record. Retain the tolerance units and calibration uncertainty when converting this theoretical wait into an acceptance decision. Review: Equations 10B–10E; Applications 5A.2 and 5A.3.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement; Chapter 5 — Application 5A.3: Convert a control state into an output level.

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V011-C05-ESSAY-004 — Restoring the previous output requires a gain change of minus 15 dB. Dividing by minus 30 dB/V gives a positive 0.5 V target change, so the target is 0.7 V. At half a time constant the state is 0.3967347 V. Its 0.1967347 V rise reduces gain by 5.90204 dB, leaving an output rise of 9.09796 dB. This is also 15 times exp of minus 0.5 dB, the residual correction still required. A falling control voltage under this negative slope would increase gain and initially worsen the output rise. The remaining transient does not imply that the steady-state target is wrong. Check the whole control range, available gain range and RF-path validity before assigning the result to a real receiver. If another input transition occurs before settling, carry the actual state into the next segment. A changed detector or gain range can also require a different identified slope or time constant. Review: Equations 10C, 10D and 10G; Application 5A.4.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

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V011-C05-ESSAY-005 — The two residuals have the same sign and decrease in magnitude. Their ratio is five over a 1.2 ms separation, giving a time constant of 1.2 divided by $\ln(5)$, or 0.7456019 ms. Extrapolating the first residual backward gives approximately minus 0.2243023 V at the time origin. From 1.5 to 2.1 ms, multiply minus 0.03 V by exp of minus 0.6 divided by the fitted time constant, giving approximately minus 0.0134164 V. An additional point should challenge that prediction using the measurement uncertainty and the validity of the common target. A material disagreement is evidence to investigate, not a reason to discard the point automatically. A wrong target, detector offset, slew-limited early interval or multiple dynamics can invalidate a single exponential. Retain the signed residuals, actual time reference and measured target. Two-point interpolation alone does not identify the loop's internal topology or justify transfer to other gain states and input excursions. Review: Equation 10F; Application 5A.5.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

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V011-C05-ESSAY-006 — The first segment leaves the initial minus 0.8 V residual multiplied by exp of minus two thirds. Its terminal state is approximately 0.4892663 V. Use that value as the second initial state: the remaining displacement from 0.3 V is 0.1892663 V times exp of minus 0.8 divided by 1.5. The final state is approximately 0.4110324 V. Incorrectly restarting from 0.9 V would instead give approximately 0.6519877 V, an overestimate of about 0.2409554 V. The error arises from assuming an equilibrium that the first interval never reached. Explain that the state is continuous under this finite-rate model even though the target and time constant change. The result requires both segment parameters to be applicable and the transition time to be known. In repeated bursts, preserve enough history to determine the initial state or establish a validated periodic trajectory; a trigger does not reset the physical control. Review: Equation 10G; Application 5A.6.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

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V011-C05-ESSAY-007 — Attack ends at approximately 0.6661219 V, calculated from a 1.5-time-constant segment. The explicitly stipulated hold retains that state for 0.4 ms. Release then lasts only 0.8 ms, half its own time constant, giving final state approximately 0.4827172 V. If release were incorrectly started immediately after attack, the full 1.2 ms remainder would be used and the predicted final state would be approximately 0.4201804 V. The two values differ by about 0.0625368 V because a hold is not equivalent to a slower exponential. State what event starts the timer, what quantity is held and when release begins. The constructed hold rule is part of this example, not a universal AGC behavior. A real receiver may reset or retrigger its timer on additional events, and that logic must be observed or specified. Separate attack, hold and release records make later weak-signal suppression interpretable. Review: Equation 10G discussion; Application 5A.7.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

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V011-C05-ESSAY-008 — The elapsed ratio is 0.0625, so step completion is one minus exp of minus 0.0625, approximately 6.05869 percent. The voltage reaches approximately 0.2424109 V. Its 0.0424109 V increase changes gain by minus 1.69643 dB, leaving an output rise of approximately 26.30357 dB under the valid small-signal model. The 95-percent time is 4 times $\ln(20)$, or 11.98293 ms, much longer than the burst. The final target would provide the required minus 28 dB gain correction, but it is not approached closely during this short event. These results predict only the identified control and gain response. The initial RF peak can exceed an earlier stage's valid range before control acts, and telemetry or detector bandwidth can hide that peak. Record a suitable signal-path observable as well as control state. Do not use the model to reconstruct clipped samples or claim successful transient protection from the eventual gain reduction. Review: Equations 10B–10E; Application 5A.8.

Review: Chapter 5 — Equation 10B. Control voltage and residual; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.8: Compare burst duration with control settling.

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V011-C05-ESSAY-009 — The normalized interval is 1.5. The exact residual coefficient is exp of minus 1.5, approximately 0.2231302; after five steps the residual is 0.6 times exp of minus 7.5, approximately 0.000331851 V. Its sign stays positive and its magnitude decays monotonically. Euler instead uses one minus 1.5, or minus 0.5. Five steps give minus 0.01875 V. This Euler sequence is asymptotically stable because the coefficient magnitude is below one, but it alternates across the target and does not reproduce the stipulated physical one-pole samples. Stability alone is therefore not an accuracy or monotonicity certificate. At an interval ratio of two, Euler would have undamped sign alternation; above two its magnitude would grow. The exact recurrence avoids this approximation error for the stated model. If the implemented controller is physically discrete, identify that controller's actual update rather than assuming the continuous model is authoritative. Review: Equations 10H and 10I; Application 5A.9.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range; Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

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V011-C05-ESSAY-010 — The exponential factor is exp of minus two. Mapping the initial endpoints gives approximately 0.5823324 through 0.5958659 V. The negative slope reverses endpoint order in gain, giving approximately 12.16536 through 12.70671 dB; its width is 0.541341 dB. Final gain at 0.65 V is 10 dB, so the largest error at 1 ms is 2.70671 dB. The largest initial voltage error is 0.5 V, corresponding to 20 dB. To cover the whole interval, use 0.5 times ln of 100 ms, giving 2.302585 ms. A midpoint calculation would not cover all allowed initial states. These are deterministic bounds with fixed target, time constant and slope, not a probabilistic confidence interval. A complete gain-correction uncertainty assessment also considers those parameters, calibration, timing alignment and any departures from the stipulated path. Do not describe contraction of the initial-state interval as removal of all measurement uncertainty. Review: Equations 10C, 10E and 10J; Application 5A.10.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-ESSAY-011 — The linear power gains are 1, 10 and 100. With the stated durations, mean power gain is the weighted sum 1 plus 20 plus 100 divided by 4, or 30.25. Its logarithmic equivalent is approximately 14.80725 dB, so mean output is minus 45.19275 dBm. The time-weighted arithmetic mean gain is instead 10 dB, which would give minus 50 dBm and answers a different question. For a time-resolved input estimate, apply the calibrated gain corresponding to each actual signal sample or interval before forming the intended power statistic. Retain timing alignment, gain transitions and the detector's operation. A mean gain value cannot generally reverse a nonlinear averaging order. These calculations assume fixed input, valid linear transfer in each state and no missing clipped data. An AGC history may be useful for reconstruction, but it does not supply information destroyed by saturation or absent from the acquisition. Review: Equation 10D discussion; Verify the detector and control path as part of the IF result; Chapter 8 connection.

Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

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V011-C05-ESSAY-012 — Convert the frequency span to angular-frequency span by multiplying 200000 Hz by two pi. The negative phase slope divided by that span gives positive group delay approximately 3 microseconds. State that the finite-difference calculation represents a constant slope only because linear phase has been stipulated. The amplitude variation still weights spectral components differently, so exact unchanged-copy behavior does not follow. Whether the distortion is acceptable depends on the waveform and its amplitude-fidelity tolerance; the given plus-or-minus 1 dB variation cannot simply be ignored. A single center-frequency delay would be weaker evidence than the full-band linear-phase condition supplied here. If the transfer becomes too small near a notch, phase and its derivative may also become ill-conditioned. Preserve the phase reference, unwrap procedure, frequency interval and response magnitude. The result is a frequency-domain descriptor with stated conditions, not a universal transit-time claim for arbitrary pulses. Review: Choose an IF path for the quantity being measured; Chapter Glossary: Group delay.

Review: Chapter 5 — Choose an IF path for the quantity being measured; Chapter 5 — GROUP DELAY (glossary).

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V011-C05-ESSAY-013 — The farthest initial endpoint is 0.1 V, with 0.5 V error, giving a maximum initial gain error of 25 dB. The slowest admissible decay uses 1.2 ms. The conservative wait is therefore 1.2 times ln of 125 ms, approximately 5.79398 ms. Using the faster 0.8 ms endpoint would give approximately 3.86265 ms and would not cover the slower allowed case. The argument uses monotonic dependence of residual magnitude on the initial error magnitude and on the positive time constant for fixed elapsed time. It does not assign probabilities to the endpoints. The target and slope were held fixed, and the gain law and signal path were assumed valid throughout. Uncertainty in those quantities, telemetry timing, detector response and model adequacy remains outside this bound. If the target itself is uncertain, late-time convergence to a target does not remove uncertainty about its gain. Report the covered parameter domain explicitly. Review: Equations 10E and 10J; Application 5A.10 qualification.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-ESSAY-014 — Actual gain at 1 ms is 5 plus 20 times exp of minus one, approximately 12.35759 dB. The stale value from 0.8 ms is approximately 13.98658 dB. Subtracting that stale, larger gain from the actual output underestimates the input level by approximately 1.62899 dB. The sign matters: the software removes too much gain while the true gain is decreasing. This example isolates timing misalignment; it assumes the static gain calibration and the RF observations themselves are valid. A correction requires a measured relative delay or a synchronized record, with interpolation justified over the relevant dynamics. The final settled gain cannot repair the history, and fitting a control curve cannot reconstruct clipped or otherwise lost RF samples. Retain the physical time origin, telemetry timestamps and the applied alignment operation so the input-referred result can be reproduced. Review: Equation 10D; Application 5A.3.

Review: Chapter 5 — Equation 10D. Output level and gain-error magnitude; Chapter 5 — Application 5A.3: Convert a control state into an output level.

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V011-C05-ESSAY-015 — Begin with the actual path identity, reference planes, gain state and filter configuration. A swept or stepped calibrated tone can characterize passband amplitude and skirts and provides useful common response evidence. Tone amplitude needs the applicable frequency and level correction. Integrated channel power additionally needs the power weighting, effective bandwidth and detector or numerical integration convention across the occupied band. Burst peak requires a suitable impulse or step response, sufficient acquisition and detector bandwidth, known timing and peak-handling capability. A long-record energy agreement does not establish the original peak. Test fixed gain first to separate path response from control motion, then repeat relevant stimuli in the intended automatic mode. Preserve the stimulus waveform, reference measurements, response limits and uncertainty appropriate to each measurand. Do not treat one successful center-tone calibration or a shared bandwidth label as validation of all three quantities. The output should be a response matrix linked to specific measurement claims. Review: Filter Shape, Selectivity, and Time Response; Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Filter Shape, Selectivity, and Time Response.

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V011-C05-ESSAY-016 — Retain the actual transition time, range identity and control state. Apply the calibrated gain law belonging to each range over its valid voltage and signal interval; do not continue the old slope merely because the telemetry voltage is continuous. A range switch can produce an actual gain step, so continuity of RF gain is a measurement question rather than an automatic constraint. The control target and dynamic parameters can also change, requiring an applicable new segment with the actual carried state or the measured reset behavior. Synchronize the RF record with the state transition and mark any interval in which the transfer is not characterized. Verify the boundary using known stimuli on both sides and, where relevant, during the switch. Preserve correction-table identity and the observations supporting applicability. A numerically smooth corrected trace should not be manufactured by assuming away a physical discontinuity. Report any missing or invalid transition data explicitly. Review: Equations 10C and 10G; IF Acceptance and Regression Tests.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-ESSAY-017 — Maintain a known weak reference at the declared input plane and document the strong signal's delivered level and spectrum. Record control state and the path feeding the control detector, which may be wider than the displayed channel. Compare fixed-gain and intended automatic-gain operation while controlling other settings. If the weak response changes in accordance with calibrated control gain, that supports shared-control suppression, but verify that the reference remains measurable and the path remains linear. A fixed-gain result can still reveal overload or gain compression, so compare bounded strong-signal levels and appropriate attenuation or filtering with the desired reference preserved. Where accessible, observations before and after detection help localize the mechanism. A genuinely fixed injected weak reference removes source fading as the explanation for its own change, though it does not establish the behavior of a separate environmental source. Retain state, recovery and sensitivity limits, and avoid treating disappearance in the narrow display as proof that the blocker never reached the receiver. Review: Automatic Gain Control and Hidden State; Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Automatic Gain Control and Hidden State.

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V011-C05-ESSAY-018 — Each detector applies a different operation and often a different temporal selection. A peak can retain a rare excursion; a sample can miss it; a mean-square operation weights power over its stated interval; a mean of logarithmic levels gives another statistic. Burst duty, dwell, sample selection, averaging count and video filtering affect the comparison. RMS labeling does not remove bandwidth, level, crest-factor or recovery limits. Establish which physical quantity is required, then express the relevant detector operation and calibration under the actual waveform. Compare paths only after accounting for filter weighting and gain history. A quieter-looking trace is not inherently more accurate, and matching display units do not establish matching measurands. Retain raw or native observations when available so a valid alternate statistic can be reproduced. If a detector clips or misses the event, no change of averaging convention restores the absent information. Distinguish a legitimate difference in estimators from a failure of a device to meet its stated operating conditions. Review: Logarithmic Amplifiers, Detectors, and Scaling; Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

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V011-C05-ESSAY-019 — A local fit identifies an observed response under the tested target, initial state, gain range, detector conditions and level excursion. It does not uniquely determine the internal architecture. Different systems can share one small-signal response while differing in integrating action, limits, hang rules, delays, windup and overdrive behavior. Use additional step sizes, initial conditions, time samples and state transitions to challenge the empirical model. Separate measured voltage response from calibrated gain and from the recovery of preceding RF stages. Retain the fit residuals and the conditions under which the model is accepted; do not hide systematic departures by selecting only convenient points. When internal documentation is unavailable, an observed input/output model with clear configuration and waveform limits remains useful. A strong-burst claim requires actual evidence for the relevant level, duration and recovery criterion. Neither the exponential equation nor the RMS detector label supplies a universal guarantee. Review: Model 5A introduction; Application 5A.5; Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals; Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-ESSAY-020 — A settled control state does not establish that every signal-path stage has recovered. A limiter, amplifier, detector or digital normalization step can retain a different disturbance; the reference measurement itself can also be bandwidth- or floor-limited. First establish that the weak reference is observable and that its injection point exercises the intended stages. Retain control and RF timing through the disturbance. Compare fixed-gain and automatic modes where available, use relevant pre- and post-detection observations, and vary pulse duration or level while controlling other conditions. A bypass or alternate path is informative only when the remaining chain stays within its valid range and the changed transfer is accounted for. Determine return to a declared reference amplitude and, where relevant, phase tolerance rather than merely return to a flat display. A later successful check assesses the functions exercised then; it cannot retroactively prove uninterrupted validity. Report the affected interval and the unresolved stage if localization remains incomplete. Review: Verify the detector and control path as part of the IF result; IF Alignment, Calibration, and Failure Localization.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — IF Alignment, Calibration, and Failure Localization.

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V011-C05-ESSAY-021 — Identify the exact revision and inspected pages, then separate the supported qualitative discussion from the disputed printed numerical expressions. The source supports a local single-pole response for small changes, integrating control, gain polarity and distinct large-change current-limited behavior. Page 13's printed Equation 4 has an intercept-sign conflict with its explanatory text, and the page 16 capacitance, slew and bandwidth example is internally inconsistent. Do not copy those expressions into an unqualified performance claim. The chapter's synthetic cases are derived from their declared state equation and calibrated local gain map; they are not measurements of that device. An independent dimensional calculation can expose a source inconsistency but does not establish the actual part's behavior across its operating conditions. A real equipment-specific use would need applicable authoritative clarification or direct validation. Preserve accurate source identity and the narrow qualification in References and Works Cited, while retaining the original source note and its legitimate scope. Review: Model 5A introduction; source notes 14 and 15; Chapter 5 References and Works Cited.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — Intermediate Frequency as a Controlled Band; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — References and Works Cited.

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V011-C05-ESSAY-022 — Retain the old and new firmware, coefficients, sample-rate interpretation, scaling, filter selection and correction identities. A common center label does not establish unchanged physical frequency weighting, gain or time response. Apply known tones across the passband and skirts, a calibrated noise case with an appropriate effective bandwidth, and representative bursts or modulation that exercise delay and settling. Include automatic filter boundaries and any gain-control paths whose detector admission may have changed. Compare the same declared reference planes and measurands under compatible detector operations. Preserve native observations and the processing steps that form the reported values. Differences should be assessed against applicable criteria or an approved baseline rather than removed by display renormalization. If a correction table remains in use, verify its applicability to the new physical and numerical transfer. State the tested domain and any transition interval for which response is not yet characterized. Review: IF Alignment, Calibration, and Failure Localization; IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Alignment, Calibration, and Failure Localization; Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-ESSAY-023 — Identify the local gain reference, signed slope, calibrated voltage interval and applicable RF levels. Include control-voltage measurement uncertainty, reference-gain and slope uncertainty, and the relative timing of telemetry and RF observations. If a dynamic fit is used between samples, include uncertainty and adequacy of its target, time constant, initial state and segmentation. An initial-state interval propagated through Equation 10J covers only one contribution; it is not the whole budget. Establish the detector operation, filter response and waveform conditions, including whether the burst is short relative to settling or telemetry response. Mark clipping, overdrive or gain-range transitions that invalidate a simple invertible correction. Apply the correction at the appropriate times before forming the intended physical-power statistic, and retain correlations where the adopted uncertainty method requires them. A bounded result can remain useful even if some intervals are excluded, but the exclusion and its effect on the claimed burst quantity must be explicit. Review: Equations 10C–10J; Applications 5A.3 and 5A.10; Chapter 14 connection.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — Application 5A.3: Convert a control state into an output level; Chapter 5 — Application 5A.10: Propagate an initial-state interval; Chapter 14 — Use covariance and model sensitivity deliberately; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Equation 10J. Propagation of an initial-state interval.

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V011-C05-ESSAY-024 — Record exact configuration, reference planes, stimuli, correction method, environmental conditions relevant to the response and the acceptance criteria. Include several passband and skirt frequencies, applicable bandwidth and gain boundaries, a calibrated noise case, a short event and a recovery case. Use fixed gain to characterize the path and the intended automatic mode to exercise attack, release, hang and shared-channel loading. Observe an appropriate weak reference during the disturbance if continuing transfer is part of the claim. Compare with declared specifications or a compatible approved baseline and retain characteristic traces for future regression. A passing closing check establishes the functions and states actually exercised at that later time. It does not alone prove that earlier samples remained valid through a transient, nor does it cover untested configurations. The release statement should name the tested domain and any unresolved restriction, with enough evidence for another examiner to reproduce the comparison. Review: IF Acceptance and Regression Tests; Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-ESSAY-025 — Treat the three outputs as different paths until their filter, takeoff, detector, averaging and gain states are reconciled. The narrow trace may reduce a short peak through settling or selection, while the wider I/Q path can retain it and the audio path can exclude it. Moving telemetry adds a time-dependent gain factor; a final settled gain cannot correct the whole event. Preserve the native records and timing, determine whether any path clipped, and apply only validated corrections. Repeat a known representative burst with independently controlled duration and amplitude, first at fixed gain and then in the intended automatic mode. Retain a suitable weak reference and exercise relevant filter boundaries. A difference explained by receiver response is not automatically a propagation change, and an unresolved difference should not be assigned to an external source without discriminating evidence. The report should state which quantities are supported, which intervals or paths remain limited, and the specific observation that would resolve the leading alternatives. Review: Hypothetical Case Adjudication; Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 5 — Hypothetical Case Adjudication: Intermediate-Frequency Chains, Filters, AGC, Logarithmic Paths, and Detectors.

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Discussion Guidance

V011-C05-DISCUSSION-001 — Ask what quantity the observation must preserve: tone separation, channel power, modulation, onset time or peak. A narrower response can reduce admitted noise while changing settling and the signal itself. Require a measured transfer or a representative stimulus for the intended quantity. The discussion should produce a justified path choice and a declared limitation, rather than treating visual quietness as the acceptance criterion. Review: Filter Shape, Selectivity, and Time Response.

Review: Chapter 5 — Filter Shape, Selectivity, and Time Response.

V011-C05-DISCUSSION-002 — Separate the common center-to-width ratio from skirts, ripple, phase and impulse response. Determine whether the existing procedure depends on properties absent from Q. A substitution needs evidence for those properties and for detector timing under the same waveform. The useful outcome is a list of response equivalences actually established and the tests still needed. Review: Equation 9; Choose an IF path for the quantity being measured.

Review: Chapter 5 — Equation 9. Loaded quality factor; Chapter 5 — Choose an IF path for the quantity being measured.

V011-C05-DISCUSSION-003 — Examine transfer magnitude, measurement floor, phase coherence and unwrapping before accepting the derivative. Near a notch, uncertainty can dominate the phase slope. Even a valid local group delay does not establish unchanged transmission of an arbitrary pulse. The team should report the measurable frequency interval and the waveform-dependent limits of its interpretation. Review: Choose an IF path for the quantity being measured.

Review: Chapter 5 — Choose an IF path for the quantity being measured.

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V011-C05-DISCUSSION-004 — Translate the rule into the remaining fraction, approximately 4.98 percent, and compare that residual with the actual error tolerance. A large initial gain error can leave an unacceptable result after three time constants. Require compatible units, calibrated slope and an applicable model. The decision should be based on the declared error budget rather than the familiarity of the rule. Review: Equation 10E; Application 5A.2.

Review: Chapter 5 — Equation 10E. Settling time for a positive error tolerance; Chapter 5 — Application 5A.2: Set a gain-error settling requirement.

V011-C05-DISCUSSION-005 — Ask whether the target, state, acquisition or model changed. Overshoot is inconsistent with the uninterrupted monotone model, so it is evidence that deserves investigation. Establish measurement uncertainty and repeatability before deciding whether the point is erroneous. Preserve the original record and state the model's tested scope; a good fit elsewhere does not authorize deleting a meaningful departure. Review: Equation 10B and its monotonicity discussion.

Review: Chapter 5 — Equation 10B. Control voltage and residual.

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V011-C05-DISCUSSION-006 — Separate interpolation from model adequacy and internal identification. Favorable signs and decreasing residuals allow a positive time constant, but additional times, levels and states can reveal other dynamics. The team should identify the exact response supported by the two points and propose an independent challenge. A bounded empirical model is useful without claiming a unique internal circuit. Review: Equation 10F; Application 5A.5.

Review: Chapter 5 — Equation 10F. Two-point identification of the local time constant; Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

V011-C05-DISCUSSION-007 — Consider target error, detector offset, resolution and hold behavior before increasing model complexity. Examine whether the apparent floor is stable under changed references or input levels. A second pole is a hypothesis that needs discriminating evidence, not a mandatory interpretation of every departure from zero. Retain the simplest model adequate for the declared operating domain and the data. Review: Application 5A.5.

Review: Chapter 5 — Application 5A.5: Identify a time constant from two signed residuals.

V011-C05-DISCUSSION-008 — Require the signed local gain map and active gain range. A rising voltage reduces gain only for the appropriate negative slope; another circuit or mode can have the opposite polarity. Check the reference gain, valid voltage interval and RF response. The discussion should connect state direction with calibrated effect, rather than relying on a familiar control convention. Review: Equation 10C; Application 5A.4.

Review: Chapter 5 — Equation 10C. Local control-to-gain law; Chapter 5 — Application 5A.4: Check the required control polarity after a level step.

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V011-C05-DISCUSSION-009 — Regular repetition can produce a periodic trajectory that never reaches equilibrium. Carry the actual prior terminal state or establish the periodic initial state from sufficient history. Compare burst spacing with attack, hold and release behavior. The team should retain a justified initial-state rule, not a reset chosen because it simplifies arithmetic. Review: Equation 10G; Application 5A.6.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.6: Carry state across two target intervals.

V011-C05-DISCUSSION-010 — Compare the trajectories: a specified hold remains at its carried value before release, whereas a slow exponential moves immediately. The distinction can change a later weak-signal response. Define the timer trigger, retrigger rule and held quantity, then test them. A combined empirical approximation may be used only with its error and application interval stated. Review: Equation 10G discussion; Application 5A.7.

Review: Chapter 5 — Equation 10G. Carry state across a target change; Chapter 5 — Application 5A.7: Use separately identified attack and release constants.

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V011-C05-DISCUSSION-011 — Inspect the numerical recurrence and sample interval. Forward Euler can alternate or diverge even when the stipulated continuous system is stable. Compare with the exact sampled solution and distinguish stability from accuracy. If the real controller is discrete, obtain its actual update law rather than forcing either continuous or Euler behavior onto it. Review: Equations 10H and 10I; Application 5A.9.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range; Chapter 5 — Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation.

V011-C05-DISCUSSION-012 — A stable alternating approximation can still misrepresent a monotone physical response. Compare residual values and acceptance crossings with the exact recurrence for this model. State numerical error where it matters to the tolerance. The desired result is a calculation accurate for the measurement decision, not merely a sequence whose magnitude eventually decreases. Review: Equations 10H and 10I.

Review: Chapter 5 — Equation 10H. Exact sampled-state recurrence; Chapter 5 — Equation 10I. Forward-Euler residual and its validity range.

V011-C05-DISCUSSION-013 — Identify which quantities were fixed during that propagation. Target, time constant, slope, gain reference and timing can still contribute. Contraction removes only sensitivity to the uncertain initial state under the stated model. The team should distinguish a deterministic partial bound from a complete uncertainty statement and add the missing contributions appropriately. Review: Equation 10J; Application 5A.10.

Review: Chapter 5 — Equation 10J. Propagation of an initial-state interval; Chapter 5 — Application 5A.10: Propagate an initial-state interval.

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V011-C05-DISCUSSION-014 — Telemetry assesses one control state and its calibrated relationship. An RF reference can expose independent compression or recovery in the actual exercised path. Neither is automatically sufficient alone. Define the relevant stages and ensure that the reference remains observable. The discussion should identify complementary evidence and the interval for which valid transfer is actually supported. Review: Application 5A.3; Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level; Chapter 5 — Verify the detector and control path as part of the IF result.

V011-C05-DISCUSSION-015 — Trace the signal admission to the control detector and vulnerable stages rather than using the display limits as a physical filter specification. A wider shared path can drive AGC. Use a controlled blocker and retained weak reference to distinguish gain control from overload or source changes. Report the actual admitted band and state evidence. Review: Automatic Gain Control and Hidden State.

Review: Chapter 5 — Automatic Gain Control and Hidden State.

V011-C05-DISCUSSION-016 — Define whether the intended result is a rare maximum, average power or another quantity. The traces perform different operations, and each has waveform-dependent bandwidth, crest-factor and recovery limits. A quieter appearance does not make an estimator appropriate. The team should select and validate the detector for the measurand and retain its acquisition conditions. Review: Logarithmic Amplifiers, Detectors, and Scaling.

Review: Chapter 5 — Logarithmic Amplifiers, Detectors, and Scaling.

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V011-C05-DISCUSSION-017 — Identify whether each trace averages linear power, logarithmic levels, selected samples or another detector output. Matching units can conceal different operations and time weights. Reconstruct a common intended statistic only when the retained data and calibration permit it. Preserve the original operation and avoid interpreting a change of label as a change of physical measurement. Review: Verify the detector and control path as part of the IF result; Chapter 8 connection.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

V011-C05-DISCUSSION-018 — Require control-state evidence, a calibrated gain relationship and a reference demonstrating valid signal transfer under the same conditions. Consider limiting, clipping, log-detector saturation and software normalization as alternative plateau mechanisms. The team should define an observable prediction that separates them, including recovery and weak-signal response, rather than accepting flatness alone. Review: Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-DISCUSSION-019 — Examine coefficient, clock, scaling, detector and automatic-selection changes. Center agreement can coexist with altered skirts, delay or transient behavior. Repeat the cases whose assumptions could have changed and verify correction applicability. The result should state the covered configurations and waveform domain, not treat software implementation as a guarantee of invariant transfer. Review: IF Alignment, Calibration, and Failure Localization; IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Alignment, Calibration, and Failure Localization; Chapter 5 — IF Acceptance and Regression Tests.

V011-C05-DISCUSSION-020 — Distinguish the specific inconsistent expressions from the supported material, retaining exact edition and page scope. Derive synthetic teaching cases independently and do not promote a guessed correction to a verified device specification. Document the qualification and seek clarification or measurement for equipment-specific use. Responsible source criticism can preserve useful evidence without repeating an error. Review: Chapter 5 References and Works Cited; source notes 14 and 15.

Review: Chapter 5 — Intermediate Frequency as a Controlled Band; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — References and Works Cited.

V011-C05-DISCUSSION-021 — Relate the repair to the path properties and measurement claims that could have changed. Skirts, delay, gain boundaries, detection and recovery may require representative additional cases. Use declared criteria or an applicable baseline rather than expanding testing without a concrete purpose. The release should name what was verified and any remaining limitation. Review: IF Acceptance and Regression Tests.

Review: Chapter 5 — IF Acceptance and Regression Tests.

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V011-C05-DISCUSSION-022 — Keep the time scope explicit. The check assesses the functions exercised at its own time; it can reveal persistent change but does not establish uninterrupted earlier transfer. Contemporaneous references, clipping indicators and state records are needed for the burst interval. Preserve useful observations with their limits instead of silently transferring a later pass backward. Review: Verify the detector and control path as part of the IF result; Chapter 1 connection.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 1 — Evidence Record and Closing Verification.

V011-C05-DISCUSSION-023 — Ask whether a validated dynamic model and known initial state support interpolation for this regime. Without that evidence, the final value does not describe an unsettled burst. Even a valid control interpolation cannot recreate clipped RF peaks. The team should state the resulting amplitude limitation and design a faster or otherwise discriminating acquisition. Review: Application 5A.3; Application 5A.8.

Review: Chapter 5 — Application 5A.3: Convert a control state into an output level; Chapter 5 — Application 5A.8: Compare burst duration with control settling.

V011-C05-DISCUSSION-024 — Reconcile path origin, filter, detector, state and acquisition timing first. The outputs may represent different quantities, and sensitivity to one waveform does not validate another measurement. Choose the observation suited to the intended claim, retaining the others as complementary evidence. The adjudication should explain the differences or identify the next controlled test. Review: Verify the detector and control path as part of the IF result.

Review: Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-C05-DISCUSSION-025 — State the tested model, configuration, level and time domain separately from the unresolved recovery behavior. Retain the event interval, references and competing explanations, and propose a specific additional observable or controlled perturbation. A bounded result is useful when its limits are explicit. Do not turn a convenient exponential fit into a complete internal or environmental explanation. Review: Model 5A introduction; IF Acceptance and Regression Tests.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 5 — IF Acceptance and Regression Tests.

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Chapter Glossary

ATTACK TIME CONSTANT: The positive time constant identified for a specified control response following an input change that calls for gain reduction. In Model 5A it describes one applicable exponential segment, with a calibrated gain polarity and declared target. It does not include an unmodeled detector delay, slew limit or hold rule, and it need not equal the release constant.

AUTOMATIC GAIN CONTROL: Feedback or feedforward process that changes receiver gain according to detected level or state.

CALIBRATED CONTROL INTERVAL: The voltage range over which a specified control-to-gain relationship is supported by calibration and applicable operating conditions. A model trajectory used for gain prediction must remain inside this interval or be segmented under separately justified mappings. Mathematical monotonicity of voltage does not validate gain extrapolation beyond the measured range.

CONTROL POLARITY: The direction in which a control-voltage change affects receiver gain in the active calibrated range. A negative local slope means increasing voltage reduces gain; a positive slope gives the opposite relationship. Polarity belongs to the gain map and must not be confused with the positive time constant or the sign of a residual.

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CONTROL RESIDUAL: The signed difference between actual control voltage and the target used for the current segment. Under the stipulated positive-time-constant one-pole law, a nonzero residual decays without changing sign. Its magnitude can be converted into gain-error magnitude only through an applicable gain slope. A target error or detector offset can create an apparent residual floor.

CONTROL TARGET: The equilibrium control voltage toward which a particular Model 5A segment relaxes. It is constant within that segment and is distinct from the voltage already reached. A new input, range or mode can change the target. Uncertainty in the target remains a separate contribution even after uncertainty in the initial state has decayed.

DETECTOR CREST-FACTOR LIMIT: An operating restriction on waveform peak relative to its RMS level for a detector or measurement path. Exceeding the applicable limit can invalidate an RMS or power indication even when average level appears acceptable. The limit depends on the specific detector and conditions; the name RMS does not establish unlimited peak-handling capability.

DETECTOR TAKEOFF: The physical or numerical point from which a detector receives its waveform. Its position relative to filters, gain stages, limiters and converters determines what it observes and which signals can influence control or indication. Audio, spectrum and recorded I/Q outputs can use different takeoffs; common receiver identity does not make their transfer functions equivalent.

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EXACT SAMPLED RECURRENCE: The discrete update obtained by evaluating a stipulated continuous model at successive sample times without numerical integration approximation. For Model 5A with fixed target over the interval, the residual multiplier is the exponential of the negative interval-to-time-constant ratio. Exactness belongs to that model; it does not establish that a physically discrete controller implements the same rule.

FILTER RINGING: A transient oscillatory response following a change or short excitation, determined by the filter's full dynamics. Ringing can extend an apparent event or alter a detected peak even when a continuous-tone amplitude is correct. Its relevance depends on the waveform and measurand; loaded Q or a single bandwidth label does not completely specify it.

FILTER SETTLING: The approach of an IF path's output to the response required by a stated stimulus and error criterion after a change. It depends on the full filter and observation chain, not merely the gain-control time constant. A burst shorter than the relevant settling interval can be measured before its steady response develops, changing peak or timing interpretation.

FORWARD-EULER APPROXIMATION: A first-order numerical update that advances a state using the derivative at the beginning of the interval. Applied to Model 5A, its residual coefficient is one minus the interval-to-time-constant ratio. This differs from the exact exponential coefficient and can introduce sign alternation or instability when the step is too large.

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FRACTIONAL SETTLING CRITERION: A requirement expressed as the permitted residual fraction of a specified nonzero initial step. For the chapter's one-pole law, a fixed fraction gives a fixed number of time constants, independent of step magnitude. A common absolute gain tolerance can instead require different waits for different initial errors. The chosen fraction must be tied to the measurement decision.

GAIN-ERROR MAGNITUDE: The nonnegative difference from the target gain attributable to the control residual under the chapter's calibrated local affine gain map. It equals the residual magnitude multiplied by the absolute gain slope and is expressed in decibels. It is distinct from signed gain change and does not include every calibration or signal-path error automatically.

GAIN-RANGE TRANSITION: A change between receiver gain ranges whose reference gain, control slope, limits or dynamics may differ. A continuous telemetry voltage does not prove continuous RF gain through the transition. Retain the active range and switch timing, use the applicable calibration for each segment, and verify any interval in which the transfer changes or becomes undefined for the intended correction.

GAIN-STATE TELEMETRY: A time-associated record of actual receiver gain settings or control behavior. For amplitude reconstruction it needs an applicable calibration, sufficient temporal resolution and alignment with the signal observations. A final gain value does not describe an unsettled burst, and telemetry cannot restore RF information lost through clipping or missing acquisition.

GROUP DELAY: Negative derivative of phase with angular frequency, used to describe delay of spectral components through a network.

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HANG STATE: A declared control mode that delays or modifies release after a specified event. A simple held-state example retains the attained control value for a defined duration before exponential release begins. The trigger, retrigger behavior and held quantity must be identified; replacing a hold with a larger release time constant changes the predicted trajectory.

IDENTIFIED CONTROL RESPONSE: A dynamic control-state law fitted or established within a declared operating interval and configuration.

INITIAL-STATE BOUND: A declared interval containing the control voltage at the start of a model segment without necessarily assigning a probability distribution. With fixed target and time constant, Model 5A maps both endpoints through an increasing affine transformation, contracting the interval width. The resulting bound covers initial-state uncertainty only, unless other parameter contributions are treated explicitly.

INTEGRATOR WINDUP: Accumulation or displacement of an integrating controller’s internal state when the requested output cannot be achieved within an actuator or gain limit. Return to ordinary operation can then require recovery of that state. This is a possible large-change control mechanism, not a universal explanation for every slow receiver response; its presence and limits require circuit or input/output evidence.

LOCAL GAIN MAP: A calibrated relationship between control state and receiver gain over a specified range.

LOGARITHMIC AMPLIFIER: Amplifier producing an output approximately proportional to the logarithm of input amplitude over a defined range.

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LOG-AVERAGE BIAS: The difference, under a stated probability model, between the expectation of an averaged logarithmic statistic and the logarithm of mean physical power. The related finite-record distinction is visible whenever the same varying levels are averaged before versus after logarithmic conversion. State the estimator and waveform assumptions; a common display unit does not make the two operations equivalent.

LOG-DETECTOR INTERCEPT: The reference offset in a specified calibrated relationship between a logarithmic detector's output and its input level. It is meaningful only with the stated slope, units, waveform conditions and operating range. An incorrect intercept creates a systematic level error, and a printed formula must be checked for consistency with its definitions before being used as a device-specific correction.

NONALTERNATING RESIDUAL: A residual sequence that does not repeatedly change sign about the specified target. The exact sampled one-pole solution has this property for positive time constant and interval. Forward Euler preserves it only for a positive normalized interval no greater than one, a stricter condition than its asymptotic-stability limit.

NUMERICAL STABILITY: The behavior of errors or perturbations under a numerical recurrence, distinct from the stability of the physical system being modeled. For the chapter's Euler residual update, asymptotic decay requires a positive interval-to-time-constant ratio below two. A stable approximation can still have substantial error or unphysical alternation, so stability alone does not validate a settling calculation.

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PASSBAND RIPPLE: Variation of transmission magnitude across the declared useful passband under a specified normalization. It can weight parts of a wide waveform differently even when the center-frequency gain is correct. The required flatness follows the intended amplitude or modulation measurand, and equal nominal bandwidth does not establish equal ripple.

POWER-AVERAGE ESTIMATOR: An arithmetic average of calibrated instantaneous powers with declared sample selection and time weights. A logarithmic level can be formed afterward, but averaging logarithmic levels first estimates a different quantity. With changing receiver gain, the appropriate time-resolved correction and validity conditions must be applied before interpreting the intended input-referred power statistic.

RELEASE TIME CONSTANT: The positive time constant identified for the applicable gain-return segment after the controlling condition changes. The actual state at the start of release is carried forward from prior activity. A release constant does not itself specify a preceding hang duration, a timer trigger or the recovery of other RF stages.

RESIDUAL FLOOR: An apparent nonzero limiting value in a residual record. It can arise from a wrong target, detector offset, measurement resolution, a hold state or additional physical dynamics. It should not automatically be fitted as a very slow pole. The residual definition, capability and competing mechanisms must be examined before assigning a physical cause.

SETTLING TOLERANCE: The positive permitted residual in a declared state or output quantity used to determine an acceptance time.

SHAPE FACTOR: Ratio of filter bandwidths measured at two specified attenuation levels.

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SHARED AGC DETECTOR: A level detector whose output controls gain used by more than one selected signal or observation path. Its admitted band can be wider than a displayed channel, allowing an off-channel signal to suppress a desired weak response. Interpretation requires the detector takeoff, admitted spectrum, gain distribution and control state, rather than the display span alone.

SLEW-LIMITED CONTROL: A regime in which the control state changes at an imposed maximum rate rather than following the small-change exponential law over the whole excursion. Limited charging or discharging current can produce an approximately linear voltage ramp. The applicable rate, transition and control range require their own evidence; a later exponential fit does not describe the earlier ramp automatically.

STATE CARRYOVER: Use of the actual ending state of one dynamic interval as the initial state of the next.

TIMING SKEW: Relative delay between nominally simultaneous channels, triggers or signal-path observations. In a control-based amplitude correction, skew can associate a calibrated gain with the wrong RF sample during a transient. The delay and its uncertainty should be measured or otherwise justified; static gain calibration alone does not establish temporal alignment.

TWO-POINT TIME-CONSTANT IDENTIFICATION: Estimation of a candidate one-pole time constant from two nonzero, same-sign residuals about one fixed target, with decreasing magnitude over a positive time separation. The elapsed time divided by the natural logarithm of their ratio gives the candidate constant. Additional observations are needed to establish model adequacy and its operating domain.

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UNWRAPPED PHASE: A phase branch that retains accumulated cycles over a declared valid interval instead of leaving principal-value jumps. In IF transfer measurements it supports a meaningful local phase slope and group-delay estimate only where the response is measurable and the reference coherent. Unwrapping cannot recover reliable phase from an unobservable transfer or establish missing phase information by itself.

VIDEO BANDWIDTH: Post-detection or display filtering bandwidth that controls trace smoothing and response time.

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References and Works Cited

United States Navy. NEETS, Module 17: Radio-Frequency Communications Principles. NAVEDTRA 14189, September 1998. Printed pages 2-11–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8389–8392.

Annotation. Supports the bounded discussion of IF amplification, detection, multiple conversion, selectivity and fidelity. The inspected historical architecture examples do not establish every filter technology's response or universal modern modulation-bandwidth rules. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver's actual topology. Ideal mixer identities do not establish that a real component is free of compression, leakage, spurs or path-dependent calibration errors. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Analog Devices. AD8367: 500 MHz Linear-in-dB VGA with AGC Detector. Revision A, July 2005. Pages 13 and 15–16, including RMS Detection and AGC Operation.
https://www.analog.com/media/en/technical-documentation/data-sheets/AD8367.pdf

Annotation. Supports local small-change single-pole behavior, integrating control, calibrated gain polarity, waveform-conditioned RMS detection and distinct large-change current-limited or windup behavior. Page 13 Equation 4 has an intercept-sign conflict with its explanatory text; the page 16 capacitance, slew and bandwidth example is internally inconsistent. Those printed numerical expressions are not adopted or silently repaired as verified device specifications. The chapter's calculations are independently constructed cases under Model 5A, not measurements of the AD8367. The device documentation describes a particular variable-gain and detector implementation, including gain-control behaviour that may affect observed amplitudes. Receiver evidence must distinguish commanded gain, settling behaviour and gain actually applied during a transient or intermittent transmission. The data sheet is not proof that the same response occurs in a different receiver or in an untested overload state.

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Chapter 6. Analog Modulation Reception: AM, SSB, FM, PM, and Pulsed Signals

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6.1 Carrier, Sidebands, and Modulation Evidence

Analog modulation places information in amplitude, frequency, phase, pulse parameters, or a combination of them. The receiver should preserve enough bandwidth and linearity to observe the relevant structure before demodulation. Carrier frequency, sideband symmetry, occupied bandwidth, deviation, pulse repetition, duty factor, and state changes can support classification. They do not by themselves prove the content, source, or purpose of the transmission.[1]

Modulation analysis begins with raw RF or IF data and a stated reference. Demodulated audio is a derived product whose fidelity depends on filter, detector, tuning, carrier recovery, de-emphasis, squelch, limiting, and recording settings. When the technical question concerns waveform identity or unintended information, the original complex or real-valued capture is preserved alongside any audio rendering.

1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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6.2 Amplitude Modulation and Envelope Detection

Conventional amplitude modulation produces a carrier and sidebands displaced by the modulating frequencies. Modulation depth affects envelope variation and sideband power. Overmodulation causes envelope reversal and distortion in a simple envelope detector. Suppressed-carrier and single-sideband signals require a coherent or product detector because the envelope alone does not preserve the original baseband relationship.

Receiver gain compression and AGC can alter measured modulation depth. Selective fading or multipath can unbalance sidebands. A narrow IF filter can attenuate high-frequency modulation, while detector time constants can introduce diagonal clipping or ripple. AM measurements should therefore include carrier level, sideband levels, bandwidth, detector mode, gain state, and a reference modulation test.

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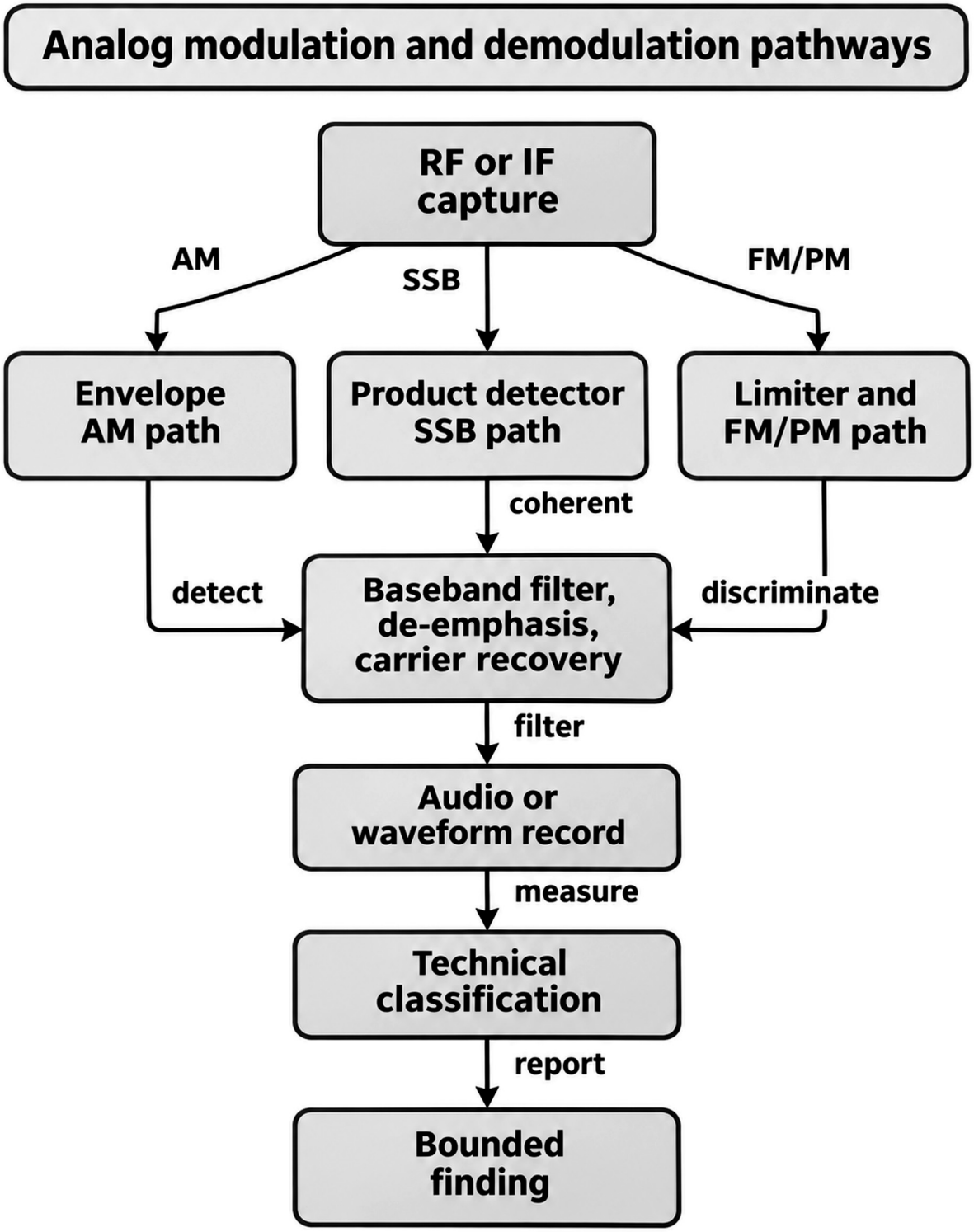

Figure 22. Analogue modulation and demodulation paths.

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6.3 Single Sideband and Coherent Reception

Single-sideband reception depends on accurate carrier reinsertion and sideband selection. Frequency error shifts recovered audio and can make speech unintelligible without changing the RF signal. Carrier and timing references can be obtained from residual pilots, external standards, known content, or estimators. The receiver should document whether the recovered frequency scale was measured or adjusted by ear.

Coherent detectors can also recover double-sideband suppressed-carrier and phase-related signals, but phase ambiguity and reference instability matter. Product-detector balance, I/Q mismatch, filter asymmetry, and LO phase noise can create residual carrier or opposite-sideband leakage. An apparently unusual modulation may therefore be a normal signal viewed through an improperly configured detector.

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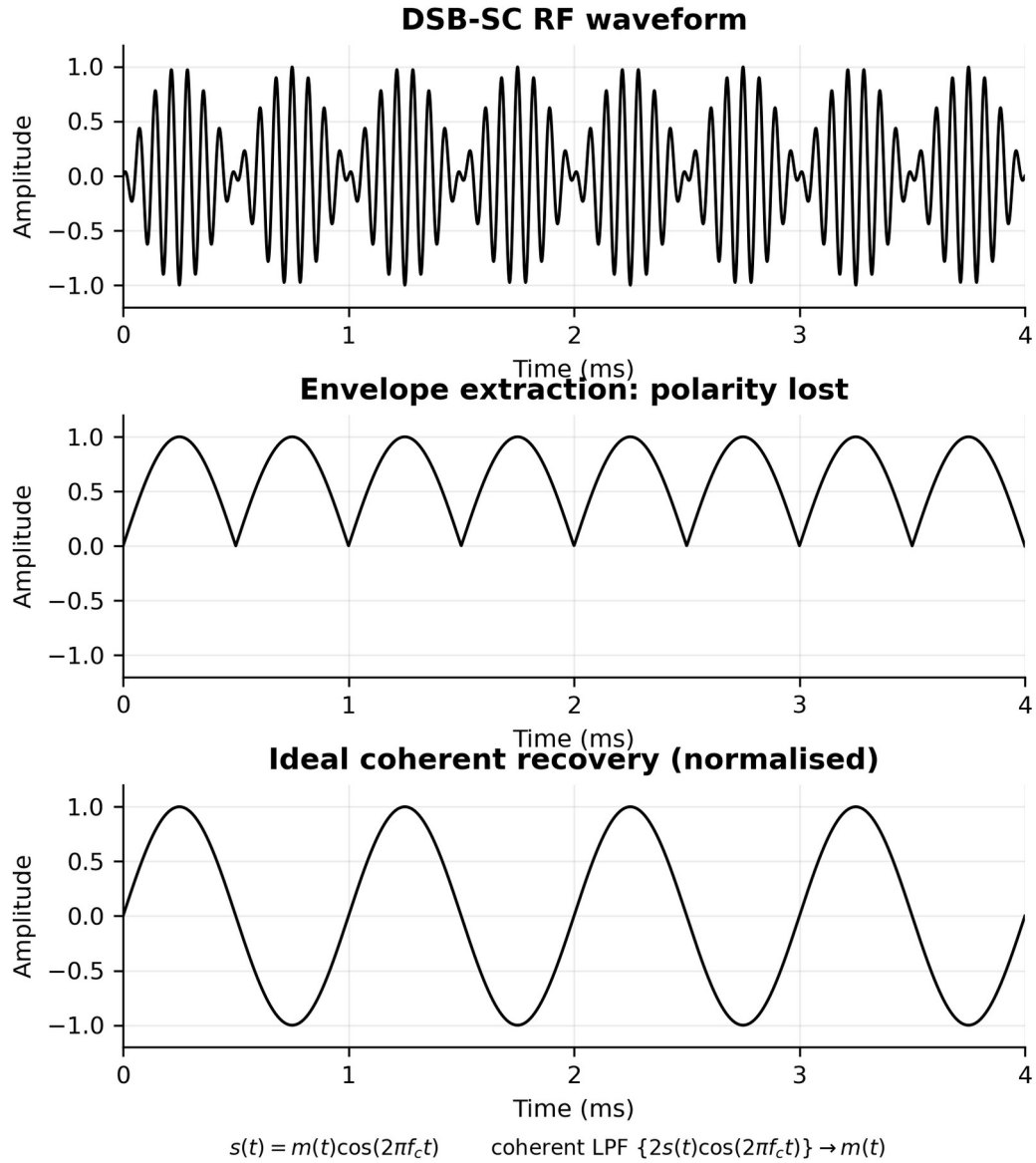

TECHNICAL INTERPRETATION

A suppressed-carrier signal loses message polarity under envelope extraction. A phase-coherent product detector can recover it.

Figure 23. Envelope versus coherent detection.

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6.4 Model 6A: preserve the complex envelope

An envelope is useful only after its voltage and frequency conventions have been fixed. Model 6A represents a real RF waveform as the real part of a complex peak-voltage envelope translated to a positive carrier. The envelope occupies a baseband narrower than the carrier frequency, so the positive and negative RF bands remain separated. This convention connects analog reception to the complex conversion in Model 4A and the sampled I/Q records in Chapter 10. It also makes clear which information is lost when a receiver retains only envelope magnitude or one real audio channel.

Equation 11A. Real RF waveform and its complex envelope

$$x(t)=\Re\left\{u(t)\exp\left(j2\pi f_c t\right)\right\}$$
$$supp\,U \subset [-B,B], 0 \le B < f_c$$

Here x and u are in volts, R is the positive load resistance in ohms, frequencies f_c, f_m and B are in hertz, and time is in seconds. The symbol U denotes the envelope spectrum. Angle brackets denote the declared time average, with the carrier and envelope terms satisfying the stated orthogonality; a peak is taken over the specified observation interval or complete periodic waveform. The imaginary unit j has square minus one. Modulation depth μ and the normalized message m are dimensionless.

At a positive real load resistance, the mean RF power under the stated carrier and message orthogonality convention equals the mean squared envelope magnitude divided by twice the resistance. For periodic examples, the mean is taken over complete common periods or as the long-time mean; carrier-cycle averaging gives the same envelope-power convention. Peak envelope power uses the largest squared envelope magnitude with that

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same factor. Instantaneous RF voltage squared has a different peak-to-average relation and should not be substituted without stating the change.

Equation 11B. Envelope power convention

$$P=\frac{\langle |u(t)|^2 \rangle}{2R}, R>0$$
$$P_{PEP}=\frac{max|u(t)|^2}{2R}$$

Conventional AM uses a real envelope consisting of a positive carrier amplitude plus a scaled real message. Bound the message magnitude by one and state its normalization. With modulation depth between zero and one, the signed envelope remains nonnegative. For a sinusoidal message, its extrema give the retained modulation-index formula. The Navy modulation course presents the carrier/sideband and envelope relationship in a directly inspectable form; the following derivation makes the peak-voltage and linear-path assumptions explicit.[2]

Equation 11C. Conventional AM and nonnegative-envelope condition

$$u(t)=A[1+\mu m(t)], A>0, \mid m(t) \mid \leq 1$$
$$0 \leq \mu \leq 1 \Rightarrow u(t) \geq 0$$

Equation 11D. Sinusoidal AM extrema and their inversion

$$E_{max}=A(1+\mu), E_{min}=A(1-\mu)$$
$$A=\frac{E_{max}+E_{min}}{2}, \mu=\frac{E_{max}-E_{min}}{E_{max}+E_{min}}$$
$$m(t)=\cos(2\pi f_m t), 0 \leq \mu \leq 1$$

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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Expanding the product of the message cosine and carrier cosine gives two sidebands, each with half the modulation-scaled carrier peak. Squaring their peak amplitudes and dividing by twice the load resistance produces the sideband powers. Over the orthogonality interval, the carrier and two sideband powers add. The resulting total-power expression is exact for this sinusoidal, linear AM model. It is not a universal correction for a voice waveform, an asymmetric channel response, or a transmitter whose amplitude law has clipped.

Equation 11E. Sinusoidal sideband amplitudes and powers

$$A_{+¿=A_{-}=\frac{A\mu}{2},P_c=\frac{A^2}{2R}¿}P_{+¿=P_{-}=\frac{P_c\mu^2}{4}}$$

$$¿$$

Equation 11F. Total sinusoidal-AM power

$$P_{total}=P_c\left(1+\frac{\mu^2}{2}\right)$$

For a different zero-mean message, use its actual mean square. The total-to-carrier power ratio then depends on the product of squared modulation scale and message mean square. This is one reason to retain the waveform or a reproducible message definition with a modulation-depth result. The same maximum excursion can accompany different average powers. A broadband message can also place appreciable energy in parts of the IF response that a center-frequency amplitude calibration never tested.

Equation 11G. Power for a zero-mean nonsinusoidal message

$$\langle m\rangle=0\Rightarrow P_{total}=P_c\left[1+\mu^2\langle m^2\rangle\right]$$

Use the declared averaging and spectral-separation conditions.

Overmodulation is a particularly useful boundary test. In the ideal algebraic waveform, the signed envelope becomes negative while the RF expression

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can still consist of only the original carrier and two sidebands. A magnitude-only detector replaces that signed envelope by its absolute value, losing the sign and distorting the recovered message. A physical transmitter that cannot realize the negative part may clip and generate additional RF components. Those are distinct mechanisms. The observed envelope alone does not establish which one occurred.

Equation 11H. Magnitude detection after envelope reversal

$$e_{mag}(t) = |\ A[1+\mu\cos(2\pi f_m t)]\ |$$

μ > 1: signed envelope reversal is lost in magnitude detection

A properly normalized real product detector multiplies by twice its LO cosine and removes the translated sum band. What remains is the real projection of the complex envelope after residual frequency and phase rotation. With exact frequency agreement, a real AM message is scaled by the cosine of the reference phase error. A 90-degree error can null that real output even though a quadrature recording retains the signal. Frequency error is more consequential than a fixed scale: the projection rotates with time, so an AM or suppressed-carrier message can be mixed with a residual low-frequency cosine.

Equation 11I. Real coherent recovery with residual reference error

$$y_R(t) = \Re\left\{u(t)\exp\left(j\left(2\pi(f_c - f_{LO})t - \theta_{LO}\right)\right)\right\}$$
$$f_{LO} = f_c, u\,real \Rightarrow y_R(t) = u(t)\cos\theta_{LO}$$

Equation 11J. Complex coherent recovery

$$y_C(t) = u(t)\exp\left(j\left(2\pi(f_c - f_{LO})t - \theta_{LO}\right)\right)$$

For the SSB examples, specify the envelope directly as a positive- or negative-frequency complex exponential, or as a finite sum of such components. This avoids ambiguity about which sideband has been

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retained. A general real message can be paired with its Hilbert transform to construct an analytic upper-sideband envelope under the same band-separation assumptions. The actual receiver may implement that operation with a filter, a phasing network, or digital processing; the model does not assume that its opposite-sideband rejection is perfect.

Equation 11K. Explicit upper and lower single-sideband envelopes

$$u_{USB}(t)=A\exp(j2\pi f_m t),u_{LSB}(t)=A\exp(-j2\pi f_m t)$$
$$f_{BB,USB}=f_c+f_m-f_{LO}$$
$$f_{BB,LSB}=f_c-f_m-f_{LO}$$

An unequal response to the two AM sidebands generally turns a purely real envelope into a complex one. Its in-phase part and quadrature part then carry different combinations of the sidebands. A magnitude trace can hide that distinction. Compare the measured complex response with the known input before calling the resulting envelope variation the source modulation depth. Gain control and limiting add further transformations, so a detector output is accepted as a modulation measurement only within a verified path state.

Equation 11L. In-phase and quadrature terms after unequal sideband response

$$u=c_0+c_{+¿}\exp(j\omega t)+c_-\exp(-j\omega t)¿u=c_0+(c_{+¿}+c_-)\cos(\omega t)¿+j(c_{+¿}-c_-)\sin(\omega t)¿I=\Re(u),Q=\Im(u),\omega=2\pi f_m$$

In Equation 11L, c_0 is the complex carrier-envelope coefficient and c_+ and c_- are the complex upper- and lower-sideband coefficients after the path response, all in volts. Expanding the two exponentials into cosine and sine gives the second form directly. Taking its real and imaginary parts defines I and Q without assuming that the three coefficients are real or that the sideband responses are conjugate.

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6.5 Worked applications with hypothetical inputs

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6.6 Application 6A.1: Close the power accounting for sinusoidal AM

A 1 MHz carrier has peak voltage 1 V across 50 Ω and is sinusoidally modulated at 2 kHz with depth 0.6. The envelope ranges from 0.4 to 1.6 V. Carrier power is 10.000 mW, each sideband is 0.900 mW, and total power is 11.800 mW. The corresponding levels are 10.0000, -0.4576, and 10.7188 dBm.

A spectrum-based check sums the three resolved line powers in linear units. An envelope-based check recovers the same depth from the extrema. Agreement tests the normalization only if the receiver has retained both sidebands, remains linear, and uses compatible reference planes. A lower sideband reading caused by IF attenuation would change the output waveform and would not prove that the source depth had changed.

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6.7 Application 6A.2: Infer the conventional-AM envelope parameters

A calibrated conventional-AM envelope has maximum 2.4 V and minimum 0.8 V. Their midpoint gives a carrier peak of 1.6 V, and their normalized difference gives depth 0.5. For a 75 Ω load and sinusoidal modulation, carrier power is 17.066667 mW, each sideband is 1.066667 mW, and total power is 19.200000 mW.

The estimate requires both extrema to belong to the same stable gain state. Selecting a maximum before AGC reduction and a minimum afterward can produce a depth that no single waveform had. Likewise, a noisy minimum near zero is sensitive to detector offset and bandwidth. Preserve the interval from which the extrema were selected and repeat the calculation on a known modulation reference using the same detector path.

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6.8 Application 6A.3: Infer modulation depth from one resolved sideband

One resolved sinusoidal-AM sideband is 18 dB below its carrier. Convert the power ratio to a peak-amplitude ratio before applying the sideband relation: the inferred modulation depth is $2 \times 10^{\frac{-18}{20}}$, or 0.251785. The total-to-carrier power ratio is 1.031698, corresponding to an increase of 0.135525 dB.

This calculation uses one sideband only because symmetry is an explicit assumption. Measure the other sideband to challenge that assumption. A difference can indicate source asymmetry, a filter response, coherent interference, or measurement error. The single-sideband estimate should then be reported as conditional rather than averaged into an apparently more precise depth without investigating the discrepancy.

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6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal

Let the ideal signed envelope be $1+1.3\cos\backslash(\text{modulation angle}\backslash)$. Its extrema are −0.3 and 2.3 V. The observed magnitude envelope reaches zero at the sign crossings, so applying the ordinary extrema formula gives 1.0 instead of the true scale 1.3. The signed envelope is negative for 22.064 percent of each modulation period.

The failed inversion is caused by loss of sign. A complex or correctly phased coherent record can reveal the reversal, whereas a magnitude-only record cannot reconstruct it from the two extrema. This synthetic RF waveform has not been clipped by a transmitter. Additional RF sidebands would require another mechanism, such as a physical amplitude limit, and must not be attributed to the absolute-value detector after the RF record was already acquired.

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6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery

A real coherent detector receives AM with carrier peak 0.8 V and depth 0.5, with exact frequency agreement but a 35-degree reference phase error. The recovered DC term is 0.655322 V, and the recovered message peak is 0.327661 V. Relative to perfect phase alignment, the message amplitude change is -1.732710 dB. At 90 degrees the ideal real message output is zero.

The null is not a loss of RF energy. It is a projection onto the wrong real axis. Recording both quadratures permits the phase rotation to be examined and, where an independent reference justifies it, corrected. A recovered-audio level is therefore not a direct RF modulation-depth measurement unless the phase and gain conventions of the detector are known.

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6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error

Take a DSB-SC complex envelope equal to a 1 kHz cosine and a real coherent detector with a residual 50 Hz frequency offset. The recovered waveform is the product of those cosines. Expanding it gives tones at 950 and 1,050 Hz, each with peak 0.5 under the declared normalization. It does not give one unchanged 1 kHz tone with a constant amplitude error.

A short audio segment may sound like a changing level rather than two distinct tones because the observation is too brief to resolve their separation. Preserve the time record and analysis duration. Correcting the residual frequency from an independently established reference restores the intended projection; simply moving a displayed spectral marker does not correct the underlying time-domain waveform.

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6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong

A 20 MHz carrier has a 1.5 kHz upper-sideband tone. Reinsertion at 20,000,120 Hz produces a signed complex audio frequency of +1,380 Hz. A separate lower-sideband tone under the same LO produces −1,620 Hz. If only real audio magnitudes are retained, these become 1,380 and 1,620 Hz and their orientation is lost.

The 120 Hz tuning error shifts the two signed examples in the same algebraic direction, but it changes their real-audio magnitudes differently. This is why an operator adjustment that improves apparent intelligibility is a processing choice requiring a record. The corrected frequency scale should be tied to a measured reference or a stated estimator, not reconstructed afterward from what the audio was expected to sound like.

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6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones

A two-tone SSB envelope contains 0.8 V at +1 kHz and 0.6 V at +2 kHz. Its mean squared magnitude is 1 V^2 under complete-period averaging, giving 10 mW average RF power in 50 Ω. When the two envelope components align, the peak is 1.4 V and peak envelope power is 19.6 mW. The peak-envelope-to-average ratio is 2.922561 dB.

A receiver can remain acceptable on average power while clipping that envelope peak. The appropriate headroom check therefore retains the waveform-dependent peak definition. Conversely, an instantaneous RF peak-voltage calculation would include the carrier oscillation and is not the same reported quantity as peak envelope power. State which limit the hardware specification and acceptance rule actually use.

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6.14 Application 6A.9: Separate sideband filtering from source modulation depth

An input depth of 0.8 produces ideal sideband peaks 0.4 relative to a unit carrier. Suppose the output retains the upper sideband at 0.4 but reduces the lower to 0.2, with their stated phases unchanged. Its complex envelope is $1+0.6\cos\backslash(\text{modulation angle}\backslash)+j\ \ 0.2\sin\backslash(\text{modulation angle}\backslash)$. The real message component is 0.6 rather than 0.8, a -2.498775 dB change.

The output magnitude extrema are 0.4 and 1.6, so a naive envelope-depth calculation gives 0.6. That number describes a distorted output and does not recover the source depth. The nonzero quadrature term is additional evidence of the asymmetric path. A coherent transfer measurement of the two sidebands can identify the response that a single envelope trace hides.

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6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut

Use a message consisting of a 0.5-amplitude cosine at 1 kHz and a 0.25-amplitude cosine at 2 kHz, with modulation scale 0.8 and unit carrier peak. Its magnitude is bounded by 0.75, so the signed envelope is safely bounded below by 0.4 V. The mean message square is 0.15625, and total RF power is 1.10 times carrier power. The two sidebands associated with 1 kHz each have peak 0.2 V; the pair associated with 2 kHz each have peak 0.1 V.

The bound on envelope minimum is conservative and need not be attained, because the two message cosines do not reach every sign combination together. The power result uses their actual orthogonality over complete 1 ms message periods. Substituting the sinusoidal shortcut would give the wrong total because the message is not a unit-peak single cosine. This distinction is useful whenever an envelope statistic is used to infer total modulated power.

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6.16 Frequency and Phase Modulation

Frequency modulation encodes information in instantaneous frequency, while phase modulation encodes information in phase. Their spectra depend on modulation frequency, deviation or phase excursion, waveform, and index. Narrowband approximations are useful only when the index is sufficiently small. Wideband FM can occupy many significant sidebands, and Carson's rule provides an engineering estimate rather than an exact spectral boundary.

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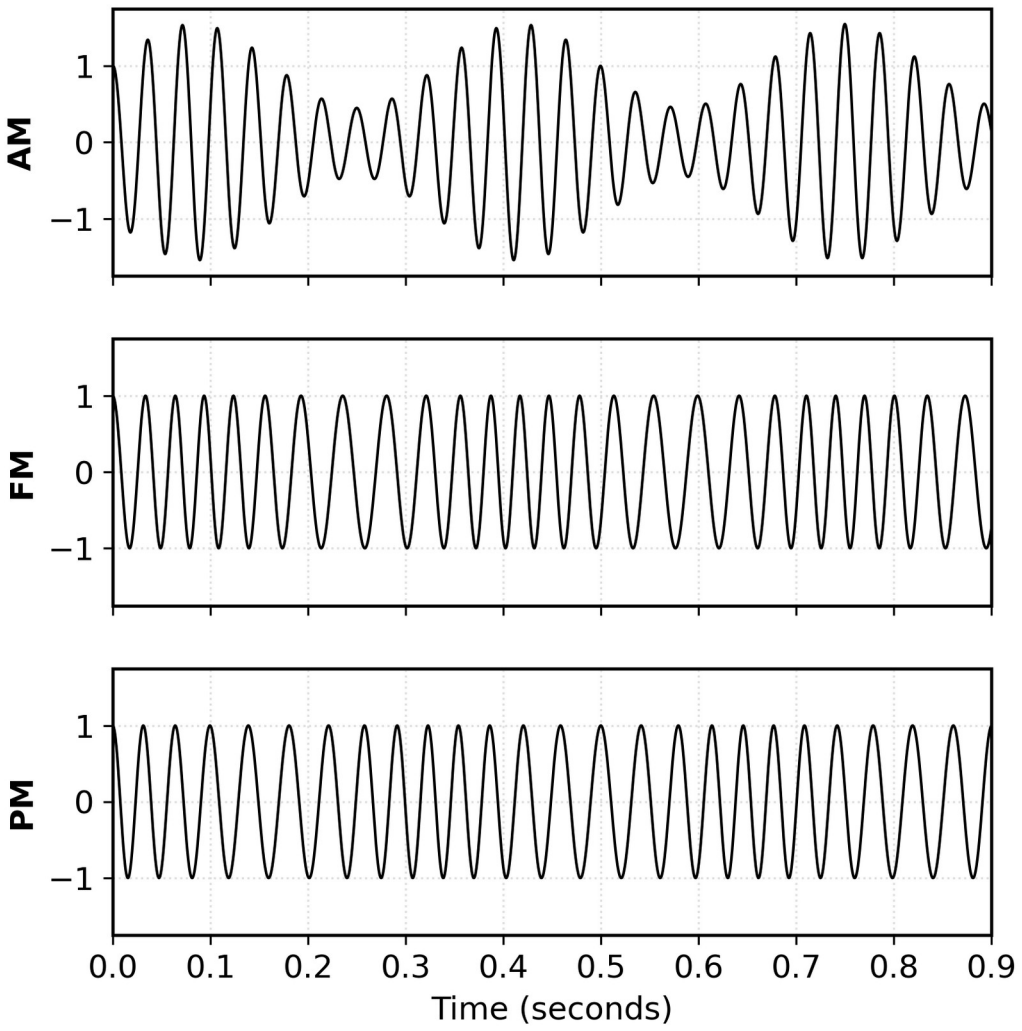

Why it matters: demodulators recover different quantities;
waveform, phase continuity and frequency-deviation claims need separation.

Figure 24. AM, FM and PM signal characteristics.

FM receivers commonly use limiting to suppress amplitude variation, followed by a discriminator, quadrature detector, phase-locked loop, or digital estimator. Capture effect, threshold behavior, multipath, de-emphasis, and squelch can dramatically change recovered audio. A

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demodulator can produce noise bursts or tonal artifacts even when no intelligible information is present. Deviation and baseband bandwidth should be measured from calibrated data, not inferred only from loudness.

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6.17 Model 6B: phase is the quantity that frequency differentiates

A phase-based measurement begins with a complex signal whose phase has a defined continuous branch over the interval of interest. Model 6B uses a positive, constant amplitude and a declared unwrapped phase added to the carrier. The frequency deviation is the phase derivative divided by two pi wherever that derivative exists. The Navy modulation course distinguishes the amount of frequency deviation from the rate at which it varies; writing the phase equation prevents those two quantities from being confused.[3]

Equation 12A. Complex phase and instantaneous frequency

$$z(t) = A\exp\left(j\left(2\pi f_c t + \varphi(t)\right)\right), A > 0$$
$$f_{inst}(t) = f_c + \frac{1}{2\pi}\frac{d\varphi}{dt} \; almost\ everywhere$$

The nonzero complex amplitude A is in volts, carrier and modulation frequencies are in hertz, time is in seconds, and phase φ is in radians. Frequency offset δf is measured relative to f_c. A phase-modulator coefficient k_p has radians per unit of its specified message, while β is a dimensionless peak phase expressed in radians. A finite multi-tone expansion uses a positive integer count L, with each phase amplitude, frequency and initial phase explicitly assigned. The frequency derivative is a local statement; the phase branch and any reset must already be known.

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3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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The complex representation is a stipulated signal model. A noisy real waveform with several unresolved components does not automatically supply one physically meaningful instantaneous phase. Near zero amplitude, its phase estimate can become undefined or highly unstable. A limiter can suppress amplitude variation while retaining or introducing its own errors. Record how the complex signal was formed, its admitted bandwidth, any amplitude exclusions, and the phase-unwrapping convention before treating a derivative as frequency.

For a sinusoidal FM deviation, integration gives a sinusoidal phase whose amplitude equals peak deviation divided by modulation frequency. The modulation frequency must be positive for that expression; a constant offset instead gives a linear phase ramp. In PM, the message directly controls phase, so differentiation makes frequency deviation depend on both message amplitude and message frequency. A fixed phase excursion is therefore not equivalent to a fixed frequency excursion when the modulation rate changes.

Equation 12B. Sinusoidal FM phase and modulation index

$$\varphi(t)=\beta\sin(2\pi f_m t)+\varphi_0,\ \beta=\frac{\Delta f}{f_m}$$
$$f_{inst}(t)-f_c=\Delta f\cos(2\pi f_m t),\ f_m>0$$

Equation 12C. Sinusoidal PM and its frequency deviation

$$\varphi(t)=k_p M\cos(2\pi f_m t)$$
$$f_{inst}(t)-f_c=-k_p M f_m\sin(2\pi f_m t)$$
$$\Delta f_{peak}=|k_p|\,M f_m,\ M\geq 0$$

Equation 12D. Integration of a general deterministic frequency offset

$$\varphi(t)=\varphi(t_0)+2\pi\int_{t_0}^{t}\delta f(s)\,ds$$
$$f_{inst}(t)=f_c+\delta f(t)$$

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For a sum of differentiable phase components, their frequency deviations add. Bounding the sum by the sum of component magnitudes is always conservative, but the bound is attained only when the component phases permit it. This matters when a highest modulating frequency and a peak deviation are used together in a bandwidth estimate. They describe different aspects of the waveform and should be measured or stipulated independently rather than inferred from a single spectral peak.

Equation 12E. Deviation from several phase components

$$\varphi(t)=\sum_{\ell=1}^{L}\beta_\ell \sin(2\pi f_\ell t+\psi_\ell)$$

$$\delta f(t)=\sum_{\ell=1}^{L}\beta_\ell f_\ell \cos(2\pi f_\ell t+\psi_\ell)$$

$$|\,\delta f(t)\,| \le \sum_{\ell=1}^{L}\left|\beta_\ell f_\ell\right|$$

A sampled phase difference gives the average frequency over its interval when the phase is correctly unwrapped and absolutely continuous. It need not equal the instantaneous frequency at either endpoint or midpoint. The principal complex argument is periodic, so an observed increment is ambiguous by whole turns. A frequency estimate from it requires a justified interval of admissible frequencies and continuity assumptions. Increasing the number of displayed decimal places does not resolve an alias or recover a phase turn that the data cannot distinguish.

Equation 12F. Finite-interval frequency from unwrapped phase

$$f_{avg}=f_c+\frac{\varphi(t+\Delta t)-\varphi(t)}{2\pi\Delta t}$$

$$¿\frac{1}{\Delta t}\int_{t}^{t+\Delta t} f_{inst}(s)\,ds\,,\ \Delta t>0$$

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Equation 12G. Principal-increment frequency and its alias class

$$f_{principal} = \frac{f_s}{2\pi} Arg\left(z_{k+1} z_k^{*}\right)$$
$$Arg \in ¿$$
¿

A small-phase approximation can be useful, but its error should accompany it. The complex exponential equals one plus j times phase plus a remainder bounded pointwise by half the squared phase. For sinusoidal phase, the retained linear term gives two first-order sidebands. Their quoted power is relative to an unmodulated unit carrier; the exact modulated carrier amplitude is not silently treated as unchanged at arbitrary phase excursion. Chapter 11 uses the related remainder discipline when translating LO phase noise into admitted noise.

Equation 12H. Pointwise small-phase remainder

$$\exp(j\varphi) = 1 + j\varphi + r(\varphi)$$
$$|\, r(\varphi)\,| \le \frac{\varphi^2}{2}, \varphi \in \mathbb{R}$$

Equation 12I. First-order sidebands for sinusoidal small phase

$$\exp\left(j\beta \sin(\omega t)\right) \approx 1 + \frac{\beta}{2}\exp(j\omega t) - \frac{\beta}{2}\exp(-j\omega t)$$
$$\frac{P_{\pm,retained}}{P_{unmodulated}} = \frac{\beta^2}{4}, \; |\, r(t)\,| \le \frac{\beta^2}{2}$$

Carson's rule combines peak frequency deviation and the highest significant modulating frequency into a useful engineering estimate. It does not uniquely define the transmitted spectrum or an IF filter response. The IRIG telemetry appendix explicitly treats it as an estimate and shows that its relation to a stated power-containment bandwidth depends on how the modulation energy is distributed. This chapter uses the rule for planning

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and comparison, then requires the actual waveform and filter response for a distortion or containment decision.[4]

Equation 12J. Carson estimate and its stated inputs

$$B_C \approx 2\left(\Delta f_{peak} + f_{m,max}\right)$$

Engineering estimate; exact passed power requires spectrum and filter.

A frequency-reference offset adds a linear phase trend, while a constant phase-reference offset disappears on differentiation. A phase reset is different from either: it interrupts the continuous branch and must split the analysis into separately identified segments. Correcting an offset from the same weak data being evaluated also introduces an estimation dependency. Retain the uncorrected phase, the independent reference or training interval, and the corrected result so that the correction can be evaluated rather than assumed.

Equation 12K. Separate modulation, frequency offset and phase offset

$$\varphi_{BB}(t) = \varphi_{mod}(t) + 2\pi\,\delta f_{res}\,t + \theta_{res}$$

$$\delta f_{res} = f_c - f_{LO},\; f_{BB}(t) = \delta f_{res} + \frac{\varphi_{mod}'(t)}{2\pi}$$

4 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers” (June 14, 2013), “Baseline Case: Cascade of Linear Circuit Blocks” and “Noise Temperature,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and synthetic cases are stated in Model 2B.

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6.18 Worked applications with hypothetical inputs

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6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion

A sinusoidal FM waveform has peak deviation 4.5 kHz at a 1.5 kHz modulation frequency. Its phase index is 3 radians. Differentiating that phase recovers the 4.5 kHz deviation, while Carson's estimate gives 12 kHz total bandwidth. The phase index is dimensionless, deviation is in hertz, and the rate of deviation is another frequency; the three quantities are not interchangeable.

A receiver check should verify both deviation scale and modulation-frequency scale with a known reference. The bandwidth estimate can guide an initial IF choice, but the accepted result still depends on the actual passband, phase response, and demodulator. A narrower path might bias the measured deviation before an obvious amplitude failure appears.

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6.20 Application 6B.2: Differentiate a sinusoidal PM phase

A PM sensitivity of 0.8 rad/V is driven by a 1.5 V peak, 2 kHz cosine. The phase peak is 1.2 radians. Its derivative produces a 2.4 kHz peak frequency deviation, with a sine-shaped sign convention determined by the derivative of the cosine. Using that deviation and 2 kHz message frequency gives an 8.8 kHz Carson estimate.

The phase and frequency records contain related information, but they are not pointwise copies of the message. A calibration that compares their peaks without their timing relationship can misidentify a quadrature shift as delay or distortion. Use the declared time reference and derive the expected waveform, including sign, before comparing the recovered phase and frequency channels.

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6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation

Hold phase excursion at 1.2 radians while changing a sinusoidal message from 1 to 4 kHz. The frequency-deviation peaks change from 1.2 to 4.8 kHz. Alternatively, hold FM deviation at 1.2 kHz over those two message frequencies; the phase indices become 1.2 and 0.3 radians. These are different stimulus families even though one of their operating points coincides.

A demodulator verification should say which quantity the generator holds fixed. Otherwise a changing frequency-deviation reading can be mistaken for detector error when it is the correct consequence of a fixed phase-modulation setting. Preserve the generator mode and its actual calibration alongside the receiver output, especially when a source offers both FM and PM controls with similar front-panel labels.

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6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase

Let the unwrapped modulation phase be $0.3\sin[2\pi(1\ \text{kHz})t]+0.1\sin[2\pi(3\ \text{kHz})t]$, in radians. Differentiation gives frequency components of 300 Hz at each modulation frequency. Both cosine terms reach +300 Hz at the time origin and −300 Hz at 0.5 ms, so the attained peak deviation is 600 Hz. With highest message frequency 3 kHz, Carson's estimate is 7.2 kHz.

The attainable peak follows from the stated phases, not just from the two amplitudes. Changing relative phase can change the peak while preserving the component frequencies and powers. This is a useful reason to preserve the modulating waveform when a peak-deviation requirement matters. An averaged spectrum of the modulating signal can omit the relative phase needed for that decision.

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6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns

A frequency offset ramps linearly from −2 to +2 kHz in 4 ms. Its slope is 1,000,000 Hz/s. Integrating from zero initial modulation phase gives -4π radians at the midpoint and zero again at the endpoint. The midpoint therefore lies two complete negative phase turns from the start even though the start and end phases agree.

An endpoint-only phase comparison would miss the excursion. Preserve the continuous trajectory or enough unambiguous samples to reconstruct it under a valid bandwidth model. A phase-wrap display can be useful for periodicity but cannot replace the unwrapped record when evaluating accumulated phase. The carrier remains a separate positive reference; the negative values here are deviations from it, not negative physical RF frequencies.

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6.24 Application 6B.6: Expose the ambiguity of sampled phase increments

At 48,000 samples per second, a +7 kHz complex offset advances by 0.916298 radians per sample, within the principal interval. A +31 kHz offset instead gives a principal increment -2.225295 radians, which is identical to −17 kHz at that sample rate. The principal-increment estimator therefore reports +7 and −17 kHz for the two cases.

No phase-unwrapping algorithm can select +31 kHz from those samples without additional prior information about the admitted band or a changed observation. The usual principal interval spans −24 to +24 kHz, with one endpoint excluded by convention. This is the same sampling-equivalence issue treated in Chapter 10, now expressed in phase increments rather than DFT bins.

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6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value

Four unwrapped phase observations are 0, 0.12, 0.29, and 0.51 radians, separated by 100 μs. Successive interval-average offsets are 190.986, 270.563, and 350.141 Hz. The centered two-interval average at the second observation is 230.775 Hz.

The interval-average derivatives follow exactly from the stipulated phase record, while the reported numerical values are rounded. Calling them instantaneous values requires a further local approximation that the four samples alone do not establish. A shorter difference interval can improve locality while increasing sensitivity to phase error. The acceptance record should name the difference operator and interval so that two frequency traces with different smoothing are not compared as if they were identical measurements.

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6.26 Application 6B.8: Bound a small-phase approximation before using it

A sinusoidal phase has peak 0.1 radian. The complex first-order approximation has a pointwise remainder no larger than 0.005000. Each retained first-order sideband has peak 0.05 relative to a unit unmodulated carrier, hence power ratio 0.0025, or -26.020600 dBc. The sideband calculation is approximate; the stated remainder bound is exact for real phase.

This distinction permits a bounded use of the approximation without pretending that it is a complete spectrum model. If the intended error tolerance is below the remainder bound, use the full complex exponential or a stronger analysis. A phase excursion larger than 0.1 radian is not automatically invalid, but it changes the bound and can make the retained terms inadequate for the decision being made.

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6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response

For 5 kHz peak deviation and significant message content through 3 kHz, Carson's estimate is 16 kHz. A nominal 12.5 kHz IF width has a half-width label of 6.25 kHz, while a 25 kHz width has 12.5 kHz. The estimate's half-width is 8 kHz. These comparisons identify which responses deserve examination; they do not determine an exact fraction of signal power passed by either filter.

The complete waveform spectrum and filter transfer function are missing. A nominal width may describe a −3 dB or −6 dB point, and the transition and phase response can differ between filters with similar labels. Measure the recovered waveform, deviation, and relevant distortion under the intended setting. The appropriate conclusion from the supplied numbers is that filter suitability remains to be established, rather than that clipping has already been proved.

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6.28 Application 6B.10: Separate reference offset from a deterministic modulation

A phase modulation of 0.75 radian at 2 kHz produces 1.5 kHz peak frequency deviation. Add a known +80 Hz carrier-minus-LO offset and a constant 35-degree phase offset. The positive residual follows Model 4A's baseband sign convention. The observed frequency deviation relative to the nominal reference spans −1,420 to +1,580 Hz. Over 2 ms, the residual offset contributes 0.16 cycle, or 57.6 degrees, while the constant phase contributes no frequency change.

Removing the independently measured 80 Hz offset restores a symmetric ±1.5 kHz deviation. Estimating it from a short portion of the modulated record can instead absorb part of the modulation, especially when the observation does not cover whole message periods. Keep the estimation interval and residual checks with the correction. A neat centered trace is not evidence that the chosen correction preserved the original modulation.

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6.29 Pulse, Radar, and Transient Reception

Pulsed signals require adequate instantaneous bandwidth, detector response, sample rate, and trigger strategy. Peak power, pulse width, rise and fall time, repetition interval, intrapulse modulation, and timing stability can be lost in an averaged or narrowband trace. Front-end protection and recovery are particularly important because a short pulse can compress a receiver whose average input power appears modest.

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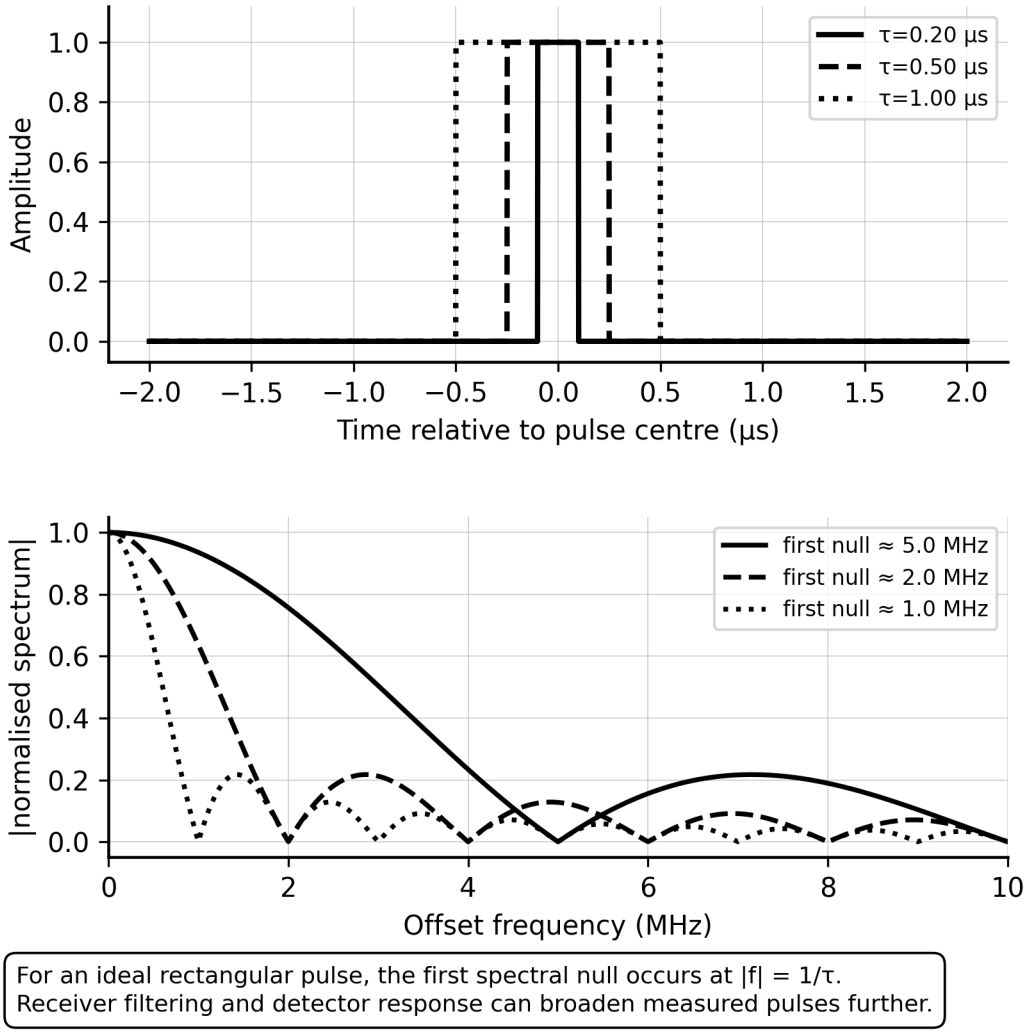

Figure 25. Pulse bandwidth and filter memory.

A pulse observed in one channel should be challenged for local digital switching, power-converter transients, analyzer sweep artifacts, and cross-channel coupling. Synchronized multichannel capture, antenna substitution, polarization, blanking, and known-source tests help distinguish external RF

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from conducted or internal events. When pulse content or radar association is outside V011's ownership, the report cross-references V101 or V110 rather than duplicating their system analysis.

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6.30 Preserve pulse and demodulator evidence across representations

A pulse adds an event boundary to the modulation problem. A long-time spectrum can characterize its repeated frequency content while concealing which part of the pulse produced it. A time trace can reveal onset and recovery while omitting the filter that shaped them. Link both views to the same native record, use the finite-window conventions in Chapter 9, and use Model 15A to distinguish a missed acquisition from a captured but distorted waveform. A pulse that never entered the usable observation window cannot be restored by a different demodulator.

For analog demodulation, begin with a known carrier and independently calibrated modulation. Verify the RF path, then compare recovered amplitude, phase or frequency against the expected baseband under several levels and bandwidths. Preserve the limiter, squelch, de-emphasis, carrier-recovery and audio-normalization settings. Each of those operations can change the derived output without any change to the external signal. Where a setting is automatic, retain its state or identify the interval over which it can be treated as fixed.

A recovered audio product should carry a reproducible link to the original RF or IF samples, the tuning and phase convention, the chosen sideband, the processing version, and any excluded interval. Subjective intelligibility may help an authorized investigation, but it does not calibrate deviation or prove a source identity. A comparison with a known reference and a challenge using another plausible demodulator setting are more informative about whether the processing has preserved the signal relationship being claimed.

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When the receiver changes gain or loses lock during a burst, retain the affected segment as a separate state. Do not silently splice the stable pieces into an apparently continuous waveform. The continuity and filter-history rules in Model 10E apply before a phase derivative, envelope statistic, or audio export is trusted. A reproducible failure to recover an event can still be useful evidence about the receiver method; it should not be converted into an assertion that the external waveform lacked modulation.

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6.31 Analog Demodulator Verification

Demodulator verification uses calibrated carrier, modulation, and pulse references across the stated bandwidth and level range. Measurements include recovered amplitude, frequency response, distortion, residual carrier, sideband rejection, deviation accuracy, limiter threshold, squelch state, and transient response. The test is repeated near the sensitivity threshold and near the strong-signal limit because different impairments dominate those regions.

Audio or baseband recordings are linked to their RF or IF source file, demodulator configuration, de-emphasis, sample rate, and time basis. When intelligibility is reported, the method distinguishes objective technical quality from subjective listening. Incidental content is minimized, and the primary technical record remains the calibrated signal capture.

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6.32 Quantitative Model for Analog Modulation Reception: AM, SSB, FM, PM, and Pulsed Signals

Equation 1. AM modulation index

$$m_{\mathrm{AM}} = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}}$$

For a sinusoidal conventional AM envelope without overmodulation, modulation index m_{AM} is estimated from maximum and minimum envelope amplitudes. Receiver compression, selective fading, noise, and detector filtering bias the result.

Equation 2. Carson bandwidth estimate

$$B_{\mathrm{FM}} \approx 2\left(\Delta f_{\mathrm{peak}} + f_{\mathrm{m,max}}\right)$$

Carson's rule estimates occupied bandwidth for frequency modulation using peak deviation Δf_{peak} and highest significant modulating frequency $f_{m,\max}$. It is an engineering approximation, not an exact emissions mask or universal containment criterion.

The envelope assumptions behind Equation 11 are developed in Model 6A and Applications 6A.1–6A.10. Equation 12 is the bounded engineering estimate used in Model 6B and Applications 6B.1–6B.10. Neither a scalar modulation index nor the bandwidth estimate replaces examination of the admitted waveform and its receiver transfer.

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Table 1. Chapter 6 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
AM and sidebands	Carrier, sideband levels, modulation depth, IF bandwidth, and detector	Supports modulation classification and linearity assessment	AGC, fading, and filter asymmetry can distort the envelope
SSB or suppressed carrier	Sideband selection, carrier reference, frequency error, and opposite-sideband rejection	Supports coherent baseband recovery	Manual tuning can create misleading audio
FM or PM	Deviation, phase excursion, baseband bandwidth, limiter, discriminator, and de-emphasis	Characterizes instantaneous-frequency or phase behavior	Threshold and capture effects can hide weak components
Pulse or transient	Peak level, width, rise time, repetition, trigger, sample rate, and recovery	Preserves timing and intrapulse structure	Averaging or narrow filters can erase decisive features

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6.33 Hypothetical Applied Calculation: Analog Modulation Reception: AM, SSB, FM, PM, and Pulsed Signals

An FM signal has measured peak deviation of 5.0 kHz and significant baseband content to 3.0 kHz. Carson's engineering estimate is about 16 kHz. Comparing 12.5 kHz and 25 kHz IF settings requires the actual waveform spectrum and filter transfer responses: the estimate alone does not establish passed power or distortion, even with the carrier centered. The wider setting can admit more noise and adjacent-channel energy according to its actual weighting. Model 6B develops this qualification.

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6.34 Hypothetical Case Adjudication: Analog Modulation Reception: AM, SSB, FM, PM, and Pulsed Signals

A narrowband receiver produces intelligible speech after an operator tunes 1.8 kHz below a weak component. Complex baseband analysis shows that the signal is ordinary upper-sideband voice with a suppressed carrier, not a novel low-frequency modulation. The recovered audio and the tuning offset are retained as derived evidence, while the original I/Q recording remains the primary record.

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6.35 Analogue demodulation as a source of systematic rather than merely random impairment

Demodulation changes which properties of the intercepted RF waveform survive in the output record. An amplitude detector discards much of the original carrier phase; an FM discriminator responds to instantaneous frequency under its own bandwidth and limiting assumptions; a product detector may translate phase or carrier-offset errors into audible or measurable low-frequency components. Thus a spectrum that shows a clean carrier cannot guarantee that a recovered analogue waveform reflects the original modulation without distortion. A receiver can produce apparently persuasive intelligibility while remaining outside its calibrated amplitude, timing or phase domain. For defensive measurement, the goal is usually to assess waveform structure and receiver validity, not to acquire unnecessary communications content. A lawful test should use synthetic modulation with known reference parameters and established collection boundaries.

A useful controlled comparison begins with a single-tone laboratory FM reference for which instantaneous phase is phi(t) = 2 pi f_c t + beta sin(2 pi f_m t), where carrier frequency f_c and modulation frequency f_m are in hertz and beta is dimensionless modulation index. The peak frequency deviation is beta f_m under that convention. For beta = 2.5 and f_m = 1 kHz, the stipulated peak deviation is 2.5 kHz. A discriminator's apparent output amplitude should track this deviation over the chosen passband and input-power range, within a separately measured uncertainty. A limiter that introduces recovery effects or a filter that suppresses significant sidebands can violate the result without shifting the displayed centre frequency. The

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numerical case is a stimulus definition, not a characterization of any field receiver.

AM and single-sideband reception require equally explicit analysis. A simple linear AM reference $s(t) = A[1 + mu \cos(2 pi f_m t)] \cos(2 pi f_c t)$ has conventional modulation depth mu when zero through unity; beyond that interval envelope detection no longer reproduces the baseband sinusoid in the ideal elementary form. A strong adjacent signal can alter detector operating point or gain, making a fixed external AM modulation appear to change. In SSB reception a beat-frequency oscillator misaligned with the transmitter shifts the audio spectrum. A tone moved by 30 Hz in the output is not proof that the remote source emitted a different audio tone; it may reflect the relative oscillator offset. Accordingly, reference-clock and demodulator calibration records must accompany any quantitative conclusion about original modulation.

A useful reporting table separates RF input observation, demodulator setting, recovered statistic and untested content assumptions. A lawful laboratory-generated waveform can be compared through alternate bandwidth, gain and oscillator states; the resulting error vector or distortion measure should be computed in the baseband only after demonstrating that the reference survives the analogue chain. A loud or smooth audio output is not a substitute for this comparison. The aim is to prevent useful diagnostic demodulation from being converted into an unsupported claim about source identity or an unauthorised interpretation of private communication, while still retaining the measurable impairments that reveal receiver failure.

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6.36 Advanced technical expansion. Complex envelopes, demodulation pathology and transient fidelity

An analogue receiver observing amplitude, phase or frequency modulation must distinguish the transmitted waveform from the transformations imposed by its own local oscillator, filter and detector. A real narrowband waveform may be represented by a complex envelope z(t) multiplying a carrier at an explicitly stated centre frequency. The instantaneous envelope magnitude describes an amplitude-related quantity, while the derivative of the unwrapped envelope phase describes frequency deviation relative to the chosen carrier convention. Neither is automatically the same as a transmitter's internal modulation variable, because propagation, phase noise, filtering and sampling can alter the observed envelope. For a professional measurement, the complex representation should therefore be retained before selecting AM, FM or PM demodulation, provided the acquisition and lawful-use scope permit its retention.

For an ideal frequency-modulated signal, a phase perturbation theta(t) produces instantaneous deviation delta_f(t) = (1/(2 pi)) d theta(t)/dt in hertz. This derivative amplifies high-frequency noise and becomes unstable near envelope nulls where phase is poorly determined. A phase trace that unwraps cleanly under strong-signal laboratory conditions may become a sequence of spurious frequency spikes near fades or interference cancellation. One must impose and record a validity mask based on signal amplitude, phase-estimation uncertainty and acquisition continuity. For a hypothetical linear phase increase of 0.4 radians over 200 microseconds, the mean deviation is approximately 318.31 Hz. That arithmetic does not

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establish an actual 318.31-Hz source modulation if the phase increase arose from LO drift, a reset, path movement or an unrecognised cycle slip.

Amplitude modulation measurements are similarly contingent on spectral symmetry. Unequal upper and lower sideband levels can originate in source modulation, asymmetric receiver passband gain, a nearby interferer or a drifting local oscillator. A receiver that reports accurate total power may nonetheless deliver a distorted recovered message because different sidebands experience different amplitude and phase transfer. To discriminate, inject a known double-sideband reference at the input plane, measure both sideband transfers, and repeat after a controlled carrier-frequency displacement within the same filter. A source effect follows the source, while a receiver filter artefact often follows position in the passband. The comparison requires enough sensitivity to observe the reference across the band and must account for any AGC response produced by the injection itself.

Pulsed modulation adds a time-frequency tradeoff. Multiplying an otherwise continuous waveform by a short gate spreads its spectrum, while finite filter settling modifies the pulse envelope in the time domain. A narrow IF filter can reduce broadband noise yet reject the high-frequency envelope components that define a sharp pulse onset. The operator should not claim a longer transmitted pulse merely because a detector output remained elevated after the input was removed. A useful laboratory challenge applies pulses of several known durations through the identical path and compares the returned envelope with the independently recorded input. Derive the convolutional response or characterise it empirically, and preserve the uncertainty of trigger time and filter state. Such a test may support

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deconvolution for a limited signal family, but cannot restore arbitrary waveform details that the acquisition never retained.

Multipath and fading deserve a distinct causal analysis. A coherent sum of delayed replicas can create amplitude nulls, rapid phase rotations and frequency-selective fading even when the transmitter is stable. Moving an antenna by a small fraction of a wavelength may change the resultant complex phasor substantially. One must distinguish the physics of the local propagation environment from the source modulation before assigning a fault or identifying a device. A set of spatially separated, phase-aware observations can help, but it must not be treated as independent confirmation when the sensors share a reference, antenna cable or demodulation implementation. The applicable error covariance and geometry belong in the report.

A defensible demodulation laboratory record contains source waveform identity, modulation index or deviation, occupied spectrum, input-plane power, receiver state, local-oscillator reference, digital processing version, complex samples and the recovered quantity with uncertainty. Verify source purity and instrument linearity. Compare coherent and noncoherent demodulators on held-out waveforms, especially near fading, overdeviation and pulse-edge conditions. Treat unintelligible audio as a limited result rather than evidence that no modulation existed; conversely, an intelligible recovered fragment does not establish ownership, intent or collection authority. The role of demodulation in a forensic argument is to add specific, reproducible waveform observations, not to convert apparent intelligibility into unsupported attribution.

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6.37 Analogue demodulation as a chain of estimators rather than a faithful copy of the transmitter

Analogue reception is often taught as a catalogue of modulation types. A postgraduate treatment must begin instead with the observable signal and the inverse operation proposed by the receiver. Let the real RF voltage at a declared port be $v(t)=\mathrm{Re}\{u(t)\exp(j2\pi f_c t)\}$, where $u(t)$ is the complex envelope in volts, f_c is a stipulated carrier frequency in hertz and the real-part operator converts the analytic representation to a physical waveform. Recovering a message from $v(t)$ requires decisions about carrier reference, observation bandwidth, amplitude scaling, phase continuity, filtering and noise. These decisions determine the result as surely as the transmitter's modulation law. A usable demodulation report therefore identifies whether the retained quantity is a physical input voltage, analytic IF samples, instantaneous phase, differentiated frequency, envelope magnitude or a post-filtered audio signal. These representations are not equivalent when clipping, loss of phase or inadequate sampling has occurred.

In a linear receive path, the complex envelope at the demodulator can be represented as $r(t)=h(t)*u(t)+n(t)$, after suitable carrier translation, where $*$ denotes convolution, $h(t)$ is a characterised complex impulse response and $n(t)$ is a residual whose statistics and dependence on $u(t)$ are not assumed without evidence. This expression is already a restricted model. Receiver automatic gain control makes h time dependent; limiting or saturation destroys linear superposition; a multipath channel introduces delayed replicas; a digital resampler contributes its own filtering and timing law. Derivations below state when the simple linear case applies and where they

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do not. The objective is not a pleasing recovered sound but a reproducible measurement of the modulation feature required by a lawful defensive question.

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6.38 Amplitude modulation beyond the textbook envelope formula

For conventional double-sideband amplitude modulation with a single sinusoidal message, write $u(t)=A_c[1+\mu \cos(2\pi f_m t)]$, with carrier-envelope peak voltage A_c, modulation frequency f_m and dimensionless modulation index μ. For a matched resistance R, carrier mean power $P_c=A_c^2/(2R)$. With $0\leq\mu\leq1$, the envelope magnitude is proportional to $1+\mu \cos(2\pi f_m t)$, and an ideal envelope detector can recover the sinusoidal message up to scale and DC removal. At $\mu>1$ the signed envelope crosses zero. A magnitude-only detector loses that sign and folds the recovered waveform, so a familiar extrema formula derived for nonovermodulated AM becomes invalid. A coherent receiver with a maintained carrier reference can in principle retain the sign, subject to its filter, phase and operating-state limitations.

The two sinusoidal sidebands at $f_c\pm f_m$ each have power $P_c \mu^2/4$, while the total RF mean power is $P_c(1+\mu^2/2)$ under the stipulated matched sinusoidal model. This decomposition does not establish the envelope of a general programme, multitone transmission, or an interfered receive signal. For a multitone message the peak envelope may be governed by relative phases even where average modulation power is unchanged. A receiver whose detector measures mean-square power over an interval cannot automatically infer the maximum modulation depth. The analytical distinction matters when comparing an apparently narrow, quiet trace with a signal carrying short, high-envelope peaks. Preserve amplitude calibration and detector time constants before attempting an inversion.

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An envelope detector introduces a dynamical compromise. A simple diode-capacitor model charges rapidly near RF peaks and discharges through a load with time constant $\tau=RC$, where R is the effective load resistance in ohms and C is capacitance in farads. For plausible envelope recovery, the time constant must be long enough to suppress carrier ripple yet short enough to follow the falling message envelope; there may be no feasible τ if the carrier and modulation time scales are poorly separated. The familiar inequalities $1/f_c \ll \tau \ll 1/f_m$ are only rough design guides and conceal diode threshold, source impedance, droop curvature and large-signal behaviour. A quantitative acceptance should inject known envelope shapes, measure recovered delay and distortion, and verify behaviour at several carrier levels rather than relying on one nominal RC calculation.

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6.39 Coherent AM, suppressed carriers and single-sideband ambiguity

Synchronous detection multiplies the observed carrier by a locally generated reference and removes the high-frequency product. The recovered baseband of an ideal double-sideband AM signal is scaled by cos θ where θ is the phase error between receiver and desired carrier reference, assuming negligible frequency offset, adequate low-pass filtering and a suitable amplitude convention. A 90-degree reference error can null the desired in-phase component despite a strong RF carrier. If a receiver has both I and Q channels, the complex vector can preserve the rotated signal and enable later correction, but only if the two paths' gain, quadrature angle and timing mismatches are characterised. Magnitude formation removes much of this phase sensitivity while also discarding the sign information needed by some coherent interpretations.

A suppressed-carrier double-sideband transmission has no transmitted unmodulated carrier line from which a receiver can automatically recover the reference. Its recovered signal may have a polarity or phase ambiguity that is irrelevant for some audio-monitoring purposes and critical for others. A small carrier-frequency offset makes the recovered constellation or baseband rotate in time. Single-sideband reception brings a further sign convention: choosing upper instead of lower sideband changes whether the recovered baseband spectrum is mirrored. A sideband-selection error may produce intelligible but spectrally inverted output, while a small reinsertion-frequency error shifts every audio component. For forensic waveform

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classification, intelligibility alone cannot establish correct carrier placement or the identity of the original transmitted modulation.

The Hilbert-transform construction makes these distinctions explicit. If a real, appropriately bandlimited message is m(t) and its Hilbert transform is m_hat(t), an ideal analytic upper-sideband envelope may be written m(t)+j m_hat(t), whereas the lower sideband uses m(t)-j m_hat(t) under the chosen positive-frequency convention. Generating or recovering these forms in a finite filter introduces approximation error near band edges and transient boundaries. The implementer should verify sideband suppression and passband phase as functions of frequency, not infer them from one favourable tone. A transient burst can expose overshoot and phase settling that are invisible in a settled sinusoidal test. Preserve the filter coefficients, sample rate and edge handling for any offline reconstruction.

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6.40 Frequency modulation, phase modulation and the dangers of differentiation

For constant-envelope angle modulation write $u(t)=A \exp[j\varphi(t)]$, where $\varphi(t)$ is continuous phase in radians within the adopted convention. The instantaneous frequency is $f_{inst}(t)=f_c+(1/2\pi)d\varphi/dt$ where the derivative and sufficient observation bandwidth exist. For sinusoidal FM with peak deviation Δf and modulation frequency f_m, the phase is $\varphi(t)=(\Delta f/f_m)\sin(2\pi f_m t)$, making modulation index $\beta=\Delta f/f_m$. For sinusoidal PM with peak phase excursion β radians, differentiation instead gives peak frequency deviation $\Delta f=\beta f_m$. The distinction cannot be established by examining one bandwidth number alone. It requires the relationship between phase, frequency and the underlying message over a stated interval.

A practical FM discriminator is an estimator, not an exact derivative of an ideal noiseless phase. An arctangent phase detector applied to complex samples returns principal values; unwrapping attempts to construct a continuous phase history, but its success depends on signal-to-noise ratio, maximum phase change per sample and the absence of unrecorded gaps. A phase increment of more than π radians between samples is ambiguous modulo 2π unless other information resolves it. Even in valid intervals, differentiating phase increases the relative importance of high-frequency phase noise, and an output de-emphasis filter changes the final noise and waveform response. Narrowing the receiver passband can suppress some noise but distort wide-deviation or rapidly changing modulation.

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Consequently the measurement of frequency deviation must retain the actual IF filter, demodulator and reconstruction law.

Carson's widely used bandwidth estimate $B \approx 2(\Delta f + f_m)$ for a single-tone FM signal is a useful engineering approximation, not an exact emission boundary. The actual spectrum has infinitely many Bessel-function sidebands in the ideal sinusoidal FM model, with progressively smaller powers, and the practically relevant bandwidth depends on the chosen containment criterion. The phase-noise skirt, multipath, pre-emphasis and occupied-programme statistics can further affect a measured spectrum. For an independently reported peak deviation, the estimator must specify bandwidth, observation time and valid modulation conditions. The relevant ITU-R frequency-deviation measurement recommendation provides a useful formal reference for such monitoring measurements, but its apparatus requirements and scope must not be presumed to apply to every receiver configuration without checking the controlling version and conditions.

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6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output

A narrowband multipath channel can be modelled as $h(t)=\sum_k a_k \exp(j\theta_k)\,\delta(t-\tau_k)$, with complex amplitudes $a_k \exp(j\theta_k)$, delays τ_k and an impulse δ. The frequency response $H(f)=\sum a_k \exp(j\theta_k)\exp(-j2\pi f\tau_k)$ varies with frequency and may include deep notches. A simple amplitude limiter can remove much of the received amplitude variation without removing the multipath-induced phase and frequency distortion. A recovered FM signal may therefore sound strong while exhibiting false discriminator excursions caused by rapid phasor rotation during fading. Conversely, selective fading can produce audible distortion that is mistakenly attributed to source modulation. Characterise the selected channel by moving or varying the receiver path only through controlled, recorded interventions, without conflating the changed propagation environment with a fixed source property.

The FM capture effect complicates dual-signal observations. With two cochannel emitters, a limiter and discriminator may favour the stronger received waveform rather than produce a straightforward linear sum of their audio signals. The transition can depend on instantaneous amplitudes, frequency offsets, filter response and noise. No universal capture ratio follows from the word FM. A controlled two-source laboratory test must vary desired and undesired level under fixed reference conditions, check the output metric and preserve competing hypotheses, including receiver limiting and source spectral overlap. An externally stable signal can appear intermittent in recovered audio if the receiver switches between competing

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cochannel components or experiences a deep multipath fade. Without sample-domain evidence, those alternatives are difficult to separate.

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6.42 Pulse shape and analogue information that filters irreversibly discard

A pulse-modulated carrier is not characterised solely by its nominal peak frequency or mean power. Multiplying a continuous carrier by an envelope gate spreads energy across frequency in accordance with the Fourier transform of the gate. A rectangular pulse of duration T has a sinc-shaped envelope transform, with its first zeros separated from the centre by 1/T in either direction under the ideal continuous model. Shortening T necessarily increases the width of its spectral features. A narrow IF filter may convert the sharp pulse into a delayed, rounded response whose observed peak is reduced even though the transmitter's original envelope remains unchanged. An AGC response or detector hold function can add further memory. Correct reporting therefore distinguishes source pulse width, input-plane waveform, IF-filtered pulse duration, detector-reported peak and any digitally reconstructed display.

For a controlled transient experiment, retain a simultaneously observed wide-enough reference waveform and the receiver output, with independent source and trigger timing. Measure delay to threshold, 10–90 percent rise time where that definition is applicable, peak response, ringing, recovery and noise under several input powers and pulse widths. Change bandwidth, gain and detector settings separately, because a single attractive recovered trace can conceal lost short events. The wideband reference is not automatically ground truth if it also clips or has insufficient analogue bandwidth. The acceptance table should identify which source-

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feature claims the measurement system can sustain and which are invalid once the signal has been filtered, clipped or averaged.

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6.43 Ten numerical worked examples under declared simplified models

Application 6C.1. A conventional AM signal has 1.000 mW carrier power and sinusoidal modulation index $\mu=0.60$. Each sideband carries $P_c \mu^2/4=0.0900$ mW and the total mean power is $P_c(1+\mu^2/2)=1.180$ mW, or approximately 0.718 dBm. The calculation assumes an ideal matched linear chain and a single sinusoidal message. It cannot be used as the peak envelope power or as a field-strength correction without additional data.

Application 6C.2. An ideal nonovermodulated AM signal has envelope extrema 1.6 V and 0.4 V, measured in the same voltage convention without noise. The extrema estimator gives $\mu=(E_{max}-E_{min})/(E_{max}+E_{min})=1.2/2.0=0.60$. If the signal is actually overmodulated, taking only envelope magnitude can fold the negative signed envelope and produce misleading extrema. The original index should then be determined by a different calibrated measurement.

Application 6C.3. A coherent AM detector has a 30-degree carrier reference phase error. Under the simple in-phase product law, the desired recovered component is multiplied by $\cos 30°=0.866025$, a $20\log10(0.866025)=-1.249$ dB amplitude reduction. A change in recovered level alone is therefore not evidence of a changed RF source amplitude unless the local-reference state is controlled.

Application 6C.4. A coherent demodulator averages a complex tone over $T=40$ ms with residual frequency error $\Delta f=15$ Hz. The normalised complex-average magnitude is $|\sin(\pi\Delta fT)/(\pi\Delta fT)|=|\sin(0.6\pi)/(0.6\pi)|=0.50455$, or -5.94 dB in amplitude. The effect comes from rotation during integration, not a

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measured fall in source power. Retaining the complex samples permits a different frequency correction when the assumptions and data support it.

Application 6C.5. A sinusoidal FM signal has peak deviation 6.0 kHz and message frequency 2.0 kHz. Its modulation index is $\beta=6/2=3$, and the Carson estimate is $B\approx 2(6+2)=16$ kHz. This approximate bandwidth is not a guaranteed signal-containment interval or a validated channel-filter requirement for a different message waveform.

Application 6C.6. A sinusoidal PM signal has phase excursion 0.50 rad and message frequency 10 kHz. Its peak frequency deviation is $\beta f_m=5.0$ kHz. Keeping the phase excursion fixed while doubling f_m doubles the frequency deviation, unlike the construction in which an FM transmitter's peak frequency deviation is fixed.

Application 6C.7. An ideal single-pole de-emphasis filter with time constant $\tau=75$ microseconds has magnitude $|H(f)|=1/\mathrm{sqrt}[1+(2\pi f\tau)^2]$. At 1 kHz, $|H|\approx 0.9046$, or -0.87 dB. At 10 kHz it is approximately 0.2076, or -13.65 dB. These are deliberately chosen filter-model values; real receivers need measured transfer and any corresponding pre-emphasis convention.

Application 6C.8. A rectangular envelope pulse lasts 10 microseconds. Its first ideal sinc-spectrum zeros occur at frequency offsets $\pm 1/T=\pm 100$ kHz from the carrier. A receive channel whose useful response spans only 20 kHz about its centre cannot reproduce the sharp rectangular edges. This geometric bandwidth argument does not specify the precise distorted output peak, which depends on the complete filter impulse response and detector law.

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Application 6C.9. Under a stipulated phasor model two equal-amplitude received replicas arrive at the same narrowband frequency with relative phase 180 degrees. Their vector sum is zero even though each replica separately has nonzero power. A slight change of relative path phase moves the result away from the null. The observation demonstrates the nonuniqueness of source-power inference from one received amplitude, not a guarantee that all broadband components share that null.

Application 6C.10. A synthetic SINAD test gives total signal-plus-noise-plus-distortion power 10.0 mW and residual noise-plus-distortion power 0.10 mW after the defined notch procedure. Their ratio is 100, or 20.0 dB SINAD. The implied recovered fundamental signal power is 9.90 mW, and S/(N+D)=99, or 19.956 dB. The distinction is small here but conceptually important: SINAD includes the original residual in its numerator, and the result belongs to the specified weighting and detector conditions.

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6.44 Laboratory qualification of an analogue-demodulation measurement claim

The final acceptance should include a defined reference-plane source, independently verified modulation, representative signal powers, known reference frequency, filter and detector settings, and a record of actual sample continuity. For each intended inference establish suitable tests: amplitude index for AM, carrier phase error for coherent reception, sideband suppression and signed orientation for SSB, deviation and discriminator linearity for FM and PM, and impulse response for pulsed emissions. Repeat representative tests under noise and bounded blockers, including states where automatic gain or limiting may alter the result. Distinguish a tested detection of a waveform family from recovery of communications content, which may require separate lawful authority. The record must permit a reviewer to reproduce both the reported statistic and its limits without substituting intelligibility or display neatness for scientific validity.

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6.45 Pulse modulation as a measurable time-frequency process and not merely on-off keying

A pulse-modulated radio signal has a physical time history before it has an attractive frequency-domain representation. A finite radio-frequency burst can be described by a carrier, a complex amplitude envelope, an instantaneous phase law, and a sequence of intervals in which the transmitter enters different states. Pulse duration, pulse-repetition interval, repetition-frequency stability, rise and fall times, duty factor, centre frequency, chirp slope, intra-pulse phase code, and amplitude overshoot are different observables. A detector can recover some of them without recovering the others. For example, an envelope detector may report the presence and approximate width of a burst while destroying the sign of frequency offset and much of the intra-pulse phase structure. Conversely, a narrow frequency discriminator can report a stable carrier during a pulse while missing the leading edge entirely. The examiner must identify the acquisition operation that supports each claimed pulse characteristic, particularly when a proposed device identity is inferred from the pattern rather than established by an independently tested physical link.

Let a real RF waveform be $r(t)=\mathrm{Re}\{u(t)\exp(j\,2\pi f_c t)\}$, where f_c is a carrier in hertz, j is the positive imaginary unit, and $u(t)=a(t)\exp(j\varphi(t))$ is the complex envelope. The magnitude $a(t)$ is nonnegative and has the voltage units chosen by the measurement system; $\varphi(t)$ is measured in radians. With this convention, the instantaneous frequency departure from the carrier is $\Delta f(t)=(1/2\pi)d\varphi(t)/dt$ when the phase derivative exists and the signal magnitude is sufficiently above noise. A pulse with constant complex phase

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and approximately rectangular a(t) is fundamentally unlike a pulse in which the amplitude remains constant but φ(t) varies quadratically. The latter may implement linear frequency modulation, or chirp; its spectrum, correlation properties and required receive bandwidth differ substantially, even when the two bursts have identical start and stop times. No frequency plot can recover which phase law occurred unless the retained complex measurement preserves the relevant timing and phase references.

For an ideal rectangular complex-envelope pulse of amplitude A between time zero and duration τ, its Fourier-transform magnitude has the familiar sinc envelope $A\tau|\mathrm{sinc}(f\tau)|$, where $\mathrm{sinc}(x)=\sin(\pi x)/(\pi x)$. The first zeros occur at $\pm 1/\tau$ relative to its centre frequency and the null-to-null main-lobe width is $2/\tau$. This is not an occupied-bandwidth specification for a practical transmitter with finite edge time, chirp, modulation or spectral masks; it is a diagnostic limiting model. Abrupt edges imply extended spectral sidelobes, whereas shaped edges can redistribute sidelobe energy and broaden the principal transition. If a receiver's analog preselector removes the high-frequency components associated with an edge, subsequent digital deconvolution cannot be assumed to recover that edge, especially when the filter has deep stopband zeros or an uncertain group-delay response. This is precisely why pulse-fidelity tests must use the complete installed receive path rather than a nominal converter sampling rate alone.

A pulse train introduces a second scale. For constant pulse-repetition interval T_r, pulse-repetition frequency $f_r=1/T_r$ and duty factor $D=\tau/T_r$ for a nonoverlapping rectangular train. In a perfectly periodic and infinitely long model, discrete spectral lines are spaced by f_r under a broad pulse-envelope weighting. Real finite recordings, missed pulses, deliberate jitter

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and varying modulation replace that ideal comb with a measurement-limited statistical pattern. A line spacing near a claimed repetition frequency is not unique evidence of one emitting device; switch-mode power supplies, oscillator clocks, gating artifacts and internal receiver sampling structures can also create quasi-periodic features. Periodicity must be checked against native timestamped event lists and an independent receiver configuration before source identity is inferred.

A narrow 30 Hz spectrum bin can be useful for a stable carrier but is poorly matched to an isolated microsecond pulse if treated as a complete detector. Resolution is not the only problem: a filter with approximately 30 Hz noise bandwidth generally has response memory on a scale of many milliseconds, while the original event may last a millionth of a second. The display can show an attenuated, delayed, broadened response governed by the filter impulse response rather than the pulse envelope. Preserve a parallel wideband, time-resolved signal path or a hardware event trigger alongside the narrowband integration. The narrow path can subsequently quantify a persistent carrier or slow repetition feature; it must not be cited as though its temporal output were the true burst width. Where both products are made from one raw I/Q stream, their common origin and their different digital filters must be explicit in the processing record.

Noise complicates the location of pulse edges. A threshold crossing occurs where the filtered amplitude, noise and criterion meet, not necessarily where the transmitting device switches. For a finite slope $s=d\,a/dt$ expressed in volts per second, a small additive amplitude disturbance δa changes an isolated threshold-crossing time approximately by $\delta t \approx \delta a/s$, provided the linear local approximation and monotonic edge assumptions hold. Strong

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prefilter ringing can create multiple crossings; detector hysteresis can create different leading and trailing delays; gain control can change the slope. The error is therefore not generally a constant trigger latency removable from all observations by one offset. Report the threshold, hysteresis, filter state, sampling interval, observed rise/fall slopes and threshold-jitter evidence. When a sequence of bursts is used for attribution, a systematic pulse-timing bias can be more damaging than a small amount of random amplitude noise.

Pulse width is also representation-dependent. Width measured between half-power crossings of a detected envelope, between ten-percent amplitude crossings of an RF pulse, and between digital trigger events are three different quantities. A displayed width can increase after video filtering even though the RF energy interval has not changed. An envelope detector that compresses or saturates during the pulse may produce a long decay. A phase discriminator may lose lock during the leading edge and report its reacquisition transient as a chirp. A coherent matched filter intentionally compresses a longer coded or chirped pulse into a short correlation response. That correlation response is a useful range or timing statistic, not a claim that the transmitter emitted an equally short physical pulse. The manuscript must preserve the original and transformed durations as separately labelled quantities.

The engineering release test should include a known pulse source and an independently characterised observation channel. Vary pulse width, rise time, amplitude, intra-pulse phase code, chirp slope, repetition regularity and relative start phase with respect to the sample clock. Record both the transmitted reference and the receiving system's native samples. Measure

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edge bias, width bias, missed-event probability, false triggers, ringing, recovery dead time and variation across frequency slices. Challenge the acquisition with two overlapping bursts, a weak burst beside a blocker, and a burst straddling a retune or buffer handover. A clean plot of selected successes does not establish the performance of a system tasked with discovering rare unknown events. The distribution of failed conditions belongs in the acceptance evidence.

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6.46 Ten worked examples for pulse characterisation, ambiguity and false temporal precision

Application P6.1. For a rectangular 4 microsecond pulse, $\tau=4\times10^{-6}$ seconds; the ideal complex-envelope main-lobe nulls lie at ±250 kHz and its null-to-null width is 500 kHz. The 30 Hz analysis filter cannot be used to claim direct resolution of its edge. The calculation concerns a rectangular complex envelope, not a specification for all practical edge shapes.

Application P6.2. A transmitter emits 2 microsecond pulses every 2 milliseconds. The pulse-repetition frequency is 500 Hz, and duty factor is 0.001, or 0.1 percent. A swept receiver that only observes the frequency during a 100 microsecond dwell has no guarantee of intercept from these averages unless the relationship between dwell phase, sweep period and pulse start times is specified.

Application P6.3. A pulse contains 20 microseconds of linear chirp over 10 MHz. The nominal slope is $10^7/(20\times10^{-6})=5\times10^{11}$ Hz per second. The duration-bandwidth product is 200. A matched-filter correlation may yield a much narrower response than 20 microseconds, but the stored I/Q waveform must still show the emitted 20 microsecond chirped event and the filter used to produce the compressed response.

Application P6.4. A laboratory source produces pulses 50 microseconds long at 200 pulses per second. The period is 5 milliseconds and duty factor is 1 percent. An averaged full-time power level can lie about 20 dB below the pulse-on average power when the off interval contains negligible signal energy, because $10\log10(0.01)=-20$ dB. Peak and average powers must not be used interchangeably for front-end survivability.

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Application P6.5. An analogue detector has a one-pole response with 1 millisecond time constant. After one time constant a step response reaches $1-e^{-1}\approx 63.2$ percent of its final value. In a 5 microsecond pulse, its response reaches only $1-\exp(-0.005)\approx 0.499$ percent before the pulse ends under the simplified model. The small display response cannot be attributed to low transmitter pulse power without considering filter settling.

Application P6.6. A 100 mV amplitude perturbation is superimposed on a monotonic edge rising at 10^5 volts per second. The linearised crossing-time displacement is 0.0001/100000=1 nanosecond. The result assumes the local slope remains constant and ignores repeated crossings; a changing automatic-gain state invalidates those premises.

Application P6.7. A 10 MHz I/Q channel sampled at 12.5 million complex samples per second contains 62.5 samples across a 5 microsecond pulse. Finite sample placement implies that an un-interpolated edge index alone has a grid spacing of 80 nanoseconds. A finer reported edge time requires a justified interpolating estimator and a measurement uncertainty, not extra displayed decimals.

Application P6.8. A 1 microsecond pulse has a characteristic envelope spectral scale near 1 MHz. Converting its trace into a 30 Hz averaged-frequency representation replaces the original event with a much longer windowed spectral summary. For a 33.33 millisecond window, the pulse occupies only about 0.003 percent of the window time. This time fraction does not predict a universal 45 dB detection loss, because the outcome depends on coherent integration, energy, windowing and detector law.

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Application P6.9. A pulse-to-pulse phase rotation of 45 degrees at a 1 millisecond interval can be consistent with a constant 125 Hz frequency offset modulo the 1 kHz pulse-sampling alias interval, because 45/360 divided by 0.001=125 Hz. A fitted offset is ambiguous by integer multiples of the pulse-sampling frequency unless extra continuity or reference information is available.

Application P6.10. A recorded burst has a 2 microsecond leading-edge transient, 18 microseconds stable carrier, and a 4 microsecond trailing response. Reporting a single 24 microsecond width conceals three mechanisms. A calibrated comparison should report edge criteria, settled duration and the installed filter's impulse response. If an alternative preselector shortens the trailing response without changing the emitted reference, the result supports receive-path memory rather than a transmitter-length change.

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Chapter Summary

Analog demodulation is a configured inference from RF or IF data. Bandwidth, reference recovery, gain, detector, and processing settings must accompany any claim about modulation or recovered information.

Model 6A declares a complex peak-voltage envelope, load and averaging convention. Mean power follows envelope mean square; peak envelope power follows its maximum. Sinusoidal AM inversion requires a nonnegative signed envelope. General messages need their actual mean square, while magnitude detection loses reversal sign and unequal sideband transfer can introduce quadrature structure.

Coherent recovery depends on the frequency and phase reference. Preserve complex rotation and signed SSB orientation before audio folding. Model 6B relates valid unwrapped phase to frequency: finite differences give interval averages, principal increments leave aliases, nulls can invalidate phase, and resets require segmentation. FM and PM relate excursion and modulation rate differently.

The small-phase remainder bounds a specified approximation; Carson’s estimate does not certify filter suitability or exact containment. Preserve native samples, processing states and evidence for corrections. Verify modulation across applicable levels and bandwidths, and distinguish pulse coverage from waveform fidelity. Classification and intelligibility do not independently establish source identity.

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Chapter 6 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C06-MCQ-001. A receiver measures a carrier with symmetric sidebands and a stable spacing. What can these observations establish without additional evidence?

A. They prove the received envelope is unaffected by the selected IF filter.

B. They can support a modulation classification within the verified receiver response.

C. They uniquely identify the transmitter and its operational purpose.

D. They establish the original message even if the detector phase is unknown.

Answer: B. Spectral structure is technical evidence about the admitted waveform. Source identity, message reconstruction and path fidelity require different evidence and cannot be inferred from symmetry alone. Review: Carrier, Sidebands, and Modulation Evidence. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

Why the selected alternative fits: They can support a modulation classification within the verified receiver response.

Distinguishing consideration: compare this with option A, “They prove the received envelope is unaffected by the selected IF filter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

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V011-C06-MCQ-002. An audio export changes after de-emphasis is enabled while the retained RF samples are identical. Which interpretation is supported?

A. Identical RF samples require identical audio for every demodulator configuration.

B. De-emphasis can be treated as a time stamp correction with no amplitude effect.

C. The transmitter must have changed its modulation during the export.

D. The processing path has changed the derived product without demonstrating an external signal change.

Answer: D. The detector, tuning, filtering and de-emphasis help define the audio transfer. Their configuration belongs with the derived recording and must be reconciled before comparing outputs. Review: Carrier, Sidebands, and Modulation Evidence; Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why the selected alternative fits: The processing path has changed the derived product without demonstrating an external signal change.

Distinguishing consideration: compare this with option A, “Identical RF samples require identical audio for every demodulator configuration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

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V011-C06-MCQ-003. What voltage convention does Model 6A assign to its complex envelope?

A. An RMS-voltage envelope that already includes every factor of square root two.

B. A peak-voltage envelope whose real translated waveform is the physical RF voltage.

C. A dimensionless analytic envelope independent of any load or calibration.

D. An instantaneous power envelope expressed directly in watts.

Answer: B. The peak-voltage convention fixes the factor of two in the power equations. Changing to RMS normalization is possible but requires a consistent change in all associated formulas. Review: Equations 11A and 11B. Source: Equation 11A. Real RF waveform and its complex envelope (p. 3112)

Why the selected alternative fits: A peak-voltage envelope whose real translated waveform is the physical RF voltage.

Distinguishing consideration: compare this with option A, “An RMS-voltage envelope that already includes every factor of square root two”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope; Chapter 6 — Equation 11B. Envelope power convention.

Review: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope; Chapter 6 — Equation 11B. Envelope power convention.

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V011-C06-MCQ-004. Why does Model 6A require the envelope bandwidth to be smaller than the positive carrier frequency?

A. To keep the translated positive and negative RF bands separated under the stated representation.

B. To guarantee that an arbitrary IF filter passes the entire modulation unchanged.

C. To force the envelope to be real for every modulation type.

D. To make the carrier power equal to total power for all messages.

Answer: A. Spectral separation supports the selected complex-envelope and averaging convention. It does not impose a real envelope, a receiver response or a particular power distribution. Review: Equation 11A. Source: Equation 11A. Real RF waveform and its complex envelope (p. 3112)

Why the selected alternative fits: To keep the translated positive and negative RF bands separated under the stated representation.

Distinguishing consideration: compare this with option B, “To guarantee that an arbitrary IF filter passes the entire modulation unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope.

Review: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope.

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V011-C06-MCQ-005. Under the stated orthogonality and averaging conditions, a peak-voltage envelope has mean squared magnitude 1.2 square volts across 50 ohms. What is the mean RF power?

A. 24 mW.

B. 120 mW.

C. 6 mW.

D. 12 mW.

Answer: D. Divide mean squared envelope magnitude by twice the resistance: 1.2 divided by 100 equals 0.012 W. The factor of two follows the peak-voltage convention. Review: Equation 11B. Source: Equation 11B. Envelope power convention (p. 3113)

Why the selected alternative fits: 12 mW.

Distinguishing consideration: compare this with option A, “24 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11B. Envelope power convention.

Review: Chapter 6 — Equation 11B. Envelope power convention.

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V011-C06-MCQ-006. Two captures have the same mean squared envelope magnitude but different envelope maxima. What follows under otherwise identical power conventions?

A. Their instantaneous RF voltage peaks must occur at the same times.

B. They necessarily have the same peak envelope power because their means agree.

C. They have the same mean RF power but can have different peak envelope powers.

D. Their carrier powers must be equal even when one waveform has no carrier.

Answer: C. The mean and maximum are different functionals of the envelope. Equality of one does not constrain the other, or establish a particular spectral decomposition. Review: Equation 11B; Application 6A.8. Source: Equation 11B. Envelope power convention (p. 3113)

Why the selected alternative fits: They have the same mean RF power but can have different peak envelope powers.

Distinguishing consideration: compare this with option A, “Their instantaneous RF voltage peaks must occur at the same times”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

Review: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-MCQ-007. A mean-power calculation averages a periodic carrier and message over an arbitrary fraction of their common period. Which condition needs attention?

A. Whether the maximum envelope magnitude must equal its RMS magnitude.

B. Whether the omitted cross terms actually vanish over the selected interval.

C. Whether the voltage convention automatically eliminates all finite-window effects.

D. Whether resistance can be removed from the calculation because the waveform is periodic.

Answer: B. The compact envelope-power relation is used with its declared orthogonality, carrier-cycle or justified long-time averaging convention. A partial interval may retain cross terms that the derivation excluded. Review: Equation 11B and its averaging assumptions. Source: Equation 11B. Envelope power convention (p. 3113)

Why the selected alternative fits: Whether the omitted cross terms actually vanish over the selected interval.

Distinguishing consideration: compare this with option A, “Whether the maximum envelope magnitude must equal its RMS magnitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11B. Envelope power convention.

Review: Chapter 6 — Equation 11B. Envelope power convention.

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V011-C06-MCQ-008. A conventional AM envelope has positive carrier amplitude, a real message bounded in magnitude by one and modulation depth between zero and one. What is guaranteed?

A. The signed envelope is nonnegative.

B. The receiver output cannot be compressed at high input level.

C. The upper and lower received sidebands remain equal after any channel.

D. The message mean square is exactly one half.

Answer: A. The smallest possible bracket is one minus the depth, which is nonnegative. The result is a transmitter-model statement, not a guarantee about message statistics or the receiver. Review: Equation 11C. Source: Equation 11C. Conventional AM and nonnegative-envelope condition (p. 3113)

Why the selected alternative fits: The signed envelope is nonnegative.

Distinguishing consideration: compare this with option B, “The receiver output cannot be compressed at high input level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11C. Conventional AM and nonnegative-envelope condition.

Review: Chapter 6 — Equation 11C. Conventional AM and nonnegative-envelope condition.

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V011-C06-MCQ-009. For sinusoidal conventional AM within the nonnegative-envelope domain, extrema are 1.8 V and 0.6 V. What carrier peak and modulation depth follow?

A. 0.6 V and 2.

B. 1.2 V and 0.667.

C. 2.4 V and 0.5.

D. 1.2 V and 0.5.

Answer: D. The carrier peak is the half-sum of the extrema, while depth is their difference divided by their sum. These are separate inversions with compatible peak-voltage inputs. Review: Equation 11D. Source: Equation 11D. Sinusoidal AM extrema and their inversion (p. 3113)

Why the selected alternative fits: 1.2 V and 0.5.

Distinguishing consideration: compare this with option A, “0.6 V and 2”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

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V011-C06-MCQ-010. The maximum and minimum of a magnitude-only envelope are 2.3 V and zero. Why does the extrema formula alone not establish the original depth?

A. The half-sum formula remains an exact carrier estimator for every reversed envelope.

B. A zero minimum uniquely proves exactly 100 percent modulation before every receiver impairment.

C. An overmodulated signed envelope can cross zero and lose its negative part under magnitude detection.

D. The maximum alone fixes the carrier amplitude independently of the message.

Answer: C. A magnitude minimum at zero occurs for both a boundary case and many reversed envelopes. The nonnegative signed-envelope assumption must be established before using the inverse formula. Review: Equations 11D and 11H; Application 6A.4. Source: Equation 11D. Sinusoidal AM extrema and their inversion (p. 3113)

Why the selected alternative fits: An overmodulated signed envelope can cross zero and lose its negative part under magnitude detection.

Distinguishing consideration: compare this with option A, “The half-sum formula remains an exact carrier estimator for every reversed envelope”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion; Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate….

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion; Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

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V011-C06-MCQ-011. A sinusoidal AM carrier has 1.2 V peak across 75 ohms and depth 0.5. What is the carrier power?

A. 10.8 mW.

B. 19.2 mW.

C. 9.6 mW.

D. 0.6 mW.

Answer: C. Carrier power is the squared carrier peak divided by twice the resistance: 1.44 square volts divided by 150 ohms gives 0.0096 W. Total power and either sideband power are different quantities. Review: Equation 11E. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why the selected alternative fits: 9.6 mW.

Distinguishing consideration: compare this with option A, “10.8 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

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V011-C06-MCQ-012. For the same 1.2 V peak, 75-ohm, depth-0.5 sinusoidal AM case, what is the power in each sideband?

A. 4.8 mW.

B. 1.2 mW.

C. 0.6 mW.

D. 2.4 mW.

Answer: C. Each sideband has one quarter of the squared depth times the 9.6 mW carrier power. The two sidebands together contain 1.2 mW. Review: Equation 11E.

Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why the selected alternative fits: 0.6 mW.

Distinguishing consideration: compare this with option A, “4.8 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

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V011-C06-MCQ-013. For the 9.6 mW carrier at sinusoidal AM depth 0.5, what total RF power follows in the linear model?

A. 19.2 mW.

B. 12.0 mW.

C. 14.4 mW.

D. 10.8 mW.

Answer: D. The total-to-carrier ratio is one plus half the squared depth, or 1.125. Adding the two 0.6 mW sidebands gives the same result. Review: Equation 11F.

Source: Equation 11F. Total sinusoidal-AM power (p. 3114)

Why the selected alternative fits: 10.8 mW.

Distinguishing consideration: compare this with option A, “19.2 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11F. Total sinusoidal-AM power.

Review: Chapter 6 — Equation 11F. Total sinusoidal-AM power.

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V011-C06-MCQ-014. Both sidebands of a verified sinusoidal AM signal are 20 dB below the carrier in power. What depth follows?

A. 0.4.

B. 0.1.

C. 0.2.

D. 0.02.

Answer: C. A minus-20 dBc sideband has power ratio 0.01. Taking its square root and multiplying by two gives depth 0.2; using a power ratio directly as an amplitude ratio loses the square root. Review: Equation 11E; Application 6A.3. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why the selected alternative fits: 0.2.

Distinguishing consideration: compare this with option A, “0.4”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers; Chapter 6 — Application 6A.3: Infer modulation depth from one resolved sideband.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers; Chapter 6 — Application 6A.3: Infer modulation depth from one resolved sideband.

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V011-C06-MCQ-015. Only one sideband is measured at minus 20 dBc and the other lies outside the acquisition band. What is the warranted inference about AM depth?

A. A depth of 0.2 is conditional on a sinusoidal, symmetric, linear AM model that the missing sideband has not yet verified.

B. The observed sideband alone proves the carrier was suppressed.

C. The original depth is exactly 0.2 for every possible asymmetric channel.

D. The unseen sideband must have zero power because it was not recorded.

Answer: A. One sideband supports a conditional estimate. Selective filtering, fading or a different modulation can break the assumptions, so the missing evidence remains explicit. Review: Application 6A.3; Amplitude Modulation and Envelope Detection. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

Why the selected alternative fits: A depth of 0.2 is conditional on a sinusoidal, symmetric, linear AM model that the missing sideband has not yet verified.

Distinguishing consideration: compare this with option B, “The observed sideband alone proves the carrier was suppressed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6A.3: Infer modulation depth from one resolved sideband; Chapter 6 — Amplitude Modulation and Envelope Detection.

Review: Chapter 6 — Application 6A.3: Infer modulation depth from one resolved sideband; Chapter 6 — Amplitude Modulation and Envelope Detection.

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V011-C06-MCQ-016. A sinusoidal AM depth increases from 0.25 to 0.5 while carrier power remains fixed. What happens to either sideband power?

A. It increases by a factor of two, approximately 3.01 dB.

B. It increases by a factor of sixteen, approximately 12.04 dB.

C. It increases by a factor of four, approximately 6.02 dB.

D. It remains fixed because carrier power is fixed.

Answer: C. Sideband amplitude is proportional to depth, but sideband power is proportional to its square. Doubling depth therefore quadruples either sideband power. Review: Equation 11E. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why the selected alternative fits: It increases by a factor of four, approximately 6.02 dB.

Distinguishing consideration: compare this with option A, “It increases by a factor of two, approximately 3.01 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

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V011-C06-MCQ-017. A zero-mean bounded AM message has mean square 0.25 and the modulation scale is 0.8. What total-to-carrier power ratio follows?

A. 1.32.

B. 1.64.

C. 1.16.

D. 1.20.

Answer: C. Use the actual mean square: one plus 0.8 squared times 0.25 is 1.16. Substituting the unit-cosine mean square of one half would give a different, unjustified value. Review: Equation 11G. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why the selected alternative fits: 1.16.

Distinguishing consideration: compare this with option A, “1.32”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

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V011-C06-MCQ-018. Two zero-mean AM messages have equal maximum magnitude and equal modulation scale but different mean squares. What can differ even in a perfect linear chain?

A. Their total mean powers relative to the same carrier.

B. The stipulated positive carrier amplitude solely because the message peaks agree.

C. The load resistance required by the peak-voltage definition.

D. The numerical value of the stated modulation scale itself.

Answer: A. Peak normalization does not fix a waveform's time distribution. The mean-square message term determines its contribution to average power. Review: Equation 11G; Application 6A.10. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why the selected alternative fits: Their total mean powers relative to the same carrier.

Distinguishing consideration: compare this with option B, "The stipulated positive carrier amplitude solely because the message peaks agree"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

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V011-C06-MCQ-019. The arbitrary-message AM power relation is applied to a message whose mean is not zero. Which omitted term must be reconsidered?

A. A compulsory negative sideband power that restores the zero-mean formula.

B. A correction that makes peak envelope power equal mean power.

C. The term proportional to twice the modulation scale times the message mean.

D. A factor that removes all dependence on the message mean square.

Answer: C. Expanding the squared real envelope gives a constant term, a term linear in the message and a squared-message term. The linear term vanishes only under the stated zero-mean condition. Review: Equation 11G and its zero-mean assumption. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why the selected alternative fits: The term proportional to twice the modulation scale times the message mean.

Distinguishing consideration: compare this with option A, “A compulsory negative sideband power that restores the zero-mean formula”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

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V011-C06-MCQ-020. The ideal algebraic envelope is one plus 1.3 times a cosine, with no transmitter clipping. Which spectrum statement is correct?

A. The original carrier disappears whenever the signed envelope is negative.

B. The real RF product still contains the original carrier and two sinusoidal sidebands.

C. The two sidebands cease to be separated from the carrier by the message frequency.

D. Envelope reversal alone necessarily creates an unlimited set of new RF harmonics.

Answer: B. A linear product with one cosine expands into three RF terms at any scale. Rectifying the envelope or physically clipping the transmitter is a separate nonlinear operation. Review: Equation 11H; Application 6A.4. Source: Equation 11H. Magnitude detection after envelope reversal (p. 3115)

Why the selected alternative fits: The real RF product still contains the original carrier and two sinusoidal sidebands.

Distinguishing consideration: compare this with option A, “The original carrier disappears whenever the signed envelope is negative”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

Review: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

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V011-C06-MCQ-021. Why does a simple magnitude detector distort an overmodulated AM message?

A. It preserves the signed envelope but necessarily changes the RF carrier frequency.

B. It removes the carrier and both sidebands without producing any output.

C. It replaces negative signed-envelope portions by their magnitudes and therefore loses sign information.

D. It performs exact complex rotation with a known phase reference.

Answer: C. The absolute-value operation folds the reversed portions upward. That nonlinear baseband operation is distinct from coherent recovery of the original signed envelope. Review: Equation 11H. Source: Equation 11H. Magnitude detection after envelope reversal (p. 3115)

Why the selected alternative fits: It replaces negative signed-envelope portions by their magnitudes and therefore loses sign information.

Distinguishing consideration: compare this with option A, “It preserves the signed envelope but necessarily changes the RF carrier frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal.

Review: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal.

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V011-C06-MCQ-022. Additional RF components appear when an actual transmitter clips an intended overmodulated waveform. How should they be related to Model 6A?

A. They are required by any negative signed envelope even without clipping.

B. They prove the three-term cosine product identity is mathematically false.

C. They reflect a physical nonlinearity outside the unclipped algebraic AM expression.

D. They can be removed from the measured RF record by relabeling the depth.

Answer: C. The algebraic identity and the hardware transfer are different claims. A clipped amplitude law changes the waveform and can generate components absent from the ideal linear expression. Review: Equation 11H discussion; Application 6A.4.

Source: Equation 11H. Magnitude detection after envelope reversal (p. 3115)

Why the selected alternative fits: They reflect a physical nonlinearity outside the unclipped algebraic AM expression.

Distinguishing consideration: compare this with option A, “They are required by any negative signed envelope even without clipping”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

Review: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

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V011-C06-MCQ-023. A measured AM envelope flattens at its peaks as receiver input rises. Which check most directly challenges a receiver-created depth error?

A. Keep the overloaded gain state and correct depth only from its maximum.

B. Repeat the same known modulation over applicable attenuation and gain states while retaining the raw waveform.

C. Infer a transmitter depth change from the flattened audio alone.

D. Assume the extrema ratio cancels every nonlinear transfer.

Answer: B. Compression and control can alter the envelope shape. A controlled level challenge helps distinguish path distortion from a source change; ratio formation does not cancel an arbitrary nonlinearity. Review: Amplitude Modulation and Envelope Detection; Analog Demodulator Verification. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

Why the selected alternative fits: Repeat the same known modulation over applicable attenuation and gain states while retaining the raw waveform.

Distinguishing consideration: compare this with option A, “Keep the overloaded gain state and correct depth only from its maximum”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Amplitude Modulation and Envelope Detection; Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Amplitude Modulation and Envelope Detection; Chapter 6 — Analog Demodulator Verification.

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V011-C06-MCQ-024. A narrow IF response attenuates high-frequency AM sidebands more strongly than low-frequency sidebands. What must accompany a reported modulation-depth result?

A. Only the nominal IF width, with all skirt and phase properties treated as equivalent.

B. The relevant path response and the message spectrum or reference modulation used to establish applicability.

C. A claim that equal input depth forces equal output depth for all message frequencies.

D. Only the center-frequency carrier calibration, assumed to cover every sideband.

Answer: B. Depth measured after a frequency-dependent path can depend on the modulation spectrum. A carrier point alone does not establish waveform fidelity across the sidebands. Review: Amplitude Modulation and Envelope Detection; Equation 11G discussion. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why the selected alternative fits: The relevant path response and the message spectrum or reference modulation used to establish applicability.

Distinguishing consideration: compare this with option A, “Only the nominal IF width, with all skirt and phase properties treated as equivalent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Amplitude Modulation and Envelope Detection.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Amplitude Modulation and Envelope Detection.

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V011-C06-MCQ-025. For a conventional sinusoidal AM envelope of carrier peak 1 V and depth 0.6 across 50 ohms, what is peak envelope power?

A. 10 mW.

B. 51.2 mW.

C. 25.6 mW.

D. 11.8 mW.

Answer: C. The envelope maximum is 1.6 V. Its square divided by 100 ohms gives 25.6 mW, distinct from the 11.8 mW mean power and from an instantaneous RF-voltage peak convention. Review: Equation 11B; Application 6A.1. Source: Equation 11B. Envelope power convention (p. 3113)

Why the selected alternative fits: 25.6 mW.

Distinguishing consideration: compare this with option A, “10 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.1: Close the power accounting for sinusoidal AM.

Review: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.1: Close the power accounting for sinusoidal AM.

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V011-C06-MCQ-026. Why is the real product detector normalized with twice the LO cosine in Model 6A?

A. The factor compensates the one-half coefficient of the selected difference-frequency product.

B. It guarantees perfect opposite-sideband rejection in every hardware detector.

C. It removes all dependence on LO phase and frequency error.

D. It doubles the physical RF input power before any mixing operation.

Answer: A. Multiplication of two cosines produces half-amplitude sum and difference terms. The normalization defines unity amplitude for the intended difference term after the sum band is rejected. Review: Equation 11I; Model 4A conversion convention. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why the selected alternative fits: The factor compensates the one-half coefficient of the selected difference-frequency product.

Distinguishing consideration: compare this with option B, “It guarantees perfect opposite-sideband rejection in every hardware detector”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 4 — Model 4A: a declared conversion map.

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V011-C06-MCQ-027. A real AM envelope is recovered coherently at exact frequency agreement but with a 60-degree reference phase error. What is the output scale?

A. The complete envelope with only a delay.

B. One half of the signed envelope.

C. Twice the signed envelope.

D. Zero at all times.

Answer: B. The real projection multiplies the envelope by cosine of the phase error. Cosine of 60 degrees is one half, corresponding to approximately minus 6.02 dB in amplitude gain. Review: Equation 11I. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why the selected alternative fits: One half of the signed envelope.

Distinguishing consideration: compare this with option A, “The complete envelope with only a delay”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

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V011-C06-MCQ-028. A purely real AM envelope gives zero real coherent output at a 90-degree phase error. What does a simultaneous ideal I/Q record establish?

A. The phase error has removed energy from every possible measurement basis.

B. Both quadratures must be zero because one real projection is zero.

C. The RF signal must have vanished before the detector.

D. The signal can remain present in the quadrature component despite the null real projection.

Answer: D. A projection null is coordinate dependent. Complex recovery retains the rotated envelope, permitting the reference error to be observed and corrected within the valid model. Review: Equations 11I and 11J; Application 6A.5. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why the selected alternative fits: The signal can remain present in the quadrature component despite the null real projection.

Distinguishing consideration: compare this with option A, “The phase error has removed energy from every possible measurement basis”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Application 6A.5: Measure phase-dependent coherent-AM recovery.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Application 6A.5: Measure phase-dependent coherent-AM recovery.

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V011-C06-MCQ-029. A residual carrier-minus-LO frequency error remains during real coherent recovery. How does its effect differ from a constant phase error?

A. It rotates the envelope continuously with time and can mix the message with a residual low-frequency oscillation.

B. It changes only the receiver time stamp without changing recovered frequencies.

C. It always produces only one constant amplitude scale for the full record.

D. It vanishes when a real output is retained instead of complex I/Q.

Answer: A. The residual frequency appears in a time-dependent exponential. A fixed projection of that rotating envelope cannot generally be represented by a single constant gain. Review: Equations 11I and 11J; Application 6A.6. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why the selected alternative fits: It rotates the envelope continuously with time and can mix the message with a residual low-frequency oscillation.

Distinguishing consideration: compare this with option B, “It changes only the receiver time stamp without changing recovered frequencies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC....

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

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V011-C06-MCQ-030. A suppressed-carrier real envelope is a 1 kHz cosine and the real coherent detector has a 50 Hz residual rotation with zero initial phase. Which output tones result?

A. Only 1 kHz at the full original envelope peak.

B. Only 1050 Hz at the full original envelope peak.

C. 50 Hz and 2 kHz with equal original peaks.

D. 950 Hz and 1050 Hz, each with half the original envelope peak.

Answer: D. The recovered real product is the 1 kHz cosine multiplied by the 50 Hz cosine. The product-to-sum identity gives the two half-amplitude components.

Review: Application 6A.6. Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)

Why the selected alternative fits: 950 Hz and 1050 Hz, each with half the original envelope peak.

Distinguishing consideration: compare this with option A, “Only 1 kHz at the full original envelope peak”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

Review: Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

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V011-C06-MCQ-031. Under Model 6A, which operation preserves both signed baseband orientation and residual phase rotation for later analysis?

A. Retain the calibrated complex I/Q output and its reference convention.

B. Replace every negative baseband frequency with its absolute value.

C. Discard quadrature after adjusting the audio to sound plausible.

D. Retain only the magnitude of one real audio spectrum.

Answer: A. Complex data retain information that a real projection or magnitude folding can discard. The reference and calibration are still required to interpret that retained information. Review: Equations 11J and 11K. Source: Equation 11J. Complex coherent recovery (p. 3115)

Why the selected alternative fits: Retain the calibrated complex I/Q output and its reference convention.

Distinguishing consideration: compare this with option B, “Replace every negative baseband frequency with its absolute value”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

Review: Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

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V011-C06-MCQ-032. For a 10 MHz reference carrier, a 2 kHz upper-sideband tone and an LO at 10.0003 MHz, what signed complex baseband frequency follows?

A. Positive 2300 Hz.

B. Negative 1700 Hz.

C. Negative 2300 Hz.

D. Positive 1700 Hz.

Answer: D. The upper-sideband RF frequency is carrier plus message frequency. Subtracting the LO gives 10,002,000 minus 10,000,300 Hz, or positive 1700 Hz.

Review: Equation 11K. Source: Equation 11K. Explicit upper and lower single-sideband envelopes (p. 3116)

Why the selected alternative fits: Positive 1700 Hz.

Distinguishing consideration: compare this with option A, “Positive 2300 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

Review: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

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V011-C06-MCQ-033. For the same carrier and LO, what signed complex baseband frequency follows for the 2 kHz lower-sideband tone?

A. Positive 2300 Hz.

B. Positive 1700 Hz.

C. Negative 2300 Hz.

D. Negative 1700 Hz.

Answer: C. The lower-sideband RF frequency is carrier minus message frequency. Subtracting the LO gives 9,998,000 minus 10,000,300 Hz, or negative 2300 Hz.

Review: Equation 11K. Source: Equation 11K. Explicit upper and lower single-sideband envelopes (p. 3116)

Why the selected alternative fits: Negative 2300 Hz.

Distinguishing consideration: compare this with option A, “Positive 2300 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

Review: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

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V011-C06-MCQ-034. A real audio magnitude spectrum folds the preceding positive 1700 Hz and negative 2300 Hz results to positive frequencies. What information is then absent from that magnitude display alone?

A. The ability to distinguish 1700 Hz from 2300 Hz as magnitudes.

B. The original signed baseband orientation of each component.

C. The fact that the display has a frequency coordinate.

D. The two displayed absolute tone frequencies themselves.

Answer: B. A real magnitude display can retain absolute frequencies while losing their complex orientation. That loss can conceal sideband inversion or confuse the sign of a tuning correction. Review: Equation 11K; Application 6A.7. Source: Equation 11K. Explicit upper and lower single-sideband envelopes (p. 3116)

Why the selected alternative fits: The original signed baseband orientation of each component.

Distinguishing consideration: compare this with option A, “The ability to distinguish 1700 Hz from 2300 Hz as magnitudes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes; Chapter 6 — Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong.

Review: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes; Chapter 6 — Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong.

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V011-C06-MCQ-035. An operator tunes an SSB signal until speech is intelligible. What remains necessary for a measured recovered-frequency claim?

A. A claim that tuning changes the transmitted RF waveform itself.

B. An assumption that any intelligible SSB setting exactly restores the suppressed carrier.

C. A documented carrier-reference method and its frequency accuracy, separate from subjective intelligibility.

D. Only a statement that the chosen audio sounds natural.

Answer: C. Intelligibility can guide a listening task but does not establish metrological accuracy. The retained LO/reference state determines the recovered frequency scale. Review: Single Sideband and Coherent Reception. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

Why the selected alternative fits: A documented carrier-reference method and its frequency accuracy, separate from subjective intelligibility.

Distinguishing consideration: compare this with option A, “A claim that tuning changes the transmitted RF waveform itself”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Single Sideband and Coherent Reception.

Review: Chapter 6 — Single Sideband and Coherent Reception.

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V011-C06-MCQ-036. A two-tone SSB envelope has peak coefficients 0.6 V and 0.8 V at distinct harmonically related frequencies, observed over complete periods across 50 ohms. What mean RF power follows?

A. 20 mW.

B. 19.6 mW.

C. 10 mW.

D. 14 mW.

Answer: C. The cross term averages to zero, leaving 0.6 squared plus 0.8 squared, or 1 square volt. Divide by twice 50 ohms to obtain 10 mW. Review: Equation 11B; Application 6A.8. Source: Equation 11B. Envelope power convention (p. 3113)

Why the selected alternative fits: 10 mW.

Distinguishing consideration: compare this with option A, “20 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

Review: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-MCQ-037. The two SSB components in the preceding case align in phase within the observation interval. What peak envelope power follows?

A. 39.2 mW.

B. 10 mW.

C. 9.8 mW.

D. 19.6 mW.

Answer: D. Their aligned envelope peak is 1.4 V. Squaring and dividing by 100 ohms gives 19.6 mW; the coherent maximum is not the sum of separately averaged powers. Review: Application 6A.8. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

Why the selected alternative fits: 19.6 mW.

Distinguishing consideration: compare this with option A, “39.2 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

Review: Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-MCQ-038. Why must an SSB peak envelope power calculation state its observation interval or attainable phase alignment?

A. The load resistance changes automatically with the observation length.

B. A maximum is always identical to the long-time mean for multitone signals.

C. The complex envelope ceases to be defined when an interval is finite.

D. A maximum depends on the retained time domain and may not attain the sum of component magnitudes within an arbitrary finite interval.

Answer: D. The sum of magnitudes is a useful upper bound. Equality requires simultaneous phase alignment within the domain over which the maximum is taken. Review: Equation 11B; Application 6A.8. Source: Equation 11B. Envelope power convention (p. 3113)

Why the selected alternative fits: A maximum depends on the retained time domain and may not attain the sum of component magnitudes within an arbitrary finite interval.

Distinguishing consideration: compare this with option A, “The load resistance changes automatically with the observation length”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

Review: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-MCQ-039. An AM path leaves a unit real carrier coefficient and real sideband coefficients 0.4 and 0.2. What complex envelope follows?

A. A purely real envelope of one plus 0.8 times the cosine.

B. A real part of one plus 0.6 times the cosine and an imaginary part of 0.2 times the sine.

C. A constant envelope magnitude of one for every message phase.

D. A real part of one plus 0.2 times the cosine and an imaginary part of 0.6 times the sine.

Answer: B. The cosine coefficient is the sum of the sideband coefficients and the imaginary sine coefficient is their difference. Unequal sideband transfer therefore introduces a quadrature component. Review: Equation 11L; Application 6A.9. Source: Equation 11L. In-phase and quadrature terms after unequal sideband response (p. 3116)

Why the selected alternative fits: A real part of one plus 0.6 times the cosine and an imaginary part of 0.2 times the sine.

Distinguishing consideration: compare this with option A, “A purely real envelope of one plus 0.8 times the cosine”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response; Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response; Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

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V011-C06-MCQ-040. For that unequal-sideband example, a real detector reports a cosine modulation coefficient 0.6 instead of the input value 0.8. What is the correct attribution?

A. The quadrature component proves that the input was necessarily phase modulated.

B. The source must have changed its modulation depth by exactly 0.2.

C. The magnitude trace uniquely identifies which sideband the path attenuated.

D. The observed change includes the asymmetric path response and cannot be assigned to the original source depth alone.

Answer: D. A known real input can acquire a complex envelope after unequal filtering. The received scalar depth is a property of the combined source and path under the selected detector. Review: Application 6A.9. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

Why the selected alternative fits: The observed change includes the asymmetric path response and cannot be assigned to the original source depth alone.

Distinguishing consideration: compare this with option A, “The quadrature component proves that the input was necessarily phase modulated”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

Review: Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

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V011-C06-MCQ-041. Equation 11L permits complex carrier and sideband coefficients. Which extraction remains valid without assuming those coefficients are real?

A. Replace the lower-sideband coefficient by the conjugate of the upper one without checking the path.

B. Call the complete coefficient sum the real component even if it is complex.

C. Take the real and imaginary parts of the entire reconstructed complex envelope.

D. Discard every coefficient phase before computing the waveform.

Answer: C. The algebraic expansion is valid for complex coefficients, but identifying physical I and Q still requires real and imaginary extraction of the complete expression. Review: Equation 11L and coefficient definitions. Source: Equation 11L. In-phase and quadrature terms after unequal sideband response (p. 3116)

Why the selected alternative fits: Take the real and imaginary parts of the entire reconstructed complex envelope.

Distinguishing consideration: compare this with option A, “Replace the lower-sideband coefficient by the conjugate of the upper one without checking the path”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

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V011-C06-MCQ-042. A residual opposite-sideband component appears after a practical coherent detector. Which receiver mechanism belongs in the challenge?

A. A guaranteed new modulation type whenever the rejection is finite.

B. Only a change in the remote transmitter, because local conversion cannot create leakage.

C. An automatic cancellation of phase noise by the existence of two channels.

D. I/Q imbalance, filter asymmetry or imperfect product-detector balance.

Answer: D. Practical conversion can produce residual carrier or opposite-sideband leakage. The interpretation must include verified receiver rejection and reference behavior. Review: Single Sideband and Coherent Reception. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

Why the selected alternative fits: I/Q imbalance, filter asymmetry or imperfect product-detector balance.

Distinguishing consideration: compare this with option A, “A guaranteed new modulation type whenever the rejection is finite”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Single Sideband and Coherent Reception.

Review: Chapter 6 — Single Sideband and Coherent Reception.

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V011-C06-MCQ-043. A message is one half of a 1 kHz cosine plus one quarter of a 2 kHz cosine, with a common averaging period. What is its mean square?

A. 0.15625.

B. 0.5625.

C. 0.3125.

D. 0.75.

Answer: A. Each squared cosine contributes one half of its squared coefficient, and the distinct-frequency cross term averages to zero. The result is one half of 0.25 plus one half of 0.0625. Review: Equation 11G; Application 6A.10. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why the selected alternative fits: 0.15625.

Distinguishing consideration: compare this with option B, “0.5625”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

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V011-C06-MCQ-044. For that message at modulation scale 0.8, what total-to-carrier mean-power ratio follows?

A. 1.32.

B. 1.10.

C. 1.05.

D. 1.40.

Answer: B. Multiply the message mean square 0.15625 by the squared scale 0.64, then add one. The result is 1.10 under the stated averaging conditions. Review: Application 6A.10. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

Why the selected alternative fits: 1.10.

Distinguishing consideration: compare this with option A, “1.32”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

Review: Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

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V011-C06-MCQ-045. The triangle inequality bounds the magnitude of that two-cosine message by 0.75. What does this establish for an AM envelope with unit carrier and scale 0.8?

A. An exact measured minimum of 0.4 V at every combination of message phases.

B. A total mean power equal to the square of the lower envelope bound.

C. A requirement that both cosines reach minus one simultaneously.

D. A conservative lower bound of 0.4 V on the signed envelope, without proving that bound is attained.

Answer: D. The message bound gives one minus 0.8 times 0.75. It proves nonnegativity but can be loose because component extrema need not coincide.

Review: Application 6A.10. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

Why the selected alternative fits: A conservative lower bound of 0.4 V on the signed envelope, without proving that bound is attained.

Distinguishing consideration: compare this with option A, “An exact measured minimum of 0.4 V at every combination of message phases”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

Review: Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

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V011-C06-MCQ-046. A receiver limiter is inserted before an intended AM-depth measurement. Which limitation must be addressed?

A. Limiter output alone provides the original carrier-to-sideband power ratio for every input.

B. A limiter automatically restores signed envelope portions lost to magnitude detection.

C. The limiter can remove or alter amplitude information needed by the measurand.

D. Limiting preserves all envelope extrema because carrier frequency is unchanged.

Answer: C. An operation useful for suppressing amplitude variation in an angle-modulation path can destroy the amplitude relationship required by AM analysis. The appropriate path depends on the measurand. Review: Amplitude Modulation and Envelope Detection; Analog Demodulator Verification. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

Why the selected alternative fits: The limiter can remove or alter amplitude information needed by the measurand.

Distinguishing consideration: compare this with option A, “Limiter output alone provides the original carrier-to-sideband power ratio for every input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Amplitude Modulation and Envelope Detection; Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Amplitude Modulation and Envelope Detection; Chapter 6 — Analog Demodulator Verification.

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V011-C06-MCQ-047. Two candidate demodulator configurations produce plausible audio from the same stored RF capture. What is the stronger technical discriminator?

A. Average the two audio waveforms and call the result the original message.

B. Compare each output with known waveform relationships and calibrated reference tests under its recorded configuration.

C. Treat plausible audio as evidence that filter and tuning states are immaterial.

D. Accept whichever output sounds more familiar as proof of the transmitter type.

Answer: B. Multiple processing choices can produce plausible derived signals. A reproducible relationship to the native capture and a verified transfer provide stronger evidence than familiarity alone. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why the selected alternative fits: Compare each output with known waveform relationships and calibrated reference tests under its recorded configuration.

Distinguishing consideration: compare this with option A, “Average the two audio waveforms and call the result the original message”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-048. What additional condition makes the phase derivative in Model 6B a well-defined local frequency relation?

A. A supported unwrapped, absolutely continuous phase branch for the stipulated nonzero-amplitude complex signal.

B. Only a list of wrapped angles with no continuity or time basis.

C. A zero-amplitude sample at every point so that phase is unrestricted.

D. An arbitrary real audio magnitude spectrum with all phase discarded.

Answer: A. The derivative relation uses the continuous phase of the defined complex signal and holds almost everywhere under the stated regularity. An undefined or unsupported phase does not become physical frequency merely by numerical differentiation. Review: Equation 12A and Model 6B assumptions. Source: Equation 12A. Complex phase and instantaneous frequency (p. 3131)

Why the selected alternative fits: A supported unwrapped, absolutely continuous phase branch for the stipulated nonzero-amplitude complex signal.

Distinguishing consideration: compare this with option B, “Only a list of wrapped angles with no continuity or time basis”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12A. Complex phase and instantaneous frequency; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

Review: Chapter 6 — Equation 12A. Complex phase and instantaneous frequency; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

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V011-C06-MCQ-049. Why is a dramatic phase-derived frequency excursion near a signal null not automatically evidence of a transmitter chirp?

A. Numerical phase differentiation cannot respond to noise or interference.

B. Every phase derivative is exactly zero whenever amplitude varies.

C. The phase estimate can become ill-conditioned when amplitude is near zero or multiple components are unresolved.

D. A null guarantees an infinitely precise carrier-frequency estimate.

Answer: C. The single supported phase branch is a model condition. Near a null, noise or component cancellation can dominate the phase estimate and invalidate a simple physical-frequency interpretation. Review: Model 6B assumptions; Frequency and Phase Modulation. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

Why the selected alternative fits: The phase estimate can become ill-conditioned when amplitude is near zero or multiple components are unresolved.

Distinguishing consideration: compare this with option A, “Numerical phase differentiation cannot respond to noise or interference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Frequency and Phase Modulation.

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Frequency and Phase Modulation.

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V011-C06-MCQ-050. What converts an unwrapped phase derivative in radians per second to a frequency offset in hertz?

A. Multiplication by the load resistance.

B. Division by two pi.

C. Multiplication by two pi.

D. Division by the carrier amplitude.

Answer: B. A complete cycle corresponds to two pi radians. The phase derivative measures angular rate, and the conversion to cycles per second supplies the reciprocal factor. Review: Equation 12A. Source: Equation 12A. Complex phase and instantaneous frequency (p. 3131)

Why the selected alternative fits: Division by two pi.

Distinguishing consideration: compare this with option A, “Multiplication by the load resistance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12A. Complex phase and instantaneous frequency.

Review: Chapter 6 — Equation 12A. Complex phase and instantaneous frequency.

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V011-C06-MCQ-051. A sinusoidal FM signal has 4.5 kHz peak deviation at a 1.5 kHz modulation frequency. What is its phase index?

A. 6.75 radians.

B. 0.333 radian.

C. 3000 radians.

D. 3 radians.

Answer: D. The phase index is deviation divided by modulation frequency with matching units. The ratio is dimensionless, customarily reported as a phase excursion in radians. Review: Equation 12B; Application 6B.1. Source: Equation 12B. Sinusoidal FM phase and modulation index (p. 3132)

Why the selected alternative fits: 3 radians.

Distinguishing consideration: compare this with option A, “6.75 radians”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Application 6B.1: Convert a sinusoidal FM deviation into phase excursion.

Review: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Application 6B.1: Convert a sinusoidal FM deviation into phase excursion.

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V011-C06-MCQ-052. The peak frequency deviation of a sinusoidal FM signal remains fixed while its modulation frequency doubles. How does the phase index change?

A. It halves.

B. It remains fixed.

C. It becomes zero regardless of deviation.

D. It doubles.

Answer: A. The index divides a fixed deviation by modulation frequency. This differs from a PM experiment in which phase excursion is held fixed. Review: Equation 12B; Application 6B.3. Source: Equation 12B. Sinusoidal FM phase and modulation index (p. 3132)

Why the selected alternative fits: It halves.

Distinguishing consideration: compare this with option B, “It remains fixed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation.

Review: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation.

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V011-C06-MCQ-053. A sinusoidal PM experiment holds peak phase excursion fixed while modulation frequency increases from 1 kHz to 4 kHz. What happens to peak frequency deviation?

A. It increases by a factor of four.

B. It decreases by a factor of four.

C. It remains fixed.

D. It becomes a constant carrier-frequency offset.

Answer: A. Frequency offset is the phase derivative divided by two pi. Differentiating a fixed-amplitude sinusoidal phase introduces the modulation frequency. Review: Equation 12C; Application 6B.3. Source: Equation 12C. Sinusoidal PM and its frequency deviation (p. 3132)

Why the selected alternative fits: It increases by a factor of four.

Distinguishing consideration: compare this with option B, “It decreases by a factor of four”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation; Chapter 6 — Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation.

Review: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation; Chapter 6 — Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation.

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V011-C06-MCQ-054. A PM phase is 1.2 radians times a 2 kHz cosine. What frequency-offset waveform follows under the chapter convention?

A. Positive 4800 pi Hz times the corresponding sine.

B. Minus 2400 Hz times the corresponding sine.

C. Positive 2400 Hz times the corresponding cosine.

D. Minus 1.2 Hz times the corresponding sine.

Answer: B. Differentiate the cosine, including its negative sign and angular-frequency factor, then divide by two pi. The result has a 2400 Hz peak and the stated sine phase. Review: Equation 12C; Application 6B.2. Source: Equation 12C. Sinusoidal PM and its frequency deviation (p. 3132)

Why the selected alternative fits: Minus 2400 Hz times the corresponding sine. Distinguishing consideration: compare this with option A, “Positive 4800 pi Hz times the corresponding sine”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation; Chapter 6 — Application 6B.2: Differentiate a sinusoidal PM phase.

Review: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation; Chapter 6 — Application 6B.2: Differentiate a sinusoidal PM phase.

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V011-C06-MCQ-055. A constant 35-degree phase-reference offset is added to an otherwise correct continuous phase record. What frequency offset does that constant contribute?

A. 35 times the sample rate in hertz.

B. Zero.

C. One complete cycle per observation interval.

D. 35 Hz.

Answer: B. The derivative of a constant phase offset is zero. A constant phase error can matter to coherent projection while contributing no frequency error. Review: Equation 12K; Application 6B.10. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why the selected alternative fits: Zero.

Distinguishing consideration: compare this with option A, “35 times the sample rate in hertz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

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V011-C06-MCQ-056. A known positive 80 Hz carrier-minus-LO offset persists for 2 ms. What additional phase accumulation does it produce?

A. 0.16 cycle, or 57.6 degrees.

B. 160 cycles, or 57,600 degrees.

C. 0.04 cycle, or 14.4 degrees.

D. Zero because it is a constant frequency offset.

Answer: A. Cycles equal frequency offset times elapsed seconds: 80 times 0.002. A constant frequency error produces a linear phase trend, unlike a constant phase error. Review: Equation 12K; Application 6B.10. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why the selected alternative fits: 0.16 cycle, or 57.6 degrees.

Distinguishing consideration: compare this with option B, “160 cycles, or 57,600 degrees”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

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V011-C06-MCQ-057. A frequency-reference offset is estimated from a short segment of the same modulated record and then removed. What dependency should be retained?

A. A short interval necessarily spans complete periods of every modulation component.

B. The estimate can absorb part of the modulation, depending on the segment and estimator.

C. Any centered corrected trace proves that the original modulation was preserved.

D. The correction is independent of the signal because it is expressed in hertz.

Answer: B. A fitted trend can confound reference error with genuine low-frequency or incomplete-period modulation. Preserve the original record, fit interval and independent reference evidence. Review: Equation 12K discussion; Application 6B.10. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why the selected alternative fits: The estimate can absorb part of the modulation, depending on the segment and estimator.

Distinguishing consideration: compare this with option A, “A short interval necessarily spans complete periods of every modulation component”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

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V011-C06-MCQ-058. A carrier-recovery algorithm resets phase after losing lock. How should a phase derivative be handled across that boundary?

A. Assume that an arbitrary integer-cycle correction is uniquely determined by the reset alone.

B. Differentiate the jump as proof of an instantaneous physical frequency spike.

C. Treat the reset as a segment boundary and establish any intersegment relationship separately.

D. Delete the reset samples and splice the stable portions into an apparently continuous record.

Answer: C. A reference reset is not the same as continuous signal phase evolution. Bridging it without a justified relationship creates an unsupported frequency history. Review: Equation 12K discussion; Preserve pulse and demodulator evidence across representations. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why the selected alternative fits: Treat the reset as a segment boundary and establish any intersegment relationship separately.

Distinguishing consideration: compare this with option A, “Assume that an arbitrary integer-cycle correction is uniquely determined by the reset alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-059. A linear frequency offset ramps from minus 2 kHz to plus 2 kHz over 4 ms. Its net phase change is zero. What does that endpoint result establish?

A. The unwrapped phase could not have made an intermediate excursion.

B. The waveform had zero frequency offset at every time.

C. Every receiver filter must produce an unchanged waveform because the endpoints agree.

D. The signed frequency-offset integral cancels, not that frequency or phase remained unchanged throughout.

Answer: D. Equal positive and negative areas can cancel over the full interval. Endpoint phase differences alone do not reveal the intermediate trajectory. Review: Equation 12D; Application 6B.5. Source: Equation 12D. Integration of a general deterministic frequency offset (p. 3132)

Why the selected alternative fits: The signed frequency-offset integral cancels, not that frequency or phase remained unchanged throughout.

Distinguishing consideration: compare this with option A, “The unwrapped phase could not have made an intermediate excursion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

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V011-C06-MCQ-060. A frequency offset ramps linearly from minus 3 kHz to plus 3 kHz over 6 ms, starting at zero phase. What is the accumulated phase at the midpoint?

A. Minus 9 pi radians.

B. Zero radians.

C. Minus 18 pi radians.

D. Positive 9 pi radians.

Answer: A. Over the first 3 ms, the average offset is minus 1.5 kHz, giving minus 4.5 cycles. Multiplication by two pi gives minus 9 pi radians; the second half later cancels this accumulation. Review: Equation 12D; Application 6B.5 method. Source: Equation 12D. Integration of a general deterministic frequency offset (p. 3132)

Why the selected alternative fits: Minus 9 pi radians.

Distinguishing consideration: compare this with option B, “Zero radians”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

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V011-C06-MCQ-061. Phase consists of 0.3 radian times a 1 kHz sine plus 0.1 radian times a 3 kHz sine, with aligned phases. What peak frequency deviation is attained at time zero?

A. 1200 Hz.

B. 600 Hz.

C. 0.4 Hz.

D. 400 Hz.

Answer: B. Differentiation gives cosine components of 300 Hz each. Both equal their positive maxima at time zero, so their sum attains the 600 Hz triangle bound.

Review: Equation 12E; Application 6B.4. Source: Equation 12E. Deviation from several phase components (p. 3133)

Why the selected alternative fits: 600 Hz.

Distinguishing consideration: compare this with option A, “1200 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12E. Deviation from several phase components; Chapter 6 — Application 6B.4: Bound and attain the deviation of a two-tone phase.

Review: Chapter 6 — Equation 12E. Deviation from several phase components; Chapter 6 — Application 6B.4: Bound and attain the deviation of a two-tone phase.

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V011-C06-MCQ-062. For several sinusoidal phase terms with arbitrary relative phases, what does the sum of the absolute individual frequency-deviation peaks establish?

A. A conservative upper bound whose attainability requires compatible phase alignment.

B. An exact maximum for every set of phases and every observation interval.

C. A lower bound that every instantaneous deviation must exceed.

D. An exact RMS deviation independent of correlations.

Answer: A. The triangle inequality bounds the sum, but equality requires the component extrema to align with the necessary signs. That condition is not automatic. Review: Equation 12E. Source: Equation 12E. Deviation from several phase components (p. 3133)

Why the selected alternative fits: A conservative upper bound whose attainability requires compatible phase alignment.

Distinguishing consideration: compare this with option B, “An exact maximum for every set of phases and every observation interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12E. Deviation from several phase components.

Review: Chapter 6 — Equation 12E. Deviation from several phase components.

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V011-C06-MCQ-063. A constant frequency offset of 75 Hz lasts for 20 ms on a continuous phase branch. What phase accumulation follows?

A. 1500 cycles.

B. 0.15 cycle, or 0.3 pi radian.

C. 1.5 cycles, or 3 pi radians.

D. 75 radians independently of duration.

Answer: C. Integrate frequency offset over time: 75 times 0.020 gives 1.5 cycles. The conversion to radians multiplies by two pi. Review: Equation 12D. Source: Equation 12D. Integration of a general deterministic frequency offset (p. 3132)

Why the selected alternative fits: 1.5 cycles, or 3 pi radians.

Distinguishing consideration: compare this with option A, “1500 cycles”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset.

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V011-C06-MCQ-064. A phase sensitivity is specified in radians per volt and the message peak in volts. What is the unit of their product before differentiating the phase?

A. Radians of phase excursion.

B. Watts of RF power.

C. Hertz of frequency deviation without any time dependence.

D. Volts per radian.

Answer: A. The voltage units cancel, leaving a phase excursion. Frequency deviation additionally depends on the message time derivative or, for a sinusoid, its modulation frequency. Review: Equation 12C. Source: Equation 12C. Sinusoidal PM and its frequency deviation (p. 3132)

Why the selected alternative fits: Radians of phase excursion.

Distinguishing consideration: compare this with option B, “Watts of RF power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

Review: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

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V011-C06-MCQ-065. At 48,000 complex samples per second, a constant positive 31 kHz offset gives which principal-increment frequency?

A. Negative 17 kHz.

B. Negative 31 kHz.

C. Positive 31 kHz.

D. Positive 17 kHz.

Answer: A. Subtract one 48 kHz sampling-rate interval to place the frequency in the selected principal interval. The resulting minus 17 kHz has the same sampled complex progression. Review: Equation 12G; Application 6B.6. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why the selected alternative fits: Negative 17 kHz.

Distinguishing consideration: compare this with option B, “Negative 31 kHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

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V011-C06-MCQ-066. The principal argument convention is minus pi inclusive to plus pi exclusive. At a 48 kHz complex sample rate, how is the half-rate boundary represented?

A. Positive 24 kHz is included and negative 24 kHz is excluded.

B. Both boundaries are excluded and the interval is narrower than 48 kHz.

C. Negative 24 kHz is included and positive 24 kHz is excluded.

D. Both positive and negative 24 kHz are separate distinguishable endpoints.

Answer: C. The chosen argument branch determines which equivalent boundary value is retained. The two half-rate signs produce the same sampled exponential and are not distinct observations. Review: Equation 12G. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why the selected alternative fits: Negative 24 kHz is included and positive 24 kHz is excluded.

Distinguishing consideration: compare this with option A, “Positive 24 kHz is included and negative 24 kHz is excluded”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

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V011-C06-MCQ-067. Why can phase unwrapping alone not distinguish a constant positive 31 kHz offset from negative 17 kHz at a 48 kHz complex sample rate?

A. An unwrapping algorithm always selects the physically positive frequency.

B. The correct alias is uniquely determined by the final sample index.

C. A larger integer number of phase wraps necessarily has greater measured amplitude.

D. The sampled complex values are identical, so selecting an alias needs additional band information or a changed observation.

Answer: D. Unwrapping does not create information absent from the samples. An admitted-band constraint, additional reference or changed sampling condition can supply the missing evidence. Review: Equation 12G; Application 6B.6. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why the selected alternative fits: The sampled complex values are identical, so selecting an alias needs additional band information or a changed observation.

Distinguishing consideration: compare this with option A, “An unwrapping algorithm always selects the physically positive frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

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V011-C06-MCQ-068. At 64,000 complex samples per second, a constant positive 37 kHz offset is represented by which principal frequency?

A. Negative 27 kHz.

B. Positive 27 kHz.

C. Positive 5 kHz.

D. Negative 37 kHz.

Answer: A. Subtract 64 kHz to place the frequency in the half-open interval from minus 32 to plus 32 kHz. The result is minus 27 kHz. Review: Equation 12G. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why the selected alternative fits: Negative 27 kHz.

Distinguishing consideration: compare this with option B, “Positive 27 kHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

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V011-C06-MCQ-069. An unwrapped phase increment of pi divided by four radians is observed over 50 microseconds. What interval-average frequency offset follows?

A. 1250 Hz.

B. 15,708 Hz.

C. 5000 Hz.

D. 2500 Hz.

Answer: D. Divide the phase increment by two pi and by the elapsed interval in seconds. The increment is one eighth of a cycle, giving 2500 cycles per second over 50 microseconds. Review: Equation 12F. Source: Equation 12F. Finite-interval frequency from unwrapped phase (p. 3133)

Why the selected alternative fits: 2500 Hz.

Distinguishing consideration: compare this with option A, “1250 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

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V011-C06-MCQ-070. A finite difference of unwrapped phase is labeled instantaneous frequency at its midpoint. What further condition is needed for that label?

A. A declaration that carrier frequency is positive.

B. A justified local approximation relating the interval average to the midpoint derivative.

C. An arbitrary choice of midpoint with no smoothness or error consideration.

D. Only a nonzero time interval, which makes all averages equal instantaneous values.

Answer: B. The phase difference divided by interval is exactly an average derivative under the stated assumptions. Equality or approximation to a point value needs additional information about variation within the interval. Review: Equation 12F; Application 6B.7. Source: Equation 12F. Finite-interval frequency from unwrapped phase (p. 3133)

Why the selected alternative fits: A justified local approximation relating the interval average to the midpoint derivative.

Distinguishing consideration: compare this with option A, “A declaration that carrier frequency is positive”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase; Chapter 6 — Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase; Chapter 6 — Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value.

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V011-C06-MCQ-071. A shorter phase-difference interval is chosen to improve temporal locality. What tradeoff must also be assessed?

A. Conversion of a wrapped phase record into a uniquely known continuous branch.

B. Automatic elimination of all alias ambiguity.

C. Greater sensitivity of the frequency estimate to phase measurement error for a fixed phase-error scale.

D. Guaranteed reduction of both time averaging and all noise at every sample.

Answer: C. The same phase error divided by a shorter time can produce a larger frequency error. Locality, phase quality and sampling assumptions must be considered together. Review: Application 6B.7. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

Why the selected alternative fits: Greater sensitivity of the frequency estimate to phase measurement error for a fixed phase-error scale.

Distinguishing consideration: compare this with option A, “Conversion of a wrapped phase record into a uniquely known continuous branch”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value.

Review: Chapter 6 — Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value.

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V011-C06-MCQ-072. Two adjacent equal-duration intervals have average offsets 200 Hz and 400 Hz. What is the average offset over their combined interval?

A. 600 Hz.

B. 300 Hz.

C. 200 Hz.

D. A uniquely established instantaneous 300 Hz at their shared boundary.

Answer: B. Add their phase changes and divide by the combined duration. Equal durations give the arithmetic mean, but this does not establish a pointwise derivative at the boundary. Review: Equation 12F. Source: Equation 12F. Finite-interval frequency from unwrapped phase (p. 3133)

Why the selected alternative fits: 300 Hz.

Distinguishing consideration: compare this with option A, “600 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

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V011-C06-MCQ-073. An unknown but constant complex phase rotation multiplies every sample in a valid segment. What happens to adjacent phase-increment products?

A. The common rotation cancels in each sample times the conjugate of its predecessor.

B. It changes the sample interval and therefore the declared sampling rate.

C. It doubles in the increment because both samples contain it.

D. It adds a different arbitrary frequency offset to every interval.

Answer: A. The rotation and its complex conjugate multiply to one. This cancellation applies to a constant phase factor, not a time-varying reference or a reset. Review: Equation 12G; Equation 12K. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why the selected alternative fits: The common rotation cancels in each sample times the conjugate of its predecessor.

Distinguishing consideration: compare this with option B, “It changes the sample interval and therefore the declared sampling rate”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

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V011-C06-MCQ-074. A phase record has a missing interval and reacquires with an independently chosen phase origin. What should a frequency trace do at that gap?

A. Choose an integer wrap that makes the graph smooth and call it a verified correction.

B. Preserve the discontinuity in coverage and avoid an unsupported derivative across the two origins.

C. Fill the gap with a straight line and report the interpolated derivative as observed.

D. Remove the gap from the time axis so adjacent retained samples appear contiguous.

Answer: B. Continuity and reference identity are prerequisites to the derivative interpretation. Interpolation or branch selection can be a model, but it is not an observation of the missing interval. Review: Preserve pulse and demodulator evidence across representations; Model 10E cross-reference. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

Why the selected alternative fits: Preserve the discontinuity in coverage and avoid an unsupported derivative across the two origins.

Distinguishing consideration: compare this with option A, “Choose an integer wrap that makes the graph smooth and call it a verified correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10E for absolute sample continuity and retained processing state; Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 10 — Model 10E for absolute sample continuity and retained processing state; Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-075. A phase modulation gives a symmetric plus-or-minus 1500 Hz deviation and the known carrier-minus-LO offset is positive 80 Hz. What observed frequency range follows?

A. Positive 80 Hz only.

B. Minus 1500 Hz to plus 1500 Hz regardless of offset.

C. Minus 1580 Hz to plus 1420 Hz.

D. Minus 1420 Hz to plus 1580 Hz.

Answer: D. The constant frequency residual translates the full deviation range upward by 80 Hz. A constant phase offset would not translate this range. Review: Equation 12K; Application 6B.10. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why the selected alternative fits: Minus 1420 Hz to plus 1580 Hz.

Distinguishing consideration: compare this with option A, “Positive 80 Hz only”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

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V011-C06-MCQ-076. A real phase excursion is bounded in magnitude by 0.2 radian. What pointwise bound does Model 6B give for the error of the first-order complex exponential approximation?

A. 0.02 in normalized complex amplitude.

B. 0.01 Hz.

C. Exactly zero because 0.2 is smaller than one.

D. 0.2 in normalized power.

Answer: A. The remainder magnitude is bounded by half the squared phase. The largest stated bound is 0.2 squared divided by two, and it concerns complex-amplitude error, not a power probability. Review: Equation 12H. Source: Equation 12H. Pointwise small-phase remainder (p. 3134)

Why the selected alternative fits: 0.02 in normalized complex amplitude.

Distinguishing consideration: compare this with option B, “0.01 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12H. Pointwise small-phase remainder.

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder.

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V011-C06-MCQ-077. For sinusoidal phase index 0.2, what are the retained first-order sideband peak and power ratio relative to a unit unmodulated carrier?

A. Peak 0.01 and power ratio 0.1, or minus 10 dBc.

B. Peak 0.1 and power ratio 0.01, or minus 20 dBc.

C. Peak 0.2 and power ratio 0.2, or minus 6.99 dBc.

D. Peak 0.4 and power ratio 0.16, or minus 7.96 dBc.

Answer: B. The first-order expansion gives half the phase index in either sideband amplitude. Squaring gives 0.01. These retained terms are an approximation with the accompanying remainder bound. Review: Equation 12I. Source: Equation 12I. First-order sidebands for sinusoidal small phase (p. 3134)

Why the selected alternative fits: Peak 0.1 and power ratio 0.01, or minus 20 dBc.

Distinguishing consideration: compare this with option A, “Peak 0.01 and power ratio 0.1, or minus 10 dBc”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

Review: Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

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V011-C06-MCQ-078. A small-phase remainder bound is 0.005 in normalized complex amplitude. Which claim does that bound support?

A. The receiver has a 0.005 probability of missing any event.

B. The pointwise approximation error cannot exceed the stated bound under the model assumptions.

C. The actual error is exactly 0.005 at every time.

D. Exactly 0.5 percent of the signal power lies outside the retained spectrum.

Answer: B. A deterministic amplitude-error bound differs from an attained error, an integrated spectral-power fraction and a detection probability. Its scope must remain attached to the quantity bounded. Review: Equations 12H and 12I; Application 6B.8. Source: Equation 12H. Pointwise small-phase remainder (p. 3134)

Why the selected alternative fits: The pointwise approximation error cannot exceed the stated bound under the model assumptions.

Distinguishing consideration: compare this with option A, “The receiver has a 0.005 probability of missing any event”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase; Chapter 6 — Application 6B.8: Bound a small-phase approximation before….

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase; Chapter 6 — Application 6B.8: Bound a small-phase approximation before using it.

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V011-C06-MCQ-079. A first-order phase expansion is used at phase index 3 while its carrier coefficient is treated as exactly unchanged. What is the principal defect?

A. The retained approximation and its error are being used beyond the justified small-phase claim.

B. A large phase index necessarily changes the real load resistance.

C. The frequency derivative relation becomes false solely because the phase is large.

D. The exact complex exponential is undefined for phase excursions above one radian.

Answer: A. The exact phase model remains meaningful, but truncating it to the carrier and two first-order terms can be inadequate. Model 6B does not claim an unchanged exact carrier amplitude at arbitrary index. Review: Equations 12H and 12I. Source: Equation 12H. Pointwise small-phase remainder (p. 3134)

Why the selected alternative fits: The retained approximation and its error are being used beyond the justified small-phase claim.

Distinguishing consideration: compare this with option B, “A large phase index necessarily changes the real load resistance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

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V011-C06-MCQ-080. Peak frequency deviation is 5 kHz and significant modulating content extends to 3 kHz. What Carson bandwidth estimate follows?

A. 6 kHz.

B. 8 kHz.

C. 10 kHz.

D. 16 kHz.

Answer: D. The estimate is twice the sum of peak deviation and the highest significant modulation frequency. Both inputs must use the same frequency unit.
Review: Equation 12J; Application 6B.9. Source: Equation 12J. Carson estimate and its stated inputs (p. 3135)
Why the selected alternative fits: 16 kHz.
Distinguishing consideration: compare this with option A, “6 kHz”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 6 — Equation 12J. Carson estimate and its stated inputs; Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response.
Review: Chapter 6 — Equation 12J. Carson estimate and its stated inputs; Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response.

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V011-C06-MCQ-081. Why should a report define what significant modulating frequency means when applying Carson's estimate to a measured broadband message?

A. A bandwidth estimate uniquely determines all message-frequency amplitudes.

B. Any arbitrarily small spectral tail can be ignored without a stated criterion or consequence.

C. The selected upper message frequency is an input to the estimate and depends on the retained signal criterion.

D. The term always equals half the RF carrier frequency.

Answer: C. A broadband waveform may have no sharp finite spectral edge. A stated criterion and retained spectrum make the chosen planning input reproducible.

Review: Equation 12J and its stated inputs. Source: Equation 12J. Carson estimate and its stated inputs (p. 3135)

Why the selected alternative fits: The selected upper message frequency is an input to the estimate and depends on the retained signal criterion.

Distinguishing consideration: compare this with option A, "A bandwidth estimate uniquely determines all message-frequency amplitudes"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

Review: Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

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V011-C06-MCQ-082. What does the chapter's Carson estimate establish about the exact fraction of power passed by a nominal IF width?

A. No exact passed fraction without the waveform spectrum and actual filter response.

B. Exactly 99 percent for every signal and every filter with that width label.

C. Exactly zero signal power whenever the nominal width is narrower.

D. Exactly all signal power whenever the nominal width exceeds the estimate.

Answer: A. A planning bandwidth does not specify spectral weighting or filter skirts. The archival IRIG discussion also distinguishes the estimate from a universal containment result. Review: Equation 12J; Application 6B.9; IRIG 106-05 Appendix A, section 5.2.3.3. Source: Equation 12J. Carson estimate and its stated inputs (p. 3135)

Why the selected alternative fits: No exact passed fraction without the waveform spectrum and actual filter response.

Distinguishing consideration: compare this with option B, "Exactly 99 percent for every signal and every filter with that width label"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 6 — Equation 12J. Carson estimate and its stated inputs; Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response; Chapter 6 — Model 6B: phase is the....

Review: Chapter 6 — Equation 12J. Carson estimate and its stated inputs; Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

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V011-C06-MCQ-083. A 16 kHz Carson estimate is compared with IF labels of 12.5 kHz and 25 kHz. What is the appropriate next technical step?

A. Declare the 12.5 kHz setting has rejected exactly 3.5 kHz worth of uniformly distributed power.

B. Examine the actual transfer responses and recovered-waveform error under the intended settings.

C. Declare the 25 kHz setting distortion-free solely from its larger label.

D. Treat both width labels as ideal rectangular spectral masks by definition.

Answer: B. The label may describe a particular attenuation point while amplitude and phase response vary elsewhere. Suitability must be assessed against the actual waveform and measurand. Review: Application 6B.9. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

Why the selected alternative fits: Examine the actual transfer responses and recovered-waveform error under the intended settings.

Distinguishing consideration: compare this with option A, “Declare the 12.5 kHz setting has rejected exactly 3.5 kHz worth of uniformly distributed power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response.

Review: Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response.

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V011-C06-MCQ-084. A wider IF setting improves recovered deviation fidelity but admits more unwanted energy. Which selection principle follows?

A. Always maximize width because bandwidth has no measurement penalty.

B. Always minimize width because narrower paths cannot distort angle modulation.

C. Choose a response that meets the declared waveform-error criterion while evaluating its admitted noise and interference.

D. Select only by nominal carrier frequency and ignore the modulation spectrum.

Answer: C. Waveform fidelity and admitted energy are concurrent path properties. A suitable setting is justified by the intended quantity and tested operating domain, not by one universal width rule. Review: Application 6B.9; Analog Demodulator Verification. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

Why the selected alternative fits: Choose a response that meets the declared waveform-error criterion while evaluating its admitted noise and interference.

Distinguishing consideration: compare this with option A, “Always maximize width because bandwidth has no measurement penalty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response; Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response; Chapter 6 — Analog Demodulator Verification.

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V011-C06-MCQ-085. The Navy's historical FM discussion uses percent modulation relative to a stated allowed deviation. How should that be distinguished from the sinusoidal phase index?

A. Phase index is a universally fixed legal deviation limit.

B. Percent deviation uses a declared allowed-deviation reference; phase index divides actual deviation by modulation frequency.

C. A historical deviation example establishes today's allowed limit for every receiver task.

D. Both quantities are identical for every modulation frequency and service.

Answer: B. The ratios have different denominators and purposes. The chapter uses explicit phase and frequency quantities and does not import archival allocation examples as current requirements. Review: Equation 12B; NEETS Module 12, printed pages 2-12–2-13; chapter reference scope. Source: Equation 12B. Sinusoidal FM phase and modulation index (p. 3132)

Why the selected alternative fits: Percent deviation uses a declared allowed-deviation reference; phase index divides actual deviation by modulation frequency.

Distinguishing consideration: compare this with option A, "Phase index is a universally fixed legal deviation limit"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

Review: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

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V011-C06-MCQ-086. An FM limiter reduces amplitude fluctuations before a discriminator. What cannot be concluded from that operation alone?

A. That the signal path now includes a nonlinear amplitude operation.

B. That the limiter has affected the amplitude delivered to the following stage.

C. That the limiter state belongs in the demodulator configuration record.

D. That weak-signal phase noise, interference, capture or loss of the desired component has been eliminated.

Answer: D. Amplitude limiting is not a universal recovery guarantee. The phase information can remain corrupted or dominated by another component even when output amplitude appears constant. Review: Frequency and Phase Modulation; Analog Demodulator Verification. Source: §6.31 Analog Demodulator Verification (p. 3152)

Why the selected alternative fits: That weak-signal phase noise, interference, capture or loss of the desired component has been eliminated.

Distinguishing consideration: compare this with option A, “That the signal path now includes a nonlinear amplitude operation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Analog Demodulator Verification; Chapter 6 — Frequency and Phase Modulation.

Review: Chapter 6 — Analog Demodulator Verification; Chapter 6 — Frequency and Phase Modulation.

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V011-C06-MCQ-087. A strong nearby component dominates an FM output and a weaker component is not audible. What interpretation is strongest?

A. Capture or another receiver limitation may suppress the weaker component in that output; its absence from audio does not establish absence from RF.

B. The stronger component has physically removed the weaker transmission at its source.

C. Increasing audio normalization proves recovery of the original weak waveform.

D. The weaker external RF component cannot exist because no separate audio is heard.

Answer: A. The output reflects nonlinear and selective receiver behavior. A separate RF observation and a suitable challenge are needed to characterize the weaker component. Review: Frequency and Phase Modulation; Chapter Glossary: Capture effect. Source: §6.16 Frequency and Phase Modulation (p. 3128)

Why the selected alternative fits: Capture or another receiver limitation may suppress the weaker component in that output; its absence from audio does not establish absence from RF.

Distinguishing consideration: compare this with option B, “The stronger component has physically removed the weaker transmission at its source”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Frequency and Phase Modulation; Chapter 6 — CAPTURE EFFECT (glossary).

Review: Chapter 6 — Frequency and Phase Modulation; Chapter 6 — CAPTURE EFFECT (glossary).

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V011-C06-MCQ-088. A demodulator passes a reference test at moderate carrier level. Why are low-level and strong-signal tests still relevant?

A. Any later failure can be assigned to the source without checking receiver state.

B. Only RF carrier frequency can affect recovered distortion.

C. A moderate-level test proves every level state because the modulation type is unchanged.

D. Different impairments can dominate near sensitivity limits and near overload limits.

Answer: D. Threshold behavior, noise, limiting, compression and control are level dependent. The verification domain must include the conditions used by the claimed measurement. Review: Analog Demodulator Verification. Source: §6.31 Analog Demodulator Verification (p. 3152)

Why the selected alternative fits: Different impairments can dominate near sensitivity limits and near overload limits.

Distinguishing consideration: compare this with option A, “Any later failure can be assigned to the source without checking receiver state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Analog Demodulator Verification.

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V011-C06-MCQ-089. A frequency discriminator produces a large transient immediately after carrier recovery. What should be established before reporting it as intrapulse modulation?

A. The lock, limiter, filter and reference states during that transient.

B. A correction based solely on the average carrier power after the event.

C. An assumption that every post-trigger sample has settled because recording has begun.

D. Only that the final steady audio is intelligible.

Answer: A. Acquisition start and valid demodulation need not coincide. A recovery transient can arise inside the receiver and must be separated from a supported external waveform feature. Review: Preserve pulse and demodulator evidence across representations; Analog Demodulator Verification. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why the selected alternative fits: The lock, limiter, filter and reference states during that transient.

Distinguishing consideration: compare this with option B, “A correction based solely on the average carrier power after the event”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Analog Demodulator Verification.

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V011-C06-MCQ-090. A pulsed input has modest long-time average power but a high instantaneous peak. Which risk remains?

A. Guaranteed linearity because average power alone bounds every instantaneous level.

B. A requirement that peak envelope power equal average power for short events.

C. Automatic correction of any clipping by increasing observation duration.

D. Front-end compression or protection recovery during and after the pulse.

Answer: D. A short duty cycle can conceal high peaks in an average. The front end responds to its instantaneous operating conditions, and lost information is not recovered by a longer average. Review: Pulse, Radar, and Transient Reception.

Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

Why the selected alternative fits: Front-end compression or protection recovery during and after the pulse.

Distinguishing consideration: compare this with option A, “Guaranteed linearity because average power alone bounds every instantaneous level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Pulse, Radar, and Transient Reception.

Review: Chapter 6 — Pulse, Radar, and Transient Reception.

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V011-C06-MCQ-091. A pulse appears in a time capture but its peak is reduced by the selected narrow IF response. Which category best describes the problem?

A. A pure time-stamp error with no transfer-function involvement.

B. A pulse that necessarily occurred outside every acquisition window.

C. A captured but distorted observation.

D. Proof that the external source had no peak above the recorded value.

Answer: C. The event entered the record, but the path changed its waveform. This differs from a coverage failure in which no usable acquisition of the event occurred.

Review: Preserve pulse and demodulator evidence across representations; Model 15A cross-reference. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: A captured but distorted observation.

Distinguishing consideration: compare this with option A, “A pure time-stamp error with no transfer-function involvement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-092. A burst occurs while a scanning receiver is tuned elsewhere and no usable samples are retained. Can changing the demodulator after the survey recover that burst?

A. Yes, because an audio export contains every RF event in the survey interval.

B. Yes, if the output is normalized to the expected peak.

C. Yes, provided the later detector has a narrower bandwidth.

D. No; the missing acquisition is not supplied by a different later demodulator.

Answer: D. Postprocessing can reinterpret retained samples but cannot create a missing valid observation. Coverage and waveform fidelity are distinct requirements. Review: Preserve pulse and demodulator evidence across representations; Model 15A cross-reference. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: No; the missing acquisition is not supplied by a different later demodulator.

Distinguishing consideration: compare this with option A, “Yes, because an audio export contains every RF event in the survey interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-093. A long-time spectrum and a pulse time trace are used together to identify intrapulse behavior. What link is essential?

A. Discarding the time trace once a repeated spectral feature is visible.

B. A common native record and documented time, window and processing conventions.

C. An assumption that equal carrier labels prove the two displays contain the same pulse.

D. Only matching nominal frequency spans, with independent acquisition intervals treated as interchangeable.

Answer: B. The views emphasize different aspects of the event. Their relationship is defensible when the acquisition and transformations can be traced to the same data and time support. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why the selected alternative fits: A common native record and documented time, window and processing conventions.

Distinguishing consideration: compare this with option A, “Discarding the time trace once a repeated spectral feature is visible”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-094. A pulse-like feature appears on one receiver channel. Which challenge is appropriate before assigning it to an external RF source?

A. Use synchronized channels and applicable antenna or input substitutions to test internal, conducted and cross-channel explanations.

B. Treat any triggered display as conclusive source attribution.

C. Assume a stable repetition interval excludes local switching electronics.

D. Use audio intelligibility alone to eliminate analyzer sweep artifacts.

Answer: A. Local digital switching, power conversion, sweep behavior and coupling can produce pulse-like observations. Controlled changes can test these alternatives while preserving the original event record. Review: Pulse, Radar, and Transient Reception. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

Why the selected alternative fits: Use synchronized channels and applicable antenna or input substitutions to test internal, conducted and cross-channel explanations.

Distinguishing consideration: compare this with option B, “Treat any triggered display as conclusive source attribution”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Pulse, Radar, and Transient Reception.

Review: Chapter 6 — Pulse, Radar, and Transient Reception.

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V011-C06-MCQ-095. An antenna-substitution challenge changes the pulse amplitude. What does that result establish by itself?

A. The exact remote transmitter identity and purpose.

B. That every internal coupling path has been excluded regardless of substitution details.

C. A dependence on the changed input condition, with its mechanism still requiring interpretation.

D. That the original receiver never experienced compression.

Answer: C. A useful challenge constrains explanations but does not automatically identify one unique cause. Document the substituted path, matching conditions, receiver state and temporal comparability. Review: Pulse, Radar, and Transient Reception; Chapter 1 evidence-boundary principles. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

Why the selected alternative fits: A dependence on the changed input condition, with its mechanism still requiring interpretation.

Distinguishing consideration: compare this with option A, “The exact remote transmitter identity and purpose”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Pulse, Radar, and Transient Reception; Chapter 1 — Receiver as a Measurement System; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 6 — Pulse, Radar, and Transient Reception; Chapter 1 — Receiver as a Measurement System; Chapter 1 — Evidence Record and Closing Verification.

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V011-C06-MCQ-096. A receiver changes gain during a pulse and later regains stable lock. How should the affected data be retained?

A. As a silently removed segment followed by an apparently continuous splice.

B. As proof that all pre-transition and post-transition phase origins are identical.

C. As recoverable unclipped RF whenever the final gain value is known.

D. As an explicitly identified state interval, with continuity and validity limits preserved.

Answer: D. State transitions can alter scale, phase, filter history and validity. Keeping their boundaries visible avoids inventing a continuous calibrated waveform. Review: Preserve pulse and demodulator evidence across representations; Model 10E cross-reference. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

Why the selected alternative fits: As an explicitly identified state interval, with continuity and validity limits preserved.

Distinguishing consideration: compare this with option A, “As a silently removed segment followed by an apparently continuous splice”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10E for absolute sample continuity and retained processing state; Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 10 — Model 10E for absolute sample continuity and retained processing state; Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-097. A known carrier and independently calibrated modulation are available for receiver verification. Which sequence best supports localization of a demodulator error?

A. Change carrier, bandwidth and detector simultaneously without retaining the prior state.

B. Measure only one final output with no record of the applied reference waveform.

C. Adjust the final audio until it sounds correct and infer all upstream stages are valid.

D. Verify the RF path, then compare recovered quantities across applicable levels, bandwidths and demodulator states.

Answer: D. A staged comparison separates the admitted RF condition from subsequent processing. Controlled variation and recorded states help locate the mechanism rather than conceal it. Review: Analog Demodulator Verification. Source: §6.31 Analog Demodulator Verification (p. 3152)

Why the selected alternative fits: Verify the RF path, then compare recovered quantities across applicable levels, bandwidths and demodulator states.

Distinguishing consideration: compare this with option A, “Change carrier, bandwidth and detector simultaneously without retaining the prior state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Analog Demodulator Verification.

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V011-C06-MCQ-098. What makes an audio export reproducible as derived technical evidence?

A. A normalized amplitude plot with the original scale and processing states discarded.

B. A link to the native samples, tuning and phase convention, sideband, processing version, time basis and excluded intervals.

C. Only the operator's statement that the export sounded plausible.

D. Only a filename suggesting a modulation type.

Answer: B. A derived product needs sufficient lineage to regenerate its relationship to the captured signal. That lineage does not itself prove the source identity or content interpretation. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why the selected alternative fits: A link to the native samples, tuning and phase convention, sideband, processing version, time basis and excluded intervals.

Distinguishing consideration: compare this with option A, "A normalized amplitude plot with the original scale and processing states discarded"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-MCQ-099. A tested receiver configuration fails to recover modulation from a weak event. What is a defensible conclusion?

A. The transmitter necessarily emitted an unmodulated carrier.

B. All possible demodulators and acquisition settings would also fail.

C. The event can be excluded from the record because it produced no intelligible audio.

D. The stated method did not recover modulation under those recorded conditions; the external waveform's absence of modulation is not thereby proved.

Answer: D. A negative method result is bounded by coverage, sensitivity, path state and processing. It can be useful evidence without becoming an unlimited claim about the source. Review: Preserve pulse and demodulator evidence across representations; Chapter 1 bounded negative findings. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why the selected alternative fits: The stated method did not recover modulation under those recorded conditions; the external waveform's absence of modulation is not thereby proved.

Distinguishing consideration: compare this with option A, "The transmitter necessarily emitted an unmodulated carrier"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 1 — Frame a bounded finding from the completed observation.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 1 — Frame a bounded finding from the completed observation.

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V011-C06-MCQ-100. What should the chapter's final modulation report distinguish most carefully?

A. Observed waveform structure, receiver-transfer evidence, processing-dependent results and unresolved source interpretations.

B. A universal source-purpose conclusion from any one successful demodulation.

C. Only a nominal bandwidth and a subjective intelligibility score.

D. Only the preferred modulation label, with all contradictory observations removed.

Answer: A. The chapter connects models to a verified chain and retained native evidence. Each conclusion should carry the assumptions and observation limits that make it supportable. Review: Carrier, Sidebands, and Modulation Evidence; Table 6; Analog Demodulator Verification. Source: Table 6. Chapter 6 receiver controls and interpretation limits (p. 3154)

Why the selected alternative fits: Observed waveform structure, receiver-transfer evidence, processing-dependent results and unresolved source interpretations.
Distinguishing consideration: compare this with option B, "A universal source-purpose conclusion from any one successful demodulation"; that competing statement does not meet the question's stated requirement.
Basis and limitation: Chapter 6 — Table 6. Chapter 6 receiver controls and interpretation limits; Chapter 6 — Carrier, Sidebands, and Modulation Evidence; Chapter 6 — Analog Demodulator Verification.
Review: Chapter 6 — Table 6. Chapter 6 receiver controls and interpretation limits; Chapter 6 — Carrier, Sidebands, and Modulation Evidence; Chapter 6 — Analog Demodulator Verification.

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Fill-in-the-Blank Questions

V011-C06-FIB-001. A modulation label classifies observed waveform structure; it does not by itself prove transmitter _____.

Answer: identity. A waveform family can be shared by many sources. Identity, location and purpose need separate evidence. Review: Carrier, Sidebands, and Modulation Evidence. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

Why this term is required: “identity” completes the stated technical proposition.

Question context: A modulation label classifies observed waveform structure; it does not by itself prove transmitter _____

Basis and qualification: Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

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V011-C06-FIB-002. Audio produced from stored RF samples is a _____ product whose transfer depends on demodulator settings.

Answer: derived. Native samples and configuration must remain linked to the output because processing changes its amplitude and phase relationships. Review: Carrier, Sidebands, and Modulation Evidence. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

Why this term is required: “derived” completes the stated technical proposition.

Question context: Audio produced from stored RF samples is a _____ product whose transfer depends on demodulator settings

Basis and qualification: Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

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V011-C06-FIB-003. Model 6A reconstructs the physical RF voltage by taking the _____ part of the translated complex expression.

Answer: real. The complex envelope is a representation; its real translated part is the modeled physical waveform. Review: Equation 11A. Source: Equation 11A. Real RF waveform and its complex envelope (p. 3112)

Why this term is required: “real” completes the stated technical proposition.

Question context: Model 6A reconstructs the physical RF voltage by taking the _____ part of the translated complex expression

Basis and qualification: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope.

Review: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope.

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V011-C06-FIB-004. For the stated separated-band convention, envelope bandwidth B is strictly less than _____.

Answer: the positive carrier frequency. This keeps the translated positive and negative RF bands separated. It does not establish that a receiver passes the envelope unchanged. Review: Equation 11A. Source: Equation 11A. Real RF waveform and its complex envelope (p. 3112)

Why this term is required: “the positive carrier frequency” completes the stated technical proposition.

Question context: For the stated separated-band convention, envelope bandwidth B is strictly less than _____

Basis and qualification: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope.

Review: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope.

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V011-C06-FIB-005. For a peak-voltage envelope, mean squared magnitude is divided by _____ times the resistance to obtain mean RF power under the stated averaging conditions.

Answer: two. An RMS-normalized envelope would require a different consistent convention. Mixing these conventions creates a factor-of-two error. Review: Equation 11B. Source: Equation 11B. Envelope power convention (p. 3113)

Why this term is required: “two” completes the stated technical proposition.

Question context: For a peak-voltage envelope, mean squared magnitude is divided by _____ times the resistance to obtain mean RF power under the stated averaging conditions

Basis and qualification: Chapter 6 — Equation 11B. Envelope power convention.

Review: Chapter 6 — Equation 11B. Envelope power convention.

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V011-C06-FIB-006. Mean squared peak-envelope magnitude of 0.8 square volts across 50 ohms gives mean RF power _____ mW.

Answer: 8. Divide 0.8 by 100 to obtain 0.008 W, retaining the chapter's orthogonality or equivalent averaging conditions. Review: Equation 11B. Source: Equation 11B. Envelope power convention (p. 3113)

Why this term is required: "8" completes the stated technical proposition.

Question context: Mean squared peak-envelope magnitude of 0.8 square volts across 50 ohms gives mean RF power _____ mW

Basis and qualification: Chapter 6 — Equation 11B. Envelope power convention.

Review: Chapter 6 — Equation 11B. Envelope power convention.

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V011-C06-FIB-007. A peak envelope of 2 V across a 100-ohm real load gives peak envelope power _____ mW.

Answer: 20. The squared peak is 4 square volts. Divide by twice 100 ohms to obtain 0.020 W. Review: Equation 11B. Source: Equation 11B. Envelope power convention (p. 3113)

Why this term is required: “20” completes the stated technical proposition.

Question context: A peak envelope of 2 V across a 100-ohm real load gives peak envelope power _____ mW

Basis and qualification: Chapter 6 — Equation 11B. Envelope power convention.

Review: Chapter 6 — Equation 11B. Envelope power convention.

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V011-C06-FIB-008. The periodic mean-power simplification uses complete common periods or a justified _____ mean.

Answer: long-time. An arbitrary partial window may retain cross terms that the simplified relation excludes. Review: Equation 11B discussion. Source: Equation 11B. Envelope power convention (p. 3113)

Why this term is required: “long-time” completes the stated technical proposition.

Question context: The periodic mean-power simplification uses complete common periods or a justified _____ mean

Basis and qualification: Chapter 6 — Equation 11B. Envelope power convention.

Review: Chapter 6 — Equation 11B. Envelope power convention.

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V011-C06-FIB-009. A message bounded in magnitude by one and a conventional AM depth between zero and one guarantee a signed envelope that is _____.

Answer: nonnegative. The smallest possible bracket is one minus depth. A strictly positive minimum is not guaranteed at unit depth. Review: Equation 11C. Source: Equation 11C. Conventional AM and nonnegative-envelope condition (p. 3113)

Why this term is required: “nonnegative” completes the stated technical proposition.

Question context: A message bounded in magnitude by one and a conventional AM depth between zero and one guarantee a signed envelope that is _____

Basis and qualification: Chapter 6 — Equation 11C. Conventional AM and nonnegative-envelope condition.

Review: Chapter 6 — Equation 11C. Conventional AM and nonnegative-envelope condition.

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V011-C06-FIB-010. Sinusoidal AM extrema of 3 V and 1 V imply a carrier peak of _____ V.

Answer: 2. Take the half-sum of the compatible nonnegative-envelope extrema.

Review: Equation 11D. Source: Equation 11D. Sinusoidal AM extrema and their inversion (p. 3113)

Why this term is required: “2” completes the stated technical proposition.

Question context: Sinusoidal AM extrema of 3 V and 1 V imply a carrier peak of _____ V

Basis and qualification: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

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V011-C06-FIB-011. For sinusoidal AM extrema of 3 V and 1 V in the valid inverse-model domain, depth is _____.

Answer: 0.5. Divide the 2 V difference by the 4 V sum. The ratio is dimensionless.

Review: Equation 11D. Source: Equation 11D. Sinusoidal AM extrema and their inversion (p. 3113)

Why this term is required: “0.5” completes the stated technical proposition.

Question context: For sinusoidal AM extrema of 3 V and 1 V in the valid inverse-model domain, depth is _____

Basis and qualification: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

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V011-C06-FIB-012. Carrier peak 2 V and sinusoidal depth 0.3 give a lower envelope extremum of _____ V.

Answer: 1.4. Multiply carrier peak by one minus depth: 2 times 0.7. Review: Equation 11D. Source: Equation 11D. Sinusoidal AM extrema and their inversion (p. 3113)

Why this term is required: “1.4” completes the stated technical proposition.

Question context: Carrier peak 2 V and sinusoidal depth 0.3 give a lower envelope extremum of _____ V

Basis and qualification: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

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V011-C06-FIB-013. Carrier peak 2 V and sinusoidal depth 0.3 give an upper envelope extremum of _____ V.

Answer: 2.6. Multiply carrier peak by one plus depth: 2 times 1.3. Review: Equation 11D. Source: Equation 11D. Sinusoidal AM extrema and their inversion (p. 3113)

Why this term is required: “2.6” completes the stated technical proposition.

Question context: Carrier peak 2 V and sinusoidal depth 0.3 give an upper envelope extremum of _____ V

Basis and qualification: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion.

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V011-C06-FIB-014. For carrier peak 1.5 V and sinusoidal depth 0.4, either RF sideband has peak voltage _____ V.

Answer: 0.3. Each sideband peak is half the modulation-scaled carrier peak: 1.5 times 0.4 divided by two. Review: Equation 11E. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why this term is required: “0.3” completes the stated technical proposition.

Question context: For carrier peak 1.5 V and sinusoidal depth 0.4, either RF sideband has peak voltage _____ V

Basis and qualification: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

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V011-C06-FIB-015. At carrier power 20 mW and sinusoidal depth 0.4, either sideband contains _____ mW.

Answer: 0.8. Multiply carrier power by depth squared divided by four: 20 times 0.16 divided by four. Review: Equation 11E. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why this term is required: “0.8” completes the stated technical proposition.

Question context: At carrier power 20 mW and sinusoidal depth 0.4, either sideband contains _____ mW

Basis and qualification: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

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V011-C06-FIB-016. At carrier power 20 mW and sinusoidal depth 0.4, total RF power is _____ mW.

Answer: 21.6. The two 0.8 mW sidebands add to the 20 mW carrier under the declared orthogonality conditions. Review: Equations 11E and 11F. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why this term is required: “21.6” completes the stated technical proposition.

Question context: At carrier power 20 mW and sinusoidal depth 0.4, total RF power is _____ mW

Basis and qualification: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers; Chapter 6 — Equation 11F. Total sinusoidal-AM power.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers; Chapter 6 — Equation 11F. Total sinusoidal-AM power.

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V011-C06-FIB-017. A verified sinusoidal AM sideband power ratio of 0.0225 relative to the carrier implies depth _____.

Answer: 0.3. Take the square root and multiply by two, retaining the linear symmetric AM assumptions. Review: Equation 11E. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why this term is required: “0.3” completes the stated technical proposition.

Question context: A verified sinusoidal AM sideband power ratio of 0.0225 relative to the carrier implies depth _____

Basis and qualification: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

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V011-C06-FIB-018. Tripling sinusoidal AM depth while holding carrier power fixed multiplies either sideband power by _____.

Answer: nine. Sideband amplitude is linear in depth, so its power is quadratic. The comparison does not establish hardware linearity. Review: Equation 11E. Source: Equation 11E. Sinusoidal sideband amplitudes and powers (p. 3114)

Why this term is required: “nine” completes the stated technical proposition.

Question context: Tripling sinusoidal AM depth while holding carrier power fixed multiplies either sideband power by _____

Basis and qualification: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers.

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V011-C06-FIB-019. The one-half factor in sinusoidal AM total power is the mean square of a unit _____.

Answer: cosine. A different bounded message can have a different mean square despite the same peak bound. Review: Equations 11F and 11G. Source: Equation 11F. Total sinusoidal-AM power (p. 3114)

Why this term is required: “cosine” completes the stated technical proposition.

Question context: The one-half factor in sinusoidal AM total power is the mean square of a unit _____

Basis and qualification: Chapter 6 — Equation 11F. Total sinusoidal-AM power; Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

Review: Chapter 6 — Equation 11F. Total sinusoidal-AM power; Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

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V011-C06-FIB-020. For a zero-mean message of mean square 0.20 and AM scale 0.5, total-to-carrier power ratio is _____.

Answer: 1.05. One plus 0.5 squared times 0.20 equals 1.05. Use the actual message mean square. Review: Equation 11G. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why this term is required: “1.05” completes the stated technical proposition.

Question context: For a zero-mean message of mean square 0.20 and AM scale 0.5, total-to-carrier power ratio is _____

Basis and qualification: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

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V011-C06-FIB-021. A nonzero message mean retains a squared-envelope expansion term _____ in the modulation scale.

Answer: linear. The term is twice the scale times the message mean. It disappears only under the stated zero-mean assumption. Review: Equation 11G. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why this term is required: “linear” completes the stated technical proposition.

Question context: A nonzero message mean retains a squared-envelope expansion term _____ in the modulation scale

Basis and qualification: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

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V011-C06-FIB-022. For unit carrier peak and depth 1.4, the signed sinusoidal envelope ranges down to _____ V.

Answer: minus 0.4. The lower extremum is one minus 1.4. Magnitude detection is a separate operation that loses this sign. Review: Equation 11H. Source: Equation 11H. Magnitude detection after envelope reversal (p. 3115)

Why this term is required: “minus 0” completes the stated technical proposition.

Question context: For unit carrier peak and depth 1.4, the signed sinusoidal envelope ranges down to _____ V

Basis and qualification: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal.

Review: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal.

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V011-C06-FIB-023. Taking the absolute value of a reversed AM envelope discards its _____ information.

Answer: sign. Negative portions fold upward, whereas a coherent complex representation can retain the reversal. Review: Equation 11H. Source: Equation 11H. Magnitude detection after envelope reversal (p. 3115)

Why this term is required: “sign” completes the stated technical proposition.

Question context: Taking the absolute value of a reversed AM envelope discards its _____ information

Basis and qualification: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal.

Review: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal.

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V011-C06-FIB-024. The unclipped algebraic RF product of one sinusoidal message and a carrier has _____ spectral terms even above unit modulation depth.

Answer: three. It contains a carrier and two sidebands. Physical clipping is a separate nonlinearity that can add components. Review: Application 6A.4. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

Why this term is required: “three” completes the stated technical proposition.

Question context: The unclipped algebraic RF product of one sinusoidal message and a carrier has _____ spectral terms even above unit modulation depth

Basis and qualification: Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

Review: Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

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V011-C06-FIB-025. A source-depth inference from receiver extrema must challenge compression, AGC and the relevant _____ response.

Answer: filter. Filtering can alter sideband balance and modulation-frequency transfer, so the received extrema need not describe the source alone. Review: Amplitude Modulation and Envelope Detection. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

Why this term is required: “filter” completes the stated technical proposition.

Question context: A source-depth inference from receiver extrema must challenge compression, AGC and the relevant _____ response

Basis and qualification: Chapter 6 — Amplitude Modulation and Envelope Detection.

Review: Chapter 6 — Amplitude Modulation and Envelope Detection.

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V011-C06-FIB-026. The normalized real product detector multiplies by _____ times the LO cosine before sum-band rejection.

Answer: two. This compensates the half-amplitude coefficient of the retained difference product. Review: Equation 11I. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why this term is required: “two” completes the stated technical proposition.

Question context: The normalized real product detector multiplies by _____ times the LO cosine before sum-band rejection

Basis and qualification: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

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V011-C06-FIB-027. At exact frequency agreement, a real envelope with a 180-degree coherent-reference error is multiplied by _____.

Answer: minus one. Cosine of 180 degrees is minus one. The output is sign inverted rather than absent. Review: Equation 11I. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why this term is required: “minus one” completes the stated technical proposition.

Question context: At exact frequency agreement, a real envelope with a 180-degree coherent-reference error is multiplied by _____

Basis and qualification: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

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V011-C06-FIB-028. At exact frequency agreement, a real envelope with a 30-degree phase error has amplitude scale approximately _____.

Answer: 0.8660. Cosine of 30 degrees is square root three divided by two. The scale is constant only while the reference error is constant. Review: Equation 11I. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why this term is required: “0.8660” completes the stated technical proposition.

Question context: At exact frequency agreement, a real envelope with a 30-degree phase error has amplitude scale approximately _____

Basis and qualification: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error.

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V011-C06-FIB-029. A 90-degree real-projection null need not be a null in the simultaneous ideal _____ record.

Answer: complex I/Q. The signal can remain in quadrature; a projection null is not disappearance of the whole envelope. Review: Equation 11J. Source: Equation 11J. Complex coherent recovery (p. 3115)

Why this term is required: “complex I/Q” completes the stated technical proposition.

Question context: A 90-degree real-projection null need not be a null in the simultaneous ideal _____ record

Basis and qualification: Chapter 6 — Equation 11J. Complex coherent recovery.

Review: Chapter 6 — Equation 11J. Complex coherent recovery.

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V011-C06-FIB-030. The residual rotation frequency follows carrier frequency _____ LO frequency.

Answer: minus. This sign fixes complex baseband orientation and must remain consistent with the retained I/Q convention. Review: Equations 11I and 11J. Source: Equation 11I. Real coherent recovery with residual reference error (p. 3115)

Why this term is required: “minus” completes the stated technical proposition.

Question context: The residual rotation frequency follows carrier frequency _____ LO frequency

Basis and qualification: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery.

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V011-C06-FIB-031. A real 2 kHz suppressed-carrier envelope multiplied by a residual 100 Hz cosine gives lower output frequency _____ Hz.

Answer: 1900. The product-to-sum identity gives 1900 and 2100 Hz, each with half the original envelope peak. Review: Application 6A.6 method. Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)

Why this term is required: “1900” completes the stated technical proposition.

Question context: A real 2 kHz suppressed-carrier envelope multiplied by a residual 100 Hz cosine gives lower output frequency _____ Hz

Basis and qualification: Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

Review: Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

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V011-C06-FIB-032. For that 2 kHz envelope and 100 Hz residual cosine, the upper recovered frequency is _____ Hz.

Answer: 2100. A real projection of the rotating envelope contains both translated terms, not one shifted tone alone. Review: Application 6A.6 method. Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)

Why this term is required: “2100” completes the stated technical proposition.

Question context: For that 2 kHz envelope and 100 Hz residual cosine, the upper recovered frequency is _____ Hz

Basis and qualification: Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

Review: Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

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V011-C06-FIB-033. An upper-sideband tone at carrier plus 3 kHz, with an LO 200 Hz below carrier, has signed baseband frequency _____ Hz.

Answer: positive 3200. Subtract LO from RF tone. Lowering the LO increases the positive difference by 200 Hz. Review: Equation 11K. Source: Equation 11K. Explicit upper and lower single-sideband envelopes (p. 3116)

Why this term is required: “positive 3200” completes the stated technical proposition.

Question context: An upper-sideband tone at carrier plus 3 kHz, with an LO 200 Hz below carrier, has signed baseband frequency _____ Hz

Basis and qualification: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

Review: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

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V011-C06-FIB-034. The corresponding lower-sideband tone at carrier minus 3 kHz has signed baseband frequency _____ Hz.

Answer: negative 2800. It remains below that LO by 2800 Hz. Preserve the sign before any real audio folding. Review: Equation 11K. Source: Equation 11K. Explicit upper and lower single-sideband envelopes (p. 3116)

Why this term is required: “negative 2800” completes the stated technical proposition.

Question context: The corresponding lower-sideband tone at carrier minus 3 kHz has signed baseband frequency _____ Hz

Basis and qualification: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

Review: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes.

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V011-C06-FIB-035. An SSB frequency scale adjusted by ear is not thereby independently _____.

Answer: calibrated. Intelligibility is a subjective outcome. A measured scale needs a supported reference and applicable accuracy evidence. Review: Single Sideband and Coherent Reception. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)
Why this term is required: “calibrated” completes the stated technical proposition.
Question context: An SSB frequency scale adjusted by ear is not thereby independently _____
Basis and qualification: Chapter 6 — Single Sideband and Coherent Reception.
Review: Chapter 6 — Single Sideband and Coherent Reception.

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V011-C06-FIB-036. Orthogonal SSB envelope tones of 0.3 V and 0.4 V peak across 50 ohms have mean RF power _____ mW.

Answer: 2.5. Mean squared envelope magnitude is 0.09 plus 0.16, or 0.25 square volts. Divide by 100 ohms. Review: Equation 11B; Application 6A.8 method. Source: Equation 11B. Envelope power convention (p. 3113)

Why this term is required: “2.5” completes the stated technical proposition.

Question context: Orthogonal SSB envelope tones of 0.3 V and 0.4 V peak across 50 ohms have mean RF power _____ mW

Basis and qualification: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

Review: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-FIB-037. If those 0.3 V and 0.4 V components align during the observation, peak envelope power is _____ mW.

Answer: 4.9. The maximum envelope is 0.7 V; its square divided by 100 ohms gives 0.0049 W. Review: Application 6A.8 method. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

Why this term is required: “4.9” completes the stated technical proposition.

Question context: If those 0.3 V and 0.4 V components align during the observation, peak envelope power is _____ mW

Basis and qualification: Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

Review: Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-FIB-038. Equality in the sum-of-component-magnitudes envelope bound requires simultaneous _____ alignment.

Answer: phase. The observation interval and component phases determine whether the upper bound is actually attained. Review: Equation 11B; Application 6A.8. Source: Equation 11B. Envelope power convention (p. 3113)

Why this term is required: “phase” completes the stated technical proposition.

Question context: Equality in the sum-of-component-magnitudes envelope bound requires simultaneous _____ alignment

Basis and qualification: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

Review: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-FIB-039. For real upper- and lower-sideband coefficients 0.5 and 0.3, the envelope cosine coefficient is _____.

Answer: 0.8. The cosine coefficient is their sum, while the imaginary sine coefficient is their difference. Review: Equation 11L. Source: Equation 11L. In-phase and quadrature terms after unequal sideband response (p. 3116)

Why this term is required: “0.8” completes the stated technical proposition.

Question context: For real upper- and lower-sideband coefficients 0.5 and 0.3, the envelope cosine coefficient is _____

Basis and qualification: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

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V011-C06-FIB-040. For those coefficients 0.5 and 0.3, the coefficient of the imaginary sine term is _____.

Answer: 0.2. Subtract lower from upper. Unequal real coefficients create a quadrature term. Review: Equation 11L. Source: Equation 11L. In-phase and quadrature terms after unequal sideband response (p. 3116)

Why this term is required: “0.2” completes the stated technical proposition.

Question context: For those coefficients 0.5 and 0.3, the coefficient of the imaginary sine term is _____

Basis and qualification: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

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V011-C06-FIB-041. With complex sideband coefficients, I and Q are the real and imaginary parts of the _____ envelope expression.

Answer: complete. A complex coefficient sum cannot simply be renamed a real channel; its phase participates in the expansion. Review: Equation 11L. Source: Equation 11L. In-phase and quadrature terms after unequal sideband response (p. 3116)
Why this term is required: “complete” completes the stated technical proposition.
Question context: With complex sideband coefficients, I and Q are the real and imaginary parts of the _____ envelope expression
Basis and qualification: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.
Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

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V011-C06-FIB-042. A real input that becomes complex after selective sideband filtering does not prove original transmitter _____ modulation.

Answer: phase. The path itself can create quadrature content, so source and receiver contributions must be separated. Review: Application 6A.9. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
Why this term is required: “phase” completes the stated technical proposition.
Question context: A real input that becomes complex after selective sideband filtering does not prove original transmitter _____ modulation
Basis and qualification: Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.
Review: Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

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V011-C06-FIB-043. The message 0.4 times a 1 kHz cosine plus 0.2 times a 2 kHz cosine has mean square _____ over complete common periods.

Answer: 0.10. Distinct-frequency cross terms average to zero, leaving half of 0.16 plus half of 0.04. Review: Equation 11G; Application 6A.10 method. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why this term is required: “0.10” completes the stated technical proposition.

Question context: The message 0.4 times a 1 kHz cosine plus 0.2 times a 2 kHz cosine has mean square _____ over complete common periods

Basis and qualification: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

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V011-C06-FIB-044. At AM scale 0.5, that zero-mean message of mean square 0.10 gives total-to-carrier power ratio _____.

Answer: 1.025. Its contribution is 0.5 squared times 0.10, or 0.025. Add the unit carrier term. Review: Equation 11G. Source: Equation 11G. Power for a zero-mean nonsinusoidal message (p. 3114)

Why this term is required: “1.025” completes the stated technical proposition.

Question context: At AM scale 0.5, that zero-mean message of mean square 0.10 gives total-to-carrier power ratio _____

Basis and qualification: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message.

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V011-C06-FIB-045. A magnitude-only output can conceal the distinction between in-phase and _____ components.

Answer: quadrature. Different complex trajectories can share a magnitude trace. Calibrated I/Q retains the additional coordinate information. Review: Equation 11L discussion. Source: Equation 11L. In-phase and quadrature terms after unequal sideband response (p. 3116)

Why this term is required: “quadrature” completes the stated technical proposition.

Question context: A magnitude-only output can conceal the distinction between in-phase and _____ components

Basis and qualification: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

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V011-C06-FIB-046. For a supported continuous phase branch, frequency offset is the phase derivative divided by _____.

Answer: two pi. The derivative is angular rate. Division by two pi converts radians per second to cycles per second. Review: Equation 12A. Source: Equation 12A. Complex phase and instantaneous frequency (p. 3131)

Why this term is required: “two pi” completes the stated technical proposition.

Question context: For a supported continuous phase branch, frequency offset is the phase derivative divided by _____

Basis and qualification: Chapter 6 — Equation 12A. Complex phase and instantaneous frequency.

Review: Chapter 6 — Equation 12A. Complex phase and instantaneous frequency.

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V011-C06-FIB-047. Model 6B assumes unwrapped phase that is absolutely _____, supporting its derivative relation almost everywhere.

Answer: continuous. This regularity supports the integral and derivative relations within the model; arbitrary resets do not automatically satisfy it. Review: Model 6B assumptions; Equation 12A. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

Why this term is required: “continuous” completes the stated technical proposition.

Question context: Model 6B assumes unwrapped phase that is absolutely _____, supporting its derivative relation almost everywhere

Basis and qualification: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Equation 12A. Complex phase and instantaneous frequency.

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Equation 12A. Complex phase and instantaneous frequency.

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V011-C06-FIB-048. Near a complex-amplitude null, a phase estimate can become numerically _____.

Answer: ill-conditioned. Small perturbations can cause large phase changes when amplitude is weak or canceling, so the derivative needs a capability check. Review: Model 6B assumptions. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

Why this term is required: “ill-conditioned” completes the stated technical proposition.

Question context: Near a complex-amplitude null, a phase estimate can become numerically _____

Basis and qualification: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

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V011-C06-FIB-049. Sinusoidal FM deviation 6 kHz at modulation frequency 2 kHz gives phase index _____.

Answer: 3. Divide compatible frequencies. The dimensionless index is customarily expressed as a phase excursion in radians. Review: Equation 12B. Source: Equation 12B. Sinusoidal FM phase and modulation index (p. 3132)

Why this term is required: “3” completes the stated technical proposition.

Question context: Sinusoidal FM deviation 6 kHz at modulation frequency 2 kHz gives phase index _____

Basis and qualification: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index.

Review: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index.

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V011-C06-FIB-050. For fixed sinusoidal FM deviation, reducing modulation frequency to one third multiplies phase index by _____.

Answer: three. Phase index varies inversely with modulation frequency when deviation is fixed. Review: Equation 12B. Source: Equation 12B. Sinusoidal FM phase and modulation index (p. 3132)

Why this term is required: “three” completes the stated technical proposition.

Question context: For fixed sinusoidal FM deviation, reducing modulation frequency to one third multiplies phase index by _____

Basis and qualification: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index.

Review: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index.

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V011-C06-FIB-051. A PM sensitivity of 0.5 radian per volt driven by a 2 V peak message gives phase excursion _____ radian.

Answer: 1. Multiply the sensitivity by the message peak. Frequency deviation additionally depends on the message rate. Review: Equation 12C. Source: Equation 12C. Sinusoidal PM and its frequency deviation (p. 3132)

Why this term is required: “1” completes the stated technical proposition.

Question context: A PM sensitivity of 0.5 radian per volt driven by a 2 V peak message gives phase excursion _____ radian

Basis and qualification: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

Review: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

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V011-C06-FIB-052. That 1-radian phase peak at a 3 kHz sinusoidal message frequency gives peak frequency deviation _____ kHz.

Answer: 3. Differentiating the sinusoid introduces message frequency after the two-pi factors cancel. Review: Equation 12C. Source: Equation 12C. Sinusoidal PM and its frequency deviation (p. 3132)

Why this term is required: “3” completes the stated technical proposition.

Question context: That 1-radian phase peak at a 3 kHz sinusoidal message frequency gives peak frequency deviation _____ kHz

Basis and qualification: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

Review: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

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V011-C06-FIB-053. Differentiating a cosine phase gives a _____ sine-shaped frequency offset under the chapter convention.

Answer: negative. The derivative sign matters when time-aligned phase and frequency traces are compared. Review: Equation 12C. Source: Equation 12C. Sinusoidal PM and its frequency deviation (p. 3132)

Why this term is required: “negative” completes the stated technical proposition.

Question context: Differentiating a cosine phase gives a _____ sine-shaped frequency offset under the chapter convention

Basis and qualification: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

Review: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

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V011-C06-FIB-054. A fixed PM phase peak of 0.4 radian at 5 kHz corresponds to frequency-deviation peak _____ kHz.

Answer: 2. Multiply phase peak by message frequency: 0.4 times 5 kHz. Review: Equation 12C. Source: Equation 12C. Sinusoidal PM and its frequency deviation (p. 3132)
Why this term is required: “2” completes the stated technical proposition.
Question context: A fixed PM phase peak of 0.4 radian at 5 kHz corresponds to frequency-deviation peak _____ kHz
Basis and qualification: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.
Review: Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation.

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V011-C06-FIB-055. On a continuous phase branch, phase change is two pi times the time _____ of frequency offset.

Answer: integral. Integration of cycles per second gives cycles; multiplication by two pi converts cycles to radians. Review: Equation 12D. Source: Equation 12D. Integration of a general deterministic frequency offset (p. 3132)

Why this term is required: “integral” completes the stated technical proposition.

Question context: On a continuous phase branch, phase change is two pi times the time _____ of frequency offset

Basis and qualification: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset.

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V011-C06-FIB-056. A constant 125 Hz offset over 8 ms accumulates _____ complete cycle.

Answer: one. The product is 125 times 0.008. A complete cycle can disappear from a wrapped endpoint comparison. Review: Equation 12D. Source: Equation 12D. Integration of a general deterministic frequency offset (p. 3132)

Why this term is required: “one” completes the stated technical proposition.

Question context: A constant 125 Hz offset over 8 ms accumulates _____ complete cycle

Basis and qualification: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset.

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V011-C06-FIB-057. Equal wrapped endpoint phases do not exclude an intermediate excursion or an integer number of accumulated _____.

Answer: cycles. The continuous branch retains information discarded by wrapping. Endpoint agreement alone does not describe the trajectory. Review: Equation 12D; Application 6B.5. Source: Equation 12D. Integration of a general deterministic frequency offset (p. 3132)

Why this term is required: “cycles” completes the stated technical proposition.

Question context: Equal wrapped endpoint phases do not exclude an intermediate excursion or an integer number of accumulated _____

Basis and qualification: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

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V011-C06-FIB-058. A linear frequency-offset ramp from minus 1 kHz to plus 1 kHz over 2 ms has net signed phase change _____ radians.

Answer: zero. The positive and negative frequency-time areas cancel, although frequency and intermediate phase vary. Review: Application 6B.5 method. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

Why this term is required: “zero” completes the stated technical proposition.

Question context: A linear frequency-offset ramp from minus 1 kHz to plus 1 kHz over 2 ms has net signed phase change _____ radians

Basis and qualification: Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

Review: Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

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V011-C06-FIB-059. For that ramp starting at zero phase, midpoint accumulated phase is _____ radians.

Answer: minus pi. The first millisecond has average offset minus 500 Hz, giving minus one half cycle. Review: Application 6B.5 method. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

Why this term is required: “minus pi” completes the stated technical proposition.

Question context: For that ramp starting at zero phase, midpoint accumulated phase is _____ radians

Basis and qualification: Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

Review: Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

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V011-C06-FIB-060. Phase peaks of 0.2 radian at 1 kHz and 0.1 radian at 2 kHz give a triangle bound on peak deviation of _____ Hz.

Answer: 400. Each individual deviation peak is 200 Hz. The sum is a bound whose attainment depends on phase alignment. Review: Equation 12E. Source: Equation 12E. Deviation from several phase components (p. 3133)

Why this term is required: “400” completes the stated technical proposition.

Question context: Phase peaks of 0.2 radian at 1 kHz and 0.1 radian at 2 kHz give a triangle bound on peak deviation of _____ Hz

Basis and qualification: Chapter 6 — Equation 12E. Deviation from several phase components.

Review: Chapter 6 — Equation 12E. Deviation from several phase components.

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V011-C06-FIB-061. A finite unwrapped phase difference divided by its elapsed interval gives interval-_____ frequency.

Answer: average. It equals the average derivative over that interval under the model assumptions, not automatically a pointwise derivative. Review: Equation 12F.

Source: Equation 12F. Finite-interval frequency from unwrapped phase (p. 3133)

Why this term is required: “average” completes the stated technical proposition.

Question context: A finite unwrapped phase difference divided by its elapsed interval gives interval-_____ frequency

Basis and qualification: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

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V011-C06-FIB-062. A phase increase of pi divided by two radians over 0.2 ms gives average offset _____ Hz.

Answer: 1250. One quarter cycle divided by 0.0002 second is 1250 Hz. Review: Equation 12F. Source: Equation 12F. Finite-interval frequency from unwrapped phase (p. 3133)

Why this term is required: “1250” completes the stated technical proposition.

Question context: A phase increase of pi divided by two radians over 0.2 ms gives average offset _____ Hz

Basis and qualification: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

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V011-C06-FIB-063. Two adjacent equal intervals with frequency averages 100 Hz and 500 Hz have combined average _____ Hz.

Answer: 300. Equal durations give equal weights when the two phase changes are added. Review: Equation 12F. Source: Equation 12F. Finite-interval frequency from unwrapped phase (p. 3133)

Why this term is required: “300” completes the stated technical proposition.

Question context: Two adjacent equal intervals with frequency averages 100 Hz and 500 Hz have combined average _____ Hz

Basis and qualification: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

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V011-C06-FIB-064. If those interval lengths differ, the combined average uses duration _____ rather than an unweighted mean.

Answer: weights. Add each frequency average times its duration and divide by total duration. Review: Equation 12F. Source: Equation 12F. Finite-interval frequency from unwrapped phase (p. 3133)

Why this term is required: “weights” completes the stated technical proposition.

Question context: If those interval lengths differ, the combined average uses duration _____ rather than an unweighted mean

Basis and qualification: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase.

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V011-C06-FIB-065. The adjacent-sample phase method multiplies the later sample by the _____ of the earlier sample.

Answer: complex conjugate. This forms the phase difference and cancels a common constant phase rotation. Review: Equation 12G. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why this term is required: “complex conjugate” completes the stated technical proposition.

Question context: The adjacent-sample phase method multiplies the later sample by the _____ of the earlier sample

Basis and qualification: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

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V011-C06-FIB-066. At a 40 kHz complex sample rate, the selected principal-frequency interval includes minus 20 kHz but excludes _____ kHz.

Answer: positive 20. The half-open interval follows the chosen principal argument convention. The two half-rate representations are sampling equivalent. Review: Equation 12G. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why this term is required: “positive 20” completes the stated technical proposition.

Question context: At a 40 kHz complex sample rate, the selected principal-frequency interval includes minus 20 kHz but excludes _____ kHz

Basis and qualification: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

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V011-C06-FIB-067. At that 40 kHz sample rate, a constant positive 26 kHz offset has principal frequency _____ kHz.

Answer: negative 14. Subtract one full sample-rate interval to enter the principal band. Review: Equation 12G. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why this term is required: “negative 14” completes the stated technical proposition.

Question context: At that 40 kHz sample rate, a constant positive 26 kHz offset has principal frequency _____ kHz

Basis and qualification: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

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V011-C06-FIB-068. The constant-frequency aliases of a minus-14 kHz principal estimate at 40 kHz sample rate are separated by _____ kHz.

Answer: 40. Any integer multiple of the sample rate can be added without changing the sampled complex exponential. Review: Equation 12G. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why this term is required: “40” completes the stated technical proposition.

Question context: The constant-frequency aliases of a minus-14 kHz principal estimate at 40 kHz sample rate are separated by _____ kHz

Basis and qualification: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

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V011-C06-FIB-069. Selecting a physical member of the alias family requires additional band evidence or a changed _____.

Answer: observation. Unwrapping cannot distinguish identical sampled values. A different sampling condition or independent reference can constrain the alias.

Review: Application 6B.6. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

Why this term is required: “observation” completes the stated technical proposition.

Question context: Selecting a physical member of the alias family requires additional band evidence or a changed _____

Basis and qualification: Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

Review: Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

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V011-C06-FIB-070. A common constant phase rotation contributes _____ to each valid adjacent-sample phase difference.

Answer: zero. The rotation cancels with its conjugate. A time-varying reference does not cancel in the same manner. Review: Equation 12G. Source: Equation 12G. Principal-increment frequency and its alias class (p. 3134)

Why this term is required: “zero” completes the stated technical proposition.

Question context: A common constant phase rotation contributes _____ to each valid adjacent-sample phase difference

Basis and qualification: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class.

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V011-C06-FIB-071. The first-order complex-exponential approximation retains a constant term and a term _____ in phase.

Answer: linear. The retained expression is one plus j times phase; the remainder is bounded separately. Review: Equation 12H. Source: Equation 12H. Pointwise small-phase remainder (p. 3134)

Why this term is required: “linear” completes the stated technical proposition.

Question context: The first-order complex-exponential approximation retains a constant term and a term _____ in phase

Basis and qualification: Chapter 6 — Equation 12H. Pointwise small-phase remainder.

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder.

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V011-C06-FIB-072. For real phase magnitude at most 0.3 radian, the pointwise remainder bound is _____.

Answer: 0.045. Half the squared phase bound is 0.09 divided by two. The quantity is normalized complex-amplitude error. Review: Equation 12H. Source: Equation 12H. Pointwise small-phase remainder (p. 3134)

Why this term is required: “0.045” completes the stated technical proposition.

Question context: For real phase magnitude at most 0.3 radian, the pointwise remainder bound is _____

Basis and qualification: Chapter 6 — Equation 12H. Pointwise small-phase remainder.

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder.

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V011-C06-FIB-073. At sinusoidal phase index 0.06, each retained first-order sideband peak is _____ relative to the unmodulated unit carrier.

Answer: 0.03. Each peak is half the phase index. This is a retained approximation with a stated error bound. Review: Equation 12I. Source: Equation 12I. First-order sidebands for sinusoidal small phase (p. 3134)

Why this term is required: “0.03” completes the stated technical proposition.

Question context: At sinusoidal phase index 0.06, each retained first-order sideband peak is _____ relative to the unmodulated unit carrier

Basis and qualification: Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

Review: Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

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V011-C06-FIB-074. Those first-order sideband peaks of 0.03 give a power ratio of _____.

Answer: 0.0009. Square the amplitude ratio. The reference is the unmodulated carrier, not an assumed unchanged exact carrier at arbitrary index. Review: Equation 12I. Source: Equation 12I. First-order sidebands for sinusoidal small phase (p. 3134)

Why this term is required: “0.0009” completes the stated technical proposition.

Question context: Those first-order sideband peaks of 0.03 give a power ratio of _____

Basis and qualification: Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

Review: Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase.

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V011-C06-FIB-075. A pointwise amplitude remainder bound is not automatically a spectral power-_____ percentage.

Answer: containment. A bound on complex error and integrated power in a frequency interval are different quantities. Review: Equations 12H–12J. Source: Equation 12H. Pointwise small-phase remainder (p. 3134)

Why this term is required: “containment” completes the stated technical proposition.

Question context: A pointwise amplitude remainder bound is not automatically a spectral power-_____ percentage

Basis and qualification: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase; Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase; Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

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V011-C06-FIB-076. Carson's estimate adds peak deviation to the highest significant _____ frequency before doubling the sum.

Answer: modulating. The inputs describe frequency excursion and message content, not the RF carrier itself. Review: Equation 12J. Source: Equation 12J. Carson estimate and its stated inputs (p. 3135)

Why this term is required: "modulating" completes the stated technical proposition.

Question context: Carson's estimate adds peak deviation to the highest significant _____ frequency before doubling the sum

Basis and qualification: Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

Review: Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

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V011-C06-FIB-077. Peak deviation 2.5 kHz and significant message content through 1.5 kHz give Carson estimate _____ kHz.

Answer: 8. Twice their sum is 8 kHz. It remains an engineering estimate. Review: Equation 12J. Source: Equation 12J. Carson estimate and its stated inputs (p. 3135)

Why this term is required: “8” completes the stated technical proposition.

Question context: Peak deviation 2.5 kHz and significant message content through 1.5 kHz give Carson estimate _____ kHz

Basis and qualification: Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

Review: Chapter 6 — Equation 12J. Carson estimate and its stated inputs.

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V011-C06-FIB-078. Exact power passed by an IF path requires combining signal spectrum with the actual filter _____ response.

Answer: power-transfer. A width label does not supply frequency weighting. Waveform distortion additionally depends on complex transfer. Review: Application 6B.9. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

Why this term is required: “power-transfer” completes the stated technical proposition.

Question context: Exact power passed by an IF path requires combining signal spectrum with the actual filter _____ response

Basis and qualification: Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response.

Review: Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response.

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V011-C06-FIB-079. A constant reference-frequency offset gives a _____ trend in continuous phase.

Answer: linear. Integrating a fixed frequency residual gives phase proportional to elapsed time. Review: Equation 12K. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why this term is required: “linear” completes the stated technical proposition.

Question context: A constant reference-frequency offset gives a _____ trend in continuous phase

Basis and qualification: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

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V011-C06-FIB-080. A constant negative 50 Hz residual over 5 ms adds phase _____ degrees.

Answer: minus 90. The signed accumulation is minus 0.25 cycle, from minus 50 times 0.005 second. Review: Equation 12K. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why this term is required: “minus 90” completes the stated technical proposition.

Question context: A constant negative 50 Hz residual over 5 ms adds phase _____ degrees

Basis and qualification: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

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V011-C06-FIB-081. A symmetric plus-or-minus 2 kHz deviation with positive 100 Hz residual has upper observed limit _____ Hz.

Answer: positive 2100. The constant residual shifts the range upward; its lower limit is minus 1900 Hz. Review: Equation 12K. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why this term is required: “positive 2100” completes the stated technical proposition.

Question context: A symmetric plus-or-minus 2 kHz deviation with positive 100 Hz residual has upper observed limit _____ Hz

Basis and qualification: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

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V011-C06-FIB-082. Removing a trend fitted to an incomplete modulation period can absorb part of the wanted _____.

Answer: modulation. Retain the estimation interval and independent reference evidence. A centered trace is not proof of a valid correction. Review: Application 6B.10. Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

Why this term is required: “modulation” completes the stated technical proposition.

Question context: Removing a trend fitted to an incomplete modulation period can absorb part of the wanted _____

Basis and qualification: Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

Review: Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

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V011-C06-FIB-083. A phase reset divides derivative analysis into separately identified _____.

Answer: segments. A new phase origin does not establish continuity across the boundary. The intersegment relationship needs separate evidence. Review: Equation 12K discussion. Source: Equation 12K. Separate modulation, frequency offset and phase offset (p. 3135)

Why this term is required: “segments” completes the stated technical proposition.

Question context: A phase reset divides derivative analysis into separately identified _____

Basis and qualification: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset.

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V011-C06-FIB-084. Modest long-time average power does not exclude a high instantaneous pulse _____.

Answer: peak. A low duty factor can conceal peaks that compress the front end or activate protection. Review: Pulse, Radar, and Transient Reception. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

Why this term is required: “peak” completes the stated technical proposition.

Question context: Modest long-time average power does not exclude a high instantaneous pulse _____

Basis and qualification: Chapter 6 — Pulse, Radar, and Transient Reception.

Review: Chapter 6 — Pulse, Radar, and Transient Reception.

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V011-C06-FIB-085. A pulse observed through a bandwidth-limited path may be captured yet _____.

Answer: distorted. The event entered the record but its shape or amplitude can be altered, unlike a missed acquisition. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “distorted” completes the stated technical proposition.

Question context: A pulse observed through a bandwidth-limited path may be captured yet _____

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-086. A burst outside all usable acquisition windows cannot be recreated by changing the later _____.

Answer: demodulator. Postprocessing works on retained observations and cannot supply RF samples that were not validly acquired. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “demodulator” completes the stated technical proposition.

Question context: A burst outside all usable acquisition windows cannot be recreated by changing the later _____

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-087. Complementary time and spectrum views of a pulse should be linked to the same native _____.

Answer: record. Retain windows, time basis and processing to avoid silently combining distinct events. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “record” completes the stated technical proposition.

Question context: Complementary time and spectrum views of a pulse should be linked to the same native _____

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-088. A local switching transient is a competing explanation for an apparent received _____ event.

Answer: pulse. Synchronized channels and controlled input substitutions help test internal, conducted and external explanations. Review: Pulse, Radar, and Transient Reception. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

Why this term is required: “pulse” completes the stated technical proposition.

Question context: A local switching transient is a competing explanation for an apparent received _____ event

Basis and qualification: Chapter 6 — Pulse, Radar, and Transient Reception.

Review: Chapter 6 — Pulse, Radar, and Transient Reception.

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V011-C06-FIB-089. A gain change during a burst must remain an identified receiver _____ boundary.

Answer: state. Scale, phase and filter history can change. Silent splicing loses evidence needed for interpretation. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “state” completes the stated technical proposition.

Question context: A gain change during a burst must remain an identified receiver _____ boundary

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-090. A limiter can reduce amplitude variation while leaving corrupted _____ information.

Answer: phase. Constant output amplitude does not establish valid angle-modulation recovery or exclude capture and threshold behavior. Review: Frequency and Phase Modulation. Source: §6.16 Frequency and Phase Modulation (p. 3128)

Why this term is required: “phase” completes the stated technical proposition.

Question context: A limiter can reduce amplitude variation while leaving corrupted _____ information

Basis and qualification: Chapter 6 — Frequency and Phase Modulation.

Review: Chapter 6 — Frequency and Phase Modulation.

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V011-C06-FIB-091. Loss of a weak FM component in audio can reflect the receiver's _____ effect rather than RF absence.

Answer: capture. A stronger component can dominate nonlinear reception. Separate RF observations are needed to assess the weak component. Review: Chapter Glossary: Capture effect. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

Why this term is required: "capture" completes the stated technical proposition.

Question context: Loss of a weak FM component in audio can reflect the receiver's _____ effect rather than RF absence

Basis and qualification: Chapter 6 — CAPTURE EFFECT (glossary).

Review: Chapter 6 — CAPTURE EFFECT (glossary).

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V011-C06-FIB-092. Demodulator tests include sensitivity and strong-signal limits because dominant _____ can vary with level.

Answer: impairments. Noise and threshold effects can dominate one region, while compression, limiting and recovery dominate another. Review: Analog Demodulator Verification. Source: §6.31 Analog Demodulator Verification (p. 3152)

Why this term is required: “impairments” completes the stated technical proposition.

Question context: Demodulator tests include sensitivity and strong-signal limits because dominant _____ can vary with level

Basis and qualification: Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Analog Demodulator Verification.

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V011-C06-FIB-093. A modulation reference should be independently _____ before being used to establish receiver amplitude or deviation accuracy.

Answer: calibrated. Otherwise source and receiver errors can be confounded. Retain applicable conditions and uncertainty or accuracy evidence. Review: Analog Demodulator Verification. Source: §6.31 Analog Demodulator Verification (p. 3152)
Why this term is required: “calibrated” completes the stated technical proposition.
Question context: A modulation reference should be independently _____ before being used to establish receiver amplitude or deviation accuracy
Basis and qualification: Chapter 6 — Analog Demodulator Verification.
Review: Chapter 6 — Analog Demodulator Verification.

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V011-C06-FIB-094. De-emphasis, squelch, limiting and audio normalization belong in the derived-product _____ record.

Answer: configuration. Each can alter output without an external RF change. Automatic settings require actual state or interval evidence. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “configuration” completes the stated technical proposition.

Question context: De-emphasis, squelch, limiting and audio normalization belong in the derived-product _____ record

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-095. Intelligible speech is a listening outcome and does not by itself calibrate frequency _____.

Answer: deviation. Technical modulation accuracy and subjective listening quality are distinct assessments. Review: Analog Demodulator Verification. Source: §6.31 Analog Demodulator Verification (p. 3152)

Why this term is required: “deviation” completes the stated technical proposition.

Question context: Intelligible speech is a listening outcome and does not by itself calibrate frequency _____

Basis and qualification: Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Analog Demodulator Verification.

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V011-C06-FIB-096. Processing-version identity helps another examiner _____ the audio product from retained native samples.

Answer: reproduce. The version and settings identify the transformation while the native record supplies its input. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “reproduce” completes the stated technical proposition.

Question context: Processing-version identity helps another examiner _____ the audio product from retained native samples

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-097. A final-screen value for an automatic setting does not establish its earlier _____.

Answer: state. Time-varying configuration can affect each segment. Retain telemetry or bounded interval evidence. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “state” completes the stated technical proposition.

Question context: A final-screen value for an automatic setting does not establish its earlier _____

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-098. A failed receiver recovery is not universal proof that the external source lacked _____.

Answer: modulation. Coverage, sensitivity, transfer and processing limits can explain failure, so the negative finding remains bounded. Review: Preserve pulse and demodulator evidence across representations. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

Why this term is required: “modulation” completes the stated technical proposition.

Question context: A failed receiver recovery is not universal proof that the external source lacked _____

Basis and qualification: Chapter 6 — Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations.

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V011-C06-FIB-099. A successful closing reference assesses the functions exercised at the _____ of that check.

Answer: time. It does not alone prove uninterrupted earlier validity or assess an antenna path bypassed by the reference. Review: Chapter 1 verification scope; Analog Demodulator Verification. Source: §6.31 Analog Demodulator Verification (p. 3152)

Why this term is required: “time” completes the stated technical proposition.

Question context: A successful closing reference assesses the functions exercised at the _____ of that check

Basis and qualification: Chapter 6 — Analog Demodulator Verification; Chapter 1 — Evidence Record and Closing Verification.

Review: Chapter 6 — Analog Demodulator Verification; Chapter 1 — Evidence Record and Closing Verification.

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V011-C06-FIB-100. A defensible modulation conclusion retains model assumptions, receiver-transfer evidence and unresolved _____.

Answer: limitations. These constrain the supported classification, measurement and interpretation. A clean plot does not replace that reasoning. Review: Table 6; Analog Demodulator Verification. Source: Table 6. Chapter 6 receiver controls and interpretation limits (p. 3154)

Why this term is required: “limitations” completes the stated technical proposition.

Question context: A defensible modulation conclusion retains model assumptions, receiver-transfer evidence and unresolved _____

Basis and qualification: Chapter 6 — Table 6. Chapter 6 receiver controls and interpretation limits; Chapter 6 — Analog Demodulator Verification.

Review: Chapter 6 — Table 6. Chapter 6 receiver controls and interpretation limits; Chapter 6 — Analog Demodulator Verification.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C06-ESSAY-001. Derive the mean-power and peak-envelope-power relations for Model 6A. Explain why the factor of two and the averaging conditions are part of the result, and identify a plausible misuse of each relation.

- Opening: Present a thesis that answers this precise question: Derive the mean-power and peak-envelope-power relations for Model 6A. Identify which evidence would falsify the proposed conclusion Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
- Core terminology and scope: Define relations, Model, factor in the question's particular technical setting; explain how averaging, conditions, relation differ if that distinction would change the analysis of "Derive the mean-power and peak-envelope-power relations for Model 6A" Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin with the real RF waveform as the real part of its translated complex peak-voltage envelope Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the mean-power and peak-envelope-power relations for Model 6A to the claimed result, following "Application 6A.8: Compare average power with peak envelope power for two SSB tones"; name the intermediate states and measurable outputs Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the mean-power and peak-envelope-power relations for Model 6A. Expanding its square produces one term proportional to the squared envelope magnitude and another oscillating around twice the carrier Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.10: Use message mean square rather than a sinusoidal shortcut” that resolves the question about the mean-power and peak-envelope-power relations for Model 6A; derive the relevant result with units and stated validity conditions Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the mean-power and peak-envelope-power relations for Model 6A. Under the declared spectral separation and complete-period, long-time or carrier-cycle averaging convention, the latter term has zero relevant average Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
- Worked application or illustrative case: Build a worked example of “the mean-power and peak-envelope-power relations for Model 6A”, addressing this associated condition: Explain why the factor of two and the averaging conditions are part of the result, and identify a.... Begin with the real RF waveform as the real part of its translated complex peak-voltage envelope Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the mean-power and peak-envelope-power relations for Model 6A”. Using “Application 6A.10: Use message mean square rather than a sinusoidal shortcut”, specify a discriminator and the result expected under each explanation Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the mean-power and peak-envelope-power relations for Model 6A, including the effect of missing measurements and inconsistent operating conditions Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)
- Scholarly synthesis and implications: Explain what the result about the mean-power and peak-envelope-power relations for Model 6A authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
- Closing: Conclude by answering “Derive the mean-power and peak-envelope-power relations for Model 6A” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

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V011-C06-ESSAY-002. A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load. Calculate the envelope extrema, carrier power, each sideband power, total average power and peak envelope power. Describe a measurement that would challenge the calculation.

- Opening: Present a thesis that answers this precise question: A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load. Identify which evidence would falsify the proposed conclusion Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Core terminology and scope: Define sinusoidal, depth, load in the question's particular technical setting; explain how Calculate, extrema, sideband differ if that distinction would change the analysis of "A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load" Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The nonnegative envelope has extrema 0.5 V and 3.5 V Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load to the claimed result, following "Application 6A.2: Infer the conventional-AM envelope parameters"; name the

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intermediate states and measurable outputs Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load. Explain which changes in Calculate the envelope extrema, carrier power, each sideband power, total average power and peak… would invalidate an unqualified comparison Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.1: Close the power accounting for sinusoidal AM” that resolves the question about A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load; derive the relevant result with units and stated validity conditions Source: §6.6 Application 6A.1: Close the power accounting for sinusoidal AM (p. 3118)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load. Each sideband has peak 0.75 V and power 5.625 mW, so total average power is 51.25 mW Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Worked application or illustrative case: Build a worked example of “A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load”, addressing this associated

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condition: Calculate the envelope extrema, carrier power, each sideband power, total average power and peak.... The nonnegative envelope has extrema 0.5 V and 3.5 V Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load”. Using “Application 6A.1: Close the power accounting for sinusoidal AM”, specify a discriminator and the result expected under each explanation Source: §6.6 Application 6A.1: Close the power accounting for sinusoidal AM (p. 3118)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load, including the effect of missing measurements and inconsistent operating conditions Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Scholarly synthesis and implications: Explain what the result about A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Closing: Conclude by answering “A hypothetical sinusoidal AM signal has carrier peak 2 V, modulation depth 0.75 and a 50 Ω real load” using only the demonstrated evidence; state the remaining decisive

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verification step Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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V011-C06-ESSAY-003. Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale. One has mean square 0.50 and the other 0.20. With modulation scale 0.8, compare their total-to-carrier power ratios and explain what the comparison does and does not reveal about envelope peaks.

- Opening: Present a thesis that answers this precise question: Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale. Identify which evidence would falsify the proposed conclusion Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Core terminology and scope: Define scale, square, ratios in the question's particular technical setting; explain how reveal, envelope, peaks differ if that distinction would change the analysis of "Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale" Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the actual message mean square in Equation 11G Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale to the claimed result, following "Amplitude modulation beyond the textbook envelope formula"; name the

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intermediate states and measurable outputs Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale. The two total-to-carrier power ratios are 1.32 and 1.128 respectively Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.3: Infer modulation depth from one resolved sideband” that resolves the question about Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale; derive the relevant result with units and stated validity conditions Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale. The common modulation scale does not make their average powers equal, because the average of the squared message is different Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Worked application or illustrative case: Build a worked example of “Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale”, addressing this associated condition: One has mean square 0.50 and the other 0.20. Use the

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actual message mean square in Equation 11G Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale”. Using “Application 6A.3: Infer modulation depth from one resolved sideband”, specify a discriminator and the result expected under each explanation Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale, including the effect of missing measurements and inconsistent operating conditions Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Scholarly synthesis and implications: Explain what the result about Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Closing: Conclude by answering “Two zero-mean bounded messages use the same carrier amplitude and the same modulation scale” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

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V011-C06-ESSAY-004. A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state. For a 75 Ω load, infer carrier peak and modulation depth, then calculate carrier, sideband, total and peak envelope powers. State when this inversion fails.

- Opening: Present a thesis that answers this precise question: A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state. Identify which evidence would falsify the proposed conclusion Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Core terminology and scope: Define extrema, infer, depth in the question's particular technical setting; explain how calculate, inversion, fails differ if that distinction would change the analysis of "A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state" Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The half-sum gives a carrier peak of 1.8 V, while the normalized difference gives modulation depth 0.5 Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state to the claimed result, following "Application 6A.8: Compare average power with peak envelope power for two SSB tones"; name the intermediate states and

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measurable outputs Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state. Carrier power is 21.6 mW, each sideband power is 1.35 mW, total average power is 24.3 mW and peak envelope power is 48.6 mW Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.1: Close the power accounting for sinusoidal AM” that resolves the question about A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state; derive the relevant result with units and stated validity conditions Source: §6.6 Application 6A.1: Close the power accounting for sinusoidal AM (p. 3118)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state. The inference assumes the ordinary sinusoidal nonnegative envelope, linear calibrated transfer, compatible extrema and a positive real load Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Worked application or illustrative case: Build a worked example of “A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state”, addressing this

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associated condition: For a 75 Ω load, infer carrier peak and modulation depth, then calculate carrier, sideband, total and.... The half-sum gives a carrier peak of 1.8 V, while the normalized difference gives modulation depth 0.5 Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state”. Using “Application 6A.1: Close the power accounting for sinusoidal AM”, specify a discriminator and the result expected under each explanation Source: §6.6 Application 6A.1: Close the power accounting for sinusoidal AM (p. 3118)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state, including the effect of missing measurements and inconsistent operating conditions Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Scholarly synthesis and implications: Explain what the result about A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in one stable gain state authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Closing: Conclude by answering “A calibrated sinusoidal conventional-AM magnitude envelope has extrema 2.7 V and 0.9 V in

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one stable gain state" using only the demonstrated evidence; state the remaining decisive verification step Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

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V011-C06-ESSAY-005. For the ideal signed envelope $1+1.5\cos(2\pi f_m t)$ volts across 50 Ω, determine the fraction of each modulation period for which the envelope is negative, the average RF power and the peak envelope power. Explain why a magnitude-only extrema estimate would misclassify the depth.

- Opening: Present a thesis that answers this precise question: For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is negative, the average RF power and the peak.... Identify which evidence would falsify the proposed conclusion Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Core terminology and scope: Define envelope, volts, fraction in the question's particular technical setting; explain how period, extrema, depth differ if that distinction would change the analysis of "For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is negative, the average RF power and the peak..." Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The signed envelope ranges from −0.5 V to 2.5 V Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is... to the claimed result,

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following “Application 6A.4: Show why an envelope-extrema estimate fails after reversal”; name the intermediate states and measurable outputs Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is.... It is negative when the modulation cosine is less than the fraction of a complete period is divided by π, approximately 0.267720 or 26.7720 percent Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.2: Infer the conventional-AM envelope parameters” that resolves the question about For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is...; derive the relevant result with units and stated validity conditions Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is.... The ideal algebraic RF waveform still has a 10 mW carrier and two 5.625 mW sidebands, giving 21.25 mW average power Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- Worked application or illustrative case: Build a worked example of “For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is…”, addressing this associated condition: Explain why a magnitude-only extrema estimate would misclassify the depth. The signed envelope ranges from -0.5 V to 2.5 V Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is…”. Using “Application 6A.2: Infer the conventional-AM envelope parameters”, specify a discriminator and the result expected under each explanation Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is…, including the effect of missing measurements and inconsistent operating conditions Source: §6.6 Application 6A.1: Close the power accounting for sinusoidal AM (p. 3118)
- Scholarly synthesis and implications: Explain what the result about For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- Closing: Conclude by answering “For the ideal signed envelope volts across 50 Ω, determine the fraction of each modulation period for which the envelope is negative, the average RF power and the peak…” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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V011-C06-ESSAY-006. An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6. Its LO has the correct frequency but a 40° phase error. Calculate recovered DC, message peak and amplitude loss. Explain the role of a quadrature record.

- Opening: Present a thesis that answers this precise question: An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6. Identify which evidence would falsify the proposed conclusion Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)
- Core terminology and scope: Define normalized, depth, Calculate in the question's particular technical setting; explain how recovered, message, quadrature differ if that distinction would change the analysis of "An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6" Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The low-pass result is the real envelope multiplied by the cosine of the reference phase error Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6 to the claimed result, following "Application 6A.10: Use message mean square rather than a sinusoidal shortcut"; name the intermediate states and measurable

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outputs Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6. The recovered DC is approximately 0.919253 V and the sinusoidal message peak is approximately 0.551552 V Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6B.2: Differentiate a sinusoidal PM phase” that resolves the question about An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6; derive the relevant result with units and stated validity conditions Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Evidence and method: Specify the native observations, control records and calculations that would resolve An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6. The message amplitude ratio to perfect phase alignment is cos(40°), corresponding to approximately −2.314921 dB Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)
- Worked application or illustrative case: Build a worked example of “An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6”, addressing this

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associated condition: Its LO has the correct frequency but a 40° phase error. The low-pass result is the real envelope multiplied by the cosine of the reference phase error Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6”. Using “Application 6B.2: Differentiate a sinusoidal PM phase”, specify a discriminator and the result expected under each explanation Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6, including the effect of missing measurements and inconsistent operating conditions Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Scholarly synthesis and implications: Explain what the result about An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6 authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)
- Closing: Conclude by answering “An ideal normalized real product detector receives a real AM envelope with carrier peak 1.2 V and depth 0.6” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

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V011-C06-ESSAY-007. A DSB-SC envelope is $0.8\cos(2\pi \times 1500t)$ volts. A real product detector has zero initial phase error and a residual frequency difference of 80 Hz. Derive the recovered components and explain why a short audio record can be misleading.

- Opening: Present a thesis that answers this precise question: A DSB-SC envelope is volts. Identify which evidence would falsify the proposed conclusion Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)
- Core terminology and scope: Define envelope, volts, initial in the question's particular technical setting; explain how recovered, audio, misleading differ if that distinction would change the analysis of "A DSB-SC envelope is volts" Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The real detector multiplies the real message by the cosine of the residual 80 Hz rotation Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A DSB-SC envelope is volts to the claimed result, following "Application 6A.5: Measure phase-dependent coherent-AM recovery"; name the intermediate states and measurable outputs Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A DSB-SC envelope is volts. Expanding the product gives components at

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1420 Hz and 1580 Hz, each with peak 0.4 V under the declared detector normalization Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6B.10: Separate reference offset from a deterministic modulation” that resolves the question about A DSB-SC envelope is volts; derive the relevant result with units and stated validity conditions Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A DSB-SC envelope is volts. This is a time-varying projection, not one 1500 Hz tone with a fixed gain error Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)
- Worked application or illustrative case: Build a worked example of “A DSB-SC envelope is volts”, addressing this associated condition: A real product detector has zero initial phase error and a residual frequency difference of 80 Hz. The real detector multiplies the real message by the cosine of the residual 80 Hz rotation Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A DSB-SC envelope is volts”. Using “Application 6B.10: Separate reference offset from a deterministic modulation”, specify a discriminator and the result expected under each explanation Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A DSB-SC envelope is volts, including the effect of missing measurements and inconsistent operating conditions Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Scholarly synthesis and implications: Explain what the result about A DSB-SC envelope is volts authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)
- Closing: Conclude by answering “A DSB-SC envelope is volts” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)

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V011-C06-ESSAY-008. A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz. In a 50 Ω load, determine average power, peak envelope power and their ratio in decibels. Explain the observation interval needed for those results.

- Opening: Present a thesis that answers this precise question: A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz. Identify which evidence would falsify the proposed conclusion Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Core terminology and scope: Define envelope, contains, load in the question's particular technical setting; explain how average, decibels, results differ if that distinction would change the analysis of "A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz" Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Over complete beat periods, the cross term averages to zero and the mean squared envelope magnitude is or 1.06 Average RF power is therefore 10.6 mW Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz to the claimed result, following "Application 6A.10: Use message mean square rather than a sinusoidal shortcut"; name

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the intermediate states and measurable outputs Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz. When the components align, the envelope magnitude is 1.4 V and peak envelope power is 19.6 mW Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.2: Infer the conventional-AM envelope parameters” that resolves the question about A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz; derive the relevant result with units and stated validity conditions Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz. The ratio is approximately 2.669502 dB Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Worked application or illustrative case: Build a worked example of “A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz”, addressing this associated condition: In a 50 Ω load, determine average power, peak envelope power and their ratio in decibels. Over complete beat periods, the

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cross term averages to zero and the mean squared envelope magnitude is or 1.06 Average RF power is therefore 10.6 mW Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz”. Using “Application 6A.2: Infer the conventional-AM envelope parameters”, specify a discriminator and the result expected under each explanation Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz, including the effect of missing measurements and inconsistent operating conditions Source: §6.6 Application 6A.1: Close the power accounting for sinusoidal AM (p. 3118)
- Scholarly synthesis and implications: Explain what the result about A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Closing: Conclude by answering “A two-tone upper-sideband envelope contains peak components 0.9 V and 0.5 V at +1 kHz and +2 kHz” using only the demonstrated evidence; state the remaining

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decisive verification step Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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V011-C06-ESSAY-009. A filtered AM signal has real envelope coefficients $c_0 = 1$ V, $c_{+¿=0.35¿}$ V and $c_{-} = 0.15$ V. Derive I and Q, and evaluate the envelope magnitude and phase at a modulation angle of $\frac{\pi}{2}$. Explain what the result says about an envelope-only estimate of source depth.

- Opening: Present a thesis that answers this precise question: A filtered AM signal has real envelope coefficients V, V and V. Identify which evidence would falsify the proposed conclusion Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Core terminology and scope: Define filtered, envelope, angle in the question's particular technical setting; explain how says, estimate, depth differ if that distinction would change the analysis of "A filtered AM signal has real envelope coefficients V, V and V" Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Problem statement and purpose: Frame the actual measurement or decision in the question. For these explicitly real coefficients, the in-phase component is 1 + 0.50 cos of the modulation angle, while the quadrature component is 0.20 sin of that angle Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A filtered AM signal has real envelope coefficients V, V and V to the claimed result, following "Frequency modulation, phase modulation and the dangers of differentiation"; name the intermediate states and measurable outputs Source: §6.40 Frequency modulation, phase modulation and the dangers of differentiation (p. 3168)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A filtered AM signal has real envelope coefficients V, V and V. At the complex envelope is V Source: §6.40 Frequency modulation, phase modulation and the dangers of differentiation (p. 3168)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Amplitude modulation beyond the textbook envelope formula” that resolves the question about A filtered AM signal has real envelope coefficients V, V and V; derive the relevant result with units and stated validity conditions Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A filtered AM signal has real envelope coefficients V, V and V. Its magnitude is approximately 1.019804 V and its phase is approximately 0.197396 radians Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Worked application or illustrative case: Build a worked example of “A filtered AM signal has real envelope coefficients V, V and V”, addressing this associated condition: Derive I and Q, and evaluate the envelope magnitude and phase at a modulation angle of Explain what the.... For these explicitly real coefficients, the in-phase component is 1 + 0.50 cos of the modulation angle, while the quadrature component is 0.20 sin of that angle Source: §6.40 Frequency modulation, phase modulation and the dangers of differentiation (p. 3168)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “A filtered AM signal has real envelope coefficients V, V and V”. Using “Amplitude modulation beyond the textbook envelope formula”, specify a discriminator and the result expected under each explanation Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A filtered AM signal has real envelope coefficients V, V and V, including the effect of missing measurements and inconsistent operating conditions Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
- Scholarly synthesis and implications: Explain what the result about A filtered AM signal has real envelope coefficients V, V and V authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Closing: Conclude by answering “A filtered AM signal has real envelope coefficients V, V and V” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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V011-C06-ESSAY-010. A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz. Find the signed complex frequencies for the upper and lower sideband cases. Explain the information lost by retaining only real-audio magnitudes.

- Opening: Present a thesis that answers this precise question: A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz. Identify which evidence would falsify the proposed conclusion Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)
- Core terminology and scope: Define message, reinsertion, cases in the question's particular technical setting; explain how lost, retaining, magnitudes differ if that distinction would change the analysis of "A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz" Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The upper-sideband RF component is at carrier plus message frequency, so its signed complex baseband frequency is +2025 Hz Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz to the claimed result, following "Application 6A.9: Separate sideband filtering from source modulation depth";

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name the intermediate states and measurable outputs Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz. The lower-sideband component is at carrier minus message frequency, giving −2375 Hz Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6B.4: Bound and attain the deviation of a two-tone phase” that resolves the question about A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz; derive the relevant result with units and stated validity conditions Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz. Both signed frequencies have been shifted by −175 Hz relative to ideal reinsertion Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)
- Worked application or illustrative case: Build a worked example of “A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz”, addressing this associated condition: Find the signed complex frequencies for the upper and lower sideband cases. The upper-sideband RF component is at

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carrier plus message frequency, so its signed complex baseband frequency is +2025 Hz Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz”. Using “Application 6B.4: Bound and attain the deviation of a two-tone phase”, specify a discriminator and the result expected under each explanation Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz, including the effect of missing measurements and inconsistent operating conditions Source: §6.3 Single Sideband and Coherent Reception (p. 3110)
- Scholarly synthesis and implications: Explain what the result about A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)
- Closing: Conclude by answering “A carrier reference is 15 MHz, the message tone is 2.2 kHz and the reinsertion LO is 15,000,175 Hz” using only the demonstrated evidence; state the remaining decisive

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verification step Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

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V011-C06-ESSAY-011. Compare two hypothetical modulators at message frequencies 1 kHz and 4 kHz. The PM case maintains peak phase 0.9 rad; the FM case maintains peak deviation 1.8 kHz. Derive the corresponding deviations and phase indices, and explain why a spectrum or audio level alone may not distinguish their generating law.

- Opening: Present a thesis that answers this precise question: Compare two hypothetical modulators at message frequencies 1 kHz and 4 kHz. Identify which evidence would falsify the proposed conclusion Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Core terminology and scope: Define message, maintains, deviations in the question's particular technical setting; explain how indices, audio, generating differ if that distinction would change the analysis of "Compare two hypothetical modulators at message frequencies 1 kHz and 4 kHz" Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Problem statement and purpose: Frame the actual measurement or decision in the question. For the stated PM law, differentiation makes peak deviation equal to peak phase times modulation frequency Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting two hypothetical modulators at message frequencies 1 kHz and 4 kHz to the claimed result, following "Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation"; name the intermediate states and

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measurable outputs Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for two hypothetical modulators at message frequencies 1 kHz and 4 kHz. The deviations are therefore 0.9 kHz and 3.6 kHz Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6B.2: Differentiate a sinusoidal PM phase” that resolves the question about two hypothetical modulators at message frequencies 1 kHz and 4 kHz; derive the relevant result with units and stated validity conditions Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Evidence and method: Specify the native observations, control records and calculations that would resolve two hypothetical modulators at message frequencies 1 kHz and 4 kHz. For the stated FM law, integration makes the phase index equal to peak deviation divided by modulation frequency, giving 1.8 rad and 0.45 rad Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Worked application or illustrative case: Build a worked example of “two hypothetical modulators at message frequencies 1 kHz and 4 kHz”, addressing this associated condition: The PM case maintains peak phase 0.9 rad; the FM case maintains peak deviation 1.8 kHz. For the stated PM law, differentiation makes peak deviation equal to peak phase times modulation frequency Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “two hypothetical modulators at message frequencies 1 kHz and 4 kHz”. Using “Application 6B.2: Differentiate a sinusoidal PM phase”, specify a discriminator and the result expected under each explanation Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to two hypothetical modulators at message frequencies 1 kHz and 4 kHz, including the effect of missing measurements and inconsistent operating conditions Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Scholarly synthesis and implications: Explain what the result about two hypothetical modulators at message frequencies 1 kHz and 4 kHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Closing: Conclude by answering “Compare two hypothetical modulators at message frequencies 1 kHz and 4 kHz” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)

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V011-C06-ESSAY-012. A deterministic frequency deviation rises linearly from −3 kHz at $t=0$ to +3 kHz at $t=6$ ms. Starting from zero additional phase, calculate the phase at 3 ms and 6 ms. Explain why equal endpoint phase does not mean the signal had zero deviation.

- Opening: Present a thesis that answers this precise question: A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms. Identify which evidence would falsify the proposed conclusion Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)
- Core terminology and scope: Define deviation, rises, linearly in the question's particular technical setting; explain how Starting, calculate, endpoint differ if that distinction would change the analysis of "A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms" Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Integrate the frequency deviation in hertz over time in seconds and multiply the result by The first half is a negative triangle with area −4.5 cycles, so the additional phase at 3 ms is radians Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms to the claimed result, following "Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation"; name the

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intermediate states and measurable outputs Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms. The positive second half contributes +4.5 cycles and brings the additional phase at 6 ms back to zero Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6B.1: Convert a sinusoidal FM deviation into phase excursion” that resolves the question about A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms; derive the relevant result with units and stated validity conditions Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms. The net endpoint increment is therefore zero even though the deviation is nonzero almost everywhere except the midpoint Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)
- Worked application or illustrative case: Build a worked example of “A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms”, addressing this associated condition: Starting from zero additional phase, calculate the phase at 3 ms and 6 ms. Integrate

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the frequency deviation in hertz over time in seconds and multiply the result by The first half is a negative triangle with area −4.5 cycles, so the additional… Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms”. Using “Application 6B.1: Convert a sinusoidal FM deviation into phase excursion”, specify a discriminator and the result expected under each explanation Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms, including the effect of missing measurements and inconsistent operating conditions Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Scholarly synthesis and implications: Explain what the result about A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)
- Closing: Conclude by answering “A deterministic frequency deviation rises linearly from −3 kHz at to +3 kHz at ms” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

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V011-C06-ESSAY-013. For phase $\varphi(t)=0.4\sin(2\pi\times 1200t)+0.15\sin(2\pi\times 3200t)$ radians, derive the deviation components, a peak bound and a Carson estimate. Decide whether the bound is attained for these stated phases.

- Opening: Present a thesis that answers this precise question: For phase radians, derive the deviation components, a peak bound and a Carson estimate. Decide whether the bound is attained for these stated phases. Identify which evidence would falsify the proposed conclusion Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Core terminology and scope: Define radians, deviation, Carson in the question's particular technical setting; explain how estimate, attained, phases differ if that distinction would change the analysis of "For phase radians, derive the deviation components, a peak bound and a Carson estimate. Decide whether the bound is attained for these stated phases" Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Differentiation and division by give deviation components of Hz and Hz Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For phase radians, derive the deviation components, a peak bound and a Carson estimate to the claimed result, following "Application 6B.2: Differentiate a sinusoidal PM phase"; name the intermediate states

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and measurable outputs Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For phase radians, derive the deviation components, a peak bound and a Carson estimate. The magnitude is bounded by 960 Hz Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6B.1: Convert a sinusoidal FM deviation into phase excursion” that resolves the question about For phase radians, derive the deviation components, a peak bound and a Carson estimate; derive the relevant result with units and stated validity conditions Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For phase radians, derive the deviation components, a peak bound and a Carson estimate. At both cosines equal one, so the positive bound is attained for this particular phase specification; the bound is not merely a loose inequality here Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Worked application or illustrative case: Build a worked example of “For phase radians, derive the deviation components, a peak bound and a Carson estimate”, addressing this associated condition: Decide whether the bound is attained for these stated phases.

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Differentiation and division by give deviation components of Hz and Hz Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “For phase radians, derive the deviation components, a peak bound and a Carson estimate”. Using “Application 6B.1: Convert a sinusoidal FM deviation into phase excursion”, specify a discriminator and the result expected under each explanation Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For phase radians, derive the deviation components, a peak bound and a Carson estimate, including the effect of missing measurements and inconsistent operating conditions Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)
- Scholarly synthesis and implications: Explain what the result about For phase radians, derive the deviation components, a peak bound and a Carson estimate authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Closing: Conclude by answering “For phase radians, derive the deviation components, a peak bound and a Carson estimate. Decide whether the bound is attained for these stated phases” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

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V011-C06-ESSAY-014. At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment. Determine its principal-frequency representative and alias family. Explain what additional evidence could justify selecting the +43 kHz member.

- Opening: Present a thesis that answers this precise question: At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment. Identify which evidence would falsify the proposed conclusion Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)
- Core terminology and scope: Define baseband, principal, increment in the question's particular technical setting; explain how representative, family, selecting differ if that distinction would change the analysis of "At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment" Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The principal interval is from −32 kHz inclusive to +32 kHz exclusive Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment to the claimed result, following "Application 6B.2: Differentiate a sinusoidal PM

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phase"; name the intermediate states and measurable outputs Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment. The +43 kHz component therefore has representative −21 kHz, and the indistinguishable constant-frequency family is −21 kHz plus an integer multiple of 64 kHz Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 6B.10: Separate reference offset from a deterministic modulation" that resolves the question about At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment; derive the relevant result with units and stated validity conditions Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Evidence and method: Specify the native observations, control records and calculations that would resolve At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment. The principal phase increment is times radians, approximately −2.061670 radians Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)
- Worked application or illustrative case: Build a worked example of "At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment",

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addressing this associated condition: Determine its principal-frequency representative and alias family. The principal interval is from −32 kHz inclusive to +32 kHz exclusive Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment”. Using “Application 6B.10: Separate reference offset from a deterministic modulation”, specify a discriminator and the result expected under each explanation Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment, including the effect of missing measurements and inconsistent operating conditions Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Scholarly synthesis and implications: Explain what the result about At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a principal phase increment authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)
- Closing: Conclude by answering “At a complex sample rate of 64 ksample/s, a constant +43 kHz baseband component produces a

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principal phase increment" using only the demonstrated evidence; state the remaining decisive verification step Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

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V011-C06-ESSAY-015. Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier. Calculate the three interval-average deviations and the full-interval average. State whether any value is automatically the instantaneous frequency at a sample.

- Opening: Present a thesis that answers this precise question: Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier. Identify which evidence would falsify the proposed conclusion Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)
- Core terminology and scope: Define Correctly, unwrapped, Calculate in the question's particular technical setting; explain how deviations, automatically, instantaneous differ if that distinction would change the analysis of "Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier" Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Divide each phase increment by and by its 50 μs interval Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier to the claimed result, following "Application 6B.4: Bound and attain the deviation of a two-

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tone phase"; name the intermediate states and measurable outputs Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier. The three average deviations are approximately 318.309886 Hz, 509.295818 Hz and 763.943727 Hz Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Model 6B: phase is the quantity that frequency differentiates" that resolves the question about Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier; derive the relevant result with units and stated validity conditions Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier. The full 150 μs interval gives approximately 530.516477 Hz, which also equals the equally weighted mean of the three adjacent interval averages Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)
- Worked application or illustrative case: Build a worked example of "Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0,

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0.10, 0.26 and 0.50 radians relative to the carrier", addressing this associated condition: Calculate the three interval-average deviations and the full-interval average. Divide each phase increment by and by its 50 μs interval Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier". Using "Model 6B: phase is the quantity that frequency differentiates", specify a discriminator and the result expected under each explanation Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier, including the effect of missing measurements and inconsistent operating conditions Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)
- Scholarly synthesis and implications: Explain what the result about Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians relative to the carrier authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)
- Closing: Conclude by answering "Correctly unwrapped phase samples at 0, 50, 100 and 150 μs are 0, 0.10, 0.26 and 0.50 radians

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relative to the carrier" using only the demonstrated evidence; state the remaining decisive verification step Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

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V011-C06-ESSAY-016. For sinusoidal phase with peak $\beta = 0.12$ rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier, and evaluate the pointwise remainder bound. Explain the limits of the approximation.

- Opening: Present a thesis that answers this precise question: For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier, and evaluate the pointwise remainder bound. Identify which evidence would falsify the proposed conclusion Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)
- Core terminology and scope: Define sinusoidal, amplitudes, unmodulated in the question's particular technical setting; explain how pointwise, remainder, approximation differ if that distinction would change the analysis of "For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier, and evaluate the pointwise remainder bound" Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The retained linear term gives sideband peak-amplitude magnitudes of or 0.06 relative to the unmodulated unit carrier Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For sinusoidal phase with peak rad, state the first-order sideband amplitudes and

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powers relative to an unmodulated unit carrier,… to the claimed result, following “Application 6A.9: Separate sideband filtering from source modulation depth”; name the intermediate states and measurable outputs Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier,…. Each retained sideband power ratio is 0.0036, approximately −24.436975 dB relative to that stated unmodulated reference Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.3: Infer modulation depth from one resolved sideband” that resolves the question about For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier,…; derive the relevant result with units and stated validity conditions Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier,…. The pointwise complex-envelope remainder is bounded by or 0.0072 Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

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- Worked application or illustrative case: Build a worked example of “For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier,…”, addressing this associated condition: Explain the limits of the approximation. The retained linear term gives sideband peak-amplitude magnitudes of or 0.06 relative to the unmodulated unit carrier Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier,…”. Using “Application 6A.3: Infer modulation depth from one resolved sideband”, specify a discriminator and the result expected under each explanation Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier,…, including the effect of missing measurements and inconsistent operating conditions Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)
- Scholarly synthesis and implications: Explain what the result about For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier,… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

- Closing: Conclude by answering “For sinusoidal phase with peak rad, state the first-order sideband amplitudes and powers relative to an unmodulated unit carrier, and evaluate the pointwise remainder bound” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

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V011-C06-ESSAY-017. A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz. An operator proposes a nominal 16 kHz IF because Carson's rule gives 16 kHz. Assess that proposal and design an acceptance check.

- Opening: Present a thesis that answers this precise question: A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz. Identify which evidence would falsify the proposed conclusion Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)
- Core terminology and scope: Define highest, significant, modulating in the question's particular technical setting; explain how Carson, proposal, design differ if that distinction would change the analysis of "A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz" Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The arithmetic gives an engineering bandwidth estimate of 16 kHz, but equality between that estimate and a nominal IF width does not establish adequate passage or a specified power-containment... Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz to the claimed result, following "Application 6B.4: Bound and attain the deviation of a two-tone phase"; name the

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intermediate states and measurable outputs Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz. Ask which attenuation level defines the IF width, its ripple and phase response, and how the modulation energy is distributed Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6B.1: Convert a sinusoidal FM deviation into phase excursion” that resolves the question about A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz; derive the relevant result with units and stated validity conditions Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz. A nominal width also does not describe transition-band behavior or group delay Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)
- Worked application or illustrative case: Build a worked example of “A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz”, addressing this associated condition: An operator proposes a nominal 16 kHz IF because

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Carson's rule gives 16 kHz. The arithmetic gives an engineering bandwidth estimate of 16 kHz, but equality between that estimate and a nominal IF width does not establish adequate passage or a… Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz". Using "Application 6B.1: Convert a sinusoidal FM deviation into phase excursion", specify a discriminator and the result expected under each explanation Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz, including the effect of missing measurements and inconsistent operating conditions Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Scholarly synthesis and implications: Explain what the result about A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)
- Closing: Conclude by answering "A waveform has measured peak deviation 6 kHz and highest significant modulating frequency 2 kHz"

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using only the demonstrated evidence; state the remaining decisive verification step Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

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V011-C06-ESSAY-018. A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference phase of −25°. Derive its frequency range and the residual phase advance over 5 ms. Explain which corrections can remove legitimate evidence if estimated carelessly.

- Opening: Present a thesis that answers this precise question: A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference phase of −25°. Identify which evidence would falsify the proposed conclusion Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Core terminology and scope: Define contains, constant, corrections in the question's particular technical setting; explain how remove, legitimate, estimated differ if that distinction would change the analysis of "A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference phase of −25°" Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The PM contribution has peak frequency deviation 0.6 times 2500 Hz, or 1500 Hz Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference… to the claimed result,

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following “Application 6B.2: Differentiate a sinusoidal PM phase”; name the intermediate states and measurable outputs Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference…. Adding the +120 Hz residual offset yields a baseband frequency range from −1380 Hz to +1620 Hz Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong” that resolves the question about A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference…; derive the relevant result with units and stated validity conditions Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference…. The constant −25° phase offset has zero derivative Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Worked application or illustrative case: Build a worked example of “A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference…”,

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addressing this associated condition: Derive its frequency range and the residual phase advance over 5 ms. The PM contribution has peak frequency deviation 0.6 times 2500 Hz, or 1500 Hz Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference…”. Using “Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong”, specify a discriminator and the result expected under each explanation Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference…, including the effect of missing measurements and inconsistent operating conditions Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Scholarly synthesis and implications: Explain what the result about A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)
- Closing: Conclude by answering “A complex record contains PM with peak phase 0.6 rad at 2.5 kHz, a residual frequency offset of +120 Hz and a constant reference phase of −25°” using only the

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demonstrated evidence; state the remaining decisive verification step Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

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V011-C06-ESSAY-019. Design a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states. Address reference-plane consistency, sideband transfer, extrema selection and the acceptance conclusion.

- Opening: Present a thesis that answers this precise question: Design a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states. Identify which evidence would falsify the proposed conclusion Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Core terminology and scope: Define Design, support, sinusoidal in the question's particular technical setting; explain how consistency, extrema, conclusion differ if that distinction would change the analysis of "Design a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states" Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Specify the AM reference frequency, modulation rate and depth, carrier level, load and uncertainty relevant to the intended result Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states to the claimed result, following "Application 6A.3: Infer modulation depth from one resolved sideband"; name the intermediate states and measurable outputs

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Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states. Exercise levels and gain states representative of the observation while keeping the reference below applicable peak and average limits Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.9: Separate sideband filtering from source modulation depth” that resolves the question about a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states; derive the relevant result with units and stated validity conditions Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states. Verify both sidebands, not only the center-frequency carrier, and inspect complex or coherent response where asymmetry matters Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Worked application or illustrative case: Build a worked example of “a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states”, addressing this associated

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condition: Address reference-plane consistency, sideband transfer, extrema selection and the acceptance conclusion. Specify the AM reference frequency, modulation rate and depth, carrier level, load and uncertainty relevant to the intended result Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states”. Using “Application 6A.9: Separate sideband filtering from source modulation depth”, specify a discriminator and the result expected under each explanation Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states, including the effect of missing measurements and inconsistent operating conditions Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)
- Scholarly synthesis and implications: Explain what the result about a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Closing: Conclude by answering “Design a reference test that can support a sinusoidal AM modulation-depth measurement across several gain states” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

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V011-C06-ESSAY-020. A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present. Explain why capture, limiting and threshold behavior prevent an audio-only absence conclusion, and propose an evidence-preserving investigation.

- Opening: Present a thesis that answers this precise question: A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present. Identify which evidence would falsify the proposed conclusion Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)
- Core terminology and scope: Define clean, weaker, limiting in the question's particular technical setting; explain how prevent, absence, investigation differ if that distinction would change the analysis of "A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present" Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate the incoming waveform from the nonlinear and selective receiver operations Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present to the claimed result, following "Frequency and Phase Modulation"; name the

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intermediate states and measurable outputs Source: §6.16 Frequency and Phase Modulation (p. 3128)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present. Limiting can reduce amplitude variation without preserving all multi-component information Source: §6.16 Frequency and Phase Modulation (p. 3128)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Carrier, Sidebands, and Modulation Evidence” that resolves the question about A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present; derive the relevant result with units and stated validity conditions Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present. Clean audio therefore does not establish that the admitted RF contained only one source Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)
- Worked application or illustrative case: Build a worked example of “A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present”, addressing this associated condition: Explain why capture, limiting and threshold behavior prevent an audio-only absence conclusion, and.... Separate

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the incoming waveform from the nonlinear and selective receiver operations Source: §6.16 Frequency and Phase Modulation (p. 3128)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present”. Using “Carrier, Sidebands, and Modulation Evidence”, specify a discriminator and the result expected under each explanation Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present, including the effect of missing measurements and inconsistent operating conditions Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Scholarly synthesis and implications: Explain what the result about A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)
- Closing: Conclude by answering “A strong FM signal is followed by apparently clean audio, but a weaker simultaneous component may be present” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

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V011-C06-ESSAY-021. A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output. Develop a procedure to distinguish a missed event from an acquired event altered by the receiver.

- Opening: Present a thesis that answers this precise question: A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output. Identify which evidence would falsify the proposed conclusion Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Core terminology and scope: Define train, intermittently, strongly in the question's particular technical setting; explain how distorted, acquired, altered differ if that distinction would change the analysis of "A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output" Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Treat acquisition continuity and waveform transfer as separate questions Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output to the claimed result, following "Pulse, Radar, and Transient Reception"; name the intermediate states and measurable outputs Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output. Establish the expected or independently observed event timing, trigger operation, dwell or record coverage, sample continuity and any processing dead time Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.9: Separate sideband filtering from source modulation depth” that resolves the question about A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output; derive the relevant result with units and stated validity conditions Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output. A gap can explain why a pulse was not acquired Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Worked application or illustrative case: Build a worked example of “A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output”, addressing this associated condition: Develop a procedure to distinguish a missed event from an acquired event altered by the receiver. Treat

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acquisition continuity and waveform transfer as separate questions Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output”. Using “Application 6A.9: Separate sideband filtering from source modulation depth”, specify a discriminator and the result expected under each explanation Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output, including the effect of missing measurements and inconsistent operating conditions Source: §6.45 Pulse modulation as a measurable time-frequency process and not merely on-off keying (p. 3178)
- Scholarly synthesis and implications: Explain what the result about A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Closing: Conclude by answering “A pulse train appears intermittently in a spectrum display and is strongly distorted in a recorded detector output” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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V011-C06-ESSAY-022. A demodulated tone is suspected to represent unintended information. Construct three competing technical explanations and a discriminating test sequence that preserves the original evidence.

- Opening: Present a thesis that answers this precise question: A demodulated tone is suspected to represent unintended information. Construct three competing technical explanations and a discriminating test sequence that preserves the.... Identify which evidence would falsify the proposed conclusion Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Core terminology and scope: Define demodulated, suspected, unintended in the question's particular technical setting; explain how Construct, competing, discriminating differ if that distinction would change the analysis of "A demodulated tone is suspected to represent unintended information. Construct three competing technical explanations and a discriminating test sequence that preserves the..." Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Possible explanations include a genuine modulation component in the admitted RF, an internal mixing or reference artifact, and a demodulator or processing response to noise or another signal Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A demodulated tone is suspected to represent unintended information to the

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claimed result, following “Preserve pulse and demodulator evidence across representations”; name the intermediate states and measurable outputs Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A demodulated tone is suspected to represent unintended information. Begin by preserving native samples and all original settings Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Analog Demodulator Verification” that resolves the question about A demodulated tone is suspected to represent unintended information; derive the relevant result with units and stated validity conditions Source: §6.31 Analog Demodulator Verification (p. 3152)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A demodulated tone is suspected to represent unintended information. Compare whether the tone follows a predicted RF feature under a documented tuning change Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Worked application or illustrative case: Build a worked example of “A demodulated tone is suspected to represent unintended information”, addressing this associated condition: Construct three competing technical explanations and a discriminating test sequence that preserves the.... Possible explanations include a

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genuine modulation component in the admitted RF, an internal mixing or reference artifact, and a demodulator or processing response to... Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A demodulated tone is suspected to represent unintended information”. Using “Analog Demodulator Verification”, specify a discriminator and the result expected under each explanation Source: §6.31 Analog Demodulator Verification (p. 3152)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A demodulated tone is suspected to represent unintended information, including the effect of missing measurements and inconsistent operating conditions Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Scholarly synthesis and implications: Explain what the result about A demodulated tone is suspected to represent unintended information authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Closing: Conclude by answering “A demodulated tone is suspected to represent unintended information. Construct three competing technical explanations and a discriminating test sequence that preserves the...” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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V011-C06-ESSAY-023. Specify a reproducible evidence package for an audio product derived from a complex RF record. Explain how it permits a second analyst to distinguish a receiver-state change from a signal change.

- Opening: Present a thesis that answers this precise question: Specify a reproducible evidence package for an audio product derived from a complex RF record. Explain how it permits a second analyst to distinguish a receiver-state change.... Identify which evidence would falsify the proposed conclusion Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Core terminology and scope: Define Specify, reproducible, package in the question's particular technical setting; explain how audio, permits, analyst differ if that distinction would change the analysis of "Specify a reproducible evidence package for an audio product derived from a complex RF record. Explain how it permits a second analyst to distinguish a receiver-state change..." Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain the native complex data with its sample rate, center or conversion frequency, clock and time basis, channel orientation, units or scaling, continuity information and capture interval Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Specify a reproducible evidence package for an audio product derived from a complex RF record to the claimed result, following "Carrier,

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Sidebands, and Modulation Evidence"; name the intermediate states and measurable outputs Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Specify a reproducible evidence package for an audio product derived from a complex RF record. Record the exact extraction span, tuning correction, sideband convention, filter response, detector configuration, carrier or phase estimator, gain operation, limiting, squelch, de-emphasis Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Analog Demodulator Verification" that resolves the question about Specify a reproducible evidence package for an audio product derived from a complex RF record; derive the relevant result with units and stated validity conditions Source: §6.31 Analog Demodulator Verification (p. 3152)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Specify a reproducible evidence package for an audio product derived from a complex RF record. Preserve software identity and configuration where they affect the transformation Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Worked application or illustrative case: Build a worked example of "Specify a reproducible evidence package for an audio product derived from a complex RF record", addressing this associated

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condition: Explain how it permits a second analyst to distinguish a receiver-state change from a signal change. Retain the native complex data with its sample rate, center or conversion frequency, clock and time basis, channel orientation, units or scaling,... Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "Specify a reproducible evidence package for an audio product derived from a complex RF record". Using "Analog Demodulator Verification", specify a discriminator and the result expected under each explanation Source: §6.31 Analog Demodulator Verification (p. 3152)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Specify a reproducible evidence package for an audio product derived from a complex RF record, including the effect of missing measurements and inconsistent operating conditions Source: §6.16 Frequency and Phase Modulation (p. 3128)
- Scholarly synthesis and implications: Explain what the result about Specify a reproducible evidence package for an audio product derived from a complex RF record authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Closing: Conclude by answering "Specify a reproducible evidence package for an audio product derived from a complex RF record. Explain how it permits a second analyst to distinguish a receiver-state change..." using only the demonstrated evidence; state the

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remaining decisive verification step Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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V011-C06-ESSAY-024. Evaluate the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter. Explain how source authority, edition and independent derivation affect a defensible claim.

- Opening: Present a thesis that answers this precise question: Evaluate the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter. Identify which evidence would falsify the proposed conclusion Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Core terminology and scope: Define proper, cited, historical in the question's particular technical setting; explain how Navy, telemetry, derivation differ if that distinction would change the analysis of "Evaluate the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter" Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The Navy course supports the bounded carrier, sideband, envelope, modulation-rate and deviation relationships read in the identified pages Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter to the claimed result, following "Application 6B.4: Bound and attain the deviation of a two-tone

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phase"; name the intermediate states and measurable outputs Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter. Its historical allocation examples and broad noise-immunity claims are not universal modern receiver specifications Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 6B.1: Convert a sinusoidal FM deviation into phase excursion" that resolves the question about the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter; derive the relevant result with units and stated validity conditions Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter. The IRIG archive supports the stated Carson estimate and the dependence of its relation to power containment on modulating-energy distribution Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Worked application or illustrative case: Build a worked example of "the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter", addressing this

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associated condition: Explain how source authority, edition and independent derivation affect a defensible claim. The Navy course supports the bounded carrier, sideband, envelope, modulation-rate and deviation relationships read in the identified... Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter”. Using “Application 6B.1: Convert a sinusoidal FM deviation into phase excursion”, specify a discriminator and the result expected under each explanation Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter, including the effect of missing measurements and inconsistent operating conditions Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Scholarly synthesis and implications: Explain what the result about the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry appendix in this chapter authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)
- Closing: Conclude by answering “Evaluate the proper use of the cited historical Navy modulation course and the 2005 IRIG telemetry

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appendix in this chapter" using only the demonstrated evidence; state the remaining decisive verification step Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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V011-C06-ESSAY-025. An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts. Write an integrated technical assessment that separates what the record establishes from what still requires a test.

- Opening: Present a thesis that answers this precise question: An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts. Identify which evidence would falsify the proposed conclusion Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Core terminology and scope: Define asymmetric, sidebands, slowly in the question's particular technical setting; explain how drifting, integrated, separates differ if that distinction would change the analysis of "An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts" Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin with the retained RF or IF interval, reference plane and chain state Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts to the claimed result, following "Application 6A.9: Separate sideband filtering from source modulation depth"; name the intermediate states and measurable

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outputs Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts. Asymmetric sidebands may belong to the source or arise from unequal path transfer, interference or measurement error; a known coherent reference can test the relevant upper and lower responses Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Preserve pulse and demodulator evidence across representations” that resolves the question about An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts; derive the relevant result with units and stated validity conditions Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Evidence and method: Specify the native observations, control records and calculations that would resolve An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts. Pitch drift may reflect modulation, LO or recovery error, or processing, so compare the uncorrected complex phase with a justified frequency reference and retain any correction Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- Worked application or illustrative case: Build a worked example of “An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts”, addressing this associated condition: Write an integrated technical assessment that separates what the record establishes from what still.... Begin with the retained RF or IF interval, reference plane and chain state Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts”. Using “Preserve pulse and demodulator evidence across representations”, specify a discriminator and the result expected under each explanation Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts, including the effect of missing measurements and inconsistent operating conditions Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)
- Scholarly synthesis and implications: Explain what the result about An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- Closing: Conclude by answering “An observation contains asymmetric apparent AM sidebands, a slowly drifting audio pitch and occasional pulse-like dropouts” using only the demonstrated evidence; state the remaining decisive verification step Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C06-DISCUSSION-001. Should a plausible modulation classification be reported as a source identification?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a plausible modulation classification be reported as a source identification?” Put this particular dispute to the panel: Should a plausible modulation classification be reported as a source identification. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 02. Student A, terminology and scope: Agree the operational meanings of modulation, classification, reported and source, identification, measurement in “Should a plausible modulation classification be reported as a source identification”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a plausible modulation classification be reported as a source identification; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Laboratory qualification of an analogue-demodulation measurement claim”. Ask which observable features support the classification and whether the selected receiver path can create or suppress those features Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a plausible

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modulation classification be reported as a source identification; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Laboratory qualification of an analogue-demodulation measurement claim”. Ask which observable features support the classification and whether the selected receiver path can create or suppress those features Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate waveform evidence from identity, location and purpose Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a plausible modulation classification be reported as a source identification: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a plausible modulation classification be reported as a source identification; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a plausible modulation classification be reported as a source identification: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a plausible modulation classification be reported as a source identification, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a plausible modulation classification be reported as a source identification: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a plausible modulation classification be reported as a source identification. Identify independent evidence that would be needed for a source claim Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a plausible modulation classification be reported as a source identification, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a plausible modulation classification be reported as a source identification. Identify independent evidence that would be needed for a source claim Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a plausible modulation classification be reported as a source identification and Separate waveform evidence from identity, location and purpose; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a plausible modulation classification be reported as a source identification”, addressing “Separate waveform evidence from identity, location and purpose”;

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specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a plausible modulation classification be reported as a source identification”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a plausible modulation classification be reported as a source identification”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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V011-C06-DISCUSSION-002. When two analysts obtain different audio from the same native capture, what should they compare first?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When two analysts obtain different audio from the same native capture, what should they compare first?” Put this particular dispute to the panel: When two analysts obtain different audio from the same native capture, what should they compare first. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 02. Student A, terminology and scope: Agree the operational meanings of obtain, audio, same and native, capture, they in “When two analysts obtain different audio from the same native capture, what should they compare first”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When two analysts obtain different audio from the same native capture, what should they compare first; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Preserve pulse and demodulator evidence across representations”. Hold the native data fixed while changing one material processing choice at a time Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When two analysts obtain different audio from the same native capture, what should they

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compare first; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Preserve pulse and demodulator evidence across representations”. Hold the native data fixed while changing one material processing choice at a time Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare the extraction interval, signed frequency convention, tuning correction, sideband choice, detector, filters, gain operation, de-emphasis, squelch and output resampling Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving When two analysts obtain different audio from the same native capture, what should they compare first: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When two analysts obtain different audio from the same native capture, what should they compare first; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When two analysts obtain different audio from the same native capture, what should they

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compare first: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When two analysts obtain different audio from the same native capture, what should they compare first, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When two analysts obtain different audio from the same native capture, what should they compare first: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the

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panel to retain, qualify or reject the conclusion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When two analysts obtain different audio from the same native capture, what should they compare first. A reproducible difference in derived output does not imply that the external signal changed Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When two analysts obtain different audio from the same native capture, what should they compare first, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When two analysts obtain different audio from the same native capture, what should they compare first. A reproducible difference in derived output does not imply that the external signal changed Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When two analysts obtain different audio from the same native capture, what should they compare first and Compare the extraction interval, signed frequency convention, tuning correction, sideband choice, detector,…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When two analysts obtain different audio from the same native capture, what should they compare first”, addressing “Compare the extraction interval, signed frequency convention, tuning correction, sideband choice, detector,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When two analysts obtain different audio from the same native capture, what should they compare first”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When two analysts obtain different audio from the same native capture, what should they compare first”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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V011-C06-DISCUSSION-003. Is a magnitude envelope sufficient for every AM-related investigation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is a magnitude envelope sufficient for every AM-related investigation?” Put this particular dispute to the panel: Is a magnitude envelope sufficient for every AM-related investigation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 02. Student A, terminology and scope: Agree the operational meanings of magnitude, envelope, sufficient and every, AM-related, investigation in “Is a magnitude envelope sufficient for every AM-related investigation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is a

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magnitude envelope sufficient for every AM-related investigation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. A magnitude record can still answer a bounded amplitude question, but it may discard the sign or quadrature relation needed for a stronger inference Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is a magnitude envelope sufficient for every AM-related investigation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change

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your opinion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. A magnitude record can still answer a bounded amplitude question, but it may discard the sign or quadrature relation needed for a stronger inference Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss the nonnegative conventional-AM domain in which magnitude retains the signed envelope, then contrast envelope reversal and unequal complex sideband response Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Is a magnitude envelope sufficient for every AM-related investigation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is a magnitude envelope sufficient for every AM-related investigation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is a magnitude envelope sufficient for every AM-related investigation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is a magnitude envelope sufficient for every AM-related investigation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is a magnitude envelope sufficient for every AM-related investigation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is a magnitude envelope sufficient for every AM-related investigation. Decide what additional coherent or complex capture would resolve the specific ambiguity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is a magnitude envelope sufficient for every AM-related investigation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is a magnitude envelope sufficient for every AM-related investigation. Decide what additional coherent or complex capture would resolve the specific ambiguity Respond point by point

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to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is a magnitude envelope sufficient for every AM-related investigation and Discuss the nonnegative conventional-AM domain in which magnitude retains the signed envelope, then contrast…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.39 Coherent AM, suppressed carriers and single-sideband ambiguity (p. 3166)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is a magnitude envelope sufficient for every AM-related investigation”, addressing “Discuss the nonnegative conventional-AM domain in which magnitude retains the signed envelope, then contrast…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the

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narrow agreement and the specific contested proposition that remains unresolved. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Is a magnitude envelope sufficient for every AM-related investigation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Is a magnitude envelope sufficient for every AM-related investigation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

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V011-C06-DISCUSSION-004. Should inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result?” Put this particular dispute to the panel: Should inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 02. Student A, terminology and scope: Agree the operational meanings of inconsistent, sideband-power, estimates and averaged, single, modulation-depth in “Should inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. Investigate asymmetry, response, noise and clipping before combining them Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether inconsistent

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envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. Investigate asymmetry, response, noise and clipping before combining them Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. First test whether both estimates refer to the same source interval, gain state, reference plane, averaging convention and sinusoidal model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result. A discrepancy can be evidence against a shared assumption rather than two independent random errors Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement

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accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result. A discrepancy can be evidence against a shared assumption rather than two independent random errors Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result and ; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result”, addressing “”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should inconsistent envelope-extrema and sideband-power estimates be averaged into a single modulation-depth result”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

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V011-C06-DISCUSSION-005. What does a near-zero minimum in an envelope trace establish about modulation depth?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What does a near-zero minimum in an envelope trace establish about modulation depth?” Put this particular dispute to the panel: What does a near-zero minimum in an envelope trace establish about modulation depth. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- 02. Student A, terminology and scope: Agree the operational meanings of near-zero, minimum, envelope and trace, modulation, depth in “What does a near-zero minimum in an envelope trace establish about modulation depth”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What does a near-zero minimum in an envelope trace establish about modulation depth; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6A.9: Separate sideband filtering from source modulation depth”. Retain a stable interval and inspect the relevant signed or complex relationship Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What does a near-zero minimum in an envelope trace establish about modulation depth;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6A.9: Separate sideband filtering from source modulation depth”. Retain a stable interval and inspect the relevant signed or complex relationship Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A minimum near zero is compatible with the boundary of nonnegative sinusoidal AM Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What does a near-zero minimum in an envelope trace establish about modulation depth: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What does a near-zero minimum in an envelope trace establish about modulation depth; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What does a near-zero minimum in an envelope trace establish about modulation depth: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What does a near-zero minimum in an envelope trace establish about modulation depth, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What does a near-zero minimum in an envelope trace establish about modulation depth: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What does a near-zero minimum in an envelope trace establish about modulation depth. Ask whether the maximum and minimum belong to one calibrated state Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What does a near-zero minimum in an envelope trace establish about modulation depth, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What does a near-zero minimum in an envelope trace establish about modulation depth. Ask whether the maximum and minimum belong to one calibrated state Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What does a near-zero minimum in an envelope trace establish about modulation depth and A minimum near zero is compatible with the boundary of nonnegative sinusoidal AM; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What does a near-zero minimum in an envelope trace establish about modulation depth”, addressing “A minimum near zero is compatible with the boundary of nonnegative

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sinusoidal AM"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "What does a near-zero minimum in an envelope trace establish about modulation depth", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "What does a near-zero minimum in an envelope trace establish about modulation depth". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

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V011-C06-DISCUSSION-006. Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio?” Put this particular dispute to the panel: Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 02. Student A, terminology and scope: Agree the operational meanings of plus, sidebands, envelope and produces, distorted, audio in “Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. The signed envelope can reverse without adding RF terms to the linear product, while the absolute-value operation distorts the derived message Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can the RF spectrum remain a

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carrier plus two sidebands while an envelope detector produces distorted audio; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. The signed envelope can reverse without adding RF terms to the linear product, while the absolute-value operation distorts the derived message Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the ideal algebraic overmodulation example to separate the RF waveform from the magnitude detector Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can the RF spectrum remain a

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carrier plus two sidebands while an envelope detector produces distorted audio: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio. Physical clipping in a transmitter or receiver is an additional nonlinearity that can create other spectral components Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio. Physical clipping in a transmitter or receiver is an additional nonlinearity that can create other spectral components Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio and Use the ideal algebraic overmodulation example to separate the RF waveform from the magnitude detector; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio”, addressing “Use the ideal algebraic overmodulation example to separate the RF waveform from the magnitude detector”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can the RF spectrum remain a carrier plus two sidebands while an envelope detector produces distorted audio”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

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V011-C06-DISCUSSION-007. Should an operator maximize a real detector's audio level by rotating phase and then call the result calibrated?

- 01. Moderator, opening proposition: Introduce the exact dispute, "Should an operator maximize a real detector's audio level by rotating phase and then call the result calibrated?" Put this particular dispute to the panel: Should an operator maximize a real detector's audio level by rotating phase and then call the result calibrated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 02. Student A, terminology and scope: Agree the operational meanings of operator, real, detector and audio, rotating, calibrated in "Should an operator maximize a real detector's audio level by rotating phase and then call the result calibrated"; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in "Carrier, Sidebands, and Modulation Evidence". Require a declared detector normalization and an applicable reference if amplitude is the result Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether an operator maximize a real detector's audio level by rotating phase and then call the

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result calibrated; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Carrier, Sidebands, and Modulation Evidence”. Require a declared detector normalization and an applicable reference if amplitude is the result Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Maximizing a projection can be useful processing, but it does not independently establish the original phase or the complete calibration Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether an operator maximize a real detector's audio level by rotating phase and then call the

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result calibrated: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated. Preserve the original complex record, the chosen rotation and the criterion used Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated. Preserve the original complex record, the chosen rotation and the criterion used Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether an operator maximize a real detector's audio level by rotating phase and then call the result calibrated and Maximizing a projection can be useful processing, but it does not independently establish the original phase…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether an operator maximize a real detector’s audio level by rotating phase and then call the result calibrated”, addressing “Maximizing a projection can be useful processing, but it does not independently establish the original phase…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should an operator maximize a real detector’s audio level by rotating phase and then call the result calibrated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should an operator maximize a real detector’s audio level by rotating phase and then call the result calibrated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

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V011-C06-DISCUSSION-008. Why can a real-audio record be inadequate for comparing upper and lower sideband reception?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Why can a real-audio record be inadequate for comparing upper and lower sideband reception?” Put this particular dispute to the panel: Why can a real-audio record be inadequate for comparing upper and lower sideband reception. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 02. Student A, terminology and scope: Agree the operational meanings of inadequate, comparing, upper and lower, sideband, reception in “Why can a real-audio record be inadequate for comparing upper and lower sideband reception”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Why can a real-audio record be inadequate for comparing upper and lower sideband reception; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Single Sideband and Coherent Reception”. Apply one known LO offset to the signed upper and lower cases and compare the resulting magnitudes Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Why can a real-audio record be inadequate for comparing upper and lower sideband reception;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Single Sideband and Coherent Reception”. Apply one known LO offset to the signed upper and lower cases and compare the resulting magnitudes Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Real-audio frequency magnitude discards the complex sign that distinguishes the two orientations Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Why can a real-audio record be inadequate for comparing upper and lower sideband reception: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Why can a real-audio record be inadequate for comparing upper and lower sideband reception; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Why can a real-audio record be inadequate for comparing upper and lower sideband reception: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Why can a real-audio record be inadequate for comparing upper and lower sideband reception, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Why can a real-audio record be inadequate for comparing upper and lower sideband reception: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Why can a real-audio record be inadequate for comparing upper and lower sideband reception. Ask whether a stored sideband label supplies enough independent information to recover what was discarded Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Why can a real-audio record be inadequate for comparing upper and lower sideband reception, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Why can a real-audio record be inadequate for comparing upper and lower sideband reception. Ask whether a stored sideband label supplies enough independent information to recover what was discarded Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Why can a real-audio record be inadequate for comparing upper and lower sideband reception and Real-audio frequency magnitude discards the complex sign that distinguishes the two orientations; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Why can a real-audio record be inadequate for comparing upper and lower sideband reception”,

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addressing “Real-audio frequency magnitude discards the complex sign that distinguishes the two orientations”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Why can a real-audio record be inadequate for comparing upper and lower sideband reception”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Why can a real-audio record be inadequate for comparing upper and lower sideband reception”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.12 Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong (p. 3124)

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V011-C06-DISCUSSION-009. Is average RF power a sufficient headroom criterion for a two-tone SSB capture?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is average RF power a sufficient headroom criterion for a two-tone SSB capture?” Put this particular dispute to the panel: Is average RF power a sufficient headroom criterion for a two-tone SSB capture. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 02. Student A, terminology and scope: Agree the operational meanings of average, power, sufficient and headroom, criterion, capture in “Is average RF power a sufficient headroom criterion for a two-tone SSB capture”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is average RF power a sufficient headroom criterion for a two-tone SSB capture; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 6A: preserve the complex envelope”. Determine whether the relevant hardware limit concerns average power, envelope peak, instantaneous voltage or another specified quantity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is average RF power a sufficient headroom criterion for a two-tone SSB capture; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 6A: preserve the complex envelope”. Determine whether the relevant hardware limit concerns average power, envelope peak, instantaneous voltage or another specified quantity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare complete-period mean power with peak envelope power and the observation interval needed to encounter the peak Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Is average RF power a sufficient headroom criterion for a two-tone SSB capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is average RF power a sufficient headroom criterion for a two-tone SSB capture; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is average RF power a sufficient headroom criterion for a two-tone SSB capture: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is average RF power a sufficient headroom criterion for a two-tone SSB capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is average RF power a sufficient headroom criterion for a two-tone SSB capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is average RF power a sufficient headroom criterion for a two-tone SSB capture. Use a representative waveform and state history to test linear transfer Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is average RF power a sufficient headroom criterion for a two-tone SSB capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is average RF power a sufficient headroom criterion for a two-tone SSB capture. Use a representative waveform

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and state history to test linear transfer Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is average RF power a sufficient headroom criterion for a two-tone SSB capture and Compare complete-period mean power with peak envelope power and the observation interval needed to encounter…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is average RF power a sufficient headroom criterion for a two-tone SSB capture”, addressing “Compare complete-period mean power with peak envelope power and the observation interval needed to encounter…”; specify the exact measurement or evidential gap on which the speakers still

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differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Is average RF power a sufficient headroom criterion for a two-tone SSB capture”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Is average RF power a sufficient headroom criterion for a two-tone SSB capture”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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V011-C06-DISCUSSION-010. What can two unequal AM sidebands tell the analyst about a frequency-selective path?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What can two unequal AM sidebands tell the analyst about a frequency-selective path?” Put this particular dispute to the panel: What can two unequal AM sidebands tell the analyst about a frequency-selective path. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 02. Student A, terminology and scope: Agree the operational meanings of unequal, sidebands, tell and analyst, frequency-selective, path in “What can two unequal AM sidebands tell the analyst about a frequency-selective path”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What can two unequal AM sidebands tell the analyst about a frequency-selective path; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. Examine both amplitudes and phases using a known input where possible Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What can two unequal AM sidebands tell the analyst about a frequency-selective path; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Amplitude Modulation and Envelope Detection”. Examine both amplitudes and phases using a known input where possible Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Unequal measured coefficients can motivate a path hypothesis, but source asymmetry and interference may remain alternatives Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What can two unequal AM sidebands tell the analyst about a frequency-selective path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What can two unequal AM sidebands tell the analyst about a frequency-selective path; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What can two unequal AM sidebands tell the analyst about a frequency-selective path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What can two unequal AM sidebands tell the analyst about a frequency-selective path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What can two unequal AM sidebands tell the analyst about a frequency-selective path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What can two unequal AM sidebands tell the analyst about a frequency-selective path. The full complex expansion shows how unequal sidebands create in-phase and quadrature terms; an envelope-only depth does not uniquely separate source and transfer Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What can two unequal AM sidebands tell the analyst about a frequency-selective path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What can two unequal AM sidebands tell the analyst about a frequency-selective path. The full complex expansion shows how unequal sidebands create in-phase and quadrature terms; an envelope-only depth does not uniquely separate source and transfer Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What can two unequal AM sidebands tell the analyst about a frequency-selective path and Unequal measured coefficients can motivate a path hypothesis, but source asymmetry and interference may…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What can two unequal AM sidebands tell

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the analyst about a frequency-selective path", addressing "Unequal measured coefficients can motivate a path hypothesis, but source asymmetry and interference may…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "What can two unequal AM sidebands tell the analyst about a frequency-selective path", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "What can two unequal AM sidebands tell the analyst about a frequency-selective path". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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V011-C06-DISCUSSION-011. Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry?” Put this particular dispute to the panel: Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 02. Student A, terminology and scope: Agree the operational meanings of received, data, operating and point, transmitter, used in “Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6B.2: Differentiate a sinusoidal PM phase”. The waveform equations specify observable relationships, not a unique circuit architecture Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can received data at one

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operating point distinguish whether a transmitter used FM or PM circuitry; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6B.2: Differentiate a sinusoidal PM phase”. The waveform equations specify observable relationships, not a unique circuit architecture Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The same phase history can be generated through different internal control laws when the drives are appropriately related Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can received data at one operating point distinguish whether a transmitter used FM or PM

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circuitry: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the

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panel to retain, qualify or reject the conclusion. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry. A controlled change in known message rate or amplitude may discriminate a stated device hypothesis, but an unknown message does not provide that control Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.20 Application 6B.2: Differentiate a sinusoidal PM phase (p. 3138)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry. A controlled change in known message rate or amplitude may discriminate a stated device hypothesis, but an unknown message does not provide that control Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry and The same phase history can be generated through different internal control laws when the drives are…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry”, addressing “The same phase history can be generated through different internal control laws when the drives are…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can received data at one operating point distinguish whether a transmitter used FM or PM circuitry”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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V011-C06-DISCUSSION-012. Should every phase derivative in a noisy multicomponent capture be called instantaneous frequency?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should every phase derivative in a noisy multicomponent capture be called instantaneous frequency?” Put this particular dispute to the panel: Should every phase derivative in a noisy multicomponent capture be called instantaneous frequency. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 02. Student A, terminology and scope: Agree the operational meanings of phase, derivative, noisy and capture, called, instantaneous in “Should every phase derivative in a noisy multicomponent capture be called instantaneous frequency”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frequency and Phase Modulation”. At amplitude nulls or in unresolved mixtures, the phase can become unstable or represent an interference result rather than a unique component Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether every phase derivative in a noisy multicomponent capture be called

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instantaneous frequency; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frequency and Phase Modulation”. At amplitude nulls or in unresolved mixtures, the phase can become unstable or represent an interference result rather than a unique component Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require a meaningful nonzero complex representation, a justified continuous branch and adequate temporal resolution Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency. Discuss exclusions, segmentation and alternative multi-component analysis Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.16 Frequency and Phase Modulation (p. 3128)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency. Discuss exclusions, segmentation and alternative multi-component analysis Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency and Require a meaningful nonzero complex representation, a justified continuous branch and adequate temporal…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.35 Analogue demodulation as a source of systematic rather than merely random impairment (p. 3157)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether every phase derivative in a noisy multicomponent capture be called instantaneous frequency”,

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addressing “Require a meaningful nonzero complex representation, a justified continuous branch and adequate temporal…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should every phase derivative in a noisy multicomponent capture be called instantaneous frequency”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should every phase derivative in a noisy multicomponent capture be called instantaneous frequency”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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V011-C06-DISCUSSION-013. How should a team respond when endpoint phase agrees but a continuous record shows many intervening turns?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a team respond when endpoint phase agrees but a continuous record shows many intervening turns?” Put this particular dispute to the panel: How should a team respond when endpoint phase agrees but a continuous record shows many intervening turns. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 02. Student A, terminology and scope: Agree the operational meanings of respond, endpoint, continuous and shows, intervening, turns in “How should a team respond when endpoint phase agrees but a continuous record shows many intervening turns”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6B.6: Expose the ambiguity of sampled phase increments”. Positive and negative excursions can cancel Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team respond

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when endpoint phase agrees but a continuous record shows many intervening turns; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6B.6: Expose the ambiguity of sampled phase increments”. Positive and negative excursions can cancel Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. An endpoint difference constrains only the net accumulated frequency offset Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a team respond when endpoint phase agrees but a continuous record shows many

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intervening turns: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns. Preserve the trajectory and distinguish a principal phase display from an unwrapped branch Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns. Preserve the trajectory and distinguish a principal phase display from an unwrapped branch Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns and An endpoint difference constrains only the net accumulated frequency offset; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a team respond when endpoint phase agrees but a continuous record shows many intervening turns”, addressing “An endpoint difference constrains only the net accumulated frequency offset”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a team respond when endpoint phase agrees but a continuous record shows many intervening turns”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a team respond when endpoint phase agrees but a continuous record shows many intervening turns”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

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V011-C06-DISCUSSION-014. Does a successful phase-unwrapping routine resolve a sample-rate alias?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Does a successful phase-unwrapping routine resolve a sample-rate alias?” Put this particular dispute to the panel: Does a successful phase-unwrapping routine resolve a sample-rate alias. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 02. Student A, terminology and scope: Agree the operational meanings of successful, phase-unwrapping, routine and resolve, sample-rate, alias in “Does a successful phase-unwrapping routine resolve a sample-rate alias”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Does a

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successful phase-unwrapping routine resolve a sample-rate alias; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 6B: phase is the quantity that frequency differentiates”. Ask what independent admitted-band, conversion or prior-frequency information supports the selected member Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does a successful phase-unwrapping routine resolve a sample-rate alias; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change

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your opinion. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 6B: phase is the quantity that frequency differentiates”. Ask what independent admitted-band, conversion or prior-frequency information supports the selected member Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. An algorithm can impose continuity or choose a branch, but constant frequencies separated by integer sample rates can remain indistinguishable in the same samples Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Does a successful phase-unwrapping routine resolve a sample-rate alias: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does a successful phase-unwrapping routine resolve a sample-rate alias; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Does a successful phase-unwrapping routine resolve a sample-rate alias: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Does a successful phase-unwrapping routine resolve a sample-rate alias, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Does a successful phase-unwrapping routine resolve a sample-rate alias: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Does a successful phase-unwrapping routine resolve a sample-rate alias. Verify that the assumption was applicable during the interval Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Does a successful phase-unwrapping routine resolve a sample-rate alias, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Does a successful phase-unwrapping routine resolve a sample-rate alias. Verify that the assumption was

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applicable during the interval Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Does a successful phase-unwrapping routine resolve a sample-rate alias and An algorithm can impose continuity or choose a branch, but constant frequencies separated by integer sample…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.11 Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error (p. 3123)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Does a successful phase-unwrapping routine resolve a sample-rate alias”, addressing “An algorithm can impose continuity or choose a branch, but constant frequencies separated by integer sample…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another

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speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Does a successful phase-unwrapping routine resolve a sample-rate alias”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Does a successful phase-unwrapping routine resolve a sample-rate alias”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.24 Application 6B.6: Expose the ambiguity of sampled phase increments (p. 3142)

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V011-C06-DISCUSSION-015. Where should a finite-difference frequency estimate be plotted, and what should its label say?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Where should a finite-difference frequency estimate be plotted, and what should its label say?” Put this particular dispute to the panel: Where should a finite-difference frequency estimate be plotted, and what should its label say. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 02. Student A, terminology and scope: Agree the operational meanings of finite-difference, frequency, estimate and plotted, label, measurement in “Where should a finite-difference frequency estimate be plotted, and what should its label say”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Where should a finite-difference frequency estimate be plotted, and what should its label say; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6B.5: Integrate a linear frequency ramp without losing phase turns”. State the difference operator, span, overlap and any smoothing Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Where should a finite-

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difference frequency estimate be plotted, and what should its label say; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6B.5: Integrate a linear frequency ramp without losing phase turns”. State the difference operator, span, overlap and any smoothing Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Placement at an interval midpoint may be a useful convention, but the estimator remains an average over its specified interval Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Where should a finite-difference frequency estimate be plotted, and what should its label say: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Where should a finite-difference frequency estimate be plotted, and what should its label say; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Where should a finite-difference frequency estimate be plotted, and what should its label

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say: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Where should a finite-difference frequency estimate be plotted, and what should its label say, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Where should a finite-difference frequency estimate be plotted, and what should its label say: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Where should a finite-difference frequency estimate be plotted, and what should its label say. Compare traces only after reconciling those choices and their timing Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Where should a finite-difference frequency estimate be plotted, and what should its label say, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.23 Application 6B.5: Integrate a linear frequency ramp without losing phase turns (p. 3141)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Where should a finite-difference frequency estimate be plotted, and what should its label say. Compare traces only after reconciling those choices and their timing Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Where should a finite-difference frequency estimate be plotted, and what should its label say and Placement at an interval midpoint may be a useful convention, but the estimator remains an average over its…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.7 Application 6A.2: Infer the conventional-AM envelope parameters (p. 3119)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Where should a finite-difference frequency estimate be plotted, and what should its label say”,

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addressing “Placement at an interval midpoint may be a useful convention, but the estimator remains an average over its…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Where should a finite-difference frequency estimate be plotted, and what should its label say”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Where should a finite-difference frequency estimate be plotted, and what should its label say”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

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V011-C06-DISCUSSION-016. When is the first-order small-phase model adequate for an engineering decision?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When is the first-order small-phase model adequate for an engineering decision?” Put this particular dispute to the panel: When is the first-order small-phase model adequate for an engineering decision. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

- 02. Student A, terminology and scope: Agree the operational meanings of first-order, small-phase, model and adequate, engineering, decision in “When is the first-order small-phase model adequate for an engineering decision”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When is the first-order small-phase model adequate for an engineering decision; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 6B: phase is the quantity that frequency differentiates”. An exact bound on the omitted complex amplitude does not automatically become the same bound on spectral power or distortion Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When is the first-order small-

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phase model adequate for an engineering decision; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 6B: phase is the quantity that frequency differentiates”. An exact bound on the omitted complex amplitude does not automatically become the same bound on spectral power or distortion Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Relate the pointwise complex-amplitude remainder bound to the quantity and tolerance actually being evaluated Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving When is the first-order small-phase model adequate for an engineering decision: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When is the first-order small-phase model adequate for an engineering decision; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When is the first-order small-

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phase model adequate for an engineering decision: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When is the first-order small-phase model adequate for an engineering decision, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When is the first-order small-phase model adequate for an engineering decision: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When is the first-order small-phase model adequate for an engineering decision. The intended accuracy may permit the approximation or require the full exponential and a stronger calculation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When is the first-order small-phase model adequate for an engineering decision, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When is the first-order small-phase model adequate for an engineering decision. The intended accuracy may permit the approximation or require the full exponential and a stronger calculation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When is the first-order small-phase model adequate for an engineering decision and Relate the pointwise complex-amplitude remainder bound to the quantity and tolerance actually being evaluated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When is the first-order small-phase model adequate for an engineering decision”, addressing “Relate the pointwise complex-amplitude remainder bound to the quantity and tolerance actually being evaluated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When is the first-order small-phase model adequate for an engineering decision”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When is the first-order small-phase model adequate for an engineering decision”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.26 Application 6B.8: Bound a small-phase approximation before using it (p. 3144)

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V011-C06-DISCUSSION-017. Should Carson's estimate be used as a pass-or-fail threshold for nominal IF width?

- 01. Moderator, opening proposition: Introduce the exact dispute, "Should Carson's estimate be used as a pass-or-fail threshold for nominal IF width?" Put this particular dispute to the panel: Should Carson's estimate be used as a pass-or-fail threshold for nominal IF width. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

- 02. Student A, terminology and scope: Agree the operational meanings of Carson, estimate, used and threshold, nominal, width in "Should Carson's estimate be used as a pass-or-fail threshold for nominal IF width"; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in "Application 6B.1: Convert a sinusoidal FM deviation into phase excursion". For acceptance, ask for the waveform spectrum, width definition, skirts, ripple, transfer phase and the permitted effect on the desired measurement Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether Carson's estimate be

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used as a pass-or-fail threshold for nominal IF width; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6B.1: Convert a sinusoidal FM deviation into phase excursion”. For acceptance, ask for the waveform spectrum, width definition, skirts, ripple, transfer phase and the permitted effect on the desired measurement Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the estimate to guide which paths deserve evaluation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width. The same estimate can accompany different power distributions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width. The same estimate can accompany different power distributions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.22 Application 6B.4: Bound and attain the deviation of a two-tone phase (p. 3140)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width and Use the estimate to guide which paths deserve evaluation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about "whether Carson's estimate be used as a pass-or-fail threshold for nominal IF width", addressing "Use the estimate to guide which paths deserve evaluation"; specify the exact measurement or evidential gap on which the speakers still differ

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Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should Carson’s estimate be used as a pass-or-fail threshold for nominal IF width”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should Carson’s estimate be used as a pass-or-fail threshold for nominal IF width”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

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V011-C06-DISCUSSION-018. What is lost when a phase trace is detrended until it looks centered?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What is lost when a phase trace is detrended until it looks centered?” Put this particular dispute to the panel: What is lost when a phase trace is detrended until it looks centered. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 02. Student A, terminology and scope: Agree the operational meanings of lost, phase, trace and until, looks, centered in “What is lost when a phase trace is detrended until it looks centered”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What is lost when a phase trace is detrended until it looks centered; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6B.10: Separate reference offset from a deterministic modulation”. Preserve the original phase and the source of the correction Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is lost when a phase trace is detrended until it looks centered; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6B.10: Separate reference offset from a deterministic modulation”. Preserve the original phase and the source of the correction Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. An estimated linear trend may remove carrier-reference error, but over an unsuitable interval it can also absorb a slow modulation component Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What is lost when a phase trace is detrended until it looks centered: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is lost when a phase trace is detrended until it looks centered; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What is lost when a phase trace is detrended until it looks centered: specify the altered receiver state

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or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What is lost when a phase trace is detrended until it looks centered, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What is lost when a phase trace is detrended until it looks centered: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What is lost when a phase trace is detrended until it looks centered. Distinguish a fixed phase rotation, a frequency-offset correction and a phase reset Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What is lost when a phase trace is detrended until it looks centered, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.28 Application 6B.10: Separate reference offset from a deterministic modulation (p. 3146)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What is lost when a phase trace is detrended until it looks centered. Distinguish a fixed phase rotation, a frequency-offset correction and a phase reset Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.10 Application 6A.5: Measure phase-dependent coherent-AM recovery (p. 3122)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What is lost when a phase trace is detrended until it looks centered and An estimated linear trend may remove carrier-reference error, but over an unsuitable interval it can also…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What is lost when a phase trace is detrended until it looks centered”, addressing “An estimated linear trend may remove carrier-reference error, but over an unsuitable

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interval it can also…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "What is lost when a phase trace is detrended until it looks centered", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "What is lost when a phase trace is detrended until it looks centered". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

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V011-C06-DISCUSSION-019. Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope?” Put this particular dispute to the panel: Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 02. Student A, terminology and scope: Agree the operational meanings of limiting, treated, innocuous and step, nominally, envelope in “Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.35 Analogue demodulation as a source of systematic rather than merely random impairment (p. 3157)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Analogue demodulation as a source of systematic rather than merely random impairment”. Limiting can alter the evidence available for investigating those conditions even when it helps a particular demodulation task Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.35 Analogue demodulation as a source of systematic rather than merely random impairment (p. 3157)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Analogue demodulation as a source of systematic rather than merely random impairment”. Limiting can alter the evidence available for investigating those conditions even when it helps a particular demodulation task Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.35 Analogue demodulation as a source of systematic rather than merely random impairment (p. 3157)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The ideal phase-only model does not establish how a real limiter handles weak signals, multiple components, amplitude nulls, overload or recovery Put two specific questions to Student D about the stated competing options

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and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.35 Analogue demodulation as a source of systematic rather than merely random impairment (p. 3157)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope. Retain native data where possible and compare the relevant input and output behavior with a representative reference Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual

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receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.35 Analogue demodulation as a source of systematic rather than merely random impairment (p. 3157)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope. Retain native data where possible and compare the relevant input and output behavior with a representative reference Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope and The ideal phase-only model does not establish how a real limiter handles weak signals, multiple components,...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and

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field boundaries. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope”, addressing “The ideal phase-only model does not establish how a real limiter handles weak signals, multiple components,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can limiting be treated as an innocuous preprocessing step because FM is nominally constant envelope”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted

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evidence from an unsupported assertion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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V011-C06-DISCUSSION-020. What does clean recovered FM audio say about a weaker simultaneous signal?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What does clean recovered FM audio say about a weaker simultaneous signal?” Put this particular dispute to the panel: What does clean recovered FM audio say about a weaker simultaneous signal. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

- 02. Student A, terminology and scope: Agree the operational meanings of clean, recovered, audio and weaker, simultaneous, signal in “What does clean recovered FM audio say about a weaker simultaneous signal”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What does clean recovered FM audio say about a weaker simultaneous signal; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Carrier, Sidebands, and Modulation Evidence”. Examine the native band, chain linearity and a stated weaker-signal detection criterion Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What does clean recovered FM audio say about a weaker simultaneous signal; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change

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your opinion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Carrier, Sidebands, and Modulation Evidence”. Examine the native band, chain linearity and a stated weaker-signal detection criterion Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Clean audio may be compatible with capture or other nonlinear selection, so it is insufficient evidence of a single-component RF input Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

- 08. Student D, answer to Student E: Design a discriminating experiment involving What does clean recovered FM audio say

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about a weaker simultaneous signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What does clean recovered FM audio say about a weaker simultaneous signal; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What does clean recovered FM audio say about a weaker simultaneous signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What does clean recovered FM audio say about a weaker simultaneous signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What does clean recovered FM audio say about a weaker simultaneous signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What does clean recovered FM audio say about a weaker simultaneous signal. A two-signal reference can test the actual configuration, but its levels, spacing and modulation must match the inference being made Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What does clean recovered FM audio say about a weaker simultaneous signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What does clean recovered FM audio say about a weaker simultaneous signal. A two-signal reference can test the actual configuration, but its levels, spacing and modulation must

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match the inference being made Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What does clean recovered FM audio say about a weaker simultaneous signal and Clean audio may be compatible with capture or other nonlinear selection, so it is insufficient evidence of a…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.3 Single Sideband and Coherent Reception (p. 3110)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What does clean recovered FM audio say about a weaker simultaneous signal”, addressing “Clean audio may be compatible with capture or other nonlinear selection, so it is insufficient evidence of a…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another

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speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What does clean recovered FM audio say about a weaker simultaneous signal”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What does clean recovered FM audio say about a weaker simultaneous signal”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)

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V011-C06-DISCUSSION-021. How should a receiver report a pulse that falls partly outside usable acquisition coverage?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a receiver report a pulse that falls partly outside usable acquisition coverage?” Put this particular dispute to the panel: How should a receiver report a pulse that falls partly outside usable acquisition coverage. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 02. Student A, terminology and scope: Agree the operational meanings of falls, partly, outside and usable, acquisition, coverage in “How should a receiver report a pulse that falls partly outside usable acquisition coverage”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a receiver report a pulse that falls partly outside usable acquisition coverage; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten numerical worked examples under declared simplified models”. Identify the usable interval, trigger timing, continuity and any dead time before characterizing the captured portion Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a receiver report a

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pulse that falls partly outside usable acquisition coverage; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten numerical worked examples under declared simplified models”. Identify the usable interval, trigger timing, continuity and any dead time before characterizing the captured portion Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate coverage from fidelity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a receiver report a pulse that falls partly outside usable acquisition coverage: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a receiver report a pulse that falls partly outside usable acquisition coverage; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a receiver report a pulse that falls partly outside usable acquisition coverage: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a receiver report a pulse that falls partly outside usable acquisition coverage, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a receiver report a pulse that falls partly outside usable acquisition coverage: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a receiver report a pulse that falls partly outside usable acquisition coverage. A partial event may support some timing or amplitude observations while leaving the full width, peak or intrapulse structure unresolved Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a receiver report a pulse that falls partly outside usable acquisition coverage, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a receiver report a pulse that falls partly outside usable acquisition coverage. A partial event may support some timing or amplitude observations while leaving the full width, peak or intrapulse structure unresolved Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a receiver report a pulse that falls partly outside usable acquisition coverage and Identify the usable interval, trigger timing, continuity and any dead time before characterizing the captured…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a receiver report a pulse that falls partly outside usable acquisition coverage”, addressing “Identify the usable interval, trigger timing, continuity and any dead time before characterizing the captured…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a receiver report a pulse that falls partly outside usable acquisition coverage”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a receiver report a pulse that falls partly outside usable acquisition coverage”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

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V011-C06-DISCUSSION-022. When does a known-source test adequately challenge an apparent modulation artifact?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When does a known-source test adequately challenge an apparent modulation artifact?” Put this particular dispute to the panel: When does a known-source test adequately challenge an apparent modulation artifact. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 02. Student A, terminology and scope: Agree the operational meanings of test, adequately, challenge and apparent, modulation, artifact in “When does a known-source test adequately challenge an apparent modulation artifact”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When does a known-source test adequately challenge an apparent modulation artifact; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Analog Demodulator Verification”. A reference injected downstream of an antenna cannot verify the bypassed antenna path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When does a known-source test adequately challenge an apparent modulation artifact; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.40 Frequency modulation, phase modulation and the dangers of differentiation (p. 3168)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Analog Demodulator Verification”. A reference injected downstream of an antenna cannot verify the bypassed antenna path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Specify which stages and functions the stimulus actually traverses, its modulation and level range, and the time of the check Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 08. Student D, answer to Student E: Design a discriminating experiment involving When does a known-source test adequately

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challenge an apparent modulation artifact: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When does a known-source test adequately challenge an apparent modulation artifact; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.40 Frequency modulation, phase modulation and the dangers of differentiation (p. 3168)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When does a known-source test adequately challenge an apparent modulation artifact: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses

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and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When does a known-source test adequately challenge an apparent modulation artifact, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When does a known-source test adequately challenge an apparent modulation artifact: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When does a known-source test adequately challenge an apparent modulation artifact. A successful check supports the exercised configuration at that time and cannot alone establish uninterrupted earlier validity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.40 Frequency modulation, phase modulation and the dangers of differentiation (p. 3168)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When does a known-source test adequately challenge an apparent modulation artifact, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When does a known-source test adequately challenge an apparent modulation artifact. A successful check supports the exercised configuration at that time and cannot alone

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establish uninterrupted earlier validity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.40 Frequency modulation, phase modulation and the dangers of differentiation (p. 3168)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When does a known-source test adequately challenge an apparent modulation artifact and Specify which stages and functions the stimulus actually traverses, its modulation and level range, and the…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.19 Application 6B.1: Convert a sinusoidal FM deviation into phase excursion (p. 3137)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When does a known-source test adequately challenge an apparent modulation artifact”, addressing “Specify which stages and functions the stimulus actually traverses, its modulation and level range, and the…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When does a known-source test adequately challenge an apparent modulation artifact”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When does a known-source test adequately challenge an apparent modulation artifact”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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V011-C06-DISCUSSION-023. Should subjective intelligibility appear in a technical modulation report?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should subjective intelligibility appear in a technical modulation report?” Put this particular dispute to the panel: Should subjective intelligibility appear in a technical modulation report. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 02. Student A, terminology and scope: Agree the operational meanings of subjective, intelligibility, appear and technical, modulation, report in “Should subjective intelligibility appear in a technical modulation report”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of

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whether subjective intelligibility appear in a technical modulation report; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Preserve pulse and demodulator evidence across representations”. Record the processing needed to obtain it and avoid treating expected words as an independent frequency reference Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether subjective intelligibility appear in a technical modulation report; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Preserve pulse and demodulator evidence across representations”. Record the processing needed to obtain it and avoid treating expected words as an independent frequency reference Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It may be relevant to an authorized question, but it must be distinguished from calibrated amplitude, frequency, deviation or distortion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.31 Analog Demodulator Verification (p. 3152)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether subjective intelligibility appear in a technical modulation report: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether subjective intelligibility appear in a technical modulation report; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether subjective intelligibility appear in a technical modulation report: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether subjective intelligibility appear in a technical modulation report, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether subjective intelligibility appear in a technical modulation report: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.31 Analog Demodulator Verification (p. 3152)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether subjective intelligibility appear in a technical modulation report. Preserve the native technical record and minimize incidental content as the chapter directs Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether subjective intelligibility appear in a technical modulation report, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether subjective intelligibility appear in a technical modulation report. Preserve the native technical record and minimize incidental content as the chapter directs Respond

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point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether subjective intelligibility appear in a technical modulation report and It may be relevant to an authorized question, but it must be distinguished from calibrated amplitude,…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether subjective intelligibility appear in a technical modulation report”, addressing “It may be relevant to an authorized question, but it must be distinguished from calibrated amplitude,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §6.31 Analog Demodulator Verification (p. 3152)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should subjective intelligibility appear in a technical modulation report”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should subjective intelligibility appear in a technical modulation report”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.31 Analog Demodulator Verification (p. 3152)

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V011-C06-DISCUSSION-024. How should an analyst cite a useful historical manual whose wider claims are not adopted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should an analyst cite a useful historical manual whose wider claims are not adopted?” Put this particular dispute to the panel: How should an analyst cite a useful historical manual whose wider claims are not adopted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, historical, manual and wider, claims, adopted in “How should an analyst cite a useful historical manual whose wider claims are not adopted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should an analyst cite a useful historical manual whose wider claims are not adopted; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Carrier, Sidebands, and Modulation Evidence”. Preserve correct source identity and equipment or edition applicability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should an analyst cite a useful historical manual whose wider claims are not adopted; explain what each record can establish State what the existing

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record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Carrier, Sidebands, and Modulation Evidence”. Preserve correct source identity and equipment or edition applicability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the issuing body, edition and inspected pages, then attach the citation to the bounded claim actually supported Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 08. Student D, answer to Student E: Design a discriminating experiment involving how should an analyst cite a useful historical

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manual whose wider claims are not adopted: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should an analyst cite a useful historical manual whose wider claims are not adopted; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should an analyst cite a useful historical manual whose wider claims are not adopted: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable,

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expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should an analyst cite a useful historical manual whose wider claims are not adopted, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should an analyst cite a useful historical manual whose wider claims are not adopted: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should an analyst cite a useful historical manual whose wider claims are not adopted. Do not extend a relationship about a historical architecture into a universal modern performance or regulatory statement Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should an analyst cite a useful historical manual whose wider claims are not adopted, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should an analyst cite a useful historical

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manual whose wider claims are not adopted. Do not extend a relationship about a historical architecture into a universal modern performance or regulatory statement Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.15 Application 6A.10: Use message mean square rather than a sinusoidal shortcut (p. 3127)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should an analyst cite a useful historical manual whose wider claims are not adopted and Identify the issuing body, edition and inspected pages, then attach the citation to the bounded claim…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.27 Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response (p. 3145)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should an analyst cite a useful historical manual whose wider claims are not adopted”, addressing “Identify the issuing body, edition and inspected pages, then attach the citation to the bounded claim…”; specify the exact measurement

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or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should an analyst cite a useful historical manual whose wider claims are not adopted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should an analyst cite a useful historical manual whose wider claims are not adopted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.44 Laboratory qualification of an analogue-demodulation measurement claim (p. 3177)

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V011-C06-DISCUSSION-025. What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact?” Put this particular dispute to the panel: What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 02. Student A, terminology and scope: Agree the operational meanings of resolved, explanation, mechanisms and compatible, audio, artifact in “What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Carrier, Sidebands, and Modulation Evidence”. A controlled processing change on the same native data can isolate some derived effects; a separately characterized acquisition may test overload, images or external coupling Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Carrier, Sidebands, and Modulation Evidence”. A controlled processing change on the same native data can isolate some derived effects; a separately characterized acquisition may test overload, images or external coupling Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require discriminating predictions and tests rather than selecting the most familiar story Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask

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which setting or observation would discriminate between them without changing the measurand. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 08. Student D, answer to Student E: Design a discriminating experiment involving What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact. If the available tests do not distinguish the remaining mechanisms, preserve the alternatives and narrow the conclusion Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should count as a resolved explanation when several receiver mechanisms remain compatible with the

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same audio artifact, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact. If the available tests do not distinguish the remaining mechanisms, preserve the alternatives and narrow the conclusion Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact and Require discriminating predictions and tests

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rather than selecting the most familiar story; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.6 Application 6A.1: Close the power accounting for sinusoidal AM (p. 3118)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact”, addressing “Require discriminating predictions and tests rather than selecting the most familiar story”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the

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strongest evidence for and against the resolution of “What should count as a resolved explanation when several receiver mechanisms remain compatible with the same audio artifact”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

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Chapter 6 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C06-ESSAY-001 — Begin with the real RF waveform as the real part of its translated complex peak-voltage envelope. Expanding its square produces one term proportional to the squared envelope magnitude and another oscillating around twice the carrier. Under the declared spectral separation and complete-period, long-time or carrier-cycle averaging convention, the latter term has zero relevant average. Dividing by the positive real load resistance therefore gives mean RF power equal to the mean squared envelope magnitude divided by twice that resistance. Peak envelope power uses the maximum squared envelope magnitude with the same denominator. State that the envelope is a peak-voltage quantity, not an RMS voltage; omitting this convention invites a factor-of-two error. The peak is also defined over a stated observation interval or complete periodic waveform. An arbitrary short RF record need not satisfy the averaging cancellation. Moreover, the maximum instantaneous RF voltage squared divided by resistance is a different quantity from peak envelope power. A sound answer connects the representation, the load, the averaging interval and the requested measurand before applying either equation. Review: Equations 11A–11B; Model 6A voltage and averaging conventions.

Review: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope; Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Model 6A: preserve the complex envelope.

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V011-C06-ESSAY-002 — The nonnegative envelope has extrema 0.5 V and 3.5 V. Carrier power is 40 mW. Each sideband has peak 0.75 V and power 5.625 mW, so total average power is 51.25 mW. Peak envelope power is 122.5 mW. Obtain the total both from the sum of the three orthogonal spectral powers and from the envelope mean square; the agreement is an independent check on the peak-voltage convention. The peak-envelope result uses the largest envelope magnitude and is not the largest instantaneous RF power. Require a linear path that passes both sidebands, a known 50 Ω reference plane and complete-period or equivalent averaging. Challenge the ideal symmetry by measuring both sideband transfers and by testing a known modulation reference at the same gain state. If one sideband is selectively attenuated, the measured output envelope no longer follows the assumed source model. A high average-power margin alone also does not prove that the 3.5 V envelope peak remains below the relevant chain limit. Review: Equations 11C–11F; Application 6A.1; Application 6A.8.

Review: Chapter 6 — Equation 11C. Conventional AM and nonnegative-envelope condition; Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion; Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers; Chapter 6 — Equation 11F. Total sinusoidal-AM power; Chapter 6 — Application 6A.1: Close the power accounting for sinusoidal AM; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-ESSAY-003 — Use the actual message mean square in Equation 11G. The two total-to-carrier power ratios are 1.32 and 1.128 respectively. The common modulation scale does not make their average powers equal, because the average of the squared message is different. The zero-mean condition removes the cross term between carrier and message; if the message has a nonzero mean, the carrier convention or the power expansion must be reconsidered explicitly. The stated mean squares do not establish the messages' maxima, crest factors, phase relations or spectral occupation. A common bound on message magnitude supplies a common conservative bound on the envelope, but that bound may not be attained. Consequently the two average powers do not determine the two peak envelope powers. Retain a reproducible message definition or record and the averaging interval. An answer that substitutes the sinusoidal half-mean-square shortcut for both messages loses the very distinction the question asks the reader to preserve. Review: Equation 11G; Application 6A.10.

Review: Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Application 6A.10: Use message mean square rather than a sinusoidal shortcut.

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V011-C06-ESSAY-004 — The half-sum gives a carrier peak of 1.8 V, while the normalized difference gives modulation depth 0.5. Carrier power is 21.6 mW, each sideband power is 1.35 mW, total average power is 24.3 mW and peak envelope power is 48.6 mW. The inference assumes the ordinary sinusoidal nonnegative envelope, linear calibrated transfer, compatible extrema and a positive real load. It is not an unrestricted inverse of every magnitude trace. Overmodulation can make the signed envelope cross zero, after which magnitude detection loses its sign. AGC changes between selected extrema, asymmetric sideband filtering, detector offsets, noise near a minimum and clipping can also invalidate the inference. Preserve the interval and detector state from which the extrema were selected. A reference modulation test should exercise the relevant amplitude and frequency range, rather than only the unmodulated carrier at the center of the passband. Report the inferred source parameters only within that verified path and model scope. Review: Equation 11D; Applications 6A.2 and 6A.4.

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion; Chapter 6 — Application 6A.2: Infer the conventional-AM envelope parameters; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

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V011-C06-ESSAY-005 — The signed envelope ranges from −0.5 V to 2.5 V. It is negative when the modulation cosine is less than $-\frac{2}{3}$; the fraction of a complete period is $\arccos\left(\frac{2}{3}\right)$ divided by π, approximately 0.267720 or 26.7720 percent. The ideal algebraic RF waveform still has a 10 mW carrier and two 5.625 mW sidebands, giving 21.25 mW average power. Its largest envelope magnitude is 2.5 V, so peak envelope power is 62.5 mW. Magnitude detection folds the negative portion upward and reaches zero at the crossings. Applying the ordinary nonnegative-envelope inversion to extrema 2.5 V and zero would return depth 1 and carrier peak 1.25 V, neither of which recovers the stipulated signed model. Distinguish this information loss in the detector from physical transmitter clipping. The ideal waveform has only the original carrier and two RF sidebands; extra RF products require an additional mechanism. A properly phased coherent or complex record can preserve the sign needed to resolve the ambiguity. Review: Equations 11E–11H; Application 6A.4.

Review: Chapter 6 — Equation 11E. Sinusoidal sideband amplitudes and powers; Chapter 6 — Equation 11F. Total sinusoidal-AM power; Chapter 6 — Equation 11G. Power for a zero-mean nonsinusoidal message; Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

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V011-C06-ESSAY-006 — The low-pass result is the real envelope multiplied by the cosine of the reference phase error. The recovered DC is approximately 0.919253 V and the sinusoidal message peak is approximately 0.551552 V. The message amplitude ratio to perfect phase alignment is cos(40°), corresponding to approximately −2.314921 dB. This loss is a projection loss under the stipulated normalization, not proof that the received RF power has fallen. At a 90° error the ideal real projection vanishes while the complementary quadrature contains the signal. A complex record preserves the rotation and can support correction when a measured reference or justified estimator establishes the phase. Rotating a record merely to maximize an expected output is a processing choice that must be declared; it is not independent evidence of the original phase. If the LO frequency is also wrong, the projection changes with time and the fixed-cosine scale no longer describes the complete output. Review: Equations 11I–11J; Applications 6A.5–6A.6.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Application 6A.5: Measure phase-dependent coherent-AM recovery; Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

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V011-C06-ESSAY-007 — The real detector multiplies the real message by the cosine of the residual 80 Hz rotation. Expanding the product gives components at 1420 Hz and 1580 Hz, each with peak 0.4 V under the declared detector normalization. This is a time-varying projection, not one 1500 Hz tone with a fixed gain error. A short segment may show beating or changing apparent level without resolving two spectral components; the analysis duration and window therefore belong with the interpretation. The result also depends on the assumed zero initial phase error, which controls the component phases even when their frequencies and amplitudes remain as stated. Retain the native or complex record, the reinsertion reference and the derived audio. Correcting a justified residual rotation in the time record can recover the intended detector relationship. Relabeling a displayed marker cannot undo the modulation imposed by the incorrect reference. Review: Equation 11I; Application 6A.6.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Application 6A.6: Resolve the two tones caused by a DSB-SC tuning error.

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V011-C06-ESSAY-008 — Over complete beat periods, the cross term averages to zero and the mean squared envelope magnitude is $0.9^2+0.5^2$, or 1.06 V^2. Average RF power is therefore 10.6 mW. When the components align, the envelope magnitude is 1.4 V and peak envelope power is 19.6 mW. The ratio is approximately 2.669502 dB. The peak statement requires an observation long enough to include the alignment, or an analytic statement about the complete periodic waveform; an arbitrary short captured interval may have a smaller observed maximum. Initial phases can shift the alignment time without changing the complete-period mean. Maintain the peak-voltage convention and the positive real load. A receiver judged only against 10.6 mW average input may still compress on a peak, so compare the appropriate peak quantity with the applicable chain limit and verify the waveform transfer. Do not substitute the peak instantaneous RF voltage-squared quantity for peak envelope power. Review: Equations 11A–11B and 11K; Application 6A.8.

Review: Chapter 6 — Equation 11A. Real RF waveform and its complex envelope; Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

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V011-C06-ESSAY-009 — For these explicitly real coefficients, the in-phase component is 1 + 0.50 cos of the modulation angle, while the quadrature component is 0.20 sin of that angle. At $\frac{\pi}{2}$ the complex envelope is $1 + j\,0.20$ V. Its magnitude is approximately 1.019804 V and its phase is approximately 0.197396 radians. The nonzero quadrature term reveals a relation hidden by a magnitude-only display. The coefficient sum and difference follow from the full complex expansion; for generally complex coefficients, take the real and imaginary parts of the complete expression instead of treating the same real-coefficient formulas as universal. These output coefficients alone do not identify the original source depth, because the source and the two sideband transfers may both be unknown. A known input and coherent response measurements can separate those possibilities. The conclusion should concern the observed output unless the path evidence justifies a source-level inference. Review: Equation 11L; Application 6A.9.

Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response; Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

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V011-C06-ESSAY-010 — The upper-sideband RF component is at carrier plus message frequency, so its signed complex baseband frequency is +2025 Hz. The lower-sideband component is at carrier minus message frequency, giving −2375 Hz. Both signed frequencies have been shifted by −175 Hz relative to ideal reinsertion. Their real-audio frequency magnitudes, however, are 2025 Hz and 2375 Hz, which conceal the signs and can encourage an incorrect claim that the tuning error acted in opposite algebraic directions. Preserve the sideband convention and complex orientation with the LO reference. A frequency adjustment made by ear can improve perceived intelligibility without establishing an accurate RF or baseband frequency scale. Report it as a documented processing choice unless a measured reference or specified estimator supports a stronger statement. A real-audio record alone generally cannot reconstruct the discarded analytic orientation. Review: Equation 11K; Application 6A.7.

Review: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes; Chapter 6 — Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong.

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V011-C06-ESSAY-011 — For the stated PM law, differentiation makes peak deviation equal to peak phase times modulation frequency. The deviations are therefore 0.9 kHz and 3.6 kHz. For the stated FM law, integration makes the phase index equal to peak deviation divided by modulation frequency, giving 1.8 rad and 0.45 rad. Phase excursion, deviation magnitude and modulation rate are different quantities with different units or conventions. At one operating point, an appropriately chosen PM drive and FM drive can produce the same phase history, so the received waveform does not uniquely establish the internal modulator architecture. Compare controlled changes in message rate and amplitude only where the input relationship is known. Recovered loudness also depends on the demodulator transfer, filtering and de-emphasis. A sound answer derives the waveform relationships first and keeps the device-architecture inference conditional. Review: Equations 12B–12C; Applications 6B.2–6B.3.

Review: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation; Chapter 6 — Application 6B.2: Differentiate a sinusoidal PM phase; Chapter 6 — Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation.

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V011-C06-ESSAY-012 — Integrate the frequency deviation in hertz over time in seconds and multiply the result by 2π. The first half is a negative triangle with area −4.5 cycles, so the additional phase at 3 ms is -9π radians. The positive second half contributes +4.5 cycles and brings the additional phase at 6 ms back to zero. The net endpoint increment is therefore zero even though the deviation is nonzero almost everywhere except the midpoint. A frequency estimate from the full-interval phase difference gives an average deviation of zero; it does not establish zero instantaneous deviation throughout the interval. Principal phase alone would discard whole turns and further obscure the trajectory. Preserve the continuous unwrapped phase or the properly supported integration model, the time interval and any resets. The example separates a cancellation in an integral from the local derivative that defines instantaneous frequency. Review: Equations 12D and 12F; Application 6B.5.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

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V011-C06-ESSAY-013 — Differentiation and division by 2π give deviation components of $480\cos(2\pi \times 1200t)$ Hz and $480\cos(2\pi \times 3200t)$ Hz. The magnitude is bounded by 960 Hz. At $t=0$ both cosines equal one, so the positive bound is attained for this particular phase specification; the bound is not merely a loose inequality here. With the highest modulating frequency 3.2 kHz, Carson's engineering estimate is 2 times the sum of 960 Hz and 3200 Hz, or 8320 Hz. That estimate does not specify exact occupied power, individual sideband amplitudes or the performance of an 8.32 kHz IF filter. Different initial phases can change attainment without changing the componentwise triangle bound. A complete answer distinguishes the independently derived instantaneous-deviation result from the approximate bandwidth planning rule and identifies the actual spectrum and filter response needed for a containment or distortion claim. Review: Equations 12E and 12J; Application 6B.4.

Review: Chapter 6 — Equation 12E. Deviation from several phase components; Chapter 6 — Equation 12J. Carson estimate and its stated inputs; Chapter 6 — Application 6B.4: Bound and attain the deviation of a two-tone phase.

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V011-C06-ESSAY-014 — The principal interval is from −32 kHz inclusive to +32 kHz exclusive. The +43 kHz component therefore has representative −21 kHz, and the indistinguishable constant-frequency family is −21 kHz plus an integer multiple of 64 kHz. The principal phase increment is 2π times $-\frac{21}{64}$ radians, approximately −2.061670 radians. Additional decimal precision in that increment does not distinguish the family members. Selecting +43 kHz requires justified information beyond those samples alone, such as a known admitted RF band and conversion convention, a suitable prior frequency interval, or another independently informative acquisition. Merely unwrapping a constant principal sequence by assuming the desired sign embeds the answer in the processing rule. State the sampling, conversion, anti-alias and continuity assumptions, and preserve the original complex samples so the chosen branch can be reviewed. This constant-frequency example should not be generalized into a claim that every arbitrary time-varying waveform has the same simple pointwise alias description without further conditions. Review: Equation 12G; Application 6B.6.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

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V011-C06-ESSAY-015 — Divide each phase increment by 2π and by its 50 μs interval. The three average deviations are approximately 318.309886 Hz, 509.295818 Hz and 763.943727 Hz. The full 150 μs interval gives approximately 530.516477 Hz, which also equals the equally weighted mean of the three adjacent interval averages. These are exact interval-average consequences of the stipulated unwrapped, absolutely continuous phase; they are not automatically the derivatives at either endpoint or midpoint. A linear phase segment would make its interval average equal to its constant local derivative, but that additional shape assumption is not supplied. If an estimate is plotted at an interval midpoint, identify that placement as a display convention. Phase noise, amplitude nulls, resets, timing errors and branch choices need separate treatment before applying the same arithmetic to measured data. Preserve those qualifications instead of presenting the numerical precision as evidence that the underlying phase is valid. Review: Equation 12F; Application 6B.7.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase; Chapter 6 — Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value.

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V011-C06-ESSAY-016 — The retained linear term gives sideband peak-amplitude magnitudes of $\frac{\beta}{2}$, or 0.06 relative to the unmodulated unit carrier. Each retained sideband power ratio is 0.0036, approximately −24.436975 dB relative to that stated unmodulated reference. The pointwise complex-envelope remainder is bounded by $\frac{\beta^2}{2}$, or 0.0072. The opposite signs of the two first-order exponential coefficients are part of the phase-modulation representation and should not be discarded when reconstructing the complex waveform. The remainder bound applies to the complex amplitude approximation, not directly to a claimed exact occupied bandwidth or to an identical numerical error in every spectral power. Nor does it justify treating the exact modulated carrier as unchanged for arbitrary index. State the approximation order, normalization and intended accuracy. If a stronger spectral or power claim is needed, evaluate the exact waveform or a separately justified expansion and compare it with the acquisition response. Review: Equations 12H–12I; Application 6B.8.

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase; Chapter 6 — Application 6B.8: Bound a small-phase approximation before using it.

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V011-C06-ESSAY-017 — The arithmetic gives an engineering bandwidth estimate of 16 kHz, but equality between that estimate and a nominal IF width does not establish adequate passage or a specified power-containment fraction. Ask which attenuation level defines the IF width, its ripple and phase response, and how the modulation energy is distributed. A nominal width also does not describe transition-band behavior or group delay. Retain the waveform and estimate the relevant spectrum or perform a calibrated transfer check across its significant components. Compare recovered deviation, message shape and any specified distortion metric against an appropriate wider or independently characterized reference path. Include receiver linearity and detector settings so the comparison does not confuse filtering with other transformations. The archival IRIG example supports treating the rule as a planning estimate, not as a universal exact mask. The final acceptance statement should name the quantity, tolerance, tested waveform and actual path state. Review: Equation 12J; Application 6B.9; IRIG 106-05 Appendix A, printed A-12.

Review: Chapter 6 — Equation 12J. Carson estimate and its stated inputs; Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

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V011-C06-ESSAY-018 — The PM contribution has peak frequency deviation 0.6 times 2500 Hz, or 1500 Hz. Adding the +120 Hz residual offset yields a baseband frequency range from −1380 Hz to +1620 Hz. The constant −25° phase offset has zero derivative. Over 5 ms, the residual frequency offset alone advances phase by 0.6 cycle, or 216°; this is separate from the oscillatory PM phase. Correcting a justified frequency offset removes a linear phase trend, while a fixed phase rotation changes the phase origin. Neither operation authorizes bridging a phase reset or replacing an invalid branch. A fitted trend can absorb a slow genuine modulation component if the estimation interval or model is unsuitable. Retain the uncorrected record, the reference or training interval, the fitted parameters and the corrected result. A statement that the residual was removed should describe the estimation dependency rather than imply independent knowledge of the original carrier. Review: Equation 12K; Application 6B.10.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

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V011-C06-ESSAY-019 — Specify the AM reference frequency, modulation rate and depth, carrier level, load and uncertainty relevant to the intended result. Exercise levels and gain states representative of the observation while keeping the reference below applicable peak and average limits. Verify both sidebands, not only the center-frequency carrier, and inspect complex or coherent response where asymmetry matters. Select maxima and minima within one stable state and declared interval; identify AGC transitions, detector offsets and noise-sensitive minima. Compare the envelope inversion with linear-power sideband accounting under the sinusoidal model. A disagreement calls for investigation of transfer, normalization or reference validity rather than averaging the answers blindly. State the acceptance tolerance before interpreting the result. A successful check establishes the functions and states actually exercised at the time of that check. It does not prove uninterrupted validity during a previous acquisition or the source identity of an unrelated signal. Preserve the settings and the reference evidence with the measured result. Review: Amplitude Modulation and Envelope Detection; Applications 6A.1–6A.3 and 6A.9.

Review: Chapter 6 — Application 6A.1: Close the power accounting for sinusoidal AM; Chapter 6 — Application 6A.2: Infer the conventional-AM envelope parameters; Chapter 6 — Application 6A.3: Infer modulation depth from one resolved sideband; Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth; Chapter 6 — Amplitude Modulation and Envelope Detection.

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V011-C06-ESSAY-020 — Separate the incoming waveform from the nonlinear and selective receiver operations. Limiting can reduce amplitude variation without preserving all multi-component information; capture can make one component dominate the demodulated output, and threshold behavior can produce abrupt changes or noise bursts as conditions vary. Clean audio therefore does not establish that the admitted RF contained only one source. Retain the complex RF or IF record and the state of the limiter, demodulator, filters, squelch and de-emphasis. Where authorized and technically appropriate, compare a characterized wider observation path, controlled level changes and a known two-signal reference. Check for front-end overload before attributing changes to the FM detector alone. Evaluate the weaker-component question with a stated sensitivity and selectivity scope. An absence statement should be bounded by the exercised chain, interval, bandwidth and detection criterion, not by the subjective cleanliness of the recovered audio. Review: Frequency and Phase Modulation; Carrier, Sidebands, and Modulation Evidence.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence; Chapter 6 — Frequency and Phase Modulation.

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V011-C06-ESSAY-021 — Treat acquisition continuity and waveform transfer as separate questions. Establish the expected or independently observed event timing, trigger operation, dwell or record coverage, sample continuity and any processing dead time. A gap can explain why a pulse was not acquired. For events known to have entered the retained record, examine IF bandwidth and transient response, gain control, limiting, detector time constants and output sampling. Those operations can broaden, suppress or reshape a pulse without deleting the corresponding acquisition interval. Use a representative calibrated pulse or independently timed reference to challenge the relevant path. Preserve peak, width, repetition and duty definitions, together with the level and state at which they were evaluated. Neither a quiet display nor a distorted audio trace alone distinguishes absence, missed capture and transfer distortion. The report should state which events were covered, which waveform properties were verified and which uncertainty remains. Review: Pulse, Radar, and Transient Reception; Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Pulse, Radar, and Transient Reception.

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V011-C06-ESSAY-022 — Possible explanations include a genuine modulation component in the admitted RF, an internal mixing or reference artifact, and a demodulator or processing response to noise or another signal. Begin by preserving native samples and all original settings. Compare whether the tone follows a predicted RF feature under a documented tuning change, whether it persists with a suitable terminated or reference input, and whether changing only the demodulator or derived-processing configuration changes the tone while native data remain fixed. These tests need known reference planes and stable states; a termination may bypass an antenna or external coupling path and therefore cannot test every part of the chain. Check overload and images before treating a tuning response as unique evidence. Interpret the outcomes against explicit predictions for each explanation, including cases where two mechanisms remain compatible. Avoid identifying a source or message solely from resemblance in audio. Keep the tested alternative, result and remaining ambiguity with every conclusion. Review: Single Sideband and Coherent Reception; Analog Demodulator Verification; Carrier, Sidebands, and Modulation Evidence.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence; Chapter 6 — Single Sideband and Coherent Reception; Chapter 6 — Analog Demodulator Verification.

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V011-C06-ESSAY-023 — Retain the native complex data with its sample rate, center or conversion frequency, clock and time basis, channel orientation, units or scaling, continuity information and capture interval. Record the exact extraction span, tuning correction, sideband convention, filter response, detector configuration, carrier or phase estimator, gain operation, limiting, squelch, de-emphasis and output resampling. Preserve software identity and configuration where they affect the transformation. Link the audio to the source interval and keep an unaltered original alongside any corrected product. A second analyst should be able to reproduce the transformation or identify which unavailable element prevents reproduction. Compare products generated from identical native data under controlled setting changes to isolate processing effects. Provenance establishes how a file was produced; it does not by itself calibrate amplitude, validate phase or establish metrological traceability of a result. The evidence package should make those distinctions explicit rather than relying on a file name or audible similarity. Review: Carrier, Sidebands, and Modulation Evidence; Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

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V011-C06-ESSAY-024 — The Navy course supports the bounded carrier, sideband, envelope, modulation-rate and deviation relationships read in the identified pages. Its historical allocation examples and broad noise-immunity claims are not universal modern receiver specifications. The IRIG archive supports the stated Carson estimate and the dependence of its relation to power containment on modulating-energy distribution; it does not supply a current legal allocation, an exact spectrum mask or the response of the user's IF filter. Identify the edition and the pages actually inspected. The chapter independently derives its peak-voltage power, projection and phase-frequency equations under explicit assumptions, so a qualitative source citation is not being asked to certify every hypothetical numerical input. A useful answer distinguishes primary-source support for a claim from broader confidence in an issuing institution. When the proposed claim exceeds the inspected scope, obtain the applicable source or perform the necessary measurement rather than expanding the citation by implication. Review: Chapter source notes 16–19; NEETS Module 12, identified pages; IRIG 106-05 Appendix A, printed A-12.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

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V011-C06-ESSAY-025 — Begin with the retained RF or IF interval, reference plane and chain state. Asymmetric sidebands may belong to the source or arise from unequal path transfer, interference or measurement error; a known coherent reference can test the relevant upper and lower responses. Pitch drift may reflect modulation, LO or recovery error, or processing, so compare the uncorrected complex phase with a justified frequency reference and retain any correction. Pulse-like dropouts may be real amplitude changes, acquisition gaps, squelch, AGC or demodulator behavior; inspect continuity and state records before assigning a mechanism. A phase derivative near an amplitude null may be invalid and should not become an apparent frequency excursion without qualification. Propose tests that discriminate these alternatives while preserving the original record. The conclusion should identify the supported waveform features, the transformations actually verified, and any unresolved source-level inference. Neither one modulation label nor apparently intelligible audio establishes transmitter identity or operational purpose. Review: Models 6A and 6B; Pulse, Radar, and Transient Reception; Analog Demodulator Verification; Chapter Summary.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Pulse, Radar, and Transient Reception; Chapter 6 — Analog Demodulator Verification.

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Discussion Guidance

V011-C06-DISCUSSION-001 — Separate waveform evidence from identity, location and purpose. Ask which observable features support the classification and whether the selected receiver path can create or suppress those features. Identify independent evidence that would be needed for a source claim. A useful conclusion can be technically specific about the admitted waveform while leaving source identity unresolved; avoid treating uncertainty about identity as a reason to discard valid modulation measurements. Review: Carrier, Sidebands, and Modulation Evidence.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

V011-C06-DISCUSSION-002 — Compare the extraction interval, signed frequency convention, tuning correction, sideband choice, detector, filters, gain operation, de-emphasis, squelch and output resampling. Hold the native data fixed while changing one material processing choice at a time. A reproducible difference in derived output does not imply that the external signal changed. The team should identify the transformation responsible and state which product answers the intended technical question. Review: Carrier, Sidebands, and Modulation Evidence; Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Carrier, Sidebands, and Modulation Evidence.

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V011-C06-DISCUSSION-003 — Discuss the nonnegative conventional-AM domain in which magnitude retains the signed envelope, then contrast envelope reversal and unequal complex sideband response. A magnitude record can still answer a bounded amplitude question, but it may discard the sign or quadrature relation needed for a stronger inference. Decide what additional coherent or complex capture would resolve the specific ambiguity. Do not require I/Q by habit without explaining which information the intended conclusion needs. Review: Equations 11C–11L.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 6 — Equation 11C. Conventional AM and nonnegative-envelope condition; Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response.

V011-C06-DISCUSSION-004 — First test whether both estimates refer to the same source interval, gain state, reference plane, averaging convention and sinusoidal model. Investigate asymmetry, response, noise and clipping before combining them. A discrepancy can be evidence against a shared assumption rather than two independent random errors. Any combined result needs a justified measurement model and dependence treatment; numerical agreement obtained by averaging does not repair a failed model. Review: Applications 6A.1–6A.3 and 6A.9.

Review: Chapter 6 — Application 6A.1: Close the power accounting for sinusoidal AM; Chapter 6 — Application 6A.2: Infer the conventional-AM envelope parameters; Chapter 6 — Application 6A.3: Infer modulation depth from one resolved sideband; Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

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V011-C06-DISCUSSION-005 — A minimum near zero is compatible with the boundary of nonnegative sinusoidal AM, but also with overmodulation after magnitude folding, destructive interference, fading, a detector offset or a noise-sensitive sample. Retain a stable interval and inspect the relevant signed or complex relationship. Ask whether the maximum and minimum belong to one calibrated state. The discussion should distinguish an observed output minimum from a justified inverse estimate of source depth. Review: Equation 11D; Application 6A.4.

Review: Chapter 6 — Equation 11D. Sinusoidal AM extrema and their inversion; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

V011-C06-DISCUSSION-006 — Use the ideal algebraic overmodulation example to separate the RF waveform from the magnitude detector. The signed envelope can reverse without adding RF terms to the linear product, while the absolute-value operation distorts the derived message. Physical clipping in a transmitter or receiver is an additional nonlinearity that can create other spectral components. Identify which side of the detector an observation describes before attributing a new component to the source. Review: Equation 11H; Application 6A.4.

Review: Chapter 6 — Equation 11H. Magnitude detection after envelope reversal; Chapter 6 — Application 6A.4: Show why an envelope-extrema estimate fails after reversal.

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V011-C06-DISCUSSION-007 — Maximizing a projection can be useful processing, but it does not independently establish the original phase or the complete calibration. Require a declared detector normalization and an applicable reference if amplitude is the result. Preserve the original complex record, the chosen rotation and the criterion used. Discuss cases in which noise or multiple components bias the maximizing phase. The correction should improve a defined estimate without erasing its dependency on the data. Review: Equations 11I–11J; Application 6A.5.

Review: Chapter 6 — Equation 11I. Real coherent recovery with residual reference error; Chapter 6 — Equation 11J. Complex coherent recovery; Chapter 6 — Application 6A.5: Measure phase-dependent coherent-AM recovery.

V011-C06-DISCUSSION-008 — Real-audio frequency magnitude discards the complex sign that distinguishes the two orientations. Apply one known LO offset to the signed upper and lower cases and compare the resulting magnitudes. Ask whether a stored sideband label supplies enough independent information to recover what was discarded. The appropriate record depends on the intended comparison, but an irreversible loss of orientation should be disclosed rather than reconstructed from expected speech content. Review: Equation 11K; Application 6A.7.

Review: Chapter 6 — Equation 11K. Explicit upper and lower single-sideband envelopes; Chapter 6 — Application 6A.7: Retain SSB sign when the reinsertion frequency is wrong.

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V011-C06-DISCUSSION-009 — Compare complete-period mean power with peak envelope power and the observation interval needed to encounter the peak. Determine whether the relevant hardware limit concerns average power, envelope peak, instantaneous voltage or another specified quantity. Use a representative waveform and state history to test linear transfer. A comfortable average margin can coexist with peak compression; the conclusion must follow the applicable limit rather than a convenient display statistic. Review: Equation 11B; Application 6A.8.

Review: Chapter 6 — Equation 11B. Envelope power convention; Chapter 6 — Application 6A.8: Compare average power with peak envelope power for two SSB tones.

V011-C06-DISCUSSION-010 — Unequal measured coefficients can motivate a path hypothesis, but source asymmetry and interference may remain alternatives. Examine both amplitudes and phases using a known input where possible. The full complex expansion shows how unequal sidebands create in-phase and quadrature terms; an envelope-only depth does not uniquely separate source and transfer. The discussion should end with a test that changes or characterizes the path while preserving the original observation. Review: Equation 11L; Application 6A.9.

Review: Chapter 6 — Equation 11L. In-phase and quadrature terms after unequal sideband response; Chapter 6 — Application 6A.9: Separate sideband filtering from source modulation depth.

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V011-C06-DISCUSSION-011 — The same phase history can be generated through different internal control laws when the drives are appropriately related. The waveform equations specify observable relationships, not a unique circuit architecture. A controlled change in known message rate or amplitude may discriminate a stated device hypothesis, but an unknown message does not provide that control. Keep waveform classification and architecture inference separate and identify the additional evidence needed for the latter. Review: Equations 12B–12C; Application 6B.3.

Review: Chapter 6 — Equation 12B. Sinusoidal FM phase and modulation index; Chapter 6 — Equation 12C. Sinusoidal PM and its frequency deviation; Chapter 6 — Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation.

V011-C06-DISCUSSION-012 — Require a meaningful nonzero complex representation, a justified continuous branch and adequate temporal resolution. At amplitude nulls or in unresolved mixtures, the phase can become unstable or represent an interference result rather than a unique component. Discuss exclusions, segmentation and alternative multi-component analysis. A smooth computed curve is not sufficient validation. State which signal model and intervals make the derivative interpretable. Review: Equation 12A; Model 6B phase-validity conditions.

Review: Chapter 6 — Equation 12A. Complex phase and instantaneous frequency; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates.

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V011-C06-DISCUSSION-013 — An endpoint difference constrains only the net accumulated frequency offset. Positive and negative excursions can cancel. Preserve the trajectory and distinguish a principal phase display from an unwrapped branch. If the record lacks enough information to establish the intervening turns, report that ambiguity instead of inventing continuity. The team should identify whether the question concerns net phase, peak deviation or local frequency, because those require different evidence. Review: Equations 12D and 12F; Application 6B.5.

Review: Chapter 6 — Equation 12D. Integration of a general deterministic frequency offset; Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase; Chapter 6 — Application 6B.5: Integrate a linear frequency ramp without losing phase turns.

V011-C06-DISCUSSION-014 — An algorithm can impose continuity or choose a branch, but constant frequencies separated by integer sample rates can remain indistinguishable in the same samples. Ask what independent admitted-band, conversion or prior-frequency information supports the selected member. Verify that the assumption was applicable during the interval. The numerical output of an unwrapping routine should be reported with its branch rule and exclusions rather than as proof that ambiguity has disappeared. Review: Equation 12G; Application 6B.6.

Review: Chapter 6 — Equation 12G. Principal-increment frequency and its alias class; Chapter 6 — Application 6B.6: Expose the ambiguity of sampled phase increments.

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V011-C06-DISCUSSION-015 — Placement at an interval midpoint may be a useful convention, but the estimator remains an average over its specified interval. State the difference operator, span, overlap and any smoothing. Compare traces only after reconciling those choices and their timing. A shorter span can improve locality while increasing sensitivity to phase error. The discussion should preserve the distinction between a plotting coordinate and a demonstrated instantaneous derivative. Review: Equation 12F; Application 6B.7.

Review: Chapter 6 — Equation 12F. Finite-interval frequency from unwrapped phase; Chapter 6 — Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value.

V011-C06-DISCUSSION-016 — Relate the pointwise complex-amplitude remainder bound to the quantity and tolerance actually being evaluated. An exact bound on the omitted complex amplitude does not automatically become the same bound on spectral power or distortion. The intended accuracy may permit the approximation or require the full exponential and a stronger calculation. Retain the unmodulated reference convention for the quoted first-order sideband powers and avoid extending it to arbitrary phase excursion. Review: Equations 12H–12I; Application 6B.8.

Review: Chapter 6 — Equation 12H. Pointwise small-phase remainder; Chapter 6 — Equation 12I. First-order sidebands for sinusoidal small phase; Chapter 6 — Application 6B.8: Bound a small-phase approximation before using it.

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V011-C06-DISCUSSION-017 — Use the estimate to guide which paths deserve evaluation. For acceptance, ask for the waveform spectrum, width definition, skirts, ripple, transfer phase and the permitted effect on the desired measurement. The same estimate can accompany different power distributions. A wider path may also admit more interference or noise. A useful decision names the tested waveform, chain state and quantity rather than declaring one nominal width universally correct. Review: Equation 12J; Application 6B.9.

Review: Chapter 6 — Equation 12J. Carson estimate and its stated inputs; Chapter 6 — Application 6B.9: Use Carson bandwidth as an estimate, then request the actual filter response.

V011-C06-DISCUSSION-018 — An estimated linear trend may remove carrier-reference error, but over an unsuitable interval it can also absorb a slow modulation component. Preserve the original phase and the source of the correction. Distinguish a fixed phase rotation, a frequency-offset correction and a phase reset. Ask whether an independent reference or a justified training interval supports the chosen parameters, and state the residual uncertainty instead of treating visual symmetry as validation. Review: Equation 12K; Application 6B.10.

Review: Chapter 6 — Equation 12K. Separate modulation, frequency offset and phase offset; Chapter 6 — Application 6B.10: Separate reference offset from a deterministic modulation.

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V011-C06-DISCUSSION-019 — The ideal phase-only model does not establish how a real limiter handles weak signals, multiple components, amplitude nulls, overload or recovery. Limiting can alter the evidence available for investigating those conditions even when it helps a particular demodulation task. Retain native data where possible and compare the relevant input and output behavior with a representative reference. The discussion should define what the limiter is permitted to change for the intended measurement. Review: Frequency and Phase Modulation; Model 6B phase-validity conditions.

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Frequency and Phase Modulation.

V011-C06-DISCUSSION-020 — Clean audio may be compatible with capture or other nonlinear selection, so it is insufficient evidence of a single-component RF input. Examine the native band, chain linearity and a stated weaker-signal detection criterion. A two-signal reference can test the actual configuration, but its levels, spacing and modulation must match the inference being made. Report the bounded detection scope rather than equating absence from audio with absence from the RF environment. Review: Frequency and Phase Modulation; Analog Demodulator Verification.

Review: Chapter 6 — Analog Demodulator Verification; Chapter 6 — Frequency and Phase Modulation.

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V011-C06-DISCUSSION-021 — Separate coverage from fidelity. Identify the usable interval, trigger timing, continuity and any dead time before characterizing the captured portion. A partial event may support some timing or amplitude observations while leaving the full width, peak or intrapulse structure unresolved. Do not splice separate stable fragments into a continuous event without a justified reconstruction model. State what was acquired and which properties could not be established. Review: Pulse, Radar, and Transient Reception; Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Pulse, Radar, and Transient Reception.

V011-C06-DISCUSSION-022 — Specify which stages and functions the stimulus actually traverses, its modulation and level range, and the time of the check. A reference injected downstream of an antenna cannot verify the bypassed antenna path. A successful check supports the exercised configuration at that time and cannot alone establish uninterrupted earlier validity. Choose complementary checks for competing hypotheses and keep the reference result distinct from source identification. Review: Analog Demodulator Verification; Preserve pulse and demodulator evidence across representations.

Review: Chapter 6 — Preserve pulse and demodulator evidence across representations; Chapter 6 — Analog Demodulator Verification.

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V011-C06-DISCUSSION-023 — It may be relevant to an authorized question, but it must be distinguished from calibrated amplitude, frequency, deviation or distortion. Record the processing needed to obtain it and avoid treating expected words as an independent frequency reference. Preserve the native technical record and minimize incidental content as the chapter directs. The discussion should state what an intelligibility observation can support and what additional objective evidence the report needs. Review: Analog Demodulator Verification; Hypothetical Case Adjudication.

Review: Chapter 6 — Analog Demodulator Verification; Chapter 6 — Hypothetical Case Adjudication: Analog Modulation Reception: AM, SSB, FM, PM, and Pulsed Signals.

V011-C06-DISCUSSION-024 — Identify the issuing body, edition and inspected pages, then attach the citation to the bounded claim actually supported. Preserve correct source identity and equipment or edition applicability. Do not extend a relationship about a historical architecture into a universal modern performance or regulatory statement. If a source contains a questionable example outside the relied-on scope, the qualification should be precise rather than discrediting all of its valid material. Review: Chapter source notes 16–19; Chapter References and Works Cited.

Review: Chapter 6 — Carrier, Sidebands, and Modulation Evidence; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 6 — References and Works Cited.

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V011-C06-DISCUSSION-025 — Require discriminating predictions and tests rather than selecting the most familiar story. A controlled processing change on the same native data can isolate some derived effects; a separately characterized acquisition may test overload, images or external coupling. If the available tests do not distinguish the remaining mechanisms, preserve the alternatives and narrow the conclusion. A reproducible bounded result is useful even when source identity or the exact internal mechanism remains unresolved. Review: Single Sideband and Coherent Reception; Analog Demodulator Verification.

Review: Chapter 6 — Single Sideband and Coherent Reception; Chapter 6 — Analog Demodulator Verification.

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Chapter Glossary

AMPLITUDE MODULATION: A representation in which a message changes the amplitude of a carrier-related waveform. Conventional AM in Model 6A uses a positive carrier term and a real normalized message. A magnitude envelope preserves that signed relationship only while the nonnegative-envelope condition and the applicable receiver transfer hold.

CAPTURE EFFECT: Tendency of an FM receiver to favor the stronger of two signals within its passband.

CARRIER POWER: The average power associated with the specified unmodulated carrier component at a declared reference plane. Under Model 6A's peak-voltage convention it is carrier peak squared divided by twice the positive real load resistance. Sideband powers, total average power and peak envelope power are separate quantities.

CARRIER REINSERTION: The introduction of a local carrier reference for coherent recovery of a suppressed-carrier or single-sideband signal. Its frequency and phase determine the recovered baseband orientation and projection. An adjustment made by ear is a processing choice; it does not independently calibrate the original RF frequency.

CARSON BANDWIDTH ESTIMATE: The engineering estimate twice the sum of peak frequency deviation and the highest declared modulating frequency, without an automatic exact-containment or filter-distortion claim.

COHERENT DETECTOR: Detector using a phase- and frequency-related reference to recover a modulated quantity.

COHERENT PROJECTION: Recovery of the component of a complex envelope aligned with a declared real reference phase.

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COMPLEX ENVELOPE: The complex baseband voltage function whose translation to a declared carrier and subsequent real part produce the modeled RF waveform. Its magnitude and phase retain information that a magnitude-only or one-axis record can discard. Model 6A uses a peak-voltage convention, spectral separation and a stated load and averaging interval for power calculations.

DE-EMPHASIS: A frequency-dependent operation in the recovered baseband path, commonly associated with an intended complementary emphasis characteristic. It changes the derived waveform and must be recorded with an audio result. Its presence alone does not establish the transmitter's characteristic or validate an amplitude or deviation measurement.

DEMODULATED AUDIO: An audio-band product formed by applying a declared tuning, detection and processing chain to an RF or IF record. It retains only the information admitted by that transformation. Reproducibility requires a link to the native interval and configuration; intelligibility alone does not calibrate the output or identify a source.

DEMODULATOR TRANSFER: The relationship between an admitted modulated waveform and a stated recovered output under a particular receiver configuration and state. It includes tuning, filtering, detector operation and relevant gain or conditioning behavior. Verification for one level, bandwidth or waveform does not automatically establish the relationship throughout the instrument's operating range.

DEVIATION: Peak or instantaneous departure of frequency from its unmodulated reference.

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DOUBLE-SIDEBAND SUPPRESSED CARRIER: An amplitude-modulated form retaining two message-related sidebands while suppressing the intended carrier component. Coherent reception needs a declared carrier reference. In the chapter's real product-detector example, a residual frequency error creates a rotating projection and can split a recovered sinusoidal message into two tones.

ENVELOPE DETECTOR: A detector that estimates a waveform's envelope magnitude through an applicable rectifying, magnitude or equivalent operation. Its bandwidth, time constants and nonlinear behavior affect the result. It loses the sign of an overmodulated real envelope and cannot generally substitute for coherent recovery of suppressed-carrier or single-sideband information.

ENVELOPE REVERSAL: A sign change of a real modulation envelope that magnitude detection cannot preserve.

FREQUENCY DISCRIMINATOR: A receiver operation that converts frequency variation into a baseband output according to its applicable transfer characteristic. Deviation scale, bandwidth, linear range and input conditions require verification. The term does not guarantee that amplitude nulls, multiple components or threshold behavior leave the recovered frequency unambiguous.

FREQUENCY MODULATION: A signal relation in which a specified message controls frequency deviation from a declared carrier reference. Phase follows by integration. For sinusoidal deviation, the peak phase index is peak deviation divided by positive modulation frequency; a constant offset instead produces a linear phase ramp.

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INSTANTANEOUS FREQUENCY: In Model 6B, the carrier reference plus the derivative of the stipulated unwrapped phase divided by two pi, wherever that derivative exists. The model requires a meaningful nonzero complex signal and an applicable continuous phase branch. A finite phase difference instead gives an interval average, and a phase reset requires separate treatment.

INTERVAL-AVERAGE FREQUENCY: The unwrapped phase change divided by two pi and the elapsed interval, with any included phase discontinuity explicitly identified.

LOWER SIDEBAND: The message-related spectral component or band below a declared carrier. In Model 6A's single-tone complex convention its envelope rotates at negative message frequency, and translation retains that sign before any conversion to real-audio magnitude. The label depends on the reference and conversion orientation.

MESSAGE MEAN SQUARE: The declared time average of the squared normalized message. For a zero-mean AM message it determines the additional average power through the squared modulation scale. A unit cosine has mean square one half, but a general bounded message need not; its peak bound alone does not establish this statistic.

MESSAGE NORMALIZATION: The stated scaling that relates a physical or mathematical message to the dimensionless waveform used in a modulation model. In Model 6A the message magnitude is bounded by one and the separate modulation scale sets its contribution to the envelope. Changing that normalization without changing the scale alters the modeled waveform and power.

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MODULATION FREQUENCY: The rate of a sinusoidal modulating component, expressed in hertz, or an explicitly identified frequency within a more general message. It differs from peak frequency deviation and peak phase excursion. A multicomponent waveform requires the component frequencies and, for a Carson estimate, the highest significant modulating frequency under a stated criterion.

MODULATION INDEX: Dimensionless ratio describing modulation excursion relative to a modulating frequency or carrier parameter.

OPPOSITE-SIDEBAND LEAKAGE: An unwanted retained component from the sideband that a receiver or conversion process was intended to reject. It can arise from finite filter rejection, I/Q mismatch, product-detector imbalance or other path imperfections. Its observation is a receiver-performance question unless independent evidence establishes that the component belongs to the source.

PEAK ENVELOPE POWER: The maximum squared envelope magnitude divided by twice the declared real load resistance under the peak-voltage convention.

PEAK-VOLTAGE ENVELOPE: A complex envelope scaled so that its magnitude is the local peak RF voltage under the stated band-separation convention.

PHASE-INCREMENT ALIAS CLASS: Frequencies separated by integer sample rates that produce the same principal sampled phase increment.

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PHASE MODULATION: A relation in which a specified message directly controls phase relative to a declared carrier. Differentiation gives frequency deviation. For a sinusoidal message with fixed peak phase, peak frequency deviation grows in proportion to message frequency; a received phase history alone does not uniquely identify the circuitry that generated it.

PHASE RESET: An event that changes the selected phase branch discontinuously or restarts its reference. It interrupts an analysis that assumes one absolutely continuous phase history. Preserve the event and segment the record; do not interpret an ideal jump as an ordinary finite instantaneous frequency or silently bridge it with a fitted trend.

PRINCIPAL PHASE INCREMENT: The argument of the product of one complex sample and the conjugate of its predecessor, restricted here to the interval from minus pi inclusive to plus pi exclusive. It records a rotation modulo a full turn. Frequency interpretation needs a sample interval and justified information to resolve possible whole-turn aliases.

RESIDUAL FREQUENCY OFFSET: The remaining frequency difference between the signal’s declared carrier reference and the local conversion or recovery reference. Under the chapter’s convention it is carrier minus LO frequency and adds a linear baseband phase trend. Estimating that trend from modulated data can absorb part of the modulation unless the estimation model and interval are justified.

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SIDEBAND COEFFICIENT: A complex peak-voltage coefficient assigned to an upper or lower spectral component in the envelope expansion. It carries phase as well as amplitude. After a path response, the sum and difference of the two coefficients contribute to the complete in-phase and quadrature expression; real-coefficient shortcuts do not apply to arbitrary complex coefficients.

SIDEBAND IMBALANCE: A difference between the applicable amplitudes or phases of corresponding upper and lower sideband responses. It can turn an originally real envelope into a complex one and bias a source-depth inference from output magnitude. Distinguishing source asymmetry from path distortion requires an appropriate reference or additional independent information.

SINGLE SIDEBAND: Amplitude-modulation form transmitting one sideband with reduced or suppressed carrier.

SMALL-PHASE APPROXIMATION: The retention of one plus j times phase as the first-order representation of the complex phase exponential. The chapter supplies an exact pointwise complex-amplitude remainder bound of half the squared real phase. First-order sideband amplitudes are approximate and use an unmodulated carrier reference; the bound does not itself specify exact spectral containment.

SQUELCH: A receiver operation that suppresses or gates a recovered output according to a defined or automatic condition. It can change the apparent presence and continuity of audio without proving that the RF waveform disappeared. Record its state and criterion when interpreting dropouts or comparing derived products.

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UNWRAPPED PHASE: A continuous phase branch retaining accumulated cycles on a declared valid interval, with reset events treated separately.

UPPER SIDEBAND: The message-related spectral component or band above a declared carrier. In Model 6A's single-tone complex convention its envelope rotates at positive message frequency. The signed baseband result also depends on LO frequency; folding it into real-audio magnitude can hide the orientation needed for a coherent comparison.

ZERO-MEAN MESSAGE: A message whose declared average is zero over the applicable averaging interval or limiting convention. In the conventional-AM power expansion this condition removes the carrier-message cross term. It does not imply zero mean square, absence of modulation, a specified peak value or a particular spectral distribution.

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References and Works Cited

United States Navy. Navy Electricity and Electronics Training Series, Module 12: Modulation. NAVEDTRA 14184, September 1998. Printed pages 1-43–1-45 and 2-8–2-13, reproduced in SIGINTRADARTSCM.pdf, compilation pages 7308–7310 and 7349–7354; cover and edition at compilation page 7254.

Annotation. Supports the bounded discussion of carrier, sideband and envelope relationships and the distinction among frequency deviation, modulation rate and modulation index. The chapter's peak-voltage, projection and phase-frequency calculations are independently derived under their stated assumptions. Historical allocation examples and broad noise-elimination or universal performance claims outside this scope are not adopted. Figure 1-38 on printed page 1-43 labels its lower sideband 94 kHz; the adjacent prose and the stated 100 kHz carrier minus 5 kHz modulation give 95 kHz. The figure label is not adopted. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver's actual topology. Ideal mixer identities do not establish that a real component is free of compression, leakage, spurs or path-dependent calibration errors.

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Range Commanders Council. Telemetry Standards, IRIG Standard 106-05. Appendix A, “Frequency Considerations for Telemetry,” 2005 archive edition. Section 5.2.3.3, printed page A-12, Equation A-4 and Figure A-7. https://irig106.org/docs/106-05/appendixA.pdf

Annotation. Supports use of Carson’s rule as an engineering estimate and the qualification that its relationship to a specified power-containment bandwidth depends on the distribution of modulating energy. The inspected archival passage does not establish a current allocation, a universal emissions mask or the transfer performance of a particular receiver filter. The source describes relationships among modulation parameters, occupied spectrum and instrument observations. Approximate bandwidth rules depend on the signal model and the chosen significance or emission-mask criterion, rather than constituting exact occupied-band measurements. The chapter should distinguish an engineering estimate from calibrated detection and should state the assumed modulation and detector conventions. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

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Chapter 7. Digital Modulation Reception, Synchronization, EVM, and Error Metrics

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7.1 Constellations and Symbol Representation

Digital modulation maps discrete symbol values to amplitude, phase, frequency, time, code, or multicarrier states. The receiver must estimate carrier frequency, phase, symbol timing, gain, and sometimes channel response before symbols can be compared with their ideal locations. A constellation display is therefore the output of synchronization and equalization algorithms, not a direct image of the transmitted waveform.[1]

Binary and multilevel phase-shift keying, quadrature amplitude modulation, frequency-shift keying, minimum-shift keying, orthogonal frequency-division multiplexing, spread-spectrum methods, and pulsed schemes have different observables. Classification should consider cyclostationary structure, symbol rate, spectral shape, pilots, preambles, coding, and time behavior. A visual resemblance to a constellation is not sufficient when the receiver has imposed the assumed symbol timing and carrier.

1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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7.2 Carrier and Timing Synchronization

Frequency offset rotates a constellation and shifts matched-filter response. Phase offset changes symbol decision boundaries. Timing error samples the pulse away from its optimum point and can increase intersymbol interference. Practical receivers use acquisition and tracking loops, correlation with known sequences, timing-error detectors, and pilot-aided estimators. Loop bandwidth trades noise rejection against ability to follow drift and modulation.

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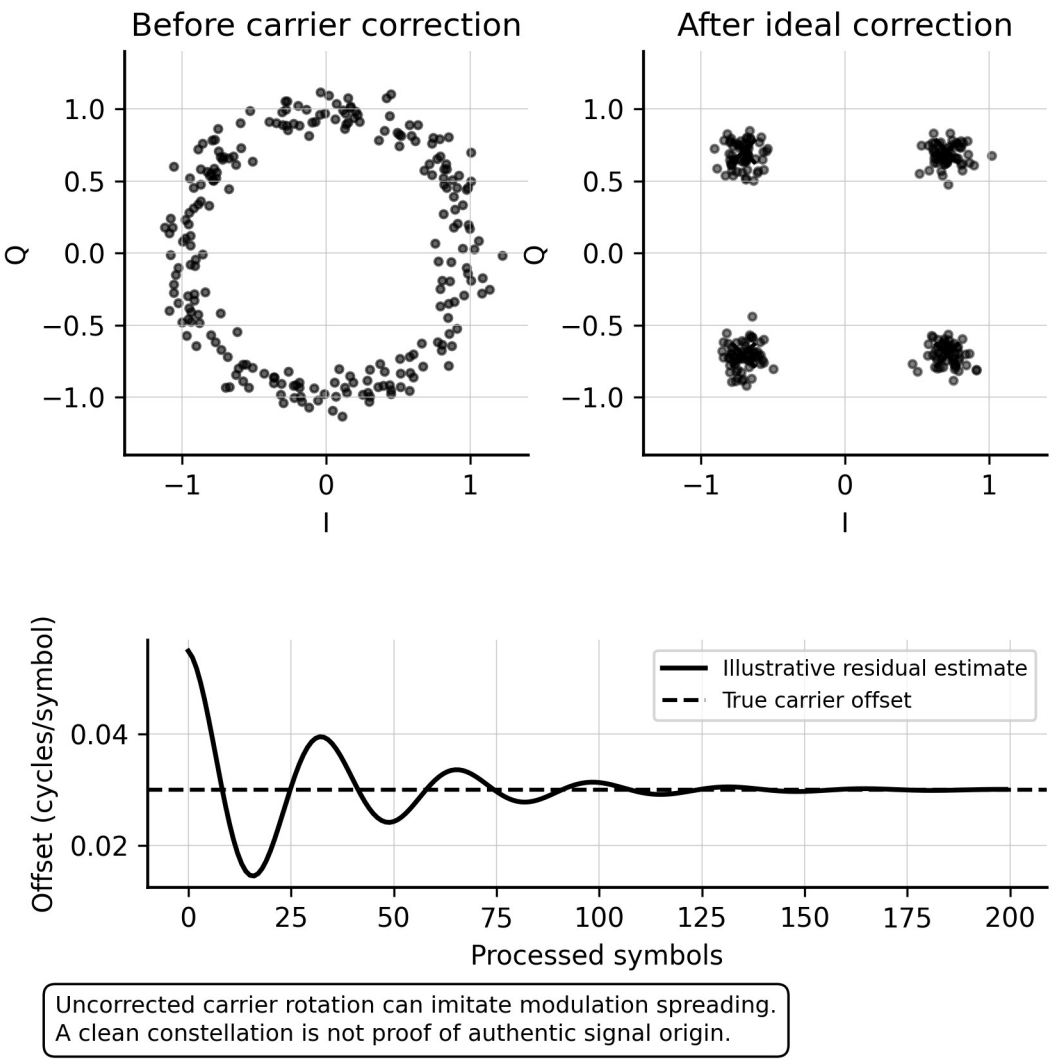

Figure 26. Carrier-offset and timing-error convergence.

Synchronization settings should be preserved with the result. A receiver can force a poor signal into an apparently stable display through narrow loops and long averaging, or can fail on a valid burst when acquisition range is too small. The practitioner records frequency and timing estimates, residual

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errors, lock indicators, slips, and the sections of data excluded from metrics. Held-out data provides a useful check against an estimator tuned to one capture.

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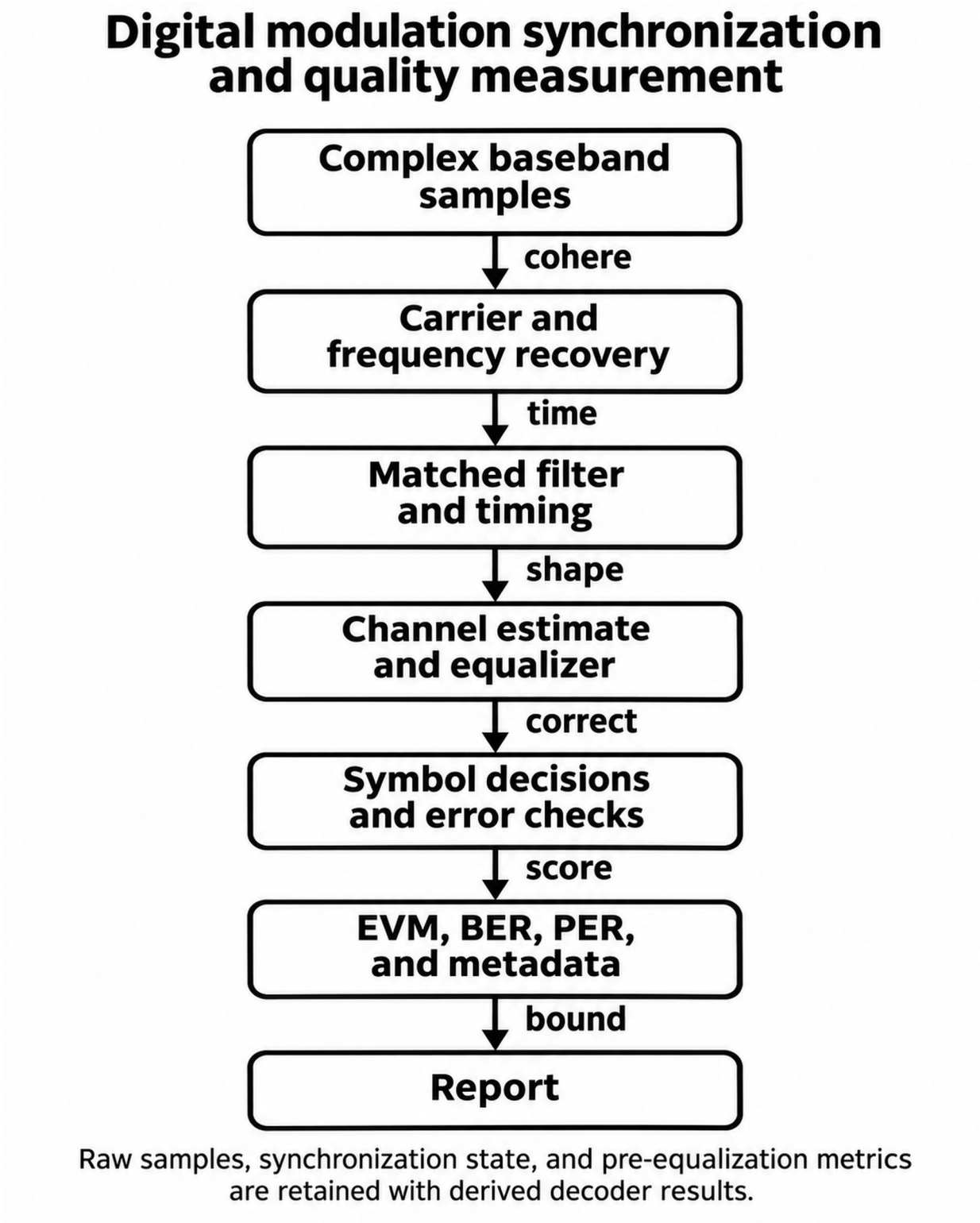

Figure 27. Digital modulation synchronisation and quality.

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7.3 Matched Filtering, Pulse Shaping, and Channel Effects

Pulse shaping controls occupied bandwidth and intersymbol interference. A matched filter maximizes signal-to-noise ratio for the assumed pulse in additive white Gaussian noise when timing and channel assumptions hold. Raised-cosine and root-raised-cosine filters are common, but implementation span, roll-off, sample rate, and scaling matter. Multipath and frequency-selective channels change the optimum response and may require equalization.

Equalizers can remove channel distortion while also hiding the physical condition being measured. A technical-security survey may need both pre-equalization and post-equalization metrics. If an equalizer with many degrees of freedom converts an unstable waveform into a tight constellation, the improvement is a processing result, not proof of a clean emission path. Coefficients, training intervals, convergence state, and regularization should be retained.

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7.4 Define the symbol experiment before fitting the constellation

A symbol-quality measurement begins with a reference relationship. Identify the transmitted or constructed reference sequence, its symbol rate, pulse shape, occupied interval, and mapping from labels to complex values. Then identify the receiver processing that makes an observed sample comparable with one reference symbol. Carrier recovery, timing selection, matched filtering, amplitude normalization, and equalization each change that comparison. A constellation plot omits much of this history, so it is a useful view of the result rather than a complete definition of the experiment.

Acquisition and tracking are separate parts of that history. A receiver can require a preamble or a sufficiently long carrier interval before its estimates become usable. Excluding that acquisition portion may be appropriate for a steady-state metric, but the excluded duration remains relevant to burst capture and packet success. Preserve both the acquisition result and the selected evaluation interval. A method that works only after most of the event has passed should not be described as though it characterized the entire event.

Pulse shaping and receive filtering determine which samples are symbol samples. State the filter coefficients or an unambiguous generation convention, span, roll-off or equivalent parameter, sample rate, delay, and initialization. A reference filter and a measurement filter may serve different purposes. Their names alone do not establish that an imported capture and a reconstructed ideal waveform are aligned. Check a known sequence with

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the same implementation and inspect the residual around transitions, where timing and filter-history errors are often clearest.

Equalization changes the question from the condition of an observed path to the condition after a specified compensation. Retain results before and after compensation when the physical channel is part of the investigation. Training length, coefficient count, regularization, adaptation interval, and held-out performance determine how much trust to place in the fitted result. An equalizer that follows each noisy sample can make a visually tight constellation without demonstrating a stable transferable channel model.

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7.5 Model 7A: a finite, declared EVM comparison

Model 7A develops the retained RMS EVM relation without introducing a probability law for symbol errors. The reference and observed vectors are finite disclosed data. Nonnegative weights identify the selected population, and the weighted reference energy must be positive. Timing, symbol mapping, filtering, and allowed corrections are fixed parts of the contract. Keysight's EVM documentation makes the symbol-location and normalization choices explicit, including differences for particular modulation formats. The model here states its own finite sample set so that no vendor-specific convention is implied.[2]

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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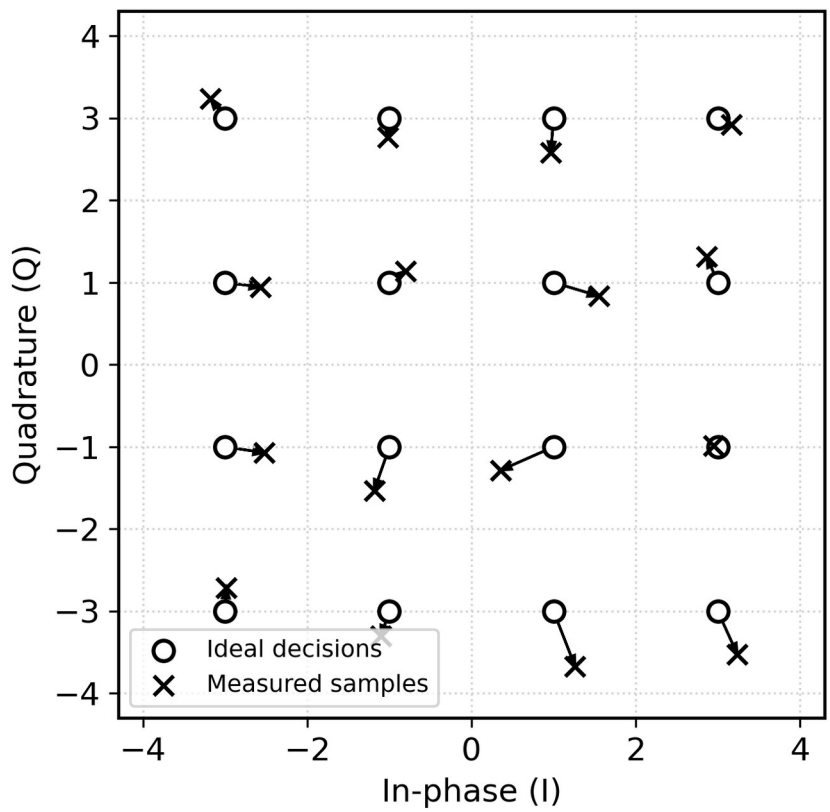

Illustrative RMS EVM = 14.0% (reference: ideal symbol RMS)

Important controls: common-phase correction, symbol alignment, reference constellation and fitting on held-out data.

Figure 28. QAM error vectors and RMS EVM.

Let s_k be the ideal complex symbol and y_k its observed counterpart at index k. The fixed comparison reference is t_k, which may equal s_k or a separately declared corrected reference. Their amplitude units must agree. The finite selected index set is S, and w_k are fixed nonnegative dimensionless weights.

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Training uses set T and held-out evaluation uses set H. E_s denotes weighted ideal-reference energy; the normalized EVM E is dimensionless. The fitted coefficient $\hat{a}$ is a dimensionless complex gain, and a star denotes complex conjugation.

Equation 13A. Finite reference energy and admissible weights

$$E_s = \sum_{k \in S} w_k |s_k|^2 > 0$$
$$w_k \geq 0, S\ finite$$

Equation 13B. Weighted fixed-reference error vector magnitude

$$E = \sqrt{\frac{\sum_{k \in S} w_k |y_k - t_k|^2}{\sum_{k \in S} w_k |t_k|^2}}$$
$$\sum_{k \in S} w_k |t_k|^2 > 0$$

The numerator is weighted squared residual distance in the complex plane, and the denominator is the corresponding reference energy. Their ratio is a power-like error ratio; taking its square root gives the amplitude-like EVM. Reporting a percentage multiplies that result by one hundred. Reporting decibels uses twenty times its logarithm. A zero residual has zero linear EVM and a limiting decibel value of minus infinity; it has no finite logarithm. A zero reference-energy record is undefined for this metric even if an instrument displays a convenient number.

Equation 13C. Percent and decibel reporting

$$E_{percent} = 100\,E$$
$$E_{dB} = 20 \log_{10}(E)\ for\ E > 0$$
$$E = 0 : limiting\ decibel\ value\ -\infty$$

An optional constant complex-gain fit can align amplitude and phase on a declared training set. Minimize the weighted sum of squared differences

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between the observations and a scaled reference. Expanding the squared magnitude separates the objective into a constant term and the reference energy multiplied by the squared distance from the fitted coefficient. The coefficient is therefore the weighted reference correlation divided by weighted reference energy. This derivation also identifies the required positive denominator.

Equation 13D. Optional complex-gain fit on a training set

$$\hat{a}=\frac{\sum_{k\in T} w_k y_k s_k^*}{\sum_{k\in T} w_k |s_k|^2}$$

$$E_{s,T}=\sum_{k\in T} w_k |s_k|^2>0$$

Equation 13E. Least-squares completion of the square

$$C=\sum_{k\in T} w_k y_k s_k^* \,,\hat{a}=\frac{C}{E_{s,T}}$$

$$J(a)=\sum_{k\in T} w_k |y_k - a s_k|^2$$

$$¿\sum_{k\in T} w_k |y_k|^2 - \frac{|C|^2}{E_{s,T}} + E_{s,T}|a-\hat{a}|^2$$

Two choices must then remain separate: which coefficient was fitted, and which reference normalizes the reported residual. If the evaluation reference is the fitted coefficient times the ideal symbols, that coefficient must be nonzero and the evaluation set must have positive ideal energy. A zero fitted coefficient can minimize residual energy while making this fitted-reference normalization undefined. Using the original ideal reference energy would be another valid declared metric, but it is not silently substituted here.

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Equation 13F. Held-out evaluation with a nonzero fitted reference

$$E_H = \sqrt{\frac{\sum_{k \in H} w_k \left| y_k - \hat{a}\, s_k \right|^2}{\left|\hat{a}\right|^2 \sum_{k \in H} w_k \left| s_k \right|^2}}$$

$$\hat{a} \neq 0,\ \sum_{k \in H} w_k \left| s_k \right|^2 > 0,\ H \cap T = \varnothing$$

A fit that reduces residual energy need not reduce every differently normalized EVM number. If the fitted reference has smaller energy, the denominator also falls. Report the coefficient, numerator, denominator, and selection when comparing results. This makes it possible to distinguish a physical improvement from a change in the metric definition. The same principle applies when a tool normalizes each trace independently before displaying it.

Constellation-maximum normalization uses a fixed ideal outer-point magnitude instead of the realized average reference magnitude. Keysight documents both choices and warns that trace normalization and error-summary normalization can differ. A multilevel constellation makes the distinction visible because its inner and outer symbols have different energies. The 16QAM example below deliberately includes every point once; a shorter or biased sequence can have a different realized average energy.[3]

3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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Equation 13G. Average-reference and maximum-reference normalization

$$W=\sum_{k\in S} w_k, e_{rms}^2=\frac{\sum_{k\in S} w_k \left|y_k-t_k\right|^2}{W}$$

$$E_{avg}=\frac{e_{rms}}{\sqrt{\frac{\sum_{k\in S} w_k \left|t_k\right|^2}{W}}}$$

$$E_{max}=\frac{e_{rms}}{S_{max}}, S_{max}>0$$

Several simple impairment relations follow directly from the same residual definition. A constant real gain error gives the absolute gain departure from one. A fixed phase rotation gives a chord length on the unit circle. An additive offset survives a gain-only fit when the balanced reference sums to zero. A conjugate leakage term survives that fit when the reference sum of squares vanishes. These are controlled examples of nonunique causes: they show what a metric can measure, not how to diagnose an unknown record from one EVM value.

Equation 13H. Fixed gain and phase impairments

$$y_k=g\, s_k \Rightarrow E=\mid g-1 \mid$$

$$y_k=\exp\left(j\theta\right) s_k \Rightarrow E=2 \mid \sin\left(\frac{\theta}{2}\right) \mid$$

Equation 13I. Balanced-reference offset and conjugate terms

$$y_k=s_k+d \Rightarrow E=\frac{\left|d\right|}{\sqrt{\frac{\sum_{k\in S} w_k \left|s_k\right|^2}{\sum_{k\in S} w_k}}}$$

$$gain\, fit\, \hat{a}=1\, if \sum_{k\in S} w_k s_k=0$$

$$y_k=s_k+\beta\, s_k^{\,*} \Rightarrow E=\mid \beta \mid$$

$$gain\, fit\, \hat{a}=1\, if \sum_{k\in S} w_k s_k^{\,2}=0$$

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The sample selection is equally consequential. A complete burst, its settled payload, and a weighted transition region are different populations. Weights must be defined before judging the result and disclosed with it. A small subset cannot stand in for an entire recording merely because its constellation is cleaner. The largest residual, acquisition duration, excluded intervals, and continuity checks can complement EVM without being folded into an undocumented composite score.

Equation 13J. Residual sums for a disclosed selection

$$N_{err} = \sum_{k \in S} w_k \left| y_k - t_k \right|^2$$

$$D_{ref} = \sum_{k \in S} w_k \left| t_k \right|^2 > 0$$

$$E^2 = \frac{N_{err}}{D_{ref}}$$

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7.6 Worked applications with hypothetical inputs

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7.7 Application 7A.1: Show which error a fitted gain removes

Use the four unit-energy reference symbols 1, j, -1, and $-j$, and multiply every observed symbol by 1.08. Relative to the fixed reference, EVM is 0.08, or 8 percent and $-21.938200\ \mathrm{dB}$. A complex-gain fit returns 1.08 and leaves zero residual when the fitted reference is used.

The gain fit has removed exactly the impairment that the first result measures. Neither result is inherently contradictory. The fixed-reference value assesses absolute amplitude agreement, while the fitted value assesses what remains after that permitted correction. If amplitude calibration is the question, the fitted coefficient itself belongs in the acceptance result rather than disappearing behind the zero residual.

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7.8 Application 7A.2: Quantify a fixed phase error

A fixed 6-degree rotation of unit-energy symbols gives a chord distance of twice the sine of 3 degrees. The exact relation $2\sin(3^\circ)$ gives an EVM of approximately 0.10467191, equivalent to approximately 10.467191 percent or $-19.603397\ \mathrm{dB}$. No phase correction is fitted in this calculation.

The small-angle approximation would use the phase in radians, but the exact geometry is simple enough here to retain. A fitted phase could remove the rotation, provided that correction is part of the intended metric. A receiver phase-calibration test and a modulation-quality test after carrier recovery may therefore report different numbers from the same samples. Their correction permissions explain the difference.

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7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain

Add the same complex offset $0.04 + j\,0.03$ to the four balanced unit-energy references. Its magnitude is 0.05, so fixed-reference EVM is 5 percent. The reference symbols sum to zero, making their correlation with the constant offset vanish. A gain-only fit remains one and the EVM remains 5 percent.

Removing the estimated mean would eliminate this offset in the constructed case, but it would add another fitted parameter and change the measurement. A DC-removal step can also discard a real component when the signal definition permits nonzero mean. Preserve the reason for that operation, its training interval, and the uncorrected result. Do not label all removed mean as receiver leakage without an independent challenge.

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7.10 Application 7A.4: Expose a conjugate-image impairment

For the same four references, form each observation as its ideal symbol plus 0.06 times the conjugate of that symbol. The balanced reference has zero sum of squares, so the fitted ordinary complex gain remains one. Both fixed-reference and gain-fitted EVM are 6 percent. The residual changes direction with the symbol because it belongs to a conjugate path.

This is a bounded model of an image-like I/Q impairment, not proof that an unknown 6 percent EVM originates in I/Q imbalance. A calibration that estimates both direct and conjugate coefficients would be a different declared model with more parameters. Check its performance on an independent sequence before using it to correct an environmental recording. The original complex data remain necessary for that comparison.

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7.11 Application 7A.5: Compare RMS and constellation-maximum normalization

Use all sixteen square-16QAM points formed from real and imaginary coordinates -3, -1, 1, and 3. Their average energy is 10 and their maximum energy is 18. Add a fixed residual $0.2+j0.1$, with energy 0.05. RMS-reference normalization gives 7.071068 percent, while constellation-maximum normalization gives 5.270463 percent.

The observed residual has not changed. The smaller second number follows from its larger denominator. A threshold written for one normalization cannot be applied to the other without an explicit conversion and the correct reference population. This is why a report should name the normalization rather than treating a percent sign or an EVM label as a complete definition.

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7.12 Application 7A.6: Make selection and weighting visible

Four unit-reference symbols have residual magnitudes 0.30, 0.10, 0.02, and 0.02. Using all four equally gives 15.874508 percent EVM. Excluding the first two acquisition symbols gives 2 percent. Weights 0.1, 0.1, 1, and 1 instead give 7.006490 percent.

These values answer different questions about the same record. The settled-payload value can be useful, but it does not erase the acquisition errors. The weighted value expresses a chosen emphasis and is not automatically a standard-defined metric. Record the indices and weights, and preserve an unweighted complete-record result when the entire burst matters to the decision.

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7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols

Fit one training reference symbol 1 to one observation $1.2+j0.1$. The fitted gain is exactly $1.2+j0.1$ and the training residual is zero. Now apply that fitted reference to held-out ideal observations j, -1, and $-j$. Relative to the fitted reference, their EVM is 18.569534 percent. Relative to the true fixed reference it is zero.

The fit absorbed the entire error in a training set with no residual freedom for checking a complex gain. Its zero training EVM offers no assurance about other data. The example is deliberately small so that the failure is transparent. Longer training, a justified coefficient model, and held-out evaluation make the same issue observable in practical synchronization and equalization work.

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7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record

A known unit pilot is sampled at 10,000 symbols per second for indices -10 through $+10$, while a residual 100 Hz offset rotates it. Phase spans -36 through $+36$ degrees. The in-sample constant-gain fit is approximately $0.92917367 + j0$. Fixed-reference EVM is 37.636773 percent; normalizing the fitted residual by the fitted-reference energy gives 39.781958 percent.

A constant coefficient cannot remove the time-dependent rotation. Its fitted magnitude is reduced because the rotating phasors partly cancel in their mean, which also changes the normalization denominator. A separately declared frequency-ramp fit could address that impairment, but it adds an estimation dependency and requires its own validation. The present result is an in-sample diagnostic, not a claim about held-out tracking performance.

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7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping

Multiply the balanced QPSK reference sequence by j. Relative to its fixed labels, the EVM is the square root of two, or 141.421356 percent. A fitted complex gain j makes the residual zero. The same four constellation locations are occupied, but the association between observed points and the original labels has rotated.

A tight constellation after the fit does not resolve that label ambiguity. Known pilots, frame structure, or another justified reference may distinguish the intended mapping, and those checks should be retained. No bit error rate follows from the geometric EVM alone. This example separates successful numerical alignment from validation of the information represented by the symbols.

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7.16 Application 7A.10: Audit a complete finite residual vector

Take references $1+j$, $1-j$, $-1+j$, and $-1-j$. Their residuals are $0.02+j0.01$, $-0.01+j0.03$, $0.04-j0.02$, and $-0.02-j0.02$. The reference-energy sum is 8 and the residual-energy sum is 0.0043. The RMS EVM is 2.318405 percent, while the largest residual normalized to reference RMS is 3.162278 percent.

All inputs are disclosed, so the result can be recalculated without a proprietary constellation display. The larger peak residual does not contradict the RMS value; it supplies different information about this finite record. Retain both only when they serve the measurement question, and keep their normalization consistent. No statistical confidence interval or error-rate prediction is implied by four deterministic points.

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7.17 Error Vector Magnitude and Quality Metrics

Error vector magnitude compares measured symbol points with ideal references after stated normalization and synchronization. It aggregates noise, distortion, imbalance, phase noise, residual frequency error, timing error, compression, and channel effects. EVM is useful because it relates several impairments to demodulation quality, but it does not uniquely identify the cause. Different standards define averaging, normalization, included symbols, and reference reconstruction differently.

Bit error rate, packet error rate, modulation error ratio, adjacent-channel power, occupied bandwidth, and spectral regrowth answer different questions. A low error rate can coexist with high emissions because coding and margin compensate. A clean spectrum can coexist with poor data recovery if timing or protocol configuration is wrong. The metric set is selected from the engineering question and documented with test duration and confidence.

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7.18 Defensive Interpretation of Digital Signals

Digital receivers and software decoders can expose identifiers, service names, frame types, timing, and metadata. Those observations can support classification and asset inventory, but they may be spoofed, stale, relayed, encrypted, or unrelated to the physical source under examination. The practitioner separates protocol decoding from emitter location and authorization. Passive technical metadata is minimized according to the engagement authority.

Challenge tests include changing antenna position or polarization, using an independent receiver, altering sample rate and front-end gain, validating synchronization on a known reference, and correlating with authorized device state. A decoder that produces plausible but inconsistent frames under noise-only input is not evidence of a transmitter. The report states decoder version, checks, error indicators, and whether recovered fields were cryptographically or physically validated.

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7.19 Turn a quality metric into a reproducible acceptance record

A digital-reception acceptance record should bind the native sample segment to the reference sequence, time and frequency estimates, filtering, fitted parameters, selection, and final residual. Preserve intermediate residuals when several corrections are applied. A large improvement after equalization identifies dependence on that compensation; it does not by itself identify whether the original distortion came from the transmitter, propagation, the receiver, or the reference reconstruction. Controlled known-signal and bypass tests are needed to separate those paths.

Use independent checks that can fail for a different reason. A reference sequence with a known timing offset tests sample selection. A deliberately rotated mapping tests ambiguity handling. A noise-only or wrong-format record tests false lock. A held-out interval tests whether fitted coefficients transfer beyond their training set. A second implementation of the same finite EVM sum checks arithmetic, but it does not independently validate a shared wrong reference or shared synchronization estimate.

Equation 14 remains a rate-accounting identity under its stated exclusions. If a constructed 16QAM stream uses four coded bits per symbol, code rate 0.75, and a separately defined payload fraction 0.8 after framing and pilots, a 2.4 Mbit/s payload requires 1 Msymbol/s under those assumptions. The payload fraction and code rate describe different reductions. Do not count the same overhead twice, and do not infer either quantity from an observed constellation alone. This accounting reuses the retained relation rather than introducing a channel-error model.

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Report decoder results at the level supported by their validation. A passed checksum is a consistency check on a decoded structure, not a physical localization result or a cryptographic authentication claim. A failed check can arise from a wrong format assumption, synchronization, corruption, or a damaged path. Preserve error indicators and negative controls instead of selecting only plausible-looking outputs. The relationship between waveform classification, recovered fields, and external attribution remains the decision framework in Chapters 1 and 16.

Finally, retain acquisition failures alongside successful metrics. If the receiver locks only in some intervals, the EVM of the successful intervals is conditional on that selection. State the total observation time, attempted acquisitions, excluded segments, and reasons. This keeps a clean conditional metric from becoming an unsupported claim about uninterrupted receiver performance. Model 15A addresses observation opportunity; a complete demodulation success probability would require additional justified acquisition and decision behavior.

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7.20 Metric Validation and Held-Out Data

Digital quality metrics are validated on reference signals with known symbol rate, pulse shape, coding, frequency offset, and impairment. Processing parameters are selected from declared criteria rather than tuned until the result appears acceptable. A portion of the capture is held out from synchronization and equalizer fitting so that reported performance can be tested on data not used to build the model.

False-lock and noise-only tests are mandatory where a decoder produces rare events. The receiver is also challenged with altered sample rate, gain, and channel grid to verify that identifiers and checks move consistently with the physical signal. A technical report distinguishes raw observations, algorithmic estimates, decoded fields, validated checks, and external attribution.

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7.21 Quantitative Model for Digital Modulation Reception, Synchronization, EVM, and Error Metrics

Equation 1. Root-mean-square EVM

$$\mathrm{EVM}_{\mathrm{RMS}} = \sqrt{\frac{\sum_k \left| S_{\mathrm{meas,k}} - S_{\mathrm{ref,k}} \right|^2}{\sum_k \left| S_{\mathrm{ref,k}} \right|^2}}$$

Root-mean-square error vector magnitude compares measured symbols $S_{\mathrm{meas},k}$ with reference symbols $S_{\mathrm{ref},k}$ after a stated normalization, synchronization, and symbol selection. The metric is dimensionless and is often reported as a percentage or in decibels.

Equation 2. Symbol-rate relation

$$R_s = \frac{R_b}{k_{\mathrm{bits}} r_{\mathrm{code}}}$$

Symbol rate R_{s} equals net bit rate R_{b} divided by bits per modulation symbol k_{bits} and code rate r_{code} when framing, pilots, retransmission, and other overhead are excluded. The actual transmitted symbol rate may differ when those terms are included.

Equation 13 is the equal-weight, positive-reference-energy case of Model 7A, whose ten applications distinguish reference choice, alignment, gain fit, and residual structure. Equation 14 is a rate-accounting identity. The payload-efficiency example above shows how additional overhead changes the denominator without introducing a new demodulation-error law.

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7.22 Model 7B: finite rate accounting for symbols, coding and payload

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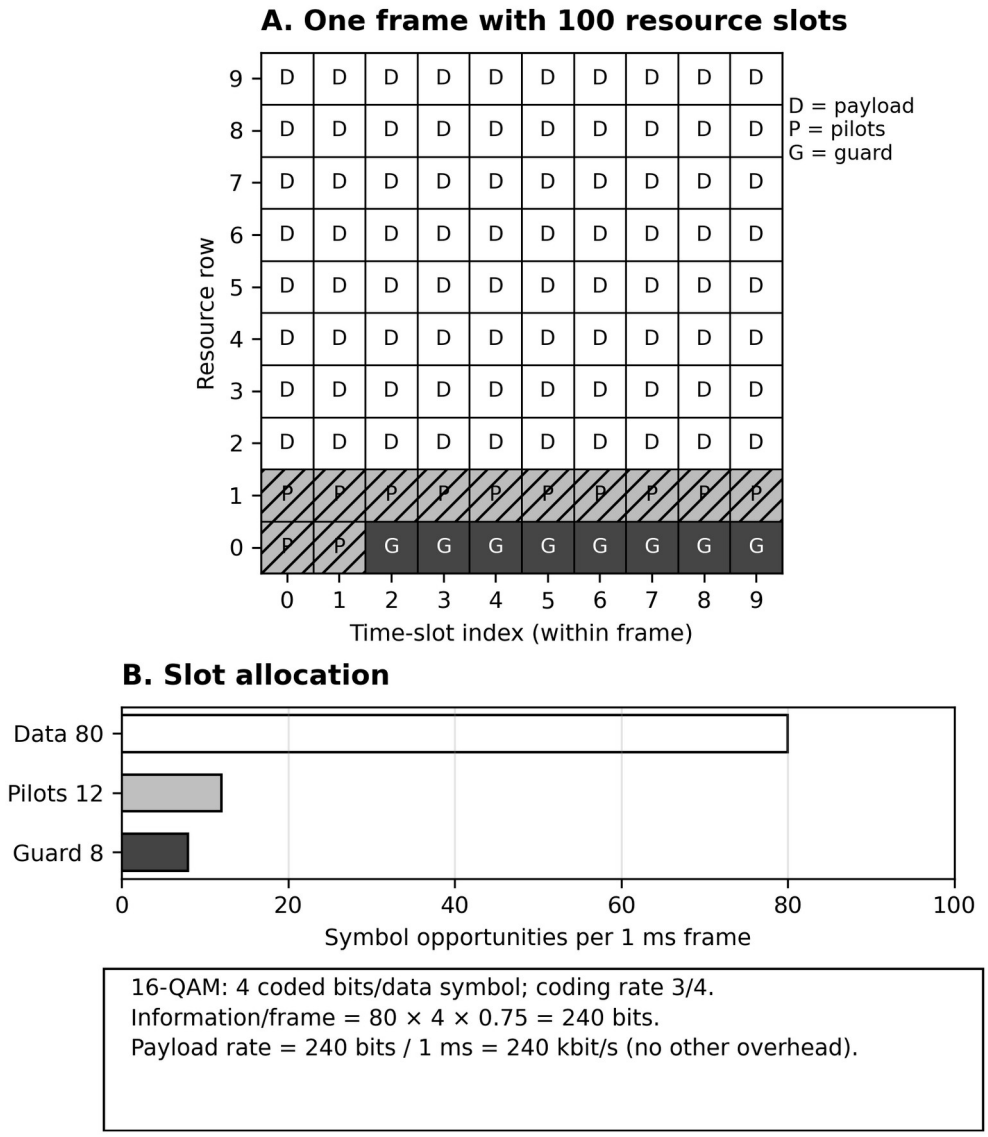

Figure 29. Finite-frame payload-rate accounting.

Equation 14 converts a declared information-bit rate into a modulation-symbol rate when its exclusions hold. A constellation supplies an alphabet, not a complete accounting of transmitted or delivered information. This development keeps the counts visible so that channel coding, pilots, framing, idle time and repeated payload cannot silently change the quantity

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called bit rate. It is one finite-count family, distinct from Model 7A's error-vector family. The examples below are independently constructed accounting cases, not protocol specifications or measurements of a commercial receiver. Unless a case gives an interval or alternative, its numerical counts, rates and durations are fixed stipulations. The examples do not represent measured observations or supply unreported timing or count uncertainties.[4] The finite-frame resource allocation is illustrated in Figure 29.

Choose a finite observation interval of duration T seconds, with T strictly positive. For the first construction, stipulate a uniform grid of N_{slot} nominal modulation opportunities. A slot may carry a data symbol, a pilot or a declared nonpayload use. Let N_{d} be the number of data-symbol slots; the two counts have units of slots and data symbols respectively. A guard or idle period belongs to this grid only when the grid has actually been defined through that period. The effective slot rate R_{slot} is N_{slot} divided by T. It must not be called the active transmitted-symbol rate when some of its opportunities contain no transmitted symbol.

Let k_{b} be the positive integer number of coded label bits assigned to each selected data symbol. For a specified power-of-two alphabet with an explicitly known binary labeling, k_{b} is the base-two logarithm of its cardinality. It counts label positions; it is not a claim about entropy, unique

4 Analog Devices, "System Noise-Figure Analysis for Modern Radio Receivers" (June 14, 2013), "Baseline Case: Cascade of Linear Circuit Blocks" and "Noise Temperature," https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and synthetic cases are stated in Model 2B.

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information, decoded correctness or stored ADC bits. Define N_c as the coded label-bit count and N_i as the input-information-bit count for the included complete coding blocks. The effective code rate r_c is N_i divided by N_c. Here the declared channel code adds redundancy without upstream compression, so the nondegenerate rate lies above zero and at most one. Puncturing, shortening, tails and boundary conventions belong in the actual finite counts.

Equation 14A. Count the distinct bit and slot populations

$$N_c = k_b N_d$$
$$r_c = \frac{N_i}{N_c}, \eta_b = \frac{N_p}{N_i}, \eta_s = \frac{N_d}{N_{slot}}$$
$$N_p = k_b r_c \eta_b \eta_s N_{slot}$$

N_p counts payload-bit instances represented by those transmissions under a stated framing rule; repeated instances are not yet deduplicated. The payload-bit fraction η_b removes declared nonpayload information bits, such as headers and padding, from N_i. The data-slot fraction η_s removes pilots or other nondata slots from N_{slot}. Both fractions lie between zero and one when their denominators are positive. These fractions operate on different populations and therefore can legitimately multiply. A single quoted efficiency that already combines those reductions must not be multiplied by either included reduction again. A code rate that already incorporates a particular termination cost must likewise not be penalized twice for that cost.

The count identity follows by cancellation, not by a channel-quality assumption: multiply the label bits per data symbol, information bits per coded bit, payload bits per information bit and data symbols per slot, then multiply by slots. Dividing both sides by the same T gives the fixed-mode

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rate law. R_{p} denotes payload bits per second, and the product $k_{\mathrm{b}}\, r_{\mathrm{c}}\, \eta_{\mathrm{b}}\, \eta_{\mathrm{s}}$ has the accounting meaning of payload bits per slot. With both overhead fractions equal to one and a fully occupied symbol grid, R_{p} is the net bit rate R_{b} of Equation 14 and R_{slot} is its R_{s}. No bandwidth, EVM or bit-error model is needed for this cancellation.

Equation 14B. Forward rate and the positive-target inverse

$$R_{\mathrm{slot}} = \frac{N_{\mathrm{slot}}}{T}$$

$$R_{\mathrm{p}} = \frac{N_{\mathrm{p}}}{T} = k_{\mathrm{b}}\, r_{\mathrm{c}}\, \eta_{\mathrm{b}}\, \eta_{\mathrm{s}}\, R_{\mathrm{slot}}$$

$$R_{\mathrm{slot}} = \frac{R_{\mathrm{p}}}{k_{\mathrm{b}}\, r_{\mathrm{c}}\, \eta_{\mathrm{b}}\, \eta_{\mathrm{s}}}\,;\, R_{\mathrm{p}} > 0\,,\, r_{\mathrm{c}}\, \eta_{\mathrm{b}}\, \eta_{\mathrm{s}} > 0$$

The empirical ratios in Equation 14A are defined only when their own denominator counts are positive. If no data slots occur, do not form an empirical code rate by dividing zero by zero; direct counting already gives no represented payload. A forward zero-throughput statement may use independently declared format factors, but it must identify their provenance. A positive payload target has no finite inverse under a zero useful-slot or zero payload fraction. For nonzero factors, a nominal inverse gives the required slot rate within the model; it does not establish that the transmitter, propagation path or receiver can realize that rate or meet an error requirement.

For successive modes, perform the accounting within each interval before combining results. If interval j has duration T_j and payload rate $R_{\mathrm{p},j}$, its payload count is $R_{\mathrm{p},j}\, T_j$. Add counts and divide by the sum of the durations. Do not average mode rates without time weights, and do not generally multiply separate averages of code rate and modulation order. Their joint

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variation determines the count. Simultaneous streams require a common time denominator and disjoint counted payload before their rates can simply be added.

Equation 14C. Combine counts before dividing by time

$$N_{\text{p,total}} = \sum_j R_{\text{p},j} T_j$$

$$R_{\text{p,total}} = \frac{\sum_j R_{\text{p},j} T_j}{\sum_j T_j}$$

$$|A \cup B| = |A| + |B| - |A \cap B|$$

The last relation in Equation 14C uses A and B as sets of identified payload-bit positions, not voltage or constellation amplitudes. It illustrates why duplicated copies cannot be counted twice when the stated result is unique delivered payload. Transmission counts, successfully decoded counts and distinct accepted delivery counts need different records. A checksum outcome alone neither identifies the physical sender nor supplies a delivery probability. In the examples, any delivery or duplicate count is explicitly stipulated as known; no probability of successful decoding is inferred from EVM or modulation order.

Finite framing introduces integer boundaries. Let U be the positive integer payload capacity of one complete fixed-length frame, S its positive integer total slot count and Q the positive integer payload demand. If the protocol sends only complete frames and pads unused final capacity, the minimum frame count is the ceiling of Q divided by U. The capacity FU can exceed the actual payload Q. Count the excess as padding under the stated rule, not as newly delivered information. For contiguous frames at a fixed positive slot rate, elapsed time is FS divided by R_{slot}. Additional interframe gaps must be added to the time denominator or explicitly included as slots.

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Equation 14D. Retain the integer frame boundary

$$F = \lceil \frac{Q}{U} \rceil, N_{\text{slot}} = F S$$

$$N_{\text{pad}} = F U - Q, T = \frac{F S}{R_{\text{slot}}}$$

$$R_{\text{p,actual}} = \frac{Q R_{\text{slot}}}{F S}$$

Uncertainty in the observation time can affect a rate even when the counted payload is exact. If T lies in a stated positive interval, the reciprocal is monotone and gives exact endpoint bounds for N_{p} divided by T. Those bounds describe the adopted timing enclosure; they are not a confidence interval without a probability model. If the count itself is ambiguous because framing or coding is unresolved, retain the discrete alternatives or a justified count enclosure instead of hiding the uncertainty in a nominal clock tolerance. No precision in a timestamp can repair a wrong population definition.

Equation 14E. Bound a rate with an exact count and uncertain positive duration

$$0 < T_{\min} \leq T \leq T_{\max}$$

$$\frac{N_{\text{p}}}{T_{\max}} \leq R_{\text{p}} \leq \frac{N_{\text{p}}}{T_{\min}}$$

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2 components × 16 bits × 100 million samples/s = 3.2 Gbit/s

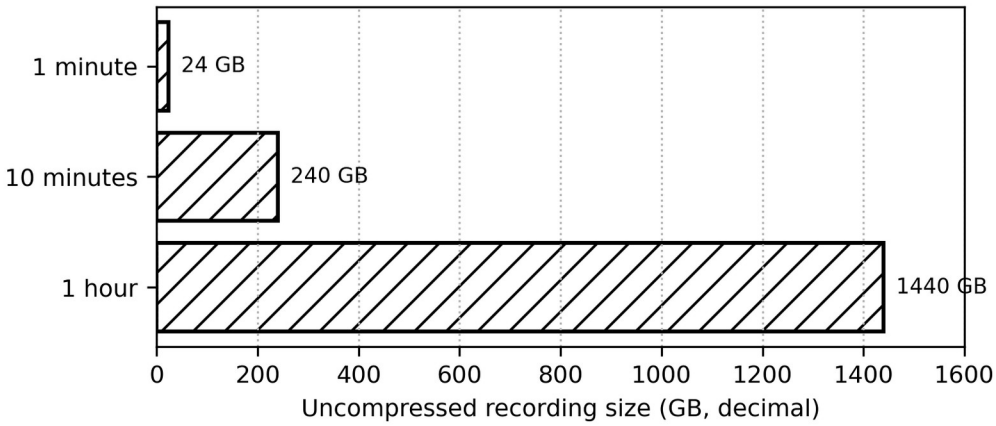

Figure 30. I/Q sample width and recording data rate.

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7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols

A constructed QPSK stream carries 4.000 Mbit/s of input information through a rate-one-half channel code. It uses two coded label bits per data symbol, has no headers, pilots, padding or idle time, and includes complete code blocks. The specified rate is an information-bit rate, not the coded bit rate and not a sample-file storage rate. Determine the required modulation-symbol rate and verify it using a 20.000 ms interval.

The coded bit rate follows by dividing 4.000 Mbit/s of information by code rate 0.5, giving 8.000 Mbit/s of coded bits. Dividing that coded rate by two coded label bits per data symbol gives 4.000 Msymbol/s. Equivalently, Equation 14 divides the information rate of 4.000 Mbit/s by the product of two coded label bits per data symbol and code rate 0.5, again giving 4.000 Msymbol/s. Each conversion retains its population label; applying the half-rate code as another multiplication would incorrectly halve the already net information rate.

Over 0.020000 s, the interval contains 80,000 data symbols, 160,000 coded bits and 80,000 information bits. The finite code ratio is $\frac{80{,}000}{160{,}000}=0.5$, and the data-symbol labeling supplies $\frac{160{,}000}{80{,}000}=2$ coded bits per symbol. Dividing the information count by the same duration returns 4.000 Mbit/s.

The agreement verifies the accounting under the stated complete-block and no-overhead assumptions. It does not predict occupied bandwidth, a receiver sample rate or delivered information after errors and repeats. If the quoted 4.000 Mbit/s had instead been the coded bit rate, the required

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symbol rate would be 2.000 Msymbol/s and the information rate 2.000 Mbit/s. The label on the given rate changes the problem before any arithmetic is performed.

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7.22.2 Application 7B.2. Separate two overhead populations without counting either twice

Use a 10.000 ms interval with 10,000 nominal slots. Exactly 9,000 slots carry 16QAM data symbols; the other 1,000 are known nondata slots. Each data symbol carries four coded label bits. The complete code blocks contain 27,000 information bits in 36,000 coded bits, and exactly 24,000 information bits are payload. Determine the slot rate, the two separate overhead fractions and the payload rate.

Dividing 10,000 nominal slots by 0.010000 s gives a slot rate of 1.000 Mslot/s. The data-slot fraction is $\frac{9,000}{10,000}=0.9$. The code rate is $\frac{27,000}{36,000}=0.75$. The payload-bit fraction is $\frac{24,000}{27,000}=\frac{8}{9}$. These fractions have different denominators: a slot count, a coded-bit count and an information-bit count. None is a substitute for the others.

Their product gives $4\times 0.75\times(\frac{8}{9})\times 0.9=2.4$ payload bits per nominal slot. At 1.000 Mslot/s, the payload rate is 2.400 Mbit/s. Dividing 24,000 payload bits by 0.010000 s gives 2,400,000 bit/s, the same 2.400 Mbit/s. The combined noncoding efficiency is $(\frac{8}{9})\times 0.9=0.8$, so the earlier concise 16QAM example with an explicitly combined 0.8 factor is recovered.

If an analyst uses that combined 0.8 and then applies the 0.9 data-slot fraction again, the predicted rate becomes 2.160 Mbit/s. The mismatch is double counting, not a receiver impairment. Retain the component counts even when a concise combined factor is reported. A different frame can have the same product 0.8 with a different division between pilots and

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information headers, and that distinction matters when the configuration changes.

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7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly

A synthetic frame has 100 slots. Twelve are pilots, and sixteen other slots are reserved for a distinct nonpayload use. These sets are explicitly disjoint. The remaining slots carry 16QAM under an effective code rate of 0.75, with every resulting information bit counted as payload. The slot rate is 3.000 Mslot/s, and successive frames are contiguous. Find payload per frame and the long-run rate for complete frames.

The data-slot count is $100-12-16=72$, giving $\eta_s=0.72$. Those symbols carry $72\times 4=288$ coded bits. The stipulated complete-block code supplies $0.75\times 288=216$ information bits, all payload. Dividing 100 slots by 3.000 million slots per second gives a frame duration of $\frac{100}{(3.000\times 10^6)}\ \mathrm{s}$, approximately 33.333333 μs.

The rate is 216 bits divided by that frame duration, giving 6.480 Mbit/s. The same result follows by multiplying the slot rate of 3.000 Mslot/s by four coded label bits per data symbol, code rate 0.75 and data-slot fraction 0.72. Multiplying the separate remaining fractions 0.88 and 0.84 would give 0.7392 instead of 0.72 and a wrong rate of 6.6528 Mbit/s. Those fractions were both defined against the original 100 slots, so sequential multiplication is unjustified.

If the two reserved sets instead overlapped in four slots, their union would contain 24 slots, leaving 76 data slots and giving 6.840 Mbit/s. That is a different stated allocation, not a rounding correction to the disjoint case. A framing record must identify whether categories overlap before an overhead calculation can be accepted. The calculation assumes complete

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frames and does not count partial boundary frames silently as complete ones.

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7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval

A burst contains exactly 4,000 data symbols sent at an active rate of 2.000 Msymbol/s. The selected alphabet is 64QAM, the complete-block code rate is two thirds and the payload-bit fraction is 0.9. No pilot slots occur inside the burst. A 0.500 ms silent guard follows each burst, and the reported wall-clock interval includes both burst and guard. Determine the payload count and both relevant rates.

Dividing 4,000 data symbols by the active rate of 2.000 Msymbol/s gives a burst duration of 0.002000 s. Six label bits per symbol give 24,000 coded bits, which represent 16,000 information bits. Multiplying by the payload-bit fraction yields 14,400 payload bits. Dividing by the active 2.000 ms gives 7.200 Mbit/s during the burst.

The complete repeating interval lasts 2.500 ms. Dividing 14,400 payload bits by 0.002500 s gives 5,760,000 bit/s, or 5.760 Mbit/s. The active-time fraction is $\frac{2.000}{2.500}=0.8$, so multiplying the active payload rate by 0.8 gives the same result. If a 0.500 μs opportunity grid is explicitly continued through the guard, it contains 5,000 nominal slots, of which 4,000 carry data; that equivalent slot accounting also gives 5.760 Mbit/s.

The physical active symbol rate remains 2.000 Msymbol/s. Calling 1.600 million transmitted symbols per wall-clock second the symbol clock would confuse an average event count with within-burst timing. Conversely, reporting 7.200 Mbit/s as the full-interval payload rate would omit the guard. State which interval and which event count define the rate before using it to compare a capture with a protocol or an equipment limit.

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7.22.5 Application 7B.5. Weight changing modes by their actual durations

A four-second record has two consecutive, fully known modes. During the first three seconds, a 2.000 Msymbol/s 16QAM stream uses code rate 0.75. During the last second, the same active symbol rate carries QPSK with code rate 0.5. Both intervals have no other overhead, idle time or duplicate payload. Calculate total information bits and the mean rate over all four seconds.

For the first mode, multiply 2.000 Msymbol/s by four coded label bits per symbol and code rate 0.75 to obtain 6.000 Mbit/s of information, hence 18.000 Mbit in three seconds. For the second mode, multiply 2.000 Msymbol/s by two coded label bits per symbol and code rate 0.5 to obtain 2.000 Mbit/s, hence 2.000 Mbit in one second. The total is 20.000 Mbit, and division by four seconds gives 5.000 Mbit/s.

An unweighted mean of the two mode rates would be 4.000 Mbit/s, which assigns the one-second mode the same time influence as the three-second mode. Even multiplying separately time-weighted factors can fail: the mean label count is 3.5 bits per symbol and the mean code rate is 0.6875, whose product with 2.000 Msymbol/s gives 4.8125 Mbit/s. Averaging the joint product is the required operation.

The mode change is part of the observation, so retain the interval boundaries and the factors belonging to each interval. A single average modulation order or code rate can be a descriptive statistic but cannot generally reconstruct the payload count. This example assumes the boundaries and durations are known and each interval contains valid

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complete blocks; uncertain transitions require separate counting or an explicit excluded interval.

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7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput

Two simultaneous streams are recorded for the same 0.250 s interval. Their reported accepted-payload rates are 2.400 Mbit/s and 1.600 Mbit/s, with compatible bit definitions. Identity-linked delivery records establish that 100,000 payload-bit positions appear in both streams and that no other duplication occurs. Determine the sum of stream counts and the count of distinct delivered payload positions.

The first stream contributes 600,000 accepted payload-bit instances, and the second contributes 400,000. Their summed instance count is 1,000,000, corresponding to 4.000 Mbit/s when copies are counted separately. The declared overlap must be subtracted once: $600{,}000 + 400{,}000 - 100{,}000 = 900{,}000$ distinct delivered positions.

Dividing 900,000 distinct delivered payload bits by 0.250 s gives unique delivered throughput of 3,600,000 bit/s, or 3.600 Mbit/s. If the records instead established disjoint payload positions, simple addition would be justified and unique throughput would be 4.000 Mbit/s. The overlap information changes the counted population; it does not change either stream’s RF symbol clock or its coded-bit count.

The duplication record is an explicit premise in this constructed case. Modulation order, low EVM, a repeated identifier or one passed checksum cannot substitute for it. If overlap is unknown but each stream’s accepted count is trusted, the union count lies between the larger individual count and their sum. That coarse interval would give 2.400 through 4.000 Mbit/s,

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without assigning a probability or deciding which physical source sent the copies.

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7.22.7 Application 7B.7. Retain integer frames and last-frame padding

A fixed frame carries 800 input-information bits, including a 32-bit header, through a stipulated 800-to-1,000-bit channel code. QPSK sends the 1,000 coded bits in 500 data symbols. The protocol sends only complete contiguous frames at 1.000 Msymbol/s and fills unused final payload capacity with padding. A request contains exactly 10,000 original payload bits. Determine frame count, elapsed transmission time and the actual request-payload rate.

Each frame has capacity $800-32=768$ payload bits. Thirteen full payload capacities provide 9,984 bits, so they are short by 16 bits. The ceiling of $\frac{10{,}000}{768}$ is 14 frames. Their available capacity is $14\times 768=10{,}752$ bits, leaving 752 padding bits in the last frame. Padding is transmitted information for the coder but is not part of the original request payload.

Fourteen frames use 7,000 symbols and therefore 0.007000 s. Dividing 10,000 request-payload bits by 0.007000 s gives an actual request rate of approximately 1.428571 Mbit/s. The fully filled repeating-frame capacity rate instead divides 768 payload bits by 0.000500 s, giving 1,536,000 bit/s, or 1.536 Mbit/s. The finite request does not achieve that capacity rate because its last frame is mostly padding.

Check the complete count chain: the code sees $14\times 800=11{,}200$ information bits and produces 14,000 coded bits. The request-specific payload-bit fraction is $\frac{10{,}000}{11{,}200}$, approximately 0.8928571429, while the code rate remains 0.8. Multiplying 1.000 Msymbol/s by two label bits per symbol, code rate 0.8 and that exact payload fraction gives approximately 1.428571 Mbit/s. A

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request ending one frame earlier would save 0.500 ms but leave the final 16 requested bits unsent.

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7.22.8 Application 7B.8. Test a positive target against the declared rate limit

A constructed fixed mode uses 16QAM, code rate 0.75, data-slot fraction 0.8 and payload-bit fraction 0.9. It must represent at least 5.000 Mbit/s of payload. A separately stipulated configuration limit permits at most 2.000 Mslot/s. Ignore errors and retransmission in this accounting calculation, and determine whether the positive payload target is feasible within those premises.

The mode supplies $4 \times 0.75 \times 0.8 \times 0.9 = 2.16$ payload bits per nominal slot. The positive-target inverse requires a slot rate at least equal to the quotient of 5.000 Mbit/s and 2.16 payload bits per nominal slot. This required rate is approximately 2.314814815 Mslot/s. It exceeds the stipulated 2.000 Mslot/s limit, so no setting within this fixed mode meets the target.

At the limit of 2.000 Mslot/s, multiplying by 2.16 payload bits per nominal slot gives a maximum represented payload rate of 4.320 Mbit/s, leaving a 0.680 Mbit/s shortfall. This is an arithmetic incompatibility among stated target, fractions and slot-rate limit. A lower EVM does not alter the count identity. If another mode were available, its different code, framing and rate factors would have to be stated and checked separately.

If the useful-slot fraction were zero, direct counting would give no represented payload at any finite slot rate. The positive inverse would be undefined rather than zero. If a factor is only unknown, it must not be replaced by zero or one merely to obtain a number. Report the actual missing premise or a justified range; the hypothetical configuration limit here is not a published performance specification for any receiver.

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7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count

Exactly 24,000 payload bits belong to an observed interval. Its duration is 10.000 ms with a deterministic timing enclosure from 9.995 ms to 10.005 ms. The payload count and its framing interpretation are stipulated exact. Calculate the nominal rate and an exact rate enclosure without assigning a probability distribution to the timing error.

Dividing 24,000 payload bits by the nominal duration of 0.010000 s gives 2,400,000 bit/s. Because the count is nonnegative and both time endpoints are positive, the smallest rate uses the largest duration. The exact lower endpoint divides 24,000 bits by 0.010005 s, giving approximately 2,398,800.5997 bit/s. The exact upper endpoint divides 24,000 bits by 0.009995 s, giving approximately 2,401,200.6003 bit/s.

The endpoint departures from nominal are approximately $-1{,}199.4003$ and $+1{,}200.6003\ \text{bit/s}$. A first-order magnitude estimate divides 24,000 bits by the square of 0.010000 s, then multiplies by 0.000005 s, giving 1,200 bit/s. It is close here, but its symmetric interval is not exactly the monotone reciprocal enclosure. Retain the exact endpoint quotients when that distinction matters.

This timing bound does not characterize frame misidentification, omitted bits, duplicate delivery or an uncertain code rate. Those would change the counted quantity and require separate evidence. Nor does the enclosure imply 95 percent coverage: it follows from the stated deterministic duration limits. If the interval could include zero duration, the positive finite reciprocal bound would no longer be available.

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7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate

A synthetic observation establishes a 1.000 Mslot/s grid, 16QAM data labels and a data-slot fraction of 0.8. The format is known to use exactly one of two code rates, 0.5 or 0.75, but the surviving record does not identify which. The payload-bit fraction is independently bounded from 0.9 to 1.0. No delivery or retransmission claim is requested. Determine the admissible represented-payload rates under these explicitly exhaustive alternatives.

For the half-rate alternative, multiply 1.000 Mslot/s by four coded label bits per data symbol, code rate 0.5 and data-slot fraction 0.8. This gives 1.600 Mbit/s before the payload-bit fraction is applied; its range from 0.9 to 1.0 therefore gives 1.440 through 1.600 Mbit/s. For code rate 0.75, the corresponding rate before the payload-bit fraction is 2.400 Mbit/s, giving 2.160 through 2.400 Mbit/s after that fraction. Positive monotonic factors place each alternative's extrema at the payload-fraction endpoints.

The admissible set is the union of those two intervals. A coarse overall enclosure from 1.440 to 2.400 Mbit/s is valid as an enclosure, but it includes rates between 1.600 and 2.160 Mbit/s that neither stated format permits. Taking the mean code rate and reporting one midpoint would invent a state or a probability weighting that the evidence has not supplied.

Retain the alternative-specific result and identify the missing coding evidence needed to select between them. The recognizable constellation alone does not resolve that gap. These are conditional represented-bit counts, not proof of correct decoder output, unique accepted delivery or transmitter identity. If the two code rates were merely examples rather than

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an exhaustive premise, even this two-interval admissible set would overstate what is known.

Table 1. Chapter 7 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Synchronization	Carrier offset, phase, timing, loop bandwidth, lock, slips, and residuals	Establishes the reference used for symbol metrics	Forced or overfit synchronization can conceal instability
Pulse shaping and equalization	Filter family, roll-off, span, channel estimate, taps, and training	Separates waveform design from channel distortion	Post-equalization quality is not the raw emission quality
EVM and MER	Normalization, included symbols, averaging, reference reconstruction, and units	Aggregates modulation impairments	Does not uniquely identify the physical cause
Decoder output	Software version, checks, error state, identifiers, timing, and validation	Supports classification and inventory	Plausible fields can result from false locks or spoofing

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7.23 Hypothetical Applied Calculation: Digital Modulation Reception, Synchronization, EVM, and Error Metrics

A QPSK capture has normalized squared symbol error sum 2.4 and normalized reference energy sum 960. The RMS EVM is 5.0 percent, or about $-26.0\ \mathrm{dB}$. If the first 200 acquisition symbols are excluded, that exclusion and the synchronization settings must accompany the reported value.

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7.24 Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics

An SDR decoder reports intermittent valid-looking packets in a quiet band. A noise-only recording passed through the same decoder produces similar identifiers at a lower rate, and the reported checksums are inconsistent. Tightening synchronization and requiring independent CRC validation removes the events. The initial packet interpretation is unvalidated and consistent with false lock. The noise-only result establishes a decoder false-output mechanism; it does not establish that every original event had that mechanism or that no communications signal was present. Waveform detection, decoded fields, and source attribution remain separate claims.

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7.25 Digital-demodulation validation by error covariance and synchronisation-state segmentation

A single error-vector-magnitude percentage compresses several physically different impairments into one statistic. Carrier-frequency offset causes a phase slope; phase noise produces stochastic rotation; clock offset creates sampling-phase drift; IQ gain and quadrature errors generate image components; channel selectivity introduces symbol-dependent amplitude and phase distortion. For a known pilot sequence, define error $e_k = z_k - a s_k$ after applying a declared complex scaling a and permissible timing alignment, where z_k is the received symbol and s_k is the expected reference symbol. A conventional RMS error measure divides the sum of $|e_k|$ squared by an explicitly chosen reference-power sum. The method of estimating a, selecting pilot positions, and excluding invalid intervals changes the result. An EVM figure that hides extensive fitted corrections does not carry the same interpretation as one produced under fixed previously calibrated parameters.

A diagnostic decomposition benefits from preserving the temporal covariance of symbol errors rather than looking only at their overall RMS. A near-constant rotation across a burst suggests a different limitation than rapid phase excursions; periodic error linked to sample index can indicate interleaving or symbol-clock structure; isolated error clusters can coincide with front-end overload and recovery. However, these signatures are not uniquely identifying. To assess an alleged external waveform property, the test must first demonstrate that a known laboratory reference exhibits different impairment when the relevant receiver mechanism is changed.

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Performing a synchronisation fit on the same suspect burst used to claim excellent demodulation can remove the very defect under examination. Report the applied fitting degrees of freedom and repeat the test with frozen parameters on held-out records.

For a simple educational example, suppose four equal-energy reference symbols each have unit magnitude, with received errors of complex magnitudes 0.10, 0.20, 0.10 and 0.20 after a stipulated fixed alignment. The sum of squared error magnitudes is 0.10, and reference-energy sum is 4. The RMS EVM is sqrt(0.10/4) = 0.15811, or 15.81 percent. If an analyst re-estimates carrier rotation separately for every symbol, the resulting error may be made artificially small without establishing a receiver capable of independently tracking that rotation. This is an identifiability problem: more adjustable parameters can absorb distortions as well as signal structure. The measurement protocol must distinguish physically justified synchronisation from overfitting.

A multi-condition validation set should vary input amplitude, frequency offset, sample-clock error, reference phase noise, modulation type, burst duration and interferer level separately. Include deliberate missing samples and frequency excursions across the channeliser boundary, while recording which pilots and symbols were actually observed. Error-rate estimates need event definitions and sufficient independent test observations; repeated bits from one corrupted frame cannot be treated as separate field incidents. When proprietary frame content is outside authorised scope, use public or synthetic test waveforms rather than recovering protected payload. A defensible technical conclusion can describe a modulation-family

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classification or demodulator failure without claiming knowledge of individual-emitter ownership.

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7.26 Advanced technical expansion. EVM as an imperfect inverse problem

Error vector magnitude is frequently presented as a convenient scalar percentage, but its scientific meaning depends on the reference constellation, alignment, equalisation and normalisation used to construct the error vectors. Let r_k be an observed complex symbol and s_k the ideal symbol assigned to it under an explicitly declared mapping. For a population of N eligible symbols, a common RMS EVM measure is sqrt(sum |r_k - s_k| squared divided by sum |s_k| squared). The definition presupposes that timing, carrier offset, phase and gain transformations have been specified, and it must say whether a fitted complex gain or equaliser is permitted before residuals are calculated. Two laboratories can obtain different EVM values from the same native samples while both calculations are internally correct, because their allowed compensation and reference sequence differ.

A useful example separates impairments. Suppose a set of ideal unit-energy symbols is observed through a constant phase rotation, plus an independent additive complex noise whose mean-square magnitude is 0.01 relative to the reference energy. Without compensating the phase, the measured error contains both phase and noise contributions; after estimating a legitimate constant phase rotation from independent pilot symbols, the residual EVM attributable to the stipulated noise alone would be 10%. If the same pilot symbols were also used to tune a highly flexible equaliser, a smaller training residual could simply reflect overfitting rather than improved receiver fidelity. A separate held-out symbol sequence is therefore needed to evaluate the selected processing and its uncertainty.

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The example is mathematical and does not purport to reproduce a real modem test.

Carrier-frequency error produces a time-dependent phase trend rather than the constant rotation just described. Sampling-clock mismatch creates a gradually changing relationship between symbol epochs and the acquisition time base. Phase noise introduces correlated random rotations whose spectrum matters, while nonlinearity can distort constellation radii and produce memory effects. An examiner should inspect error-vector trajectories, error correlation, symbol-time dependence and response to level changes before summarising them in one RMS figure. A constellation plot can conceal transient failures if thousands of satisfactory symbols dominate a small number of bursts. For an intermittent surveillance-related signal, precisely those rare intervals may determine whether classification is supported.

Equalisation improves demodulation only under an identifiable channel model. A linear adaptive filter may remove some propagation-induced intersymbol interference, but it can also compensate for receiver amplitude or phase defects that should instead be reported as instrumental uncertainty. The analysis must distinguish a desired measurement of received waveform quality from an estimate of a hypothetical transmitter output corrected for propagation. The latter requires a channel model, pilot structure or independent calibration. Unconstrained blind adaptation may produce an attractive constellation while silently changing the question being answered. Recording adaptation coefficients and their time history prevents a later reader from treating the processed waveform as an untouched observation.

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Sampling uncertainty enters both EVM and error-rate measurement. A finite number of symbols yields an estimate whose precision depends on the covariance of error vectors and on whether consecutive errors arise from independent noise or shared bursts. Counting each correlated symbol as independent narrows confidence intervals unjustifiably. Zero observed symbol errors does not establish a zero error probability; a statistical upper bound requires a specified trial model and confidence convention. Likewise, an unusually low EVM on one favourable laboratory frame does not establish field performance under drifting oscillators, strong blockers or fading. The report should identify the tested population and the selection procedure used to choose evaluated frames.

A comprehensive verification programme uses calibrated reference modulations with controlled phase, frequency, timing, amplitude and interference impairments. The receiver should preserve raw complex samples, reference pilots, equaliser state, symbol decisions, rejected intervals and all post-processing parameters. Test both during steady operation and across mode transitions. Disclose where the signal model is uncertain: if the nominal constellation or coding is unknown, a recovered constellation resemblance may support a candidate modulation family but cannot justify an exact source-quality percentage. Expert interpretation requires explaining which impairments the processing compensated, which remained and what alternative receiver-generated mechanisms could explain the observed constellation structure.

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7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution

A complex-plane trace shows the coordinates produced by the measurement chain, not the transmitter's original constellation without qualification. Constant-envelope angle-modulated signals, quadrature amplitude modulation, offset constellations, frequency shifts and transient pulses can overlap in simple moment statistics once acquisition noise, carrier offset, I/Q imbalance and timing uncertainty are introduced. Even a mathematically correct estimate of error-vector magnitude requires a declared reference constellation, fitted nuisance parameters and channel equalisation convention. If a classifier has been trained on captured samples from one SDR front end, it may learn the gain ripple, DC offset or phase-noise structure of that instrument rather than the intended emission type.

A defensible feature workflow begins with classification-independent checks of sample continuity, sign convention and frame boundaries. Form candidate feature sets from amplitude distribution, unwrapped phase increments where magnitude permits, autocorrelation, spectral occupancy, cyclostationary periodicity and modulation-likelihood calculations. Each feature has an observation period and an uncertainty model. A short chirped pulse may appear as an FM-like instantaneous-frequency trajectory, but a general FM broadcast and one phase-coded radar pulse do not have the same prior time behaviour. Correlations with known laboratory templates should be labelled as template matches and checked against realistic alternatives. A withheld test set should contain overlapping signals,

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clock offsets, incomplete bursts and capture-state changes so the claimed classifier accuracy is not measured on a conveniently homogeneous dataset.

Preserve the raw I/Q because apparently small preprocessing choices can alter identification. Blind DC removal can eliminate genuine near-zero-frequency content. Automatic frequency correction can erase a diagnostically useful offset. Magnitude-only normalisation destroys absolute-amplitude relationships that could help distinguish noise, interference and gain-control artefacts. Resampling with an undocumented antialias filter can create or suppress spectral sidebands. The correct result is a reproducible processing graph whose derived features carry source sample indices, transformation parameters and bounded confidence. A probable modulation class is scientifically valuable, but the physical emitter, geographic position and lawful authority to extract content require separate evidence.

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Chapter Summary

Digital modulation metrics depend on synchronization, reference reconstruction, filtering, equalization, and validation. Receiver software can create convincing structure, so raw samples and independent checks remain essential.

Model 7A defines the paired symbols, nonnegative weights, positive reference energy and permitted corrections before calculating EVM. Complex-gain fitting minimizes training residual energy; a changed denominator can still increase fitted-reference EVM. Held-out evaluation, residual vectors and declared normalization expose limitations hidden by a tight constellation or one scalar percentage.

Model 7B separates slots, coded bits, information bits and payload instances over a common positive duration. Overhead must be counted once. Bursts require an explicit time boundary, changing modes require count-based aggregation, complete frames require integer rounding, and unique throughput requires payload identities. Deterministic timing bounds and discrete format alternatives retain their stated limits.

A reproducible result preserves samples, reference construction, synchronization, filtering, fitted parameters, selected populations and intermediate sums or counts. Known-input challenges and negative controls test different failure mechanisms. Decoded consistency, acquisition coverage, physical attribution and authority remain separate questions; favorable quality or rate arithmetic cannot answer them without the relevant evidence.

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Chapter 7 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C07-MCQ-001. A constellation becomes tight after carrier recovery and adaptive equalization. What has that display directly characterized?

A. The selected symbols after the declared synchronization and compensation operations.

B. The transmitter output independently of the propagation and receiving paths.

C. The correctness of every original information bit without a mapping check.

D. The unprocessed received waveform before any reference reconstruction.

Answer: A. The displayed points are products of receiver processing. Their interpretation requires the reference, timing, mapping, filtering and permitted corrections; visual concentration alone does not identify the physical path or validate labels. Review: Constellations and Symbol Representation; Define the symbol experiment before fitting the constellation. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

Why the selected alternative fits: The selected symbols after the declared synchronization and compensation operations.

Distinguishing consideration: compare this with option B, “The transmitter output independently of the propagation and receiving paths”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Define the symbol experiment before fitting the constellation; Chapter 7 — Constellations and Symbol Representation.

Review: Chapter 7 — Define the symbol experiment before fitting the constellation; Chapter 7 — Constellations and Symbol Representation.

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V011-C07-MCQ-002. Which pair most directly identifies the included population and normalization denominator of a finite-record EVM result?

A. The modulation name alone, provided both receivers report lock.

B. The occupied-band labels alone, provided both results are expressed as percentages.

C. The equalizer tap count and carrier-loop bandwidth alone.

D. The selected symbol population and the normalization reference used for each result.

Answer: D. EVM is a normalized residual on a defined population. Equal units or modulation labels do not establish equal denominators, processing permissions or included symbols. Review: Model 7A; Equations 13B and 13J. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: The selected symbol population and the normalization reference used for each result.

Distinguishing consideration: compare this with option A, “The modulation name alone, provided both receivers report lock”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-MCQ-003. The observed and reference complex symbols are expressed in incompatible amplitude units. Which step is required before applying Equation 13B?

A. Use a percent sign to make the subtraction dimensionally meaningful.

B. Establish a justified common amplitude convention and preserve the conversion.

C. Increase the number of symbols until the unit mismatch averages away.

D. Take magnitudes first so that amplitude units disappear automatically.

Answer: B. The residual subtracts complex values, so their units and reference relation must agree before squaring or normalizing. Normalization cannot repair a physically undefined subtraction. Review: Model 7A symbol and unit definitions; Equation 13B. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: Establish a justified common amplitude convention and preserve the conversion.

Distinguishing consideration: compare this with option A, “Use a percent sign to make the subtraction dimensionally meaningful”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-MCQ-004. What conditions on weights and reference energy define the chapter's admissible weighted EVM experiment?

A. Fixed nonnegative weights and strictly positive selected reference energy.

B. Arbitrary signed weights, provided their algebraic sum is nonzero.

C. A nonempty index set alone, even when every selected weight is zero.

D. Positive weight sum alone, even if all selected reference symbols are zero.

Answer: A. Nonnegative weights give squared-residual and reference-energy sums their stated meaning. A positive sum of weights does not guarantee positive reference energy if the corresponding references vanish. Review: Equations 13A and 13B. Source: Equation 13A. Finite reference energy and admissible weights (p. 3746)

Why the selected alternative fits: Fixed nonnegative weights and strictly positive selected reference energy.

Distinguishing consideration: compare this with option B, "Arbitrary signed weights, provided their algebraic sum is nonzero"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-MCQ-005. A finite record has squared-residual sum 2.4 and squared-reference sum 960 in compatible units. What is its RMS EVM?

A. 0.5 percent.

B. 0.25 percent.

C. 5.0 percent.

D. 25 percent.

Answer: C. The energy ratio is $\frac{2.4}{960}=0.0025$. Its square root is 0.05, and conversion to percent gives 5.0. Reporting the unsquared-root ratio would confuse an energy ratio with amplitude-like EVM. Review: Equation 13B; Hypothetical Applied Calculation. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: 5.0 percent.

Distinguishing consideration: compare this with option A, “0.5 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Hypothetical Applied Calculation: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Hypothetical Applied Calculation: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

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V011-C07-MCQ-006. Using the chapter's EVM convention, what decibel value corresponds to a linear EVM of 0.05?

A. Approximately $-26.0206\ \mathrm{dB}$.

B. Approximately $-46.0206\ \mathrm{dB}$.

C. Approximately $+26.0206\ \mathrm{dB}$.

D. Approximately $-13.0103\ \mathrm{dB}$.

Answer: A. Apply $20\log_{10}$ to the linear amplitude-like ratio 0.05. Equivalently, apply $10\log_{10}$ to its squared value 0.0025. The percent numeral 5 must first be divided by 100. Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why the selected alternative fits: Approximately.

Distinguishing consideration: compare this with option B, "Approximately"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-MCQ-007. A report gives 12.5 percent EVM. Which linear ratio belongs in Equation 13C?

A. 0.0125.

B. 1.25.

C. 0.125.

D. 12.5.

Answer: C. A percentage is one hundred times the linear EVM. Converting 12.5 percent to 0.125 avoids a 40 dB error from taking the logarithm of the percentage numeral as if it were the ratio. Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why the selected alternative fits: 0.125.

Distinguishing consideration: compare this with option A, “0.0125”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-MCQ-008. What should a mathematically exact zero residual be assigned under the chapter's decibel convention?

A. A universal $-120\ \mathrm{dB}$ value independent of the instrument display floor.

B. Zero linear EVM and a decibel limit of negative infinity; no finite logarithm exists at zero.

C. Zero linear EVM and exactly 0 dB because no error is present.

D. Unit linear EVM and negative infinity decibels.

Answer: B. The logarithm is defined only for a positive EVM. A finite instrument floor or clipping rule may be reported separately, but it is not the mathematical logarithm of zero. Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why the selected alternative fits: Zero linear EVM and a decibel limit of negative infinity; no finite logarithm exists at zero.

Distinguishing consideration: compare this with option A, "A universal value independent of the instrument display floor"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-MCQ-009. Every selected reference symbol is zero, and the selected observations are also zero. What does Equation 13B return?

A. A finite value determined only by how many zero samples were selected.

B. A valid zero EVM because numerator and denominator cancel.

C. A valid 100 percent EVM because the reference carries no signal.

D. An undefined normalized EVM because its denominator is zero.

Answer: D. The formula requires strictly positive reference energy. A zero residual does not make the indeterminate ratio zero divided by zero a valid normalized metric. Review: Equations 13A and 13B. Source: Equation 13A. Finite reference energy and admissible weights (p. 3746)

Why the selected alternative fits: An undefined normalized EVM because its denominator is zero.

Distinguishing consideration: compare this with option A, “A finite value determined only by how many zero samples were selected”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-MCQ-010. All nonnegative weights in a valid EVM record are multiplied by the same positive constant. What happens to EVM?

A. It decreases by the square root of that constant because averaging improves.

B. It becomes undefined unless the new weights sum to one.

C. It is unchanged because numerator and denominator scale by the same factor.

D. It increases by that constant because weighted energy is larger.

Answer: C. The positive common factor cancels in the energy ratio. The chapter does not require weights to sum to one, although changing relative weights changes the metric. Review: Equations 13B and 13J. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: It is unchanged because numerator and denominator scale by the same factor.

Distinguishing consideration: compare this with option A, “It decreases by the square root of that constant because averaging improves”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-MCQ-011. A symbol has a nonzero residual but is assigned zero weight in the declared EVM calculation. Which statement is correct?

A. It proves that the corresponding physical interval was error-free.

B. It contributes only to the denominator because the reference is known.

C. It contributes to neither weighted sum, and its exclusion remains part of the reported population definition.

D. It still contributes to the numerator because every measured error must be counted.

Answer: C. A zero weight excludes that symbol from the weighted metric. It does not erase the original observation or establish performance in the excluded interval.
Review: Equation 13J; Application 7A.6. Source: Equation 13J. Residual sums for a disclosed selection (p. 3750)
Why the selected alternative fits: It contributes to neither weighted sum, and its exclusion remains part of the reported population definition.
Distinguishing consideration: compare this with option A, “It proves that the corresponding physical interval was error-free”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Application 7A.6: Make selection and weighting visible.
Review: Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Application 7A.6: Make selection and weighting visible.

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V011-C07-MCQ-012. Why does using negative weights invalidate the chapter's squared-distance interpretation?

A. Negative weights necessarily change a complex symbol into its conjugate.

B. Negative terms can cancel positive squared residuals and destroy the nonnegative energy interpretation.

C. A negative weight is equivalent to a permitted timing correction.

D. Weights must be integers because symbols have discrete labels.

Answer: B. The derivation treats weights as fixed nonnegative dimensionless coefficients. Signed cancellation would define a different expression and can remove the positivity needed for the stated metric. Review: Equations 13A and 13B.

Source: Equation 13A. Finite reference energy and admissible weights (p. 3746)

Why the selected alternative fits: Negative terms can cancel positive squared residuals and destroy the nonnegative energy interpretation.

Distinguishing consideration: compare this with option A, "Negative weights necessarily change a complex symbol into its conjugate"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-MCQ-013. A valid finite record is repeated exactly, with the same weights on every repeated copy. What happens to its EVM?

A. The EVM rises with total symbol count because the residual energy increases.

B. The EVM is unchanged; exact repetition does not by itself create new independent evidence.

C. The EVM becomes a confidence interval rather than a deterministic ratio.

D. The EVM falls as the inverse square root of the number of copies.

Answer: B. Both sums increase in the same proportion. Repeated storage of the same data is distinct from collecting independent observations under a probability model. Review: Equations 13B and 13J; Turn a quality metric into a reproducible acceptance record. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: The EVM is unchanged; exact repetition does not by itself create new independent evidence.

Distinguishing consideration: compare this with option A, “The EVM rises with total symbol count because the residual energy increases”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Turn a quality metric into a reproducible acceptance….

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-014. For two symbols with reference magnitudes 1 and 2, residual magnitudes 0.2 and 0.1, and weights 1 and 3, what energy ratio is used before the square root?

A. $\frac{0.13}{5}$.

B. $\frac{0.05}{5}$.

C. $\frac{0.07}{4}$.

D. $\frac{0.07}{13}$.

Answer: D. The weighted residual energy is 1(0.2 squared) + 3(0.1 squared) = 0.07. The weighted reference energy is 1(1 squared) + 3(2 squared) = 13. A weight sum is not the reference-energy denominator. Review: Equations 13B and 13J. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: option D contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-MCQ-015. A record has linear EVM 0.1. If the same residual energy is normalized by four times the original reference energy, what is the new EVM?

A. 0.4.

B. 0.05.

C. 0.2.

D. 0.025.

Answer: B. Multiplying the denominator energy by four divides the squared EVM by four, so EVM itself is halved. This is a normalization change, not evidence that the measured residual improved. Review: Equations 13B and 13G. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: 0.05.

Distinguishing consideration: compare this with option A, “0.4”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-MCQ-016. Which objective does the optional constant complex-gain estimate minimize?

A. Weighted squared residual energy on the declared training set.

B. Every possible EVM normalization on every future record.

C. The bit error probability without a symbol decision or channel model.

D. The physical transmitter error before propagation.

Answer: A. The least-squares fit minimizes one explicitly stated finite training objective. Its optimality does not extend automatically to differently normalized metrics, held-out data or an error-rate law. Review: Equations 13D and 13E. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: Weighted squared residual energy on the declared training set.

Distinguishing consideration: compare this with option B, “Every possible EVM normalization on every future record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square.

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V011-C07-MCQ-017. Which correlation appears in the numerator of the chapter's complex-gain estimate?

A. The weighted sum of each observation times the conjugate of its ideal reference.

B. The product of the unweighted mean observation and mean reference.

C. The weighted sum of observation magnitudes divided by reference magnitudes.

D. The weighted sum of each observation times the unconjugated reference.

Answer: A. Complex least squares uses the conjugated reference in the inner product. Omitting conjugation generally changes the estimated phase and no longer minimizes the stated objective. Review: Equations 13D and 13E. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: The weighted sum of each observation times the conjugate of its ideal reference.

Distinguishing consideration: compare this with option B, "The product of the unweighted mean observation and mean reference"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square.

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V011-C07-MCQ-018. With positive weighted training reference energy, what establishes uniqueness of the constant complex-gain minimizer?

A. The objective is a constant plus positive reference energy times the squared distance from the fitted coefficient.

B. The fitted coefficient must be constrained to have unit magnitude.

C. The training references must have zero mean and zero sum of squares simultaneously.

D. The observed symbols must all have the same magnitude.

Answer: A. Completion of the square gives a strictly positive coefficient multiplying the distance term. Balanced references and unit-magnitude restrictions are not required for this unconstrained complex-gain fit. Review: Equation 13E. Source: Equation 13E. Least-squares completion of the square (p. 3747)

Why the selected alternative fits: The objective is a constant plus positive reference energy times the squared distance from the fitted coefficient.

Distinguishing consideration: compare this with option B, “The fitted coefficient must be constrained to have unit magnitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13E. Least-squares completion of the square.

Review: Chapter 7 — Equation 13E. Least-squares completion of the square.

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V011-C07-MCQ-019. A positive-energy reference is fitted to observations that are all zero. Which pair of results follows?

A. The fitted gain is undefined because observation energy is zero.

B. The fitted gain is zero, while EVM normalized by that fitted reference is undefined.

C. The fitted gain is zero, and fitted-reference EVM is automatically zero.

D. The fitted gain is one, and fitted-reference EVM is zero.

Answer: B. The gain estimate has a valid reference-energy denominator and zero correlation numerator. However, scaling the evaluation reference by that zero gain makes its energy zero, violating the fitted-reference EVM domain. Review: Equations 13D and 13F. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: The fitted gain is zero, while EVM normalized by that fitted reference is undefined.

Distinguishing consideration: compare this with option A, “The fitted gain is undefined because observation energy is zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-MCQ-020. Every selected observation is zero, and the unscaled ideal reference has positive weighted energy. What is fixed-reference EVM?

A. Undefined solely because the observations are zero.

B. 100 percent.

C. 50 percent.

D. 0 percent.

Answer: B. The residual is the negative reference, so residual energy equals reference energy. This valid fixed-reference value differs from the undefined zero-gain fitted-reference normalization. Review: Equations 13B and 13F. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: 100 percent.

Distinguishing consideration: compare this with option A, “Undefined solely because the observations are zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-MCQ-021. The weighted training correlation is $6+j8$ and weighted training reference energy is 10. What fitted gain follows?

A. $1+j0$.

B. $0.6+j0.8$.

C. $6+j8$.

D. $0.6-j0.8$.

Answer: B. Divide the complex correlation by the real positive reference energy. Its magnitude happens to be one, but the phase remains part of the fitted coefficient and cannot be discarded. Review: Equation 13D. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: option B contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

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V011-C07-MCQ-022. An implementation mistakenly conjugates the observation instead of the reference in that fit. What is the consequence in general?

A. It changes only the number of selected symbols.

B. It conjugates the correlation and therefore generally reverses the estimated phase.

C. It always leaves the complex coefficient unchanged.

D. It guarantees a lower residual than the stated least-squares solution.

Answer: B. With real nonnegative weights, conjugating the opposite product conjugates the intended numerator. A purely real special case may hide the mistake, so a complex-phase reference is a useful check. Review: Equations 13D and 13E. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: It conjugates the correlation and therefore generally reverses the estimated phase.

Distinguishing consideration: compare this with option A, “It changes only the number of selected symbols”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square.

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V011-C07-MCQ-023. Why should a phase-bearing known case accompany a purely real gain test of the fitting implementation?

A. A phase-bearing case removes the need to disclose symbol labels.

B. A real case can conceal a conjugation or phase-sign error that a complex coefficient exposes.

C. Only phase-bearing references permit any held-out evaluation.

D. A real case has zero reference energy by definition.

Answer: B. Different controlled cases exercise different algebraic features. A real fitted coefficient equals its conjugate, so it cannot alone detect the sign error in the complex correlation. Review: Equation 13D; Turn a quality metric into a reproducible acceptance record. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: A real case can conceal a conjugation or phase-sign error that a complex coefficient exposes.

Distinguishing consideration: compare this with option A, “A phase-bearing case removes the need to disclose symbol labels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-024. A gain fit reduces residual energy, yet the reported fitted-reference EVM rises. Which explanation is possible?

A. The least-squares fit must necessarily have failed its own minimization objective.

B. Every EVM calculation must use the original reference denominator regardless of its declared convention.

C. The fitted-reference energy decreased enough to outweigh the numerator reduction.

D. The squared-residual sum must have become negative.

Answer: C. Least squares minimizes its numerator objective, not every ratio obtained with a parameter-dependent denominator. The report must retain both sums and the fitted gain to explain the change. Review: Equations 13E and 13F; Application 7A.8. Source: Equation 13E. Least-squares completion of the square (p. 3747)
Why the selected alternative fits: The fitted-reference energy decreased enough to outweigh the numerator reduction.
Distinguishing consideration: compare this with option A, “The least-squares fit must necessarily have failed its own minimization objective”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.8: Keep a residual frequency rotation….
Review: Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-MCQ-025. Which condition makes the evaluation in Equation 13F held out?

A. Its symbol indices are excluded from the training set used to estimate the applied gain.

B. Its samples are plotted in a separate window after the same indices were used for training.

C. Its EVM is smaller than the training EVM.

D. Its references have the same values as the training references, regardless of index overlap.

Answer: A. Held-out status concerns exclusion from parameter fitting, not display location or a favorable result. Reusing symbol values can be legitimate; reusing the evaluated observations for the same fit changes the claimed validation. Review: Equation 13F. Source: Equation 13F. Held-out evaluation with a nonzero fitted reference (p. 3748)

Why the selected alternative fits: Its symbol indices are excluded from the training set used to estimate the applied gain.

Distinguishing consideration: compare this with option B, “Its samples are plotted in a separate window after the same indices were used for training”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-MCQ-026. What additional nondegeneracy condition does fitted-reference EVM require beyond positive held-out ideal-reference energy?

A. The fitted complex gain must be nonzero.

B. The fitted gain must be exactly one.

C. The held-out reference mean must be zero.

D. Every observed symbol must have nonzero magnitude.

Answer: A. The fitted-reference denominator contains the squared gain magnitude. A zero gain makes that normalization undefined even when the unscaled held-out references have positive energy. Review: Equation 13F. Source: Equation 13F. Held-out evaluation with a nonzero fitted reference (p. 3748)

Why the selected alternative fits: The fitted complex gain must be nonzero.

Distinguishing consideration: compare this with option B, “The fitted gain must be exactly one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-MCQ-027. A single nonzero complex reference is fitted to one arbitrary complex observation using one unconstrained complex gain. What does a zero training residual demonstrate?

A. An independently established zero EVM for all future records.

B. A validated model of the complete propagation channel.

C. A proof that no noise or synchronization error affected the observation.

D. Exact interpolation of that one pair, with no residual freedom to test transfer to other symbols.

Answer: D. One complex coefficient can absorb the entire discrepancy in one nonzero reference pair. Held-out observations are needed to test whether that fitted relation transfers. Review: Application 7A.7. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

Why the selected alternative fits: Exact interpolation of that one pair, with no residual freedom to test transfer to other symbols.

Distinguishing consideration: compare this with option A, “An independently established zero EVM for all future records”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.7: Evaluate a fitted gain on held-out symbols.

Review: Chapter 7 — Application 7A.7: Evaluate a fitted gain on held-out symbols.

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V011-C07-MCQ-028. Training uses reference 1 and observation $1.2+j0.1$. What gain is then applied to held-out references?

A. The real magnitude square root of 1.45 only.

B. $1+j0$ because the reference is ideal.

C. $1.2-j0.1$.

D. $1.2+j0.1$.

Answer: D. The training correlation equals the observation and the training reference energy is one. Replacing the complex coefficient by its magnitude would discard the fitted phase and define a different correction. Review: Application 7A.7; Equation 13D. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

Why the selected alternative fits: option D contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units. Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 7 — Application 7A.7: Evaluate a fitted gain on held-out symbols; Chapter 7 — Equation 13D. Optional complex-gain fit on a training set. Review: Chapter 7 — Application 7A.7: Evaluate a fitted gain on held-out symbols; Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

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V011-C07-MCQ-029. If the held-out observations in that case exactly equal their unscaled ideal references, what does their zero fixed-reference EVM imply?

A. The fixed and fitted denominators are necessarily identical.

B. Any nonzero fitted-reference EVM is impossible for those observations.

C. The fitted training coefficient must necessarily have been one.

D. They agree with the fixed reference, even though applying the noisy training fit can produce nonzero fitted-reference EVM.

Answer: D. The two metrics ask different questions. The noisy one-pair training fit can introduce disagreement relative to an otherwise exact held-out record. Review: Application 7A.7. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

Why the selected alternative fits: They agree with the fixed reference, even though applying the noisy training fit can produce nonzero fitted-reference EVM.

Distinguishing consideration: compare this with option A, “The fixed and fitted denominators are necessarily identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.7: Evaluate a fitted gain on held-out symbols.

Review: Chapter 7 — Application 7A.7: Evaluate a fitted gain on held-out symbols.

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V011-C07-MCQ-030. Four balanced unit-energy references are all multiplied by 1.08. What is fixed-reference EVM?

A. Approximately 7.4074 percent.

B. 0.64 percent.

C. 108 percent.

D. 8 percent.

Answer: D. Each residual is 0.08 times its reference, so the normalized RMS error is 0.08. Dividing by 1.08 would instead introduce a different reference normalization.
Review: Equation 13H; Application 7A.1. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)
Why the selected alternative fits: 8 percent.
Distinguishing consideration: compare this with option A, “Approximately 7.4074 percent”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.1: Show which error a fitted gain removes.
Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.1: Show which error a fitted gain removes.

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V011-C07-MCQ-031. A permitted complex-gain fit is applied to that exact 1.08-scaled record. Which result must accompany a zero residual?

A. A statement that the original absolute amplitude calibration was exact.

B. A replacement of the uncorrected record by the fitted reference alone.

C. A claim that all possible channel impairments have been independently excluded.

D. The fitted gain 1.08, because the fit has removed the amplitude discrepancy being assessed.

Answer: D. The zero residual is conditional on the permitted alignment. If absolute amplitude agreement matters, the fitted coefficient is evidence rather than a nuisance value to discard. Review: Application 7A.1. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

Why the selected alternative fits: The fitted gain 1.08, because the fit has removed the amplitude discrepancy being assessed.

Distinguishing consideration: compare this with option A, “A statement that the original absolute amplitude calibration was exact”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.1: Show which error a fitted gain removes.

Review: Chapter 7 — Application 7A.1: Show which error a fitted gain removes.

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V011-C07-MCQ-032. For a fixed real gain of 0.92 with no permitted amplitude fit, what EVM follows?

A. 92 percent.

B. 8 percent.

C. Approximately 8.6957 percent.

D. 0.64 percent.

Answer: B. The chapter's fixed-reference relation is the absolute departure of gain from one. Positive and negative departures of equal magnitude give the same EVM in this bounded model. Review: Equation 13H. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)

Why the selected alternative fits: 8 percent.

Distinguishing consideration: compare this with option A, "92 percent"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

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V011-C07-MCQ-033. Why does a measured 8 percent EVM alone not identify whether a constant real gain is 0.92 or 1.08?

A. Both gains necessarily produce identical observed complex symbols.

B. The metric retains the magnitude of the gain departure, not its sign.

C. The two gains have equal power gain in linear units.

D. EVM always discards both reference and residual energy.

Answer: B. Different impairments can share one aggregate EVM. The original vectors or a separately retained gain estimate distinguish these two amplitude cases. Review: Equation 13H; Application 7A.1. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)

Why the selected alternative fits: The metric retains the magnitude of the gain departure, not its sign.

Distinguishing consideration: compare this with option A, “Both gains necessarily produce identical observed complex symbols”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.1: Show which error a fitted gain removes.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.1: Show which error a fitted gain removes.

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V011-C07-MCQ-034. A unit reference is rotated by a fixed 6 degrees without a fitted phase correction. Which expression gives the exact EVM?

A. Twice the absolute sine of 3 degrees.

B. Six as a dimensionless linear ratio.

C. Twice the cosine of 3 degrees.

D. The sine of 6 degrees without the factor of two.

Answer: A. The complex residual is the chord between two unit phasors separated by the rotation. The exact chord length is twice the absolute sine of half the angle.
Review: Equation 13H; Application 7A.2. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)
Why the selected alternative fits: Twice the absolute sine of 3 degrees.
Distinguishing consideration: compare this with option B, “Six as a dimensionless linear ratio”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.2: Quantify a fixed phase error.
Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.2: Quantify a fixed phase error.

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V011-C07-MCQ-035. What is the approximate percentage EVM for that 6-degree rotation?

A. 104.67191 percent.

B. 5.233596 percent.

C. 10.467191 percent.

D. 6 percent.

Answer: C. Evaluate 2 sin(3 degrees) = 0.10467191 and multiply by 100. Degrees must not be substituted directly as a dimensionless small-angle value. Review: Application 7A.2. Source: §7.8 Application 7A.2: Quantify a fixed phase error (p. 3753)

Why the selected alternative fits: 10.467191 percent.

Distinguishing consideration: compare this with option A, “104.67191 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.2: Quantify a fixed phase error.

Review: Chapter 7 — Application 7A.2: Quantify a fixed phase error.

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V011-C07-MCQ-036. When a small-angle approximation replaces the exact phase-error chord by the absolute phase error, which angular unit is required?

A. Any angular unit because EVM is dimensionless.

B. Degrees.

C. Cycles without conversion.

D. Radians.

Answer: D. The local approximation to sine uses a radian argument. Dimensionless output does not remove the conversion between degrees, cycles and radians.
Review: Equation 13H and the discussion in Application 7A.2. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)
Why the selected alternative fits: Radians.
Distinguishing consideration: compare this with option A, “Any angular unit because EVM is dimensionless”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.2: Quantify a fixed phase error.
Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.2: Quantify a fixed phase error.

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V011-C07-MCQ-037. A balanced QPSK record is multiplied by j. What are its fixed-reference EVM and gain-fitted residual?

A. Approximately 141.421356 percent and zero, respectively.

B. Approximately 70.710678 percent and zero, respectively.

C. Zero and zero because the constellation point set is unchanged.

D. Exactly 100 percent and exactly 100 percent, respectively.

Answer: A. A quarter-turn changes each label-associated reference by a chord of square root two. A complex gain j aligns the points exactly, but that fit does not independently validate their original label association. Review: Application 7A.9.

Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)

Why the selected alternative fits: Approximately 141.421356 percent and zero, respectively.

Distinguishing consideration: compare this with option B, “Approximately 70.710678 percent and zero, respectively”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.9: Separate constellation rotation from validated symbol mapping.

Review: Chapter 7 — Application 7A.9: Separate constellation rotation from validated symbol mapping.

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V011-C07-MCQ-038. Why does the gain-fitted zero residual in the quarter-turn QPSK example not establish zero bit error rate?

A. The fitted rotation can conceal a label ambiguity, while BER requires a validated mapping and decision comparison.

B. A fitted gain cannot be complex in a QPSK calculation.

C. A quarter-turn necessarily changes the symbol rate.

D. EVM is defined only for uncoded amplitude modulation.

Answer: A. Geometric alignment and correctness of recovered information are distinct. Known pilots, framing or another justified reference can resolve mapping, but the aggregate fitted EVM alone does not. Review: Application 7A.9; Defensive Interpretation of Digital Signals. Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)

Why the selected alternative fits: The fitted rotation can conceal a label ambiguity, while BER requires a validated mapping and decision comparison.

Distinguishing consideration: compare this with option B, “A fitted gain cannot be complex in a QPSK calculation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.9: Separate constellation rotation from validated symbol mapping; Chapter 7 — Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Application 7A.9: Separate constellation rotation from validated symbol mapping; Chapter 7 — Defensive Interpretation of Digital Signals.

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V011-C07-MCQ-039. The balanced unit references 1, j, -1 and $-j$ receive a common offset $0.04 + j\,0.03$. What fixed-reference EVM follows?

A. 0.25 percent.

B. 7 percent.

C. 1 percent.

D. 5 percent.

Answer: D. The offset magnitude is square root of 0.04 squared plus 0.03 squared, or 0.05. Every unit reference has the same residual magnitude, so RMS EVM is 5 percent. Review: Equation 13I; Application 7A.3. Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why the selected alternative fits: 5 percent.

Distinguishing consideration: compare this with option A, “0.25 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

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V011-C07-MCQ-040. Why does the gain-only fit remain one for that common-offset example?

A. A complex gain fit always removes any constant offset.

B. The weighted reference sum is zero, so the offset contributes zero to the gain-estimating correlation.

C. The offset has zero magnitude because its real and imaginary parts differ.

D. The reference sum of squared magnitudes is zero.

Answer: B. The offset contribution is the offset times the conjugate weighted reference sum. Balanced references remove that correlation term without removing the offset residual itself. Review: Equation 13I; Application 7A.3. Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why the selected alternative fits: The weighted reference sum is zero, so the offset contributes zero to the gain-estimating correlation.

Distinguishing consideration: compare this with option A, “A complex gain fit always removes any constant offset”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

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V011-C07-MCQ-041. What changes if the analyst subtracts the fitted mean to remove that offset?

A. The operation proves that the removed term originated inside the receiver.

B. The original fixed-reference experiment is unchanged because means are never part of a waveform.

C. The operation is equivalent to a phase-only alignment for every constellation.

D. The analyst has added another permitted correction and must disclose its reason, training interval and uncorrected result.

Answer: D. Mean subtraction can eliminate the constructed offset, but it changes the comparison model and can remove a legitimate nonzero-mean signal component. Physical origin needs separate evidence. Review: Application 7A.3.

Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

Why the selected alternative fits: The analyst has added another permitted correction and must disclose its reason, training interval and uncorrected result.

Distinguishing consideration: compare this with option A, “The operation proves that the removed term originated inside the receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

Review: Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

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V011-C07-MCQ-042. For the same balanced unit references, observations are ideal symbols plus 0.06 times their conjugates. What EVM follows with a fixed reference?

A. 0.36 percent.

B. 6 percent.

C. 3 percent.

D. 12 percent.

Answer: B. Conjugation preserves each reference magnitude. Thus the residual energy is 0.06 squared times reference energy, giving a linear EVM of 0.06. Review: Equation 13I; Application 7A.4. Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why the selected alternative fits: 6 percent.

Distinguishing consideration: compare this with option A, “0.36 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

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V011-C07-MCQ-043. Which balanced-reference property keeps the ordinary gain fit at one in that conjugate-leakage case?

A. The weighted sum of squared reference magnitudes is zero.

B. Every reference has zero imaginary part.

C. The weighted sum of the squared complex references is zero.

D. The conjugate coefficient is necessarily purely imaginary.

Answer: C. The conjugate residual enters the gain correlation through the conjugate of the weighted reference-square sum. This can vanish while reference energy remains positive. Review: Equation 13I; Application 7A.4. Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why the selected alternative fits: The weighted sum of the squared complex references is zero.

Distinguishing consideration: compare this with option A, “The weighted sum of squared reference magnitudes is zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

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V011-C07-MCQ-044. What would estimating both direct and conjugate coefficients change?

A. It would identify the physical source of every observed I/Q error without additional tests.

B. It would make retention of the original complex symbols unnecessary.

C. It would introduce a different correction model whose parameter estimates and held-out performance need validation.

D. It would preserve exactly the same gain-only metric definition without disclosure.

Answer: C. Adding a conjugate branch enlarges the fitted model. Better in-sample residuals under that model do not establish a transferable calibration or a unique mechanism. Review: Application 7A.4. Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)

Why the selected alternative fits: It would introduce a different correction model whose parameter estimates and held-out performance need validation.

Distinguishing consideration: compare this with option A, “It would identify the physical source of every observed I/ error without additional tests”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

Review: Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

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V011-C07-MCQ-045. All sixteen square-16QAM points with each coordinate in -3, -1, 1 and 3 occur once. What are their average and maximum symbol energies?

A. 5 and 9.

B. 10 and 18.

C. 8 and 16.

D. 18 and 10.

Answer: B. Each coordinate has average square 5, giving total average energy 10. The outer corners have energy 3 squared plus 3 squared, or 18. Review: Application 7A.5. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

Why the selected alternative fits: 10 and 18.

Distinguishing consideration: compare this with option A, “5 and 9”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

Review: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-MCQ-046. A fixed residual $0.2+j0.1$ is added to that complete 16QAM population. What residual energy does each symbol contribute before weighting?

A. 0.05.

B. 0.01.

C. 0.3.

D. 0.5.

Answer: A. Squared complex magnitude is the sum of squared real and imaginary components: $0.04+0.01=0.05$. Adding the components directly does not give energy. Review: Application 7A.5. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

Why the selected alternative fits: 0.05.

Distinguishing consideration: compare this with option B, “0.01”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

Review: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-MCQ-047. For the same complete 16QAM population and residual, what are RMS-reference and constellation-maximum EVM?

A. Exactly 0.5 percent and approximately 0.277778 percent.

B. Approximately 5.270463 percent and 7.071068 percent.

C. Approximately 7.071068 percent and 5.270463 percent.

D. Exactly 5 percent and 18 percent.

Answer: C. Take square roots of $\frac{0.05}{10}$ and $\frac{0.05}{18}$, respectively, then convert to percent. The different denominators explain the different numbers without any residual change. Review: Equation 13G; Application 7A.5. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why the selected alternative fits: Approximately 7.071068 percent and 5.270463 percent.

Distinguishing consideration: compare this with option A, “Exactly 0.5 percent and approximately 0.277778 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-MCQ-048. For fixed residual RMS, which normalization gives the smaller EVM in that complete 16QAM example?

A. The normalization choices differ only in phase, so their magnitudes cancel.

B. Constellation maximum, because its reference amplitude exceeds the realized RMS reference amplitude.

C. Reference RMS, because averaging always lowers every normalized error.

D. Both must be equal because the constellation has sixteen points.

Answer: B. The denominator is square root 18 for the maximum convention and square root 10 for the average convention. This is a normalization comparison under the stated population, not a statement about measurement quality. Review: Equation 13G; Application 7A.5. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why the selected alternative fits: Constellation maximum, because its reference amplitude exceeds the realized RMS reference amplitude.

Distinguishing consideration: compare this with option A, “The normalization choices differ only in phase, so their magnitudes cancel”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-MCQ-049. A short 16QAM sequence contains inner points more often than the full uniform constellation. What should be checked before using the average energy 10?

A. Only whether a gain fit was estimated on the selected observations.

B. Only whether the EVM is expressed in decibels.

C. Only whether the outermost ideal coordinate is still 3.

D. Whether the selected reference population actually has that average energy.

Answer: D. The realized reference RMS depends on the selected sequence and weights. The full-constellation average of 10 is not a universal value for a biased finite population. Review: Equation 13G and its normalization discussion. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why the selected alternative fits: Whether the selected reference population actually has that average energy.

Distinguishing consideration: compare this with option A, “Only whether a gain fit was estimated on the selected observations”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-MCQ-050. A threshold was specified for reference-RMS EVM, but a receiver reports constellation-maximum EVM. What is required before applying the threshold?

A. No conversion, because both values have percent units.

B. An explicit convention conversion using the correct reference population and normalization magnitudes.

C. Replacement of the measured residual by its largest symbol error.

D. A universal 3 dB adjustment for every modulation format and sequence.

Answer: B. A common label does not establish a common denominator. Conversion requires the ratio of the actual normalization amplitudes, which need not be constant across selected populations. Review: Equation 13G; Application 7A.5.

Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why the selected alternative fits: An explicit convention conversion using the correct reference population and normalization magnitudes.

Distinguishing consideration: compare this with option A, “No conversion, because both values have percent units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-MCQ-051. Four unit-energy references have residual magnitudes 0.30, 0.10, 0.02 and 0.02 with equal weights. What is their RMS EVM?

A. Approximately 25.2 percent.

B. Exactly 30 percent.

C. Approximately 15.874508 percent.

D. Exactly 11 percent.

Answer: C. The residual energies sum to 0.1008 and reference energies to 4. The square root of 0.0252 is 0.15874508. Averaging the four magnitudes or reporting the maximum gives a different statistic. Review: Application 7A.6; Equation 13B.

Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

Why the selected alternative fits: Approximately 15.874508 percent.

Distinguishing consideration: compare this with option A, “Approximately 25.2 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-MCQ-052. If only the last two symbols of that four-symbol record are retained, what does the resulting 2 percent EVM describe?

A. A guarantee that acquisition was valid because the retained result is small.

B. The entire original four-symbol record after an equivalent re-expression.

C. An unbiased estimate of all transmitted symbols without any selection model.

D. The selected two-symbol population, with the larger acquisition errors explicitly excluded.

Answer: D. Both remaining residual magnitudes are 0.02 on unit references, so their EVM is 2 percent. The computation is valid for that subset, but its favorable value does not represent the excluded symbols. Review: Application 7A.6. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

Why the selected alternative fits: The selected two-symbol population, with the larger acquisition errors explicitly excluded.

Distinguishing consideration: compare this with option A, “A guarantee that acquisition was valid because the retained result is small”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.6: Make selection and weighting visible.

Review: Chapter 7 — Application 7A.6: Make selection and weighting visible.

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V011-C07-MCQ-053. The same four residual magnitudes receive weights 0.1, 0.1, 1 and 1. What weighted EVM follows?

A. Approximately 15.874508 percent.

B. Exactly 2 percent.

C. Approximately 0.490909 percent.

D. Approximately 7.006490 percent.

Answer: D. Weighted residual energy is $0.009+0.001+0.0004+0.0004=0.0108$. Weighted reference energy is 2.2. Their ratio is about 0.00490909, whose square root is 0.07006490. Review: Application 7A.6; Equation 13J. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

Why the selected alternative fits: Approximately 7.006490 percent.

Distinguishing consideration: compare this with option A, “Approximately 15.874508 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

Review: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-MCQ-054. Two disjoint blocks have equal reference energies and EVM values of 10 and 30 percent under identical conventions. What is the EVM of their union?

A. Exactly 20 percent.

B. Exactly 40 percent.

C. Approximately 31.622777 percent.

D. Approximately 22.360680 percent.

Answer: D. Add numerator and denominator energies before taking the square root. Equal reference energies give the square root of the mean of 0.1 squared and 0.3 squared, or the square root of 0.05. Review: Equations 13B and 13J; finite-population combination. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: Approximately 22.360680 percent.

Distinguishing consideration: compare this with option A, “Exactly 20 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-MCQ-055. A receiver reports EVM only after successful lock. What additional information is needed to judge the whole acquisition experiment?

A. A claim that every excluded interval has the same EVM as the accepted population.

B. Only a smaller error threshold applied to the already selected locked intervals.

C. Only the mean EVM of successful intervals, because failures have no symbols to compare.

D. The attempted intervals, lock failures and selection rule, alongside the conditional locked-interval metric.

Answer: D. An EVM conditional on lock can be useful, but acquisition reliability and unobserved or rejected intervals are separate evidence. Omitting failures changes the population that the result can characterize. Review: Carrier and Timing Synchronization; Application 7A.6; reproducible acceptance record. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

Why the selected alternative fits: The attempted intervals, lock failures and selection rule, alongside the conditional locked-interval metric.

Distinguishing consideration: compare this with option A, “A claim that every excluded interval has the same EVM as the accepted population”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-056. Which retained quantities permit exact recombination of compatible EVM blocks with different reference energies?

A. Only the largest error in each block and the modulation name.

B. Each block's residual-energy sum and reference-energy sum under the same declared convention.

C. Only the arithmetic mean of each block's symbol-error magnitudes.

D. Only each block's EVM percentage and its display update number.

Answer: B. The combined ratio is formed from the sum of residual energies divided by the sum of reference energies. Percentages alone lose the denominator weights needed for unequal-energy blocks. Review: Equation 13B; Turn a quality metric into a reproducible acceptance record. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: Each block's residual-energy sum and reference-energy sum under the same declared convention.

Distinguishing consideration: compare this with option A, "Only the largest error in each block and the modulation name"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-057. A residual carrier offset is 100 Hz and the symbol rate is 10,000 symbols per second. What phase increment occurs per symbol?

A. 0.01 degrees.

B. 100 degrees.

C. 3.6 degrees.

D. 36 degrees.

Answer: C. The increment is $\frac{100}{10000} = 0.01$ cycles per symbol, equivalent to 3.6 degrees or 0.02π radians. Hertz must first be related to the symbol interval. Review: Application 7A.8. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

Why the selected alternative fits: 3.6 degrees.

Distinguishing consideration: compare this with option A, “0.01 degrees”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

Review: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-MCQ-058. Why can one constant complex gain not remove the entire residual of that frequency-offset record?

A. A complex coefficient can correct amplitude but cannot represent any phase.

B. A nonzero carrier offset makes the reference energy necessarily zero.

C. The phase changes with symbol time, while the fitted coefficient supplies only one constant amplitude and phase.

D. The fitting objective excludes complex-valued observations.

Answer: C. A fixed coefficient can approximate a finite phase arc but cannot equal distinct rotations at every retained time. The residual pattern and the declared correction model matter separately from the aggregate fit. Review: Equation 13D; Application 7A.8. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: The phase changes with symbol time, while the fitted coefficient supplies only one constant amplitude and phase.

Distinguishing consideration: compare this with option A, “A complex coefficient can correct amplitude but cannot represent any phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-MCQ-059. Ideal references $(1,1)$ produce observations $(1,-1)$ with equal weights. What happens to their constant-gain fit and fitted-reference EVM?

A. The gain magnitude is one because both observations have unit magnitude.

B. The gain is zero and fitted-reference EVM is zero.

C. The gain is one and fitted-reference EVM is zero.

D. The gain is zero and fitted-reference EVM is undefined.

Answer: D. The complex correlation cancels, although both observation magnitudes are one. The least-squares coefficient is zero, and its fitted reference has zero energy. Magnitude averaging would not implement this complex fit. Review: Equations 13D–13F; phase-cancellation boundary. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why the selected alternative fits: The gain is zero and fitted-reference EVM is undefined.

Distinguishing consideration: compare this with option A, “The gain magnitude is one because both observations have unit magnitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted….

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-MCQ-060. For the chapter's symmetric 21-symbol frequency-offset record, why can gain-fitted EVM exceed fixed-reference EVM even though the fitted residual energy decreases?

A. The numerator of the fitted objective becomes larger than for every other constant gain.

B. The same denominator is retained and the only change is a smaller numerator.

C. The fitted gain magnitude is about 0.929174, reducing the fitted-reference denominator enough to raise the ratio.

D. The least-squares fit changes every nonnegative weight into a negative weight.

Answer: C. The chapter obtains approximately 37.636773 percent for the fixed reference and 39.781958 percent for the fitted reference. The fit minimizes squared residual, while the second metric also divides by the fitted gain magnitude. Review: Application 7A.8; Equations 13E and 13F. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

Why the selected alternative fits: The fitted gain magnitude is about 0.929174, reducing the fitted-reference denominator enough to raise the ratio.

Distinguishing consideration: compare this with option A, "The numerator of the fitted objective becomes larger than for every other constant gain"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with….

Review: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-MCQ-061. For symmetric time indices and unit references, reversing the sign of that frequency offset can leave aggregate EVM unchanged. What remains necessary to distinguish the cases?

A. The signed phase history or equivalent retained complex record.

B. Only the EVM percentage, because it uniquely determines offset sign.

C. Only the reference-energy sum, because it changes sign with frequency.

D. Only the maximum constellation radius, because it identifies direction of rotation.

Answer: A. Conjugate phase arcs can have identical squared-distance sums. The scalar metric loses directional information that the complex time history retains.
Review: Application 7A.8; finite-record interpretation. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
Why the selected alternative fits: The signed phase history or equivalent retained complex record.
Distinguishing consideration: compare this with option B, “Only the EVM percentage, because it uniquely determines offset sign”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.
Review: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-MCQ-062. The fitted coefficient for a symmetrically indexed phase arc is real. Does that establish zero residual carrier offset?

A. Yes; any real coefficient proves every symbol has zero phase error.

B. Yes; a carrier offset always produces a purely imaginary fitted coefficient.

C. No; opposite-time imaginary components can cancel in the mean while a phase ramp remains.

D. No, solely because real coefficients are excluded by the least-squares model.

Answer: C. A real aggregate coefficient is compatible with a symmetric nonzero phase evolution. Individual residuals and timing remain necessary to determine what the fit has averaged. Review: Application 7A.8. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

Why the selected alternative fits: No; opposite-time imaginary components can cancel in the mean while a phase ramp remains.

Distinguishing consideration: compare this with option A, “Yes; any real coefficient proves every symbol has zero phase error”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

Review: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-MCQ-063. In Application 7A.10, four references each have energy 2 and residual energies total 0.0043. What is RMS EVM?

A. Approximately 3.162278 percent.

B. Approximately 4.636809 percent.

C. Approximately 0.05375 percent.

D. Approximately 2.318405 percent.

Answer: D. The reference-energy sum is 8. Taking the square root of $\frac{0.0043}{8}$ gives 0.02318405. The approximately 3.162278 percent value is the largest individually normalized residual in this constructed record. Review: Application 7A.10. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

Why the selected alternative fits: Approximately 2.318405 percent.

Distinguishing consideration: compare this with option A, “Approximately 3.162278 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

Review: Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

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V011-C07-MCQ-064. The third residual in that application has squared magnitude 0.002. What share of the total residual energy does it contribute?

A. Exactly 50 percent.

B. Exactly 25 percent.

C. Approximately 46.5116 percent.

D. Approximately 4.65116 percent.

Answer: C. Divide 0.002 by the total 0.0043. Equal reference magnitudes do not require equal residual-energy contributions, and the dominant residual can be concealed by one overall RMS statistic. Review: Application 7A.10. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

Why the selected alternative fits: Approximately 46.5116 percent.

Distinguishing consideration: compare this with option A, “Exactly 50 percent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

Review: Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

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V011-C07-MCQ-065. What does exact agreement with the four-symbol arithmetic in Application 7A.10 establish about an implementation?

A. Agreement with that deterministic reference case, without a sampling-distribution or confidence claim.

B. A universal relation from EVM to bit error probability.

C. A 95 percent confidence bound for every later measurement.

D. Statistical independence of the four complex residuals.

Answer: A. A finite constructed case tests the specified arithmetic and conventions. A probability statement requires an additional justified statistical model and appropriate observations. Review: Application 7A.10; reproducible acceptance record. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

Why the selected alternative fits: Agreement with that deterministic reference case, without a sampling-distribution or confidence claim.

Distinguishing consideration: compare this with option B, “A universal relation from EVM to bit error probability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.10: Audit a complete finite residual vector; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Application 7A.10: Audit a complete finite residual vector; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-066. Both the observed and reference vectors are multiplied by the same unit-magnitude complex rotation. What happens to fixed-reference EVM?

A. It always becomes zero because any common rotation is a perfect correction.

B. It increases by the phase angle expressed in degrees.

C. It changes sign when the rotation exceeds 180 degrees.

D. It is unchanged because each residual magnitude and each reference magnitude are unchanged.

Answer: D. The common factor rotates each difference without changing its length. This invariance is about a coordinated representation change, not a phase correction applied only to observations. Review: Equation 13B; complex-magnitude invariance. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: It is unchanged because each residual magnitude and each reference magnitude are unchanged.

Distinguishing consideration: compare this with option A, “It always becomes zero because any common rotation is a perfect correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-MCQ-067. Both observed and reference vectors are scaled by the same nonzero complex calibration factor. What can unchanged EVM fail to reveal?

A. The existence of any nonzero residual before the common scaling.

B. The algebraic cancellation of the common factor's squared magnitude.

C. A common absolute amplitude or phase calibration error shared by both vectors.

D. Whether the selected reference energy is positive before and after scaling.

Answer: C. Both energy sums receive the same positive scale factor, so the ratio remains invariant. A relative comparison can agree while both quantities share an incorrect absolute reference. Review: Equation 13B; receiver and reference validation. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: A common absolute amplitude or phase calibration error shared by both vectors.

Distinguishing consideration: compare this with option A, "The existence of any nonzero residual before the common scaling"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-MCQ-068. Observed symbols, references and weights are permuted together. What remains unchanged, and what may be lost if the original order is discarded?

A. Aggregate EVM remains unchanged, while evidence of temporal drift or acquisition structure may be lost.

B. The symbol labels remain correct regardless of whether observations and references are paired.

C. The reference-energy sum becomes zero, while the residual history is unchanged.

D. Aggregate EVM necessarily doubles, while temporal information is preserved.

Answer: A. Finite sums are invariant to a common permutation of paired records. Time-dependent interpretation still requires the original sequence and timestamps; separately permuting only one vector changes the pairing. Review: Equation 13B; Error Vector Magnitude and Quality Metrics. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why the selected alternative fits: Aggregate EVM remains unchanged, while evidence of temporal drift or acquisition structure may be lost.
Distinguishing consideration: compare this with option B, “The symbol labels remain correct regardless of whether observations and references are paired”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Error Vector Magnitude and Quality Metrics.
Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Error Vector Magnitude and Quality Metrics.

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V011-C07-MCQ-069. Training and evaluation use disjoint symbol indices from the same slowly varying channel record. What does disjointness alone establish?

A. Exclusion of evaluation indices from that fit, not statistical independence of the physical observations.

B. Independent channel realizations by definition.

C. A guarantee that the evaluation population represents every future channel state.

D. Zero covariance between all training and evaluation residuals.

Answer: A. Held-out indexing limits a fitting dependency, but temporal correlation and shared impairments can remain. Independence or generalization requires further assumptions and evidence. Review: Equation 13F; synchronization and validation scope. Source: Equation 13F. Held-out evaluation with a nonzero fitted reference (p. 3748)

Why the selected alternative fits: Exclusion of evaluation indices from that fit, not statistical independence of the physical observations.

Distinguishing consideration: compare this with option B, “Independent channel realizations by definition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-MCQ-070. Two records have equal RMS EVM but different residual histories. Which comparison best tests whether the same impairment mechanism is plausible?

A. Treat equal RMS values as proof of identical physical error sources.

B. Compare only the mean error vector while discarding its second moment and time dependence.

C. Replace each record by an independently shuffled set of residual magnitudes.

D. Compare complex error versus time and symbol state, together with the declared synchronization and corrections.

Answer: D. A scalar norm discards sign, direction, temporal ordering and state dependence. Structured residuals can test proposed mechanisms, although resemblance alone is not unique physical attribution. Review: Error Vector Magnitude and Quality Metrics; Applications 7A.1–7A.10. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: Compare complex error versus time and symbol state, together with the declared synchronization and corrections.

Distinguishing consideration: compare this with option A, “Treat equal RMS values as proof of identical physical error sources”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Error Vector Magnitude and Quality Metrics; Chapter 7 — Application 7A.1: Show which error a fitted gain removes; Chapter 7 — Application….

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Error Vector Magnitude and Quality Metrics; Chapter 7 — Application 7A.1: Show which error a fitted gain removes; Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

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V011-C07-MCQ-071. Two implementations use nominally the same pulse-shaping filter name but disagree near record boundaries. What should be compared first?

A. Actual coefficients, span, delay convention, initialization and the treatment of transient samples.

B. Only the final EVM percentage after discarding different edge intervals.

C. Only whether both implementations represent symbols as complex numbers.

D. Only the nominal roll-off label, because it uniquely determines every finite implementation.

Answer: A. A filter family name does not fix its finite realization or record-edge history. Different initialization and alignment rules can produce different sampled references even when steady-state labels agree. Review: Matched Filtering, Pulse Shaping, and Channel Effects. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

Why the selected alternative fits: Actual coefficients, span, delay convention, initialization and the treatment of transient samples.

Distinguishing consideration: compare this with option B, “Only the final EVM percentage after discarding different edge intervals”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-MCQ-072. Under the conventional known-pulse, additive-white-noise model with a properly timed decision sample, what does a matched filter optimize?

A. The occupied bandwidth independently of the transmitted pulse.

B. Every receiver metric under arbitrary colored interference and unknown timing.

C. The signal-to-noise ratio at that specified decision sample.

D. Bit error probability without a decision rule or symbol mapping.

Answer: C. The matched-filter statement has a defined signal, noise and sampling model. It does not remove the need to specify timing, interference covariance, subsequent decisions or the quantity being assessed. Review: Matched Filtering, Pulse Shaping, and Channel Effects. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

Why the selected alternative fits: The signal-to-noise ratio at that specified decision sample.

Distinguishing consideration: compare this with option A, “The occupied bandwidth independently of the transmitted pulse”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-MCQ-073. What tradeoff should be assessed when increasing a synchronization loop's bandwidth?

A. Every larger bandwidth guarantees lower residual error for every record.

B. Bandwidth changes only the displayed axes and cannot alter recovered symbols.

C. Faster tracking of changes may admit more noise or unwanted modulation into the estimate.

D. A wider loop necessarily resolves all symbol-label ambiguities.

Answer: C. Acquisition speed, tracking, jitter and disturbance rejection depend on the loop and signal conditions. A smaller selected EVM does not by itself justify a different permitted correction bandwidth. Review: Carrier and Timing Synchronization. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why the selected alternative fits: Faster tracking of changes may admit more noise or unwanted modulation into the estimate.

Distinguishing consideration: compare this with option A, "Every larger bandwidth guarantees lower residual error for every record"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Carrier and Timing Synchronization.

Review: Chapter 7 — Carrier and Timing Synchronization.

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V011-C07-MCQ-074. Why must filter group delay and symbol timing be handled consistently in reference reconstruction?

A. The residual must compare corresponding decision instants rather than differently delayed waveform locations.

B. Delay can be ignored whenever the reference and observation have equal total energies.

C. A delay correction proves the signal originated at the expected transmitter.

D. Any integer number of stored samples always equals one symbol interval.

Answer: A. Energy equality cannot establish temporal correspondence. Sample rate, symbol rate, filter delays and alignment conventions determine which values belong to the same intended symbol comparison. Review: Matched Filtering, Pulse Shaping, and Channel Effects; Model 7A experiment definition. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: The residual must compare corresponding decision instants rather than differently delayed waveform locations.

Distinguishing consideration: compare this with option B, “Delay can be ignored whenever the reference and observation have equal total energies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-MCQ-075. A processing change excludes acquisition transients and lowers reported EVM. Which conclusion is warranted without additional evidence?

A. The physical receiver has necessarily acquired every signal faster.

B. The newly selected settled-interval metric is lower; whole-record acquisition performance has not thereby improved.

C. The deleted symbols can be treated as error-free because they no longer enter the sum.

D. The previous result was mathematically wrong solely because it included transients.

Answer: B. Both selection rules can produce valid but differently scoped metrics. Report the inclusion policy and failures rather than treating a changed denominator population as a physical improvement. Review: Application 7A.6; Carrier and Timing Synchronization. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

Why the selected alternative fits: The newly selected settled-interval metric is lower; whole-record acquisition performance has not thereby improved.

Distinguishing consideration: compare this with option A, “The physical receiver has necessarily acquired every signal faster”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Carrier and Timing Synchronization.

Review: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Carrier and Timing Synchronization.

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V011-C07-MCQ-076. A known signed frequency offset is injected to challenge a demodulator. Which result should be checked beyond a small final EVM?

A. Only whether the equalizer can fit a compact constellation after unlimited adaptation.

B. Only whether an unrelated checksum passes on one output frame.

C. Only whether the constellation centroid is at the origin.

D. The estimated offset sign and magnitude, phase progression and retained correction convention.

Answer: D. A controlled challenge should exercise the intended relationship. A flexible fit can hide a sign convention or reference mistake, so the intermediate estimate and uncorrected behavior belong in the check. Review: Define the symbol experiment before fitting the constellation; reproducible acceptance record. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

Why the selected alternative fits: The estimated offset sign and magnitude, phase progression and retained correction convention.

Distinguishing consideration: compare this with option A, “Only whether the equalizer can fit a compact constellation after unlimited adaptation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Define the symbol experiment before fitting the constellation; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Define the symbol experiment before fitting the constellation; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-077. What is the sound interpretation of pre-equalization and post-equalization EVM measured on the same observations?

A. A post-equalization result is invalid merely because compensation was applied.

B. They characterize different declared processing states and should be retained with the equalizer settings and purpose.

C. Their numerical difference uniquely identifies the transmitter's hardware impairment.

D. The smaller post-equalization value universally replaces the unprocessed result for every measurand.

Answer: B. Compensation can be appropriate for an operational demodulation question and inappropriate for isolating an uncompensated path. Neither result is meaningful without its measurement boundary and allowed corrections. Review: Matched Filtering, Pulse Shaping, and Channel Effects; Defensive Interpretation of Digital Signals. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

Why the selected alternative fits: They characterize different declared processing states and should be retained with the equalizer settings and purpose.

Distinguishing consideration: compare this with option A, "A post-equalization result is invalid merely because compensation was applied"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects; Chapter 7 — Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects; Chapter 7 — Defensive Interpretation of Digital Signals.

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V011-C07-MCQ-078. An adaptive equalizer gains additional parameters and fits one short record extremely well. Which test most directly examines whether that fit transfers?

A. Infer physical channel uniqueness from the number of plotted constellation clusters.

B. Use only the training result and count fitted coefficients as independent observations.

C. Add more parameters until the same training residual is exactly zero.

D. Evaluate a separately reserved record under a declared fitting and validation policy.

Answer: D. Greater flexibility can absorb noise or incidental structure. Held-out evaluation and controlled cases test transfer under stated conditions; they do not create universal validity automatically. Review: Matched Filtering, Pulse Shaping, and Channel Effects; Equation 13F validation principle. Source: Equation 13F. Held-out evaluation with a nonzero fitted reference (p. 3748)

Why the selected alternative fits: Evaluate a separately reserved record under a declared fitting and validation policy.

Distinguishing consideration: compare this with option A, “Infer physical channel uniqueness from the number of plotted constellation clusters”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-MCQ-079. Two implementations agree exactly on EVM while sharing the same wrongly mapped reference symbols. What has their agreement failed to validate?

A. The correctness of the reference mapping and its relation to the intended transmitted symbols.

B. The fact that both implementations use the same numerical input records.

C. The arithmetic equality of the reported values.

D. The possibility of checking the common convention with a known reference.

Answer: A. Independent arithmetic does not remove a shared model or input error. Reference construction, label mapping and acquisition conditions need their own tests. Review: Defensive Interpretation of Digital Signals; reproducible acceptance record. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

Why the selected alternative fits: The correctness of the reference mapping and its relation to the intended transmitted symbols.

Distinguishing consideration: compare this with option B, “The fact that both implementations use the same numerical input records”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Defensive Interpretation of Digital Signals; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Defensive Interpretation of Digital Signals; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-080. A noise-only input sometimes produces plausible recovered symbol clusters. What should this control establish in the report?

A. That real digital transmissions cannot produce the same constellation geometry.

B. That every previously observed signal was necessarily noise.

C. That the numerical EVM formula should be abandoned for all records.

D. That the tested processing can generate such structure under that control, requiring additional validation of candidate locks.

Answer: D. The control exposes a possible false-lock mechanism under its actual conditions. It does not retroactively classify every other observation; the candidate record still needs its own discriminating evidence. Review: Carrier and Timing Synchronization; Hypothetical Case Adjudication. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why the selected alternative fits: That the tested processing can generate such structure under that control, requiring additional validation of candidate locks.

Distinguishing consideration: compare this with option A, “That real digital transmissions cannot produce the same constellation geometry”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

Review: Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

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V011-C07-MCQ-081. A coded QPSK stream carries 4 Mbit/s of information at code rate one half, with no other overhead or idle time. What symbol rate is required?

A. 2 Msymbol/s.

B. 8 Msymbol/s.

C. 4 Msymbol/s.

D. 1 Msymbol/s.

Answer: C. QPSK carries two coded bits per data symbol. The information rate is two times one half times the symbol rate, so the required symbol rate is 4 million symbols per second. Review: Equation 14; Model 7B rate accounting. Source: Equation 14. Symbol-rate relation (p. 3767)

Why the selected alternative fits: 4 Msymbol/s.

Distinguishing consideration: compare this with option A, “2 Msymbol/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 14. Symbol-rate relation; Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Equation 14. Symbol-rate relation; Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-MCQ-082. A 16QAM link has code rate 0.75 and data-slot fraction 0.8. Every information bit is payload, with no additional overhead. What symbol-slot rate supports 2.4 Mbit/s of payload under this model?

A. 0.8 Msymbol-slot/s.

B. 1 Msymbol-slot/s.

C. 0.6 Msymbol-slot/s.

D. 1.25 Msymbol-slot/s.

Answer: B. Each useful slot carries four coded bits and therefore three information bits before the separate slot fraction. Payload rate is $4 \times 0.75 \times 0.8$ times the slot rate, so 2.4 Mbit/s requires 1 million slots per second. Review: Turn a quality metric into a reproducible acceptance record; Model 7B. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: 1 Msymbol-slot/s.

Distinguishing consideration: compare this with option A, “0.8 Msymbol-slot/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-083. Why must a code rate and a separate payload-overhead factor have explicitly disjoint definitions?

A. Because multiplying two dimensionless factors is mathematically prohibited.

B. Because a code rate is measured in hertz while an overhead fraction is measured in bits.

C. Otherwise the same overhead can be counted twice or assigned to incompatible bit and symbol populations.

D. Because any two efficiency factors must always have numerically equal values.

Answer: C. The product is useful only when each factor represents a different declared conversion in the count chain. A reported payload fraction that already includes coding must not be multiplied by that coding reduction again. Review: Equation 14 limitations; Model 7B count definitions. Source: Equation 14. Symbol-rate relation (p. 3767)

Why the selected alternative fits: Otherwise the same overhead can be counted twice or assigned to incompatible bit and symbol populations.

Distinguishing consideration: compare this with option A, “Because multiplying two dimensionless factors is mathematically prohibited”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Equation 14. Symbol-rate relation; Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Equation 14. Symbol-rate relation; Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-MCQ-084. A uniform 64QAM stream has slot rate 2 Msymbol-slot/s, code rate two thirds and data-slot fraction 0.9. Every information bit is payload, with no additional overhead. What payload rate follows?

A. 10.8 Mbit/s.

B. 18 Mbit/s.

C. 7.2 Mbit/s.

D. 1.2 Mbit/s.

Answer: C. There are six coded bits per 64QAM data symbol. Multiply 2 million slots per second by 6, by two thirds and by 0.9. Each factor has a stated role; coding does not create extra information bits. Review: Model 7B fixed-mode rate identity. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: 7.2 Mbit/s.

Distinguishing consideration: compare this with option A, “10.8 Mbit/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-MCQ-085. A calculation counts all transmitted payload-bearing bits, including repeats of the same packet. What additional evidence is needed to report unique delivered payload throughput?

A. A delivery and duplication rule with packet outcomes or equivalent identity-linked counts.

B. Only the nominal code rate, because it already includes all retransmission outcomes.

C. Only EVM, converted through a universal bit-error formula.

D. Only the modulation order, because every transmitted label necessarily delivers new information.

Answer: A. The physical transmission rate and the rate of distinct accepted payload are different populations. Repeat and delivery accounting needs its own observations and convention. Review: Turn a quality metric into a reproducible acceptance record; Model 7B scope. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: A delivery and duplication rule with packet outcomes or equivalent identity-linked counts.

Distinguishing consideration: compare this with option B, “Only the nominal code rate, because it already includes all retransmission outcomes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-086. A 100-slot frame reserves 12 slots for pilots and 16 other disjoint slots for nonpayload use. The remaining slots carry 16QAM with code rate 0.75 at 3 million slots per second; every resulting information bit is payload. What payload rate follows?

A. 8.64 Mbit/s.

B. 6.48 Mbit/s.

C. 9 Mbit/s.

D. 2.16 Mbit/s.

Answer: B. There are 72 useful slots per 100, so the usable fraction is 0.72. Multiply 3 million by 4 coded bits per symbol, 0.75 information fraction and 0.72 useful-slot fraction. Review: Model 7B finite-frame count example. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: 6.48 Mbit/s.

Distinguishing consideration: compare this with option A, “8.64 Mbit/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-MCQ-087. A receiver identifies a 16QAM-like constellation but has not established coding or framing. What payload-rate conclusion is justified from constellation order alone?

A. Four coded label bits can be assigned per such symbol, but payload rate still needs rate, coding and overhead definitions.

B. Payload rate is necessarily four times the RF carrier frequency.

C. All observed symbols necessarily contain four distinct accepted payload bits.

D. The code rate must be one because there are sixteen states.

Answer: A. Constellation cardinality describes an alphabet under a mapping, not the full protocol or delivery population. Coding, pilots, headers, duty and outcome accounting remain separate. Review: Equation 14 and its limitations; Defensive Interpretation of Digital Signals. Source: Equation 14. Symbol-rate relation (p. 3767)
Why the selected alternative fits: Four coded label bits can be assigned per such symbol, but payload rate still needs rate, coding and overhead definitions.
Distinguishing consideration: compare this with option B, “Payload rate is necessarily four times the RF carrier frequency”; that competing statement does not meet the question’s stated requirement.
Basis and limitation: Chapter 7 — Equation 14. Symbol-rate relation; Chapter 7 — Defensive Interpretation of Digital Signals.
Review: Chapter 7 — Equation 14. Symbol-rate relation; Chapter 7 — Defensive Interpretation of Digital Signals.

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V011-C07-MCQ-088. Two simultaneous, disjoint payload streams deliver 2.4 Mbit/s and 1.6 Mbit/s over the same declared wall-clock interval. What aggregate payload rate follows?

A. 2.0 Mbit/s, because parallel streams must be averaged rather than added.

B. 3.84 Mbit/s, because rates combine by multiplication.

C. The larger stream's 2.4 Mbit/s, regardless of the second stream's payload.

D. 4.0 Mbit/s, provided their counted payload is disjoint and the rate definitions agree.

Answer: D. Counts of disjoint delivered payload over a common interval add. Duplicated diversity copies or incompatible time bases would require a different accounting before addition. Review: Model 7B aggregate count identity. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: 4.0 Mbit/s, provided their counted payload is disjoint and the rate definitions agree.

Distinguishing consideration: compare this with option A, "2.0 Mbit/s, because parallel streams must be averaged rather than added"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-MCQ-089. A link delivers 6 Mbit/s for 3 seconds and 2 Mbit/s for 1 second, with no other interval. What is its payload rate over the complete 4 seconds?

A. 5 Mbit/s.

B. 8 Mbit/s.

C. 3 Mbit/s.

D. 4 Mbit/s.

Answer: A. The payload count is 18 million plus 2 million bits. Divide by 4 seconds. An unweighted mean of the two mode rates would incorrectly give the shorter mode equal time weight. Review: Model 7B duration-weighted mode accounting.

Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: 5 Mbit/s.

Distinguishing consideration: compare this with option B, “8 Mbit/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-MCQ-090. Under the finite-slot model, the usable-symbol fraction is zero while a positive payload rate is required. What does the inverse rate calculation imply?

A. The code rate can be ignored to avoid the zero denominator.

B. The receiver may replace the zero fraction by one without changing the model.

C. No finite slot rate satisfies that positive payload requirement within the stated zero-useful-slot model.

D. The required symbol rate is zero because the usable fraction is zero.

Answer: C. A zero useful-slot factor makes the modeled payload count zero at every finite slot rate. The positive-target inverse is outside its domain, so the premises or requirement must change. Review: Model 7B inverse-domain boundary.

Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: No finite slot rate satisfies that positive payload requirement within the stated zero-useful-slot model.

Distinguishing consideration: compare this with option A, “The code rate can be ignored to avoid the zero denominator”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-MCQ-091. A decoded frame passes its declared cyclic-redundancy check. What does that fact alone fail to establish?

A. Consistency with that particular implemented check rule.

B. Authenticity, emitter location or lawful acquisition authority.

C. The possibility of preserving the frame and decoder configuration for review.

D. The existence of the observed check outcome in the retained decoder record.

Answer: B. A check result is evidence about a defined code relation under a decoder. It does not by itself authenticate a sender, locate an emitter or establish authority for the acquisition. Review: Defensive Interpretation of Digital Signals.

Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

Why the selected alternative fits: Authenticity, emitter location or lawful acquisition authority.

Distinguishing consideration: compare this with option A, “Consistency with that particular implemented check rule”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Defensive Interpretation of Digital Signals.

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V011-C07-MCQ-092. A noise-only control also produces a passing short check on one trial. Which inference is defensible?

A. The control demonstrates a false-accept possibility under the tested search and check procedure, not universal invalidity of every candidate.

B. All real frames must now be rejected regardless of independent evidence.

C. The probability of any future false acceptance is exactly the fraction from that one trial without further assumptions.

D. A check pass guarantees a true signal because the control was unexpected.

Answer: A. Search multiplicity, trial definitions and the control population matter. One event can disprove an absolute impossibility claim but does not by itself supply a transferable false-accept rate. Review: Hypothetical Case Adjudication; decoder validation limits. Source: §7.24 Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics (p. 3794)

Why the selected alternative fits: The control demonstrates a false-accept possibility under the tested search and check procedure, not universal invalidity of every candidate.

Distinguishing consideration: compare this with option B, “All real frames must now be rejected regardless of independent evidence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

Review: Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

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V011-C07-MCQ-093. A candidate component shifts in a repeatable way when only the sampling rate or digital grid is changed. What should be investigated?

A. Only the final EVM threshold, with all rate metadata discarded.

B. Only the transmitter location, because processing cannot move a displayed component.

C. An assumption that every rate-dependent component is necessarily malicious.

D. Sampling, alias, reference and processing dependencies before treating the display as a fixed external emission.

Answer: D. A controlled receiver-state challenge tests whether the observation behaves as the proposed physical signal should. The result can implicate a processing mechanism without uniquely identifying it or establishing intent. Review: Defensive Interpretation of Digital Signals; Hypothetical Case Adjudication. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

Why the selected alternative fits: Sampling, alias, reference and processing dependencies before treating the display as a fixed external emission.

Distinguishing consideration: compare this with option A, “Only the final EVM threshold, with all rate metadata discarded”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Defensive Interpretation of Digital Signals; Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

Review: Chapter 7 — Defensive Interpretation of Digital Signals; Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

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V011-C07-MCQ-094. Why is agreement between two decoders insufficient when both import the same incorrect sample-rate metadata?

A. A shared metadata error is automatically removed by RMS normalization.

B. Sample-rate metadata cannot affect any digital demodulation result.

C. They can share the same time-axis and synchronization error despite separate implementations.

D. Different implementations can never produce numerically equal results.

Answer: C. Independence must be assessed at the level of assumptions, references and inputs as well as code. A known time/frequency reference can expose a shared metadata error that duplicate processing preserves. Review: Carrier and Timing Synchronization; reproducible acceptance record. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why the selected alternative fits: They can share the same time-axis and synchronization error despite separate implementations.

Distinguishing consideration: compare this with option A, “A shared metadata error is automatically removed by RMS normalization”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-095. Which record best supports a later reviewer's evaluation of failed acquisition attempts?

A. Only the final accepted constellation with failed intervals replaced by zero errors.

B. Only screenshots from successful locks, labeled as representative of all attempts.

C. Native samples where retained, timestamps, attempted settings, state evidence and explicit failure outcomes under the declared retention policy.

D. Only the decoder's nominal modulation list without the attempted settings.

Answer: C. The acquisition population includes attempted and excluded intervals. Reproducible records distinguish a valid negative observation, an unobserved interval and a processing failure. Review: Carrier and Timing Synchronization; record and acceptance discussion. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why the selected alternative fits: Native samples where retained, timestamps, attempted settings, state evidence and explicit failure outcomes under the declared retention policy.

Distinguishing consideration: compare this with option A, "Only the final accepted constellation with failed intervals replaced by zero errors"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Carrier and Timing Synchronization; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-MCQ-096. What does preserving a processing script's file hash establish directly?

A. That the file was necessarily executed on every reported record.

B. The identity of that retained file, with execution, configuration and metrological validity requiring additional evidence.

C. That every physical reference used by the receiver is traceable to an appropriate standard.

D. That the script implements the correct reference mapping for every signal format.

Answer: B. A file identity check supports provenance. It does not prove execution or correctness, and it is distinct from the evidence supporting a measurement result and its reference chain. Review: Turn a quality metric into a reproducible acceptance record; Chapter 1 traceability boundary. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

Why the selected alternative fits: The identity of that retained file, with execution, configuration and metrological validity requiring additional evidence.

Distinguishing consideration: compare this with option A, "That the file was necessarily executed on every reported record"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Turn a quality metric into a reproducible acceptance record; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 7 — Turn a quality metric into a reproducible acceptance record; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C07-MCQ-097. Which retained material is most useful for reproducing the chapter's finite-record EVM result?

A. The paired complex observations and references, selected indices and weights, fitted parameters, processing versions and both energy sums.

B. Only the final percentage and the modulation name.

C. Only the receiver's nominal maximum sample rate.

D. Only a constellation screenshot after automatic scaling.

Answer: A. These records expose the numerator, denominator and transformations that produced the metric. A scalar or image alone generally cannot reconstruct the selected finite experiment. Review: Equations 13A–13J; reproducible acceptance record. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: The paired complex observations and references, selected indices and weights, fitted parameters, processing versions and both energy sums.

Distinguishing consideration: compare this with option B, "Only the final percentage and the modulation name"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Turn a quality metric into a reproducible acceptance record; Chapter 7 — Equation 13A. Finite reference energy and admissible weights;....

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Turn a quality metric into a reproducible acceptance record; Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-MCQ-098. A monitoring task authorizes spectral characterization but does not establish permission for content recovery. What should the analyst establish before expanding processing?

A. The actual authorized scope for the proposed acquisition, recovery, retention and reporting operations.

B. That a low EVM itself grants permission to recover content.

C. That successfully decoded bits can always be retained because they were technically accessible.

D. That a modulation label alone resolves every acquisition and retention boundary.

Answer: A. Technical capability and task authority are separate conditions. The chapter requires an explicit boundary for the operation being proposed rather than inferring permission from successful processing. Review: Defensive Interpretation of Digital Signals; Chapter 1 mission scope. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

Why the selected alternative fits: The actual authorized scope for the proposed acquisition, recovery, retention and reporting operations.

Distinguishing consideration: compare this with option B, “That a low EVM itself grants permission to recover content”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Defensive Interpretation of Digital Signals; Chapter 1 — Mission Authority and Collection Boundaries.

Review: Chapter 7 — Defensive Interpretation of Digital Signals; Chapter 1 — Mission Authority and Collection Boundaries.

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V011-C07-MCQ-099. Why can an RF spectral-emission result and a decoded-content result require different validation records?

A. Because a common input cable forces both results to have identical uncertainty and authority requirements.

B. Because a spectral measurement is always independent of receiver configuration.

C. They concern different quantities and propositions, with different receiver operations and success conditions.

D. Because decoded content automatically validates all earlier amplitude and bandwidth measurements.

Answer: C. Shared hardware does not make the measurement questions identical. Each result needs its own processing boundary, relevant reference, validity evidence and claim limits. Review: Defensive Interpretation of Digital Signals; receiver-system boundary. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

Why the selected alternative fits: They concern different quantities and propositions, with different receiver operations and success conditions.

Distinguishing consideration: compare this with option A, “Because a common input cable forces both results to have identical uncertainty and authority requirements”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Defensive Interpretation of Digital Signals.

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V011-C07-MCQ-100. A vendor demodulator's documented normalization differs from the chapter's explicitly defined finite-record convention. What is the correct comparison policy?

A. Treat matching percentage units as sufficient proof that the thresholds are interchangeable.

B. Preserve both definitions, compute any justified conversion explicitly and validate applicability to the actual format and selected population.

C. Assume the chapter formula silently replaces every documented vendor convention.

D. Assume every format uses the same constellation-maximum denominator.

Answer: B. The chapter's model is a declared mathematical experiment. Actual implementations can use format-dependent reference and sample conventions, so comparison requires a stated relation rather than an assumed universal EVM label.
Review: Model 7A normalization scope; Keysight EVM and EVM Normalization Reference help. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
Why the selected alternative fits: Preserve both definitions, compute any justified conversion explicitly and validate applicability to the actual format and selected population.
Distinguishing consideration: compare this with option A, "Treat matching percentage units as sufficient proof that the thresholds are interchangeable"; that competing statement does not meet the question's stated requirement.
Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Model 7A: a finite, declared EVM comparison.
Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Model 7A: a finite, declared EVM comparison.

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Fill-in-the-Blank Questions

V011-C07-FIB-001. Before subtracting observed and reference complex symbols, their amplitude conventions must be _____.

Answer: compatible. The difference is meaningful only after the values share a justified amplitude scale and unit convention. A normalized output does not repair an incompatible subtraction. Review: Model 7A experiment definition. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why this term is required: “compatible” completes the stated technical proposition.

Question context: Before subtracting observed and reference complex symbols, their amplitude conventions must be _____

Basis and qualification: Chapter 7 — Model 7A: a finite, declared EVM comparison.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison.

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V011-C07-FIB-002. The weighted EVM formula requires each fixed weight to be _____.

Answer: nonnegative. A negative weight would permit cancellation of positive squared distances and would define a different expression from the declared energy ratio. Review: Equations 13A–13B. Source: Equation 13A. Finite reference energy and admissible weights (p. 3746)

Why this term is required: “nonnegative” completes the stated technical proposition.

Question context: The weighted EVM formula requires each fixed weight to be _____

Basis and qualification: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-003. The reference-energy denominator must be strictly _____ for a normalized EVM to exist.

Answer: positive. A nonempty set and a positive weight sum are insufficient if every weighted reference is zero. Zero divided by zero is not a defined zero EVM. Review: Equations 13A–13B. Source: Equation 13A. Finite reference energy and admissible weights (p. 3746)

Why this term is required: “positive” completes the stated technical proposition.

Question context: The reference-energy denominator must be strictly _____ for a normalized EVM to exist

Basis and qualification: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-004. EVM is an amplitude-like ratio obtained by taking the _____ of the residual-to-reference energy ratio.

Answer: square root. The numerator and denominator are sums of squared complex magnitudes. Omitting the square root would report squared EVM rather than EVM. Review: Equation 13B. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “square root” completes the stated technical proposition.

Question context: EVM is an amplitude-like ratio obtained by taking the _____ of the residual-to-reference energy ratio

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-005. For a complex residual with real component 0.03 and imaginary component 0.04, the squared magnitude is _____.

Answer: 0.0025. Square both components and add: 0.0009 plus 0.0016 is 0.0025. The residual magnitude is 0.05 in the shared amplitude unit. Review: Equation 13B complex magnitude. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “0.0025” completes the stated technical proposition.

Question context: For a complex residual with real component 0.03 and imaginary component 0.04, the squared magnitude is _____

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-006. A fixed reference is selected independently of the measured record's fitted corrections; a fitted reference must disclose its estimated _____ as well as the resulting metric.

Answer: parameters. Gain, phase, timing or equalizer estimates change the comparison. Retaining them exposes which discrepancies were removed and permits the declared calculation to be reproduced. Review: Model 7A; Equations 13D–13F. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why this term is required: "parameters" completes the stated technical proposition.

Question context: A fixed reference is selected independently of the measured record's fitted corrections; a fitted reference must disclose its estimated _____ as well as the resulting metric

Basis and qualification: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 —....

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-FIB-007. The selected symbol indices, zero weights and excluded intervals define the metric's observation _____.

Answer: population. A result applies to the included finite population. Exclusion can be justified, but it must not silently turn a conditional result into a whole-record claim. Review: Equation 13J; Application 7A.6. Source: Equation 13J. Residual sums for a disclosed selection (p. 3750)

Why this term is required: "population" completes the stated technical proposition.

Question context: The selected symbol indices, zero weights and excluded intervals define the metric's observation _____

Basis and qualification: Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Application 7A.6: Make selection and weighting visible.

Review: Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Application 7A.6: Make selection and weighting visible.

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V011-C07-FIB-008. An error vector is the complex observed value minus its paired _____ value.

Answer: reference. Pairing includes symbol identity and decision instant under the declared synchronization and mapping. Equal-looking point sets without correspondence do not define the same residuals. Review: Equations 13A–13B.

Source: Equation 13A. Finite reference energy and admissible weights (p. 3746)

Why this term is required: “reference” completes the stated technical proposition.

Question context: An error vector is the complex observed value minus its paired _____ value

Basis and qualification: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-009. The numerator and denominator energy sums have the same squared-amplitude units, so their ratio is _____.

Answer: dimensionless. The unit cancellation is valid after compatible inputs and reference conventions have been established. It does not make absolute calibration or the reference plane irrelevant. Review: Equation 13B. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “dimensionless” completes the stated technical proposition.

Question context: The numerator and denominator energy sums have the same squared-amplitude units, so their ratio is _____

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-010. If the selected residual energy is zero and reference energy is positive, linear EVM is _____.

Answer: zero. Every positive-weight residual then has zero magnitude. This conclusion is restricted to the included comparison and permitted corrections.
Review: Equations 13A–13C. Source: Equation 13A. Finite reference energy and admissible weights (p. 3746)
Why this term is required: “zero” completes the stated technical proposition.
Question context: If the selected residual energy is zero and reference energy is positive, linear EVM is _____
Basis and qualification: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13C. Percent and decibel reporting.
Review: Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-FIB-011. A linear EVM of 0.08 is _____ percent.

Answer: 8. Percentage EVM is one hundred times the linear ratio. The numeral 8 must be divided by one hundred before applying the linear-ratio logarithm. Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why this term is required: “8” completes the stated technical proposition.

Question context: A linear EVM of 0.08 is _____ percent

Basis and qualification: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-FIB-012. Using $20\log_{10}$ of a positive linear EVM, 0.08 corresponds to approximately _____ dB.

Answer: -21.9382. The logarithm of 0.08 multiplied by twenty gives approximately $-21.9382\ \text{dB}$. Ten times the logarithm of 0.08 squared gives the same result.

Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why this term is required: "The logarithm of 0" completes the stated technical proposition.

Question context: Using of a positive linear EVM, 0.08 corresponds to approximately _____ dB

Basis and qualification: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-FIB-013. An EVM of $-40\ \mathrm{dB}$ under the chapter convention is _____ percent.

Answer: 1. The linear ratio is ten raised to $\frac{-40}{20}$, or 0.01. Multiplication by one hundred gives 1 percent. Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why this term is required: “1” completes the stated technical proposition.

Question context: An EVM of under the chapter convention is _____ percent

Basis and qualification: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-FIB-014. If squared residuals sum to 2 and squared references sum to 200, the RMS EVM is _____ percent.

Answer: 10. The energy ratio is 0.01, its square root is 0.1 and the percentage is 10. This is a finite-record arithmetic result. Review: Equation 13B. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “10” completes the stated technical proposition.

Question context: If squared residuals sum to 2 and squared references sum to 200, the RMS EVM is _____ percent

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-015. If EVM doubles while the normalization convention stays fixed, its decibel value increases by approximately _____ dB.

Answer: 6.0206. Twenty times $\log_{10}$ of two is approximately 6.0206. The squared energy ratio increases fourfold. Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why this term is required: “6.0206” completes the stated technical proposition.

Question context: If EVM doubles while the normalization convention stays fixed, its decibel value increases by approximately _____ dB

Basis and qualification: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-FIB-016. A finite lower display limit substituted for the logarithm of zero is a declared display _____, not the exact logarithm.

Answer: floor. Zero linear EVM has a negative-infinity decibel limit. A finite floor may be useful operationally but must not be presented as the mathematical value.

Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why this term is required: “floor” completes the stated technical proposition.

Question context: A finite lower display limit substituted for the logarithm of zero is a declared display _____, not the exact logarithm

Basis and qualification: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-FIB-017. For EVM 0.2, the residual-energy sum is _____ times the reference-energy sum.

Answer: 0.04. Square the amplitude-like EVM to recover the energy ratio. This relation assumes the same selected weights and normalization. Review: Equation 13B. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)
Why this term is required: “0.04” completes the stated technical proposition.
Question context: For EVM 0.2, the residual-energy sum is _____ times the reference-energy sum
Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.
Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-018. A fourfold increase in residual energy with unchanged positive reference energy multiplies EVM by _____.

Answer: 2. EVM scales as the square root of its numerator energy. The result is not a fourfold EVM increase. Review: Equation 13B. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “2” completes the stated technical proposition.

Question context: A fourfold increase in residual energy with unchanged positive reference energy multiplies EVM by _____

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-019. If reference energy alone increases ninefold, EVM becomes _____ of its original value.

Answer: one third. The denominator change divides squared EVM by nine. Its square root divides EVM by three, even though the residual itself has not improved.
Review: Equations 13B and 13G. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)
Why this term is required: “one third” completes the stated technical proposition.
Question context: If reference energy alone increases ninefold, EVM becomes _____ of its original value
Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.
Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-FIB-020. An 8 percent EVM must enter the decibel expression as the linear ratio _____.

Answer: 0.08. Taking the logarithm of the percentage numeral 8 would introduce a 40 dB offset relative to taking the logarithm of 0.08. Review: Equation 13C. Source: Equation 13C. Percent and decibel reporting (p. 3746)

Why this term is required: “0.08” completes the stated technical proposition.

Question context: An 8 percent EVM must enter the decibel expression as the linear ratio _____

Basis and qualification: Chapter 7 — Equation 13C. Percent and decibel reporting.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-FIB-021. In the complex-gain fit, the reference factor in the weighted correlation is complex _____.

Answer: conjugated. The correlation is the weighted sum of observation times conjugated ideal reference. Conjugating the other factor instead generally reverses the fitted phase. Review: Equation 13D. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why this term is required: “conjugated” completes the stated technical proposition.

Question context: In the complex-gain fit, the reference factor in the weighted correlation is complex _____

Basis and qualification: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

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V011-C07-FIB-022. A training correlation of $4 - j3$ and reference energy of 5 give fitted gain _____.

Answer: $0.8 - j0.6$. Divide the complex numerator by the real positive denominator. The coefficient has unit magnitude but a nonzero phase. Review: Equation 13D. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why this term is required: "Divide the complex numerator by the real positive denominator" completes the stated technical proposition.

Question context: A training correlation of and reference energy of 5 give fitted gain _____

Basis and qualification: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

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V011-C07-FIB-023. A training correlation of $2+j2$ and reference energy of 8 give fitted gain _____.

Answer: $0.25+j0.25$. The real and imaginary correlation components are each divided by eight. Replacing that coefficient by its magnitude would define a different correction. Review: Equation 13D. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why this term is required: "The real and imaginary correlation components are each divided by eight" completes the stated technical proposition.

Question context: A training correlation of and reference energy of 8 give fitted gain _____

Basis and qualification: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set.

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V011-C07-FIB-024. With observation energy 10, correlation magnitude squared 25 and reference energy 5, the minimized training residual energy is _____.

Answer: 5. Completion of the square gives the minimum as 10 minus $\frac{25}{5}$, which equals 5 in the squared-amplitude convention of the input sums. Review: Equation 13E. Source: Equation 13E. Least-squares completion of the square (p. 3747)

Why this term is required: “5” completes the stated technical proposition.

Question context: With observation energy 10, correlation magnitude squared 25 and reference energy 5, the minimized training residual energy is _____

Basis and qualification: Chapter 7 — Equation 13E. Least-squares completion of the square.

Review: Chapter 7 — Equation 13E. Least-squares completion of the square.

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V011-C07-FIB-025. If training reference energy is 5 and a trial gain differs from the minimizer by magnitude 0.2, its excess residual energy is _____.

Answer: 0.2. The completed-square penalty is reference energy times squared gain displacement: 5 times 0.04 equals 0.2. Review: Equation 13E. Source: Equation 13E. Least-squares completion of the square (p. 3747)

Why this term is required: “0.2” completes the stated technical proposition.

Question context: If training reference energy is 5 and a trial gain differs from the minimizer by magnitude 0.2, its excess residual energy is _____

Basis and qualification: Chapter 7 — Equation 13E. Least-squares completion of the square.

Review: Chapter 7 — Equation 13E. Least-squares completion of the square.

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V011-C07-FIB-026. A positive-energy training reference with zero weighted observation-reference correlation has fitted gain _____.

Answer: zero. The gain estimate is defined, but using that zero gain to form an EVM normalization reference would create a zero denominator. Review: Equations 13D and 13F. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)
Why this term is required: “zero” completes the stated technical proposition.
Question context: A positive-energy training reference with zero weighted observation-reference correlation has fitted gain _____
Basis and qualification: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.
Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-FIB-027. Evaluation indices excluded from the parameter-estimation set are described as _____ data.

Answer: held-out. The exclusion limits reuse of the evaluated observations for fitting. It does not by itself establish physical or statistical independence. Review: Equation 13F. Source: Equation 13F. Held-out evaluation with a nonzero fitted reference (p. 3748)

Why this term is required: “held-out” completes the stated technical proposition.

Question context: Evaluation indices excluded from the parameter-estimation set are described as _____ data

Basis and qualification: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-FIB-028. For a fitted-reference EVM, positive ideal-reference energy is insufficient if the fitted gain is _____.

Answer: zero. The denominator also includes the squared magnitude of the fitted coefficient. Its vanishing makes the fitted-reference metric undefined. Review: Equation 13F. Source: Equation 13F. Held-out evaluation with a nonzero fitted reference (p. 3748)

Why this term is required: “zero” completes the stated technical proposition.

Question context: For a fitted-reference EVM, positive ideal-reference energy is insufficient if the fitted gain is _____

Basis and qualification: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-FIB-029. Completion of the square establishes a unique complex-gain minimizer when the training reference energy is strictly _____.

Answer: positive. That positive coefficient multiplies the squared distance from the minimizing gain. A zero reference-energy case lacks this uniqueness argument and lies outside the stated fit. Review: Equation 13E. Source: Equation 13E. Least-squares completion of the square (p. 3747)

Why this term is required: “positive” completes the stated technical proposition.

Question context: Completion of the square establishes a unique complex-gain minimizer when the training reference energy is strictly _____

Basis and qualification: Chapter 7 — Equation 13E. Least-squares completion of the square.

Review: Chapter 7 — Equation 13E. Least-squares completion of the square.

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V011-C07-FIB-030. A fit minimizes the declared training residual _____, not every later normalized error ratio.

Answer: energy. A denominator depending on the fitted gain can change even while the numerator decreases. Held-out records also have a different objective from the fitted training record. Review: Equations 13E–13F; Application 7A.8. Source: Equation 13E. Least-squares completion of the square (p. 3747)

Why this term is required: “energy” completes the stated technical proposition.

Question context: A fit minimizes the declared training residual _____, not every later normalized error ratio

Basis and qualification: Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in….

Review: Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-FIB-031. A real gain of 1.12 applied to every reference without a permitted gain fit produces _____ percent fixed-reference EVM.

Answer: 12. The residual is 0.12 times each reference, so the normalized RMS magnitude is 0.12. Review: Equation 13H. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)

Why this term is required: “12” completes the stated technical proposition.

Question context: A real gain of 1.12 applied to every reference without a permitted gain fit produces _____ percent fixed-reference EVM

Basis and qualification: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

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V011-C07-FIB-032. A real gain of 0.88 produces the same fixed-reference EVM as gain 1.12 because EVM retains the _____ of the gain departure.

Answer: magnitude. Both departures from one have magnitude 0.12. The scalar result alone does not preserve whether the amplitude is high or low. Review: Equation 13H. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)

Why this term is required: “magnitude” completes the stated technical proposition.

Question context: A real gain of 0.88 produces the same fixed-reference EVM as gain 1.12 because EVM retains the _____ of the gain departure

Basis and qualification: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

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V011-C07-FIB-033. A constant phase rotation of 60 degrees gives exactly _____ percent fixed-reference EVM.

Answer: 100. The chord is twice sin of 30 degrees, which is one. Percentage conversion gives 100, despite unchanged individual reference magnitudes. Review: Equation 13H. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)
Why this term is required: “100” completes the stated technical proposition.
Question context: A constant phase rotation of 60 degrees gives exactly _____ percent fixed-reference EVM
Basis and qualification: Chapter 7 — Equation 13H. Fixed gain and phase impairments.
Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

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V011-C07-FIB-034. A constant phase reversal of 180 degrees gives a linear fixed-reference EVM of _____.

Answer: 2. Each observation is the negative of its reference, making the residual negative twice the reference. EVM need not be bounded by one. Review: Equation 13H. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)

Why this term is required: “2” completes the stated technical proposition.

Question context: A constant phase reversal of 180 degrees gives a linear fixed-reference EVM of _____

Basis and qualification: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments.

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V011-C07-FIB-035. The small-angle approximation to phase-only EVM uses the phase error in _____.

Answer: radians. The local sine approximation requires a radian argument. Degrees and cycles need explicit conversion. Review: Equation 13H; Application 7A.2. Source: Equation 13H. Fixed gain and phase impairments (p. 3749)

Why this term is required: “radians” completes the stated technical proposition.

Question context: The small-angle approximation to phase-only EVM uses the phase error in _____

Basis and qualification: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.2: Quantify a fixed phase error.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.2: Quantify a fixed phase error.

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V011-C07-FIB-036. A common offset of $0.06 + j\,0.08$ on balanced unit-energy references gives _____ percent fixed-reference EVM.

Answer: 10. The offset magnitude is 0.10, obtained from the square root of 0.06 squared plus 0.08 squared. Unit reference RMS gives EVM 0.10. Review: Equation 13I. Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why this term is required: “10” completes the stated technical proposition.

Question context: A common offset of on balanced unit-energy references gives _____ percent fixed-reference EVM

Basis and qualification: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms.

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V011-C07-FIB-037. For a common offset, a zero weighted reference _____ prevents that offset from changing the gain-fit correlation.

Answer: sum. The offset contribution is the offset multiplied by the conjugate of that sum. The offset residual can remain even when its contribution to the gain estimate vanishes. Review: Equation 13I; Application 7A.3. Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why this term is required: “sum” completes the stated technical proposition.

Question context: For a common offset, a zero weighted reference _____ prevents that offset from changing the gain-fit correlation

Basis and qualification: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

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V011-C07-FIB-038. A conjugate-leakage coefficient of $j0.08$ gives _____ percent fixed-reference EVM under the chapter's ideal-plus-conjugate model.

Answer: 8. Conjugation preserves reference magnitude, so the residual-to-reference magnitude ratio is the coefficient magnitude, 0.08. Review: Equation 13I.

Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why this term is required: "8" completes the stated technical proposition.

Question context: A conjugate-leakage coefficient of gives _____ percent fixed-reference EVM under the chapter's ideal-plus-conjugate model

Basis and qualification: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms.

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V011-C07-FIB-039. To keep the ordinary gain fit at one in the balanced conjugate-leakage example, the weighted sum of complex reference _____ must vanish.

Answer: squares. This is the sum of the references squared as complex numbers, not the sum of their squared magnitudes. The latter remains positive in a valid reference experiment. Review: Equation 13I; Application 7A.4. Source: Equation 13I. Balanced-reference offset and conjugate terms (p. 3749)

Why this term is required: “squares” completes the stated technical proposition.

Question context: To keep the ordinary gain fit at one in the balanced conjugate-leakage example, the weighted sum of complex reference _____ must vanish

Basis and qualification: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

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V011-C07-FIB-040. Removing a fitted mean adds an offset-correction _____ to the originally gain-only comparison.

Answer: parameter. The extra correction can remove a common offset but changes what the residual measures. Its training and permitted use must be stated. Review: Application 7A.3. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

Why this term is required: “parameter” completes the stated technical proposition.

Question context: Removing a fitted mean adds an offset-correction _____ to the originally gain-only comparison

Basis and qualification: Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

Review: Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain.

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V011-C07-FIB-041. For all sixteen square-16QAM points with coordinates ±1 and ±3 represented equally, each coordinate's average squared value is _____.

Answer: 5. The four possible coordinate squares are 1, 1, 9 and 9; their mean is 5. Summing two coordinates gives average symbol energy 10. Review: Application 7A.5. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

Why this term is required: "5" completes the stated technical proposition.

Question context: For all sixteen square-16QAM points with coordinates ±1 and ±3 represented equally, each coordinate's average squared value is _____

Basis and qualification: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

Review: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-FIB-042. For that square-16QAM alphabet, the maximum symbol energy is _____.

Answer: 18. Each outer corner has two coordinates of magnitude three, giving 9 plus 9. The constellation maximum is distinct from its average energy 10. Review: Application 7A.5. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

Why this term is required: “18” completes the stated technical proposition.

Question context: For that square-16QAM alphabet, the maximum symbol energy is _____

Basis and qualification: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

Review: Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-FIB-043. A selected record using only the four inner square-16QAM points has reference energy _____ per symbol.

Answer: 2. Each inner point has coordinates of magnitude one, so each symbol has energy 1 plus 1. The full-alphabet average energy 10 does not apply to this selected record. Review: Equation 13G finite-population normalization. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why this term is required: “2” completes the stated technical proposition.

Question context: A selected record using only the four inner square-16QAM points has reference energy _____ per symbol

Basis and qualification: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-FIB-044. For those inner points, a fixed residual magnitude 0.1 gives reference-RMS EVM of approximately _____ percent.

Answer: 7.071068. The residual energy per symbol is 0.01 and the reference energy per symbol is 2. The square root of $\frac{0.01}{2}$ times one hundred gives the stated value.

Review: Equation 13G. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why this term is required: “7.071068” completes the stated technical proposition.

Question context: For those inner points, a fixed residual magnitude 0.1 gives reference-RMS EVM of approximately _____ percent

Basis and qualification: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-FIB-045. The same inner-point residual normalized to the 16QAM maximum magnitude gives approximately _____ percent EVM.

Answer: 2.357023. Use maximum reference energy 18 in the denominator: one hundred times the square root of $\frac{0.01}{18}$ is approximately 2.357023. The residual is unchanged. Review: Equation 13G. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why this term is required: “2.357023” completes the stated technical proposition.

Question context: The same inner-point residual normalized to the 16QAM maximum magnitude gives approximately _____ percent EVM

Basis and qualification: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-FIB-046. For the inner-point record, reference-RMS EVM is _____ times its constellation-maximum EVM.

Answer: 3. The maximum normalization magnitude is the square root of 18, while the realized RMS magnitude is the square root of 2. Their ratio is three. Review: Equation 13G. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why this term is required: “3” completes the stated technical proposition.

Question context: For the inner-point record, reference-RMS EVM is _____ times its constellation-maximum EVM

Basis and qualification: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-FIB-047. A threshold and a measured EVM can share percent units while having different normalization _____.

Answer: references. Matching unit labels do not establish a common denominator, selected population or correction policy. An explicit conversion is needed before comparing thresholds. Review: Equation 13G; implementation comparison. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why this term is required: “references” completes the stated technical proposition.

Question context: A threshold and a measured EVM can share percent units while having different normalization _____

Basis and qualification: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-FIB-048. If the same nonzero complex factor scales both observations and references, the residual-energy and reference-energy sums receive the same positive _____.

Answer: scale factor. The factor is the squared magnitude of the common complex multiplier. It cancels from EVM, which is why common absolute errors can remain hidden. Review: Equation 13B invariance. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “scale factor” completes the stated technical proposition.

Question context: If the same nonzero complex factor scales both observations and references, the residual-energy and reference-energy sums receive the same positive _____

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-049. A common permutation preserves EVM only when observations, references and weights keep their original _____.

Answer: pairing. A finite sum is unchanged by rearranging paired terms. Permuting only one vector can create different residuals and a different experiment. Review: Equation 13B. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “pairing” completes the stated technical proposition.

Question context: A common permutation preserves EVM only when observations, references and weights keep their original _____

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-050. A constellation-maximum denominator is based on the declared alphabet convention, while a reference-RMS denominator depends on the selected reference _____.

Answer: population. The realized symbol occurrence counts and weights can change its RMS value. A full uniform constellation average is not universal for short or biased records. Review: Equation 13G. Source: Equation 13G. Average-reference and maximum-reference normalization (p. 3749)

Why this term is required: “population” completes the stated technical proposition.

Question context: A constellation-maximum denominator is based on the declared alphabet convention, while a reference-RMS denominator depends on the selected reference _____

Basis and qualification: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

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V011-C07-FIB-051. Four unit-energy references have only one nonzero residual, of magnitude 0.2. Their RMS EVM is _____ percent.

Answer: 10. Residual energy is 0.04 and reference energy is 4. The square root of 0.01 gives 10 percent, while the peak individually normalized residual is 20 percent. Review: Equation 13B; peak versus RMS interpretation. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “10” completes the stated technical proposition.

Question context: Four unit-energy references have only one nonzero residual, of magnitude 0.2. Their RMS EVM is _____ percent

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-052. For that one-error, four-symbol record, peak individually normalized error is _____ times RMS EVM.

Answer: 2. The peak is 0.2 and the RMS value is 0.1. A largest-error metric retains information that one overall RMS value does not. Review: Application 7A.10 principle. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
Why this term is required: “2” completes the stated technical proposition.
Question context: For that one-error, four-symbol record, peak individually normalized error is _____ times RMS EVM
Basis and qualification: Chapter 7 — Application 7A.10: Audit a complete finite residual vector.
Review: Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

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V011-C07-FIB-053. Two unit references have residual magnitudes 0.1 and 0.2 with weights 1 and 3. The weighted residual-energy sum is _____.

Answer: 0.13. The sum is 1 times 0.01 plus 3 times 0.04. The weighted reference-energy sum is four. Review: Equation 13J. Source: Equation 13J. Residual sums for a disclosed selection (p. 3750)

Why this term is required: “0.13” completes the stated technical proposition.

Question context: Two unit references have residual magnitudes 0.1 and 0.2 with weights 1 and 3. The weighted residual-energy sum is _____

Basis and qualification: Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

Review: Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-FIB-054. For those two weighted residuals, RMS EVM is approximately _____ percent.

Answer: 18.027756. The square root of $\frac{0.13}{4}$ is approximately 0.18027756. Weights act on squared magnitudes before the square root. Review: Equation 13J. Source: Equation 13J. Residual sums for a disclosed selection (p. 3750)

Why this term is required: “18.027756” completes the stated technical proposition.

Question context: For those two weighted residuals, RMS EVM is approximately _____ percent

Basis and qualification: Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

Review: Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-FIB-055. Two compatible blocks have reference energies 100 and 900 and linear EVM values 0.1 and 0.2. Their combined residual energy is _____.

Answer: 37. The first residual energy is 100 times 0.1 squared, or 1. The second is 900 times 0.2 squared, or 36. Add these energies to obtain 37. Review: Equation 13B block combination. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “37” completes the stated technical proposition.

Question context: Two compatible blocks have reference energies 100 and 900 and linear EVM values 0.1 and 0.2. Their combined residual energy is _____

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-056. Those two blocks have combined reference energy 1,000, so their union EVM is approximately _____ percent.

Answer: 19.235384. Take the square root of $\frac{37}{1000}$ and multiply by one hundred. An unweighted average of 10 and 20 percent would incorrectly ignore the unequal reference energies. Review: Equation 13B block combination. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “19.235384” completes the stated technical proposition.

Question context: Those two blocks have combined reference energy 1,000, so their union EVM is approximately _____ percent

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-057. Copies of the same finite record do not by themselves increase the number of _____ observations.

Answer: independent. Duplicating stored samples repeats their information and scales both EVM sums together. Statistical independence needs a justified observation model. Review: Equation 13B; validation scope. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)

Why this term is required: “independent” completes the stated technical proposition.

Question context: Copies of the same finite record do not by themselves increase the number of _____ observations

Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-058. An EVM reported only after lock is a metric _____ on successful acquisition.

Answer: conditional. The included population has been selected by the lock outcome. Whole-experiment reporting also needs attempted acquisitions, failures and exclusions. Review: Carrier and Timing Synchronization; Application 7A.6.

Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

Why this term is required: “conditional” completes the stated technical proposition.

Question context: An EVM reported only after lock is a metric _____ on successful acquisition

Basis and qualification: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Carrier and Timing Synchronization.

Review: Chapter 7 — Application 7A.6: Make selection and weighting visible; Chapter 7 — Carrier and Timing Synchronization.

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V011-C07-FIB-059. Equal RMS EVM values do not establish equal residual phase, timing structure or physical _____.

Answer: cause. The scalar squared-distance aggregate can arise from different impairments. Retained vectors and controlled challenges are needed to test candidate mechanisms. Review: Error Vector Magnitude and Quality Metrics. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

Why this term is required: “cause” completes the stated technical proposition.

Question context: Equal RMS EVM values do not establish equal residual phase, timing structure or physical _____

Basis and qualification: Chapter 7 — Error Vector Magnitude and Quality Metrics.

Review: Chapter 7 — Error Vector Magnitude and Quality Metrics.

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V011-C07-FIB-060. A scalar EVM discards the original temporal _____ unless the associated record is retained separately.

Answer: ordering. The same paired terms can be permuted without changing their sums. The order remains necessary to evaluate drift, bursts and acquisition history.
Review: Equation 13B; residual history. Source: Equation 13B. Weighted fixed-reference error vector magnitude (p. 3746)
Why this term is required: “ordering” completes the stated technical proposition.
Question context: A scalar EVM discards the original temporal _____ unless the associated record is retained separately
Basis and qualification: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.
Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude.

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V011-C07-FIB-061. A residual offset of 50 Hz at 2,000 symbols per second advances phase by _____ degrees per symbol.

Answer: 9. The offset contributes $\frac{50}{2000} = 0.025$ cycles in each symbol interval.

Multiplying by 360 degrees gives 9 degrees. Review: Application 7A.8 frequency-offset construction. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

Why this term is required: “9” completes the stated technical proposition.

Question context: A residual offset of 50 Hz at 2,000 symbols per second advances phase by _____ degrees per symbol

Basis and qualification: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

Review: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-FIB-062. For that phase increment, symbols indexed -2 through 2 with zero phase at index zero reach a largest absolute phase of _____ degrees.

Answer: 18. The two endpoint indices are two symbol intervals from the center. Their phases are minus and plus eighteen degrees. Review: Application 7A.8 finite symmetric interval. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

Why this term is required: “18” completes the stated technical proposition.

Question context: For that phase increment, symbols indexed through 2 with zero phase at index zero reach a largest absolute phase of _____ degrees

Basis and qualification: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

Review: Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-FIB-063. Five equally weighted ideal pilot references all equal 1. Their unit-magnitude observations have phases -18, -9, 0, 9 and 18 degrees. The imaginary part of their fitted constant gain is _____.

Answer: zero. Opposite-phase sine terms cancel in the equal-weight mean. This real fitted coefficient does not imply that the frequency offset is zero. Review: Equation 13D; Application 7A.8. Source: Equation 13D. Optional complex-gain fit on a training set (p. 3747)

Why this term is required: “zero” completes the stated technical proposition.

Question context: Five equally weighted ideal pilot references all equal 1. Their unit-magnitude observations have phases 0, 9 and 18 degrees. The imaginary part of their fitted constant gain is _____

Basis and qualification: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-FIB-064. A symbol-clock mismatch can make errors grow away from the selected alignment point because timing offset _____ with elapsed time.

Answer: accumulates. A rate error changes the relative timing progressively. One fixed timing shift cannot remove an accumulating mismatch over an arbitrarily long interval. Review: Carrier and Timing Synchronization; symbol-rate configuration.

Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why this term is required: “accumulates” completes the stated technical proposition.

Question context: A symbol-clock mismatch can make errors grow away from the selected alignment point because timing offset _____ with elapsed time

Basis and qualification: Chapter 7 — Carrier and Timing Synchronization.

Review: Chapter 7 — Carrier and Timing Synchronization.

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V011-C07-FIB-065. The loop parameter that controls the tracking-versus-noise-admission tradeoff is its _____.

Answer: bandwidth. The consequence depends on the actual loop and signal conditions. Selecting a wider value merely to lower one fitted metric does not establish validity. Review: Carrier and Timing Synchronization. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why this term is required: “bandwidth” completes the stated technical proposition.

Question context: The loop parameter that controls the tracking-versus-noise-admission tradeoff is its _____

Basis and qualification: Chapter 7 — Carrier and Timing Synchronization.

Review: Chapter 7 — Carrier and Timing Synchronization.

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V011-C07-FIB-066. A quarter-turn ambiguity in a QPSK constellation can preserve its point set while changing its bit-label _____.

Answer: mapping. Geometric coincidence after rotation is distinct from correspondence to the intended labels. Known references or other justified structure are needed to resolve the ambiguity. Review: Application 7A.9. Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)

Why this term is required: “mapping” completes the stated technical proposition.

Question context: A quarter-turn ambiguity in a QPSK constellation can preserve its point set while changing its bit-label _____

Basis and qualification: Chapter 7 — Application 7A.9: Separate constellation rotation from validated symbol mapping.

Review: Chapter 7 — Application 7A.9: Separate constellation rotation from validated symbol mapping.

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V011-C07-FIB-067. An equalizer's large training improvement does not uniquely identify the physical _____ of the removed distortion.

Answer: origin. The fitted response can absorb transmitter, channel, receiver or reconstruction effects. Separate known-signal and bypass evidence is needed for path attribution. Review: Matched Filtering, Pulse Shaping, and Channel Effects.

Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

Why this term is required: "origin" completes the stated technical proposition.

Question context: An equalizer's large training improvement does not uniquely identify the physical _____ of the removed distortion

Basis and qualification: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-FIB-068. Plausible symbol structure recovered from a noise-only control demonstrates a possible _____ mechanism under that processing.

Answer: false-lock. The control shows that the tested process can generate apparently structured output without the intended signal. It does not establish that every original candidate had that origin. Review: Hypothetical Case Adjudication.

Source: §7.24 Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics (p. 3794)

Why this term is required: “false-lock” completes the stated technical proposition.

Question context: Plausible symbol structure recovered from a noise-only control demonstrates a possible _____ mechanism under that processing

Basis and qualification: Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

Review: Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

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V011-C07-FIB-069. Finite-filter disagreements near a record edge can arise from different assumed initial _____.

Answer: conditions. Filter memory must be supplied, initialized or excluded by a declared rule. A shared filter-family name does not guarantee identical boundary output. Review: Matched Filtering, Pulse Shaping, and Channel Effects. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

Why this term is required: “conditions” completes the stated technical proposition.

Question context: Finite-filter disagreements near a record edge can arise from different assumed initial _____

Basis and qualification: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-FIB-070. To compare corresponding symbol decision instants after filtering, the processing must account for the relevant filter _____.

Answer: delay. The delay convention connects reference and observation times. Equal energy or identical modulation labels cannot substitute for this alignment.

Review: Matched Filtering, Pulse Shaping, and Channel Effects. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

Why this term is required: “delay” completes the stated technical proposition.

Question context: To compare corresponding symbol decision instants after filtering, the processing must account for the relevant filter _____

Basis and qualification: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-FIB-071. A known 64QAM labeling places six coded bits in each data symbol. Exactly 1,000 data symbols therefore represent _____ coded bits.

Answer: 6000. The finite label count is six times one thousand. This count does not yet remove coding redundancy or information headers. Review: Equation 14A.

Source: Equation 14A. Count the distinct bit and slot populations (p. 3771)

Why this term is required: “6000” completes the stated technical proposition.

Question context: A known 64QAM labeling places six coded bits in each data symbol. Exactly 1,000 data symbols therefore represent _____ coded bits

Basis and qualification: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

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V011-C07-FIB-072. Complete coding blocks with 4,500 input-information bits and 6,000 coded label bits have effective code rate _____.

Answer: 0.75. Divide the input-information count by the coded count. These are the explicitly included complete-block populations. Review: Equation 14A. Source: Equation 14A. Count the distinct bit and slot populations (p. 3771)

Why this term is required: “0.75” completes the stated technical proposition.

Question context: Complete coding blocks with 4,500 input-information bits and 6,000 coded label bits have effective code rate _____

Basis and qualification: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

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V011-C07-FIB-073. If 3,600 of those 4,500 input-information bits are payload, the payload-bit fraction is _____.

Answer: 0.8. The ratio $\frac{3600}{4500}$ removes the separately identified nonpayload information bits. It is distinct from the code rate. Review: Equation 14A. Source: Equation 14A. Count the distinct bit and slot populations (p. 3771)

Why this term is required: “0.8” completes the stated technical proposition.

Question context: If 3,600 of those 4,500 input-information bits are payload, the payload-bit fraction is _____

Basis and qualification: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

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V011-C07-FIB-074. If 1,000 data-symbol slots occupy a known grid of 1,250 nominal slots, the data-slot fraction is _____.

Answer: 0.8. The denominator includes the declared nondata opportunities. This fraction acts on slots, whereas the payload-bit fraction acts on information bits.

Review: Equation 14A. Source: Equation 14A. Count the distinct bit and slot populations (p. 3771)

Why this term is required: “0.8” completes the stated technical proposition.

Question context: If 1,000 data-symbol slots occupy a known grid of 1,250 nominal slots, the data-slot fraction is _____

Basis and qualification: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations.

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V011-C07-FIB-075. If the 3,600 payload bits belong to exactly 1.000 ms, their represented payload rate is _____ Mbit/s.

Answer: 3.6. Divide the exact payload count by 0.001 seconds. The same rate follows from the complete count chain when every factor uses the same interval.
Review: Equations 14A–14B. Source: Equation 14A. Count the distinct bit and slot populations (p. 3771)
Why this term is required: “3.6” completes the stated technical proposition.
Question context: If the 3,600 payload bits belong to exactly 1.000 ms, their represented payload rate is _____ Mbit/s
Basis and qualification: Chapter 7 — Equation 14A. Count the distinct bit and slot populations; Chapter 7 — Equation 14B. Forward rate and the positive-target inverse.
Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations; Chapter 7 — Equation 14B. Forward rate and the positive-target inverse.

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V011-C07-FIB-076. Applying a pilot reduction again after using an efficiency factor that already includes it is _____ counting.

Answer: double. The combined factor has already removed that population. Repeating the reduction changes the count rather than adding a justified margin.

Review: Application 7B.2. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

Why this term is required: “double” completes the stated technical proposition.

Question context: Applying a pilot reduction again after using an efficiency factor that already includes it is _____ counting

Basis and qualification: Chapter 7 — Application 7B.2. Separate two overhead populations without counting either twice.

Review: Chapter 7 — Application 7B.2. Separate two overhead populations without counting either twice.

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V011-C07-FIB-077. A burst represents 2,400 payload bits in 1.000 ms, followed by a 0.250 ms guard. Including the guard, its payload rate is _____ Mbit/s.

Answer: 1.92. The full interval is 0.00125 seconds, so 2400 divided by that duration is 1,920,000 bit/s. The active-burst rate would instead be 2.4 Mbit/s. Review: Application 7B.4 time-denominator principle. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

Why this term is required: “1.92” completes the stated technical proposition.

Question context: A burst represents 2,400 payload bits in 1.000 ms, followed by a 0.250 ms guard. Including the guard, its payload rate is _____ Mbit/s

Basis and qualification: Chapter 7 — Application 7B.4. Distinguish active-burst rate from rate over the full interval.

Review: Chapter 7 — Application 7B.4. Distinguish active-burst rate from rate over the full interval.

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V011-C07-FIB-078. A link represents 4 Mbit/s for three seconds and 8 Mbit/s for one second. Over all four seconds, its mean rate is _____ Mbit/s.

Answer: 5. The total is 12 plus 8 million bits, divided by four seconds. Equal weighting of the two modes would give an incorrect 6 Mbit/s. Review: Equation 14C.

Source: Equation 14C. Combine counts before dividing by time (p. 3773)

Why this term is required: “5” completes the stated technical proposition.

Question context: A link represents 4 Mbit/s for three seconds and 8 Mbit/s for one second. Over all four seconds, its mean rate is _____ Mbit/s

Basis and qualification: Chapter 7 — Equation 14C. Combine counts before dividing by time.

Review: Chapter 7 — Equation 14C. Combine counts before dividing by time.

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V011-C07-FIB-079. When code rate and constellation order change together, first sum each interval's payload _____ and then divide by total duration.

Answer: counts. Calculate each interval's payload count from its own joint factors and duration. Separate averages of the factors generally do not reproduce the average of their product. Review: Equation 14C; Application 7B.5. Source: Equation 14C. Combine counts before dividing by time (p. 3773)

Why this term is required: "counts" completes the stated technical proposition.

Question context: When code rate and constellation order change together, first sum each interval's payload _____ and then divide by total duration

Basis and qualification: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.5. Weight changing modes by their actual durations.

Review: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.5. Weight changing modes by their actual durations.

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V011-C07-FIB-080. To add simultaneous stream rates as unique payload throughput, their counted payload must be _____ and their time bases compatible.

Answer: disjoint. If the same identified payload appears in more than one stream, duplicate instances must be removed for a unique-delivery claim. Review: Equation 14C; Application 7B.6. Source: Equation 14C. Combine counts before dividing by time (p. 3773)

Why this term is required: “disjoint” completes the stated technical proposition.

Question context: To add simultaneous stream rates as unique payload throughput, their counted payload must be _____ and their time bases compatible

Basis and qualification: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.6. Remove duplicate payload before reporting unique throughput.

Review: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.6. Remove duplicate payload before reporting unique throughput.

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V011-C07-FIB-081. A complete frame has payload capacity 256 bits and a request contains 257 bits. At least _____ complete frames are needed.

Answer: 2. One frame is short by one bit. The ceiling of $\frac{257}{256}$ is two, under the stated complete-frame rule. Review: Equation 14D. Source: Equation 14D. Retain the integer frame boundary (p. 3774)

Why this term is required: “2” completes the stated technical proposition.

Question context: A complete frame has payload capacity 256 bits and a request contains 257 bits. At least _____ complete frames are needed

Basis and qualification: Chapter 7 — Equation 14D. Retain the integer frame boundary.

Review: Chapter 7 — Equation 14D. Retain the integer frame boundary.

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V011-C07-FIB-082. If the unused capacity of those two frames is padded, the padding count is _____ bits.

Answer: 255. Two frames provide 512 payload positions, and the request fills 257. Their difference is 255, which must not be counted as original request payload.

Review: Equation 14D. Source: Equation 14D. Retain the integer frame boundary (p. 3774)

Why this term is required: “255” completes the stated technical proposition.

Question context: If the unused capacity of those two frames is padded, the padding count is _____ bits

Basis and qualification: Chapter 7 — Equation 14D. Retain the integer frame boundary.

Review: Chapter 7 — Equation 14D. Retain the integer frame boundary.

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V011-C07-FIB-083. If each of those frames uses 200 slots at 1.000 Mslot/s with no gaps, the total time is _____ μs.

Answer: 400. Two frames require 400 slots, each lasting one microsecond. A complete-frame boundary prevents stopping after only the 257 requested bits have been placed conceptually. Review: Equation 14D. Source: Equation 14D. Retain the integer frame boundary (p. 3774)

Why this term is required: “400” completes the stated technical proposition.

Question context: If each of those frames uses 200 slots at 1.000 Mslot/s with no gaps, the total time is _____ μs

Basis and qualification: Chapter 7 — Equation 14D. Retain the integer frame boundary.

Review: Chapter 7 — Equation 14D. Retain the integer frame boundary.

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V011-C07-FIB-084. The 257-bit request sent in 400 μs has an actual request-payload rate of _____ Mbit/s.

Answer: 0.6425. Divide 257 by 0.0004 seconds to obtain 642,500 bit/s. The unused final capacity is excluded from the actual request numerator. Review: Equation 14D.

Source: Equation 14D. Retain the integer frame boundary (p. 3774)

Why this term is required: “0.6425” completes the stated technical proposition.

Question context: The 257-bit request sent in 400 μs has an actual request-payload rate of _____ Mbit/s

Basis and qualification: Chapter 7 — Equation 14D. Retain the integer frame boundary.

Review: Chapter 7 — Equation 14D. Retain the integer frame boundary.

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V011-C07-FIB-085. For full 256-bit payloads in every 200-slot frame at 1.000 Mslot/s, the repeating-frame capacity rate is _____ Mbit/s.

Answer: 1.28. A full frame takes 0.0002 seconds, so $\frac{256}{0.0002}$ is 1,280,000 bit/s. A short padded request can have a lower actual payload rate. Review: Equation 14D; finite request versus capacity. Source: Equation 14D. Retain the integer frame boundary (p. 3774)

Why this term is required: “1.28” completes the stated technical proposition.

Question context: For full 256-bit payloads in every 200-slot frame at 1.000 Mslot/s, the repeating-frame capacity rate is _____ Mbit/s

Basis and qualification: Chapter 7 — Equation 14D. Retain the integer frame boundary.

Review: Chapter 7 — Equation 14D. Retain the integer frame boundary.

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V011-C07-FIB-086. For slot rate 2 Mslot/s, four label bits, code rate 0.75 and data-slot fraction 0.8, the upper payload rate with payload-bit fraction at most one is _____ Mbit/s.

Answer: 4.8. Multiply 2 by 4 by 0.75 by 0.8 by the upper payload-bit fraction one. A lower fraction would reduce the rate. Review: Equation 14B; monotone factor bounds. Source: Equation 14B. Forward rate and the positive-target inverse (p. 3772)

Why this term is required: “4.8” completes the stated technical proposition.

Question context: For slot rate 2 Mslot/s, four label bits, code rate 0.75 and data-slot fraction 0.8, the upper payload rate with payload-bit fraction at most one is _____ Mbit/s

Basis and qualification: Chapter 7 — Equation 14B. Forward rate and the positive-target inverse.

Review: Chapter 7 — Equation 14B. Forward rate and the positive-target inverse.

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V011-C07-FIB-087. Exactly 1,000 payload bits belong to a duration between 1.000 and 1.250 ms. The smallest admissible rate is _____ bit/s.

Answer: 800000. Use the largest positive duration: $\frac{1000}{0.00125}$ equals 800,000 bit/s.

The smaller duration gives the upper rate of 1,000,000 bit/s. Review: Equation 14E.

Source: Equation 14E. Bound a rate with an exact count and uncertain positive duration (p. 3774)

Why this term is required: “800000” completes the stated technical proposition.

Question context: Exactly 1,000 payload bits belong to a duration between 1.000 and 1.250 ms. The smallest admissible rate is _____ bit/s

Basis and qualification: Chapter 7 — Equation 14E. Bound a rate with an exact count and uncertain positive duration.

Review: Chapter 7 — Equation 14E. Bound a rate with an exact count and uncertain positive duration.

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V011-C07-FIB-088. With an exact nonnegative count, the smallest rate uses the _____ admissible positive duration.

Answer: largest. The reciprocal decreases as positive time increases. A deterministic duration enclosure does not itself assign a coverage probability. Review: Equation 14E. Source: Equation 14E. Bound a rate with an exact count and uncertain positive duration (p. 3774)

Why this term is required: “largest” completes the stated technical proposition.

Question context: With an exact nonnegative count, the smallest rate uses the _____ admissible positive duration

Basis and qualification: Chapter 7 — Equation 14E. Bound a rate with an exact count and uncertain positive duration.

Review: Chapter 7 — Equation 14E. Bound a rate with an exact count and uncertain positive duration.

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V011-C07-FIB-089. If both coded and information counts are zero, their empirical code-rate ratio is _____.

Answer: undefined. Zero divided by zero cannot establish a code rate. A configured format parameter may be known separately, but it must not be inferred from the empty empirical count. Review: Model 7B zero-count domain. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why this term is required: “undefined” completes the stated technical proposition.

Question context: If both coded and information counts are zero, their empirical code-rate ratio is _____

Basis and qualification: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-FIB-090. The logarithm base two of a known power-of-two constellation cardinality counts coded _____ positions per symbol.

Answer: label-bit. That count does not establish entropy, delivered unique information or a stored ADC-bit rate. The binary labeling and selected symbol type must be declared. Review: Model 7B label and count definitions. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why this term is required: “label-bit” completes the stated technical proposition.

Question context: The logarithm base two of a known power-of-two constellation cardinality counts coded _____ positions per symbol

Basis and qualification: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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V011-C07-FIB-091. A CRC pass is a check on the decoded code relation and is not, by itself, cryptographic _____.

Answer: authentication. A passed consistency check does not prove who originated the signal or where it was transmitted. The validation claim must match the check actually performed. Review: Defensive Interpretation of Digital Signals. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

Why this term is required: “authentication” completes the stated technical proposition.

Question context: A CRC pass is a check on the decoded code relation and is not, by itself, cryptographic _____

Basis and qualification: Chapter 7 — Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Defensive Interpretation of Digital Signals.

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V011-C07-FIB-092. Preserving only a final EVM percentage generally prevents full _____ of the selected finite experiment.

Answer: reproduction. The paired observations and references, selection, weights, fitted parameters and both energy sums are needed to reconstruct the calculation and its conventions. Review: Turn a quality metric into a reproducible acceptance record. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

Why this term is required: “reproduction” completes the stated technical proposition.

Question context: Preserving only a final EVM percentage generally prevents full _____ of the selected finite experiment

Basis and qualification: Chapter 7 — Turn a quality metric into a reproducible acceptance record.

Review: Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-FIB-093. Separate implementations can still agree wrongly if they share the same incorrect reference or synchronization _____.

Answer: assumption. Different code does not remove a common input or model error. A known-reference challenge must test that shared premise independently.
Review: Metric Validation and Held-Out Data. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
Why this term is required: “assumption” completes the stated technical proposition.
Question context: Separate implementations can still agree wrongly if they share the same incorrect reference or synchronization _____
Basis and qualification: Chapter 7 — Metric Validation and Held-Out Data.
Review: Chapter 7 — Metric Validation and Held-Out Data.

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V011-C07-FIB-094. Converting EVM into a bit-error probability requires an additional justified channel, _____ and coding model.

Answer: decision. The metric alone does not define how observations become labels or bits. Different impairments and mappings can produce the same EVM with different decision outcomes. Review: Error Vector Magnitude and Quality Metrics.

Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

Why this term is required: “decision” completes the stated technical proposition.

Question context: Converting EVM into a bit-error probability requires an additional justified channel, _____ and coding model

Basis and qualification: Chapter 7 — Error Vector Magnitude and Quality Metrics.

Review: Chapter 7 — Error Vector Magnitude and Quality Metrics.

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V011-C07-FIB-095. A sample-rate error shared by two processing chains can produce a shared error in the time _____.

Answer: axis. Agreement under the same wrong metadata is not an independent timing validation. Retain and check the rate and clock references actually used.

Review: Carrier and Timing Synchronization. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why this term is required: “axis” completes the stated technical proposition.

Question context: A sample-rate error shared by two processing chains can produce a shared error in the time ____

Basis and qualification: Chapter 7 — Carrier and Timing Synchronization.

Review: Chapter 7 — Carrier and Timing Synchronization.

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V011-C07-FIB-096. A noise-only false output identifies a possible processing mechanism; it does not establish that _____ original candidate had that mechanism.

Answer: every. The control limits an absolute signal claim, but each original observation still requires its own evidence. The chapter explicitly preserves this inference boundary. Review: Hypothetical Case Adjudication. Source: §7.24 Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics (p. 3794)

Why this term is required: “every” completes the stated technical proposition.

Question context: A noise-only false output identifies a possible processing mechanism; it does not establish that _____ original candidate had that mechanism

Basis and qualification: Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

Review: Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

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V011-C07-FIB-097. An acquisition success fraction requires a declared denominator of attempted _____, not only saved successful constellations.

Answer: acquisitions. The trial definition and attempted population must be known. A set selected for successful lock cannot by itself characterize how often acquisition succeeded. Review: Carrier and Timing Synchronization; acceptance record. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

Why this term is required: “acquisitions” completes the stated technical proposition.

Question context: An acquisition success fraction requires a declared denominator of attempted _____, not only saved successful constellations

Basis and qualification: Chapter 7 — Carrier and Timing Synchronization.

Review: Chapter 7 — Carrier and Timing Synchronization.

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V011-C07-FIB-098. A processing-script hash directly supports file identity and _____, while actual execution and validity require additional evidence.

Answer: provenance. A matching file digest does not demonstrate that the file ran with the stated input and settings. It also does not establish a result's metrological traceability. Review: Reproducible acceptance record; Chapter 1 result traceability.

Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

Why this term is required: "provenance" completes the stated technical proposition.

Question context: A processing-script hash directly supports file identity and _____, while actual execution and validity require additional evidence

Basis and qualification: Chapter 7 — Turn a quality metric into a reproducible acceptance record; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

Review: Chapter 7 — Turn a quality metric into a reproducible acceptance record; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C07-FIB-099. A favorable post-equalization metric must retain the equalizer's settings and the _____ for permitting that compensation.

Answer: purpose. The processing should answer a declared measurement or reception question. Removing a distortion for operational decoding differs from measuring the original uncompensated path. Review: Matched Filtering, Pulse Shaping, and Channel Effects. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

Why this term is required: "purpose" completes the stated technical proposition.

Question context: A favorable post-equalization metric must retain the equalizer's settings and the _____ for permitting that compensation

Basis and qualification: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-FIB-100. Before expanding a spectral task into content recovery, the proposed acquisition, retention and reporting must fit the established engagement _____.

Answer: authority. Technical success does not supply permission. The actual task boundary governs the additional operation, independent of how plausible the recovered fields appear. Review: Defensive Interpretation of Digital Signals. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

Why this term is required: “authority” completes the stated technical proposition.

Question context: Before expanding a spectral task into content recovery, the proposed acquisition, retention and reporting must fit the established engagement _____

Basis and qualification: Chapter 7 — Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Defensive Interpretation of Digital Signals.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C07-ESSAY-001. Develop the weighted finite-record EVM definition from paired complex observations and references. State the admissible weights, units, normalization domain, percentage and decibel conventions, and what changes when some symbols receive zero weight.

- Opening: Present a thesis that answers this precise question: Develop the weighted finite-record EVM definition from paired complex observations and references. Identify which evidence would falsify the proposed conclusion Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Core terminology and scope: Define paired, admissible, weights in the question's particular technical setting; explain how percentage, conventions, weight differ if that distinction would change the analysis of "Develop the weighted finite-record EVM definition from paired complex observations and references" Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start with a finite set of paired observations and references in compatible complex-amplitude units Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the weighted finite-record EVM definition from paired complex observations and references to the claimed result, following "Application 7A.10: Audit a complete finite residual vector"; name the intermediate states and measurable outputs Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the weighted finite-record EVM definition from paired complex observations and references. Subtract each reference from its observation, square the complex magnitude, multiply by a fixed nonnegative dimensionless weight and sum Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.3: Preserve a DC impairment when fitting only complex gain” that resolves the question about the weighted finite-record EVM definition from paired complex observations and references; derive the relevant result with units and stated validity conditions Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the weighted finite-record EVM definition from paired complex observations and references. Divide by the correspondingly weighted reference-energy sum, which must be strictly positive, and take the square root Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Worked application or illustrative case: Build a worked example of “the weighted finite-record EVM definition from paired complex observations and references”, addressing this associated condition: State the admissible weights, units, normalization domain, percentage and decibel conventions, and what.... Start with a finite set of paired observations and references in compatible complex-

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amplitude units Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the weighted finite-record EVM definition from paired complex observations and references”. Using “Application 7A.3: Preserve a DC impairment when fitting only complex gain”, specify a discriminator and the result expected under each explanation Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the weighted finite-record EVM definition from paired complex observations and references, including the effect of missing measurements and inconsistent operating conditions Source: §7.25 Digital-demodulation validation by error covariance and synchronisation-state segmentation (p. 3795)
- Scholarly synthesis and implications: Explain what the result about the weighted finite-record EVM definition from paired complex observations and references authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Closing: Conclude by answering “Develop the weighted finite-record EVM definition from paired complex observations and references” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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V011-C07-ESSAY-002. Derive the constant complex-gain estimator by completing the weighted least-squares objective. Explain why the conjugate appears in the correlation, identify the uniqueness condition, and distinguish minimizing residual energy from minimizing a fitted-reference EVM.

- Opening: Present a thesis that answers this precise question: Derive the constant complex-gain estimator by completing the weighted least-squares objective. Identify which evidence would falsify the proposed conclusion Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Core terminology and scope: Define completing, weighted, objective in the question's particular technical setting; explain how conjugate, uniqueness, minimizing differ if that distinction would change the analysis of "Derive the constant complex-gain estimator by completing the weighted least-squares objective" Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Write the training objective as the weighted sum of squared magnitudes of observation minus times ideal reference Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the constant complex-gain estimator by completing the weighted least-squares objective to the claimed result, following "Application 7A.7: Evaluate a fitted gain on held-out symbols"; name the intermediate states

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and measurable outputs Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the constant complex-gain estimator by completing the weighted least-squares objective. Define as the weighted sum of observation times conjugated reference, and as the weighted ideal-reference energy Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.4: Expose a conjugate-image impairment” that resolves the question about the constant complex-gain estimator by completing the weighted least-squares objective; derive the relevant result with units and stated validity conditions Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the constant complex-gain estimator by completing the weighted least-squares objective. Expansion gives observation energy minus twice the real part of plus Completing the square gives observation energy minus plus When is positive Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Worked application or illustrative case: Build a worked example of “the constant complex-gain estimator by completing the weighted least-squares objective”, addressing this associated condition: Explain why the conjugate appears in the correlation, identify the uniqueness condition, and distinguish.... Write the training objective

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as the weighted sum of squared magnitudes of observation minus times ideal reference Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the constant complex-gain estimator by completing the weighted least-squares objective”. Using “Application 7A.4: Expose a conjugate-image impairment”, specify a discriminator and the result expected under each explanation Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the constant complex-gain estimator by completing the weighted least-squares objective, including the effect of missing measurements and inconsistent operating conditions Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Scholarly synthesis and implications: Explain what the result about the constant complex-gain estimator by completing the weighted least-squares objective authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Closing: Conclude by answering “Derive the constant complex-gain estimator by completing the weighted least-squares objective” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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V011-C07-ESSAY-003. Use ideal references $(1, j, 2, -2j)$, observations $(1.1+j0.05, -0.05+j1.2, 1.8+j0.1, 0.1-j2.1)$ and weights $(1, 2, 1, 0.5)$. Compute fixed-reference EVM, then the complex-gain fit and minimized training residual energy. All amplitudes use the same normalized unit; no further corrections are permitted.

- Opening: Present a thesis that answers this precise question: Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training residual energy. Identify which evidence would falsify the proposed conclusion Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Core terminology and scope: Define weights, Compute, minimized in the question's particular technical setting; explain how training, amplitudes, permitted differ if that distinction would change the analysis of "Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training residual energy" Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The residuals are Their weighted squared magnitudes are 0.0125, 0.085, 0.05 and 0.01, totaling 0.1575 Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training… to the claimed

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result, following “Application 7A.1: Show which error a fitted gain removes”; name the intermediate states and measurable outputs Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training.... Weighted reference energy is so fixed-reference EVM is the square root of or approximately 13.228757 percent Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.3: Preserve a DC impairment when fitting only complex gain” that resolves the question about Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training...; derive the relevant result with units and stated validity conditions Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training.... The weighted observation-reference correlation is giving fitted gain Weighted observation energy is 9.5575; subtracting yields minimized residual energy approximately 0.13055556 Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- Worked application or illustrative case: Build a worked example of “Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training…”, addressing this associated condition: All amplitudes use the same normalized unit; no further corrections are permitted. The residuals are Their weighted squared magnitudes are 0.0125, 0.085, 0.05 and 0.01, totaling 0.1575 Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training…”. Using “Application 7A.3: Preserve a DC impairment when fitting only complex gain”, specify a discriminator and the result expected under each explanation Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training…, including the effect of missing measurements and inconsistent operating conditions Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
- Scholarly synthesis and implications: Explain what the result about Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- Closing: Conclude by answering “Use ideal references observations and weights Compute fixed-reference EVM, then the complex-gain fit and minimized training residual energy” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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V011-C07-ESSAY-004. For two equal-weight ideal references $(1,1)$ and observations $(1,0)$, compare fixed-reference EVM with the in-sample fitted-reference EVM after the chapter's constant-gain fit. Explain why the fitted result can be larger despite successful least-squares minimization.

- Opening: Present a thesis that answers this precise question: For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after the chapter's constant-gain fit. Identify which evidence would falsify the proposed conclusion Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Core terminology and scope: Define references, fitted, larger in the question's particular technical setting; explain how despite, successful, minimization differ if that distinction would change the analysis of "For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after the chapter's constant-gain fit" Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The fixed residuals are zero and minus one Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after… to the claimed result, following "Application 7A.7: Evaluate a fitted gain on held-out

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symbols"; name the intermediate states and measurable outputs Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after…. Their energy is one and the reference energy is two, giving fixed-reference EVM approximately 70.710678 percent Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 7A.8: Keep a residual frequency rotation in a finite symbol record" that resolves the question about For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after…; derive the relevant result with units and stated validity conditions Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after…. The correlation is one, so the fitted gain is 0.5 Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Worked application or illustrative case: Build a worked example of "For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after…", addressing this associated condition: Explain why the fitted

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result can be larger despite successful least-squares minimization. The fixed residuals are zero and minus one Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after…”. Using “Application 7A.8: Keep a residual frequency rotation in a finite symbol record”, specify a discriminator and the result expected under each explanation Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after…, including the effect of missing measurements and inconsistent operating conditions Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Scholarly synthesis and implications: Explain what the result about For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Closing: Conclude by answering “For two equal-weight ideal references and observations compare fixed-reference EVM with the in-sample fitted-reference EVM after the chapter’s constant-gain fit”

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using only the demonstrated evidence; state the remaining decisive verification step Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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V011-C07-ESSAY-005. A training set has ideal symbols $(1, j)$ and observations $(1.1, j1.1)$. A separate evaluation set has ideal symbols $(-1, -j)$ and identical ideal observations. Fit on the training set only, then compare fixed-reference and fitted-reference evaluation EVM. Explain what the comparison can and cannot establish.

- Opening: Present a thesis that answers this precise question: A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations. Identify which evidence would falsify the proposed conclusion Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Core terminology and scope: Define training, ideal, symbols in the question's particular technical setting; explain how observations, evaluation, identical differ if that distinction would change the analysis of "A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations" Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The training correlation is 2.2 and its ideal energy is two, so the fitted gain is 1.1 and the training residual is zero Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations to the claimed result,

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following “Application 7A.1: Show which error a fitted gain removes”; name the intermediate states and measurable outputs Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations. On the evaluation set, the fixed references agree exactly with the observations, giving zero fixed-reference EVM Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 7A: a finite, declared EVM comparison” that resolves the question about A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations; derive the relevant result with units and stated validity conditions Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations. The fitted references are and each residual has magnitude 0.1 Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Worked application or illustrative case: Build a worked example of “A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations”,

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addressing this associated condition: Fit on the training set only, then compare fixed-reference and fitted-reference evaluation EVM. The training correlation is 2.2 and its ideal energy is two, so the fitted gain is 1.1 and the training residual is zero Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations”. Using “Model 7A: a finite, declared EVM comparison”, specify a discriminator and the result expected under each explanation Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations, including the effect of missing measurements and inconsistent operating conditions Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Scholarly synthesis and implications: Explain what the result about A training set has ideal symbols and observations A separate evaluation set has ideal symbols and identical ideal observations authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Closing: Conclude by answering “A training set has ideal symbols and observations A separate evaluation set has ideal symbols and

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identical ideal observations" using only the demonstrated evidence; state the remaining decisive verification step Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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V011-C07-ESSAY-006. For equally weighted references $(1, j, -1, -j)$, form each observation as its reference plus d plus β times its conjugate, where $d = 0.03 - j0.04$ and $\beta = 0.06$. Derive the gain fit and fixed-reference EVM. Identify residual information that the scalar alone loses.

- Opening: Present a thesis that answers this precise question: For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain fit and fixed-reference EVM. Identify which evidence would falsify the proposed conclusion Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)
- Core terminology and scope: Define equally, weighted, form in the question's particular technical setting; explain how conjugate, scalar, loses differ if that distinction would change the analysis of "For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain fit and fixed-reference EVM" Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The references have unit energy, zero sum and zero sum of complex squares Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain… to the claimed result, following "Application 7A.3: Preserve a DC impairment when

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fitting only complex gain”; name the intermediate states and measurable outputs Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain.... The offset contribution to the gain correlation vanishes because the conjugated references sum to zero; the conjugate-leakage contribution also vanishes because their conjugate squares sum to... Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.1: Show which error a fitted gain removes” that resolves the question about For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain...; derive the relevant result with units and stated validity conditions Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Evidence and method: Specify the native observations, control records and calculations that would resolve For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain.... The ordinary fitted gain therefore remains one Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)
- Worked application or illustrative case: Build a worked example of “For equally weighted references form each observation as its

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reference plus d plus times its conjugate, where and Derive the gain…", addressing this associated condition: Identify residual information that the scalar alone loses. The references have unit energy, zero sum and zero sum of complex squares Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain…". Using "Application 7A.1: Show which error a fitted gain removes", specify a discriminator and the result expected under each explanation Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain…, including the effect of missing measurements and inconsistent operating conditions Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Scholarly synthesis and implications: Explain what the result about For equally weighted references form each observation as its reference plus d plus times its conjugate, where and Derive the gain… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)
- Closing: Conclude by answering "For equally weighted references form each observation as its reference plus d plus times its

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conjugate, where and Derive the gain fit and fixed-reference EVM" using only the demonstrated evidence; state the remaining decisive verification step Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)

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V011-C07-ESSAY-007. Derive the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees. State the angular-unit convention and explain what a subsequent phase fit would change.

- Opening: Present a thesis that answers this precise question: Derive the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees. Identify which evidence would falsify the proposed conclusion Source: §7.8 Application 7A.2: Quantify a fixed phase error (p. 3753)
- Core terminology and scope: Define constant, rotation, approximation in the question's particular technical setting; explain how degrees, convention, subsequent differ if that distinction would change the analysis of "Derive the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees" Source: §7.8 Application 7A.2: Quantify a fixed phase error (p. 3753)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Subtract the unrotated reference from its rotated observation Source: §7.8 Application 7A.2: Quantify a fixed phase error (p. 3753)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees to the claimed result, following "Application 7A.8: Keep a residual frequency rotation in a finite symbol record"; name the intermediate states and measurable

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outputs Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees. The common reference magnitude factors out of the residual-to-reference ratio Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.7: Evaluate a fitted gain on held-out symbols” that resolves the question about the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees; derive the relevant result with units and stated validity conditions Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees. The small-angle approximation uses in radians, giving or approximately 52.359878 percent Source: §7.8 Application 7A.2: Quantify a fixed phase error (p. 3753)
- Worked application or illustrative case: Build a worked example of “the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees”, addressing this associated condition: State the angular-unit convention and explain what a subsequent phase fit would change.

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Subtract the unrotated reference from its rotated observation Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees”. Using “Application 7A.7: Evaluate a fitted gain on held-out symbols”, specify a discriminator and the result expected under each explanation Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees, including the effect of missing measurements and inconsistent operating conditions Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Scholarly synthesis and implications: Explain what the result about the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.8 Application 7A.2: Quantify a fixed phase error (p. 3753)
- Closing: Conclude by answering “Derive the exact fixed-reference EVM of a constant phase rotation and compare it with the small-angle approximation at 30 degrees” using only the demonstrated

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evidence; state the remaining decisive verification step Source: §7.8

Application 7A.2: Quantify a fixed phase error (p. 3753)

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V011-C07-ESSAY-008. A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen. Every symbol has a residual $0.1 + j0.1$. Compute reference-RMS and constellation-maximum EVM, and show the error caused by substituting the full uniformly used alphabet's mean energy.

- Opening: Present a thesis that answers this precise question: A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen. Identify which evidence would falsify the proposed conclusion Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Core terminology and scope: Define inner, eighteen, Compute in the question's particular technical setting; explain how substituting, uniformly, alphabet differ if that distinction would change the analysis of "A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen" Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The selected reference-energy sum is six times two plus two times eighteen, or 48; with eight equal weights, its mean is six Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen to the claimed result,

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following “Application 7A.10: Audit a complete finite residual vector”; name the intermediate states and measurable outputs Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen. Each residual has energy 0.02, so reference-RMS EVM is the square root of approximately 5.773503 percent Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.9: Separate constellation rotation from validated symbol mapping” that resolves the question about A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen; derive the relevant result with units and stated validity conditions Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen. The declared square-16QAM maximum energy is eighteen, giving constellation-maximum EVM approximately 3.333333 percent Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

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- Worked application or illustrative case: Build a worked example of “A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen”, addressing this associated condition: Every symbol has a residual Compute reference-RMS and constellation-maximum EVM, and show the error.... The selected reference-energy sum is six times two plus two times eighteen, or 48; with eight equal weights, its mean is... Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen”. Using “Application 7A.9: Separate constellation rotation from validated symbol mapping”, specify a discriminator and the result expected under each explanation Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen, including the effect of missing measurements and inconsistent operating conditions Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Scholarly synthesis and implications: Explain what the result about A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen authorises the investigator or engineer to claim, and what stronger proposition

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remains unsupported Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- Closing: Conclude by answering “A selected square-16QAM record contains six inner symbols of energy two and two outer-corner symbols of energy eighteen” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

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V011-C07-ESSAY-009. Four unit-energy reference symbols have residual magnitudes $(0.25, 0.15, 0.05, 0.05)$. Compare equal-weight complete-record EVM, evaluation of only the last two symbols, and weights $(0.2, 0.2, 1, 1)$. Explain the reporting consequences if the first two symbols belong to acquisition.

- Opening: Present a thesis that answers this precise question: Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last two symbols, and weights Explain the.... Identify which evidence would falsify the proposed conclusion Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Core terminology and scope: Define magnitudes, evaluation, weights in the question's particular technical setting; explain how reporting, consequences, belong differ if that distinction would change the analysis of "Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last two symbols, and weights Explain the..." Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The equal-weight residual-energy sum is Dividing by four and taking the square root gives 15 percent Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last... to the claimed

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result, following “Application 7A.10: Audit a complete finite residual vector”; name the intermediate states and measurable outputs Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last.... The last two symbols alone have energy sum 0.005 and reference energy two, giving 5 percent Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.5: Compare RMS and constellation-maximum normalization” that resolves the question about Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last...; derive the relevant result with units and stated validity conditions Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last.... With the stated weights, the numerator is and the denominator is 2.4, giving approximately 9.574271 percent Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Worked application or illustrative case: Build a worked example of “Four unit-energy reference symbols have residual magnitudes

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Compare equal-weight complete-record EVM, evaluation of only the last…", addressing this associated condition: The equal-weight residual-energy sum is Dividing by four and taking the square root gives 15 percent. The equal-weight residual-energy sum is Dividing by four and taking the square root gives 15 percent Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last…". Using "Application 7A.5: Compare RMS and constellation-maximum normalization", specify a discriminator and the result expected under each explanation Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last…, including the effect of missing measurements and inconsistent operating conditions Source: §7.25 Digital-demodulation validation by error covariance and synchronisation-state segmentation (p. 3795)
- Scholarly synthesis and implications: Explain what the result about Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

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- Closing: Conclude by answering “Four unit-energy reference symbols have residual magnitudes Compare equal-weight complete-record EVM, evaluation of only the last two symbols, and weights Explain the…” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

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V011-C07-ESSAY-010. Two disjoint blocks use the same fixed reference convention and correction policy. Their reference-energy sums are 40 and 160, and their EVM values are 5 and 15 percent. Derive the pooled EVM and identify the extra issue if each block instead used a separately fitted gain.

- Opening: Present a thesis that answers this precise question: Two disjoint blocks use the same fixed reference convention and correction policy. Identify which evidence would falsify the proposed conclusion Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Core terminology and scope: Define disjoint, blocks, policy in the question's particular technical setting; explain how sums, extra, issue differ if that distinction would change the analysis of "Two disjoint blocks use the same fixed reference convention and correction policy" Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Convert the percentages to linear values before reconstructing residual energies Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Two disjoint blocks use the same fixed reference convention and correction policy to the claimed result, following "Application 7A.7: Evaluate a fitted gain on held-out symbols"; name the intermediate states and measurable outputs Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Two disjoint blocks use the same fixed reference convention and correction policy. The first block contributes 40 times 0.05 squared, or 0.1; the second contributes 160 times 0.15 squared, or 3.6 Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.8: Keep a residual frequency rotation in a finite symbol record” that resolves the question about Two disjoint blocks use the same fixed reference convention and correction policy; derive the relevant result with units and stated validity conditions Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Two disjoint blocks use the same fixed reference convention and correction policy. The combined energy ratio is giving pooled EVM approximately 13.601471 percent Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Worked application or illustrative case: Build a worked example of “Two disjoint blocks use the same fixed reference convention and correction policy”, addressing this associated condition: Their reference-energy sums are 40 and 160, and their EVM values are 5 and 15 percent. Convert the percentages to linear values before reconstructing residual energies Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Two disjoint blocks use the same fixed reference convention and correction policy”. Using “Application 7A.8: Keep a residual frequency rotation in a finite symbol record”, specify a discriminator and the result expected under each explanation Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Two disjoint blocks use the same fixed reference convention and correction policy, including the effect of missing measurements and inconsistent operating conditions Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Scholarly synthesis and implications: Explain what the result about Two disjoint blocks use the same fixed reference convention and correction policy authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Closing: Conclude by answering “Two disjoint blocks use the same fixed reference convention and correction policy” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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V011-C07-ESSAY-011. Three equally weighted ideal pilot references all equal 1 at indices -1, 0 and 1. Their unit-magnitude observations have phases -60, 0 and 60 degrees. Compute the fixed-reference EVM, constant complex-gain fit and in-sample fitted-reference EVM. Explain why a real fitted coefficient does not establish zero frequency offset.

- Opening: Present a thesis that answers this precise question: Three equally weighted ideal pilot references all equal 1 at indices 0 and 1. Identify which evidence would falsify the proposed conclusion Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Core terminology and scope: Define equally, weighted, pilot in the question's particular technical setting; explain how phases, Compute, fitted differ if that distinction would change the analysis of "Three equally weighted ideal pilot references all equal 1 at indices 0 and 1" Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The three observed phasors sum to two, so the correlation is two and the ideal-reference energy is three Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Three equally weighted ideal pilot references all equal 1 at indices 0 and 1 to the claimed result, following "Application 7A.8: Keep a residual frequency rotation in a finite symbol record"; name the intermediate states and measurable outputs Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Three equally weighted ideal pilot references all equal 1 at indices 0 and 1. The fitted constant gain is therefore with zero imaginary part Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.7: Evaluate a fitted gain on held-out symbols” that resolves the question about Three equally weighted ideal pilot references all equal 1 at indices 0 and 1; derive the relevant result with units and stated validity conditions Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Three equally weighted ideal pilot references all equal 1 at indices 0 and 1. The fixed residual energies are one, zero and one, giving fixed-reference EVM equal to the square root of approximately 81.649658 percent Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Worked application or illustrative case: Build a worked example of “Three equally weighted ideal pilot references all equal 1 at indices 0 and 1”, addressing this associated condition: Their unit-magnitude observations have phases 0 and 60 degrees. The three observed phasors sum to two, so the correlation is two and the ideal-reference energy is three Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Three equally weighted ideal pilot references all equal 1 at indices 0 and 1”. Using “Application 7A.7: Evaluate a fitted gain on held-out symbols”, specify a discriminator and the result expected under each explanation Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Three equally weighted ideal pilot references all equal 1 at indices 0 and 1, including the effect of missing measurements and inconsistent operating conditions Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)
- Scholarly synthesis and implications: Explain what the result about Three equally weighted ideal pilot references all equal 1 at indices 0 and 1 authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Closing: Conclude by answering “Three equally weighted ideal pilot references all equal 1 at indices 0 and 1” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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V011-C07-ESSAY-012. Use references $(1+j, 1-j, -1+j, -1-j)$ and residuals $(0.03+j0.04, 0, 0.06+j0.08, 0)$. Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual energy in the third symbol. Explain why these finite numbers do not supply a confidence interval.

- Opening: Present a thesis that answers this precise question: Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual energy in the third symbol. Identify which evidence would falsify the proposed conclusion Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Core terminology and scope: Define residuals, Calculate, largest in the question's particular technical setting; explain how normalized, numbers, confidence differ if that distinction would change the analysis of "Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual energy in the third symbol" Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Every reference has energy two, so their sum is eight and reference RMS magnitude is the square root of two Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual… to the claimed result,

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following “Application 7A.5: Compare RMS and constellation-maximum normalization”; name the intermediate states and measurable outputs Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual.... Residual energies are 0.0025, zero, 0.01 and zero, totaling 0.0125 Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7A.9: Separate constellation rotation from validated symbol mapping” that resolves the question about Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual...; derive the relevant result with units and stated validity conditions Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual.... RMS EVM is the square root of approximately 3.952847 percent Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Worked application or illustrative case: Build a worked example of “Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual...”,

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addressing this associated condition: Explain why these finite numbers do not supply a confidence interval. Every reference has energy two, so their sum is eight and reference RMS magnitude is the square root of two Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual…”. Using “Application 7A.9: Separate constellation rotation from validated symbol mapping”, specify a discriminator and the result expected under each explanation Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual…, including the effect of missing measurements and inconsistent operating conditions Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Scholarly synthesis and implications: Explain what the result about Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- Closing: Conclude by answering “Use references and residuals Calculate RMS EVM, the largest residual normalized to reference RMS and the fraction of residual energy in the third symbol” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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V011-C07-ESSAY-013. Design a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping and false-lock errors. Include held-out evaluation and state which checks can fail independently.

- Opening: Present a thesis that answers this precise question: Design a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping and false-lock errors. Identify which evidence would falsify the proposed conclusion Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Core terminology and scope: Define Design, validation, implementation in the question's particular technical setting; explain how mapping, evaluation, fail differ if that distinction would change the analysis of "Design a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping and false-lock errors" Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin with disclosed complex vectors whose squared distances and reference energies can be calculated independently, including a nonzero fit, a zero residual and an inadmissible zero denominator Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a validation sequence for a new EVM implementation that distinguishes

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arithmetic errors from shared reference, timing, mapping… to the claimed result, following “Metric Validation and Held-Out Data”; name the intermediate states and measurable outputs Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping…. This checks arithmetic and domain handling Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 7A: a finite, declared EVM comparison” that resolves the question about a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping…; derive the relevant result with units and stated validity conditions Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping…. Then use a known sequence with an imposed timing displacement and a separately known symbol rate to challenge sample selection and clock metadata Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- Worked application or illustrative case: Build a worked example of “a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping…”, addressing this associated condition: Include held-out evaluation and state which checks can fail independently. Begin with disclosed complex vectors whose squared distances and reference energies can be calculated independently, including a nonzero… Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping…”. Using “Model 7A: a finite, declared EVM comparison”, specify a discriminator and the result expected under each explanation Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping…, including the effect of missing measurements and inconsistent operating conditions Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Scholarly synthesis and implications: Explain what the result about a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping… authorises the investigator or engineer to claim, and

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what stronger proposition remains unsupported Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- Closing: Conclude by answering “Design a validation sequence for a new EVM implementation that distinguishes arithmetic errors from shared reference, timing, mapping and false-lock errors” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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V011-C07-ESSAY-014. A flexible equalizer dramatically reduces training EVM while held-out EVM worsens. Develop a technically justified interpretation and a bounded follow-up plan without assigning the original distortion to the transmitter, channel or receiver prematurely.

- Opening: Present a thesis that answers this precise question: A flexible equalizer dramatically reduces training EVM while held-out EVM worsens. Identify which evidence would falsify the proposed conclusion Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Core terminology and scope: Define flexible, equalizer, dramatically in the question's particular technical setting; explain how training, technically, assigning differ if that distinction would change the analysis of "A flexible equalizer dramatically reduces training EVM while held-out EVM worsens" Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The observations show that the selected parameterization fits the training record better but transfers less well under the stated evaluation Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A flexible equalizer dramatically reduces training EVM while held-out EVM worsens to the claimed result, following "Matched Filtering, Pulse Shaping, and Channel Effects"; name the intermediate states and

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measurable outputs Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A flexible equalizer dramatically reduces training EVM while held-out EVM worsens. Check that the evaluation uses fixed coefficients, compatible reference normalization and an interval excluded from fitting; otherwise the two values may describe different experiments Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 7A: a finite, declared EVM comparison” that resolves the question about A flexible equalizer dramatically reduces training EVM while held-out EVM worsens; derive the relevant result with units and stated validity conditions Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A flexible equalizer dramatically reduces training EVM while held-out EVM worsens. Retain pre-equalization and post-equalization residuals, tap count, training length, regularization, convergence state and adaptation policy Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Worked application or illustrative case: Build a worked example of “A flexible equalizer dramatically reduces training EVM while held-out EVM worsens”, addressing this associated condition: Develop a technically justified interpretation and a bounded follow-up plan

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without assigning the.... The observations show that the selected parameterization fits the training record better but transfers less well under the stated evaluation Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A flexible equalizer dramatically reduces training EVM while held-out EVM worsens”. Using “Model 7A: a finite, declared EVM comparison”, specify a discriminator and the result expected under each explanation Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A flexible equalizer dramatically reduces training EVM while held-out EVM worsens, including the effect of missing measurements and inconsistent operating conditions Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Scholarly synthesis and implications: Explain what the result about A flexible equalizer dramatically reduces training EVM while held-out EVM worsens authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Closing: Conclude by answering “A flexible equalizer dramatically reduces training EVM while held-out EVM worsens” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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V011-C07-ESSAY-015. Explain the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations that claim to use the same root-raised-cosine filter. Address finite-record boundaries and the measurement question.

- Opening: Present a thesis that answers this precise question: Explain the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations that claim to use the same.... Identify which evidence would falsify the proposed conclusion Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)
- Core terminology and scope: Define assumptions, specify, information in the question's particular technical setting; explain how implementations, claim, boundaries differ if that distinction would change the analysis of "Explain the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations that claim to use the same..." Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The stated matched-filter benefit assumes the relevant known pulse and additive white Gaussian noise, with the timing and channel relationship required for the comparison Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations... to the

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claimed result, following “Define the symbol experiment before fitting the constellation”; name the intermediate states and measurable outputs Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations…. It is not a universal claim that any filter carrying that label is optimal in an unknown channel or colored interference Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Carrier and Timing Synchronization” that resolves the question about the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations…; derive the relevant result with units and stated validity conditions Source: §7.2 Carrier and Timing Synchronization (p. 3737)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations…. Specify coefficients or a reproducible generation convention, roll-off, span, sample rate, scaling, delay, initialization and treatment of unavailable samples at the record edges Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

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- Worked application or illustrative case: Build a worked example of “the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations…”, addressing this associated condition: Address finite-record boundaries and the measurement question. The stated matched-filter benefit assumes the relevant known pulse and additive white Gaussian noise, with the timing and channel relationship… Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations…”. Using “Carrier and Timing Synchronization”, specify a discriminator and the result expected under each explanation Source: §7.2 Carrier and Timing Synchronization (p. 3737)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations…, including the effect of missing measurements and inconsistent operating conditions Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Scholarly synthesis and implications: Explain what the result about the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

- Closing: Conclude by answering “Explain the assumptions behind using a matched filter in this chapter, then specify the information needed to compare two implementations that claim to use the same…” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

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V011-C07-ESSAY-016. In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each. Complete code blocks have rate 0.75, and 36,000 input bits are payload. Reconstruct every count and efficiency, then calculate the payload rate and one double-counting error.

- Opening: Present a thesis that answers this precise question: In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each. Identify which evidence would falsify the proposed conclusion Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Core terminology and scope: Define slots, coded, blocks in the question's particular technical setting; explain how Reconstruct, efficiency, calculate differ if that distinction would change the analysis of "In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each" Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The slot rate is slots per second Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each to the claimed result, following "Application 7B.3. Count disjoint pilot and nonpayload slots

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explicitly"; name the intermediate states and measurable outputs Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each. The data-slot fraction is Coded label bits total 16,000 times four, or 64,000; the 0.75 complete-block code rate gives 48,000 input-information bits Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate" that resolves the question about In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each; derive the relevant result with units and stated validity conditions Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Evidence and method: Specify the native observations, control records and calculations that would resolve In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each. Payload-bit fraction is Multiplying slot rate, four label bits, code rate 0.75, data-slot fraction 0.8 and payload-bit fraction 0.75 gives 1.8 Mbit/s, matching directly Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

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- Worked application or illustrative case: Build a worked example of “In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each”, addressing this associated condition: Complete code blocks have rate 0.75, and 36,000 input bits are payload. The slot rate is slots per second Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each”. Using “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”, specify a discriminator and the result expected under each explanation Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Scholarly synthesis and implications: Explain what the result about In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

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- Closing: Conclude by answering “In exactly 20 ms, a stipulated uniform grid contains 20,000 slots, of which 16,000 carry four coded label bits each” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

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V011-C07-ESSAY-017. A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and payload-bit fraction 0.9. A 0.2 ms guard follows. Derive active and wall-interval payload rates, and explain when a 6,000-slot accounting grid is legitimate.

- Opening: Present a thesis that answers this precise question: A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and payload-bit fraction 0.9. Identify which evidence would falsify the proposed conclusion Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Core terminology and scope: Define active, coded, guard in the question's particular technical setting; explain how slot, accounting, legitimate differ if that distinction would change the analysis of "A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and payload-bit fraction 0.9" Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The burst carries 20,000 coded bits, 16,000 input-information bits and 14,400 payload bits Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and… to the claimed result,

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following “Application 7B.1. Reconcile coded bits, information bits and modulation symbols”; name the intermediate states and measurable outputs Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and…. Five thousand symbols at 5 Msymbol/s occupy 1 ms, giving an active-interval payload rate of 14.4 Mbit/s Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.5. Weight changing modes by their actual durations” that resolves the question about A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and…; derive the relevant result with units and stated validity conditions Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and…. Including the supplied 0.2 ms guard gives a total interval of 1.2 ms and payload rate 12 Mbit/s Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Worked application or illustrative case: Build a worked example of “A burst has 5,000 data symbols at an active symbol rate of 5

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Msymbol/s, four coded label bits per symbol, code rate 0.8 and…", addressing this associated condition: A 0.2 ms guard follows. The burst carries 20,000 coded bits, 16,000 input-information bits and 14,400 payload bits Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and…". Using "Application 7B.5. Weight changing modes by their actual durations", specify a discriminator and the result expected under each explanation Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and…, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Scholarly synthesis and implications: Explain what the result about A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per symbol, code rate 0.8 and… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Closing: Conclude by answering "A burst has 5,000 data symbols at an active symbol rate of 5 Msymbol/s, four coded label bits per

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symbol, code rate 0.8 and payload-bit fraction 0.9” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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V011-C07-ESSAY-018. A stipulated link uses 1 Msymbol/s throughout. For two seconds it uses two label bits and code rate 0.5; for one second it uses six label bits and code rate $\frac{2}{3}$. All information bits are payload and there is no other overhead. Compute the aggregate rate and test the product of separately time-averaged factors.

- Opening: Present a thesis that answers this precise question: A stipulated link uses 1 Msymbol/s throughout. Identify which evidence would falsify the proposed conclusion Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)
- Core terminology and scope: Define link, payload, overhead in the question's particular technical setting; explain how Compute, aggregate, factors differ if that distinction would change the analysis of "A stipulated link uses 1 Msymbol/s throughout" Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)
- Problem statement and purpose: Frame the actual measurement or decision in the question. The first mode represents 1 Mbit/s and contributes 2 Mbit over two seconds Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A stipulated link uses 1 Msymbol/s throughout to the claimed result, following "Application 7B.1. Reconcile coded bits, information bits and modulation symbols"; name the intermediate states and measurable outputs Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A stipulated link uses 1 Msymbol/s throughout. The second represents 4 Mbit/s and contributes 4 Mbit over one second Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.2. Separate two overhead populations without counting either twice” that resolves the question about A stipulated link uses 1 Msymbol/s throughout; derive the relevant result with units and stated validity conditions Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A stipulated link uses 1 Msymbol/s throughout. Total payload is therefore 6 Mbit in three seconds, giving 2 Mbit/s Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)
- Worked application or illustrative case: Build a worked example of “A stipulated link uses 1 Msymbol/s throughout”, addressing this associated condition: For two seconds it uses two label bits and code rate 0.5; for one second it uses six label bits and code.... The first mode represents 1 Mbit/s and contributes 2 Mbit over two seconds Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “A stipulated link uses 1 Msymbol/s

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throughout". Using "Application 7B.2. Separate two overhead populations without counting either twice", specify a discriminator and the result expected under each explanation Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A stipulated link uses 1 Msymbol/s throughout, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)
- Scholarly synthesis and implications: Explain what the result about A stipulated link uses 1 Msymbol/s throughout authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)
- Closing: Conclude by answering "A stipulated link uses 1 Msymbol/s throughout" using only the demonstrated evidence; state the remaining decisive verification step Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

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V011-C07-ESSAY-019. Each complete frame contains 1,200 payload positions plus a 40-bit information header. Coding at rate $\frac{4}{5}$ yields 1,550 coded bits, mapped two per data symbol. At 2.5 Msymbol/s with no gaps, send a 5,000-bit request using whole padded frames. Calculate frame count, padding, time, actual request rate and full-frame capacity rate.

- Opening: Present a thesis that answers this precise question: Each complete frame contains 1,200 payload positions plus a 40-bit information header. Identify which evidence would falsify the proposed conclusion Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)
- Core terminology and scope: Define header, gaps, request in the question's particular technical setting; explain how padded, padding, capacity differ if that distinction would change the analysis of "Each complete frame contains 1,200 payload positions plus a 40-bit information header" Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)
- Problem statement and purpose: Frame the actual measurement or decision in the question. One frame uses 1,240 input-information bits, 1,550 coded bits and 775 symbols Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Each complete frame contains 1,200 payload positions plus a 40-bit information header to the claimed result, following "Application 7B.1. Reconcile coded bits, information bits and modulation symbols"; name the

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intermediate states and measurable outputs Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Each complete frame contains 1,200 payload positions plus a 40-bit information header. The ceiling of requires five complete frames Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.2. Separate two overhead populations without counting either twice” that resolves the question about Each complete frame contains 1,200 payload positions plus a 40-bit information header; derive the relevant result with units and stated validity conditions Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Each complete frame contains 1,200 payload positions plus a 40-bit information header. They provide 6,000 payload positions, so 1,000 positions are padding and the final frame carries 200 original request bits Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)
- Worked application or illustrative case: Build a worked example of “Each complete frame contains 1,200 payload positions plus a 40-bit information header”, addressing this associated condition: Coding at rate yields 1,550 coded bits, mapped two per data symbol. One frame uses 1,240 input-information bits, 1,550 coded bits and 775

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symbols Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Each complete frame contains 1,200 payload positions plus a 40-bit information header”. Using “Application 7B.2. Separate two overhead populations without counting either twice”, specify a discriminator and the result expected under each explanation Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Each complete frame contains 1,200 payload positions plus a 40-bit information header, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Scholarly synthesis and implications: Explain what the result about Each complete frame contains 1,200 payload positions plus a 40-bit information header authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)
- Closing: Conclude by answering “Each complete frame contains 1,200 payload positions plus a 40-bit information header” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

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V011-C07-ESSAY-020. Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms. Derive the admissible rate interval, compare it with first-order propagation about 20 ms, and explain why neither result is automatically a 95 percent interval.

- Opening: Present a thesis that answers this precise question: Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms. Identify which evidence would falsify the proposed conclusion Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)
- Core terminology and scope: Define payload, belong, enclosure in the question's particular technical setting; explain how admissible, propagation, automatically differ if that distinction would change the analysis of "Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms" Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Rate is the fixed count divided by positive duration, so its minimum uses 20.02 ms and its maximum uses 19.98 ms Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms to the claimed result, following "Application 7B.4. Distinguish active-burst rate from rate over the full interval"; name

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the intermediate states and measurable outputs Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms. The exact bounds are approximately 1,998,001.998 and 2,002,002.002 bit/s Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.2. Separate two overhead populations without counting either twice” that resolves the question about Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms; derive the relevant result with units and stated validity conditions Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms. The central 20 ms value is 2,000,000 bit/s Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)
- Worked application or illustrative case: Build a worked example of “Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms”, addressing this associated condition: Derive the admissible rate interval, compare it with first-order propagation about 20 ms, and explain.... Rate is the

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fixed count divided by positive duration, so its minimum uses 20.02 ms and its maximum uses 19.98 ms Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms”. Using “Application 7B.2. Separate two overhead populations without counting either twice”, specify a discriminator and the result expected under each explanation Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)
- Scholarly synthesis and implications: Explain what the result about Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)
- Closing: Conclude by answering “Exactly 40,000 payload bits belong to a duration whose deterministic enclosure is 19.98 to 20.02 ms” using only the demonstrated evidence; state the remaining decisive

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verification step Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

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V011-C07-ESSAY-021. A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75. The only admissible code rates are 0.5 and 0.8, and payload-bit fraction is independently admissible anywhere from 0.8 to 1. Give the exact union of rate intervals and determine whether 2.6 Mbit/s is admissible.

- Opening: Present a thesis that answers this precise question: A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75. Identify which evidence would falsify the proposed conclusion Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Core terminology and scope: Define slot, coded, fraction in the question's particular technical setting; explain how admissible, rates, union differ if that distinction would change the analysis of "A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75" Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Before code and payload-bit reductions, the product is 1.5 times four times 0.75, or 4.5 Mbit/s Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75 to the claimed result, following "Application 7B.2. Separate two overhead populations without counting either twice";

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name the intermediate states and measurable outputs Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75. Code rate 0.5 gives the interval from 4.5 times 0.5 times 0.8 to 4.5 times 0.5, namely 1.8 to 2.25 Mbit/s Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.8. Test a positive target against the declared rate limit” that resolves the question about A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75; derive the relevant result with units and stated validity conditions Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75. Code rate 0.8 gives 2.88 to 3.6 Mbit/s Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Worked application or illustrative case: Build a worked example of “A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75”, addressing this associated condition: The only admissible code rates are 0.5 and 0.8, and

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payload-bit fraction is independently admissible.... Before code and payload-bit reductions, the product is 1.5 times four times 0.75, or 4.5 Mbit/s Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75”. Using “Application 7B.8. Test a positive target against the declared rate limit”, specify a discriminator and the result expected under each explanation Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)
- Scholarly synthesis and implications: Explain what the result about A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75 authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Closing: Conclude by answering “A slot rate is fixed at 1.5 Mslot/s with four coded label bits per data slot and data-slot fraction 0.75” using only the demonstrated evidence; state the remaining decisive

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verification step Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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V011-C07-ESSAY-022. During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000. Each stream has no internal duplicates. Exactly 250,000 positions appear in both. Compute summed instance rate and unique-position rate, then give bounds when the overlap count is unavailable.

- Opening: Present a thesis that answers this precise question: During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000. Identify which evidence would falsify the proposed conclusion Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)
- Core terminology and scope: Define accepts, appear, Compute in the question's particular technical setting; explain how summed, instance, unavailable differ if that distinction would change the analysis of "During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000" Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Adding stream instances gives 1,600,000 accepted instances over half a second, or 3.2 Mbit/s Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000 to the claimed result,

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following “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”; name the intermediate states and measurable outputs Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000. For unique positions, apply inclusion and exclusion to the stated identity sets: 900,000 plus 700,000 minus 250,000 equals 1,350,000 positions, giving 2.7 Mbit/s Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.4. Distinguish active-burst rate from rate over the full interval” that resolves the question about During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000; derive the relevant result with units and stated validity conditions Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Evidence and method: Specify the native observations, control records and calculations that would resolve During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000. The overlap is defined by common payload identities, not by equal binary values or similar waveforms Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

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- Worked application or illustrative case: Build a worked example of “During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000”, addressing this associated condition: Each stream has no internal duplicates. Adding stream instances gives 1,600,000 accepted instances over half a second, or 3.2 Mbit/s Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000”. Using “Application 7B.4. Distinguish active-burst rate from rate over the full interval”, specify a discriminator and the result expected under each explanation Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Scholarly synthesis and implications: Explain what the result about During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000

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authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- Closing: Conclude by answering “During one common 0.5 s interval, stream A accepts 900,000 identified payload-bit positions and stream B accepts 700,000” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

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V011-C07-ESSAY-023. An analyst compares the chapter's finite EVM with a vendor summary and finds different values despite using the same capture. Develop an audit based on the cited normalization and symbol-location documentation without treating one implementation's rules as a universal EVM standard.

- Opening: Present a thesis that answers this precise question: An analyst compares the chapter's finite EVM with a vendor summary and finds different values despite using the same capture. Identify which evidence would falsify the proposed conclusion Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Core terminology and scope: Define summary, finds, despite in the question's particular technical setting; explain how audit, cited, documentation differ if that distinction would change the analysis of "An analyst compares the chapter's finite EVM with a vendor summary and finds different values despite using the same capture" Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Problem statement and purpose: Frame the actual measurement or decision in the question. First compare the exact paired symbol population, permitted corrections, reference reconstruction and denominator Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting An analyst compares the chapter's finite EVM with a vendor summary and finds different values despite using the same capture to the claimed

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result, following “Application 7A.10: Audit a complete finite residual vector”; name the intermediate states and measurable outputs Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture. The cited implementation documents a choice between reference-RMS and constellation-maximum normalization, and warns that trace normalization can differ from error-summary normalization Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 7A: a finite, declared EVM comparison” that resolves the question about An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture; derive the relevant result with units and stated validity conditions Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Evidence and method: Specify the native observations, control records and calculations that would resolve An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture. Particular formats can also use special sampling or normalization rules, so retain the selected mode and documented software scope Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

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- Worked application or illustrative case: Build a worked example of “An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture”, addressing this associated condition: Develop an audit based on the cited normalization and symbol-location documentation without treating one.... First compare the exact paired symbol population, permitted corrections, reference reconstruction and... Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture”. Using “Model 7A: a finite, declared EVM comparison”, specify a discriminator and the result expected under each explanation Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture, including the effect of missing measurements and inconsistent operating conditions Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)
- Scholarly synthesis and implications: Explain what the result about An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- Closing: Conclude by answering “An analyst compares the chapter’s finite EVM with a vendor summary and finds different values despite using the same capture” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

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V011-C07-ESSAY-024. A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output. Construct a defensible assessment of waveform evidence, decoded fields, checks, trial population and external attribution. Do not invent an error probability from the supplied facts.

- Opening: Present a thesis that answers this precise question: A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output. Identify which evidence would falsify the proposed conclusion Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Core terminology and scope: Define decoder, decoded, trial in the question's particular technical setting; explain how population, invent, facts differ if that distinction would change the analysis of "A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output" Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Keep the raw waveform observation separate from algorithmic synchronization, decoded fields and any external source claim Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output to the claimed result, following "Defensive Interpretation of Digital Signals"; name

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the intermediate states and measurable outputs Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output. Record decoder version, format assumptions, search alternatives, attempted intervals, exclusions and the actual checks performed Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Turn a quality metric into a reproducible acceptance record” that resolves the question about A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output; derive the relevant result with units and stated validity conditions Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Evidence and method: Specify the native observations, control records and calculations that would resolve A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output. The noise-only control demonstrates that the tested process can produce false structure; it does not establish that every original candidate has that origin or that no signal exists Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Worked application or illustrative case: Build a worked example of “A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output”,

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addressing this associated condition: Construct a defensible assessment of waveform evidence, decoded fields, checks, trial population and.... Keep the raw waveform observation separate from algorithmic synchronization, decoded fields and any external... Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output”. Using “Turn a quality metric into a reproducible acceptance record”, specify a discriminator and the result expected under each explanation Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Scholarly synthesis and implications: Explain what the result about A decoder search yields a few plausible frames from an unknown recording, and a noise-only control also produces plausible output authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Closing: Conclude by answering “A decoder search yields a few plausible frames from an unknown recording, and a noise-only

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control also produces plausible output" using only the demonstrated evidence; state the remaining decisive verification step Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

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V011-C07-ESSAY-025. Design a reproducible acceptance record combining the chapter's EVM and rate-accounting models for an authorized receiver test. Specify the minimum retained data and explain why the two successful calculations still do not establish source identity, uninterrupted acquisition or unique delivered throughput automatically.

- Opening: Present a thesis that answers this precise question: Design a reproducible acceptance record combining the chapter's EVM and rate-accounting models for an authorized receiver test. Identify which evidence would falsify the proposed conclusion Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Core terminology and scope: Define combining, authorized, calculations in the question's particular technical setting; explain how uninterrupted, unique, throughput differ if that distinction would change the analysis of "Design a reproducible acceptance record combining the chapter's EVM and rate-accounting models for an authorized receiver test" Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Bind the sample segment and timing metadata to its reference sequence Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reproducible acceptance record combining the chapter's EVM and rate-accounting models for an authorized receiver test to the claimed result, following "Application 7B.1. Reconcile coded bits, information

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bits and modulation symbols"; name the intermediate states and measurable outputs Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a reproducible acceptance record combining the chapter's EVM and rate-accounting models for an authorized receiver test. Retain the fitted coefficients and both EVM energy sums so the scalar can be reconstructed Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Model 7B: finite rate accounting for symbols, coding and payload" that resolves the question about a reproducible acceptance record combining the chapter's EVM and rate-accounting models for an authorized receiver test; derive the relevant result with units and stated validity conditions Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reproducible acceptance record combining the chapter's EVM and rate-accounting models for an authorized receiver test. For rate accounting, record the positive time interval, slot convention, data symbols, coded bits, complete-block information bits, payload instances, exclusions and any identified duplicate... Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- Worked application or illustrative case: Build a worked example of “a reproducible acceptance record combining the chapter’s EVM and rate-accounting models for an authorized receiver test”, addressing this associated condition: Specify the minimum retained data and explain why the two successful calculations still do not establish.... Bind the sample segment and timing metadata to its reference sequence Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a reproducible acceptance record combining the chapter’s EVM and rate-accounting models for an authorized receiver test”. Using “Model 7B: finite rate accounting for symbols, coding and payload”, specify a discriminator and the result expected under each explanation Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reproducible acceptance record combining the chapter’s EVM and rate-accounting models for an authorized receiver test, including the effect of missing measurements and inconsistent operating conditions Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)
- Scholarly synthesis and implications: Explain what the result about a reproducible acceptance record combining the chapter’s EVM and rate-accounting models for an authorized receiver test authorises the investigator or engineer to claim, and what stronger proposition

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remains unsupported Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- Closing: Conclude by answering “Design a reproducible acceptance record combining the chapter’s EVM and rate-accounting models for an authorized receiver test” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C07-DISCUSSION-001. Should the smallest available EVM value be selected as the receiver's headline quality result?

- 01. Moderator, opening proposition: Introduce the exact dispute, "Should the smallest available EVM value be selected as the receiver's headline quality result?" Put this particular dispute to the panel: Should the smallest available EVM value be selected as the receiver's headline quality result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 02. Student A, terminology and scope: Agree the operational meanings of smallest, available, value and receiver, headline, quality in "Should the smallest available EVM value be selected as the receiver's headline quality result"; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether the smallest available EVM value be selected as the receiver's headline quality result; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in "Application 7A.7: Evaluate a fitted gain on held-out symbols". A smaller number may follow from a changed denominator, greater fitting freedom or removal of difficult intervals Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether the smallest available

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EVM value be selected as the receiver's headline quality result; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in "Application 7A.7: Evaluate a fitted gain on held-out symbols". A smaller number may follow from a changed denominator, greater fitting freedom or removal of difficult intervals Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare the questions answered by fixed-reference, fitted-reference, post-equalization and selected-interval metrics Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether the smallest available EVM value be selected as the receiver's headline quality result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether the smallest available EVM value be selected as the receiver's headline quality result; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether the smallest available

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EVM value be selected as the receiver's headline quality result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether the smallest available EVM value be selected as the receiver's headline quality result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether the smallest available EVM value be selected as the receiver's headline quality result: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether the smallest available EVM value be selected as the receiver's headline quality result. The group should agree on the measurement purpose before selecting the primary result, then retain the permitted correction policy, coefficients and population Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether the smallest available EVM value be selected as the receiver's headline quality result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether the smallest available EVM value be selected as the receiver's headline quality result. The group should agree on the measurement purpose before selecting the primary result, then retain the permitted correction policy, coefficients and population Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether the smallest available EVM value be selected as the receiver's headline quality result and Compare the questions answered by fixed-reference, fitted-reference, post-equalization and selected-interval…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and

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field boundaries. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether the smallest available EVM value be selected as the receiver’s headline quality result”, addressing “Compare the questions answered by fixed-reference, fitted-reference, post-equalization and selected-interval…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should the smallest available EVM value be selected as the receiver’s headline quality result”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should the smallest available EVM value be selected as the receiver’s headline quality result”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported

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assertion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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V011-C07-DISCUSSION-002. A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. How should the team respond?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. How should the team respond?” Put this particular dispute to the panel: A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. How should the team respond. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, requests, decibels and values, errors, respond in “A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. How should the team respond”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.5: Compare RMS and constellation-maximum normalization”. Ratios below one have negative decibel values under twenty times the base-ten logarithm Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.5: Compare RMS and constellation-maximum normalization”. Ratios below one have negative decibel values under twenty times the base-ten logarithm Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish the nonnegative linear magnitude ratio from its logarithmic representation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A reviewer requests that negative EVM decibels be changed to

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positive values because errors cannot be negative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. Changing the sign would define another reported quantity and reverse the stated convention Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what

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evidence would reverse the conclusion. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. Changing the sign would define another reported quantity and reverse the stated convention Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative and How should the team respond; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative”, addressing “How should the team respond”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. How should the team respond”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reviewer requests that negative EVM decibels be changed to positive values because errors cannot be negative. How should the team respond”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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V011-C07-DISCUSSION-003. When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested?” Put this particular dispute to the panel: When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 02. Student A, terminology and scope: Agree the operational meanings of complex-gain, justified, correction and conceal, quantity, tested in “When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Removing a constant gain and phase offset may be appropriate for residual modulation quality after alignment; it can conceal a discrepancy when absolute amplitude or phase calibration is the… Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Removing a constant gain and phase offset may be appropriate for residual modulation quality after alignment; it can conceal a discrepancy when absolute amplitude or phase calibration is the… Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Relate the fit to the intended measurand Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 08. Student D, answer to Student E: Design a discriminating experiment involving When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When is a complex-gain fit a justified correction, and when would it

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conceal the quantity being tested: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested. Keep the fitted coefficient visible and specify its training set, allowed complexity and evaluation use Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested. Keep the fitted coefficient visible and specify its training set, allowed complexity and evaluation use Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested and Removing a constant gain and phase offset may be appropriate for residual modulation quality after alignment;…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested”, addressing “Removing a constant gain and phase offset may be appropriate for residual modulation quality after alignment;...”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When is a complex-gain fit a justified correction, and when would it conceal the quantity being tested”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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V011-C07-DISCUSSION-004. Does using a held-out interval make an EVM assessment independent?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Does using a held-out interval make an EVM assessment independent?” Put this particular dispute to the panel: Does using a held-out interval make an EVM assessment independent. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 02. Student A, terminology and scope: Agree the operational meanings of held-out, interval, make and assessment, independent, measurement in “Does using a held-out interval make an EVM assessment independent”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Does

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using a held-out interval make an EVM assessment independent; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Holding out symbol pairs avoids direct fitting on those pairs for the declared estimator, but shared clock metadata, reference construction, signal conditions and later tuning can preserve… Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does using a held-out interval make an EVM assessment independent; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Holding out symbol pairs avoids direct fitting on those pairs for the declared estimator, but shared clock metadata, reference construction, signal conditions and later tuning can preserve… Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State exactly what has been excluded from fitting and parameter selection Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Does using a held-out interval make an EVM assessment independent: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does using a held-out interval make an EVM assessment independent; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Does using a held-out interval make an EVM assessment independent: specify the altered receiver

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state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Does using a held-out interval make an EVM assessment independent, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Does using a held-out interval make an EVM assessment independent: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Does using a held-out interval make an EVM assessment independent. If results from the held-out interval guide another parameter choice, its role has changed and another evaluation strategy may be needed Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Does using a held-out interval make an EVM assessment independent, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Does using a held-out interval make an EVM assessment independent. If results from the held-out interval guide another parameter choice, its role has changed and another evaluation strategy may be needed Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.9 Application 7A.3: Preserve a DC impairment when fitting only complex gain (p. 3754)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Does using a held-out interval make an EVM assessment independent and State exactly what has been excluded from fitting and parameter selection; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Does using a held-out interval make an EVM assessment independent”, addressing “State exactly what has

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been excluded from fitting and parameter selection"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Does using a held-out interval make an EVM assessment independent", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Does using a held-out interval make an EVM assessment independent". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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V011-C07-DISCUSSION-005. Two records have the same EVM. What additional retained evidence would help distinguish a common offset, conjugate leakage and a frequency ramp?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two records have the same EVM. What additional retained evidence would help distinguish a common offset, conjugate leakage and a frequency ramp?” Put this particular dispute to the panel: Two records have the same EVM. What additional retained evidence would help distinguish a common offset, conjugate leakage and a frequency ramp. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 02. Student A, terminology and scope: Agree the operational meanings of records, additional, help and conjugate, leakage, ramp in “Two records have the same EVM. What additional retained evidence would help distinguish a common offset, conjugate leakage and a frequency ramp”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two records have the same EVM; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.4: Expose a conjugate-image impairment”. A common offset can appear in the residual mean; a conjugate term can vary with the conjugated reference; a frequency ramp can produce ordered phase progression Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two records have the same EVM; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.4: Expose a conjugate-image impairment”. A common offset can appear in the residual mean; a conjugate term can vary with the conjugated reference; a frequency ramp can produce ordered phase progression Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Inspect the residual vector and its association with symbol identity and time Put two specific questions to Student D about the stated competing options

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and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two records have the same EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two records have the same EVM; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two records have the same EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two records have the same EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two records have the same EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two records have the same EVM. Those patterns guide hypotheses but do not alone prove their physical origin Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two records have the same EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.10 Application 7A.4: Expose a conjugate-image impairment (p. 3755)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two records have the same EVM. Those patterns guide hypotheses but do not alone prove their physical origin Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two records have the same EVM and What additional retained evidence would help distinguish a common offset, conjugate leakage and a…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two records have the same EVM”, addressing “What additional retained evidence would help distinguish a common offset, conjugate leakage and a…”; specify the exact measurement or evidential gap on which the speakers still

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differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two records have the same EVM. What additional retained evidence would help distinguish a common offset, conjugate leakage and a frequency ramp”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two records have the same EVM. What additional retained evidence would help distinguish a common offset, conjugate leakage and a frequency ramp”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

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V011-C07-DISCUSSION-006. Should acquisition symbols be excluded from a modulation-quality result?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should acquisition symbols be excluded from a modulation-quality result?” Put this particular dispute to the panel: Should acquisition symbols be excluded from a modulation-quality result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 02. Student A, terminology and scope: Agree the operational meanings of acquisition, symbols, excluded and modulation-quality, measurement, evidence in “Should acquisition symbols be excluded from a modulation-quality result”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of

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whether acquisition symbols be excluded from a modulation-quality result; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define the symbol experiment before fitting the constellation”. Exclusion can define a useful steady-state result, but acquisition duration, errors and failures remain relevant to the broader task Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether acquisition symbols be excluded from a modulation-quality result; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define the symbol experiment before fitting the constellation”. Exclusion can define a useful steady-state result, but acquisition duration, errors and failures remain relevant to the broader task Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider whether the decision concerns settled payload quality, burst capture success or the complete event Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether acquisition symbols be excluded from a modulation-quality result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether acquisition symbols be excluded from a modulation-quality result; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether acquisition symbols be excluded from a modulation-quality result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether acquisition symbols be excluded from a modulation-quality result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether acquisition symbols be excluded from a modulation-quality result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether acquisition symbols be excluded from a modulation-quality result. Specify the selection criterion before judging the result and retain enough information to reconstruct complete-record and conditional metrics where needed Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether acquisition symbols be excluded from a modulation-quality result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether acquisition symbols be excluded from a

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modulation-quality result. Specify the selection criterion before judging the result and retain enough information to reconstruct complete-record and conditional metrics where needed Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether acquisition symbols be excluded from a modulation-quality result and Consider whether the decision concerns settled payload quality, burst capture success or the complete event; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether acquisition symbols be excluded from a modulation-quality result”, addressing “Consider whether the decision concerns settled payload quality, burst capture success or the complete event”; specify the exact measurement or evidential

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gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should acquisition symbols be excluded from a modulation-quality result”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should acquisition symbols be excluded from a modulation-quality result”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

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V011-C07-DISCUSSION-007. Can two EVM percentages be compared after confirming only that both instruments use the same modulation label?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can two EVM percentages be compared after confirming only that both instruments use the same modulation label?” Put this particular dispute to the panel: Can two EVM percentages be compared after confirming only that both instruments use the same modulation label. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 02. Student A, terminology and scope: Agree the operational meanings of percentages, compared, instruments and same, modulation, label in “Can two EVM percentages be compared after confirming only that both instruments use the same modulation label”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can two EVM percentages be compared after confirming only that both instruments use the same modulation label; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Error Vector Magnitude and Quality Metrics”. The same format label can coexist with different summary and trace conventions or special handling for a particular mode Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can two EVM percentages be

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compared after confirming only that both instruments use the same modulation label; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Error Vector Magnitude and Quality Metrics”. The same format label can coexist with different summary and trace conventions or special handling for a particular mode Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Audit reference construction, selected symbol locations, allowed corrections, weighting, timing, normalization and implementation scope Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can two EVM percentages be compared after confirming only that both instruments use the same modulation label: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can two EVM percentages be compared after confirming only that both instruments use the same modulation label; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can two EVM percentages be compared after confirming only that both instruments use the same

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modulation label: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can two EVM percentages be compared after confirming only that both instruments use the same modulation label, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can two EVM percentages be compared after confirming only that both instruments use the same modulation label: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can two EVM percentages be compared after confirming only that both instruments use the same modulation label. Determine whether exported paired symbols permit a common recalculation; if not, describe the unresolved comparison limit Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can two EVM percentages be compared after confirming only that both instruments use the same modulation label, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can two EVM percentages be compared after confirming only that both instruments use the same modulation label. Determine whether exported paired symbols permit a common recalculation; if not, describe the unresolved comparison limit Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can two EVM percentages be compared after confirming only that both instruments use the same modulation label and Audit reference construction, selected symbol locations, allowed corrections, weighting, timing,…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can two EVM percentages be compared after confirming only that both instruments use the same modulation label”, addressing “Audit reference construction, selected symbol locations, allowed corrections, weighting, timing,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can two EVM percentages be compared after confirming only that both instruments use the same modulation label”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can two EVM percentages be compared after confirming only that both instruments use the same modulation label”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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V011-C07-DISCUSSION-008. A single severe residual barely changes a long-record RMS EVM. Should the report add a peak metric?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A single severe residual barely changes a long-record RMS EVM. Should the report add a peak metric?” Put this particular dispute to the panel: A single severe residual barely changes a long-record RMS EVM. Should the report add a peak metric. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 02. Student A, terminology and scope: Agree the operational meanings of single, residual, changes and report, peak, metric in “A single severe residual barely changes a long-record RMS EVM. Should the report add a peak metric”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A single severe residual barely changes a long-record RMS EVM; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.5: Compare RMS and constellation-maximum normalization”. A largest residual can expose a feature that a long RMS aggregate dilutes, but it does not replace the energy measure or identify the fault mechanism Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A single severe residual barely changes a long-record RMS EVM; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.5: Compare RMS and constellation-maximum normalization”. A largest residual can expose a feature that a long RMS aggregate dilutes, but it does not replace the energy measure or identify the fault mechanism Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask whether isolated errors matter to the decision and define the peak’s population and normalization if it is reported Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A single severe residual barely changes a long-record RMS EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A single severe residual barely changes a long-record RMS EVM; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A single severe residual barely changes a long-record RMS EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A single severe residual barely changes a long-record RMS EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A single severe residual barely changes a long-record RMS EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A single severe residual barely changes a long-record RMS EVM. Retain the time location and surrounding data so a transient can be examined against acquisition, filtering and continuity records Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A single severe residual barely changes a long-record RMS EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A single severe residual barely changes a long-record RMS EVM. Retain the time location and surrounding data so a transient can be examined against acquisition, filtering and continuity records Respond point by point to Student J. Distinguish a

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verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A single severe residual barely changes a long-record RMS EVM and Should the report add a peak metric; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A single severe residual barely changes a long-record RMS EVM”, addressing “Should the report add a peak metric”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A single severe residual barely changes a long-record RMS EVM. Should the report add a peak metric”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A single severe residual barely changes a long-record RMS EVM. Should the report add a peak metric”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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V011-C07-DISCUSSION-009. Two software tools agree to every displayed digit. Is that enough to accept a symbol-quality result?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two software tools agree to every displayed digit. Is that enough to accept a symbol-quality result?” Put this particular dispute to the panel: Two software tools agree to every displayed digit. Is that enough to accept a symbol-quality result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 02. Student A, terminology and scope: Agree the operational meanings of software, tools, agree and displayed, accept, symbol-quality in “Two software tools agree to every displayed digit. Is that enough to accept a symbol-quality result”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two software tools agree to every displayed digit; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Turn a quality metric into a reproducible acceptance record”. Tools can reproduce the same finite sum correctly while using the same wrong reference, clock metadata, mapping or synchronization estimate Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two software tools agree to every displayed digit; explain what each record can establish State

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what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Turn a quality metric into a reproducible acceptance record”. Tools can reproduce the same finite sum correctly while using the same wrong reference, clock metadata, mapping or synchronization estimate Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate arithmetic agreement from validation of shared premises Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two software tools agree to every displayed digit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two software tools agree to every displayed digit; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two software tools agree to every displayed digit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two software tools agree to every displayed digit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two software tools agree to every displayed digit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two software tools agree to every displayed digit. Identify a known-input challenge that would fail under the suspected common error, and retain its actual outcome Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two software tools agree to every displayed digit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two software tools agree to every displayed digit. Identify a known-input challenge that would fail under the suspected common error, and retain its actual outcome Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two software tools agree to every displayed digit and Is that enough to accept a symbol-quality result; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.15 Application 7A.9: Separate constellation rotation from validated symbol mapping (p. 3760)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two software tools agree to every displayed digit”, addressing “Is that enough to accept a symbol-quality result”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two software tools agree to every displayed digit. Is that enough to accept a symbol-quality result”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two software tools agree to every displayed digit. Is that enough to accept a symbol-quality result”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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V011-C07-DISCUSSION-010. A more flexible equalizer improves both the constellation display and training EVM. What evidence would justify retaining it?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A more flexible equalizer improves both the constellation display and training EVM. What evidence would justify retaining it?” Put this particular dispute to the panel: A more flexible equalizer improves both the constellation display and training EVM. What evidence would justify retaining it. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 02. Student A, terminology and scope: Agree the operational meanings of flexible, equalizer, improves and constellation, training, retaining in “A more flexible equalizer improves both the constellation display and training EVM. What evidence would justify retaining it”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A more flexible equalizer improves both the constellation display and training EVM; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Retain coefficient count, regularization, training duration, convergence and adaptation policy, along with pre-compensation results when the original path matters Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A more flexible equalizer improves both the constellation display and training EVM; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Retain coefficient count, regularization, training duration, convergence and adaptation policy, along with pre-compensation results when the original path matters Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Define the intended compensation and inspect performance on data excluded from selecting and fitting the model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A more flexible equalizer improves both the constellation display and training EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A more flexible equalizer improves both the constellation display and training EVM; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A more flexible equalizer improves both the constellation display and training EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A more flexible equalizer improves both the constellation display and training EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A more flexible equalizer improves both the constellation display

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and training EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A more flexible equalizer improves both the constellation display and training EVM. A stable improvement under appropriate challenges can support the chosen processing, but visual tightness alone cannot establish transfer or locate distortion Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A more flexible equalizer improves both the constellation display and training EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A more flexible equalizer improves both the constellation display and training EVM. A stable improvement under appropriate challenges can support the chosen processing, but visual tightness alone cannot establish transfer or locate distortion Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A more flexible equalizer improves both the constellation display and training EVM and What evidence would justify retaining it; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A more flexible equalizer improves both the constellation display and training EVM”, addressing “What evidence would justify retaining it”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A more flexible equalizer improves both the constellation display and training EVM. What evidence would justify retaining it”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A more flexible equalizer improves both the constellation display and training EVM. What evidence would justify retaining it”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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V011-C07-DISCUSSION-011. A receiver locks only after a long interval. Can the successful final constellation characterize a short transient that began the capture?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A receiver locks only after a long interval. Can the successful final constellation characterize a short transient that began the capture?” Put this particular dispute to the panel: A receiver locks only after a long interval. Can the successful final constellation characterize a short transient that began the capture. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

- 02. Student A, terminology and scope: Agree the operational meanings of locks, long, successful and final, constellation, characterize in “A receiver locks only after a long interval. Can the successful final constellation characterize a short transient that began the capture”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A receiver locks only after a long interval; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define the symbol experiment before fitting the constellation”. A later settled result may describe a different interval and cannot retroactively establish valid synchronization during the transient Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A receiver locks only after a long interval; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define the symbol experiment before fitting the constellation”. A later settled result may describe a different interval and cannot retroactively establish valid synchronization during the transient Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare the event duration with the acquisition history and the actual symbols included in the metric Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A receiver locks only after a long interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver locks only after a long interval; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A receiver locks only after a long interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a

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repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A receiver locks only after a long interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A receiver locks only after a long interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A receiver locks only after a long interval. Preserve lock indicators, timing estimates, excluded samples and any independent waveform evidence from the early interval Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A receiver locks only after a long interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A receiver locks only after a long interval. Preserve lock indicators, timing estimates, excluded samples and any independent waveform evidence from the early interval Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A receiver locks only after a long interval and Can the successful final constellation characterize a short transient that began the capture; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A receiver locks only after a long interval”, addressing “Can the successful final constellation characterize a short transient that began the capture”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A receiver locks only after a long interval. Can the successful final constellation characterize a short transient that began the capture”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A receiver locks only after a long interval. Can the successful final constellation characterize a short transient that began the capture”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

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V011-C07-DISCUSSION-012. How should the team handle differences between two nominally identical receive filters at the start and end of a capture?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should the team handle differences between two nominally identical receive filters at the start and end of a capture?” Put this particular dispute to the panel: How should the team handle differences between two nominally identical receive filters at the start and end of a capture. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 02. Student A, terminology and scope: Agree the operational meanings of differences, nominally, identical and filters, start, capture in “How should the team handle differences between two nominally identical receive filters at the start and end of a capture”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should the team handle differences between two nominally identical receive filters at the start and end of a capture; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Turn a quality metric into a reproducible acceptance record”. Boundary handling can differ when prior or future samples are unavailable, even with the same filter-family name Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of how should the team handle differences between two nominally identical receive filters at the start and end of a capture; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Turn a quality metric into a reproducible acceptance record”. Boundary handling can differ when prior or future samples are unavailable, even with the same filter-family name Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare actual coefficients, span, delay, sample-rate convention, scaling and initialization before attributing the difference to the signal Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 08. Student D, answer to Student E: Design a discriminating experiment involving how should the team handle differences between two nominally identical receive filters at the start and end of a capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should the team handle differences between two nominally identical receive filters at the start and end of a capture; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should the team handle differences between two nominally identical receive filters at the start and end of a capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should the team handle differences between two nominally identical receive filters at the start and end of a capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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how should the team handle differences between two nominally identical receive filters at the start and end of a capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should the team handle differences between two nominally identical receive filters at the start and end of a capture. Use a known sequence with disclosed history to test the implementations, and define any excluded edge interval before evaluating quality Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should the team handle differences between two nominally identical receive filters at the start and end of a capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible

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instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should the team handle differences between two nominally identical receive filters at the start and end of a capture. Use a known sequence with disclosed history to test the implementations, and define any excluded edge interval before evaluating quality Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.3 Matched Filtering, Pulse Shaping, and Channel Effects (p. 3741)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should the team handle differences between two nominally identical receive filters at the start and end of a capture and Compare actual coefficients, span, delay, sample-rate convention, scaling and initialization before…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within

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authorised laboratory and field boundaries. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should the team handle differences between two nominally identical receive filters at the start and end of a capture”, addressing “Compare actual coefficients, span, delay, sample-rate convention, scaling and initialization before…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should the team handle differences between two nominally identical receive filters at the start and end of a capture”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should the team handle differences between two nominally identical receive filters at the start and end of a capture”. Allocate the next measurement and documentary action to named student roles, and require each

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participant to distinguish accepted evidence from an unsupported assertion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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V011-C07-DISCUSSION-013. What claim does a noise-only decoder control support when it produces apparently plausible identifiers?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What claim does a noise-only decoder control support when it produces apparently plausible identifiers?” Put this particular dispute to the panel: What claim does a noise-only decoder control support when it produces apparently plausible identifiers. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 02. Student A, terminology and scope: Agree the operational meanings of claim, decoder, control and support, produces, identifiers in “What claim does a noise-only decoder control support when it produces apparently plausible identifiers”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What claim does a noise-only decoder control support when it produces apparently plausible identifiers; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Defensive Interpretation of Digital Signals”. It does not prove that every candidate from the original capture was false or that the band contained no communication signal Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What claim does a noise-only decoder control support when it produces apparently plausible

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identifiers; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Defensive Interpretation of Digital Signals”. It does not prove that every candidate from the original capture was false or that the band contained no communication signal Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It demonstrates a false-output mechanism for the tested processing and control conditions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What claim does a noise-only decoder control support when it produces apparently plausible identifiers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What claim does a noise-only decoder control support when it produces apparently plausible identifiers; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What claim does a noise-only decoder control support when it produces apparently plausible identifiers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a

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repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What claim does a noise-only decoder control support when it produces apparently plausible identifiers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What claim does a noise-only decoder control support when it produces apparently plausible identifiers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What claim does a noise-only decoder control support when it produces apparently plausible identifiers. Preserve trial counts, format searches, checks and failed outputs so apparent rarity is not overstated Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What claim does a noise-only decoder control support when it produces apparently plausible identifiers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What claim does a noise-only decoder control

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support when it produces apparently plausible identifiers. Preserve trial counts, format searches, checks and failed outputs so apparent rarity is not overstated Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What claim does a noise-only decoder control support when it produces apparently plausible identifiers and It demonstrates a false-output mechanism for the tested processing and control conditions; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What claim does a noise-only decoder control support when it produces apparently plausible identifiers”, addressing “It demonstrates a false-output mechanism for the

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tested processing and control conditions"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "What claim does a noise-only decoder control support when it produces apparently plausible identifiers", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "What claim does a noise-only decoder control support when it produces apparently plausible identifiers". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

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V011-C07-DISCUSSION-014. Should a passed CRC permit an analyst to attribute a frame to a specific physical emitter?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a passed CRC permit an analyst to attribute a frame to a specific physical emitter?” Put this particular dispute to the panel: Should a passed CRC permit an analyst to attribute a frame to a specific physical emitter. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 02. Student A, terminology and scope: Agree the operational meanings of passed, permit, analyst and specific, physical, emitter in “Should a passed CRC permit an analyst to attribute a frame to a specific physical emitter”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Metric Validation and Held-Out Data”. A pass can strengthen confidence in a particular decoded structure under the tested assumptions, while identity or physical-origin claims need different evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Metric Validation and Held-Out Data”. A pass can strengthen confidence in a particular decoded structure under the tested assumptions, while identity or physical-origin claims need different evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate the decoded consistency relation from authentication and localization Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter: specify

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the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter. Discuss replay, relaying, spoofed fields and common-format reuse as possibilities only where relevant, without claiming that they occurred Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter. Discuss replay, relaying, spoofed fields and common-format reuse as possibilities only where relevant, without claiming that they occurred Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a passed CRC permit an analyst to attribute a frame to a specific physical emitter and Separate the decoded consistency relation from authentication and localization; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a passed CRC permit an analyst

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to attribute a frame to a specific physical emitter", addressing "Separate the decoded consistency relation from authentication and localization"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Should a passed CRC permit an analyst to attribute a frame to a specific physical emitter", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Should a passed CRC permit an analyst to attribute a frame to a specific physical emitter". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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V011-C07-DISCUSSION-015. Can a valid waveform-quality result authorize deeper content recovery?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a valid waveform-quality result authorize deeper content recovery?” Put this particular dispute to the panel: Can a valid waveform-quality result authorize deeper content recovery. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 02. Student A, terminology and scope: Agree the operational meanings of waveform-quality, authorize, deeper and content, recovery, measurement in “Can a valid waveform-quality result authorize deeper content recovery”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a

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valid waveform-quality result authorize deeper content recovery; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.6: Make selection and weighting visible”. Review the agreed acquisition, processing, retention and reporting scope before expanding from waveform classification to content Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a valid waveform-quality result authorize deeper content recovery; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.6: Make selection and weighting visible”. Review the agreed acquisition, processing, retention and reporting scope before expanding from waveform classification to content Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Technical capability and task authority answer different questions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a valid waveform-quality result authorize

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deeper content recovery: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a valid waveform-quality result authorize deeper content recovery; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a valid waveform-quality result authorize deeper content recovery: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a valid waveform-quality result authorize deeper content recovery, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a valid waveform-quality result authorize deeper content recovery: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a valid waveform-quality result authorize deeper content recovery. A valid EVM or plausible decoder output does not supply missing authorization Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a valid waveform-quality result authorize deeper content recovery, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a valid waveform-quality result authorize deeper content recovery. A valid EVM or plausible decoder output does not supply missing authorization Respond point by point to Student J. Distinguish a verified observation from a conditional

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inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a valid waveform-quality result authorize deeper content recovery and Technical capability and task authority answer different questions; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a valid waveform-quality result authorize deeper content recovery”, addressing “Technical capability and task authority answer different questions”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that

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remains unresolved. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can a valid waveform-quality result authorize deeper content recovery”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can a valid waveform-quality result authorize deeper content recovery”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.17 Error Vector Magnitude and Quality Metrics (p. 3762)

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V011-C07-DISCUSSION-016. Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations?” Put this particular dispute to the panel: Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 02. Student A, terminology and scope: Agree the operational meanings of slots, coded, bits and payload, instances, populations in “Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.1. Reconcile coded bits, information bits and modulation symbols”. A pilot consumes a slot, coding adds label-bit redundancy, headers consume information-bit capacity and repeated payload can add instances without adding unique content Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.1. Reconcile coded bits, information bits and modulation symbols”. A pilot consumes a slot, coding adds label-bit redundancy, headers consume information-bit capacity and repeated payload can add instances without adding unique content Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Each count supports a different reduction and denominator Put two specific questions to

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Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should

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be collected first and what uncertainty remains if it is missing. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations. Reconstruct the count chain for a concrete complete interval and check that every ratio uses its own population Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

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- 14. Student J, Socratic challenge to Student I: For the precise observation involving Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations. Reconstruct the count chain for a concrete complete interval and check that every ratio uses its own population Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Why does the chapter keep symbol slots,

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coded bits, information bits and payload instances as separate populations and Each count supports a different reduction and denominator; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations”, addressing “Each count supports a different reduction and denominator”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations”, specifying the next test, responsible measurement

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record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Why does the chapter keep symbol slots, coded bits, information bits and payload instances as separate populations”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

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V011-C07-DISCUSSION-017. Should a burst link advertise its active symbol clock or its wall-interval payload rate?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a burst link advertise its active symbol clock or its wall-interval payload rate?” Put this particular dispute to the panel: Should a burst link advertise its active symbol clock or its wall-interval payload rate. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 02. Student A, terminology and scope: Agree the operational meanings of burst, link, active and symbol, clock, payload in “Should a burst link advertise its active symbol clock or its wall-interval payload rate”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a burst link advertise its active symbol clock or its wall-interval payload rate; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 7B: finite rate accounting for symbols, coding and payload”. The active clock describes symbol spacing during transmission; the wall-interval payload rate includes the declared guards, idle periods or other elapsed time Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a burst link advertise

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its active symbol clock or its wall-interval payload rate; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 7B: finite rate accounting for symbols, coding and payload”. The active clock describes symbol spacing during transmission; the wall-interval payload rate includes the declared guards, idle periods or other elapsed time Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Both can be useful when clearly named Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a burst link advertise its active symbol clock or its wall-interval payload rate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a burst link advertise its active symbol clock or its wall-interval payload rate; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a burst link advertise its active symbol clock or its wall-interval payload rate: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a burst link advertise its active symbol clock or its wall-interval payload rate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a burst link advertise its active symbol clock or its wall-interval payload rate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a burst link advertise its active symbol clock or its wall-interval payload rate. Define the numerator, interval and any nominal opportunity grid, then calculate the relationship from common counts Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a burst link advertise its active symbol clock or its wall-interval payload rate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a burst link advertise its active symbol clock or its wall-interval payload rate. Define the numerator, interval and any nominal opportunity grid, then calculate the relationship from common counts Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a burst link advertise its active symbol clock or its wall-interval payload rate and The active clock describes symbol spacing during transmission; the wall-interval payload rate includes the…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a burst link advertise its active symbol clock or its wall-interval payload rate”, addressing “The active clock describes symbol spacing during transmission; the wall-interval payload rate includes the…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a burst link advertise its active symbol clock or its wall-interval payload rate”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a burst link advertise its active symbol clock or its wall-interval payload rate”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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V011-C07-DISCUSSION-018. Is one average modulation order and one average code rate enough to summarize an adaptive link?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is one average modulation order and one average code rate enough to summarize an adaptive link?” Put this particular dispute to the panel: Is one average modulation order and one average code rate enough to summarize an adaptive link. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 02. Student A, terminology and scope: Agree the operational meanings of average, modulation, order and code, adaptive, link in “Is one average modulation order and one average code rate enough to summarize an adaptive link”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is one average modulation order and one average code rate enough to summarize an adaptive link; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”. The aggregate payload rate follows total counts divided by total elapsed time; separate averages can destroy the joint relationship and give the wrong result Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is one average modulation order and one average code rate enough to summarize an adaptive link; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”. The aggregate payload rate follows total counts divided by total elapsed time; separate averages can destroy the joint relationship and give the wrong result Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check how the two factors vary together and how long each realized mode persists Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or

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observation would discriminate between them without changing the measurand. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Is one average modulation order and one average code rate enough to summarize an adaptive link: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is one average modulation order and one average code rate enough to summarize an adaptive link; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is one average modulation order and one average code rate enough to summarize an adaptive link: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is one average modulation order and one average code rate enough to summarize an adaptive link, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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Is one average modulation order and one average code rate enough to summarize an adaptive link: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is one average modulation order and one average code rate enough to summarize an adaptive link. A distribution or schedule may summarize the modes only when it is actually known and its weighting is stated Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is one average modulation order and one average code rate enough to summarize an adaptive link, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is one average modulation order and one average code rate enough to summarize an adaptive link. A distribution or schedule may summarize the modes only when it is actually known and its weighting is stated Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is one average modulation order and one average code rate enough to summarize an adaptive link and Check how the two factors vary together and how long each realized mode persists; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is one average modulation order and one average code rate enough to summarize an adaptive link”, addressing “Check how the two factors vary together and how long each realized mode persists”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Is one average modulation order and one average code rate enough to summarize an adaptive link”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Is one average modulation order and one average code rate enough to summarize an adaptive link”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

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V011-C07-DISCUSSION-019. A short request achieves less payload rate than the advertised full-frame capacity. When is that expected rather than evidence of a receiver defect?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A short request achieves less payload rate than the advertised full-frame capacity. When is that expected rather than evidence of a receiver defect?” Put this particular dispute to the panel: A short request achieves less payload rate than the advertised full-frame capacity. When is that expected rather than evidence of a receiver defect. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 02. Student A, terminology and scope: Agree the operational meanings of request, payload, advertised and capacity, expected, defect in “A short request achieves less payload rate than the advertised full-frame capacity. When is that expected rather than evidence of a receiver defect”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A short request achieves less payload rate than the advertised full-frame capacity; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.3. Count disjoint pilot and nonpayload slots explicitly”. A request that does not fill the final frame can use the same symbol clock and coding correctly while delivering fewer original request bits per elapsed time than a repeating full-frame stream Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A short request achieves less payload rate than the advertised full-frame capacity; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.3. Count disjoint pilot and nonpayload slots explicitly”. A request that does not fill the final frame can use the same symbol clock and coding correctly while delivering fewer original request bits per elapsed time than a repeating full-frame stream Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the actual frame

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rules to count whole frames, headers and final padding Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A short request achieves less payload rate than the advertised full-frame capacity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A short request achieves less payload rate than the advertised full-frame capacity; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.10 Application 7B.10.

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Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A short request achieves less payload rate than the advertised full-frame capacity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A short request achieves less payload rate than the advertised full-frame capacity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A short request achieves less payload rate than the advertised full-frame capacity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A short request achieves less payload rate than the advertised full-frame capacity. Preserve both the capacity denominator and the actual request numerator Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A short request achieves less payload rate than the advertised full-frame capacity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the

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proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A short request achieves less payload rate than the advertised full-frame capacity. Preserve both the capacity denominator and the actual request numerator Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A short request achieves less payload rate than the advertised full-frame capacity and When is that expected rather than evidence of a receiver defect; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and

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field boundaries. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A short request achieves less payload rate than the advertised full-frame capacity”, addressing “When is that expected rather than evidence of a receiver defect”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A short request achieves less payload rate than the advertised full-frame capacity. When is that expected rather than evidence of a receiver defect”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A short request achieves less payload rate than the advertised full-frame capacity. When is that expected rather than evidence of a receiver defect”. Allocate the next measurement and documentary action to named student roles, and require each participant to

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distinguish accepted evidence from an unsupported assertion.

Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

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V011-C07-DISCUSSION-020. When may simultaneous stream rates be added as useful throughput?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When may simultaneous stream rates be added as useful throughput?” Put this particular dispute to the panel: When may simultaneous stream rates be added as useful throughput. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 02. Student A, terminology and scope: Agree the operational meanings of simultaneous, stream, rates and added, useful, throughput in “When may simultaneous stream rates be added as useful throughput”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When may simultaneous stream rates be added as useful throughput; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “I/Q-derived modulation identity: distinguish discriminating features from unique source attribution”. Equal binary values are not sufficient to establish duplicates, and differing waveforms are not sufficient to establish unique content Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When may simultaneous

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stream rates be added as useful throughput; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “I/Q-derived modulation identity: distinguish discriminating features from unique source attribution”. Equal binary values are not sufficient to establish duplicates, and differing waveforms are not sufficient to establish unique content Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require compatible elapsed intervals and acceptance definitions, then determine whether the payload identities are disjoint Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source:

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§7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 08. Student D, answer to Student E: Design a discriminating experiment involving When may simultaneous stream rates be added as useful throughput: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When may simultaneous stream rates be added as useful throughput; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When may simultaneous stream rates be added as useful throughput: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When may simultaneous stream rates be added as useful throughput, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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When may simultaneous stream rates be added as useful throughput: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When may simultaneous stream rates be added as useful throughput. If overlap is known, remove repeated identified positions for a unique-count claim; if it is unknown, state bounds or retain the instance-rate label Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When may simultaneous stream rates be added as useful throughput, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When may simultaneous stream rates be added as useful throughput. If overlap is known, remove repeated identified positions for a unique-count claim; if it is unknown, state bounds or retain the instance-rate label Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When may simultaneous stream rates be added as useful throughput and Require compatible elapsed intervals and acceptance definitions, then determine whether the payload…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains

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within authorised laboratory and field boundaries. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When may simultaneous stream rates be added as useful throughput”, addressing “Require compatible elapsed intervals and acceptance definitions, then determine whether the payload…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When may simultaneous stream rates be added as useful throughput”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When may simultaneous stream rates be added as useful throughput”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence

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from an unsupported assertion. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

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V011-C07-DISCUSSION-021. Should a deterministic rate enclosure be reported with a confidence percentage?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a deterministic rate enclosure be reported with a confidence percentage?” Put this particular dispute to the panel: Should a deterministic rate enclosure be reported with a confidence percentage. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

- 02. Student A, terminology and scope: Agree the operational meanings of deterministic, rate, enclosure and reported, confidence, percentage in “Should a deterministic rate enclosure be reported with a confidence percentage”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a deterministic rate enclosure be reported with a confidence percentage; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.4. Distinguish active-burst rate from rate over the full interval”. Exact count divided by a positive duration enclosure yields endpoint bounds, but no coverage probability follows without a justified uncertainty or statistical construction Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of whether a deterministic rate enclosure be reported with a confidence percentage; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.4. Distinguish active-burst rate from rate over the full interval”. Exact count divided by a positive duration enclosure yields endpoint bounds, but no coverage probability follows without a justified uncertainty or statistical construction Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify what the supplied interval means Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a deterministic rate enclosure be reported with a confidence percentage: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a deterministic rate enclosure be reported with a confidence percentage; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a deterministic rate enclosure be reported with a confidence percentage: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a deterministic rate enclosure be reported with a confidence percentage, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a deterministic rate enclosure be reported with a

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confidence percentage: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a deterministic rate enclosure be reported with a confidence percentage. Compare exact reciprocal bounds with a linear approximation and label the latter's approximation status Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a deterministic rate enclosure be reported with a confidence percentage, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a deterministic rate enclosure be reported with a confidence percentage. Compare exact reciprocal bounds with a linear approximation and label the latter's approximation status Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a deterministic rate enclosure be reported with a confidence percentage and Exact count divided by a positive duration enclosure yields endpoint bounds, but no coverage probability…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a deterministic rate enclosure be reported with a confidence percentage”, addressing “Exact count divided by a positive duration enclosure yields endpoint bounds, but no coverage probability…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a deterministic rate enclosure be reported with a confidence percentage”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a deterministic rate enclosure be reported with a confidence percentage”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

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V011-C07-DISCUSSION-022. What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range?” Put this particular dispute to the panel: What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 02. Student A, terminology and scope: Agree the operational meanings of lost, disjoint, admissible and replaced, overall, range in “What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.5. Weight changing modes by their actual durations”. Retain the union when admissibility or feasibility depends on those gaps, and state any independence or joint constraints among the factors Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is lost when two disjoint

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admissible rate intervals are replaced by their overall minimum-to-maximum range; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.5. Weight changing modes by their actual durations”. Retain the union when admissibility or feasibility depends on those gaps, and state any independence or joint constraints among the factors Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The broad enclosure preserves the extremes but can include rates that no supplied configuration produces Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What is lost when two disjoint

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admissible rate intervals are replaced by their overall minimum-to-maximum range: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range. An actual time-sharing schedule could produce another aggregate rate, but it is new evidence that must be accounted for through counts and durations Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range. An actual time-sharing schedule could produce another aggregate rate, but it is new evidence that must be accounted for through counts and durations Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range and The broad enclosure preserves the extremes but can include rates that no supplied configuration produces; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and

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field boundaries. Source: §7.22.9 Application 7B.9. Propagate a positive timing enclosure through an exact count (p. 3790)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range”, addressing “The broad enclosure preserves the extremes but can include rates that no supplied configuration produces”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What is lost when two disjoint admissible rate intervals are replaced by their overall minimum-to-maximum range”. Allocate the next measurement and documentary

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action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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V011-C07-DISCUSSION-023. If a payload efficiency is unknown, is setting it to zero a conservative calculation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “If a payload efficiency is unknown, is setting it to zero a conservative calculation?” Put this particular dispute to the panel: If a payload efficiency is unknown, is setting it to zero a conservative calculation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 02. Student A, terminology and scope: Agree the operational meanings of payload, efficiency, unknown and setting, conservative, calculation in “If a payload efficiency is unknown, is setting it to zero a conservative calculation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of If a payload efficiency is unknown, is setting it to zero a conservative calculation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”. A known zero fraction implies no represented payload in the specified population and prevents a finite positive-target inverse through that configuration Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of If a payload efficiency is unknown, is setting it to zero a conservative calculation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”. A known zero fraction implies no represented payload in the specified population and prevents a finite positive-target inverse through that configuration Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Unknown and zero represent different premises Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 08. Student D, answer to Student E: Design a discriminating experiment involving If a payload efficiency is unknown, is setting it to zero a conservative calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of If a payload efficiency is unknown, is setting it to zero a conservative calculation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving If a payload efficiency is unknown, is setting it to zero a conservative calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving If a payload efficiency is unknown, is setting it to zero a conservative calculation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving If a payload efficiency is unknown, is setting it to zero a conservative

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calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for If a payload efficiency is unknown, is setting it to zero a conservative calculation. An unknown fraction may require an admissible range, additional evidence or an explicitly conditional result Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving If a payload efficiency is unknown, is setting it to zero a conservative calculation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source:

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§7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for If a payload efficiency is unknown, is setting it to zero a conservative calculation. An unknown fraction may require an admissible range, additional evidence or an explicitly conditional result Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about If a payload efficiency is unknown, is setting it to zero a conservative calculation and A known zero fraction implies no represented payload in the specified population and prevents a finite…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “If a payload efficiency is unknown, is setting it to zero a conservative calculation”, addressing “A known zero fraction implies no represented payload in the specified population and prevents a finite…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “If a payload efficiency is unknown, is setting it to zero a conservative calculation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “If a payload efficiency is unknown, is setting it to zero a conservative calculation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.8 Application 7B.8. Test a positive target against the declared rate limit (p. 3789)

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V011-C07-DISCUSSION-024. A recorded script hash matches the approved implementation. What remains to be checked before accepting its EVM and rate outputs?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A recorded script hash matches the approved implementation. What remains to be checked before accepting its EVM and rate outputs?” Put this particular dispute to the panel: A recorded script hash matches the approved implementation. What remains to be checked before accepting its EVM and rate outputs. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 02. Student A, terminology and scope: Agree the operational meanings of script, hash, matches and approved, implementation, checked in “A recorded script hash matches the approved implementation. What remains to be checked before accepting its EVM and rate outputs”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A recorded script hash matches the approved implementation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. It does not establish which inputs were processed, which settings were active, whether execution succeeded or whether the model premises held Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A recorded script hash matches the approved implementation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. It does not establish which inputs were processed, which settings were active, whether execution succeeded or whether the model premises held Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The matching digest supports file identity and provenance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A recorded script hash matches the approved implementation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A recorded script hash matches the approved implementation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A recorded script hash matches the approved implementation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A recorded script hash matches the approved implementation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A recorded script hash matches the approved implementation:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A recorded script hash matches the approved implementation. Bind the run to its actual data, version, arguments, selected intervals, intermediate counts and residual sums Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A recorded script hash matches the approved implementation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A recorded script hash matches the approved implementation. Bind the run to its actual data, version, arguments, selected intervals, intermediate counts and residual sums Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.16 Application 7A.10: Audit a complete finite residual vector (p. 3761)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A recorded script hash matches the approved implementation and What remains to be checked before accepting its EVM and rate outputs; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A recorded script hash matches the approved implementation”, addressing “What remains to be

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checked before accepting its EVM and rate outputs”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A recorded script hash matches the approved implementation. What remains to be checked before accepting its EVM and rate outputs”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A recorded script hash matches the approved implementation. What remains to be checked before accepting its EVM and rate outputs”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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V011-C07-DISCUSSION-025. What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and acquisition coverage remain unresolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and acquisition coverage remain unresolved?” Put this particular dispute to the panel: What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and acquisition coverage remain unresolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 02. Student A, terminology and scope: Agree the operational meanings of statement, arithmetic, accounting and pass, coverage, unresolved in “What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and acquisition coverage remain unresolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Turn a quality metric into a reproducible acceptance record”. State that source attribution and unobserved or unsuccessful acquisition intervals remain unresolved, rather than weakening the valid arithmetic or expanding it into a broader claim Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Turn a quality metric into a reproducible acceptance record”. State that source attribution and unobserved or unsuccessful acquisition intervals remain unresolved, rather than weakening the valid arithmetic or expanding it into a broader claim Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

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- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Report the verified finite comparison and count relationship with their declared scope, including normalization, processing, population and elapsed interval Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 08. Student D, answer to Student E: Design a discriminating experiment involving What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and...: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting

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both pass but the source and…; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would

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expose a false positive or incorrect source attribution. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…. Identify the specific additional evidence needed for those questions, such as authorized device-state correlation, a known timing reference or a complete acquisition log Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…. Identify the specific additional evidence needed for those questions, such as authorized device-state correlation, a known timing reference or a complete acquisition log Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and… and Report the verified finite comparison and count relationship with their declared scope, including…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.2 Carrier and Timing Synchronization (p. 3737)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and…”, addressing “Report the verified finite comparison and count relationship with their declared scope, including…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and acquisition coverage remain unresolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should a chapter-level acceptance statement say when EVM arithmetic and rate accounting both pass but the source and acquisition coverage remain unresolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

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Chapter 7 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C07-ESSAY-001 — Start with a finite set of paired observations and references in compatible complex-amplitude units. Subtract each reference from its observation, square the complex magnitude, multiply by a fixed nonnegative dimensionless weight and sum. Divide by the correspondingly weighted reference-energy sum, which must be strictly positive, and take the square root. The result is dimensionless; percentage reporting multiplies it by one hundred. For positive EVM, use twenty times its base-ten logarithm, equivalently ten times the logarithm of the energy ratio. Zero residual energy gives zero linear EVM and a negative-infinity decibel limit, not a finite logarithm. A zero denominator leaves the metric undefined. Zero weights remove those pairs from the effective population, so the selection and its reason belong to the result. The formula is a deterministic description of the disclosed record. It supplies neither a probability distribution nor an error-rate prediction without additional justified models. Review: Model 7A; Equations 13A–13C and 13J.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13A. Finite reference energy and admissible weights; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13C. Percent and decibel reporting; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-ESSAY-002 — Write the training objective as the weighted sum of squared magnitudes of observation minus a times ideal reference. Define C as the weighted sum of observation times conjugated reference, and $E_{\mathrm{s},T}$ as the weighted ideal-reference energy. Expansion gives observation energy minus twice the real part of $a^{*}C$ plus $|a|^{2}E_{\mathrm{s},T}$. Completing the square gives observation energy minus $\frac{|C|^{2}}{E_{\mathrm{s},T}}$ plus $E_{\mathrm{s},T}\left|a-\frac{C}{E_{\mathrm{s},T}}\right|^{2}$. When $E_{\mathrm{s},T}$ is positive, the last term is nonnegative and vanishes uniquely at $a=\frac{C}{E_{\mathrm{s},T}}$.

Conjugating the observation instead would generally reverse the fitted phase and would not minimize the stated objective. The estimator minimizes the training numerator. If a fitted reference also supplies the normalization, its energy depends on the coefficient; a smaller numerator therefore need not produce a smaller normalized EVM. A zero fitted coefficient can be the unique least-squares answer while making that fitted-reference EVM undefined. Evaluation on excluded data is a separate calculation. Review: Equations 13D–13F.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-ESSAY-003 — The residuals are $(0.1+j0.05, -0.05+j0.2, -0.2+j0.1, 0.1-j0.1)$. Their weighted squared magnitudes are 0.0125, 0.085, 0.05 and 0.01, totaling 0.1575. Weighted reference energy is $1+2+4+2=9$, so fixed-reference EVM is the square root of $\frac{0.1575}{9}$, or approximately 13.228757 percent. The weighted observation-reference correlation is $9.2+j0.45$, giving fitted gain $1.022222+j0.05$. Weighted observation energy is 9.5575; subtracting $\frac{|9.2+j0.45|^2}{9}$ yields minimized residual energy approximately 0.13055556. These quantities use the stated finite weights, which are not sample probabilities. If a fitted-reference EVM is also reported, its denominator must use the squared magnitude of this nonzero fitted coefficient times nine. Do not silently retain the old denominator while giving the result the fitted-reference name. Neither fit nor finite sum establishes a physical cause or a confidence interval. Review: Equations 13B, 13D–13F; Application 7A.10.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

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V011-C07-ESSAY-004 — The fixed residuals are zero and minus one. Their energy is one and the reference energy is two, giving fixed-reference EVM approximately 70.710678 percent. The correlation is one, so the fitted gain is 0.5. The fitted residuals are 0.5 and -0.5, reducing the residual-energy sum from one to 0.5. However, the fitted references are both 0.5 and their total energy is also 0.5. The fitted-reference EVM is therefore 100 percent. No optimization failure has occurred: the fit minimized residual energy, while the reported ratio also changed its denominator. This is an in-sample demonstration, not held-out validation. State both energy sums, the fitted coefficient and the allowed correction when comparing the results. The zero observation also does not, by itself, identify a dropout mechanism; the example supplies numerical observations without a physical fault history. Review: Equations 13D–13F; normalization distinction after Equation 13F.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference.

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V011-C07-ESSAY-005 — The training correlation is 2.2 and its ideal energy is two, so the fitted gain is 1.1 and the training residual is zero. On the evaluation set, the fixed references agree exactly with the observations, giving zero fixed-reference EVM. The fitted references are -1.1 and $-j1.1$; each residual has magnitude 0.1. The evaluation numerator is therefore 0.02 and the fitted-reference denominator is 2 times 1.1 squared, or 2.42. Their square-root ratio is approximately 9.090909 percent. A zero training residual did not guarantee useful transfer to the excluded symbols. The example is deliberately deterministic and supplies no distribution from which to estimate a general failure probability. Separating training and evaluation prevents direct reuse of those evaluation pairs for this fit, but does not establish statistical independence, correct reference generation or common physical conditions. Those premises need their own evidence. Review: Equation 13F; Application 7A.7.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.7: Evaluate a fitted gain on held-out symbols.

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V011-C07-ESSAY-006 — The references have unit energy, zero sum and zero sum of complex squares. The offset contribution to the gain correlation vanishes because the conjugated references sum to zero; the conjugate-leakage contribution also vanishes because their conjugate squares sum to zero. The ordinary fitted gain therefore remains one. Each residual is the offset d plus β multiplied by the conjugated reference. Summing its squared magnitude eliminates the cross terms on this balanced set, giving average residual energy $|d|^2+|\beta|^2=0.0025+0.0036=0.0061$. Unit average reference energy gives EVM approximately 7.810250 percent. The residual mean retains d, while the direction-dependent component retains the conjugate relationship. The scalar discards that distinction: a different impairment can have the same aggregate energy. An offset-removal or direct-plus-conjugate fit would add parameters and change the declared measurement. The constructed coefficients are supplied premises, not an inference that a similarly sized unknown EVM has those causes. Review: Equation 13I; Applications 7A.3–7A.4.

Review: Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment.

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V011-C07-ESSAY-007 — Subtract the unrotated reference from its rotated observation. The common reference magnitude factors out of the residual-to-reference ratio, leaving $|\exp(j\theta)-1|$. Multiplying by a unit-magnitude half-angle factor or using the cosine identity gives $2\left|\sin\left(\frac{\theta}{2}\right)\right|$. At 30 degrees, the exact linear value is approximately 0.51763809, or 51.763809 percent. The small-angle approximation uses θ in radians, giving $\frac{\pi}{6}$, or approximately 52.359878 percent. Its excess is about 0.596069 percentage points, so it should not be treated as exact at this angle. EVM is not limited to 100 percent; a 180-degree reversal reaches 200 percent under the same fixed-reference convention. Permitting a constant phase fit could remove the stipulated rotation entirely. That result would assess the residual after the allowed correction, while the fitted phase would remain evidence of the original alignment discrepancy. Review: Equation 13H; Application 7A.2.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Application 7A.2: Quantify a fixed phase error.

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V011-C07-ESSAY-008 — The selected reference-energy sum is six times two plus two times eighteen, or 48; with eight equal weights, its mean is six. Each residual has energy 0.02, so reference-RMS EVM is the square root of $\frac{0.02}{6}$, approximately 5.773503 percent. The declared square-16QAM maximum energy is eighteen, giving constellation-maximum EVM approximately 3.333333 percent. Substituting the full-alphabet mean energy ten would give approximately 4.472136 percent, which is a different denominator from the realized selected record. The correct answer must preserve the supplied symbol multiplicities rather than assume uniform use of every constellation point. The two legitimate normalization results describe the same residual under distinct conventions; the smaller value does not indicate a cleaner waveform. None of these calculations estimates symbol probabilities or changes the permitted synchronization and correction policy. Review: Equation 13G; Application 7A.5.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Application 7A.5: Compare RMS and constellation-maximum normalization.

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V011-C07-ESSAY-009 — The equal-weight residual-energy sum is $0.0625+0.0225+0.0025+0.0025=0.09$. Dividing by four and taking the square root gives 15 percent. The last two symbols alone have energy sum 0.005 and reference energy two, giving 5 percent. With the stated weights, the numerator is $0.0125+0.0045+0.0025+0.0025=0.022$ and the denominator is 2.4, giving approximately 9.574271 percent. These are three defined populations or emphases, not three physical improvements to the same observations. If acquisition is excluded from the settled metric, preserve its duration, attempted captures, errors and selection rule. Choosing weights after looking for a favorable result must be disclosed as a different exploratory procedure. The four fixed magnitudes supply no sampling distribution, and a clean settled subset cannot establish that the receiver characterized the entire burst. Review: Equation 13J; Application 7A.6; acquisition record.

Review: Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Application 7A.6: Make selection and weighting visible.

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V011-C07-ESSAY-010 — Convert the percentages to linear values before reconstructing residual energies. The first block contributes 40 times 0.05 squared, or 0.1; the second contributes 160 times 0.15 squared, or 3.6. The combined energy ratio is $\frac{3.7}{200}$, giving pooled EVM approximately 13.601471 percent. Averaging the two percentages would give 10 percent and would not reproduce the finite pooled energy ratio. The weighting is by reference energy, not merely block count or duration. If each block has its own fitted gain, their sums can still describe a declared piecewise-corrected record, but that record is not automatically equivalent to one common-gain experiment. A common fit must be estimated from its declared training population and evaluated consistently. Preserve the coefficients and denominator conventions before claiming a single whole-record measure. Review: Equations 13B, 13D–13F and 13J.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Equation 13J. Residual sums for a disclosed selection.

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V011-C07-ESSAY-011 — The three observed phasors sum to two, so the correlation is two and the ideal-reference energy is three. The fitted constant gain is therefore $\frac{2}{3}$ with zero imaginary part. The fixed residual energies are one, zero and one, giving fixed-reference EVM equal to the square root of $\frac{2}{3}$, approximately 81.649658 percent. Observation energy is three; the minimized residual energy is $3-\frac{4}{3}=\frac{5}{3}$. The fitted-reference energy is $\left(\frac{2}{3}\right)$ squared times three, or $\frac{4}{3}$, giving fitted-reference EVM equal to the square root of $\frac{5}{4}$, approximately 111.803399 percent. Symmetric phase contributions cancel in the imaginary part of their mean, despite the persistent phase ramp. A phase advance of 60 degrees per symbol corresponds to one sixth of the symbol rate in this constructed unwrapped interpretation. A separate frequency estimator would add a model and would need validation; the present results are in-sample diagnostics. Review: Equations 13D–13F; Application 7A.8.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

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V011-C07-ESSAY-012 — Every reference has energy two, so their sum is eight and reference RMS magnitude is the square root of two. Residual energies are 0.0025, zero, 0.01 and zero, totaling 0.0125. RMS EVM is the square root of $\frac{0.0125}{8}$, approximately 3.952847 percent. The largest residual has magnitude 0.1, so its normalization by reference RMS gives approximately 7.071068 percent. The third symbol supplies $\frac{0.01}{0.0125}=0.8$, or 80 percent of the residual energy. The peak and concentration identify features hidden by the average, without contradicting it. Four disclosed deterministic pairs are sufficient to reproduce these arithmetic statements, but provide no asserted random sampling scheme, repeated-trial model or confidence procedure. Any uncertainty claim must identify its actual sources and coverage construction instead of attaching an unsupported probability to this finite record. Review: Equations 13B and 13J; Application 7A.10.

Review: Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

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V011-C07-ESSAY-013 — Begin with disclosed complex vectors whose squared distances and reference energies can be calculated independently, including a nonzero fit, a zero residual and an inadmissible zero denominator. This checks arithmetic and domain handling. Then use a known sequence with an imposed timing displacement and a separately known symbol rate to challenge sample selection and clock metadata. A deliberately rotated mapping tests whether label ambiguity survives a tight constellation. Preserve the training interval and apply fixed fitted parameters to excluded data to test transfer. Noise-only and wrong-format records challenge false structure, with the number of attempts and exclusions recorded. A second implementation of the same sum can detect coding mistakes, but agreement under a shared wrong reference or timing estimate does not validate those premises. Report the actual outcomes and coverage of each challenge; a planned validation sequence is not evidence that the checks have passed. Review: Metric Validation and Held-Out Data; reproducible acceptance record.

Review: Chapter 7 — Metric Validation and Held-Out Data; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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V011-C07-ESSAY-014 — The observations show that the selected parameterization fits the training record better but transfers less well under the stated evaluation. Check that the evaluation uses fixed coefficients, compatible reference normalization and an interval excluded from fitting; otherwise the two values may describe different experiments. Retain pre-equalization and post-equalization residuals, tap count, training length, regularization, convergence state and adaptation policy. Reduce or challenge model flexibility only against declared criteria, then test the revised model on data not used for that choice. Known-signal and bypass comparisons can separate processing dependence from physical-path effects. The training improvement can arise from fitting noise, nonstationary behavior or a wrong reconstruction premise, so it does not uniquely locate an impairment. A defensible conclusion identifies dependence on the compensation and the limits of demonstrated transfer while leaving unresolved causes explicit. Review: Matched Filtering, Pulse Shaping, and Channel Effects; Model 7A training and evaluation.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-ESSAY-015 — The stated matched-filter benefit assumes the relevant known pulse and additive white Gaussian noise, with the timing and channel relationship required for the comparison. It is not a universal claim that any filter carrying that label is optimal in an unknown channel or colored interference. Specify coefficients or a reproducible generation convention, roll-off, span, sample rate, scaling, delay, initialization and treatment of unavailable samples at the record edges. Confirm the same symbol decision instants and reference construction with a known sequence. Two truncated realizations can differ around transitions and boundaries even when their family names agree. If equalization follows, preserve its coefficients and permitted role separately. For reception quality, compensation may be useful; for the original path condition, its effects must remain visible in pre-compensation results. The comparison should reproduce the declared experiment rather than choose whichever implementation yields the smallest displayed EVM. Review: Matched Filtering, Pulse Shaping, and Channel Effects; definition of the symbol experiment.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects; Chapter 7 — Define the symbol experiment before fitting the constellation.

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V011-C07-ESSAY-016 — The slot rate is $\frac{20{,}000}{0.020} = 1{,}000{,}000$ slots per second. The data-slot fraction is $\frac{16{,}000}{20{,}000} = 0.8$. Coded label bits total 16,000 times four, or 64,000; the 0.75 complete-block code rate gives 48,000 input-information bits. Payload-bit fraction is $\frac{36{,}000}{48{,}000} = 0.75$. Multiplying slot rate, four label bits, code rate 0.75, data-slot fraction 0.8 and payload-bit fraction 0.75 gives 1.8 Mbit/s, matching $\frac{36{,}000}{0.020}$ directly. The combined noncoding efficiency is 0.8 times 0.75, or 0.6. If that combined factor is used and the data-slot reduction is then applied again, the erroneous result becomes 1.44 Mbit/s. Keep count populations and reductions separate; the stipulated values are not measured uncertainties or inferred format properties. The numerator counts represented payload instances and has not established unique successful delivery. Review: Equations 14A–14B; Application 7B.2.

Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations; Chapter 7 — Equation 14B. Forward rate and the positive-target inverse; Chapter 7 — Application 7B.2. Separate two overhead populations without counting either twice.

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V011-C07-ESSAY-017 — The burst carries 20,000 coded bits, 16,000 input-information bits and 14,400 payload bits. Five thousand symbols at 5 Msymbol/s occupy 1 ms, giving an active-interval payload rate of 14.4 Mbit/s. Including the supplied 0.2 ms guard gives a total interval of 1.2 ms and payload rate 12 Mbit/s. A deliberately continued nominal grid at the active clock would contain 6,000 opportunities over that interval, with data-slot fraction $\frac{5{,}000}{6{,}000}=\frac{5}{6}$; the complete rate product then gives the same 12 Mbit/s. This is a stated accounting convention, not evidence that physical symbols were transmitted during the guard. The wall-interval average of transmitted data-symbol instances is $\frac{5{,}000}{0.0012}$, which differs from the active clock. Do not reduce for the guard both in the duration and again through a redundant efficiency. Actual acquisition success and unique delivery require separate observations. Review: Equations 14A–14B; Application 7B.4.

Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations; Chapter 7 — Equation 14B. Forward rate and the positive-target inverse; Chapter 7 — Application 7B.4. Distinguish active-burst rate from rate over the full interval.

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V011-C07-ESSAY-018 — The first mode represents 1 Mbit/s and contributes 2 Mbit over two seconds. The second represents 4 Mbit/s and contributes 4 Mbit over one second. Total payload is therefore 6 Mbit in three seconds, giving 2 Mbit/s. The duration-weighted mean label-bit count is $\frac{2\times 2+1\times 6}{3}=\frac{10}{3}$. The duration-weighted mean code rate is $\frac{2\times 0.5+1\times \frac{2}{3}}{3}=\frac{5}{9}$. Multiplying those separate means by 1 Msymbol/s gives $\frac{50}{27}\ \mathrm{Mbit/s}$, approximately 1.851852 Mbit/s, which is incorrect. The factors change jointly, so average their realized products through interval counts. The result uses the stipulated durations and complete-block rates, with no additional transition cost or other overhead. It does not license treating an unobserved mode distribution as a probability model. Review: Equation 14C; Application 7B.5.

Review: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.5. Weight changing modes by their actual durations.

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V011-C07-ESSAY-019 — One frame uses 1,240 input-information bits, 1,550 coded bits and 775 symbols. The ceiling of $\frac{5{,}000}{1{,}200}$ requires five complete frames. They provide 6,000 payload positions, so 1,000 positions are padding and the final frame carries 200 original request bits. Five frames use 3,875 symbols and take $\frac{3{,}875}{2{,}500{,}000} = 0.00155$ seconds. Actual request-payload rate is $\frac{5{,}000}{0.00155}$, approximately 3.225806 Mbit/s. The repeating full-frame capacity rate is 1,200 times $\frac{2{,}500{,}000}{775}$, approximately 3.870968 Mbit/s. The request spans 6,200 input-information bits, so its realized payload-bit fraction is $\frac{5{,}000}{6{,}200}$, approximately 0.80645161. The capacity result assumes every payload position is useful; it must not count the padded final positions as request data. These complete-frame counts are exact stipulations, with no unspecified gaps or retransmissions inserted. Review: Equation 14D; Application 7B.7.

Review: Chapter 7 — Equation 14D. Retain the integer frame boundary; Chapter 7 — Application 7B.7. Retain integer frames and last-frame padding.

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V011-C07-ESSAY-020 — Rate is the fixed count divided by positive duration, so its minimum uses 20.02 ms and its maximum uses 19.98 ms. The exact bounds are approximately 1,998,001.998 and 2,002,002.002 bit/s. The central 20 ms value is 2,000,000 bit/s. Its departures are therefore about $-1{,}998.002$ and $+2{,}002.002\ \text{bit/s}$, slightly asymmetric. Linearizing the reciprocal at 20 ms gives a magnitude of 40,000 times 0.00002 divided by 0.020 squared, or 2,000 bit/s, which is an approximation rather than the exact endpoint result. The supplied enclosure assigns no probability distribution or coverage level. If the payload count, population boundary or format is also uncertain, the premises of this one-variable bound change and those effects must be assessed explicitly. Do not import an unreported timer accuracy or treat the nominal center as a measured unbiased estimate. Review: Equation 14E; Application 7B.9.

Review: Chapter 7 — Equation 14E. Bound a rate with an exact count and uncertain positive duration; Chapter 7 — Application 7B.9. Propagate a positive timing enclosure through an exact count.

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V011-C07-ESSAY-021 — Before code and payload-bit reductions, the product is 1.5 times four times 0.75, or 4.5 Mbit/s. Code rate 0.5 gives the interval from 4.5 times 0.5 times 0.8 to 4.5 times 0.5, namely 1.8 to 2.25 Mbit/s. Code rate 0.8 gives 2.88 to 3.6 Mbit/s. The admissible set is the union of those two closed intervals. The proposed 2.6 Mbit/s lies in their gap and is not represented by any stipulated alternative, even though it falls inside the coarser enclosure from 1.8 to 3.6 Mbit/s. A mean code rate would invent an unsupported intermediate configuration unless an actual time-sharing schedule were supplied and accounted for separately. The interval premise allows the payload fraction independently across the stated range; a dependence constraint would require a narrower admissible set. No probabilities are assigned to the two formats. Review: Equations 14B and 14C; Application 7B.10.

Review: Chapter 7 — Equation 14B. Forward rate and the positive-target inverse; Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate.

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V011-C07-ESSAY-022 — Adding stream instances gives 1,600,000 accepted instances over half a second, or 3.2 Mbit/s. For unique positions, apply inclusion and exclusion to the stated identity sets: 900,000 plus 700,000 minus 250,000 equals 1,350,000 positions, giving 2.7 Mbit/s. The overlap is defined by common payload identities, not by equal binary values or similar waveforms. If only the two stream counts are known, overlap can range from zero to 700,000 under the supplied no-internal-duplicates premise. Unique counts then range from 900,000 to 1,600,000, giving 1.8 to 3.2 Mbit/s. A narrower result requires evidence of the common positions. Time bases and acceptance rules must match before aggregation. The finite accepted-position count still does not identify the original emitter or establish that every intended request bit was delivered. Review: Equation 14C; Application 7B.6.

Review: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.6. Remove duplicate payload before reporting unique throughput.

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V011-C07-ESSAY-023 — First compare the exact paired symbol population, permitted corrections, reference reconstruction and denominator. The cited implementation documents a choice between reference-RMS and constellation-maximum normalization, and warns that trace normalization can differ from error-summary normalization. Particular formats can also use special sampling or normalization rules, so retain the selected mode and documented software scope. Recalculate the chapter's finite numerator and denominator from the exported pairs, then reproduce the implementation convention only where its actual rules and exported data support that reconstruction. A shared capture filename or percent unit does not establish equivalent experiments. Avoid converting one threshold using a generic constellation factor when the selected reference population or a special format changes that factor. State the implementation version or help edition actually inspected and the bounded sections used. A documented difference can explain the discrepancy without establishing which convention answers the user's measurement question. Review: Equation 13G; cited EVM Normalization Reference and EVM (Digital Demod) help.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Model 7A: a finite, declared EVM comparison.

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V011-C07-ESSAY-024 — Keep the raw waveform observation separate from algorithmic synchronization, decoded fields and any external source claim. Record decoder version, format assumptions, search alternatives, attempted intervals, exclusions and the actual checks performed. The noise-only control demonstrates that the tested process can produce false structure; it does not establish that every original candidate has that origin or that no signal exists. Recheck candidates with independently justified timing, reference structure and validation rules, and preserve failures as well as apparent successes. A CRC pass supports a consistency relation but is not cryptographic authentication or physical localization. Without a declared trial model, dependence structure and relevant null behavior, the rarity of a few outputs cannot be converted into a numerical false-alarm probability. Further content recovery, retention and reporting must remain within the engagement authority. Report the narrowest supported finding and the unresolved alternatives. Review: Defensive Interpretation of Digital Signals; Hypothetical Case Adjudication.

Review: Chapter 7 — Defensive Interpretation of Digital Signals; Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

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V011-C07-ESSAY-025 — Bind the sample segment and timing metadata to its reference sequence, mapping, processing version, filters, synchronization estimates, weights, training and evaluation sets, allowed corrections and residuals. Retain the fitted coefficients and both EVM energy sums so the scalar can be reconstructed. For rate accounting, record the positive time interval, slot convention, data symbols, coded bits, complete-block information bits, payload instances, exclusions and any identified duplicate positions. Derive rates from those common counts and distinguish full-frame capacity from actual request data. Preserve acquisition attempts, failures, lock gaps and reasons for omitted intervals alongside successful metrics. A low residual tests the declared symbol comparison; a rate identity tests internally consistent populations and time. Neither supplies source attribution, proof of every interval's validity or evidence that repeated payload instances are unique delivery. Add independent known-signal, bypass, timing and authorized device-state checks where those broader claims are required, and state their actual scope. Review: Reproducible acceptance record; Models 7A–7B.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

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Discussion Guidance

V011-C07-DISCUSSION-001 — Compare the questions answered by fixed-reference, fitted-reference, post-equalization and selected-interval metrics. A smaller number may follow from a changed denominator, greater fitting freedom or removal of difficult intervals. The group should agree on the measurement purpose before selecting the primary result, then retain the permitted correction policy, coefficients and population. A useful report can include several clearly defined metrics when each supports a different decision. Reject an unqualified ranking based solely on the smallest percentage, while recognizing that an appropriately compensated metric can be the relevant reception measure. Review: Model 7A; Equations 13B–13G.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Equation 13B. Weighted fixed-reference error vector magnitude; Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization.

V011-C07-DISCUSSION-002 — Distinguish the nonnegative linear magnitude ratio from its logarithmic representation. Ratios below one have negative decibel values under twenty times the base-ten logarithm. Changing the sign would define another reported quantity and reverse the stated convention. Show one disclosed conversion and check whether the reviewer actually expects a reciprocal measure such as a differently defined quality ratio. Agree on the metric name and convention before changing labels. Also distinguish zero linear EVM from a finite display floor, and avoid treating a minus sign as evidence of a physically negative error energy. Review: Equation 13C.

Review: Chapter 7 — Equation 13C. Percent and decibel reporting.

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V011-C07-DISCUSSION-003 — Relate the fit to the intended measurand. Removing a constant gain and phase offset may be appropriate for residual modulation quality after alignment; it can conceal a discrepancy when absolute amplitude or phase calibration is the question. Keep the fitted coefficient visible and specify its training set, allowed complexity and evaluation use. Discuss whether a fixed reference, a fitted reference or both should normalize the reported result. A fit is justified by the declared purpose and validation, not by its ability to improve the display. Review: Equations 13D–13F; Applications 7A.1–7A.2.

Review: Chapter 7 — Equation 13D. Optional complex-gain fit on a training set; Chapter 7 — Equation 13E. Least-squares completion of the square; Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Application 7A.1: Show which error a fitted gain removes; Chapter 7 — Application 7A.2: Quantify a fixed phase error.

V011-C07-DISCUSSION-004 — State exactly what has been excluded from fitting and parameter selection. Holding out symbol pairs avoids direct fitting on those pairs for the declared estimator, but shared clock metadata, reference construction, signal conditions and later tuning can preserve dependence. If results from the held-out interval guide another parameter choice, its role has changed and another evaluation strategy may be needed. The discussion should distinguish a procedural holdout from statistical independence and independent physical validation. Record the actual sequence of choices rather than use the word independent as a blanket guarantee. Review: Equation 13F; Metric Validation and Held-Out Data.

Review: Chapter 7 — Equation 13F. Held-out evaluation with a nonzero fitted reference; Chapter 7 — Metric Validation and Held-Out Data.

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V011-C07-DISCUSSION-005 — Inspect the residual vector and its association with symbol identity and time. A common offset can appear in the residual mean; a conjugate term can vary with the conjugated reference; a frequency ramp can produce ordered phase progression. Those patterns guide hypotheses but do not alone prove their physical origin. Check permitted fits, population balance and whether preprocessing removed the feature. Propose known-reference or bypass challenges that test different mechanisms. Equal scalar energy is compatible with several structures, so the report should avoid assigning a unique cause from the shared EVM. Review: Equations 13H–13J; Applications 7A.3–7A.4 and 7A.8.

Review: Chapter 7 — Equation 13H. Fixed gain and phase impairments; Chapter 7 — Equation 13I. Balanced-reference offset and conjugate terms; Chapter 7 — Equation 13J. Residual sums for a disclosed selection; Chapter 7 — Application 7A.3: Preserve a DC impairment when fitting only complex gain; Chapter 7 — Application 7A.4: Expose a conjugate-image impairment; Chapter 7 — Application 7A.8: Keep a residual frequency rotation in a finite symbol record.

V011-C07-DISCUSSION-006 — Consider whether the decision concerns settled payload quality, burst capture success or the complete event. Exclusion can define a useful steady-state result, but acquisition duration, errors and failures remain relevant to the broader task. Specify the selection criterion before judging the result and retain enough information to reconstruct complete-record and conditional metrics where needed. Discuss how a burst that ends before usable lock should enter the record. The choice should answer a stated question, with no implication that omitted intervals were successfully characterized. Review: Application 7A.6; acquisition and tracking record.

Review: Chapter 7 — Application 7A.6: Make selection and weighting visible.

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V011-C07-DISCUSSION-007 — Audit reference construction, selected symbol locations, allowed corrections, weighting, timing, normalization and implementation scope. The same format label can coexist with different summary and trace conventions or special handling for a particular mode. Determine whether exported paired symbols permit a common recalculation; if not, describe the unresolved comparison limit. A declared conversion is useful only when its denominator assumptions actually apply to the selected records. The group should decide what evidence is sufficient for a threshold comparison, rather than infer equivalence from the label and percent sign. Review: Equation 13G; cited implementation help.

Review: Chapter 7 — Equation 13G. Average-reference and maximum-reference normalization; Chapter 7 — Model 7A: a finite, declared EVM comparison.

V011-C07-DISCUSSION-008 — Ask whether isolated errors matter to the decision and define the peak's population and normalization if it is reported. A largest residual can expose a feature that a long RMS aggregate dilutes, but it does not replace the energy measure or identify the fault mechanism. Retain the time location and surrounding data so a transient can be examined against acquisition, filtering and continuity records. Discuss susceptibility to record length and selection. Avoid an undocumented combined score; each supplementary statistic should have a clear purpose and reproducible definition. Review: Application 7A.10; residual selection.

Review: Chapter 7 — Application 7A.10: Audit a complete finite residual vector.

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V011-C07-DISCUSSION-009 — Separate arithmetic agreement from validation of shared premises. Tools can reproduce the same finite sum correctly while using the same wrong reference, clock metadata, mapping or synchronization estimate. Identify a known-input challenge that would fail under the suspected common error, and retain its actual outcome. Compare intermediate residuals and energy sums to localize arithmetic differences when they exist. Agreement is useful evidence within its scope; the group should state which dependencies remain common before calling the overall result independently verified. Review: Reproducible acceptance record; Metric Validation and Held-Out Data.

Review: Chapter 7 — Metric Validation and Held-Out Data; Chapter 7 — Turn a quality metric into a reproducible acceptance record.

V011-C07-DISCUSSION-010 — Define the intended compensation and inspect performance on data excluded from selecting and fitting the model. Retain coefficient count, regularization, training duration, convergence and adaptation policy, along with pre-compensation results when the original path matters. A stable improvement under appropriate challenges can support the chosen processing, but visual tightness alone cannot establish transfer or locate distortion. Discuss whether the additional parameters answer the engineering question and whether their effect remains reproducible. Avoid selecting flexibility solely because it produces the lowest training residual. Review: Matched Filtering, Pulse Shaping, and Channel Effects.

Review: Chapter 7 — Matched Filtering, Pulse Shaping, and Channel Effects.

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V011-C07-DISCUSSION-011 — Compare the event duration with the acquisition history and the actual symbols included in the metric. A later settled result may describe a different interval and cannot retroactively establish valid synchronization during the transient. Preserve lock indicators, timing estimates, excluded samples and any independent waveform evidence from the early interval. Discuss whether a known repeated event or a separately validated acquisition method can answer the original question. Report what was measured successfully while leaving the uncharacterized interval explicit. Review: Carrier and Timing Synchronization; acquisition record.

Review: Chapter 7 — Carrier and Timing Synchronization.

V011-C07-DISCUSSION-012 — Compare actual coefficients, span, delay, sample-rate convention, scaling and initialization before attributing the difference to the signal. Boundary handling can differ when prior or future samples are unavailable, even with the same filter-family name. Use a known sequence with disclosed history to test the implementations, and define any excluded edge interval before evaluating quality. The discussion should distinguish an implementation mismatch from a legitimate difference in the declared finite-record experiment. Preserve the choice in the acceptance record rather than trimming until the values agree. Review: Definition of the symbol experiment; filter-history treatment.

Review: Chapter 7 — Define the symbol experiment before fitting the constellation.

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V011-C07-DISCUSSION-013 — It demonstrates a false-output mechanism for the tested processing and control conditions. It does not prove that every candidate from the original capture was false or that the band contained no communication signal. Preserve trial counts, format searches, checks and failed outputs so apparent rarity is not overstated. Discuss further known-reference and independent validation challenges appropriate to the authorized task. A useful conclusion can reject an unvalidated identification while retaining valid waveform observations and unresolved alternatives. Review: Hypothetical Case Adjudication.

Review: Chapter 7 — Hypothetical Case Adjudication: Digital Modulation Reception, Synchronization, EVM, and Error Metrics.

V011-C07-DISCUSSION-014 — Separate the decoded consistency relation from authentication and localization. A pass can strengthen confidence in a particular decoded structure under the tested assumptions, while identity or physical-origin claims need different evidence. Discuss replay, relaying, spoofed fields and common-format reuse as possibilities only where relevant, without claiming that they occurred. State which checks actually ran and whether cryptographic or physical validation was performed. Keep the permitted level of metadata recovery and retention tied to the engagement authority. Review: Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Defensive Interpretation of Digital Signals.

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V011-C07-DISCUSSION-015 — Technical capability and task authority answer different questions. Review the agreed acquisition, processing, retention and reporting scope before expanding from waveform classification to content. A valid EVM or plausible decoder output does not supply missing authorization. The discussion should identify a useful result that can be reported within the current scope and what additional authority would be required for any proposed expansion. Avoid introducing speculative legal conclusions; apply the actual engagement boundary and retain only the information needed for the approved technical purpose. Review: Defensive Interpretation of Digital Signals.

Review: Chapter 7 — Defensive Interpretation of Digital Signals.

V011-C07-DISCUSSION-016 — Each count supports a different reduction and denominator. A pilot consumes a slot, coding adds label-bit redundancy, headers consume information-bit capacity and repeated payload can add instances without adding unique content. Reconstruct the count chain for a concrete complete interval and check that every ratio uses its own population. Discuss how a combined efficiency can be valid when its components are explicit, and how applying a component again creates double counting. The separation also exposes zero-denominator cases and prevents an observed constellation from supplying unknown code or framing assumptions. Review: Equation 14A; Applications 7B.1–7B.3.

Review: Chapter 7 — Equation 14A. Count the distinct bit and slot populations; Chapter 7 — Application 7B.1. Reconcile coded bits, information bits and modulation symbols; Chapter 7 — Application 7B.2. Separate two overhead populations without counting either twice; Chapter 7 — Application 7B.3. Count disjoint pilot and nonpayload slots explicitly.

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V011-C07-DISCUSSION-017 — Both can be useful when clearly named. The active clock describes symbol spacing during transmission; the wall-interval payload rate includes the declared guards, idle periods or other elapsed time. Define the numerator, interval and any nominal opportunity grid, then calculate the relationship from common counts. Discuss which quantity answers the user's performance question and why one cannot be substituted for the other. A continued accounting grid through a guard does not assert that physical symbols were transmitted there. Review: Application 7B.4.

Review: Chapter 7 — Application 7B.4. Distinguish active-burst rate from rate over the full interval.

V011-C07-DISCUSSION-018 — Check how the two factors vary together and how long each realized mode persists. The aggregate payload rate follows total counts divided by total elapsed time; separate averages can destroy the joint relationship and give the wrong result. A distribution or schedule may summarize the modes only when it is actually known and its weighting is stated. Discuss transitions, overhead and incomplete blocks if they belong to the interval. Do not invent intermediate formats or probabilities from an unqualified mean. Review: Equation 14C; Application 7B.5.

Review: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.5. Weight changing modes by their actual durations.

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V011-C07-DISCUSSION-019 — Use the actual frame rules to count whole frames, headers and final padding. A request that does not fill the final frame can use the same symbol clock and coding correctly while delivering fewer original request bits per elapsed time than a repeating full-frame stream. Preserve both the capacity denominator and the actual request numerator. Discuss whether gaps, retransmissions or failed frames were supplied as evidence before including them. A count difference explained by finite-frame structure does not establish that every implementation detail is correct, but it prevents misclassifying predictable padding as a fault. Review: Equation 14D; Application 7B.7.

Review: Chapter 7 — Equation 14D. Retain the integer frame boundary; Chapter 7 — Application 7B.7. Retain integer frames and last-frame padding.

V011-C07-DISCUSSION-020 — Require compatible elapsed intervals and acceptance definitions, then determine whether the payload identities are disjoint. Equal binary values are not sufficient to establish duplicates, and differing waveforms are not sufficient to establish unique content. If overlap is known, remove repeated identified positions for a unique-count claim; if it is unknown, state bounds or retain the instance-rate label. Discuss internal duplicates separately from cross-stream overlap. The arithmetic aggregation should not imply emitter identity or completion of an intended request that was never checked. Review: Equation 14C; Application 7B.6.

Review: Chapter 7 — Equation 14C. Combine counts before dividing by time; Chapter 7 — Application 7B.6. Remove duplicate payload before reporting unique throughput.

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V011-C07-DISCUSSION-021 — Identify what the supplied interval means. Exact count divided by a positive duration enclosure yields endpoint bounds, but no coverage probability follows without a justified uncertainty or statistical construction. Compare exact reciprocal bounds with a linear approximation and label the latter's approximation status. Discuss which additional count, boundary or format uncertainties are actually present, rather than adding hypothetical instrument specifications. A transparent enclosure can be useful without claiming a confidence level that the evidence does not support. Review: Equation 14E; Application 7B.9.

Review: Chapter 7 — Equation 14E. Bound a rate with an exact count and uncertain positive duration; Chapter 7 — Application 7B.9. Propagate a positive timing enclosure through an exact count.

V011-C07-DISCUSSION-022 — The broad enclosure preserves the extremes but can include rates that no supplied configuration produces. Retain the union when admissibility or feasibility depends on those gaps, and state any independence or joint constraints among the factors. An actual time-sharing schedule could produce another aggregate rate, but it is new evidence that must be accounted for through counts and durations. Discuss whether the decision only needs a conservative bound or needs the exact feasible set. Do not interpret the empty gap as low probability when no probability model was supplied. Review: Application 7B.10.

Review: Chapter 7 — Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate.

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V011-C07-DISCUSSION-023 — Unknown and zero represent different premises. A known zero fraction implies no represented payload in the specified population and prevents a finite positive-target inverse through that configuration. An unknown fraction may require an admissible range, additional evidence or an explicitly conditional result. Discuss whether a lower bound alone answers the engineering question and whether an upper feasibility bound remains available from other factors. The report should not convert missing information into a measured absence or use an invented nominal value without labeling the assumption. Review: Model 7B domain; Application 7B.8.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 7 — Application 7B.8. Test a positive target against the declared rate limit.

V011-C07-DISCUSSION-024 — The matching digest supports file identity and provenance. It does not establish which inputs were processed, which settings were active, whether execution succeeded or whether the model premises held. Bind the run to its actual data, version, arguments, selected intervals, intermediate counts and residual sums. Then validate the timing, reference, corrections and population boundaries relevant to the result. Discuss an execution record and known-input challenge that would reveal a wrong setup despite a correct file hash. Keep result traceability distinct from the provenance of one software artifact. Review: Reproducible acceptance record; Chapter 1 measurement-chain evidence.

Review: Chapter 7 — Turn a quality metric into a reproducible acceptance record; Chapter 1 — Keep the evidence chain reversible to its declared inputs.

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V011-C07-DISCUSSION-025 — Report the verified finite comparison and count relationship with their declared scope, including normalization, processing, population and elapsed interval. State that source attribution and unobserved or unsuccessful acquisition intervals remain unresolved, rather than weakening the valid arithmetic or expanding it into a broader claim. Identify the specific additional evidence needed for those questions, such as authorized device-state correlation, a known timing reference or a complete acquisition log. The discussion should produce a usable bounded finding whose wording matches the checks actually completed and preserves the remaining uncertainties. Review: Models 7A–7B; acceptance record and inference limits.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload.

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Chapter Glossary

ACQUISITION-CONDITIONED METRIC: A result calculated only on intervals for which the receiver met its declared acquisition or lock criterion. It describes that selected population and must be accompanied by attempted acquisitions, failures and exclusions when the complete event matters. It does not establish uninterrupted reception during omitted intervals.

ACTIVE SYMBOL RATE: The rate of transmitted symbol instances during a declared active interval, determined from their spacing or count under the stated clock convention. It can differ from the average number of transmitted data symbols per second over an interval that also includes guards or idle time. A nominal accounting grid must be identified separately.

ADMISSIBLE RATE SET: The collection of rates permitted by all supplied count, duration and format premises. Discrete alternatives combined with bounded continuous factors can produce a union of separated intervals. Its overall minimum-to-maximum enclosure can include values that no stipulated configuration realizes; neither representation assigns probabilities without additional evidence.

ALIGNMENT TRAINING SET: The disclosed samples or symbols used to estimate the corrections applied before an error-vector evaluation.

CARRIER PHASE AMBIGUITY: An unresolved choice among carrier-phase alignments that can preserve the apparent constellation point set while changing the association between points and intended labels. A tight fitted constellation does not resolve the ambiguity. Known reference structure or another justified check must establish the required mapping.

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CARRIER SYNCHRONIZATION: The estimation and tracking of the frequency and phase relationship needed to compare an observed modulated signal with its declared carrier reference. Its acquisition range, loop behavior, fitted parameters and slips affect the symbol experiment. Successful numerical alignment does not by itself establish source identity or correct symbol labels.

CEILING FRAME COUNT: The smallest integer number of complete frames whose stated payload capacities can contain a positive request. With fixed positive capacity, it is the request size divided by capacity rounded upward. This rule preserves the complete-frame boundary; multiplying that count by full capacity can include final padding that is not original request payload.

CODED LABEL BIT: A bit position in the specified binary label mapped to a data symbol. A known power-of-two constellation with its declared labeling determines how many such positions belong to each symbol. This count does not by itself specify input-information bits, entropy, delivered unique payload or stored ADC data.

CODE RATE: For the complete-block count convention in Model 7B, the number of input-information bits divided by the corresponding coded label bits. The model scopes this ratio to redundancy-adding coding without compression. It is distinct from framing efficiency and cannot be estimated as a zero-over-zero empirical ratio from an empty record; a configured rate may be known separately.

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COMPLETE CODE BLOCK: An included input-and-output population whose coding relationship is fully represented for the declared count ratio. Counting only a partial segment can require explicit treatment of boundaries, termination and other coding structure. The chapter's fixed code-rate products assume complete stipulated populations rather than inferring them from a constellation display.

COMPLETE-FRAME PAYLOAD CAPACITY: The number of useful payload positions available in one fully specified frame after the separately declared coding and header conventions. Repeating full frames can achieve a capacity rate different from the actual rate for a finite request whose last frame contains padding. Capacity is not evidence that every position was filled with requested data or delivered successfully.

CONSTANT COMPLEX-GAIN FIT: A weighted least-squares estimate of one complex coefficient that scales and rotates a disclosed ideal-reference sequence. Positive training reference energy makes the minimizer unique. The fit minimizes training residual energy, not every normalized EVM or held-out error, and its coefficient remains part of the result when the correction is permitted.

CONSTELLATION MAPPING: The declared correspondence between symbol labels and complex reference values. A geometric point set alone does not establish this correspondence. Rotation or relabeling can preserve a constellation's appearance while changing the represented labels, so mapping validation is separate from a visually tight or numerically well-aligned display.

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DATA-SLOT FRACTION: The number of data-symbol slots divided by all nominal opportunities on the explicitly declared finite grid. It accounts for pilot or other nondata opportunities in that grid and differs from a payload-bit fraction. Its denominator must be positive, and any combined efficiency that already includes this reduction must not apply it again.

DECISION INSTANT: The declared time at which an observed, processed waveform sample is paired with a reference symbol for detection or quality assessment. Filtering, delay, symbol-clock configuration and timing recovery determine that pairing. Samples between decision instants are not silently included in a metric whose stated population consists only of symbol points.

DURATION-WEIGHTED AGGREGATION: A rate calculation that adds each interval's represented count and divides the total by the sum of compatible elapsed durations. It preserves the joint modulation, coding and efficiency factors realized within each interval. Separately averaging factors, or assigning equal weight to unequal-duration modes, generally gives a different result.

EQUALIZER: Adaptive or fixed filter used to compensate channel distortion and intersymbol interference.

ERROR VECTOR: The complex difference between an observed symbol value and its paired reference under the declared amplitude, timing and mapping conventions. Its real and imaginary components retain directional information. Squared magnitude contributes to residual energy, while the scalar EVM aggregate discards information about direction, symbol dependence and temporal ordering.

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ERROR VECTOR MAGNITUDE: Normalized distance between measured and reference modulation symbols after stated processing.

FALSE LOCK: Apparent synchronization to noise or an incorrect structure.

FITTED-REFERENCE EVM: The normalized residual magnitude when the permitted fitted complex gain multiplies the ideal symbols in both the comparison reference and its energy denominator. The fitted coefficient must be nonzero and evaluation reference energy positive. Reducing the residual numerator does not guarantee a smaller ratio if the fitted denominator also falls.

FIXED-REFERENCE EVM: The normalized residual magnitude relative to a declared reference that is not adjusted by fitting the evaluated observation record. It can retain an amplitude or phase discrepancy that an allowed fit would remove. The reference, population, weights and compatible amplitude convention must still be specified; fixed does not mean independently validated.

FRAME PADDING: Unused positions filled under the declared complete-frame rule when a finite request does not occupy all available payload capacity. These positions consume transmitted frame resources but do not add original request bits. Padding must be distinguished from headers, coding redundancy and retransmitted payload to avoid double counting their effects.

HELD-OUT SYMBOL EVALUATION: Error-vector assessment on symbols excluded from fitting the stated alignment parameters.

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INFORMATION-BIT COUNT: The number of input bits belonging to the complete coding populations included in Model 7B. This count can include payload, headers and padding under the stated framing convention. It is therefore different from both coded label-bit count and useful request-payload count; its interpretation must accompany any code-rate or payload-fraction calculation.

MATCHED FILTER: Filter designed to maximize output signal-to-noise ratio for a known waveform under specified noise assumptions.

MAXIMUM-REFERENCE NORMALIZATION: Normalization of residual mean square by a declared maximum ideal-symbol energy rather than the record's average reference energy.

NOMINAL SLOT GRID: An explicitly defined sequence of equal-duration opportunities used for finite rate accounting. It can be continued through a guard interval when that convention is stated, without asserting that physical symbols were transmitted in every opportunity. Its count divided by the common elapsed duration defines the slot rate used by the model.

OVERLAP-CORRECTED THROUGHPUT: A rate based on unique identified accepted payload positions after repeated instances across compatible streams have been removed. For two sets, add their counts and subtract the known intersection before dividing by their common duration. Equal bit values do not establish duplicate identity, and unknown overlap supports bounds rather than an invented exact unique rate.

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PAYLOAD-BIT FRACTION: The useful represented payload-instance count divided by the corresponding input-information count under the declared framing convention. It excludes separately identified nonpayload information positions such as headers or padding. It acts on bits rather than slots, differs from code rate, and requires a positive information-count denominator.

PAYLOAD INSTANCE: One counted occurrence of a payload bit in the specified transmission or accepted-stream population. Retransmissions or parallel streams can contain additional occurrences of the same identified payload position. An instance count is valid for its stated purpose but does not automatically equal the number of unique useful positions delivered.

REFERENCE-RMS NORMALIZATION: Normalization by the root mean square magnitude of the actual selected reference symbols under the declared weights. In a multilevel constellation, that realized energy depends on the included symbol population and need not equal a uniformly used alphabet's mean energy. It is distinct from normalization by a fixed constellation maximum.

RESIDUAL-ENERGY SUM: The sum of the declared nonnegative weights times squared complex error-vector magnitudes over the selected population. It retains squared-amplitude units before division by reference energy. The same sum can arise from different residual directions and time histories, so it does not uniquely identify an impairment or its physical origin.

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RESIDUAL FREQUENCY OFFSET: The remaining frequency difference between the signal's declared carrier reference and the local conversion or recovery reference. Under the chapter's convention it is carrier minus LO frequency and adds a linear baseband phase trend. Estimating that trend from modulated data can absorb part of the modulation unless the estimation model and interval are justified.

SYMBOL-RATE MISMATCH: A difference between the actual symbol timing rate and the rate assumed by the reconstruction or demodulator. It can make relative decision timing drift away from a chosen alignment point across a finite record. A constant timing adjustment does not generally remove that accumulating discrepancy; clock and processing premises require separate checks.

SYMBOL TIMING: Estimate of the sampling instant associated with each transmitted symbol.

UNIQUE PAYLOAD POSITION: A payload identity counted once in a declared accepted set, even when several transmission instances refer to it. Identity requires more than the binary value zero or one. Unique-position counting must specify the request or sequence boundary, acceptance rule and time interval before it can support a delivered-throughput claim.

WALL-INTERVAL PAYLOAD RATE: The represented payload-instance count divided by a stated elapsed interval that includes all specified active, guard and idle portions. Its numerator and time boundary must match. It differs from active-burst rate and becomes a unique-delivery rate only when the acceptance and duplicate-removal evidence supports that additional interpretation.

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WEIGHTED COMPLEX CORRELATION: In the chapter's gain fit, the sum of each training observation multiplied by the conjugate of its paired ideal reference and its fixed nonnegative weight. Dividing this complex quantity by positive training reference energy gives the fitted coefficient. The conjugation direction matters because it determines the estimated phase.

WEIGHTED REFERENCE ENERGY: The positive sum of declared nonnegative weights times squared reference-symbol magnitudes used in an EVM normalization.

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References and Works Cited

Keysight Technologies. Digital Modulation in Communications Systems: An Introduction. Application note 5965-7160E, 5 July 2024. Official 56-page PDF, printed pages 13–14, 38–39 and 41–43. https://www.keysight.com/us/en/assets/7018-09093/application-notes/5965-7160.pdf

Annotation. Supports the bounded distinction between bit rate and symbol rate for declared modulation labels, with synchronization and error-correction overhead explicitly excluded in the introductory comparison, and the discussion of carrier recovery and reference-based modulation accuracy. Models 7A and 7B independently develop their finite normalization and count conventions. No dated data-rate capability, frequency allocation, EVM-standard adoption or commercial performance claim is adopted from this source. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver’s actual topology. Ideal mixer identities do not establish that a real component is free of compression, leakage, spurs or path-dependent calibration errors. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

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Keysight Technologies. “EVM Normalization Reference (Digital Demod).” 89600 VSA help, 2026 Update 2.0, accessed 2 November 2026. https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/digdemod/content/dlg_digdemod_comp_evmnormref.htm

Cross-volume technical interface. S001-V009(Antenna Theory for TSCM and Technical Security) andS001-V010(Survey Antennas Probes Fixtures and Direction Finding Apparatus) provide the companion treatment of receiving aperture, polarisation, antenna factors and field probes.S001-V016(EMI EMC Shielding Grounding Bonding and Power Integrity) treats the interference environments in which these measurements are made. The procedure in this chapter remains independently executable: retain the configured reference plane, input attenuation, preselection, RBW, VBW, detector law, trace averaging and overload challenges in the measurement record; do not infer field strength from the analyser trace without an appropriate and uncertainty-bounded antenna/probe conversion.

Annotation. Documents reference-RMS and constellation-maximum choices and the distinction between trace and error-summary normalization in this implementation. Model 7A states its own finite selected population and independently derives its ratios. The source’s informal inverse-SNR wording is not adopted as a general EVM, noise or error-probability theorem. This measurement reference concerns digitally modulated signals and settings that affect an error-vector or constellation result. Error-vector normalisation, pulse-shaping filters, symbol timing and reference-signal construction must be known before results from two receivers can be compared. A proprietary default or measurement-guide illustration should not be treated as a universal

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numerical definition. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

Keysight Technologies. “EVM (Custom IQ).” 89600 VSA help, 2026 Update 2.0, accessed 2 November 2026. https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/customIq/content/customiq_symtblerrdata_evm.htm

Annotation. Supports the existing native source note on error vectors at declared symbol decision locations and the need to inspect the selected custom-IQ mode’s normalization rules. Its specific format exceptions do not replace Model 7A’s explicit finite sample and reference contract. This measurement reference concerns digitally modulated signals and settings that affect an error-vector or constellation result. Error-vector normalisation, pulse-shaping filters, symbol timing and reference-signal construction must be known before results from two receivers can be compared. A proprietary default or measurement-guide illustration should not be treated as a universal numerical definition. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions.

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Chapter 8. Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity

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8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method

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8.1.1 Learning outcomes, measurement purpose, and the nature of a spectrum

A spectrum analyser is a frequency-domain measurement instrument. It normally represents frequency on the horizontal axis and measured amplitude, power, or power density on the vertical axis. It is not merely a colourful radio display. Its interpretation depends upon the reference plane, the acquisition architecture, the frequency selectivity, the amplitude estimator, and the period during which signals were actually observed. The novice's first obligation is to write a measurement question before adjusting a knob: is the object to find a carrier, measure its power, distinguish two nearby components, characterise broadband noise, observe an intermittent burst, or compare two operating states? These objectives do not necessarily require the same instrument settings.

In a classical swept-tuned analyser, a receiver tunes successive frequencies through a resolution filter; the completed trace combines observations made at different instants. An FFT-based instrument analyses a captured time record, perhaps over a bounded instantaneous bandwidth, and may still scan or stitch additional bands. A real-time mode can maintain gap-free capture only within its qualified bandwidth, memory, trigger and processing limits. Consequently, a trace is a measurement product, not proof that every point in a wide frequency range was simultaneously monitored. The following introductory method supplies the operating vocabulary required for the advanced treatment in Sections 8.2–8.27.

Upon completing this section, a learner should be able to identify the RF input and its safe limits; configure frequency and amplitude axes; choose

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reasonable RBW, VBW, sweep and detector settings; obtain and interpret marker readings; perform reference-plane corrections and elementary uncertainty calculations; and design a repeatable laboratory record that can distinguish actual RF activity from instrument artefacts. The reader must also explain what a negative search does not establish when the receiver was not continuously observing the entire stated span.

Operational interpretation. In measurement purpose and the nature of a spectrum, the central rule is that the trace should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about frequency occupancy, discrete carriers, and wideband noise. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is treating a colourful display as if it were self-executing proof. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to time coverage, reference plane, and selectivity. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary,

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or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

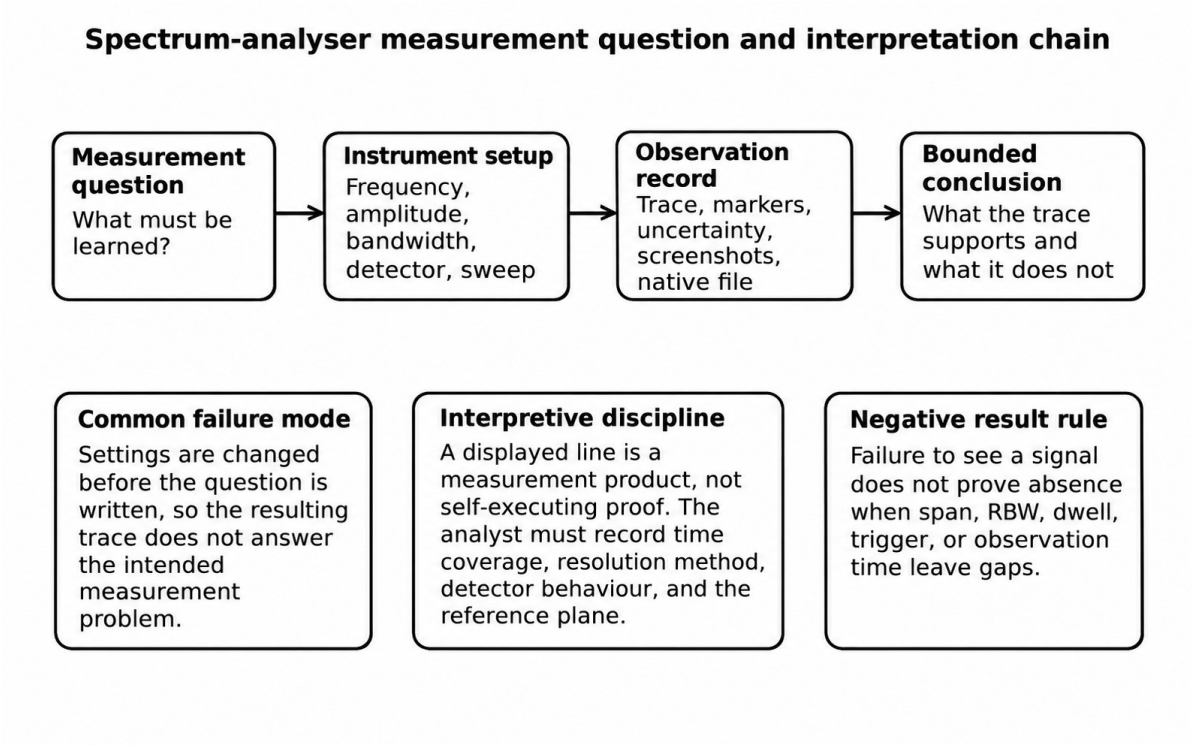

Figure 31. Spectrum-analyser measurement question and interpretation chain.

Laboratory method. The working rule for this topic is to state the measurement question before touching the instrument. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide

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whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

Measurement consequences. This topic should also be tied explicitly to frequency occupancy, discrete carriers, and wideband noise. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit measurement purpose and the nature of a spectrum during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how time coverage, reference plane, and selectivity shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.2 Front-panel controls, connections, and the signal path

Locate the RF input connector, its nominal impedance and coupling mode, the applicable maximum continuous and peak input ratings, the permitted DC level, the protective attenuator or limiter, and the instrument's reference-frequency connector before applying an external signal. Typical controls include frequency, span, amplitude, bandwidth, sweep, trigger, detector, trace, marker, measurement, system or calibration, preset, and save or recall. Modern analysers may implement them as soft keys, touch menus or remote-control commands; the measurement meaning, rather than the shape of a physical button, governs the record. A display's status region should be copied into the acquisition log because auto-coupled settings can change when the operator changes only one apparent control.

The simplified conducted path is: calibrated source or antenna terminal; any external protection and known cable; RF input attenuator; preselector and gain stages; conversion or digitisation; resolution-selective or transform processing; detection and averaging; marker or measurement calculation; and displayed or exported result. Each component can contribute loss, gain, mismatch, nonlinear distortion, time delay or uncertainty. The true input power at an antenna connector is not automatically the number indicated at the analyser display. When an external preamplifier is present, record its power supply, gain calibration, overload limit and noise behaviour as part of the path, not as an optional accessory.

On first use, obtain the instrument manual and calibration-status record, check connectors for damage, choose a harmless test level at the input, select a recognised frequency standard if required, and record the

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instrument configuration before connecting any unknown source. Never assume that a displayed reference level constitutes an input-power safety rating. Use conducted, terminated laboratory sources initially; do not connect an unidentified aerial, power circuit, radiating transmitter or active line directly to a sensitive input.

Operational interpretation. In front-panel controls and the signal path, the central rule is that the instrument control state should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about input protection, gain distribution, and detector selection. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is changing settings without recording coupled parameters. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to safe connection practice, power limits, and calibration status. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later

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reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

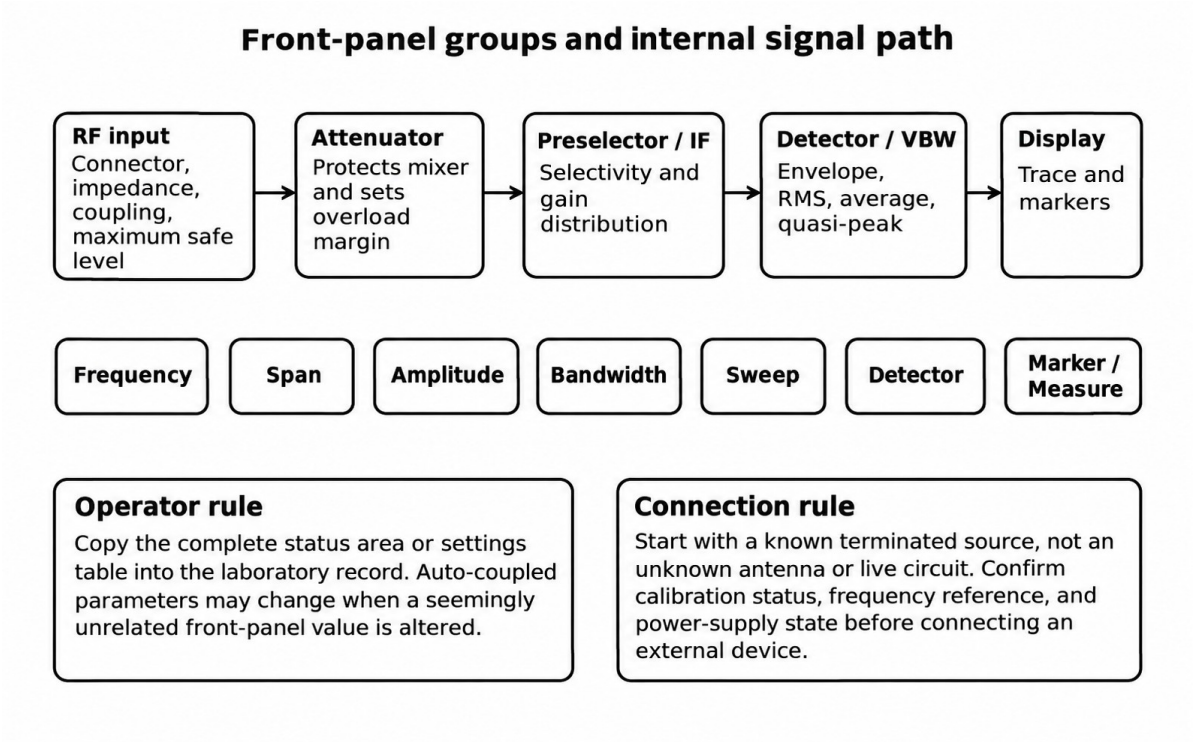

Figure 32. Front-panel groups and internal signal path.

Laboratory method. The working rule for this topic is to copy the status line and all active control states. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to input protection, gain distribution, and detector selection. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit front-panel controls and the signal path during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how safe connection practice, power limits, and calibration status shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.3 Frequency coordinates, span, and horizontal resolution

The centre frequency f_c is the midpoint of the requested frequency interval. For start frequency f_s and stop frequency f_e, $f_c = (f_s + f_e)/2$ and span $S = f_e - f_s$. Conversely, $f_s = f_c - S/2$ and $f_e = f_c + S/2$. All variables must use consistent frequency units. If the display has D equal horizontal divisions, the nominal frequency-per-division is S/D, although a discrete trace has finite frequency-bin or point spacing that must be considered separately. Zero span is a time-domain observation at a selected tuning frequency or filter, not a promise of infinitely fine spectral resolution.

A broad search span is valuable for discovery but may hide two nearby carriers within one display point or resolution-filter response. Narrow the span around a candidate, then verify that the actual resolution bandwidth and detector still support the claim. A centre-frequency marker identifies a displayed or fitted feature according to the instrument's algorithm; it does not automatically yield the absolute frequency accuracy of an independent counter. Frequency-reference error, local-oscillator stability, bin interpolation and the signal's own modulation can all affect an apparent peak position.

Operational interpretation. In frequency coordinates and span control, the central rule is that the horizontal axis should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about centre frequency, start/stop limits, and point spacing. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any

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reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is assuming that a broad span gives fine resolution. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to frequency accuracy, interpolation, and display spacing. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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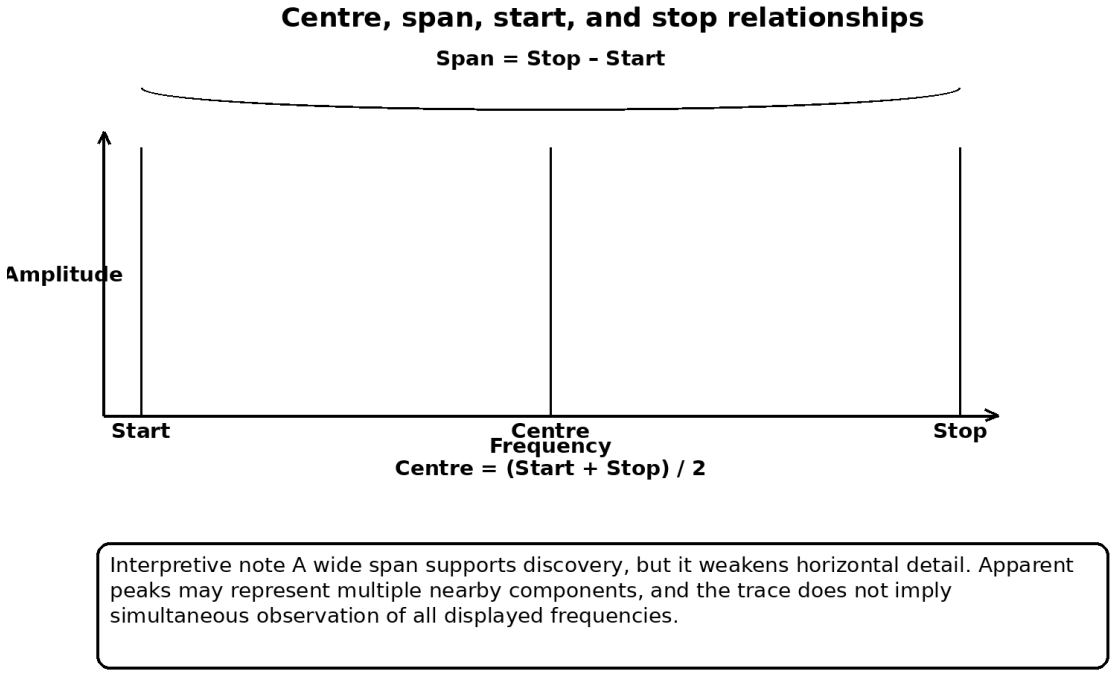

Figure 33. Centre, span, start, and stop relationships.

Laboratory method. The working rule for this topic is to shrink the span as the question becomes more specific. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to centre frequency, start/stop limits, and point spacing. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit frequency coordinates and span control during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how frequency accuracy, interpolation, and display spacing shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.4 Amplitude scale, reference level, input attenuation, and overload

A logarithmic display usually expresses power as dBm, with 0 dBm representing 1 milliwatt in the stated measurement convention. For power P in milliwatts, P_dBm = 10 log10(P/1 mW); P_mW = 10^(P_dBm/10). The reference level normally locates a designated amplitude near the top of the graticule; the scale may be 5 dB or 10 dB per vertical division. The reference level affects display placement and often interacts with automatic gain or attenuation, but it must not be mistaken for a hardware input rating. A linear-voltage display uses different interpretation and calibration rules.

Input attenuation reduces the signal presented to subsequent nonlinear stages and increases the apparent room for high-power blockers; it generally raises the effective input-referred noise floor when downstream noise dominates. Reducing attenuation may expose a weak carrier but can also provoke mixer compression or intermodulation. A preamplifier may improve sensitivity while sacrificing blocker tolerance. Select attenuation first according to the highest plausible aggregate signal, not merely the desired weak component. Examine overload annunciators, unexpected harmonics, gain-state logs and the response to a controlled attenuation change; a peak that changes by 20 dB when an external signal changes by 10 dB is not behaving as a simple linear external tone.

The protection plan must account for the maximum possible RF power and DC bias at the connector, plus transients, electrostatic discharge, mismatches and unknown energy outside the visible span. Apply rated external protection or an isolation network where warranted and obtain

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confirmation of its frequency response and power handling. The analyser's internal attenuator may not protect every coupling mode or every vulnerable component. Disconnect before changing uncertain paths.

Operational interpretation. In amplitude scaling and overload control, the central rule is that the amplitude scale should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about reference level, attenuation, and headroom. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is confusing display placement with safe power handling. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to compression, intermodulation, and protection margins. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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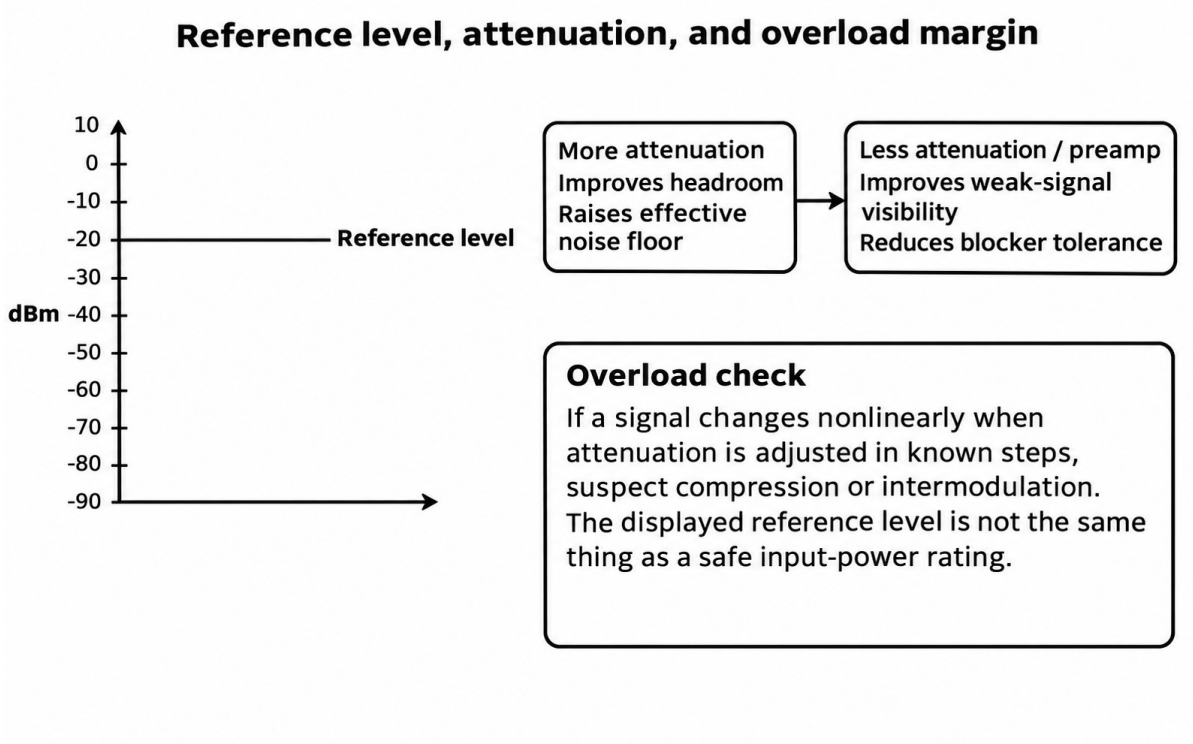

Figure 34. Reference level, attenuation, and overload margin.

Laboratory method. The working rule for this topic is to set attenuation for the strongest plausible signal first. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to reference level, attenuation, and headroom. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit amplitude scaling and overload control during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how compression, intermodulation, and protection margins shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.5 Resolution bandwidth, selectivity, and noise measurement

Resolution bandwidth (RBW) describes the effective frequency selectivity of the measurement filter or equivalent digital estimator. A smaller RBW may separate close signals and admits less approximately white noise; it may also require longer settling or observation. Different filter shapes and FFT windows possess different 3 dB bandwidths, equivalent noise bandwidths and sidelobes. Thus, a nominal RBW value alone does not define two-tone resolvability or amplitude accuracy. Distinguish a narrow continuous wave, whose integrated tone power can remain roughly constant after proper detector and calibration corrections, from noise power, which scales with equivalent noise bandwidth.

For thermal noise near 290 K, a commonly used reference density is approximately -174 dBm/Hz at a matched measurement plane. With equivalent noise bandwidth B_e in hertz and receiver noise figure NF in decibels, the simplified input-referred estimate is $N_{dBm} \approx -174 + 10 \log10(B_e/1\ Hz) + NF$. The approximation assumes stationary white noise over the selected interval, a defined impedance, valid calibration, and no dominating external noise or spur. When RBW and equivalent noise bandwidth differ, use the latter in the power equation. A smaller RBW lowers the noise measured in that filter; it does not physically remove noise from the incoming signal.

Operational interpretation. In resolution bandwidth and selectivity, the central rule is that the RBW choice should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a

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machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about two-tone separation, equivalent noise bandwidth, and settling time. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is using nominal RBW alone to justify a resolution claim. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to tone power, noise power, and filter shape. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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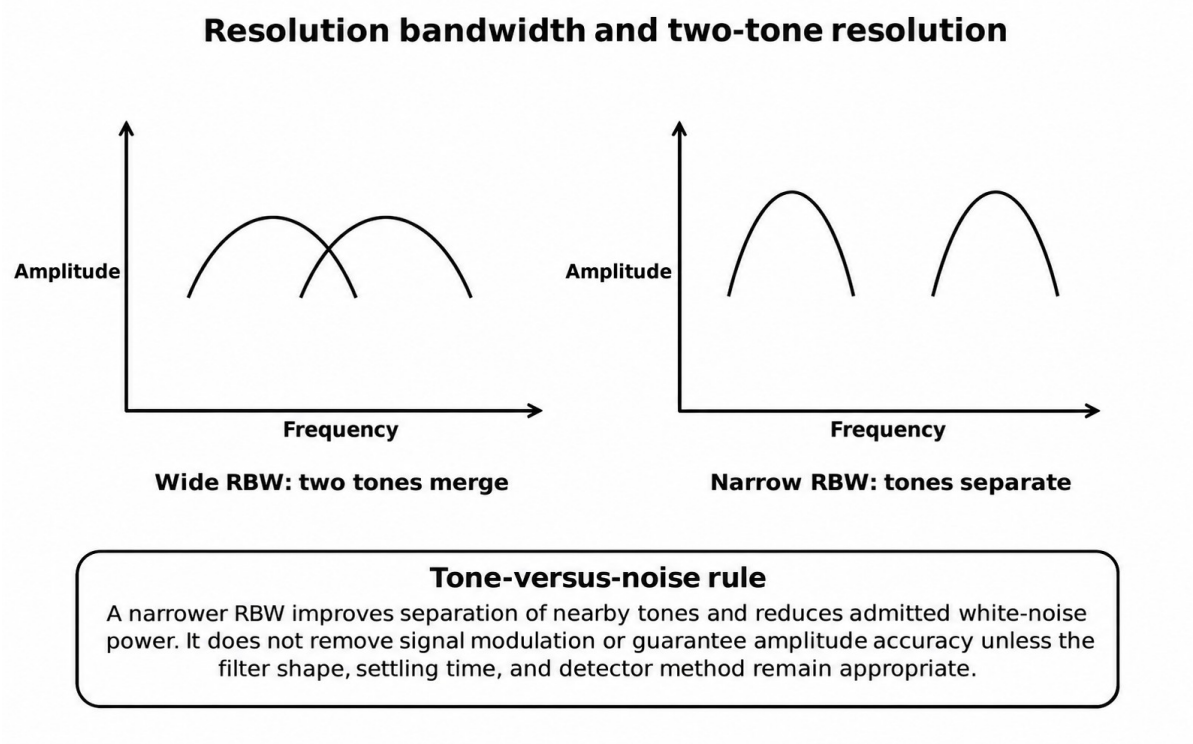

Figure 35. Resolution bandwidth and two-tone resolution.

Laboratory method. The working rule for this topic is to relate RBW to the specific measurement objective. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to two-tone separation, equivalent noise bandwidth, and settling time. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit resolution bandwidth and selectivity during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how tone power, noise power, and filter shape shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.6 Video bandwidth, smoothing, and averaging

Video bandwidth (VBW) is ordinarily a post-detection smoothing or filtering parameter, although its exact implementation depends on the analyser. Lowering VBW can make a noisy trace appear quieter without creating additional frequency resolution or reducing the noise already admitted through the RBW filter. Excessively narrow VBW may distort pulse amplitudes, smear changing signals or require more sweep time. Similarly, trace averaging is meaningful only after one identifies what is averaged: linear power, envelope voltage, logarithmic amplitude, complex FFT bins or another quantity. Arithmetic averaging in watts followed by conversion to dBm need not equal averaging the dBm readings. The two operations are mathematically different.

Record RBW, VBW, averaging count and mathematical domain. The variance reduction ordinarily attributed to averaging presumes an effective number of independent observations. Consecutive heavily overlapped FFT frames or repeated readings of the same slowly varying filter output are correlated; they must not be counted as independent evidence. For transient discovery, compare a relatively unsmoothed acquisition with a deliberately smoothed display and preserve both configurations.

Operational interpretation. In video bandwidth and smoothing, the central rule is that the display treatment should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about trace readability, post-detection filtering, and variance reduction. For that reason, the student should learn to read each

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displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is mistaking a smoother display for better resolution. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to display cosmetics, pulse fidelity, and response lag. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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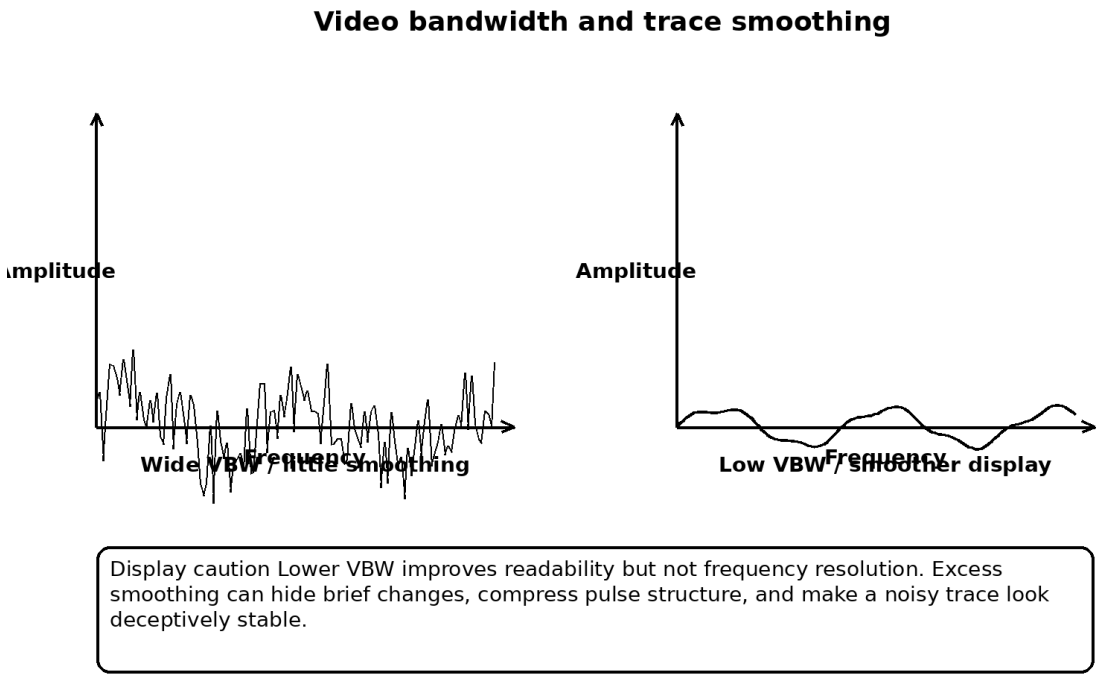

Figure 36. Video bandwidth and trace smoothing.

Laboratory method. The working rule for this topic is to state whether VBW or averaging was changed. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

Measurement consequences. This topic should also be tied explicitly to trace readability, post-detection filtering, and variance reduction. In practice,

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these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit video bandwidth and smoothing during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how display cosmetics, pulse fidelity, and response lag shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.7 Sweep time, dwell, triggering, and temporal coverage

Sweep time is the interval associated with a frequency traversal or a stated acquisition, not a guarantee that every frequency was observed throughout that interval. In a swept analyser, the resolution-filter response must settle sufficiently at successive tuned frequencies. Narrow RBW and VBW settings can lengthen the sweep, although automatic controls and digital architectures complicate any simple sweep-time law. Detector bucket dwell, inter-sweep dead time, retrace, triggering, preselection switching and hidden averaging each alter the likelihood of intercepting a brief emission. Record the actual sweep or capture time, trace points, trigger condition, holdoff and observed occupancy.

A triggered trace may begin after an event, depending upon detection latency and pre-trigger storage. Zero-span recording measures amplitude versus time only within the chosen IF or digital analysis bandwidth. For a suspected short burst, select a time-resolved or real-time mode whose specified instantaneous bandwidth and probability-of-intercept limits are appropriate, rather than mistaking a static max-hold peak for complete temporal evidence. In any negative-result report, state the observation interval and the instrument's unobserved intervals explicitly.

Operational interpretation. In sweep time, dwell, and temporal coverage, the central rule is that the time coverage should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about revisit interval, dwell, and trigger state. For that reason, the student should learn to read each displayed trace as the

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consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is claiming absence when the instrument was elsewhere in frequency. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to intermittent bursts, revisit probability, and acceptance criteria. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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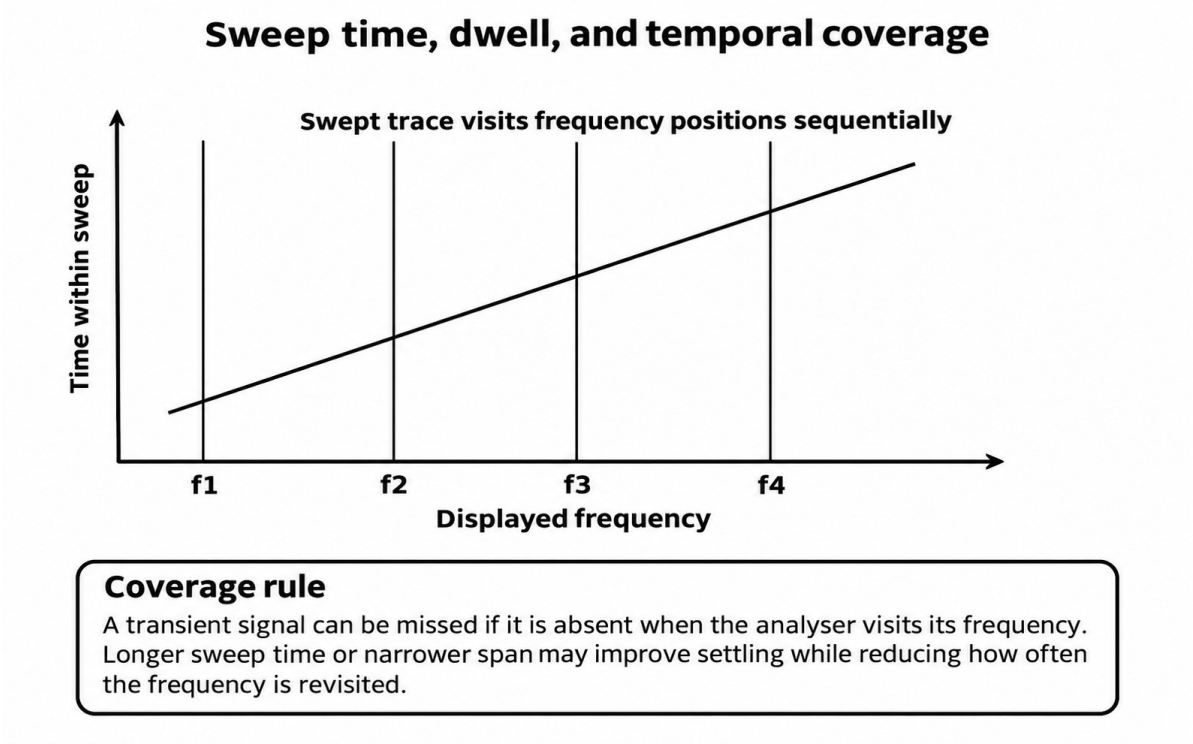

Figure 37. Sweep time, dwell, and temporal coverage.

Laboratory method. The working rule for this topic is to link sweep settings to signal persistence and duty cycle. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to revisit interval, dwell, and trigger state. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit sweep time, dwell, and temporal coverage during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how intermittent bursts, revisit probability, and acceptance criteria shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.8 Detector modes, trace functions, and truthful displays

Peak, negative-peak, sample, RMS or power-average, quasi-peak and other detector modes answer different questions. Peak detection emphasises the largest selected amplitude within a bucket, often helping discover intermittent activity; negative peak emphasises the smallest. A sample detector retains a selected sample and may miss an isolated event. RMS or power-based methods estimate average energy under the instrument's documented sample and bandwidth model. Quasi-peak is a weighted response specified by particular measurement conventions, not an interchangeable synonym for peak. The label on the display must be interpreted with the actual detector implementation and any correction factors.

Max hold retains the largest displayed value over multiple traces and is useful for discovering intermittent spectral components, but the resulting composite is not a spectrum acquired at one instant. Min hold and averaging have similarly distinct interpretations. Document the starting time, reset action, number of contributing sweeps, detector mode, and any missing acquisition interval. An investigator must not claim that a max-hold line represents simultaneous emissions unless independent time-aligned records support that conclusion.

Operational interpretation. In detector modes and trace functions, the central rule is that the detector model should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about peak, sample, average, RMS, and trace

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persistence. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is mixing detector results as if they were directly comparable. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to regulatory compatibility, repeatability, and statistical meaning. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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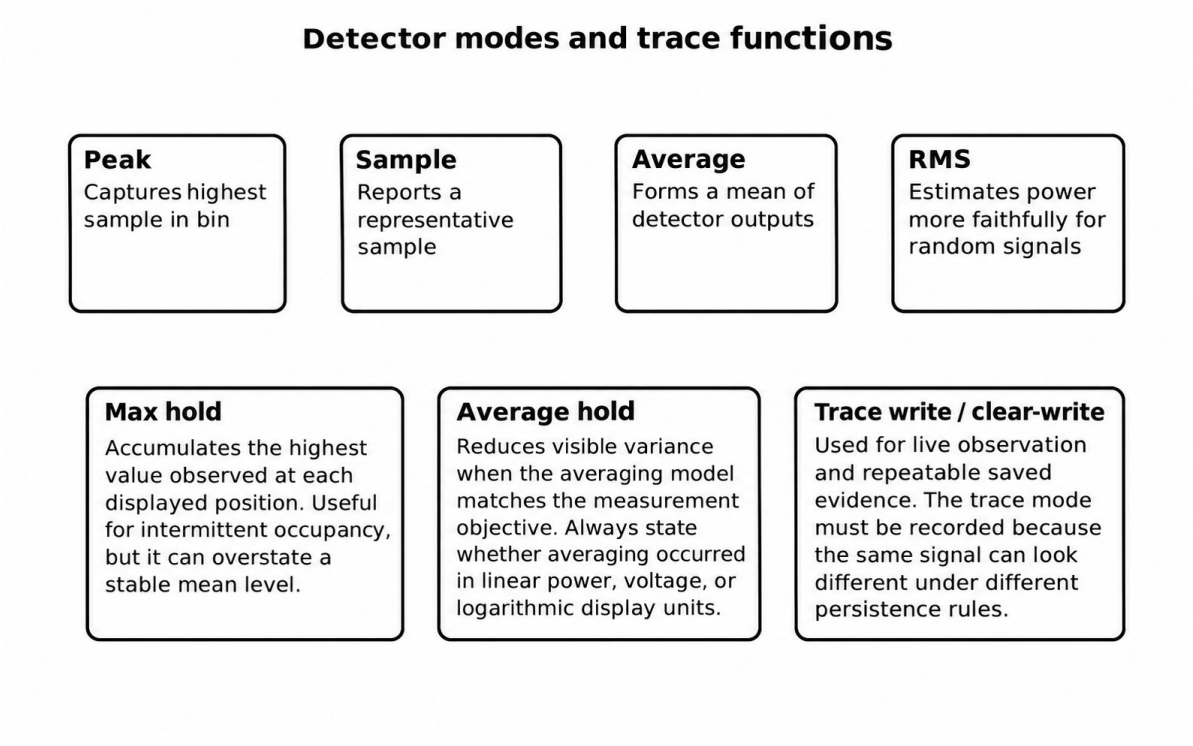

Figure 38. Detector modes and trace functions.

Laboratory method. The working rule for this topic is to record the detector and trace mode on every saved record. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to peak, sample, average, RMS, and trace persistence. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit detector modes and trace functions during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how regulatory compatibility, repeatability, and statistical meaning shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.9 Markers, delta measurements, and amplitude corrections

A marker usually returns the frequency coordinate and displayed amplitude of one trace point or a fitted estimate. A delta marker returns a difference relative to a reference marker, potentially in frequency and dB. Peak-search, next-peak, noise-marker, occupied-bandwidth and channel-power functions are not equivalent. In particular, an amplitude marker on a noise trace is not automatically the integrated power of a whole channel. For calibrated channel-power measurements, specify integration limits, instrument resolution, detector or estimator law, corrections and uncertainty.

Inspect the marker's trace source and correction table. A cable-loss table, antenna factor, external attenuation or gain compensation can shift the displayed level or change its physical unit. A correction may be expressed at a specified reference plane only. For comparative measurements, apply identical detection, resolution and reference settings or document a validated correction. Preserve the original raw trace or complex samples when possible, together with the transformed result and its settings.

Operational interpretation. In markers and delta measurements, the central rule is that the marker report should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about frequency offset, amplitude difference, and applied correction. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in

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plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is copying the readout without stating its correction basis. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to cable loss, gain offsets, and frequency-reference limits. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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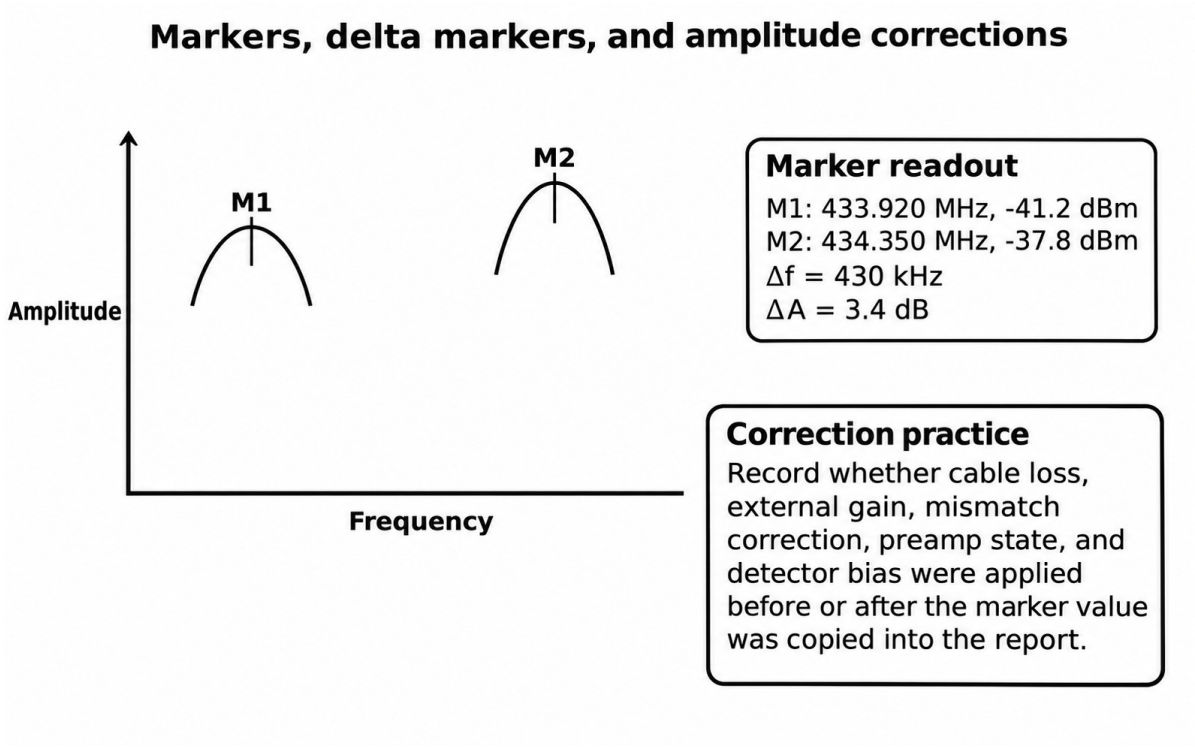

Figure 39. Markers, delta markers, and amplitude corrections.

Laboratory method. The working rule for this topic is to write down both the raw and corrected marker values. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to frequency offset, amplitude difference, and applied correction. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit markers and delta measurements during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how cable loss, gain offsets, and frequency-reference limits shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.10 Calibration, traceability, reference planes, and daily verification

Calibration establishes specified relations between a measurement indication and quantities realised through a traceable measurement chain, with associated uncertainty; an instrument's internal alignment routine is not a universal substitute for external calibration. Confirm the calibration date and stated interval, warm-up requirements, amplitude and frequency accuracy, reference clock selection, connector condition, firmware configuration, and the applicable operating temperature. Where power is transferred through a cable or attenuator, define a connector reference plane and distinguish scalar insertion loss from mismatch uncertainty. For precision frequency work, verify the internal reference or lock to a documented external standard and record the lock state.

A daily verification should use a known, appropriately low-level reference signal at a frequency inside the planned working range, with a check at another frequency or amplitude when relevant. Compare the indicated reading with an acceptance interval formed from the reference specification and the analyser's published uncertainty, and document any failure before measuring unknown signals. Conduct a repeatability test, an input-attenuation challenge, a noise-floor check and a connector inspection as the scope warrants. An apparent correction that merely makes a trace pleasing to the eye is not calibration.

Operational interpretation. In calibration, traceability, and reference planes, the central rule is that the calibration chain should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a

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machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about known sources, correction tables, and uncertainty terms. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is reporting corrected amplitudes without naming a reference plane. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to traceability, uncertainty budgets, and daily confidence checks. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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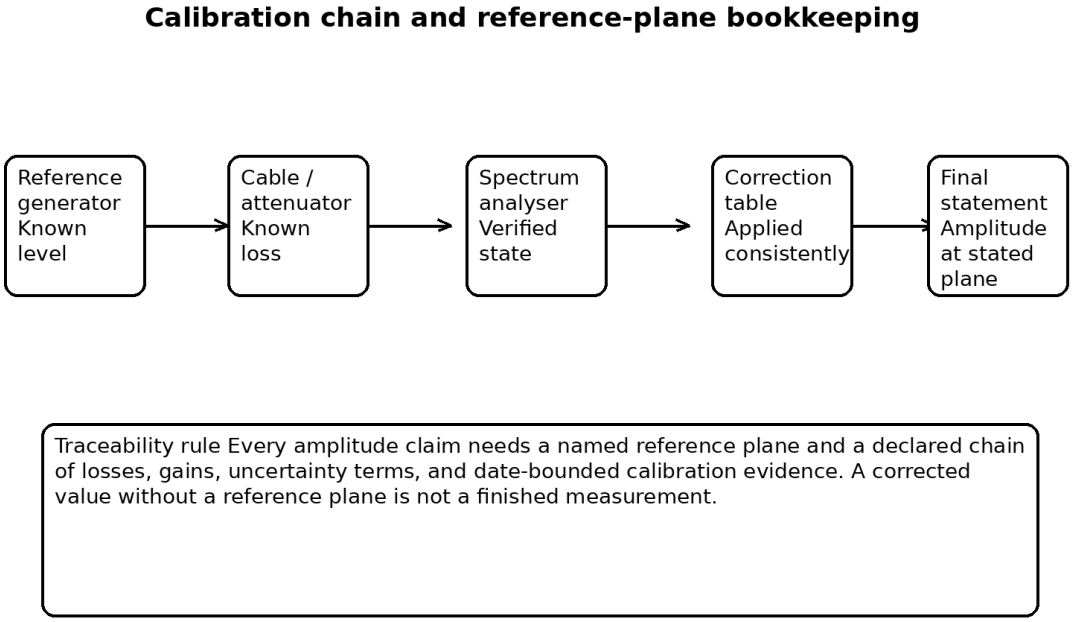

Figure 40. Calibration chain and reference-plane bookkeeping.

Laboratory method. The working rule for this topic is to tie every correction to a date-bounded calibration record. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to known sources, correction tables, and uncertainty terms. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit calibration, traceability, and reference planes during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how traceability, uncertainty budgets, and daily confidence checks shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.11 Ten worked examples: elementary calculations and their limitations

Worked example 1. Frequency centre and span. A student specifies f_s = 145.000 MHz and f_e = 149.000 MHz across D = 8 horizontal divisions. The frequency centre is 147.000 MHz and span is 4.000 MHz; each division represents 0.500 MHz. A marker at 148.250 MHz lies 1.250 MHz to the right of the centre, corresponding to 2.5 divisions. These are display coordinates, not a proof of absolute marker-frequency accuracy.

> $f_c = (145 + 149)/2 = 147$ MHz; $S = 149 - 145 = 4$ MHz; $S/D = 4/8 = 0.5$ MHz/div.

Worked example 2. Converting dBm to watts and voltage. Assume a matched 50-ohm system and a steady sinusoidal signal measured at -30 dBm. The corresponding power is $10^{(-3)}$ mW = 0.001 mW = 1.0 microwatt. The associated RMS voltage across an actual 50-ohm load is sqrt(P R) = 7.071 millivolts. The voltage calculation must not be transferred unchanged to an unmatched connector or an unknown impedance.

> $P = 10^{(-30/10)}$ mW = 0.001 mW = 10^{-6} W; $V_{rms} = \sqrt{(10^{-6}\ W)(50\ ohm)} = 7.071$ mV.

Worked example 3. Correcting a known conducted-path loss. A generator produces -20.0 dBm at its specified output reference plane. A calibrated external attenuator and cable have a combined insertion loss of 10.0 dB at the measurement frequency. The ideal analyser input is -30.0 dBm. If the analyser reads -30.0 dBm with its internal correction disabled, then the inferred generator-plane power is -20.0 dBm after adding the

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external loss. The analysis must separately account for mismatch and calibration uncertainty.

> P_{input} = -20.0 dBm - 10.0 dB = -30.0 dBm; P_{source} = -30.0 dBm + 10.0 dB = -20.0 dBm.

Worked example 4. Noise power and RBW. Assume a 290 K input, equivalent noise bandwidth B_e = 10,000 Hz, and an effective system noise figure NF = 12 dB. The estimated input-referred noise is -122 dBm. Reducing B_e to 1,000 Hz, with all else unchanged, reduces noise in the filter by 10 dB to -132 dBm. The assumption of unchanged NF may fail if the gain or attenuation state changes between the two measurements.

> N_{10k} = -174 + 10 log10(10000) + 12 = -122 dBm; N_{1k} = -174 + 10 log10(1000) + 12 = -132 dBm.

Worked example 5. Two-tone spacing and RBW choice. Two steady carriers are at 100.000 MHz and 100.004 MHz, giving a 4 kHz separation. An RBW of 10 kHz is generally inadequate to distinguish them as separate narrow responses, while 1 kHz is a more defensible starting choice. Final resolvability still depends on filter shape, relative carrier amplitudes, dynamic range and window sidelobes. The spacing itself is 4 kHz, regardless of the display span.

> Delta f = 100.004 MHz - 100.000 MHz = 0.004 MHz = 4 kHz; choose RBW << Delta f, then verify experimentally.

Worked example 6. Averaging and the independence assumption. Suppose one independent power observation has a standard deviation equal to its own mean under a specified exponential-noise model. The relative standard deviation of the mean of N independent observations is

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1/sqrt(N). Twenty-five independent observations give 20%; 100 give 10%; 400 give 5%. This is an averaging calculation, not a universal prediction from selecting a particular VBW; correlated records reduce the effective sample count.

> Relative sigma_mean = 1/sqrt(N); N = 25: 20%; N = 100: 10%; N = 400: 5%.

Worked example 7. Dwell and minimum frame duration. An illustrative sweep has 200 independent frequency positions, each requiring at least 2 ms of observation and settling. Its dwell-only lower bound is 400 ms, excluding retrace, calibration actions and processing. A 1 ms burst is shorter than an individual 2 ms dwell, and may fail to coincide with the tuned frequency. It is therefore wrong to infer complete time coverage from the nominal 400 ms sweep time.

> T_dwell,min = N_positions x t_position = 200 x 0.002 s = 0.400 s; T_actual >= 0.400 s.

Worked example 8. Peak indication versus mean power. Consider three equal-duration, independently sampled power readings of -40, -35 and -50 dBm in a stated RBW. Their linear powers are 100.00 nW, approximately 316.23 nW and 10.00 nW. The largest is -35 dBm; the arithmetic mean of the linear powers is approximately 142.08 nW, equivalent to -38.47 dBm. Simply averaging the three dBm labels would give -41.67 dBm, a different statistical operation.

> P_mean = (100 + 316.23 + 10)/3 = 142.08 nW; 10 log10(142.08 nW/1 mW) = -38.47 dBm.

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Worked example 9. Delta-marker frequency and amplitude. A reference marker identifies a component at 2450.000 MHz and -42.0 dBm. A second marker identifies another component at 2450.025 MHz and -48.0 dBm. Their frequency separation is 25 kHz, while the second component is 6.0 dB lower. For comparable corrected powers the power ratio is approximately 0.251. Neither delta alone proves whether the components are harmonically related or originate outside the analyser.

> Delta f = 0.025 MHz = 25 kHz; Delta P = -48 - (-42) = -6 dB; P_2/P_1 = 10^(-6/10) = 0.251.

Worked example 10. Reference-plane correction and combined uncertainty. An analyser displays -60.0 dBm at its RF input. The cable loss to the declared source plane is 1.7 dB, so the inferred source-plane power is -58.3 dBm. Assume independent standard uncertainties of 0.6 dB for the amplitude indication and 0.3 dB for the cable correction. Their root-sum-square combination is 0.671 dB; an illustrative expanded uncertainty with coverage factor k = 2 is about 1.34 dB. If the two uncertainties are correlated, the covariance term must be included rather than omitted.

> P_source = -60.0 + 1.7 = -58.3 dBm; u_c = sqrt(0.6^2 + 0.3^2) = 0.671 dB; U(k=2) = 1.34 dB.

These examples are controlled instructional models. An actual instrument may add filter-shape corrections, nonlinear responses, averaging bias, mismatch, time-varying gain, trace quantisation and specification limits. Each student should document assumptions and compare the analytic estimate with an independently checked physical measurement.

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Operational interpretation. In worked calculations and interpretive discipline, the central rule is that the calculation should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about unit conversion, dBm arithmetic, and sanity checking. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is trusting automation without an order-of-magnitude estimate. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to rounding, assumptions, and configuration-specific limits. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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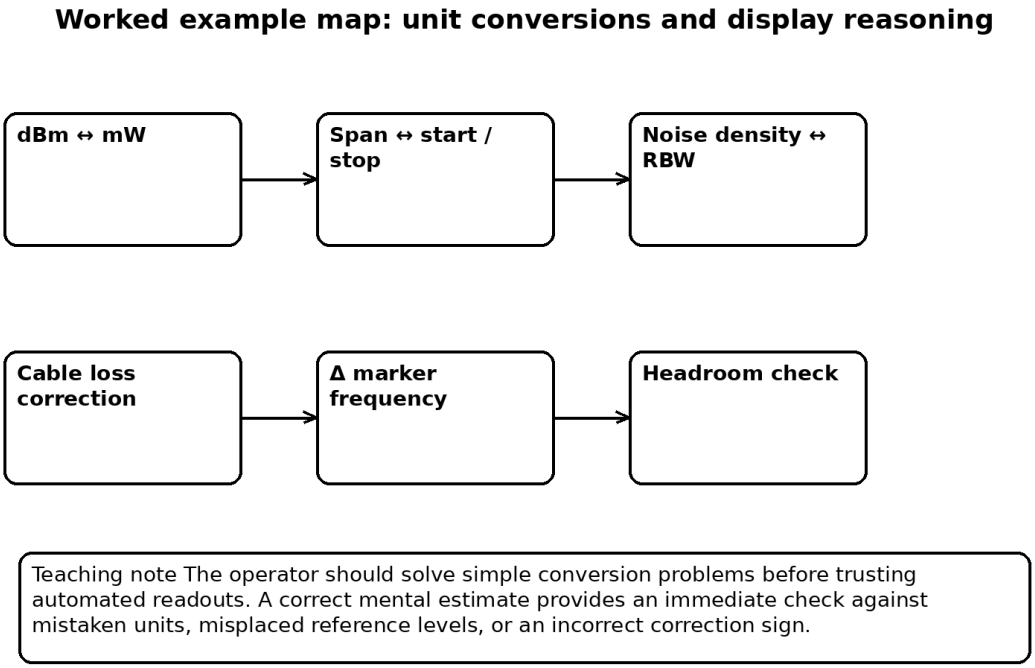

Figure 41. Worked example map: unit conversions and display reasoning.

Laboratory method. The working rule for this topic is to solve the simple version by hand before accepting the display. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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Measurement consequences. This topic should also be tied explicitly to unit conversion, dBm arithmetic, and sanity checking. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit worked calculations and interpretive discipline during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how rounding, assumptions, and configuration-specific limits shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.12 Supervised laboratory exercises and acceptance criteria

Practical A. Front-panel identification and safe conducted connection. Objective: identify the principal control groups and the chain from source to analyser input. Apparatus: a serviceable analyser, its current instruction manual, a 50-ohm termination, a calibrated low-power source, a rated attenuator, and suitable coaxial leads. With the generator output disabled, record the analyser model, RF input ratings, connector condition, coupling mode, reference source, attenuation state and calibration status. Connect the terminated path, enable a harmless known source at least the margin specified by the laboratory safety procedure below the RF input rating, then save a complete instrument-state record. Acceptance: the student can reconstruct the connection and explain why reference level is not a safety limit.

Practical B. Frequency, span, power scales, and markers. Objective: measure the frequency and amplitude of a stable continuous-wave signal. Configure a broad span to find a calibrated generator tone, narrow the span, and report centre, start, stop, span, division spacing, marker frequency, marker amplitude, RBW, detector mode and connector reference plane. Repeat after shifting the source frequency by a known interval. Acceptance: the reported marker difference agrees with the source shift within the combined instrument and source accuracy; an unexplained disagreement is investigated rather than erased.

Practical C. RBW, selectivity and noise-floor contrast. Objective: distinguish the displayed continuous-wave response from the stationary

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noise background. Select a safe fixed-power tone, then measure at two RBW values differing by a factor of ten. Preserve the same reference plane, attenuation and other states, and record whether the tone power is consistent while the noise in a resolution filter changes. Use two low-level tones of known separation to explore filter selectivity if suitable equipment is available. Acceptance: the report states the RBW filter shape or ENBW convention and explains why a wider filter may conceal a weak adjacent tone.

Practical D. VBW, detectors and trace statistics. Objective: separate display smoothing from measurement bandwidth. With a stable source and noise background, hold RBW constant while changing VBW and averaging configuration. Capture unsmoothed and smoothed traces, then compare sample, peak and power-average modes where the instrument offers them. Acceptance: the student identifies which changes affect apparent ripple, which change spectral resolution, and why an average of dBm values differs from a dBm conversion of mean linear power. Do not infer independent samples merely from a trace count.

Practical E. Intermittent-signal visibility and sweep-time bias. Objective: demonstrate that swept traces do not provide gap-free time observation across the entire span. Use a laboratory-approved low-power burst generator through a conducted and shielded path; select two sweep times and two detector/trace combinations, recording every trigger and reset state. Compare detections with an independent time-stamped observation at the source. Acceptance: state the measured detection fraction for the tested stimulus, the acquisition conditions, and a bounded negative

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conclusion; do not generalise that fraction to signals with unknown timing. The exercise must not radiate outside authorised test facilities.

Practical F. Calibration check, overload challenge and uncertainty budget. Objective: verify a traceable input level while demonstrating protection of the receiver. Start with a suitably weak known tone and an adequate rated attenuation path. Record raw amplitude, cable correction, gain or attenuation state, reference accuracy, and the resultant standard and expanded uncertainties. Reduce source level or add external attenuation in controlled increments and check for expected linear change; do not deliberately exceed instrument ratings or induce damage. Acceptance: provide a configuration-specific measurement statement, a dated calibration and uncertainty record, an identified reference plane, a saved native trace, and a rule for suspending work if overload or calibration failure occurs.

Laboratory logistics and authorisation. A two-semester instructor-led course should begin with conducted connections into terminated loads, then progress to an RF-isolated chamber under a documented site procedure, followed by supervised indoor and outdoor test ranges when the instructor can establish lawful operation, emission control, personnel exclusion zones and frequency coordination. An anechoic chamber is not automatically a perfectly isolated chamber, and a shielded enclosure does not make excessive RF exposure or poor electrical practice acceptable. Never use a live service, a third-party transmission, a mains connection, or personal communications content as an unapproved test source. Record spectrum occupancy and non-content technical observables only within the authority granted for the exercise.

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Common laboratory reporting template. Every exercise report must identify the measurement question, test date and place, instrument identity and calibration status, source characteristics, permitted operating authority, reference planes, impedance, external losses and gains, attenuation, RBW, VBW, detector, sweep time, trigger, frequency reference, correction tables, saved native observations, uncertainty, operator notes and final bounded conclusion. Distinguish an observed spectral feature from an assertion concerning its source, purpose or lawfulness. Export the settings and the raw record before producing annotated figures for an assessment submission.

Competency and progression. A student should not advance to blind-survey or transient-evidence exercises merely because a frequency peak can be located. Progress requires a repeatable setup, adequate overload margin, correct conversion between linear power and dBm, an explanation of the noise and selectivity tradeoffs, a defensible time-coverage statement, and correct use of marker and reference-plane uncertainty. Advanced treatments of RBW, detector statistics, sweep validity, transient probability and amplitude uncertainty follow in the remaining sections of this chapter.

Operational interpretation. In supervised laboratory exercises, the central rule is that the laboratory record should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about conducted setups, chamber work, and range progression. For that reason, the student should learn to read each displayed trace as the consequence of a method. Before copying any reading into a notebook or report, the operator should state the problem in

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plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is jumping to radiated work before mastering conducted control. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to safety, legal authority, and reproducibility. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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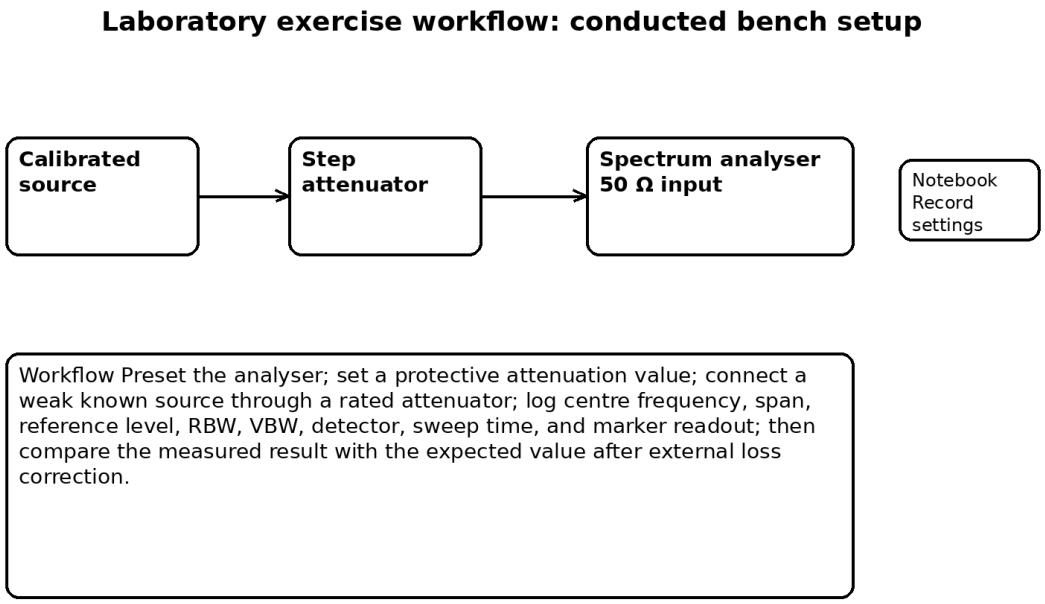

Figure 42. Laboratory exercise workflow: conducted bench setup.

Laboratory method. The working rule for this topic is to advance only when repeatability and authority are established. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

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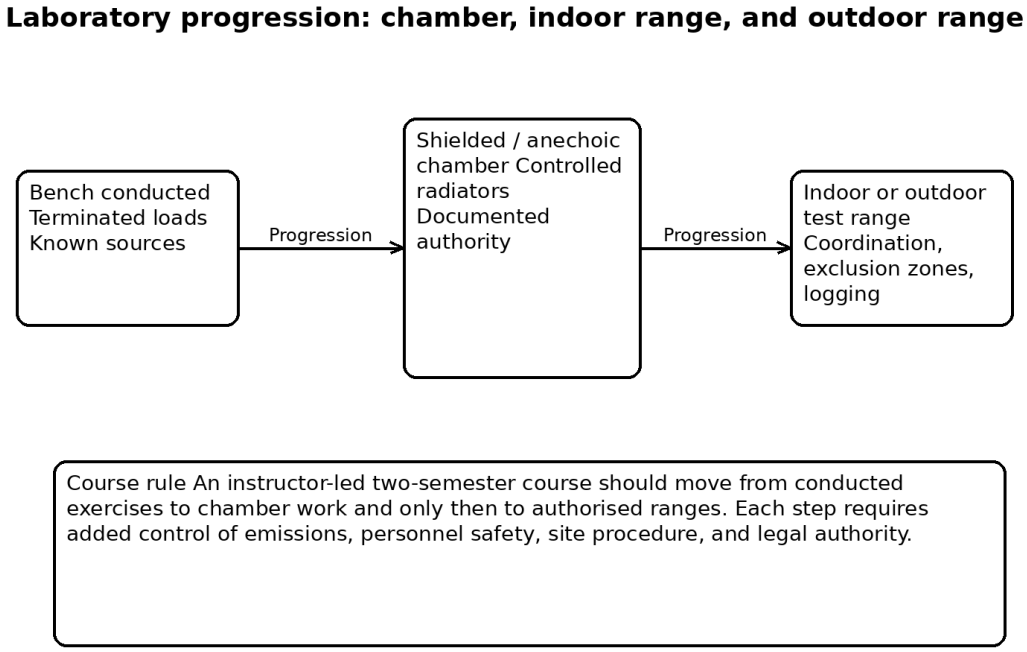

Figure 43. Laboratory progression: chamber, indoor range, and outdoor range.

Measurement consequences. This topic should also be tied explicitly to conducted setups, chamber work, and range progression. In practice, these details govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

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Instructional emphasis. Instructors should revisit supervised laboratory exercises during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how safety, legal authority, and reproducibility shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

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8.1.13 Swept Architecture and Frequency-Time Mapping

A swept-tuned spectrum analyzer translates successive input frequencies through a narrow resolution filter while its local oscillator moves across the selected span. The horizontal axis is therefore generated over time, not acquired simultaneously. A signal that changes during the sweep can appear at the wrong amplitude, be split, be missed, or be drawn as a misleading shape. Sweep time, span, resolution bandwidth, detector, and trigger determine whether the display represents the event.[5]

The analyzer may contain multiple conversions, tracking preselection, step attenuators, logarithmic IF paths, digital IF filters, and display processing. Modern instruments can combine swept and FFT techniques, so the selected mode should be identified rather than inferred. The practitioner records whether the trace was continuously swept, stepped, FFT-based, max-held over many passes, or assembled from segments.

Operational interpretation. In swept architecture and frequency-time mapping, the central rule is that the architecture statement should answer the measurement question actually posed by the analyst. A spectrum analyser is not simply a machine that paints peaks on a screen; it is a bounded measurement system whose display reflects choices about local-oscillator motion, filter settling, and trace assembly. For that reason, the student should learn to read each displayed trace as the consequence of a

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5 H. T. Friis, “Noise Figures of Radio Receivers,” Proceedings of the IRE 32, no. 7 (July 1944): 419–22, https://doi.org/10.1109/JRPROC.1944.232049. The publisher’s abstract was read for the historical network, component, mismatch, and measurement framing. The full paper was not accessed; Model 2B supplies its own stated derivation and working conventions.

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method. Before copying any reading into a notebook or report, the operator should state the problem in plain language and then explain why the chosen settings are suited to that problem. This habit prevents the common error of letting the instrument's convenience determine the observation, rather than letting the observation requirement determine the settings.

Common interpretive failure. A persistent error in beginner work is forgetting that a swept trace is a time-sequenced product. The operator may obtain a trace that appears neat and plausible, yet still answers the wrong question or answers it only weakly. The corrective discipline is to write a short statement of intent in the record, then justify the chosen configuration with reference to visit order, missed events, and interpretive bounds. If the intent changes, the setup should change as well, and the change should be written down. This practice is particularly important in forensic, evidentiary, or acceptance-testing environments where a later reviewer was not present when the measurement was made and must reconstruct the logic of the setup from the record alone.

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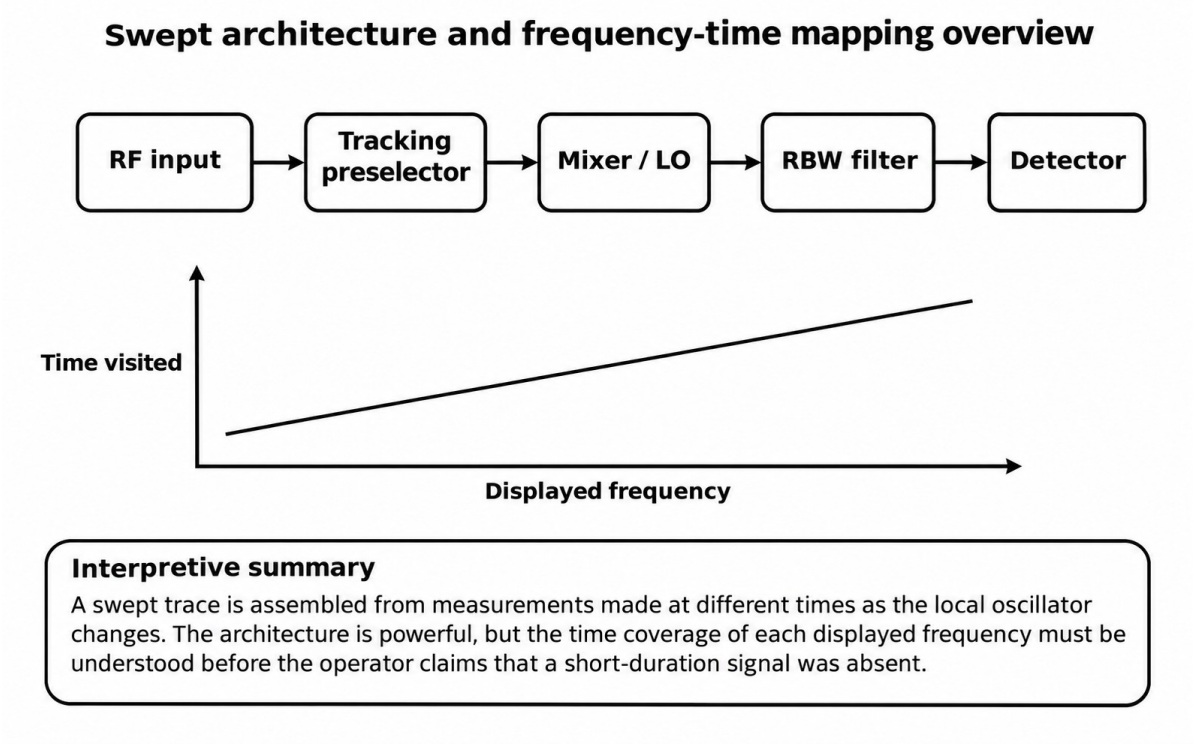

Figure 44. Swept architecture and frequency-time mapping overview.

Laboratory method. The working rule for this topic is to describe how the displayed line was acquired. That instruction sounds simple, but it creates a measurable increase in repeatability because it forces the student to pause and connect the physical setup, the displayed trace, and the final conclusion. In class, an instructor should require the student to record at least the instrument identity, reference plane, active settings, and the reason those settings were selected. If repeated measurements are made under apparently identical conditions, any remaining variation then becomes analytically useful rather than mysterious. The student can compare runs, compute deltas, and decide whether the difference arises from the source, the path, the detector model, or the observer's own procedural change.

Measurement consequences. This topic should also be tied explicitly to local-oscillator motion, filter settling, and trace assembly. In practice, these details

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govern whether a reported value is simply a useful indication or a defensible measurement statement. A good educational method is to ask the learner what would happen if one of the controlling assumptions were changed: What if the signal became intermittent? What if the span were widened? What if the reference level were moved without changing attenuation? What if external loss were omitted from the correction? Such counterfactual checks train the learner to view the trace as conditional. The analyser is excellent at displaying behaviour, but the analyst remains responsible for stating the conditions under which the displayed behaviour was obtained.

Instructional emphasis. Instructors should revisit swept architecture and frequency-time mapping during practical exercises so that students hear the same doctrine in conducted work, chamber work, and authorised range work. The educational aim is not rote control-pushing; it is the formation of judgement. When a student can explain, in complete sentences, how visit order, missed events, and interpretive bounds shaped the displayed result and why an alternative setup would have produced a different answer, that student has moved beyond superficial instrument familiarity. This deeper understanding is what allows later chapters on selectivity, detector statistics, and uncertainty to remain connected to laboratory reality rather than floating free as abstract formulas.

Field-minded caution. Spectrum analysers are frequently used by intelligent operators who are nevertheless tempted to move too quickly from observation to attribution. An observed emission line may be real while its origin remains uncertain. A clean display may still conceal missed events, detector bias, or an incorrect correction sign. A beautifully smoothed trace may tell less truth than a rough one if the smoothing process masks the

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temporal behaviour that matters to the question. For that reason, the fundamental doctrine of this introductory section is restraint joined to precision: connect safely, declare the question, choose settings that suit the question, record them faithfully, check the result against a simple hand estimate, and state the conclusion in bounded terms. Once that discipline has become habitual, the student is ready to approach resolution filters, detector statistics, swept acceptance criteria, and FFT methods as tools of professional measurement rather than as isolated menu selections on a screen.

Synthesis for advanced work. Before leaving the introductory material, the learner should be able to narrate a full measurement sequence from start to finish. A good oral check is to ask the student to explain what happens when a weak carrier is sought in the presence of stronger neighbours. The student should mention the reference plane, safe connection practice, input attenuation, reference level, preamplifier use, span choice, RBW, VBW, detector model, marker method, and the uncertainty of the corrected amplitude. The student should then explain what evidence would show overload or misleading smoothing, what record would be saved for later review, and what negative conclusion would remain impermissible if the time coverage were incomplete. This integrated explanation is often more revealing than a single numerical answer because it shows whether the learner understands the relationship between settings, architecture, and interpretation. It also prepares the learner to read the more exact sections that follow in this chapter, where selectivity, detector mathematics, and sweep validity are treated with greater depth and where the language of the

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manufacturer's specification must be reconciled with classroom demonstrations.

Course transition. The reader should therefore enter the remainder of Chapter 8 with a disciplined checklist already internalised: define the question, protect the input, set a justifiable span, choose attenuation and reference level together, relate RBW and VBW to the signal model, state the detector and trace mode, document marker corrections, verify calibration lineage, and describe what time interval and probability of observation the trace actually represents. When this checklist is used consistently, later discussions of selectivity curves, sweep acceptance, amplitude uncertainty, and missed-event probability become easier to understand because each advanced concept already has a practical home in the operator's routine.

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8.2 Resolution Bandwidth and Selectivity

Resolution bandwidth controls the analyzer's ability to separate nearby components and the noise admitted to the detector. Narrowing RBW lowers displayed noise and improves frequency discrimination, but increases filter settling and sweep time. The filter's noise bandwidth, shape factor, and response to pulsed or frequency-agile signals matter. An RBW label does not fully describe the filter.

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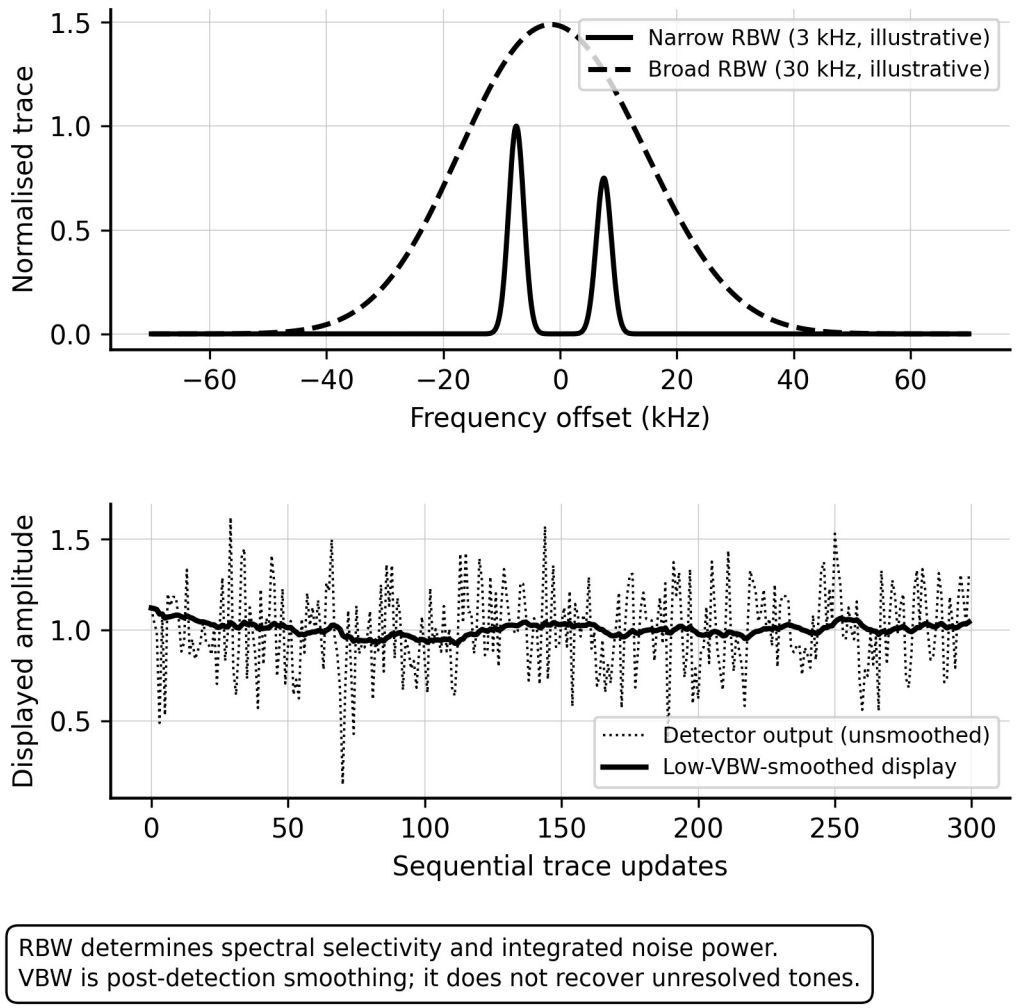

Figure 45. Resolution versus video bandwidth.

Measurements such as channel power, occupied bandwidth, phase noise, adjacent-channel power, and discrete spur amplitude have different RBW requirements. If the RBW is wider than the signal, the analyzer integrates most of the signal but also more noise. If it is narrower, a modulated signal

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is measured in pieces as the filter sweeps. The method should follow the desired measurand rather than a habit of selecting the narrowest available bandwidth.

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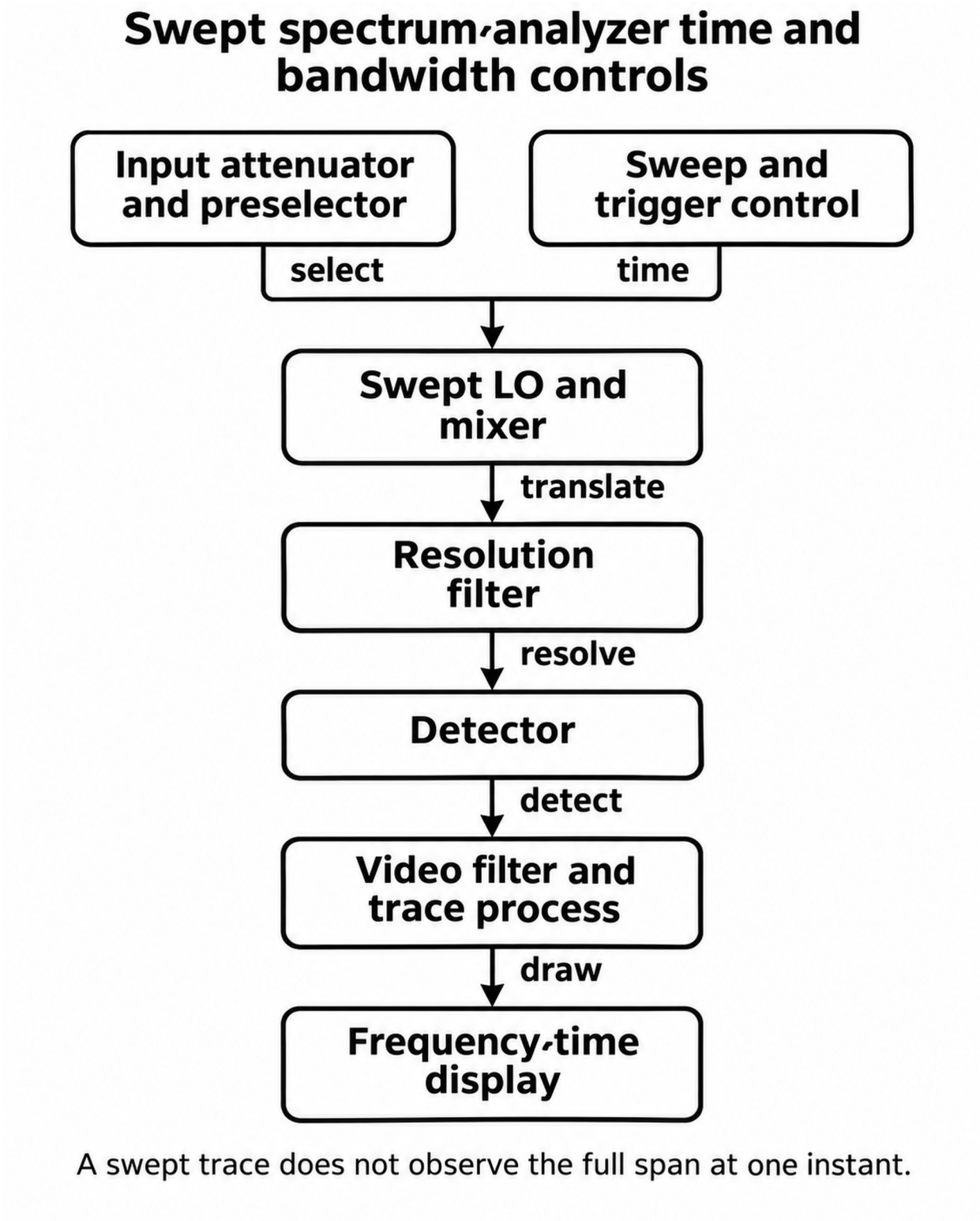

Figure 46. Swept spectrum-analyser control chain.

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8.3 Video Bandwidth, Averaging, and Detector Choice

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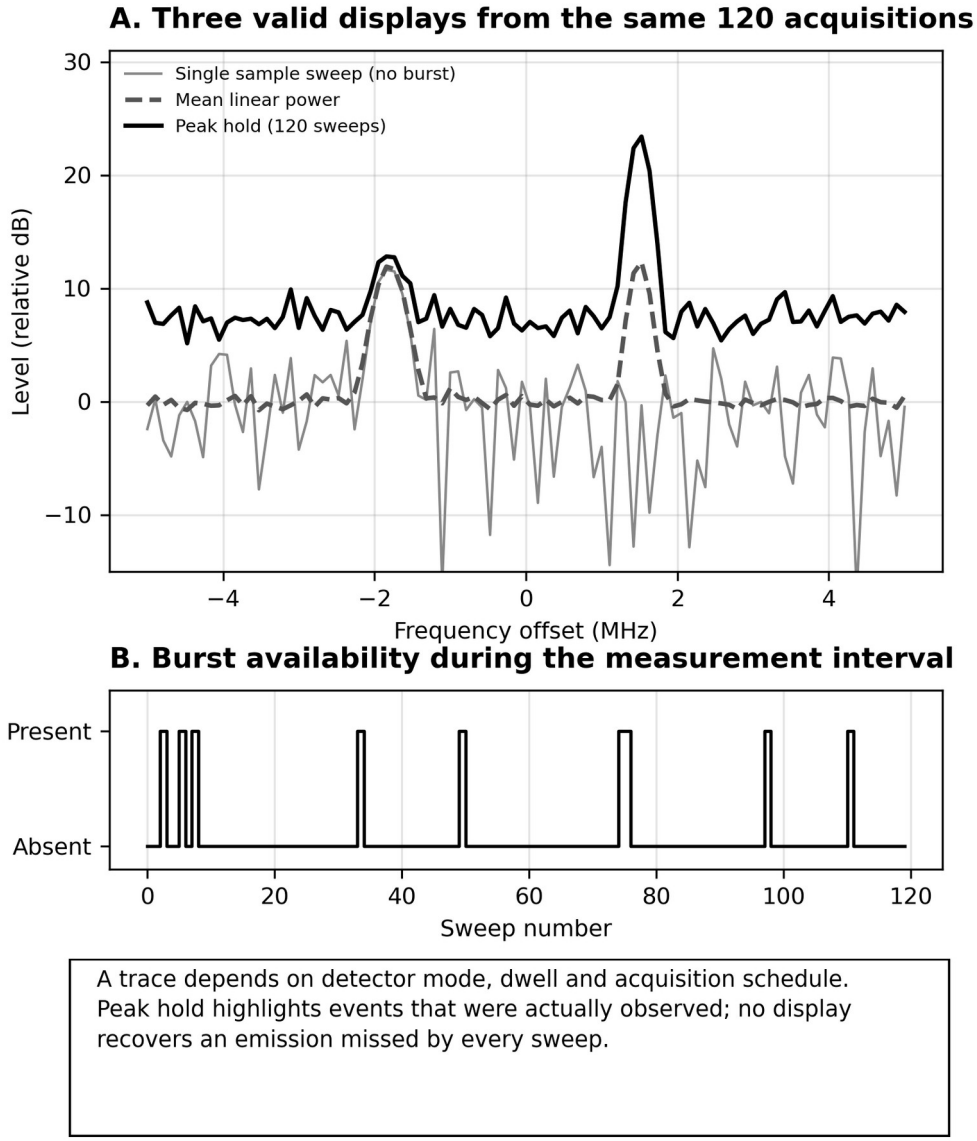

Figure 47. Detector modes and intermittent RF bursts.

Video bandwidth or post-detection filtering smooths the trace and reduces visible noise variation at the cost of response time. Trace averaging can improve repeatability for stationary random processes, while max hold captures intermittent peaks across repeated sweeps. Neither creates simultaneous observation. A short burst may be caught on one sweep and

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missed on the next, producing a partial spectral outline. The detector-dependent burst example is illustrated in Figure 33.

Peak, sample, negative peak, average, RMS, and quasi-peak detectors produce different results. Regulatory measurements may prescribe a detector and time behavior. A survey search may use positive peak and max hold for discovery, then RMS or averaging for power estimates. The detector setting is part of the measurement definition and should not be changed between traces that are compared quantitatively.

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8.4 Noise averages, detector statistics, and the meaning of a decibel trace

The word average does not identify a noise-power estimator. A receiver may average instantaneous powers, voltage magnitudes or logarithmic readings, then apply another detector or marker correction. A logarithmic display of an already averaged power is not equivalent to an average of logarithmic power samples. Two traces can therefore differ systematically even when their analog input, bandwidth and gain are unchanged. Equation 16 remains useful only after these estimator conventions have been reconciled.

The distinction appears explicitly in manufacturer help. The Keysight E505xA spectrum-analyzer application describes separate voltage, power and logarithmic video-averaging operations, applied after the DFT and before image rejection; its detector selection is another operation on display buckets. Those details describe that implementation, not every analyzer.[6] The N9000B CXA specification guide, edition 6 of May 2024, states at printed page 56, note d, that its cited DANL uses logarithmic averaging and therefore lies 2.51 dB below the corresponding noise density before a separate bandwidth correction. This is a specification convention, not

6 International Electrotechnical Commission, CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus, 5th ed. (May 22, 2019), official publication scope, https://webstore.iec.ch/en/publication/60774, checked November 1, 2026. The public scope identifies the 9 kHz–18 GHz apparatus range and EMI receivers and spectrum analyzers. No access to or clause-by-clause compliance review of the complete standard is claimed.

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evidence that every reported noise marker needs the same added correction.[7]

7 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers,” June 14, 2013, “Baseline Case: Cascade of Linear Circuit Blocks,” “A Heterodyne Receiver,” “Noise Temperature,” and “Y-Factor,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html. The scalar derivation and numerical cases here are original and explicitly exclude unmodeled image contributions.

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8.4.1 A stated statistical model

Take a fixed frequency, a linear receiver, and stationary zero-mean circular complex Gaussian noise at a calibrated power-estimation plane. Let X and Y be independent real Gaussian quadrature components with mean zero and variance one. Define an instantaneous power sample $P = \frac{\mu (X^2 + Y^2)}{2}$, where $\mu > 0$ is mean noise power in watts. This normalization incorporates reference resistance and gain calibration; P is not an uncalibrated ADC count. The dimensionless variable $U = \frac{P}{\mu}$ has exponential density $\exp(-u)$ for $u \geq 0$, with mean and variance both one. Consequently $\mathrm{E}[P] = \mu$ and $\mathrm{Var}(P) = \mu^2$. A deterministic tone, clipped envelope or mixture of changing noise levels generally lacks this distribution.

For N equally weighted positive samples, with $P_{ref} = 1\ \mathrm{mW}$, define

Equation 16A. Log averages and the logarithm of average power

$$L_N = \frac{10}{N \ln 10} \sum_{i=1}^{N} \ln\left(\frac{P_i}{P_{ref}}\right)$$

$$A_N = \frac{10}{\ln 10} \ln\left(\frac{\sum_{i=1}^{N} P_i}{N P_{ref}}\right)$$

Both statistics are in dBm, but L_N averages logarithms while A_N logs an arithmetic power mean. Concavity of logarithm gives $L_N \leq A_N$ for every realized record, with equality only when all sampled powers are equal. This inequality establishes direction, not a numerical correction or Gaussian statistics.

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Let γ be Euler's constant, approximately 0.5772156649. Substitution $P = \mu U$ and the integral $\int_0^\infty \exp(-u) \ln(u)\, du = -\gamma$ over the positive real axis give

Equation 16B. Expected logarithmic noise level

$$E[L_N] = 10 \log_{10}\left(\frac{\mu}{P_{ref}}\right) - \frac{10\gamma}{\ln 10}$$

$$E[L_N] \approx 10 \log_{10}\left(\frac{\mu}{P_{ref}}\right) - 2.506815781\, dB$$

NIST DLMF equation 5.9.18 supplies the integral.[8] Identically distributed samples suffice for this expectation; independence is not required. More independent log samples reduce fluctuation but do not remove the mean offset. Adding the modeled offset, approximately 2.5068 dB, is an unbiased correction in decibel expectation for this specified statistic and single exponential distribution. It is not distribution-free and does not make the exponentiated estimate unbiased in watts.

The 2024 edition of Keysight's Spectrum and Signal Analyzer Measurements and Noise distinguishes log-envelope under-response from equivalent-noise-bandwidth correction.[9] The statistical derivation here states the

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8 Keysight Technologies, Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide, part N9069-90001, edition 1 (March 2016), 10–11, 73–81, especially "Using Loss Compensation" and "Setting Temperature of Loss," https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf. This identified edition supports the stated measurement controls, not a claim about every current analyzer.

9 James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. Its historical

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assumed distribution explicitly; these are separate corrections with different causes.

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radiometer thresholds are not adopted as acceptance limits for the present constructed receiver.

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8.4.2 Power averaging before the logarithm

For N independent exponential power samples, $S=\frac{\sum_{i=1}^{N} P_i}{\mu}$ has density $\frac{s^{N-1}\exp\backslash(-s\backslash)}{\backslash(N-1\backslash)!}$ on $s\geq 0$, by repeated convolution. Differentiating the gamma integral yields $\mathrm{E}[\ln S]=\psi\backslash(N\backslash)=H_{N-1}-\gamma$, where H_n is the sum $1+\frac{1}{2}+\cdots+\frac{1}{n}$ and $H_0=0$. DLMF equations 5.9.16 and 5.9.19 give the corresponding harmonic and logarithmic-moment identities. Therefore

Equation 16C. Finite-record logarithmic bias after power averaging

$$E[A_N]=10\log_{10}(\frac{\mu}{P_{ref}})+b_N$$

$$b_N=\frac{10}{\ln 10}[H_{N-1}-\gamma-\ln N]$$

The arithmetic power mean is unbiased in watts. Its conversion to decibels has finite-record bias b_N. At $N=1$ the two formulas agree. At $N=4$, $b_N\approx-0.565350\ \mathrm{dB}$; at $N=100$, $b_N\approx-0.021751\ \mathrm{dB}$. It tends to zero from below. Adding 2.5068 dB to a well-averaged power estimate would introduce error. The relevant N counts independent exponential samples entering this estimator, not automatically sweeps, FFT samples or display pixels.

For independent samples the arithmetic mean has relative standard deviation $\frac{1}{\sqrt{N}}$. The exponential density's second logarithmic moment gives variance $\backslash(\frac{10}{\ln\backslash(10\backslash)}\backslash)^2\frac{\pi^2}{6}$ for one log sample, and thus standard deviation $\frac{10\pi}{\ln\backslash(10\backslash)\times\sqrt{6N}}$ for L_N. Dependence changes these variance results. For power samples with common variance μ^2 and common pairwise correlation

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ρ, direct expansion of the variance of their sum gives relative standard deviation $\sqrt{\frac{1+\backslash(N-1\backslash)\rho}{N}}$. This is a stipulated covariance illustration, not a substitute for investigating overlap or filter correlation. The gamma formula in Equation 16C generally does not survive that dependence.

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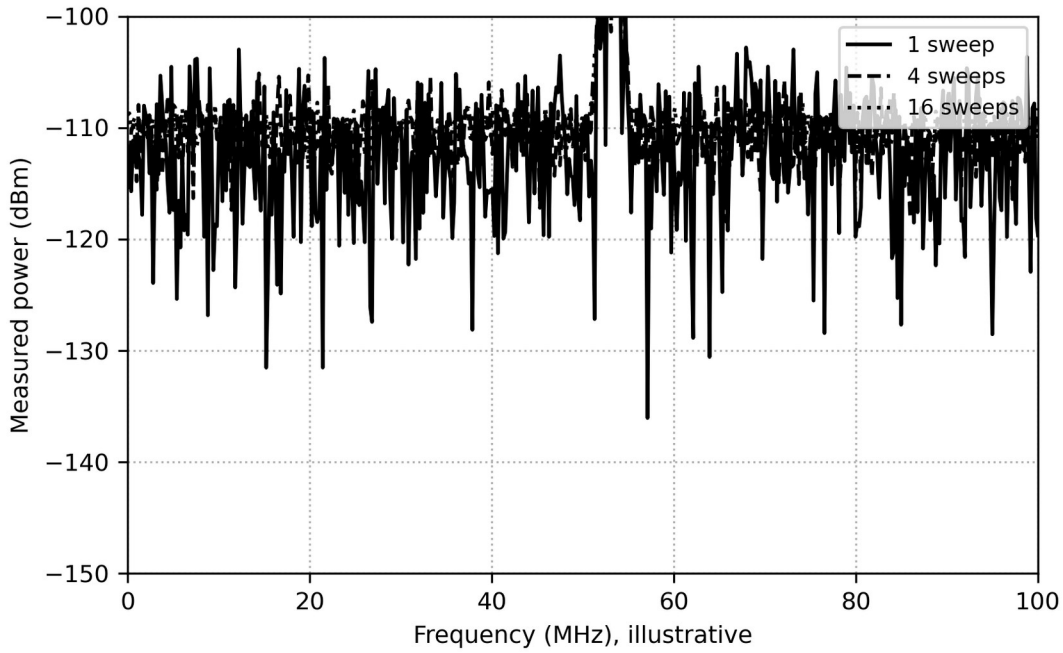

Noise variance decreases with averaging when acquisition conditions are stationary.

No average can reconstruct a burst that was never acquired.

Figure 48. Spectrum averaging and missed events.

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8.4.3 Ten worked applications

All cases are hypothetical model calculations, not measured performance of a named receiver.

1. Order of operations. Two power samples are 0.1 and 1.9 mW. Their arithmetic mean is 1 mW, so $A_2 = 0\ \text{dBm}$. Their log average is $\frac{10\log_{10}\backslash(0.1\backslash) + 10\log_{10}\backslash(1.9\backslash)}{2}\ \text{dBm} \approx -3.606232\ \text{dBm}$. This particular record satisfies the inequality, but its observed difference need not equal an ensemble-mean correction.

2. The specified log statistic. A long log average of single-sample Gaussian-noise powers is -102.00 dBm. Equation 16B associates it with approximately $\backslash(-102.00 + 2.506816\backslash)\ \text{dBm} = -99.493184\ \text{dBm}$ mean-power level, before other calibration and bandwidth corrections. Keep the original statistic and correction in the record. This corrected value is not an upper confidence bound.

3. Constant-envelope counterexample. Suppose every calibrated sample represents an ideal tone at -102.00 dBm. Both Equation 16A statistics equal -102.00 dBm for any N. Adding the Gaussian correction gives -99.493184 dBm, overstating the tone by 2.506816 dB. A dBm axis does not establish applicability of a noise correction.

4. Noise-bandwidth change. A flat mean power spectral density of -150 dBm/Hz in 100 kHz equivalent noise bandwidth gives mean power -100 dBm and expected $L_N \approx -102.506816\ \text{dBm}$. At 1 kHz the corresponding levels are -120 and -122.506816 dBm. The change is -20 dB in both conventions because the identical bias cancels. The bandwidth ratio therefore identifies a

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change in integrated noise even when the absolute log level differs from mean power.

5. RBW label versus integration bandwidth. Stipulate a filter labeled 1 kHz whose independently established noise bandwidth is 1128 Hz; no universal filter factor is assumed. At -150 dBm/Hz the integrated mean is -119.476909 dBm and expected uncorrected log average is -121.983725 dBm. Recovery gives

$$[-121.983725+2.506816-10\log_{10}\left(\frac{1128\ \text{Hz}}{1\ \text{Hz}}\right)]\ \text{dBm/Hz}\approx-150.000000\ \text{dBm/Hz}.$$

Subtracting just 30 dB for the label instead gives -149.476909 dBm/Hz, 0.523091 dB high.

6. Four powers averaged first. For $N=4$, Equation 16C gives $\frac{10}{\ln(10)}\left(1+\frac{1}{2}+\frac{1}{3}-\gamma-\ln(4)\right)\ \text{dB}\approx-0.565350\ \text{dB}$. A statistic with expectation -100.565350 dBm corresponds to a -100 dBm mean-power level. Adding 2.506816 dB produces -98.058534 dBm, 1.941466 dB too high in expectation. With 100 independent powers the finite-log correction is just 0.021751 dB. An algorithm already correcting its statistic must not receive another correction.

7. Repeatability versus bias. At $N=100$ the arithmetic power mean has relative standard deviation 0.1. The log mean has standard deviation $\frac{10\pi}{\ln(10)\times\sqrt{600}}\ \text{dB}\approx0.557004\ \text{dB}$, yet its expectation remains 2.506816 dB low. For a sufficiently concentrated arithmetic power mean, first-order propagation gives approximate decibel standard deviation $\frac{10}{10\times\ln(10)}\ \text{dB}\approx0.434294\ \text{dB}$. That local approximation is not an exact

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confidence interval. A steadier trace need not estimate the intended quantity accurately.

8. Correlated records. For $N = 100$ and stipulated $\rho = 0.2$, relative standard deviation is $\sqrt{\frac{1 + 99 \times 0.2}{100}} \approx 0.456070$, not 0.1. If one sample is copied 100 times, $\rho = 1$ and relative standard deviation remains one. Storage count creates no independent information. Substituting the duplicate count into the gamma correction is unjustified.

9. Removing a Gaussian background. Two independent zero-mean Gaussian contributions each have mean power -100 dBm in the same bandwidth and at the same plane. Their total mean is 2×10^{-10} mW, or -96.989700 dBm. Converting normalized mean-power estimates to linear units and subtracting the background leaves 10^{-10} mW, or -100 dBm. The 3.010300 dB level difference is a ratio, not the desired power. Subtraction becomes ill-conditioned as the estimated total and background approach each other. This case excludes correlated background and coherent tones.

10. A changing noise level. Suppose 90% of records have Gaussian mean power 1 mW and 10% have Gaussian mean power 100 mW. Overall arithmetic mean is 10.9 mW, or 10.374265 dBm. Conditional use of Equation 16B gives an approximate expected log average \(0.9 \times 0 + 0.1 \times 20 - 2.506816 \) $\text{dBm} = -0.506816\ \text{dBm}$. Adding 2.506816 gives 2.000000 dBm, still 8.374265 dB below the overall mean-power level. The mixture is not one exponential distribution with one μ. Retain state-resolved results and durations instead of hiding the change under a constant correction.

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8.4.4 Measurement consequence

Specify input plane, effective bandwidth, pre-log statistic, detector order, averaging weights, independence assumptions, corrections already applied and excluded intervals. A power or RMS label may describe a bucket detector, video operation or final output; the applicable documentation must resolve the sequence. A screenshot without processing history cannot be repaired automatically by adding 2.51 dB. Chapter 9 owns FFT-window normalization and overlapping estimates; Chapter 14 owns calibration and the complete uncertainty budget.

Where the instrument suppresses values below a detection or display threshold, the unreported power is a censored observation, not a measured zero and not necessarily an observation at the threshold. Replacing it with an arbitrary positive number merely to permit a logarithm changes both the arithmetic mean power and the mean of logarithmic power readings. Retain the native power or I/Q record when available, together with the censoring indication, detector and gain state, frequency-time opportunity, calibration plane and threshold-setting history. Where an inference requires the distribution of unobserved values, state and test the statistical model rather than treating substituted data as measurements. The applicable statistical distinction is established in the censored-sample work of Rukhin and Samarov (2011) and the bias investigation by George and colleagues (2021); neither source, without receiver-specific validation, establishes the sensitivity or source attribution of a particular RF instrument.

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8.5 Sweep Time, Triggering, and Transient Signals

Sweep time must allow the resolution and video filters to settle as the analyzer moves. Instruments often calculate a minimum value, but automatic settings can fail for unusual signals, segmented sweeps, gated measurements, or external triggering. Too-fast sweeps broaden or lower narrow components and distort noise. Too-slow sweeps can miss state changes or make the result vulnerable to drift.

Triggering can align a sweep with a repetitive burst, pulse, or controlled state. Gated sweep or time-selective analysis restricts measurement to a portion of the event. Trigger delay, gate width, jitter, and repetition stability then become part of the uncertainty. If the event is not repeatable, a real-time or digitized capture may be more appropriate than forcing a swept instrument to portray it.

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8.6 Interpret a swept trace through its frequency-time trajectory

A swept trace should be read as a sequence of observations along a frequency-time trajectory. A stationary source can produce a stable spectral outline because the signal remains comparable while the analyzer visits successive frequencies. A changing source may instead contribute different states at different trace locations. Repeated sweeps and max hold retain more observations, but the assembled result still need not describe any one simultaneous waveform. The distinction follows directly from swept architecture and is also explicit in the Tektronix discussion of successive-frequency analysis.[10]

Map the intended event onto the actual sweep before choosing settings. Identify the interval during which the channel response and detector are valid at each frequency. For a stepped implementation, exclude tuning and settling intervals rather than counting every commanded dwell as fully usable. For a continuously swept implementation, use the validated relationship among sweep rate, filter response, and amplitude error. Equation 15 expresses a common qualitative dependence; it is not a universal numerical timing law because filter shape, processing architecture, and acceptance criterion determine the missing proportionality.

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10 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf; MACOM, “Designing with Diodes: Protecting Sensitive Components” (September 2, 2022), receiver-protector operation and recovery discussion, https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting. These are identified examples of preselection, gain placement, and protection, not a universal front-end architecture or an instrument-independent limit.

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Model 15A can describe conditional coverage at one frequency when the usable observation windows and required event overlap are established. It does not turn a swept instrument into a simultaneous wideband recorder. If an event changes frequency during the sweep, its trajectory and the analyzer trajectory must be compared, or the event must be captured in a mode whose instantaneous bandwidth contains it. A trace assembled from several bursts can reveal that activity exists while leaving its instantaneous spectral shape unresolved.

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8.7 Choose bandwidth from the quantity being estimated

Resolution bandwidth has several consequences that should be separated. It controls the frequency weighting applied before detection, influences the time needed for the response to develop, and changes the integrated noise admitted to the estimator. The nominal width, equivalent noise bandwidth, passband shape, and transient response are distinct properties. Model 2B uses noise bandwidth for a flat input-referred density; Model 11B uses the actual weighting when phase noise varies across the admitted band. The same front-panel label cannot replace both calculations without supporting characterization.

When a modulated signal extends across several resolution filters, one marker reading is generally not its total power. A channel-power calculation must identify the integration interval, spectral weighting, detector statistic, and calibration. Conversely, a broad filter can admit a neighboring component into a marker intended for one tone. The choice should follow the measurand and the signal environment. Narrower settings may reduce a noise display while slowing response or excluding signal energy needed by the measurement.

The statistical treatment earlier in this chapter explains why averaging in logarithmic units and logging an average power differ. Keep that distinction when changing bandwidth. Equation 16 compares integrated white-noise powers through compatible equivalent bandwidths and processing. A change in detector, averaging order, state distribution, or noise color can create an additional difference. A noise marker that already applies a correction should not receive the same correction again in postprocessing.

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Use a controlled comparison to separate the possible causes. Preserve the input and receiver state while changing one bandwidth parameter, and retain linear-power data when the instrument provides them. Compare the result with the declared filter response and estimator. Then challenge the source or environment separately. A mismatch with the simple bandwidth ratio is evidence that one of its assumptions needs examination; it does not by itself identify an external interferer or prove an instrument fault.

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8.8 Validate transient and gated measurements with the intended waveform

A continuous calibration tone verifies only part of a burst measurement. A gated or triggered method must also reproduce the relevant turn-on behavior, duration, repetition, frequency trajectory, and prior receiver state. Model 5A shows how a bounded AGC response can depend on the time available to settle. Model 6B separates instantaneous frequency from an interval average. Chapter 15 distinguishes trigger location from the data path. These mechanisms can all change a transient indication while leaving a long continuous-tone check apparently correct.

If repeated events are used to build a spectrum, establish the aspect of repeatability needed by that construction. Matching nominal repetition periods is insufficient when phase, amplitude, modulation, or startup varies from event to event. A trigger can align a chosen edge without aligning the internal waveform. Retain event-resolved records where practical and compare the proposed aggregate with them. When repeatability is not established, describe the aggregate as a collection of observations rather than one reconstructed event.

For a negative result, report the validated event class and coverage. State which bands were observed, how long each usable observation lasted, what transient criterion the method could meet, and which gaps or automatic state changes occurred. A max-hold trace with no peak can support a bounded statement about that procedure. It cannot establish that every short, weak, hopping, or out-of-band event was absent. The next observation should target the remaining uncertainty, using a different

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timing strategy or acquisition architecture when the existing method cannot resolve it.

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8.9 Amplitude Accuracy and Analyzer Self-Tests

Amplitude accuracy depends on input attenuation, preamplifier state, mixer level, IF gain, detector, reference level, frequency response, impedance, and calibration. The analyzer should be tested for compression and spurious response in the actual environment. Changing input attenuation while correcting the indicated level is a fundamental linearity check. A component that does not follow the expected relationship may be internally generated.

Self-alignment and internal calibration improve confidence but do not test the external cable, antenna, filter, or overload caused by the site. Known external references at several frequencies and levels verify the complete chain. The practitioner also checks frequency accuracy, residual responses with a terminated input, and responses to strong out-of-band signals. The final trace is accepted only after these challenges are recorded.

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8.10 Sweep Method Acceptance

A swept method is accepted only after its ability to represent the target signal has been demonstrated with a known continuous, modulated, pulsed, or frequency-agile reference. The test uses the same span, RBW, VBW, detector, sweep time, trigger, trace mode, and gain state as the survey. Where the method cannot reproduce the reference without distortion or missed events, a different architecture is selected.

The trace archive retains setup files and native data rather than only images. Segment boundaries, masked bands, averaging counts, sweep repetitions, and time stamps are documented. This permits a later reviewer to determine which frequencies were observed at each moment and whether a transient could have escaped the sweep.

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8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity

Equation 3. FFT-independent sweep-time scaling

$$T_{\text{sweep}} \propto \frac{\text{Span}}{\text{RBW}^2}$$

For many swept analyzers, minimum sweep time scales approximately with frequency span divided by the square of resolution bandwidth, with a proportionality determined by filter and instrument design. The relation is qualitative unless the manufacturer's validated model is used.

Equation 4. Noise normalization between bandwidths

$$P_{\text{n,2,dB}} = P_{\text{n,1,dB}} + 10\log_{10}\left(\frac{B_2}{B_1}\right)$$

For stationary white noise measured with compatible detectors and equivalent noise bandwidths, integrated noise changes by ten times the logarithm of the bandwidth ratio. Nonwhite interference, different filters, and trace processing invalidate the simple correction.

Equation 15 describes the familiar conditional trend for a swept filter implementation; its proportionality factor is not specified here and must not be invented for an unknown analyzer. Equation 16 follows by integrating an unchanged white power density over two positive equivalent noise bandwidths. Model 2B, the averaging treatment in this chapter, and the finite-window normalization in Chapter 9 identify the separate assumptions behind those statements.

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Table 2. Chapter 8 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Sweep mode	Continuous, stepped, segmented, FFT-assisted, trigger, and time mapping	Establishes whether frequencies were observed simultaneously	Changing signals can be drawn at misleading positions
Resolution bandwidth	Bandwidth definition, filter shape, noise bandwidth, and settling	Controls frequency resolution and integrated noise	Narrow filters can miss or distort bursts
Detector and trace	Peak, sample, RMS, average, quasi-peak, max hold, and averaging	Defines the displayed statistic	Different trace processes cannot be compared directly
Linearity challenge	Attenuation, preamplifier, reference level, terminated input, and known source	Separates external signals from analyzer products	Internal alignment does not test the external chain

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8.12 Hypothetical Applied Calculation: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity

A white-noise trace reads -102 dBm in a 100 kHz noise bandwidth. Reducing the equivalent noise bandwidth to 1 kHz should lower integrated noise by about 20 dB, to -122 dBm, if the detector and processing are compatible. A smaller change suggests nonwhite interference, instrument noise, or inconsistent normalization.

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8.13 Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity

A max-hold sweep shows a comb of narrow peaks around a pulsed device. Real-time capture reveals that the peaks are fragments of a chirped burst observed at different moments during repeated sweeps. The comb is a sweep-time portrayal artifact, not a set of simultaneous carriers.

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8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference

A swept-tuned analyser samples different frequencies at different times. Its plotted spectral line is therefore a synthesis of observations made at successive tuning states, not a simultaneous picture of an instantaneous wideband field. Let the instrument traverse span F_{span} over sweep duration T_s, and write the nominal local tuning velocity $v = F_{span}/T_s$ in hertz per second. A feature occupying effective filter bandwidth B is available for approximately B/v seconds during a uniform sweep, excluding additional settling and detector-memory constraints. A brief pulse may fall entirely outside that interval even while the frequency coordinate is present on the eventual trace. A later viewer can easily mistake a blank trace for a negative observation of a whole span; in reality it may document only a sequence of narrow temporal opportunities.

A synthetic example illustrates the scale: a 100 MHz uniform span traversed in 1 s has velocity 100 MHz per second. A 100 kHz instantaneous analysis bandwidth corresponds to approximately 1 ms of nominal frequency-specific observation. A single 100 microsecond pulse, arriving at a time unrelated to the sweep, need not overlap that millisecond. A detector configured for persistence or maximum hold can accumulate successive detections and produce a stable-looking line, yet this display does not establish continuous monitoring of the line's frequency. The duty factor of the observed opportunity and the pulse arrival distribution are needed to estimate capture probability. The calculation is deliberately idealised; real

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instruments have varying filter and sweep response, dwell overhead and detector settling.

Some measurements require a dwell sufficient for the selected IF and postdetection weighting to respond. A nominal short RBW may narrow the noise bandwidth and improve separation of carriers while increasing settling time; reducing sweep time without establishing adequate response can bias level and broaden or shift a short component. The trace's video-bandwidth setting changes displayed variability and temporal memory, not necessarily the original analogue channel's admitted noise. Where an applicable EMI receiver method specifies detector weighting and measurement time, the programme should retain the actual detector law and validity conditions rather than substitute generic speed settings. The official apparatus scope of CISPR 16-1-1:2019 covers specified radio-disturbance measuring equipment, not universal proof of TSCM emitter identity.

A defensible challenge uses a calibrated synthesised burst at prearranged frequencies, varied relative to sweep start, with actual instrument time markers and independent event timing. Repeat at different sweep speeds, resolution and video bandwidths, detector modes and preselection states. Keep source amplitude constant and test both in-span and near-boundary pulses. Record missed-event counts separately from underestimated amplitudes or invalid detector states. A negative swept trace should be reported with its actual frequency-time coverage and the tested event class. If the engagement demands continuous coverage of a rare short burst, a real-time digitising path or parallel receiver may be required, and its own bandwidth and overload limitations must then be verified independently.

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8.15 Swept-spectrum observation as a sampling-design and probability problem

The displayed span of a swept-tuned analyser is not equivalent to continuous simultaneous observation of every frequency in that span. A swept architecture selects successive frequency positions through an RF or IF passband and integrates a detector response over time. An intermittent emission may begin, end or change frequency between relevant dwells. A trace that includes a beautifully resolved noise floor therefore supplies no direct evidence about an event that occurred outside the time-frequency observation window. To make the inference reviewable, define the tune trajectory $f_c(t)$, effective filter response $H(f-f_c(t))$, settling exclusions, detector response and valid acquisition intervals. Only then can a specific class of burst be assigned a demonstrated opportunity for observation.

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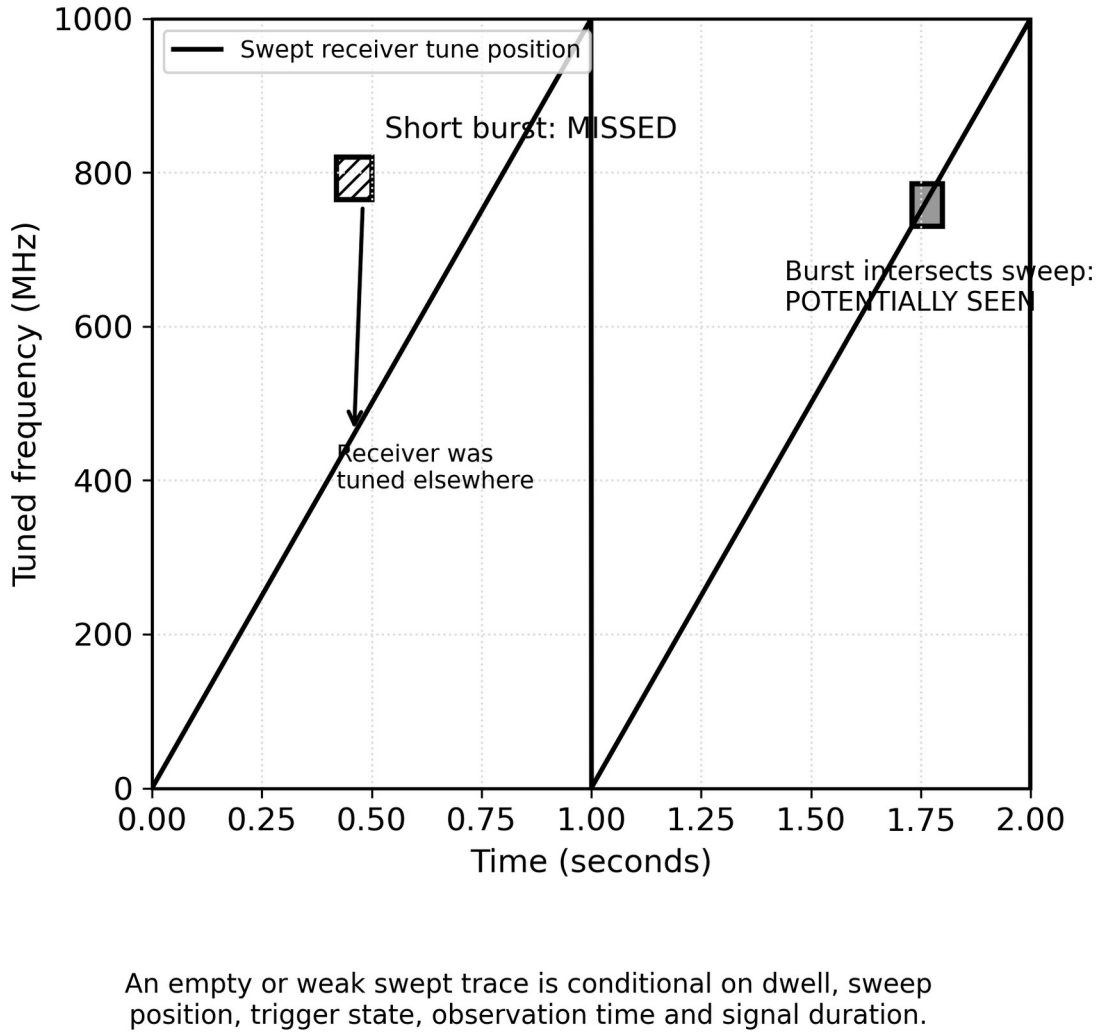

Figure 49. Sweep trajectory versus intermittent emissions.

Suppose an idealised scan repeats once every T seconds and a particular narrow channel is monitored for dwell duration d seconds in each cycle, with the receiver settled throughout and zero sensitivity outside the dwell. Assume a burst of duration b shorter than T occurs with start time uniformly

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distributed over one scan period. The burst overlaps the monitored interval if its start falls within the dwell enlarged by b in the circular time domain. Provided d+b is no greater than T, the overlap probability is (d+b)/T. With T = 5 s, d = 25 ms and b = 10 ms, the ideal overlap probability is 0.035/5 = 0.007, or 0.7 per cent. This is not the probability of detecting the burst, because overlap may occur for too little time or with too little signal-to-noise ratio for the chosen detector. It is not valid if event start time is synchronised to the scan, if scan intervals vary, or if the channel's effective coverage extends beyond the idealised dwell.

A stronger capture criterion requires the receiver to observe at least q seconds of the burst after settling, where q is defined by the detector and signal amplitude. For one valid dwell of length d and event duration b, the interval of start times that yields an overlap of at least q has length max(0,d+b-2q) when 0 less than q less than or equal to min(d,b), subject to the periodic-boundary conditions. With the previous d and b and q = 5 ms, the admissible length is 25 ms, giving 0.5 per cent under the ideal uniform-start model. A duty-cycle figure alone cannot distinguish the 0.7 per cent any-overlap opportunity from the 0.5 per cent five-millisecond opportunity. The probability of a valid decision must also incorporate signal retention, calibrated noise and detector statistics. This example illustrates a mathematical distinction, not an actual instrument's probability of intercept.

The minimum sweep time implied by an RBW setting is also a conditional engineering relation. A high-selectivity resolution filter requires a finite time to respond to frequencies that move through its passband. If frequency changes rapidly compared with the filter's response, the displayed amplitude of a continuous tone can be biased and its apparent frequency

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distorted. Sweep time depends on filter shape and response, centre-frequency trajectory, detector averaging, available preselection, and the acceptable error criterion. A familiar proportional rule in span divided by RBW squared may be a useful instrument-specific approximation, but it is not a universal law for all filter topologies, FFT-assisted sweep modes or detector implementations. The proper acceptance test compares swept readings against a verified reference while varying sweep rate and measuring convergence under the actual observation mode.

It is particularly important to separate the first crossing of a pulse from later detector persistence. Video filtering can smear a genuine burst across time samples, while peak hold can preserve a former event in the displayed trace long after the source has ceased. A max-hold trace conveys the highest retained statistic across a specified set of visits; it does not provide a continuously observed event history. Conversely, zero detections in a sparse set of dwells do not establish continuous absence between visits. Retain the number, duration and placement of valid observations as part of the forensic record. A line on a waterfall cannot replace the original trace acquisition timestamps and instrument-state transitions.

A practical experiment uses a shielded controlled source with independently recorded randomised burst times. Prepare narrow continuous signals, short and long pulses, frequency-agile bursts and signals near a resolution-filter skirt. Repeat the challenge at several RBW, VBW, detector and sweep-time settings. Measure actual event coverage from hardware timing or native acquisition logs rather than assuming ideal scan scheduling. Report the fraction of source events overlapping a valid dwell, the fraction meeting the required retained-response criterion, the false-alarm behaviour in source-off

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trials, and the uncertainty in each fraction. Sources and receiver must remain within a valid linear range, and the burst programme should be held out from any settings used to tune the detection threshold. The chapter can then distinguish waveform capture, peak-level fidelity and broad discovery screening, which are different engineering objectives even when all three are displayed in a spectrum-analyser interface.

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8.16 Additional study: swept observation as a space-time sampling experiment

A swept spectrum analyser does not observe every frequency throughout the duration of a scan. Its tuned passband occupies a moving neighbourhood of the frequency axis, and its response at one nominal display bin depends on the frequency trajectory, filter memory, detector integration interval and trace-processing rule. The familiar image of a stationary spectrum can consequently conceal a complex sequence of observations separated in both frequency and time. To interpret a brief or intermittent emission, define the acquisition as a time-varying observation operator rather than a completed rectangular measurement of the frequency-time plane. This formulation is essential for distinguishing a genuine absent signal from an unobserved event and a receiver-generated product that appears only during a particular sweep state.

Let the nominal tuned frequency be $f_c(t)$, measured in hertz as a known function of time in seconds. Let $H(f; f_c(t))$ describe the selected IF resolution filter translated to that centre frequency under the bounded approximation that its response follows tuning without an additional unmodelled transition. An input component at frequency $f_s(t)$ contributes significantly only while its instantaneous spectral support overlaps the admitted response. For a stationary narrow tone, a first approximation to its time in an effective passband of width B_{eff} during a linear sweep at rate $v = |df_c/dt|$ is $T_{cross} \approx B_{eff}/v$. This is a geometric overlap, not automatically a usable independent measurement. If the resolution filter requires settling time comparable to or longer than T_{cross}, the displayed amplitude may be

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systematically biased. The trajectory also needs guards for preselector switching and gain-state transitions.

The same relation gives a transparent planning inequality. Suppose a linear sweep covers span S in total active sweep time T_s, so $v=S/T_s$. To provide at least a stated overlap duration T_{req} for a stationary tone under the boxcar approximation, require $B_{eff} T_s/S \geq T_{req}$, or $T_s \geq S\, T_{req}/B_{eff}$. All quantities must use compatible hertz and seconds. For a filter whose effective response and settling differ materially from a boxcar, replace the approximation by the actual time-domain convolution of the swept response and stipulated input waveform. A sweep-time setting derived from filter bandwidth alone does not certify the observed amplitude unless the detector and control state have also been considered.

A short burst presents a second sampling problem. Let an emission occupy frequency f_0 for event duration T_b, and let an analyser admit that frequency during actual valid time intervals I_j. If event start time t_0 is unknown and the detection rule requires overlap of at least δ seconds, a start is eligible for detection only when the shifted event interval $[t_0, t_0+T_b]$ overlaps at least one I_j by δ. The union of eligible starts can be computed from the real intervals, including gaps due to switching or loss of valid IF response. It may be very small even when the total scan duration is large. A probability of capture additionally requires a stated distribution of event start times. Without that distribution, the mathematically defensible statement is a coverage set, not a numerical probability.

The difference becomes especially serious for frequency-agile signals. If the emitter's frequency evolves as $f_s(t)$, the instrument acquires a substantial fraction of its energy only when the separation $|f_s(t)-f_c(t)|$ lies within the

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actual filter response and the acquisition state is valid. Two trajectories can cross at one instant but have very different dwell within the passband. A waveform that follows the analyser sweep rate may remain visible much longer than a stationary burst of the same duration, while one moving in the opposite direction can traverse the passband very quickly. A display that assigns the peak to a single stationary frequency can misrepresent its physical history. The raw sweep timing and any reconstruction of frequency-time motion should therefore be preserved separately.

Detection also depends on the detector's selection law. A peak detector may register an event whose instantaneous IF power is high enough during one brief overlap, while an average or RMS detector can dilute its contribution across an interval that includes a larger amount of noise-only data. A video filter may reduce trace variance while broadening the temporal response and increasing persistence. These are measurements of different statistics. To compare them, the test must stipulate the same physical event, input level, analysis band, source state and observation opportunities, then identify the statistic each mode reports. A cleaner-looking average spectrum is not proof of improved sensitivity to rare bursts.

Preselector behaviour adds hidden discontinuities to the sweep geometry. An instrument may switch front-end filters as its nominal centre frequency passes a boundary. The selected preselector has its own insertion loss, image rejection, switching transient and thermal behaviour, and a transition can exclude some observation intervals. An older static contents table may imply continuous coverage across the boundary even where the installed receiver was blind or in a different gain state. Forensic capture coverage should be computed from the actual interval record, not solely from the

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requested centre-frequency list or the final rendered trace. If the instrument does not expose exact switching intervals, a calibrated challenge source spanning the boundary can bound the blind period, but that result is valid only for the tested operating states.

One synthetic sweep illustration uses a span of 200 MHz traversed in 100 ms with an effective resolution-filter width of 20 kHz. The sweep rate is 2 GHz/s, so geometric overlap with a stationary tone is 20,000/2,000,000,000 seconds, or 10 μs. If the filter and detector need at least 100 μs of usable response to provide the declared amplitude criterion, this sweep does not meet that criterion. The requested sweep time would have to rise at least to one second under the elementary boxcar calculation, before adding settling and switching guards. A manufacturer-recommended sweep-time model may require a different factor because a resolution filter is not a perfect brick-wall gate. The example is a planning counterexample, not an instrument-specific specification.

A second illustration examines a rare ten-millisecond burst in a channel revisited every two seconds, with a valid observation window of five milliseconds per cycle. Assume the event start phase is uniform relative to the cycle, and detection requires at least one millisecond of overlap. The eligible start interval around each five-millisecond valid window has length $T_b + 5\ \text{ms} - 2\delta = 13\ \text{ms}$, assuming no wrap-around interactions among windows. The idealised capture probability is 13 ms/2 s = 0.0065, or 0.65 percent, for one randomly phased event. This value is conditional on the assumed start-phase distribution, waveform retention, detector validity and one-millisecond criterion. A deterministic transmitter synchronised to the

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scan could repeatedly miss the windows, even after many scans; the uniform-phase model would then be inappropriate.

A third synthetic example considers a centre-frequency trajectory moving upward at 100 MHz/s and a chirp sweeping upward at 90 MHz/s. Their relative sweep rate is 10 MHz/s, so an effective 10 kHz passband gives a nominal encounter of one millisecond. If the chirp instead moves downward at 90 MHz/s while the analyser moves upward, relative rate becomes 190 MHz/s, giving approximately 52.63 μs. The two events may therefore produce substantially different IF amplitudes even if the instantaneous input spectral density is equal. A strong conclusion about RF event duration or intensity would require accounting for the relative time-frequency trajectory and filter impulse response.

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8.17 Distinguishing a spectral estimator from a persuasive-looking display

A sweep trace is a collection of filtered, detected and often logarithmically transformed observations. Its bin values may not share a common acquisition time, and the detector may have visited different physical states along the axis. The operation that averages traces across several sweeps adds another time model: it combines observations of a possibly changing environment, not repeated samples of one unchanged random variable by definition. For stationary signals and validated conditions such averaging may reduce variability; for intermittent emissions it can conceal the event frequency, time or peak level. A final interpretation must therefore specify whether the reported quantity is peak observed level, mean occupancy, a percentile, a fitted amplitude or a threshold-crossing count.

When deriving uncertainty, separate amplitude calibration from sampling uncertainty. A calibrated reference tone can establish the scale of a valid filtered measurement without establishing that a rare event would have been observed. The probability of observing an event is not a conventional dB correction. Similarly, a sweep trajectory can visit the correct nominal frequency but fail to deliver enough integration time for the required detector statistic. These two limitations should be reported in different parts of the result: amplitude uncertainty for valid observations and conditional coverage for unobserved opportunities. Combining them into one unexplained uncertainty number would obscure the reason a negative survey might fail.

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A defensible experiment must contain known positive trials, negative controls and held-out combinations. Generate short CW bursts, chirps, frequency hops and modulated transients under lawful shielded conditions, with independent waveform truth and independently verified source amplitudes. Randomise event starts relative to the analyser sweep, vary duration and frequency slope, and document all receiver configuration transitions. Freeze the event-detection rule before examining held-out trials. For each trial record whether the receiver actually observed the relevant channel, whether its IF path was settled, whether the detector crossed the criterion, and whether source or analyser artefacts could mimic the result. A false negative caused by no observation opportunity must not be pooled indiscriminately with one caused by insufficient instantaneous sensitivity.

For quantitative reporting, a coverage map may list the valid time intervals at every tested frequency and the event classes for which detection has been demonstrated. If a probability is desired, specify the event-start distribution and show how its density is integrated over the union of eligible start intervals. The same framework accommodates a regular scan, a deliberately jittered sweep and an adaptive monitoring schedule. An adaptive schedule requires special caution: future measurement decisions can depend on earlier observations, so the schedule may be correlated with the event process. An assumption of independently random timing would then need evidence rather than assertion. This is particularly consequential when a receiver changes bandwidth or sweep speed in response to a possible anomaly.

A fourth hypothetical example demonstrates an adaptive bias. Suppose the instrument sweeps a particular band quickly after three quiet passes and

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slowly immediately after a threshold crossing. If a later analyst averages only the slow passes, the selected traces will disproportionately represent periods following apparent activity. An apparent high occupancy fraction may be caused partly by the selection rule rather than the underlying emitter duty cycle. The correct estimator needs the complete observation schedule and an explicit description of the selection mechanism. A software file containing only the positive traces cannot establish the required denominator for an occupancy estimate.

A fifth example considers video filtering of a finite pulse. Let a detector produce a unit rectangular output for 0.5 ms, and let a subsequent one-pole video filter have time constant 2 ms. Under a simple linear filter assumption, the maximum rise before the pulse ends is $1-\exp(-0.5/2) = 0.2212$ of the unit step. A threshold set to 0.3 would not be crossed even though the unfiltered pulse reached unit amplitude. Increasing display averaging would not repair the miss. Conversely, the post-event decay can produce a trace response after the physical event has ended. To assert event timing, the report must refer to the detector and video-filter temporal response rather than treating the displayed peak position as the incident emission time.

The proposed qualification standard is therefore two-dimensional at minimum: sensitivity to a specified event when the channel is validly observed, and the opportunities for observation under the actual sweep schedule. More elaborate receiver plans may need further dimensions for blockers, environmental noise, gain, preselector state and frequency-dependent detector response. The resulting acceptance surface can support useful, carefully bounded negative statements. It cannot prove that every

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conceivable transmission was absent from an unobserved or invalid region of the frequency-time plane.

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8.18 Advanced technical expansion. Swept observation as a sampling problem in time and frequency

A swept spectrum analyser does not observe every frequency continuously. Its local oscillator follows a trajectory through a span while a resolution filter, envelope detector and display estimator each retain memory of earlier inputs. A screen containing many frequency points is therefore a map of measurements made at different times. An intermittent emitter can be active at a frequency when the analyser is elsewhere, and a short burst can begin while the filter has not settled sufficiently to produce a valid displayed peak. A rigorous survey must record sweep direction, sweep period, active frequency trajectory, preselector selection, resolution-bandwidth filter, video bandwidth and detector type. The difference between physical opportunity to observe and amplitude sensitivity during that opportunity should remain visible in the result.

An illustrative filter-limited lower bound on swept time has the form T_sweep proportional to span divided by B squared, with the coefficient depending on filter response and tolerated amplitude error. This relation is documented in Rohde & Schwarz application literature for classical swept analysis; it is an engineering approximation rather than a universally valid timing law for FFT-based or hybrid analysers. If a chosen span is 10 MHz and the relevant bandwidth B is 10 kHz, the ratio span/B squared has units of 0.1 second; a dimensionless filter factor of 2.5 yields 0.25 second under the stated simple model. Reducing B to 1 kHz increases the same term by a factor of 100. This is the physical reason a narrow displayed noise floor may cost observation speed and event-capture opportunity. The exact

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instrument behaviour must be verified rather than assumed from the illustrative coefficient.

There are two distinct forms of error during a fast sweep. First, a continuous tone may fail to drive the filter to its steady amplitude before the LO moves on, biasing level and sometimes frequency. Second, an intermittent emission may not occur during the analyser's valid observation opportunity at that frequency. Slowing a sweep may repair the first deficiency while increasing the interval between revisits, worsening the second for some event distributions. A single sweep-time setting cannot optimise all objectives simultaneously. The proper experimental design states the event family, required amplitude accuracy, detector response and tolerated revisit interval, then characterises the instrument against a pulsed reference with a known onset schedule independent of the sweep clock.

A probability-of-observation model begins with a binary coverage function $c_f(t)$ that equals one when a particular frequency is being observed under valid conditions and zero otherwise. For a burst with start time t_0 and duration d, successful capture depends on the intersection of $[t_0, t_0+d]$ with intervals where $c_f(t)=1$, together with a required overlap or signal-detection criterion. If start time is assumed uniform on a stated period, the eligible fraction can be calculated from the geometry of these intervals. No probability follows without an event-time model; periodic transmitters synchronised to the sweep may repeatedly fall in the same blind window. The correct report can state measured or derived opportunity and the model assumptions rather than translating a coverage fraction into universal confidence.

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Resolution and video filters also alter the display statistic. A peak detector operating on unsmoothed eligible samples can show rare excursions differently from a sample or average detector; video smoothing reduces visible fluctuations but may conceal brief peaks. A logarithmic video average is not the same as an arithmetic mean of linear power. A quasi-peak detector applies a specified temporal weighting and cannot be equated with a generic maximum-hold trace. A defensible report names the detector and processing conventions and retains the native trace where possible. Comparing two spectra without matching those conventions can produce apparently contradictory results that are entirely explained by instrumentation.

Acceptance testing should include a continuous reference for level accuracy, an independently triggered burst source for observation probability, and controlled blockers for overload behaviour. Vary burst duration, repetition, phase relative to sweep and frequency position, especially near preselector transitions. Preserve every trial including misses, record the actual analyser trace and state, and compare with an independently monitored source schedule. A single successful capture does not establish universal sensitivity; a single missed event may establish either a coverage gap or a deficient detector, depending on the independently verified opportunity. The distinction is central when using swept measurements to defend a negative technical-security finding.

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8.19 Swept analysis as a moving, state-dependent measurement aperture

A conventional swept-tuned spectrum analyser does not observe a displayed span simultaneously. It moves a frequency-selective response through the spectrum, integrating, detecting and displaying each part at a different time. A trace is therefore a constructed function of frequency and observation time, not an instantaneous photograph of the electromagnetic environment. The distinction becomes decisive when an intermittent transmitter changes carrier, pulse duration or modulation while the analyser is tuned elsewhere. A clean final trace may be entirely consistent with an external signal that occurred during an unobserved frequency-time interval. Conversely, a displayed peak may derive from a response that persisted within the analyser after the external event ended. The scientific task is to connect every plotted point with the physical interval, admitted frequency response and detector law that produced it.

For an ideal linear sweep across span S hertz in time T_s seconds, the nominal tuned centre is $f_s(t)=f_{start}+(S/T_s)t$ for $0 \le t \le T_s$. The sweep rate $v=S/T_s$ has units hertz per second. A stationary tone at f_0 spends approximately $t_{pass}=B_R/v$ seconds within a nominal resolution-filter width B_R hertz if the sweep law and passband shape can be approximated as locally constant. This is a kinematic estimate, not a calibrated response model. A real filter has an impulse response, a centre-frequency-dependent tuning transfer and a finite time to settle after excitation; a tone passing briefly through it may be reported with a diminished amplitude, broadened

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profile or shifted apparent frequency. The governing condition must involve the filter's actual transient response, not merely its nominal 3 dB bandwidth.

For a family of similarly shaped filters one may use an approximate settling time $t_{set}=k/B_R$, with dimensionless constant k fixed by the required amplitude and timing accuracy. Requiring $t_{pass}\geq t_{set}$ gives $T_s\geq kS/B_R^2$. The square-law dependence is a powerful engineering scaling, but k is not a universal number. A Gaussian-like analogue RBW filter, a digitally synthesised filter and a steep multi-section IF filter can have different ringing and measurement criteria. If the output detector requires additional dwell or the analyser has discrete tuning steps, the actual minimum may be longer. The relevant data are the specified filter family, its centre and shape, detector mode, input signal type and required measurement accuracy.

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8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms

The indicated resolution bandwidth is not automatically the equivalent noise bandwidth of the same filter, nor is either one the instantaneous spectrum of the input signal. The resolution specification commonly describes selectivity or a response-width convention, while equivalent noise bandwidth B_{eq} is defined from the power response $H(f)$: $B_{eq}=[\text{integral } |H(f)|^2 df]/|H(f_c)|^2$ for a reference frequency f_c and a normalised gain convention. For white input noise with applicable spectral density N_0, admitted mean noise is $N_0 B_{eq}$. A narrow filter can improve separation of two stable tones and lower admitted white noise, yet attenuate or temporally smear short pulses. Noise-floor improvement and preservation of a transient are independent measurements, not two names for the same bandwidth trade.

A finite-resolution filter also has asymmetry, group delay and memory. If a swept tone changes frequency while passing the filter, its response is not necessarily the response that would have been measured by dwelling at the final frequency. A narrowband filter can remain excited after the instantaneous LO tuning has moved, generating a trace feature displaced from the actual tone. An analyser whose sweep-time coupling is overridden may therefore produce consistent but wrong results on repeated sweeps. A useful calibration includes a known continuous tone, a stepped tone near passband boundaries, a controlled pulse and a frequency-agile source, each with independent confirmation of the actual waveform. Separating centre-

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frequency error from settling error prevents correction of one with an unrelated scalar offset.

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8.21 Detector laws, video filtering and the asymmetry of logarithmic statistics

A swept analyser can use peak, negative-peak, sample, RMS, quasi-peak or average detectors, depending on its architecture and intended standard. A peak detector retains a maximum in the samples assigned to a pixel or bin; RMS detection estimates a mean-square quantity; a sample detector reports one selected observation. These operations may agree for a stable continuous tone but diverge greatly for a noise-like signal or rare pulse. Their numerical outputs must not be treated as interchangeable merely because the vertical unit is dBm. The precise quantity measured depends on the placement of the detector relative to the resolution filter, video filter and logarithmic conversion. An instruction to use average trace is incomplete unless it states whether linear power, voltage, logarithmic level or selected detector outputs are averaged.

Video bandwidth typically acts after part of the amplitude detection process. It controls the display or measured envelope's time response and can suppress visible fluctuations, but it does not automatically reduce the thermal noise admitted by the front-end resolution filter. A low VBW can conceal narrow peaks or make a brief event appear as a delayed broad hump. For an ideal first-order low-pass video filter with 3 dB bandwidth B_V, $\tau=1/(2\pi B_V)$. Its step response reaches about 95 percent after approximately three τ, under the specific first-order model. Real detector and instrument filters need separate calibration. One cannot safely use a bandwidth value alone to infer a universal recovery delay, particularly when

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a swept trace contains automatic detector transitions or quasi-peak weighting.

For an ideal complex Gaussian noise sample, instantaneous detected power is exponentially distributed with mean P_bar. The expected logarithm of one sample lies below the logarithm of that mean: $E[10\log10(P/P_bar)]= -10\gamma/\ln10\approx-2.5068$ dB, where γ is Euler's constant. This is a mathematical consequence of taking the logarithm before averaging, not a calibration loss in the receiver. If K independent exponential power samples are averaged in linear units before taking the logarithm, the bias is $(10/\ln10)[\psi(K)-\ln K]$, where ψ is the digamma function; it becomes smaller in magnitude as K increases. Correlated samples, non-Gaussian interference and a different detector invalidate the particular distributions. Consequently a visually smoother or lower average trace does not automatically demonstrate a physically lower noise temperature.

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8.22 Periodic sweeps and the probability of observing a rare event

For a fixed frequency f_0, let $c_f(t)$ equal one during intervals where the analyser can validly observe a specified event and zero during retune, filter-settling, blanking, overload or off-frequency periods. For a known event $e(t)$, the observation can be analysed deterministically from the overlap of its occurrence and $c_f(t)$. A probability requires an additional stochastic model of event start times, durations, frequencies and the detector's response conditional on overlap. Uniform start phase is sometimes a useful hypothetical assumption, but must not be silently adopted for intentional, phase-locked or environmentally correlated transmitters. Repeated sweeps create periodic holes; an emitter whose start time is synchronised to those holes may be missed indefinitely despite a large number of apparently complete traces.

Consider a single valid observation window of duration W in each period T, a fixed-frequency burst of duration d, and a requirement for at least q seconds of temporal overlap to achieve a specified detection statistic. Under uniformly distributed burst start phase on the periodic interval, and assuming one simple window and $q \leq \min(W,d)$, the eligible start-phase measure is $W+d-2q$, clipped to the periodic domain when necessary. Thus $P_{overlap}=\min[1,(W+d-2q)/T]$ for nonnegative eligible width in this idealised geometry. This is not automatically a calibrated probability of RF detection; it ignores receiver sensitivity, burst spectral energy, nonlinear response and threshold variability. The overlap rule also requires modification when multiple observation windows interact or the event can overlap a window

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across the periodic boundary. A full implementation should calculate the eligible set explicitly rather than extrapolate this simple case.

The operator may try to improve capture by reducing span, enlarging RBW, increasing dwell, triggering a narrow watch channel, or using a wideband real-time parallel acquisition. Each changes different properties of the observation. Reducing span increases revisit opportunity at frequencies inside the new span but removes all coverage outside it. Enlarging RBW can shorten filter settling while admitting more noise and potentially stronger blockers. A continuous narrow watch channel gives uninterrupted time coverage in its passband but cannot see frequency-agile components outside that region. A real-time analyser can reduce sweep-specific temporal gaps within its actual instantaneous bandwidth while retaining front-end, converter, memory and trigger limits. Claims of universal 100 percent probability of intercept must state the tested event class, duration, power, bandwidth and internal instrument state.

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8.23 False alarms, maximum hold and selected displays

Maximum hold is useful for detecting rare excursions but is a selection operation. Even in noise-only data, the maximum tends to rise as the number of independent opportunities grows. If a fixed threshold has a stipulated false-alarm probability p per independent trial, the probability of at least one false alarm in K trials is 1-(1-p)^K. Actual spectral bins and successive traces may be correlated because of filter bandwidth, overlap and shared disturbances; replacing K with the visible number of pixels is not a justified independence argument. Threshold studies should include noise-only survey-length records and a declaration of how many frequencies, sweeps and detector outputs were searched. An apparent peak discovered after extensive parameter tuning is vulnerable to selection bias unless confirmed on a distinct, predeclared acquisition.

Peak response is also affected by limited sampling of the detector output. A very short pulse may occur between sample points, while a peak detector with suitable internal sub-sampling may retain it. The instrument's detector definition and trace resolution matter. A post-event display showing one isolated peak can be authentic yet lack enough temporal data to establish its physical duration, source waveform or exact event time. A screen capture should therefore be a presentation artifact linked to the native trace and settings. It is not a substitute for state records, actual sweep timing or an independently captured transient waveform.

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8.24 Ten worked calculations and controlled counterexamples

Application 8C.1. For span S=1 MHz, RBW B_R=10 kHz and stipulated filter factor k=2, the scaling estimate $T_s \geq kS/B_R^2$ is 2×10^6/10^8=0.020 s. Reducing RBW to 1 kHz makes the estimate 2×10^6/10^6=2.0 s, a hundredfold increase for a tenfold narrower filter. These are hypothetical filter-family estimates; an instrument's permitted minimum sweep time and amplitude-error criterion must be checked independently.

Application 8C.2. A sweep spans 40 MHz in T_s=1 s. Its nominal rate is 40 MHz/s. For a 20 kHz effective pass window, the ideal time a stationary tone remains within the window is 20,000/(40×10^6)=0.00050 s, or 0.50 ms. A 2 ms burst may overlap that window or miss it altogether, depending on start phase. Its actual detected amplitude still depends on filter settling and detector processing.

Application 8C.3. An ideal one-pole VBW filter has B_V=100 Hz. Its time constant is 1/(2π×100)=1.592 ms and its ideal 95-percent step-response time is approximately 3τ=4.775 ms. A 0.5 ms burst cannot be inferred to have reached full steady-state video amplitude. This does not imply that a peak detector positioned before that filter would necessarily miss the event; the actual signal path must be established.

Application 8C.4. A white-noise input has flat density -150 dBm/Hz under a stipulated reference convention, and the receiver's equivalent noise bandwidth changes from 100 kHz to 10 kHz with unchanged gain and noise law. Integrated mean noise changes from -100 dBm to -110 dBm, a 10 dB

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difference. The underlying spectral density has not changed, and a desired burst may lose energy in the narrower response.

Application 8C.5. A single exponentially distributed power sample is converted to decibels before averaging over repeated independent noise realisations. Its expected reported level lies 2.5068 dB below the logarithm of its physical mean. If four independent power samples are averaged before logarithmic conversion, the digamma formula gives approximately -0.565 dB instead. The values are model-dependent mathematical biases, not universal spectrum-analyser calibration corrections.

Application 8C.6. One eligible observation window of W=1 ms occurs every T=100 ms, while a fixed-frequency event has d=2 ms duration and a successful observation requires q=0.2 ms overlap. Under the stated uniform random start phase and adequate amplitude, P_overlap=(1+2-0.4)/100=0.026, or 2.6 percent. Repeating the sweep does not guarantee independent event phases if the source repetition is synchronised to the same cycle.

Application 8C.7. An instrument scans a 100 MHz span with a 10 kHz approximate pass window and nominal 1 s sweep. Under the linear mapping, the local time in the window is (10,000×1)/100,000,000=0.0001 s, or 0.1 ms. If the relevant filter needs 0.3 ms of response under a specified amplitude criterion, the chosen sweep cannot satisfy that criterion. Lengthening the sweep to at least 3 s would provide the nominal 0.3 ms window, subject to the filter's true transient response and other detector constraints.

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Application 8C.8. A noise-only detector has a stipulated threshold-crossing probability p=0.01 in each of 100 independent sweeps. Maximum-hold selection produces at least one crossing with probability 1-(0.99)^100≈0.634, or 63.4 percent. This does not imply any external transmitter. Actual correlated noise requires a different calculation or an empirical full-survey false-alarm validation.

Application 8C.9. The analyser's nominal sweep covers 10 seconds, but 2 seconds are lost to settling and 1 second to an independently recorded overload episode. If these intervals are disjoint, the demonstrated valid time fraction is 7/10=70 percent. If overload lies entirely within settling, the valid fraction is 8/10=80 percent. Neither fraction gives a probability of intercept without a model of event time, frequency and amplitude response.

Application 8C.10. A fixed calibrated tone gives -80 dBm in a sufficiently slow sweep and -83 dBm after a faster sweep with unchanged frequency, input path, gain and detector mode. The 3 dB discrepancy is compatible with a transient-response bias but does not uniquely prove it. A controlled step of sweep time, with source verification, fixed RBW/VBW and recorded internal state, tests whether the level approaches the slow-sweep value as the available filter dwell increases. An amplitude correction of +3 dB should not be applied universally to unknown pulses without this separate validation.

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8.25 A robust acceptance test for transient and stationary measurements

A credible instrument acceptance programme compares four classes: a stable continuous tone to establish level and frequency calibration, two closely spaced tones to test resolution and sweep transient effects, a controlled burst population to measure actual observation probability, and strong blockers to test overload and spurious response. Each class must be tested at more than one centre frequency, detector mode and relevant gain state. The source path must be independently checked to prevent generator products from being assigned to the analyser. Preserve the actual tuning schedule, filters, detectors, video processing, trigger state and native traces. When the result depends on a subtle frequency-time interaction, supplement the swept measurement with a suitable independent coherent capture rather than converting a plausible-looking display into unsupported source chronology.

The final report should distinguish stationary-spectrum accuracy, transient-event observation, probability of capture and validity under blockers as four separate acceptance claims. It must state how unobserved frequency-time regions were handled, whether calibration was applied at the correct reference plane and whether measurements from different sweep settings were made commensurate. A defensible negative statement is that no event meeting the specified criterion was detected during the demonstrated eligible coverage, not that an entire wideband environment remained silent. That language preserves scientific utility without allowing the convenient

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vertical scale or quiet screen to exceed the evidential meaning of the acquisition.

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8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse

Swept analysis is a controlled experiment in which the receiver's frequency-time acceptance changes while the external environment continues to evolve. Let $f_s(t)$ denote the instantaneous tuning trajectory, $H(f,t)$ the state-dependent RF and resolution-filter transfer, and $v(t)$ the video or detector output. The recorded trace is a set of summaries of different parts of the environment observed at different times. It is generally not the spectrum of one common RF instant. A slowly swept display may provide excellent frequency discrimination and amplitude measurement for a stationary calibrated carrier; it need not offer comprehensive evidence about nanosecond or microsecond bursts, coincident signals in distant bands, or a transmitter that changes state between dwell intervals. The distinction becomes acute when the user requests a 40 GHz monitored range and 30 Hz narrowband resolution simultaneously.

For a simple uniform sweep covering span S hertz over time T_s seconds, the nominal sweep rate is $R=S/T_s$ hertz per second. If a resolution filter has an effective passband B_r hertz, the nominal tuning trajectory spends approximately B_r/R seconds near one frequency, before allowing for the filter's impulse response, detector integration, retuning pauses and preselector switching. When $S=40\times10^9$ Hz, $B_r=30$ Hz and $T_s=1$ second, this nominal opportunity is 7.5×10^{-10} seconds. That figure is not an actual achievable dwell for a 30 Hz filter. Rather, it demonstrates the internal contradiction of treating an extremely fast 40 GHz swept trace as though every narrow filter had time to settle. Increasing sweep time alone cannot

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restore simultaneous observation of frequencies that were scanned at different times.

A 30 Hz rectangular-window DFT bin spacing corresponds to approximately 33.33 milliseconds of phase-continuous sample data; a Hann-window measurement with a 30 Hz equivalent noise bandwidth requires a longer interval because its ENBW is 1.5 times its bin spacing. Even this duration says nothing by itself about the ability to see an event lasting much less than the window. A real-time channel can compute narrowband spectral products from a continuous I/Q buffer while a parallel short-window energy detector examines the same samples, but a conventional tuned sweep observes a given RF region only when its analogue path actually accepts that region. Where a trigger occurs during an unobserved interval, no later mathematical increase in display resolution restores the lost waveform.

A credible wideband receiver acceptance test must therefore publish a coverage matrix. For each candidate frequency and time interval, the matrix records whether the analogue path accepted the energy, whether the converter was linear, whether native data were retained, whether a detector examined the event class, and whether a valid calibration was in force. A spectral heat map is not an equivalent of this matrix. Averaging and maximum hold create representations with different selection laws. A maximum-hold point is the maximum of a succession of detector outputs acquired at different times; it cannot establish that all maxima existed simultaneously. A blank region may mean lower signal amplitude, insufficient dwell, detector response, data loss, input filtering, or simply that the environment was never observed at that moment.

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Where a swept and a channelised wideband receiver are compared, the valid experiment retains the same calibration planes and comparable admitted environments. The narrow swept system is often better suited to sensitive slow measurements in a constrained band; the wideband channelised system is suited to simultaneous transient observation in the bandwidth it actually digitises. Neither dominates by definition. A wideband system must contend with more total admitted noise, blockers, ADC headroom and data rate. A swept system must contend with dwell coverage, settling and tuning-state dependence. A defensive technical report should present these complementary roles rather than advertise that a single sweep setting is both narrowest in resolution and greatest in transient probability of intercept.

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8.27 Quantitative worked contrasts: sweep coverage, channelised capture and resolution claims

Application W8.1. A 40 GHz nominal sweep in one second with a 30 Hz frequency acceptance has a geometric dwell of 0.75 nanoseconds at a fixed frequency. This is far shorter than a 33 millisecond measurement window, confirming that the proposed combination cannot be interpreted as settled 30 Hz measurement at every tuned location.

Application W8.2. A 100 MHz simultaneous complex channel contains 100,000,000/30≈3.33 million nominal 30 Hz DFT bins if rectangular bin spacing is taken as the resolution measure. The transform needs roughly 33.33 milliseconds of data and must be repeated or overlapped as required by the event-monitoring strategy.

Application W8.3. With a Hann window whose equivalent noise bandwidth is 1.5 bins, 30 Hz ENBW calls for 20 Hz bin spacing and a 50 millisecond observation, assuming the conventional periodic Hann approximation. Labelling a 30 Hz bin width as a 30 Hz noise bandwidth without identifying the window would understate admitted noise by about 1.76 dB.

Application W8.4. A 500 microsecond burst repeats every 100 milliseconds and begins with uniformly random phase relative to an isolated 1 millisecond valid dwell. In the absence of filter memory, capture opportunity for some overlap is approximately min[1,(0.001+0.0005)/0.1]=1.5 percent under an idealised periodic observation model. The event duration and criterion must be defined before this overlap probability becomes a detection probability.

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Application W8.5. Two 10 GHz halves of a monitoring range are observed in alternation, one for 250 milliseconds and the other for 250 milliseconds. Even with perfect equipment, a pulse seen in the first half cannot be assumed simultaneous with an apparent pulse in the second half. Time alignment in a concatenated display does not recreate simultaneous acquisition.

Application W8.6. A swept detector reports 100 maximum-hold results from 100 distinct dwells. If each independent noise-only dwell has a 1 percent probability of crossing a selected threshold, the probability of at least one crossing is $1-0.99^{100}\approx 63.4$ percent. In a correlated sequence the actual figure differs. A conspicuous maximum is not a stand-alone signal-identification result.

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Chapter Summary

A swept spectrum is a frequency-time construction. RBW, VBW, detector, sweep, triggering, and linearity controls determine whether the trace represents a stationary spectrum, a partial transient, or an analyzer artifact.

Bandwidth selection follows the intended quantity. Nominal resolution width, equivalent noise bandwidth and transient response have different roles. A narrow setting can improve separation while excluding useful signal energy or leaving insufficient settling time. Gated and repeated-event methods require waveform-specific validation, with usable observation intervals distinguished from commanded sweep time.

Noise estimates also depend on operation order. Averaging individual logarithmic powers differs from logging their arithmetic average. The chapter derives separate corrections for its stated Gaussian-noise model and shows how finite sample count, correlation, changing states and already-applied processing affect the interpretation. A smoother trace does not establish an unbiased or compatible power estimate.

Acceptance connects the displayed trace to native data, configuration, frequency-time mapping and controlled references. Attenuation challenges, terminated-input observations and representative transient tests probe different limitations. Preserve excluded intervals and unsuccessful captures. A negative trace supports a finding only for the validated event class and actual coverage; it cannot establish universal absence.

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Chapter 8 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C08-MCQ-001. A conventional swept analyzer constructs its horizontal frequency axis by which process?

A. Visiting successive input frequencies over time

B. Averaging all input frequencies into one detector value

C. Storing only one fixed-frequency time record

D. Observing the full displayed span at one instant

Answer: A. Successive tuning makes the trace a frequency-time construction; a displayed span is not necessarily instantaneous coverage. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

Why the selected alternative fits: Visiting successive input frequencies over time.

Distinguishing consideration: compare this with option B, “Averaging all input frequencies into one detector value”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

Review: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

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V011-C08-MCQ-002. An instrument offers swept, FFT-assisted, and segmented modes. What establishes the acquisition model for an archived trace?

A. The selected mode and its documented acquisition sequence

B. The analyzer product-family name without the selected acquisition mode

C. The displayed span compared with the nominal RBW alone

D. The use of a logarithmic amplitude scale rather than a linear scale

Answer: A. Hybrid instruments can implement different architectures. The selected mode must be recorded rather than inferred from the enclosure or display. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

Why the selected alternative fits: The selected mode and its documented acquisition sequence.

Distinguishing consideration: compare this with option B, “The analyzer product-family name without the selected acquisition mode”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

Review: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

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V011-C08-MCQ-003. A trace is assembled from several frequency segments. Which additional record is most useful when interpreting an intermittent source?

A. The total averaging count without segment boundaries

B. The common final RBW without segment timing

C. The acquisition times and boundaries of the segments

D. The maximum amplitude within each segment without acquisition times

Answer: C. Segment timing reveals which frequencies were observed during each source state; one image can conceal those gaps. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why the selected alternative fits: The acquisition times and boundaries of the segments.

Distinguishing consideration: compare this with option A, “The total averaging count without segment boundaries”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-MCQ-004. Why can narrowing RBW make a brief emission harder to characterize despite a lower displayed noise floor?

A. The narrower filter takes longer to develop a valid response

B. The whole span becomes simultaneous when RBW is narrow

C. The detector becomes immune to startup behavior

D. Narrower RBW always increases the emission's duration

Answer: A. Improved separation and lower admitted noise are accompanied by slower settling; a short event may end before a representative response forms.

Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

Why the selected alternative fits: The narrower filter takes longer to develop a valid response.

Distinguishing consideration: compare this with option B, “The whole span becomes simultaneous when RBW is narrow”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Resolution Bandwidth and Selectivity.

Review: Chapter 8 — Resolution Bandwidth and Selectivity.

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V011-C08-MCQ-005. Two filters have the same nominal RBW but different skirts. Which property helps explain their different rejection of a nearby strong component?

A. The nominal RBW label by itself

B. The total frequency span

C. The averaging count after detection

D. Filter shape factor

Answer: D. The nominal width does not describe the complete frequency weighting. Skirt shape affects nearby-signal rejection. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

Why the selected alternative fits: Filter shape factor.

Distinguishing consideration: compare this with option A, “The nominal RBW label by itself”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Resolution Bandwidth and Selectivity.

Review: Chapter 8 — Resolution Bandwidth and Selectivity.

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V011-C08-MCQ-006. A wide resolution filter contains a wanted tone and a neighboring tone. What is the principal risk in treating its marker as wanted-tone power?

A. The marker resolves the two components whenever it is RMS detected

B. The marker may include energy from the neighboring component

C. The marker must be the arithmetic mean of the two tone powers

D. The marker necessarily reports only the stronger tone

Answer: B. A broad filter can admit more than the intended component; its reading is then not uniquely attributable to the wanted tone. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: The marker may include energy from the neighboring component.

Distinguishing consideration: compare this with option A, “The marker resolves the two components whenever it is RMS detected”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-007. A modulated signal occupies several resolution filters. What is generally required to estimate its total channel power?

A. The narrowest available RBW regardless of signal width

B. The highest single marker without further information

C. The lowest negative-peak reading across the band

D. A declared integration interval, weighting, detector statistic, and calibration

Answer: D. A single narrowband reading measures only part of the occupied signal; a defined integration is required for total power. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: A declared integration interval, weighting, detector statistic, and calibration.

Distinguishing consideration: compare this with option A, “The narrowest available RBW regardless of signal width”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-008. What tradeoff accompanies stronger video filtering?

A. Less visible trace variation with slower response

B. Improved separation of adjacent frequencies with no timing cost

C. Reduced sweep duration because less video noise is visible

D. Lower integrated pre-detection noise with unchanged transient response

Answer: A. VBW acts after detection and smooths fluctuations, but its time response can obscure short changes. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why the selected alternative fits: Less visible trace variation with slower response.

Distinguishing consideration: compare this with option B, “Improved separation of adjacent frequencies with no timing cost”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-MCQ-009. Trace averaging is most readily interpreted as improved repeatability when what condition holds?

A. All records have equal length even when their source distributions differ

B. The detector is changed to follow the largest reading on each sweep

C. Each sweep is separately normalized despite changing source states

D. The random process is stationary over the averaging interval

Answer: D. Stationarity supports combining repeated estimates of the same quantity; state changes can make the average represent a mixture. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why the selected alternative fits: The random process is stationary over the averaging interval.

Distinguishing consideration: compare this with option A, “All records have equal length even when their source distributions differ”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-MCQ-010. A max-hold comb disappears into a chirped burst on simultaneous capture. What explains the original comb?

A. Different burst fragments populated different frequencies on repeated sweeps

B. The chirp proves a separate continuous carrier at every tooth

C. The swept analyzer had measured all teeth simultaneously

D. Max hold converted frequency into absolute phase

Answer: A. The chapter's case shows that repeated swept observations can assemble a comb that no single waveform contained at one instant. Source: §8.13 Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4453)

Why the selected alternative fits: Different burst fragments populated different frequencies on repeated sweeps.

Distinguishing consideration: compare this with option B, “The chirp proves a separate continuous carrier at every tooth”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-MCQ-011. Two traces are compared quantitatively after one changes from sample to peak detection. What should happen before interpreting their difference?

A. Match RBW alone and treat the detector change as irrelevant

B. Interpret the difference as a change of mean input power without checking statistics

C. Apply the same bandwidth correction and assume the detectors then agree

D. Reconcile the detector statistics or repeat with compatible settings

Answer: D. Different detectors estimate different quantities. A change in indication need not reflect an input-power change. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why the selected alternative fits: Reconcile the detector statistics or repeat with compatible settings.

Distinguishing consideration: compare this with option A, “Match RBW alone and treat the detector change as irrelevant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-MCQ-012. Which pairing matches the chapter's example of discovery followed by power estimation?

A. Positive peak with max hold, then an appropriate RMS or averaging method

B. Positive peak for both discovery and mean power without a detector model

C. Negative peak with averaging, then positive-peak max hold as mean power

D. Max hold for discovery, then the uncorrected largest marker as channel power

Answer: A. Discovery and power estimation have different aims. The final method must still identify the statistic and suit the signal. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why the selected alternative fits: Positive peak with max hold, then an appropriate RMS or averaging method.

Distinguishing consideration: compare this with option B, “Positive peak for both discovery and mean power without a detector model”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-MCQ-013. A prescribed measurement requires a particular detector and time behavior. What is the sound response?

A. Replace it with RMS whenever average power is desired

B. Match the nominal RBW while substituting a faster detector

C. Use positive peak and regard it as conservative for every specified quantity

D. Use that prescribed behavior and document it

Answer: D. A detector and its timing can be part of the measurement definition; an attractive display is not a valid substitute. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why the selected alternative fits: Use that prescribed behavior and document it.

Distinguishing consideration: compare this with option A, “Replace it with RMS whenever average power is desired”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-MCQ-014. A menu contains both an RMS bucket detector and logarithmic video averaging. Which conclusion is justified?

A. The two settings necessarily describe the same operation

B. The full processing sequence must be established before interpreting the final statistic

C. The log averaging automatically cancels the detector's time response

D. The RMS label guarantees an unbiased final mean in watts

Answer: B. Detector selection and averaging can occur at different stages; a label alone does not specify their composition. Source: §8.4.4 Measurement consequence (p. 4440)

Why the selected alternative fits: The full processing sequence must be established before interpreting the final statistic.

Distinguishing consideration: compare this with option A, “The two settings necessarily describe the same operation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Measurement consequence.

Review: Chapter 8 — Measurement consequence.

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V011-C08-MCQ-015. Only a noise-trace screenshot survives. Why is adding 2.51 dB automatically unjustified?

A. Every noise marker requires both the log offset and the nominal-RBW correction

B. A displayed average always means the arithmetic power mean

C. The dBm label proves logarithms were averaged rather than powers

D. The pre-log statistic, correction history, and distribution may be unknown

Answer: D. The modeled offset applies to a specified statistic and distribution, not to every image with a dBm axis. Source: §8.4.4 Measurement consequence (p. 4440)

Why the selected alternative fits: The pre-log statistic, correction history, and distribution may be unknown.

Distinguishing consideration: compare this with option A, “Every noise marker requires both the log offset and the nominal-RBW correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Measurement consequence.

Review: Chapter 8 — Measurement consequence.

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V011-C08-MCQ-016. What defines the logarithmic average L_N?

A. Take the logarithm after averaging the powers

B. Choose the greatest power and convert it to decibels

C. Average the logarithms of the individual positive powers

D. Average the complex voltage phasors and square once

Answer: C. L_N applies the logarithm before averaging. Reversing those operations produces A_N, a different estimator. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: Average the logarithms of the individual positive powers.

Distinguishing consideration: compare this with option A, "Take the logarithm after averaging the powers"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-017. Which operation defines A_N in Equation 16A?

A. Average the individual dBm readings

B. Convert the arithmetic mean of the powers to decibels

C. Convert the sum to decibels without dividing by sample count

D. Take the median of the log powers

Answer: B. A_N logs the mean power; the division by N is part of the mean and must not be omitted. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: Convert the arithmetic mean of the powers to decibels.

Distinguishing consideration: compare this with option A, “Average the individual dBm readings”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-018. For any realized record of positive powers, what does logarithm concavity establish?

A. L_N is no less than A_N

B. Their ensemble expectations must be equal whenever samples are independent

C. L_N is no greater than A_N

D. L_N is always exactly 2.5068 dB below A_N

Answer: C. The inequality is deterministic. A particular offset requires distributional assumptions and is not implied by concavity alone. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: is no greater than.

Distinguishing consideration: compare this with option A, “is no less than”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-019. When are L_N and A_N equal for a positive finite record?

A. Whenever the detector is calibrated in dBm

B. When all sampled powers are equal

C. Whenever N exceeds 100

D. Whenever samples are independent

Answer: B. Strict concavity makes equality occur for equal powers; sample count and independence do not force it. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: When all sampled powers are equal.

Distinguishing consideration: compare this with option A, "Whenever the detector is calibrated in dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-020. What does the inequality between L_N and A_N fail to establish by itself?

A. A numerical noise correction

B. The direction of their difference

C. A consequence of operation order

D. Equality for a constant-power record

Answer: A. Concavity gives direction for positive records, but neither Gaussian statistics nor a fixed bias follows from it. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: A numerical noise correction.

Distinguishing consideration: compare this with option B, “The direction of their difference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-021. Which quadrature model underlies the chapter's exponential instantaneous-power distribution?

A. Independent zero-mean Gaussian components with equal normalized variance

B. Clipped quadratures with unknown distribution

C. An arbitrary changing mixture of quadrature means

D. Two fixed quadrature constants

Answer: A. Circular complex Gaussian noise with the stated normalization yields exponential power; other models require separate analysis. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: Independent zero-mean Gaussian components with equal normalized variance.

Distinguishing consideration: compare this with option B, “Clipped quadratures with unknown distribution”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-022. Why does the definition of instantaneous power incorporate reference resistance and gain calibration?

A. To establish independence between successive power estimates

B. To express power at a calibrated estimation plane rather than raw ADC counts

C. To make the exponential model valid regardless of clipping

D. To make the measured noise bandwidth equal to the nominal RBW

Answer: B. The statistical power variable is calibrated. Applying its units and correction to uncalibrated counts would omit the measurement mapping. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: To express power at a calibrated estimation plane rather than raw ADC counts.

Distinguishing consideration: compare this with option A, “To establish independence between successive power estimates”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-023. For the model's U = P divided by mean power, what are its mean and variance?

A. Zero and one

B. One and one

C. One and zero

D. Two and four

Answer: B. The stipulated normalized exponential density has unit mean and unit variance, which gives the stated moments of P. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: One and one.

Distinguishing consideration: compare this with option A, “Zero and one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-024. If the modeled mean power is mu, what is the instantaneous-power variance?

A. Zero because the receiver is linear

B. mu divided by N for every single sample

C. The logarithm of mu

D. mu squared

Answer: D. The single exponential power sample has variance equal to the square of its mean. Averaging changes this only under additional assumptions. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: mu squared.

Distinguishing consideration: compare this with option A, “Zero because the receiver is linear”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-025. Which observation directly challenges use of the single exponential-power model?

A. A documented calibrated power plane

B. Independent zero-mean Gaussian quadratures

C. A clipped envelope caused by overload

D. A positive equivalent noise bandwidth

Answer: C. Clipping changes the distribution; the model's exponential moments and resulting correction then need not apply. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: A clipped envelope caused by overload.

Distinguishing consideration: compare this with option A, “A documented calibrated power plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-026. For the expected value of L_N, which condition suffices without requiring independence?

A. Every sample is copied from a deterministic tone

B. Each sample has the same stipulated exponential distribution

C. Every record contains a different unrecorded mean power

D. Only the first sample has known statistics

Answer: B. Linearity of expectation gives the mean log offset from the marginal distribution. Independence is needed for the simple variance reduction, not this expectation. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: Each sample has the same stipulated exponential distribution.

Distinguishing consideration: compare this with option A, “Every sample is copied from a deterministic tone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-027. One thousand independent single-sample log powers are averaged. What happens to the modeled mean offset?

A. It falls in inverse proportion to the number of logarithmic samples

B. It is replaced by the much smaller bias of a logged thousand-power arithmetic mean

C. It remains about 2.5068 dB while random fluctuation decreases

D. It vanishes once the standard deviation is smaller than the offset

Answer: C. Averaging more logarithms reduces variance under independence but does not change their common expectation. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: It remains about 2.5068 dB while random fluctuation decreases.

Distinguishing consideration: compare this with option A, “It falls in inverse proportion to the number of logarithmic samples”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-028. Adding the modeled log correction is unbiased in which stated sense?

A. Expectation in watts after arbitrary exponentiation

B. A guaranteed upper confidence bound for every record

C. An exact recovery of every individual noise sample

D. Expectation in decibel units for the specified statistic and model

Answer: D. An unbiased decibel expectation does not imply an unbiased exponentiated estimator or a confidence limit. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: Expectation in decibel units for the specified statistic and model.

Distinguishing consideration: compare this with option A, “Expectation in watts after arbitrary exponentiation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-MCQ-029. What is the correct log-bias adjustment for an ideal constant-envelope tone when all powers are equal?

A. Subtract 2.5068 dB regardless of calibration

B. No Gaussian-noise log-bias adjustment

C. Add the finite-sample gamma correction for white noise

D. Add 2.5068 dB regardless of sample count

Answer: B. Both operation orders coincide for equal powers. Applying the exponential-noise correction would overstate the tone. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: No Gaussian-noise log-bias adjustment.

Distinguishing consideration: compare this with option A, “Subtract 2.5068 dB regardless of calibration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-030. How are the log-envelope correction and equivalent-noise-bandwidth correction related?

A. One automatically determines the other from the RBW label

B. They are two names for exactly the same factor

C. They address different causes and must be tracked separately

D. Both are universally equal to 2.5068 dB

Answer: C. One concerns estimator statistics; the other concerns integrated bandwidth. Neither substitutes for the other's characterization. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

Why the selected alternative fits: They address different causes and must be tracked separately.

Distinguishing consideration: compare this with option A, “One automatically determines the other from the RBW label”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

Review: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

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V011-C08-MCQ-031. Which assumption is essential to the chapter's gamma-sum formula for A_N?

A. Any N overlapping samples regardless of correlation

B. Arbitrary detector outputs mixed across changing states

C. Independent exponential power samples with the stated common mean

D. A constant-envelope tone at each sample

Answer: C. The finite-record expression is derived for a sum of independent exponentials. Correlation or a different distribution changes that sum law. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: Independent exponential power samples with the stated common mean.

Distinguishing consideration: compare this with option A, “Any N overlapping samples regardless of correlation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-032. What should N count in Equation 16C?

A. Every display bucket after the detector

B. Every FFT record entering an overlapping average without a dependence check

C. Independent exponential samples actually entering the power mean

D. Every repeated sweep regardless of the statistic entering the mean

Answer: C. The formula's sample count belongs to its statistical model and estimator, not automatically to a storage or display count. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: Independent exponential samples actually entering the power mean.

Distinguishing consideration: compare this with option A, “Every display bucket after the detector”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-033. Four independent, identically distributed exponential power samples with the same positive mean are averaged before logging. Which correction addresses the stated expected bias?

A. Minus 10 log10 of 4 dB

B. Exactly zero for any four-sample mean

C. About plus 2.50682 dB

D. About plus 0.56535 dB

Answer: D. The finite-log bias at N = 4 is about minus 0.56535 dB; the single-sample log correction would overcorrect this statistic. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: About plus 0.56535 dB.

Distinguishing consideration: compare this with option A, “Minus 10 log10 of 4 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-034. At N = 100 independent, identically distributed exponential powers with the same positive mean, what is the approximate bias magnitude after averaging powers and then logging?

A. Exactly 0.56535 dB

B. Exactly 20 dB

C. About 2.5068 dB

D. About 0.02175 dB

Answer: D. Equation 16C approaches zero from below as N grows; its N = 100 magnitude is much smaller than the log-sample offset. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: About 0.02175 dB.

Distinguishing consideration: compare this with option A, “Exactly 0.56535 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-035. An instrument's noise marker already corrects the reported statistic. What should postprocessing do?

A. Replace the applied correction by the nominal RBW in decibels

B. Add the log correction again because offline processing is a new measurement

C. Identify and retain the applied correction without applying it a second time

D. Apply the finite-sample correction solely from the number of displayed points

Answer: C. Duplicating a valid correction introduces error. The record must show which stage already applied it. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: Identify and retain the applied correction without applying it a second time.

Distinguishing consideration: compare this with option A, “Replace the applied correction by the nominal RBW in decibels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-036. For 100 independent, identically distributed exponential powers with the same positive mean, what is the relative standard deviation of their arithmetic mean?

A. 10

B. 0.01

C. 0.1

D. 1

Answer: C. The independent mean has relative standard deviation 1 divided by the square root of N, giving 0.1 at N = 100. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: 0.1.

Distinguishing consideration: compare this with option A, “10”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-037. For 100 independent log-power samples under the stated model, what is approximately the standard deviation of L_N?

A. 20 dB

B. 0.02175 dB

C. 2.507 dB

D. 0.557 dB

Answer: D. The chapter's log-sample variance gives about 0.557 dB. The mean offset and finite-log bias are different quantities. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: 0.557 dB.

Distinguishing consideration: compare this with option A, “20 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-038. A very steady log-averaged trace remains systematically below the mean-power level. What does this illustrate?

A. Improved repeatability does not establish absence of estimator bias

B. The reduced trace scatter proves that the mean-power estimate is now unbiased

C. A smaller sample standard deviation automatically supplies the missing mean correction

D. Averaging logarithms and logging average power become equivalent once the trace is smooth

Answer: A. Random scatter and mean bias are separate properties. More independent log samples can reduce scatter while retaining the offset. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: Improved repeatability does not establish absence of estimator bias.

Distinguishing consideration: compare this with option B, “The reduced trace scatter proves that the mean-power estimate is now unbiased”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-039. For 100 equal-mean exponential power samples, the common correlation between every distinct pair of power samples is 0.2. What is the approximate relative standard deviation of their arithmetic mean?

A. 0.020

B. 0.456

C. 0.010

D. 0.100

Answer: B. The stipulated covariance model gives sqrt[(1 + 99 times 0.2)/100] = sqrt(0.208), approximately 0.456. This is a variance calculation, not a claim that the dependent sum retains a gamma distribution. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: 0.456.

Distinguishing consideration: compare this with option A, “0.020”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-040. A single random power sample is copied 100 times. What happens to the relative standard deviation of their average in the stipulated model?

A. It becomes one hundredth

B. It remains one

C. It vanishes exactly

D. It becomes one tenth

Answer: B. Perfectly correlated copies add no independent information; averaging them reproduces the original random sample. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: It remains one.

Distinguishing consideration: compare this with option A, "It becomes one hundredth"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-041. A noise record mixes two distinct operating levels. Why can the single-level log correction fail for its overall mean power?

A. A mixture of means is not the single exponential distribution assumed

B. The logarithm becomes undefined for every positive sample

C. The two states necessarily have identical arithmetic means

D. Averaging always removes the higher state

Answer: A. Correcting each conditional log expectation does not make the average of state log levels equal the log of the overall linear mean. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: A mixture of means is not the single exponential distribution assumed.

Distinguishing consideration: compare this with option B, “The logarithm becomes undefined for every positive sample”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-042. Ninety percent of records have mean 1 mW and ten percent have mean 100 mW. What is their overall arithmetic mean power?

A. 50.5 mW

B. 10.9 mW

C. 2 mW

D. 100 mW

Answer: B. The time or record weights apply in linear power: 0.9 times 1 plus 0.1 times 100 equals 10.9 mW. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: 10.9 mW.

Distinguishing consideration: compare this with option A, “50.5 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-043. Under the chapter's independent Gaussian-contribution model, compatible total and background mean-power estimates at the same plane and bandwidth are minus 60 and minus 70 dBm. What is the background-subtracted mean-power level?

A. Minus 10 dBm

B. Approximately minus 59.59 dBm

C. Approximately minus 60.46 dBm

D. Minus 130 dBm

Answer: C. The estimates are 1 nW and 0.1 nW. Their linear difference is 0.9 nW, or approximately minus 60.46 dBm. Direct dBm subtraction gives a ratio; adding the linear powers gives the wrong sign of correction. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: Approximately minus 60.46 dBm.

Distinguishing consideration: compare this with option A, “Minus 10 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-044. Why is background subtraction fragile when estimated total and background nearly coincide?

A. A small level difference directly gives a precise residual power

B. Subtracting in logarithmic units eliminates the near-cancellation problem

C. The residual uncertainty equals the smaller of the two input uncertainties

D. A small difference is sensitive to errors in either estimate

Answer: D. Subtracting similar numbers can make the residual poorly determined relative to its size; the uncertainty cannot be ignored. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: A small difference is sensitive to errors in either estimate.

Distinguishing consideration: compare this with option A, “A small level difference directly gives a precise residual power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-045. Which situation lies outside the chapter's independent Gaussian-background subtraction example?

A. Two independent zero-mean Gaussian contributions

B. Matched bandwidths at the same estimation plane

C. Normalized linear mean-power estimates

D. A coherent tone interfering with a correlated background

Answer: D. The worked example excludes coherent tones and correlated contributions because cross terms can alter the simple power sum. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: A coherent tone interfering with a correlated background.

Distinguishing consideration: compare this with option A, “Two independent zero-mean Gaussian contributions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-046. Compatible stationary white noise is measured first in 80 kHz and then in 20 kHz equivalent bandwidth. What is the expected change?

A. About minus 12.04 dB

B. About minus 4 dB

C. About minus 6.02 dB

D. About plus 6.02 dB

Answer: C. Integrated white-noise power is proportional to equivalent bandwidth; 10 log10 of one quarter is about minus 6.02 dB. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why the selected alternative fits: About minus 6.02 dB.

Distinguishing consideration: compare this with option A, “About minus 12.04 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-MCQ-047. For a flat mean density of minus 160 dBm per hertz in 10 kHz equivalent bandwidth, what is mean integrated power before estimator bias?

A. Minus 150 dBm

B. Minus 120 dBm

C. Minus 40 dBm

D. Minus 200 dBm

Answer: B. The bandwidth contributes 10 log10 of 10000, or 40 dB, to the density level. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why the selected alternative fits: Minus 120 dBm.

Distinguishing consideration: compare this with option A, “Minus 150 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-MCQ-048. A filter labeled 1 kHz has measured equivalent noise bandwidth 1128 Hz. Which bandwidth belongs in white-noise normalization?

A. The video bandwidth irrespective of filtering order

B. The frequency span

C. 1128 Hz

D. 1000 Hz solely because it is the label

Answer: C. The integrated noise uses actual equivalent noise bandwidth, whose difference from the nominal label is independently established here. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: 1128 Hz.

Distinguishing consideration: compare this with option A, “The video bandwidth irrespective of filtering order”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-049. Why can a measured minus 20 dB bandwidth change be correct even when both absolute log levels are biased?

A. The identical estimator bias cancels under unchanged valid noise and processing assumptions

B. Decibel subtraction always converts a mixture to white noise

C. Every relative measurement cancels every error

D. A bandwidth change proves the source is a tone

Answer: A. A common offset cancels in the difference if the same model and statistic remain applicable; that does not validate the absolute levels. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: The identical estimator bias cancels under unchanged valid noise and processing assumptions.

Distinguishing consideration: compare this with option B, “Decibel subtraction always converts a mixture to white noise”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-050. Noise drops less than the simple bandwidth ratio predicts. What does this result establish first?

A. The source must have vanished

B. The receiver is certainly defective

C. At least one assumption of the simple comparison needs examination

D. An external interferer has been proven

Answer: C. Noise color, receiver noise, filtering, and processing can all affect the comparison. The mismatch alone does not identify its cause. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: At least one assumption of the simple comparison needs examination.

Distinguishing consideration: compare this with option A, “The source must have vanished”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-051. Why cannot Equation 15 alone supply an absolute sweep time for an unknown analyzer?

A. Its proportionality depends on the filter, architecture, and acceptance criterion

B. Its qualitative trend automatically includes every gated-mode timing requirement

C. Its factor is always one when frequencies are entered in hertz

D. Its proportionality is fixed by the selected span alone

Answer: A. The qualitative scaling omits the instrument-specific factor; using it as an absolute timing law invents missing information. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why the selected alternative fits: Its proportionality depends on the filter, architecture, and acceptance criterion.

Distinguishing consideration: compare this with option B, “Its qualitative trend automatically includes every gated-mode timing requirement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-MCQ-052. Within one validated regime, doubling span with unchanged RBW has what conditional effect on the Equation 15 scaling?

A. It doubles the predicted sweep-time scale

B. It halves the predicted sweep-time scale

C. It leaves the scale unchanged

D. It increases the scale fourfold

Answer: A. The stated proportionality is linear in span when the implementation and all other applicable conditions remain fixed. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why the selected alternative fits: It doubles the predicted sweep-time scale.

Distinguishing consideration: compare this with option B, “It halves the predicted sweep-time scale”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-MCQ-053. Within one validated regime, halving RBW at fixed span changes the Equation 15 sweep-time scale by what factor?

A. One half

B. One quarter

C. Four

D. Two

Answer: C. The denominator contains RBW squared. Halving RBW gives a fourfold scale, subject to the same validated timing regime. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why the selected alternative fits: Four.

Distinguishing consideration: compare this with option A, “One half”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-MCQ-054. Why should automatic sweep-time selection be challenged for unusual gated or segmented signals?

A. The trigger edge guarantees a settled response throughout every gate

B. The automatic minimum also validates every event reconstruction assumption

C. A segmented sweep has no settling interval if all segments share RBW

D. The automatic rule may not cover the actual waveform and acquisition timing

Answer: D. A nominal automatic minimum need not validate a specialized acquisition; representative signal tests remain necessary. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why the selected alternative fits: The automatic rule may not cover the actual waveform and acquisition timing.

Distinguishing consideration: compare this with option A, “The trigger edge guarantees a settled response throughout every gate”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-MCQ-055. What can an excessively fast sweep do to a narrow component?

A. Resolve closer tones because less time is spent in the filter

B. Lower or broaden its displayed response

C. Guarantee the response of a short burst once the center frequency is correct

D. Preserve exact amplitude while changing only displayed noise variance

Answer: B. Insufficient settling while tuning can distort both amplitude and shape; a visually narrow input is not necessarily faithfully portrayed. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why the selected alternative fits: Lower or broaden its displayed response.

Distinguishing consideration: compare this with option A, “Resolve closer tones because less time is spent in the filter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-MCQ-056. What risk can arise from making a sweep unnecessarily slow?

A. Longer sweep time always increases the usable overlap with every short event

B. A longer sweep guarantees a simultaneous representation of a changing source

C. State changes and drift can affect different trace locations

D. A slower sweep eliminates all need to examine source stationarity

Answer: C. A longer construction interval exposes the trace to changes between frequency visits; slow is not an unconditional improvement. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why the selected alternative fits: State changes and drift can affect different trace locations.

Distinguishing consideration: compare this with option A, “Longer sweep time always increases the usable overlap with every short event”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-MCQ-057. A triggered sweep uses an undocumented trigger delay. What uncertainty is introduced?

A. Whether the pre-log statistic is a power or a voltage average

B. Which part of the event was actually observed

C. The correct nominal RBW for separating two stationary tones

D. The equivalent noise bandwidth of the resolution filter

Answer: B. Delay determines alignment between trigger and usable measurement interval, so its omission obscures event coverage. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why the selected alternative fits: Which part of the event was actually observed.

Distinguishing consideration: compare this with option A, “Whether the pre-log statistic is a power or a voltage average”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-MCQ-058. Which trio directly describes the temporal placement and repeatability of gated waveform samples?

A. Input attenuation, mixer level, and steady-state gain correction

B. Nominal span, displayed point count, and center-frequency accuracy

C. Nominal RBW, filter shape factor, and reference impedance

D. Gate width, trigger jitter, and repetition stability

Answer: D. These quantities affect where valid observation falls within the event and whether repeated observations are comparable. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why the selected alternative fits: Gate width, trigger jitter, and repetition stability.

Distinguishing consideration: compare this with option A, “Input attenuation, mixer level, and steady-state gain correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-MCQ-059. A nonrepeatable event cannot be represented without missed portions by the swept mode. What is an appropriate next step?

A. Increase max-hold count and assume the assembled peaks are one event

B. Select a suitable real-time or digitized capture method

C. Use the longest automatic sweep and infer complete transient coverage

D. Reduce VBW until repeated sweeps have the same outline

Answer: B. An acquisition architecture whose instantaneous coverage contains the event may resolve a limitation that sweep processing cannot repair. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why the selected alternative fits: Select a suitable real-time or digitized capture method.

Distinguishing consideration: compare this with option A, “Increase max-hold count and assume the assembled peaks are one event”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-MCQ-060. In a stepped sweep, how should commanded dwell time be treated?

A. Count all commanded dwell as valid once the center frequency is set

B. Subtract tuning time but count filter settling as valid observation

C. Treat equal commanded dwells as equal usable intervals despite different responses

D. Exclude tuning and settling before counting usable observation

Answer: D. A command duration includes intervals when the channel response may not yet be valid; coverage uses the usable interval. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why the selected alternative fits: Exclude tuning and settling before counting usable observation.

Distinguishing consideration: compare this with option A, “Count all commanded dwell as valid once the center frequency is set”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-MCQ-061. An event changes frequency while an analyzer sweeps. What must be compared to judge observation?

A. Only their mean frequency and mean repetition rate

B. The event trajectory and analyzer frequency-time trajectory

C. Only the largest displayed span and the number of stored sweeps

D. Only the common overall frequency band and survey duration

Answer: B. A frequency-time intersection and valid response determine whether the moving event could be observed; a common band label is insufficient. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why the selected alternative fits: The event trajectory and analyzer frequency-time trajectory.

Distinguishing consideration: compare this with option A, “Only their mean frequency and mean repetition rate”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-MCQ-062. What property must a proposed simultaneous capture have to contain an event's frequency excursion?

A. Adequate instantaneous bandwidth for that excursion

B. A swept span larger than the excursion even with narrow instantaneous coverage

C. An RBW label smaller than the closest frequency spacing alone

D. A max-hold interval longer than the event regardless of acquisition bandwidth

Answer: A. Displayed span and instantaneous acquisition bandwidth are distinct. The latter must contain the event for simultaneous capture. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why the selected alternative fits: Adequate instantaneous bandwidth for that excursion.

Distinguishing consideration: compare this with option B, “A swept span larger than the excursion even with narrow instantaneous coverage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-MCQ-063. Repeated bursts share a nominal period but vary in startup modulation. What prevents straightforward reconstruction of one spectrum?

A. A stable trigger period makes any within-burst modulation difference irrelevant

B. Matching the average repetition period also establishes identical startup modulation

C. The same RBW guarantees the same waveform segment is represented each time

D. The waveform features needed by the reconstruction are not repeatable

Answer: D. Matching repetition periods alone does not ensure equal amplitude, phase, modulation, or startup at corresponding measurement times. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: The waveform features needed by the reconstruction are not repeatable.

Distinguishing consideration: compare this with option A, “A stable trigger period makes any within-burst modulation difference irrelevant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-064. Why does repeatable trigger-edge alignment alone fail to establish repeatability of the waveform inside a burst?

A. Startup modulation, amplitude, or phase can vary relative to the aligned edge

B. Matching the burst period is sufficient even when modulation changes

C. A stable trigger edge forces every internal waveform feature to repeat

D. The same gate width guarantees identical samples regardless of waveform evolution

Answer: A. The trigger constrains a selected edge, not every internal feature. The relevant waveform and its relationship to the gate require event-resolved validation.

Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: Startup modulation, amplitude, or phase can vary relative to the aligned edge.

Distinguishing consideration: compare this with option B, “Matching the burst period is sufficient even when modulation changes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-065. Why should a burst validation reproduce the prior receiver state?

A. A trigger reset guarantees the same AGC state in every instrument

B. A continuous-tone calibration makes recovery history irrelevant

C. AGC and other transient responses can depend on that state

D. Only the final steady-state gain can affect a short burst

Answer: C. The response available during a burst can depend on preceding gain or recovery conditions; a continuous-tone check can miss this behavior. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: AGC and other transient responses can depend on that state.

Distinguishing consideration: compare this with option A, “A trigger reset guarantees the same AGC state in every instrument”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-066. A long continuous calibration tone measures correctly. What remains unvalidated for a short burst?

A. Turn-on, duration, repetition, and transient acquisition behavior

B. The ability to display the tested continuous tone at its measured level

C. The use of the same amplitude reference unit for both signals

D. The steady-state gain at the tested tone and configuration

Answer: A. A steady tone checks only part of the method. Burst-specific timing and waveform behavior require representative tests. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: Turn-on, duration, repetition, and transient acquisition behavior.

Distinguishing consideration: compare this with option B, “The ability to display the tested continuous tone at its measured level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-067. How can event-resolved records support assessment of a repeated-event spectral aggregate?

A. They remove the need to establish the trigger-to-waveform relationship

B. They make a repeated-sweep aggregate simultaneous without waveform comparison

C. They permit comparison of the aggregate with the individual events

D. They ensure phase-coherent reconstruction solely because timestamps exist

Answer: C. Keeping individual events allows the claimed repeatability and aggregate construction to be examined. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: They permit comparison of the aggregate with the individual events.

Distinguishing consideration: compare this with option A, “They remove the need to establish the trigger-to-waveform relationship”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-068. A no-peak max-hold result is reported. What scope is defensible?

A. Any event weaker than the validated reference regardless of duration

B. Every possible emission at the site

C. The validated event class under the actual observed bands and usable intervals

D. All out-of-band signals for the full survey day

Answer: C. A negative result is bounded by tested sensitivity, waveform class, timing, and coverage; unobserved possibilities remain unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: The validated event class under the actual observed bands and usable intervals.

Distinguishing consideration: compare this with option A, “Any event weaker than the validated reference regardless of duration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-069. Which event is plainly outside a negative result restricted to a documented frequency band?

A. A captured calibration tone in the band

B. The validated reference within the band

C. A stored in-band control signal

D. An emission entirely outside that band

Answer: D. Frequency coverage is one of the explicit boundaries of the finding. Lack of an in-band peak says nothing directly about an out-of-band event. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: An emission entirely outside that band.

Distinguishing consideration: compare this with option A, “A captured calibration tone in the band”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-070. After a swept procedure repeatedly misses the target reference, what should guide the next observation?

A. Accept only the sweeps that happened to capture the reference

B. Increase the repetition count while leaving the demonstrated timing gap unchanged

C. The specific remaining uncertainty and a method capable of resolving it

D. Apply the white-noise bandwidth ratio to compensate for missed reference bursts

Answer: C. A failed representative challenge identifies a capability gap; a different timing strategy or architecture may be necessary. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: The specific remaining uncertainty and a method capable of resolving it.

Distinguishing consideration: compare this with option A, “Accept only the sweeps that happened to capture the reference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-071. Which configuration belongs in the amplitude-accuracy record?

A. Center frequency and nominal RBW alone

B. Input attenuation, preamplifier state, mixer level, and reference level

C. Internal alignment date and displayed amplitude alone

D. Detector label and total averaging count alone

Answer: B. Amplitude response depends on the actual gain and detector configuration as well as calibration and frequency. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why the selected alternative fits: Input attenuation, preamplifier state, mixer level, and reference level.

Distinguishing consideration: compare this with option A, “Center frequency and nominal RBW alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-MCQ-072. What is the purpose of changing input attenuation and correcting the indicated level for that change?

A. Guarantee that every unchanged peak is external

B. Challenge linearity and possible internally generated responses

C. Convert the trace from swept to simultaneous acquisition

D. Measure trigger jitter directly

Answer: B. The expected input-referred relationship is a controlled challenge; departures can indicate nonlinear or internal behavior and require interpretation.

Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why the selected alternative fits: Challenge linearity and possible internally generated responses.

Distinguishing consideration: compare this with option A, “Guarantee that every unchanged peak is external”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-MCQ-073. Why is a successful internal alignment insufficient to verify the complete survey chain?

A. It does not test the external cable, antenna, filter, or site overload

B. Internal alignment proves that external losses remain at their calibration values

C. Internal alignment establishes the antenna response at the site automatically

D. Internal alignment validates every strong out-of-band input condition

Answer: A. Internal routines cover their own paths. Installed external components and environmental stresses require external checks. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why the selected alternative fits: It does not test the external cable, antenna, filter, or site overload.

Distinguishing consideration: compare this with option B, “Internal alignment proves that external losses remain at their calibration values”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-MCQ-074. What does a terminated-input observation help characterize?

A. The original antenna-path field strength without retaining the antenna connection

B. Complete rejection of every external out-of-band blocker

C. Residual analyzer responses under that test condition

D. The transient interception capability of the full installed chain

Answer: C. Termination removes the ordinary antenna input path for a challenge, making residual responses informative without proving universal absence. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why the selected alternative fits: Residual analyzer responses under that test condition.

Distinguishing consideration: compare this with option A, “The original antenna-path field strength without retaining the antenna connection”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-MCQ-075. Why include strong out-of-band signals in an analyzer challenge?

A. An internally aligned analyzer is insensitive to out-of-band mixer loading

B. They can reveal overload or spurious behavior not visible in an isolated weak-tone check

C. A low displayed noise floor proves that all earlier stages remain linear

D. Only signals inside final RBW can affect receiver linearity

Answer: B. The actual environment can stress stages before final selectivity; the method must be tested against relevant blockers. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why the selected alternative fits: They can reveal overload or spurious behavior not visible in an isolated weak-tone check.

Distinguishing consideration: compare this with option A, “An internally aligned analyzer is insensitive to out-of-band mixer loading”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-MCQ-076. Which reference set best challenges complete-chain amplitude performance?

A. A terminated-input residual trace used alone as an amplitude-gain calibration

B. Known external references at several frequencies and levels

C. Repeated internal alignment at one frequency without the external path

D. One external reference level at one frequency used to certify the full range

Answer: B. Multiple external frequencies and levels probe response and linearity across the installed chain instead of relying solely on an internal routine. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why the selected alternative fits: Known external references at several frequencies and levels.

Distinguishing consideration: compare this with option A, “A terminated-input residual trace used alone as an amplitude-gain calibration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-MCQ-077. Which settings should a representative sweep-method acceptance test reproduce?

A. Trigger period and reference level without reproducing trace mode or sweep time

B. RBW and VBW while substituting a continuous untriggered acquisition

C. Center frequency and span while allowing detector and gain to vary

D. Span, RBW, VBW, detector, sweep time, trigger, trace mode, and gain state

Answer: D. The validity of the test is configuration-bound. Changing acquisition or gain settings can change the method's performance. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why the selected alternative fits: Span, RBW, VBW, detector, sweep time, trigger, trace mode, and gain state.

Distinguishing consideration: compare this with option A, “Trigger period and reference level without reproducing trace mode or sweep time”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-MCQ-078. The reference is repeatedly distorted in the survey configuration. What is the chapter's acceptance consequence?

A. Accept because a separate continuous tone measured correctly

B. Accept after averaging until the distorted reference trace becomes smooth

C. Remove unsuccessful reference captures and assess only detections

D. Use a different suitable architecture when the method cannot reproduce it

Answer: D. A method that cannot represent its target reference has not demonstrated the needed capability; failures belong in the record. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why the selected alternative fits: Use a different suitable architecture when the method cannot reproduce it.

Distinguishing consideration: compare this with option A, “Accept because a separate continuous tone measured correctly”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-MCQ-079. Why retain setup files and native trace data alongside images?

A. They reconstruct emissions that were outside all usable acquisition intervals

B. They allow later examination of acquisition and processing details

C. They remove the need to identify detector and correction history

D. They establish independence of all stored records automatically

Answer: B. Native data and configuration support reconstruction and audit; a picture alone omits essential state and processing information. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why the selected alternative fits: They allow later examination of acquisition and processing details.

Distinguishing consideration: compare this with option A, “They reconstruct emissions that were outside all usable acquisition intervals”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-MCQ-080. Which archive entry is especially important when some bands were intentionally omitted?

A. Only the final minimum and maximum displayed frequencies

B. Only a total sweep duration that includes masked intervals

C. Only the number of successful sweeps in the unmasked regions

D. Masked-band boundaries and their timing

Answer: D. Excluded bands and intervals bound the claim of coverage and must remain visible in the record. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why the selected alternative fits: Masked-band boundaries and their timing.

Distinguishing consideration: compare this with option A, “Only the final minimum and maximum displayed frequencies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-MCQ-081. An unknown source is challenged while RBW and gain are also changed. What is the main interpretation problem?

A. Several causes can explain the changed indication

B. The source and RBW changes cancel automatically if their level effects oppose

C. A gain change can be ignored whenever the display remains in dBm

D. The comparison isolates bandwidth because the source challenge is deliberate

Answer: A. A controlled comparison preserves input and receiver state while changing one bandwidth parameter, then challenges the source separately. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: Several causes can explain the changed indication.

Distinguishing consideration: compare this with option B, “The source and RBW changes cancel automatically if their level effects oppose”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-082. Why retain linear-power data during a bandwidth comparison when available?

A. They preserve the estimator domain needed to examine integration and normalization

B. They establish independence between overlapping records

C. They permit arbitrary mixtures to use the single-exponential correction

D. They remove the need to characterize equivalent noise bandwidth

Answer: A. Linear data help distinguish power integration from later logarithmic processing; they do not cure invalid acquisition assumptions. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: They preserve the estimator domain needed to examine integration and normalization.

Distinguishing consideration: compare this with option B, “They establish independence between overlapping records”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-083. Which combination can invalidate a simple white-noise bandwidth correction even when nominal RBWs are known?

A. Positive equivalent bandwidths at a fixed plane

B. Identical valid processing and a flat density

C. A stable source with the same calibration

D. Changed detector order and a nonwhite input spectrum

Answer: D. Equation 16 requires compatible processing and unchanged white density; known labels alone do not supply those assumptions. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why the selected alternative fits: Changed detector order and a nonwhite input spectrum.

Distinguishing consideration: compare this with option A, “Positive equivalent bandwidths at a fixed plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-MCQ-084. Under the stated model, what happens to the finite-record bias of A_N as independent N grows?

A. It approaches zero from below

B. It remains exactly minus 2.5068 dB for every N

C. It increases without bound

D. It becomes positive after N = 4

Answer: A. Power averaging concentrates the mean; its subsequent logarithm still has a finite-record negative bias that decreases with N. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: It approaches zero from below.

Distinguishing consideration: compare this with option B, “It remains exactly minus 2.5068 dB for every N”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-085. What is the status of the approximate 0.434 dB fluctuation obtained by first-order propagation at N = 100?

A. The fixed log-average mean bias

B. A local approximation, not an exact confidence interval

C. A correction valid for every changing mixture

D. An exact universal 95 percent bound

Answer: B. First-order propagation describes a concentrated arithmetic mean locally; it must not be presented as an exact probabilistic bound. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: A local approximation, not an exact confidence interval.

Distinguishing consideration: compare this with option A, “The fixed log-average mean bias”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-086. If power samples share covariance, which claim needs particular caution?

A. The definition of a positive arithmetic mean

B. The identity of the reference power unit

C. The independent gamma formula for the logged power mean

D. Linearity of expectation for identical log marginals

Answer: C. Dependence changes the sum distribution and variance; the chapter explicitly warns against retaining the gamma bias formula automatically. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: The independent gamma formula for the logged power mean.

Distinguishing consideration: compare this with option A, “The definition of a positive arithmetic mean”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-087. Why is counting overlapping FFT records as independent N unsafe?

A. The nominal FFT length alone determines independent sample count

B. Overlap necessarily makes every power sample an exact duplicate

C. Every FFT estimate has the same independence properties regardless of window

D. Overlap can create dependence that violates the estimator's assumed sample model

Answer: D. The actual dependence must be established; a record count does not by itself justify independent-exponential formulas. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why the selected alternative fits: Overlap can create dependence that violates the estimator's assumed sample model.

Distinguishing consideration: compare this with option A, “The nominal FFT length alone determines independent sample count”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-MCQ-088. What should be reported if repeatability needed for reconstruction cannot be established?

A. A universal absence finding

B. An aggregate collection of observations with its limitations

C. A reconstructed phase-coherent waveform

D. A proven instantaneous spectrum of one event

Answer: B. The chapter permits the observations to remain useful while limiting the aggregate's interpretation to what was demonstrated. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: An aggregate collection of observations with its limitations.

Distinguishing consideration: compare this with option A, “A universal absence finding”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-089. Why must nominal RBW and equivalent noise bandwidth remain distinct in analysis?

A. Equivalent noise bandwidth also determines every transient settling response

B. The two widths are interchangeable once both are expressed in hertz

C. They describe different filter properties and answer different measurement questions

D. Nominal RBW always specifies the same integrated noise for every filter shape

Answer: C. Noise integration uses equivalent bandwidth, whereas detailed response and transient questions can require the actual weighting and time behavior. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: They describe different filter properties and answer different measurement questions.

Distinguishing consideration: compare this with option A, “Equivalent noise bandwidth also determines every transient settling response”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-090. Which claim about max hold is defensible without additional waveform evidence?

A. Every event in the displayed span was detected

B. All retained peaks were present simultaneously

C. Its level is the mean channel power

D. It retains observed maxima across the repeated acquisitions

Answer: D. Max hold is an aggregation of observed extrema. Coexistence, complete interception, and mean-power interpretation require separate evidence. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why the selected alternative fits: It retains observed maxima across the repeated acquisitions.

Distinguishing consideration: compare this with option A, “Every event in the displayed span was detected”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-MCQ-091. For two powers 0.1 and 1.9 mW, what is their arithmetic mean before conversion to decibels?

A. 1 mW

B. 2 mW

C. 1.8 mW

D. 0.19 mW

Answer: A. The sum is 2 mW and division by two gives 1 mW; averaging their logarithms would produce a different statistic. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: 1 mW.

Distinguishing consideration: compare this with option B, “2 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-092. A bandwidth comparison keeps the filter ratio but changes the source between two operating states. What essential condition has been lost?

A. An unchanged input density or state for the comparison

B. The ability to compare two positive equivalent bandwidths mathematically

C. The identity of the filter label even when the source density changes

D. The same pre-log statistic for every possible state automatically

Answer: A. The predicted ratio concerns the same stationary density. State changes introduce another cause for a level difference. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: An unchanged input density or state for the comparison.

Distinguishing consideration: compare this with option B, “The ability to compare two positive equivalent bandwidths mathematically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-093. What is required when a phase-noise density varies across the admitted band?

A. Use the actual frequency weighting appropriate to that density

B. Assume the RBW label alone gives the integrated result

C. Apply the single exponential log correction as a filter model

D. Replace every density by its center-frequency value without qualification

Answer: A. The chapter distinguishes flat-density noise bandwidth from integration of a varying spectrum through the actual weighting. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: Use the actual frequency weighting appropriate to that density.

Distinguishing consideration: compare this with option B, “Assume the RBW label alone gives the integrated result”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-094. A gated test reproduces burst duration but ignores frequency trajectory. What relevant behavior remains untested?

A. The static nominal filter width independently of waveform evolution

B. The nominal period label rather than actual event alignment

C. Whether the event and receiver trajectories permit a representative response

D. The steady-state power calibration at an already tested fixed frequency

Answer: C. Transient validation must reproduce the relevant waveform, including its frequency evolution, rather than duration alone. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: Whether the event and receiver trajectories permit a representative response.

Distinguishing consideration: compare this with option A, “The static nominal filter width independently of waveform evolution”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-095. Why should excluded intervals be retained in the archive?

A. They bound usable coverage and show where conclusions cannot be drawn

B. They establish that the source was inactive whenever the analyzer was settling

C. They increase the demonstrated transient sensitivity of the observed intervals

D. They can be counted as valid exposure if the total run time is documented

Answer: A. Omitted or invalid acquisition intervals are part of the evidence for a bounded finding, not empty time to conceal. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why the selected alternative fits: They bound usable coverage and show where conclusions cannot be drawn.

Distinguishing consideration: compare this with option B, “They establish that the source was inactive whenever the analyzer was settling”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-MCQ-096. Repeated bursts have matching power envelopes and trigger times but varying carrier phase. What is justified before coherent waveform reconstruction?

A. Matching power envelopes proves identical carrier phase

B. A repeatable trigger edge supplies the missing carrier-phase relationship automatically

C. Validate the phase repeatability required by that reconstruction separately from power-envelope repeatability

D. Equal mean power permits coherent combination without retaining phase information

Answer: C. Repeatability is specific to the construction. Matching timing and power does not establish the phase relationship needed to combine waveforms coherently. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: Validate the phase repeatability required by that reconstruction separately from power-envelope repeatability.

Distinguishing consideration: compare this with option A, “Matching power envelopes proves identical carrier phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-097. A lower noise display follows a narrower filter. Why might that be unhelpful for the desired measurand?

A. The narrower filter removes all uncertainty

B. The filter may exclude signal energy needed for that measurement

C. Lower displayed noise guarantees total-power accuracy

D. The source's entire bandwidth necessarily shrinks with RBW

Answer: B. Bandwidth selection serves the quantity being estimated; reducing the display floor alone can sacrifice relevant signal content or response time. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why the selected alternative fits: The filter may exclude signal energy needed for that measurement.

Distinguishing consideration: compare this with option A, “The narrower filter removes all uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-MCQ-098. What makes a negative trace's conclusion reproducible?

A. A stated event criterion, actual usable coverage, configuration, and retained failed or excluded observations

B. A continuous-tone test applied without limits to every burst duration

C. A large number of repeated files without the usable observation intervals

D. One no-peak image with the maximum advertised span

Answer: A. A reviewer needs the tested capability and actual coverage to assess what absence claim is supported. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why the selected alternative fits: A stated event criterion, actual usable coverage, configuration, and retained failed or excluded observations.

Distinguishing consideration: compare this with option B, “A continuous-tone test applied without limits to every burst duration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-MCQ-099. Which statement correctly treats the chapter's numerical noise examples?

A. They replace calibration of the installed chain

B. They are hypothetical model calculations, not measured specifications of a named receiver

C. They prove every real noise process is Gaussian

D. They certify every analyzer with the same detector label

Answer: B. The examples illustrate declared assumptions and arithmetic; transferring them to equipment requires evidence that those assumptions and settings apply. Source: §8.4.3 Ten worked applications (p. 4437)

Why the selected alternative fits: They are hypothetical model calculations, not measured specifications of a named receiver.

Distinguishing consideration: compare this with option A, “They replace calibration of the installed chain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-MCQ-100. What is the central acceptance question for a swept measurement?

A. Does the averaged trace have sufficiently small visible variation?

B. Do maximum span and minimum RBW alone meet the target requirement?

C. Does a successful internal alignment cover all external-chain behavior?

D. Can this configured method represent the intended signal class with demonstrated limits?

Answer: D. Acceptance links the trace to a validated measurement capability, configuration, and event class, rather than an attractive appearance or large archive. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why the selected alternative fits: Can this configured method represent the intended signal class with demonstrated limits?.

Distinguishing consideration: compare this with option A, “Does the averaged trace have sufficiently small visible variation?”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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Fill-in-the-Blank Questions

V011-C08-FIB-001. In the conventional swept architecture, successive input frequencies pass through a narrow _____ filter.

Answer: resolution. The moving local oscillator presents successive frequencies to the resolution filter; the display is built sequentially. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

Why this term is required: “resolution” completes the stated technical proposition.

Question context: In the conventional swept architecture, successive input frequencies pass through a narrow _____ filter

Basis and qualification: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

Review: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

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V011-C08-FIB-002. A continuously swept frequency axis has an associated _____ axis even when it is not shown on the display.

Answer: time. Each trace location is observed at a different time, which matters for changing signals. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why this term is required: “time” completes the stated technical proposition.

Question context: A continuously swept frequency axis has an associated _____ axis even when it is not shown on the display

Basis and qualification: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-FIB-003. To distinguish a stepped trace from a swept or FFT-assisted trace, retain the selected acquisition _____.

Answer: mode. Modern instruments can support several architectures whose limitations differ. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

Why this term is required: “mode” completes the stated technical proposition.

Question context: To distinguish a stepped trace from a swept or FFT-assisted trace, retain the selected acquisition _____

Basis and qualification: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

Review: Chapter 8 — Swept Architecture and Frequency-Time Mapping.

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V011-C08-FIB-004. The nominal width alone does not specify a filter's skirts; the chapter also requires attention to its _____ factor.

Answer: shape. The shape factor describes selectivity beyond one nominal bandwidth value. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

Why this term is required: “shape” completes the stated technical proposition.

Question context: The nominal width alone does not specify a filter's skirts; the chapter also requires attention to its _____ factor

Basis and qualification: Chapter 8 — Resolution Bandwidth and Selectivity.

Review: Chapter 8 — Resolution Bandwidth and Selectivity.

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V011-C08-FIB-005. For noise integration, the relevant filter width is its equivalent _____ bandwidth.

Answer: noise. Integrated flat-density noise depends on this bandwidth, which need not equal the nominal RBW label. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why this term is required: “noise” completes the stated technical proposition.

Question context: For noise integration, the relevant filter width is its equivalent _____ bandwidth

Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-006. After narrowing RBW, the time needed for a valid filter response is its _____ time.

Answer: settling. A narrow filter can improve frequency discrimination while taking longer to respond. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

Why this term is required: “settling” completes the stated technical proposition.

Question context: After narrowing RBW, the time needed for a valid filter response is its _____ time

Basis and qualification: Chapter 8 — Resolution Bandwidth and Selectivity.

Review: Chapter 8 — Resolution Bandwidth and Selectivity.

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V011-C08-FIB-007. The post-detection bandwidth commonly used to smooth a displayed trace is called _____ bandwidth.

Answer: video. Video bandwidth affects visible variation and response after detection; it does not create simultaneous coverage. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why this term is required: “video” completes the stated technical proposition.

Question context: The post-detection bandwidth commonly used to smooth a displayed trace is called _____ bandwidth

Basis and qualification: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-FIB-008. The trace process that retains the largest observed value in each bucket across repeated acquisitions is _____ hold.

Answer: max. Max hold preserves observed extrema, which can come from different events and times. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why this term is required: “max” completes the stated technical proposition.

Question context: The trace process that retains the largest observed value in each bucket across repeated acquisitions is _____ hold

Basis and qualification: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-FIB-009. A statistic intended to represent average power should not be inferred solely from the word _____ in a menu.

Answer: average. Averaging voltage magnitudes, powers, and logarithms are different operations. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

Why this term is required: “average” completes the stated technical proposition.

Question context: A statistic intended to represent average power should not be inferred solely from the word _____ in a menu

Basis and qualification: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

Review: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

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V011-C08-FIB-010. For repeat estimates of one unchanged random process, the chapter identifies _____ as the condition supporting ordinary trace averaging.

Answer: stationarity. A mixture of operating states can change the meaning of an aggregate even when many traces are included. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why this term is required: “stationarity” completes the stated technical proposition.

Question context: For repeat estimates of one unchanged random process, the chapter identifies _____ as the condition supporting ordinary trace averaging

Basis and qualification: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-FIB-011. An RMS bucket detector can precede a different averaging operation, so the record must state the processing _____.

Answer: order. The sequence determines the final statistic; an isolated RMS label is insufficient. Source: §8.4.4 Measurement consequence (p. 4440)

Why this term is required: “order” completes the stated technical proposition.

Question context: An RMS bucket detector can precede a different averaging operation, so the record must state the processing _____

Basis and qualification: Chapter 8 — Measurement consequence.

Review: Chapter 8 — Measurement consequence.

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V011-C08-FIB-012. For regulatory or other prescribed methods, the required detector's time _____ is part of the measurement.

Answer: behavior. The specified detector and temporal response should be reproduced rather than replaced by a convenient display mode. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

Why this term is required: “behavior” completes the stated technical proposition.

Question context: For regulatory or other prescribed methods, the required detector's time _____ is part of the measurement

Basis and qualification: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

Review: Chapter 8 — Video Bandwidth, Averaging, and Detector Choice.

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V011-C08-FIB-013. In Equation 16A, L_N applies the logarithm _____ averaging.

Answer: before. It averages individual log powers, unlike A_N, which logs an arithmetic power mean. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “before” completes the stated technical proposition.

Question context: In Equation 16A, applies the logarithm _____ averaging

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-014. In Equation 16A, A_N applies the logarithm _____ averaging.

Answer: after. The order preserves a linear power average before conversion to decibels. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “after” completes the stated technical proposition.

Question context: In Equation 16A, applies the logarithm _____ averaging

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-015. For positive powers, the deterministic relation L_N no greater than A_N follows from logarithm _____.

Answer: concavity. This mathematical property establishes the direction of the difference without specifying a noise distribution. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “concavity” completes the stated technical proposition.

Question context: For positive powers, the deterministic relation no greater than follows from logarithm _____

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-016. For the inequality L_N no greater than A_N for positive powers, equality holds only when all sampled powers are _____.

Answer: equal. Strict concavity makes equality depend on equal powers, not independence or sample count. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: "equal" completes the stated technical proposition.

Question context: For the inequality no greater than for positive powers, equality holds only when all sampled powers are _____

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-017. The reference power used for dBm in Equation 16A is one _____.

Answer: milliwatt. The logarithm is applied to a dimensionless ratio to this reference power. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “milliwatt” completes the stated technical proposition.

Question context: The reference power used for dBm in Equation 16A is one _____

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-018. The quadrature components in the stated circular Gaussian model have _____ mean.

Answer: zero. The specified model is zero-mean noise; a deterministic component changes the power distribution. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “zero” completes the stated technical proposition.

Question context: The quadrature components in the stated circular Gaussian model have _____ mean

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-019. The two normalized Gaussian quadratures are assumed _____ of one another.

Answer: independent. Their independence, equal variance, and zero means yield the stated exponential power model. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “independent” completes the stated technical proposition.

Question context: The two normalized Gaussian quadratures are assumed _____ of one another

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-020. The power variable is defined at a calibrated estimation _____, rather than as an uncalibrated count.

Answer: plane. Reference resistance and gain calibration connect the random variable to physical power. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “plane” completes the stated technical proposition.

Question context: The power variable is defined at a calibrated estimation _____, rather than as an uncalibrated count

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-021. The normalized instantaneous power U has an _____ distribution under the chapter's Gaussian model.

Answer: exponential. Its density on nonnegative u is exp(-u), with unit mean and variance. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “exponential” completes the stated technical proposition.

Question context: The normalized instantaneous power U has an _____ distribution under the chapter's Gaussian model

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-022. If mean power is mu, the modeled single-sample standard deviation in watts is _____.

Answer: mu. The exponential power variance is mu squared, so its standard deviation equals its mean. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “mu” completes the stated technical proposition.

Question context: If mean power is mu, the modeled single-sample standard deviation in watts is _____

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-023. The expectation of the logarithmic average contains Euler's constant, conventionally denoted _____.

Answer: gamma. The integral of exp(-u) times ln(u) is minus gamma, producing the expected log offset. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “gamma” completes the stated technical proposition.

Question context: The expectation of the logarithmic average contains Euler's constant, conventionally denoted _____

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-024. To four decimal places, the specified mean log-power under-response is _____ dB.

Answer: 2.5068. The value is 10 times Euler's constant divided by ln(10); it is tied to the stipulated exponential model. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “2.5068” completes the stated technical proposition.

Question context: To four decimal places, the specified mean log-power under-response is _____ dB

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-025. Identical marginal distributions suffice for the expectation of L_N; _____ is not required for that expectation.

Answer: independence. Expectation is linear even when samples are dependent, although the simple variance reductions change. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “independence” completes the stated technical proposition.

Question context: Identical marginal distributions suffice for the expectation of _____ is not required for that expectation

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-026. An unbiased estimate in decibel expectation need not remain unbiased after conversion back to _____.

Answer: watts. Exponentiation is nonlinear, so unbiasedness does not automatically survive the transformation. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “watts” completes the stated technical proposition.

Question context: An unbiased estimate in decibel expectation need not remain unbiased after conversion back to _____

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-027. The corrected expected log level is not, merely by being corrected, an upper confidence _____.

Answer: bound. A bias correction and a confidence statement answer different statistical questions. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “bound” completes the stated technical proposition.

Question context: The corrected expected log level is not, merely by being corrected, an upper confidence _____

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-028. A _____ envelope caused by receiver overload is one example that invalidates the stipulated exponential-noise distribution.

Answer: clipped. Clipping changes the sample distribution and the resulting logarithmic moments. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “clipped” completes the stated technical proposition.

Question context: A _____ envelope caused by receiver overload is one example that invalidates the stipulated exponential-noise distribution

Basis and qualification: Chapter 8 — A stated statistical model.

Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-029. The sum of N independent, identically distributed exponential powers with a common positive mean has a _____ distribution.

Answer: gamma. The common scale and independence are needed for the finite-record gamma-sum derivation. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “gamma” completes the stated technical proposition.

Question context: The sum of N independent, identically distributed exponential powers with a common positive mean has a _____ distribution

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-030. In Equation 16C, the harmonic sum stops at index _____.

Answer: N minus 1. The expectation uses H_{N-1} minus gamma and ln(N), with H_0 defined as zero. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: "N minus 1" completes the stated technical proposition.

Question context: In Equation 16C, the harmonic sum stops at index _____

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-031. For N = 1, the finite-record formula and the single-sample logarithmic formula _____.

Answer: agree. A one-sample power mean and its individual log reading are the same statistic. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “agree” completes the stated technical proposition.

Question context: For N = 1, the finite-record formula and the single-sample logarithmic formula _____

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-032. The arithmetic power mean is unbiased in watts, but its logarithm has finite-record _____.

Answer: bias. Nonlinear conversion creates a negative expected offset for the stated finite independent sample model. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “bias” completes the stated technical proposition.

Question context: The arithmetic power mean is unbiased in watts, but its logarithm has finite-record _____

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-033. For four independent, identically distributed exponential powers with a common positive mean, logging their arithmetic mean gives an expected level about _____ dB below the true mean-power level.

Answer: 0.56535. Equation 16C applies to the stated common-scale gamma sum; it differs from averaging individual logarithms. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “0.56535” completes the stated technical proposition.

Question context: For four independent, identically distributed exponential powers with a common positive mean, logging their arithmetic mean gives an expected level about _____ dB below the true mean-power level

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-034. For 100 independent, identically distributed exponential powers with a common positive mean averaged before logging, the finite-log correction is about _____ dB upward.

Answer: 0.021751. The gamma-mean bias is negative and small at this independent sample count. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “0.021751” completes the stated technical proposition.

Question context: For 100 independent, identically distributed exponential powers with a common positive mean averaged before logging, the finite-log correction is about _____ dB upward

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-035. For independent, identically distributed exponential powers with a common positive mean, the relative standard deviation of their arithmetic mean scales as the inverse _____ root of N.

Answer: square. Variance of the independent sum yields relative standard deviation $\frac{1}{\sqrt{N}}$. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “square” completes the stated technical proposition.

Question context: For independent, identically distributed exponential powers with a common positive mean, the relative standard deviation of their arithmetic mean scales as the inverse _____ root of N

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-036. For 25 independent, identically distributed exponential powers with a common positive mean, the relative standard deviation of their arithmetic mean is _____.

Answer: 0.2. Under these marginals and independence, $\frac{1}{\sqrt{25}}$ = 0.2. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “0.2” completes the stated technical proposition.

Question context: For 25 independent, identically distributed exponential powers with a common positive mean, the relative standard deviation of their arithmetic mean is _____

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-037. For the same independent, identically distributed exponential-power model, halving the relative standard deviation of the mean requires _____ times as many independent samples.

Answer: four. The inverse-square-root relation makes a factor-of-two scatter reduction require a factor of four in N. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “four” completes the stated technical proposition.

Question context: For the same independent, identically distributed exponential-power model, halving the relative standard deviation of the mean requires _____ times as many independent samples

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-038. The count needed by the gamma formula is not automatically the count of saved display _____.

Answer: pixels. Storage and display elements can be correlated or derive from a different estimator. Source: §8.4.2 Power averaging before the logarithm (p. 4434)
Why this term is required: “pixels” completes the stated technical proposition.
Question context: The count needed by the gamma formula is not automatically the count of saved display _____
Basis and qualification: Chapter 8 — Power averaging before the logarithm.
Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-039. The covariance illustration uses rho to represent common pairwise _____.

Answer: correlation. It changes the variance of the power mean even when marginal variances are unchanged. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “correlation” completes the stated technical proposition.

Question context: The covariance illustration uses rho to represent common pairwise _____

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-040. For perfect copies, rho equals _____ in the chapter's covariance illustration.

Answer: one. All samples move together, so averaging them adds no independent information. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “one” completes the stated technical proposition.

Question context: For perfect copies, rho equals _____ in the chapter's covariance illustration

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-041. For four equal-mean exponential power samples with common pairwise power correlation 0.25, the relative variance of their arithmetic mean is _____.

Answer: 0.4375. The covariance calculation gives (1 + 3 times 0.25)/4 = 0.4375; its square root is relative standard deviation. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “0.4375” completes the stated technical proposition.

Question context: For four equal-mean exponential power samples with common pairwise power correlation 0.25, the relative variance of their arithmetic mean is ____

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-042. Overlapping records require a dependence analysis before they are counted as _____ samples.

Answer: independent. The number of records alone cannot justify the independent gamma model or its variance law. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

Why this term is required: “independent” completes the stated technical proposition.

Question context: Overlapping records require a dependence analysis before they are counted as _____ samples

Basis and qualification: Chapter 8 — Power averaging before the logarithm.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-FIB-043. An average can show less random fluctuation without removing its systematic _____.

Answer: bias. Repeatability and expected accuracy are separate properties of an estimator. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “bias” completes the stated technical proposition.

Question context: An average can show less random fluctuation without removing its systematic _____

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-044. First-order propagation of a concentrated power mean into decibels is a _____ approximation.

Answer: local. It should not be described as an exact confidence interval for arbitrary distributions. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “local” completes the stated technical proposition.

Question context: First-order propagation of a concentrated power mean into decibels is a _____ approximation

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-045. The chapter's unchanged white-noise bandwidth law uses ten times the base-ten _____ of the bandwidth ratio.

Answer: logarithm. Integrated white-noise power is proportional to positive equivalent noise bandwidth. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: “logarithm” completes the stated technical proposition.

Question context: The chapter's unchanged white-noise bandwidth law uses ten times the base-ten _____ of the bandwidth ratio

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-046. Changing equivalent bandwidth from 10 kHz to 1 kHz produces a modeled noise change of _____ dB with compatible processing.

Answer: minus 10. The ratio is 0.1, whose ten-times logarithm is minus 10 dB.

Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: “minus 10” completes the stated technical proposition.

Question context: Changing equivalent bandwidth from 10 kHz to 1 kHz produces a modeled noise change of _____ dB with compatible processing

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-047. Changing equivalent bandwidth from 1 kHz to 2 kHz produces a modeled increase of approximately _____ dB.

Answer: 3.0103. The bandwidth doubles; 10 log10(2) is approximately 3.0103 dB.

Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: "3.0103" completes the stated technical proposition.

Question context: Changing equivalent bandwidth from 1 kHz to 2 kHz produces a modeled increase of approximately _____ dB

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-048. A flat density of minus 170 dBm per hertz integrated over 100 kHz gives mean power of _____ dBm before estimator bias.

Answer: minus 120. A 100000 Hz equivalent bandwidth contributes 50 dB to the density level. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: “minus 120” completes the stated technical proposition.

Question context: A flat density of minus 170 dBm per hertz integrated over 100 kHz gives mean power of _____ dBm before estimator bias

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-049. If a 1 kHz nominal filter has 1128 Hz noise bandwidth, normalization using 1000 Hz alone introduces about _____ dB of density error.

Answer: 0.5231. The difference is 10 $\log_{10}(\frac{1128}{1000})$; the example's stated noise bandwidth is not a universal factor. Source: §8.4.3 Ten worked applications (p. 4437)
Why this term is required: “0.5231” completes the stated technical proposition.
Question context: If a 1 kHz nominal filter has 1128 Hz noise bandwidth, normalization using 1000 Hz alone introduces about _____ dB of density error
Basis and qualification: Chapter 8 — Ten worked applications.
Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-050. The identical log offset cancels from a bandwidth difference only while the input and processing assumptions remain _____.

Answer: valid. A change in distribution, detector order, or correction can prevent the supposed common bias from canceling. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “valid” completes the stated technical proposition.

Question context: The identical log offset cancels from a bandwidth difference only while the input and processing assumptions remain _____

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-051. The chapter's power subtraction example first converts compatible readings to _____ units.

Answer: linear power. Subtracting dBm levels gives a logarithmic ratio rather than the desired residual power. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “linear power” completes the stated technical proposition.

Question context: The chapter's power subtraction example first converts compatible readings to _____ units

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-052. If independent Gaussian contributions each have mean power 0.1 nW, their total mean power is _____ nW.

Answer: 0.2. Under the stated independent zero-mean model, the mean powers add at the same plane and bandwidth. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “0.2” completes the stated technical proposition.

Question context: If independent Gaussian contributions each have mean power 0.1 nW, their total mean power is _____ nW

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-053. Subtracting nearly equal total and background estimates is described as ill-_____.

Answer: conditioned. Small errors in either input can be large relative to the small residual. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “conditioned” completes the stated technical proposition.

Question context: Subtracting nearly equal total and background estimates is described as ill-_____

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-054. The simple background example excludes _____ tones because phase-dependent cross terms can matter.

Answer: coherent. The stated independent Gaussian-power subtraction is not a general coherent-voltage subtraction rule. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “coherent” completes the stated technical proposition.

Question context: The simple background example excludes _____ tones because phase-dependent cross terms can matter

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-055. For a mixture with conditional exponential-power means 1 mW in 90 percent of records and 100 mW in 10 percent, the overall arithmetic mean has level approximately _____ dBm.

Answer: 10.3743. The weighted linear mean is 10.9 mW; converting that mean to decibels gives about 10.3743 dBm. Source: §8.4.3 Ten worked applications (p. 4437)
Why this term is required: “10.3743” completes the stated technical proposition.
Question context: For a mixture with conditional exponential-power means 1 mW in 90 percent of records and 100 mW in 10 percent, the overall arithmetic mean has level approximately _____ dBm
Basis and qualification: Chapter 8 — Ten worked applications.
Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-056. For conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent, adding the single-state log offset to the overall expected log average gives _____ dBm.

Answer: 2. Conditional expected log levels yield 0.9 times 0 plus 0.1 times 20 after correction, which differs from the log of the overall power mean. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “2” completes the stated technical proposition.

Question context: For conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent, adding the single-state log offset to the overall expected log average gives _____ dBm

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-057. When noise states change, retain state-resolved results and their _____.

Answer: durations. Weights and state changes matter to the aggregate mean and must not be hidden by one constant correction. Source: §8.4.3 Ten worked applications (p. 4437)

Why this term is required: “durations” completes the stated technical proposition.

Question context: When noise states change, retain state-resolved results and their _____

Basis and qualification: Chapter 8 — Ten worked applications.

Review: Chapter 8 — Ten worked applications.

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V011-C08-FIB-058. A source with unequal density across frequency is _____ noise for purposes of the simple flat-density bandwidth assumption.

Answer: nonwhite. Its integrated power requires attention to the actual density and filter weighting. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why this term is required: “nonwhite” completes the stated technical proposition.

Question context: A source with unequal density across frequency is _____ noise for purposes of the simple flat-density bandwidth assumption

Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-059. For a modulated signal wider than RBW, a single marker generally cannot replace a defined channel-power _____ over the occupied band.

Answer: integration. The intended total requires an interval, weighting, detector statistic, and calibration. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why this term is required: “integration” completes the stated technical proposition.

Question context: For a modulated signal wider than RBW, a single marker generally cannot replace a defined channel-power _____ over the occupied band

Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-060. The integration limits for a channel-power result define its frequency _____.

Answer: interval. Total-power interpretation requires a declared band together with weighting, detector statistic, and calibration. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why this term is required: “interval” completes the stated technical proposition.

Question context: The integration limits for a channel-power result define its frequency _____

Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-061. To isolate a bandwidth effect, preserve input and receiver state while changing _____ bandwidth parameter at a time.

Answer: one. This controlled comparison separates the bandwidth change from concurrent source or gain changes. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why this term is required: “one” completes the stated technical proposition.

Question context: To isolate a bandwidth effect, preserve input and receiver state while changing _____ bandwidth parameter at a time

Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-062. If both source state and bandwidth are changed in one comparison, the observed level difference has _____ possible causes that the test has not separated.

Answer: multiple. A controlled bandwidth comparison preserves input and receiver state; source/environment challenges then test another cause. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why this term is required: “multiple” completes the stated technical proposition.

Question context: If both source state and bandwidth are changed in one comparison, the observed level difference has _____ possible causes that the test has not separated

Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-063. When the bandwidth-ratio prediction fails, the discrepancy first calls for examining the model's _____.

Answer: assumptions. It does not by itself prove a specific interferer or hardware fault. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

Why this term is required: “assumptions” completes the stated technical proposition.

Question context: When the bandwidth-ratio prediction fails, the discrepancy first calls for examining the model's _____

Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-064. A too-fast sweep can lower or _____ a narrow displayed component.

Answer: broaden. The response may not settle while the analyzer moves through the component. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why this term is required: “broaden” completes the stated technical proposition.

Question context: A too-fast sweep can lower or _____ a narrow displayed component

Basis and qualification: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-FIB-065. A too-slow sweep can make a trace vulnerable to _____.

Answer: drift. The source and receiver can change while different frequency locations are observed. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why this term is required: “drift” completes the stated technical proposition.

Question context: A too-slow sweep can make a trace vulnerable to _____

Basis and qualification: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-FIB-066. In a stepped implementation, exclude tuning and _____ intervals from usable observation time.

Answer: settling. Commanded dwell includes time during which the channel response may be invalid. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why this term is required: “settling” completes the stated technical proposition.

Question context: In a stepped implementation, exclude tuning and _____ intervals from usable observation time

Basis and qualification: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-FIB-067. For a continuously swept implementation, validate the relationship among sweep rate, filter response, and amplitude _____.

Answer: error. A qualitative timing trend does not establish a numerical acceptance limit for the actual instrument. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why this term is required: “error” completes the stated technical proposition.

Question context: For a continuously swept implementation, validate the relationship among sweep rate, filter response, and amplitude _____

Basis and qualification: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-FIB-068. Equation 15 states sweep time proportional to span divided by RBW _____.

Answer: squared. The relation is conditional and qualitative unless an instrument-specific numerical model is validated. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: "squared" completes the stated technical proposition.

Question context: Equation 15 states sweep time proportional to span divided by RBW _____

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-069. If span triples at fixed RBW within the same validated regime, the sweep-time scale changes by a factor of _____.

Answer: three. The stated proportionality is linear in span under unchanged applicable conditions. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: “three” completes the stated technical proposition.

Question context: If span triples at fixed RBW within the same validated regime, the sweep-time scale changes by a factor of _____

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-070. If RBW doubles at fixed span within that regime, the sweep-time scale becomes _____ of its earlier value.

Answer: one quarter. The squared bandwidth in the denominator gives a factor of four reduction in the scale. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: “one quarter” completes the stated technical proposition.

Question context: If RBW doubles at fixed span within that regime, the sweep-time scale becomes _____ of its earlier value

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-071. The omitted proportionality in the sweep-time trend depends in part on filter and instrument _____.

Answer: design. Without this factor and an acceptance criterion, the trend cannot supply an absolute number of seconds. Source: §8.11 Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4450)

Why this term is required: “design” completes the stated technical proposition.

Question context: The omitted proportionality in the sweep-time trend depends in part on filter and instrument _____

Basis and qualification: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-072. A trigger aligns acquisition to a selected event _____, but does not necessarily align the event's internal waveform.

Answer: edge. Internal modulation or startup can vary despite consistent edge triggering. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “edge” completes the stated technical proposition.

Question context: A trigger aligns acquisition to a selected event _____, but does not necessarily align the event's internal waveform

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-073. The interval between the trigger and the chosen observation is affected by trigger _____.

Answer: delay. The delay must be recorded to determine which portion of the event was measured. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
Why this term is required: “delay” completes the stated technical proposition.
Question context: The interval between the trigger and the chosen observation is affected by trigger _____
Basis and qualification: Chapter 8 — Sweep Time, Triggering, and Transient Signals.
Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-FIB-074. Random variation in trigger timing is called trigger _____.

Answer: jitter. It can move the measurement interval within the event and enter the uncertainty of a gated method. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why this term is required: “jitter” completes the stated technical proposition.

Question context: Random variation in trigger timing is called trigger _____

Basis and qualification: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-FIB-075. A gate must include a valid response interval after relevant tuning, filter, and control _____ have been excluded.

Answer: settling. Selecting an event portion does not by itself ensure the receiver response has become valid. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “settling” completes the stated technical proposition.

Question context: A gate must include a valid response interval after relevant tuning, filter, and control _____ have been excluded

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-076. Agreement of nominal repetition periods alone does not prove waveform _____.

Answer: repeatability. Amplitude, phase, modulation, and startup can differ from event to event. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “repeatability” completes the stated technical proposition.

Question context: Agreement of nominal repetition periods alone does not prove waveform _____

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-077. An AGC response during a burst can depend on the receiver's _____ state.

Answer: prior. Representative validation must include relevant initial or recovery conditions, not just a long steady tone. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “prior” completes the stated technical proposition.

Question context: An AGC response during a burst can depend on the receiver's _____ state

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-078. The burst validation should reproduce relevant turn-on behavior, duration, repetition, and frequency _____.

Answer: trajectory. The changing frequency must be compatible with the analyzer's frequency-time observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “trajectory” completes the stated technical proposition.

Question context: The burst validation should reproduce relevant turn-on behavior, duration, repetition, and frequency _____

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-079. When available, _____-resolved records allow examination of whether an aggregate represents repeatable behavior.

Answer: event. Individual event records reveal differences that an assembled trace can conceal. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “event” completes the stated technical proposition.

Question context: When available, _____-resolved records allow examination of whether an aggregate represents repeatable behavior

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-080. A nonrepeatable event may require real-time or _____ capture instead of a forced swept representation.

Answer: digitized. A suitable simultaneous acquisition can address transient limitations of a swept method. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

Why this term is required: “digitized” completes the stated technical proposition.

Question context: A nonrepeatable event may require real-time or _____ capture instead of a forced swept representation

Basis and qualification: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

Review: Chapter 8 — Sweep Time, Triggering, and Transient Signals.

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V011-C08-FIB-081. To contain a hopping event simultaneously, the acquisition needs sufficient _____ bandwidth.

Answer: instantaneous. A large displayed swept span does not mean the complete span was acquired at once. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why this term is required: “instantaneous” completes the stated technical proposition.

Question context: To contain a hopping event simultaneously, the acquisition needs sufficient _____ bandwidth

Basis and qualification: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-FIB-082. A no-peak result should state its validated event _____ as well as actual coverage.

Answer: class. Sensitivity and timing claims are tied to the tested kinds of signals, not every possible emission. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “class” completes the stated technical proposition.

Question context: A no-peak result should state its validated event _____ as well as actual coverage

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-083. For a negative result, count usable observation intervals rather than merely commanded sweep _____.

Answer: time. Tuning, settling, excluded intervals, and automatic changes can limit valid coverage. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “time” completes the stated technical proposition.

Question context: For a negative result, count usable observation intervals rather than merely commanded sweep _____

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-084. Unobserved or masked bands are coverage _____ that must remain in the archive.

Answer: gaps. They bound what the procedure can support and should not be silently treated as negative observations. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why this term is required: “gaps” completes the stated technical proposition.

Question context: Unobserved or masked bands are coverage _____ that must remain in the archive

Basis and qualification: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-FIB-085. The gain component enabled ahead of the analyzer can be a _____, whose state affects amplitude behavior.

Answer: preamplifier. Preamplifier state changes gain, noise, and possible overload and must be recorded. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why this term is required: “preamplifier” completes the stated technical proposition.

Question context: The gain component enabled ahead of the analyzer can be a _____, whose state affects amplitude behavior

Basis and qualification: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-FIB-086. Changing input attenuation while correcting the indication is a test of receiver _____.

Answer: linearity. Departures from the expected input-referred relationship can reveal compression or internal products. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why this term is required: “linearity” completes the stated technical proposition.

Question context: Changing input attenuation while correcting the indication is a test of receiver _____

Basis and qualification: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-FIB-087. An external cable is outside the path checked by many internal self-_____ routines.

Answer: alignment. A successful internal routine does not by itself validate the installed measurement chain. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why this term is required: “alignment” completes the stated technical proposition.

Question context: An external cable is outside the path checked by many internal self-_____ routines

Basis and qualification: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-FIB-088. A terminated input can expose _____ responses under the stated test condition.

Answer: residual. Such observations help challenge analyzer-generated responses without establishing universal site absence. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why this term is required: “residual” completes the stated technical proposition.

Question context: A terminated input can expose _____ responses under the stated test condition

Basis and qualification: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-FIB-089. Strong signals outside final RBW can still produce _____ in earlier receiver stages.

Answer: overload. Final frequency selectivity does not by itself protect all preceding stages from relevant blockers. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why this term is required: “overload” completes the stated technical proposition.

Question context: Strong signals outside final RBW can still produce _____ in earlier receiver stages

Basis and qualification: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-FIB-090. Complete-chain amplitude checks use known _____ references at several frequencies and levels.

Answer: external. External references include installed components that an internal alignment may bypass. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

Why this term is required: “external” completes the stated technical proposition.

Question context: Complete-chain amplitude checks use known _____ references at several frequencies and levels

Basis and qualification: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-FIB-091. Acceptance should reproduce the survey's span, bandwidths, detector, trigger, trace mode, and _____ state.

Answer: gain. A test in a different gain configuration may not establish the actual method's capability. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why this term is required: “gain” completes the stated technical proposition.

Question context: Acceptance should reproduce the survey's span, bandwidths, detector, trigger, trace mode, and _____ state

Basis and qualification: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-FIB-092. If the chosen method cannot reproduce the reference, the chapter calls for a different acquisition _____.

Answer: architecture. A capability failure cannot be repaired merely by relabeling or smoothing the same invalid trace. Source: §8.10 Sweep Method Acceptance (p. 4449)
Why this term is required: “architecture” completes the stated technical proposition.
Question context: If the chosen method cannot reproduce the reference, the chapter calls for a different acquisition _____
Basis and qualification: Chapter 8 — Sweep Method Acceptance.
Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-FIB-093. The archive should retain setup files and _____ data as well as images.

Answer: native. Native records preserve acquisition and processing information for later review. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why this term is required: “native” completes the stated technical proposition.

Question context: The archive should retain setup files and _____ data as well as images

Basis and qualification: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-FIB-094. Segment boundaries, averaging counts, sweep repetitions, and time _____ support reconstruction of coverage.

Answer: stamps. These records connect each frequency observation to when and how it was acquired. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why this term is required: “stamps” completes the stated technical proposition.

Question context: Segment boundaries, averaging counts, sweep repetitions, and time _____ support reconstruction of coverage

Basis and qualification: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-FIB-095. In the chirped-burst example, the apparent comb is a sweep-time portrayal _____.

Answer: artifact. It arose from fragments at different moments rather than simultaneous carriers. Source: §8.13 Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity (p. 4453)

Why this term is required: "artifact" completes the stated technical proposition.

Question context: In the chirped-burst example, the apparent comb is a sweep-time portrayal _____

Basis and qualification: Chapter 8 — Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

Review: Chapter 8 — Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-FIB-096. Max hold estimates observed per-bucket _____ across acquisitions, not a mean-power spectrum.

Answer: maxima. These extrema can originate at different times; they do not establish simultaneous coexistence. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why this term is required: “maxima” completes the stated technical proposition.

Question context: Max hold estimates observed per-bucket _____ across acquisitions, not a mean-power spectrum

Basis and qualification: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-C08-FIB-097. Before repeated bursts are used to reconstruct one event, the relevant waveform and trigger relationship require demonstrated _____.

Answer: repeatability. Period and edge alignment alone do not establish the amplitude, phase, modulation, and startup properties needed by the construction.

Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

Why this term is required: “repeatability” completes the stated technical proposition.

Question context: Before repeated bursts are used to reconstruct one event, the relevant waveform and trigger relationship require demonstrated _____

Basis and qualification: Chapter 8 — Validate transient and gated measurements with the intended waveform.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-FIB-098. A trace correction ledger should distinguish a required correction from one already _____ by the instrument.

Answer: applied. Without this history, offline processing can double-correct the statistic. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
Why this term is required: “applied” completes the stated technical proposition.
Question context: A trace correction ledger should distinguish a required correction from one already _____ by the instrument
Basis and qualification: Chapter 8 — Choose bandwidth from the quantity being estimated.
Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-FIB-099. Before transferring a hypothetical exponential-noise calculation to an actual trace, establish the trace statistic and the applicable power-sample _____.

Answer: distribution. The model does not automatically cover tones, clipping, or mixtures of changing means. Source: §8.4.1 A stated statistical model (p. 4431)
Why this term is required: “distribution” completes the stated technical proposition.
Question context: Before transferring a hypothetical exponential-noise calculation to an actual trace, establish the trace statistic and the applicable power-sample _____
Basis and qualification: Chapter 8 — A stated statistical model.
Review: Chapter 8 — A stated statistical model.

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V011-C08-FIB-100. The chapter's acceptance record links the displayed trace to controlled references, configuration, native data, and frequency-time _____.

Answer: mapping. Those elements support a reproducible interpretation of what the swept procedure actually observed. Source: §8.10 Sweep Method Acceptance (p. 4449)

Why this term is required: “mapping” completes the stated technical proposition.

Question context: The chapter's acceptance record links the displayed trace to controlled references, configuration, native data, and frequency-time _____

Basis and qualification: Chapter 8 — Sweep Method Acceptance.

Review: Chapter 8 — Sweep Method Acceptance.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C08-ESSAY-001. Develop a validation plan for a swept analyzer intended to characterize a short frequency-agile burst. Explain how you would decide whether the swept mode remains suitable.

- Opening: Present a thesis that answers this precise question: Develop a validation plan for a swept analyzer intended to characterize a short frequency-agile burst. Explain how you would decide whether the swept mode remains suitable. Identify which evidence would falsify the proposed conclusion Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Core terminology and scope: Define validation, swept, analyzer in the question's particular technical setting; explain how intended, characterize, mode differ if that distinction would change the analysis of "Develop a validation plan for a swept analyzer intended to characterize a short frequency-agile burst. Explain how you would decide whether the swept mode remains suitable" Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the event's time-frequency trajectory and the receiver's valid frequency-time intervals Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a validation plan for a swept analyzer intended to characterize a short frequency-agile burst to the claimed result, following "Validate transient and gated measurements with the intended waveform"; name the

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intermediate states and measurable outputs Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a validation plan for a swept analyzer intended to characterize a short frequency-agile burst. Compare event-resolved reference captures with the aggregate Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Swept Architecture and Frequency-Time Mapping” that resolves the question about a validation plan for a swept analyzer intended to characterize a short frequency-agile burst; derive the relevant result with units and stated validity conditions Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a validation plan for a swept analyzer intended to characterize a short frequency-agile burst. Select a capture architecture with sufficient instantaneous bandwidth if the method misses or distorts the target Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Worked application or illustrative case: Build a worked example of “a validation plan for a swept analyzer intended to characterize a short frequency-agile burst”, addressing this associated condition: Explain how you would decide whether the swept mode remains suitable. Identify the event's time-frequency trajectory and the receiver's valid

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frequency-time intervals Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a validation plan for a swept analyzer intended to characterize a short frequency-agile burst”. Using “Swept Architecture and Frequency-Time Mapping”, specify a discriminator and the result expected under each explanation Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a validation plan for a swept analyzer intended to characterize a short frequency-agile burst, including the effect of missing measurements and inconsistent operating conditions Source: §8.10 Sweep Method Acceptance (p. 4449)
- Scholarly synthesis and implications: Explain what the result about a validation plan for a swept analyzer intended to characterize a short frequency-agile burst authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Closing: Conclude by answering “Develop a validation plan for a swept analyzer intended to characterize a short frequency-agile burst. Explain how you would decide whether the swept mode remains suitable” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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V011-C08-ESSAY-002. Derive the deterministic relation between L_N and A_N and explain what it says about a record containing unequal powers.

- Opening: Define L_N as the arithmetic mean of logarithmic power readings and A_N as the logarithm of mean linear power; give a falsifiable thesis for the inequality L_N <= A_N when all P_i are strictly positive and share a reference P_ref. Distinguish this deterministic inequality from any distribution-dependent numerical offset. Source: §8.4.3 Ten worked applications (p. 4437)
- Core terminology and scope: State N (sample count), P_i (positive linear power in milliwatts at the declared reference plane), P_ref (one milliwatt), L_N (mean logarithmic power in dBm) and A_N (logarithm of arithmetic mean power in dBm). Distinguish an average of decibel readings, an RMS-power detector, a voltage-envelope mean and a video-bandwidth-smoothed display. Source: §8.4.3 Ten worked applications (p. 4437)
- Problem statement and purpose: Formulate the measurement as the comparison of two estimators derived from the same N calibrated linear-power observations. Establish which detector, trace statistic, bandwidth, time interval, input attenuation and reference plane generated P_i. Explain why a nominally identical dBm label does not establish identical estimands. Source: §8.4.3 Ten worked applications (p. 4437)
- Physical and computational context: Follow the chain from analogue input and IF filtering through sampled I/Q, power formation, calibration and averaging. For L_N apply 10 log10(P_i/P_ref) before taking the mean; for A_N average P_i first and then apply 10 log10.

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Identify where window energy, equivalent noise bandwidth, detector choice and any trace-level clipping enter. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- Assumptions, conditions and reference planes: Require finite strictly positive P_i, a common P_{ref} and comparable acquisition states. Apply strict concavity of ln to derive $L_N <= A_N$ for every realised record, with equality if and only if the sample powers are identical. State why this direction-of-inequality proof does not assume Gaussian noise, stationarity or statistical independence. Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Analytical framework: Starting from Equation 16A derive $A_N - L_N = 10 \log10[(\text{arithmetic mean of } P_i)/(\text{geometric mean of } P_i)] >= 0$ dB. Verify that the argument of the logarithm is dimensionless, and separate this exact finite-record identity from the asymptotic approximately 2.5068 dB ensemble correction for independent exponential power samples. Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Evidence and method: Preserve timestamped linear-power samples or calibrated complex I/Q, receiver gain and attenuation states, detector settings, RBW and equivalent noise bandwidth, window coefficients, averaging order, rejected samples and any logarithmic floor. State a reproducible calculation that independently reconstructs both L_N and A_N and tests their source-record consistency. Source: §8.4.3 Ten worked applications (p. 4437)
- Worked application or illustrative case: For two equal-duration samples $P_1 = 1$ mW and $P_2 = 4$ mW with $P_{ref} = 1$ mW, calculate

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L_2 = 3.010300 dBm and A_2 = 3.979400 dBm; explain the 0.969100 dB disparity using the arithmetic/geometric mean ratio. Repeat under a uniform calibration gain to show which quantities shift and which contrast remains invariant. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- Alternative explanations and failure modes: Distinguish estimator-order bias from a changing mixture of receiver states, signal intermittency, saturated or censored samples, noise-floor subtraction and vendor-specific detector algorithms. Specify controlled interventions, including a constant reference level and a recorded state change, that would discriminate two plausible explanations of an observed trace discrepancy. Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Uncertainty and evidential limits: Propagate uncertainty in the calibrated powers using sensitivity coefficients and covariance rather than treating all samples or calibration channels as independent. Distinguish aleatory noise fluctuations, shared systematic error, finite-sample uncertainty, dependence induced by overlapping FFT windows and selection bias due to threshold censoring. Explain when the logarithm is undefined for nonpositive reconstructed powers. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Scholarly synthesis and implications: Establish what the deterministic L_N <= A_N relation proves about the recorded numbers, then state separately the evidence required to attribute any gap to Gaussian-noise statistics or instrument architecture.

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Treat the often-cited 2.5 dB offset as a qualified response for specified conditions, never a universal correction for a tone, impulsive signal or arbitrary mixture. Source: §8.4.3 Ten worked applications (p. 4437)

- Closing: Present both labelled statistics L_N and A_N, their observed difference in dB, the common reference power, the detector/averaging chain and uncertainty limitations. Conclude whether the measurements support the narrower arithmetic claim; identify the decisive independent calibration or replay experiment still needed before any stronger forensic or engineering inference. Source: §8.4.3 Ten worked applications (p. 4437)

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V011-C08-ESSAY-003. Explain the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model.

- Opening: Present a thesis that answers this precise question: Explain the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model. Identify which evidence would falsify the proposed conclusion Source: §8.4.1 A stated statistical model (p. 4431)
- Core terminology and scope: Define derivation, limits, expected in the question's particular technical setting; explain how offset, noise, model differ if that distinction would change the analysis of "Explain the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model" Source: §8.4.1 A stated statistical model (p. 4431)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Begin with independent zero-mean equal-variance Gaussian quadratures and calibrated exponential power Source: §8.4.1 A stated statistical model (p. 4431)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model to the claimed result, following "Ten worked applications"; name the intermediate states and measurable outputs Source: §8.4.3 Ten worked applications (p. 4437)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model. Normalize by its mean, use the integral

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of exp(-u) ln(u) to obtain minus Euler's constant, and convert to decibels Source: §8.4.3 Ten worked applications (p. 4437)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Power averaging before the logarithm” that resolves the question about the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model; derive the relevant result with units and stated validity conditions Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model. Distinguish identical marginal distributions needed for expectation from independence needed for simple scatter reduction Source: §8.4.1 A stated statistical model (p. 4431)
- Worked application or illustrative case: Build a worked example of “the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model”, addressing this associated condition: Begin with independent zero-mean equal-variance Gaussian quadratures and calibrated exponential power. Begin with independent zero-mean equal-variance Gaussian quadratures and calibrated exponential power Source: §8.4.3 Ten worked applications (p. 4437)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model”. Using “Power averaging before the logarithm”, specify a discriminator and

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the result expected under each explanation Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model, including the effect of missing measurements and inconsistent operating conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Scholarly synthesis and implications: Explain what the result about the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.1 A stated statistical model (p. 4431)
- Closing: Conclude by answering “Explain the derivation and limits of the 2.5068 dB expected log-power offset in the chapter's noise model” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4.1 A stated statistical model (p. 4431)

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V011-C08-ESSAY-004. Compare averaging logarithms with logging averaged powers for four independent exponential samples. Account for the different corrections and the risk of applying the wrong one.

- Opening: Present a thesis that answers this precise question: Compare averaging logarithms with logging averaged powers for four independent exponential samples. Account for the different corrections and the risk of applying the wrong.... Identify which evidence would falsify the proposed conclusion Source: §8.4.3 Ten worked applications (p. 4437)
- Core terminology and scope: Define logarithms, logging, averaged in the question's particular technical setting; explain how Account, risk, wrong differ if that distinction would change the analysis of "Compare averaging logarithms with logging averaged powers for four independent exponential samples. Account for the different corrections and the risk of applying the wrong..." Source: §8.4.3 Ten worked applications (p. 4437)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define both operation orders Source: §8.4.3 Ten worked applications (p. 4437)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting averaging logarithms with logging averaged powers for four independent exponential samples to the claimed result, following "Power averaging before the logarithm"; name the intermediate states and measurable outputs Source: §8.4.2 Power averaging before the logarithm (p. 4434)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for averaging logarithms with logging averaged powers for four independent exponential samples. For the log average, retain the minus 2.5068 dB expectation Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose bandwidth from the quantity being estimated” that resolves the question about averaging logarithms with logging averaged powers for four independent exponential samples; derive the relevant result with units and stated validity conditions Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Evidence and method: Specify the native observations, control records and calculations that would resolve averaging logarithms with logging averaged powers for four independent exponential samples. For the logged four-power mean, use minus gamma minus ln(4) to obtain approximately minus 0.56535 dB Source: §8.4.3 Ten worked applications (p. 4437)
- Worked application or illustrative case: Build a worked example of “averaging logarithms with logging averaged powers for four independent exponential samples”, addressing this associated condition: Account for the different corrections and the risk of applying the wrong one. Define both operation orders Source: §8.4.2 Power averaging before the logarithm (p. 4434)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “averaging logarithms with logging averaged powers for four independent exponential samples”. Using “Choose bandwidth from the quantity being estimated”, specify a discriminator and the result expected under each explanation Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to averaging logarithms with logging averaged powers for four independent exponential samples, including the effect of missing measurements and inconsistent operating conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Scholarly synthesis and implications: Explain what the result about averaging logarithms with logging averaged powers for four independent exponential samples authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.3 Ten worked applications (p. 4437)
- Closing: Conclude by answering “Compare averaging logarithms with logging averaged powers for four independent exponential samples. Account for the different corrections and the risk of applying the wrong…” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4.3 Ten worked applications (p. 4437)

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V011-C08-ESSAY-005. Design an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted.

- Opening: Present a thesis that answers this precise question: Design an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted. Identify which evidence would falsify the proposed conclusion Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Core terminology and scope: Define Design, experiment, genuine in the question's particular technical setting; explain how integrated, display, processing differ if that distinction would change the analysis of "Design an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted" Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Hold source and receiver state fixed, characterize both equivalent noise bandwidths, retain linear-power data, and use compatible detector and averaging order Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted to the claimed result, following "Resolution, equivalent noise bandwidth and distortion of transient waveforms"; name the intermediate states and

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measurable outputs Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted. Predict 10 log10 of the bandwidth ratio for unchanged white density Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Resolution Bandwidth and Selectivity” that resolves the question about an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted; derive the relevant result with units and stated validity conditions Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted. Separate source/environment challenges from bandwidth changes Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Worked application or illustrative case: Build a worked example of “an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted”, addressing this associated condition: Hold source and receiver state fixed, characterize both equivalent noise bandwidths, retain linear-

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power.... Hold source and receiver state fixed, characterize both equivalent noise bandwidths, retain linear-power data,... Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted". Using "Resolution Bandwidth and Selectivity", specify a discriminator and the result expected under each explanation Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted, including the effect of missing measurements and inconsistent operating conditions Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Scholarly synthesis and implications: Explain what the result about an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Closing: Conclude by answering "Design an experiment to distinguish a genuine change in integrated noise from a change in display processing when RBW is adjusted" using only the demonstrated evidence; state the remaining decisive verification step Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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V011-C08-ESSAY-006. Analyze a data set in which one random power estimate has been replicated many times and compared with the same number of independent estimates.

- Opening: Present a thesis that answers this precise question: Analyze a data set in which one random power estimate has been replicated many times and compared with the same number of independent estimates. Identify which evidence would falsify the proposed conclusion Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Core terminology and scope: Define random, estimate, times in the question's particular technical setting; explain how compared, number, estimates differ if that distinction would change the analysis of "Analyze a data set in which one random power estimate has been replicated many times and compared with the same number of independent estimates" Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the independent inverse-square-root scatter relation and the stipulated common-correlation variance Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a data set in which one random power estimate has been replicated many times and compared with the same number of independent… to the claimed result, following "Ten worked applications"; name the

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intermediate states and measurable outputs Source: §8.4.3 Ten worked applications (p. 4437)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a data set in which one random power estimate has been replicated many times and compared with the same number of independent.... Perfect copies have rho = 1 and retain the original relative standard deviation; independent samples can reduce it Source: §8.4.3 Ten worked applications (p. 4437)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Power averaging before the logarithm” that resolves the question about a data set in which one random power estimate has been replicated many times and compared with the same number of independent...; derive the relevant result with units and stated validity conditions Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a data set in which one random power estimate has been replicated many times and compared with the same number of independent.... Explain why file or record count does not establish independence and why the gamma correction cannot automatically use the duplicate count Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Worked application or illustrative case: Build a worked example of “a data set in which one random power estimate has been replicated many times and compared with the same number of

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independent…", addressing this associated condition: Use the independent inverse-square-root scatter relation and the stipulated common-correlation variance. Use the independent inverse-square-root scatter relation and the stipulated common-correlation variance Source: §8.4.3 Ten worked applications (p. 4437)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "a data set in which one random power estimate has been replicated many times and compared with the same number of independent…". Using "Power averaging before the logarithm", specify a discriminator and the result expected under each explanation Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a data set in which one random power estimate has been replicated many times and compared with the same number of independent…, including the effect of missing measurements and inconsistent operating conditions Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)
- Scholarly synthesis and implications: Explain what the result about a data set in which one random power estimate has been replicated many times and compared with the same number of independent… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Closing: Conclude by answering "Analyze a data set in which one random power estimate has been replicated many times and compared with the same number of independent estimates" using

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only the demonstrated evidence; state the remaining decisive verification step Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)

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V011-C08-ESSAY-007. Explain why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single overall log correction.

- Opening: Present a thesis that answers this precise question: Explain why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single overall log correction. Identify which evidence would falsify the proposed conclusion Source: §8.4.3 Ten worked applications (p. 4437)
- Core terminology and scope: Define conditional, means, percent in the question's particular technical setting; explain how records, defeats, overall differ if that distinction would change the analysis of "Explain why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single overall log correction" Source: §8.4.3 Ten worked applications (p. 4437)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compute the weighted linear mean of 1 and 100 mW as 10.9 mW and its level as about 10.3743 dBm Source: §8.4.3 Ten worked applications (p. 4437)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single… to the claimed result, following "Power averaging before the logarithm"; name the intermediate states and measurable outputs Source: §8.4.2 Power averaging before the logarithm (p. 4434)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single.... Compute the corrected weighted log levels as 2 dBm Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Ten worked calculations and controlled counterexamples" that resolves the question about why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single...; derive the relevant result with units and stated validity conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single.... Attribute the remaining difference to operation order across changing means, not an arithmetic error in the single-state offset Source: §8.4.3 Ten worked applications (p. 4437)
- Worked application or illustrative case: Build a worked example of "why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single...", addressing this associated condition: Compute the weighted linear mean of 1 and 100 mW as 10.9 mW and its level as about 10.3743 dBm. Compute the weighted linear mean of 1 and

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100 mW as 10.9 mW and its level as about 10.3743 dBm Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single…”. Using “Ten worked calculations and controlled counterexamples”, specify a discriminator and the result expected under each explanation Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single…, including the effect of missing measurements and inconsistent operating conditions Source: §8.4.1 A stated statistical model (p. 4431)
- Scholarly synthesis and implications: Explain what the result about why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.3 Ten worked applications (p. 4437)
- Closing: Conclude by answering “Explain why a mixture with conditional exponential-power means of 1 mW in 90 percent of records and 100 mW in 10 percent defeats a single overall log correction” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §8.4.3 Ten worked applications (p. 4437)

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V011-C08-ESSAY-008. Write a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture.

- Opening: Present a thesis that answers this precise question: Write a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture. Identify which evidence would falsify the proposed conclusion Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Core terminology and scope: Define defensible, interpretation, comb in the question's particular technical setting; explain how resolves, burst, capture differ if that distinction would change the analysis of "Write a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture" Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain how successive frequency visits and repeated max hold can combine different time fragments Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture to the claimed result, following "Validate transient and gated measurements with the intended waveform"; name the intermediate states and measurable outputs Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture. Distinguish observed activity from simultaneous carriers Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Video Bandwidth, Averaging, and Detector Choice” that resolves the question about a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture; derive the relevant result with units and stated validity conditions Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture. Use event-resolved capture to support the trajectory interpretation, identify the capture's bandwidth and timing limits, and retain both records and configurations Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Worked application or illustrative case: Build a worked example of “a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture”, addressing this associated condition: Explain how successive frequency visits and repeated max hold can combine different time fragments. Explain how successive frequency visits and repeated max hold can combine

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different time fragments Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture”. Using “Video Bandwidth, Averaging, and Detector Choice”, specify a discriminator and the result expected under each explanation Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture, including the effect of missing measurements and inconsistent operating conditions Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)
- Scholarly synthesis and implications: Explain what the result about a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Closing: Conclude by answering “Write a defensible interpretation of a max-hold comb that resolves into a chirped burst in a suitable real-time capture” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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V011-C08-ESSAY-009. Develop a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient.

- Opening: Present a thesis that answers this precise question: Develop a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient. Identify which evidence would falsify the proposed conclusion Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Core terminology and scope: Define method, modulated, wider in the question's particular technical setting; explain how single, marker, insufficient differ if that distinction would change the analysis of "Develop a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient" Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Specify the measurand, integration interval, spectral weighting, appropriate power statistic, calibration plane, and source state Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient to the claimed result, following "Resolution Bandwidth and Selectivity"; name the intermediate states and measurable outputs Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient. Explain that a narrow filter samples only part of the occupied energy and a broad filter can include neighbors Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Ten worked calculations and controlled counterexamples" that resolves the question about a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient; derive the relevant result with units and stated validity conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient. Account for filter settling and compatible processing Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Worked application or illustrative case: Build a worked example of "a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient", addressing this associated condition: Specify the measurand, integration interval, spectral weighting, appropriate power statistic, calibration.... Specify the measurand, integration interval, spectral weighting, appropriate

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power statistic, calibration plane, and source... Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient”. Using “Ten worked calculations and controlled counterexamples”, specify a discriminator and the result expected under each explanation Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient, including the effect of missing measurements and inconsistent operating conditions Source: §8.10 Sweep Method Acceptance (p. 4449)
- Scholarly synthesis and implications: Explain what the result about a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Closing: Conclude by answering “Develop a channel-power method for a modulated signal wider than RBW and explain why a single marker is insufficient” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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V011-C08-ESSAY-010. Assess what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep.

- Opening: Present a thesis that answers this precise question: Assess what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep. Identify which evidence would falsify the proposed conclusion Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Core terminology and scope: Define inferred, successful, internal in the question's particular technical setting; explain how alignment, trace, sweep differ if that distinction would change the analysis of "Assess what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep" Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate the paths and failure modes each challenge probes Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep to the claimed result, following "Validate transient and gated measurements with the intended waveform"; name the intermediate states and measurable outputs Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep. Internal alignment may omit cables, antennas, filters, and environmental overload Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Sweep Time, Triggering, and Transient Signals” that resolves the question about what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep; derive the relevant result with units and stated validity conditions Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Evidence and method: Specify the native observations, control records and calculations that would resolve what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep. Explain why agreement among these tests strengthens a bounded result but does not establish all transient behavior or universal source absence Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Worked application or illustrative case: Build a worked example of “what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep”, addressing this associated condition: Separate the paths and failure modes each challenge probes. Separate the paths and

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failure modes each challenge probes Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep”. Using “Sweep Time, Triggering, and Transient Signals”, specify a discriminator and the result expected under each explanation Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep, including the effect of missing measurements and inconsistent operating conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Scholarly synthesis and implications: Explain what the result about what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Closing: Conclude by answering “Assess what can and cannot be inferred from successful internal alignment, a terminated-input trace, and an external reference sweep” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

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V011-C08-ESSAY-011. Describe how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum.

- Opening: Present a thesis that answers this precise question: Describe how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum. Identify which evidence would falsify the proposed conclusion Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Core terminology and scope: Define trigger, jitter, gate in the question's particular technical setting; explain how width, repeatability, enter differ if that distinction would change the analysis of "Describe how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum" Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Map trigger and gate to the valid response interval Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum to the claimed result, following "Sweep Time, Triggering, and Transient Signals"; name the intermediate states and measurable outputs Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum. Require enough settling within the selected portion, and examine changes in startup, amplitude, phase, and modulation across events Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Ten worked calculations and controlled counterexamples" that resolves the question about how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum; derive the relevant result with units and stated validity conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum. Explain why aligning an edge or matching repetition period is insufficient Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Worked application or illustrative case: Build a worked example of "how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum", addressing this associated condition: Map trigger and gate to the valid response interval. Map trigger and gate to the valid response interval Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum”. Using “Ten worked calculations and controlled counterexamples”, specify a discriminator and the result expected under each explanation Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum, including the effect of missing measurements and inconsistent operating conditions Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)
- Scholarly synthesis and implications: Explain what the result about how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Closing: Conclude by answering “Describe how trigger delay, jitter, gate width, and waveform repeatability enter acceptance of a repeated-burst spectrum” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-ESSAY-012. Derive the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing recommendation.

- Opening: Present a thesis that answers this precise question: Derive the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing recommendation. Identify which evidence would falsify the proposed conclusion Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Core terminology and scope: Define conditional, sweep-time, span in the question's particular technical setting; explain how absolute, timing, recommendation differ if that distinction would change the analysis of "Derive the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing recommendation" Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use proportionality to span divided by RBW squared to obtain an eightfold scale within one validated regime Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing… to the claimed result, following "Sweep-time adequacy as a dynamic measurement rather than a display preference"; name the intermediate states and

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measurable outputs Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing.... Identify the omitted filter/architecture factor and acceptance criterion Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Resolution Bandwidth and Selectivity” that resolves the question about the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing...; derive the relevant result with units and stated validity conditions Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing.... Explain that automatic or qualitative timing does not validate unusual signals, segmentation, or gating; use the instrument's validated model and a representative reference for an absolute... Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Worked application or illustrative case: Build a worked example of “the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing...”,

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addressing this associated condition: Use proportionality to span divided by RBW squared to obtain an eightfold scale within one validated regime. Use proportionality to span divided by RBW squared to obtain an eightfold scale within one validated regime Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing…”. Using “Resolution Bandwidth and Selectivity”, specify a discriminator and the result expected under each explanation Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing…, including the effect of missing measurements and inconsistent operating conditions Source: §8.10 Sweep Method Acceptance (p. 4449)
- Scholarly synthesis and implications: Explain what the result about the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Closing: Conclude by answering “Derive the conditional sweep-time change when span doubles and RBW halves, and state why this does not give an absolute timing recommendation” using only the

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demonstrated evidence; state the remaining decisive verification step Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

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V011-C08-ESSAY-013. Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals.

- Opening: Present a thesis that answers this precise question: Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals. Identify which evidence would falsify the proposed conclusion Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Core terminology and scope: Define finding, swept, included in the question's particular technical setting; explain how masked, bands, settling differ if that distinction would change the analysis of "Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals" Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the validated event class, tested level and waveform criterion, observed bands, usable durations, gain and acquisition settings, and excluded intervals Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals to the claimed result, following "Interpret a swept trace through its frequency-time trajectory"; name the intermediate states and measurable outputs Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals. Distinguish no observed qualifying event from universal absence Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Sweep Method Acceptance” that resolves the question about Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals; derive the relevant result with units and stated validity conditions Source: §8.10 Sweep Method Acceptance (p. 4449)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals. Retain unsuccessful captures and automatic state changes Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Worked application or illustrative case: Build a worked example of “Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals”, addressing this associated condition: State the validated event class, tested level and waveform criterion, observed bands, usable durations, gain.... State the validated event class, tested level and waveform criterion, observed bands, usable durations, gain... Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals”. Using “Sweep Method Acceptance”, specify a discriminator and the result expected under each explanation Source: §8.10 Sweep Method Acceptance (p. 4449)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals, including the effect of missing measurements and inconsistent operating conditions Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)
- Scholarly synthesis and implications: Explain what the result about Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Closing: Conclude by answering “Formulate a negative finding after a swept survey that observed no peak but included masked bands and settling intervals” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-ESSAY-014. Explain why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements.

- Opening: Present a thesis that answers this precise question: Explain why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements. Identify which evidence would falsify the proposed conclusion Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Core terminology and scope: Define filters, nominal, yield in the question's particular technical setting; explain how noise, transient, measurements differ if that distinction would change the analysis of "Explain why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements" Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish nominal width, equivalent noise bandwidth, passband/skirt weighting, and impulse or settling response Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements to the claimed result, following "Resolution, equivalent noise bandwidth and distortion of transient waveforms"; name the intermediate states and measurable outputs Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements. Use flat-density integration for noise and actual weighting for a varying spectrum Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Resolution Bandwidth and Selectivity” that resolves the question about why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements; derive the relevant result with units and stated validity conditions Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements. Explain nearby-tone leakage and the time needed for burst response Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Worked application or illustrative case: Build a worked example of “why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements”, addressing this associated condition: Distinguish nominal width, equivalent noise bandwidth, passband/skirt weighting, and impulse or settling.... Distinguish nominal width, equivalent noise bandwidth, passband/skirt weighting, and impulse or settling response Source:

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§8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements”. Using “Resolution Bandwidth and Selectivity”, specify a discriminator and the result expected under each explanation Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements, including the effect of missing measurements and inconsistent operating conditions Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)
- Scholarly synthesis and implications: Explain what the result about why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Closing: Conclude by answering “Explain why two filters with the same nominal RBW can yield different noise, transient, and neighboring-tone measurements” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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V011-C08-ESSAY-015. Develop an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have escaped.

- Opening: Present a thesis that answers this precise question: Develop an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have escaped. Identify which evidence would falsify the proposed conclusion Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Core terminology and scope: Define sufficient, reconstruct, segmented in the question's particular technical setting; explain how swept, intermittent, escaped differ if that distinction would change the analysis of "Develop an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have escaped" Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Problem statement and purpose: Frame the actual measurement or decision in the question. the specific operating conditions identified in the accompanying guidance Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have… to the claimed result, following "Swept analysis as a moving, state-dependent measurement aperture"; name the intermediate states and

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measurable outputs Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have.... Relate these to the event's trajectory and duration Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Ten worked calculations and controlled counterexamples” that resolves the question about an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have...; derive the relevant result with units and stated validity conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have.... Explain what remains unknowable if only a final image survives and why a later correction cannot restore unobserved data Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Worked application or illustrative case: Build a worked example of “an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have...”, addressing this associated condition: the specific operating

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conditions identified in the accompanying guidance. the specific operating conditions identified in the accompanying guidance Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have…”. Using “Ten worked calculations and controlled counterexamples”, specify a discriminator and the result expected under each explanation Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have…, including the effect of missing measurements and inconsistent operating conditions Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Scholarly synthesis and implications: Explain what the result about an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Closing: Conclude by answering “Develop an archival record sufficient to reconstruct a segmented swept measurement and evaluate whether an intermittent event could have escaped” using only the demonstrated evidence; state the remaining decisive

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verification step Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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V011-C08-ESSAY-016. Evaluate use of the chapter's independent-background subtraction procedure when total and background are almost equal.

- Opening: Present a thesis that answers this precise question: Evaluate use of the chapter's independent-background subtraction procedure when total and background are almost equal. Identify which evidence would falsify the proposed conclusion Source: §8.4.1 A stated statistical model (p. 4431)
- Core terminology and scope: Define independent-background, subtraction, procedure in the question's particular technical setting; explain how total, background, equal differ if that distinction would change the analysis of "Evaluate use of the chapter's independent-background subtraction procedure when total and background are almost equal" Source: §8.4.1 A stated statistical model (p. 4431)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Require compatible mean-power estimators at the same plane and bandwidth and justify the independent zero-mean Gaussian model Source: §8.4.1 A stated statistical model (p. 4431)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting use of the chapter's independent-background subtraction procedure when total and background are almost equal to the claimed result, following "Ten worked applications"; name the intermediate states and measurable outputs Source: §8.4.3 Ten worked applications (p. 4437)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for use of the chapter's independent-background subtraction procedure when total and background are almost equal. Convert to linear units, subtract there, and interpret a small residual with the errors of both estimates Source: §8.4.3 Ten worked applications (p. 4437)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose bandwidth from the quantity being estimated” that resolves the question about use of the chapter's independent-background subtraction procedure when total and background are almost equal; derive the relevant result with units and stated validity conditions Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Evidence and method: Specify the native observations, control records and calculations that would resolve use of the chapter's independent-background subtraction procedure when total and background are almost equal. Explain ill-conditioning, avoid treating the dB difference as residual power, and identify coherent or correlated cases outside the example Source: §8.4.1 A stated statistical model (p. 4431)
- Worked application or illustrative case: Build a worked example of “use of the chapter's independent-background subtraction procedure when total and background are almost equal”, addressing this associated condition: Require compatible mean-power estimators at the same plane and bandwidth and justify the independent.... Require compatible mean-power estimators at the

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same plane and bandwidth and justify the independent zero-mean Gaussian model Source: §8.4.3 Ten worked applications (p. 4437)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “use of the chapter's independent-background subtraction procedure when total and background are almost equal”. Using “Choose bandwidth from the quantity being estimated”, specify a discriminator and the result expected under each explanation Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to use of the chapter's independent-background subtraction procedure when total and background are almost equal, including the effect of missing measurements and inconsistent operating conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Scholarly synthesis and implications: Explain what the result about use of the chapter's independent-background subtraction procedure when total and background are almost equal authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.1 A stated statistical model (p. 4431)
- Closing: Conclude by answering “Evaluate use of the chapter's independent-background subtraction procedure when total and background are almost equal” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4.1 A stated statistical model (p. 4431)

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V011-C08-ESSAY-017. Construct a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction.

- Opening: Present a thesis that answers this precise question: Construct a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction. Identify which evidence would falsify the proposed conclusion Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Core terminology and scope: Define Construct, audit, distinguishes in the question's particular technical setting; explain how choice, video, marker differ if that distinction would change the analysis of "Construct a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction" Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Trace each operation in its actual sequence, state its input/output statistic and weighting, and preserve software/mode settings Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction to the claimed result, following "Measurement consequence"; name the intermediate states and measurable outputs Source: §8.4.4 Measurement consequence (p. 4440)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction. Resolve ambiguous RMS or average labels using the relevant implementation record Source: §8.4.4 Measurement consequence (p. 4440)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Noise averages, detector statistics, and the meaning of a decibel trace” that resolves the question about a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction; derive the relevant result with units and stated validity conditions Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction. Determine whether the log or finite-power correction applies and whether it has already been applied Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Worked application or illustrative case: Build a worked example of “a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction”, addressing this associated condition: Trace each operation in its actual sequence, state its input/output statistic and weighting, and preserve.... Trace each operation in its actual sequence, state its

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input/output statistic and weighting, and preserve... Source: §8.4.4 Measurement consequence (p. 4440)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction”. Using “Noise averages, detector statistics, and the meaning of a decibel trace”, specify a discriminator and the result expected under each explanation Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction, including the effect of missing measurements and inconsistent operating conditions Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Scholarly synthesis and implications: Explain what the result about a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Closing: Conclude by answering “Construct a measurement audit that distinguishes detector choice, video averaging, trace averaging, and final marker correction” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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V011-C08-ESSAY-018. Compare the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are documented.

- Opening: Present a thesis that answers this precise question: Compare the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are documented. Identify which evidence would falsify the proposed conclusion Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Core terminology and scope: Define evidential, trace, estimator in the question's particular technical setting; explain how acquisition, dependence, documented differ if that distinction would change the analysis of "Compare the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are documented" Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate visual scatter, mean bias, and uncertainty Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are… to the claimed result, following "Ten worked applications"; name the intermediate states and measurable outputs Source: §8.4.3 Ten worked applications (p. 4437)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are.... Use independent averaging to explain legitimate repeatability improvement, then show how correlation and log bias survive a smooth display Source: §8.4.3 Ten worked applications (p. 4437)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Ten worked calculations and controlled counterexamples" that resolves the question about the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are...; derive the relevant result with units and stated validity conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are.... Require sample provenance, distribution, stationarity, and correction history Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Worked application or illustrative case: Build a worked example of "the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are...", addressing this associated condition: Separate visual scatter, mean bias, and uncertainty. Separate visual scatter, mean bias, and uncertainty Source: §8.4.3 Ten worked applications (p. 4437)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are…”. Using “Ten worked calculations and controlled counterexamples”, specify a discriminator and the result expected under each explanation Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are…, including the effect of missing measurements and inconsistent operating conditions Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)
- Scholarly synthesis and implications: Explain what the result about the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are… authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Closing: Conclude by answering “Compare the evidential value of a smoother noise trace with that of a trace whose estimator model and acquisition dependence are documented” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

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V011-C08-ESSAY-019. Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal.

- Opening: Present a thesis that answers this precise question: Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal. Identify which evidence would falsify the proposed conclusion Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Core terminology and scope: Define challenge, burst, recovering in the question's particular technical setting; explain how preceding, strong, signal differ if that distinction would change the analysis of "Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal" Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Reproduce the preceding state, recovery interval, burst turn-on, duration, modulation, and repetition Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal to the claimed result, following "Interpret a swept trace through its frequency-time trajectory"; name the intermediate states and measurable outputs Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal. Test with the actual gain, bandwidth, detector, trigger, and gate settings Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Sweep Time, Triggering, and Transient Signals” that resolves the question about Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal; derive the relevant result with units and stated validity conditions Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal. Compare the usable response with a steady-tone check and explain why steady agreement is incomplete Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Worked application or illustrative case: Build a worked example of “Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal”, addressing this associated condition: Reproduce the preceding state, recovery interval, burst turn-on, duration, modulation, and repetition. Reproduce the preceding state, recovery interval, burst

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turn-on, duration, modulation, and repetition Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal”. Using “Sweep Time, Triggering, and Transient Signals”, specify a discriminator and the result expected under each explanation Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal, including the effect of missing measurements and inconsistent operating conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Scholarly synthesis and implications: Explain what the result about Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Closing: Conclude by answering “Prepare a reference challenge for a burst measurement in which AGC may still be recovering from a preceding strong signal” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-ESSAY-020. Explain how the chapter's constant-envelope counterexample protects against misuse of a noise correction.

- Opening: Present a thesis that answers this precise question: Explain how the chapter's constant-envelope counterexample protects against misuse of a noise correction. Identify which evidence would falsify the proposed conclusion Source: §8.4.3 Ten worked applications (p. 4437)
- Core terminology and scope: Define constant-envelope, counterexample, protects in the question's particular technical setting; explain how misuse, noise, correction differ if that distinction would change the analysis of "Explain how the chapter's constant-envelope counterexample protects against misuse of a noise correction" Source: §8.4.3 Ten worked applications (p. 4437)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Show that equal positive powers give = independent of N Source: §8.4.3 Ten worked applications (p. 4437)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how the chapter's constant-envelope counterexample protects against misuse of a noise correction to the claimed result, following "Ten worked calculations and controlled counterexamples"; name the intermediate states and measurable outputs Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how the chapter's constant-envelope counterexample protects against

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misuse of a noise correction. Applying the exponential-noise offset then overstates the tone by about 2.5068 dB Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose bandwidth from the quantity being estimated” that resolves the question about how the chapter's constant-envelope counterexample protects against misuse of a noise correction; derive the relevant result with units and stated validity conditions Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how the chapter's constant-envelope counterexample protects against misuse of a noise correction. Connect the error to an unsupported distributional assumption rather than a failure of calibration units Source: §8.4.3 Ten worked applications (p. 4437)
- Worked application or illustrative case: Build a worked example of “how the chapter's constant-envelope counterexample protects against misuse of a noise correction”, addressing this associated condition: Show that equal positive powers give = independent of N. Show that equal positive powers give = independent of N Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how the chapter's constant-envelope counterexample protects against misuse of a noise correction”. Using “Choose bandwidth from the quantity being estimated”,

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specify a discriminator and the result expected under each explanation Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how the chapter's constant-envelope counterexample protects against misuse of a noise correction, including the effect of missing measurements and inconsistent operating conditions Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)
- Scholarly synthesis and implications: Explain what the result about how the chapter's constant-envelope counterexample protects against misuse of a noise correction authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.3 Ten worked applications (p. 4437)
- Closing: Conclude by answering “Explain how the chapter's constant-envelope counterexample protects against misuse of a noise correction” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4.3 Ten worked applications (p. 4437)

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V011-C08-ESSAY-021. Propose a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted.

- Opening: Present a thesis that answers this precise question: Propose a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted. Identify which evidence would falsify the proposed conclusion Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Core terminology and scope: Define sequence, controlled, challenges in the question's particular technical setting; explain how displayed, component, attenuation differ if that distinction would change the analysis of "Propose a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted" Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the expected corrected input-referred behavior and retain attenuation, preamplifier, mixer level, reference level, and source conditions Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted to the claimed result, following "Ten worked calculations and controlled counterexamples"; name the intermediate states and measurable

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outputs Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted. Repeat controlled settings, compare terminated-input and external-reference observations, and consider compression or internal products Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Validate transient and gated measurements with the intended waveform" that resolves the question about a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted; derive the relevant result with units and stated validity conditions Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted. Explain that the challenge reveals a departure needing localization rather than proving a unique origin from one change Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)
- Worked application or illustrative case: Build a worked example of "a sequence of controlled challenges when a displayed component

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changes unexpectedly after input attenuation is adjusted", addressing this associated condition: State the expected corrected input-referred behavior and retain attenuation, preamplifier, mixer level,.... State the expected corrected input-referred behavior and retain attenuation, preamplifier, mixer level, reference... Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted". Using "Validate transient and gated measurements with the intended waveform", specify a discriminator and the result expected under each explanation Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted, including the effect of missing measurements and inconsistent operating conditions Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)
- Scholarly synthesis and implications: Explain what the result about a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

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- Closing: Conclude by answering “Propose a sequence of controlled challenges when a displayed component changes unexpectedly after input attenuation is adjusted” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

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V011-C08-ESSAY-022. Compare a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions.

- Opening: Present a thesis that answers this precise question: Compare a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions. Identify which evidence would falsify the proposed conclusion Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Core terminology and scope: Define swept, reconstruction, simultaneous in the question's particular technical setting; explain how capture, nonstationary, signal differ if that distinction would change the analysis of "Compare a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions" Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Describe successive frequency-time visits versus the instantaneous bandwidth and record of the capture Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions to the claimed result, following "Swept Architecture and Frequency-Time Mapping"; name the intermediate states and measurable

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outputs Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions. Identify which signal evolution each preserves or loses, including repeated-event assumptions for reconstruction Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Swept-spectrum observation as a sampling-design and probability problem” that resolves the question about a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions; derive the relevant result with units and stated validity conditions Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions. Match bandwidth, detector, and calibration before quantitative comparisons Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Worked application or illustrative case: Build a worked example of “a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions”, addressing this associated condition: Describe successive frequency-

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time visits versus the instantaneous bandwidth and record of the capture. Describe successive frequency-time visits versus the instantaneous bandwidth and record of the capture Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions”. Using “Swept-spectrum observation as a sampling-design and probability problem”, specify a discriminator and the result expected under each explanation Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions, including the effect of missing measurements and inconsistent operating conditions Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)
- Scholarly synthesis and implications: Explain what the result about a swept reconstruction and a simultaneous capture of the same nonstationary signal as two different measurement constructions authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Closing: Conclude by answering “Compare a swept reconstruction and a simultaneous capture of the same nonstationary signal as two

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different measurement constructions" using only the demonstrated evidence; state the remaining decisive verification step Source: §8.6

Interpret a swept trace through its frequency-time trajectory (p. 4442)

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V011-C08-ESSAY-023. Analyze how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script.

- Opening: Present a thesis that answers this precise question: Analyze how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script. Identify which evidence would falsify the proposed conclusion Source: §8.4.4 Measurement consequence (p. 4440)
- Core terminology and scope: Define noise, marker, accurate in the question's particular technical setting; explain how well-intentioned, correction, script differ if that distinction would change the analysis of "Analyze how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script" Source: §8.4.4 Measurement consequence (p. 4440)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the marker's pre-log statistic, bandwidth normalization, and correction history Source: §8.4.4 Measurement consequence (p. 4440)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script to the claimed result, following "Ten worked applications"; name the intermediate states and measurable outputs Source: §8.4.3 Ten worked applications (p. 4437)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how an already-corrected noise marker could be made less accurate by a

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well-intentioned offline correction script. Distinguish the single-log offset, finite-power-log bias, and noise-bandwidth correction Source: §8.4.3 Ten worked applications (p. 4437)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose bandwidth from the quantity being estimated” that resolves the question about how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script; derive the relevant result with units and stated validity conditions Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script. Show why applying an already included correction twice shifts the reported value Source: §8.4.4 Measurement consequence (p. 4440)
- Worked application or illustrative case: Build a worked example of “how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script”, addressing this associated condition: Identify the marker's pre-log statistic, bandwidth normalization, and correction history. Identify the marker's pre-log statistic, bandwidth normalization, and correction history Source: §8.4.3 Ten worked applications (p. 4437)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction

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script". Using "Choose bandwidth from the quantity being estimated", specify a discriminator and the result expected under each explanation Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script, including the effect of missing measurements and inconsistent operating conditions Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)
- Scholarly synthesis and implications: Explain what the result about how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.4 Measurement consequence (p. 4440)
- Closing: Conclude by answering "Analyze how an already-corrected noise marker could be made less accurate by a well-intentioned offline correction script" using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4.4 Measurement consequence (p. 4440)

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V011-C08-ESSAY-024. Explain the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement.

- Opening: Present a thesis that answers this precise question: Explain the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement. Identify which evidence would falsify the proposed conclusion Source: §8.4.4 Measurement consequence (p. 4440)
- Core terminology and scope: Define hypothetical, applications, transferring in the question's particular technical setting; explain how mathematical, model, instrument differ if that distinction would change the analysis of "Explain the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement" Source: §8.4.4 Measurement consequence (p. 4440)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish arithmetic consistency from demonstrated model applicability Source: §8.4.4 Measurement consequence (p. 4440)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement to the claimed result, following "Ten worked applications"; name the intermediate states and measurable outputs Source: §8.4.3 Ten worked applications (p. 4437)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the role of the ten hypothetical applications in transferring a mathematical

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model to an actual instrument measurement. Identify required evidence for calibrated power plane, input distribution, stationarity, independence, bandwidth, and processing sequence Source: §8.4.3 Ten worked applications (p. 4437)

- Analytical framework: Identify the equation, calibration or evidential decision test in “A stated statistical model” that resolves the question about the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement; derive the relevant result with units and stated validity conditions Source: §8.4.1 A stated statistical model (p. 4431)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement. Use examples as checks of interpretation, not as measured specifications or universal detector constants Source: §8.4.4 Measurement consequence (p. 4440)
- Worked application or illustrative case: Build a worked example of “the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement”, addressing this associated condition: Distinguish arithmetic consistency from demonstrated model applicability. Distinguish arithmetic consistency from demonstrated model applicability Source: §8.4.3 Ten worked applications (p. 4437)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the role of the ten hypothetical applications in transferring a mathematical model to an actual

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instrument measurement". Using "A stated statistical model", specify a discriminator and the result expected under each explanation Source: §8.4.1 A stated statistical model (p. 4431)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement, including the effect of missing measurements and inconsistent operating conditions Source: §8.24 Ten worked calculations and controlled counterexamples (p. 4482)
- Scholarly synthesis and implications: Explain what the result about the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.4 Measurement consequence (p. 4440)
- Closing: Conclude by answering "Explain the role of the ten hypothetical applications in transferring a mathematical model to an actual instrument measurement" using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4.4 Measurement consequence (p. 4440)

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V011-C08-ESSAY-025. Write a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge.

- Opening: Present a thesis that answers this precise question: Write a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge. Identify which evidence would falsify the proposed conclusion Source: §8.10 Sweep Method Acceptance (p. 4449)
- Core terminology and scope: Define release, swept, method in the question's particular technical setting; explain how passes, fails, burst differ if that distinction would change the analysis of "Write a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge" Source: §8.10 Sweep Method Acceptance (p. 4449)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Describe both successful and failed tests, the configuration and waveform differences, and the specific capability not established Source: §8.10 Sweep Method Acceptance (p. 4449)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge to the claimed result, following "Validate transient and gated measurements with the intended waveform"; name the intermediate states and measurable outputs Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge. Avoid allowing the continuous test to overrule transient failure Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Why a swept analyser cannot certify continuous capture of an unknown wideband pulse" that resolves the question about a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge; derive the relevant result with units and stated validity conditions Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge. Propose a suitable alternate timing or capture architecture, repeat acceptance in the survey settings, and constrain any interim findings to the event classes and usable coverage actually... Source: §8.10 Sweep Method Acceptance (p. 4449)
- Worked application or illustrative case: Build a worked example of "a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge", addressing this associated condition: Describe both successful and failed tests, the configuration and waveform differences, and the specific.... Describe both successful and failed tests, the

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configuration and waveform differences, and the specific... Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge”. Using “Why a swept analyser cannot certify continuous capture of an unknown wideband pulse”, specify a discriminator and the result expected under each explanation Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge, including the effect of missing measurements and inconsistent operating conditions Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Scholarly synthesis and implications: Explain what the result about a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.10 Sweep Method Acceptance (p. 4449)
- Closing: Conclude by answering “Write a release justification for a swept survey method that passes continuous-tone tests but fails one relevant burst challenge” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.10 Sweep Method Acceptance (p. 4449)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C08-DISCUSSION-001. A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. What evidence should the review group request before accepting that description?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. What evidence should the review group request before accepting that description?” Put this particular dispute to the panel: A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. What evidence should the review group request before accepting that description. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of smooth, instantaneous, review and group, request, description in “A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. What evidence should the review group request before accepting that description”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the

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outcome and request a specific example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Video Bandwidth, Averaging, and Detector Choice”. Discuss whether repeatable-event reconstruction is supportable or a simultaneous capture is needed Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Video Bandwidth, Averaging, and Detector Choice”. Discuss whether repeatable-event reconstruction is supportable or a simultaneous capture is needed Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require acquisition mode, timing, native records, and evidence that all displayed components coexisted Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask

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which setting or observation would discriminate between them without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. A defensible outcome may retain the trace as observations while revising the instantaneous-spectrum claim; visual smoothness alone is insufficient Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. A defensible outcome may retain the trace as observations while revising the instantaneous-spectrum claim; visual smoothness alone is insufficient Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device and What evidence should the review group request before accepting that description; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device”, addressing “What evidence should the review group request before accepting that description”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. What evidence should the review group request before accepting that description”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A colleague wants to publish a smooth max-hold trace as the instantaneous spectrum of a device. What evidence should the review group request before accepting that description”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted

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evidence from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-002. Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. How should they resolve the choice?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. How should they resolve the choice?” Put this particular dispute to the panel: Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. How should they resolve the choice. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 02. Student A, terminology and scope: Agree the operational meanings of disagree, minimum, follows and procedure, resolve, choice in “Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. How should they resolve the choice”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Compare separation, integrated noise, neighbor inclusion, and transient response Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Compare separation, integrated noise, neighbor inclusion, and transient response Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Begin with the intended quantity and signal width Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. Require a defined power integration and representative validation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts.

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Request an explicit statement of what evidence would reverse the conclusion. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. Require a defined power integration and representative validation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure and How should they resolve the choice; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure”, addressing “How should they resolve the choice”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. How should they resolve the choice”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two teams disagree because one always uses minimum RBW and the other follows a channel-power procedure. How should they resolve the choice”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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V011-C08-DISCUSSION-003. A technician proposes a universal plus 2.51 dB adjustment to every archived noise image. What would make the proposal defensible or require rejecting it?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A technician proposes a universal plus 2.51 dB adjustment to every archived noise image. What would make the proposal defensible or require rejecting it?” Put this particular dispute to the panel: A technician proposes a universal plus 2.51 dB adjustment to every archived noise image. What would make the proposal defensible or require rejecting it. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.4.4 Measurement consequence (p. 4440)

- 02. Student A, terminology and scope: Agree the operational meanings of universal, plus, adjustment and proposal, defensible, rejecting in “A technician proposes a universal plus 2.51 dB adjustment to every archived noise image. What would make the proposal defensible or require rejecting it”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.4.4 Measurement consequence (p. 4440)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A technician proposes a universal plus 2.51 dB adjustment to every archived noise image; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.3 Ten worked applications (p. 4437)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications”. Separate the specified single-exponential log model from tones, power-averaged outputs, mixtures, and already corrected markers Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.3 Ten worked applications (p. 4437)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A technician proposes a universal plus 2.51 dB adjustment to every archived noise image; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications”. Separate the specified single-exponential log model from tones, power-averaged outputs, mixtures, and already corrected markers Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.3 Ten worked applications (p. 4437)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask for pre-log statistic, distribution, correction history, and bandwidth definitions for each record Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.4.4 Measurement consequence (p. 4440)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A technician proposes a universal plus 2.51 dB adjustment to every archived noise image: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.4.4 Measurement consequence (p. 4440)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A technician proposes a universal plus 2.51 dB adjustment to every archived noise image; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A technician proposes a universal plus 2.51 dB adjustment to every archived noise image:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.4.4 Measurement consequence (p. 4440)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A technician proposes a universal plus 2.51 dB adjustment to every archived noise image, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.3 Ten worked applications (p. 4437)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A technician proposes a universal plus 2.51 dB adjustment to every archived noise image: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.4.4 Measurement consequence (p. 4440)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A technician proposes a universal plus 2.51 dB adjustment to every archived noise image. Discuss which records can be recovered and which retain irreducible uncertainty; do not invent missing metadata Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A technician proposes a universal plus 2.51 dB adjustment to every archived noise image, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.4.3 Ten worked applications (p. 4437)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A technician proposes a universal plus 2.51 dB

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adjustment to every archived noise image. Discuss which records can be recovered and which retain irreducible uncertainty; do not invent missing metadata Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A technician proposes a universal plus 2.51 dB adjustment to every archived noise image and What would make the proposal defensible or require rejecting it; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A technician proposes a universal plus 2.51 dB adjustment to every archived noise image”, addressing “What would make the proposal defensible or require rejecting it”; specify the exact measurement or evidential gap on which the

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speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.4.4 Measurement consequence (p. 4440)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A technician proposes a universal plus 2.51 dB adjustment to every archived noise image. What would make the proposal defensible or require rejecting it”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A technician proposes a universal plus 2.51 dB adjustment to every archived noise image. What would make the proposal defensible or require rejecting it”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.4.4 Measurement consequence (p. 4440)

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V011-C08-DISCUSSION-004. The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. How should it prioritize the archive for this measurement?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. How should it prioritize the archive for this measurement?” Put this particular dispute to the panel: The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. How should it prioritize the archive for this measurement. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 02. Student A, terminology and scope: Agree the operational meanings of storage, screenshots, fewer and captures, settings, archive in “The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. How should it prioritize the archive for this measurement”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The survey team has enough storage to save either many screenshots or fewer native captures with complete settings; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.4 Measurement consequence (p. 4440)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measurement consequence”. Native data and settings generally retain more measurement meaning than repeated images Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.4 Measurement consequence (p. 4440)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The survey team has enough storage to save either many screenshots or fewer native captures with complete settings; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measurement consequence”. Native data and settings generally retain more measurement meaning than repeated images Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.4 Measurement consequence (p. 4440)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Assess what each record permits a reviewer to reconstruct: timing, detector sequence, corrections, segments, and excluded intervals Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The survey team has enough storage to save either many screenshots or fewer native captures with complete settings: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The survey team has enough storage to save either many screenshots or fewer native captures with complete settings; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The survey team has enough

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storage to save either many screenshots or fewer native captures with complete settings: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The survey team has enough storage to save either many screenshots or fewer native captures with complete settings, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.4 Measurement consequence (p. 4440)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The survey team has enough storage to save either many screenshots or fewer native captures with complete settings: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. Consider practical volume and necessary images, but avoid counting stored files as independent observations or as proof of coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The survey team has enough storage to save either many screenshots or fewer native captures with complete settings, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what

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evidence would reverse the conclusion. Source: §8.4.4 Measurement consequence (p. 4440)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. Consider practical volume and necessary images, but avoid counting stored files as independent observations or as proof of coverage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The survey team has enough storage to save either many screenshots or fewer native captures with complete settings and How should it prioritize the archive for this measurement; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The survey team has enough storage to save either many screenshots or fewer native captures with complete settings”, addressing “How should it prioritize the archive for this measurement”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. How should it prioritize the archive for this measurement”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The survey team has enough storage to save either many screenshots or fewer native captures with complete settings. How should it prioritize the archive for this measurement”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.10 Sweep Method Acceptance (p. 4449)

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V011-C08-DISCUSSION-005. A customer interprets a negative max-hold trace as proof that no short transmission occurred. How should the team explain the result without discarding its valid evidence?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A customer interprets a negative max-hold trace as proof that no short transmission occurred. How should the team explain the result without discarding its valid evidence?” Put this particular dispute to the panel: A customer interprets a negative max-hold trace as proof that no short transmission occurred. How should the team explain the result without discarding its valid evidence. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of interprets, trace, proof and transmission, occurred, discarding in “A customer interprets a negative max-hold trace as proof that no short transmission occurred. How should the team explain the result without discarding its valid evidence”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A customer interprets a negative max-hold trace as proof that no short transmission occurred; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Explain possible gaps for weak, short, hopping, or out-of-band events Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A customer interprets a negative max-hold trace as proof that no short transmission occurred; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Explain possible gaps for weak, short, hopping, or out-of-band events Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the tested event class, usable observation intervals, bands, and sensitivity/timing criteria Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A customer interprets a negative max-hold trace as proof that no short transmission occurred: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A customer interprets a negative max-hold trace as proof that no short transmission occurred; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A customer interprets a negative max-hold trace as proof that no short transmission occurred: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A customer interprets a negative max-hold trace as proof that no short transmission occurred, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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A customer interprets a negative max-hold trace as proof that no short transmission occurred: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A customer interprets a negative max-hold trace as proof that no short transmission occurred. Preserve the bounded negative finding and propose a targeted next observation where the present method cannot resolve the concern Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A customer interprets a negative max-hold trace as proof that no short transmission occurred, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A customer interprets a negative max-hold trace as proof that no short transmission occurred. Preserve the bounded negative finding and propose a targeted next observation where the present method cannot resolve the concern Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A customer interprets a negative max-hold trace as proof that no short transmission occurred and How should the team explain the result without discarding its valid evidence; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A customer interprets a negative max-hold trace as proof that no short transmission occurred”, addressing “How should the team explain the result without discarding its valid evidence”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A customer interprets a negative max-hold trace as proof that no short transmission occurred. How should the team explain the result without discarding its valid evidence”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A customer interprets a negative max-hold trace as proof that no short transmission occurred. How should the team explain the result without discarding its valid evidence”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from

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an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-006. A repeatable trigger edge is available, but the burst's internal modulation changes. Should the group combine sweeps into one spectrum?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A repeatable trigger edge is available, but the burst's internal modulation changes. Should the group combine sweeps into one spectrum?” Put this particular dispute to the panel: A repeatable trigger edge is available, but the burst's internal modulation changes. Should the group combine sweeps into one spectrum. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of repeatable, edge, internal and group, combine, sweeps in “A repeatable trigger edge is available, but the burst's internal modulation changes. Should the group combine sweeps into one spectrum”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A repeatable trigger edge is available, but the burst's internal modulation changes; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Sweep Time, Triggering, and Transient Signals”. Request event-resolved records and compare phase, amplitude, startup, and modulation where relevant Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A repeatable trigger edge is available, but the burst's internal modulation changes; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.22 Periodic sweeps and the probability of observing a rare event (p. 4479)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Sweep Time, Triggering, and Transient Signals”. Request event-resolved records and compare phase, amplitude, startup, and modulation where relevant Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss which waveform features must be repeatable for the intended aggregate Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A repeatable trigger edge is available, but the burst's internal modulation changes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A repeatable trigger edge is available, but the burst's internal modulation changes; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.22 Periodic sweeps and the probability of observing a rare event (p. 4479)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A repeatable trigger edge is

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available, but the burst's internal modulation changes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A repeatable trigger edge is available, but the burst's internal modulation changes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A repeatable trigger edge is available, but the burst's internal modulation changes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A repeatable trigger edge is available, but the burst's internal modulation changes. An aggregate can document activity without representing one event; choose its label and subsequent capture method accordingly Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.22 Periodic sweeps and the probability of observing a rare event (p. 4479)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A repeatable trigger edge is available, but the burst's internal modulation changes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A repeatable trigger edge is available, but the burst's internal modulation changes. An aggregate can document activity without representing one event; choose its label and subsequent capture method accordingly Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.22 Periodic sweeps and the probability of observing a rare event (p. 4479)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A repeatable trigger edge is available, but the burst's internal modulation changes and Should the group combine sweeps into one spectrum; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A repeatable trigger edge is available, but the burst's internal modulation changes”, addressing “Should the

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group combine sweeps into one spectrum”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A repeatable trigger edge is available, but the burst's internal modulation changes. Should the group combine sweeps into one spectrum”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A repeatable trigger edge is available, but the burst's internal modulation changes. Should the group combine sweeps into one spectrum”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-007. One analyst reports excellent repeatability from 100 overlapping records. Another questions independence. What would settle the disagreement?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One analyst reports excellent repeatability from 100 overlapping records. Another questions independence. What would settle the disagreement?” Put this particular dispute to the panel: One analyst reports excellent repeatability from 100 overlapping records. Another questions independence. What would settle the disagreement. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, excellent, overlapping and questions, settle, disagreement in “One analyst reports excellent repeatability from 100 overlapping records. Another questions independence. What would settle the disagreement”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One analyst reports excellent repeatability from 100 overlapping records; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.4 Measurement consequence (p. 4440)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measurement consequence”. Examine overlap, filter correlation, and sample provenance; use the stipulated covariance example only as an illustration Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.4 Measurement consequence (p. 4440)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One analyst reports excellent repeatability from 100 overlapping records; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measurement consequence”. Examine overlap, filter correlation, and sample provenance; use the stipulated covariance example only as an illustration Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.4 Measurement consequence (p. 4440)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate the empirical scatter of the actual estimator from the independent-sample formulas Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving One analyst reports excellent repeatability from 100 overlapping records: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One analyst reports excellent repeatability from 100 overlapping records; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One analyst reports excellent repeatability from 100 overlapping records: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One analyst reports excellent repeatability from 100 overlapping records, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.4 Measurement consequence (p. 4440)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One analyst reports excellent repeatability from 100 overlapping records: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One analyst reports excellent repeatability from 100 overlapping records. Do not infer a gamma correction from count alone, and state limitations if dependence has not been characterized Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One analyst reports excellent repeatability from 100 overlapping records, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.4.4 Measurement consequence (p. 4440)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One analyst reports excellent repeatability from 100 overlapping records. Do not infer a gamma correction from count alone, and state limitations if dependence has not been characterized Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One analyst reports excellent repeatability from 100 overlapping records and Another questions independence; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One analyst reports excellent repeatability from 100 overlapping records”, addressing “Another questions independence”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One analyst reports excellent repeatability from 100 overlapping records. Another questions independence. What would settle the disagreement”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One analyst reports excellent repeatability from 100 overlapping records. Another questions independence. What would settle the disagreement”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-008. An internal alignment succeeds immediately before an unexpected field response. How much weight should that success receive in diagnosing the response?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An internal alignment succeeds immediately before an unexpected field response. How much weight should that success receive in diagnosing the response?” Put this particular dispute to the panel: An internal alignment succeeds immediately before an unexpected field response. How much weight should that success receive in diagnosing the response. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 02. Student A, terminology and scope: Agree the operational meanings of internal, alignment, immediately and unexpected, weight, success in “An internal alignment succeeds immediately before an unexpected field response. How much weight should that success receive in diagnosing the response”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An internal alignment succeeds immediately before an unexpected field response; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Validate transient and gated measurements with the intended waveform”. Discuss cable, antenna, filter, gain state, blockers, and transient behavior Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An internal alignment succeeds immediately before an unexpected field response; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Validate transient and gated measurements with the intended waveform”. Discuss cable, antenna, filter, gain state, blockers, and transient behavior Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify what the internal path actually tests and what remains external or environment-dependent Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An internal alignment succeeds immediately before an unexpected field response: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An internal alignment succeeds immediately before an unexpected field response; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An internal alignment succeeds immediately before an unexpected field response: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An internal alignment succeeds immediately before an unexpected field response, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An internal alignment succeeds immediately before an unexpected

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field response: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An internal alignment succeeds immediately before an unexpected field response. Use external references, attenuation challenges, and termination as complementary evidence rather than treating alignment as either worthless or conclusive Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An internal alignment succeeds immediately before an unexpected field response, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An internal alignment succeeds immediately before an unexpected field response. Use external references, attenuation challenges, and termination as complementary evidence rather than treating alignment as either worthless or conclusive Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An internal alignment succeeds immediately before an unexpected field response and How much weight should that success receive in diagnosing the response; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.25 A robust acceptance test for transient and stationary measurements (p. 4485)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An internal alignment succeeds immediately before an unexpected field response”, addressing “How much weight should that success receive in diagnosing the response”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An internal alignment succeeds immediately before an unexpected field response. How much weight should that success receive in diagnosing the response”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An internal alignment succeeds immediately before an unexpected field response. How much weight should that success receive in diagnosing the response”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

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V011-C08-DISCUSSION-009. A bandwidth reduction gives a smaller noise drop than predicted. The team is divided between blaming a nearby transmitter and replacing the analyzer. What sequence of evidence would improve the decision?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A bandwidth reduction gives a smaller noise drop than predicted. The team is divided between blaming a nearby transmitter and replacing the analyzer. What sequence of evidence would improve the decision?” Put this particular dispute to the panel: A bandwidth reduction gives a smaller noise drop than predicted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 02. Student A, terminology and scope: Agree the operational meanings of reduction, smaller, predicted and nearby, transmitter, replacing in “A bandwidth reduction gives a smaller noise drop than predicted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A bandwidth reduction gives a smaller noise drop than predicted; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Resolution, equivalent noise bandwidth and distortion of transient waveforms”. Discuss how each observation narrows possible causes Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A bandwidth reduction gives a smaller noise drop than predicted; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Resolution, equivalent noise bandwidth and distortion of transient waveforms”. Discuss how each observation narrows possible causes Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Hold state fixed, verify equivalent bandwidth and processing, inspect noise color and receiver contribution, then challenge source/environment separately Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A bandwidth reduction gives a smaller noise drop than predicted: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A bandwidth reduction gives a smaller noise drop than predicted; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A bandwidth reduction gives a smaller noise drop than predicted: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A bandwidth reduction gives a smaller noise drop than predicted, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A bandwidth reduction gives a smaller noise drop than predicted: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A bandwidth reduction gives a smaller noise drop than predicted. The initial discrepancy tests a compound assumption and cannot alone choose between the proposed diagnoses Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A bandwidth reduction gives a smaller noise drop than predicted, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.20 Resolution, equivalent noise bandwidth and distortion of transient waveforms (p. 4475)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A bandwidth reduction gives a smaller noise drop than predicted. The initial discrepancy tests a compound assumption and cannot alone choose between the proposed diagnoses Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A bandwidth reduction gives a smaller noise drop than predicted and The team is divided between blaming a nearby transmitter and replacing the analyzer; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A bandwidth reduction gives a smaller noise drop than predicted”, addressing “The team is divided between blaming a nearby transmitter and replacing the analyzer”; specify the exact measurement or evidential gap on which the

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speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A bandwidth reduction gives a smaller noise drop than predicted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A bandwidth reduction gives a smaller noise drop than predicted. The team is divided between blaming a nearby transmitter and replacing the analyzer. What sequence of evidence would improve the decision”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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V011-C08-DISCUSSION-010. The field deadline favors accepting a method that occasionally misses the representative burst. What limits would a technically honest interim report need?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The field deadline favors accepting a method that occasionally misses the representative burst. What limits would a technically honest interim report need?” Put this particular dispute to the panel: The field deadline favors accepting a method that occasionally misses the representative burst. What limits would a technically honest interim report need. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of method, misses, representative and limits, technically, need in “The field deadline favors accepting a method that occasionally misses the representative burst. What limits would a technically honest interim report need”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The field deadline favors accepting a method that occasionally misses the representative burst; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Sweep Method Acceptance”. Discuss a different architecture or timing strategy and its validation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The field deadline favors accepting a method that occasionally misses the representative burst; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Sweep Method Acceptance”. Discuss a different architecture or timing strategy and its validation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the missed event class and conditions, retain unsuccessful tests, and restrict findings to demonstrated capability and actual coverage Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The field deadline favors accepting a method that occasionally misses the representative burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The field deadline favors accepting a method that occasionally misses the representative burst; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The field deadline favors accepting a method that occasionally misses the representative burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The field deadline favors accepting a method that occasionally misses the representative burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The field deadline favors accepting a method that occasionally

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misses the representative burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The field deadline favors accepting a method that occasionally misses the representative burst. Do not turn schedule pressure into an unsupported universal negative statement Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The field deadline favors accepting a method that occasionally misses the representative burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The field deadline favors accepting a method that occasionally misses the representative burst. Do not turn schedule pressure into an unsupported universal negative statement Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The field deadline favors accepting a method that occasionally misses the representative burst and What limits would a technically honest interim report need; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The field deadline favors accepting a

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method that occasionally misses the representative burst", addressing "What limits would a technically honest interim report need"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "The field deadline favors accepting a method that occasionally misses the representative burst. What limits would a technically honest interim report need", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "The field deadline favors accepting a method that occasionally misses the representative burst. What limits would a technically honest interim report need". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-011. A vendor labels an output RMS while documentation also mentions logarithmic video averaging. How should the team document its uncertainty until the sequence is resolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A vendor labels an output RMS while documentation also mentions logarithmic video averaging. How should the team document its uncertainty until the sequence is resolved?” Put this particular dispute to the panel: A vendor labels an output RMS while documentation also mentions logarithmic video averaging. How should the team document its uncertainty until the sequence is resolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.4.4 Measurement consequence (p. 4440)

- 02. Student A, terminology and scope: Agree the operational meanings of labels, documentation, logarithmic and video, document, resolved in “A vendor labels an output RMS while documentation also mentions logarithmic video averaging. How should the team document its uncertainty until the sequence is resolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially

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change the outcome and request a specific example from the stated receiver scenario. Source: §8.4.4 Measurement consequence (p. 4440)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A vendor labels an output RMS while documentation also mentions logarithmic video averaging; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Noise averages, detector statistics, and the meaning of a decibel trace”. Preserve native outputs, settings, and version information; avoid assuming the RMS label determines the final mean-power statistic Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A vendor labels an output RMS while documentation also mentions logarithmic video averaging; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.21 Detector laws, video filtering and the asymmetry of logarithmic statistics (p. 4477)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Noise averages, detector statistics, and the meaning of a decibel trace”. Preserve native outputs, settings, and version information; avoid assuming the RMS label determines the final mean-power statistic Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. List the unresolved stages and the interpretations they would support Put two specific questions to Student D about the stated competing options and the

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instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.4.4 Measurement consequence (p. 4440)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A vendor labels an output RMS while documentation also mentions logarithmic video averaging: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.4.4 Measurement consequence (p. 4440)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A vendor labels an output RMS while documentation also mentions logarithmic video averaging; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.21 Detector laws, video filtering and the asymmetry of logarithmic statistics (p. 4477)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A vendor labels an output RMS while documentation also mentions logarithmic video averaging: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.4.4 Measurement consequence (p. 4440)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A vendor labels an output RMS while documentation also mentions logarithmic video averaging, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A vendor labels an output RMS while documentation also mentions

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logarithmic video averaging: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.4.4 Measurement consequence (p. 4440)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A vendor labels an output RMS while documentation also mentions logarithmic video averaging. Request or test the actual operation order, then apply only justified corrections and retain the original values Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.21 Detector laws, video filtering and the asymmetry of logarithmic statistics (p. 4477)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A vendor labels an output RMS while documentation also mentions logarithmic video averaging, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A vendor labels an output RMS while documentation also mentions logarithmic video averaging. Request or test the actual operation order, then apply only justified corrections and retain the original values Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.21 Detector laws, video filtering and the asymmetry of logarithmic statistics (p. 4477)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A vendor labels an output RMS while documentation also mentions logarithmic video averaging and How should the team document its uncertainty until the sequence is resolved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A vendor labels an output RMS while documentation also mentions logarithmic video averaging”, addressing “How should the team document its uncertainty until the sequence is resolved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.4.4 Measurement consequence (p. 4440)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A vendor labels an output RMS while documentation also mentions logarithmic video averaging. How should the team document its uncertainty until the sequence is resolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A vendor labels an output RMS while documentation also mentions logarithmic video averaging. How should the team document its uncertainty until the sequence is resolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.4.4 Measurement consequence (p. 4440)

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V011-C08-DISCUSSION-012. Is a larger averaging count necessarily preferable during a survey of changing operating states?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is a larger averaging count necessarily preferable during a survey of changing operating states?” Put this particular dispute to the panel: Is a larger averaging count necessarily preferable during a survey of changing operating states. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 02. Student A, terminology and scope: Agree the operational meanings of larger, count, necessarily and preferable, survey, operating in “Is a larger averaging count necessarily preferable during a survey of changing operating states”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is a larger averaging count necessarily preferable during a survey of changing operating states; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Power averaging before the logarithm”. Use state-resolved means and durations where changes matter, and distinguish repeated independent estimates from correlated or duplicated data Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is a larger averaging count necessarily preferable during a survey of changing operating states;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Power averaging before the logarithm”. Use state-resolved means and durations where changes matter, and distinguish repeated independent estimates from correlated or duplicated data Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss the trade between scatter reduction and mixing different quantities Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Is a larger averaging count necessarily preferable during a survey of changing operating states: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is a larger averaging count necessarily preferable during a survey of changing operating states; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is a larger averaging count necessarily preferable during a survey of changing operating states:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is a larger averaging count necessarily preferable during a survey of changing operating states, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is a larger averaging count necessarily preferable during a survey of changing operating states: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is a larger averaging count necessarily preferable during a survey of changing operating states. Choose the averaging interval based on stationarity and the question being answered, not the largest available count Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is a larger averaging count necessarily preferable during a survey of changing operating states, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is a larger averaging count necessarily preferable during a survey of changing operating states. Choose the averaging interval based on stationarity and the question being answered, not the largest available count Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is a larger averaging count necessarily preferable during a survey of changing operating states and Discuss the trade between scatter reduction and mixing different quantities; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is a larger averaging count necessarily preferable during a survey of changing operating states”,

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addressing “Discuss the trade between scatter reduction and mixing different quantities”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Is a larger averaging count necessarily preferable during a survey of changing operating states”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Is a larger averaging count necessarily preferable during a survey of changing operating states”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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V011-C08-DISCUSSION-013. A real-time capture contradicts a swept comb interpretation. How should the two records be presented in a review?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A real-time capture contradicts a swept comb interpretation. How should the two records be presented in a review?” Put this particular dispute to the panel: A real-time capture contradicts a swept comb interpretation. How should the two records be presented in a review. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 02. Student A, terminology and scope: Agree the operational meanings of contradicts, swept, comb and interpretation, presented, review in “A real-time capture contradicts a swept comb interpretation. How should the two records be presented in a review”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A real-time capture contradicts a swept comb interpretation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Why a swept analyser cannot certify continuous capture of an unknown wideband pulse”. Establish that the simultaneous capture had suitable bandwidth and timing for the event Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A real-time capture contradicts

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a swept comb interpretation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Why a swept analyser cannot certify continuous capture of an unknown wideband pulse”. Establish that the simultaneous capture had suitable bandwidth and timing for the event Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Preserve both configurations and explain their different frequency-time constructions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A real-time capture contradicts a swept comb interpretation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A real-time capture contradicts a swept comb interpretation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A real-time capture contradicts a swept comb interpretation: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A real-time capture contradicts a swept comb interpretation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A real-time capture contradicts a swept comb interpretation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A real-time capture contradicts a swept comb interpretation. Treat the contradiction as evidence for the tested portrayal mechanism, while avoiding claims that every comb or every swept measurement is unreliable Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A real-time capture contradicts a swept comb interpretation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A real-time capture contradicts a swept comb

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interpretation. Treat the contradiction as evidence for the tested portrayal mechanism, while avoiding claims that every comb or every swept measurement is unreliable Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.1 Fundamentals of Spectrum Analyser Operation and Laboratory Method (p. 4360)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A real-time capture contradicts a swept comb interpretation and How should the two records be presented in a review; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A real-time capture contradicts a swept comb interpretation”, addressing “How should the two records be presented in a review”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker

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before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A real-time capture contradicts a swept comb interpretation. How should the two records be presented in a review”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A real-time capture contradicts a swept comb interpretation. How should the two records be presented in a review”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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V011-C08-DISCUSSION-014. A software developer wants to hide all correction details and display only a final dBm value. What minimum provenance should the measurement team insist on?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A software developer wants to hide all correction details and display only a final dBm value. What minimum provenance should the measurement team insist on?” Put this particular dispute to the panel: A software developer wants to hide all correction details and display only a final dBm value. What minimum provenance should the measurement team insist on. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.4.4 Measurement consequence (p. 4440)

- 02. Student A, terminology and scope: Agree the operational meanings of hide, details, display and final, minimum, provenance in “A software developer wants to hide all correction details and display only a final dBm value. What minimum provenance should the measurement team insist on”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §8.4.4 Measurement consequence (p. 4440)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A software developer wants to hide all correction details and display only a final dBm value; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.3 Ten worked applications (p. 4437)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications”. Discuss a readable final result with accessible provenance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.3 Ten worked applications (p. 4437)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A software developer wants to hide all correction details and display only a final dBm value; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications”. Discuss a readable final result with accessible provenance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.3 Ten worked applications (p. 4437)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require original statistic, power plane, bandwidth, detector/averaging order, sample dependence assumptions, corrections and their order, and excluded intervals Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.4.4 Measurement consequence (p. 4440)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A software developer wants to hide all correction details and display only a final dBm value: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.4.4 Measurement consequence (p. 4440)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A software developer wants to hide all correction details and display only a final dBm value; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A software developer wants to hide all correction details and display only a final dBm value: specify

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the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.4.4 Measurement consequence (p. 4440)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A software developer wants to hide all correction details and display only a final dBm value, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.3 Ten worked applications (p. 4437)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A software developer wants to hide all correction details and display only a final dBm value: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.4.4 Measurement consequence (p. 4440)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A software developer wants to hide all correction details and display only a final dBm value. A simplified interface should not make double correction or unsupported reinterpretation impossible to detect Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A software developer wants to hide all correction details and display only a final dBm value, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.4.3 Ten worked applications (p. 4437)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A software developer wants to hide all

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correction details and display only a final dBm value. A simplified interface should not make double correction or unsupported reinterpretation impossible to detect Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A software developer wants to hide all correction details and display only a final dBm value and What minimum provenance should the measurement team insist on; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A software developer wants to hide all correction details and display only a final dBm value”, addressing “What minimum provenance should the measurement team insist on”; specify the exact measurement or evidential gap on which the

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speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.4.4 Measurement consequence (p. 4440)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A software developer wants to hide all correction details and display only a final dBm value. What minimum provenance should the measurement team insist on”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A software developer wants to hide all correction details and display only a final dBm value. What minimum provenance should the measurement team insist on”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.4.4 Measurement consequence (p. 4440)

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V011-C08-DISCUSSION-015. The only surviving evidence is a screenshot with a detector label and RBW. What can the team reasonably recover, and what should remain unresolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The only surviving evidence is a screenshot with a detector label and RBW. What can the team reasonably recover, and what should remain unresolved?” Put this particular dispute to the panel: The only surviving evidence is a screenshot with a detector label and RBW. What can the team reasonably recover, and what should remain unresolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.4.4 Measurement consequence (p. 4440)

- 02. Student A, terminology and scope: Agree the operational meanings of surviving, screenshot, label and recover, remain, unresolved in “The only surviving evidence is a screenshot with a detector label and RBW. What can the team reasonably recover, and what should remain unresolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.4.4 Measurement consequence (p. 4440)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The only surviving evidence is a screenshot with a detector label and RBW; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Avoid automatic log correction or reconstruction of unobserved events Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The only surviving evidence is a screenshot with a detector label and RBW; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Avoid automatic log correction or reconstruction of unobserved events Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Read the visible settings as evidence, but identify missing equivalent bandwidth, processing sequence, timing, gain, native data, and correction history Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.4.4 Measurement consequence (p. 4440)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The only surviving evidence is a screenshot

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with a detector label and RBW: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.4.4 Measurement consequence (p. 4440)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The only surviving evidence is a screenshot with a detector label and RBW; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The only surviving evidence is a screenshot with a detector label and RBW: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a

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rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.4.4 Measurement consequence (p. 4440)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The only surviving evidence is a screenshot with a detector label and RBW, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The only surviving evidence is a screenshot with a detector label and RBW: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.4.4 Measurement consequence (p. 4440)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The only surviving evidence is a screenshot

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with a detector label and RBW. Distinguish a descriptive record of the image from a validated power or absence claim Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The only surviving evidence is a screenshot with a detector label and RBW, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The only surviving evidence is a screenshot with a detector label and RBW. Distinguish a descriptive record of the image from a validated power or absence claim Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test

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or uncertainty term that limits confidence. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The only surviving evidence is a screenshot with a detector label and RBW and What can the team reasonably recover, and what should remain unresolved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The only surviving evidence is a screenshot with a detector label and RBW”, addressing “What can the team reasonably recover, and what should remain unresolved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.4.4 Measurement consequence (p. 4440)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The only surviving evidence is a screenshot with a detector label and RBW. What can the team reasonably recover, and what should remain unresolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The only surviving evidence is a screenshot with a detector label and RBW. What can the team reasonably recover, and what should remain unresolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.4.4 Measurement consequence (p. 4440)

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V011-C08-DISCUSSION-016. A group argues that a narrower filter must improve a weak-burst search because the display floor falls. What countervailing evidence belongs in the discussion?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A group argues that a narrower filter must improve a weak-burst search because the display floor falls. What countervailing evidence belongs in the discussion?” Put this particular dispute to the panel: A group argues that a narrower filter must improve a weak-burst search because the display floor falls. What countervailing evidence belongs in the discussion. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 02. Student A, terminology and scope: Agree the operational meanings of group, narrower, search and falls, belongs, discussion in “A group argues that a narrower filter must improve a weak-burst search because the display floor falls. What countervailing evidence belongs in the discussion”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A group argues that a narrower filter must improve a weak-burst search because the display floor falls; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Test the intended waveform in the actual configuration Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A group argues that a narrower filter must improve a weak-burst search because the display floor falls; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Test the intended waveform in the actual configuration Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine filter settling, burst duration, frequency trajectory, signal energy excluded, and detector time response Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A group argues that a narrower filter must improve a weak-burst search because the display floor falls: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A group argues that a narrower filter must improve a weak-burst search because the display floor falls; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A group argues that a narrower

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filter must improve a weak-burst search because the display floor falls: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A group argues that a narrower filter must improve a weak-burst search because the display floor falls, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A group argues that a narrower filter must improve a weak-burst search because the display floor falls: specify the altered receiver state or source condition, predicted change, test statistic and

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rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A group argues that a narrower filter must improve a weak-burst search because the display floor falls. The best choice follows demonstrated detection or measurement capability for the target class, not noise-floor appearance alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A group argues that a narrower filter must improve a weak-burst search because the display floor falls, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A group argues that a narrower filter must improve a weak-burst search because the display floor falls. The best choice follows demonstrated detection or measurement capability for the target class, not noise-floor appearance alone Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A group argues that a narrower filter must improve a weak-burst search because the display floor falls and What countervailing evidence belongs in the discussion; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.16 Additional study: swept observation as a space-time sampling experiment (p. 4461)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A group argues that a narrower filter must improve a weak-burst search because the display floor falls”, addressing “What countervailing evidence belongs in the discussion”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A group argues that a narrower filter must improve a weak-burst search because the display floor falls. What countervailing evidence belongs in the discussion”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A group argues that a narrower filter must improve a weak-burst search because the display floor falls. What countervailing evidence belongs in the discussion”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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V011-C08-DISCUSSION-017. How should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction?” Put this particular dispute to the panel: How should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of repeated, bursts, sufficiently and similar, particular, reconstruction in “How should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “8. Distinguishing a spectral estimator from a persuasive-looking display”. A nominal period match is insufficient Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.25 A robust acceptance test for transient and stationary measurements (p. 4485)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “8. Distinguishing a spectral estimator from a persuasive-looking display”. A nominal period match is insufficient Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Define which features the reconstruction relies on, then inspect event-resolved amplitude, phase, modulation, startup, timing, and prior receiver state as appropriate Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.25 A robust acceptance test for transient and stationary measurements (p. 4485)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction. Record the acceptance criterion and describe any unresolved variation rather than demanding or assuming irrelevant universal identity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.25 A robust acceptance test for transient and stationary measurements (p. 4485)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement

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accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction. Record the acceptance criterion and describe any unresolved variation rather than demanding or assuming irrelevant universal identity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.25 A robust acceptance test for transient and stationary measurements (p. 4485)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction and Define which features the reconstruction relies on, then inspect event-resolved amplitude, phase, modulation,...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and

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ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction”, addressing “Define which features the reconstruction relies on, then inspect event-resolved amplitude, phase, modulation,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a team decide whether its repeated bursts are sufficiently similar for its particular spectral reconstruction”. Allocate the next measurement

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and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-018. An analyst subtracts two dBm readings and labels the result residual background-free power. How should a peer review correct the work?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An analyst subtracts two dBm readings and labels the result residual background-free power. How should a peer review correct the work?” Put this particular dispute to the panel: An analyst subtracts two dBm readings and labels the result residual background-free power. How should a peer review correct the work. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.4.1 A stated statistical model (p. 4431)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, subtracts, readings and peer, review, work in “An analyst subtracts two dBm readings and labels the result residual background-free power. How should a peer review correct the work”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.4.1 A stated statistical model (p. 4431)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An analyst subtracts two dBm readings and labels the result residual background-free power; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.3 Ten worked applications (p. 4437)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications”. Examine near-cancellation uncertainty and coherent/correlated exceptions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.3 Ten worked applications (p. 4437)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst subtracts two dBm readings and labels the result residual background-free power;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications”. Examine near-cancellation uncertainty and coherent/correlated exceptions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.3 Ten worked applications (p. 4437)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain that the dB difference is a ratio, verify compatible mean estimators at the same plane and bandwidth, and subtract in linear units only under the stated model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.4.1 A stated statistical model (p. 4431)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An analyst subtracts two dBm readings and labels the result residual background-free power: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.4.1 A stated statistical model (p. 4431)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst subtracts two dBm readings and labels the result residual background-free power; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An analyst subtracts two dBm readings and labels the result residual background-free power: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable,

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authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.4.1 A stated statistical model (p. 4431)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An analyst subtracts two dBm readings and labels the result residual background-free power, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.3 Ten worked applications (p. 4437)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An analyst subtracts two dBm readings and labels the result residual background-free power: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.4.1 A stated statistical model (p. 4431)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An analyst subtracts two dBm readings and labels the result residual background-free power. Preserve original readings and the revised derivation rather than silently replacing them Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An analyst subtracts two dBm readings and labels the result residual background-free power, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.4.3 Ten worked applications (p. 4437)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An analyst subtracts two dBm readings and labels the result residual background-free power. Preserve original readings and the revised derivation rather than silently replacing them Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An analyst subtracts two dBm readings and labels the result residual background-free power and How should a peer review correct the work; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.4.4 Measurement consequence (p. 4440)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An analyst subtracts two dBm readings and labels the result residual background-free power”, addressing “How should a peer review correct the work”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.4.1 A stated statistical model (p. 4431)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An analyst subtracts two dBm readings and labels the result residual background-free power. How should a peer review correct the work”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An analyst subtracts two dBm readings and labels the result residual background-free power. How should a peer review correct the work”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.4.1 A stated statistical model (p. 4431)

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V011-C08-DISCUSSION-019. Two instruments produce different absolute noise levels but the same bandwidth-related change. Does agreement of the change validate either absolute level?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two instruments produce different absolute noise levels but the same bandwidth-related change. Does agreement of the change validate either absolute level?” Put this particular dispute to the panel: Two instruments produce different absolute noise levels but the same bandwidth-related change. Does agreement of the change validate either absolute level. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 02. Student A, terminology and scope: Agree the operational meanings of instruments, produce, absolute and levels, agreement, validate in “Two instruments produce different absolute noise levels but the same bandwidth-related change. Does agreement of the change validate either absolute level”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two instruments produce different absolute noise levels but the same bandwidth-related change; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.3 Ten worked applications (p. 4437)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications”. Agreement can support a conditional bandwidth trend while absolute calibration or statistics remain unresolved Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.3 Ten worked applications (p. 4437)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two instruments produce different absolute noise levels but the same bandwidth-related change; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications”. Agreement can support a conditional bandwidth trend while absolute calibration or statistics remain unresolved Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.3 Ten worked applications (p. 4437)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss cancellation of common offsets within each compatible comparison and the remaining differences in estimator, bandwidth, gain, and correction Put two specific questions to Student D about the stated competing

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options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two instruments produce different absolute noise levels but the same bandwidth-related change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two instruments produce different absolute noise levels but the same bandwidth-related change; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two instruments produce different absolute noise levels but the same bandwidth-related change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two instruments produce different absolute noise levels but the same bandwidth-related change, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.3 Ten worked applications (p. 4437)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving Two instruments produce different absolute noise levels but the same bandwidth-related change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two instruments produce different absolute noise levels but the same bandwidth-related change. Request the information needed to compare the mean-power quantities themselves Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two instruments produce different absolute noise levels but the same bandwidth-related change, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §8.4.3 Ten worked applications (p. 4437)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two instruments produce different absolute noise levels but the same bandwidth-related change. Request the information needed to compare the mean-power quantities themselves Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two instruments produce different absolute noise levels but the same bandwidth-related change and Does agreement of the change validate either absolute level; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two instruments produce different absolute noise levels but the same bandwidth-related change”, addressing “Does agreement of the change validate either absolute level”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two instruments produce different absolute noise levels but the same bandwidth-related change. Does agreement of the change validate either absolute level”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two instruments produce different absolute noise levels but the same bandwidth-related change. Does agreement of the change validate either absolute level”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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V011-C08-DISCUSSION-020. The team wants one default sweep time for every mode because Equation 15 is easy to automate. What safeguards would a technically sound implementation need?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The team wants one default sweep time for every mode because Equation 15 is easy to automate. What safeguards would a technically sound implementation need?” Put this particular dispute to the panel: The team wants one default sweep time for every mode because Equation 15 is easy to automate. What safeguards would a technically sound implementation need. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 02. Student A, terminology and scope: Agree the operational meanings of sweep, easy, technically and sound, implementation, need in “The team wants one default sweep time for every mode because Equation 15 is easy to automate. What safeguards would a technically sound implementation need”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a

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specific example from the stated receiver scenario. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The team wants one default sweep time for every mode because Equation 15 is easy to automate; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Test representative signals and retain actual usable timing Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The team wants one default sweep time for every mode because Equation 15 is easy to automate; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Test representative signals and retain actual usable timing Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Limit the scaling to validated regimes, include instrument/filter factors and acceptance criteria, and detect settings such as segmentation or gating outside that scope Put two specific questions to Student D about the stated

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competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The team wants one default sweep time for every mode because Equation 15 is easy to automate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The team wants one default sweep time for every mode because Equation 15 is easy to automate; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The team wants one default sweep time for every mode because Equation 15 is easy to automate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The team wants one default sweep time for every mode because Equation 15 is easy to automate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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The team wants one default sweep time for every mode because Equation 15 is easy to automate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The team wants one default sweep time for every mode because Equation 15 is easy to automate. The software should not manufacture an absolute timing law from a proportionality Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The team wants one default sweep time for every mode because Equation 15 is easy to automate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The team wants one default sweep time for every mode because Equation 15 is easy to automate. The software should not manufacture an absolute timing law from a proportionality Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The team wants one default sweep time for every mode because Equation 15 is easy to automate and What safeguards would a technically sound implementation need; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The team wants one default sweep time for every mode because Equation 15 is easy to automate”, addressing “What safeguards would a technically sound implementation need”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The team wants one default sweep time for every mode because Equation 15 is easy to automate. What safeguards would a technically sound implementation need”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The team wants one default sweep time for every mode because Equation 15 is easy to automate. What safeguards would a technically sound implementation need”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.5 Sweep Time, Triggering, and Transient Signals (p. 4441)

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V011-C08-DISCUSSION-021. A method passes at one attenuation setting but changes interpretation at another. Should the review accept the preferred trace and discard the other?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A method passes at one attenuation setting but changes interpretation at another. Should the review accept the preferred trace and discard the other?” Put this particular dispute to the panel: A method passes at one attenuation setting but changes interpretation at another. Should the review accept the preferred trace and discard the other. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 02. Student A, terminology and scope: Agree the operational meanings of passes, setting, review and accept, preferred, discard in “A method passes at one attenuation setting but changes interpretation at another. Should the review accept the preferred trace and discard the other”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A method passes at one attenuation setting but changes interpretation at another; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Validate transient and gated measurements with the intended waveform”. Examine compression, internal products, mixer level, and external source changes through controlled challenges Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A method passes at one attenuation setting but changes interpretation at another; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Validate transient and gated measurements with the intended waveform”. Examine compression, internal products, mixer level, and external source changes through controlled challenges Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain both states and their expected corrected relationships Put two specific questions to Student D about the stated competing options and the

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instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A method passes at one attenuation setting but changes interpretation at another: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A method passes at one attenuation setting but changes interpretation at another; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A method passes at one attenuation setting but changes interpretation at another: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A method passes at one attenuation setting but changes interpretation at another, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A method passes at one attenuation setting but changes

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interpretation at another: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A method passes at one attenuation setting but changes interpretation at another. Accept only a configuration-bound interpretation supported by the evidence; disagreement is a diagnostic observation, not a reason to delete data Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A method passes at one attenuation setting but changes interpretation at another, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A method passes at one attenuation setting but changes interpretation at another. Accept only a configuration-bound interpretation supported by the evidence; disagreement is a diagnostic observation, not a reason to delete data Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A method passes at one attenuation setting but changes interpretation at another and Should the review accept the preferred trace and discard the other; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.14 Sweep-time adequacy as a dynamic measurement rather than a display preference (p. 4454)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A method passes at one attenuation setting but changes interpretation at another”, addressing “Should the review accept the preferred trace and discard the other”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A method passes at one attenuation setting but changes interpretation at another. Should the review accept the preferred trace and discard the other”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A method passes at one attenuation setting but changes interpretation at another. Should the review accept the preferred trace and discard the other”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.9 Amplitude Accuracy and Analyzer Self-Tests (p. 4448)

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V011-C08-DISCUSSION-022. How should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run?” Put this particular dispute to the panel: How should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of survey, automatic, masked and occurred, nominally, continuous in “How should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Sweep Method Acceptance”. Discuss whether additional observation is needed Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a survey report

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describe automatic gain changes and masked intervals that occurred during a nominally continuous run; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.4.4 Measurement consequence (p. 4440)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Sweep Method Acceptance”. Discuss whether additional observation is needed Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish clock duration from valid observation, record the state transitions and excluded bands/times, and explain their effect on event coverage Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.4.4 Measurement consequence (p. 4440)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a survey report

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describe automatic gain changes and masked intervals that occurred during a nominally continuous run: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run. Avoid representing the entire run as one uninterrupted uniform-capability exposure Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.4.4 Measurement consequence (p. 4440)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run. Avoid representing the entire run as one uninterrupted uniform-capability exposure Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.4.4 Measurement consequence (p. 4440)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run and Distinguish clock duration from valid observation, record the state transitions and excluded bands/times, and…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run”, addressing “Distinguish clock duration from valid observation, record the state transitions and excluded bands/times, and…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a survey report describe automatic gain changes and masked intervals that occurred during a nominally continuous run”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence

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from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-023. A reviewer asks for a probability that any possible emission escaped the swept survey. Can the chapter's bandwidth and log-noise formulas supply it?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reviewer asks for a probability that any possible emission escaped the swept survey. Can the chapter's bandwidth and log-noise formulas supply it?” Put this particular dispute to the panel: A reviewer asks for a probability that any possible emission escaped the swept survey. Can the chapter's bandwidth and log-noise formulas supply it. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, possible, emission and escaped, swept, supply in “A reviewer asks for a probability that any possible emission escaped the swept survey. Can the chapter's bandwidth and log-noise formulas supply it”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reviewer asks for a probability that any possible emission escaped the swept survey; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Sweep Method Acceptance”. Require a defined event class, timing/coverage model, and validated acquisition behavior for any probabilistic claim Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer asks for a probability that any possible emission escaped the swept survey; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Sweep Method Acceptance”. Require a defined event class, timing/coverage model, and validated acquisition behavior for any probabilistic claim Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain that those formulas concern specific filter/noise estimators and do not supply a universal interception model Put two specific questions to Student D about the stated competing options and the instrument

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configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A reviewer asks for a probability that any possible emission escaped the swept survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer asks for a probability that any possible emission escaped the swept survey; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reviewer asks for a probability that any possible emission escaped the swept survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reviewer asks for a probability that any possible emission escaped the swept survey, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A reviewer asks for a probability that any possible emission escaped

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the swept survey: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reviewer asks for a probability that any possible emission escaped the swept survey. Offer bounded observed findings and unresolved classes rather than assigning an unsupported number Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reviewer asks for a probability that any possible emission escaped the swept survey, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reviewer asks for a probability that any possible emission escaped the swept survey. Offer bounded observed findings and unresolved classes rather than assigning an unsupported number Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reviewer asks for a probability that any possible emission escaped the swept survey and Can the chapter's bandwidth and log-noise formulas supply it; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reviewer asks for a probability that any possible emission escaped the swept survey”, addressing “Can the chapter's bandwidth and log-noise formulas supply it”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reviewer asks for a probability that any possible emission escaped the swept survey. Can the chapter's bandwidth and log-noise formulas supply it”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reviewer asks for a probability that any possible emission escaped the swept survey. Can the chapter's bandwidth and log-noise formulas supply it”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-C08-DISCUSSION-024. When is it reasonable to keep a swept method even though a simultaneous capture system is available?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When is it reasonable to keep a swept method even though a simultaneous capture system is available?” Put this particular dispute to the panel: When is it reasonable to keep a swept method even though a simultaneous capture system is available. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 02. Student A, terminology and scope: Agree the operational meanings of swept, method, though and simultaneous, capture, available in “When is it reasonable to keep a swept method even though a simultaneous capture system is available”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When is it reasonable to keep a swept method even though a simultaneous capture system is available; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. A swept method may be adequate for a demonstrated stationary or repeatable class Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When is it reasonable to keep a swept method even though a simultaneous capture system is

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available; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. A swept method may be adequate for a demonstrated stationary or repeatable class Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare the actual measurand, stationarity, required frequency range, validated sensitivity, timing, and evidence needs Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving When is it reasonable to keep a swept method even though a simultaneous capture system is available: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When is it reasonable to keep a swept method even though a simultaneous capture system is available; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When is it reasonable to keep a swept method even though a simultaneous capture system is available: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a

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repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When is it reasonable to keep a swept method even though a simultaneous capture system is available, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When is it reasonable to keep a swept method even though a simultaneous capture system is available: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When is it reasonable to keep a swept method even though a simultaneous capture system is available. Availability of another architecture does not itself invalidate it, but relevant failed challenges require a capable alternative Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When is it reasonable to keep a swept method even though a simultaneous capture system is available, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When is it reasonable to keep a swept method even though a simultaneous capture system is available. Availability of another architecture does not itself invalidate it, but relevant failed challenges require a capable alternative Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.15 Swept-spectrum observation as a sampling-design and probability problem (p. 4456)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When is it reasonable to keep a swept method even though a simultaneous capture system is available and Compare the actual measurand, stationarity, required frequency range, validated sensitivity, timing, and…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.26 Why a swept analyser cannot certify continuous capture of an unknown wideband pulse (p. 4487)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When is it reasonable to keep a swept

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method even though a simultaneous capture system is available", addressing "Compare the actual measurand, stationarity, required frequency range, validated sensitivity, timing, and…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "When is it reasonable to keep a swept method even though a simultaneous capture system is available", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "When is it reasonable to keep a swept method even though a simultaneous capture system is available". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.10 Sweep Method Acceptance (p. 4449)

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V011-C08-DISCUSSION-025. What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator?” Put this particular dispute to the panel: What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, able, completed and acceptance, package, operator in “What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Discuss native data and timestamps as supporting evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a second

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reviewer be able to determine from the completed acceptance package without speaking to the operator; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.4.4 Measurement consequence (p. 4440)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Discuss native data and timestamps as supporting evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The reviewer should reconstruct mode and settings, source/reference class, calibration plane, processing and corrections, frequency-time coverage, failures, exclusions, and the scope of each… Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.10 Sweep Method Acceptance (p. 4449)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.4.4 Measurement consequence (p. 4440)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should a second reviewer

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be able to determine from the completed acceptance package without speaking to the operator: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator. Identify remaining assumptions explicitly so that independent review does not depend on undocumented operator memory Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.4.4 Measurement consequence (p. 4440)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator. Identify remaining assumptions explicitly so that independent review does not depend on undocumented operator memory Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.4.4 Measurement consequence (p. 4440)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator and The reviewer should reconstruct mode and settings, source/reference class, calibration plane, processing and…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator”, addressing “The reviewer should reconstruct mode and settings, source/reference class, calibration plane, processing and…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.10 Sweep Method Acceptance (p. 4449)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should a second reviewer be able to determine from the completed acceptance package without speaking to the operator”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.10 Sweep Method Acceptance (p. 4449)

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Chapter 8 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C08-ESSAY-001 — Identify the event's time-frequency trajectory and the receiver's valid frequency-time intervals; exclude tuning and settling; test the actual duration, startup, repetition, and prior gain state; reproduce survey span, RBW, VBW, detector, sweep time, trigger, trace, and gain. Compare event-resolved reference captures with the aggregate. Select a capture architecture with sufficient instantaneous bandwidth if the method misses or distorts the target. State the event class and remaining gaps rather than claiming universal coverage.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

V011-C08-ESSAY-002 — Define each statistic with the same reference power. Apply concavity of ln to show the average logarithm is no greater than the logarithm of the arithmetic mean. State that equality requires equal positive powers. Explain that the inequality applies record by record but supplies no fixed correction, Gaussian model, or confidence statement.

Review: Chapter 8 — A stated statistical model.

V011-C08-ESSAY-003 — Begin with independent zero-mean equal-variance Gaussian quadratures and calibrated exponential power. Normalize by its mean, use the integral of exp(-u) ln(u) to obtain minus Euler's constant, and convert to decibels. Distinguish identical marginal distributions needed for expectation from independence needed for simple scatter reduction. Exclude tones, clipping, and changing mixtures; state that corrected decibel expectation does not imply watt unbiasedness.

Review: Chapter 8 — A stated statistical model.

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V011-C08-ESSAY-004 — Define both operation orders. For the log average, retain the minus 2.5068 dB expectation. For the logged four-power mean, use H_3 minus gamma minus ln(4) to obtain approximately minus 0.56535 dB. Explain why adding 2.5068 dB to the latter overcorrects by about 1.94147 dB in expectation. Preserve the original statistic and already-applied corrections.

Review: Chapter 8 — Power averaging before the logarithm.

V011-C08-ESSAY-005 — Hold source and receiver state fixed, characterize both equivalent noise bandwidths, retain linear-power data, and use compatible detector and averaging order. Predict 10 log10 of the bandwidth ratio for unchanged white density. Separate source/environment challenges from bandwidth changes. Investigate nonwhite input, receiver noise, filter weighting, and correction history when the comparison fails; do not infer a unique cause from the mismatch.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

V011-C08-ESSAY-006 — Use the independent inverse-square-root scatter relation and the stipulated common-correlation variance. Perfect copies have rho = 1 and retain the original relative standard deviation; independent samples can reduce it. Explain why file or record count does not establish independence and why the gamma correction cannot automatically use the duplicate count. Preserve the acquisition relationship rather than presenting storage volume as evidence strength.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-ESSAY-007 — Compute the weighted linear mean of 1 and 100 mW as 10.9 mW and its level as about 10.3743 dBm. Compute the corrected weighted log levels as 2 dBm. Attribute the remaining difference to operation order across changing means, not an arithmetic error in the single-state offset. Retain state durations and state-resolved estimates and avoid describing the mixture as one exponential distribution.

Review: Chapter 8 — Ten worked applications.

V011-C08-ESSAY-008 — Explain how successive frequency visits and repeated max hold can combine different time fragments. Distinguish observed activity from simultaneous carriers. Use event-resolved capture to support the trajectory interpretation, identify the capture's bandwidth and timing limits, and retain both records and configurations. Report the comb as a portrayal artifact in this tested case without declaring every comb an artifact.

Review: Chapter 8 — Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

V011-C08-ESSAY-009 — Specify the measurand, integration interval, spectral weighting, appropriate power statistic, calibration plane, and source state. Explain that a narrow filter samples only part of the occupied energy and a broad filter can include neighbors. Account for filter settling and compatible processing. Validate with a representative modulated reference and avoid treating a minimum noise display as proof of total-power accuracy.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

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V011-C08-ESSAY-010 — Separate the paths and failure modes each challenge probes. Internal alignment may omit cables, antennas, filters, and environmental overload; termination exposes residual responses under that condition; external references at several frequencies and levels probe the installed chain. Explain why agreement among these tests strengthens a bounded result but does not establish all transient behavior or universal source absence.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

V011-C08-ESSAY-011 — Map trigger and gate to the valid response interval. Require enough settling within the selected portion, and examine changes in startup, amplitude, phase, and modulation across events. Explain why aligning an edge or matching repetition period is insufficient. Compare event-resolved records with the proposed aggregate and describe the result as a collection when reconstruction assumptions are unproven.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

V011-C08-ESSAY-012 — Use proportionality to span divided by RBW squared to obtain an eightfold scale within one validated regime. Identify the omitted filter/architecture factor and acceptance criterion. Explain that automatic or qualitative timing does not validate unusual signals, segmentation, or gating; use the instrument's validated model and a representative reference for an absolute setting.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

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V011-C08-ESSAY-013 — State the validated event class, tested level and waveform criterion, observed bands, usable durations, gain and acquisition settings, and excluded intervals. Distinguish no observed qualifying event from universal absence. Retain unsuccessful captures and automatic state changes. Identify a next timing or acquisition strategy directed at the unresolved classes or gaps.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

V011-C08-ESSAY-014 — Distinguish nominal width, equivalent noise bandwidth, passband/skirt weighting, and impulse or settling response. Use flat-density integration for noise and actual weighting for a varying spectrum. Explain nearby-tone leakage and the time needed for burst response. Reject a universal conversion factor inferred only from the label and specify characterization evidence required for comparison.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

V011-C08-ESSAY-015 — Include native data and setup, mode, segment boundaries and timestamps, usable intervals, span, bandwidth definitions, detector order, gain state, averaging counts, max-hold repetitions, masked bands, and trigger settings. Relate these to the event's trajectory and duration. Explain what remains unknowable if only a final image survives and why a later correction cannot restore unobserved data.

Review: Chapter 8 — Sweep Method Acceptance.

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V011-C08-ESSAY-016 — Require compatible mean-power estimators at the same plane and bandwidth and justify the independent zero-mean Gaussian model. Convert to linear units, subtract there, and interpret a small residual with the errors of both estimates. Explain ill-conditioning, avoid treating the dB difference as residual power, and identify coherent or correlated cases outside the example.

Review: Chapter 8 — Ten worked applications.

V011-C08-ESSAY-017 — Trace each operation in its actual sequence, state its input/output statistic and weighting, and preserve software/mode settings. Resolve ambiguous RMS or average labels using the relevant implementation record. Determine whether the log or finite-power correction applies and whether it has already been applied. Explain why a screenshot and a dBm axis cannot supply this audit retrospectively.

Review: Chapter 8 — Measurement consequence.

V011-C08-ESSAY-018 — Separate visual scatter, mean bias, and uncertainty. Use independent averaging to explain legitimate repeatability improvement, then show how correlation and log bias survive a smooth display. Require sample provenance, distribution, stationarity, and correction history. Do not promote smoothness to an accuracy guarantee or turn a local propagated standard deviation into an exact interval.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-ESSAY-019 — Reproduce the preceding state, recovery interval, burst turn-on, duration, modulation, and repetition. Test with the actual gain, bandwidth, detector, trigger, and gate settings. Compare the usable response with a steady-tone check and explain why steady agreement is incomplete. Define the validated initial-state/event combinations and retain failures instead of averaging them away.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

V011-C08-ESSAY-020 — Show that equal positive powers give $L_N = A_N$, independent of N. Applying the exponential-noise offset then overstates the tone by about 2.5068 dB. Connect the error to an unsupported distributional assumption rather than a failure of calibration units. Require evidence for the actual statistic and signal class before applying any correction.

Review: Chapter 8 — Ten worked applications.

V011-C08-ESSAY-021 — State the expected corrected input-referred behavior and retain attenuation, preamplifier, mixer level, reference level, and source conditions. Repeat controlled settings, compare terminated-input and external-reference observations, and consider compression or internal products. Explain that the challenge reveals a departure needing localization rather than proving a unique origin from one change.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

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V011-C08-ESSAY-022 — Describe successive frequency-time visits versus the instantaneous bandwidth and record of the capture. Identify which signal evolution each preserves or loses, including repeated-event assumptions for reconstruction. Match bandwidth, detector, and calibration before quantitative comparisons. Keep the limits of both methods explicit and choose according to the target measurand.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

V011-C08-ESSAY-023 — Identify the marker's pre-log statistic, bandwidth normalization, and correction history. Distinguish the single-log offset, finite-power-log bias, and noise-bandwidth correction. Show why applying an already included correction twice shifts the reported value. Require retained raw/native values and an explicit correction ledger so the original indication and derived result can both be audited.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

V011-C08-ESSAY-024 — Distinguish arithmetic consistency from demonstrated model applicability. Identify required evidence for calibrated power plane, input distribution, stationarity, independence, bandwidth, and processing sequence. Use examples as checks of interpretation, not as measured specifications or universal detector constants. State which additional representative references and configuration records are needed for acceptance.

Review: Chapter 8 — Ten worked applications.

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V011-C08-ESSAY-025 — Describe both successful and failed tests, the configuration and waveform differences, and the specific capability not established. Avoid allowing the continuous test to overrule transient failure. Propose a suitable alternate timing or capture architecture, repeat acceptance in the survey settings, and constrain any interim findings to the event classes and usable coverage actually demonstrated.

Review: Chapter 8 — Sweep Method Acceptance.

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Discussion Guidance

V011-C08-DISCUSSION-001 — Require acquisition mode, timing, native records, and evidence that all displayed components coexisted. Discuss whether repeatable-event reconstruction is supportable or a simultaneous capture is needed. A defensible outcome may retain the trace as observations while revising the instantaneous-spectrum claim; visual smoothness alone is insufficient.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

V011-C08-DISCUSSION-002 — Begin with the intended quantity and signal width. Compare separation, integrated noise, neighbor inclusion, and transient response. Require a defined power integration and representative validation. Accept different settings for different measurands rather than treating one front-panel choice as universally superior.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

V011-C08-DISCUSSION-003 — Ask for pre-log statistic, distribution, correction history, and bandwidth definitions for each record. Separate the specified single-exponential log model from tones, power-averaged outputs, mixtures, and already corrected markers. Discuss which records can be recovered and which retain irreducible uncertainty; do not invent missing metadata.

Review: Chapter 8 — Measurement consequence.

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V011-C08-DISCUSSION-004 — Assess what each record permits a reviewer to reconstruct: timing, detector sequence, corrections, segments, and excluded intervals. Native data and settings generally retain more measurement meaning than repeated images. Consider practical volume and necessary images, but avoid counting stored files as independent observations or as proof of coverage.

Review: Chapter 8 — Sweep Method Acceptance.

V011-C08-DISCUSSION-005 — State the tested event class, usable observation intervals, bands, and sensitivity/timing criteria. Explain possible gaps for weak, short, hopping, or out-of-band events. Preserve the bounded negative finding and propose a targeted next observation where the present method cannot resolve the concern.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

V011-C08-DISCUSSION-006 — Discuss which waveform features must be repeatable for the intended aggregate. Request event-resolved records and compare phase, amplitude, startup, and modulation where relevant. An aggregate can document activity without representing one event; choose its label and subsequent capture method accordingly.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

V011-C08-DISCUSSION-007 — Separate the empirical scatter of the actual estimator from the independent-sample formulas. Examine overlap, filter correlation, and sample provenance; use the stipulated covariance example only as an illustration. Do not infer a gamma correction from count alone, and state limitations if dependence has not been characterized.

Review: Chapter 8 — Power averaging before the logarithm.

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V011-C08-DISCUSSION-008 — Identify what the internal path actually tests and what remains external or environment-dependent. Discuss cable, antenna, filter, gain state, blockers, and transient behavior. Use external references, attenuation challenges, and termination as complementary evidence rather than treating alignment as either worthless or conclusive.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

V011-C08-DISCUSSION-009 — Hold state fixed, verify equivalent bandwidth and processing, inspect noise color and receiver contribution, then challenge source/environment separately. Discuss how each observation narrows possible causes. The initial discrepancy tests a compound assumption and cannot alone choose between the proposed diagnoses.

Review: Chapter 8 — Choose bandwidth from the quantity being estimated.

V011-C08-DISCUSSION-010 — Identify the missed event class and conditions, retain unsuccessful tests, and restrict findings to demonstrated capability and actual coverage. Discuss a different architecture or timing strategy and its validation. Do not turn schedule pressure into an unsupported universal negative statement.

Review: Chapter 8 — Sweep Method Acceptance.

V011-C08-DISCUSSION-011 — List the unresolved stages and the interpretations they would support. Preserve native outputs, settings, and version information; avoid assuming the RMS label determines the final mean-power statistic. Request or test the actual operation order, then apply only justified corrections and retain the original values.

Review: Chapter 8 — Measurement consequence.

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V011-C08-DISCUSSION-012 — Discuss the trade between scatter reduction and mixing different quantities. Use state-resolved means and durations where changes matter, and distinguish repeated independent estimates from correlated or duplicated data. Choose the averaging interval based on stationarity and the question being answered, not the largest available count.

Review: Chapter 8 — Ten worked applications.

V011-C08-DISCUSSION-013 — Preserve both configurations and explain their different frequency-time constructions. Establish that the simultaneous capture had suitable bandwidth and timing for the event. Treat the contradiction as evidence for the tested portrayal mechanism, while avoiding claims that every comb or every swept measurement is unreliable.

Review: Chapter 8 — Hypothetical Case Adjudication: Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

V011-C08-DISCUSSION-014 — Require original statistic, power plane, bandwidth, detector/averaging order, sample dependence assumptions, corrections and their order, and excluded intervals. Discuss a readable final result with accessible provenance. A simplified interface should not make double correction or unsupported reinterpretation impossible to detect.

Review: Chapter 8 — Measurement consequence.

V011-C08-DISCUSSION-015 — Read the visible settings as evidence, but identify missing equivalent bandwidth, processing sequence, timing, gain, native data, and correction history. Avoid automatic log correction or reconstruction of unobserved events. Distinguish a descriptive record of the image from a validated power or absence claim.

Review: Chapter 8 — Measurement consequence.

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V011-C08-DISCUSSION-016 — Examine filter settling, burst duration, frequency trajectory, signal energy excluded, and detector time response. Test the intended waveform in the actual configuration. The best choice follows demonstrated detection or measurement capability for the target class, not noise-floor appearance alone.

Review: Chapter 8 — Resolution Bandwidth and Selectivity.

V011-C08-DISCUSSION-017 — Define which features the reconstruction relies on, then inspect event-resolved amplitude, phase, modulation, startup, timing, and prior receiver state as appropriate. A nominal period match is insufficient. Record the acceptance criterion and describe any unresolved variation rather than demanding or assuming irrelevant universal identity.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

V011-C08-DISCUSSION-018 — Explain that the dB difference is a ratio, verify compatible mean estimators at the same plane and bandwidth, and subtract in linear units only under the stated model. Examine near-cancellation uncertainty and coherent/correlated exceptions. Preserve original readings and the revised derivation rather than silently replacing them.

Review: Chapter 8 — Ten worked applications.

V011-C08-DISCUSSION-019 — Discuss cancellation of common offsets within each compatible comparison and the remaining differences in estimator, bandwidth, gain, and correction. Agreement can support a conditional bandwidth trend while absolute calibration or statistics remain unresolved. Request the information needed to compare the mean-power quantities themselves.

Review: Chapter 8 — Ten worked applications.

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V011-C08-DISCUSSION-020 — Limit the scaling to validated regimes, include instrument/filter factors and acceptance criteria, and detect settings such as segmentation or gating outside that scope. Test representative signals and retain actual usable timing. The software should not manufacture an absolute timing law from a proportionality.

Review: Chapter 8 — Quantitative Model for Swept-Tuned Spectrum Analyzers, RBW, VBW, Detectors, and Sweep Validity.

V011-C08-DISCUSSION-021 — Retain both states and their expected corrected relationships. Examine compression, internal products, mixer level, and external source changes through controlled challenges. Accept only a configuration-bound interpretation supported by the evidence; disagreement is a diagnostic observation, not a reason to delete data.

Review: Chapter 8 — Amplitude Accuracy and Analyzer Self-Tests.

V011-C08-DISCUSSION-022 — Distinguish clock duration from valid observation, record the state transitions and excluded bands/times, and explain their effect on event coverage. Discuss whether additional observation is needed. Avoid representing the entire run as one uninterrupted uniform-capability exposure.

Review: Chapter 8 — Sweep Method Acceptance.

V011-C08-DISCUSSION-023 — Explain that those formulas concern specific filter/noise estimators and do not supply a universal interception model. Require a defined event class, timing/coverage model, and validated acquisition behavior for any probabilistic claim. Offer bounded observed findings and unresolved classes rather than assigning an unsupported number.

Review: Chapter 8 — Validate transient and gated measurements with the intended waveform.

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V011-C08-DISCUSSION-024 — Compare the actual measurand, stationarity, required frequency range, validated sensitivity, timing, and evidence needs. A swept method may be adequate for a demonstrated stationary or repeatable class. Availability of another architecture does not itself invalidate it, but relevant failed challenges require a capable alternative.

Review: Chapter 8 — Sweep Method Acceptance.

V011-C08-DISCUSSION-025 — The reviewer should reconstruct mode and settings, source/reference class, calibration plane, processing and corrections, frequency-time coverage, failures, exclusions, and the scope of each finding. Discuss native data and timestamps as supporting evidence. Identify remaining assumptions explicitly so that independent review does not depend on undocumented operator memory.

Review: Chapter 8 — Sweep Method Acceptance.

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Chapter Glossary

AVERAGE OF LOGARITHMIC POWERS: The arithmetic mean of calibrated power levels after each sample has been converted to logarithmic units. It estimates a different statistic from the logarithm of an arithmetic power mean. Under the chapter's single exponential noise-power model, its decibel expectation has a fixed offset that additional independent averaging does not remove.

CHANNEL-POWER INTEGRATION: An estimate formed by combining calibrated spectral contributions over a declared channel interval using the appropriate frequency weighting and detector convention. A single narrow marker is generally insufficient when a modulated signal spans several filters. The integration limits, normalization and calibration must distinguish wanted energy from neighboring admitted components.

DISPLAY BUCKET: The group of processed observations assigned to one displayed trace location before the selected detector reduces them to an ordinate. Bucket formation and detector operation are implementation details that affect the statistic. A display pixel count cannot be treated automatically as a count of independent calibrated power samples.

EFFECTIVE SAMPLE INDEPENDENCE: Degree to which samples supply distinct information after filtering, overlap and processing, rather than their nominal count.

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EQUIVALENT NOISE BANDWIDTH: The bandwidth of an ideal rectangular power weighting that admits the same integrated white-noise power as the actual filter under the stated gain normalization. It can differ from a nominal resolution-bandwidth label. Nonuniform spectra require the actual weighting or a justified approximation rather than automatic multiplication by this one number.

EVENT REPEATABILITY: Consistency of the particular waveform properties that a repeated-event measurement needs to combine. Similar nominal repetition periods alone do not establish stable amplitude, phase, modulation or startup behavior. A spectrum assembled from repeated bursts requires evidence for the relevant consistency; otherwise it remains an aggregate of different observations.

EXPONENTIAL POWER DISTRIBUTION: The positive power distribution generated by the squared magnitude of the chapter's zero-mean circular complex Gaussian sample at a calibrated plane. Its mean fixes its scale, and its variance is the square of that mean. A tone, clipping or a mixture of changing noise levels does not automatically have this distribution.

FILTER SETTLING: The development of a filter response toward the state required by the measurement criterion after tuning, switching or a change in input. A short commanded dwell may include an unusable settling portion. The necessary interval depends on filter shape, architecture and accepted error, so bandwidth alone does not supply a universal wait time.

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FINITE-RECORD LOGARITHMIC BIAS: The difference between the expected logarithm of a finite arithmetic power average and the logarithm of its underlying mean power. For the chapter's independent exponential samples this depends on sample count and approaches zero as that count increases. It differs from the fixed offset of averaging the individual logarithms.

FREQUENCY SPAN: The frequency interval covered by a stated analyzer acquisition or display. In a swept mode, covering that span takes time and does not establish simultaneous observation of all included frequencies. Span must be interpreted with the actual sweep trajectory, selected filters, segment boundaries and usable observation intervals.

FREQUENCY-TIME TRAJECTORY: The sequence of frequency regions observed as a swept or stepped instrument progresses through its acquisition.

GAMMA POWER-SUM MODEL: The probability model for the normalized sum of the chapter's independent, identically distributed exponential power samples. It supplies the logarithmic moment used to derive the finite-record correction. Repeated copies, overlapping observations or other dependence do not acquire this model merely because the file contains the same nominal number of samples.

GATED SWEEP: Measurement restricted to a selected time interval relative to a trigger.

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GATE WIDTH: The duration of the selected time interval admitted by a gated measurement. It determines which part of the event contributes, together with trigger delay, timing uncertainty and receiver response. A narrow gate does not by itself establish settled operation or capture of all the signal energy required by the intended measurand.

LINEARITY CHALLENGE: A controlled change of input attenuation or another justified operating condition whose predicted response is tested while reference-plane corrections are retained. Departure from the prediction can expose overload or internally generated structure. It does not alone identify the cause, so the comparison must preserve or explicitly model other changed states.

LINEAR-POWER SUBTRACTION: Removal of an identified additive power contribution after converting compatible estimates to linear power units at the same reference plane and bandwidth. It requires justified power additivity. Subtracting decibel levels gives a ratio, and near-cancellation of total and background can make the recovered difference highly sensitive to measurement errors.

LOGARITHM CONCAVITY: The mathematical property that makes the average of positive-power logarithms no greater than the logarithm of their arithmetic average. Equality holds when all included powers are equal. This establishes the direction of the difference for each record; it does not prescribe a universal numerical correction or prove a Gaussian noise model.

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LOGARITHM OF AVERAGED POWER: A level obtained by first averaging calibrated powers in linear units and then taking the logarithm of that average relative to the reference power. The linear average is unbiased under the stated stationary model, while its logarithmic conversion can retain a finite-record bias. The number and dependence of the contributing samples matter.

LOG-AVERAGE BIAS: Difference between the expectation of an averaged logarithmic noise statistic and the logarithm of mean power under a specified probability model.

MAX HOLD: Trace process retaining the highest detected value at each display point over repeated acquisitions.

NEGATIVE-PEAK DETECTOR: A detector that retains the lowest indication within its specified observation or display bucket. Its meaning depends on the quantity entering the detector and the instrument's bucket convention. It does not estimate the same statistic as a positive-peak, sample or power detector simply because all results share a decibel display axis.

NOISE-MARKER CORRECTION: A declared processing adjustment used by an instrument or analysis method to convert its measured noise statistic into a specified reported convention. Detector-statistic and noise-bandwidth adjustments have different causes. Establish which adjustments are already present before applying additional corrections, and do not infer the sequence from a marker name alone.

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NOISE POWER SPECTRAL DENSITY: Mean noise power per unit frequency at a declared reference plane, with the side convention and units stated. A flat density gives integrated mean power proportional to equivalent noise bandwidth. A logarithmic noise display also depends on detector and averaging conventions, so its ordinate is not automatically the density times a front-panel bandwidth label.

PAIRWISE POWER CORRELATION: A stated covariance relationship between two power samples after normalization by their standard deviations. In the chapter's equal-variance illustration, positive common correlation slows the reduction in the arithmetic mean's variance. A nominal sample count therefore cannot replace evidence about filtering, overlap or duplication when estimating repeatability.

POSITIVE-PEAK DETECTOR: A detector that retains the largest indication within its specified observation or display bucket. It can aid discovery of brief activity, but its population and timing differ from an average-power estimate. Changing to this detector changes the measurement statistic and must be disclosed when traces are compared.

POWER-AVERAGE ESTIMATOR: Arithmetic mean of calibrated instantaneous powers; subsequent logarithmic conversion has distinct finite-record statistical properties.

POWER-ESTIMATION PLANE: The declared point in a calibrated measurement model at which samples represent a specified power quantity. Resistance, gain calibration, admitted bandwidth and processing connect that quantity to the original signal path. Raw converter counts are not power samples until that relationship is established; comparisons must use compatible planes.

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RESOLUTION BANDWIDTH: Analyzer filter bandwidth determining frequency discrimination and admitted noise.

RMS DETECTOR: A detector whose intended power-related statistic derives from mean square signal magnitude before square-root or level reporting. Its actual bucket operation, weighting, normalization and subsequent video or trace processing must be established from the instrument implementation. The name alone does not determine every operation that produced the displayed number.

SAMPLE DETECTOR: A detector that selects a sample according to a defined rule for each display bucket instead of retaining the bucket's extremum or a power average. Its sampling rule and relation to the input processing must be documented. A short event between selected samples may not appear in the resulting trace.

SAMPLE INDEPENDENCE: The joint statistical condition in which the samples' probability law factors into their individual laws. It is an additional premise for the chapter's gamma sum and simple variance reductions. Distinct timestamps or storage positions do not establish independence when filters, overlapping records or repeated data create shared information.

SEGMENTED SWEEP: A sweep assembled from separately specified frequency or acquisition segments. Each segment's limits, settings and time position belong in the record so the combined trace can be reconstructed. Segmenting can change which events are observed and when; it does not make the full assembled frequency range simultaneous.

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STATE MIXTURE: An observation population containing contributions from distinct receiver or source states with different stated distributions or mean powers. Averaging their logarithmic levels and then applying a single-state correction generally does not recover the overall arithmetic mean power. Preserve state-resolved measurements and their weights when those differences matter.

STATIONARITY: The assumed stability of the statistical properties needed by a specified estimator over its included observations. The chapter's noise-power calculations hold one distribution and mean fixed unless a case explicitly varies them. A stable-looking averaged trace does not prove this premise, because averaging can conceal changes in the underlying state.

STEPPED SWEEP: An acquisition that visits selected frequency settings through successive tuning and dwell intervals. The usable part of each dwell excludes whatever settling or invalid state the validated method requires. Commanded dwell duration is therefore not automatically valid observation time, and the resulting trace still combines observations made at different times.

SWEEP TIME: Time required for the analyzer to traverse the selected frequency span or measurement points.

TRANSIENT VALIDATION: A controlled check that the selected receiver method represents the event duration, modulation, timing and prior state required by the intended measurement.

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TRIGGER DELAY: The specified interval between the trigger reference and the acquisition or gate position used for the measurement. Its sign and time reference must follow the instrument convention. Delay, jitter and the event's own repeatability determine which portion of a burst is observed; matching a trigger edge does not align every internal waveform feature.

USABLE OBSERVATION WINDOW: The portion of an acquisition during which its channel response, detector and receiver state meet the declared measurement requirements. Tuning and recovery intervals may need exclusion. In a sweep, the windows at different frequencies occur at different times, which limits what can be concluded about a changing or intermittent event.

VIDEO BANDWIDTH: Post-detection filtering bandwidth controlling trace smoothing and response time.

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References and Works Cited

Tektronix. Fundamentals of Real-Time Spectrum Analysis. 37W-17249-4, August 2009. Printed page 5, “The Swept Spectrum Analyzer.” https://download.tek.com/document/37W_17249_4.pdf

Annotation. Supports the successive-frequency architecture and its transient limitation. The chapter does not use this historical explanation to describe every current hybrid, FFT-assisted or real-time mode; the actual selected acquisition architecture must be documented. The publication explains analyser operation and measurement settings governing spectral detection, resolution and transient capture. Resolution bandwidth, video filtering, detector mode and acquisition duty cycle can alter a displayed spectrum without changing the external transmitter. A manufacturer’s application note supports stated instrument behaviour but does not certify that a particular survey captured every possible short-duration event. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

Keysight Technologies. “Spectrum Analyzer.” E505xA help, “SA Setup Dialog,” Detector Type and Video Averaging Type entries. Accessed 30 October 2026. https://helpfiles.keysight.com/csg/e5055a/Applications/Spectrum_Analyzer.htm

Annotation. Documents the detector and video-averaging sequence of this specified implementation. It supports the need to establish processing order, not a universal convention for all spectrum analyzers.

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The publication explains analyser operation and measurement settings governing spectral detection, resolution and transient capture. Resolution bandwidth, video filtering, detector mode and acquisition duty cycle can alter a displayed spectrum without changing the external transmitter. A manufacturer's application note supports stated instrument behaviour but does not certify that a particular survey captured every possible short-duration event. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Keysight Technologies. N9000B CXA Signal Analyzer Specification Guide. N9000-90035, edition 6, May 2024. Printed page 56, note d. https://www.keysight.com.cn/cn/zh/assets/9018-04781/technical-specifications/9018-04781.pdf

Annotation. Supports the stated logarithmic-averaging convention for the cited displayed-average-noise-level specification. No device performance rating is generalized to another instrument or configuration. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. The cited work is a

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methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

National Institute of Standards and Technology. Digital Library of Mathematical Functions. Equations 5.9.16, 5.9.18 and 5.9.19. Accessed 30 October 2026. https://dlmf.nist.gov/5.9

Annotation. Supplies the logarithmic-moment identities used in the exponential and gamma derivations. The finite-record substitutions, covariance illustration and ten hypothetical applications are independently developed in the chapter. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions.

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Keysight Technologies. Spectrum and Signal Analyzer Measurements and Noise. Application note 5966-4008E, 21 August 2024. Printed pages 7–10, especially “Logarithmic Processing,” “Equivalent Noise Bandwidth,” and the noise-marker discussion. https://www.keysight.com/us/en/assets/7018-06765/application-notes/5966-4008.pdf

Annotation. Supports the distinction between noise-statistic and bandwidth corrections. The official publisher PDF was directly inspected in the inherited evidence. Its processing explanation does not replace the chapter’s explicit probability, averaging and calibration premises. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

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Chapter 9. FFT Analyzers, Windowing, Averaging, and Spectral Estimation

Cross-volume technical interface. S001-V008(RF Theory Propagation and Spectrum Behaviour) treats time-varying channels and their physical coherence assumptions, whileS001-V022(Computational Electromagnetics Modelling Simulation and Diagnostic Mathematics) supplies a wider modelling context.S001-V024(Series Conventions Standards Units and Citation Practice) governs the terminology and units shared across the series. The present derivation must nevertheless state the sampled-data convention, window sum, coherent gain, equivalent noise bandwidth, sidedness, spectral units, estimator averaging rule and covariance assumptions here. FFT zero-padding changes frequency-grid display density, not the physical information or equivalent noise bandwidth in the original record.

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9.1 Discrete Records and Spectral Estimates

An FFT analyzer begins with a finite sampled record. The transform returns coefficients associated with discrete frequency bins, but the underlying signal is not necessarily periodic within that record or centered on a bin. Record length determines nominal bin spacing, while sample rate determines the represented Nyquist interval. The displayed spectrum is an estimate conditioned by acquisition length, window, overlap, averaging, scaling, and any preprocessing.[1]

A single transform does not distinguish a stable tone from a short transient, a drifting carrier, or a windowed fragment. Time-domain inspection and repeated records are essential. The practitioner preserves the original samples, trigger, time stamps, overflow flags, and acquisition parameters rather than only exporting an image of the spectrum. This permits later checks of clipping, nonstationarity, and processing choices.

Harris's 1978 review organized window selection around finite observations: a weak tone near a strong one, nearby tones of comparable strength, moving tones, and biased parameter estimates. That historical framing remains useful because the measurement question determines the acceptable tradeoff. Model 9W makes the finite record, weight sums, and amplitude or noise normalization explicit. Its calculations let the reader test a proposed window against the quantity being estimated. Model 9C adds a

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1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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separate paired-record question: how much of one measured series is represented by the declared reference series under the stated estimator. Neither a window choice nor a high coherence value supplies a physical source attribution. Those conclusions require the acquisition controls and competing-path checks developed through this chapter.[2]

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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9.2 Spectral Leakage and Window Selection

A finite record implicitly multiplies the signal by a time window. A rectangular window offers narrow main-lobe width for bin-centered coherent tones but high sidelobes for off-bin components. Tapered windows reduce sidelobes at the cost of wider main lobes and different amplitude and noise corrections. No window is universally best; selection follows the need to resolve close tones, measure amplitude, estimate noise, or observe transients.

Window coherent gain, equivalent noise bandwidth, scalloping loss, and sidelobe behavior should be included when quantitative results are reported. Software may normalize some effects automatically, but the normalization convention must be known. Applying two different windows to the same samples is a useful interpretive challenge because a genuine component and leakage from a stronger component change differently.

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9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy

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9.3.1 Define the record before interpreting the display

A spectrum requires a normalization as well as a frequency axis. Let x_n be N samples of voltage, measured in volts, at sampling frequency f_s in hertz, and let w_n be a specified dimensionless real window for $n=0,\ldots,N-1$. The data can be real or complex, but that choice changes how a one-sided display is constructed. Here no mean subtraction or other detrending is applied. If preprocessing is used, x_n denotes its output and the reported result must identify that preprocessing. Define

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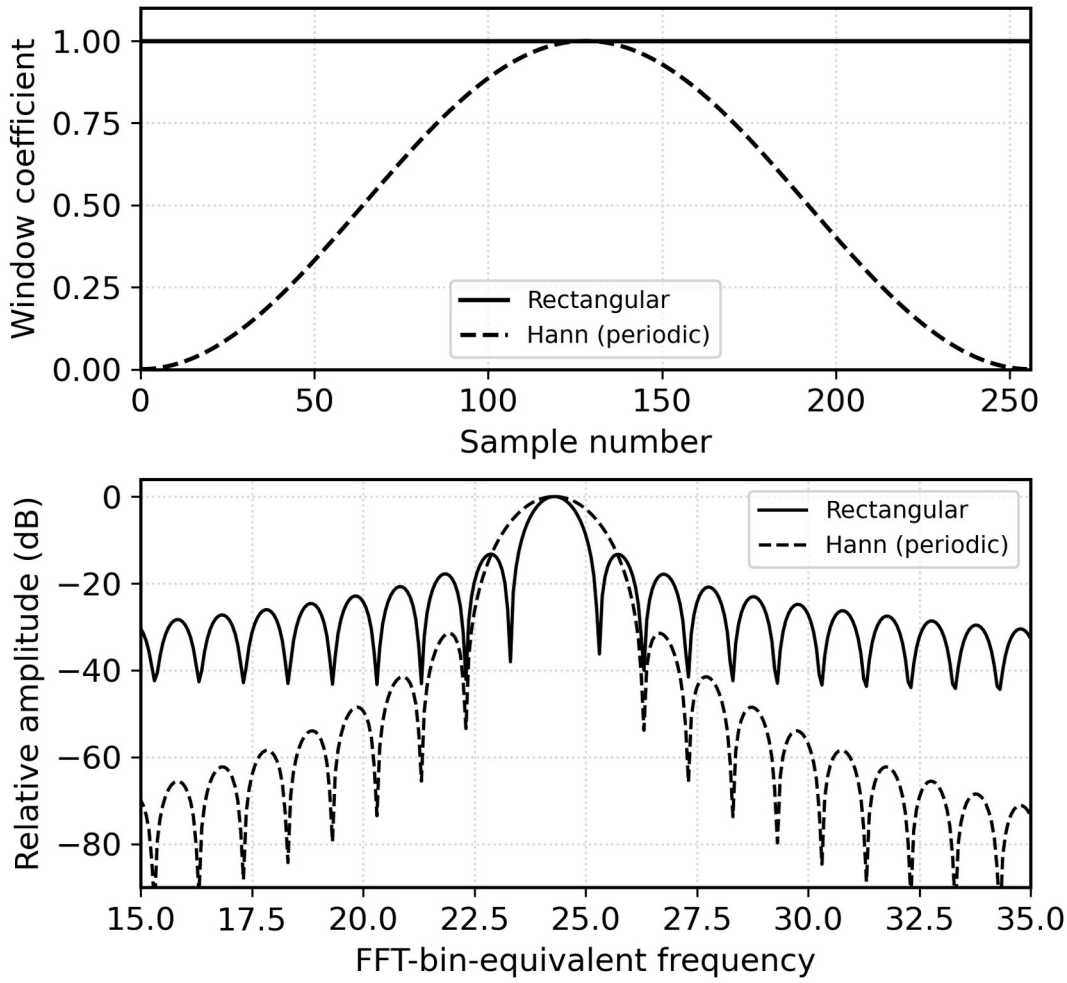

Hann reduces far sidelobes but broadens the main lobe.
Equivalent noise bandwidth: 1.0 bin (rectangular), ~1.5 bins (Hann).

Figure 50. Rectangular and Hann spectral windows.

Equation 9W1.

$$X_w[k] = \sum_{n=0}^{N-1} w_n x_n \exp\left(-j\frac{2\pi k n}{N}\right)$$

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$$S_1 = \sum_{n=0}^{N-1} w_n, S_2 = \sum_{n=0}^{N-1} w_n^2, CG = \frac{S_1}{N}$$

The transform X_w has units of volts because the sum is dimensionless apart from x_n. Require $S_2 > 0$; require $S_1 \neq 0$ whenever coherent-gain normalization is used. For the coherent complex tone $x_n = a \exp\backslash(j 2\pi k_0 \frac{n}{N} \backslash)$, substitution gives $X_w[k_0] = a S_1$. Thus $\frac{X_w[k_0]}{S_1}$ recovers the complex amplitude a under these assumptions. Harris distinguishes the coherent sum of the weights from their squared sum when discussing coherent signal gain and noise gain.[3] These are different operations, even though a rectangular window makes their associated bandwidths particularly simple.

For a real sinusoid $A \cos\backslash(2\pi k_0 \frac{n}{N} + \varphi \backslash)$, the negative-frequency image must also be retained in the derivation. Write $W[r] = \sum_n w_n \exp\backslash(- j 2\pi \frac{r n}{N} \backslash)$. At the positive-frequency bin,

$$X_w[k_0] = \frac{A}{2}\left(e^{j\varphi} S_1 + e^{-j\varphi} W[2k_0]\right).$$

Consequently, $\frac{2 \mid X_w[k_0] \mid}{\mid S_1 \mid}$ equals A only when the image term vanishes, or is negligible to a justified accuracy. A coherent frequency alone is insufficient for an arbitrary window and bin. DC and the Nyquist bin are special cases, not ordinary positive-frequency sinusoids. Off-grid tones

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3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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introduce a further window-response error. The examples below separate these conditions instead of treating coherent gain as a universal amplitude correction.

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9.3.2 Noise density uses a different denominator

Suppose initially that the samples have zero mean and covariance $\mathrm{E}[x_n x_m^*]=\sigma^2\delta_{nm}$, where σ^2 has units V². Expanding the squared transform gives $\mathrm{E}\,|\,X_w[k]\,|^2=\sigma^2\sum_n w_n^2=\sigma^2 S_2$: the cross terms vanish by the covariance assumption. Gaussianity is unnecessary for this expectation. Define the two-sided density estimate D_2 and the tone-normalized squared spectrum Q_2 by

Equation 9W2.

$$D_2[k]=\frac{|X_w[k]|^2}{f_s S_2},\ Q_2[k]=\frac{|X_w[k]|^2}{|S_1|^2}$$

$$B_e=\frac{f_s S_2}{|S_1|^2},\ Q_2[k]=B_e D_2[k]$$

D_2 has units V²/Hz, Q_2 has units V², and the equivalent noise bandwidth B_e has units Hz. Under the white covariance assumption, $\mathrm{E}\,D_2=\frac{\sigma^2}{f_s}$. The last identity in 9W2, however, is an algebraic equality for every record with the stated nonzero denominators; it does not require whiteness. A line-calibrated spectrum and a density estimate can therefore be consistent while showing different numerical ordinates. The report by Heinzel, Rüdiger and Schilling derives the two weight sums and the resulting conversion between squared spectrum and density.[4]

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4 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers” (June 14, 2013), “Baseline Case: Cascade of Linear Circuit Blocks” and “Noise Temperature,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and synthetic cases are stated in Model 2B.

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For real data, combine the equal contributions at positive and negative frequencies. Double interior positive-frequency values of D_2 and Q_2, but do not double DC or, when N is even, the Nyquist value. For odd N there is no Nyquist sample and the highest retained positive bin is doubled. Complex records do not generally have this conjugate symmetry and normally retain a two-sided density. The Heinzel report explicitly sets aside the DC and Nyquist corrections in its presentation; the endpoint convention used here instead preserves the exact finite-record sum. This distinction must survive implementation. The current SciPy periodogram documentation supplies the same spectrum-to-density ratio and describes one-sided folding, but its default detrending removes a constant: reproducing the present model requires that option to be disabled.[5] Agreement with a software convention does not establish that a receiver uses it.

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5 H. T. Friis, “Noise Figures of Radio Receivers,” Proceedings of the IRE 32, no. 7 (July 1944): 419–22, https://doi.org/10.1109/JRPROC.1944.232049. The publisher’s abstract was read for the historical network, component, mismatch, and measurement framing. The full paper was not accessed; Model 2B supplies its own stated derivation and working conventions.

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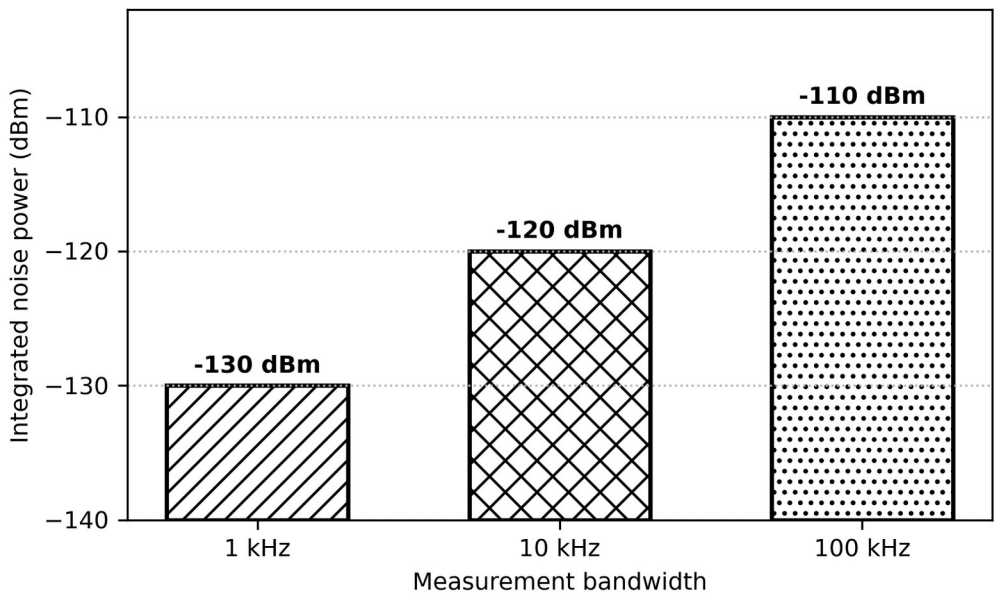

Illustrative flat density: −160 dBm/Hz.

$P_N\,(\text{dBm}) = N_0\,(\text{dBm/Hz}) + 10\log_{10}(B/1\text{Hz})$

Use equivalent noise bandwidth when filtering alters the integration kernel.

Figure 51. Spectral density versus integrated noise.

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9.3.3 Energy closure and its limits

Discrete Fourier orthogonality gives $\sum_k | X_w[k] |^2 = N \sum_n w_n^2 | x_n |^2$ for this unnormalized transform. Multiplying D_2 by the frequency spacing $\frac{f_s}{N}$ therefore yields

Equation 9W3.

$$\sum_{k=0}^{N-1} D_2[k] \frac{f_s}{N} = \frac{\sum_{n=0}^{N-1} w_n^2 |x_n|^2}{S_2}$$

The correctly folded one-sided sum has the same value for real records. The right side is a window-weighted mean square. It is not necessarily the unweighted sample mean square $\frac{\sum_n | x_n |^2}{N}$. For stationary white samples their expectations agree, but an individual transient can be suppressed or emphasized by its position within the window. This is a material limitation when a sweep is intended to detect an intermittent signal. Energy closure checks arithmetic and normalization; it does not validate stationarity, sampling adequacy, sensor calibration, source attribution, or the absence of overload.

For the periodic Hann window $w_n = \frac{1 - \cos \backslash(\frac{2\pi n}{N} \backslash)}{2}$ and $N > 2$, finite trigonometric sums give $S_1 = \frac{N}{2}$ and $S_2 = \frac{3N}{8}$. Hence $\mathrm{CG} = \frac{1}{2}$ and $B_e = \frac{3 f_s}{2N}$, equal to 1.5 unpadded bin intervals. The endpoint-symmetric Hann window instead uses $N-1$ in the cosine denominator. For $N > 3$ it has $S_1 = \frac{N-1}{2}$,

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$S_2 = \frac{3(N-1)}{8}$, and $B_e = \frac{3 f_s}{2(N-1)}$. These statements are derived from the actual coefficient vectors, not adopted from a window table. The official Hann documentation distinguishes the symmetric filter-design form from the periodic spectral-analysis form.[6] Their difference is appreciable for short records.

Multiplying all weights by one nonzero real constant changes X_w, S_1 and S_2 together and leaves Q_2, D_2 and B_e unchanged. It does not excuse mixing sums calculated from different vectors. Cauchy–Schwarz gives $|S_1|^2 \le N S_2$ and therefore $B_e \ge \frac{f_s}{N}$ whenever S_1 is nonzero. A zero-sum window still permits density normalization if $S_2 > 0$, but neither Q_2 nor B_e as defined here exists. That domain restriction matters more than assigning an arbitrarily large display correction.

Zero-padding evaluates the same finite-record transform at additional frequencies. If the windowed record is padded to $M \ge N$ samples, use spacing $\frac{f_s}{M}$ on the left of 9W3 while retaining the original S_1 and S_2 in 9W2. No new observations have been acquired and B_e has not narrowed. Rust and Donnelly discuss zero-padding in the context of finite-record spectral estimates; their original paper also emphasizes that infinitely many

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6 International Electrotechnical Commission, CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus, 5th ed. (May 22, 2019), official publication scope, https://webstore.iec.ch/en/publication/60774, checked November 1, 2026. The public scope identifies the 9 kHz–18 GHz apparatus range and EMI receivers and spectrum analyzers. No access to or clause-by-clause compliance review of the complete standard is claimed.

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continuous signals can agree at the observed samples.[7] Interpolation can make a peak easier to locate, but cannot independently resolve two components whose window responses overlap.

7 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers,” June 14, 2013, “Baseline Case: Cascade of Linear Circuit Blocks,” “A Heterodyne Receiver,” “Noise Temperature,” and “Y-Factor,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html. The scalar derivation and numerical cases here are original and explicitly exclude unmodeled image contributions.

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9.3.4 Ten worked applications of the normalization model

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9.3.4.1 Application 1: A coherent tone with a stated image condition

Take $N = 1024$, $f_s = 48{,}000\ \text{Hz}$ and the periodic Hann window. For a real 0.100 V peak sinusoid at $k_0 = 64$, $W[128] = 0$. The sums are $S_1 = 512$ and $S_2 = 384$. Thus $|X_w[64]| = \frac{0.100 \times 512}{2}\ \text{V} = 25.6\ \text{V}$, and the recovered peak is $\frac{2 \times 25.6}{512}\ \text{V} = 0.100\ \text{V}$. The one-sided Q value is $\frac{2\backslash(25.6\backslash)^2}{512^2}\ \text{V}^2 = 0.005\ \text{V}^2$. Across a stipulated purely resistive 50 Ω load this is 0.000100 W, or −10.000 dBm. This is a hypothetical voltage-to-power conversion, not an instrument calibration or antenna-power claim.

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9.3.4.2 Application 2: White-noise density and noise bandwidth

Keep the same record and window, but stipulate white real noise with variance $\sigma^2 = 10^{-6}\ \mathrm{V}^2$. The interior one-sided density expectation is $\frac{2\sigma^2}{f_s} \approx 4.166666667 \times 10^{-11}\ \mathrm{V}^2/\mathrm{Hz}$. Its square root is 6.454972244 μV/√Hz. Here $B_e = 70.3125\ \mathrm{Hz}$, so the expected interior Q value is $B_e \mathrm{E}[D_1] = 2.9296875 \times 10^{-9}\ \mathrm{V}^2$, corresponding to 54.12658774 μV rms. Dividing this expected mean square by 50 Ω and converting to dBm gives −72.32148706 dBm. This is the logarithm of expected power; it is not the expectation of a logarithmic display, whose averaging bias is treated in Chapter 8.

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9.3.4.3 Application 3: Do not sum line-calibrated ordinates as independent powers

In Application 1, the positive-frequency central Q value is 0.005 V^2 and each adjacent Hann bin has 0.00125 V^2. Their sum is 0.0075 V^2, apparently 50 percent above the sinusoid's mean square. This is not additional physical power. Q is calibrated for a coherent line at a selected frequency. To integrate the spectrum, convert to density and multiply by the 46.875 Hz spacing: $\frac{0.0075 \times 46.875}{70.3125}\ \mathrm{V}^2 = 0.005\ \mathrm{V}^2$. The finite Hann side bins are part of the same window response, not three independently generated signals.

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9.3.4.4 Application 4: Padding does not replace N in the bandwidth

Pad the 1024-sample record to $M = 8192$. The displayed spacing becomes $\frac{48,000\ \text{Hz}}{8192} = 5.859375\ \text{Hz}$, while B_e remains 70.3125 Hz, now twelve displayed intervals. Incorrectly using $\frac{1.5 f_s}{M}$ would give 8.7890625 Hz. Dividing the unchanged Q ordinate by that erroneous bandwidth would overstate its density by a factor of eight, or $10 \log_{10} \backslash(8 \backslash)\ \text{dB} \approx 9.03089987\ \text{dB}$. At every eighth padded bin the transform equals its original unpadded value; the correctly weighted density integral is unchanged.

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9.3.4.5 Application 5: Short symmetric and periodic windows differ

Set $N=16$ and $f_s=1600\ \text{Hz}$. The symmetric Hann vector gives $S_1=7.5$, $S_2=5.625$ and $B_e=160\ \text{Hz}$; the periodic vector gives $S_1=8$, $S_2=6$ and $B_e=150\ \text{Hz}$. For a coherent complex tone processed with the symmetric vector, erroneously dividing its transform by 8 produces $\frac{7.5}{8}=0.9375$ times the true amplitude, an error of −0.56057447 dB. Converting the symmetric Q value to density with 150 rather than 160 Hz overstates density by 0.28028724 dB. A real-tone measurement additionally needs the image-term condition; it is not silently substituted for this complex-tone calculation.

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9.3.4.6 Application 6: Coherent gain does not remove scalloping

For a complex tone halfway between bins of an $N = 1024$ record, compare the nearest-bin magnitude with $|aS_1|$. The rectangular-window ratio is $\frac{1}{N \sin[\frac{\pi}{\backslash(2N\backslash)}]} \approx 0.6366200220$, or −3.92239413 dB. Evaluating the periodic Hann coefficient sum gives 0.8488263632, or −1.42362281 dB. The latter reduces this particular error but does not make it zero. Padding to $2N$ places a sample at this stipulated half-bin tone frequency and can recover the response peak for the isolated complex tone. It does not narrow the underlying window response or establish separation from another nearby component.

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9.3.4.7 Application 7: DC and Nyquist are not doubled

Use $N = 16$, a rectangular window and the constant record $x_n = 0.002\ \mathrm{V}$. Then $X[0] = 0.032\ \mathrm{V}$ and $Q[0] = \backslash(\frac{0.032}{16}\backslash)^2\ \mathrm{V}^2 = 4 \times 10^{-6}\ \mathrm{V}^2$. The alternating record $x_n = 0.002(-1)^n\ \mathrm{V}$ gives the same mean square entirely at the Nyquist bin. Both bins retain their two-sided values in the one-sided sum. Doubling either would introduce a factor-of-two error, 3.01029996 dB. Removing the mean first would eliminate the DC example: that changes the processed measurand rather than correcting its normalization.

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9.3.4.8 Application 8: Window position changes transient energy

For $N=16$ with periodic Hann weights, $S_2=6$. A single 1 V sample among fifteen zero samples has unweighted mean square $\frac{1}{16}\ \mathrm{V}^2=0.0625\ \mathrm{V}^2$ regardless of location. At $n=0$, the Hann weight is zero, so its windowed density integrates to zero. At $n=8$, the weight is one, so the integral is $\frac{1}{6}\ \mathrm{V}^2\approx 0.16666667\ \mathrm{V}^2$. Both outcomes satisfy 9W3. Neither is a contradiction of Parseval's identity. A single window can therefore miss an edge impulse completely; an acquisition strategy must address temporal coverage separately from spectral normalization.

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9.3.4.9 Application 9: Colored covariance changes an ordinate, not energy closure

Take $N=8$, $f_s=800\ \mathrm{Hz}$ and rectangular weights. Specify stationary covariance $R_{nm}=\left(\frac{3}{5}\right)^{|n-m|}\ \mathrm{V}^2$, realizable by a stationary first-order process with coefficient $\frac{3}{5}$ and innovation variance $\frac{16}{25}\ \mathrm{V}^2$. At DC,

$\mathrm{E}\,|\,X[0]\,|^2=[8+2\sum_{h=1}^{7}\backslash(8-h\backslash)\left(\frac{3}{5}\right)^h]\ \mathrm{V}^2=\frac{1923904}{78125}\ \mathrm{V}^2$. Hence

$\mathrm{E}\,D_2[0]=0.003847808\ \mathrm{V}^2/\mathrm{Hz}$. The white assumption with the same variance would give $\frac{1}{800}\ \mathrm{V}^2/\mathrm{Hz}=0.00125\ \mathrm{V}^2/\mathrm{Hz}$, lower by a factor of 3.0782464. Summing the expected density across all eight bins with 100 Hz spacing still gives 1 V^2. A correct integrated level alone cannot establish a white spectrum.

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9.3.4.10 Application 10: A valid density can coexist with undefined coherent normalization

Choose four weights (1,−1,1,−1) at $f_s = 400\ \mathrm{Hz}$. They have $S_1 = 0$ and $S_2 = 4$. For unit-variance white samples, $\mathrm{E}\,|\,X_w[k]\,|^2 = 4\ \mathrm{V}^2$ and $\mathrm{E}\,D_2[k] = \frac{4}{400 \times 4}\ \mathrm{V}^2/\mathrm{Hz} = 0.0025\ \mathrm{V}^2/\mathrm{Hz}$. Density normalization remains well-defined, while Q_2 and B_e in 9W2 involve division by zero. A constant complex tone at its coherent bin has zero response. It is therefore invalid to interpret this operation as an ordinary line-amplitude window using a numerical coherent-gain correction.

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9.3.5 Measurement consequence

A reproducible spectral result states the coefficient vector or its unambiguous generation convention, sample count, sample rate, transform length, preprocessing, side convention, ordinate units and power-conversion impedance. The worked examples use stipulated sequences and covariance models. They do not identify the origin of a field signal, validate a specific analyzer, or supply uncertainty bounds for an acquisition chain. Chapter 8's averaging treatment remains necessary when repeated noisy records are combined, and the existing coherence discussion addresses a different cross-channel question. Window normalization supplies neither of those conclusions by itself.

For a transient, the window-weighted spectrum describes the samples admitted to that estimator. It does not establish that the acquisition offered a usable observation of the event. Model 15A treats that separate opportunity through validated record windows and the required contiguous overlap. Model 10E determines which processed samples retain valid source dependencies across recording boundaries; Model 5A identifies a control-recovery exclusion when its local response assumptions apply. Establish those continuity and receiver-state conditions before interpreting a transient spectrum, and retain the actual spectral weighting rather than replacing it with the timing-window geometry.

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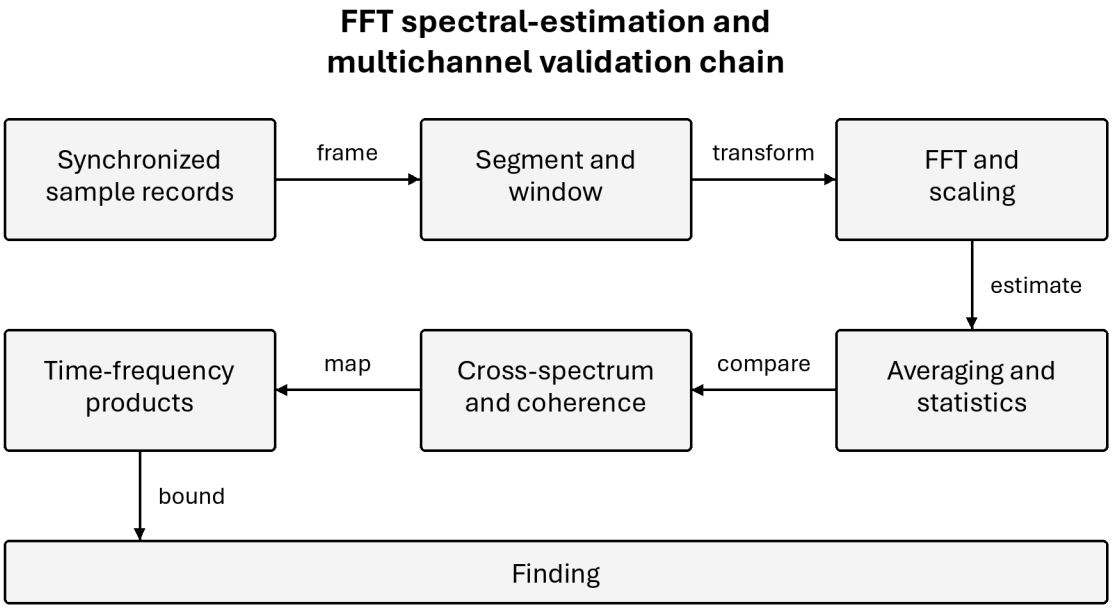

The original samples, analysis parameters, and channel calibration remain linked to every derived spectrum.

Figure 52. FFT spectral estimation and multichannel checks.

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9.4 Averaging and Statistical Stability

Linear power averaging reduces random variation for a stationary process, while vector averaging preserves coherent phase and can suppress uncorrelated components. Exponential averaging weights recent records more heavily. Peak hold and percentile displays answer different questions. The number of averages alone does not state effective independence when records overlap or the process is correlated.

Averaging can conceal intermittency and state changes. A weak burst repeated once in a hundred records may disappear in a simple average yet dominate a high percentile or max-hold result. Conversely, a coherent internal spur can become increasingly prominent under vector averaging. The analysis plan uses multiple summaries and retains the distribution of per-record measurements when probability of occurrence matters.

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9.5 Cross-Spectra, Coherence, and Multichannel Analysis

Cross-spectral methods compare two synchronized channels. A component common to both can be enhanced while independent receiver noise is reduced. Magnitude-squared coherence quantifies the fraction of output spectral power linearly related to an input under the measurement conditions. High coherence supports a relationship but does not prove causality, direction, or a unique physical path.

Phase and delay estimates require calibrated channel skew, common clock behavior, sample alignment, and stable geometry. Leakage, common power, shared references, and direct cable coupling can create coherence without an environmental field. Channel swapping, independent terminations, physical separation, and known injected references challenge those alternatives. Multichannel conclusions are reported with the synchronization and calibration residuals.

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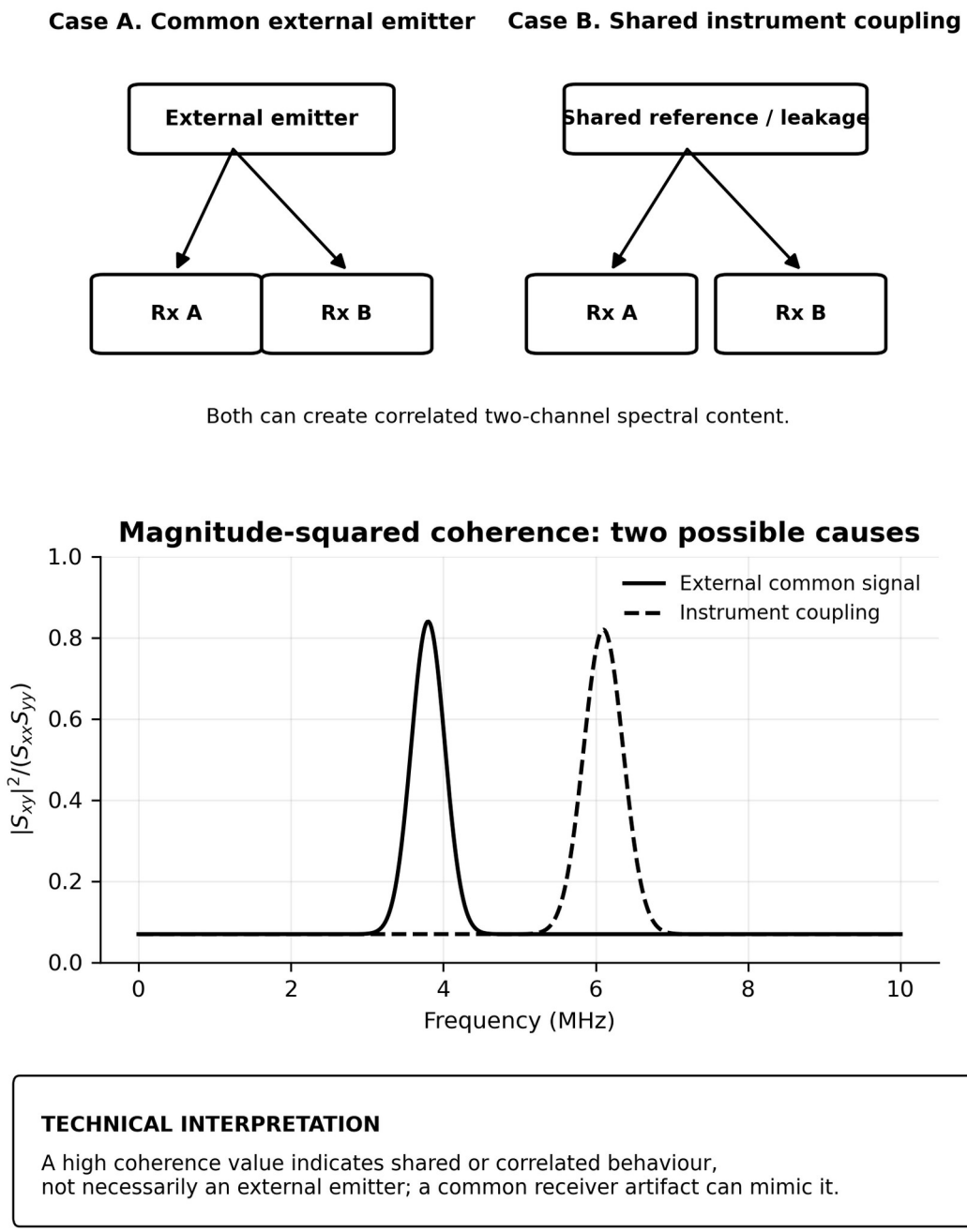

Figure 53. Coherence and the limits of source attribution.

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9.5.1 Define the ensemble before normalizing

Equation 18 concerns a relationship between channels, whereas the preceding window-normalization model concerns the scaling of one channel. At a fixed frequency bin, let X_r and Y_r be corresponding complex windowed Fourier coefficients from paired records $r=1,\ldots,K$. The samples must represent the same acquisition times after declared alignment and preprocessing. Suppose x is voltage in volts and y is current in amperes. Define nonnegative weights a_r summing to one and a common positive density normalization $d=\frac{1}{f_s S_2}$, where f_s is sample rate in hertz and S_2 is the window squared sum from 9W2. For an interior positive-frequency bin of real records, use $d=\frac{2}{f_s S_2}$ consistently in all three spectra. All numerical applications below are hypothetical. Define the paired spectral estimates by

$$P_{xx}=d\sum_{r=1}^{K} a_r \left|X_r\right|^2$$

$$P_{yy}=d\sum_{r=1}^{K} a_r \left|Y_r\right|^2$$

$$P_{xy}=d\sum_{r=1}^{K} a_r X_r^{*} Y_r$$

$$C=\frac{\left|P_{xy}\right|^2}{P_{xx}P_{yy}} \quad (9C1)$$

The autospectra have units V^2/Hz and A^2/Hz, and the cross-spectrum has units V A/Hz. C is dimensionless. If both channels measure voltage, replace amperes with volts throughout. Require positive P_{xx} and P_{yy}; a zero denominator makes C undefined, not zero. The asterisk means complex conjugation. Our P_{xy} convention conjugates X, matching SciPy's

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documented cross-spectral estimator. Nelson, Hati and Howe instead describe $X Y^*$. Conjugating the whole cross-spectrum reverses its phase but leaves C unchanged. A delay claim must state which convention was used.[8]

Apply Cauchy–Schwarz to vectors $\sqrt{a_r} X_r$ and $\sqrt{a_r} Y_r$. Their squared inner-product magnitude cannot exceed the product of their squared lengths; multiplication by d^2 gives $|P_{xy}|^2 \le P_{xx} P_{yy}$. Hence $0 \le C \le 1$ for these paired, consistently weighted estimates. Equality holds when $Y_r = H X_r$ for one complex scalar H on every positive-weight record, provided neither vector vanishes. Independence between records is not needed for this algebraic bound. Independence, stationarity, overlap and record selection do matter for statistical uncertainty. A large record count is not a substitute for establishing effective independent information.

The order of operations is essential. Average complex products first, then square their magnitude. Do not average the per-record normalized magnitudes: each nonzero single-record ratio is identically one. Nor may one estimate the three spectra from different retained records and assume that the bound survives. The displayed coherence is an estimator conditioned by these processing choices; it is not an intrinsic probability that a transmitter caused a receiver output.

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8 Keysight Technologies, Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide, part N9069-90001, edition 1 (March 2016), 10–11, 73–81, especially “Using Loss Compensation” and “Setting Temperature of Loss,” https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf. This identified edition supports the stated measurement controls, not a claim about every current analyzer.

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This bound applies to a common nonnegative weighted mean, not automatically to separately chosen robust summaries. For example, take three paired voltage coefficients $X = \(1, 10, 0\)\ \mathrm{V}$ and $Y = \(10, 1, 0\)\ \mathrm{V}$ with $d = 1\ \mathrm{Hz}^{-1}$. The three X autospectral products are \(1, 100, 0\), the Y products are \(100, 1, 0\), and the cross-products are \(10, 10, 0\), all in V^2/Hz. Separate medians give autospectra 1 and 1 but cross-spectrum 10, so their substituted ratio is 100. Common mean estimates instead give autospectra $\frac{101}{3}$ and cross-spectrum $\frac{20}{3}$, hence $C = \frac{400}{10201} \approx 0.03921184$. A common positive bias correction cancels from either ratio. The failure is loss of a single paired Gram-matrix construction, not negative input weights or floating-point error. SciPy documents a median option for csd; selecting that option separately for the three spectra does not inherit the weighted-mean proof. This qualification does not claim that the coherence routine itself uses that median construction.

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9.5.2 The projection interpretation and its boundary

For a trial complex gain H, form the weighted residual density $J(H) = d\sum_{r=1}^{K} a_r \left|Y_r - H X_r\right|^2$. Expanding and completing the square gives

$$\hat{H} = \frac{P_{xy}}{P_{xx}}$$

$$J(H) = P_{yy} - \frac{\left|P_{xy}\right|^2}{P_{xx}} + P_{xx} \mid H - \hat{H} \mid^2 (9C2)$$

Thus $J_{\min} = P_{yy}(1 - C)$. $\hat{H}$ has units A/V for the example channels. This proves precisely the fraction interpretation: C is the fraction of the output spectral sum of squares explained by the best single complex gain at that bin under the stated weights. For ensemble spectra of a stationary linear system it has a corresponding second-order interpretation. For finite records it is a fitted relationship, and a perfect fit can occur for trivial reasons. It does not prove a causal direction, a unique physical path, statistical independence of the residual, or a valid extrapolation to other states.

If $Y = H X + N$ and the input and output disturbance have zero cross-spectrum, ensemble spectra give $P_{xy} = H P_{xx}$ and $P_{yy} = \left|H\right|^2 P_{xx} + P_{nn}$. Therefore $C = \frac{\left|H\right|^2 P_{xx}}{\left|H\right|^2 P_{xx} + P_{nn}}$. The associated output signal-to-noise ratio is $\frac{C}{1-C}$ only under this model. Noise in the measured input violates its premise. In particular, $X = S + U$ and $Y = H S + N$ with mutually uncorrelated components gives $C = \frac{\left|H\right|^2 P_{ss}^2}{(P_{ss} + P_{uu})(\left|H\right|^2 P_{ss} + P_{nn})}$. Several different noise allocations can produce the same C. No universal input-noise correction follows from coherence alone.

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Cross-channel cancellation is another limitation. If independent components S and D enter $X = S + D$ and $Y = S - D$, then $P_{xy} = P_{ss} - P_{dd}$ while both autospectra equal $P_{ss} + P_{dd}$. Equal component spectra give $C = 0$ although both physical components occur in both channels. This is the mechanism discussed by Nelson, Hati and Howe in their original cross-spectrum analysis. The manuscript example below is independently stipulated arithmetic, not a replication of their measurements.[9]

9 James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. Its historical radiometer thresholds are not adopted as acceptance limits for the present constructed receiver.

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9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization

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9.5.3.1 Application 1 One record cannot establish a relationship

At a selected bin let $X = \backslash(1 + j\backslash)\ \mathrm{V}$ and $Y = \backslash(2 - j\backslash)\ \mathrm{V}$, with any common $d > 0$. Then $|X|^2 = 2\ \mathrm{V}^2$, $|Y|^2 = 5\ \mathrm{V}^2$, and $X^* Y = \backslash(1 - 3j\backslash)\ \mathrm{V}^2$. Consequently $C = \frac{d^2 \backslash(1^2 + 3^2 \backslash)}{2d \times 5d} = 1$. The fitted gain is $\frac{1 - 3j}{2}$. Any nonzero pair permits such a fit. Reporting unity from this single pair supplies no evidence of repeatable coupling.

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9.5.3.2 Application 2 Average complex products before taking the magnitude

Use two equal-weight pairs $X = \backslash(1,1\backslash)\ \mathrm{V}$ and $Y = \backslash(1,-1\backslash)\ \mathrm{V}$. Set $d = 1\ \mathrm{Hz}^{-1}$ for these normalized coefficients. The autospectra are both 1 V^2/Hz; $P_{xy} = \frac{1-1}{2}\ \mathrm{V}^2/\mathrm{Hz} = 0\ \mathrm{V}^2/\mathrm{Hz}$ and $C = 0$. Each individual normalized ratio is one, whose average would also be one. The discrepancy is entirely the order of operations, not a numerical rounding issue.

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9.5.3.3 Application 3 Conjugation changes a delay sign

At $f = 1000\ \mathrm{Hz}$, stipulate $Y = \exp\backslash(-j2\pi f\tau\backslash)X$ with $\tau = 125\ \mu\mathrm{s}$ and repeatable nonzero input. Then $H = \exp\backslash(\frac{-j\pi}{4}\backslash)$, $\frac{P_{xy}}{P_{xx}} = H$ and $C = 1$. Under $X^* Y$ the phase is −45 degrees, yielding $\tau = -\frac{\arg\backslash(H\backslash)}{2\pi f} = 125\ \mu\mathrm{s}$ on the chosen phase branch. Under $X Y^*$ it is +45 degrees. A single-bin phase also allows integer-cycle delay ambiguities; the calculation alone does not determine an absolute propagation delay.

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9.5.3.4 Application 4 Fixed channel gains cancel from coherence

Take two voltage-channel spectra $P_{xx}=2\ \mathrm{V}^2/\mathrm{Hz}$, $P_{yy}=8\ \mathrm{V}^2/\mathrm{Hz}$ and $P_{xy}=2\ \mathrm{V}^2/\mathrm{Hz}$, so $C=\frac{4}{16}=0.25$. Rescale X by 3 and Y by $2j$. The new autospectra are 18 and 32 V^2/Hz and the new cross-spectrum is $12j\ \mathrm{V}^2/\mathrm{Hz}$. Thus $C=\frac{144}{18\times 32}=0.25$. The fitted gain and phase have changed. Coherence invariance does not make amplitude or phase calibration unnecessary, and a zero channel gain would destroy the denominator.

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9.5.3.5 Application 5 Calculate the least-squares residual

Let $P_{xx} = 4\ \mathrm{V}^2/\mathrm{Hz}$, $P_{yy} = 5\ \mathrm{A}^2/\mathrm{Hz}$ and $P_{xy} = \backslash(3 + j\backslash)\ \mathrm{V}\ \mathrm{A}/\mathrm{Hz}$. Then $C = \frac{10}{20} = 0.5$, $\widehat{H} = \backslash(0.75 + 0.25j\backslash)\ \mathrm{A}/\mathrm{V}$, and $J_{\min} = \backslash(5 - \frac{10}{4}\backslash)\ \mathrm{A}^2/\mathrm{Hz} = 2.5\ \mathrm{A}^2/\mathrm{Hz}$. Using the trial gain $H = 1\ \mathrm{A}/\mathrm{V}$ gives $J = [5 + 4 - 2\mathrm{Re}\backslash(3 + j\backslash)]\ \mathrm{A}^2/\mathrm{Hz} = 3\ \mathrm{A}^2/\mathrm{Hz}$. The excess 0.5 equals $4\left|1 - (0.75 + 0.25j)\right|^2$, checking the completed-square result. Half the spectral sum of squares is explained by this fit; half remains residual.

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9.5.3.6 Application 6 An SNR interpretation needs a noise model

Stipulate exact input observation, unit transfer gain, input spectrum 9 V^2/Hz and uncorrelated output disturbance 1 V^2/Hz. Then $P_{xx} = 9\ \mathrm{V}^2/\mathrm{Hz}$, $P_{xy} = 9\ \mathrm{V}^2/\mathrm{Hz}$ and $P_{yy} = 10\ \mathrm{V}^2/\mathrm{Hz}$, giving $C = \frac{81}{90} = 0.9$. The model's output SNR is 9, or 9.542425 dB, also $\frac{C}{1-C}$. A measured value of 0.9 without the exact-input and uncorrelated-output assumptions does not establish that SNR.

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9.5.3.7 Application 7 The same coherence does not locate the noise

Let $H=1$ and $P_{ss}=1\ \mathrm{V}^2/\mathrm{Hz}$. If $P_{uu}=P_{nn}=1\ \mathrm{V}^2/\mathrm{Hz}$, then $P_{xx}=P_{yy}=2\ \mathrm{V}^2/\mathrm{Hz}$, $P_{xy}=1\ \mathrm{V}^2/\mathrm{Hz}$ and $C=0.25$; the output SNR is 1. Instead let $P_{uu}=0\ \mathrm{V}^2/\mathrm{Hz}$ and $P_{nn}=3\ \mathrm{V}^2/\mathrm{Hz}$. Then $P_{xx}=1\ \mathrm{V}^2/\mathrm{Hz}$, $P_{yy}=4\ \mathrm{V}^2/\mathrm{Hz}$, $P_{xy}=1\ \mathrm{V}^2/\mathrm{Hz}$ and C remains 0.25, but output SNR is $\frac{1}{3}$. Applying $\frac{C}{1-C}$ to the first case would incorrectly infer $\frac{1}{3}$. Equal coherence has not identified where the disturbance entered.

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9.5.3.8 Application 8 Common source and direct path are observationally ambiguous

With independent unit spectra for S, U and N, take $X = S + U$ and $Y = 2S + N$. The spectra are $P_{xx} = 2\ \mathrm{V}^2/\mathrm{Hz}$, $P_{yy} = 5\ \mathrm{V}^2/\mathrm{Hz}$ and $P_{xy} = 2\ \mathrm{V}^2/\mathrm{Hz}$, so $C = \frac{4}{10} = 0.4$. These same second-order spectra arise from $Y = X + R$ with an uncorrelated residual spectrum $P_{rr} = 3\ \mathrm{V}^2/\mathrm{Hz}$. The first construction has a common latent source; the second is an alternative linear representation. No choice between those physical narratives follows from this spectral matrix alone.

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9.5.3.9 Application 9 Two shared sources can cancel

Use $X = S + D$ and $Y = S - D$ with uncorrelated component spectra $P_{ss} = P_{dd} = 1\ \mathrm{V}^2/\mathrm{Hz}$. Both autospectra are 2 V²/Hz, but $P_{xy} = 0\ \mathrm{V}^2/\mathrm{Hz}$ and $C = 0$. If P_{dd} instead equals 0.8 V²/Hz, both autospectra become 1.8, P_{xy} becomes 0.2, and $C = \frac{0.04}{3.24} = \frac{1}{81} \approx 0.01234568$. Low coherence therefore does not exclude components shared by the channels. Complex cross-spectrum inspection and changes to the coupling configuration address a different question from increasing the number of averages.

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9.5.3.10 Application 10 State mixing can erase perfect within-state coherence

Use four equal-weight records $X = \backslash(1,1,1,1\backslash)\ \mathrm{V}$ and $Y = \backslash(1,1,-1,-1\backslash)\ \mathrm{V}$. In either pair of same-sign states, $C = 1$, with fitted gain +1 or −1. Pooling all four gives $P_{xx} = P_{yy} = d\backslash(1\ \mathrm{V}^2\backslash)$, $P_{xy} = 0\ \mathrm{V}^2/\mathrm{Hz}$ and $C = 0$. If the positive-gain state receives total weight $\frac{3}{4}$ and the negative-gain state $\frac{1}{4}$, $P_{xy} = \frac{d}{2}\backslash(1\ \mathrm{V}^2\backslash)$ and $C = \frac{1}{4}$. The result depends on state weighting. State-conditioned reporting requires a defensible state rule specified independently of the desired result.

The paired-spectrum complex-gain projection and Model 7A share a least-squares structure, but their reference sets, weights, and normalization denominators serve different questions. Model 7A uses declared finite symbol references; the spectral treatment here uses the paired spectral quantities defined above. Do not substitute one error percentage for the other without preserving those definitions. Model 12A addresses deterministic timing and phase conventions, while Model 12B develops covariance-dependent coherent power under its stated assumptions. Its jointly Gaussian phase-vector requirement belongs to that particular coherent-power expression and is not an additional assumption for Equation 18.

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9.6 Time-Frequency and Nonstationary Methods

Short-time Fourier transforms divide a record into overlapping windows to show spectral evolution. Wavelets, filter banks, reassigned spectra, and cyclostationary methods can reveal transients, chirps, periodic statistics, and symbol timing. Their time and frequency resolution are linked, and postprocessing parameters can create apparent structure. A compelling image is not a substitute for a quantified detection rule.

Time-frequency products should be traceable to the original samples and analysis script. Color scales, thresholds, interpolation, and normalization affect what appears visible. The practitioner verifies important features in the raw record, with alternate window or segment lengths, and on held-out data. Results are described as processing-dependent estimates rather than direct photographs of the spectrum.

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9.7 Estimator Validation and Reporting

Spectral estimators are validated with known tones, noise, bursts, chirps, and multichannel references selected to exercise the method's intended use. The validation includes amplitude bias, frequency bias, leakage, noise statistics, time localization, overlap, and confidence under the actual record length. Processing parameters are frozen before evaluation on held-out data.

The report states whether results are single-record, averaged, cross-spectral, coherence-based, or time-frequency estimates. It identifies window corrections, excluded intervals, threshold selection, and the relationship between plotted color or amplitude and the physical quantity. Derived images remain linked to source samples and executable analysis.

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9.8 Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation

Equation 1. DFT bin spacing

$$\Delta f = \frac{f_s}{N}$$

Nominal frequency-bin spacing Δf equals sample rate f_s divided by record length N samples. Actual resolution also depends on window main-lobe width, signal-to-noise ratio, estimator, and observation duration.

Equation 2. Magnitude-squared coherence

$$\gamma_{xy}^2(f) = \frac{\left|S_{xy}(f)\right|^2}{S_{xx}(f)S_{yy}(f)}$$

Magnitude-squared coherence compares cross-spectrum S_{xy} with autospectra S_{xx} and S_{yy}. Values lie between zero and one for valid estimates. Bias, averaging, leakage, common references, and nonstationarity must be considered.

Equation 17 uses the record length when the transform length equals that length; zero padding changes the displayed grid without creating observation time. The finite-window treatment and its ten applications establish the amplitude and power normalizations. Equation 18 belongs to the paired spectral-estimate treatment and its ten applications; positive autospectra and the same paired records are required for its stated normalization.

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Table 1. Chapter 9 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Record and sample rate	N, f_s, trigger, time stamps, clipping, and gaps	Defines the data supporting every spectral estimate	A display export cannot reveal all acquisition defects
Window	Type, coherent gain, noise bandwidth, sidelobes, and scalloping	Controls leakage and amplitude correction	Different windows trade resolution against sidelobe suppression
Averaging	Power, vector, exponential, percentile, overlap, and record count	Changes variance and sensitivity to intermittency	Correlated records do not provide independent averages
Multichannel estimate	Clock, skew, phase calibration, cross-spectrum, coherence, and channel swap	Supports relationship and delay inference	Shared leakage or references can create false coherence

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9.9 Hypothetical Applied Calculation: FFT Analyzers, Windowing, Averaging, and Spectral Estimation

A 2.0 MS/s acquisition uses 131,072 samples, giving nominal bin spacing of about 15.26 Hz. Applying a tapered window with a main-lobe width spanning several bins means two components 20 Hz apart may not be resolved despite the bin spacing. Increasing record length improves nominal spacing but also lengthens the period over which stationarity is assumed.

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9.10 Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation

Hypothetical case. A line at 19.2 MHz appears in a room probe and a power-line current probe with coherence above 0.9. Swapping the probes between two isolated digitizers destroys the coherence, and an injected reference reveals a shared-clock leakage path in the original recorder. The original recorder therefore has a mechanism that can contaminate the paired measurement, so its high coherence does not establish coupling through the room. Any remaining room-coupling claim requires a comparison that preserves the declared measurement sensitivity and state while testing that path.

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9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation

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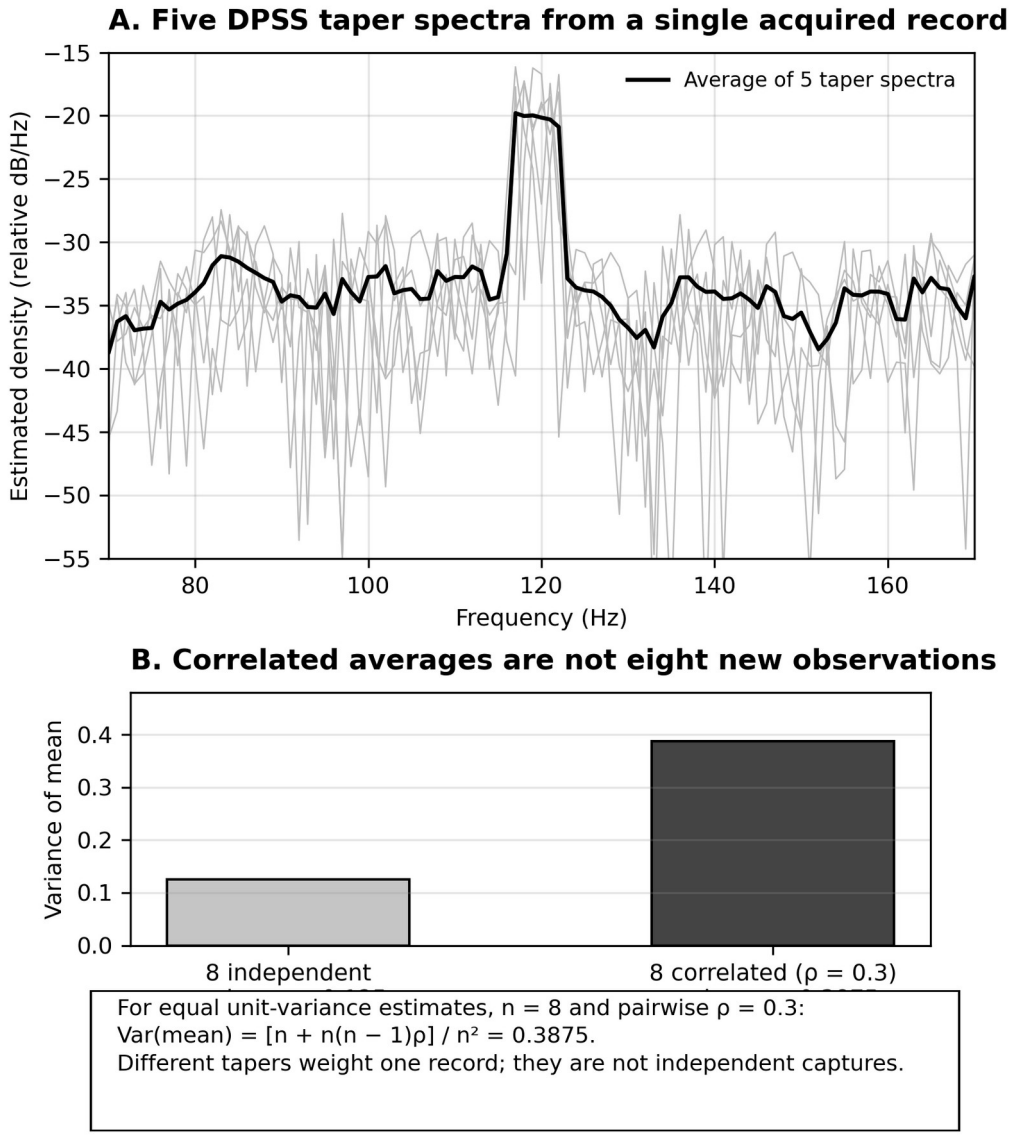

Figure 54. Multitaper spectra and estimator dependence.

A spectrum is an estimate conditioned upon a time record and an analysis operator, not a natural image of the electromagnetic field. If N complex samples x[n] are acquired at a valid uniform rate f_s, then a windowed transform X_w[k] = sum over n of x[n] w[n] exp(-j2 pi kn/N) reports the coefficients of the observed product x[n]w[n]. Its frequency-bin spacing is

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f_s/N, but the ability to resolve or quantify closely spaced components additionally depends on window response, effective observation duration, leakage and signal coherence. Zero padding can interpolate the sampled transform; it does not introduce new independent information about the underlying waveform. Treating an interpolated peak's many output digits as evidence of corresponding frequency accuracy confuses numerical representation with instrument uncertainty. The shared-record covariance example is illustrated in Figure 40.

Multitaper estimation addresses a particular weakness of using one taper by averaging spectra obtained from several orthogonal concentration windows over the same observation. The method can reduce estimator variability and leakage under appropriate stationarity and bandwidth assumptions, but each taper is a different mathematical weighting of the same acquired record. The resulting spectra are not independent field acquisitions, and confidence calculations must account for the taper design and statistical dependence. A rapidly changing intermittent burst can violate a stationary-spectrum model even when each taper is calculated correctly. The investigator should record the tapers, time-bandwidth product, number retained, normalization, overlap, sample gaps and any selection of favourable segments. It is particularly dangerous to discard windows in which an unusual emission does not fit a presumed spectral model, then claim sensitivity established from the survivors.

A quantitative example shows the independent-information trap. Imagine eight nominally equal-power spectral estimates, each with variance one squared power unit and equal pairwise correlation 0.3. The average's variance is [8 + 8(7)(0.3)]/64 = 0.3875 squared units, whereas independence

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would predict 0.125. Its standard deviation is approximately 0.6225 rather than 0.3536. This equicorrelation model is an educational illustration, not the covariance structure of any specific multitaper implementation. Its lesson is to estimate or justify the actual dependence. Adjacent overlapped windows, shared phase-noise processes and a common strong interferer can prevent nominal segment counts from translating into independent evidence.

The correct analysis should preserve the time-frequency support of the observation. When acquisition contains gaps or receiver retuning, do not compute one continuous FFT by concatenating the surviving samples and pretending that missing physical time never occurred. Instead retain separate valid segments or a justified missing-data model. A robust spectral estimator can be cross-checked against a deliberately different taper and a second receiver path, but agreement is persuasive only when likely shared errors are challenged. The report should distinguish a statistic of the retained samples from the possibility of an unobserved transient in a discarded interval. This preserves the useful precision of spectral methods without allowing the algorithm to replace the evidence it was supposed to interpret.

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9.12 Spectral confidence intervals and why averaging is not the same as independence

An FFT produces coefficients determined by a finite sequence of samples, a window, a sampling rate and a normalisation. The numerical output is not a direct census of continuously existing electromagnetic amplitudes at labelled frequencies. A finite observation convolves the input spectrum with a spectral window, producing leakage and estimator bias. For a continuous sinusoid not located at the centre of an FFT bin, the apparent peak depends on its fractional-bin offset and the selected window. For a stochastic input, the periodogram is itself a random statistic whose variance may remain substantial even when the record length increases. The laboratory must therefore distinguish frequency resolution, amplitude accuracy and statistical precision; increasing the number of plotted bins by zero-padding changes interpolation but not the physical observation duration.

For a zero-mean stationary Gaussian process and an appropriate independent-segment idealisation, each properly normalised raw periodogram ordinate behaves as an exponential-like power statistic with variance equal to the square of its mean. Averaging K independent identically distributed such ordinates reduces that ideal variance by a factor K. Yet practical Welch processing often overlaps windows, and the resulting segment estimates are correlated. If their common variance is sigma squared and their cross-covariances are C_ij, the variance of the average is K^-2 times the sum of all K squared covariance entries. This identity should be the default reasoning tool for claimed noise-floor precision. The

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independent K^-1 simplification is earned by an actual covariance argument, not by the existence of K saved spectra.

Multitaper estimation uses several orthogonal concentration sequences designed to control leakage and variance for a specified frequency bandwidth and sample interval. Orthogonality of the tapers as vectors does not guarantee independent spectral estimates for every coloured or deterministic interference environment. The analyst must check the estimator assumptions, taper bandwidth, adaptive weights if used, and confidence interpretation. Strong isolated tones can contaminate neighbouring spectral bands, while nonstationary bursts violate the single stationary-spectrum premise over the full observation. A reported confidence interval around a smoothed estimate may quantify estimator variability under a model while excluding model bias, receiver overload and missing time coverage entirely.

A controlled comparison can make the distinction concrete. Consider K = 12 equal-quality segment power estimates, each with variance 9 squared arbitrary units, and assume equal pairwise correlation rho = 0.2. Their average variance is 9[1 + 11(0.2)]/12 = 2.4 squared units. Under independence it would be 9/12 = 0.75. Thus the standard-deviation ratio is sqrt(2.4/0.75), approximately 1.789. The example's equicorrelation assumption is artificial and must not be transferred to any particular implementation; its purpose is to show that overlapping or shared-noise observations can substantially weaken the improvement inferred from file count alone. An honest measurement report documents the basis of its covariance or effective-degrees-of-freedom estimate.

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Cross-spectral techniques add another nuance. Coherence between two channels may reveal a shared deterministic or stochastic component, but a shared acquisition clock, power-supply disturbance or digital reference can produce coherence without an external RF emitter. The instrument should record cross-spectra and phase conventions at declared reference planes, then compare paths in which suspected common-mode errors change. Averaging spectra in power units is appropriate for specified average-power targets; averaging complex amplitudes can destroy a phase-incoherent signal or enhance a phase-locked one. Neither operation is inherently superior without a defined measurand. A narrow candidate appearing in several derived transforms from the same raw samples is not independent corroboration.

Missing samples create a separate class of error. Concatenating valid pieces of a record without representing the missing physical time changes the sampling law and can produce incorrect spectral interpretation. Zero-filling gaps creates yet another window with its own leakage, and can falsely suggest that the input was zero during unobserved intervals. Preserve a binary validity mask or an equivalent segment register. Compute spectra on justified valid intervals, or employ an explicit missing-data model whose assumptions are tested with known signals. The released result should identify what the retained data support and which unobserved events no spectral estimator can reconstruct without additional assumptions.

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9.13 Advanced technical expansion. Spectral-estimator confidence beyond a clean FFT display

A discrete Fourier transform provides a representation of retained samples, not a unique description of the original electromagnetic field. The physical measurement requires an acquisition record, an analogue anti-aliasing response, an effective sample clock, a window, a normalisation convention and an estimator whose statistical properties are understood. For N samples x[n] and a deterministic window w[n], a windowed transform X[k] = sum from n=0 to N-1 of x[n] w[n] exp(-j2 pi kn/N) preserves a clear mathematical relation between the stored sequence and the reported bins. It does not establish that a sinusoid necessarily falls at a bin centre or that an observed bin is attributable to an external emitter. The digital frequency axis also assumes the actual sampling interval. If the converter clock was different from the nominal setting, a spectrally sharp display can have a wrong physical-frequency calibration while retaining entirely correct FFT arithmetic.

Amplitude estimation and noise-density estimation need different window normalisations. A coherent tone at a bin centre experiences the window's coherent gain, proportional to the sum of its coefficients, whereas white noise passes according to the sum of squared coefficients. The equivalent noise bandwidth of the window, expressed in bin widths, is N times sum(w[n]^2) divided by [sum(w[n])]^2, provided the coefficient sum is nonzero. A rectangular window has an equivalent width of one bin under that convention, but other windows generally trade a wider equivalent noise bandwidth for reduced sidelobe leakage. A report that applies the coherent-gain correction to random noise without the corresponding power

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normalisation can be wrong even when its displayed trace looks plausible. Both correction factors must accompany the reported quantity.

For a simple numerical experiment, consider a 4,096-point transform at a true sample rate of 4.096 MHz, giving bin spacing exactly 1 kHz. A 100.0-kHz continuous tone corresponds to the hundredth bin; a 100.3-kHz tone falls between bins and distributes energy according to the chosen finite window. The presence of power in several bins does not by itself establish several transmitted components. Conversely, a strong tone's sidelobes can conceal a weak neighbour. The measured peak of the windowed transform therefore cannot be interpreted as absolute power without accounting for leakage, coherent gain, overlap with other components and the actual amplitude reference plane. The values in this example are stipulated for explanation; they are not recordings from a receiver.

Averaging periodograms reduces the variability of a suitable spectral estimate when successive data segments carry sufficiently independent information. Overlapping segments do not automatically create independent averages. If the jth segment estimator has covariance with its neighbours, the variance of the mean includes all cross-covariances divided by the square of the number of segments. Merely doubling the number of overlapped FFT frames may produce a smoother plot without halving variance or creating twice the observational evidence. Welch processing is useful when its window, overlap and estimator are declared; multitaper processing can reduce leakage sensitivity through several orthogonal concentration windows, but its statistical interpretation depends on the taper eigenvalues and signal class. Neither technique is an unrestricted cure for nonstationary bursts or receiver artefacts.

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Cross-spectral analysis can help distinguish common signals from channel-specific noise, but coherence also has failure modes. Two receivers sharing a local oscillator or digital processing artefact may exhibit strong cross-spectral coherence even when the source is internal to the measurement system. A common antenna feed may make the sensor outputs more dependent, not more independently corroborative. Magnitude-squared coherence is calculated from averaged cross- and auto-spectral estimates, and its bias and confidence depend on effective degrees of freedom. A high number cannot be interpreted sensibly without the signal and noise covariance and the measurement architecture that produced it. A controlled test with an independently injected reference, alternative clock or changed signal path can supply more information about physical origin than a raw coherence threshold.

The final measurement protocol should preserve raw samples, realised sample rate and clock source, FFT length, window coefficients, overlap rule, transform sign, normalisation, detector statistic, accepted records and every automatic rejection decision. Validate on synthetic records with known tones, adjacent blockers, impulses and gaps, then use physically measured references to challenge assumptions about analogue bandwidth and digitiser linearity. When a receiver cannot retain the raw samples, the report must identify which subsequent analyses are impossible and which estimates remain meaningful. Spectral-estimator elegance is not a substitute for a valid acquisition record and a falsifiable explanation of observed spectral structure.

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9.14 Thirty-hertz spectral resolution is a measurement design, not a guarantee of pulse detection

The manuscript must distinguish DFT bin separation from noise equivalent bandwidth, waveform resolving power and frequency-estimator precision. For N complex samples collected at rate F_s, a conventional N-point DFT has nominal bin spacing $\Delta f=F_s/N=1/T$, where $T=N/F_s$ is the uninterrupted observation duration. That identity fixes a time scale but not the point-spread function or sensitivity. Spectral leakage follows the selected window, coherent tones may fall between bins, and uncertain frequency drift smears energy during a long transform. A frequency estimator fitting a stable sinusoid may achieve standard uncertainty much smaller than one bin under sufficiently strong and appropriately modelled observations, whereas two uncalibrated pulse events separated by one bin cannot automatically be resolved as distinct emitters.

For white input noise from an approximately matched 290 K source, the conventional available noise spectral density is $10 \log10(kT/0.001\ W)$, approximately −173.98 dBm per hertz. A 30 Hz ideal rectangular noise bandwidth admits $-173.98+10 \log10(30)=-159.21$ dBm, before front-end loss, receiver-added noise and detector correction. A reported −170 dBm noise value needs a specified bandwidth and representation. A figure of −170 dBm/Hz can represent an input-referred spectral density for a low-noise receiver whose noise factor raises the −174 dBm/Hz thermal limit by roughly 4 dB. A display line at −170 dBm can also describe a signal estimate after coherent processing against a larger integrated noise background, but it cannot simultaneously be described as an uncorrected total thermal input-

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noise power at 290 K in a 30 Hz bandwidth. The distinction is an engineering requirement, not a semantic preference.

Thermal noise in a frequency channel is not the only limiting interference. At 40 GHz RF frequency, oscillator phase noise, nearby broadband interferers, image bands, converter spurs, ADC aperture jitter and lossy preselection may dominate. A 30 Hz analysis band may suppress broadband thermal noise yet remain vulnerable to a phase-noise skirt from a strong adjacent carrier. The appropriate model integrates a measured noise power spectral density through the actual filter and includes any deterministic or correlated terms separately. A laboratory terminated-input result is useful for the configured hardware, but a survey connected to an antenna sees a different source temperature, impedance and set of environmental emissions. A single global noise-floor label for a continuously distributed 0–40 GHz architecture is therefore inadequate.

Narrowband averaging must be assessed by its estimator. For independent, zero-mean measurement noise, a coherent integration of a known, stable complex waveform can increase detectability with observation time; a noncoherent power average reduces the variance of the noise-power estimate without necessarily reducing its physical mean. Averaging independent receiver output noise by cross-correlation can suppress uncorrelated internal components, but it does not eliminate common source noise, a coherent interferer or common clock-related error. Two channels driven by the same 290 K input termination can agree because they receive the same thermal realization; that agreement must not be misreported as discovery of a weak external emitter.

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Wideband detection must preserve a fast observation branch. An energy detector with submicrosecond time resolution should be evaluated with bandwidth and false-alarm rates appropriate to the pulse. A secondary slow branch can compute fine spectral summaries for stable lines and persistent emissions. Candidate triggers are linked to sample indices in a rolling raw I/Q buffer. The long-window spectrum can then support frequency refinement, while the time-resolved record supports pulse duration, repetition and intra-pulse modulation. Both branch results require validation in the presence of blockers and data gaps; neither can replace the missing input samples if they were not recorded.

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9.15 Numerical reality checks for resolution, noise density and detection

Application F9.1. At 290 K and 30 Hz ideal noise bandwidth, P=kTB=1.201×10^-19 watts and the level is about −159.2 dBm. A 3 dB receiver noise figure raises the equivalent input noise by about 3 dB under the matched reference convention, yielding −156.2 dBm in that 30 Hz band before other site contributions.

Application F9.2. −170 dBm denotes 10^-20 watt. Dividing by k times 30 Hz yields an equivalent input noise temperature of approximately 24.14 K. This is below room temperature and therefore cannot arise as uncorrected total noise from a conventional matched 290 K termination under the declared assumptions.

Application F9.3. A nominal −170 dBm/Hz density integrated over 30 Hz corresponds to −155.23 dBm, not −170 dBm. Confusion between per-hertz density and a thirty-hertz total changes the result by 14.77 dB.

Application F9.4. A 1,000 Hz white-noise measurement referenced to −174 dBm/Hz contains approximately −144 dBm of thermal noise. Narrowing the effective bandwidth to 30 Hz reduces the integrated power by 10 log10(1000/30)=15.23 dB under identical source conditions. It does not recover waveform components rejected by the narrower filter.

Application F9.5. A one-second complex recording with 100 million samples per second contains 100 million samples and 1 Hz nominal DFT spacing. A 30 Hz display can average or rebin that representation, but the extra duration does not imply a broader instantaneous RF input band.

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9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins

A multi-day spectral archive should be designed as a hierarchy of time-frequency observations, not as a single full-bandwidth waterfall file. For the stipulated forty gigahertz of simultaneous useful coverage, the nominal thirty-hertz frequency grid contains roughly 1.333 billion bins. Storing every bin in a sixteen-bit scalar format consumes about 2.667 decimal gigabytes for one complete frequency snapshot before any clock, calibration, validity or event metadata. One complete snapshot per second would therefore yield approximately 38.4 terabytes over four hours and 691.2 terabytes over seventy-two hours. A snapshot every ten seconds would reduce volume by a factor of ten but would also eliminate recoverable short-time ordering in the intervals between summaries. Neither policy is equivalent to archiving raw complex samples, and both require an explicit statement of how continuous observation, detector behaviour and loss are recorded.

A hierarchical solution can retain coarse time-frequency summaries for the whole fifteen-minute to seventy-two-hour run, fine-resolution spectra around occupied or suspicious areas, and short raw-I/Q segments where an event meets an authorised technical criterion. The layers should carry different decision purposes: low-rate summary for navigation through days of data, stable noise and calibration profiles for metrological interpretation, event-centred fine spectra for classification, and original complex samples for reprocessing or adversarial challenge. Selecting a period from the list of fifteen, sixty, two hundred and forty, four hundred and eighty, seven hundred and twenty, fourteen hundred and forty, eighteen hundred and

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four thousand three hundred and twenty minutes does not confer the same ability to reconstruct an unsaved pulse. The record must distinguish long-duration monitoring from long-duration raw waveform retention.

Sparse spectral recording presents a selection-bias problem. If bins are committed to long-term storage only when a trigger exceeds a threshold, an investigator examining the archive later will find a distribution enriched for large excursions. Treating that selected distribution as representative of the underlying noise law can create false occupancy estimates, distorted amplitude histograms or spuriously precise claims about emitter duty cycle. Preserve the detector threshold, background estimation history, hysteresis, event-coalescing behaviour, overload exclusions, and negative-test opportunities, and retain periodic or randomised control records independent of the event trigger. A non-triggered interval may be validly labelled no detector event meeting criterion C, but not no RF event of any physical kind.

The FFT response to a pulse depends upon its time of arrival and the analysis window. A thirty-hertz bin grid cannot supply thirty-hertz-independent assurance about a microsecond event; the event may excite a broad set of spectral bins and its energy may be diluted by the window length. A separate fast multiresolution path, including short-window transforms, pulse-energy statistics or suitable matched filters, must be available for event families the surveillance objective names. A GPU cannot reconstruct pulse phase and precise onset from averaged magnitude-only bins. If an event is identified later from a spectral summary, raw waveform preservation depends upon whether the rolling buffer still contains the source samples when the retrospective trigger fires.

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A useful long-duration archive index is ordered by acquisition sample counter, UTC time mapping and local oscillator/clock epoch, then by absolute RF frequency and receiver slice. This permits exact association of a coarse spectral anomaly with the original complex samples, subject to demonstrated buffer retention. The frequency-time map must include missing acquisitions, ADC overload, calibration transitions, failed FFT buffers and detected source packets that arrived too late for preservation. Signal extraction then proceeds by searching a small number of candidate intervals and verifying their original sampling context. That approach limits petabyte ingestion without mistaking selective storage for universal capture or treating a pretty waterfall as a complete forensic record.

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9.17 The spectral measurand: differentiating a line, a density, a band power, and a probability of observation

The central intellectual difficulty of advanced spectrum analysis is not the Fourier transform itself. It is the choice of the quantity which the Fourier transform is being asked to estimate. A laboratory operator may use the same graphical axis to display the amplitude of a narrow coherent carrier, the mean power in a resolution filter, a one-sided power spectral density, the integrated energy of a brief emission, a channel-occupancy statistic, or a maximum value accumulated across many acquisition intervals. Those quantities are not interchangeable. Their units, estimators, uncertainties, and validity conditions differ. When an instrument reports a single ordinate in dBm, the reader must ask whether it refers to power in a nominal filter, total power from a calibrated tone, or an integrated result corrected for equivalent noise bandwidth. The answer depends on the physical measurement architecture and on the detector selected. A source can be weak in band-integrated power yet conspicuous in a narrow-resolution display; conversely, a signal that is strong in peak amplitude can have little average power when its duty factor is small. The first responsibility of an expert is therefore to define the measurand in words, mathematical notation, reference plane, and time interval before invoking a spectral estimator. [C9-01; C9-02; C9-18]

Let x[n] denote N complex baseband samples acquired at sample frequency f_s samples per second, and let w[n] be a finite window. Define X_w[k] as the sum, for n from zero to N minus one, of x[n]w[n]exp(-j2πkn/N). A discrete spectral ordinate is a complex projection of the observed record; it is not by

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itself a physical power density. For a resistance-referenced voltage recording, an appropriate normalization must incorporate the voltage calibration, the load or reference resistance, sample frequency, and window energy. If the digitised values are already power-wave quantities, the normalization changes accordingly. A narrowband sinusoid and a stationary random process require different denominators: line amplitude involves coherent gain $G_c = \mathrm{sum}(w[n])/N$, whereas white-noise density depends on $\mathrm{sum}(w[n]^2)$ and f_s. To quote a line-calibrated amplitude spectrum as though it were a density spectrum is to confuse coherent accumulation with incoherent energy. To sum line-calibrated bins and call the result total noise power is equally hazardous, particularly after overlapping windows or averaging. A manuscript that teaches spectral analysis at postgraduate level must make this distinction unavoidable. [C9-03; C9-20; C9-23]

For a one-sided power spectral density, the factor of two applied to positive-frequency interior bins requires special care. DC and, when N is even, the Nyquist-frequency bin are not duplicated. Complex analytic or complex baseband data ordinarily retain a two-sided spectral convention unless a specific one-sided transformation is defined. The effective noise bandwidth $B_e = f_s\, \mathrm{sum}(w[n]^2)/(\mathrm{sum}(w[n]))^2$, expressed in hertz, describes the relationship between a window's coherent response and the white noise admitted to its spectral estimator. These expressions presume that the window sum is nonzero and that the quantities being transformed have been calibrated in compatible units. A coherent-gain correction may become ill-conditioned for some specially constructed filters or differenced records; it is not a licence to divide by a near-zero number. In a forensic report, every figure should therefore state whether it presents amplitude, power, or

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density, what one-sided convention was used, and whether the display has been corrected for gain and effective bandwidth. [C9-18; C9-20; C9-23]

A further complication arises when the signal is intermittent. An FFT applied to a ten-millisecond window containing a half-millisecond burst does not estimate the same physical quantity as a window drawn entirely from inside that burst. The former may describe energy accumulated across a longer observation, while the latter may describe the spectral character of the active state. Neither is inherently superior, but their conclusions must be framed differently. The investigator should preserve the start sample, stop sample, trigger event, discontinuity mask, and relationship between the local record clock and the stated time origin. If those fields are missing, no amount of elegant frequency-domain processing can retrospectively reconstruct precisely when the emission was present. The estimate remains scientifically interesting yet evidentially limited. [C9-02; C9-10; C9-26]

Consider three observations of the same nominal 146 MHz source. The first is a narrow line measured at -72 dBm with a detector appropriate for stable tones; the second is a channel-power result of -58 dBm over a declared 200 kHz integration; the third is a peak-hold value of -49 dBm accumulated during fifteen minutes of surveillance. The numbers do not disagree merely because they are different. They represent different estimands. A proper comparison begins by asking whether the signal was active during all three measurements, whether the integration bandwidth included modulation sidebands, whether the maximum detector selected rare bursts, and whether every result refers to the same antenna-terminal plane. Only then may one construct a common scale. The same principle applies to historical analog analysers and modern FFT instruments. The newer instrument is not

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automatically more truthful; it is capable of more elaborate operations whose meaning must be stated with greater precision. [C9-06; C9-07; C9-11]

An adequate scholarly report consequently records at least six contracts: the physical source and measurement boundary; the acquisition interval and its clock; the frequency-band and one-sided or two-sided convention; the selected window and normalization; the detector or averaging operation; and the uncertainty model under which a value is offered as evidence. When comparison is sought, a seventh contract is necessary: a mapping that makes the two reported measurands genuinely commensurable. Instrument screens are convenient interfaces, not substitutes for those contracts. [C9-18; C9-24]

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9.18 Window families as measurement decisions rather than decorative software choices

Windowing is frequently introduced as a remedy for leakage, but that formulation conceals the important fact that leakage suppression is bought with changes in coherent gain, equivalent noise bandwidth, main-lobe width, sidelobe pattern, and transient weighting. A finite record can be understood as an infinite record multiplied by a time-limiting window. In the frequency domain, the desired spectrum is convolved with the window transform; energy from one component is therefore distributed across spectral frequencies according to that transform. The analyst never observes a pure underlying spectrum without a measurement kernel. The rectangular window gives a relatively narrow central lobe for a coherent sinusoid but substantial sidelobes. A Hann window reduces distant sidelobes at the cost of a wider main lobe and a greater white-noise bandwidth. A flat-top window improves amplitude stability under frequency-bin mismatch but sacrifices resolution and typically admits more noise. These are not mere software preferences. They determine which signals are distinguishable and which amplitude claims are defensible. [C9-03; C9-20; C9-23]

To see the practical implications, imagine a weak spectral line a few kilohertz away from a strong carrier. The problem is not simply whether the weak line lies on a different nominal FFT bin. The strong carrier's window sidelobes may dominate the very part of the spectrum where the weak line would otherwise be visible. A window with more sidelobe suppression could uncover the weak line, while a narrower window might distinguish two

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comparable carriers whose separation is barely larger than a bin. Choosing one window to optimize both tasks may be impossible. A mature procedure states which error is more costly: failing to resolve adjacent equal-power signals, losing a weak signal beside a strong interferer, or estimating the amplitude of a sinusoid whose exact frequency is unknown. Each goal implies a different weighting of main-lobe and sidelobe behaviour. [C9-20; C9-22; C9-23]

The coherent-gain correction is $G_c = (1/N)\mathrm{sum}(w[n])$, whereas the equivalent noise bandwidth is $B_e = f_s\, \mathrm{sum}(w[n]^2)/(\mathrm{sum}(w[n]))^2$. These measures should be computed from the actual sampled window coefficients, not copied uncritically from a convenient reference table. A symmetric N-point Hann window and its periodic counterpart differ at the endpoints, which produces measurable differences at small N. A library that silently changes its convention can invalidate an exact reproduction of a historical data product. Recording the formula, number of points, coefficient precision, and relevant software version is therefore part of the measurement. A laboratory should retain a short test vector of a coherent tone, an off-bin tone, and stationary synthetic noise, together with expected results. If a software change alters the numerical answer, the operator has an immediate basis for investigating its cause. [C9-18; C9-23]

Scalloping loss describes the change in a line's indicated amplitude as its frequency moves relative to the DFT grid. For an uncorrected rectangular window the worst half-bin offset produces a familiar attenuation approaching 3.92 dB in the long-record idealisation. That figure is not a general statement about every detector, every interpolation scheme, or every subsequent amplitude correction. A peak-interpolated estimate can

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perform differently; a flat-top window is designed to be much less sensitive to bin-centre placement. In the presence of noise, however, interpolation also changes estimator variance and selection bias. One cannot simultaneously promise unbiased peak selection, arbitrarily fine frequency resolution, and zero statistical cost merely by adding more displayed FFT points. Zero padding samples the same continuous windowed transform at more frequency coordinates; it does not lengthen the underlying acquisition record. [C9-03; C9-04; C9-20]

A second window issue is often neglected: weighting changes the temporal importance assigned to events. A burst near the centre of a Hann-weighted record contributes much more to the result than the same burst near an endpoint. This is sensible when the intention is to reduce leakage for an approximately stationary process. It is potentially misleading when the task is to compare short emissions at unknown times. Moving the frame by a small amount may change the indicated peak dramatically, even if the physical emission is perfectly repeatable. A robust transient procedure archives the unwindowed samples, repeats analysis at several time positions, and reports the selected window explicitly. If a feature is found only after trying dozens of frame positions, the selection procedure must also enter the statistical interpretation. [C9-10; C9-18]

The original contributions of Harris and the subsequent practical work by Heinzel, Rüdiger and Schilling help establish a disciplined sequence. Identify the signal model; evaluate leakage hazards; determine amplitude or density calibration; compute coherent gain and equivalent bandwidth; estimate loss and bias; and test the implemented code against known signals. The result should be a stated measurement rule, not an incantation to use a favourite

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window because it looks tidy. In a safety-critical or evidential context, the choice must remain reconstructable after the original operator has left the laboratory. [C9-20; C9-23]

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9.19 FFT frequency resolution, physical time, and the illusion of finer displays

The relation $\Delta f = f_s/N = 1/T$, where $T = N/f_s$, is basic but persistently misunderstood. It specifies the spacing of DFT samples for a record of duration T, not an unconditional guarantee that two arbitrary sinusoids separated by Δf can be resolved. The shape and width of the window response, signal-to-noise ratio, phase relationship, coherent frequency offset, and detector design all matter. When the record length is doubled while the sample rate is held constant, the nominal FFT spacing is halved and the measurement integrates over twice as much time. When only the zero-padded transform length is doubled, the displayed grid becomes finer without changing the temporal aperture or the underlying information. A responsible figure caption distinguishes these operations. [C9-04; C9-06; C9-18]

A claim of 30 Hz spectral resolution therefore begins with a measurement design. An FFT of 33.333 ms of contiguous data yields nominal bin spacing near 30 Hz. The selected window usually broadens the main lobe beyond that spacing; filter-equivalent and density conventions must also be declared. To detect a brief event lasting 100 microseconds while preserving that 30 Hz spacing, the investigator confronts a conflict between the long observation necessary for narrow spectral bins and the short temporal support of the event. The event may occupy a tiny fraction of the window and become diluted when the output is normalised as a stationary amplitude. Triggered short-window analysis provides better temporal localisation, but it cannot preserve the same narrow-frequency information

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from that short event alone. The correct response is multiresolution analysis and bounded reporting, not an assertion that one FFT has magically achieved both aims. [C9-03; C9-10; C9-11]

This distinction is especially important when comparing a swept analyzer with an FFT processor. The swept instrument's nominal resolution bandwidth reflects its filter shape and settling; the FFT display's apparent spacing reflects the finite record, window, sampling and possibly zero padding. These can be made approximately comparable for a specified stable signal, but they are not automatically equivalent. A fair comparison should use a common source, input reference plane, detector objective, integration or dwell time, and amplitude correction. The operator may need to adjust the FFT window's equivalent noise bandwidth or the swept instrument's resolution filter to produce matched white-noise readings. The instruments can then be evaluated against the same physical question rather than against each other's marketing description. [C9-01; C9-02; C9-11]

Consider a record sampled at 4 MS/s. With N = 200,000 samples, the acquisition lasts 50 ms and the nominal spacing is 20 Hz. Increasing the transform length to 400,000 by appending zeros gives a displayed increment of 10 Hz; it does not improve the ability to separate physical lines by the factor implied by that display. Instead, acquiring 400,000 genuine consecutive samples at the same sample rate yields 100 ms of observation and a genuine 10 Hz native bin spacing. Those two processing histories must not be conflated. A laboratory that stores only the final plot, without N, f_s and the actual number of observed samples, may be unable to distinguish them later. [C9-04; C9-18]

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Another distinction concerns chirps and nonstationary oscillators. A 50 ms window can yield narrow bins for a stationary tone, yet a source whose carrier sweeps several kilohertz during that interval spreads energy across numerous bins. Treating the widened spectrum as an increase in transmitter noise may be mistaken. The signal might instead have coherent frequency motion. Time-frequency representations, phase unwrapping and instantaneous-frequency analysis can help, but each relies on its own bandwidth and noise assumptions. Narrower frequency bins do not preserve a source's instantaneous frequency trajectory unless the measurement method retains the relevant temporal information. [C9-10; C9-24]

The pedagogical rule is straightforward. Whenever a spectrum is described as high resolution, print the number of observed samples, the sample frequency, record duration, window family, equivalent bandwidth, transform length and whether padding was applied. Explain which physical discrimination task was tested. If those details are absent, the phrase high resolution is a visual description, not a metrological certification. [C9-20; C9-23]

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9.20 Welch averaging, overlapping records, and statistical dependence

Averaging individual periodograms is a powerful way to reduce the notorious variability of finite-record power spectral estimates. Welch's 1967 construction divides a record into shorter pieces, typically overlapping them, multiplies each by a specified window, calculates modified periodograms and averages the resulting powers. It exchanges some frequency resolution for more stable estimates. The method is ubiquitous because it is computationally straightforward and interpretable, but an important qualification is often omitted: overlapping records are not statistically independent merely because the program displays a separate FFT for each one. Their samples are shared, and their windowed estimates can be correlated. A confidence interval that assumes independent averages without testing that condition may be too narrow. [C9-19; C9-22; C9-24]

Let T_r denote the total available duration, L the segment length in samples, O the number of overlapping samples, and $H = L - O$ the hop size. The number of complete segments is $K = 1 + \mathrm{floor}((N_{total} - L)/H)$, provided N_{total} is at least L. This count is an accounting identity; it is not the number of independent statistical observations. Two adjacent Hann-weighted segments with fifty per cent overlap may share half their raw samples, although the covariance between their spectral estimates depends on window weights and the underlying process. For white Gaussian noise, the covariance can be studied analytically or with controlled Monte Carlo experiments; for coloured noise or bursty interference it may be markedly different. The effective degrees of freedom ν_{eff} should therefore be

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derived or validated for the actual averaging scheme before a chi-square interval is invoked. [C9-18; C9-19; C9-22]

A common mistake is to average decibels instead of linear powers. If P_i denotes a positive power estimate, $10 \log10((1/K)\text{sum}(P_i))$ is generally not equal to $(1/K)\text{sum}(10 \log10(P_i))$. Jensen's inequality explains the direction of the difference under the usual conditions. The logarithm of the arithmetic mean is at least the arithmetic mean of the logarithms. When a noise estimator averages logarithmic display values, the resulting number can carry a systematic offset from a mean-power estimate. An instrument may include correction functions, but the operator must identify them rather than assume the display's word average is unambiguous. Report averaging domain, detector, number of transforms, overlap fraction, and any bias correction. [C9-01; C9-02; C9-06]

For a worked numerical illustration, suppose twelve segments yield estimates fluctuating around a common noise density. The arithmetical average can suppress variation, but if adjacent segments share substantial samples, it would be misleading to report twelve independent spectral observations. If a conservative covariance analysis determines that the equivalent number is eight, the relative standard deviation of a simple mean based on exponentially distributed single-bin powers is closer to $1/\text{sqrt}(8)$ than $1/\text{sqrt}(12)$. The difference is not cosmetic when the resulting confidence interval governs a threshold decision. For a two-sided interval based on a chi-square approximation, the analyst must state the degrees of freedom, tail probabilities, and whether the assumptions of a stationary Gaussian process have been assessed. If interference bursts contaminate

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only two segments, the mean and interval may reflect a mixture of process states rather than one stationary population. [C9-18; C9-19]

One suitable laboratory exercise uses a reproducible synthetic complex Gaussian sequence with a fixed seed and known variance. Students estimate its power spectral density using nonoverlapping records, fifty per cent overlap, and seventy-five per cent overlap while holding the total observation time fixed. They compare empirical variance over many independent trials and the achieved frequency resolution. A further experiment inserts short bursts at controlled times and tests how much the estimate and confidence interval are altered. The experiment should be repeated for rectangular and Hann windows, because window weights change the covariance structure. The conclusion should include a table of effective rather than merely nominal averaging counts, together with the consequences for false-alarm decisions. [C9-18; C9-19; C9-23]

The forensic lesson is that displaying a smoother spectrum cannot by itself justify a stronger claim. Smoothing may reduce random fluctuations, conceal intermittent behaviour, and make dependent records look deceptively numerous. A defensible statement names the population, period of observation, method of averaging, independence assumptions and quantitative uncertainty. Whenever those conditions cannot be established, the result should be called a descriptive average rather than a statistically certified estimate. [C9-24; C9-26]

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9.21 Multitaper spectra, bias, variance, and the meaning of several views of one record

The multitaper method addresses the instability and leakage of spectral estimates through a carefully chosen family of orthogonal data tapers, commonly the discrete prolate spheroidal sequences. Thomson's construction exploits the concentration properties of these sequences so that several differently weighted estimates can be formed from the same finite record. An appropriately weighted combination can reduce variance while controlling spectral leakage, particularly when the underlying process is sufficiently stationary for the model to make sense. The point is not that the tapers manufacture independent physical measurements. Rather, they offer multiple nearly orthogonal projections of the same observation and a means of balancing bandwidth, bias and variance. Their apparent independence is limited by the actual process covariance and finite-sample conditions. [C9-21; C9-22; C9-18]

The time-bandwidth product NW governs the trade between spectral concentration and the number of useful tapers. It should be presented as a dimensionless design parameter, with N equal to the number of samples and W equal to a specified half-bandwidth in cycles per sample. A familiar practical choice uses approximately 2NW - 1 well-concentrated tapers, but this is a heuristic, not a universal rule for deciding how many independent claims can be made from the data. The eigenvalues of the discrete prolate spheroidal concentration problem describe the proportion of taper energy retained within the design band. At higher taper indices that concentration can deteriorate, allowing more leakage. Adaptive weighting may help, but it

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introduces further model assumptions that should be disclosed. [C9-21; C9-22]

A key virtue of the method becomes apparent beside a strong spectral line. A single rectangular or short Hann window can spread line energy across adjacent bins, masking a much weaker component. Multitaper averaging with carefully selected bandwidth can suppress some of that leakage while producing a more stable background estimate. Nevertheless, if the desired weak line lies inside the multitaper smoothing bandwidth of a strong line, the method can still blur the distinction. The correct question is not whether multitaper is better in the abstract, but whether a particular taper set and bandwidth provide acceptable bias and detection power for the specific spectral separation. The researcher should test with injected tones of known amplitude and frequency before relying on the method in a contested measurement. [C9-21; C9-18]

A practical verification should compare three outcomes from the same retained raw record: a Hann-window single periodogram, Welch-averaged periodograms, and a multitaper spectrum. For each output, provide the analysis bandwidth, coherent or density normalization, effective degrees of freedom, and controlled-injection recovery error. For a stationary white-noise simulation, record empirical variance over many independent seeds. For a coloured process, test whether the fitted background and taper adaptation distort a weak local line. For a short transient, move the transient through the record and quantify the sensitivity of each method to time location. A method that performs admirably on stationary noise may be a poor discovery tool for a rare emission. [C9-18; C9-21; C9-23]

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The statistical inference must also separate exploratory and confirmatory stages. If a researcher tries ten time-bandwidth products, several adaptive weights, many frequency ranges and different thresholds before selecting the most favourable picture, the selection is part of the experiment. A small nominal p value derived as though that final configuration had been fixed in advance is not reliable. A stronger protocol identifies a discovery set and an independent validation set, or uses a pre-registered method on an archived acquisition. Even where the measurement is not a formal hypothesis test, reporting all materially different processing choices helps a later reviewer evaluate robustness. [C9-21; C9-24]

The consequence for a technical textbook is a clearer doctrine of estimator choice. Multitaper belongs in the toolkit for stationary-spectrum inference and line detection, but its status as an advanced method does not excuse failure to specify the physical measurand, acquisition continuity, taper family, bandwidth, calibration and uncertainty. Every spectral estimator is an answer to a stated question under a set of assumptions. A disciplined investigator learns to move between methods without allowing their attractive graphical differences to decide which one must be true. [C9-18; C9-22]

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9.22 Transient-spectrum analysis, time gating, and the interpretation of spectrograms

Spectrum analysers increasingly combine frequency-domain measurements with time-domain selection. This is valuable because many RF systems do not transmit continuously: digital radios share channels in time, radar returns are pulses, control systems emit bursts, and faults may produce sporadic interference. Traditional sweep measurements can combine successive states into one trace without revealing that the state changed during acquisition. Time-gated spectral analysis narrows the interval from which samples contribute to the estimate. A gate can isolate one time slot of a repeating system, exclude an unrepresentative switching transient, or focus analysis on the interior of a pulse. It cannot, however, turn a poorly specified observation into a complete record of the source. The gate's origin, delay, duration, trigger uncertainty and edge effects must be preserved. [C9-01; C9-02; C9-10]

Suppose two transmitters alternately occupy a common channel, each for one millisecond. A swept analyser that visits frequencies over many alternations can display a composite spectrum. A gate synchronized to the first transmitter may isolate its signal under the condition that the slot timing is stable and the analyser observes enough repeats. A triggered FFT capture may instead analyse a particular slot directly, assuming that its instantaneous acquisition bandwidth covers the feature and its duration is sufficient for the desired resolution. If the slots drift or fail to repeat, an accumulated gated sweep may mix states unexpectedly. The operator should therefore specify whether the reported spectrum is based on

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repeated equivalent bursts or on one native time record. These are distinct types of evidence. [C9-01; C9-02; C9-04]

The short-time Fourier transform produces a sequence of windowed spectra whose centres progress through time. The spectrogram is a visualisation of a squared magnitude or power estimate as a function of time and frequency. Its time-frequency trade-off is not simply a graphics setting: a shorter window gives better localisation of rapid changes but broader spectral responses, while a longer window improves narrowband discrimination but smears temporal boundaries. Overlap can make the image look fluid while leaving its independent information essentially unchanged. A colour scale adds yet another transformation; logarithmic compression can reveal small components but can also distort intuitive impressions of relative energy. Captions should give time resolution, frequency resolution, overlap, colour quantity and dynamic range. [C9-10; C9-18; C9-23]

A spectrogram is often treated as a moving picture of an RF environment. That metaphor is helpful but dangerous. A pixel represents the result of a finite windowed computation, not an infinitesimal event. Energy may bleed into neighbouring time and frequency cells because of the analysis kernel. A narrow carrier switching on midway through a window can appear to have started earlier; a short pulse can occupy several frequency bins despite being narrowband in its instantaneous carrier. Conversely, an emission that lies outside the receiver's instantaneous capture band is absent from the spectrogram regardless of how alarming the outside world might have been at that moment. A properly described spectrogram is therefore a map of a

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particular acquisition and computation, not a universal chronicle of the ether. [C9-10; C9-11]

When the measurement concerns rare events, trigger strategy is part of the scientific method. An amplitude trigger can miss a weak frequency-specific spur hidden under broadband noise; a frequency-mask trigger may be more selective, provided the analyser processes the entire relevant instantaneous band without gaps and the event exceeds the specified duration and amplitude. Trigger thresholds create selection bias: events below the threshold will not enter the retained set, and the stored population therefore cannot be mistaken for the complete population of events. To estimate event rates, a separate account of monitored time, trigger dead time and excluded intervals is necessary. [C9-10; C9-12; C9-28]

A rigorous field record should preserve the complex samples when practical, the original spectrogram settings, an unaltered copy of the detection log, and a mapping from every analysis frame to input sample indices. A review script should be capable of recomputing selected frames and demonstrating the effect of alternative window lengths. If a finding depends entirely on a narrow colour-scale choice or one gate position, the conclusion should say so. The best forensic outcome is not necessarily the most persuasive image; it is a result that survives reasonable perturbations of an explicitly justified analysis plan. [C9-18; C9-26]

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9.23 Real-time spectrum analysis, overlapping FFT engines, and probability of intercept

The expression real time has become a technical selling point, but a scholarly treatment must replace marketing terminology with a testable acquisition contract. The practical distinction is not merely how frequently a spectrum graph is repainted. An analyser may present an impressive stream of visual updates while its processor discards samples between transform frames, or it may acquire continuously yet store only sparse derived summaries. The relevant questions are whether every sample in a specified instantaneous bandwidth is acquired, whether the digital processing can maintain that throughput indefinitely, whether triggering operates on all relevant samples, and whether the stored record retains enough information to reconstruct the detected event. Real-time bandwidth is the width of the frequency band over which these conditions hold under the stated instrument configuration, not necessarily the full tuning range printed on the instrument's front panel. [C9-10; C9-11; C9-28]

A mathematical expression for the overlap of consecutive Fourier records helps identify the limitations. Let N be the number of samples in each transform and H the hop length between successive transforms. The overlap fraction is $r = 1 - H/N$ for $0 < H \leq N$. For a sample frequency f_s, the nominal transform arrival rate is f_s/H transforms per second, assuming no scheduling gaps. A 1,024-sample transform operating at 102.4 MS/s with a hop of 256 samples produces 400,000 overlapping transform opportunities per second. This arithmetic does not alone establish uninterrupted input acquisition or a guaranteed event-detection threshold; the front-end filters,

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window weighting, analysis bandwidth, trigger algorithm, processing backlog and memory pathway must be considered. If a vendor specifies a minimum detectable duration for a particular resolution bandwidth and span, that specification applies to that stated configuration, not to all possible settings. [C9-10; C9-12; C9-30]

Probability of intercept deserves especially careful definition. The phrase can refer to a statistical probability under an assumed random event arrival process, or to a manufacturer's guaranteed detection criterion for events meeting specified amplitude and duration conditions. These are not equivalent. A randomly arriving burst may be detected with some probability determined by the ratio of observed to unobserved intervals when its onset is uniformly distributed and the receiver's duty cycle is stable. A guaranteed trigger statement requires stronger engineering assumptions. It must show that every qualifying event, regardless of arrival phase, lasts long enough to be detected under the actual window, overlap, threshold and instantaneous bandwidth. The Tektronix literature provides illustrative instrument-specific duration tables; a textbook must teach the logic of interpreting those tables rather than transplanting one model's values into a universal law. [C9-12; C9-30]

For a hypothetical periodic acquisition system, suppose a 1 ms observation is followed by a 3 ms blind interval. An instantaneous event with uniformly random onset and negligible duration has an approximate intercept probability of one quarter, under the stated simplifying assumptions. A longer burst that can intersect an observation window has a greater probability, but the calculation must account for its duration and the periodic boundary conditions. This idealised duty-cycle computation should

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not be confused with a real-time analyser that continuously samples a bounded band yet retains only events satisfying its trigger. In the latter case, the sampling duty cycle may be unity while the *reporting* duty cycle is selective. A complete claim requires both acquisition coverage and decision-rule coverage. [C9-10; C9-28]

Spectral persistence displays, sometimes called digital phosphor or density displays, accumulate counts or intensities corresponding to repeated spectral observations. Their principal value is that rare emissions can become visible as faint traces or density clouds which a conventional maximum or average display might conceal. Yet display persistence itself introduces an aggregation process. A colour intensity is meaningful only when its counting period, transform rate, amplitude binning, reference correction and normalisation are known. A density hotspot does not automatically provide the event rate per hour; it may reflect different dwell periods, gain changes or unequal acquisition coverage. If two sessions are to be compared, the operator must establish a common denominator of valid observation time and comparable instrument states. [C9-10; C9-12]

A robust validation exercise injects pulses of varying duration and amplitude into a terminated and calibrated RF path. The instructor specifies a fixed analysis bandwidth and a set of RBW and trigger configurations. Students record the fraction of deliberately injected events detected under each condition, then distinguish an empirical detection frequency from a manufacturer's guaranteed minimum-duration specification. They should also inspect false triggers caused by background fluctuations and compute the consequences of increasing trigger sensitivity. The exercise ends with a bounded acceptance statement: within a declared band, observation time,

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source range and detection threshold, the system intercepted a stated fraction of events of specified duration. It does not end with the assertion that no unseen transmitter could have escaped observation. [C9-12; C9-18]

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9.24 Spectral confidence intervals, model adequacy, and the danger of a single smooth curve

A periodogram estimate of power spectral density is a random variable, even when the underlying process is stationary. A plotted point is therefore not the spectrum itself; it is an estimate whose variability depends on the number of effectively independent observations and on the process distribution. Under a simplified complex Gaussian model, the squared magnitude of a single properly normalised Fourier coefficient behaves approximately like an exponential variable at many frequencies. Averaging independent periodograms can reduce variance, and a scaled chi-square approximation can yield confidence intervals. But the approximation requires assumptions about stationarity, independence, estimator bandwidth and sometimes asymptotic behaviour that must be stated. Colour, line smoothness or the absence of a visible error bar supplies none of those assumptions. [C9-18; C9-19; C9-24]

For ν effective degrees of freedom, the form ν S_hat(f) / S(f) approximately follows a chi-square distribution under the appropriate model. A two-sided confidence interval for the unknown S(f) is then constructed by dividing ν S_hat(f) by suitable upper and lower chi-square quantiles. The direction of the inequalities is important, and a student should verify it against a known tabulated case rather than rely on memory. The estimate S_hat(f) must be positive, and the degrees of freedom must represent actual effective information rather than the raw number of overlapping FFT frames. If confidence intervals are formed at thousands of frequency bins, simultaneous coverage and multiple-testing questions arise. A nominal 95

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per cent interval for each bin is not a guarantee that 95 per cent of an entire plotted curve lies within all displayed bounds at once. [C9-18; C9-22]

The difficulty intensifies for coloured noise. Adjacent frequency samples can be correlated by the window response, while the underlying power density may vary across the equivalent bandwidth. In that situation a simple white-noise model can understate bias, and an apparently narrow interval can be centred on a systematically inaccurate value. Instruments may also include detector corrections, smoothing, preselection, trace averaging and logarithmic conversion before showing a result. Each of those transformations can change the estimator's distribution. The aim of statistical verification is not to decorate a graph with standard errors but to establish whether its uncertainty statement corresponds to the actual calculation and physical process. [C9-18; C9-23]

A useful forensic example concerns an apparent weak line standing 6 dB above a fluctuating background. A peak selected because it is the tallest among ten thousand searched bins is not statistically equivalent to a pre-specified bin tested at one frequency. Even when every individual noise bin follows the assumed distribution, the maximum across many bins is expected to be larger than a typical one. The correct null model is the distribution of the selected maximum or a multiple-comparison procedure, not an unadjusted single-bin tail probability. If the analyst also varied window length, taper, threshold and time position until the line became conspicuous, the search space is larger still. Independent validation with a fresh acquisition and a fixed method is often more persuasive than an elaborate nominal probability calculated after the fact. [C9-18; C9-21; C9-24]

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Confidence in a spectral finding should also be stratified by the kind of claim. The presence of a spectral feature above the instrument's internal background may be established with modest evidence. Its existence at the antenna terminal requires calibration and external-state checks. Its assignment to an external transmitter requires receiver-artifact challenges and localisation evidence. Its attribution to a particular person, device or purpose requires an entirely different evidential chain. Statistical confidence intervals for power density are relevant to only the first parts of that progression. They are not an automatic bridge from a line in a plot to a forensic attribution. [C9-26; C9-27]

The recommended reporting standard therefore presents a primary estimate, the estimator family, effective bandwidth, actual number and dependence of records, chosen confidence method, validation tests, and any sensitivity analysis performed. It may also report a robust median or trimmed alternative for descriptive purposes, provided the difference in estimand is explained. Where assumptions fail, the analyst should resist producing a mathematically precise but conceptually fictitious interval. An honest range of plausible values, tied to stated calibration limitations and explicitly missing information, may be more scientifically useful. [C9-18; C9-24]

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9.25 Cross-spectral analysis, coherence, and causal restraint in multichannel measurements

Two measurement channels can observe related signals without establishing that one caused the other. The cross-power spectral density $S_{xy}(f)$ describes frequency-dependent joint second-order behaviour between $x(t)$ and $y(t)$. The magnitude-squared coherence $C_{xy}(f) = |S_{xy}(f)|^2 / (S_{xx}(f)S_{yy}(f))$ lies between zero and one for a physically valid ensemble spectral matrix, with appropriate qualifications for finite estimates and numerical roundoff. High coherence indicates a strong linear relationship in the analysed ensemble and band. It does not, by itself, distinguish direct coupling from a common source, reveal the propagation path, prove the signals originated at the same physical location, or establish that an emission was deliberate. [C9-18; C9-24]

The phase of a cross-spectrum can support a delay estimate when the channels share a coherent source and their relative phase responses have been calibrated. Under a pure-delay model $y(t) = x(t - \tau)$, the cross-spectrum carries an approximately linear phase term with frequency; the slope determines delay, subject to the sign convention chosen for conjugation. If cable lengths, sample-clock offsets, group-delay ripple or frequency-dependent front-end filters are not corrected, an apparent delay may be an instrument property. Moreover, phase unwrapping is not unique when the bandwidth is too narrow or signal-to-noise ratio is poor. A reported delay should therefore include frequency range, coherence support, phase convention, uncertainty and the channel calibration record. [C9-18; C9-25]

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Consider two receivers in adjacent rooms that show a similar narrowband signal at the same time. Their spectra may be correlated because a building-wide electrical system radiates into both channels, because a common antenna splitter connects them, because their oscillators share a spurious reference product, or because an external transmitter illuminates both positions. Coherence helps establish common temporal or spectral structure; it does not distinguish these physical alternatives automatically. A good challenge programme changes one path at a time, adds calibrated attenuation, inserts a known terminating load where authorised, varies independent reference clocks, and examines whether the correlation survives. If the signal disappears under a change that should affect only internal coupling, the original external-source theory requires revision. [C9-01; C9-10; C9-26]

The estimation method should preserve complex products until averaging is complete. Computing cross-spectral magnitude separately for each short record and then averaging magnitudes generally produces a different answer from averaging complex cross-spectral products first. The latter retains phase cancellation that is essential to a coherent relationship. Likewise, coherence based on one unaveraged Fourier pair can become trivially unity under certain definitions, giving the appearance of a perfect relationship without genuine replication. Independent or at least properly modelled ensembles are necessary. The textbook should teach students to distrust coherence numbers stripped of their averaging protocol. [C9-19; C9-24]

A valuable multi-instrument laboratory exercise begins with one calibrated signal generator feeding two known paths through a splitter. Students

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measure the complex transfer ratio, obtain a cross-spectrum and estimate relative delay. They then add a short length of cable, a filter with frequency-dependent group delay, and a small independent noise contribution. Finally, they repeat with the two inputs terminated and an independently observed environmental signal. They must explain what changed in magnitude, phase and coherence and what the changes do not prove. The expected written result is a table that separates instrument calibration, physical path, statistical estimate and causal claim. [C9-06; C9-18]

Multichannel claims become especially delicate when the observer combines samples taken at different times. A pair of receivers may be disciplined to a common frequency reference yet not aligned in sample epoch; a third system may be separately accurate in frequency but have an unknown phase history. Cross-channel spectral statistics without time alignment can be biased or meaningless for fast transients. A complete record therefore includes clock source, frequency alignment, sample-index offset, buffering delay, correction coefficients and the uncertainty of each. The existence of a common ten-megahertz reference alone does not establish coherent sampling. [C9-25; C9-28]

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9.26 Phase noise, close-in skirts, and the limits of interpreting narrow spectral features

A spectrum surrounding a stable carrier may contain phase-noise skirts, amplitude modulation, discrete reference spurs, intermodulation products and external signals. Distinguishing them requires a model that respects the instrument's own oscillator and conversion system. A swept or FFT spectrum analyser can introduce close-in noise through its local oscillator and sampling clock, sometimes obscuring a source's true performance. A narrow line close to a strong carrier may also arise from modulation or power-supply coupling rather than a second independent transmitter. Therefore, the phrase nearby emission is a description of the display, not an attribution. [C9-01; C9-06; C9-25]

For a sinusoidal carrier with small phase fluctuation φ(t), the single-sideband phase-noise function L(f) is often reported in dBc/Hz at positive offset f from the carrier, under a specified convention and small-noise approximation. The conversion between a phase-fluctuation power spectral density and L(f) depends on one-sided versus two-sided definitions. A student should never apply a factor of two or a decibel correction from memory without writing the adopted convention. Near the carrier, flicker processes, drift, finite acquisition duration and reference instability further complicate the assumption of stationary noise. NIST guidance on frequency stability provides the appropriate broader context for considering phase noise alongside Allan deviation and other time-domain measures. [C9-25; C9-24]

One elementary check uses the instrument's own floor. Terminate the RF input appropriately and observe the response under a valid self-noise

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condition. Introduce a stable known carrier at a safe level and measure the apparent skirt. Repeat using another source or reference arrangement, and change attenuation by a controlled amount. A residual that scales with the injected source may be external to one stage; a component that follows the analyser's frequency plan may be internally generated. None of these tests alone provides absolute proof, but their combined pattern can distinguish hypotheses. Particular care is required when increasing source power in an attempt to improve signal-to-noise ratio, because a strong carrier can drive nonlinear or reciprocal-mixing behaviour in the analyser itself. [C9-01; C9-06]

The use of phase-noise markers deserves its own uncertainty budget. A marker may integrate or estimate density across a filter whose equivalent noise bandwidth differs from its nominal resolution setting. It may remove or retain discrete spurs according to an undocumented algorithm. Its reported dBc/Hz value is meaningful only relative to a specified carrier power, offset frequency and density conversion. A report should record the instrument state and whether residual instrument noise was measured or subtracted. Subtraction in decibels is not a valid generic operation on powers; if subtraction is physically justified, the analyst must move to consistent linear quantities and propagate the associated uncertainties. [C9-01; C9-25]

A thought experiment shows the danger of visual certainty. Two oscillators have apparently identical close-in skirts on one analyser; a second instrument produces a different ordering of their phase-noise performance. The discrepancy could reflect different internal oscillator floors, correlation properties, measurement bandwidths or calibration. Before declaring one instrument defective, the analyst should compare the complete

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measurement chains and select a reference method capable of discriminating the oscillator under test from instrument limitations. For high-precision work, a dedicated cross-correlation phase-noise instrument may be more appropriate than a general-purpose spectrum display, but the comparison must still respect its statistical and calibration assumptions. [C9-06; C9-25]

Phase noise is thus a meeting point between instrument engineering and statistical signal processing. A beautiful close-in spectrum cannot rescue an unknown measurement configuration. The expert records the source and instrument contributions, frequency and time reference, offset range, density definition, estimation method and conditions under which the result ceases to be valid. [C9-25; C9-18]

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9.27 Noise-floor measurement, gain distribution, and the difference between a displayed floor and an environmental floor

The noise floor of a spectral display is not the minimum possible signal at the antenna. It is a result of input loss, internal noise, frequency filtering, detector choice, averaging, display correction and the source conditions during observation. In a properly calibrated matched system at about 290 kelvin, the thermal reference density is approximately -174 dBm per hertz. A first-order estimate of noise power in bandwidth B is $N_{dBm} \approx -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF$, where NF is the applicable noise figure in decibels and B is the equivalent noise bandwidth. The formula presumes a stationary thermal reference and appropriate impedance. Its simplicity is useful for hand calculations; its assumptions are frequently violated in field RF surveys. [C9-01; C9-02; C9-18]

For example, with an equivalent noise bandwidth of 1 kHz and a 12 dB receiver noise figure, the simplified internal reference floor is -174 + 30 + 12 = -132 dBm. A tenfold decrease in equivalent bandwidth should reduce white-noise power by approximately 10 dB, all else being equal. If the displayed floor does not behave that way, the cause may be external interference, coloured receiver noise, an offset introduced by a detector, gain compression, or a change in the instrument's auto-coupled configuration. The operator should not force the measured number to match the thermal approximation by arbitrary offsets; the discrepancy is valuable evidence about the measurement system. [C9-07; C9-18]

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An external low-noise amplifier can improve receiver-system sensitivity only if its gain and noise performance are understood in relation to losses preceding it and to the rest of the receiver chain. Friis's cascade relation quantifies this interaction for appropriate linear matched conditions. But greater gain can reduce blocker tolerance, allowing a strong out-of-band source to create intermodulation products that resemble weak in-band emissions. A preselector can suppress those blockers at the cost of loss; moving it before the amplifier can change the noise figure and compression balance. The optimal configuration therefore depends on both weak-signal sensitivity and the maximum plausible aggregate power, rather than the desired line alone. [C9-01; C9-02; C9-06]

Displayed average noise level, often abbreviated DANL, is typically defined under specified instrument conditions. It must not be transcribed into an environmental noise measurement without the appropriate antenna factor, cable loss, external gain, impedance, detector and bandwidth corrections. A portable antenna outdoors may receive atmospheric noise, broadcast signals and impulsive man-made interference that dominate the analyser's internal reference. In a shielded chamber, the same instrument may show primarily its own system floor. Both traces can be accurate descriptions of their respective systems, but they answer different questions. [C9-07; C9-26]

A strong laboratory procedure repeats noise measurements with a matched termination, with an approved calibrated noise source, with the actual antenna path, and with controlled changes to input attenuation. Each observation should record whether the front end was preamplified, the reference plane, the instrument temperature and the stability of the sample clock or local oscillator where relevant. The resulting report compares

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expected and observed noise changes in linear units and decibels. It also documents any discrete spurs or nonstationary impulses, since a single median-noise number may conceal precisely the phenomenon a TSCM survey seeks to understand. [C9-01; C9-18]

A negative result should finally be expressed as a bounded sensitivity statement. The investigator can report that no component exceeding a stated level under defined dwell, detector and bandwidth conditions was observed at the measured plane during a named interval. The result does not warrant a universal statement that no emitter exists, especially if the instrument swept intermittently, its input experienced compression, or the emission could have been outside the selected band. [C9-26; C9-27]

The numerical value labelled resolution bandwidth is not, by itself, the bandwidth that multiplies a white-noise spectral density. For a filter with power transfer response |H(f)| squared and passband reference f_0, define the equivalent noise bandwidth as B_ENBW = [integral |H(f)| squared df]/|H(f_0)| squared; the result is measured in hertz. The 3 dB bandwidth characterises a pair of amplitude-response points, whereas B_ENBW characterises admitted noise power relative to the stated reference gain. One documented family of near-Gaussian analyser filters has B_ENBW approximately 1.05 to 1.13 times its nominal 3 dB bandwidth. A nominal 10 kHz filter in that family therefore admits the same white-noise power as a 10.5 to 11.3 kHz ideal rectangular filter. That manufacturer- and implementation-conditioned range cannot be transferred automatically to a digital window, an EMI receiver or an arbitrary IF filter.

For the specified near-Gaussian filter family, a density calculation normalised to 10,000 Hz from observations made over 10,500 to 11,300 Hz

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uses the power correction 10 log10(10,000/B_ENBW), giving approximately −0.212 to −0.531 dB. The correction changes when the actual response departs from the assumed shape. It is conceptually distinct from the change caused by averaging a logarithmic envelope instead of linearly averaged power. Thus one must identify, in order, the analogue or digital filter response, detector statistic, order of averaging, gain calibration and final display transformation. A 2.5 dB logarithmic-noise correction is conditional upon the particular Rayleigh/Gaussian and detector model used in the relevant instrument guidance; neither that figure nor the bandwidth adjustment is a universal property of a trace labelled dBm.

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9.28 Multiple comparisons, threshold design, and weak-line detection in a searched spectrum

A spectrum search usually evaluates many frequencies, time intervals, antenna positions and instrument configurations. Even when the background model is correct, selecting the largest observed excursion creates a different statistical problem from testing one pre-registered frequency. This selection effect must be addressed whenever a claim relies on a weak peak near the noise floor. A rule declaring a detection whenever one periodogram ordinate exceeds a threshold will generate false alarms whose expected number increases with the number of effectively independent tests. Correlation between neighbouring FFT bins, overlap between time records, and searching different window functions complicate the count, but they do not make the issue disappear. [C9-18; C9-19; C9-24]

If a single noise-only test exceeds its threshold with probability α, then M independent such tests have probability 1 - (1 - α)^M of at least one exceedance. For α = 0.001 and M = 1,000 independent tests, the family-wise probability is approximately 0.632. Thus, a criterion that sounds very stringent per bin can become weak when applied to a large blind search. The independence assumption is deliberately simplified; it serves to reveal the scale of the problem. In real spectra, leakage couples nearby bins and may reduce the effective number of tests, while repeated choices of time windows, detectors and thresholds may increase the true search space. A defensible assessment should state which tests were planned in advance and how selection was handled. [C9-18; C9-20]

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A practical approach uses discovery and confirmation. The discovery phase may employ sensitive detectors, broad searches, multiple windows and adaptive analysis in order to find candidate signals. The analyst records the full discovery history and does not describe its resulting peak as an independently validated probability statement. The confirmation phase then fixes the frequency band, window, detector, threshold, sample duration and calibration before examining new data. If independent data are unavailable, the report should state the limitation and use appropriately cautious descriptive language. The distinction is particularly important when a weak line is later used to justify an intrusive investigative conclusion. [C9-18; C9-26]

Detection also depends on the target class. A continuous narrow carrier is well suited to long coherent integration if its phase and frequency are sufficiently stable. A frequency-hopping emission may require time-frequency search, greater instantaneous bandwidth and a detector that integrates a trajectory rather than one stationary bin. A short chirp has a different time-frequency footprint; a pulsed emission with uncertain occurrence time calls for windowed or triggered approaches that respect its duty factor. There is no universal best threshold without a target model and a cost assigned to missed detections and false alarms. [C9-10; C9-12; C9-28]

A rigorous synthetic exercise begins with a fixed noise model and a seeded pseudorandom generator. Students inject a line at a known frequency and amplitude into only some trials; they then run two detection algorithms over pre-specified windows. They construct empirical receiver-operating-characteristic curves relating probability of detection and false alarm, and assess sensitivity to record length, RBW, input attenuation and phase

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instability. Each class must distinguish the true positive rate measured under the laboratory model from the confidence that an unknown field signal has any particular provenance. Instrument detection is only one link in the evidentiary chain. [C9-18; C9-24]

Where regulatory or compliance thresholds are involved, the test configuration and acceptance limit may be specified by a standard rather than selected solely by statistical optimisation. The operator must then respect the required detector, bandwidth, dwell and test method. A research threshold that is excellent for discovery may not correspond to a legally defined compliance detector. Conversely, a compliance scan may not be optimised for finding the rarest weak emission. Reporting should identify the governing standard where applicable and separate its prescribed decision rule from exploratory spectral analysis. [C9-26; C9-29]

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9.29 Parametric spectral estimation: when a model buys apparent resolution

A conventional periodogram deliberately makes few assumptions about the observed process. Parametric spectral estimation proceeds differently. It supposes that the data are adequately described by a particular family of stochastic or deterministic models and then estimates the parameters of that family. In an autoregressive model of order p, the present value of a stationary sequence is expressed as a weighted sum of p preceding values plus a driving innovation. If the coefficients are a_1 through a_p and the innovation variance is σ_e squared, the resulting spectral density has the rational form $S_x(f) = \sigma_e^2$ divided by the squared magnitude of 1 minus the sum of $a_k \exp(-j2\pi fk/f_s)$. This formula may produce a smooth, sharply defined estimate using a comparatively short record. It does not create additional experimental observations. Its apparent precision depends upon the adequacy of the chosen model, its stationarity assumptions, the order p and the numerical conditioning of the estimation. [C9-24]

The elementary autoregressive estimator is often obtained through the Yule–Walker equations linking sample autocovariances to the coefficients. A least-squares estimate instead minimises one-step prediction residuals. Burg's method is a forward-and-backward prediction procedure that imposes a stable autoregressive structure under appropriate conditions; it can be useful for short records, but it is not immune to producing artificial narrow peaks when the model order is excessive. Levinson–Durbin recursion exploits the Toeplitz structure of the autocorrelation equations and gives an efficient route to successive model orders. All three

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approaches can return different spectra from the same finite record because they optimise different finite-sample objectives and handle boundary data differently. They must be reported with the model order, the covariance or prediction method, regularisation, residual diagnostics and stability test. [C9-24]

Moving-average models construct a stationary process by filtering an innovation through a finite impulse-response polynomial; autoregressive-moving-average models combine poles and zeros. A line-like peak in a fitted AR spectrum is not necessarily evidence for an external oscillator. A broadband process passing through a resonant RF front end can produce a similar spectral shape, while an unmodelled transient can force the parameter estimator to fit a fictitious narrow resonance. The analyst should therefore test whiteness of the residual innovations, examine the prediction error on held-out samples, inspect sensitivity to model order, and compare a nonparametric density estimate produced from the same calibrated raw data. When the fitted and nonparametric spectra disagree, the difference is evidence of model sensitivity, not a reason to select whichever curve looks more impressive. [C9-18; C9-24]

This distinction matters in forensic receiver work. A short acquisition contaminated by receiver gain changes, clock discontinuities or intermittently active transmitters is not well described by a single stationary ARMA model. Rather than applying a high-order fit to the entire record, divide it into physically justified states, preserve the boundaries, and test the parametric model within each. Report negative results no more broadly than the observed states and the model actually examined. Parametric estimators belong in postgraduate treatment because their conditional

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sharpness can be valuable; their fragility belongs in that same treatment because an attractive narrow peak is not proof of a physical spectral line. [C9-24; C9-18]

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9.30 Sinusoids in noise, model order and the limits of super-resolution

Line-spectral estimation begins with a different question from density estimation: how many coherent sinusoidal components are present, what are their frequencies and complex amplitudes, and what noise model makes those estimates identifiable? A useful model is $x[n] = \sum_{k=1}^{K} c_k \exp(j2\pi f_k n/f_s) + e[n]$, where K is the number of components, c_k their complex amplitudes, f_k their frequencies and $e[n]$ a noise or interference process. The model assumes that the frequencies remain stable during the observation and that phase coherence exists over the period used for inference. If an emitter hops, chirps, changes modulation state or suffers phase discontinuity, a static sinusoidal model becomes an approximation whose validity must be demonstrated. [C9-24]

Nonlinear least squares fits the sinusoids directly and can obtain high precision when the signal-to-noise ratio, model order and starting values are favourable. The frequency parameters make the optimisation nonlinear, so local minima and component swapping must be considered. A simple FFT peak can supply an initial estimate, but one should then examine the residual spectrum and vary the starting point. The maximum-likelihood interpretation additionally requires a specified probability law for the disturbance. Under a misspecified coloured-noise model, a small residual sum of squares may coexist with a biased uncertainty statement. An estimator can be numerically repeatable and still scientifically wrong. [C9-24]

Methods commonly grouped under subspace analysis exploit the eigenstructure of a sample covariance matrix. The MUSIC method examines

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an orthogonality relation between candidate sinusoidal steering vectors and an estimated noise subspace; ESPRIT uses rotational relationships between displaced subarrays or delayed sample structures. The minimum-norm and Pisarenko approaches are historically related but have different requirements and failure modes. These methods can distinguish components closer than the nominal DFT-bin spacing when their assumptions are met, but the resolution is not guaranteed by the name of the algorithm. High coherence, small sample numbers, incorrect source count, mutual coupling, correlated noise, numerical ill-conditioning and rapid frequency drift can destroy the supposed super-resolution advantage. [C9-24]

The source-count problem must precede a claim about precisely resolved frequencies. Information criteria such as AIC or MDL, eigenvalue-gap procedures and cross-validated prediction error may suggest a model order; none replaces an experimental challenge. Where a suspected weak carrier is found beside a strong emission, perform controlled injections and compare the detection threshold with that of a windowed FFT. The conclusion should report the source-count selection method, sample count, covariance dimension, any smoothing or regularisation, the estimated frequencies, their uncertainty and whether the same candidate survives materially different estimators. High-resolution mathematical inference becomes evidentially useful only when its prerequisites can be inspected. [C9-24; C9-18]

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9.31 Filter-bank analysis, Capon spectra and aperture-dependent selectivity

A bank of bandpass filters is a physical and mathematical alternative to the familiar FFT display. Each filter produces an estimate at a selected centre frequency or frequency interval, with a defined response, equivalent noise bandwidth, group delay and settling behaviour. A conventional FFT can itself be interpreted as a bank of windowed matched filters, but more general filter-bank approaches permit adaptive weights, unequal bandwidths and time-dependent responses. That flexibility is useful when a signal occupies a narrow but shifting part of a much broader acquisition. It also requires the analyst to disclose which filter outputs were observed and when they were observed. The name of a filter does not establish that its output is a calibrated power measurement. [C9-24; C9-23]

The Capon, or minimum-variance distortionless-response, estimator chooses weights that maintain unit response to a selected steering vector while minimising estimated output power. For a complex covariance matrix R and steering vector a(f), the familiar spectral form is proportional to 1 divided by a(f)^H R^(-1) a(f), subject to the adopted normalisation. This can suppress interference and sharpen an apparent peak, but inversion of a poorly estimated covariance matrix can magnify numerical noise. Diagonal loading and other regularisation can improve stability at the cost of changing the estimator's effective response. The covariance length, loading rule, training data and sample support therefore belong in the measurement record. [C9-24]

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A Capon peak should never be mistaken for the same kind of display ordinate as a power density from a properly normalised periodogram. Adaptive cancellation can suppress energy that a conventional display shows, or create high apparent contrast at frequencies selected by the covariance geometry. An analyst comparing the methods should specify whether each ordinate expresses power, inverse adaptive residual power, a pseudo-spectrum, or another statistic. An overlay without those definitions can mislead even a highly educated reader. Equally, the use of a common training record to select and then validate an adaptive filter makes the resulting confidence claim circular unless the selection uncertainty is accounted for. [C9-24; C9-18]

For the laboratory, use a weak line adjacent to a stronger interferer, repeat the acquisition with controlled phase and frequency drift, and compare a Hann-window estimate, a fixed filter bank and a loaded adaptive estimator. Measure false detections on independent noise-only records and record the point at which the adaptive method becomes unstable. This experiment turns an appealing mathematical method into a demonstrated engineering trade-off. [C9-24]

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9.32 Frequency stability, oscillator noise and the distinction between drift and random phase

A spectral peak with a broad skirt can arise from the transmitter, the receiver local oscillator, modulation, vibration, amplitude noise, or a combination of mechanisms. A single spectrum therefore rarely identifies the physical origin of close-in noise. For single-sideband phase noise L(f_m), expressed in dBc/Hz at offset f_m from a carrier, the usual small-angle approximation relates L(f_m) to one-half the one-sided phase-fluctuation density, subject to convention. The instrument's own reference and conversion chain can contribute noise. A measurement report must state the offset frequency, measurement bandwidth, carrier level, detector or cross-correlation configuration, instrument floor and correction method. [C9-06; C9-25]

Time-domain frequency stability methods answer related but different questions. Fractional frequency deviation y(t) is the instantaneous frequency error divided by nominal frequency. Allan variance forms the expectation of one-half the squared difference between adjacent average frequency deviations over an averaging interval tau. Modified Allan variance, total variance and other statistics alter the weighting and confidence characteristics to improve discrimination among noise types or finite-record behaviour. A spectrum measured over seconds and an Allan deviation measured over hours cannot be treated as duplicate descriptions of the same phenomenon without an explicit transformation and compatible noise model. The record length, sample interval, gaps, outlier handling and type of variance estimator must all be reported. [C9-25]

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An FFT with an unusually narrow resolution bin can make a drifting oscillator look like a broader stationary source, because a finite observation integrates motion across the selected window. Shorter records may resolve the oscillator's instantaneous carrier more clearly but have less frequency discrimination. A spectrogram reveals motion over time yet introduces its own time-frequency smoothing. When an attribution depends upon oscillator stability, compare complementary windows and independent references, then ask whether the observed phase noise could be the receiver's own. A reference oscillator and phase detector may provide deeper phase-noise measurement than a direct spectrum trace, but only when the reference's noise and loop transfer functions are established. [C9-06; C9-25]

The instructional test should include a calibrated synthesiser and a second traceable reference, with intentionally programmed small frequency steps and controlled phase perturbations. Students calculate frequency error, reproduce a phase-noise offset value from the appropriate linear quantities, and compare Allan deviation under at least two averaging times. They must then explain why an impressive narrow spectral trace is not proof of long-term timekeeping accuracy. [C9-25]

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9.33 Spurious-response searches, hybrid sweep-and-FFT acquisition, and search-time economics

A spurious-emissions search normally combines a very wide frequency range with a stringent amplitude threshold. A narrow resolution bandwidth may be needed to distinguish low-level components from noise, while the same narrow bandwidth lengthens a classical swept measurement because each frequency position must be visited and the filter allowed to settle. This is an engineering scheduling problem rather than simply a request for a high-resolution display. Some modern instruments accelerate portions of the search by processing wide instantaneous bands through FFT techniques and then stepping or sweeping the front end to cover frequencies outside that band. The resulting performance depends upon the instantaneous processing bandwidth, filter skirts, overlap between tuning positions, detector behaviour and final validation method. [C9-08; C9-01]

There are at least three distinct time scales. Acquisition time is the time for which the input is actually sampled at a given frequency. Processing time is the interval required to transform, detect and store that acquisition. Scan time is the elapsed wall-clock interval to cover the requested search range, including tuning, settling, data transfer and any verification rescan. An instrument may reduce processing time while leaving blind intervals between disjoint tuning positions; it may also maintain continuous acquisition within one processed band yet pause when shifting the analogue front end. The analyst should record each time scale separately when asserting that a frequency range was continuously monitored. [C9-08; C9-10]

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A defensible spurious search therefore adopts two stages. The initial discovery pass uses bandwidth and timing settings that cover the specified range economically, while retaining enough metadata to identify candidate responses. The confirmatory pass narrows the span, measures amplitude with the required detector and RBW, tests for internally generated mixer images or intermodulation, and repeats in a controlled input state. The candidate list must include negative results only for the actually qualified frequency-time cells. A fine-looking stitched spectrum, however complete it appears across its horizontal axis, does not prove that every frequency was observed at every instant. [C9-01; C9-08]

The laboratory should require students to measure the wall-clock search time for two methods, compute the total observable dwell per frequency interval and document any retune gaps. They should then insert a brief known carrier during a deliberately unobserved interval and confirm that the failure to record it is consistent with the declared acquisition model. This converts an instrument speed claim into an evidence-coverage statement. [C9-08; C9-10]

The frequently quoted classical sweep-time heuristic T_s proportional to S/B squared requires qualification at the architectural boundary. Here S is the searched span in hertz, B is the selected resolution-filter bandwidth in hertz, and a proportionality factor absorbs settling criterion, filter shape, detector operation and sweep strategy. It describes a class of swept-filter measurements, not a universal timing law for every modern spectral receiver. FFT-based analysis covers an instantaneous acquisition band through finite records and may stitch multiple tunings; its computational complexity, record duration, retune settling and unobserved intervals are

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separate constraints. A defensible comparison therefore records the observation time per frequency cell, the number and overlap of processed acquisitions, the computational latency and the wall-clock completion time. Neither a short displayed sweep time nor a fast FFT alone demonstrates uninterrupted interception of a transient emission.

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9.34 Pulsed RF, gating, coherent repetition and missing transient evidence

A pulsed carrier is not a steady sinusoid merely because its instantaneous frequency is fixed. Multiplication of a continuous carrier by a finite envelope convolves the carrier's spectral line with the spectrum of that envelope. A rectangular pulse of duration T produces a sinc-shaped amplitude envelope in the idealisation, with frequency features governed by the inverse pulse duration. A periodic pulse train produces a comb-like structure whose line spacing depends upon the pulse repetition frequency, while the overall envelope depends upon pulse width and shape. A short burst can therefore appear much wider than its underlying carrier modulation, and changing the pulse duty factor changes average power without necessarily changing peak envelope power. [C9-17; C9-10]

Peak and average power must be kept separate. If a transmitter emits constant power P_on for a fraction d of the wall-clock period and emits negligible power otherwise, the average power is approximately d times P_on, and the decibel difference between mean and on-state power is 10 log10(d). This relation assumes stable on-state power, a defined duty factor and an averaging interval containing enough repetitions. It does not by itself specify the result of a peak detector, an RMS detector with finite time response or a gated channel-power algorithm. A proper test distinguishes the time window over which the instrument reports power from the time window over which the physical signal exists. [C9-17; C9-06]

When bursts repeat, an instrument may synchronise and accumulate many nominally identical intervals to improve sensitivity. This is useful only if

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repetition timing, amplitude and phase are stable to the degree required by the method. A single missed sample, an unrecorded clock adjustment or an unnoticed variation of duty cycle can bias the result. If the source is a one-off emission, repetition-averaged methods are not applicable. Record the trigger source, pre-trigger samples, gate start and end, clock calibration, missing-sample flags and whether the displayed spectrum was reconstructed from one event or many equivalent events. [C9-10; C9-17; C9-28]

The classical literature remains valuable because it exposes the measurement physics independently of modern touchscreen conveniences. Its analytical rules must nevertheless be translated through the modern instrument's actual digital IF filters, triggers and detector conventions. A historical pulsed-RF application note can justify a method to investigate, not the uncritical reuse of settings on an instrument with a different acquisition architecture. [C9-15; C9-17; C9-01]

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9.35 EMI receivers, quasi-peak detection, time-domain scan and measurement compliance

Electromagnetic-compatibility measurements and general-purpose spectrum discovery are related but not identical enterprises. Compliance receivers may use prescribed bandwidths, detector time constants, dwell requirements, preselection and scan procedures derived from the applicable standard. A quasi-peak detector weights repeated disturbances in a manner different from a simple peak or RMS estimator; a rapid repetition pattern may yield a different indication from an isolated impulse of the same instantaneous amplitude. This behaviour is intentional within the relevant compliance regime. An analyst must not present an ordinary peak-hold trace as if it were a quasi-peak compliant result merely because the image resembles one. [C9-29; C9-06]

Time-domain scanning can accelerate the collection of wideband emissions data by capturing a broad time record and performing spectral calculations digitally. The method must still reproduce the required detector behaviour, measurement bandwidth, overload performance, scan completeness and calibration. A fast FFT is not by itself proof of regulatory equivalence. The analyst should keep the acquisition and processing contract traceable to the standard actually being applied, record any settings that were outside the standard method, and distinguish engineering diagnostics from accredited compliance measurement. [C9-29; C9-02]

A spectrogram can be particularly valuable when emissions are state-dependent: a motor drive, switching supply or digital controller may emit only during a particular phase of operation. The display permits an engineer

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to align interference events with the device state. The hazard is that the same colour image can contain spectral leakage, interpolation artifacts, nonuniform temporal weighting or gaps caused by retuning. It should therefore be accompanied by the native waveform where available, declared frequency and time scales, uncertainty or threshold basis, and a clear description of which portions of the operational cycle were actually sampled. [C9-29; C9-10]

The laboratory should compare peak, average and quasi-peak detector results on the same controlled disturbance, using a properly specified receiver or emulation whose detector parameters are known. Students must justify which measurement is appropriate for diagnosis and which might qualify for a regulatory submission. The lesson is to distinguish an instrument capability from authority to make a compliance claim. [C9-29]

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9.36 Automated monitoring, event provenance and networked spectrum-survey architecture

Continuous RF monitoring extends the spectral measurand into the temporal and operational domains. A monitoring system is no longer one instrument and one human operator. It may comprise several remotely controlled receivers, preselectors, reference clocks, antennas, storage nodes, event detectors and automated notifications. The central engineering question becomes which observations survive failures of the network, power, software and human workflow. The system must define what it means by a detection, which intervals were searched, which settings were active, which data were retained and which events were missed or deferred. An apparently complete historical dashboard can conceal long intervals of silent failure unless health status is recorded with the measurements. [C9-13; C9-14; C9-26]

A robust architecture separates the raw-observation plane from the derived-event plane. The former contains native samples or instrument traces, timestamps, equipment states and calibration records; the latter contains threshold crossings, classified features, alarms and reports. The relationship should be reversible: a reviewer must be able to follow a reported event back to the original record and reproduce the derived quantity from documented settings. If data are retained selectively, the selection criteria and dropped-event counters must be recorded as evidence, because an absent event record may mean that the event did not occur, that it was below threshold, that storage failed, or that the monitored receiver was simply not observing the frequency at the relevant moment. [C9-13; C9-26]

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Geographically distributed observations require clock-quality and frequency-reference metadata. A common time label is not necessarily proof of synchronous sampling. Propagation delay, sample-clock drift, front-end delay, cable calibration and interpolation error can all affect a comparison among receivers. The network transport may introduce variable delivery latency, which must not be confused with the physical time at which a radio event was acquired. Store the acquisition timestamp near the sampling hardware, identify its clock source and uncertainty, and preserve the original data ordering and loss masks. A later network time-synchronisation correction can be offered as a derived product, not silently substituted for the primary record. [C9-13; C9-25]

The instructional exercise is a simulated remote-monitoring outage. Students run an authorised bench signal source while a separate logger records the source duty schedule, then intentionally interrupt only the communications link to the remote receiver. They compare local acquisition, transmitted event logs and dashboard summaries, identifying exactly which evidential claims survive. The exercise teaches that a monitoring system needs both spectral competence and computer-network forensic discipline. [C9-13; C9-14]

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9.37 Higher-order spectra, spectral kurtosis and departures from Gaussian noise

Ordinary second-order spectral estimates are powerful because they characterise the distribution of variance with frequency under familiar stationarity assumptions. They do not distinguish every physically interesting process. Two signals can possess similar second-order spectra while differing substantially in phase coupling, impulsiveness, higher-order moments or modulation structure. Higher-order statistics and related techniques are therefore useful in selected diagnostic contexts, but only after the analyst has stated why the second-order model is insufficient. An abrupt burst within noise can raise fourth-order moments; a nonlinear system can create phase-coupled harmonics that are not explained by independently generated spectral lines. [C9-24; C9-18]

A bispectrum is derived from a third-order cumulant or from an expectation involving three Fourier factors whose frequencies sum according to a specified convention. Under ideal Gaussian assumptions, higher-order cumulants beyond second order vanish, so nonzero structure can indicate non-Gaussian behaviour or phase coupling. Yet finite-sample bispectral estimates can be noisy, require many averaging intervals and produce spurious peaks when the process changes during acquisition. Their normalisation, symmetries, leakage control and statistical threshold must be stated. The detection of a bispectral feature does not, without corroboration, identify the physical source or prove malicious intent. [C9-24]

Spectral kurtosis approaches examine departures from the distribution predicted for a selected noise model within time-frequency cells. Such

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measures can identify intermittent interference hidden in a broadband average, but their thresholds depend on the accumulation scheme, sample dependence, detector statistics and the assumed noise law. A receiver whose front end compresses intermittently can also create non-Gaussian artifacts. Accordingly, an apparently informative impulsiveness map should be compared with raw time samples, overload logs and an independently controlled source. [C9-18; C9-24]

An advanced laboratory can compare a Gaussian-noise record, a Gaussian record with rare injected impulses and a record passed through a controlled nonlinear element. Students compute ordinary PSDs and an appropriately calibrated higher-order statistic, then determine whether the latter adds genuine discrimination. The educational goal is not to pronounce a sophisticated statistic universally superior, but to demonstrate precisely which difference in physical behaviour it measures and under which assumptions the inference holds. [C9-24]

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9.38 Digital radiometry, quadratic spectral estimators and uncertainty budgets

Spectral estimation becomes metrology when the numerical estimator itself is treated as a source of measurement bias and uncertainty. A digital radiometer calculates spectral power from calibrated time-series samples, yet finite windows, nonideal sampling, covariance structure and processing choices can alter the estimate. One convenient mathematical framework is the quadratic form $x^H Q(f) x$, where x is a finite complex data vector and $Q(f)$ is a Hermitian estimator matrix determined by the chosen method. The conventional windowed periodogram is a special case, but other nonnegative quadratic estimators can be constructed with different bias, variance and computational cost. The critical metrological question is whether the estimator's bias relative to the intended spectrum is acceptable for the application. [C9-18]

Bias and variance trade against one another. A narrow effective analysis kernel may preserve line resolution while producing a highly variable random-power estimate; heavier smoothing may reduce variance while blending neighbouring components. The familiar mean-squared-error criterion is the sum of squared bias and variance for a scalar estimator, under a particular statistical expectation. Its minimisation depends upon the unknown or modelled signal distribution and an explicit loss function. Thus an estimator optimised for one radiometric background is not automatically optimal for a transient interference search. The operator must name the spectrum class, estimator family, training evidence and uncertainty evaluation used to justify the choice. [C9-18]

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A complete uncertainty budget should distinguish calibration uncertainty of the analogue front end, clock and sampling errors, processing bias, finite-record variance, reference-impedance uncertainty and repeatability under changed operating state. These terms are not necessarily independent. A shared reference frequency can create common errors across bins, while overlapping windows generate dependence among estimates drawn from the same record. Summing individual variances as though every term were independent can therefore produce an unrealistically narrow interval. Where correlations are significant, use an appropriate covariance expression or a validated simulation. [C9-18; C9-25]

The classroom application is to compare two windowed estimators on simulated white noise, coloured noise and a weak line. Estimate empirical bias and variance over independent realisations, then repeat the exercise when each realisation is artificially subdivided into overlapping windows. Students should explain why the increased number of plotted periodograms does not create a corresponding number of independent experiments. The instructor should insist on a written uncertainty statement tied to the actual acquisition and processing model. [C9-18]

An “optimal” spectral window is optimal only relative to an explicit estimation problem. In a quadratic estimate $x^H Q(f)x$, x is the finite sampled record and Q(f) represents the weighting and spectral measurement operator; the admissible family of Q, the assumed spectrum subspace, record length, target bandwidth and loss function delimit the optimisation. Mean-squared error balances variance against local and broadband bias, but a taper that suppresses remote leakage can also widen the response to neighbouring tones or reduce the effective number of independent

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estimates. The 2024 digital-radiometry analysis by Gu, Rezac, Lu and Kuester studies precisely such conditional bias-and-variance choices. It does not establish one universally best taper for intermittent emissions, weak-line searches, coherent amplitude measurement and stationary radiometric noise simultaneously. Every assertion of optimum performance should therefore state the signal class, prior model, estimator family, reference response and the independent experiment used to verify the claimed advantage.

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9.39 Spectrum-monitoring surveys, occupancy statistics and evidential limits

Spectrum monitoring is commonly undertaken to answer questions about occupancy, interference, use of allocated frequencies or the compliance of observed emissions with a defined regulatory regime. These questions are not identical. A momentary signal detection may establish that energy above a particular threshold was observed at a frequency and time, but it does not necessarily identify a transmitter, infer a communication service or establish an ongoing violation. The survey design must distinguish frequency coverage, geographic coverage, observation periods, antenna selection, receiver sensitivity and threshold policy. Administrative and legal findings require an authority and method appropriate to the jurisdiction. [C9-26; C9-27]

A channel-occupancy statistic might be written as the number of time-frequency cells meeting a declared detection rule divided by the number of cells actually observed. This expression is meaningful only if the denominator excludes intervals when the receiver was not collecting valid samples. If a scanned receiver revisits a channel once every several seconds, a brief transmission may occur entirely between visits. Counting the intervening time as verified unoccupied time would underestimate occupancy. A survey should therefore report duty-cycle sensitivity, gap policy, confidence bounds and the meaning of any interpolation between measured intervals. [C9-26; C9-10]

When spectral observations support interference resolution, the analyst should seek repeatability under changes that can distinguish receiver

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artifacts from external sources. Suitable challenges include path attenuation, input termination, preselector change, alternate receiver, reference-clock substitution and controlled source isolation. A legitimate external signal may change under propagation and antenna conditions; an internally generated spur may respond primarily to receiver tuning or overload state. The resulting case record should preserve both positive findings and unsuccessful challenges rather than selecting only the images that support an initial theory. [C9-01; C9-26]

A university or military-school field exercise may compare a conducted laboratory reference, an RF-isolated chamber and an authorised outdoor range, with emission permissions and safety controls established beforehand. Students should formulate the limits of any occupancy claim, explain why a frequency plan matters, and demonstrate that the forensic trace of a reported event is reproducible from a known recording. This is the link between mathematical Chapter 9 and operational monitoring doctrine. [C9-26; C9-13]

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9.40 Ten fully specified spectral-estimation exercises with numerical checks

Example 1: noise-bandwidth scaling. Assume the equivalent noise bandwidth changes from 100 Hz to 1,000 Hz while the density of stationary white noise is unchanged. The expected ratio of admitted noise powers is 1,000/100 = 10. In decibels the change is 10 log10(10) = 10 dB. The result depends on equivalent noise bandwidth rather than a filter-label convention and is not valid without qualification for a coherent tone. [C9-01; C9-23]

Example 2: record duration and nominal bin spacing. For a sample rate f_s = 2,000,000 samples/s and a record of N = 100,000 samples, the duration is $T = N/f_s = 0.05$ s and the unpadded DFT-bin spacing is $\Delta f = f_s/N = 20$ Hz. Padding the record to 200,000 points makes the displayed interpolation grid 10 Hz, but it does not double the physical observation duration or create independent 10 Hz resolution. [C9-23]

Example 3: coherent-gain correction. Consider a sinusoidal component whose sampled window has coherent gain $G_c = 0.5$. If the reported raw complex DFT amplitude is 0.4 V by the selected two-sided convention, the corrected coherent amplitude is 0.4/0.5 = 0.8 V. The operation requires a stable tone near the assumed bin and must not be reused to normalise random noise density. [C9-20; C9-23]

Example 4: duty-cycle power. A device emits at 10 mW only during 2% of a sufficiently long averaging interval. The mean power is approximately 0.02 × 10 mW = 0.2 mW, or 10 log10(0.2) = -6.99 dBm. The on-state power is +10 dBm. The difference, approximately 16.99 dB, reflects duty factor and does not itself describe a peak detector's response. [C9-17]

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Example 5: independent-record averaging. If eight independent exponential noise-power periodograms have the same mean μ and variance μ^2, their arithmetic mean has variance $\mu^2/8$. Under the idealised model the relative standard deviation becomes 1/sqrt(8) ≈ 0.354. If the records overlap and are correlated, the true variance reduction is smaller and depends upon the covariance among estimates. [C9-19; C9-18]

Example 6: window overlap accounting. For N = 2,048 samples per FFT and hop H = 512 samples, the overlap fraction is 1 - 512/2,048 = 0.75, or 75%. At sample rate f_s = 10.24 MS/s, the nominal transform initiation rate is f_s/H = 20,000 per second. This does not establish that the analogue front end, memory or processor is gap-free; those components require independent verification. [C9-10; C9-12]

Example 7: marker difference. A first marker lies at 433.920 MHz with amplitude -41.2 dBm and a second at 434.350 MHz with amplitude -37.8 dBm. The frequency difference is 0.430 MHz = 430 kHz. The amplitude difference is (-37.8) - (-41.2) = +3.4 dB. These are relative display values until path corrections and uncertainties are evaluated. [C9-01; C9-06]

Example 8: calibration-plane correction. An analyser measures -65 dBm at its input, and an independently characterised cable presents 2.5 dB insertion loss between the declared source terminal and that input. Assuming compatible impedance and no additional intervening gain, the source-terminal estimate is -65 + 2.5 = -62.5 dBm. If an external amplifier of 10 dB precedes the same cable, the corresponding source-plane correction changes; the whole path must be recorded in order. [C9-01; C9-02]

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Example 9: frequency-error fraction. A synthesiser set to 1 GHz is measured 10 Hz high against a qualified reference. The fractional frequency error is y = 10 / 1,000,000,000 = 1 × 10^-8. This number represents a particular measurement interval, not an Allan deviation over all averaging times or a phase-noise specification. [C9-25]

Example 10: observed-time occupancy. An instrument observes a channel for 300 valid seconds across a 600-second wall-clock survey, and valid cells above threshold sum to 45 seconds. Occupancy relative to observed time is 45/300 = 15%. A naïve 45/600 = 7.5% statement would misclassify the unobserved half of the survey as empty. The report must disclose the scan coverage and any time-weighting assumptions before presenting an occupancy estimate. [C9-26]

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Chapter Summary

FFT analysis is an estimator built from finite records. Window, averaging, synchronization, and nonstationarity controls determine whether spectral structure is environmental, processing-induced, or shared through the instrument chain.

Model 9W separates coherent line amplitude from noise-density scaling by using the actual window coefficients and their different sums. Correct side conventions preserve DC and Nyquist contributions. Zero padding refines the evaluation grid without adding observations or narrowing the window response. Exact energy closure checks normalization while retaining the window's position-dependent weighting of a transient.

Model 9C requires paired records, compatible scaling and common nonnegative weights. Its coherence bound and least-squares residual describe that finite construction. Conjugation determines phase sign; shared disturbances, cancellation and changing states limit causal interpretations. A single nonzero pair fits perfectly, and an SNR interpretation requires additional justified assumptions about the input and disturbance.

A defensible result preserves samples, preprocessing, coefficient vectors, timing and channel calibration with its plots. Compare alternate windows and inspect event-resolved data when averaging hides activity. Validate the intended estimator on known signals and held-out observations. Acquisition continuity and usable event coverage remain separate requirements that favorable spectral arithmetic cannot establish.

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Chapter 9 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C09-MCQ-001. What directly supports an FFT spectral estimate?

A. A window-independent picture of the source

B. A continuous observation of every possible frequency

C. A finite sampled record with declared processing

D. An assumption that every input is periodic

Answer: C. Record duration, sampling, window, and processing condition the estimate. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

Why the selected alternative fits: A finite sampled record with declared processing.

Distinguishing consideration: compare this with option A, “A window-independent picture of the source”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Discrete Records and Spectral Estimates.

Review: Chapter 9 — Discrete Records and Spectral Estimates.

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V011-C09-MCQ-002. An unpadded 4096-sample record is acquired at 40960 samples per second. What is its nominal bin spacing?

A. 5 Hz

B. 100 Hz

C. 10 Hz

D. 20 Hz

Answer: C. Unpadded spacing is sample rate divided by sample count, here 40960/4096. Source: §9.8 Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5073)

Why the selected alternative fits: 10 Hz.

Distinguishing consideration: compare this with option A, “5 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-MCQ-003. Which parameter determines the represented Nyquist interval for a sampled record?

A. Coherent window gain alone

B. Sample rate

C. Zero-padding length alone

D. Number of averages alone

Answer: B. Record length affects bin spacing; sample rate sets the represented Nyquist interval. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

Why the selected alternative fits: Sample rate.

Distinguishing consideration: compare this with option A, “Coherent window gain alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Discrete Records and Spectral Estimates.

Review: Chapter 9 — Discrete Records and Spectral Estimates.

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V011-C09-MCQ-004. An observed tone does not complete an integer number of cycles in the record. Which inference is unsafe?

A. The finite window influences its spectrum

B. Its energy must appear in only one DFT bin

C. Its apparent sidelobes depend on the window

D. Its peak can lie between displayed bins

Answer: B. A non-bin-centered component generally produces a distributed finite-window response. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why the selected alternative fits: Its energy must appear in only one DFT bin.

Distinguishing consideration: compare this with option A, “The finite window influences its spectrum”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-MCQ-005. Why inspect time samples in addition to one transform?

A. A single spectrum can represent a tone, drift, transient, or windowed fragment

B. A transform always identifies the time of every event uniquely

C. A second view proves that clipping never occurred

D. The time record removes all window corrections

Answer: A. Time inspection helps distinguish constructions that can have similar spectral displays. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

Why the selected alternative fits: A single spectrum can represent a tone, drift, transient, or windowed fragment.

Distinguishing consideration: compare this with option B, “A transform always identifies the time of every event uniquely”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Discrete Records and Spectral Estimates.

Review: Chapter 9 — Discrete Records and Spectral Estimates.

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V011-C09-MCQ-006. Which retained record supports later checking of acquisition clipping?

A. Original samples and overflow flags with acquisition parameters

B. Only the maximum displayed spectral level

C. Only a window name without sample values

D. Only a normalized spectrum image

Answer: A. Native samples and flags retain evidence that a spectral image may hide. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

Why the selected alternative fits: Original samples and overflow flags with acquisition parameters.

Distinguishing consideration: compare this with option B, “Only the maximum displayed spectral level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Discrete Records and Spectral Estimates.

Review: Chapter 9 — Discrete Records and Spectral Estimates.

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V011-C09-MCQ-007. What is a characteristic rectangular-window tradeoff?

A. Automatic rejection of all negative-frequency images

B. Low sidelobes and no scalloping for every frequency

C. Narrow main lobe with relatively high sidelobes for off-bin components

D. A main lobe that narrows when zeros are appended

Answer: C. The rectangular window can separate coherent tones well but leaks strongly for off-grid components. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why the selected alternative fits: Narrow main lobe with relatively high sidelobes for off-bin components.

Distinguishing consideration: compare this with option A, “Automatic rejection of all negative-frequency images”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-MCQ-008. What normally accompanies reduced sidelobes from tapering?

A. Unchanged main-lobe width with no correction changes

B. A wider main lobe and altered amplitude/noise normalization

C. A guarantee that nearby tones are resolved

D. Elimination of the finite-record duration limit

Answer: B. Tapering redistributes the window response; lower sidelobes have costs relevant to the measurand. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why the selected alternative fits: A wider main lobe and altered amplitude/noise normalization.

Distinguishing consideration: compare this with option A, “Unchanged main-lobe width with no correction changes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-MCQ-009. Which criterion should guide window selection?

A. The largest zero-padded transform regardless of record length

B. The intended amplitude, noise, separation, or transient measurement

C. The greatest possible displayed peak alone

D. One window name used for every measurement

Answer: B. No window is universally best; its tradeoffs serve a declared question.

Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why the selected alternative fits: The intended amplitude, noise, separation, or transient measurement.

Distinguishing consideration: compare this with option A, “The largest zero-padded transform regardless of record length”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-MCQ-010. Why process the same samples with two different windows as a challenge?

A. The two outputs become independent acquisitions

B. It doubles the physical observation duration

C. A component and leakage from a stronger component can respond differently

D. Agreement proves a unique external source

Answer: C. The controlled processing change probes leakage interpretation without creating new observations. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why the selected alternative fits: A component and leakage from a stronger component can respond differently.

Distinguishing consideration: compare this with option A, “The two outputs become independent acquisitions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-MCQ-011. Why does coherent-tone normalization use the sum of weights rather than their squared sum?

A. Tone powers from all samples are necessarily independent

B. The window's noise bandwidth equals every bin spacing

C. Coherently aligned amplitudes add before squaring

D. The square sum is always zero for a coherent tone

Answer: C. The coherent tone produces amplitude times S_1; white-noise covariance instead leaves S_2 in expected squared magnitude. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: Coherently aligned amplitudes add before squaring.

Distinguishing consideration: compare this with option A, “Tone powers from all samples are necessarily independent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-MCQ-012. Which window sum enters the white-noise expected squared transform magnitude?

A. Only the square of the sum S_1

B. The maximum window coefficient alone

C. The count of padded zeros

D. The sum of squared weights S_2

Answer: D. Uncorrelated sample cross terms vanish, leaving variance times the squared-weight sum. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: The sum of squared weights.

Distinguishing consideration: compare this with option A, “Only the square of the sum”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-013. With voltage samples and dimensionless weights, what are the units of the unnormalized windowed DFT coefficient?

A. Volts

B. Volts per hertz

C. Watts

D. Volts squared per hertz

Answer: A. The finite sum changes scale but introduces no time or frequency unit factor. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: Volts.

Distinguishing consideration: compare this with option B, “Volts per hertz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-MCQ-014. What condition permits the density denominator in Model 9W?

A. S_1 exactly zero only

B. S_2 greater than zero

C. The transform length equal to one

D. Every weight equal to one

Answer: B. A nonzero squared-weight sum and positive sample rate define density even when coherent gain is zero. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: greater than zero.

Distinguishing consideration: compare this with option A, “exactly zero only”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-015. What additional condition is required for the model's coherent-gain normalization?

A. All frequencies confined to DC

B. All samples statistically independent

C. A Gaussian amplitude distribution

D. S_1 not equal to zero

Answer: D. Division by S_1 is undefined for a zero-sum window even if density normalization is valid. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: not equal to zero.

Distinguishing consideration: compare this with option A, “All frequencies confined to DC”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-MCQ-016. A bin-centered complex tone has coefficient a times S_1. How is its complex amplitude recovered?

A. Divide by the padded transform length

B. Divide that coefficient by S_1

C. Divide by S_2 regardless of S_1

D. Double its magnitude and discard phase for every signal

Answer: B. The stated complex-tone derivation uses the coherent weight sum and retains complex amplitude. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: Divide that coefficient by.

Distinguishing consideration: compare this with option A, “Divide by the padded transform length”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-MCQ-017. When is twice the positive-bin magnitude divided by the magnitude of S_1 an exact real-sinusoid peak amplitude in the stated derivation?

A. Whenever S_2 is positive regardless of the image

B. Whenever the tone is coherent for any arbitrary window and bin

C. Whenever a one-sided display is selected

D. When the frequency condition holds and the negative-image term vanishes

Answer: D. The real signal has a negative-frequency image; its window contribution must vanish or be negligibly bounded. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: When the frequency condition holds and the negative-image term vanishes.

Distinguishing consideration: compare this with option A, “Whenever is positive regardless of the image”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-MCQ-018. Why are DC and the even-length Nyquist bin not ordinary positive-frequency sinusoid bins?

A. Their voltages must always be zero

B. They do not have distinct opposite-frequency partners to fold

C. They always require the same doubling as interior bins

D. They have no contribution to mean square

Answer: B. Doubling those endpoints would count their contributions twice. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: They do not have distinct opposite-frequency partners to fold.

Distinguishing consideration: compare this with option A, “Their voltages must always be zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-019. What remains after applying coherent-gain correction to an off-grid tone?

A. A possible window-response or scalloping error

B. An automatic proof of two-tone separation

C. A guaranteed exact amplitude at the nearest bin

D. A doubled physical observation time

Answer: A. Coherent gain alone does not correct arbitrary off-grid window response. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: A possible window-response or scalloping error.

Distinguishing consideration: compare this with option B, “An automatic proof of two-tone separation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-MCQ-020. A processing script removes the mean before the DFT. What must the result state?

A. That DC normalization has merely been corrected

B. That the original DC measurand is unchanged

C. That the spectrum is of the preprocessed record

D. That every window now has unit coherent gain

Answer: C. Mean removal changes the signal being estimated; it is not just a scale adjustment. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: That the spectrum is of the preprocessed record.

Distinguishing consideration: compare this with option A, “That DC normalization has merely been corrected”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-MCQ-021. What denominator defines the two-sided density D_2?

A. Sample count times sample rate without window terms

B. Sample rate times S_2

C. The maximum DFT magnitude

D. The magnitude of S_1 squared alone

Answer: B. Density normalization uses $f_s S_2$ and has squared-voltage-per-hertz units. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Sample rate times.

Distinguishing consideration: compare this with option A, “Sample count times sample rate without window terms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-022. What denominator defines the tone-normalized squared spectrum Q2?

A. The squared magnitude of S_1

B. The number of averaged spectra

C. Only the unpadded bin spacing

D. Sample rate times S_2

Answer: A. Q2 is line calibrated and differs from a density by the equivalent noise bandwidth. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: The squared magnitude of.

Distinguishing consideration: compare this with option B, “The number of averaged spectra”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-023. How is equivalent noise bandwidth defined in Model 9W when S_1 is nonzero?

A. S_1 divided by S_2 without units

B. Sample rate divided by padded transform length for every window

C. Sample rate times S_2 divided by the squared magnitude of S_1

D. Nominal bin spacing times coherent gain

Answer: C. This ratio converts a line-normalized squared ordinate to density for the same coefficient vector. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Sample rate times divided by the squared magnitude of.

Distinguishing consideration: compare this with option A, “divided by without units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-024. Under what condition does Q2 equal equivalent noise bandwidth times D_2?

A. For every record with the stated nonzero denominators

B. Only for bin-centered tones

C. Only after infinitely many averages

D. Only for Gaussian white noise

Answer: A. This conversion is algebraic; whiteness is required for a particular expectation, not the identity. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: For every record with the stated nonzero denominators.

Distinguishing consideration: compare this with option B, “Only for bin-centered tones”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-025. What covariance condition gives expected D_2 equal to variance divided by sample rate?

A. Zero-mean samples with zero off-diagonal covariance and common variance

B. Any colored covariance with the same diagonal variance

C. Any deterministic tone regardless of window

D. Every sample identical to the first

Answer: A. The white covariance makes the squared-transform cross terms vanish.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Zero-mean samples with zero off-diagonal covariance and common variance.

Distinguishing consideration: compare this with option B, “Any colored covariance with the same diagonal variance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-026. Is Gaussianity necessary for the model's expected white-noise density calculation?

A. Yes, without it Parseval fails

B. No, because no covariance assumption is needed

C. No, the stated second-order covariance is sufficient

D. Yes, otherwise every cross term is nonzero

Answer: C. The expectation uses means and covariances, not the full Gaussian distribution. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: No, the stated second-order covariance is sufficient.

Distinguishing consideration: compare this with option A, “Yes, without it Parseval fails”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-027. For a real record, how are interior positive-frequency density values converted to a one-sided display?

A. Double every retained bin including endpoints

B. Double them while retaining DC and even-length Nyquist unchanged

C. Discard negative frequencies without any adjustment

D. Halve the interior bins and double endpoints

Answer: B. Correct folding retains total finite-record energy without double-counting endpoints. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Double them while retaining DC and even-length Nyquist unchanged.

Distinguishing consideration: compare this with option A, “Double every retained bin including endpoints”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-028. For odd sample count, how is the highest retained positive-frequency bin treated?

A. It is never doubled because it is last on the display

B. It is divided by two because no negative partner exists

C. It is discarded as an undefined frequency

D. It is doubled because it is not a Nyquist endpoint

Answer: D. Odd-length real records have no Nyquist sample; the highest retained positive bin has a distinct partner. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: It is doubled because it is not a Nyquist endpoint.

Distinguishing consideration: compare this with option A, “It is never doubled because it is last on the display”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-029. Why normally retain two sides for complex records?

A. They generally lack the conjugate symmetry used for real-record folding

B. Complex voltages have no physical units

C. Their positive spectrum always equals their negative spectrum

D. Every negative frequency is necessarily instrument noise

Answer: A. Real-record folding assumptions cannot automatically be transferred to arbitrary complex samples. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: They generally lack the conjugate symmetry used for real-record folding.

Distinguishing consideration: compare this with option B, “Complex voltages have no physical units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-030. What distinguishes the units of Q2 and D_2 for voltage samples?

A. Both must be dBm without an impedance

B. Both are dimensionless after normalization

C. Q2 is volts and D_2 is watts

D. Q2 is V squared and D_2 is V squared per hertz

Answer: D. A bandwidth factor relates squared spectrum and density; physical power conversion also needs a stated impedance. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Q2 is V squared and is V squared per hertz.

Distinguishing consideration: compare this with option A, “Both must be dBm without an impedance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-MCQ-031. What does the integrated density equal for an arbitrary finite record in Model 9W?

A. The squared-window-weighted mean square divided by S_2

B. Always the unweighted sample mean square

C. Always the square of the sample mean

D. Only the mean square of a periodic extension

Answer: A. The exact sum retains window-position weighting; it need not equal unweighted record energy per sample. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: The squared-window-weighted mean square divided by.

Distinguishing consideration: compare this with option B, “Always the unweighted sample mean square”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-032. Does exact density energy closure prove that noise is white?

A. Yes, any colored covariance violates Parseval

B. Yes, if all bins have been summed

C. No, the identity holds record by record for colored data too

D. Only when a Hann window is used

Answer: C. A correct integral checks normalization but cannot establish the covariance that determines spectral shape. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: No, the identity holds record by record for colored data too.

Distinguishing consideration: compare this with option A, "Yes, any colored covariance violates Parseval"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-033. A single impulse falls at a zero Hann weight. What can its windowed spectrum show?

A. A failure of Fourier orthogonality

B. The same integrated energy as an impulse at the window center

C. An automatically corrected impulse energy from coherent gain

D. Zero despite nonzero unweighted record energy

Answer: D. Window position can suppress a transient completely while the exact weighted-energy identity still holds. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: Zero despite nonzero unweighted record energy.

Distinguishing consideration: compare this with option A, “A failure of Fourier orthogonality”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-034. For periodic Hann with N = 16, what are S_1 and S_2?

A. 16 and 16

B. 8 and 8

C. 7.5 and 5.625

D. 8 and 6

Answer: D. The periodic sums are $\frac{N}{2}$ and $\frac{3N}{8}$ for the stated domain. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: 8 and 6.

Distinguishing consideration: compare this with option A, “16 and 16”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-035. For periodic Hann with N = 16 and sample rate 1600 Hz, what is equivalent noise bandwidth?

A. 50 Hz

B. 150 Hz

C. 100 Hz

D. 160 Hz

Answer: B. The bandwidth is 1.5 times the unpadded spacing of 100 Hz. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: 150 Hz.

Distinguishing consideration: compare this with option A, “50 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-036. For endpoint-symmetric Hann with the same N and sample rate, what is equivalent noise bandwidth?

A. 150 Hz

B. 160 Hz

C. 100 Hz

D. 106.67 Hz

Answer: B. The symmetric coefficient sums use N minus 1, giving $\frac{3f_s}{[2(N-1)]}$.

Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: 160 Hz.

Distinguishing consideration: compare this with option A, “150 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-037. A symmetric 16-point Hann complex-tone coefficient is incorrectly divided by 8 instead of 7.5. What amplitude ratio results?

A. 1.0667 of the true amplitude

B. 1.5 of the true amplitude

C. Exactly the true amplitude

D. 0.9375 of the true amplitude

Answer: D. The actual coherent sum is 7.5, so the erroneous divisor gives 7.5/8.

Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: 0.9375 of the true amplitude.

Distinguishing consideration: compare this with option A, “1.0667 of the true amplitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-038. What happens to D_2, Q2, and equivalent noise bandwidth if all window weights are multiplied by the same nonzero real constant?

A. Only density remains unchanged

B. The bandwidth narrows by the constant

C. All three increase by the constant squared

D. All three remain unchanged with consistent sums

Answer: D. The coefficient and weight sums scale together; mixing sums from different vectors would break this invariance. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: All three remain unchanged with consistent sums.

Distinguishing consideration: compare this with option A, “Only density remains unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-039. What lower bound follows for equivalent noise bandwidth when S_1 is nonzero?

A. It is no smaller than the unpadded bin spacing

B. It is always one hertz

C. It is always exactly half the padded spacing

D. It is no larger than the unpadded bin spacing

Answer: A. Cauchy–Schwarz gives the squared coherent sum no greater than N times S_2. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: It is no smaller than the unpadded bin spacing.

Distinguishing consideration: compare this with option B, “It is always one hertz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-040. A window has weights 1, minus 1, 1, minus 1. Which normalization remains valid at positive sample rate?

A. Density using S_2

B. Equivalent noise bandwidth as defined by division by S_1 squared

C. Coherent amplitude using S_1

D. Q2 using the squared coherent sum

Answer: A. S_1 is zero but S_2 is four; only the stated density denominator remains nonzero. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: Density using.

Distinguishing consideration: compare this with option B, “Equivalent noise bandwidth as defined by division by squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-041. Padding a record eightfold has what effect on its equivalent noise bandwidth when the original window is retained?

A. It becomes the new display-bin spacing

B. It increases eightfold

C. It decreases eightfold

D. None

Answer: D. Padding changes the evaluation mesh, not the observed samples or weight sums. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: None.

Distinguishing consideration: compare this with option A, “It becomes the new display-bin spacing”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-042. An N-sample record is padded to M samples. Which spacing belongs in its density sum?

A. Sample rate divided by N while summing all M bins

B. One hertz regardless of sampling

C. Equivalent noise bandwidth divided by M

D. Sample rate divided by M

Answer: D. The denser evaluation grid uses $\frac{f_s}{M}$, while original window sums remain in the density normalization. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: Sample rate divided by M.

Distinguishing consideration: compare this with option A, “Sample rate divided by N while summing all M bins”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-043. Why can a denser zero-padded grid fail to resolve nearby tones?

A. It adds independent observations only at DC

B. It necessarily discards the original bins

C. It does not narrow the underlying window response

D. It reduces coherent gain to zero

Answer: C. Interpolation may locate peaks more finely but does not create observation duration or separation information. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: It does not narrow the underlying window response.

Distinguishing consideration: compare this with option A, “It adds independent observations only at DC”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-044. Why is directly summing the neighboring Hann line-calibrated Q ordinates unsafe as total signal power?

A. Each side bin always represents another independent tone

B. All side bins are numerical errors to delete

C. Q must be multiplied by bandwidth twice

D. They include the same tone's window response and need density integration scaling

Answer: D. The coherent line calibration is not a per-bin integrated-power calibration. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: They include the same tone's window response and need density integration scaling.

Distinguishing consideration: compare this with option A, “Each side bin always represents another independent tone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-045. A Hann tone's summed Q is 0.0075 V squared, spacing is 46.875 Hz, and bandwidth is 70.3125 Hz. What integrated mean square follows?

A. 0.0075 V squared

B. 0.01125 V squared

C. 0.005 V squared

D. 0.00375 V squared

Answer: C. Convert Q to density and multiply by grid spacing: 0.0075 times 46.875/70.3125. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: 0.005 V squared.

Distinguishing consideration: compare this with option A, “0.0075 V squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-046. What does the half-bin Hann example show about scalloping?

A. It resolves any two tones after 2N padding

B. It guarantees zero error for every off-bin component

C. It makes coherent gain unnecessary

D. It reduces the stated error relative to rectangular but does not eliminate it

Answer: D. The stated nearest-bin ratios differ; interpolation can sample the response peak without changing its width. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: It reduces the stated error relative to rectangular but does not eliminate it.

Distinguishing consideration: compare this with option A, “It resolves any two tones after 2N padding”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-047. A 0.100 V peak sinusoid is across a stipulated 50 ohm resistive load. What is its mean power?

A. 0.000200 W

B. 0.000050 W

C. 0.005 W

D. 0.000100 W

Answer: D. Its mean square is peak squared divided by two; dividing 0.005 V squared by 50 ohms gives 0.0001 W. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: 0.000100 W.

Distinguishing consideration: compare this with option A, “0.000200 W”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-048. A 1 V impulse is at the center of a 16-point periodic Hann record with S_2 = 6. What is the integrated windowed density?

A. One sixth V squared

B. One sixteenth V squared

C. One V squared

D. One eighth V squared

Answer: A. The squared center weight is one, so weighted energy divided by S_2 is 1/6. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: One sixth V squared.

Distinguishing consideration: compare this with option B, “One sixteenth V squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-049. What does subtracting the mean do to the constant-record DC example?

A. It repairs a missing factor-of-two endpoint correction

B. It leaves the original DC measurement unchanged

C. It converts DC to a Nyquist component

D. It removes that processed DC component

Answer: D. Preprocessing changes the measurand; it must be documented rather than treated as normalization. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why the selected alternative fits: It removes that processed DC component.

Distinguishing consideration: compare this with option A, “It repairs a missing factor-of-two endpoint correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-MCQ-050. Why is specifying only the name Hann insufficient for short records?

A. Every Hann implementation uses random coefficients

B. The difference disappears exactly for all N greater than two

C. The name specifies only a detector, not a window

D. Periodic and endpoint-symmetric coefficient vectors have different sums

Answer: D. The generation convention matters appreciably at short N and must be unambiguous. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why the selected alternative fits: Periodic and endpoint-symmetric coefficient vectors have different sums.

Distinguishing consideration: compare this with option A, “Every Hann implementation uses random coefficients”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-MCQ-051. Which average combines squared spectral magnitudes for stationary random-power estimates?

A. Averaging individual logarithmic spectral levels

B. Taking only the largest record

C. Linear power averaging

D. Vector averaging of complex coefficients

Answer: C. Power averaging addresses the power statistic; complex averaging preserves phase and answers a different question. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: Linear power averaging.

Distinguishing consideration: compare this with option A, “Averaging individual logarithmic spectral levels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-052. What does vector averaging retain that power averaging discards?

A. A guarantee of external source origin

B. An unbiased occurrence probability

C. Coherent phase

D. Every independent noise realization separately

Answer: C. A coherent component can survive complex averaging while uncorrelated components tend to cancel under suitable conditions. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: Coherent phase.

Distinguishing consideration: compare this with option A, “A guarantee of external source origin”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-053. How does exponential averaging differ from equal-weight record averaging?

A. It necessarily averages logarithms

B. It selects only record maxima

C. It makes overlapping records independent

D. It gives greater weight to recent records

Answer: D. The temporal weights differ; the name does not itself imply a logarithmic estimator. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: It gives greater weight to recent records.

Distinguishing consideration: compare this with option A, “It necessarily averages logarithms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-054. Why might a percentile or max-hold result reveal a burst missed in an ordinary average?

A. A percentile creates missing bursts from unobserved intervals

B. Max hold proves all frequencies coexisted

C. A simple average always overstates rare-event power

D. Rare high records can be diluted by the many quiet records

Answer: D. Different summaries answer different questions about occurrence and magnitude. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: Rare high records can be diluted by the many quiet records.

Distinguishing consideration: compare this with option A, “A percentile creates missing bursts from unobserved intervals”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-055. What does an average count fail to establish when records overlap?

A. The fact that a calculation was performed

B. Effective independent information

C. The existence of a chosen window

D. The literal number of stored estimates

Answer: B. Correlation changes statistical uncertainty; count alone is not an independence measure. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: Effective independent information.

Distinguishing consideration: compare this with option A, “The fact that a calculation was performed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-056. How should a burst occurring in one of a hundred records be retained for occurrence analysis?

A. Discard the rare record as incompatible with stationarity

B. Treat its max-hold level as a 100 percent occurrence rate

C. Report only the one overall power average

D. Keep the distribution or event-resolved measurements as well as summaries

Answer: D. Per-record information preserves intermittency that a single aggregate can hide. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: Keep the distribution or event-resolved measurements as well as summaries.

Distinguishing consideration: compare this with option A, “Discard the rare record as incompatible with stationarity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-057. A line grows prominent under vector averaging. What alternative to an environmental source must remain open?

A. A mathematically impossible Fourier artifact

B. A necessarily random-phase external burst

C. Only uncorrelated thermal noise

D. A coherent internal spur

Answer: D. Coherence is a processing property, not a guarantee of external origin.

Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: A coherent internal spur.

Distinguishing consideration: compare this with option A, “A mathematically impossible Fourier artifact”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-058. What is the benefit of multiple declared summaries of the same per-record measurements?

A. They are independent acquisitions by definition

B. They prove a unique source when their plots look similar

C. They expose different power, peak, and occurrence properties

D. They eliminate the need to freeze analysis choices

Answer: C. Complementary summaries can reveal state changes; their relationship to source records and selection must remain clear. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why the selected alternative fits: They expose different power, peak, and occurrence properties.

Distinguishing consideration: compare this with option A, “They are independent acquisitions by definition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-MCQ-059. Which records should enter the paired spectra used for coherence?

A. Only the records maximizing each channel separately

B. Independently selected records optimized for each spectrum

C. Corresponding aligned X and Y records with common weights

D. Unmatched records from different acquisition times

Answer: C. The bound and interpretation depend on one paired construction, not arbitrary combinations of spectra. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: Corresponding aligned X and Y records with common weights.

Distinguishing consideration: compare this with option A, “Only the records maximizing each channel separately”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-060. If either autospectrum is zero, what is coherence under the stated ratio?

A. Zero by definition

B. The value of the other autospectrum

C. One by definition

D. Undefined

Answer: D. The denominator fails; assigning zero would add an unsupported physical interpretation. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: Undefined.

Distinguishing consideration: compare this with option A, “Zero by definition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-061. With voltage input and current output, what are cross-spectrum units?

A. Amperes per volt

B. Volt ampere per hertz

C. Volts squared per hertz for every channel pair

D. Dimensionless

Answer: B. The cross-product carries both channel units and the common density normalization. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: Volt ampere per hertz.

Distinguishing consideration: compare this with option A, “Amperes per volt”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-062. What happens when the entire cross-spectrum convention is conjugated?

A. Both phase and coherence signs reverse

B. Its phase sign reverses while magnitude-squared coherence is unchanged

C. Its autospectra become negative

D. Its fitted physical delay becomes uniquely unambiguous

Answer: B. Magnitude is unchanged by conjugation, but phase-based delay requires the declared convention. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: Its phase sign reverses while magnitude-squared coherence is unchanged.

Distinguishing consideration: compare this with option A, “Both phase and coherence signs reverse”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-063. What ensures the finite coherence ratio lies between zero and one?

A. A logarithmic display of the ratio

B. Any three separately summarized spectra with the same units

C. One consistently paired estimate with common nonnegative weights and positive autospectra

D. A large record count regardless of selection

Answer: C. The Cauchy–Schwarz proof applies to a common weighted pair of coefficient vectors. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: One consistently paired estimate with common nonnegative weights and positive autospectra.

Distinguishing consideration: compare this with option A, “A logarithmic display of the ratio”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-064. When does the finite paired estimate attain coherence one?

A. One complex gain relates Y to X on every positive-weight record, with nonzero vectors

B. Whenever the average record count exceeds the bin count

C. Whenever X and Y share a nominal sample rate

D. Whenever the two autospectra have equal units

Answer: A. Equality is a proportional-vector condition; it does not identify a physical causal path. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: One complex gain relates Y to X on every positive-weight record, with nonzero vectors.

Distinguishing consideration: compare this with option B, “Whenever the average record count exceeds the bin count”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-065. Why can the algebraic coherence bound hold without a valid confidence interval?

A. The bound itself proves independent samples

B. Any value between zero and one is an exact probability

C. The bound does not require record independence, while uncertainty needs additional assumptions

D. More digits in the ratio remove sampling uncertainty

Answer: C. The finite inequality and a statistical uncertainty claim have different premises. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: The bound does not require record independence, while uncertainty needs additional assumptions.

Distinguishing consideration: compare this with option A, “The bound itself proves independent samples”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-066. In the chapter's estimator, what operation precedes taking the cross-spectrum magnitude squared?

A. Average the complex cross-products

B. Select the largest positive product

C. Average the per-record normalized magnitudes

D. Take each product's magnitude and discard its phase

Answer: A. Complex averaging preserves cancellation and phase relationships that magnitude-first processing would erase. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: Average the complex cross-products.

Distinguishing consideration: compare this with option B, “Select the largest positive product”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-067. For a single nonzero paired coefficient, what is the normalized coherence ratio?

A. A unique measure of causal probability

B. Undefined for every complex pair

C. Zero unless the two coefficients are identical

D. One regardless of whether a repeatable relationship is established

Answer: D. Any nonzero one-pair vectors admit a perfect scalar fit; unity is then not evidence of repeatable coupling. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: One regardless of whether a repeatable relationship is established.

Distinguishing consideration: compare this with option A, “A unique measure of causal probability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-068. What can happen if each of the three spectra uses different retained records?

A. Only the phase changes, never the magnitude

B. The common paired-estimate bound need not survive

C. The denominator automatically restores pairing

D. The ratio necessarily becomes more conservative

Answer: B. Changing the record set breaks the common inner-product construction on which the bound rests. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: The common paired-estimate bound need not survive.

Distinguishing consideration: compare this with option A, “Only the phase changes, never the magnitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-069. Separate medians of X powers, Y powers, and cross-products give 1, 1, and 10 in the chapter's example. What ratio results?

A. 0.1, because the cross-product must be inverted

B. 0, because medians remove every shared component

C. 1, because all coherence ratios are clipped by algebra

D. 100, exposing the loss of the weighted-mean construction

Answer: D. The formal substitution gives 10 squared divided by 1; separate robust summaries do not inherit the mean-based proof. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: 100, exposing the loss of the weighted-mean construction.

Distinguishing consideration: compare this with option A, “0.1, because the cross-product must be inverted”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-070. Common paired means give $P_{xx} = P_{yy} = \frac{101}{3}$ and $P_{xy} = \frac{20}{3}$ in compatible density units. What is magnitude-squared coherence approximately?

A. 0.03921

B. 100

C. 0.19802

D. 1

Answer: A. The ratio is $\frac{400}{10201}$; averaging consistently restores the stated paired bound. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: 0.03921.

Distinguishing consideration: compare this with option B, “100”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-071. What is the best fitted complex gain for the declared output-on-input projection?

A. The square root of coherence alone

B. P_{xy} divided by P_{xx}

C. The magnitude of P_{xy} divided by P_{xx} with phase discarded

D. P_{xy} divided by P_{yy}

Answer: B. Completing the residual square gives the complex gain, with units of output per input. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why the selected alternative fits: divided by.

Distinguishing consideration: compare this with option A, “The square root of coherence alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-MCQ-072. What is the minimum residual density in that fit?

A. P_{yy} divided by coherence

B. P_{yy} times one minus coherence

C. The magnitude of P_{xy} alone

D. P_{xx} times coherence

Answer: B. The unexplained output sum of squares is the output autospectrum minus squared cross-spectrum over input autospectrum. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why the selected alternative fits: times one minus coherence.

Distinguishing consideration: compare this with option A, “divided by coherence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-MCQ-073. What does the fitted fraction interpretation of coherence establish for finite records?

A. The probability that X physically caused Y

B. How much output spectral sum of squares the best one-gain fit explains

C. Statistical independence of the residual from every input feature

D. Validity of the gain in all future operating states

Answer: B. It is a conditional finite fit; causal direction, residual independence, and extrapolation require other evidence. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why the selected alternative fits: How much output spectral sum of squares the best one-gain fit explains.

Distinguishing consideration: compare this with option A, “The probability that X physically caused Y”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-MCQ-074. Under which model does coherence divided by one minus coherence equal output SNR?

A. Any state mixture with positive autospectra

B. Any single nonzero paired record

C. Exact input observation with linear gain and uncorrelated additive output disturbance

D. Any two noisy channels with the same coherence

Answer: C. Input noise or correlated disturbance violates the stated derivation's premise. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why the selected alternative fits: Exact input observation with linear gain and uncorrelated additive output disturbance.

Distinguishing consideration: compare this with option A, “Any state mixture with positive autospectra”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-MCQ-075. Why can equal coherence arise from different output SNRs?

A. Noise can enter the measured input and output in different allocations

B. The density normalization alone determines noise location

C. The coherence formula has units of decibels

D. Every finite fit has identical residual variance

Answer: A. The noisy-input expression contains both input and output disturbance terms; coherence alone does not identify them. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why the selected alternative fits: Noise can enter the measured input and output in different allocations.

Distinguishing consideration: compare this with option B, “The density normalization alone determines noise location”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-MCQ-076. In the stated exact-input model, coherence is 0.9. What is output SNR as a linear power ratio?

A. 0.1

B. 9

C. 0.9

D. 10

Answer: B. The model-specific ratio is $\frac{0.9}{(1-0.9)}$; the premises are essential. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: 9.

Distinguishing consideration: compare this with option A, “0.1”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-077. What does a common latent-source model sharing the same spectral matrix as a direct-path model demonstrate?

A. Second-order spectra alone cannot choose the physical narrative

B. A positive cross-spectrum excludes common excitation

C. One representation must violate the coherence bound

D. Coherence uniquely proves the direct path

Answer: A. Several physical constructions can produce the same paired spectra.

Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: Second-order spectra alone cannot choose the physical narrative.

Distinguishing consideration: compare this with option B, “A positive cross-spectrum excludes common excitation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-078. For equal-power uncorrelated S and D entering X = S + D and Y = S minus D, what is coherence?

A. Undefined because the autospectra cancel

B. One because both components are shared

C. Zero despite both components being shared

D. One half because two sources are present

Answer: C. The cross contributions cancel while each autospectrum remains positive. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why the selected alternative fits: Zero despite both components being shared.

Distinguishing consideration: compare this with option A, “Undefined because the autospectra cancel”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-MCQ-079. What does a negative real cross-spectrum imply by itself?

A. Absence of any shared component

B. An invalid estimator for every possible signal

C. Negative physical mean power in one channel

D. A relative-phase relationship under the stated convention, not negative autospectral power

Answer: D. Cross-spectra can be negative or complex while autospectra remain nonnegative. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: A relative-phase relationship under the stated convention, not negative autospectral power.

Distinguishing consideration: compare this with option A, “Absence of any shared component”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-MCQ-080. Equal-weight records have X all ones and Y signs +, +,minus,minus. What happens on pooling?

A. Coherence is zero although each same-sign state has coherence one

B. Coherence stays one because every per-record ratio is one

C. The cross-spectrum must be positive

D. The autospectra become zero

Answer: A. Opposite state gains cancel in the complex mean; pooling changes the relationship being estimated. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: Coherence is zero although each same-sign state has coherence one.

Distinguishing consideration: compare this with option B, “Coherence stays one because every per-record ratio is one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-081. If the positive-gain state has total weight three quarters and the negative-gain state one quarter, what coherence follows in that example?

A. One quarter

B. One half

C. One

D. Three quarters

Answer: A. The cross mean is one half of the common scale; its squared normalized magnitude is one quarter. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: One quarter.

Distinguishing consideration: compare this with option B, “One half”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-082. How should states be defined for state-conditioned coherence reporting?

A. By a defensible rule independent of the desired coherence result

B. By deleting all negative cross-products automatically

C. By selecting whichever records maximize coherence

D. By assigning a separate state to every nonzero pair

Answer: A. Postselecting to force a desired fit obscures the claimed ensemble and its interpretation. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: By a defensible rule independent of the desired coherence result.

Distinguishing consideration: compare this with option B, “By deleting all negative cross-products automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-083. Why does coherence invariance to fixed nonzero channel gains not remove calibration requirements?

A. Every gain change leaves the physical delay calibration identical

B. The fitted amplitude and phase can change even when coherence does not

C. A zero channel gain preserves the denominator

D. Coherence also supplies absolute voltage automatically

Answer: B. The normalized ratio can cancel fixed gain factors while gain and phase measurands still depend on them. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: The fitted amplitude and phase can change even when coherence does not.

Distinguishing consideration: compare this with option A, “Every gain change leaves the physical delay calibration identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-084. For P_{xx} = 4, P_{yy} = 5, and P_{xy} = 3 + j in compatible density units, what is coherence?

A. 0.75

B. 0.25

C. 0.4

D. 0.5

Answer: D. The cross magnitude squared is 10 and the autospectral product is 20.

Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: 0.5.

Distinguishing consideration: compare this with option A, “0.75”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-085. For those same spectra, what is the minimum output residual density in output squared units per hertz?

A. 1

B. 5

C. 2.5

D. 3

Answer: C. The residual is P_{yy} times (1-C), or 5 times 0.5. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: 2.5.

Distinguishing consideration: compare this with option A, “1”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-086. With X conjugated in the cross-spectrum, a delay gives Y = exp(minus j two pi f tau) X. What is its phase slope sign for positive delay?

A. Zero whenever coherence is one

B. Undefined solely because the gain magnitude is one

C. Negative on the stated continuous branch

D. Positive under every convention

Answer: C. The declared exponential and conjugation convention determine the sign; branch ambiguity remains. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: Negative on the stated continuous branch.

Distinguishing consideration: compare this with option A, “Zero whenever coherence is one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-087. What prevents a single-bin phase from establishing a unique absolute propagation delay?

A. Integer-cycle ambiguity in addition to channel calibration limits

B. The fact that phase is always unrelated to delay

C. Coherence must be zero at one bin

D. A one-sided spectrum has no phase

Answer: A. Several delays differ by whole cycles at one frequency; the chosen branch and timing evidence matter. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why the selected alternative fits: Integer-cycle ambiguity in addition to channel calibration limits.

Distinguishing consideration: compare this with option B, “The fact that phase is always unrelated to delay”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-MCQ-088. Which challenge directly investigates a possible recorder-mediated coherence path?

A. Selecting only the frequency bin with greatest coherence

B. Increasing the coherence display's averaging count alone

C. Channel swapping, independent terminations, and known injected references

D. Replacing phase by magnitude before averaging

Answer: C. Controlled path changes probe alternatives such as shared references and cable leakage. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

Why the selected alternative fits: Channel swapping, independent terminations, and known injected references.

Distinguishing consideration: compare this with option A, “Selecting only the frequency bin with greatest coherence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis.

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V011-C09-MCQ-089. High coherence collapses after isolated-digitizer substitution and an injected reference reveals clock leakage. What is supported?

A. Coherence is mathematically meaningless in all instruments

B. The room contains no possible coupling under any condition

C. The original recorder has a contaminating path that limits the room-coupling inference

D. Every original spectral line was absent

Answer: C. The specific challenge identifies a mechanism without proving universal absence of another path. Source: §9.10 Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5076)

Why the selected alternative fits: The original recorder has a contaminating path that limits the room-coupling inference.

Distinguishing consideration: compare this with option A, “Coherence is mathematically meaningless in all instruments”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-MCQ-090. Why preserve sensitivity and receiver state during a path challenge?

A. Otherwise a changed indication may reflect changed capability rather than removal of the path

B. Only geometry matters for the comparison

C. Any lower noise floor guarantees a fair comparison

D. A different gain state never affects coherence interpretation

Answer: A. A causal interpretation of the challenge requires comparable measurement capability and declared conditions. Source: §9.10 Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5076)

Why the selected alternative fits: Otherwise a changed indication may reflect changed capability rather than removal of the path.

Distinguishing consideration: compare this with option B, “Only geometry matters for the comparison”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-MCQ-091. What does an STFT represent?

A. One spectrum with unlimited time and frequency resolution

B. Spectral estimates over successive finite windows

C. A direct photograph independent of processing

D. A new simultaneous acquisition created after recording

Answer: B. Window placement and duration condition the evolving estimates and link time and frequency resolution. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

Why the selected alternative fits: Spectral estimates over successive finite windows.

Distinguishing consideration: compare this with option A, “One spectrum with unlimited time and frequency resolution”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Time-Frequency and Nonstationary Methods.

Review: Chapter 9 — Time-Frequency and Nonstationary Methods.

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V011-C09-MCQ-092. Why should color scales and thresholds be reported for a time-frequency image?

A. They influence which features appear visible

B. They fix all leakage corrections automatically

C. They replace the need for raw samples

D. They establish physical source identity

Answer: A. Visual structure depends on mapping and threshold choices as well as the signal. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

Why the selected alternative fits: They influence which features appear visible.

Distinguishing consideration: compare this with option B, “They fix all leakage corrections automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Time-Frequency and Nonstationary Methods.

Review: Chapter 9 — Time-Frequency and Nonstationary Methods.

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V011-C09-MCQ-093. Which procedure reduces the risk of tuning analysis to a desired feature?

A. Delete records that do not reproduce the picture

B. Choose the window after seeing each desired outcome

C. Freeze parameters before evaluating held-out data

D. Use the same data to select and certify a threshold without qualification

Answer: C. The chapter separates parameter choice from held-out evaluation of the intended estimator. Source: §9.7 Estimator Validation and Reporting (p. 5072)

Why the selected alternative fits: Freeze parameters before evaluating held-out data.

Distinguishing consideration: compare this with option A, “Delete records that do not reproduce the picture”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Estimator Validation and Reporting.

Review: Chapter 9 — Estimator Validation and Reporting.

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V011-C09-MCQ-094. Which reference set best exercises a general spectral-estimation method?

A. Only one stationary tone regardless of use

B. Known tones, noise, bursts, chirps, and appropriate multichannel references

C. Only white noise for every transient claim

D. Only a plot generated by the same script

Answer: B. Different references challenge amplitude, noise, time localization, leakage, and channel relationships. Source: §9.7 Estimator Validation and Reporting (p. 5072)

Why the selected alternative fits: Known tones, noise, bursts, chirps, and appropriate multichannel references.

Distinguishing consideration: compare this with option A, “Only one stationary tone regardless of use”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Estimator Validation and Reporting.

Review: Chapter 9 — Estimator Validation and Reporting.

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V011-C09-MCQ-095. Increasing record length improves nominal spacing but introduces what consideration?

A. A longer interval over which stationarity may be assumed

B. A guarantee that every transient is resolved

C. An automatic doubling of independent averages

D. A reduction of sample rate by definition

Answer: A. More observation time can improve spacing while mixing changes that shorter records would separate. Source: §9.8 Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5073)

Why the selected alternative fits: A longer interval over which stationarity may be assumed.

Distinguishing consideration: compare this with option B, “A guarantee that every transient is resolved”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-MCQ-096. Two tones are 20 Hz apart and nominal bins are about 15.26 Hz apart. What is justified?

A. Their separation is impossible to estimate under any processing

B. They may remain unresolved because window response and estimator matter

C. They become resolved merely by eightfold padding

D. They must be resolved because they occupy different numerical frequencies

Answer: B. Bin spacing alone is not actual two-tone resolution. Source: §9.8 Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5073)

Why the selected alternative fits: They may remain unresolved because window response and estimator matter.

Distinguishing consideration: compare this with option A, “Their separation is impossible to estimate under any processing”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-MCQ-097. Which record uniquely defines a reproducible window normalization?

A. The coefficient vector or unambiguous generation convention with N and sample rate

B. Only the number of padded bins

C. Only a familiar window name

D. Only the final dBm axis limits

Answer: A. Actual coefficients determine S_1, S_2, and the resulting amplitude and density scales. Source: §9.3.5 Measurement consequence (p. 5050)

Why the selected alternative fits: The coefficient vector or unambiguous generation convention with N and sample rate.

Distinguishing consideration: compare this with option B, “Only the number of padded bins”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Measurement consequence.

Review: Chapter 9 — Measurement consequence.

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V011-C09-MCQ-098. What remains unproven even when spectral energy arithmetic closes exactly?

A. The retained numerical weight sums

B. Acquisition continuity and usable transient coverage

C. The chosen frequency-grid spacing used in the sum

D. The algebraic equality actually checked

Answer: B. Correct spectral arithmetic does not establish that valid source samples covered the event. Source: §9.3.5 Measurement consequence (p. 5050)

Why the selected alternative fits: Acquisition continuity and usable transient coverage.

Distinguishing consideration: compare this with option A, “The retained numerical weight sums”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Measurement consequence.

Review: Chapter 9 — Measurement consequence.

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V011-C09-MCQ-099. Why must a plotted spectrum remain linked to executable analysis and original samples?

A. Scripts eliminate all receiver calibration uncertainty

B. Every replot becomes an independent measurement

C. A reviewer must reconstruct preprocessing, scaling, exclusion, and display choices

D. The link itself proves a physical emitter

Answer: C. Reproducibility requires the data-to-estimate transformation and its parameters, not only the image. Source: §9.7 Estimator Validation and Reporting (p. 5072)

Why the selected alternative fits: A reviewer must reconstruct preprocessing, scaling, exclusion, and display choices.

Distinguishing consideration: compare this with option A, “Scripts eliminate all receiver calibration uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Estimator Validation and Reporting.

Review: Chapter 9 — Estimator Validation and Reporting.

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V011-C09-MCQ-100. Which conclusion best integrates Models 9W and 9C?

A. Energy closure supplies a confidence interval for coherence

B. Window normalization and paired-channel relationship are separate defined estimators with distinct limits

C. High coherence makes amplitude normalization unnecessary

D. Correct window gain alone proves a causal multichannel path

Answer: B. The models answer different questions and cannot substitute for each other's acquisition or inference requirements. Source: §9.7 Estimator Validation and Reporting (p. 5072)

Why the selected alternative fits: Window normalization and paired-channel relationship are separate defined estimators with distinct limits.

Distinguishing consideration: compare this with option A, “Energy closure supplies a confidence interval for coherence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Estimator Validation and Reporting.

Review: Chapter 9 — Estimator Validation and Reporting.

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Fill-in-the-Blank Questions

V011-C09-FIB-001. An FFT starts from a _____ sampled record rather than an infinite observation.

Answer: finite. Record length and preprocessing bound what the estimate represents. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

Why this term is required: “finite” completes the stated technical proposition.

Question context: An FFT starts from a _____ sampled record rather than an infinite observation

Basis and qualification: Chapter 9 — Discrete Records and Spectral Estimates.

Review: Chapter 9 — Discrete Records and Spectral Estimates.

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V011-C09-FIB-002. For an unpadded record, nominal frequency spacing is sample rate divided by sample _____.

Answer: count. The record length N appears in the bin-spacing formula. Source: §9.8 Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5073)

Why this term is required: “count” completes the stated technical proposition.

Question context: For an unpadded record, nominal frequency spacing is sample rate divided by sample _____

Basis and qualification: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-FIB-003. At 1000 samples per second with 250 unpadded samples, nominal spacing is _____ Hz.

Answer: 4. Dividing 1000 by 250 gives 4 Hz; actual resolution also depends on the window and signal. Source: §9.8 Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5073)

Why this term is required: “4” completes the stated technical proposition.

Question context: At 1000 samples per second with 250 unpadded samples, nominal spacing is _____ Hz

Basis and qualification: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-FIB-004. At fixed sample rate, doubling the observed sample count halves nominal bin _____.

Answer: spacing. This also doubles the acquisition duration and can affect stationarity. Source: §9.8 Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation (p. 5073)

Why this term is required: “spacing” completes the stated technical proposition.

Question context: At fixed sample rate, doubling the observed sample count halves nominal bin _____

Basis and qualification: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-FIB-005. The represented Nyquist interval is determined by sample _____.

Answer: rate. Padding changes the grid, not the sampling interval's spectral representation. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
Why this term is required: “rate” completes the stated technical proposition.
Question context: The represented Nyquist interval is determined by sample _____
Basis and qualification: Chapter 9 — Discrete Records and Spectral Estimates.
Review: Chapter 9 — Discrete Records and Spectral Estimates.

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V011-C09-FIB-006. A tone whose frequency lies between DFT grid points is described here as off-_____.

Answer: grid. Its nearest-bin amplitude includes the window's off-grid response.

Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “grid” completes the stated technical proposition.

Question context: A tone whose frequency lies between DFT grid points is described here as off-_____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-007. The spectral spreading caused by finite-window multiplication is called spectral _____.

Answer: leakage. Its pattern depends on the window and tone position. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why this term is required: “leakage” completes the stated technical proposition.

Question context: The spectral spreading caused by finite-window multiplication is called spectral _____

Basis and qualification: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-FIB-008. Tapering commonly lowers sidelobes while widening the main _____.

Answer: lobe. That tradeoff affects the ability to distinguish close components.

Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why this term is required: “lobe” completes the stated technical proposition.

Question context: Tapering commonly lowers sidelobes while widening the main _____

Basis and qualification: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-FIB-009. The window characteristic describing loss when a tone falls between bins is _____ loss.

Answer: scalloping. Coherent-gain correction alone does not eliminate the off-grid amplitude error. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

Why this term is required: “scalloping” completes the stated technical proposition.

Question context: The window characteristic describing loss when a tone falls between bins is _____ loss

Basis and qualification: Chapter 9 — Spectral Leakage and Window Selection.

Review: Chapter 9 — Spectral Leakage and Window Selection.

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V011-C09-FIB-010. The original sample record should retain acquisition _____ flags to support checks for saturation.

Answer: overflow. A spectral image may conceal clipped acquisition behavior.

Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

Why this term is required: “overflow” completes the stated technical proposition.

Question context: The original sample record should retain acquisition _____ flags to support checks for saturation

Basis and qualification: Chapter 9 — Discrete Records and Spectral Estimates.

Review: Chapter 9 — Discrete Records and Spectral Estimates.

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V011-C09-FIB-011. The window coefficients in Model 9W are dimensionless and _____.

Answer: real. The defined model uses a specified real coefficient vector. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “real” completes the stated technical proposition.

Question context: The window coefficients in Model 9W are dimensionless and _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-012. The coherent sum of window coefficients is denoted _____.

Answer: S_1. A coherent complex tone's transform coefficient equals amplitude times this sum. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “A coherent complex tone's transform coefficient equals amplitude times this sum” completes the stated technical proposition.

Question context: The coherent sum of window coefficients is denoted _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-013. The sum of squared window coefficients is denoted _____.

Answer: S_2. It supplies the white-noise gain and density normalization. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “It supplies the white-noise gain and density normalization” completes the stated technical proposition.

Question context: The sum of squared window coefficients is denoted _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-014. Coherent gain equals S_1 divided by

_____.

Answer: N. The model normalizes the coherent weight sum by observed sample count. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “N” completes the stated technical proposition.

Question context: Coherent gain equals divided by _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-015. For a rectangular N-point window of ones, S_1 equals _____.

Answer: N. All N unit weights add coherently. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “N” completes the stated technical proposition.

Question context: For a rectangular N-point window of ones, equals _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-016. For that same rectangular window, S_2 also equals _____.

Answer: N. Squaring each unit weight leaves N terms of one. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “N” completes the stated technical proposition.

Question context: For that same rectangular window, also equals _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-017. A complex coherent tone is recovered by dividing its bin coefficient by the coherent _____ sum.

Answer: weight. The correct sum is S_1, not S_2 or padded length. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “weight” completes the stated technical proposition.

Question context: A complex coherent tone is recovered by dividing its bin coefficient by the coherent _____ sum

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-018. The real-sinusoid derivation retains the negative-frequency _____ term.

Answer: image. It can contribute at the positive bin through the window response.

Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “image” completes the stated technical proposition.

Question context: The real-sinusoid derivation retains the negative-frequency _____ term

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-019. For exact real-tone recovery by the simple doubled magnitude, that image term must _____.

Answer: vanish. A sufficiently small contribution may instead be bounded to a justified accuracy. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “vanish” completes the stated technical proposition.

Question context: For exact real-tone recovery by the simple doubled magnitude, that image term must _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-020. Removing a record mean before transformation is a form of _____.

Answer: preprocessing. The reported result must identify that change to the estimated record. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “preprocessing” completes the stated technical proposition.

Question context: Removing a record mean before transformation is a form of _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-FIB-021. The two-sided density D_2 has voltage units squared per _____.

Answer: hertz. Its denominator contains sample rate times the squared-weight sum. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “hertz” completes the stated technical proposition.

Question context: The two-sided density has voltage units squared per _____

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-022. The line-normalized squared spectrum Q2 has units of volts _____.

Answer: squared. It is related to density through equivalent noise bandwidth.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “squared” completes the stated technical proposition.

Question context: The line-normalized squared spectrum Q2 has units of volts _____

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-023. Equivalent noise bandwidth has units of

_____.

Answer: hertz. It converts a density ordinate to a line-normalized squared ordinate.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “hertz” completes the stated technical proposition.

Question context: Equivalent noise bandwidth has units of _____

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-024. Under the stipulated white covariance, expected squared transform magnitude equals variance times _____.

Answer: S_2. The off-diagonal covariance terms vanish in the expansion. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: "The off-diagonal covariance terms vanish in the expansion" completes the stated technical proposition.

Question context: Under the stipulated white covariance, expected squared transform magnitude equals variance times _____

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-025. The Kronecker-delta covariance assumption makes distinct sample cross terms have _____ expectation.

Answer: zero. This is the second-order reason for the white density expectation.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “zero” completes the stated technical proposition.

Question context: The Kronecker-delta covariance assumption makes distinct sample cross terms have _____ expectation

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-026. The white-noise density expectation does not require a _____ probability distribution.

Answer: Gaussian. The stated mean and covariance suffice for the calculation.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “Gaussian” completes the stated technical proposition.

Question context: The white-noise density expectation does not require a _____ probability distribution

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-027. With S_1 nonzero and D_2 greater than zero, Q2 divided by D_2 equals equivalent noise _____.

Answer: bandwidth. The identity is recordwise and is not restricted to white noise.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “bandwidth” completes the stated technical proposition.

Question context: With nonzero and greater than zero, Q2 divided by equals equivalent noise _____

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-028. Interior positive bins of a real-record density are _____ in a one-sided fold.

Answer: doubled. They combine equal positive and negative contributions. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “doubled” completes the stated technical proposition.

Question context: Interior positive bins of a real-record density are _____ in a one-sided fold

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-029. The zero-frequency endpoint is commonly called _____.

Answer: DC. It is retained without the interior-bin doubling. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “DC” completes the stated technical proposition.

Question context: The zero-frequency endpoint is commonly called _____

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-030. For even N, the other undoubled endpoint is the _____ bin.

Answer: Nyquist. It has no distinct opposite-frequency partner in the finite transform. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “Nyquist” completes the stated technical proposition.

Question context: For even N, the other undoubled endpoint is the _____ bin

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-031. An odd-length real record has no sampled _____ endpoint.

Answer: Nyquist. Its highest positive bin is an interior contribution and is doubled.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “Nyquist” completes the stated technical proposition.

Question context: An odd-length real record has no sampled _____ endpoint

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-032. Complex records generally lack the conjugate _____ used for real one-sided folding.

Answer: symmetry. Their positive and negative spectra need not be equal. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “symmetry” completes the stated technical proposition.

Question context: Complex records generally lack the conjugate _____ used for real one-sided folding

Basis and qualification: Chapter 9 — Noise density uses a different denominator.

Review: Chapter 9 — Noise density uses a different denominator.

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V011-C09-FIB-033. Exact density integration gives a window-weighted mean _____.

Answer: square. The squared weights remain in the finite-record energy identity.

Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “square” completes the stated technical proposition.

Question context: Exact density integration gives a window-weighted mean _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-034. To integrate a discrete density, multiply ordinates by frequency-grid _____.

Answer: spacing. A density is per hertz; summation requires the bin interval. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “spacing” completes the stated technical proposition.

Question context: To integrate a discrete density, multiply ordinates by frequency-grid _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-035. The window-weighted mean square need not equal the _____ sample mean square for a particular transient.

Answer: unweighted. The transient's location in the coefficient vector matters.

Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “unweighted” completes the stated technical proposition.

Question context: The window-weighted mean square need not equal the _____ sample mean square for a particular transient

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-036. Fourier energy closure is often associated with _____ identity.

Answer: Parseval's. Closure checks consistent transform arithmetic and normalization. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “Parseval's” completes the stated technical proposition.

Question context: Fourier energy closure is often associated with _____ identity

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-037. A correct energy sum does not establish the _____ of a noise spectrum.

Answer: whiteness. Colored covariance can change individual ordinates while preserving total closure. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “whiteness” completes the stated technical proposition.

Question context: A correct energy sum does not establish the _____ of a noise spectrum

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-038. For periodic Hann and N greater than two, S_1 is N divided by _____.

Answer: two. The finite sum of the periodic coefficients is $\frac{N}{2}$. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “two” completes the stated technical proposition.

Question context: For periodic Hann and N greater than two, is N divided by _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-039. For periodic Hann in that domain, S_2 is three N divided by _____.

Answer: eight. The squared-coefficient sum is $\frac{3N}{8}$. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “eight” completes the stated technical proposition.

Question context: For periodic Hann in that domain, is three N divided by _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-040. Periodic Hann equivalent noise bandwidth is _____ times unpadded bin spacing.

Answer: 1.5. Substitution of its sums yields $\frac{3 f_s}{(2N)}$. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “1.5” completes the stated technical proposition.

Question context: Periodic Hann equivalent noise bandwidth is _____ times unpadded bin spacing

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-041. The endpoint-symmetric Hann uses N minus _____ in its cosine denominator.

Answer: one. Its finite sums differ from the periodic convention, especially for short records. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “one” completes the stated technical proposition.

Question context: The endpoint-symmetric Hann uses N minus _____ in its cosine denominator

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-042. Scaling all window weights by the same nonzero real constant leaves normalized density _____.

Answer: unchanged. The coefficient magnitude squared and S_2 scale together.

Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “unchanged” completes the stated technical proposition.

Question context: Scaling all window weights by the same nonzero real constant leaves normalized density _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-043. The equivalent-noise-bandwidth lower bound follows from the _____ inequality used on window sums.

Answer: Cauchy–Schwarz. The squared sum is no greater than N times the squared-weight sum. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “Cauchy–Schwarz” completes the stated technical proposition.

Question context: The equivalent-noise-bandwidth lower bound follows from the _____ inequality used on window sums

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-044. A zero-sum window makes coherent-gain normalization _____.

Answer: undefined. Division by S_1 is not meaningful when S_1 is zero. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “undefined” completes the stated technical proposition.

Question context: A zero-sum window makes coherent-gain normalization _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-045. That zero-sum window can still define density if S_2 is _____.

Answer: positive. Density uses the squared-weight sum and positive sample rate rather than S_1. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “positive” completes the stated technical proposition.

Question context: That zero-sum window can still define density if is _____

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-046. Adding zeros after a record increases transform length without adding _____.

Answer: observations. It samples the same finite-record transform on a denser grid. Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “observations” completes the stated technical proposition.

Question context: Adding zeros after a record increases transform length without adding _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-047. With padding to M, displayed spacing is sample rate divided by _____.

Answer: M. The integral uses this grid while normalization retains original sums.

Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “M” completes the stated technical proposition.

Question context: With padding to M, displayed spacing is sample rate divided by _____

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-048. An eightfold padding leaves the original equivalent noise bandwidth _____ in hertz.

Answer: unchanged. The observed coefficients and window vector have not changed. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)
Why this term is required: “unchanged” completes the stated technical proposition.
Question context: An eightfold padding leaves the original equivalent noise bandwidth _____ in hertz
Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.
Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-049. Using padded length as though it were observed N can falsely narrow the estimated noise _____.

Answer: bandwidth. The chapter's example shows an eightfold density error from that substitution. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “bandwidth” completes the stated technical proposition.

Question context: Using padded length as though it were observed N can falsely narrow the estimated noise _____

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-050. For the periodic Hann example, adjacent tone bins are part of the same window _____.

Answer: response. They should not be counted as independent physical lines without further evidence. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “response” completes the stated technical proposition.

Question context: For the periodic Hann example, adjacent tone bins are part of the same window _____

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-051. To integrate Q ordinates, first divide by equivalent noise bandwidth to obtain _____.

Answer: density. Then multiply by actual frequency-grid spacing and sum. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “density” completes the stated technical proposition.

Question context: To integrate Q ordinates, first divide by equivalent noise bandwidth to obtain _____

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-052. Padding can improve peak _____ without narrowing the underlying response.

Answer: location. A denser grid can sample an isolated response peak more closely.

Source: §9.3.3 Energy closure and its limits (p. 5036)

Why this term is required: “location” completes the stated technical proposition.

Question context: Padding can improve peak _____ without narrowing the underlying response

Basis and qualification: Chapter 9 — Energy closure and its limits.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-FIB-053. For a 0.2 V peak sinusoid averaged over complete cycles, mean square is _____ V squared.

Answer: 0.02. Over complete cycles, the cosine-squared average is one half, giving $\frac{0.04}{2}$ V squared; an arbitrary finite fragment need not share that average. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “0.02” completes the stated technical proposition.

Question context: For a 0.2 V peak sinusoid averaged over complete cycles, mean square is _____ V squared

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-054. Across a stipulated 50 ohm resistor, that 0.02 V squared is _____ W.

Answer: 0.0004. Power is mean square voltage divided by resistance in this hypothetical conversion. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “0.0004” completes the stated technical proposition.

Question context: Across a stipulated 50 ohm resistor, that 0.02 V squared is _____ W

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-055. Doubling a DC or Nyquist contribution introduces approximately _____ dB error.

Answer: 3.0103. The erroneous factor of two has a ten-times logarithm of about 3.0103 dB. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “3.0103” completes the stated technical proposition.

Question context: Doubling a DC or Nyquist contribution introduces approximately _____ dB error

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-056. In the 16-point Hann impulse example, a sample at the zero-weight edge contributes _____ to the windowed energy.

Answer: zero. The estimator can suppress that event despite nonzero unweighted energy. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “zero” completes the stated technical proposition.

Question context: In the 16-point Hann impulse example, a sample at the zero-weight edge contributes _____ to the windowed energy

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-057. The same impulse at the unit-weight center with S_2 = 6 contributes one _____ V squared.

Answer: sixth. The exact weighted mean square is 1/6. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “sixth” completes the stated technical proposition.

Question context: The same impulse at the unit-weight center with = 6 contributes one _____ V squared

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-058. For weights 1, minus 1, 1, minus 1, the squared-weight sum is _____.

Answer: four. Every squared coefficient is one even though the coherent sum cancels. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

Why this term is required: “four” completes the stated technical proposition.

Question context: For weights 1, minus 1, 1, minus 1, the squared-weight sum is _____

Basis and qualification: Chapter 9 — Ten worked applications of the normalization model.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-FIB-059. Physical power conversion from voltage mean square requires a stated conversion _____.

Answer: impedance. The chapter's 50 ohm examples stipulate a resistive load rather than certify an instrument plane. Source: §9.3.5 Measurement consequence (p. 5050)

Why this term is required: “impedance” completes the stated technical proposition.

Question context: Physical power conversion from voltage mean square requires a stated conversion _____

Basis and qualification: Chapter 9 — Measurement consequence.

Review: Chapter 9 — Measurement consequence.

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V011-C09-FIB-060. A reproducible spectral result declares its ordinate _____ as well as its frequency axis.

Answer: units. Line amplitude, mean square, density, and power are distinct quantities. Source: §9.3.5 Measurement consequence (p. 5050)

Why this term is required: “units” completes the stated technical proposition.

Question context: A reproducible spectral result declares its ordinate _____ as well as its frequency axis

Basis and qualification: Chapter 9 — Measurement consequence.

Review: Chapter 9 — Measurement consequence.

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V011-C09-FIB-061. Linear power averaging and _____ averaging treat phase differently.

Answer: vector. Vector averaging combines complex values and retains coherent phase. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why this term is required: “vector” completes the stated technical proposition.

Question context: Linear power averaging and _____ averaging treat phase differently

Basis and qualification: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-FIB-062. Exponential averaging gives more weight to _____ records.

Answer: recent. It is a temporal weighting convention, not necessarily logarithmic averaging. Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why this term is required: “recent” completes the stated technical proposition.

Question context: Exponential averaging gives more weight to _____ records

Basis and qualification: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-FIB-063. For occurrence questions, retain the distribution of per-_____ measurements.

Answer: record. A single average can conceal rare bursts and changing states.

Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why this term is required: “record” completes the stated technical proposition.

Question context: For occurrence questions, retain the distribution of per-_____ measurements

Basis and qualification: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-FIB-064. A coherent internal spur may become more prominent under _____ averaging.

Answer: vector. Coherent components survive while suitable uncorrelated components can diminish. Source: §9.4 Averaging and Statistical Stability (p. 5052)
Why this term is required: “vector” completes the stated technical proposition.
Question context: A coherent internal spur may become more prominent under _____ averaging
Basis and qualification: Chapter 9 — Averaging and Statistical Stability.
Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-FIB-065. Overlapping records need not provide statistically _____ averages.

Answer: independent. Shared samples and processing can create dependence.

Source: §9.4 Averaging and Statistical Stability (p. 5052)

Why this term is required: “independent” completes the stated technical proposition.

Question context: Overlapping records need not provide statistically _____ averages

Basis and qualification: Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 9 — Averaging and Statistical Stability.

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V011-C09-FIB-066. Cross-spectral methods compare _____ channels with declared alignment.

Answer: synchronized. The paired records must represent corresponding acquisition times. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

Why this term is required: “synchronized” completes the stated technical proposition.

Question context: Cross-spectral methods compare _____ channels with declared alignment

Basis and qualification: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis.

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V011-C09-FIB-067. The cross-spectrum convention in Model 9C conjugates the _____ coefficient.

Answer: X. The product is X conjugate times Y, fixing the phase sign convention.

Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “X” completes the stated technical proposition.

Question context: The cross-spectrum convention in Model 9C conjugates the _____ coefficient

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-068. For voltage and current channels, the fitted gain has units amperes per _____.

Answer: volt. It maps input voltage to output current in the declared projection.

Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: “volt” completes the stated technical proposition.

Question context: For voltage and current channels, the fitted gain has units amperes per _____

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-069. The record weights in the finite coherence proof are common and _____.

Answer: nonnegative. They define one paired weighted inner-product construction.

Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “nonnegative” completes the stated technical proposition.

Question context: The record weights in the finite coherence proof are common and _____

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-070. Those weights sum to _____.

Answer: one. The spectral quantities use a normalized weighted mean. Source: §9.5.1

Define the ensemble before normalizing (p. 5055)

Why this term is required: “one” completes the stated technical proposition.

Question context: Those weights sum to _____

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-071. The density normalization factor used in all three spectra must be _____.

Answer: common. Consistent scaling and pairing support the stated bound. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “common” completes the stated technical proposition.

Question context: The density normalization factor used in all three spectra must be _____

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-072. Coherence is _____ rather than a spectral-density unit.

Answer: dimensionless. Channel units and common normalization cancel in the ratio. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “dimensionless” completes the stated technical proposition.

Question context: Coherence is _____ rather than a spectral-density unit

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-073. The ratio requires both autospectra to be _____.

Answer: positive. A zero denominator is undefined and should not be given an absence meaning. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “positive” completes the stated technical proposition.

Question context: The ratio requires both autospectra to be _____

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-074. Complex cross-products must be averaged before their magnitude is _____.

Answer: squared. Magnitude-first processing loses phase cancellation across records. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “squared” completes the stated technical proposition.

Question context: Complex cross-products must be averaged before their magnitude is _____

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-075. Every nonzero single-pair normalized coherence ratio equals _____.

Answer: one. One complex gain can fit one pair exactly without demonstrating repeatability. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why this term is required: “one” completes the stated technical proposition.

Question context: Every nonzero single-pair normalized coherence ratio equals _____

Basis and qualification: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-FIB-076. Conjugating the entire cross-spectrum reverses its _____ sign.

Answer: phase. The magnitude-squared coherence remains the same. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “phase” completes the stated technical proposition.

Question context: Conjugating the entire cross-spectrum reverses its _____ sign

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-077. A negative real cross-spectrum can encode a relative _____ relationship.

Answer: phase. It does not require negative autospectral power. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “phase” completes the stated technical proposition.

Question context: A negative real cross-spectrum can encode a relative _____ relationship

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-078. The finite coherence upper bound follows from a weighted _____-product inequality.

Answer: inner. Cauchy–Schwarz bounds the paired coefficient vectors. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “inner” completes the stated technical proposition.

Question context: The finite coherence upper bound follows from a weighted _____-product inequality

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-079. For unity coherence, one complex _____ must relate every positive-weight pair.

Answer: gain. Proportional nonzero vectors attain equality in the bound. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “gain” completes the stated technical proposition.

Question context: For unity coherence, one complex _____ must relate every positive-weight pair

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-080. Separate robust medians need not preserve the paired _____-matrix construction.

Answer: Gram. The chapter's median example produces a substituted ratio above one despite nonnegative inputs. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “Gram” completes the stated technical proposition.

Question context: Separate robust medians need not preserve the paired _____-matrix construction

Basis and qualification: Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-FIB-081. The least-squares gain estimate divides P_{xy} by _____.

Answer: P_{xx}. The declared projection estimates output from input, not the reverse regression. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: "The declared projection estimates output from input, not the reverse regression" completes the stated technical proposition.

Question context: The least-squares gain estimate divides by _____

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-082. The minimum residual is output autospectrum times one minus _____.

Answer: coherence. It is the unexplained output spectral sum of squares for the fitted gain. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: “coherence” completes the stated technical proposition.

Question context: The minimum residual is output autospectrum times one minus ____

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-083. If output autospectrum is 12 and coherence is 0.75, the minimum residual is _____.

Answer: 3. The stated fit gives 12 times (1-0.75), in output squared units per hertz.

Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: “3” completes the stated technical proposition.

Question context: If output autospectrum is 12 and coherence is 0.75, the minimum residual is _____

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-084. If P_{xx} is 2 and P_{xy} is 1 plus j, the fitted gain is _____ plus 0.5j.

Answer: 0.5. Dividing the complex cross-spectrum by the real input autospectrum preserves phase. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: “0.5” completes the stated technical proposition.

Question context: If is 2 and is 1 plus j, the fitted gain is _____ plus 0.5j

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-085. A fitted relationship does not by itself establish causal _____.

Answer: direction. Common excitation and alternative physical paths can share a spectral matrix. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
Why this term is required: “direction” completes the stated technical proposition.
Question context: A fitted relationship does not by itself establish causal _____
Basis and qualification: Chapter 9 — The projection interpretation and its boundary.
Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-086. The simple coherence-to-SNR expression requires exact observation of the _____.

Answer: input. Noise in the measured input changes the relation. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: “input” completes the stated technical proposition.

Question context: The simple coherence-to-SNR expression requires exact observation of the _____

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-087. The additive output disturbance must have zero _____-spectrum with the input in that SNR model.

Answer: cross. The absence of this cross term gives the stated decomposition.

Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: “cross” completes the stated technical proposition.

Question context: The additive output disturbance must have zero _____-spectrum with the input in that SNR model

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-088. With coherence 0.8 under that specific model, output SNR is _____ as a linear ratio.

Answer: 4. The ratio is $\frac{0.8}{0.2}$*;* it is not valid merely because coherence was measured.

Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

Why this term is required: “4” completes the stated technical proposition.

Question context: With coherence 0.8 under that specific model, output SNR is _____ as a linear ratio

Basis and qualification: Chapter 9 — The projection interpretation and its boundary.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-FIB-089. Equal coherence can leave the location of measurement _____ unresolved.

Answer: noise. Different input/output allocations can produce the same normalized value. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why this term is required: “noise” completes the stated technical proposition.

Question context: Equal coherence can leave the location of measurement _____ unresolved

Basis and qualification: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-FIB-090. Equal shared components with opposite signs can _____ in the cross-spectrum.

Answer: cancel. Autospectra can remain positive while the cross mean is zero.

Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why this term is required: “cancel” completes the stated technical proposition.

Question context: Equal shared components with opposite signs can _____ in the cross-spectrum

Basis and qualification: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-FIB-091. Pooling states with gains plus one and minus one can erase perfect within-state _____.

Answer: coherence. The complex products can cancel when states are mixed.

Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why this term is required: “coherence” completes the stated technical proposition.

Question context: Pooling states with gains plus one and minus one can erase perfect within-state _____

Basis and qualification: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-FIB-092. State rules should be specified independently of the desired _____.

Answer: result. Selecting states to manufacture coherence biases the claimed interpretation. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why this term is required: “result” completes the stated technical proposition.

Question context: State rules should be specified independently of the desired _____

Basis and qualification: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-FIB-093. Fixed nonzero channel gains cancel from coherence but not necessarily from the fitted gain and _____.

Answer: phase. Normalized invariance does not replace calibration of other measurands. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why this term is required: “phase” completes the stated technical proposition.

Question context: Fixed nonzero channel gains cancel from coherence but not necessarily from the fitted gain and _____

Basis and qualification: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-FIB-094. A single-bin delay estimate retains integer-_____ ambiguity.

Answer: cycle. Multiple delays produce the same phase at a single frequency.

Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

Why this term is required: “cycle” completes the stated technical proposition.

Question context: A single-bin delay estimate retains integer-_____ ambiguity

Basis and qualification: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-FIB-095. Shared references and direct cable coupling can create coherence without an environmental _____.

Answer: field. Controlled path challenges are needed before source attribution.

Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

Why this term is required: “field” completes the stated technical proposition.

Question context: Shared references and direct cable coupling can create coherence without an environmental _____

Basis and qualification: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis.

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V011-C09-FIB-096. Short-time Fourier analysis divides samples into overlapping _____.

Answer: windows. The duration and placement condition the evolving estimates.

Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

Why this term is required: “windows” completes the stated technical proposition.

Question context: Short-time Fourier analysis divides samples into overlapping _____

Basis and qualification: Chapter 9 — Time-Frequency and Nonstationary Methods.

Review: Chapter 9 — Time-Frequency and Nonstationary Methods.

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V011-C09-FIB-097. Time-frequency features should be checked in raw data, alternate windows, and held-_____ data.

Answer: out. Held-out evaluation helps distinguish robust findings from tuned processing choices. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
Why this term is required: “out” completes the stated technical proposition.
Question context: Time-frequency features should be checked in raw data, alternate windows, and held-_____ data
Basis and qualification: Chapter 9 — Time-Frequency and Nonstationary Methods.
Review: Chapter 9 — Time-Frequency and Nonstationary Methods.

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V011-C09-FIB-098. Before held-out evaluation, the chapter directs that processing parameters be _____.

Answer: frozen. This prevents selecting the evaluation procedure to fit the desired result. Source: §9.7 Estimator Validation and Reporting (p. 5072)

Why this term is required: “frozen” completes the stated technical proposition.

Question context: Before held-out evaluation, the chapter directs that processing parameters be _____

Basis and qualification: Chapter 9 — Estimator Validation and Reporting.

Review: Chapter 9 — Estimator Validation and Reporting.

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V011-C09-FIB-099. Plots remain traceable to source samples and executable analysis _____.

Answer: scripts. The data-to-image transformation must be reproducible. Source: §9.7 Estimator Validation and Reporting (p. 5072)

Why this term is required: “scripts” completes the stated technical proposition.

Question context: Plots remain traceable to source samples and executable analysis _____

Basis and qualification: Chapter 9 — Estimator Validation and Reporting.

Review: Chapter 9 — Estimator Validation and Reporting.

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V011-C09-FIB-100. Correct spectral arithmetic cannot alone establish usable event _____.

Answer: coverage. Acquisition continuity and receiver-state validity are separate requirements. Source: §9.7 Estimator Validation and Reporting (p. 5072)

Why this term is required: “coverage” completes the stated technical proposition.

Question context: Correct spectral arithmetic cannot alone establish usable event _____

Basis and qualification: Chapter 9 — Estimator Validation and Reporting.

Review: Chapter 9 — Estimator Validation and Reporting.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C09-ESSAY-001. Derive the two different window sums needed for coherent complex-tone amplitude and white-noise density.

- Opening: Present a thesis that answers this precise question: Derive the two different window sums needed for coherent complex-tone amplitude and white-noise density. Identify which evidence would falsify the proposed conclusion Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Core terminology and scope: Define window, sums, coherent in the question's particular technical setting; explain how amplitude, white-noise, density differ if that distinction would change the analysis of "Derive the two different window sums needed for coherent complex-tone amplitude and white-noise density" Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Substitute a bin-centered complex tone into the unnormalized DFT to obtain a times Expand squared magnitude under zero-mean white covariance to obtain variance times Identify units Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the two different window sums needed for coherent complex-tone amplitude and white-noise density to the claimed result, following "Windowed DFT normalization: line amplitude, noise density, and finite-record energy"; name the intermediate states and measurable outputs

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Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the two different window sums needed for coherent complex-tone amplitude and white-noise density. Explain why substituting one sum for the other changes the measurand Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Spectral Leakage and Window Selection” that resolves the question about the two different window sums needed for coherent complex-tone amplitude and white-noise density; derive the relevant result with units and stated validity conditions Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the two different window sums needed for coherent complex-tone amplitude and white-noise density. Explain why substituting one sum for the other changes the measurand Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Worked application or illustrative case: Build a worked example of “the two different window sums needed for coherent complex-tone amplitude and white-noise density”, addressing this associated condition: Substitute a bin-centered complex tone into the unnormalized DFT to obtain a times Expand squared magnitude.... Substitute a bin-centered complex tone into the unnormalized DFT

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to obtain a times Expand squared magnitude under zero-mean white... Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the two different window sums needed for coherent complex-tone amplitude and white-noise density”. Using “Spectral Leakage and Window Selection”, specify a discriminator and the result expected under each explanation Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the two different window sums needed for coherent complex-tone amplitude and white-noise density, including the effect of missing measurements and inconsistent operating conditions Source: §9.15 Numerical reality checks for resolution, noise density and detection (p. 5090)
- Scholarly synthesis and implications: Explain what the result about the two different window sums needed for coherent complex-tone amplitude and white-noise density authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Closing: Conclude by answering “Derive the two different window sums needed for coherent complex-tone amplitude and white-noise density” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.3.2 Noise density uses a different denominator (p. 5033)

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V011-C09-ESSAY-002. Analyze the additional condition needed when recovering a real sinusoid rather than a complex tone.

- Opening: Present a thesis that answers this precise question: Analyze the additional condition needed when recovering a real sinusoid rather than a complex tone. Identify which evidence would falsify the proposed conclusion Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Core terminology and scope: Define additional, condition, recovering in the question's particular technical setting; explain how real, sinusoid, tone differ if that distinction would change the analysis of "Analyze the additional condition needed when recovering a real sinusoid rather than a complex tone" Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain both frequency images and derive the contribution of W at twice the tone bin Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the additional condition needed when recovering a real sinusoid rather than a complex tone to the claimed result, following "Spectral Leakage and Window Selection"; name the intermediate states and measurable outputs Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the additional condition needed when recovering a real sinusoid rather

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than a complex tone. Require the stated frequency condition and a vanishing or bounded image term before using doubled magnitude over the coherent sum Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Multitaper spectra, estimator covariance and uncertainty under intermittent observation” that resolves the question about the additional condition needed when recovering a real sinusoid rather than a complex tone; derive the relevant result with units and stated validity conditions Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the additional condition needed when recovering a real sinusoid rather than a complex tone. Treat DC, Nyquist, and off-grid cases separately; coherent gain is not a universal correction Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Worked application or illustrative case: Build a worked example of “the additional condition needed when recovering a real sinusoid rather than a complex tone”, addressing this associated condition: Retain both frequency images and derive the contribution of W at twice the tone bin. Retain both frequency images and derive the contribution of W at twice the tone bin Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the additional condition needed when

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recovering a real sinusoid rather than a complex tone". Using "Multitaper spectra, estimator covariance and uncertainty under intermittent observation", specify a discriminator and the result expected under each explanation Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the additional condition needed when recovering a real sinusoid rather than a complex tone, including the effect of missing measurements and inconsistent operating conditions Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Scholarly synthesis and implications: Explain what the result about the additional condition needed when recovering a real sinusoid rather than a complex tone authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Closing: Conclude by answering "Analyze the additional condition needed when recovering a real sinusoid rather than a complex tone" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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V011-C09-ESSAY-003. Construct a density integration check that remains correct for real odd-length and even-length records.

- Opening: Present a thesis that answers this precise question: Construct a density integration check that remains correct for real odd-length and even-length records. Identify which evidence would falsify the proposed conclusion Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Core terminology and scope: Define Construct, density, integration in the question's particular technical setting; explain how check, remains, records differ if that distinction would change the analysis of "Construct a density integration check that remains correct for real odd-length and even-length records" Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start with the two-sided density, fold equal conjugate contributions, double interior positive bins, retain DC and even-length Nyquist once, and double the last positive bin for odd N Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a density integration check that remains correct for real odd-length and even-length records to the claimed result, following "Measurement consequence"; name the intermediate states and measurable outputs Source: §9.3.5 Measurement consequence (p. 5050)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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density integration check that remains correct for real odd-length and even-length records. Explain which changes in Start with the two-sided density, fold equal conjugate contributions, double interior positive bins, retain… would invalidate an unqualified comparison Source: §9.3.5 Measurement consequence (p. 5050)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Noise density uses a different denominator” that resolves the question about a density integration check that remains correct for real odd-length and even-length records; derive the relevant result with units and stated validity conditions Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a density integration check that remains correct for real odd-length and even-length records. Show that the sum equals the squared-window-weighted mean square, not necessarily unweighted mean square Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Worked application or illustrative case: Build a worked example of “a density integration check that remains correct for real odd-length and even-length records”, addressing this associated condition: Start with the two-sided density, fold equal conjugate contributions, double interior positive bins, retain…. Start with the two-sided density, fold equal conjugate contributions, double interior positive bins, retain DC and even-length Nyquist… Source: §9.3.5 Measurement consequence (p. 5050)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a density integration check that remains correct for real odd-length and even-length records”. Using “Noise density uses a different denominator”, specify a discriminator and the result expected under each explanation Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a density integration check that remains correct for real odd-length and even-length records, including the effect of missing measurements and inconsistent operating conditions Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Scholarly synthesis and implications: Explain what the result about a density integration check that remains correct for real odd-length and even-length records authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Closing: Conclude by answering “Construct a density integration check that remains correct for real odd-length and even-length records” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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V011-C09-ESSAY-004. Explain why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration.

- Opening: Present a thesis that answers this precise question: Explain why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration. Identify which evidence would falsify the proposed conclusion Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Core terminology and scope: Define padding, plotted, spacing in the question's particular technical setting; explain how changing, equivalent, duration differ if that distinction would change the analysis of "Explain why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration" Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain the original coefficient vector, and N while increasing transform length M Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration to the claimed result, following "Discrete Records and Spectral Estimates"; name the intermediate states and measurable outputs Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration. Use in density integration Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Estimator Validation and Reporting” that resolves the question about why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration; derive the relevant result with units and stated validity conditions Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration. Explain peak interpolation and the unchanged response width, and derive the error from replacing N by M in a window bandwidth formula Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Worked application or illustrative case: Build a worked example of “why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration”, addressing this associated condition: Retain the original coefficient vector, and N while increasing transform length M. Retain the original coefficient vector, and N while increasing transform length M Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration”. Using “Estimator Validation and Reporting”, specify a discriminator and the result expected under each explanation Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration, including the effect of missing measurements and inconsistent operating conditions Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)
- Scholarly synthesis and implications: Explain what the result about why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Closing: Conclude by answering “Explain why zero padding changes plotted spacing without changing equivalent noise bandwidth or physical observation duration” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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V011-C09-ESSAY-005. Evaluate a transient energy estimate when the same impulse falls at the edge and center of a Hann window.

- Opening: Present a thesis that answers this precise question: Evaluate a transient energy estimate when the same impulse falls at the edge and center of a Hann window. Identify which evidence would falsify the proposed conclusion Source: §9.3.3 Energy closure and its limits (p. 5036)
- Core terminology and scope: Define transient, estimate, impulse in the question's particular technical setting; explain how falls, edge, window differ if that distinction would change the analysis of "Evaluate a transient energy estimate when the same impulse falls at the edge and center of a Hann window" Source: §9.3.3 Energy closure and its limits (p. 5036)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the squared coefficient at each position and divide by For the stated 16-point periodic example, compare zero and V squared with unweighted V squared Source: §9.3.3 Energy closure and its limits (p. 5036)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a transient energy estimate when the same impulse falls at the edge and center of a Hann window to the claimed result, following "Measurement consequence"; name the intermediate states and measurable outputs Source: §9.3.5 Measurement consequence (p. 5050)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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transient energy estimate when the same impulse falls at the edge and center of a Hann window. Explain why all satisfy exact energy closure and why capture opportunity and window placement require separate validation Source: §9.3.5 Measurement consequence (p. 5050)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Estimator Validation and Reporting” that resolves the question about a transient energy estimate when the same impulse falls at the edge and center of a Hann window; derive the relevant result with units and stated validity conditions Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a transient energy estimate when the same impulse falls at the edge and center of a Hann window. Explain why all satisfy exact energy closure and why capture opportunity and window placement require separate validation Source: §9.3.3 Energy closure and its limits (p. 5036)
- Worked application or illustrative case: Build a worked example of “a transient energy estimate when the same impulse falls at the edge and center of a Hann window”, addressing this associated condition: Use the squared coefficient at each position and divide by For the stated 16-point periodic example, compare.... Use the squared coefficient at each position and divide by For the stated 16-point periodic example, compare zero and V squared with... Source: §9.3.5 Measurement consequence (p. 5050)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a transient energy estimate when the

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same impulse falls at the edge and center of a Hann window". Using "Estimator Validation and Reporting", specify a discriminator and the result expected under each explanation Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a transient energy estimate when the same impulse falls at the edge and center of a Hann window, including the effect of missing measurements and inconsistent operating conditions Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Scholarly synthesis and implications: Explain what the result about a transient energy estimate when the same impulse falls at the edge and center of a Hann window authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.3.3 Energy closure and its limits (p. 5036)
- Closing: Conclude by answering "Evaluate a transient energy estimate when the same impulse falls at the edge and center of a Hann window" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.3.3 Energy closure and its limits (p. 5036)

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V011-C09-ESSAY-006. Design a test for distinguishing a weak tone from leakage of a nearby strong tone.

- Opening: Present a thesis that answers this precise question: Design a test for distinguishing a weak tone from leakage of a nearby strong tone. Identify which evidence would falsify the proposed conclusion Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Core terminology and scope: Define Design, distinguishing, weak in the question's particular technical setting; explain how leakage, nearby, strong differ if that distinction would change the analysis of "Design a test for distinguishing a weak tone from leakage of a nearby strong tone" Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain the same native samples while applying declared alternate windows, compare sidelobe and main-lobe behavior, and inspect time evolution and repeated records Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a test for distinguishing a weak tone from leakage of a nearby strong tone to the claimed result, following "Discrete Records and Spectral Estimates"; name the intermediate states and measurable outputs Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a test for distinguishing a weak tone from leakage of a nearby strong tone.

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Calibrate amplitude with actual sums and account for off-grid effects Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Estimator Validation and Reporting” that resolves the question about a test for distinguishing a weak tone from leakage of a nearby strong tone; derive the relevant result with units and stated validity conditions Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a test for distinguishing a weak tone from leakage of a nearby strong tone. Use appropriate known tones and held-out observations; changed window response alone does not identify physical origin Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Worked application or illustrative case: Build a worked example of “a test for distinguishing a weak tone from leakage of a nearby strong tone”, addressing this associated condition: Retain the same native samples while applying declared alternate windows, compare sidelobe and main-lobe.... Retain the same native samples while applying declared alternate windows, compare sidelobe and main-lobe behavior, and inspect time evolution and repeated... Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a test for distinguishing a weak tone from leakage of a nearby strong tone”. Using “Estimator Validation and Reporting”, specify a discriminator and the result expected

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under each explanation Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a test for distinguishing a weak tone from leakage of a nearby strong tone, including the effect of missing measurements and inconsistent operating conditions Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Scholarly synthesis and implications: Explain what the result about a test for distinguishing a weak tone from leakage of a nearby strong tone authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Closing: Conclude by answering “Design a test for distinguishing a weak tone from leakage of a nearby strong tone” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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V011-C09-ESSAY-007. Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square.

- Opening: Present a thesis that answers this precise question: Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square. Identify which evidence would falsify the proposed conclusion Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Core terminology and scope: Define Reconcile, summed, ordinates in the question's particular technical setting; explain how exceed, mean, square differ if that distinction would change the analysis of "Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square" Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain that adjacent bins are part of one finite-window response, not independent powers Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square to the claimed result, following "Discrete Records and Spectral Estimates"; name the intermediate states and measurable outputs Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square. Convert Q to D with equivalent noise bandwidth, multiply by actual grid spacing, and sum Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Spectral Leakage and Window Selection” that resolves the question about Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square; derive the relevant result with units and stated validity conditions Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square. Reproduce the 0.0075 times = 0.005 V squared example Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Worked application or illustrative case: Build a worked example of “Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square”, addressing this associated condition: Explain that adjacent bins are part of one finite-window response, not independent powers. Explain that adjacent bins are part of one finite-window response, not independent powers Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Reconcile a Hann spectrum whose

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summed line-calibrated ordinates exceed the known tone mean square". Using "Spectral Leakage and Window Selection", specify a discriminator and the result expected under each explanation Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square, including the effect of missing measurements and inconsistent operating conditions Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)
- Scholarly synthesis and implications: Explain what the result about Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Closing: Conclude by answering "Reconcile a Hann spectrum whose summed line-calibrated ordinates exceed the known tone mean square" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

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V011-C09-ESSAY-008. Compare periodic and endpoint-symmetric Hann normalization for a short record.

- Opening: Present a thesis that answers this precise question: Compare periodic and endpoint-symmetric Hann normalization for a short record. Identify which evidence would falsify the proposed conclusion Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)
- Core terminology and scope: Define periodic, endpoint-symmetric, Hann in the question's particular technical setting; explain how normalization, short, record differ if that distinction would change the analysis of "Compare periodic and endpoint-symmetric Hann normalization for a short record" Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Give their distinct cosine conventions and finite and values Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting periodic and endpoint-symmetric Hann normalization for a short record to the claimed result, following "Discrete Records and Spectral Estimates"; name the intermediate states and measurable outputs Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for periodic and endpoint-symmetric Hann normalization for a short record. At N

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= 16 and = 1600 Hz, obtain 150 and 160 Hz bandwidths Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Ten worked applications of the normalization model” that resolves the question about periodic and endpoint-symmetric Hann normalization for a short record; derive the relevant result with units and stated validity conditions Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)
- Evidence and method: Specify the native observations, control records and calculations that would resolve periodic and endpoint-symmetric Hann normalization for a short record. Explain the complex-amplitude error from using 8 instead of 7.5 as coherent sum and the separate density error from mixing bandwidths Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)
- Worked application or illustrative case: Build a worked example of “periodic and endpoint-symmetric Hann normalization for a short record”, addressing this associated condition: Give their distinct cosine conventions and finite and values. Give their distinct cosine conventions and finite and values Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “periodic and endpoint-symmetric Hann normalization for a short record”. Using “Ten worked applications of the normalization model”, specify a discriminator and the result expected under each explanation Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to periodic and endpoint-symmetric Hann normalization for a short record, including the effect of missing measurements and inconsistent operating conditions Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Scholarly synthesis and implications: Explain what the result about periodic and endpoint-symmetric Hann normalization for a short record authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)
- Closing: Conclude by answering “Compare periodic and endpoint-symmetric Hann normalization for a short record” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

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V011-C09-ESSAY-009. Describe what an exact Parseval closure test verifies and what acquisition claims it cannot support.

- Opening: Present a thesis that answers this precise question: Describe what an exact Parseval closure test verifies and what acquisition claims it cannot support. Identify which evidence would falsify the proposed conclusion Source: §9.3.3 Energy closure and its limits (p. 5036)
- Core terminology and scope: Define closure, test, verifies in the question's particular technical setting; explain how acquisition, claims, support differ if that distinction would change the analysis of "Describe what an exact Parseval closure test verifies and what acquisition claims it cannot support" Source: §9.3.3 Energy closure and its limits (p. 5036)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the recordwise weighted-energy identity and correct frequency spacing Source: §9.3.3 Energy closure and its limits (p. 5036)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting what an exact Parseval closure test verifies and what acquisition claims it cannot support to the claimed result, following "Measurement consequence"; name the intermediate states and measurable outputs Source: §9.3.5 Measurement consequence (p. 5050)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for what an exact Parseval closure test verifies and what acquisition claims it

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cannot support. Explain its validity for colored covariance and transient records Source: §9.3.5 Measurement consequence (p. 5050)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Multitaper spectra, estimator covariance and uncertainty under intermittent observation” that resolves the question about what an exact Parseval closure test verifies and what acquisition claims it cannot support; derive the relevant result with units and stated validity conditions Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)
- Evidence and method: Specify the native observations, control records and calculations that would resolve what an exact Parseval closure test verifies and what acquisition claims it cannot support. Separate arithmetic normalization from stationarity, alias-free sampling, calibration, source attribution, overload, and usable observation intervals Source: §9.3.3 Energy closure and its limits (p. 5036)
- Worked application or illustrative case: Build a worked example of “what an exact Parseval closure test verifies and what acquisition claims it cannot support”, addressing this associated condition: State the recordwise weighted-energy identity and correct frequency spacing. State the recordwise weighted-energy identity and correct frequency spacing Source: §9.3.5 Measurement consequence (p. 5050)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “what an exact Parseval closure test verifies and what acquisition claims it cannot support”. Using “Multitaper spectra, estimator covariance and uncertainty under intermittent observation”, specify a discriminator and the result

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expected under each explanation Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to what an exact Parseval closure test verifies and what acquisition claims it cannot support, including the effect of missing measurements and inconsistent operating conditions Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Scholarly synthesis and implications: Explain what the result about what an exact Parseval closure test verifies and what acquisition claims it cannot support authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.3.3 Energy closure and its limits (p. 5036)
- Closing: Conclude by answering “Describe what an exact Parseval closure test verifies and what acquisition claims it cannot support” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.3.3 Energy closure and its limits (p. 5036)

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V011-C09-ESSAY-010. Develop a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging.

- Opening: Present a thesis that answers this precise question: Develop a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging. Identify which evidence would falsify the proposed conclusion Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Core terminology and scope: Define reproducible, analysis, record in the question's particular technical setting; explain how noise, includes, averaging differ if that distinction would change the analysis of "Develop a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging" Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain samples, sample rate, observed N, transform length, coefficient convention, side folding, units, impedance, and preprocessing Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging to the claimed result, following "Discrete Records and Spectral Estimates"; name the intermediate states and measurable outputs Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging. State linear, logarithmic, vector, or weighted averaging and record overlap/dependence Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Measurement consequence” that resolves the question about a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging; derive the relevant result with units and stated validity conditions Source: §9.3.5 Measurement consequence (p. 5050)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging. Identify corrections already applied and the distinction between logarithm of expected power and expected log display Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Worked application or illustrative case: Build a worked example of “a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging”, addressing this associated condition: Retain samples, sample rate, observed N, transform length, coefficient convention, side folding, units,.... Retain samples, sample rate, observed N, transform length, coefficient convention, side folding, units, impedance, and preprocessing Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging”. Using “Measurement consequence”, specify a discriminator and the result expected under each explanation Source: §9.3.5 Measurement consequence (p. 5050)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging, including the effect of missing measurements and inconsistent operating conditions Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Scholarly synthesis and implications: Explain what the result about a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Closing: Conclude by answering “Develop a reproducible analysis record for an FFT noise measurement that includes preprocessing and averaging” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.4 Averaging and Statistical Stability (p. 5052)

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V011-C09-ESSAY-011. Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition.

- Opening: Present a thesis that answers this precise question: Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition. Identify which evidence would falsify the proposed conclusion Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Core terminology and scope: Define Prove, coherence, paired in the question's particular technical setting; explain how weighted, estimates, equality differ if that distinction would change the analysis of "Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition" Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Form vectors from square-root nonnegative weights times the paired coefficients Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition to the claimed result, following "Cross-Spectra, Coherence, and Multichannel Analysis"; name the intermediate states and measurable outputs Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Prove

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the finite coherence bound for the stated paired weighted estimates and identify the equality condition. Apply Cauchy–Schwarz with common positive density scaling and positive autospectra Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Discrete Records and Spectral Estimates” that resolves the question about Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition; derive the relevant result with units and stated validity conditions Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition. Give the proportional-vector equality condition Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Worked application or illustrative case: Build a worked example of “Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition”, addressing this associated condition: Form vectors from square-root nonnegative weights times the paired coefficients. Form vectors from square-root nonnegative weights times the paired coefficients Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Prove the finite coherence bound for the stated paired weighted estimates and identify the equality

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condition". Using "Discrete Records and Spectral Estimates", specify a discriminator and the result expected under each explanation Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition, including the effect of missing measurements and inconsistent operating conditions Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Scholarly synthesis and implications: Explain what the result about Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Closing: Conclude by answering "Prove the finite coherence bound for the stated paired weighted estimates and identify the equality condition" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

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V011-C09-ESSAY-012. Explain why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator.

- Opening: Present a thesis that answers this precise question: Explain why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator. Identify which evidence would falsify the proposed conclusion Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Core terminology and scope: Define averaging, coherence, ratios in the question's particular technical setting; explain how replace, declared, estimator differ if that distinction would change the analysis of "Explain why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator" Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Show that each nonzero one-pair ratio is one Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator to the claimed result, following "Estimator Validation and Reporting"; name the intermediate states and measurable outputs Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why averaging per-record coherence ratios cannot replace the declared

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paired-spectrum estimator. Use X = (1,1) and Y = (1,minus 1) to obtain zero averaged complex cross-product and zero proper coherence despite unit per-record ratios Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Cross-Spectra, Coherence, and Multichannel Analysis” that resolves the question about why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator; derive the relevant result with units and stated validity conditions Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator. Identify the lost phase cancellation and distinguish this exact processing error from rounding or finite-sample uncertainty Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Worked application or illustrative case: Build a worked example of “why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator”, addressing this associated condition: Show that each nonzero one-pair ratio is one. Show that each nonzero one-pair ratio is one Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “why averaging per-record coherence

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ratios cannot replace the declared paired-spectrum estimator". Using "Cross-Spectra, Coherence, and Multichannel Analysis", specify a discriminator and the result expected under each explanation Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator, including the effect of missing measurements and inconsistent operating conditions Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Scholarly synthesis and implications: Explain what the result about why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Closing: Conclude by answering "Explain why averaging per-record coherence ratios cannot replace the declared paired-spectrum estimator" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

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V011-C09-ESSAY-013. Assess the separate-median counterexample and its implications for robust spectral processing.

- Opening: Present a thesis that answers this precise question: Assess the separate-median counterexample and its implications for robust spectral processing. Identify which evidence would falsify the proposed conclusion Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Core terminology and scope: Define separate-median, counterexample, implications in the question's particular technical setting; explain how robust, spectral, processing differ if that distinction would change the analysis of "Assess the separate-median counterexample and its implications for robust spectral processing" Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Calculate autospectral medians 1 and 1 and cross median 10, yielding 100 Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the separate-median counterexample and its implications for robust spectral processing to the claimed result, following "Cross-Spectra, Coherence, and Multichannel Analysis"; name the intermediate states and measurable outputs Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the separate-median counterexample and its implications for robust spectral processing. Contrast common means yielding 400/10201 Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Analytical framework: Identify the equation, calibration or evidential decision test in “The projection interpretation and its boundary” that resolves the question about the separate-median counterexample and its implications for robust spectral processing; derive the relevant result with units and stated validity conditions Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the separate-median counterexample and its implications for robust spectral processing. Explain the loss of one paired Gram construction rather than negative weights or floating-point error Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Worked application or illustrative case: Build a worked example of “the separate-median counterexample and its implications for robust spectral processing”, addressing this associated condition: Calculate autospectral medians 1 and 1 and cross median 10, yielding 100. Calculate autospectral medians 1 and 1 and cross median 10, yielding 100 Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the separate-median counterexample

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and its implications for robust spectral processing". Using "The projection interpretation and its boundary", specify a discriminator and the result expected under each explanation Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the separate-median counterexample and its implications for robust spectral processing, including the effect of missing measurements and inconsistent operating conditions Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Scholarly synthesis and implications: Explain what the result about the separate-median counterexample and its implications for robust spectral processing authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Closing: Conclude by answering "Assess the separate-median counterexample and its implications for robust spectral processing" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

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V011-C09-ESSAY-014. Derive the best complex gain and residual for the output-on-input spectral projection.

- Opening: Present a thesis that answers this precise question: Derive the best complex gain and residual for the output-on-input spectral projection. Identify which evidence would falsify the proposed conclusion Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Core terminology and scope: Define best, complex, gain in the question's particular technical setting; explain how residual, spectral, projection differ if that distinction would change the analysis of "Derive the best complex gain and residual for the output-on-input spectral projection" Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Expand the weighted squared residual, complete the square, and obtain and minus squared cross magnitude over Give gain and residual units and the explained-fraction interpretation Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the best complex gain and residual for the output-on-input spectral projection to the claimed result, following "Cross-Spectra, Coherence, and Multichannel Analysis"; name the intermediate states and measurable outputs Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the best complex gain and residual for the output-on-input spectral projection. Separate a finite fit from causal direction, residual independence, and extrapolation to other states Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Spectral confidence intervals and why averaging is not the same as independence” that resolves the question about the best complex gain and residual for the output-on-input spectral projection; derive the relevant result with units and stated validity conditions Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the best complex gain and residual for the output-on-input spectral projection. Separate a finite fit from causal direction, residual independence, and extrapolation to other states Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Worked application or illustrative case: Build a worked example of “the best complex gain and residual for the output-on-input spectral projection”, addressing this associated condition: Expand the weighted squared residual, complete the square, and obtain and minus squared cross magnitude over.... Expand the weighted squared residual, complete the square, and obtain and minus

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squared cross magnitude over Give gain and residual units and the... Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the best complex gain and residual for the output-on-input spectral projection”. Using “Spectral confidence intervals and why averaging is not the same as independence”, specify a discriminator and the result expected under each explanation Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the best complex gain and residual for the output-on-input spectral projection, including the effect of missing measurements and inconsistent operating conditions Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Scholarly synthesis and implications: Explain what the result about the best complex gain and residual for the output-on-input spectral projection authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Closing: Conclude by answering “Derive the best complex gain and residual for the output-on-input spectral projection” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

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V011-C09-ESSAY-015. Determine when coherence can be converted to output SNR and illustrate failure with noisy input.

- Opening: Present a thesis that answers this precise question: Determine when coherence can be converted to output SNR and illustrate failure with noisy input. Identify which evidence would falsify the proposed conclusion Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Core terminology and scope: Define coherence, converted, output in the question's particular technical setting; explain how failure, noisy, input differ if that distinction would change the analysis of "Determine when coherence can be converted to output SNR and illustrate failure with noisy input" Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State exact input observation, linear gain, and zero input-disturbance cross-spectrum Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Determine when coherence can be converted to output SNR and illustrate failure with noisy input to the claimed result, following "Estimator Validation and Reporting"; name the intermediate states and measurable outputs Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Determine when coherence can be converted to output SNR and

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illustrate failure with noisy input. Derive Compare the chapter's equal-coherence cases with different input/output noise allocations and output SNRs Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Noise density uses a different denominator” that resolves the question about Determine when coherence can be converted to output SNR and illustrate failure with noisy input; derive the relevant result with units and stated validity conditions Source: §9.3.2 Noise density uses a different denominator (p. 5033)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Determine when coherence can be converted to output SNR and illustrate failure with noisy input. Explain why a measured value alone cannot locate noise or supply an input-noise correction Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Worked application or illustrative case: Build a worked example of “Determine when coherence can be converted to output SNR and illustrate failure with noisy input”, addressing this associated condition: State exact input observation, linear gain, and zero input-disturbance cross-spectrum. State exact input observation, linear gain, and zero input-disturbance cross-spectrum Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Determine when coherence can be converted to output SNR and illustrate failure with noisy input”. Using “Noise density uses a different denominator”, specify a

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discriminator and the result expected under each explanation Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Determine when coherence can be converted to output SNR and illustrate failure with noisy input, including the effect of missing measurements and inconsistent operating conditions Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Scholarly synthesis and implications: Explain what the result about Determine when coherence can be converted to output SNR and illustrate failure with noisy input authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Closing: Conclude by answering “Determine when coherence can be converted to output SNR and illustrate failure with noisy input” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-ESSAY-016. Analyze how two shared sources can produce nearly zero coherence.

- Opening: Present a thesis that answers this precise question: Analyze how two shared sources can produce nearly zero coherence. Identify which evidence would falsify the proposed conclusion Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Core terminology and scope: Define shared, sources, produce in the question's particular technical setting; explain how nearly, zero, coherence differ if that distinction would change the analysis of "Analyze how two shared sources can produce nearly zero coherence" Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use X = S + D and Y = S minus D with uncorrelated components Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how two shared sources can produce nearly zero coherence to the claimed result, following "Multitaper spectra, estimator covariance and uncertainty under intermittent observation"; name the intermediate states and measurable outputs Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how two

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shared sources can produce nearly zero coherence. Derive autospectra as sums and cross-spectrum as a difference Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Averaging and Statistical Stability” that resolves the question about how two shared sources can produce nearly zero coherence; derive the relevant result with units and stated validity conditions Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how two shared sources can produce nearly zero coherence. Show exact cancellation for equal spectra and the case when spectra are 1 and 0.8 Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Worked application or illustrative case: Build a worked example of “how two shared sources can produce nearly zero coherence”, addressing this associated condition: Use X = S + D and Y = S minus D with uncorrelated components. Use X = S + D and Y = S minus D with uncorrelated components Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how two shared sources can produce nearly zero coherence”. Using “Averaging and Statistical Stability”, specify a discriminator and the result expected under each explanation Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how two shared sources can produce

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nearly zero coherence, including the effect of missing measurements and inconsistent operating conditions Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

- Scholarly synthesis and implications: Explain what the result about how two shared sources can produce nearly zero coherence authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Closing: Conclude by answering “Analyze how two shared sources can produce nearly zero coherence” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-ESSAY-017. Explain how pooling operating states can erase a relationship that is exact within each state.

- Opening: Present a thesis that answers this precise question: Explain how pooling operating states can erase a relationship that is exact within each state. Identify which evidence would falsify the proposed conclusion Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Core terminology and scope: Define pooling, operating, states in the question's particular technical setting; explain how erase, relationship, within differ if that distinction would change the analysis of "Explain how pooling operating states can erase a relationship that is exact within each state" Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use opposite gains and equal weights to show canceled cross-spectrum with positive autospectra Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how pooling operating states can erase a relationship that is exact within each state to the claimed result, following "Averaging and Statistical Stability"; name the intermediate states and measurable outputs Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how pooling operating states can erase a relationship that is exact within

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each state. Then weight states three quarters and one quarter to obtain coherence one quarter Source: §9.4 Averaging and Statistical Stability (p. 5052)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Estimator Validation and Reporting” that resolves the question about how pooling operating states can erase a relationship that is exact within each state; derive the relevant result with units and stated validity conditions Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how pooling operating states can erase a relationship that is exact within each state. Define a defensible state rule independently of the desired result and retain state-resolved records Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Worked application or illustrative case: Build a worked example of “how pooling operating states can erase a relationship that is exact within each state”, addressing this associated condition: Use opposite gains and equal weights to show canceled cross-spectrum with positive autospectra. Use opposite gains and equal weights to show canceled cross-spectrum with positive autospectra Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how pooling operating states can erase a relationship that is exact within each state”. Using “Estimator Validation and Reporting”, specify a discriminator and the result

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expected under each explanation Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how pooling operating states can erase a relationship that is exact within each state, including the effect of missing measurements and inconsistent operating conditions Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Scholarly synthesis and implications: Explain what the result about how pooling operating states can erase a relationship that is exact within each state authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Closing: Conclude by answering “Explain how pooling operating states can erase a relationship that is exact within each state” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-ESSAY-018. Develop a delay-estimation report that is explicit about cross-spectrum convention and branch limits.

- Opening: Present a thesis that answers this precise question: Develop a delay-estimation report that is explicit about cross-spectrum convention and branch limits. Identify which evidence would falsify the proposed conclusion Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Core terminology and scope: Define delay-estimation, report, explicit in the question's particular technical setting; explain how convention, branch, limits differ if that distinction would change the analysis of "Develop a delay-estimation report that is explicit about cross-spectrum convention and branch limits" Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State which channel is conjugated, the signal delay exponential, phase sign, calibrated skew, sample alignment, clock behavior, and phase branch Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a delay-estimation report that is explicit about cross-spectrum convention and branch limits to the claimed result, following "Energy closure and its limits"; name the intermediate states and measurable outputs Source: §9.3.3 Energy closure and its limits (p. 5036)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a delay-

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estimation report that is explicit about cross-spectrum convention and branch limits. Use the stated 1000 Hz and 125 microsecond example to obtain minus 45 degrees under X conjugate Y Source: §9.3.3 Energy closure and its limits (p. 5036)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Averaging and Statistical Stability” that resolves the question about a delay-estimation report that is explicit about cross-spectrum convention and branch limits; derive the relevant result with units and stated validity conditions Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a delay-estimation report that is explicit about cross-spectrum convention and branch limits. Explain integer-cycle ambiguity and why coherence alone does not calibrate absolute delay Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Worked application or illustrative case: Build a worked example of “a delay-estimation report that is explicit about cross-spectrum convention and branch limits”, addressing this associated condition: State which channel is conjugated, the signal delay exponential, phase sign, calibrated skew, sample.... State which channel is conjugated, the signal delay exponential, phase sign, calibrated skew, sample alignment, clock behavior, and phase branch Source: §9.3.3 Energy closure and its limits (p. 5036)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a delay-estimation report that is explicit

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about cross-spectrum convention and branch limits". Using "Averaging and Statistical Stability", specify a discriminator and the result expected under each explanation Source: §9.4 Averaging and Statistical Stability (p. 5052)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a delay-estimation report that is explicit about cross-spectrum convention and branch limits, including the effect of missing measurements and inconsistent operating conditions Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)
- Scholarly synthesis and implications: Explain what the result about a delay-estimation report that is explicit about cross-spectrum convention and branch limits authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Closing: Conclude by answering "Develop a delay-estimation report that is explicit about cross-spectrum convention and branch limits" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-ESSAY-019. Design controlled challenges to distinguish environmental coupling from shared recorder leakage.

- Opening: Present a thesis that answers this precise question: Design controlled challenges to distinguish environmental coupling from shared recorder leakage. Identify which evidence would falsify the proposed conclusion Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Core terminology and scope: Define Design, challenges, environmental in the question's particular technical setting; explain how shared, recorder, leakage differ if that distinction would change the analysis of "Design controlled challenges to distinguish environmental coupling from shared recorder leakage" Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Preserve comparable sensitivity and state while using channel swaps, independent terminations, separation, and injected references Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting controlled challenges to distinguish environmental coupling from shared recorder leakage to the claimed result, following "Energy closure and its limits"; name the intermediate states and measurable outputs Source: §9.3.3 Energy closure and its limits (p. 5036)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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controlled challenges to distinguish environmental coupling from shared recorder leakage. Record clock and synchronization paths Source: §9.3.3 Energy closure and its limits (p. 5036)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Discrete Records and Spectral Estimates” that resolves the question about controlled challenges to distinguish environmental coupling from shared recorder leakage; derive the relevant result with units and stated validity conditions Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Evidence and method: Specify the native observations, control records and calculations that would resolve controlled challenges to distinguish environmental coupling from shared recorder leakage. Interpret a revealed recorder path as a mechanism that limits the original claim, without asserting universal absence of room coupling Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Worked application or illustrative case: Build a worked example of “controlled challenges to distinguish environmental coupling from shared recorder leakage”, addressing this associated condition: Preserve comparable sensitivity and state while using channel swaps, independent terminations, separation,.... Preserve comparable sensitivity and state while using channel swaps, independent terminations, separation, and injected references Source: §9.3.3 Energy closure and its limits (p. 5036)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “controlled challenges to distinguish environmental coupling from shared recorder leakage”. Using

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"Discrete Records and Spectral Estimates", specify a discriminator and the result expected under each explanation Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to controlled challenges to distinguish environmental coupling from shared recorder leakage, including the effect of missing measurements and inconsistent operating conditions Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Scholarly synthesis and implications: Explain what the result about controlled challenges to distinguish environmental coupling from shared recorder leakage authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Closing: Conclude by answering "Design controlled challenges to distinguish environmental coupling from shared recorder leakage" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-ESSAY-020. Evaluate the tradeoffs in extending a record to separate two nearby tones in a changing signal.

- Opening: Present a thesis that answers this precise question: Evaluate the tradeoffs in extending a record to separate two nearby tones in a changing signal. Identify which evidence would falsify the proposed conclusion Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Core terminology and scope: Define extending, record, separate in the question's particular technical setting; explain how nearby, tones, changing differ if that distinction would change the analysis of "Evaluate the tradeoffs in extending a record to separate two nearby tones in a changing signal" Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish bin spacing from window response, SNR, and estimator resolution Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the tradeoffs in extending a record to separate two nearby tones in a changing signal to the claimed result, following "Estimator Validation and Reporting"; name the intermediate states and measurable outputs Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the tradeoffs in extending a record to separate two nearby tones in a

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changing signal. Explain how longer duration improves nominal spacing while increasing exposure to drift or state mixing Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Multitaper spectra, estimator covariance and uncertainty under intermittent observation” that resolves the question about the tradeoffs in extending a record to separate two nearby tones in a changing signal; derive the relevant result with units and stated validity conditions Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the tradeoffs in extending a record to separate two nearby tones in a changing signal. Compare alternate lengths on known and held-out signals, preserve time data, and choose the interval that supports the intended measurand Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Worked application or illustrative case: Build a worked example of “the tradeoffs in extending a record to separate two nearby tones in a changing signal”, addressing this associated condition: Distinguish bin spacing from window response, SNR, and estimator resolution. Distinguish bin spacing from window response, SNR, and estimator resolution Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the tradeoffs in extending a record to separate two nearby tones in a changing signal”. Using “Multitaper

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spectra, estimator covariance and uncertainty under intermittent observation", specify a discriminator and the result expected under each explanation Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the tradeoffs in extending a record to separate two nearby tones in a changing signal, including the effect of missing measurements and inconsistent operating conditions Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Scholarly synthesis and implications: Explain what the result about the tradeoffs in extending a record to separate two nearby tones in a changing signal authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Closing: Conclude by answering "Evaluate the tradeoffs in extending a record to separate two nearby tones in a changing signal" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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V011-C09-ESSAY-021. Prepare a validation plan for a time-frequency image used to report intermittent activity.

- Opening: Present a thesis that answers this precise question: Prepare a validation plan for a time-frequency image used to report intermittent activity. Identify which evidence would falsify the proposed conclusion Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Core terminology and scope: Define validation, image, used in the question's particular technical setting; explain how report, intermittent, activity differ if that distinction would change the analysis of "Prepare a validation plan for a time-frequency image used to report intermittent activity" Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Declare window and segment lengths, overlap, normalization, thresholds, interpolation, and color mapping Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Prepare a validation plan for a time-frequency image used to report intermittent activity to the claimed result, following "Estimator Validation and Reporting"; name the intermediate states and measurable outputs Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Prepare a validation plan for a time-frequency image used to report

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intermittent activity. Validate known bursts and chirps, inspect raw records and alternate settings, freeze parameters before held-out evaluation, and retain excluded intervals Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Spectral confidence intervals and why averaging is not the same as independence” that resolves the question about Prepare a validation plan for a time-frequency image used to report intermittent activity; derive the relevant result with units and stated validity conditions Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Prepare a validation plan for a time-frequency image used to report intermittent activity. Require a quantified detection rule rather than treating a compelling image as direct physical evidence Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Worked application or illustrative case: Build a worked example of “Prepare a validation plan for a time-frequency image used to report intermittent activity”, addressing this associated condition: Declare window and segment lengths, overlap, normalization, thresholds, interpolation, and color mapping. Declare window and segment lengths, overlap, normalization, thresholds, interpolation, and color mapping Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Prepare a validation plan for a time-

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frequency image used to report intermittent activity". Using "Spectral confidence intervals and why averaging is not the same as independence", specify a discriminator and the result expected under each explanation Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Prepare a validation plan for a time-frequency image used to report intermittent activity, including the effect of missing measurements and inconsistent operating conditions Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Scholarly synthesis and implications: Explain what the result about Prepare a validation plan for a time-frequency image used to report intermittent activity authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)
- Closing: Conclude by answering "Prepare a validation plan for a time-frequency image used to report intermittent activity" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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V011-C09-ESSAY-022. Compare power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component.

- Opening: Present a thesis that answers this precise question: Compare power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component. Identify which evidence would falsify the proposed conclusion Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Core terminology and scope: Define vector, exponential, percentile in the question's particular technical setting; explain how summaries, rare, intermittent differ if that distinction would change the analysis of "Compare power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component" Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define each summary's relevant statistic or weighting Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component to the claimed result, following "Define the record before interpreting the display"; name the intermediate states and measurable outputs Source: §9.3.1 Define the record before interpreting the display (p. 5029)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for power, vector, exponential, percentile, and max-hold summaries for a rare

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intermittent component. Explain how ordinary averaging can hide rare bursts Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Multitaper spectra, estimator covariance and uncertainty under intermittent observation” that resolves the question about power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component; derive the relevant result with units and stated validity conditions Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)
- Evidence and method: Specify the native observations, control records and calculations that would resolve power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component. Retain per-record distributions and select summaries according to the question Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Worked application or illustrative case: Build a worked example of “power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component”, addressing this associated condition: Define each summary's relevant statistic or weighting. Define each summary's relevant statistic or weighting Source: §9.3.1 Define the record before interpreting the display (p. 5029)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component”. Using “Multitaper spectra, estimator covariance and uncertainty under intermittent observation”, specify a discriminator and the result

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expected under each explanation Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component, including the effect of missing measurements and inconsistent operating conditions Source: §9.5.2 The projection interpretation and its boundary (p. 5058)
- Scholarly synthesis and implications: Explain what the result about power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Closing: Conclude by answering “Compare power, vector, exponential, percentile, and max-hold summaries for a rare intermittent component” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.4 Averaging and Statistical Stability (p. 5052)

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V011-C09-ESSAY-023. Analyze a zero-sum window as a test of normalization-domain discipline.

- Opening: Present a thesis that answers this precise question: Analyze a zero-sum window as a test of normalization-domain discipline. Identify which evidence would falsify the proposed conclusion Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Core terminology and scope: Define zero-sum, window, test in the question's particular technical setting; explain how normalization-domain, discipline, measurement differ if that distinction would change the analysis of "Analyze a zero-sum window as a test of normalization-domain discipline" Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use weights 1, minus 1, 1, minus 1 to obtain = 0 and = 4 Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a zero-sum window as a test of normalization-domain discipline to the claimed result, following "Numerical reality checks for resolution, noise density and detection"; name the intermediate states and measurable outputs Source: §9.15 Numerical reality checks for resolution, noise density and detection (p. 5090)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a zero-sum window as a test of normalization-domain discipline. Show valid density for positive sample rate and the stated white expectation,

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but undefined Q and equivalent noise bandwidth in that definition Source: §9.15 Numerical reality checks for resolution, noise density and detection (p. 5090)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy” that resolves the question about a zero-sum window as a test of normalization-domain discipline; derive the relevant result with units and stated validity conditions Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a zero-sum window as a test of normalization-domain discipline. Explain why an arbitrary numerical correction cannot restore a canceled coherent tone Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Worked application or illustrative case: Build a worked example of “a zero-sum window as a test of normalization-domain discipline”, addressing this associated condition: Use weights 1, minus 1, 1, minus 1 to obtain = 0 and = 4. Use weights 1, minus 1, 1, minus 1 to obtain = 0 and = 4 Source: §9.15 Numerical reality checks for resolution, noise density and detection (p. 5090)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a zero-sum window as a test of normalization-domain discipline”. Using “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”, specify a discriminator and the result expected under each

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explanation Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a zero-sum window as a test of normalization-domain discipline, including the effect of missing measurements and inconsistent operating conditions Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Scholarly synthesis and implications: Explain what the result about a zero-sum window as a test of normalization-domain discipline authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.2 Spectral Leakage and Window Selection (p. 5027)
- Closing: Conclude by answering “Analyze a zero-sum window as a test of normalization-domain discipline” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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V011-C09-ESSAY-024. Explain why equal second-order spectral matrices can support different physical narratives.

- Opening: Present a thesis that answers this precise question: Explain why equal second-order spectral matrices can support different physical narratives. Identify which evidence would falsify the proposed conclusion Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Core terminology and scope: Define equal, second-order, spectral in the question's particular technical setting; explain how support, physical, narratives differ if that distinction would change the analysis of "Explain why equal second-order spectral matrices can support different physical narratives" Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compare the common latent-source construction with an alternative direct linear representation having an uncorrelated residual Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why equal second-order spectral matrices can support different physical narratives to the claimed result, following "Averaging and Statistical Stability"; name the intermediate states and measurable outputs Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why

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equal second-order spectral matrices can support different physical narratives. State which autospectra, cross-spectrum, and coherence agree Source: §9.4 Averaging and Statistical Stability (p. 5052)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Estimator Validation and Reporting” that resolves the question about why equal second-order spectral matrices can support different physical narratives; derive the relevant result with units and stated validity conditions Source: §9.7 Estimator Validation and Reporting (p. 5072)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why equal second-order spectral matrices can support different physical narratives. Explain that algebraic equivalence does not select causality or unique path, and identify controlled acquisition/path evidence needed beyond the matrix Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Worked application or illustrative case: Build a worked example of “why equal second-order spectral matrices can support different physical narratives”, addressing this associated condition: Compare the common latent-source construction with an alternative direct linear representation having an.... Compare the common latent-source construction with an alternative direct linear representation having an uncorrelated residual Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “why equal second-order spectral

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matrices can support different physical narratives". Using "Estimator Validation and Reporting", specify a discriminator and the result expected under each explanation Source: §9.7 Estimator Validation and Reporting (p. 5072)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why equal second-order spectral matrices can support different physical narratives, including the effect of missing measurements and inconsistent operating conditions Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)
- Scholarly synthesis and implications: Explain what the result about why equal second-order spectral matrices can support different physical narratives authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Closing: Conclude by answering "Explain why equal second-order spectral matrices can support different physical narratives" using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-ESSAY-025. Write an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage.

- Opening: Present a thesis that answers this precise question: Write an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage. Identify which evidence would falsify the proposed conclusion Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Core terminology and scope: Define rationale, integrating, normalization in the question's particular technical setting; explain how inference, usable, coverage differ if that distinction would change the analysis of "Write an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage" Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate Model 9W scaling, Model 9C relationships, and continuity/timing requirements Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage to the claimed result, following "Discrete Records and Spectral Estimates"; name the intermediate states and measurable outputs Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage. Require correct actual coefficients, side conventions, sample provenance, paired weighting, calibration, state controls, and representative held-out tests Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Ten worked applications of the normalization model" that resolves the question about an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage; derive the relevant result with units and stated validity conditions Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage. State limitations on source attribution and negative findings even when both algebraic models pass their checks Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Worked application or illustrative case: Build a worked example of "an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage", addressing this associated condition: Separate Model 9W scaling, Model 9C relationships, and continuity/timing requirements. Separate Model

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9W scaling, Model 9C relationships, and continuity/timing requirements Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage”. Using “Ten worked applications of the normalization model”, specify a discriminator and the result expected under each explanation Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage, including the effect of missing measurements and inconsistent operating conditions Source: §9.3.5 Measurement consequence (p. 5050)
- Scholarly synthesis and implications: Explain what the result about an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)
- Closing: Conclude by answering “Write an acceptance rationale integrating normalization, paired-channel inference, and usable acquisition coverage” using only the demonstrated evidence; state the remaining decisive verification step Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C09-DISCUSSION-001. A colleague treats a denser padded spectrum as evidence of newly resolved carriers. What should the review establish?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A colleague treats a denser padded spectrum as evidence of newly resolved carriers. What should the review establish?” Put this particular dispute to the panel: A colleague treats a denser padded spectrum as evidence of newly resolved carriers. What should the review establish. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 02. Student A, terminology and scope: Agree the operational meanings of treats, padded, newly and resolved, carriers, review in “A colleague treats a denser padded spectrum as evidence of newly resolved carriers. What should the review establish”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A colleague treats a denser padded spectrum as evidence of newly resolved carriers; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3.5 Measurement consequence (p. 5050)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measurement consequence”. Request raw record, N, M, window, SNR, and a two-tone validation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3.5 Measurement consequence (p. 5050)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A colleague treats a denser padded spectrum as evidence of newly resolved carriers; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measurement consequence”. Request raw record, N, M, window, SNR, and a two-tone validation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3.5 Measurement consequence (p. 5050)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish grid interpolation from the unchanged finite-window response and observation duration Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A colleague treats a denser padded spectrum

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as evidence of newly resolved carriers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A colleague treats a denser padded spectrum as evidence of newly resolved carriers; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A colleague treats a denser padded spectrum as evidence of newly resolved carriers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative

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that could survive the proposed test. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A colleague treats a denser padded spectrum as evidence of newly resolved carriers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3.5 Measurement consequence (p. 5050)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A colleague treats a denser padded spectrum as evidence of newly resolved carriers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A colleague treats a denser padded spectrum as evidence of newly resolved carriers. Preserve any improved peak-location estimate while rejecting unsupported separation claims Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A colleague treats a denser padded spectrum as evidence of newly resolved carriers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3.5 Measurement consequence (p. 5050)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A colleague treats a denser padded spectrum as evidence of newly resolved carriers. Preserve any improved peak-location estimate while rejecting unsupported separation claims

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Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A colleague treats a denser padded spectrum as evidence of newly resolved carriers and What should the review establish; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A colleague treats a denser padded spectrum as evidence of newly resolved carriers”, addressing “What should the review establish”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A colleague treats a denser padded spectrum as evidence of newly resolved carriers. What should the review establish”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A colleague treats a denser padded spectrum as evidence of newly resolved carriers. What should the review establish”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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V011-C09-DISCUSSION-002. Two analysts prefer different windows for the same data. How can both be right, and what must they agree on?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two analysts prefer different windows for the same data. How can both be right, and what must they agree on?” Put this particular dispute to the panel: Two analysts prefer different windows for the same data. How can both be right, and what must they agree on. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 02. Student A, terminology and scope: Agree the operational meanings of windows, same, data and right, they, agree in “Two analysts prefer different windows for the same data. How can both be right, and what must they agree on”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two analysts prefer different windows for the same data; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Require exact coefficients and clear claims Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two analysts prefer different windows for the same data; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Require exact coefficients and clear claims Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify their measurands, main-lobe/sidelobe tradeoffs, amplitude and density normalization, and transient weighting Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two analysts prefer different windows for the

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same data: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two analysts prefer different windows for the same data; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two analysts prefer different windows for the same data: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two analysts prefer different windows for the same data, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two analysts prefer different windows for the same data: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two analysts prefer different windows for the same data. Agreement on reproducible inputs and limits

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matters more than imposing a universal preferred window Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two analysts prefer different windows for the same data, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two analysts prefer different windows for the same data. Agreement on reproducible inputs and limits matters more than imposing a universal preferred window Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two analysts prefer different windows for the same data and How can both be right, and what must they agree on; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two analysts prefer different windows for the same data”, addressing “How can both be right, and what must they agree on”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two analysts prefer different windows for the

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same data. How can both be right, and what must they agree on", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Two analysts prefer different windows for the same data. How can both be right, and what must they agree on". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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V011-C09-DISCUSSION-003. A spectrum closes its energy sum exactly but misses an edge burst. Is that contradictory?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A spectrum closes its energy sum exactly but misses an edge burst. Is that contradictory?” Put this particular dispute to the panel: A spectrum closes its energy sum exactly but misses an edge burst. Is that contradictory. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.3.5 Measurement consequence (p. 5050)

- 02. Student A, terminology and scope: Agree the operational meanings of closes, energy, exactly and misses, edge, contradictory in “A spectrum closes its energy sum exactly but misses an edge burst. Is that contradictory”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.3.5 Measurement consequence (p. 5050)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A

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spectrum closes its energy sum exactly but misses an edge burst; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Spectral Leakage and Window Selection”. Discuss actual capture windows, valid samples, and alternate window placement Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A spectrum closes its energy sum exactly but misses an edge burst; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Spectral Leakage and Window Selection”. Discuss actual capture windows, valid samples, and alternate window placement Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use window-position weighting to explain valid arithmetic with poor event opportunity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.3.5 Measurement consequence (p. 5050)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A spectrum closes its energy sum exactly but misses an edge burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how

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you would document an unexpected observation. Source: §9.3.5 Measurement consequence (p. 5050)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A spectrum closes its energy sum exactly but misses an edge burst; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A spectrum closes its energy sum exactly but misses an edge burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.3.5 Measurement consequence (p. 5050)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A spectrum closes its energy

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sum exactly but misses an edge burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A spectrum closes its energy sum exactly but misses an edge burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.3.5 Measurement consequence (p. 5050)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A spectrum closes its energy sum exactly but misses an edge burst. Do not use Parseval success to dismiss the missed transient or to certify coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 14. Student J, Socratic challenge to Student I: For the precise observation involving A spectrum closes its energy sum exactly but misses an edge burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A spectrum closes its energy sum exactly but misses an edge burst. Do not use Parseval success to dismiss the missed transient or to certify coverage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A spectrum closes its energy sum exactly but

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misses an edge burst and Is that contradictory; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A spectrum closes its energy sum exactly but misses an edge burst”, addressing “Is that contradictory”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.3.5 Measurement consequence (p. 5050)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A spectrum closes its energy sum exactly but misses an edge burst. Is that contradictory”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A spectrum closes its energy sum exactly but misses an edge burst. Is that contradictory”. Allocate the next measurement and documentary action to named student roles, and require each

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participant to distinguish accepted evidence from an unsupported assertion. Source: §9.3.5 Measurement consequence (p. 5050)

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V011-C09-DISCUSSION-004. Should a team silently enable mean removal because a software function defaults to it?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a team silently enable mean removal because a software function defaults to it?” Put this particular dispute to the panel: Should a team silently enable mean removal because a software function defaults to it. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 02. Student A, terminology and scope: Agree the operational meanings of silently, enable, mean and removal, software, function in “Should a team silently enable mean removal because a software function defaults to it”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a team silently enable mean removal because a software function defaults to it; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Require explicit preprocessing and comparison with the intended measurand Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a team silently enable

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mean removal because a software function defaults to it; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Require explicit preprocessing and comparison with the intended measurand Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain the change to DC and other processed-record meanings Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a team silently enable mean removal because a software function defaults to it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a team silently enable mean removal because a software function defaults to it; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a team silently enable mean removal because a software function defaults to it: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a team silently enable mean removal because a software function defaults to it, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a team silently enable mean removal because a software function defaults to it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a team silently enable mean removal because a software function defaults to it. A useful detrend may be justified, but it must not be represented as a mere normalization fix Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a team silently enable mean removal because a software function defaults to it, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a team silently enable mean removal because a software function defaults to it. A useful detrend may be justified, but it must not be represented as a mere normalization fix Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a team silently enable mean removal because a software function defaults to it and Explain the change to DC and other processed-record meanings; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.3.5 Measurement consequence (p. 5050)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a team silently enable mean removal because a software function defaults to it”, addressing “Explain the change to DC and other processed-record meanings”; specify the exact measurement or evidential gap on which the

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speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a team silently enable mean removal because a software function defaults to it”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a team silently enable mean removal because a software function defaults to it”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

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V011-C09-DISCUSSION-005. The archive names a Hann window but omits whether it is periodic or symmetric. How should an amplitude discrepancy be investigated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The archive names a Hann window but omits whether it is periodic or symmetric. How should an amplitude discrepancy be investigated?” Put this particular dispute to the panel: The archive names a Hann window but omits whether it is periodic or symmetric. How should an amplitude discrepancy be investigated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 02. Student A, terminology and scope: Agree the operational meanings of archive, names, omits and symmetric, discrepancy, investigated in “The archive names a Hann window but omits whether it is periodic or symmetric. How should an amplitude discrepancy be investigated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The archive names a Hann window but omits whether it is periodic or symmetric; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Avoid selecting the convention that happens to match the desired result Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The archive names a Hann window but omits whether it is periodic or symmetric; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Avoid selecting the convention that happens to match the desired result Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Recover coefficients or the generation convention if possible, recompute and and examine short-record sensitivity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The archive names a Hann window but omits whether it is periodic or symmetric: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The archive names a Hann window but omits whether it is periodic or symmetric; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The archive names a Hann window but omits whether it is periodic or symmetric: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The archive names a Hann window but omits whether it is periodic or symmetric, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The archive names a Hann window but omits whether it is periodic

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or symmetric: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The archive names a Hann window but omits whether it is periodic or symmetric. Report unresolved normalization limits if the actual vector cannot be established Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The archive names a Hann window but omits whether it is periodic or symmetric, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The archive names a Hann window but omits whether it is periodic or symmetric. Report unresolved normalization limits if the actual vector cannot be established Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The archive names a Hann window but omits whether it is periodic or symmetric and How should an amplitude discrepancy be investigated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The archive names a Hann window but omits whether it is periodic or symmetric”, addressing “How should

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an amplitude discrepancy be investigated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The archive names a Hann window but omits whether it is periodic or symmetric. How should an amplitude discrepancy be investigated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The archive names a Hann window but omits whether it is periodic or symmetric. How should an amplitude discrepancy be investigated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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V011-C09-DISCUSSION-006. A noise plot and a line-calibrated plot have different ordinates. Does one have to be wrong?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A noise plot and a line-calibrated plot have different ordinates. Does one have to be wrong?” Put this particular dispute to the panel: A noise plot and a line-calibrated plot have different ordinates. Does one have to be wrong. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 02. Student A, terminology and scope: Agree the operational meanings of noise, plot, line-calibrated and have, ordinates, wrong in “A noise plot and a line-calibrated plot have different ordinates. Does one have to be wrong”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A noise plot and a line-calibrated plot have different ordinates; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Use Q = Be D to compare like quantities Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A noise plot and a line-calibrated plot have different ordinates; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Use Q = Be D to compare like quantities Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check units, coefficient vector, side convention, and equivalent noise bandwidth Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A noise plot and a line-calibrated plot have

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different ordinates: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A noise plot and a line-calibrated plot have different ordinates; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A noise plot and a line-calibrated plot have different ordinates: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A noise plot and a line-calibrated plot have different ordinates, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A noise plot and a line-calibrated plot have different ordinates: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A noise plot and a line-calibrated plot have different ordinates. Distinguish an algebraically consistent representation from proof of calibration or white input assumptions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A noise plot and a line-calibrated plot have different ordinates, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A noise plot and a line-calibrated plot have different ordinates. Distinguish an algebraically consistent representation from proof of calibration or white input assumptions Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A noise plot and a line-calibrated plot have different ordinates and Does one have to be wrong; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A noise plot and a line-calibrated plot have different ordinates”, addressing “Does one have to be wrong”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A noise plot and a line-calibrated plot have different ordinates. Does one have to be wrong”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A noise plot and a line-calibrated plot have different ordinates. Does one have to be wrong”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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V011-C09-DISCUSSION-007. A researcher claims high coherence proves the transmitter-to-receiver path. What alternative explanations deserve testing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A researcher claims high coherence proves the transmitter-to-receiver path. What alternative explanations deserve testing?” Put this particular dispute to the panel: A researcher claims high coherence proves the transmitter-to-receiver path. What alternative explanations deserve testing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of claims, proves, alternative and explanations, deserve, testing in “A researcher claims high coherence proves the transmitter-to-receiver path. What alternative explanations deserve testing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A researcher claims high coherence proves the transmitter-to-receiver path; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications of Equation 18 and its paired-spectrum realization”. Request paired data, calibration, and controlled path changes with comparable sensitivity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A researcher claims high

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coherence proves the transmitter-to-receiver path; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications of Equation 18 and its paired-spectrum realization”. Request paired data, calibration, and controlled path changes with comparable sensitivity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss common sources, shared clocks or references, direct cable leakage, and state-conditioned fit Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A researcher claims high coherence proves the transmitter-to-receiver path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A researcher claims high coherence proves the transmitter-to-receiver path; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A researcher claims high coherence proves the transmitter-to-receiver path: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A researcher claims high coherence proves the transmitter-to-receiver path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A researcher claims high coherence proves the transmitter-to-receiver path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A researcher claims high coherence proves the transmitter-to-receiver path. Preserve the relationship evidence while limiting causal attribution Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A researcher claims high coherence proves the transmitter-to-receiver path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A researcher claims high coherence proves the transmitter-to-receiver path. Preserve the relationship evidence while limiting causal attribution Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A researcher claims high coherence proves the transmitter-to-receiver path and What alternative explanations deserve testing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A researcher claims high coherence proves the transmitter-to-receiver path”, addressing “What alternative explanations deserve testing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A researcher claims high coherence proves the transmitter-to-receiver path. What alternative explanations deserve testing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A researcher claims high coherence proves the transmitter-to-receiver path. What alternative explanations deserve testing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-DISCUSSION-008. Another researcher claims zero coherence proves the channels share no physical component. How should the group respond?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Another researcher claims zero coherence proves the channels share no physical component. How should the group respond?” Put this particular dispute to the panel: Another researcher claims zero coherence proves the channels share no physical component. How should the group respond. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of claims, coherence, proves and share, group, respond in “Another researcher claims zero coherence proves the channels share no physical component. How should the group respond”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Another researcher claims zero coherence proves the channels share no physical component; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Spectral confidence intervals and why averaging is not the same as independence”. Inspect complex cross-spectra and independent state rules, and propose configuration challenges Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Another researcher claims zero coherence proves the channels share no physical component; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Spectral confidence intervals and why averaging is not the same as independence”. Inspect complex cross-spectra and independent state rules, and propose configuration challenges Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use shared-source cancellation and state mixing as concrete alternatives Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Another researcher claims zero coherence proves the channels share no physical component: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Another researcher claims zero coherence proves the channels share no physical component; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Another researcher claims zero coherence proves the channels share no physical component: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Another researcher claims zero coherence proves the channels share no physical component, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Another researcher claims zero coherence proves the channels

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share no physical component: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Another researcher claims zero coherence proves the channels share no physical component. Low coherence can describe the pooled fit without proving physical independence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Another researcher claims zero coherence proves the channels share no physical component, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Another researcher claims zero coherence proves the channels share no physical component. Low coherence can describe the pooled fit without proving physical independence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Another researcher claims zero coherence proves the channels share no physical component and How should the group respond; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Another researcher claims zero coherence proves the channels share no physical component”, addressing “How should the group respond”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Another researcher claims zero coherence proves the channels share no physical component. How should the group respond”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Another researcher claims zero coherence proves the channels share no physical component. How should the group respond”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-DISCUSSION-009. Is unity coherence from one nonzero record impressive evidence of coupling?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is unity coherence from one nonzero record impressive evidence of coupling?” Put this particular dispute to the panel: Is unity coherence from one nonzero record impressive evidence of coupling. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 02. Student A, terminology and scope: Agree the operational meanings of unity, coherence, nonzero and record, impressive, coupling in “Is unity coherence from one nonzero record impressive evidence of coupling”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is unity

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coherence from one nonzero record impressive evidence of coupling; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. Discuss repeatability, ensemble definition, uncertainty, and competing paths Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is unity coherence from one nonzero record impressive evidence of coupling; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. Discuss repeatability, ensemble definition, uncertainty, and competing paths Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Show that a single pair always permits a complex scalar fit Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Is unity coherence from one nonzero record impressive evidence of coupling: specify the altered receiver state or

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source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is unity coherence from one nonzero record impressive evidence of coupling; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is unity coherence from one nonzero record impressive evidence of coupling: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is unity coherence from one nonzero record impressive evidence of coupling, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is unity coherence from one nonzero record impressive evidence of coupling: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is unity coherence from one nonzero record impressive evidence of coupling. Require meaningful multiple observations and controls before drawing a physical relationship conclusion Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is unity coherence from one nonzero record impressive evidence of coupling, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is unity coherence from one nonzero record impressive evidence of coupling. Require meaningful multiple observations and controls before drawing a physical relationship conclusion Respond point by point to Student J. Distinguish a

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verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is unity coherence from one nonzero record impressive evidence of coupling and Show that a single pair always permits a complex scalar fit; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is unity coherence from one nonzero record impressive evidence of coupling”, addressing “Show that a single pair always permits a complex scalar fit”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Is unity coherence from one nonzero record impressive evidence of coupling”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Is unity coherence from one nonzero record impressive evidence of coupling”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

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V011-C09-DISCUSSION-010. A team wants to average per-record coherence values because it seems easier to explain. What must change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team wants to average per-record coherence values because it seems easier to explain. What must change?” Put this particular dispute to the panel: A team wants to average per-record coherence values because it seems easier to explain. What must change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of wants, average, per-record and coherence, values, seems in “A team wants to average per-record coherence values because it seems easier to explain. What must change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team wants to average per-record coherence values because it seems easier to explain; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Averaging and Statistical Stability”. Keep the proper estimator and explain it clearly Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team wants to average per-record coherence values because it seems easier to explain; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Averaging and Statistical Stability”. Keep the proper estimator and explain it clearly Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Demonstrate the phase-cancellation example and distinguish averaging complex products from averaging already normalized magnitudes Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A team wants to average per-record coherence values because it seems easier to explain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team wants to average per-record coherence values because it seems easier to explain; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team wants to average per-record coherence values because it seems easier to explain: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team wants to average per-record coherence values because it seems easier to explain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team wants to average per-record coherence values because it seems easier to explain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team wants to average per-record coherence values because it seems easier to explain. If another statistic is retained, give it an accurate separate definition and do not inherit the coherence proof Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team wants to average per-record coherence values because it seems easier to explain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team wants to average per-record coherence

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values because it seems easier to explain. If another statistic is retained, give it an accurate separate definition and do not inherit the coherence proof Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team wants to average per-record coherence values because it seems easier to explain and What must change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team wants to average per-record coherence values because it seems easier to explain”, addressing “What must change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker

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before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team wants to average per-record coherence values because it seems easier to explain. What must change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team wants to average per-record coherence values because it seems easier to explain. What must change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-DISCUSSION-011. Can a robust median option be substituted independently into three spectral estimates without revalidation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a robust median option be substituted independently into three spectral estimates without revalidation?” Put this particular dispute to the panel: Can a robust median option be substituted independently into three spectral estimates without revalidation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 02. Student A, terminology and scope: Agree the operational meanings of robust, option, substituted and independently, spectral, estimates in “Can a robust median option be substituted independently into three spectral estimates without revalidation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a robust median option be substituted independently into three spectral estimates without revalidation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications of Equation 18 and its paired-spectrum realization”. Require a valid estimator definition, domain, and uncertainty assessment Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a robust median option be substituted independently into three spectral estimates without

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revalidation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications of Equation 18 and its paired-spectrum realization”. Require a valid estimator definition, domain, and uncertainty assessment Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss the loss of a common paired construction and the counterexample above one Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a robust median option be substituted independently into three spectral estimates without revalidation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a robust median option be substituted independently into three spectral estimates without revalidation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a robust median option be substituted independently into three spectral estimates without revalidation: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a robust median option be substituted independently into three spectral estimates without revalidation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a robust median option be substituted independently into three spectral estimates without revalidation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the

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panel to retain, qualify or reject the conclusion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a robust median option be substituted independently into three spectral estimates without revalidation. Avoid generalizing the specific failure to every robust method or claiming that clipping an invalid ratio repairs it Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a robust median option be substituted independently into three spectral estimates without revalidation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a robust median option be substituted independently into three spectral estimates without revalidation. Avoid generalizing the specific failure to every robust method or claiming that clipping an invalid ratio repairs it Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a robust median option be substituted independently into three spectral estimates without revalidation and Discuss the loss of a common paired construction and the counterexample above one; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a robust median option be substituted independently into three spectral estimates without revalidation”, addressing “Discuss the loss of a common paired construction and the counterexample above one”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can a robust median option be substituted independently into three spectral estimates without revalidation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can a robust median option be substituted independently into three spectral estimates without revalidation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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V011-C09-DISCUSSION-012. Two systems have the same coherence but different measured output noise. Is that inconsistent?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two systems have the same coherence but different measured output noise. Is that inconsistent?” Put this particular dispute to the panel: Two systems have the same coherence but different measured output noise. Is that inconsistent. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of systems, same, coherence and output, noise, inconsistent in “Two systems have the same coherence but different measured output noise. Is that inconsistent”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two systems have the same coherence but different measured output noise; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Spectral Leakage and Window Selection”. Require calibrated autospectra and justified model assumptions before applying Equal normalized coherence need not identify equal SNR or noise location Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two systems have the same coherence but different measured output noise; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Spectral Leakage and Window Selection”. Require calibrated autospectra and justified model assumptions before applying Equal normalized coherence need not identify equal SNR or noise location Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain the role of input noise and disturbance allocation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two systems have the same coherence but

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different measured output noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two systems have the same coherence but different measured output noise; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two systems have the same coherence but different measured output noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two systems have the same coherence but different measured output noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two systems have the same coherence but different measured output noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two systems have the same coherence but different measured output noise. Require calibrated autospectra and justified model assumptions before applying Equal normalized coherence need not identify equal SNR or noise location Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two systems have the same coherence but different measured output noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two systems have the same coherence but different measured output noise. Require calibrated autospectra and justified model assumptions before applying Equal normalized

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coherence need not identify equal SNR or noise location Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two systems have the same coherence but different measured output noise and Is that inconsistent; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two systems have the same coherence but different measured output noise”, addressing “Is that inconsistent”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two systems have the same coherence but different measured output noise. Is that inconsistent”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two systems have the same coherence but different measured output noise. Is that inconsistent”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-DISCUSSION-013. A convenient state split sharply raises coherence. How should reviewers assess whether it is defensible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A convenient state split sharply raises coherence. How should reviewers assess whether it is defensible?” Put this particular dispute to the panel: A convenient state split sharply raises coherence. How should reviewers assess whether it is defensible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of convenient, split, sharply and raises, coherence, defensible in “A convenient state split sharply raises coherence. How should reviewers assess whether it is defensible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A convenient state split sharply raises coherence; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Spectral confidence intervals and why averaging is not the same as independence”. Preserve pooled and state-resolved estimates and their weights Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A convenient state split sharply raises coherence; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Spectral confidence intervals and why averaging is not the same as independence”. Preserve pooled and state-resolved estimates and their weights Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask whether the state rule was specified independently of the desired result and corresponds to a meaningful operating condition Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A convenient state split sharply raises

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coherence: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A convenient state split sharply raises coherence; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A convenient state split sharply raises coherence: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A convenient state split sharply raises coherence, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A convenient state split sharply raises coherence: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A convenient state split sharply raises coherence. Reject postselection that merely manufactures proportional vectors Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A convenient state split sharply raises coherence, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A convenient state split sharply raises coherence. Reject postselection that merely manufactures proportional vectors Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A convenient state split sharply raises coherence and How should reviewers assess whether it is defensible; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A convenient state split sharply raises coherence”, addressing “How should reviewers assess whether it is defensible”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A convenient state split sharply raises coherence. How should reviewers assess whether it is defensible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A convenient state split sharply raises coherence. How should reviewers assess whether it is defensible”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-DISCUSSION-014. Should amplitude calibration be skipped when coherence is invariant to fixed gains?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should amplitude calibration be skipped when coherence is invariant to fixed gains?” Put this particular dispute to the panel: Should amplitude calibration be skipped when coherence is invariant to fixed gains. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of amplitude, calibration, coherence and invariant, fixed, gains in “Should amplitude calibration be skipped when coherence is invariant to fixed gains”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether amplitude calibration be skipped when coherence is invariant to fixed gains; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Estimator Validation and Reporting”. Discuss nonzero-gain assumptions and calibration residuals Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether amplitude calibration be skipped when coherence is invariant to fixed gains; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Estimator Validation and Reporting”. Discuss nonzero-gain assumptions and calibration residuals Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate normalized relationship from absolute amplitude, fitted gain, and phase/delay quantities Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether amplitude calibration be skipped

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when coherence is invariant to fixed gains: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether amplitude calibration be skipped when coherence is invariant to fixed gains; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether amplitude calibration be skipped when coherence is invariant to fixed gains: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses

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and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether amplitude calibration be skipped when coherence is invariant to fixed gains, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether amplitude calibration be skipped when coherence is invariant to fixed gains: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether amplitude calibration be skipped when coherence is invariant to fixed gains. Coherence invariance does not validate the full multichannel measurement chain Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether amplitude calibration be skipped when coherence is invariant to fixed gains, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether amplitude calibration be skipped when coherence is invariant to fixed gains. Coherence invariance does not validate the full multichannel measurement chain Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether amplitude calibration be skipped when coherence is invariant to fixed gains and Separate normalized relationship from absolute amplitude, fitted gain, and phase/delay quantities; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.3.5 Measurement consequence (p. 5050)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether amplitude calibration be skipped when coherence is invariant to fixed gains”, addressing “Separate normalized relationship from absolute amplitude, fitted gain, and phase/delay quantities”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should amplitude calibration be skipped when coherence is invariant to fixed gains”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should amplitude calibration be skipped when coherence is invariant to fixed gains”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-DISCUSSION-015. A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. How should it be explained?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. How should it be explained?” Put this particular dispute to the panel: A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. How should it be explained. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 02. Student A, terminology and scope: Agree the operational meanings of negative, alarms, reviewer and thinks, power, nonnegative in “A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. How should it be explained”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. State conjugation and units, inspect the paired construction, and avoid interpreting a negative real cross term as negative physical mean power Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. State conjugation and units, inspect the paired construction, and avoid interpreting a negative real cross term as negative physical mean power Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish nonnegative autospectra from complex cross-spectra encoding relative phase Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. State conjugation and units, inspect the paired construction, and avoid interpreting a negative real cross term as negative physical mean power Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. State conjugation and units, inspect the paired construction, and avoid interpreting a negative real cross term as negative physical mean power Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative and How should it be explained; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative”, addressing “How

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should it be explained”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. How should it be explained”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A negative cross-spectrum alarms a reviewer who thinks power must be nonnegative. How should it be explained”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

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V011-C09-DISCUSSION-016. An injected-reference test reveals a shared-clock path. How should the original room-coupling report be revised?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An injected-reference test reveals a shared-clock path. How should the original room-coupling report be revised?” Put this particular dispute to the panel: An injected-reference test reveals a shared-clock path. How should the original room-coupling report be revised. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of test, reveals, path and original, report, revised in “An injected-reference test reveals a shared-clock path. How should the original room-coupling report be revised”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An injected-reference test reveals a shared-clock path; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Discrete Records and Spectral Estimates”. Preserve evidence, test remaining paths with comparable sensitivity and state, and avoid declaring universal absence of environmental coupling solely because one instrument artifact was found Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An injected-reference test reveals a shared-clock path; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Discrete Records and Spectral Estimates”. Preserve evidence, test remaining paths with comparable sensitivity and state, and avoid declaring universal absence of environmental coupling solely because one instrument artifact was found Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the contaminating mechanism and qualify the inference supported by original high coherence Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An injected-reference test reveals a shared-clock path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An injected-reference test reveals a shared-clock path; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An injected-reference test reveals a shared-clock path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An injected-reference test reveals a shared-clock path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An injected-reference test reveals a shared-clock path: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An injected-reference test reveals a shared-clock path. Preserve evidence, test remaining paths with comparable sensitivity and state, and avoid declaring universal absence of environmental coupling solely because one instrument artifact was found Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An injected-reference test reveals a shared-clock path, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An injected-reference test reveals a shared-clock path. Preserve evidence, test remaining paths with comparable sensitivity and state, and avoid declaring universal absence of

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environmental coupling solely because one instrument artifact was found Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An injected-reference test reveals a shared-clock path and How should the original room-coupling report be revised; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An injected-reference test reveals a shared-clock path”, addressing “How should the original room-coupling report be revised”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An injected-reference test reveals a shared-clock path. How should the original room-coupling report be revised”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An injected-reference test reveals a shared-clock path. How should the original room-coupling report be revised”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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V011-C09-DISCUSSION-017. How much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records?” Put this particular dispute to the panel: How much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 02. Student A, terminology and scope: Agree the operational meanings of confidence, image, carry and parameters, frozen, tested in “How much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Estimator Validation and Reporting”. Require raw-record corroboration and intended-use references Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how much confidence should a

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beautiful time-frequency image carry before its parameters are frozen and tested on held-out records; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Estimator Validation and Reporting”. Require raw-record corroboration and intended-use references Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss thresholds, interpolation, color mapping, window lengths, and selection effects Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records: specify the altered receiver

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state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely

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what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records. The image can motivate a hypothesis, but detection claims need an explicit tested rule Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records. The image can motivate a hypothesis, but detection claims need an explicit tested rule Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records and Discuss thresholds, interpolation, color mapping, window lengths, and selection effects; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records”, addressing “Discuss thresholds, interpolation, color mapping, window lengths, and selection effects”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How much confidence should a beautiful time-frequency image carry before its parameters are frozen and tested on held-out records”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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V011-C09-DISCUSSION-018. A rare burst vanishes in a long average but appears in max hold. Which result should be reported?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A rare burst vanishes in a long average but appears in max hold. Which result should be reported?” Put this particular dispute to the panel: A rare burst vanishes in a long average but appears in max hold. Which result should be reported. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 02. Student A, terminology and scope: Agree the operational meanings of rare, vanishes, long and appears, hold, reported in “A rare burst vanishes in a long average but appears in max hold. Which result should be reported”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.4 Averaging and Statistical Stability (p. 5052)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A rare burst vanishes in a long average but appears in max hold; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins”. Use multiple declared summaries for power and occurrence, without treating max hold as mean power or simultaneous coexistence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A rare burst vanishes in a long average but appears in max hold; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins”. Use multiple declared summaries for power and occurrence, without treating max hold as mean power or simultaneous coexistence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain each statistic and preserve event-resolved frequency and duration information Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or

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observation would discriminate between them without changing the measurand. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A rare burst vanishes in a long average but appears in max hold: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A rare burst vanishes in a long average but appears in max hold; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A rare burst vanishes in a long average but appears in max hold: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A rare burst vanishes in a long average but appears in max hold, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A rare burst vanishes in a long average but appears in max hold: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A rare burst vanishes in a long average but appears in max hold. Report the behavior that actually answers the survey question Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A rare burst vanishes in a long average but appears in max hold, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A rare burst vanishes in a long average but appears in max hold. Report the behavior that actually answers the survey question Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A rare burst vanishes in a long average but appears in max hold and Which result should be reported; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A rare burst vanishes in a long average but appears in max hold”, addressing “Which result should be reported”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A rare burst vanishes in a long average but appears in max hold. Which result should be reported”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A rare burst vanishes in a long average but appears in max hold. Which result should be reported”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.4 Averaging and Statistical Stability (p. 5052)

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V011-C09-DISCUSSION-019. When could extending the acquisition record make an estimate less useful despite finer nominal bins?

- 01. Moderator, opening proposition: Introduce the exact dispute, “When could extending the acquisition record make an estimate less useful despite finer nominal bins?” Put this particular dispute to the panel: When could extending the acquisition record make an estimate less useful despite finer nominal bins. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 02. Student A, terminology and scope: Agree the operational meanings of extending, acquisition, make and estimate, despite, bins in “When could extending the acquisition record make an estimate less useful despite finer nominal bins”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of When could extending the acquisition record make an estimate less useful despite finer nominal bins; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins”. Balance resolution against the time interval over which the signal is comparable Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When could extending the acquisition record make an estimate less useful despite finer

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nominal bins; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins”. Balance resolution against the time interval over which the signal is comparable Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss drift, nonstationarity, changing states, and transient dilution Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving When could extending the acquisition record make an estimate less useful despite finer nominal bins: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of When could extending the acquisition record make an estimate less useful despite finer nominal bins; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving When could extending the acquisition record make an estimate less useful despite finer nominal bins: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a

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repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving When could extending the acquisition record make an estimate less useful despite finer nominal bins, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving When could extending the acquisition record make an estimate less useful despite finer nominal bins: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for When could extending the acquisition record make an estimate less useful despite finer nominal bins. Validate chosen lengths against intended references rather than maximizing N automatically Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving When could extending the acquisition record make an estimate less useful despite finer nominal bins, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.16 Long-duration multiresolution spectrum retention and the limits of thirty-hertz FFT bins (p. 5091)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for When could extending the acquisition record make an estimate less useful despite finer nominal bins. Validate chosen lengths against intended references rather than maximizing N automatically Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about When could extending the acquisition record make an estimate less useful despite finer nominal bins and Discuss drift, nonstationarity, changing states, and transient dilution; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “When could extending the acquisition record make an estimate less useful despite finer nominal bins”,

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addressing “Discuss drift, nonstationarity, changing states, and transient dilution”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “When could extending the acquisition record make an estimate less useful despite finer nominal bins”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “When could extending the acquisition record make an estimate less useful despite finer nominal bins”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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V011-C09-DISCUSSION-020. A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Why is that insufficient?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Why is that insufficient?” Put this particular dispute to the panel: A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Why is that insufficient. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, replacing, failed and fact, coherence, insufficient in “A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Why is that insufficient”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Spectral confidence intervals and why averaging is not the same as independence”. A bounded estimator is not automatically an exact probability or confidence statement Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Spectral confidence intervals and why averaging is not the same as independence”. A bounded estimator is not automatically an exact probability or confidence statement Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain the algebraic bound separately from sampling variation, overlap, independence, and record selection Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Identify evidence needed for the uncertainty claim Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what

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evidence would reverse the conclusion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Identify evidence needed for the uncertainty claim Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one and Why is that insufficient; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.4 Averaging and Statistical Stability (p. 5052)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one”, addressing “Why is that insufficient”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Why is that insufficient”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reviewer proposes replacing a failed uncertainty analysis with the fact that coherence lies between zero and one. Why is that insufficient”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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V011-C09-DISCUSSION-021. What should be preserved when alternative windows give conflicting weak-feature interpretations?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should be preserved when alternative windows give conflicting weak-feature interpretations?” Put this particular dispute to the panel: What should be preserved when alternative windows give conflicting weak-feature interpretations. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 02. Student A, terminology and scope: Agree the operational meanings of preserved, alternative, windows and conflicting, weak-feature, interpretations in “What should be preserved when alternative windows give conflicting weak-feature interpretations”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should be preserved when alternative windows give conflicting weak-feature interpretations; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Discrete Records and Spectral Estimates”. Compare predicted leakage behavior and time structure, then test on independent records Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should be preserved when alternative windows give conflicting weak-feature interpretations; explain what each record can establish State what

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the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Discrete Records and Spectral Estimates”. Compare predicted leakage behavior and time structure, then test on independent records Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain original samples, both exact processing paths, settings, and relevant controls Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should be preserved when alternative windows give conflicting weak-feature interpretations: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should be preserved when alternative windows give conflicting weak-feature interpretations; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should be preserved when alternative windows give conflicting weak-feature interpretations: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion

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Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should be preserved when alternative windows give conflicting weak-feature interpretations, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should be preserved when alternative windows give conflicting weak-feature interpretations: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should be preserved when alternative windows give conflicting weak-feature interpretations. Avoid deleting the less convenient interpretation or claiming processing variation identifies the physical source by itself Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should be preserved when alternative windows give conflicting weak-feature interpretations, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should be preserved when alternative

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windows give conflicting weak-feature interpretations. Avoid deleting the less convenient interpretation or claiming processing variation identifies the physical source by itself Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should be preserved when alternative windows give conflicting weak-feature interpretations and Retain original samples, both exact processing paths, settings, and relevant controls; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.5.2 The projection interpretation and its boundary (p. 5058)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should be preserved when alternative windows give conflicting weak-feature interpretations”, addressing “Retain original samples, both exact processing paths, settings, and relevant controls”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should be preserved when alternative windows give conflicting weak-feature interpretations”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should be preserved when alternative windows give conflicting weak-feature interpretations”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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V011-C09-DISCUSSION-022. Should DC and Nyquist be doubled for consistency with every other point on a one-sided display?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should DC and Nyquist be doubled for consistency with every other point on a one-sided display?” Put this particular dispute to the panel: Should DC and Nyquist be doubled for consistency with every other point on a one-sided display. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 02. Student A, terminology and scope: Agree the operational meanings of Nyquist, consistency, other and point, one-sided, display in “Should DC and Nyquist be doubled for consistency with every other point on a one-sided display”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.3.3 Energy closure and its limits (p. 5036)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether DC and Nyquist be doubled for consistency with every other point on a one-sided display; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define the record before interpreting the display”. Distinguish odd and even N and preserve the actual quantity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether DC and Nyquist be doubled for consistency with every other point on a one-sided display; explain what each record can establish State what the

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existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define the record before interpreting the display”. Distinguish odd and even N and preserve the actual quantity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use conjugate-pair counting and energy closure to explain endpoint treatment Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether DC and Nyquist be doubled for consistency with every other point on a one-sided display: specify

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the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether DC and Nyquist be doubled for consistency with every other point on a one-sided display; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether DC and Nyquist be doubled for consistency with every other point on a one-sided display: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H

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to identify an alternative that could survive the proposed test. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether DC and Nyquist be doubled for consistency with every other point on a one-sided display, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether DC and Nyquist be doubled for consistency with every other point on a one-sided display: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.3.3 Energy closure and its limits (p. 5036)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether DC and Nyquist be doubled for consistency with every other point on a one-sided display. Consistent physics requires different endpoint handling rather than visually uniform arithmetic Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether DC and Nyquist be doubled for consistency with every other point on a one-sided display, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether DC and Nyquist be doubled for consistency with every other point on a one-sided display.

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Consistent physics requires different endpoint handling rather than visually uniform arithmetic Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether DC and Nyquist be doubled for consistency with every other point on a one-sided display and Use conjugate-pair counting and energy closure to explain endpoint treatment; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether DC and Nyquist be doubled for consistency with every other point on a one-sided display”, addressing “Use conjugate-pair counting and energy closure to explain endpoint treatment”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should DC and Nyquist be doubled for consistency with every other point on a one-sided display”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should DC and Nyquist be doubled for consistency with every other point on a one-sided display”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.3.3 Energy closure and its limits (p. 5036)

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V011-C09-DISCUSSION-023. How should a team choose between vector averaging and power averaging when an internal coherent spur is suspected?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a team choose between vector averaging and power averaging when an internal coherent spur is suspected?” Put this particular dispute to the panel: How should a team choose between vector averaging and power averaging when an internal coherent spur is suspected. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 02. Student A, terminology and scope: Agree the operational meanings of vector, averaging, internal and coherent, spur, suspected in “How should a team choose between vector averaging and power averaging when an internal coherent spur is suspected”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.4 Averaging and Statistical Stability (p. 5052)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. Use controlled receiver/path challenges, since coherent persistence alone does not prove an external source Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team choose between vector averaging and power averaging when an internal

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coherent spur is suspected; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. Use controlled receiver/path challenges, since coherent persistence alone does not prove an external source Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the statistic each method retains and examine per-record phase and magnitude Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.4 Averaging and Statistical Stability (p. 5052)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected: specify the altered receiver state or

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source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would

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lead the panel to retain, qualify or reject the conclusion. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected. Retain both methods as declared diagnostics if they answer different questions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected. Retain both methods as declared diagnostics if they answer different questions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected and State the statistic each method retains and examine per-record phase and magnitude; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a team choose between vector averaging and power averaging when an internal coherent spur is suspected”, addressing “State the statistic each method retains and examine per-record phase and magnitude”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a team choose between vector averaging and power averaging when an internal coherent spur is suspected”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a team choose between vector averaging and power averaging when an internal coherent spur is suspected”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.4 Averaging and Statistical Stability (p. 5052)

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V011-C09-DISCUSSION-024. An analyst can reproduce a plot from an image-editing file but not from native samples. Is the measurement reproducible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An analyst can reproduce a plot from an image-editing file but not from native samples. Is the measurement reproducible?” Put this particular dispute to the panel: An analyst can reproduce a plot from an image-editing file but not from native samples. Is the measurement reproducible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, reproduce, plot and file, native, reproducible in “An analyst can reproduce a plot from an image-editing file but not from native samples. Is the measurement reproducible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An analyst can reproduce a plot from an image-editing file but not from native samples; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Discrete Records and Spectral Estimates”. Require samples, preprocessing, coefficients, units, exclusions, and executable analysis Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst can reproduce a plot from an image-editing file but not from native samples; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Discrete Records and Spectral Estimates”. Require samples, preprocessing, coefficients, units, exclusions, and executable analysis Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish visual recreation from data-to-estimate reproducibility Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An analyst can reproduce a plot from an

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image-editing file but not from native samples: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst can reproduce a plot from an image-editing file but not from native samples; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An analyst can reproduce a plot from an image-editing file but not from native samples: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative

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that could survive the proposed test. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An analyst can reproduce a plot from an image-editing file but not from native samples, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An analyst can reproduce a plot from an image-editing file but not from native samples: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An analyst can reproduce a plot from an

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image-editing file but not from native samples. State what the surviving image supports while identifying missing evidence instead of inventing a reconstruction Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An analyst can reproduce a plot from an image-editing file but not from native samples, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An analyst can reproduce a plot from an image-editing file but not from native samples. State what the surviving image supports while identifying missing evidence instead of inventing a reconstruction Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An analyst can reproduce a plot from an image-editing file but not from native samples and Is the measurement reproducible; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.11 Multitaper spectra, estimator covariance and uncertainty under intermittent observation (p. 5077)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An analyst can reproduce a plot from an image-editing file but not from native samples”, addressing “Is the measurement reproducible”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An analyst can reproduce a plot from an image-editing file but not from native samples. Is the measurement reproducible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An analyst can reproduce a plot from an image-editing file but not from native samples. Is the measurement reproducible”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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V011-C09-DISCUSSION-025. What should constitute acceptance of a multichannel spectral method intended for intermittent survey work?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should constitute acceptance of a multichannel spectral method intended for intermittent survey work?” Put this particular dispute to the panel: What should constitute acceptance of a multichannel spectral method intended for intermittent survey work. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 02. Student A, terminology and scope: Agree the operational meanings of multichannel, method, intended and intermittent, survey, work in “What should constitute acceptance of a multichannel spectral method intended for intermittent survey work”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should constitute acceptance of a multichannel spectral method intended for intermittent survey work; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Estimator Validation and Reporting”. Discuss artifact challenges and report scope Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should constitute acceptance of a multichannel spectral method intended for intermittent survey work; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Estimator Validation and Reporting”. Discuss artifact challenges and report scope Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require correct normalization, paired records, clock/skew calibration, uncertainty limits, representative transient and channel references, held-out tests, and usable sample coverage Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should constitute acceptance of a multichannel spectral method intended for intermittent survey work: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should constitute acceptance of a multichannel spectral method intended for intermittent survey work; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should constitute acceptance of a multichannel spectral method intended for intermittent survey work: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should constitute acceptance of a multichannel spectral method intended for intermittent survey work, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should constitute acceptance of a multichannel spectral method intended for intermittent survey work: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should constitute acceptance of a multichannel spectral method intended for intermittent survey work. No single attractive spectrum, coherence value, or energy check replaces this combined evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should constitute acceptance of a multichannel spectral method intended for intermittent survey work, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should constitute acceptance of a multichannel spectral method intended for intermittent survey work. No single attractive spectrum, coherence value, or energy check replaces this combined evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should constitute acceptance of a multichannel spectral method intended for intermittent survey work and Require correct normalization, paired records, clock/skew calibration, uncertainty limits, representative…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should constitute acceptance of a multichannel spectral method intended for intermittent survey work”, addressing “Require correct normalization, paired records, clock/skew calibration, uncertainty limits, representative…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should constitute acceptance of a multichannel spectral method intended for intermittent survey work”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should constitute acceptance of a multichannel spectral method intended for intermittent survey work”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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Chapter 9 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C09-ESSAY-001 — Substitute a bin-centered complex tone into the unnormalized DFT to obtain a times S_1. Expand squared magnitude under zero-mean white covariance to obtain variance times S_2. Identify units, nonzero denominator conditions, and why Gaussianity is unnecessary for the expectation. Explain why substituting one sum for the other changes the measurand.

Review: Chapter 9 — Noise density uses a different denominator.

V011-C09-ESSAY-002 — Retain both frequency images and derive the contribution of W at twice the tone bin. Require the stated frequency condition and a vanishing or bounded image term before using doubled magnitude over the coherent sum. Treat DC, Nyquist, and off-grid cases separately; coherent gain is not a universal correction.

Review: Chapter 9 — Define the record before interpreting the display.

V011-C09-ESSAY-003 — Start with the two-sided density, fold equal conjugate contributions, double interior positive bins, retain DC and even-length Nyquist once, and double the last positive bin for odd N. Use actual grid spacing. Show that the sum equals the squared-window-weighted mean square, not necessarily unweighted mean square.

Review: Chapter 9 — Energy closure and its limits.

V011-C09-ESSAY-004 — Retain the original coefficient vector, S_1, S_2, and N while increasing transform length M. Use $\frac{f_s}{M}$ in density integration. Explain peak interpolation and the unchanged response width, and derive the error from replacing N by M in a window bandwidth formula. State the limit on resolving overlapping components.

Review: Chapter 9 — Energy closure and its limits.

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V011-C09-ESSAY-005 — Use the squared coefficient at each position and divide by S_2. For the stated 16-point periodic example, compare zero and $\frac{1}{6}$ V squared with unweighted $\frac{1}{16}$ V squared. Explain why all satisfy exact energy closure and why capture opportunity and window placement require separate validation.

Review: Chapter 9 — Ten worked applications of the normalization model.

V011-C09-ESSAY-006 — Retain the same native samples while applying declared alternate windows, compare sidelobe and main-lobe behavior, and inspect time evolution and repeated records. Calibrate amplitude with actual sums and account for off-grid effects. Use appropriate known tones and held-out observations; changed window response alone does not identify physical origin.

Review: Chapter 9 — Spectral Leakage and Window Selection.

V011-C09-ESSAY-007 — Explain that adjacent bins are part of one finite-window response, not independent powers. Convert Q to D with equivalent noise bandwidth, multiply by actual grid spacing, and sum. Reproduce the 0.0075 times $\frac{46.875}{70.3125}$ = 0.005 V squared example. Preserve side conventions and impedance if converting to power.

Review: Chapter 9 — Ten worked applications of the normalization model.

V011-C09-ESSAY-008 — Give their distinct cosine conventions and finite S_1 and S_2 values. At N = 16 and f_s = 1600 Hz, obtain 150 and 160 Hz bandwidths. Explain the complex-amplitude error from using 8 instead of 7.5 as coherent sum and the separate density error from mixing bandwidths. Do not silently substitute a real tone without its image condition.

Review: Chapter 9 — Ten worked applications of the normalization model.

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V011-C09-ESSAY-009 — State the recordwise weighted-energy identity and correct frequency spacing. Explain its validity for colored covariance and transient records. Separate arithmetic normalization from stationarity, alias-free sampling, calibration, source attribution, overload, and usable observation intervals. Propose additional tests for those distinct claims.

Review: Chapter 9 — Energy closure and its limits.

V011-C09-ESSAY-010 — Retain samples, sample rate, observed N, transform length, coefficient convention, side folding, units, impedance, and preprocessing. State linear, logarithmic, vector, or weighted averaging and record overlap/dependence. Identify corrections already applied and the distinction between logarithm of expected power and expected log display. Link plots to executable analysis.

Review: Chapter 9 — Measurement consequence.

V011-C09-ESSAY-011 — Form vectors from square-root nonnegative weights times the paired coefficients. Apply Cauchy–Schwarz with common positive density scaling and positive autospectra. Give the proportional-vector equality condition. Explain that independence is not needed for this algebraic bound but is relevant to uncertainty, and that different record selections break the construction.

Review: Chapter 9 — Define the ensemble before normalizing.

V011-C09-ESSAY-012 — Show that each nonzero one-pair ratio is one. Use X = (1,1) and Y = (1,minus 1) to obtain zero averaged complex cross-product and zero proper coherence despite unit per-record ratios. Identify the lost phase cancellation and distinguish this exact processing error from rounding or finite-sample uncertainty.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-ESSAY-013 — Calculate autospectral medians 1 and 1 and cross median 10, yielding 100. Contrast common means yielding 400/10201. Explain the loss of one paired Gram construction rather than negative weights or floating-point error. Do not claim that every robust method fails or that a named coherence routine necessarily uses this separate-median construction.

Review: Chapter 9 — Define the ensemble before normalizing.

V011-C09-ESSAY-014 — Expand the weighted squared residual, complete the square, and obtain $\frac{P_{xy}}{P_{xx}}$ and P_{yy} minus squared cross magnitude over P_{xx}. Give gain and residual units and the explained-fraction interpretation. Separate a finite fit from causal direction, residual independence, and extrapolation to other states.

Review: Chapter 9 — The projection interpretation and its boundary.

V011-C09-ESSAY-015 — State exact input observation, linear gain, and zero input-disturbance cross-spectrum. Derive $\frac{C}{(1-C)}$. Compare the chapter's equal-coherence cases with different input/output noise allocations and output SNRs. Explain why a measured value alone cannot locate noise or supply an input-noise correction.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-ESSAY-016 — Use X = S + D and Y = S minus D with uncorrelated components. Derive autospectra as sums and cross-spectrum as a difference. Show exact cancellation for equal spectra and the $\frac{1}{81}$ case when spectra are 1 and 0.8. Recommend complex-spectrum inspection and coupling challenges rather than treating low coherence as proof of independent physical causes.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

V011-C09-ESSAY-017 — Use opposite gains and equal weights to show canceled cross-spectrum with positive autospectra. Then weight states three quarters and one quarter to obtain coherence one quarter. Define a defensible state rule independently of the desired result and retain state-resolved records. Discuss what the pooled estimator actually describes.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

V011-C09-ESSAY-018 — State which channel is conjugated, the signal delay exponential, phase sign, calibrated skew, sample alignment, clock behavior, and phase branch. Use the stated 1000 Hz and 125 microsecond example to obtain minus 45 degrees under X conjugate Y. Explain integer-cycle ambiguity and why coherence alone does not calibrate absolute delay.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-ESSAY-019 — Preserve comparable sensitivity and state while using channel swaps, independent terminations, separation, and injected references. Record clock and synchronization paths. Interpret a revealed recorder path as a mechanism that limits the original claim, without asserting universal absence of room coupling. Retain both original and challenged native records.

Review: Chapter 9 — Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

V011-C09-ESSAY-020 — Distinguish bin spacing from window response, SNR, and estimator resolution. Explain how longer duration improves nominal spacing while increasing exposure to drift or state mixing. Compare alternate lengths on known and held-out signals, preserve time data, and choose the interval that supports the intended measurand.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

V011-C09-ESSAY-021 — Declare window and segment lengths, overlap, normalization, thresholds, interpolation, and color mapping. Validate known bursts and chirps, inspect raw records and alternate settings, freeze parameters before held-out evaluation, and retain excluded intervals. Require a quantified detection rule rather than treating a compelling image as direct physical evidence.

Review: Chapter 9 — Time-Frequency and Nonstationary Methods.

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V011-C09-ESSAY-022 — Define each summary's relevant statistic or weighting. Explain how ordinary averaging can hide rare bursts, how coherent internal spurs can survive vector averaging, and why peak or percentile summaries do not establish simultaneous occurrence or independent trials. Retain per-record distributions and select summaries according to the question.

Review: Chapter 9 — Averaging and Statistical Stability.

V011-C09-ESSAY-023 — Use weights 1, minus 1, 1, minus 1 to obtain S_1 = 0 and S_2 = 4. Show valid density for positive sample rate and the stated white expectation, but undefined Q and equivalent noise bandwidth in that definition. Explain why an arbitrary numerical correction cannot restore a canceled coherent tone.

Review: Chapter 9 — Ten worked applications of the normalization model.

V011-C09-ESSAY-024 — Compare the common latent-source construction with an alternative direct linear representation having an uncorrelated residual. State which autospectra, cross-spectrum, and coherence agree. Explain that algebraic equivalence does not select causality or unique path, and identify controlled acquisition/path evidence needed beyond the matrix.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

V011-C09-ESSAY-025 — Separate Model 9W scaling, Model 9C relationships, and continuity/timing requirements. Require correct actual coefficients, side conventions, sample provenance, paired weighting, calibration, state controls, and representative held-out tests. State limitations on source attribution and negative findings even when both algebraic models pass their checks.

Review: Chapter 9 — Estimator Validation and Reporting.

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Discussion Guidance

V011-C09-DISCUSSION-001 — Distinguish grid interpolation from the unchanged finite-window response and observation duration. Request raw record, N, M, window, SNR, and a two-tone validation. Preserve any improved peak-location estimate while rejecting unsupported separation claims.

Review: Chapter 9 — Energy closure and its limits.

V011-C09-DISCUSSION-002 — Identify their measurands, main-lobe/sidelobe tradeoffs, amplitude and density normalization, and transient weighting. Require exact coefficients and clear claims. Agreement on reproducible inputs and limits matters more than imposing a universal preferred window.

Review: Chapter 9 — Spectral Leakage and Window Selection.

V011-C09-DISCUSSION-003 — Use window-position weighting to explain valid arithmetic with poor event opportunity. Discuss actual capture windows, valid samples, and alternate window placement. Do not use Parseval success to dismiss the missed transient or to certify coverage.

Review: Chapter 9 — Ten worked applications of the normalization model.

V011-C09-DISCUSSION-004 — Explain the change to DC and other processed-record meanings. Require explicit preprocessing and comparison with the intended measurand. A useful detrend may be justified, but it must not be represented as a mere normalization fix.

Review: Chapter 9 — Define the record before interpreting the display.

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V011-C09-DISCUSSION-005 — Recover coefficients or the generation convention if possible, recompute S_1 and S_2, and examine short-record sensitivity. Avoid selecting the convention that happens to match the desired result. Report unresolved normalization limits if the actual vector cannot be established.

Review: Chapter 9 — Ten worked applications of the normalization model.

V011-C09-DISCUSSION-006 — Check units, coefficient vector, side convention, and equivalent noise bandwidth. Use Q = Be D to compare like quantities. Distinguish an algebraically consistent representation from proof of calibration or white input assumptions.

Review: Chapter 9 — Noise density uses a different denominator.

V011-C09-DISCUSSION-007 — Discuss common sources, shared clocks or references, direct cable leakage, and state-conditioned fit. Request paired data, calibration, and controlled path changes with comparable sensitivity. Preserve the relationship evidence while limiting causal attribution.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis.

V011-C09-DISCUSSION-008 — Use shared-source cancellation and state mixing as concrete alternatives. Inspect complex cross-spectra and independent state rules, and propose configuration challenges. Low coherence can describe the pooled fit without proving physical independence.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

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V011-C09-DISCUSSION-009 — Show that a single pair always permits a complex scalar fit. Discuss repeatability, ensemble definition, uncertainty, and competing paths. Require meaningful multiple observations and controls before drawing a physical relationship conclusion.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

V011-C09-DISCUSSION-010 — Demonstrate the phase-cancellation example and distinguish averaging complex products from averaging already normalized magnitudes. Keep the proper estimator and explain it clearly. If another statistic is retained, give it an accurate separate definition and do not inherit the coherence proof.

Review: Chapter 9 — Define the ensemble before normalizing.

V011-C09-DISCUSSION-011 — Discuss the loss of a common paired construction and the counterexample above one. Require a valid estimator definition, domain, and uncertainty assessment. Avoid generalizing the specific failure to every robust method or claiming that clipping an invalid ratio repairs it.

Review: Chapter 9 — Define the ensemble before normalizing.

V011-C09-DISCUSSION-012 — Explain the role of input noise and disturbance allocation. Require calibrated autospectra and justified model assumptions before applying $\frac{C}{(1-C)}$. Equal normalized coherence need not identify equal SNR or noise location.

Review: Chapter 9 — The projection interpretation and its boundary.

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V011-C09-DISCUSSION-013 — Ask whether the state rule was specified independently of the desired result and corresponds to a meaningful operating condition. Preserve pooled and state-resolved estimates and their weights. Reject postselection that merely manufactures proportional vectors.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

V011-C09-DISCUSSION-014 — Separate normalized relationship from absolute amplitude, fitted gain, and phase/delay quantities. Discuss nonzero-gain assumptions and calibration residuals. Coherence invariance does not validate the full multichannel measurement chain.

Review: Chapter 9 — Ten worked applications of Equation 18 and its paired-spectrum realization.

V011-C09-DISCUSSION-015 — Distinguish nonnegative autospectra from complex cross-spectra encoding relative phase. State conjugation and units, inspect the paired construction, and avoid interpreting a negative real cross term as negative physical mean power.

Review: Chapter 9 — Define the ensemble before normalizing.

V011-C09-DISCUSSION-016 — Identify the contaminating mechanism and qualify the inference supported by original high coherence. Preserve evidence, test remaining paths with comparable sensitivity and state, and avoid declaring universal absence of environmental coupling solely because one instrument artifact was found.

Review: Chapter 9 — Hypothetical Case Adjudication: FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

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V011-C09-DISCUSSION-017 — Discuss thresholds, interpolation, color mapping, window lengths, and selection effects. Require raw-record corroboration and intended-use references. The image can motivate a hypothesis, but detection claims need an explicit tested rule.

Review: Chapter 9 — Time-Frequency and Nonstationary Methods.

V011-C09-DISCUSSION-018 — Explain each statistic and preserve event-resolved frequency and duration information. Use multiple declared summaries for power and occurrence, without treating max hold as mean power or simultaneous coexistence. Report the behavior that actually answers the survey question.

Review: Chapter 9 — Averaging and Statistical Stability.

V011-C09-DISCUSSION-019 — Discuss drift, nonstationarity, changing states, and transient dilution. Balance resolution against the time interval over which the signal is comparable. Validate chosen lengths against intended references rather than maximizing N automatically.

Review: Chapter 9 — Quantitative Model for FFT Analyzers, Windowing, Averaging, and Spectral Estimation.

V011-C09-DISCUSSION-020 — Explain the algebraic bound separately from sampling variation, overlap, independence, and record selection. A bounded estimator is not automatically an exact probability or confidence statement. Identify evidence needed for the uncertainty claim.

Review: Chapter 9 — Define the ensemble before normalizing.

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V011-C09-DISCUSSION-021 — Retain original samples, both exact processing paths, settings, and relevant controls. Compare predicted leakage behavior and time structure, then test on independent records. Avoid deleting the less convenient interpretation or claiming processing variation identifies the physical source by itself.

Review: Chapter 9 — Spectral Leakage and Window Selection.

V011-C09-DISCUSSION-022 — Use conjugate-pair counting and energy closure to explain endpoint treatment. Distinguish odd and even N and preserve the actual quantity. Consistent physics requires different endpoint handling rather than visually uniform arithmetic.

Review: Chapter 9 — Noise density uses a different denominator.

V011-C09-DISCUSSION-023 — State the statistic each method retains and examine per-record phase and magnitude. Use controlled receiver/path challenges, since coherent persistence alone does not prove an external source. Retain both methods as declared diagnostics if they answer different questions.

Review: Chapter 9 — Averaging and Statistical Stability.

V011-C09-DISCUSSION-024 — Distinguish visual recreation from data-to-estimate reproducibility. Require samples, preprocessing, coefficients, units, exclusions, and executable analysis. State what the surviving image supports while identifying missing evidence instead of inventing a reconstruction.

Review: Chapter 9 — Estimator Validation and Reporting.

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V011-C09-DISCUSSION-025 — Require correct normalization, paired records, clock/skew calibration, uncertainty limits, representative transient and channel references, held-out tests, and usable sample coverage. Discuss artifact challenges and report scope. No single attractive spectrum, coherence value, or energy check replaces this combined evidence.

Review: Chapter 9 — Estimator Validation and Reporting.

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Chapter Glossary

AUTOSPECTRUM: A spectral estimate formed from weighted squared magnitudes of a channel's Fourier coefficients. Its units follow the measured quantity and density normalization. The chapter's coherence ratio requires both autospectra to be positive and to use the same paired record population and compatible weighting as the cross-spectrum.

CHANNEL SKEW: A relative timing offset between measurement channels caused by acquisition or processing paths. It can introduce a frequency-dependent phase difference into paired analysis. Phase and delay conclusions therefore require alignment and calibration of the relevant channel paths, together with the common-clock and geometry conditions used in the comparison.

COHERENCE: Normalized spectral measure of linear relationship between two signals under stated averaging conditions.

COHERENCE RESIDUAL: The minimum weighted spectral residual $P_{yy}(1-C)$ for a single complex-gain fit, conditional on positive autospectra and the declared estimator.

COHERENT GAIN: Window-dependent amplitude scaling for a sinusoid centered on a transform bin.

COHERENT WEIGHT SUM: The signed sum of the actual window coefficients. For the chapter's coherent complex tone it is the factor multiplying that tone's complex amplitude in the selected transform coefficient. Coherent-amplitude normalization requires this sum to be nonzero; it must not be confused with the sum of squared weights.

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COMPLEX CROSS-PRODUCT AVERAGING: Averaging the complex paired-channel products before taking the magnitude used in a coherence calculation. Opposing phases can cancel in this operation. Averaging the individual normalized magnitude ratios instead loses that information and gives unity for every nonzero single pair, regardless of a repeatable relationship.

CONJUGATE SPECTRAL SYMMETRY: The relationship in which the negative-frequency coefficient of a real windowed record is the complex conjugate of its positive-frequency counterpart. Their squared magnitudes are equal, allowing the stated one-sided folding. A general complex record need not satisfy this relationship, so the same doubling rule cannot be applied automatically.

CROSS-SPECTRAL CONJUGATION CONVENTION: The declared choice of which channel coefficient is complex-conjugated in each cross-product. Reversing that choice conjugates the resulting cross-spectrum, reverses its phase and leaves magnitude-squared coherence unchanged. A delay inference must retain the selected convention and any remaining phase-branch ambiguity.

CROSS-SPECTRUM: A complex spectral estimate formed from products of corresponding Fourier coefficients from two aligned channels, with a stated conjugation direction, common weights and compatible normalization. Its magnitude and phase describe a second-order relationship under that construction. Neither a nonzero value nor its phase alone identifies a unique physical coupling path.

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CROSS-SPECTRUM CANCELLATION: Reduction or disappearance of an averaged complex cross-spectrum because admitted shared components contribute opposing signs or phases. Both channels can still contain substantial shared power. The chapter's two-source and changing-state examples show why low coherence does not by itself establish that the channels have no common contribution.

DC BIN: The zero-frequency transform coefficient. It represents the retained record's weighted constant component under the stated preprocessing. It is not doubled in the one-sided power sum, and subtracting a mean before transformation can remove it by changing the analyzed record rather than merely changing normalization.

DETRENDING: Removal of a specified fitted or fixed trend from the retained samples before spectral estimation. Even constant detrending can eliminate the DC component. The chapter's finite-window model assumes no detrending unless explicitly stated, so a software default that removes a mean changes the model input and must be accounted for.

DFT BIN SPACING: The separation between adjacent frequencies at which a discrete Fourier transform is evaluated. It is the sample rate divided by transform length, with the record length used when no padding is applied. This grid spacing does not by itself establish the ability to resolve nearby components through the actual window response.

EQUIVALENT NOISE BANDWIDTH: Rectangular-filter bandwidth passing the same noise power as a processing window or filter.

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FINITE-RECORD ENERGY CLOSURE: The exact agreement between the correctly normalized discrete spectral integral and the corresponding window-weighted time-domain mean square. It checks transform scaling, side conventions and frequency spacing. It does not establish white noise, adequate sampling, physical calibration, source identity or valid observation of every transient.

NYQUIST BIN: The transform bin at one half of the sample rate when the transform has even length. For a real record it is its own conjugate-frequency partner and is counted once in the chapter's one-sided power sum. An odd-length transform has no bin exactly at that endpoint.

ONE-SIDED SPECTRUM: A frequency representation that combines the conjugate positive- and negative-frequency contributions of a real record under a declared folding rule. Interior positive-frequency powers are doubled, while DC and an even-length Nyquist bin are retained once. Complex records generally lack the symmetry required for this construction.

PAIRED SPECTRAL ESTIMATE: Autospectral and cross-spectral sums formed from the same paired records with compatible weights and normalization.

PERIODIC WINDOW CONVENTION: A coefficient-vector convention intended for periodic DFT use; for Hann it uses N in the cosine denominator, unlike the endpoint-symmetric $N-1$ form.

RECORD LENGTH: The number of acquired samples retained for a stated finite analysis before any zero padding. Together with the sample rate it defines the observation duration. Changing this length can change leakage, nominal bin spacing and the interval over which statistical or signal-state assumptions must hold.

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SCALLOPING LOSS: The reduction in a selected bin's response when a tone lies between the transform's evaluation frequencies instead of at the stated coherent location. Its magnitude depends on the actual window and offset. A coherent-gain correction alone does not remove this error, while denser evaluation can help locate an isolated response peak.

SHORT-TIME FOURIER TRANSFORM: Sequence of transforms applied to overlapping time segments to estimate spectral evolution.

SPECTRAL DENSITY NORMALIZATION: Scaling squared transform magnitude by the sample rate and the actual squared window-weight sum so that the ordinate has input-squared units per hertz. Under the chapter's white-covariance premise its expectation is flat. Integrating this finite-record density gives the stated window-weighted mean square even without that whiteness assumption.

SPECTRAL GRAM MATRIX: The matrix formed from consistently weighted paired spectral vectors, with autospectra on its diagonal and conjugate cross-spectra off the diagonal. Common nonnegative weights give the positivity structure behind the coherence bound. Separately chosen medians need not retain that structure and can produce a substituted ratio above one.

SPECTRAL LEAKAGE: Distribution of energy into neighboring transform bins caused by finite observation and windowing.

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SPECTRAL PREPROCESSING: The declared operations applied to acquired samples before the analyzed transform, such as mean subtraction or other detrending. These operations can change which physical or statistical components remain in the analyzed record. Reproducibility requires their order and parameters alongside the window, sample rate and retained data.

SQUARED WINDOW-WEIGHT SUM: The sum of the squared real window coefficients, which is positive unless every coefficient is zero. It sets the chapter's noise-density normalization and window-weighted energy denominator. Using a coherent weight sum or sums calculated from a different coefficient vector changes the estimated quantity.

STATE-CONDITIONED COHERENCE: A paired spectral result calculated within observations assigned to a defined state instead of pooling different transfer conditions. Opposing within-state gains can produce low pooled coherence even when each state is perfectly related. The state rule must be independently defensible, rather than selected merely to obtain a preferred relationship.

SYMMETRIC WINDOW CONVENTION: A coefficient-vector convention with matching endpoints, distinguished from the periodic form used in many spectral calculations. The chapter's symmetric Hann window uses the record length minus one in its cosine denominator. For short records its weight sums and equivalent noise bandwidth differ materially from the periodic form.

TONE-NORMALIZED SQUARED SPECTRUM: The squared windowed transform divided by the squared coherent weight sum, with side conventions specified. Its units are those of input mean square, but summing its ordinates requires bandwidth correction.

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TRANSFORM LENGTH: The number of values supplied to the discrete transform, including any appended zeros. It determines the displayed frequency grid. When it exceeds the acquired record length, normalization must retain the sums of the original window coefficients; a longer transform does not represent more acquired observation time.

TWO-SIDED SPECTRUM: A spectral representation retaining both positive and negative frequencies in the chosen sampled-frequency interval. The chapter's density model begins with this convention before any justified folding for real data. Its ordinate units and integration spacing must remain explicit, especially when comparing a complex baseband record with a one-sided real-signal display.

VECTOR AVERAGING: Combining complex spectral coefficients while retaining their phase relationships. A phase-aligned component can persist while varying components partly cancel. The resulting quantity differs from an average of nonnegative powers, and its usefulness depends on the stated alignment, stationarity and meaning of the retained records.

WINDOW COEFFICIENT VECTOR: The complete sequence of real, dimensionless weights multiplied into the retained samples before transformation. Its values determine coherent gain, density scaling and the weighting of transient energy. A window name alone is insufficient when endpoint conventions, normalization or coefficient generation can differ.

WINDOW MAIN LOBE: The central region of a window's frequency response around a tone's shifted center. Its width affects separation of neighboring components and differs from the transform-bin spacing. Reducing sidelobes generally changes this central response, so the relevant tradeoff follows the quantity and interference conditions being measured.

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WINDOW SCALING INVARIANCE: The property that multiplying all window coefficients by one nonzero real constant leaves the chapter's normalized squared spectrum, density and equivalent noise bandwidth unchanged when all associated sums are changed consistently. It does not permit mixing a transform from one vector with normalization sums from another.

WINDOW SIDELOBE: A secondary region of a finite window's frequency response away from its main lobe. A strong component can therefore contribute an indication at other frequencies even without another physical tone. Window choice and controlled reprocessing help test this leakage explanation, with amplitude and noise normalizations kept consistent.

WINDOW-WEIGHTED MEAN SQUARE: The ratio $\frac{\sum_{n=0}^{N-1} w_n^{\ 2} \left| x_n \right|^2}{\sum_{n=0}^{N-1} w_n^{\ 2}}$. It is the integrated density of the stated finite-record normalization and can depend strongly on transient position.

ZERO PADDING: Appending zeros to an acquired, windowed record before calculating its transform. It evaluates the same finite-record transform on a denser frequency grid. It does not narrow the underlying window response, create independent observations or replace the original window sums in amplitude and density normalization.

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References and Works Cited

Harris, Fredric J. “On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform.” Proceedings of the IEEE 66, no. 1 (1978): 51–83. Printed pages 51, 54 and 56, sections III.A–B and equations 8–14. https://amst.ece.iastate.edu/paper/comparative_study/window_1.pdf

Annotation. Supports the historical finite-observation framing and distinction between coherent and squared weight sums. The stated pages were read in the inherited source evidence; window-table coefficients are not adopted. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Heinzel, Gerhard, Albrecht Rüdiger, and Roland Schilling. Spectrum and Spectral Density Estimation by the Discrete Fourier Transform (DFT), Including a Comprehensive List of Window Functions and Some New Flat-Top Windows. 15 February 2002. Sections 8–9, printed pages 12–16, equations 17–24. https://holometer.fnal.gov/GH_FFT.pdf

Annotation. Supports the different window-sum normalizations and spectrum-to-density conversion. The source sets aside DC and Nyquist endpoint corrections; the chapter derives its explicit endpoint rules to retain exact finite-record energy closure. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

SciPy. “scipy.signal.periodogram.” Official documentation, parameters and Notes. Accessed 30 October 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.periodogram.html

Annotation. An implementation-convention check for density/spectrum scaling, one-sided folding and default detrending. No installed software

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version or equivalence with receiver firmware is asserted; reproducing the no-detrending model requires the appropriate setting. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

SciPy. "scipy.signal.windows.hann." Official documentation, sym parameter and Notes. Accessed 30 October 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.windows.hann.html

Cross-volume technical interface. S001-V007(Electronics Foundations for TSCM Practitioners) treats clock, converter and analogue-front-end device foundations;S001-V019(Computer Network and Digital Forensic Interfaces with TSCM) addresses the digital-evidence environment after samples enter software and storage. Here, distinguish analogue instantaneous bandwidth, sample rate, usable alias-free bandwidth, converter effective number of bits, reference-clock uncertainty, host transport loss, and retained sample provenance. Aggregating converters or changing decimation does not,

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without a substantiated coherent measurement model, add nominal ADC bit depths or create information above the analogue and quantisation limits.

Annotation. Distinguishes periodic spectral-analysis and endpoint-symmetric coefficient conventions. Finite sums and worked numerical values are independently calculated in the chapter. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

Rust, Bert, and Denis Donnelly. “The Fast Fourier Transform for Experimentalists Part III: Classical Spectral Analysis.” Computing in Science & Engineering 7, no. 5 (September/October 2005): 74–78. Especially pages 74–75. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=150010

Annotation. Supports the finite-record and zero-padding discussion. The original paper’s title and author order are used; the hosting landing page differs in those metadata. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and

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described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

SciPy. “scipy.signal.coherence” and “scipy.signal.csd.” Reference documentation, version 1.18.0; coherence definition and csd Notes and average parameter. Accessed 31 October 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.coherence.html and https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.csd.html

Annotation. Supports the cited estimator and conjugation conventions. The chapter independently proves the common-weight finite construction and distinguishes it from separately substituted robust summaries. No instrument equivalence is inferred. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions.

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The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

Nelson, Craig W., Archita Hati, and David A. Howe. “Phase Inversion and Collapse of the Cross-Spectral Function.” arXiv:1307.6605v1, 24 July 2013. Pages 1–3, Cases i–iv and equations (1), (9), (10) and (12). https://arxiv.org/pdf/1307.6605v1

Annotation. Identifies the extended manuscript actually read and supports the cancellation mechanism. No figure or experimental value is adopted, and the extracted equation (11) is not relied upon. The chapter’s numerical examples are independently constructed. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Supplementary research bibliography and source concordance

These entries identify publications used to frame the newly expanded spectral-analysis sections. Citation identifiers [C9-01] through [C9-30] appear within the added prose. Titles listed from catalogues or abstracts must be verified against the underlying edition before any comprehensive source-to-claim certification is issued.

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Chapter 10. Software-Defined Radios, Sampling, Quantization, DDC, and Channelization

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10.1 SDR Boundary and Partitioning

A software-defined radio moves functions traditionally performed by analog hardware into configurable digital processing. The boundary can occur at audio, baseband, IF, or direct RF sampling. Analog protection, filtering, gain, clocking, and converter performance remain essential even when tuning, filtering, detection, and demodulation are implemented in software. The practitioner documents where the analog chain ends, where samples are formed, and which functions are performed by firmware, programmable logic, driver, host software, and analysis script.[1]

An SDR configuration is executable measurement logic. Center frequency, sample rate, analog bandwidth, gain distribution, decimation, digital oscillator, filter coefficients, data type, scaling, and packet format determine the samples. Configuration files, device serial number, gateware, driver, software build, and calibration data should accompany a significant capture. A generic label such as 20 MS/s I/Q is insufficient when hidden decimation or analog filtering changes the actual bandwidth.

1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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10.2 Sampling, Aliasing, and Band Selection

Sampling maps input spectrum into periodic replicas around multiples of sample rate. A band-limited real signal requires adequate anti-alias filtering, while complex sampling can represent a selected band with different symmetry. Undersampling may intentionally translate a higher-frequency band into a lower Nyquist zone, but noise, harmonics, converter bandwidth, and filter response also fold. An aliased component can look stable and repeatable while being assigned to the wrong external frequency.

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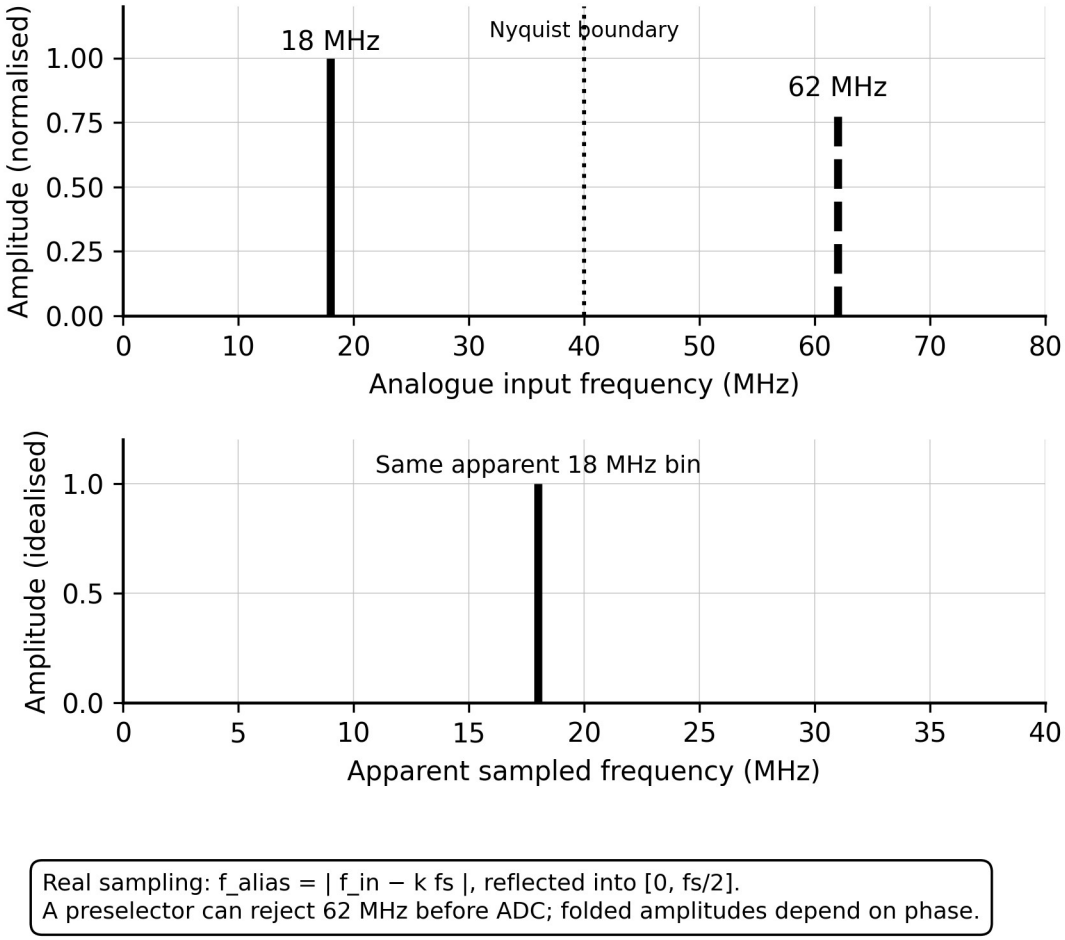

Figure 55. ADC aliasing and preselection.

Aliasing challenges include changing sample rate, analog center frequency, front-end filter, and tuner plan. A genuine RF component maps predictably through those changes. A component fixed in digital frequency may be generated after sampling, while one moving according to a different Nyquist

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relationship may be an alias. These tests are recorded before a software display is treated as a physical spectrum.

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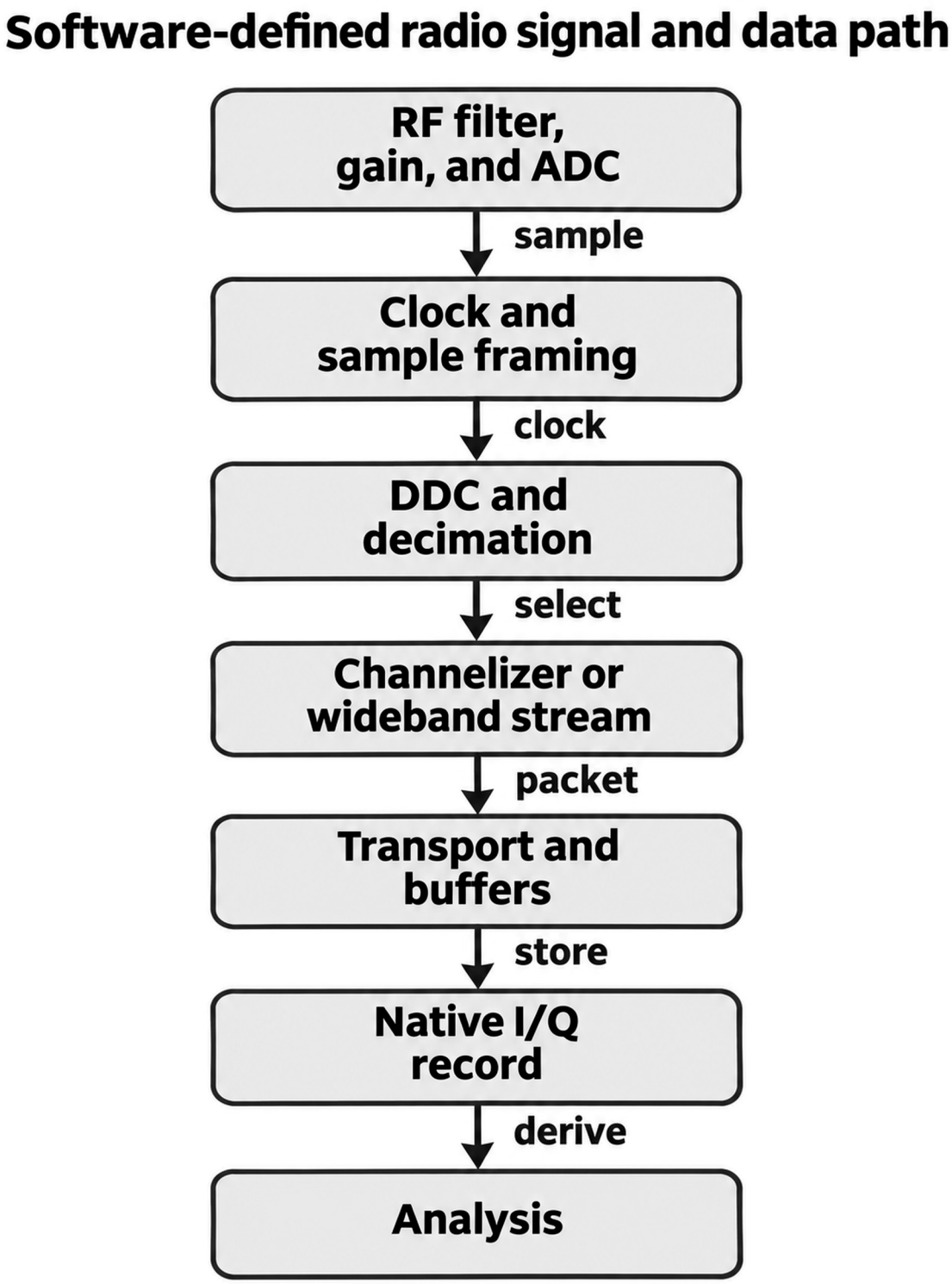

Figure 56. Software-defined radio signal path.

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10.3 Quantization, Clipping, and Converter Performance

An analog-to-digital converter represents amplitude with finite codes. Quantization noise is one contributor among thermal noise, clock jitter, aperture error, differential and integral nonlinearity, reference noise, distortion, and digital truncation. The ideal relationship between bit depth and signal-to-quantization-noise ratio is a planning limit for a full-scale sinusoid, not a guarantee of effective performance.

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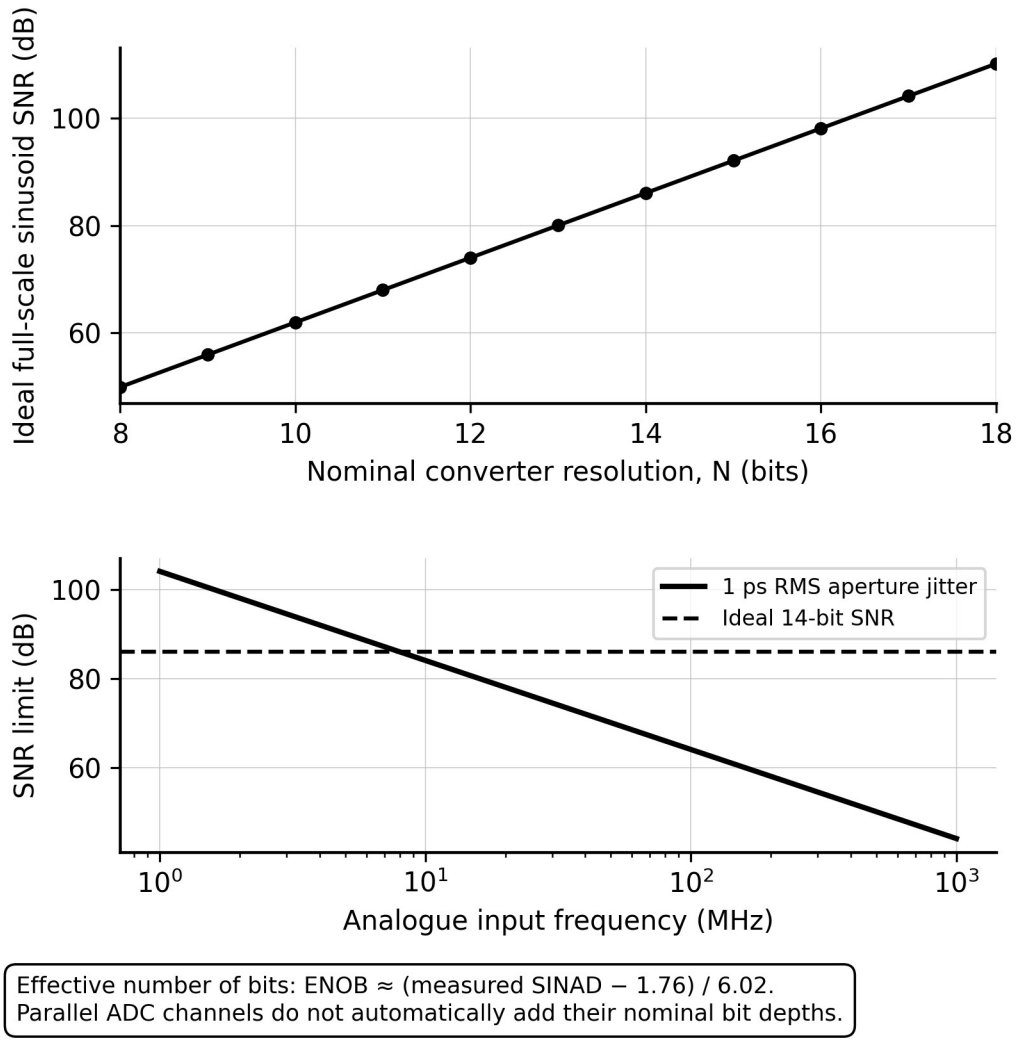

Figure 57. ADC effective bits, clipping and jitter.

Clipping is especially damaging because it generates broad harmonics and intermodulation. A trace can appear normal after digital scaling even when the ADC has clipped. Overflow flags, sample histograms, peak-to-full-scale ratio, and repeated captures with changed analog attenuation are needed.

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Effective number of bits varies with input frequency and sample rate. The converter's analog input bandwidth can pass out-of-band energy that aliases even when the selected digital span is narrow.

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10.4 Digital Downconversion and Channelization

A digital downconverter multiplies samples by a numerically controlled oscillator, filters the translated band, and decimates to a lower sample rate. Numerically controlled oscillator phase and tuning word, filter response, decimation ratio, arithmetic precision, and scaling determine the result. Half-band, polyphase, finite impulse response, cascaded-integrator-comb, and multistage filters have different passband, alias rejection, group delay, and transient behavior.

Channelizers divide a wideband stream into many subchannels using filter banks or FFT structures. They are efficient for monitoring, but channel boundaries, oversampling, scalloping, leakage, and per-channel gain must be understood. A narrow signal near a boundary can split between outputs or appear at different levels as the channel grid changes. Verification uses known tones across channel centers and edges.

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10.5 Model 10B for digital mixing filtering and decimation

A recorded channel is defined by its transformation from the original samples. A center-frequency label and an output rate leave amplitude, phase, rejected-band contamination, and time origin unspecified. The useful starting point is an explicit mixer, finite impulse response filter, and retained-sample rule. The three-stage architecture is established in the original manufacturer explanation cited here. The derivation and numerical applications below use stipulated signals and filters; they are not measurements of a named receiver.[2]

Let $F_s > 0$ be the input sampling frequency in hertz, n the integer input index, and $x[n]$ a real or complex sample expressed in calibrated volts. Let f_n be the NCO frequency in hertz and φ_0 its initial phase in radians. Use the negative complex exponential convention, with $j^2 = -1$. The mixed sequence $v[n]$, also in volts, is

$$v[n] = x[n] \exp\{-j[\frac{2\pi f_n n}{F_s} + \varphi_0]\}$$

For a causal FIR filter, $h[k]$ is the dimensionless coefficient at integer lag k, and $L \geq 1$ is its integer length. Coefficients outside $0 \leq k < L$ are zero. The filtered sequence $w[n]$ and retained output $y[m]$ are

$$w[n] = \sum_{k=0}^{L-1} h[k] v[n-k]$$

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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$$y[m]=w[mM+p], F_o=\frac{F_s}{M}$$

Here m is the integer output index, $M \geq 1$ is the integer decimation factor, p is the retained input phase with $0 \leq p < M$, and F_o is the output sampling frequency in hertz. The phase p is an index residue, not an angle. Both w and y retain voltage units. These relations assume exact linear arithmetic, fixed coefficients, and a continuous input clock. They exclude saturation, coefficient rounding, gaps, clock error, and undocumented state resets. A finite record also requires an initial filter-state rule; zero padding is one possible rule, not a statement that the physical signal was zero before recording.

For a steady complex tone, define $A \geq 0$ as its voltage amplitude, f as its signed input frequency in hertz, and θ as its phase in radians. Set $\omega=\frac{2\pi \backslash(f-f_n \backslash)}{F_s}$, in radians per input sample. Then

$$x[n]=A\exp\{j[\frac{2\pi f n}{F_s}+\theta]\}$$

$$H(\omega)=\sum_{k=0}^{L-1} h[k]\exp(-j\omega k)$$

$H \backslash(\omega \backslash)$ is the dimensionless complex filter response. Substitution into the convolution factors out the common tone and leaves H as the weighted sum of its delayed phases. Substituting $n=mM+p$ then gives the complete steady-state result

$$y[m]=A\,H(\omega)\exp\{j[\theta-\varphi_0+\omega p+M\omega m]\}$$

The output phase increment is $M\omega$ radians per output sample. Its signed frequency representative f_o is therefore $f-f_n$ modulo F_o, chosen in the half-

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open interval $-\frac{F_o}{2} \leq f_o < \frac{F_o}{2}$. Amplitude is $A \mid H \backslash(\omega \backslash) \mid$. Keeping every Mth value introduces no automatic factor $\frac{1}{M}$ in that tone amplitude. Frequency-domain alias-sum formulas must be interpreted with the corresponding frequency scaling; their prefactor is not a voltage-loss rule for an individual retained sinusoid.[3]

The response H must be evaluated at the translated frequency before sample deletion. Different translated tones separated by an integer multiple of F_o can reach the same output frequency while receiving different gains from this filter. Once those contributions have combined in a retained sequence, a subsequent linear filter cannot separate them solely by their former frequencies. The model also starts after sampling: its frequency translation does not identify which analog member of an existing alias class produced $x[n]$.

3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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10.6 Ten worked applications of Model 10B

Each application states a separate test condition. Frequencies are referenced to the input of the stated stage, and MS/s means one million samples per second. Unity or specified gains below are assumptions used to isolate a mechanism. A physical acceptance result requires the actual coefficients, gain conventions, state handling, and measured errors.

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10.7 Application 10B1 Mixer sign and the output frequency label

Use a complex 9 MHz input tone, $F_s = 48\ \mathrm{MS/s}$, $f_n = 8\ \mathrm{MHz}$, $M = 8$, $p = 0$, and $\varphi_0 = 0$. The translated frequency is 1 MHz and $F_o = 6\ \mathrm{MS/s}$. With H at 1 MHz equal to one, the output retains amplitude A and advances by $\frac{2\pi}{6}$ radians per output sample. The same voltage sequence must be interpreted on the 6 MS/s clock. If the mixer sign is reversed, the intermediate frequency becomes 17 MHz; its representative after unfiltered deletion is \$(17 - 3 \times 6\$) $\mathrm{MHz} = -1\ \mathrm{MHz}$. A low-pass filter can instead reject that misplaced tone. Neither outcome is explained by changing only a display label. Record the complex sign convention before assigning an output offset to RF frequency.

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10.8 Application 10B2 Real input and complex amplitude normalization

Let $x[n]$ be a 2 V peak real cosine at 10 MHz, with $F_s = 48\ \mathrm{MS/s}$ and $f_n = 9\ \mathrm{MHz}$. Euler expansion produces two mixed components: +1 MHz and −19 MHz, each with a 1 V complex coefficient. Assume a filter with unit gain at +1 MHz and zero response at −19 MHz, followed by $M = 8$. The retained complex tone has amplitude 1 V. Its mean square $|y|^2$ is 1 V², whereas the original real cosine has mean square 2 V². This explicitly defined comparison is −3.0103 dB. The coefficient amplitude is half the original real peak, giving $20\log_{10}\backslash(\frac{1}{2}\backslash)\ \mathrm{dB} \approx -6.0206\ \mathrm{dB}$. These are different normalization questions.

Multiplying the complex output by two recovers a 2 V analytic-signal amplitude but gives 4 V² complex mean square. Without image rejection, the −19 MHz component would alias to −1 MHz at the 6 MS/s output. A claimed conversion loss is uninterpretable until peak, branch, complex mean-square, and full-scale references are identified.

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10.9 Application 10B3 An irreversible blocker combination

At the mixer output, stipulate two equal-amplitude complex tones at 1 MHz and 7 MHz with the same initial phase. Take $F_s = 48\ \mathrm{MS/s}$, $M = 8$, and $p = 0$. Bare deletion maps both to +1 MHz at $F_o = 6\ \mathrm{MS/s}$, because their input phase difference at $n = 8m$ is $2\pi m$. Their equal coefficients add to twice one coefficient. Instead place a filter before deletion with real gains of 1 at 1 MHz and 0.001 at 7 MHz in this stipulated example. The desired coefficient is retained and the blocker coefficient is 60 dB lower in amplitude ratio, leaving a combined coefficient 1.001 times the original desired value. A filter applied only after bare deletion sees the single combined tone and cannot reconstruct the two original coefficients. This is an information-loss counterexample, not a proposed realizable two-point filter specification.

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10.10 Application 10B4 Allocate attenuation across actual stage frequencies

Consider two decimation stages: $M_1 = 2$ reduces 48 MS/s to 24 MS/s, then $M_2 = 4$ reduces 24 MS/s to 6 MS/s. Both retain phase zero. A 1 MHz desired tone remains at 1 MHz with unit gain in both stages. A 13 MHz blocker becomes −11 MHz after the first deletion and +1 MHz after the second. Suppose the first filter attenuates its 13 MHz input by 30 dB and the second attenuates its −11 MHz input by 50 dB. Their magnitude ratios multiply, so the total attenuation is 80 dB. A second blocker initially at 7 MHz remains at 7 MHz after the first deletion and also ends at +1 MHz. If the two filters give only 5 dB and 60 dB at this path, its total is 65 dB.

Use a common mean-square reference of 1 V^2 and define a level as $10 \log_{10} \backslash(\frac{P}{1\ \mathrm{V}^2} \backslash)$, where P is the tone mean square. For either blocker initially at −5 dB relative to that reference, an allowed contribution of −85 dB requires 80 dB attenuation. The 13 MHz path reaches that limit; the 7 MHz path leaves −70 dB and misses it by 15 dB. These are individual blocker contributions; a combined limit additionally requires their relative phases or a justified power-combination rule. The calculation concerns digital alias contamination and says nothing about earlier analog or converter overload. Each stage needs a frequency-specific rejection ledger on its own sampling clock.

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10.11 Application 10B5 A moving-average null is not a rejection band

Choose the exact four-tap filter $h[k]=\frac{1}{4}$ for $k=0,1,2,3$ at $F_s=48\ \mathrm{MS/s}$, followed by $M=4$. Summing the finite geometric series gives

$$H(\omega)=\exp\left(\frac{-j3\omega}{2}\right)\frac{\sin(2\omega)}{4\sin\left(\frac{\omega}{2}\right)}$$

The removable singularity at $\omega=0$ has limit one. At a translated 12 MHz, $\omega=\frac{\pi}{2}$ and the response is exactly zero. At 6 MHz, however, $|H|\approx 0.653281$, or −3.69799 dB. At 15 MHz, $|H|\approx 0.212608$, or −13.4484 dB; that component maps to +3 MHz on the 12 MS/s output clock. Thus a successful rejection test at the exact null does not establish rejection of a neighboring alias band. The 6 MHz value lies at the output half-rate boundary and is used here only as a filter-response diagnostic, not as an admissible general passband endpoint. Acceptance must cover the intended band and the frequencies capable of entering it.

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10.12 Application 10B6 Group delay and first complete filter history

A real symmetric FIR of length $L=33$ has coefficients symmetric about input lag 16. Away from response zeros its linear-phase group delay is 16 input samples, or $\frac{16}{48\times10^6\ \mathrm{s}^{-1}}\approx333.333\ \mathrm{ns}$ at $F_s=48\ \mathrm{MS/s}$. For $M=8$ this is two output sample intervals. With retained phase $p=3$, an output at index m corresponds to the filter center time

$$t_{center}[m]=\frac{mM+p-16}{F_s}$$

The result is in seconds relative to input sample zero. For $m=2$ the retained input index is 19, while the filter center is index 3, giving 62.5 ns. Labeling this value only with the retained-index time would omit the 333.333 ns filter delay. If acquisition begins at $n=0$ and both end coefficients are nonzero, a complete 33-sample history first exists at $n\geq32$. The first retained index meeting that condition is 35, at $m=4$, whose center is $\frac{19}{48\times10^6\ \mathrm{s}^{-1}}\approx395.833\ \mathrm{ns}$. Group delay and startup support answer different questions. Symmetry alone supplies neither flat amplitude nor a passband error tolerance.[4]

4 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers” (June 14, 2013), “Baseline Case: Cascade of Linear Circuit Blocks” and “Noise Temperature,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and synthetic cases are stated in Model 2B.

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10.13 Application 10B7 Retained phase creates a coherent offset

Compare two otherwise identical settled channels for a translated 1 MHz tone at $F_s = 48\ \mathrm{MS/s}$ and $M = 8$. Let one retain $p = 0$ and the other $p = 3$, with the same NCO phase and filter. At a common output index, their phase difference is $\omega \times 3 = \frac{2\pi \times 3}{48}\ \mathrm{rad} = \frac{\pi}{8}\ \mathrm{rad}$, or 22.5°. Their physical retained-time origins differ by $\frac{3}{48 \times 10^6\ \mathrm{s}^{-1}} = 62.5\ \mathrm{ns}$. Both report a 6 MS/s rate and a 1 MHz tone, yet direct sample-by-sample phase comparison includes that offset. It is not evidence of a different propagation path. The tone-specific correction follows from the known frequency; a broadband alignment needs the actual timing and filtering relationship, not one constant phase correction for every frequency.

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10.14 Application 10B8 Tuning resolution and accumulated phase error

For an ideal b-bit phase accumulator clocked at F_s, let K be the integer phase-increment word, f_t the requested frequency, and f_n the generated frequency, both in hertz. Nearest-word tuning uses

$$K = round\left[\frac{2^b f_t}{F_s}\right], f_n = \frac{K F_s}{2^b}$$

The frequency grid is $\frac{F_s}{2^b}$ and the nearest-word error is at most half a grid interval. With $b = 32$, $F_s = 48\ \mathrm{MS/s}$, and $f_t = 9.1\ \mathrm{MHz}$, $K = 814254217$. The generated frequency is 9,100,000.005215406 Hz, an error of +0.005215406 Hz; the grid is 0.011175871 Hz. Over 10 s the NCO phase leads the requested oscillator by $\backslash(360 \times 0.005215406 \times 10\backslash)^\circ \approx 18.7755^\circ$. The negative-exponential mixer consequently adds a −18.7755° baseband phase drift relative to an ideal requested-frequency mixer. Fine frequency resolution can therefore matter in a long coherent comparison. This calculation assumes an exact clock and evaluates only accumulator quantization. Truncated phase addresses, waveform-table amplitudes, arithmetic, and clock instability need separate error models; bit width alone does not establish spur performance.[5]

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5 H. T. Friis, “Noise Figures of Radio Receivers,” Proceedings of the IRE 32, no. 7 (July 1944): 419–22, https://doi.org/10.1109/JRPROC.1944.232049. The publisher’s abstract was read for the historical network, component, mismatch, and measurement framing. The full paper was not accessed; Model 2B supplies its own stated derivation and working conventions.

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10.15 Application 10B9 Polyphase computation preserves the specified filter

Partition the convolution lag as $k = sM + r$, with branch index $r = 0, \ldots, M-1$ and nonnegative integer s. Continue h by zeros outside its finite support. Regrouping, without approximating, gives

$$y[m] = \sum_{r=0}^{M-1} \sum_{s \geq 0} h[sM + r] v[M(m-s) + p - r]$$

For $M = 3$, $p = 0$, $L = 6$, choose $h = \frac{[1,2,3,4,5,6]}{21}$. Use the local input sequence $v[n] = n \ \mathrm{V}$ for $n = 1$ through 6 and evaluate $m = 2$. Direct filtering at retained index 6 gives $\frac{6+10+12+12+10+6}{21} \ \mathrm{V} = \frac{56}{21} \ \mathrm{V} = \frac{8}{3} \ \mathrm{V}$. The three branch contributions are $\frac{6+12}{21}$, $\frac{10+10}{21}$, and $\frac{12+6}{21} \ \mathrm{V}$, respectively, and sum to the same $\frac{8}{3}$ V. The ramp is a finite arithmetic test, not a bounded steady-state tone. Polyphase organization can avoid computing filtered samples that would be discarded. It does not improve the rejection of unchanged coefficients. If a deployed implementation rounds branch products or sums differently, equality must be checked under that specified arithmetic, including state and commutator order.

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10.16 Application 10B10 A block reset can imitate a phase event

Use $F_s = 48\ \mathrm{MS/s}$, $f_n = 9\ \mathrm{MHz}$, $M = 8$, and $p = 0$. Process consecutive blocks of $B = 1000$ input samples. A continuous NCO advances $\frac{9 \times 1000}{48} = 187.5$ cycles per block, leaving a half-cycle phase change modulo one cycle. If software instead restarts its NCO at zero at every block, its mixed samples differ from the continuous-NCO result by $\exp\backslash(\frac{j2\pi f_n c B}{F_s}\backslash) = \backslash(-1\backslash)^c$ in block c, where c is a nonnegative block index. Thus alternate blocks acquire an artificial 180° sign reversal even though the input samples are continuous.

Each block contains 125 retained samples and lasts 20.8333 μs. The corresponding sign is exact before filtering and after the filter history lies wholly within a block. Near boundaries, a preserved FIR state also contains samples mixed under the preceding phase, so its transient must be evaluated from the full convolution. Resetting that state adds a separate startup artifact. A correct streaming reproduction carries both NCO phase and FIR history, along with the retained-phase schedule. A file with uninterrupted sample counters can still contain a processing-induced phase discontinuity.

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10.17 Interpretation of the DDC evidence

A reproducible channel record links original sample indices to output indices, identifies the signed mixer convention and NCO state, supplies coefficients and scaling for every rate-changing stage, and records any discarded startup interval. These facts permit a second analyst to predict the channel response and to distinguish retained environmental content from a transformation artifact. They do not establish analog-source uniqueness or physical calibration by themselves. A channelizer extends this problem to several interacting selected bands; its common prototype, channel grid, overlap, and branch phase relationships require a separate analysis.

The unit-magnitude complex oscillator in Model 10B translates a complex component without an automatic amplitude factor. A real input cosine contributes half its peak amplitude to each complex-frequency component, as Application 10B2 makes explicit. Model 4A and Model 6A use their declared real-mixer and peak-envelope scalings, so an amplitude comparison must carry the selected sideband and any explicit reconstruction factor between conventions. A decimation factor is not that reconstruction factor. When the selected channel is subsequently aligned to symbol references, Model 7A supplies the finite-record fitting and EVM definitions; the DDC output alone does not define them.

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10.18 Model 10C for a polyphase analysis channelizer

A channelizer applies a family of related filters to one sampled input. Separate output labels do not imply separate sources, disjoint information, equal gain, or independent noise. The common prototype and the timing convention determine how those outputs relate. The MIT lecture cited here develops modulated filter banks and their polyphase and Fourier-transform realization. The following derivation fixes a causal lag convention explicitly and extends Model 10B to a complete analysis bank. Its calculations are stipulated digital examples, not measurements of a deployed receiver.[6]

6 International Electrotechnical Commission, CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus, 5th ed. (May 22, 2019), official publication scope, https://webstore.iec.ch/en/publication/60774, checked November 1, 2026. The public scope identifies the 9 kHz–18 GHz apparatus range and EMI receivers and spectrum analyzers. No access to or clause-by-clause compliance review of the complete standard is claimed.

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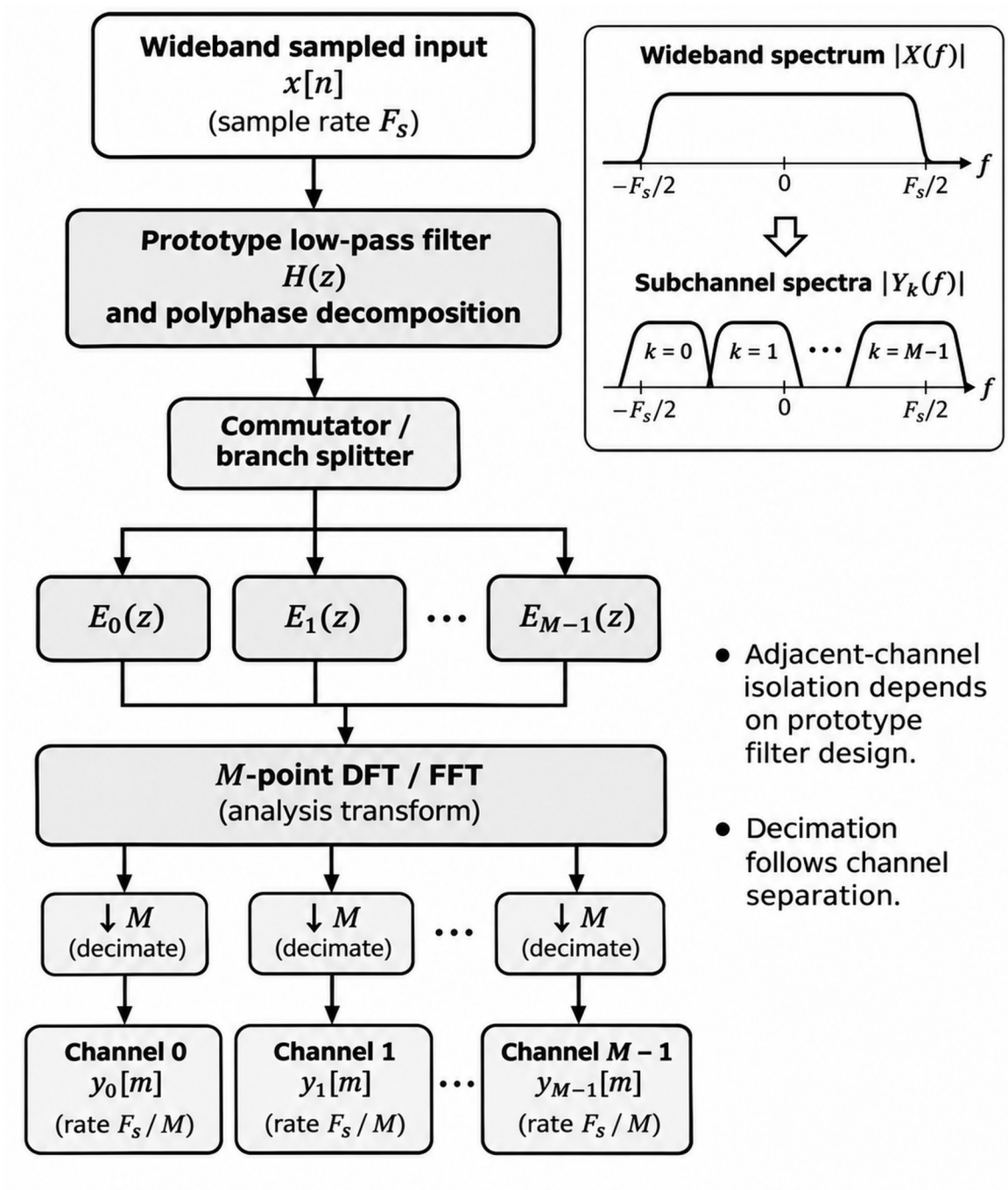

Figure 58. Polyphase filter-bank channelisation.

In this model, $M \geq 1$ is the integer number of channels and D is the integer decimation factor, with $1 \leq D \leq M$. These roles are deliberately separated; M was the decimation factor in Model 10B. Let $F_s > 0$ be the input sampling frequency in hertz, n the integer input index, and $x[n]$ the complex input

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voltage. Let $h[\ell]$ be a dimensionless, possibly complex FIR coefficient at integer lag ℓ, with nominal length $L \geq 1$ and zero coefficients outside $0 \leq \ell < L$. A real input is a special case, but its conjugate-frequency relationships must then be retained. Channel index k runs from zero through $M-1$. Define its angular center ω_k, in radians per input sample, and the output sampling frequency F_o by

$$\omega_k = \frac{2\pi k}{M}, F_o = \frac{F_s}{D}$$

The signed center frequency is the representative of $\frac{k F_s}{M}$ in the half-open interval $[\frac{-F_s}{2}, \frac{F_s}{2}\backslash)$. The grid spacing is $\frac{F_s}{M}$ hertz. Let m be the integer output index and p a fixed retained input-index residue, $0 \leq p < D$, so the absolute retained input index is $n_m = m D + p$. With $j^2 = -1$, each channel first mixes by a negative complex exponential, then applies the same prototype and retains the specified indices:

$$y_k[m] = \sum_{\ell=0}^{L-1} h[\ell] x[n_m - \ell] \exp\{-j \omega_k (n_m - \ell)\}$$

The result $y_k[m]$ remains in volts. The equation assumes a known uninterrupted input clock, exact linear arithmetic, fixed coefficients, and a specified filter history. It excludes clipping, finite-word rounding, dropped samples, and undocumented resets. A finite recording requires an initial-state rule; the settled-tone calculations below use a tone extending through the required history. The formula does not identify the analog source of an already sampled alias.

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Write a complex tone as $x[n]=A\exp[j(\omega n+\theta)]$, where $A\geq 0$ is voltage amplitude, θ is phase in radians, and $\omega=\frac{2\pi f}{F_s}$ is the angular frequency corresponding to signed digital-input frequency f in hertz. Define the channel offset $\delta_k=\omega-\omega_k$. The prototype response and output are

$$H(\delta_k)=\sum_{\ell=0}^{L-1} h[\ell]\exp(-j\delta_k\ell)$$

$$y_k[m]=A\,H(\delta_k)\exp\{j[\theta+\delta_k(mD+p)]\}$$

H is dimensionless and periodic with period 2π. Output amplitude is $A\,|\,H(\delta_k)\,|$, and its phase advances by $D\delta_k$ radians per output sample. Its frequency in hertz is $f-\frac{kF_s}{M}$ modulo F_o, represented in $[\frac{-F_o}{2},\frac{F_o}{2})$. The prototype response must be evaluated before that output-frequency reduction. Two inputs sharing an output-frequency label need not receive the same prototype gain.

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10.19 Causal polyphase grouping and the transform convention

Partition the filter lag as $\ell = qM + r$, where r is an integer branch index from zero through $M-1$ and q is a nonnegative integer. Zero extension of h makes the following sum finite. Define the branch value $s_r[m]$, in volts, by

$$s_r[m] = \sum_{q \geq 0} h[qM + r]\, x[n_m - qM - r]$$

Substitution into the direct sum gives $\exp[j\omega_k \backslash(qM + r\backslash)] = \exp\backslash(\frac{j2\pi kr}{M}\backslash)$, because the factor $\exp\backslash(j2\pi kq\backslash)$ equals one. Hence the exact analysis-bank identity is

$$y_k[m] = \exp(-j\omega_k n_m) \sum_{r=0}^{M-1} s_r[m] \exp(\frac{j2\pi kr}{M})$$

The inner sum uses the positive exponential sign. Define an inverse DFT here with the positive exponential and a normalization of $\frac{1}{M}$. The inner sum is then M times that inverse DFT. A negative-exponential FFT applied to this same ordered branch vector requires the output-bin mapping $k \mapsto \backslash(-k \bmod M\backslash)$; the outer phase still uses the desired channel k. Reversing branch order is a different implementation choice and must be traced explicitly. Neither the word FFT nor the name polyphase fixes sign, order, or amplitude normalization.

When $D = M$ and $p = 0$, $\exp\backslash(-j\omega_k n_m\backslash) = 1$. For $D < M$ that simplification generally fails. In addition, the input residue used by branch r is $\backslash(mD + p - r\backslash)$ modulo M and changes with m. Its schedule repeats after $\frac{M}{\gcd\backslash(M, D\backslash)}$ output steps, where gcd denotes the greatest common divisor.

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This algebraic grouping therefore does not authorize an unchanged critically sampled commutator for an oversampled implementation. The manufacturer algorithm reference separately describes output rates, transform arrangements, and phase correction for an oversampled bank.[7]

Critical sampling means $D = M$, so the sum of the M output sample rates equals F_s. Oversampling means $D < M$, giving an aggregate rate $\frac{M F_s}{D}$ and a ratio $\frac{M}{D}$ relative to the input rate. This rate accounting establishes neither a passband specification nor invertibility. The analysis bank may retain redundant information, suppress information, or admit a synthesis inverse, depending on its actual coefficients and timing. A receiver implementation also needs its own state, scaling, and phase comparison. The current manufacturer HDL documentation explicitly describes a phase difference from its other channelizer implementation and a configuration-dependent correction; that example supports checking conventions, not a universal phase value for other equipment.[8]

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7 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers,” June 14, 2013, “Baseline Case: Cascade of Linear Circuit Blocks,” “A Heterodyne Receiver,” “Noise Temperature,” and “Y-Factor,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html. The scalar derivation and numerical cases here are original and explicitly exclude unmodeled image contributions.

8 Keysight Technologies, Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide, part N9069-90001, edition 1 (March 2016), 10–11, 73–81, especially “Using Loss Compensation” and “Setting Temperature of Loss,” https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf. This identified edition supports the stated measurement controls, not a claim about every

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10.20 Ten worked applications of Model 10C

These ten applications examine distinct consequences of the defined analysis bank. All rates and frequencies refer to its digital input. Rectangular prototypes are intentionally simple arithmetic examples; their leakage is not a recommended receiver specification. Unless stated otherwise, $p=0$, the arithmetic is exact, and the input history needed by each calculation is available.

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current analyzer.

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10.21 Application 10C1 Signed channel centers and residual frequency

Take $F_s = 64\ \mathrm{MS/s}$ and $M = D = 8$. The signed center list for $k = 0, \ldots, 7$ is $[0, 8, 16, 24, -32, -24, -16, -8]\ \mathrm{MHz}$. A complex input at −13 MHz lies 3 MHz above channel 6, whose positive-grid center 48 MHz represents −16 MHz on the input clock. Its unreduced difference from 48 MHz is −61 MHz; reducing modulo F_s gives +3 MHz. For $h[\ell] = \frac{1}{8}$ at $\ell = 0, \ldots, 7$, the channel response is therefore H\($\frac{2\pi \cdot 3}{64}$\). The output rate is 8 MS/s, and the retained tone is at +3 MHz, with phase increment $\frac{3\pi}{4}\ \mathrm{rad}$ per output sample. Channel 7 instead has residual −5 MHz before output reduction, which also becomes +3 MHz at 8 MS/s. Their matching displayed output frequencies do not make the channel centers identical: their amplitudes and phases are evaluated at different prototype offsets. Record both the channel index and the residual frequency when reconstructing a frequency label.

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10.22 Application 10C2 Transform sign and amplitude normalization

Use $M=D=L=4$ and $h=\frac{[1,1,1,1]}{4}$. At retained index $n_m=4$, stipulate the newest-to-oldest input vector $[x[4],x[3],x[2],x[1]]=[1,2,3,4]\ \mathrm{V}$. The branch vector is $s=\frac{[1,2,3,4]}{4}\ \mathrm{V}$ and the outer phase is one. The required channel vector, ordered by increasing k, is

$$y=[2.5,-0.5-j0.5,-0.5,-0.5+j0.5]\ \mathrm{V}$$

A normalized inverse DFT applied directly to s produces $[0.625,-0.125-j0.125,-0.125,-0.125+j0.125]\ \mathrm{V}$, one quarter of the required voltage. Multiplication by $M=4$ restores the defined gain. A negative-exponential FFT of s instead interchanges channels 1 and 3. These are observable errors even when magnitude-only plots hide the interchange. The sum of squared output magnitudes is 7.5 V^2, equal to $\frac{1^2+2^2+3^2+4^2}{4}\ \mathrm{V}^2$. This is a block-energy identity under the stated normalization, not an RF power measurement into an unspecified impedance.

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10.23 Application 10C3 One tone at a channel boundary

Return to $F_s = 64\ \mathrm{MS/s}$, $M = D = L = 8$, and $h[\ell] = \frac{1}{8}$. A 1 V complex tone at 4 MHz lies halfway between the centers of channels 0 and 1. Their prototype offsets are $+\frac{\pi}{8}$ and $-\frac{\pi}{8}$ rad per input sample. A finite geometric sum gives $H(\frac{\pi}{8}) \approx 0.125 - j\,0.628417437$ and $H(\frac{-\pi}{8})$ as its conjugate. Both magnitudes are $\frac{1}{8\sin(\frac{\pi}{16})} \approx 0.640728862$, or −3.86651 dB relative to unit voltage gain.

Each output has mean square 0.410533475 V^2. The two contributions total 0.821066949 V^2; the remaining six channels carry the rest of the 1 V^2 sum for this rectangular bank.

On the 8 MS/s output clock, the two offsets lie at opposite half-rate endpoints and both generate an alternating exponential, with different complex coefficients. One input tone thus yields two strong boundary responses. Counting those traces as two emitters is not supported by this transformation. Conversely, adding their powers without the specified gain convention is not automatically a calibrated estimate of input power. The complete response vector and the channel grid explain the duplication.

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10.24 Application 10C4 A single-channel alias and a distinguishable full bank

Keep the same eight-channel rectangular bank. A 1 MHz input and a 9 MHz input both appear at +1 MHz in channel 0 after decimation. Their channel-0 responses are $H_1 \approx 0.917898901 - j\,0.328429478$ and $H_9 \approx 0.111746556 + j\,0.005489756$, where the subscripts denote the input frequency in megahertz for this application. Their magnitudes are 0.974886821 and 0.111881322. The ratio $\left|\frac{H_9}{H_1}\right|$ is 0.114763396, or −18.80393 dB. A 9 MHz complex coefficient $C = \frac{H_1}{H_9}$ volts, approximately \(8.050297987 - j\,3.334542607 \) V, produces exactly the same channel-0 sequence as the 1 V, zero-phase 1 MHz tone. Here C includes initial phase as well as amplitude.

The full bank distinguishes these inputs. For their unscaled unit-voltage tones, channel 1 has respective magnitudes 0.141991302 and 0.974886821. More generally define $b_r[m] = x[8m - r]$, in volts, for $r = 0, \ldots, 7$. With this particular length-eight rectangular prototype, the complete output vector is the normalized inverse DFT of b, so the negative-exponential DFT of all eight outputs reconstructs b exactly for each fully observed block. The two tone-response vectors are orthogonal over this block, because their input-frequency difference spans one complete Fourier cycle across eight lags. Saving only channel 0 discards that distinction. This inverse is specific to the stated block prototype and complete set of channels; it is not a perfect-reconstruction claim for every critically sampled filter bank.

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10.25 Application 10C5 Oversampling changes the required channel phase

Choose $M=L=8$, $D=4$, $p=0$, and $h[\ell]=\frac{1}{8}$. Drive the input with $x[n]=\exp\left(\frac{j\pi n}{4}\right)\ \mathrm{V}$, a channel-1 center tone. Its offset δ_1 is zero, so the direct mixer-filter definition gives $y_1[m]=1\ \mathrm{V}$ for all settled outputs. The raw positive-exponential transform of the branch vector instead gives $\exp(j\pi m)\ \mathrm{V}$, or $[1,-1,1,-1,\ldots]\ \mathrm{V}$. The outer phase $\exp(-j\omega_1 4m)=(-1)^m$ restores the constant output. At $F_s=64\ \mathrm{MS/s}$ the output rate is 16 MS/s, so omitting this factor places a channel-center tone at the output half-rate boundary. The branch residue schedule also repeats every $\frac{8}{\gcd(8,4)}=2$ output steps. A code path copied from $D=M$ without those phase and schedule changes does not implement the stated oversampled bank.

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10.26 Application 10C6 Oversampling and the complete recording rate

For $F_s = 64\ \mathrm{MS/s}$, $M = 8$, and $D = 4$, each channel emits 16 million complex samples per second and the bank emits 128 million. Suppose a stored complex sample contains one signed 16-bit I value and one signed 16-bit Q value, totaling four bytes. The sample payload is 512 million bytes per second, or 512 MB/s in decimal units. Sixty seconds requires 30.72 GB before headers, alignment, timestamps, and continuity records. With $D = 8$, the corresponding payload is 256 MB/s and 15.36 GB per minute. The factor of two follows from $\frac{M}{D}$; it does not establish twice as much independent environmental information. Selecting fewer stored channels reduces the payload but can remove distinctions such as those in Application 10C4. A recording claim must therefore identify which channels and samples were actually retained.

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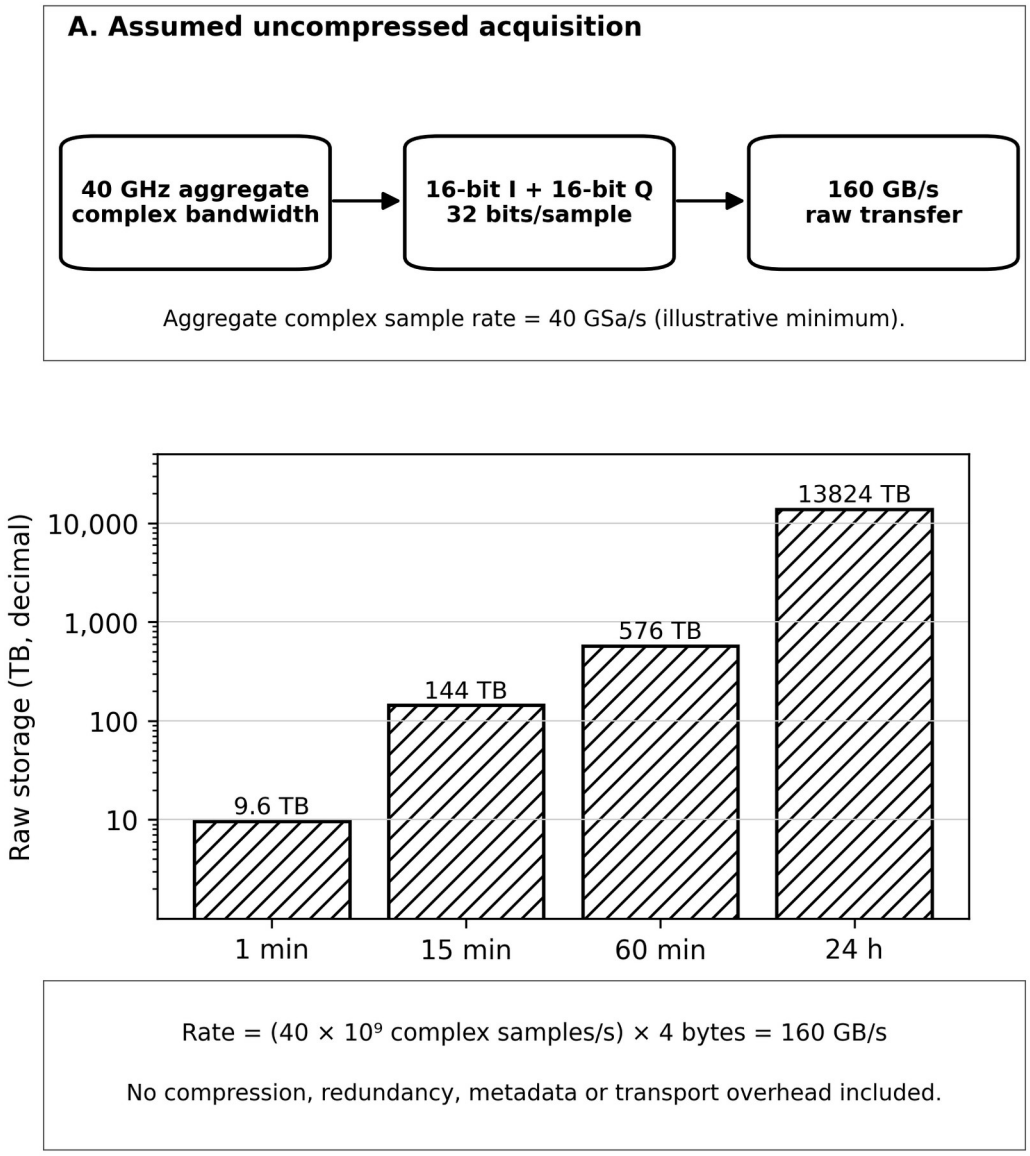

Illustrative aggregate 40-GHz complex coverage with 16-bit I and Q. Actual sampling, guard bands and clocking may increase rates.

Figure 59. Wideband I/Q recording capacity.

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10.27 Application 10C7 White input can give correlated simultaneous channels

Stipulate zero-mean complex input with $\mathrm{E}[x[t]x^*[u]]=\sigma^2$ when $t=u$ and zero otherwise, where t and u are integer sample indices, the star means complex conjugation, E denotes expectation, and σ^2 is input mean-square voltage in V². This is a second-order white-input assumption; it does not assert independent samples. For two channel indices a and b observed at the same retained input index n, define $C_{ab}\backslash(n\backslash)=\mathrm{E}[y_a y_b^*]$ in V² and $\Delta\omega_{ab}=\omega_a-\omega_b$ in radians per input sample. Expanding the two finite sums leaves only terms sharing the same input sample:

$$C_{ab}(n)=\sigma^2\exp(-j\Delta\omega_{ab}n)\sum_{\ell=0}^{L-1}|h[\ell]|^2\exp(j\Delta\omega_{ab}\ell)$$

Choose $M=D=4$, $p=0$, $h=\frac{[1,2,2,1]}{6}$, and $\sigma^2=1\ \mathrm{V}^2$. Each channel variance is $\frac{1+4+4+1}{36}\ \mathrm{V}^2=\frac{5}{18}\ \mathrm{V}^2$. At $n=4m$, $C_{01}=\frac{1-4j-4+j}{36}\ \mathrm{V}^2=\frac{-1-j}{12}\ \mathrm{V}^2$. Its normalized complex correlation is $\frac{C_{01}}{\backslash(\frac{5}{18}\backslash)\ \mathrm{V}^2}=-0.3-j0.3$, with magnitude 0.424264069.

The opposite-channel covariance C_{02} is zero. Distinct center frequencies therefore do not guarantee uncorrelated simultaneous outputs. Equal input variance without the stated white cross-moments would not even justify this calculation. Zero covariance alone would still be insufficient to claim independence without a suitable joint distribution; proper jointly complex Gaussian variables provide one such additional condition.

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10.28 Application 10C8 Same-frame decorrelation does not remove time overlap

Use $M=4$, $D=2$, $p=0$, $h=\frac{[1,1,1,1]}{4}$, and the same zero-mean white-input second moments with $\sigma^2=1\ \mathrm{V}^2$. At each output time the channel covariance matrix is diagonal, with every variance $\frac{1}{4}\ \mathrm{V}^2$, because the four equal tap energies have zero nonzero-bin DFT coefficients. Yet adjacent frames share two input samples. In the same channel, those common samples have the same mixer phases in both frames, so their two contributions give

$$E[y_k[m+1]y_k{}^*[m]]=\frac{2}{16}\sigma^2=\frac{1}{8}V^2$$

The adjacent-frame normalized correlation is $\frac{\frac{1}{8}}{\frac{1}{4}}=\frac{1}{2}$. For an explicit cross-channel, cross-time calculation, $y_0[1]$ and $y_1[0]$ share input indices 0 and -1. Their phase-weighted covariance $\mathrm{E}[y_0[1]y_1^*[0]]$ is $\frac{1-j}{16}\ \mathrm{V}^2$ and normalized magnitude $\frac{\sqrt{2}}{4}\approx 0.353553391$. These results assume available prehistory, not a zero-padded acquisition boundary. Treating each frame and channel as a new independent noise observation would discard this known overlap. The same-frame diagonal covariance describes one slice of the record, not the independence of entire channel streams.

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10.29 Application 10C9 Critical sampling can retain a complete blind residue

Set $M=D=4$, $p=0$, and $h=\frac{[1,1,1,0]}{3}$ with nominal length four. Let $x[1]=A$, with nonzero A in volts, and every other input sample be zero. A contribution at retained index $4m$ requires lag $\ell=4m-1$ within $0,\ldots,3$. The only possibility is $m=1$ and $\ell=3$, whose coefficient is zero. Every channel output is consequently zero at every output time. The same reasoning applies to any input supported on indices congruent to 1 modulo four. Although the prototype has $H\backslash(0\backslash)=1$ and the aggregate output rate equals the input rate, the bank loses that entire sample residue. Unit DC gain and critical rate accounting therefore do not establish injectivity, the property that distinct admissible inputs give distinct complete outputs.

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10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage

Keep $M=4$ and $h=\frac{[1,1,1,0]}{3}$, but change D to two. For the same isolated sample $x[1]=A$, the only nonzero retained frame is $m=1$, with $n_m=2$ and lag $\ell=1$. The complete channel vector is $\frac{[A,-jA,-A,jA]}{3}$, in volts, so the previously invisible sample is observed. Every odd-index input sample now occurs once among the nonzero taps of the retained windows, and every even-index sample occurs twice. For a finite-energy input and complete observation of all affected frames, Fourier orthogonality within each frame yields

$$E_y=\frac{4}{9}(2E_e+E_o)$$

Here E_y is the sum of $|y_k[m]|^2$ over every channel and frame, E_e is the sum of $|x[n]|^2$ over even n, and E_o is the corresponding odd-index sum; all three are discrete sums in V², without a time-interval multiplier. The input sum is $E_x=E_e+E_o$. Thus $\frac{4}{9}E_x\leq E_y\leq\frac{8}{9}E_x$. The positive lower bound excludes a nonzero finite-energy input with all outputs zero for this exact bank, while the unequal bounds show that its energy gain depends on sample placement. They are not a time-integrated electrical-energy calibration. Oversampling repairs the particular blind residue in Application 10C9; it does not prove that every oversampled prototype is invertible or that a truncated recording preserves the complete-frame bound.

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10.31 Interpretation and reproducibility of the channelized record

The strongest comparison starts from the defined direct mixer-filter sum, then checks the implemented polyphase scheduling, transform order, normalization, and output phase against it. A complete record identifies the input clock, signed grid, retained phase, actual coefficients, initial history, selected output channels, and arithmetic scaling. Center and boundary tones, a finite nonsymmetric input vector, and a sparse impulse exercise different failure mechanisms. Their expected responses must be computed from the actual configuration before hardware observations are interpreted.

Model 10C provides a defined exact-arithmetic channelizer reference. Its covariance and energy relations explain the specified configurations; they do not establish general statistical detection performance or complete filter-bank synthesis. Model 10D develops fixed-point arithmetic and saturation with explicit coefficient, product, accumulator, and transform scaling. Comparing that implementation with the exact-arithmetic reference distinguishes numerical processing errors from analog receiver behavior.

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10.32 Model 10D for fixed point channelizer arithmetic

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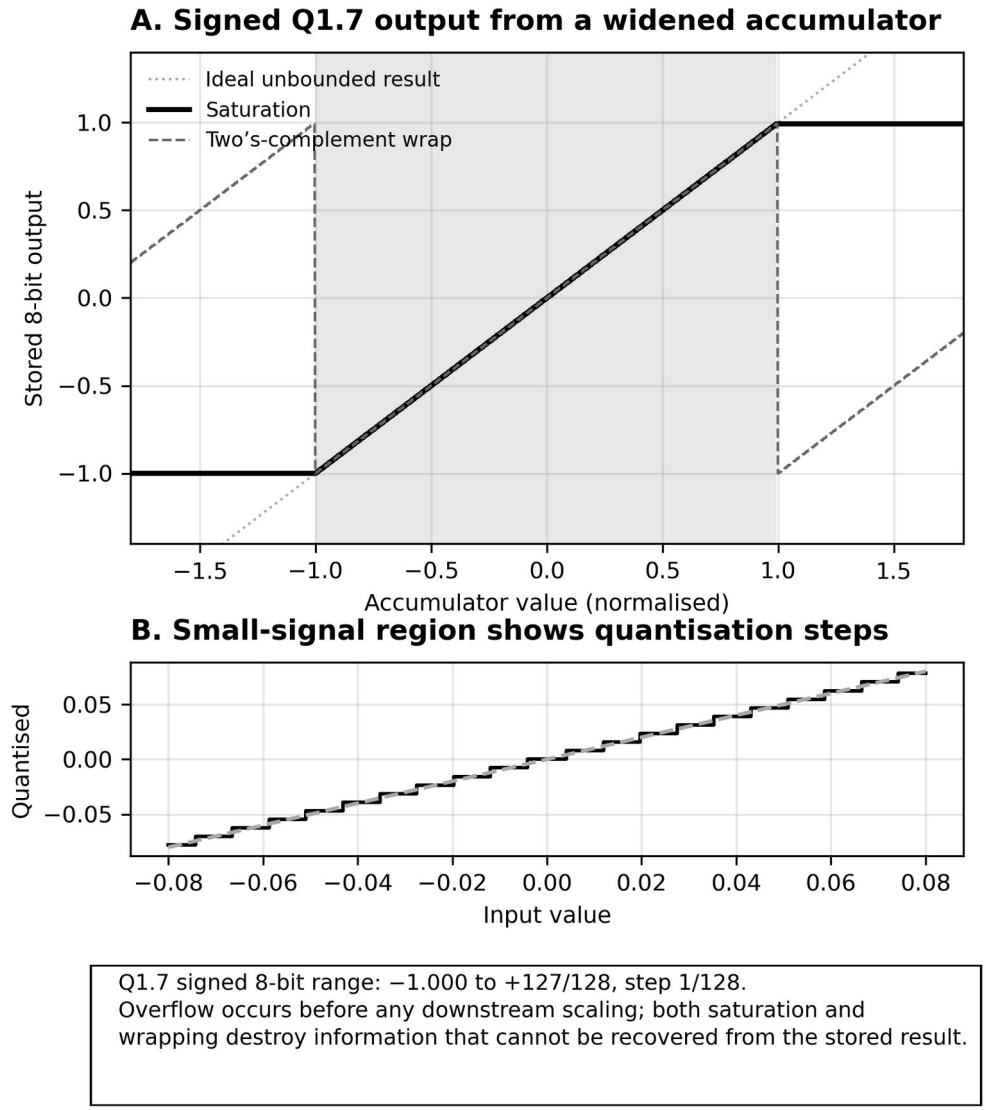

Figure 60. Fixed-point overflow: wrapping versus saturation.

The exact bank in Model 10C supplies a comparison standard, but a stored channel value also depends on where an implementation changes numerical representation. Rounding coefficients changes the filter. Rounding branch sums changes the arithmetic. Overflow can destroy a result before a later output scale brings its displayed value into range. This

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treatment therefore specifies each conversion and derives a deterministic error bound. Its numerical records are stipulated tests, not observations from a commercial receiver. The numerical-overflow comparison is illustrated in Figure 46.

Use the channel count M, decimation D, lag length L, retained index $n_m = mD + p$, angular center $\omega_k = \frac{2\pi k}{M}$, and imaginary unit j from Model 10C. All counts and indices are integers; angles are radians per input sample. Introduce a positive calibration factor V_* in volts and a dimensionless complex sequence $u[n] = \frac{x[n]}{V_*}$. The present prototype coefficients $h[\ell]$ are real and dimensionless. The input samples are already represented exactly on their stated digital grid; analog conversion error belongs to the preceding acquisition model. Preserve the same absolute sample indices and initial history in the exact and finite-word calculations.

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10.33 Signed formats and explicit conversion points

Write $S\backslash(W,F\backslash)$ for a signed two's-complement format with $W \geq 2$ total bits and $F \geq 0$ fractional bits. W and F are dimensionless integer counts. Its stored integer code c represents $c\,2^{-F}$, giving step $\Delta = 2^{-F}$ and the asymmetric interval below. This notation avoids the differing conventions attached to a bare Q-format label. The same representation applies separately to real and imaginary components.

$$\Delta = 2^{-F}, -2^{W-F-1} \leq c\Delta \leq 2^{W-F-1} - \Delta$$

Let $R\backslash(t\backslash)$ select the nearest integer to the real number t, with exact halfway cases assigned to the even integer. Define $Q_{W,F}\backslash(v\backslash)$ by rounding $2^F v$, clamping that integer to the allowed code interval, and restoring the factor 2^{-F}. Clamping is saturation; write sat_W for this integer-code clamp. When the rounded code lies within range, the real error is at most $\frac{\Delta}{2}$. Once saturation occurs, that bound is unavailable. Wrapping is a different operation, defined below for integer c; it discards multiples of the code range and can reverse the sign of an over-range result.

$$Q_{W,F}(v) = 2^{-F} sat_W[R(2^F v)]$$

$$wrap_W(c) = [(c + 2^{W-1}) mod\, 2^W] - 2^{W-1}$$

For fixed-point multiplication, an exact signed real product can be carried with $W_p = W_x + W_h$ bits and $F_p = F_x + F_h$ fractional bits, where subscripts x, h, and p identify input, coefficient, and product formats. Aligned additions need a range sufficient for every intermediate sum. Assignment to a narrower format is itself an arithmetic operation and must be specified even when no explicit rounding instruction appears in source code. The

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manufacturer reference illustrates these distinctions; the numerical construction here defines its own tie and overflow rules.[9]

Round each coefficient once to $\hat{h}[\ell]$ using format $S\backslash(W_h, F_h\backslash)$. Compute products and the finite branch sum $a_r[m]$ exactly using those quantized coefficients, then round each real and imaginary component once to the branch format $S\backslash(W_b, F_b\backslash)$. The resulting branch value is $b_r[m]$. Coefficients outside the original support remain zero. Let Q_b^{C} denote this componentwise branch conversion and let $\Delta_b = 2^{-F_b}$.

$$a_r[m] = \sum_{q \geq 0} \hat{h}[qM + r]\, u[n_m - qM - r],\; b_r = Q_b^{\,C}(a_r)$$

Next compute the positive-exponent transform and the outer phase exactly, producing dimensionless $w_k[m]$. Apply one recorded nonnegative integer shift s, then convert each component once to output format $S\backslash(W_z, F_z\backslash)$, with step $\Delta_z = 2^{-F_z}$. Subscript z identifies the output format and its componentwise conversion Q_z^{C}. The stored value is $v_k[m]$, while the recovered voltage $\hat{y}_k[m]$ multiplies it by V_* and 2^s. Recovery must use an adequately wide representation.

$$w_k[m] = \exp(-j\omega_k n_m) \sum_{r=0}^{M-1} b_r[m] \exp\left(\frac{j2\pi kr}{M}\right)$$

$$v_k = Q_z^{\,C}(2^{-s} w_k),\; \hat{y}_k = V_* 2^s v_k$$

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9 James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. Its historical radiometer thresholds are not adopted as acceptance limits for the present constructed receiver.

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For $M = 4$, all transform weights and outer phases are among 1, -1, j, and $-j$. Widened addition, subtraction, component exchange, and sign change can therefore realize the stipulated exact transform without irrational twiddle coefficients. Negating the most negative signed code still requires sufficient width. The ten applications below use this four-channel construction. The algebraic error bound also applies to an exact transform of any M, but a larger finite-word FFT usually adds twiddle and intermediate-rounding errors that must be budgeted separately.

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10.34 Range and error are separate obligations

Range proof precedes the rounding bound. For any real branch, suppose every input component lies in $[u_{\min}, u_{\max}]$, with $u_{\min} \le 0 \le u_{\max}$. Let G_r^+ be the sum of its positive quantized coefficients and G_r^- the sum of its negative coefficients. Zero coefficients contribute nothing. Maximizing or minimizing each independent product over the interval gives the following branch limits. The same argument applies separately to I and Q because the prototype is real. A component bound is not a bound on complex magnitude.[10]

$$a_{min} = G_r^{+¿} u_{min} + G_r^{-} u_{max} ¿$$

$$a_{max} = G_r^{+¿} u_{max} + G_r^{-} u_{min} ¿$$

With exact products, an accumulator can retain $F_a = F_x + F_h$ fractional bits. Choose its integer code range to contain both endpoints multiplied by 2^{F_a}. Because the permitted input interval contains zero, each partial coefficient subset has extrema no farther from zero than those of the complete branch. Thus the same interval bound protects a direct accumulation with no other operations. A transformed, scaled, or feedback topology needs its own intermediate analysis. Test the positive endpoint explicitly, since a signed format has one fewer positive code.

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10 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf; MACOM, “Designing with Diodes: Protecting Sensitive Components” (September 2, 2022), receiver-protector operation and recovery discussion, https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting. These are identified examples of preselection, gain placement, and protection, not a universal front-end architecture or an instrument-independent limit.

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To bound error, assume no coefficient, branch, transform, or output overflow, exact products and accumulations, and the two stated rounding locations. Let $B \geq 0$ bound $|u[n]|$ over all required history. Define $\delta h[\ell] = \hat{h}[\ell] - h[\ell]$. The coefficient contribution to any output is bounded by B times the sum of $|\delta h[\ell]|$, since each mixer factor has unit magnitude. Each rounded complex branch contributes at most $\frac{\Delta_b}{\sqrt{2}}$, obtained by combining two component errors bounded by $\frac{\Delta_b}{2}$. The unscaled transform sums M such contributions; the outer phase preserves magnitude. Restoring the output shift magnifies its final rounding error by 2^s. Hence

$$|\hat{y}_k - y_k| \leq E = V_* \left[B \sum_{\ell=0}^{L-1} |\delta h[\ell]| + \frac{M \Delta_b}{\sqrt{2}} + \frac{2^s \Delta_z}{\sqrt{2}}\right]$$

Here E is a nonnegative voltage bound and $|\hat{y}_k - y_k|$ is complex error magnitude in volts at the same channel and retained index. The bound is conservative and deterministic. It assumes neither a white spectrum nor independent, uniform, or zero-mean errors. If coefficient rounding is also unsaturated, the sum of coefficient errors is at most $\frac{L \Delta_h}{2}$, where $\Delta_h = 2^{-F_h}$. Exact binary coefficients, exact branch sums, or exact output values allow their corresponding actual error terms to vanish. Recorded residuals can tighten the envelope, but cannot validate unobserved operating ranges.

Real implementations need architecture-specific accounting. AMD's July 2026 PG109 distinguishes unscaled, scheduled, and block-floating scaling, and states that its convergent option does not cover every internal reduction. It also describes wrap overflow for the relevant scaled FFT interface. Those details demonstrate why a named rounding setting is

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insufficient to establish this model's two-conversion architecture; they are not asserted as universal behavior of FFT hardware.[11]

11 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf. The manual identifies firmware 3.20 and higher; the cited architecture is a specific instrument example.

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10.35 Ten worked applications of Model 10D

All ten tests set $V_* = 1\ \mathrm{V}$. A numerical value described as dimensionless becomes volts only after the stated calibration and scale restoration. Unless an application deliberately exercises failure, products, sums, phase operations, and output storage have sufficient range and precision. Input vectors are ordered newest to oldest, coefficients are ordered by increasing lag, and the output vector is ordered by increasing channel index k.

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10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection

Take $M=D=L=4$, $h=[0.1,0.2,0.3,0.4]$, and coefficient format $S\backslash(5,4\backslash)$, whose step is $\frac{1}{16}$. Nearest-even rounding gives $\hat{h}=[\frac{1}{8},\frac{3}{16},\frac{5}{16},\frac{3}{8}]$. Both coefficient sums equal one, so their DC gains agree exactly. At angular offset π, however, the ideal response is $0.1-0.2+0.3-0.4=-0.2$, while the quantized response is $\frac{2-3+5-6}{16}=-0.125$. Their difference is +0.075. For a unit-magnitude alternating input and otherwise exact arithmetic, the coefficient error reaches the bound $\sum_{\ell=0}^{L-1}|\delta h[\ell]|=0.075$. Its magnitude response changes from 0.2 to 0.125, a ratio of 0.625 or −4.08240 dB. A successful DC gain test therefore does not test the implemented frequency response at this offset.

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10.37 Application 10D2 Size a branch accumulator from its signed endpoints

Let one branch contain coefficients $[\frac{3}{4},\frac{-1}{2},\frac{1}{4}]$, represented exactly in $S\backslash(3,2\backslash)$, and let each real input component use $S\backslash(4,3\backslash)$, with range $[-1,\frac{7}{8}]$. The positive coefficient sum is one and the negative sum is $-\frac{1}{2}$. Therefore $a_{\min}=-1-\frac{7}{16}=-\frac{23}{16}$ and $a_{\max}=\frac{7}{8}+\frac{1}{2}=\frac{11}{8}$. Full product precision requires $F_a=3+2=5$ fractional bits. The endpoint codes are −46 and 44. Six total bits allow only −32 through 31 and fail; seven allow −64 through 63 and suffice, including every partial direct sum. The minimum is attained by input components $[-1,\frac{7}{8},-1]$ assigned to those three lags. Using the coefficient signs saves width compared with blindly adding guard bits, while retaining an explicit range proof.

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10.38 Application 10D3 The negative rail creates a positive product

Choose input and coefficient values both equal to −1 in $S\backslash(4,3\backslash)$. Their exact product is +1. $S\backslash(8,6\backslash)$, the full product format, stores this as code 64 without overflow. Narrowing to $S\backslash(7,6\backslash)$ permits only codes −64 through 63, so +1 is not representable. Saturation returns $\frac{63}{64}=0.984375$; wrap returns $-\frac{64}{64}=-1$. The respective errors are $\frac{-1}{64}$ and −2. A subsequent gain adjustment cannot determine which value was lost from the stored code alone. This endpoint calculation explains why a product-width rule must include signed asymmetry rather than rely on the informal assertion that two magnitudes no greater than one produce an in-range fraction.

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10.39 Application 10D4 Rounding once and rounding each product differ

Consider two products in the same branch, each formed from coefficient $\frac{5}{16}$ and input $\frac{1}{4}$. Each exact product is $\frac{5}{64}$. Their exact sum is $\frac{5}{32}$. With branch step $\Delta_b = \frac{1}{8}$, rounding once after accumulation produces $\frac{1}{8}$ because $\frac{5}{32}$ is closer to $\frac{1}{8}$ than to $\frac{1}{4}$. Rounding each product first instead gives $\frac{1}{8} + \frac{1}{8} = \frac{1}{4}$. The two implementations differ by $\frac{1}{8}$ even though they use the same coefficients and nominal branch format. For this test their errors relative to the exact sum are $\frac{-1}{32}$ and $+\frac{3}{32}$. Model 10D admits the first placement. The second requires a separate per-product error budget and may not borrow the single-rounding branch term.

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10.40 Application 10D5 Intermediate saturation makes association consequential

Use a fixed accumulator $S\backslash(4,2\backslash)$, whose range is $[-2,\frac{7}{4}]$, and successive exactly represented products $[\frac{3}{2},\frac{3}{2},\frac{-3}{2}]$. The exact total is $\frac{3}{2}$. Adding the first two products and saturating gives $\frac{7}{4}$; adding the last then gives $\frac{1}{4}$. Combining the last two products first gives zero, followed by the correct $\frac{3}{2}$. Thus saturation has made two algebraically equivalent associations disagree by $\frac{5}{4}$. Wrapping this particular sequential sum produces -1 after the first overflow and then $\frac{3}{2}$ after another wrap, accidentally recovering the final modular result. That coincidence does not prove absence of internal overflow. Preserve stage flags and use a sufficient-width accumulator when the exact-linear comparison is required.

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10.41 Application 10D6 Transform normalization is part of voltage gain

At n_m divisible by four, set the rounded branch vector to $b=[\frac{1}{4},\frac{1}{2},\frac{-1}{4},0]$. The outer phase equals one. The required positive-exponent unscaled transform is $w=[\frac{1}{2},\frac{1}{2}+\frac{j}{2},\frac{-1}{2},\frac{1}{2}-\frac{j}{2}]$. A normalized inverse DFT instead returns $\frac{w}{4}$. Without an explicitly recorded restoration by four, each nonzero amplitude is smaller by $20\log_{10}\backslash(4\backslash)\ \mathrm{dB}\approx 12.0412\ \mathrm{dB}$. The sum of squared branch magnitudes is $\frac{3}{8}$, and the unscaled output sum is $\frac{3}{2}$, exactly four times greater. This equality checks the chosen transform convention. It is a discrete voltage-squared identity and does not supply electrical power without a load and calibration model.

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10.42 Application 10D7 Restoring a shift also restores its coarse spacing

Stipulate an exact real transform component $w=\frac{5}{16}$ and output format $S\backslash(4,3\backslash)$, with $\Delta_z=\frac{1}{8}$. Without a shift, nearest-even rounding maps $\frac{5}{16}$, halfway between $\frac{1}{4}$ and $\frac{3}{8}$, to $\frac{1}{4}$; voltage error is $\frac{-1}{16}$ V. With $s=2$, the stored input is $\frac{5}{64}$, which rounds to $\frac{1}{8}$. Restoring the shift gives $4\times\frac{1}{8}\ \mathrm{V}=\frac{1}{2}\ \mathrm{V}$, an error of $\frac{+3}{16}$ V. The restored real-component error limit is $\frac{2^2\Delta_z}{2}\ \mathrm{V}=\frac{1}{4}\ \mathrm{V}$. The shift can provide headroom for other values but increases the restored output step to $\frac{1}{2}$ V. Merely multiplying the stored numbers back to the desired display range does not restore the discarded low bits.

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10.43 Application 10D8 Exact codes still require phase order and history

Take $M=L=4$, $D=2$, $p=0$, $h[\ell]=\frac{1}{4}$, and the exactly represented center tone $u[n]=\frac{j^n}{2}$. The positive transform in channel 1 is $\frac{\backslash(-1\backslash)^m}{2}$. The required outer phase is also $\backslash(-1\backslash)^m$, leaving the correct constant output $\frac{1}{2}$ V. Omitting that phase produces alternating $\frac{+1}{2}$ and $\frac{-1}{2}$ V, with a 1 V discrepancy on odd frames despite exact arithmetic. A negative-exponent transform without the required bin remapping instead places this tone in channel 3. Neither defect is fixed by adding fractional bits.

For a separate history test, use $M=D=4$, $p=0$, eight taps all equal to $\frac{1}{8}$, and constant $u[n]=\frac{1}{2}$. A settled bank gives channel 0 equal to $\frac{1}{2}$ V and other channels zero. Resetting the history immediately before input sample zero makes the first output at $n=0$ equal to $\frac{1}{16}$ V in every channel. At $n=4$, channel 0 is $\frac{5}{16}$ V and each other channel is $\frac{1}{16}$ V; by $n=8$ the full history has restored the settled result. These values follow directly from one, five, and then eight available taps. The hardware channelizer documentation separately identifies valid-input handling, resets, and phase options, so such control settings belong in a reproducible numerical comparison.[12]

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12 MACOM, “Designing with Diodes: Protecting Sensitive Components,” September 2, 2022, receiver-protector limiter operation and recovery paragraphs, https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting. The discussion is used for the stated PIN-limiter mechanism, not as a universal quantitative

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10.44 Application 10D9 A constant error does not become white noise

Use $M=D=L=4$, $h[\ell]=\frac{1}{4}$, and constant input $u[n]=\frac{5}{8}$ with complete history. Every exact branch value is $\frac{5}{32}$. Branch step $\Delta_b=\frac{1}{8}$ rounds each to $\frac{1}{8}$, giving channel 0 equal to $\frac{1}{2}$ V instead of the exact $\frac{5}{8}$ V. The error is the constant $\frac{-1}{8}$ V; the three other channels remain zero. Its variance about its own mean is zero, while its mean-square error is $\frac{1}{64}$ V². Averaging more identical frames retains the same bias. A formula that distributes independent uniform rounding noise across channels would misdescribe this deliberately coherent record, even though every branch conversion obeys its half-step error bound.

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recovery law.

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10.45 Application 10D10 Audit a complete finite word output vector

Return to the coefficients and coefficient format of Application 10D1. Use $M=D=L=4$, $p=0$, n_m divisible by four, and input vector $u=[\frac{3}{4},\frac{-1}{2},\frac{1}{4},\frac{-3}{4}]$ in $S\backslash(4,2\backslash)$. Exact filtering with the original coefficients gives $y=[\frac{-1}{4},\frac{j}{5},\frac{11}{20},\frac{-j}{5}]$ V. The quantized coefficients give branch products $[\frac{3}{32},\frac{-3}{32},\frac{5}{64},\frac{-9}{32}]$. These products are carried exactly in $S\backslash(9,6\backslash)$. Converting once to $S\backslash(6,5\backslash)$ changes only $\frac{5}{64}$: it is halfway between codes two and three and rounds to the even code two. Thus $b=\frac{[3,-3,2,-9]}{32}$.

$$\hat{y}=[-\frac{7}{32},\frac{1}{32}+j\frac{3}{16},\frac{17}{32},\frac{1}{32}-j\frac{3}{16}]V$$

Store the unscaled result in $S\backslash(8,5\backslash)$, with $s=0$; every displayed component is exact on that output grid. Channel errors are $\frac{+1}{32}$, $\frac{1}{32}-\frac{j}{80}$, $\frac{-3}{160}$, and $\frac{1}{32}+\frac{j}{80}$ volts. Their largest magnitude is $\frac{\sqrt{29}}{160}$ V ≈ 0.0336572800 V. The general envelope uses $B=\frac{3}{4}$, $\sum_{\ell=0}^{L-1}|\delta h[\ell]|=\frac{3}{40}$, and $\Delta_b=\Delta_z=\frac{1}{32}$, giving $E\approx 0.166735435$ V. Inspecting the actual residuals tightens this to $\backslash(0.05625+0.015625+0\backslash)$ V $=0.071875$ V: the coefficient term retains its worst-case bound, only one branch incurs rounding, and output rounding vanishes. Both bounds contain all four observed errors. The tighter result is an audit of this specified vector, not a uniform guarantee for another input range or conversion schedule.

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10.46 What the arithmetic comparison establishes

These examples turn numerical reproducibility into a finite specification: signed formats at every conversion, actual quantized coefficients, product and accumulator widths, rounding locations and ties, overflow policy and status, transform sign and normalization, scale exponents, channel order, and preserved history. An exact-code implementation can be checked against Model 10C before its hardware output is interpreted. Passing these stipulated vectors establishes agreement only for the tested arithmetic cases. A deployed pipeline still requires its actual stage graph, twiddle formats, timing controls, overflow telemetry, and input-range evidence. The deterministic envelope does not certify receiver sensitivity, false-alarm performance, or absence of a source.

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10.47 Data Transport, Gaps, and Reproducible Recording

High-rate I/Q recording depends on device buffers, bus throughput, packet transport, operating-system scheduling, storage, and file format. Dropped samples, repeated packets, timestamp discontinuities, USB resets, network loss, or disk throttling can create spectral splatter and false transients. Many formats store samples without complete metadata, while others embed center frequency, sample rate, time, scaling, and device state.

The capture system monitors sequence numbers, overflow indicators, time stamps, storage margin, and clock lock. A known reference or loopback tests continuity. Native samples are preserved before conversion or compression, and processing scripts record exact parameters and software versions. When a gap is filled with zeros or interpolated, the change is explicitly logged because it changes the spectrum.

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10.48 Model 10E for absolute sample continuity and retained processing state

The arithmetic in Models 10B through 10D presumes an identified input history. A recording can violate that premise while retaining plausible amplitudes, a convenient file length, and an apparently stable spectrum. Model 10E therefore treats continuity as a mapping from stored positions to original sample indices. It then asks whether each retained output has all the inputs and state required by its stated calculation. The model concerns sample behavior inside a declared clock segment. Chapter 15 addresses the separate obligations of survey coverage, record custody, access, and reproducible evidence handling.

Assume one complex input stream with a fixed sampling frequency over the segment, no unmodeled change of sample format, and an unwrapped integer source counter. The counter is associated with the sampling event, not with a host buffer arrival. A clock reset, unresolved counter wrap, rate change, or incompatible source-index declaration ends this segment until a new mapping is established. Numerical examples below are constructed calculations with stated inputs. They are not measurements of a receiver or claims about deployed transport reliability.

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10.49 Source indices, stored offsets, and time anchors

Let $x[n]$ be the original complex sample in volts at integer source index n. Let $z[k]$ be the stored sample at integer file-sample offset k. Block r has stored start s_r, source start n_r, and positive integer length N_r, all measured in samples. Its internal index i takes the integer values 0 through $N_r - 1$. A faithful block satisfies the following relation; contiguous file placement alone says nothing about source continuity.

$$z[s_r + i] = x[n_r + i], 0 \le i < N_r$$

For adjacent blocks in the declared source ordering, define the signed boundary discrepancy G_r. A positive value counts source positions between this pair, zero identifies adjoining indices, and a negative value identifies an overlap. The positive interval is missing only if no other accepted block supplies it; resolve overlapping coverage before declaring a global gap. A negative result does not establish that overlapping payloads agree. Blocks received out of order must first be associated with their declared indices; arrival order cannot silently replace source order.

$$G_r = n_{r+1} - (n_r + N_r)$$

A recording format can preserve this distinction explicitly. In SigMF 1.2.6, sample_start identifies the capture position in the stored dataset, whereas global_index identifies its position in the original stream. The capture datetime anchors the indicated sample. The specified default equating an absent global_index to sample_start is a decoding rule, not evidence that the physical acquisition lost no samples. Segment metadata must carry the values that apply to that segment. The mathematical continuity decisions

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here require verified declarations, not merely a syntactically valid metadata file.[13]

Let f_s be the declared positive sampling frequency in samples per second. An anchor associates source index n_a with time t_a in seconds on a declared time scale. Under the constant-rate assumption, the sample time is obtained from the index difference. A timestamp describing buffer delivery or file creation is a different event and cannot be substituted without an established relationship to sampling.

$$t(n) = t_a + \frac{n - n_a}{f_s}$$

The receiving implementation also matters. UHD receive metadata identifies the time of the first sample, distinguishes packet fragmentation through fragment offsets, and reports overflow or sequence conditions. Its out_of_sequence field helps distinguish a sequence error from a receive-buffer overflow.

These indicators guide reconstruction, but an error flag alone does not supply the exact number of absent source samples. A short application receive buffer can divide one packet into fragments without causing a gap. Inspect the returned sample counts, index or time declarations, and error context together.[14]

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13 Analog Devices, ADL8201: DC to 30 GHz, RF Limiter, data sheet, rev. 0 (January 2026), tables 1–6, 3–5, https://www.analog.com/media/en/technical-documentation/data-sheets/adl8201.pdf. Device performance, survivability, and absolute maximum ratings have separate conditions; no numerical device rating is transferred to the synthetic front-end cases.

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10.50 A continuity condition for finite filtering and decimation

The processing contract uses a complex mixer followed by a causal finite impulse response filter and decimation. Let j satisfy $j^2=-1$. The mixer frequency f_0 is in hertz, its angular increment ω_0 equals $\frac{2\pi f_0}{f_s}$ radians per input sample, and its phase at source index zero is φ_0 radians. The fixed coefficients $h[\ell]$ are dimensionless and have declared length L, a positive integer. The lag ℓ ranges from zero to $L-1$. The output sample $y[m]$ remains in volts. Its source-grid index $n_m=n_0+mD$, where n_0 is a fixed integer epoch, D is the positive integer decimation factor, and m is an integer output index.

$$n_m=n_0+mD\,,\omega_0=\frac{2\pi f_0}{f_s}$$

$$y[m]=\sum_{\ell=0}^{L-1} h[\ell]x[n_m-\ell]\exp\left(-j[\varphi_0+\omega_0(n_m-\ell)]\right)$$

This expression fixes both the waveform history and the phase convention. An arbitrary file-block boundary changes neither. For a channelizer, apply the same construction at each channel frequency while retaining the established output epoch and branch ordering of Model 10C. The present continuity model assumes exact linear arithmetic for its counterfactual comparisons. Model 10D supplies the separate rounding, range, saturation, and implementation-graph qualifications; a continuity flag does not certify those numerical properties.

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14 Walt Kester, MT-080, Mixers and Modulators, rev. 0 (Analog Devices, October 2008), 1–2 and 5, including the multiplier model and “Image Response,” https://www.analog.com/media/en/training-seminars/tutorials/mt-080.pdf. The ideal product identities are developed in Model 4A; its candidate spur locations do not establish the amplitudes of real mixer products.

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Define the coefficient support H as the set of lags whose declared coefficients are nonzero. Exclude the identically zero filter from this discussion. Let $v[n]$ equal one only when source sample n is uniquely resolved and available, or when its prehistory is legitimately known by the stated experiment. Otherwise let $v[n]$ equal zero. An absent sample and an unresolved conflicting duplicate both fail this availability condition. The output continuity indicator $\kappa[m]$ is the product of these binary inputs over the coefficient support.

$$\kappa[m] = \prod_{\ell \in H} v[n_m - \ell], v[n] \in \{0,1\}$$

For unrestricted unknown missing values, $\kappa[m]$ equals one exactly when the output is independent of those unknowns. Each nonzero coefficient multiplies a distinct source sample, and the mixer has unit magnitude. Consequently, an unknown sample with a nonzero coefficient can change the output even if the particular observed waveform happens to conceal its effect. This is a dependency test, not a probability of correctness. A valid dependency mask does not establish calibration accuracy, the truth of a timestamp, or the authenticity of a source counter.

A finite filter can be evaluated in blocks while retaining state equivalent to its required input history. One implementation example is SciPy lfilter: its documented zi argument supplies initial delay state, an omitted initial state means rest, and zf returns the final delay state when initial state was supplied. That implementation uses a direct form II transposed realization. Its delay-state coordinates should not be confused with a raw list of

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preceding samples; transfer the documented state of the same realization or reconstruct the equivalent history correctly.[15]

When every lag from zero through $L-1$ is nonzero and a single missing interval spans the inclusive source indices a through b, the potentially affected output source indices span a through $b+L-1$. Suppose the declared output record contains integer indices $m_{\min}$ through $m_{\max}$. Intersecting this interval with the retained decimation grid gives the first and last affected output indices below. Ceiling means the least integer not smaller than its argument; floor means the greatest integer not larger.

$$m_{lo}=max\left(m_{min},\lceil\frac{a-n_0}{D}\rceil\right)$$

$$m_{hi}=min\left(m_{max},\lfloor\frac{b+L-1-n_0}{D}\rfloor\right)$$

$$C=max\left(0,m_{hi}-m_{lo}+1\right)$$

Here C is the number of affected retained outputs, a nonnegative count. If the intersection is empty, C is zero. The full interval construction is exact for a contiguous nonzero support; a sparse filter instead uses the actual support in $\kappa[m]$. Several missing intervals can overlap after filtering, so add the affected sets by union rather than summing counts that double-count an output. A finite history becomes independent of an old gap after the required known samples have entered it. This finite recovery rule does not

15 Walt Kester, MT-080, Mixers and Modulators, rev. 0 (Analog Devices, October 2008), 1–2 and 5, especially the multiplier scaling and “Image Response,” https://www.analog.com/media/en/training-seminars/tutorials/mt-080.pdf. The ideal normalization and synthetic cases here are explicitly derived and do not quote a device conversion-loss specification.

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extend automatically to recursive filters, adaptive coefficients, gain-control loops, or phase-tracking loops.

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10.51 Gap representations, phase, and the limits of timing claims

Zero filling creates a derived sequence on the original index grid while preserving a separate validity mask. Let $\tilde{x}[n]$ equal the available value where $v[n]$ is one and equal zero where it is zero. Let $\tilde{y}[m]$ be the result of applying the same declared processing to that sequence. Let U_m be the subset of supported lags for which $v[n_m-\ell]$ is zero. Relative to the counterfactual complete record, the output error $e[m]=\tilde{y}[m]-y[m]$. Subtracting the two finite sums gives the missing-input contribution directly.

$$e[m]=-\sum_{\ell \in U_m} h[\ell]x[n_m-\ell]\exp\left(-j[\varphi_0+\omega_0(n_m-\ell)]\right)$$

If a justified bound B in volts limits the magnitude of each missing input contributing to this output, the triangle inequality yields the following conditional deterministic bound. The bound is not a noise variance, and the zero-filled output remains marked invalid even when the bound is small. If no input bound is justified, this model supplies no finite numerical error limit. Interpolation introduces another assumed sequence and requires its own error assumptions.

$$|\, e[m] \,| \leq B \sum_{\ell \in U_m} |\, h[\ell] \,|$$

Deleting missing positions instead compresses the index axis. It changes which physical samples become neighbors in the filter history, unless a separate reconstruction restores the original grid. It also changes a numerically controlled oscillator if the oscillator advances by stored offset rather than source index. Let $g=n-k$, the difference between the source index and its compressed stored index after a gap. At that sample, a mixer

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using k instead of n has the following multiplicative phase error relative to the correct mixer.

$$\frac{\exp(-j[\varphi_0+\omega_0 k])}{\exp(-j[\varphi_0+\omega_0 n])}=\exp(j\omega_0 g), g=n-k$$

Both oscillators in this ratio use the same phase constant φ_0. When g is constant across an entire filter support, this is a constant output rotation when corresponding source instants are compared. A decimator advancing on compact k selects the intended source grid only when its mapped n is congruent to n_0 modulo D. A nonzero gap residue otherwise changes the retained source instants. Across a gap boundary, different retained samples can have different deficits, so a single rotation does not repair the altered convolution. The first sample after G missing samples is $G+1$ sampling intervals after the last retained sample. Computing phase from absolute indices avoids confusing this interval with the number of missing positions.

Continuity of indices also leaves a distinct clock-rate question. Suppose the true constant sampling frequency is f_s\($1+\varepsilon$\), the signed fractional rate error is ε, its magnitude is bounded by $\varepsilon_{\max}<1$, and anchor-time uncertainty is bounded by A seconds. Let $t_{\text{true}}[n]$ be the actual sample time and $t_{\text{nom}}[n]$ the time calculated from the declared rate and anchor. Subtracting the reciprocal rates and using the smallest allowed denominator gives this conservative elapsed-time bound.

$$|t_{true}[n]-t_{nom}[n]| \le A+\frac{|n-n_a|\,\varepsilon_{max}}{f_s(1-\varepsilon_{max})}$$

The absolute index distance is measured in samples, so the second term has units of seconds. The bound includes neither stochastic clock wander nor an unmodeled time step. Those require a richer timing model or a new

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segment. The applications below exercise one continuity model at different points in the same recording and processing chain; they do not declare separate comprehensive treatments of transport protocols, clock synchronization, or recursive-state recovery.

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10.52 Application 10E.1: a file offset that conceals forty missing samples

Take $f_s = 1,000,000$ samples per second and an anchor at source index 1,000,000 with $t_a = 0$ seconds. A first block contains 128 samples beginning at that source index. The next block begins at source index 1,000,168 but is stored immediately after the first, at file-sample offset 128. The gap relation gives 1,000,168 minus (1,000,000 plus 128), or 40 missing samples. The next block begins at 168 microseconds on the source clock, not the 128 microseconds implied by its compact file offset.

Seven positions into the second block, the stored offset is 135 while the source index is 1,000,175 and the time is 175 microseconds. Using the file offset as elapsed sample count makes the time 40 microseconds early. The last retained sample before the gap was at source index 1,000,127; its separation from the next retained sample is 41 microseconds. Forty missing positions therefore produce forty-one intervals between the bounding retained samples. A correct block map preserves both the gap count and that endpoint distinction.

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10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads

A block beginning at source index 2,000 contains 64 samples. A second block begins at 2,032 and also contains 64. Their boundary discrepancy is minus 32, so the stored 128 values cover only 96 distinct source indices, from 2,000 through 2,095. With a two-megasample-per-second clock anchored at the first sample, the second block starts 16 microseconds later. Its compact stored offset of 64 would suggest 32 microseconds if source identity were ignored.

Agreement of the 32 overlapping values permits a declared duplicate-resolution policy to retain one value per source index. Disagreement requires investigation or an invalidity flag; averaging the conflicting values manufactures a third value without resolving which observation belongs to the source event. Repetition of a periodic waveform at different source indices is not a duplicate index. The overlap calculation is about declared sample identity, so waveform resemblance cannot replace the counter and timing evidence.

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10.54 Application 10E.3: a continuous record with uncertain elapsed time

Let the declared rate be 5,000,000 samples per second. A separation of 40,000,000 source indices corresponds nominally to eight seconds. Assume a constant fractional rate error bounded by 20 parts per million and an anchor uncertainty of two microseconds. The timing bound is two microseconds plus eight seconds multiplied by 0.000020 and divided by 0.999980. The result is approximately 162.0032 microseconds.

At exactly 20 parts per million fast, the elapsed-time difference from nominal is approximately minus 159.9968 microseconds; at the same fractional rate error slow, it is approximately plus 160.0032 microseconds. The extra two microseconds permits the anchor error in either direction. No sample need be missing for either case to occur. The calculation is a bounded timing statement under a constant-rate assumption, not a probability distribution, an assertion of clock performance, or a reason to insert missing samples.

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10.55 Application 10E.4: an ordinary block boundary preserves filter history

For Applications 10E.4 through 10E.8, set $f_0 = 0$ and $\varphi_0 = 0$. Applications 10E.4 through 10E.7 additionally use $D = 1$ and $n_0 = 0$. Use the three-tap FIR coefficients one-half, one-quarter, and one-quarter, with explicitly known zero prehistory. Input samples at indices zero through three are 2, 4, 6, and 8 volts. Process indices zero and one as the first block. Their outputs are 1 and 2.5 volts. Retaining the equivalent history for the second block produces 4.5 volts at index two and 6.5 volts at index three.

Resetting the filter to rest at index two instead produces 3 volts and then 5.5 volts. Those errors, minus 1.5 volts and minus 1 volt, arise despite complete input continuity. A transport or file partition has been mistaken for a physical startup. Passing implementation state or the equivalent preceding input history gives the full-record result. Knowing that the experiment began at rest does not authorize imposing a new rest condition at every later buffer boundary.

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10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail

Keep that filter and extend the complete synthetic input to 2, 4, 6, 8, 10, and 12 volts. Suppose source sample two is absent. In this constructed counterfactual its value was 6 volts, but an actual missing record would not disclose that value. Zero filling only source position two gives outputs of 1.5, 5, 7, and 10.5 volts at indices two through five. The complete-record outputs at those positions are 4.5, 6.5, 8.5, and 10.5 volts.

The errors are minus 3, minus 1.5, minus 1.5, and zero volts. The dependency mask rejects outputs two, three, and four; output five has recovered because all its contributing input positions are known. If the missing input is independently bounded by 12 volts, the corresponding magnitude bounds are 6, 3, and 3 volts. These are conservative limits, not estimates of the actual errors. Filling the gap has made the calculation executable while leaving its uncertainty visible.

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10.57 Application 10E.6: deleting the same gap changes a different operator

Delete source sample two instead of reserving its position. The compact sequence becomes 2, 4, 8, 10, and 12 volts. Applying the same three coefficients to this new sequence gives 5.5 volts at compact index two, which corresponds to source index three. The complete-record output at source index three was 6.5 volts, so the error is minus 1 volt. At compact index three, corresponding to source index four, the result is 8 volts instead of 8.5 volts.

At compact index four the result is 10.5 volts and the finite filter history again matches source index five. Nevertheless, a timestamp obtained by dividing the compact index by the sample rate remains one sampling interval early. Zero filling had produced 5 volts at source index three, not the 5.5 volts produced by deletion. The two procedures are therefore different transformations even when both eventually recover the same local finite history. Retain the original source map with either derived representation.

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10.58 Application 10E.7: a zero coefficient changes the validity pattern

Choose a three-position filter with coefficients one-half, zero, and one-half. Keep the six-input sequence from Application 10E.5 and lose source sample two. The declared coefficient support contains only lags zero and two. Output two depends on the missing sample at lag zero, and output four depends on it at lag two. Output three uses the known samples at source indices three and one, giving one-half times 8 plus one-half times 4, or 6 volts.

Thus output three remains continuity-valid even though the contiguous-length envelope spans outputs two through four. The exact support mask avoids discarding that usable result. This reasoning requires an exactly zero coefficient in the stated implementation. A small nonzero coefficient still creates a dependency, although a justified amplitude bound may limit its consequence. Changing coefficients merely to avoid an invalidity indication would define a different filter and require a separate declared processing result.

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10.59 Application 10E.8: decimation retains two outputs from a longer gap tail

Use seven nonzero FIR coefficients, an output epoch $n_0 = 1$, and decimation factor $D = 4$. Suppose input indices ten through twelve are missing. The finite-filter dependency interval extends from ten through eighteen. Nearby retained output source indices are nine, thirteen, seventeen, and twenty-one. Only thirteen and seventeen fall inside the interval.

The lower affected output index is the ceiling of (10 minus 1) divided by 4, which is 3. The upper is the floor of (12 plus 6 minus 1) divided by 4, which is 4. Provided the output record includes those indices, C equals 4 minus 3 plus 1, or two outputs. Input index nineteen is the first source time after the contiguous dependency tail, while the first retained output after that tail is at twenty-one. Retaining the original decimation epoch makes this distinction reproducible.

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10.60 Application 10E.9: absolute phase survives three missing positions

Set the mixer frequency to one-eighth of the sampling rate, so ω_0 equals $\frac{\pi}{4}$ radians per sample, and let $\varphi_0 = 0$. For the unit-amplitude complex tone $x[n] = \exp\backslash(\frac{j\pi n}{4}\backslash)$ volts, the correctly indexed mixer gives one volt. After deleting three positions, a compact counter has $k = n - 3$. Its mixer instead produces $\exp\backslash(\frac{j3\pi}{4}\backslash)$ volts, approximately $-0.707107 + j0.707107$ volts.

The magnitude of its difference from the correct one-volt result is the square root of (2 plus the square root of 2), approximately 1.847759 volts. If source index nine is followed by thirteen, the correct oscillator advances through four sample intervals, or π radians. Advancing through one interval misses $\frac{3\pi}{4}$ radians. The constant-rotation interpretation applies once a whole filter support shares the same index deficit; it cannot restore a support assembled from samples on both sides of a compressed gap. If $D = 4$ and the intended source epoch is zero, selecting compact indices divisible by four after this three-sample gap selects source indices congruent to three modulo four. A constant phase correction cannot replace the missing output instants on the intended grid.

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10.61 Application 10E.10: one missing input appears in idle channels

Construct a four-channel bank with channel frequencies $\omega_k = \frac{2\pi k}{4}$ for integer channel labels k from zero through three, phase $\varphi_0 = 0$, output epoch zero, decimation by four, and an eight-tap prototype whose coefficients all equal one-eighth. This k is a channel label local to the example, not the earlier stored-file index. Let every input sample be one volt, with known prior history. At output source indices divisible by four, the complete channel vector is $[1,0,0,0]$ volts. This elementary prototype is chosen for transparent arithmetic and makes no practical selectivity claim.

Lose source sample one hundred and zero-fill that position. At output source index one hundred it contributes through lag zero; at one hundred four it contributes through lag four. Its phase factor is one in every channel, so each affected channel output loses one-eighth volt. The vector becomes $[\frac{7}{8},\frac{-1}{8},\frac{-1}{8},\frac{-1}{8}]$ volts at both retained outputs. All four outputs at each time are invalid under the common support mask. At source index one hundred eight the full vector returns because the gap has left the finite history. The apparent activity in the three previously idle channels is a consequence of the recording discontinuity, without any additional transmitted tone.

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10.62 Interpretation and continuation boundary for Model 10E

This bounded model supplies a reproducible way to distinguish source chronology, stored position, and processing state. Its ten applications show why a cleanly parsed file, continuous output array, or plausible spectrum cannot by itself establish a continuous observation. Preserve the sample map and uncertainty mask through derived processing, retain the correct phase and output epoch, and interpret only the dependency-valid results under their separate amplitude and timing qualifications. General recursive-state recovery, clock-wander estimation, counter-wrap reconciliation, and empirical transport testing remain extensions requiring additional assumptions and evidence.

Dependency-valid output samples are candidates for usable acquisition windows, not a complete signal-validity certificate. Before applying Model 15A, establish that the signal lies within the accepted channel response, that control and overload recovery have ended, and that the sample timing meets the event criterion. Preserve contiguous record boundaries when forming the overlap intervals. Model 12A supplies deterministic clock, phase, and delay conventions, and Model 12B treats the separate stochastic phase and coherence questions under its specified covariance assumptions. These additional qualifications do not repair an invalid source dependency; they define when a dependency-valid interval supports the intended observation.

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10.63 SDR Acceptance and Supply-Chain Controls

SDR acceptance covers analog response, filters, gain states, ADC range, sample-rate accuracy, alias rejection, DDC response, channelizer boundaries, sample continuity, timestamp behavior, and software reproducibility. Firmware, gateware, driver, and application hashes are recorded with device identity. An update is treated as a configuration change requiring regression testing.

Unknown or modified software is not permitted to become the only evidence path. Reference recordings are processed through independent tools where practical, and the device is challenged with noise-only and known-source data. A technically attractive open architecture still requires supply-chain, rights, security, and reproducibility controls before field deployment.

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10.64 Framework 10F for bounded SDR acceptance

Acceptance establishes that a particular receiver configuration satisfies stated requirements under a stated examination. Its object is the configured measurement path, including the software that interprets the samples. A release label, a successful installation, and an attractive spectrum display establish different facts. None specifies, by itself, which input levels, sample rates, gain states, channels, or recording conditions were examined. The useful result is a bounded claim that another examiner can evaluate against the same criteria.

Framework 10F organizes that claim without assigning a numerical confidence score to incomplete evidence. It joins artifact identity, configuration identity, test applicability, and technical results through mandatory criteria. The ten applications are constructed acceptance cases, not observations of a commercial receiver. Their numerical limits are expressly chosen for the examples and are not universal SDR specifications. Chapter 15 remains the home of legal authority, retention, access, and evidentiary governance; the present section concerns which technical behavior an acceptance result actually supports.

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10.65 Define the case before testing

Begin with a declared use and a finite configuration envelope. Identify the receiving channels, analog input reference plane, admitted frequency band, permitted input levels, gain and filter states, clock and time sources, sample formats, rate changes, processing stages, and recording destination. Include environmental and host-load conditions when they can affect a requirement. An acceptance case for one channel at one rate is legitimate if that narrow scope is useful. It cannot be relabeled as acceptance of every channel and rate after the tests are complete.

Give each criterion a stable identifier and a proposition that can be satisfied or contradicted. A useful criterion identifies its subject, allowed configuration, stimulus or documentary examination, required observable, decision rule, and evidence. For example, a declared sample-format test can require exact recovery of specified integer code words; an analog-response test needs a reference plane, frequency points, gain state, uncertainty treatment, and allowed error. A statement such as works normally supplies neither a discriminating observation nor a boundary for the conclusion.

Determine applicability separately from the result. A criterion explicitly outside the declared case may be excluded only with a recorded technical rationale. Transmit spectral purity can be outside a receive-only acceptance case when no transmitting operation is being claimed; the exclusion does not establish that transmission is disabled or harmless. If the operating modes, signal path, or requirement interpretation are not yet known, applicability is unresolved. Do not remove a difficult requirement by

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marking it nonapplicable after an unfavorable result. A changed scope creates a new case whose narrower claim must be stated.

For every mandatory applicable criterion, retain one of three evidence states. Satisfied means that adequate, applicable evidence meets its stated rule. Contradicted means that adequate evidence demonstrates a breach of that rule. Unresolved means that the necessary evidence, its applicability, or its interpretation is insufficient. An invalid test does not demonstrate either compliant or noncompliant receiver behavior. A failed signature check, however, can contradict a requirement for successful verification without establishing why the check failed or what the receiver would do. Evidence of a breach must be attributable to the case. If observations conflict, examine their subjects, conditions, and validity; a favorable repetition does not erase an earlier valid breach of a criterion that permits none.

Table 10F1 Decision states for mandatory applicable criteria

Evidence state	Meaning for one criterion	Effect on the acceptance case
Satisfied	Applicable evidence meets the declared rule.	Required for every mandatory applicable criterion.
Contradicted	Applicable evidence demonstrates a breach.	The case fails; retain any other unresolved matters.
Unresolved	Evidence or applicability is insufficient.	Acceptance is not demonstrated unless the matter is resolved.

The decision follows directly from the conjunction of requirements. If any mandatory applicable criterion is contradicted, the case fails. If none is contradicted but a required result or applicability decision remains unresolved, acceptance is not demonstrated. Acceptance is supported only

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when all mandatory applicable criteria are satisfied and every exclusion has a defensible rationale. An empty set of criteria, an undefined envelope, or an exclusion without justification cannot produce acceptance. Numerous favorable results cannot compensate for a failed mandatory condition, and unresolved conditions are not assigned fractional passes.

This logic is deliberately conditional. It does not calculate the probability that the receiver is secure, the chance of an undetected fault, or the frequency of future data loss. A test suite can omit a relevant failure mode even when every listed test passes. The completeness and relevance of the criteria therefore need technical review independently of the mechanical aggregation of their results. Record the remaining boundaries of an accepted case as carefully as its successful observations.

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10.66 Separate signed artifacts from operating configurations

Code signing authenticates signed content under a verification and trust policy. The verifier must use appropriate trust anchors and validate the relevant signature, certificate, and time information. NIST also identifies the possibility that unauthorized or malicious code is itself signed. Thus a valid signature is evidence about integrity and the signing source, not a measurement of filter response, sample scaling, or numerical correctness. Those behavioral propositions need their own examination.[16]

A build attestation requires more than a visible signature symbol. SLSA version 1.2 calls for checking the artifact digest against the attestation subject, the provenance type, trusted builder identity, and expected build information. Its verification guidance includes the source repository, buildType, and externalParameters, and recommends rejection of unrecognized external parameters. The receiver acceptance case must state which of these expectations it actually checks; a general statement that provenance was present is insufficient.[17]

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16 United States Navy, NEETS, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-11–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8389–8392, on IF amplification, detection, and multiple conversion; Analog Devices, AD8367: 500 MHz Linear-in-dB VGA with AGC Detector, rev. A (2005), 13 and 16, https://www.analog.com/media/en/technical-documentation/data-sheets/AD8367.pdf. The former supports the IF architecture and the latter supplies a specific gain-control example. Neither establishes every filter technology's response.

17 Analog Devices, AD8367: 500 MHz Linear-in-dB VGA with AGC Detector, rev. A (2005), 13, "RMS Detection," and 16, "AGC Operation," https://www.analog.com/media/en/technical-documentation/data-sheets/AD8367.pdf. The small-change single-pole response and separate large-change slew and clamp behavior motivate the stated local model boundary; the teaching cases are not AD8367 measurements.

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Bind these documentary results to the executable files, loaded modules, firmware, gateware, calibration data, and configuration that the test used. A digest identifies declared bytes under the selected hash algorithm. It does not show that those bytes were loaded, that all executable dependencies were included, or that a compromised reporting component described its state honestly. Record whether each identity came from a file examination, a loader record, a device response, or a stronger authenticated mechanism. Do not describe ordinary version strings as attestation.

Image selection can be part of the configuration. UHD documents different loading arrangements among device families, including runtime loading and images held in device storage. Its image downloader obtains images compatible with the host software, and its image-search configuration can include multiple ordered paths. These are concrete reasons to distinguish the downloaded file, the file selected for loading, and the image operating in the device. The applicable device documentation determines which observations can support that association.[18]

A configuration manifest should use explicit field names, units, channel identifiers, and unambiguous values. Retain actual values as well as requests. UHD documents that set_rx_rate can coerce a requested rate and directs the caller to get_rx_rate for the resulting value. It similarly distinguishes requested and actual tuning or gain values. A successful call is

18 United States Navy, Navy Electricity and Electronics Training Series, Module 12: Modulation, NAVEDTRA 14184 (September 1998), 1-43–1-45 and 2-8–2-13, reproduced in SIGINTRADARTSCM.pdf, compilation pages 7308–7310 and 7349–7354. The cited passages distinguish sinusoidal AM envelope and sideband structure from frequency deviation and modulation rate. Classification and attribution limits here are methodological conclusions, not claims that the source proves an emitter’s identity or purpose.

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therefore not sufficient evidence that the requested operating point was established.[19]

The interface boundary also matters. UHD distinguishes the CPU sample format, the over-the-wire format, additional stream arguments, and channel mapping. Host-memory and transport representations are not interchangeable descriptions. A separate recording serializer introduces another format contract. Fix the sign convention, numerical scaling, byte order where applicable, I/Q order, and channel order at the boundary actually being tested.[20]

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19 United States Navy, Navy Electricity and Electronics Training Series, Module 12: Modulation, NAVEDTRA 14184 (September 1998), 1-43–1-45, reproduced in SIGINTRADARTSCM.pdf, PDF pages 7308–7310; title and edition at compilation page 7254. The cited treatment concerns the sinusoidal AM envelope and sidebands, not a current regulatory allocation.

20 United States Navy, NEETS, Module 12: Modulation, NAVEDTRA 14184 (September 1998), 2-8–2-13, reproduced in SIGINTRADARTSCM.pdf, PDF pages 7349–7354. The cited discussion distinguishes frequency deviation from the rate of the modulating signal.

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10.67 Choose evidence that can discriminate the required behavior

A functional test needs an expected result derived independently enough to expose the proposed failure. Known integer vectors can distinguish data-format mistakes that a smooth waveform conceals. Analytically selected tones can distinguish channel permutation, frequency-sign reversal, and an incorrect decimation epoch. Reference processing from Models 10B through 10E can supply the appropriate finite-record assumptions and state conventions. Reusing those established derivations avoids replacing a precise test oracle with an undocumented display comparison.

An analog test additionally needs a known applied stimulus and a characterized path to the declared reference plane. State which source uncertainty, cable correction, mismatch effect, receiver repeatability, and drift are included in the decision. A displayed amplitude alone does not separate receiver error from stimulus or fixture error. For a frequency grid, distinguish acceptance at the tested points from a claim over the continuous interval between them. Neither interpolation nor a smooth plot supplies a worst-case bound without an additional justified model.

Choose the decision rule before examining the results. One conservative example is to accept a bounded error interval only when the entire interval lies inside the allowed region, declare a contradiction when the entire interval lies outside it, and otherwise retain an unresolved result. The interval must have the interpretation stated in the test. An expanded uncertainty is not automatically a deterministic bound, and a stated coverage probability is not a certainty. Chapter 14 develops the

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measurement-uncertainty and decision-risk treatment; the example below uses a stipulated bound only.

Test names also have boundaries. The UHD R&D testing chapter expressly distinguishes development tests from manufacturing or production tests. Its devtests exercise basic functionality, while the FPGA functional procedure examines data flow at specified rates and channel configurations using benchmark_rate. The procedure names error indications and device-specific exceptions. Passing such a procedure supports its stated conditions; it does not silently validate an unexercised recording destination, analog acceptance limit, or mission workload.[21]

Evidence must remain applicable through the end of the test. Changing a driver, FPGA image, coefficient file, calibration correction, clock source, packet setting, or recording program can invalidate a prior result. Assess the dependencies of each criterion rather than assuming that only the component named in a release note can be affected. A data-type conversion can change amplitude, clipping, and file interpretation simultaneously. An uncertain dependency is a reason to retain an unresolved result or expand testing, not a reason to declare the old result unaffected.

Component provenance must also be usable after an update. NIST SSDF version 1.1 calls for release-integrity information, protected release

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21 Range Commanders Council, Telemetry Standards, IRIG Standard 106-05 (2005), appendix A, “Frequency Considerations for Telemetry,” sec. 5.2.3.3, A-12, eq. A-4 and the stated limitation on correspondence with 99-percent power bandwidth, https://irig106.org/docs/106-05/appendixA.pdf. The engineering estimate is used here without adopting the document’s historical frequency allocations or implying current regulatory guidance.

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material, and maintained provenance for software components, including through an SBOM. Here that information supports comparison of the tested and proposed configurations. An inventory records the components within its declared scope; it does not itself prove absence of vulnerabilities or establish the identity of hardware or firmware omitted from that scope.[22]

22 Keysight Technologies, Digital Modulation in Communications Systems, application note 5965-7160E (July 5, 2024), 38–39 and 41–43, https://www.keysight.com/us/en/assets/7018-09093/application-notes/5965-7160.pdf. These passages describe carrier and symbol-clock recovery and comparison with an ideal reference waveform. The historical system examples and dated claims about adoption of EVM standards are not adopted. Model 7A fixes its own finite-record normalization and alignment permissions.

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10.68 Ten worked applications of Framework 10F

Each application supplies hypothetical evidence and a declared rule. Satisfied, contradicted, and unresolved refer to the stated criterion, not to a universal product rating. Unless an application says otherwise, the remaining mandatory criteria are assumed satisfied so that the consequence of the particular issue is explicit. Hexadecimal bytes are written in their stored order. No case represents an actual device test, security incident, or vendor certification.

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10.69 Application 10F.1 A familiar filename with different bytes

A release manifest identifies the accepted application file by a full digest. The installation directory contains the same filename and release label, but a direct computation gives a different digest. The mandatory identity criterion requires equality with the authenticated manifest entry. It is contradicted: matching names do not satisfy the byte-identity rule. A normal-looking spectrum from that installation cannot repair the failed comparison, because it does not establish which release was executed.

The case fails without an inference that an attacker modified the file. A packaging change, a local rebuild, or an unintended download could also explain the difference. Resolution requires a separately justified artifact identity and the corresponding acceptance work. Replacing the expected digest with the observed value merely to clear the failure would change the criterion after the result and would not authenticate the new artifact.

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10.70 Application 10F.2 A valid signature with an unacceptable build claim

A hypothetical receiver application has an authentic attestation whose subject matches its file digest. The declared policy permits one builder, one source repository, and a release build with a fixed set of external parameters. The attestation instead identifies a laboratory fork and an additional parameter enabling a diagnostic path. Signature verification is satisfied, but the source and parameter expectations are contradicted. The combined provenance requirement fails, so the acceptance case fails despite the valid signature.

The failure concerns the declared production configuration; it does not prove that the diagnostic path is malicious. A laboratory case might explicitly admit that fork and parameter, but it would need its own requirements and tests. Conversely, an unavailable attestation would leave verification unresolved rather than proving that the software was modified. This distinction separates missing evidence from an observed policy mismatch.

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10.71 Application 10F.3 The verified image was never shown to be loaded

An examiner verifies the expected FPGA image in a download directory and records a successful device connection. The loading mechanism searches two image directories, and the connection report gives only a compatibility number shared by several image builds. The criterion requires association of the tested device session with the intended image. File verification is satisfied, but the loaded-image association is unresolved. The evidence does not show that the intended file won the search or that the compatibility label uniquely identifies its contents.

The examiner establishes the actual selected image path through the applicable loading procedure, verifies that file, and repeats the session initialization with the controlled selection. Where the device cannot provide authenticated runtime identity, the report states the narrower assurance supplied by the observed loading process. It does not invent a runtime attestation. Tests performed before that association was established are not automatically transferred to the newly identified session.

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10.72 Application 10F.4 A requested sample rate is not the established rate

The hypothetical acceptance rule permits an actual receive rate from 9.999 to 10.001 megasamples per second. An application requests 10 megasamples per second, but the documented readback for the established configuration is 9.6 megasamples per second. The difference is 0.4 megasamples per second, or 4 percent of the request, far beyond the allowed 0.001-megasample-per-second deviation. The operating-point criterion is contradicted. No inference about clock accuracy follows from a readback alone; that is a separate measurement criterion.

Even if the samples are continuous, labeling them with the requested rate misstates their time axis. Using those nominal configured rates, a digital feature at one-tenth of the readback rate is labeled 0.96 megahertz, while use of the requested rate would label it 1 megahertz. The correction is to establish an admitted rate or create an explicitly different acceptance case, then use the actual rate consistently. An unresolved clock-reference measurement cannot be replaced by this arithmetic check.

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10.73 Application 10F.5 A serialization error survives successful installation

At a declared file boundary, three real test samples are signed 16-bit two’s complement codes in little-endian byte order, with values 1, 256, and minus 256. The stored byte pairs are 01 00, 00 01, and 00 FF. A reader using big-endian interpretation returns 256, 1, and 255. The criterion requires exact recovery of all three code values, so it is contradicted in every position. The values are integer codes, not voltages; no analog calibration is implied.

A zero-only vector would have passed both interpretations and concealed the defect. The asymmetric positive and negative vector discriminates byte order and sign handling without relying on a plausible waveform shape. This example specifies a recording format independently of UHD transport packing. A verified driver package does not establish that a separate serializer and reader agreed on their interface. Correct the format boundary and repeat the reference-vector and affected scaling tests.

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10.74 Application 10F.6 A bounded amplitude result near an acceptance limit

At one stated frequency and gain state, the allowed amplitude error is from minus 0.50 to plus 0.50 decibel, including both endpoints. The test stipulates a justified deterministic error-bound half-width of 0.18 decibel, including the declared source and fixture contributions. A corrected estimate of plus 0.30 decibel therefore permits errors from plus 0.12 to plus 0.48 decibel. Every permitted value lies inside the allowed interval, so this criterion is satisfied under the stated conservative rule.

With the same bound, an estimate of plus 0.42 decibel permits plus 0.24 through plus 0.60 decibel. The interval overlaps the acceptance boundary, so the result is unresolved, even though the estimate itself is inside. An estimate of plus 0.74 decibel permits plus 0.56 through plus 0.92 decibel, entirely outside, and contradicts the criterion. If the stated half-width were only a coverage interval, these classifications would require the corresponding probabilistic decision rule. None of the three outcomes establishes performance at untested frequencies or gain states.

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10.75 Application 10F.7 A streaming pass leaves the recording path unresolved

A hypothetical rule requires a continuous sixty-second, two-channel recording at 20 megasamples per second per channel, through the designated disk-writing application under a declared host workload. A benchmark streams the two channels for sixty seconds with no reported errors, but discards the received buffers. It exercises a different endpoint from the required recording. The benchmark result may satisfy its own streaming criterion; the complete recording criterion remains unresolved.

For the declared interval, the expected count is 1,200,000,000 complex samples per channel, or 2,400,000,000 across both channels. With two signed 16-bit components per complex sample, the payload alone is 9,600,000,000 bytes, before headers or metadata. These counts help define the test but do not establish continuity: duplicated samples can replace missing samples without changing file length. The completed test must exercise the actual writer, examine the relevant error indications, and apply the source-index and state checks of Model 10E. No error-free finite run establishes a future loss probability of zero.

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10.76 Application 10F.8 Two agreeing programs share the same fault

The criterion requires an independent reference check of a four-channel output ordering. Two applications agree on every output, but both call the same conversion library and use the same channel-map table. Their agreement is not independent evidence for that mapping. The required independent reference check remains unsupplied, so that criterion is unresolved. The assertion that these two implementations are independent is contradicted by their known common dependency. Their agreement remains a narrower reproducibility observation.

For a constructed single-channel basis test, the declared oracle is the ordered vector $[0,1,0,0]$ in normalized dimensionless units. Both applications instead return $[0,0,0,1]$. Comparison with the explicit oracle now contradicts the mapping criterion. A tone of equal amplitude in every channel would not have exposed the permutation. After correction, different software names are still insufficient: document the implementation or analytical independence actually used for the comparison.

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10.77 Application 10F.9 An inventory omits a required component

A supplier provides a signed software inventory for the host application and its libraries. The acceptance case separately requires provenance for the FPGA image and the calibration file used by the receiver session. Those two artifacts are absent from the inventory and no separate evidence is supplied. The inventory may be valid within its stated software scope; the two required provenance criteria remain unresolved. Neither the signature nor the inventory length converts absence of evidence into verified coverage.

The remedy is to obtain applicable component evidence or explicitly revise the claimed configuration and its acceptance scope before retesting. Calling the missing artifacts hardware would not justify exclusion when their contents influence required sample processing or correction. Likewise, a statement that the listed software has no reported vulnerability does not establish absence of defects in unlisted components. The result remains an incomplete acceptance case, without a claim that the omitted artifacts are defective.

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10.78 Application 10F.10 An update closes a precisely bounded case

A hypothetical receive-only case has eight mandatory applicable criteria: artifact identity, provenance policy, loaded-image association, actual configuration, sample representation, analog response, recording continuity, and reference independence. A driver update changes the artifact and provenance evidence and may affect configuration, conversion, and recording behavior. The reviewer also reopens loaded-image association because the driver participates in loading, bringing the reopened set to six criteria. Analog response and reference independence are retained only after a documented dependency review establishes that their subjects and conditions did not change; uncertainty about any dependency would reopen it as well.

The first update examination produces seven satisfied criteria and unresolved recording continuity. Acceptance is not demonstrated. After the complete recording-path test supplies applicable evidence, all eight are satisfied. A transmit-only criterion is excluded with the established receive-only scope and an explicit rationale, not counted as a ninth pass. The resulting acceptance statement identifies the exact updated configuration, tested frequency and gain conditions, and recording workload. It does not extend to another rate, channel count, or transmitting mode. A later permitted configuration change starts a new applicability and impact review rather than inheriting this conclusion by release-name similarity.

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10.79 Acceptance as a reproducible technical argument

The strength of this framework lies in keeping evidence attached to the proposition it can support. Identity evidence constrains which artifact was examined; configuration evidence constrains what was operating; a valid test constrains behavior under its stimulus and conditions. Their conjunction can support a useful acceptance claim while leaving broader claims unmade. A rejected or unresolved case should identify the specific contradiction or missing association so that further work can change the result through evidence, rather than through a more favorable description.

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10.80 Quantitative Model for Software-Defined Radios, Sampling, Quantization, DDC, and Channelization

Equation 1. Nyquist condition for a baseband signal

$$f_s > 2\,B_{\text{signal}}$$

For a real baseband signal band-limited to B_{signal} hertz, sample rate f_s must exceed twice that bandwidth to avoid spectral overlap in the ideal model. Practical anti-alias filters require transition margin, and band-pass or complex-sampling cases use different conditions.

The ten sampling-equivalence applications in this chapter make Equation 19's signal-class condition explicit. The inequality is a sufficient separation condition for the stated real baseband class, not a general identification rule for an arbitrary analog tone or a substitute for the front-end admission model.

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10.81 Sampling equivalence, admissible bands, and receiver interpretation

Uniform sampling constrains frequency through an equivalence relation. Let $x(t) = A\cos(2\pi f t + \varphi)$, where A is peak voltage, f is frequency in hertz, t is time in seconds and φ is phase in radians. An ideal real sampler observes $x[n] = A\cos(\frac{2\pi f n}{f_s} + \varphi)$ at integer n, with positive rate f_s in samples per second. Adding $k f_s$ to f, for integer k, adds $2\pi k n$ to the sampled phase and leaves every sample unchanged. Replacing f by $-f$ changes the sign convention for phase; a cosine with frequency $-f$ and phase $-\varphi$ is the original waveform. Consequently a magnitude spectrum cannot distinguish f from any member of $\{k f_s \pm f\}$. This is an algebraic ambiguity before finite record length, noise or converter defects enter the problem.

$$x[n] = A\cos\left(\frac{2\pi f n}{f_s} + \varphi\right)$$

Define the signed representative $r = f - f_s \operatorname{floor}(\frac{f}{f_s} + \frac{1}{2})$, lying in $[\frac{-f_s}{2}, \frac{f_s}{2})$. The representative folded frequency for a real magnitude spectrum is the absolute value of r. At an exact half-rate boundary the signed representative convention is arbitrary, because the two endpoints describe the same sampled exponential. For real sinusoids the boundary is more serious: at $f = \frac{f_s}{2}$, $x[n] = A(-1)^n \cos\varphi$. The samples do not separately determine A and φ; with $\varphi = \frac{\pi}{2}$ every sample is zero. Thus the strict inequality in Equation 19 deliberately avoids an endpoint ambiguity for unrestricted sinusoidal phase. It is not merely a numerical preference.

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$$r = f - f_s floor\left(\frac{f}{f_s} + \frac{1}{2}\right), f_a = |r|$$

$$x[n] = A(-1)^n \cos\varphi \; when \; f = \frac{f_s}{2}$$

A reconstruction claim adds an admissible signal class. Let B denote the positive upper baseband frequency in hertz. If an ideal real signal has no spectral content outside $|f| \leq B$ and $f_s > 2B$, its translated spectra are separated. A physical receiver must provide evidence that unwanted components reaching the sampler are sufficiently attenuated; knowledge of the desired signal's nominal bandwidth alone is insufficient. The source tutorial describes analog filtering and zone translation. The derivations and hypothetical cases below are independent applications, not measured converter results.[23]

The rate-change challenge in the earlier prose is therefore a test of candidate explanations, not a uniqueness theorem. Before changing a rate, list the analog bands admitted by the front end and all intervening mixers. Predict the signed or folded mapping under each acquisition configuration. Reject candidates whose predictions contradict the observed movement, but retain multiple candidates when their mappings coincide. Automatic software retuning can change both the frequency conversion and the rate; that experiment is not equivalent to changing only the sampler clock.

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23 Keysight Technologies, “EVM (Custom IQ),” 89600 VSA Help, 2026 Update 2.0, opening definition and symbol-time measurement convention, accessed November 1, 2026, https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/customIq/content/customiq_symtblerrdata_evm.htm. Instrument-specific exceptions and metric settings must be checked before comparing a reported value with the declared finite-vector model.

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Likewise, a stable displayed frequency does not prove generation after sampling.

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10.82 Ten worked sampling applications

All inputs, filters and clocks in these applications are hypothetical. Rates and tone frequencies refer to the sampler input rather than an RF label after undocumented frequency conversion. Ideal point samples are assumed unless an explicit limitation is introduced.

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10.83 Sampling application 1 Baseband transition allowance

A real desired band extends from DC to 4 MHz and the rate is 12 MS/s. Equation 19 is satisfied because $12 > 8$. The nearest image band that folds into the retained 0–4 MHz interval begins at $f_s - B = 8\ \text{MHz}$, so the available analog transition interval from 4 to 8 MHz is 4 MHz. At 10 MS/s it narrows to 4–6 MHz, only 2 MHz. Writing W for the transition width in hertz, this calculation locates the first unwanted band relevant to the retained channel; it does not determine filter order or the allowed ripple. An interferer near 6 MHz at 12 MS/s lies outside the retained 4 MHz band, but could still overload the converter before digital rejection.

$$W = f_s - 2B = (12 - 8)\,MHz = 4\,MHz$$

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10.84 Sampling application 2 The half-rate phase failure

Let $f_s = 20\ \mathrm{MS/s}$ and $f = 10\ \mathrm{MHz}$. With $A = 1\ \mathrm{V}$ and $\varphi = 0$, the samples alternate +1 and −1 V. With the same amplitude but $\varphi = \frac{\pi}{2}$, all samples are zero. More generally any pair satisfying $A\cos\varphi = c$ gives the same alternating amplitude c. A zero sequence cannot distinguish this quadrature sinusoid from no input. Choosing 24 MS/s removes this particular boundary degeneracy for the 10 MHz tone, although it does not exclude higher admitted aliases.

$$x[n] = (-1)^n\ \mathrm{V} \quad \text{or} \quad x[n] = 0\ \mathrm{V}$$

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10.85 Sampling application 3 A folded upper-zone tone

At 16 MS/s, a 21 MHz cosine has $r = \backslash(21 - 16\backslash)\ \mathrm{MHz} = 5\ \mathrm{MHz}$ and $f_a = 5\ \mathrm{MHz}$. A 5 MHz cosine of the same phase gives identical ideal samples. A tone at 11 MHz has $r = -5\ \mathrm{MHz}$; choosing its phase as the negative of the 5 MHz tone's phase again gives the same real samples. Input filtering must distinguish these analog candidates before conversion if the later record is to identify their origin. The folded magnitude itself supplies no attenuation estimate.

$r(21\ \mathrm{MHz}) = 5\ \mathrm{MHz}; r(11\ \mathrm{MHz}) = -5\ \mathrm{MHz}$

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10.86 Sampling application 4 A useful rate change

Retain a 21 MHz tone but increase the rate from 16 to 18 MS/s, keeping the analog path fixed. Its folded position moves from 5 MHz to 3 MHz because $21-18=3$. A true 5 MHz input would remain at 5 MHz at both rates. These two candidates are distinguishable by this challenge in the ideal model. Their relative amplitudes need not remain equal in a physical receiver if gain, aperture response or analog bandwidth changes with the new configuration.

$f_a(21,16)=5\,MHz\,;f_a(21,18)=3\,MHz$

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10.87 Sampling application 5 A failed two-rate uniqueness claim

Compare 10 MHz and 110 MHz zero-phase cosines. At 100 MS/s, $110 = 100 + 10$, so both fold to 10 MHz with identical samples. At 120 MS/s, $110 = 120 - 10$; cosine evenness again makes their samples identical. Thus observing 10 MHz at both rates does not establish the lower-frequency origin. The ambiguity survives records of arbitrary length under these stipulated phases. An independently justified analog input limit below 50 MHz would eliminate 110 MHz, but that information comes from the admitted-band specification rather than the two records alone.

$110 = 100 + 10 = 120 - 10 \quad \backslash(\mathrm{MHz}\backslash)$

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10.88 Sampling application 6 Band location and spectral reversal

Suppose the only admitted real band is 31–33 MHz and $f_s = 20\ \mathrm{MS/s}$. This band lies inside the 30–40 MHz Nyquist zone. The folded map is $40\ \mathrm{MHz} - f$, sending 31 MHz to 9 MHz and 33 MHz to 7 MHz. Its 2 MHz width is retained with reversed order. Moving the band to 29–31 MHz crosses the 30 MHz boundary: both 29 and 31 MHz fold to 9 MHz. Merely noting that 20 MS/s exceeds twice the 2 MHz bandwidth fails to detect this overlap. Band placement, not bandwidth alone, controls this particular undersampling plan.

$f_a(31\,MHz) = 9\,MHz\,;\, f_a(33\,MHz) = 7\,MHz$

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10.89 Sampling application 7 Complex coordinates retain a sign

Let j denote the imaginary unit, with $j^2 = -1$. For ideal complex samples $z[n] = A \exp \backslash(\frac{j 2 \pi f n}{f_s} \backslash)$, an 11 MHz input sampled at 16 MS/s has signed representative −5 MHz. It is not the +5 MHz sequence: at $n = 1$ their imaginary parts have opposite signs. If only the real part is retained, that distinction is lost after suitable phase interpretation. This calculation explains why a complex channel's signed frequency convention must be recorded. It does not establish that a physical I/Q receiver has perfect quadrature or image rejection.

$r = 11 - 16 = -5 \text{ MHz}$

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10.90 Sampling application 8 Required pre-sampling attenuation

At 20 MS/s, an 18 MHz interferer folds to 2 MHz. Suppose the desired 2 MHz input is −80 dBm, the interfering input is −20 dBm, and the permitted aliased contribution is at most −90 dBm, all referred to the same matched input and unit desired-band transmission. Writing L for filter attenuation in decibels, the filter needs at least 70 dB attenuation at 18 MHz because \$(-20\ \text{dBm}\$)-70\ \text{dB}=-90\ \text{dBm}$. A measured 60 dB would leave −80 dBm, equal to the desired level. The arithmetic assumes a linear non-overloaded path; an attenuated output spectrum cannot repair intermodulation generated upstream.

$$L \geq (-20)-(-90)=70\ \text{dB}$$

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10.91 Sampling application 9 Coherent aliases can cancel

At 16 MS/s choose $x(t)=[\cos(2\pi\cdot 5\ \text{MHz}\cdot t)-\cos(2\pi\cdot 21\ \text{MHz}\cdot t)](1\ \text{V})$, with each tone having 1 V peak. At every sample the two cosine arguments differ by $2\pi n$, so $x[n]=0$. The corresponding plus sign gives a 2 V peak sampled cosine. Adding the two analog tone powers would miss both results because these distinct analog frequencies become coherent at the same discrete frequency. Uncorrelated random components permit a different mean-power argument, but that assumption is absent here.

$$\cos\left(\frac{2\pi\cdot 21n}{16}\right)=\cos\left(\frac{2\pi\cdot 5n}{16}\right)$$

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10.92 Sampling application 10 Clock error shifts a folded result

Stipulate an exact 21 MHz tone and a true sampling rate $f_s = 16\ \text{MHz}\backslash(1+\varepsilon\backslash)$, where ε is the dimensionless fractional clock offset and $|\varepsilon| \leq 10$ parts per million. The signed alias remains on the same branch and is $5\ \text{MHz} - 16\ \text{MHz}\ \varepsilon$. Its physical-rate frequency therefore lies from 4,999,840 to 5,000,160 Hz. If software instead labels frequency using the nominal 16 MHz clock, it reports $[\frac{21\ \text{MHz}}{f_s} - 1] \cdot 16\ \text{MHz}$; that expression has a different error dependence. A frequency-axis uncertainty budget must specify which clock establishes the displayed hertz. The calculations concern constant clock offset, not random aperture jitter.

$$f_a = 5{,}000{,}000 - 16{,}000{,}000\,\varepsilon\ Hz$$

$$f_{display} = \left(\frac{21\,MHz}{f_s} - 1\right) \times 16\,MHz$$

Equation 2. Ideal quantization SNR

$$\text{SNR}_{\text{Q,dB}} \approx 6.02\,N_{\text{bits}} + 1.76$$

For an ideal N-bit converter driven by a full-scale sinusoid with uniformly distributed quantization error, signal-to-quantization-noise ratio is approximately $\backslash(6.02\,N + 1.76\backslash)\ \text{dB}$. Effective performance is lower when jitter, noise, nonlinearity, or reduced amplitude is present.

The quantization treatment and its ten applications derive the domain of Equation 20. The ideal full-scale sine-wave estimate is conditional on the stipulated error model; code alignment, clipping, correlation, dither, and

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admitted channel bandwidth can change the result. It is not a measured converter specification.

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10.93 Quantization margin and channel bandwidth

A code count determines amplitude spacing, whereas a noise claim also requires a distribution and a bandwidth. Let F be the nominal peak-to-peak input span in volts, N the integer bit count, and $\Delta = \frac{F}{2^N}$ volts the ideal interior code spacing. The nominal positive peak $\frac{F}{2}$ is a reference amplitude; the actual finite-code endpoint convention must be checked separately before driving a converter to its rail. For a rounding quantizer away from overload, define the error $e = Q(x) - x$. Its bound $|e| \leq \frac{\Delta}{2}$ does not alone establish its mean, variance, correlation with x, or spectrum. A constant input at a code center has zero error; another constant input can have a fixed error. Neither record becomes white noise merely because the converter has many bits.

$$\Delta = \frac{F}{2^N}, \; |e| \leq \frac{\Delta}{2}$$

The familiar planning model stipulates error uniformly distributed over an interval of width Δ centered on zero. Direct integration gives $\mathrm{E}[e] = 0$ and $\mathrm{E}[e^2] = \frac{\Delta^2}{12}$. For a zero-mean sinusoid with peak amplitude $\frac{aF}{2}$, its mean square is $\frac{a^2 F^2}{8}$, provided the sampled record adequately represents the sinusoid's phase. Dividing these quantities gives a signal-to-error-power ratio of $\frac{3}{2} a^2 2^{2N}$, or $20 N \log_{10}(2) + 10 \log_{10}(\frac{3}{2}) + 20 \log_{10}(a)$ decibels. This

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derivation is conditional on the uniform-error model; the power ratio is not a universal property of every sequence passed through a quantizer.[24]

$$E[e]=0, E[e^2]=\frac{\Delta^2}{12}$$

$$\mathrm{SQNR}=20N\log_{10}(2)+10\log_{10}\left(\frac{3}{2}\right)+20\log_{10}(a)$$

A further assumption is needed to predict noise in a channel. If the sampled error is white with variance $\frac{\Delta^2}{12}$, its one-sided density over zero to $\frac{f_s}{2}$ is $\frac{\Delta^2}{6f_s}$, in volts squared per hertz. For a digital filter with unit reference gain and one-sided equivalent noise bandwidth B_e, the output error power is $\frac{\Delta^2 B_e}{6f_s}$. This follows by integrating the density against squared filter magnitude. The improvement relative to full-Nyquist error is $10\log_{10}[\frac{f_s}{2B_e}]$. It requires anti-alias filtering before decimation and retained signal gain. Merely selecting every Dth sample does not reduce the variance of independent samples. Neither the white-error premise nor this bandwidth calculation applies automatically to deterministic quantization lines.[25]

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24 Keysight Technologies, “EVM Normalization Reference (Digital Demod),” 89600 VSA Help, 2026 Update 2.0, constellation-maximum and reference-RMS alternatives and trace-versus-metric distinction, accessed November 1, 2026, https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/digdemod/content/dlg_digdemod_comp_evmnormref.htm.

25 Keysight Technologies, Digital Modulation in Communications Systems: An Introduction, application note 5965-7160E (5 July 2024), printed pages 13–14, https://www.keysight.com/us/en/assets/7018-09093/application-notes/5965-7160.pdf. These introductory passages distinguish bit and symbol rates while explicitly excluding

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$$S_e = \frac{\Delta^2}{6 f_s}, P_e = \frac{\Delta^2 B_e}{6 f_s}$$

$$G = 10 \log_{10}[\frac{f_s}{2 B_e}]$$

Here f_s is the sampling frequency and B_e the one-sided equivalent noise bandwidth, both in hertz; S_e is the one-sided error spectral density in volts squared per hertz, P_e is error mean square in volts squared, and G is the improvement in decibels. These symbols describe the stated error model, not independent measured specifications.

The original tutorial cited here derives the uniform-error estimate and distinguishes correlated errors from a broad noise spectrum. Its formula describes an ideal model, not a calibration certificate. The following calculations are independent examples derived from the stated assumptions; they do not import plot coordinates or equipment observations.

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synchronization and error-correction overhead. Model 7B independently derives its finite coding, framing, time and duplicate-payload accounting under the stated premises; no commercial performance or error-probability claim is imported.

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10.94 Application 1 Voltage spacing and error budget

A hypothetical 10-bit channel has a 2 V nominal span. $\Delta = \frac{2\ \mathrm{V}}{1024} = 1.953125\ \mathrm{mV}$.

Uniform error would have RMS $\frac{\Delta}{\sqrt{12}} \approx 0.563819\ \mathrm{mV}$, whereas the deterministic magnitude bound is 0.9765625 mV. A specification requiring an error smaller than 0.7 mV for every sample is not met merely because the model RMS is below that value. The distinction is between a mean-square prediction and a maximum-error requirement.

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10.95 Application 2 A small signal in a fixed range

A nominal 10-bit sine at one quarter of the reference peak has ideal SQNR $[61.9669 + 20\log_{10}\backslash(\frac{1}{4}\backslash)]\ \mathrm{dB} \approx 49.9257\ \mathrm{dB}$. Keeping Δ fixed while halving amplitude once more removes another 6.0206 dB. Increasing digital gain after conversion scales both signal and error and restores neither lost amplitude distinctions nor their ratio.

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10.96 Application 3 Crest-factor headroom

Suppose a non-sinusoidal signal has peak-to-RMS ratio four and its peak is limited to $\frac{F}{2}$. Its mean square is $\frac{F^2}{64}$. Relative to a full-reference sine, whose mean square is $\frac{F^2}{8}$, it loses $10\log_{10}\backslash(8\backslash)\ \mathrm{dB} \approx 9.0309\ \mathrm{dB}$ of model margin at the same peak. For $N = 10$, its ratio is therefore 52.9360 dB if the uniform error assumption still holds. Peak control alone does not specify RMS margin.

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10.97 Application 4 Filtered noise power

Let $f_s = 8\ \text{MHz}$ and $B_e = 125\ \text{kHz}$, with unity signal gain. The retained white-error fraction is $\frac{2B_e}{f_s} = \frac{1}{32}$. Its RMS is reduced by $\sqrt{32}$, and its signal-to-error ratio improves by 15.0515 dB. This is an integration over squared response, so substituting a filter's nominal 3 dB bandwidth for B_e without verification can misstate the result.

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10.98 Application 5 Minimum integer code count

A quarter-reference sine needs at least 60 dB of model SQNR over the full Nyquist band. Solving $N \geq \frac{60 - 10\log_{10}\left(\frac{3}{2}\right) - 20\log_{10}\left(\frac{1}{4}\right)}{20\log_{10}(2)}$ gives a numerical threshold of approximately 11.6733 for the bit count, hence at least 12 bits. Eleven bits give 55.9463 dB; twelve give 61.9669 dB. This is an ideal necessary planning choice under the model, not sufficient acceptance of a physical converter.

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10.99 Application 6 Exact code-center counterexample

For an unsaturated rounding quantizer $Q(x) = \Delta \operatorname{round}(\frac{x}{\Delta})$, choose the deterministic record $\frac{x}{\Delta} = [-2, -1, 0, 1, 2]$. Every output equals its input, so all five errors and their mean square are exactly zero. Substituting $\frac{\Delta^2}{12}$ would be incorrect for this record. A favorable code-center test is therefore not evidence that other input levels have no quantization error.

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10.100 Application 7 A periodic error sequence

Let $\frac{x}{\Delta}=[\frac{1}{4},\frac{3}{4},\frac{1}{4},\frac{3}{4}]$, repeated. Rounding gives $\frac{Q\backslash(x\backslash)}{\Delta}=[0,1,0,1]$, hence $\frac{e}{\Delta}=[\frac{-1}{4},\frac{1}{4},\frac{-1}{4},\frac{1}{4}]$. Its mean is zero, mean square is $\frac{\Delta^2}{16}$, and lag-one correlation is negative rather than zero. All error energy lies in the alternating component. A broad-band white-noise allocation would distribute that error into channels incorrectly.

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10.101 Application 8 Mean-square error is not always variance

The constant input $x = \frac{\Delta}{4}$ rounds to zero. Error is $-\frac{\Delta}{4}$, variance around its own mean is zero, and mean-square error relative to the original input is $\frac{\Delta^2}{16}$. Removing DC from both input and output before comparing them can hide this bias. The relevant metric depends on whether the measurement seeks an AC waveform or an absolute input level.

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10.102 Application 9 Averaging correlated versus independent errors

Four independent zero-mean errors of common variance $\frac{\Delta^2}{12}$ have average variance $\frac{\Delta^2}{48}$. Four identical errors instead retain variance $\frac{\Delta^2}{12}$, because all covariance terms contribute. Independence thus yields 6.0206 dB improvement, while perfect correlation yields none. The constant-bias record in Application 8 retains its bias under averaging regardless of sample count.

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10.103 Application 10 Decimation without filtering

Take independent zero-mean white errors of variance $\frac{\Delta^2}{12}$ and keep every fourth sample. Each retained sample has the same distribution and variance; the output rate becomes $\frac{f_s}{4}$. A mistaken use of a fourfold process gain would predict $\frac{\Delta^2}{48}$, which belongs to a suitable averaging/filtering operation, not bare sample deletion. In a physical chain, out-of-band components can additionally alias into the retained band.

Table 1. Chapter 10 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Analog-digital boundary	Protection, filters, gain, converter range, clock, and calibration	Defines what the samples physically represent	Software cannot recover information lost before conversion
Sampling and alias control	Sample rate, Nyquist zone, analog bandwidth, filters, and rate-change tests	Maps digital frequency to possible RF origins	Stable aliases can be misattributed
DDC and channelizer	NCO, filters, decimation, scaling, channel grid, and transient state	Creates efficient selected-band data	Boundary and alias behavior can change amplitude and timing
Recording path	Buffers, packet sequence, timestamps, overflow, file format, storage, and hashes	Preserves sample continuity and data lineage	Dropped or repeated samples generate false spectral features

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10.104 Hypothetical Applied Calculation: Software-Defined Radios, Sampling, Quantization, DDC, and Channelization

A 14-bit ADC has an ideal full-scale sinusoidal quantization SNR near 86.0 dB. If the signal uses only one eighth of full-scale amplitude, its power is 18.1 dB lower while quantization step size is unchanged, reducing the ideal relative margin to about 67.9 dB before other converter impairments.

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10.105 Hypothetical Case Adjudication: Software-Defined Radios, Sampling, Quantization, DDC, and Channelization

An SDR recording shows periodic broadband impulses every 1.024 s. The same interval appears in the USB packet sequence log as buffer overflows, and changing the storage destination removes both the overflow and the impulses. These observations support a recording-path explanation and require checking sample continuity and the processing of affected records before using those impulses as evidence of an environmental transmitter. The stated observations do not by themselves establish that no environmental burst was present.

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10.106 Converter and Waveform-Recorder Validation Boundary

IEEE 1241-2023 provides current terminology and test methods for analog-to-digital converters sampled at known time intervals. IEEE 1057-2017 separately governs digitizing waveform recorders.[26] A complete SDR or receiver result depends upon the converter, clock, analog front end, digital downconverter, firmware, host interface, dropped-sample behavior, scaling, metadata, and software processing. Converter compliance alone does not validate the receiver system.[27]

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26 Tektronix, Fundamentals of Real-Time Spectrum Analysis, 37W-17249-4 (August 2009), 5, “The Swept Spectrum Analyzer,” https://download.tek.com/document/37W_17249_4.pdf. This source supports the successive-frequency architecture and its transient limitation. Current hybrid, FFT-assisted, or real-time instrument modes require their own documented acquisition model.

27 Keysight Technologies, “Spectrum Analyzer,” E505xA help, “SA Setup Dialog,” Detector Type and Video Averaging Type entries, https://helpfiles.keysight.com/csg/e5055a/Applications/Spectrum_Analyzer.htm, accessed October 30, 2026. One implementation, not all analyzers.

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10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio

Engineering question. Estimate the ideal full-scale sine-wave quantization signal-to-noise ratio for a nominal 12-bit converter.

Variables and units. $N = 12$ bits; $\mathrm{SNR}_{\mathrm{ideal}}$ is in decibels.

$$\mathrm{SNR}_{\mathrm{ideal,dB}} \approx 6.02\,N + 1.76$$

Calculation. $\mathrm{SNR}_{\mathrm{ideal}} \approx \backslash(6.02 \times 12 + 1.76\backslash)\ \mathrm{dB} = 74.0\ \mathrm{dB}$.

Dimensional check. Bit count is dimensionless and the coefficients produce a logarithmic result in decibels.

Uncertainty and valid range. The relation is an ideal quantization limit for a full-scale sine wave. It excludes aperture jitter, thermal noise, nonlinearity, missing codes, clock phase noise, front-end distortion, clipping, spurs, and digital processing.

Practical meaning. A 12-bit label does not establish 74 dB of usable dynamic range. Effective number of bits and system-level tests must be measured for the actual sampling condition.

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10.108 Parallel ADC arrays, correlated quantisation error and claims of synthetic resolution

Parallel ADCs can reduce certain noise contributions through averaging, or extend time sampling through deliberately offset aperture phases, but the two architectures solve different problems. Suppose M simultaneously sampling channels measure the same bounded analogue voltage x(t) with individual additive errors e_i(t). The average sample y(t) = (1/M) sum_i [x(t) + e_i(t)] retains the signal while averaging the errors. Its error variance is (1/M squared) times the sum of every pairwise error covariance. Only under independent, zero-mean, equal-variance errors does this reduce to sigma squared divided by M. Quantisation errors may be highly correlated when all channels share the same input and thresholds, so independence cannot be asserted from separate package serial numbers. An input dither or deliberate threshold offset may alter the dependence, but introduces other calibration and dynamic-range obligations.

For M = 16 independent equal-noise channels, averaging reduces random error variance by a factor of sixteen and standard deviation by four. The ideal improvement in amplitude-related signal-to-noise ratio is 20 log10(4) = 12.041 dB, often colloquially equivalent to approximately two additional bits under an appropriately defined quantisation-limited ENOB model. Sixteen nominal 14-bit converters do not thereby become one physical 224-bit converter, nor is 14 plus 14 a justified 28-bit accuracy claim. Shared reference errors, analogue nonlinearity, threshold integral nonlinearity, clock jitter, power-supply coupling and finite input bandwidth can remain

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unchanged under averaging. The useful figure is measured signal fidelity under stated conditions, not a sum of nominal label widths.

A time-interleaved array uses staggered aperture times to increase the aggregate sample-event rate. For four channels each sampling at 250 MS/s with ideal quarter-period placement, the aggregate sequence can provide a nominal 1 GS/s set of sample times. Yet it does not increase the signal-to-noise ratio by the simultaneous averaging law because each channel observes a different instant. Timing skew, offset, gain mismatch and frequency-response mismatch produce structured spurs. At input frequency f_{in}, a small rms aperture timing uncertainty σ_t yields an idealised jitter-limited ratio $SNR_j = -20 \log_{10}(2 \pi f_{in} \sigma_t)$, provided the small-error approximation applies and the error model is appropriate. For 100 MHz and 1 ps, the calculated limit is about 64.04 dB. Any other distortion or noise will worsen system performance; this is not the achieved ENOB of the array.

Engineering qualification should therefore begin with a declared architecture: simultaneous coherent averaging, time interleaving, spatial sampling, or a hybrid. Characterise each channel's analogue transfer, converter linearity, aperture timing and output statistics, then verify the combined signal with known multi-tone and pulse stimuli across the intended frequency and amplitude range. Preserve the raw per-channel records before combining them; otherwise a spurious improvement cannot be independently explained. IEEE 1241-2023 provides terminology and ADC evaluation methods, while waveform-recording performance must additionally be assessed as a system. The public standard abstracts do not

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certify a particular implementation or justify assigning a new nominal word length without a traceable experiment.

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10.109 Advanced technical expansion. Converter-array resolution and physical information limits

The nominal bit width of an ADC describes a digital encoding arrangement, not a guarantee of equal physical accuracy. Quantisation error may be approximated as uniform and uncorrelated with the input only under specified conditions; differential and integral nonlinearity, aperture jitter, reference-voltage variation, harmonic distortion and correlated front-end noise limit realised performance. IEEE 1241-2023 provides public terminology and test-method scope for converters sampling at known intervals, but individual device compliance and performance require actual measurements and the applicable complete standard. The technical argument must therefore distinguish nominal code precision, SINAD-based effective resolution, dynamic range in a stated bandwidth and the reproducibility of a particular waveform estimate. A display reporting a 32-bit floating-point sample has not thereby created 32 bits of analogue knowledge.

Consider N simultaneous converters measuring the same stable input and providing individually calibrated samples with independent, equal-variance, zero-mean random errors. Their arithmetic average has error variance $sigma^2/N$, so ideal SNR improves by 10 log10(N) decibels, equivalent to 0.5 $log_2(N)$ extra bits under the restrictive assumptions of a suitable noise-limited comparison. Sixteen channels yield 12.04 dB or two ideal effective bits. However, if error covariance has nonzero off-diagonal terms, the variance of the average becomes $(1/N^2)$ times the sum of all entries of the covariance matrix, and an uncalibrated common error may remain

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unchanged by averaging. This explicit covariance formula is the correct replacement for the alluring but false proposition that concatenating the output words of two 14-bit converters yields a physical 28-bit measurement.

Time interleaving is a different architecture. Multiple converters sample at staggered instants and can increase aggregate temporal sampling rate, but each converter's offset, gain, aperture skew and bandwidth difference produces periodic artefacts. A two-channel interleaver with a relative time skew delta_t introduces a small frequency-dependent phase error approximately 2 pi f delta_t at physical frequency f. At 100 MHz, a 10-ps skew corresponds to 0.006283 radians or about 0.36 degrees. The result grows with frequency; a correction fitted only at baseband may not remain applicable near the upper useful input band. Oversampling also does not repeal the analogue bandwidth, anti-aliasing, timing and memory-throughput limits that determine which physical information was ever admitted.

Aperture jitter is often assessed using the ideal sinusoidal relation SNR_jitter approximately -20 log10(2 pi f_in sigma_t), where f_in is sinusoidal input frequency and sigma_t is RMS timing uncertainty under the defined jitter model. This relation arises because small sampling-time errors create voltage errors proportional to waveform slope; it is not a universal SINAD model including every distortion source. For a hypothetical 100-MHz sine wave and 100-fs RMS jitter, 2 pi f sigma_t is approximately 6.283 × 10^-5 and the corresponding ideal upper SNR is about 84.04 dB. This says nothing about reference spurs, thermal noise, harmonic distortion or whether the jitter was correlated across multiple converter channels. The full receiver chain needs independent measurement of those other effects.

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Parallel converter claims should be accepted through a controlled test whose reference system is superior in the quantities under examination. Measure each channel's input transfer, spur levels, gain and offset, clock relationships and response to amplitude and frequency changes. Form the array estimator only after recording its weights and calibration, then evaluate on held-out signals not used to fit the correction. Compare the result with both the best individual channel and a suitably calibrated reference instrument. Include large blockers and brief pulses, because an average that performs well for a slowly varying sine may smear a transient or reproduce a shared overload. Preserve the individual-channel raw records so an apparent gain cannot be manufactured by selecting only favourable channels after seeing the desired outcome.

The digital downconverter and channeliser must also be represented as measurements with state and bandwidth. Frequency translation, filtering and decimation can preserve a selected complex band if the alias rejection and filter response meet the intended requirements. Once spectral content has been rejected, no subsequent interpolation restores it. Quantisation inside a fixed-point filter can change noise and spur behaviour according to word length, scaling and saturation policy; floating-point processing has different numerical boundaries, not automatic physical fidelity. Reproducibility requires sample ordering, numerical format, complex sign convention, filter coefficients, overflow handling and software revision. Engineering precision and forensic trust converge in the ability to reconstruct exactly which acquired information each output retained.

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10.110 Complex I/Q acquisition: physical meaning, signed frequency, calibration and defensible identification

A recorded complex signal consists of two simultaneously indexed coordinate sequences, conventionally called in-phase and quadrature, rather than two independent radio transmissions. The receiver forms these coordinates by projecting the incident real-valued RF waveform upon approximately orthogonal reference oscillations, low-pass filtering and sampling. In an ideal sign convention, mixing with cosine produces I(t) and mixing with the negative sine produces Q(t), so that $z(t)=I(t)+jQ(t)$ represents an analytic equivalent about a declared reference frequency. The sign of Q, the local-oscillator reference convention, anti-alias filter response and sample-clock rate determine the meaning of positive and negative digital frequency. Interchanging I and Q, reversing the Q sign, or changing the complex-oscillator sign mirrors or rotates a spectrum; a silent convention change can convert an apparently positive carrier offset into a negative one. The unambiguous quantity is not a display colour but the complete recorded mapping of RF frequency onto complex sample frequency.

Write the ideal complex-baseband observation as $z[n]=g\, s(nT_s-\tau) \exp\{j(2\pi\Delta f\, nT_s+\varphi_0)\}+d+\eta[n]$, where n is an integer sample index, T_s is the sample period in seconds, s is the incident complex waveform referred to a named input plane, g is a complex conversion gain, τ is a physical and computational delay, Δf is residual frequency offset in hertz, φ_0 is initial phase in radians, d is a fixed or slowly varying complex DC term and η is receiver-added noise plus any excluded residual. This is a local model for a specified fixed state, not a universal law through compression, missing

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buffers or automatic-gain transitions. It demonstrates why waveform classification is conditional: the same emitter waveform can have different digitised phases, offsets, amplitude scaling and carrier placements on two instruments. Before comparing them, estimate or bound the nuisance parameters with an independent calibration or a transparent joint estimator.

An uncalibrated I/Q imbalance is conveniently written in a widely linear form $z_{obs}[n]=\alpha\, z_{ideal}[n]+\beta\, \mathrm{conj}(z_{ideal}[n])+d+\eta[n]$. Here α is the wanted complex response and β multiplies the conjugate, representing image leakage under the local model. Their ratio controls how a mirror-frequency feature can imitate a second emitter. For a single isolated complex tone, the image-rejection ratio is approximately $20 \log10(|\alpha|/|\beta|)$ dB when other terms are negligible. An apparent pair of equal and opposite digital-frequency lines therefore does not necessarily indicate two radios. Test with a known single-sideband reference at several offsets, gain states and sample rates. Correcting one observed image with an arbitrary notch can destroy the evidence needed to reconstruct the original converter imbalance.

Amplitude, instantaneous phase, differential phase, complex autocorrelation, cyclic spectral coherence, occupied bandwidth, pulse-repetition structure and modulation-specific statistics can all be derived from I/Q. None singly constitutes a unique transmitter fingerprint. A raised-cosine symbol envelope or a particular cyclic frequency may suggest a waveform family, but multiple implementations can share it. Likewise, a stable oscillator offset can arise from reference mismatch or frequency translation in the measurement chain. Class labels should be expressed as

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hypotheses supported by measured features, a specified classifier or tested likelihood, and comparison data from other plausible signal classes. Distinguish waveform-family identification from an inference about the physical emitter, geographic source, intended recipient or carried content.

Signal extraction begins with defining the objective and available acquisition. After verifying original sample continuity, sample rate, gain, timing and frequency convention, apply a frequency translation, a known filter and a justified decimation only when the desired waveform fits the preserved passband and the out-of-band rejection is sufficient. If decimation reduces sample rate by D, the retained Nyquist region shrinks accordingly. A narrow extracted channel is a derivative of a wider record; it does not restore anything that analog preselection, clipping or original capture never admitted. Preserve a cryptographic digest of the source chunk, the exact input-sample index interval, filter coefficients, processing code revision, complex-oscillator phase convention and output transformation. A derived audio file, constellation plot or decoded packet is not a substitute for those original coordinates.

A full validation combines authorised synthetic signals with field-like noise, blockers and deliberately ambiguous waveforms. Acquire controlled positive and negative frequency offsets, stable tones, frequency-agile bursts, AM, SSB, FM, phase-coded pulses and a known null case. Test the complete conversion and extraction chain using withheld signal instances, not merely the training signals with a new name. For every inferred signal report detection opportunity, extracted bandwidth, actual receiver state, occupied time span, classification confidence if calibrated, unresolved alternatives and any information that was discarded. Where legal collection authority is

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limited to technical characteristics, decoding arbitrary communication content is not an automatic or necessary part of signal identification.

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10.111 Eight-, twelve-, fourteen-, sixteen- and twenty-four-bit complex sample representations

Sample width must be separated into analogue converter resolution, effective noise-and-distortion performance and file representation. A converter advertised with N physical output bits can exhibit fewer effective bits because of thermal noise, aperture jitter, differential and integral nonlinearity, reference errors, interleaving mismatch or analogue distortion. A signed complex sample stored with twenty-four bits each for I and Q is simply a numerical representation unless a calibrated analogue path demonstrates corresponding information content. Padding a fourteen-bit ADC result into a twenty-four-bit integer does not create ten extra physically meaningful bits, just as averaging sixteen channels does not manufacture sixteen independent observations of one transient without noise independence and temporal coincidence.

For an ideal full-scale sinusoid and uniform independent quantisation error, the conventional approximate signal-to-quantisation-noise ratio is $SQNR \approx 6.02N+1.76$ dB, where N is the quantiser's nominal bit count. The ideal figures are 49.9, 74.0, 86.0, 98.1 and 146.2 dB for 8, 12, 14, 16 and 24 bits, respectively. These are teaching upper benchmarks under the stated sinusoidal and quantisation assumptions, not measured converter specifications, and they say nothing about sensitivity when analogue noise dominates. Effective number of bits inferred from SINAD is conditional upon test waveform, frequency, amplitude, bandwidth, clock and method. IEEE 1241-2023 supplies public terminology and methods for ADC assessment; its

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publication scope is not evidence that any particular proposed converter meets those ideals.

Eight-bit complex samples are economical for high-rate occupancy analysis and event triggers, but insufficient analogue headroom can make small signals disappear behind quantisation or large-signal clipping. Twelve-bit packed recording gives a better nominal resolution-to-bandwidth balance, provided samples are truly packed into three bytes per complex pair rather than promoted to two sixteen-bit words. Fourteen-bit packed samples nominally use 3.5 bytes per complex pair; practical interfaces may pad them to four bytes or impose lane alignment, which must appear in ingestion budgets. Sixteen-bit I and sixteen-bit Q offer convenient arithmetic and interoperable file formats, but the additional transport width cannot be treated as additional analogue precision when the source converter has fewer meaningful bits. Twenty-four-bit fixed-point I and Q can be useful for accumulated gain corrections or preserving high-dynamic-range processed results, at a six-byte payload per complex sample; it makes no promise about physical input ENOB. Floating-point processing changes the numerical range and rounding behaviour further without undoing earlier clipping or lost information.

Data-rate calculations require both components. If R is the aggregate rate of valid complex samples in samples per second and b is the stored bits per I or Q component, an ideally packed payload needs R(2b)/8 bytes per second. For R=40×10^9 complex samples/s, the five formats require 80, 120, 140, 160 and 240 GB/s, respectively, using decimal gigabytes. Across 14,400 seconds, their exact ideal raw payloads are 1.152, 1.728, 2.016, 2.304 and 3.456 PB. This simplification assumes aggregate complex sample rate equals

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the intended 40 GHz total useful passband, with no oversampling, guard bands, receiver overlap, framing or loss. Physical implementation normally requires additional spectral margins and may need more aggregate samples. It is incorrect to multiply forty gigahertz of coverage by every channel's independent sample rate without first identifying overlap and total represented passband.

The expected input to the GPU differs from the disk representation. An FPGA might perform sign extension and convert packed fourteen-bit I/Q to sixteen-bit lanes for a general-purpose I/O interface, or even float32 pairs for frequency-domain processing. In the latter case, the internal buffer traffic becomes eight bytes per complex point, giving 320 GB/s for a hypothetical aggregate 40 Gsamples/s. Copying each block host-to-device and back doubles or triples some fabric movements. The bandwidth claim must therefore be made for every segment of the path, including ADC link, FPGA lanes, network encapsulation, PCIe or other device fabric, GPU ingress, memory read/write traffic, and storage. GPUDirect transfers can avoid some host-memory copies on supported topologies, but they do not remove the source rate or the need to measure sustained rather than headline peak throughput.

A verification fixture should generate a weak controlled tone alongside a stronger blocker and measure noise floor, clipping frequency, spurious-free dynamic range, missing-sample rate and output spectral bias in every packing mode. Repeat at temperature and with the same analogue gain state. Show whether an observed difference is caused by the converter, FPGA bit-shifting, scaling, arithmetic precision, or transport layout. Archive sample-packing test vectors containing negative full-scale, zero, positive full-

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scale and sign-boundary values; a single endian error or mistaken offset-binary interpretation can turn ordinary noise into an apparent spectral line or a correlated complex-plane feature.

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Chapter Summary

An SDR is a configurable analog and digital measurement chain. Sample-rate challenges, converter-state checks, channelizer verification, and continuity metadata are required before software-derived spectra or decodes are assigned to the environment.

Sampling leaves frequency equivalence classes that must be restricted by the admitted analog band and supported conversion plan. Ideal quantization estimates require stated error distributions; filtering gains require additional spectral assumptions. Digital mixing, filtering and channelization preserve meaning only when signs, coefficient vectors, normalization, retained phases and output labels are explicit.

Finite arithmetic adds its own conversion schedule, range proof and rounding bounds. Output rescaling cannot repair earlier clipping or lost precision. Continuity then ties stored positions to source indices, valid filter history and clock segments. Zero filling, deletion and state resets change different aspects of the operation and must remain visible.

Framework 10F binds the tested behavior to actual loaded artifacts, configuration and applicable criteria. A valid signature, successful installation or agreeing software outputs cannot replace the relevant technical evidence. Acceptance requires every mandatory applicable criterion to be satisfied; unresolved conditions retain that status, and changes trigger review of the affected dependencies.

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Chapter 10 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C10-MCQ-001. Why is an SDR configuration described as executable measurement logic?

A. It makes all digital outputs independent of firmware state

B. It determines the transformations and meaning of the stored samples

C. It replaces the need to characterize the analog input path

D. It guarantees every software label identifies an RF source

Answer: B. Rates, gain, coefficients, scaling, and formats define the actual measurement path. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

Why the selected alternative fits: It determines the transformations and meaning of the stored samples.

Distinguishing consideration: compare this with option A, “It makes all digital outputs independent of firmware state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — SDR Boundary and Partitioning.

Review: Chapter 10 — SDR Boundary and Partitioning.

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V011-C10-MCQ-002. Which condition can digital amplitude scaling conceal without repairing?

A. Clipping that already occurred at the ADC

B. An unchanged sample-counter origin

C. The documented multiplication factor itself

D. A known linear conversion of intact samples

Answer: A. Clipped information is lost before rescaling; examine flags, histograms, and gain-step behavior. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

Why the selected alternative fits: Clipping that already occurred at the ADC.

Distinguishing consideration: compare this with option B, “An unchanged sample-counter origin”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization, Clipping, and Converter Performance.

Review: Chapter 10 — Quantization, Clipping, and Converter Performance.

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V011-C10-MCQ-003. With negative-exponential mixing, a 9 MHz complex tone and an 8 MHz NCO produce what translated frequency before filtering?

A. Minus 1 MHz

B. Minus 17 MHz

C. Plus 1 MHz

D. Plus 17 MHz

Answer: C. The declared mixer subtracts NCO frequency from the input frequency.

Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: Plus 1 MHz.

Distinguishing consideration: compare this with option A, “Minus 1 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-004. A DDC takes every eighth filtered sample. Does this automatically divide a settled tone's voltage amplitude by eight?

A. No; amplitude remains the input amplitude times the filter-response magnitude

B. Yes; every retained tone loses a factor of eight in voltage

C. Yes; but only complex tones lose that factor

D. No; decimation instead multiplies every tone voltage by eight

Answer: A. Sample selection changes rate and phase progression, not an automatic individual-tone amplitude scale. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why the selected alternative fits: No; amplitude remains the input amplitude times the filter-response magnitude.

Distinguishing consideration: compare this with option B, “Yes; every retained tone loses a factor of eight in voltage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-MCQ-005. What does retained phase p denote in the DDC model?

A. An oscillator angle in radians

B. The number of independent channels

C. An input-index residue within the decimation interval

D. The filter's passband ripple

Answer: C. The output samples are taken at input indices mM+p; p is an index, not an angle. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why the selected alternative fits: An input-index residue within the decimation interval.

Distinguishing consideration: compare this with option A, “An oscillator angle in radians”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-MCQ-006. At what frequency should the pre-decimation filter response be evaluated for a tone?

A. Only the analog RF label without conversion history

B. The nearest channel center regardless of offset

C. Only its final folded output label

D. Its translated frequency on that filter's input clock

Answer: D. Different pre-deletion frequencies can fold together while receiving different filter gains. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why the selected alternative fits: Its translated frequency on that filter's input clock.

Distinguishing consideration: compare this with option A, “Only the analog RF label without conversion history”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-MCQ-007. Two tones have already combined at the same complex output frequency after unfiltered decimation. What can a later linear filter do?

A. Recover both original coefficients solely by narrowing its passband

B. Apply one response to the combined sequence, without separating former frequencies alone

C. Undo the combination automatically if output rate is known

D. Reject only the former blocker by using its original RF label

Answer: B. The retained sequence no longer carries separate frequency coordinates for those contributions. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why the selected alternative fits: Apply one response to the combined sequence, without separating former frequencies alone.

Distinguishing consideration: compare this with option A, “Recover both original coefficients solely by narrowing its passband”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-MCQ-008. A 2 V peak real cosine is multiplied by a unit-amplitude complex exponential, with no additional factor-two scaling, and one sideband is retained through unit gain. What is its complex coefficient amplitude?

A. One eighth V solely because decimation is eight

B. 1 V

C. 4 V

D. 2 V

Answer: B. A real cosine has two complex coefficients, each half its peak amplitude; normalization must remain explicit. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: 1 V.

Distinguishing consideration: compare this with option A, “One eighth V solely because decimation is eight”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-009. Why must a multistage rejection ledger use each stage's actual input frequency?

A. Final folded frequency uniquely specifies each earlier gain

B. Earlier rate changes can move a blocker before later filtering

C. The attenuation at the original RF frequency applies unchanged at every stage

D. All filters have identical frequency coordinates

Answer: B. Stage gains multiply along the actual frequency path, including intermediate folding. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: Earlier rate changes can move a blocker before later filtering.

Distinguishing consideration: compare this with option A, “Final folded frequency uniquely specifies each earlier gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-010. A filter rejects a test tone exactly at one moving-average null. What has been demonstrated?

A. Uniform rejection throughout the entire stopband

B. Rejection at that tested frequency, not the surrounding alias band

C. Perfect blocker control for every decimation ratio

D. Absence of earlier analog overload

Answer: B. A narrow zero does not establish neighboring response; the actual alias-entry band needs testing. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: Rejection at that tested frequency, not the surrounding alias band.

Distinguishing consideration: compare this with option A, “Uniform rejection throughout the entire stopband”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-011. Why is FIR group delay insufficient to choose the startup discard interval?

A. One output interval is sufficient for every linear-phase filter

B. A symmetric FIR has no startup behavior

C. Startup depends on coefficient support, initial history, retained phase, and error criterion

D. Group delay always equals the number of missing input samples

Answer: C. Settled phase slope and complete history are different properties.

Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: Startup depends on coefficient support, initial history, retained phase, and error criterion.

Distinguishing consideration: compare this with option A, “One output interval is sufficient for every linear-phase filter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-012. A symmetric 33-tap FIR at 48 MS/s has ordinary linear-phase delay away from zeros. What is that delay?

A. 16 input samples, about 333.33 ns

B. 32 input samples, about 666.67 ns

C. Zero because symmetry removes delay

D. 33 output samples regardless of decimation

Answer: A. The center lag is $\frac{(33-1)}{2}$ = 16; startup support remains a separate question. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: 16 input samples, about 333.33 ns.

Distinguishing consideration: compare this with option B, “32 input samples, about 666.67 ns”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-013. Two otherwise identical settled channels retain phases p=0 and p=3 for a 1 MHz tone at 48 MS/s. What phase difference is introduced at a common output index?

A. 3 degrees

B. 180 degrees

C. 60 degrees

D. 22.5 degrees

Answer: D. Three input intervals produce 360 times $\frac{1}{48}$ times 3 degrees, with a 62.5 ns time-origin difference. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: 22.5 degrees.

Distinguishing consideration: compare this with option A, “3 degrees”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-014. What does a b-bit ideal NCO accumulator determine directly under the stated exact-clock model?

A. A guarantee of zero phase drift over arbitrary duration

B. A universal measured spur-free dynamic range

C. The analog anti-alias filter rejection

D. A frequency grid of input sample rate divided by two to the b

Answer: D. Accumulator word quantization sets tuning resolution; other truncation, arithmetic, and clock effects remain separate. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: A frequency grid of input sample rate divided by two to the b.

Distinguishing consideration: compare this with option A, “A guarantee of zero phase drift over arbitrary duration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-015. Why can a small constant NCO frequency error matter in a long coherent comparison?

A. It changes the FIR coefficients automatically

B. It vanishes when the output rate is lower

C. Its phase error accumulates with elapsed time

D. It necessarily reduces every sample magnitude to zero

Answer: C. Frequency error integrates into phase; fine tuning resolution does not make the accumulated error negligible. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: Its phase error accumulates with elapsed time.

Distinguishing consideration: compare this with option A, “It changes the FIR coefficients automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-016. Does exact polyphase regrouping improve rejection of unchanged coefficients?

A. Yes; branch count directly multiplies stopband attenuation

B. Only if the same coefficients are written in a different order without tracing indices

C. Yes; discarded computations remove additional blockers

D. No; it preserves the original input-output relation

Answer: D. Efficiency changes do not create a new filter response; finite arithmetic differences require separate checking. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: No; it preserves the original input-output relation.

Distinguishing consideration: compare this with option A, "Yes; branch count directly multiplies stopband attenuation"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-017. What must support a phase-continuity claim across files?

A. Only contiguous file counters

B. Input timing, NCO evolution, filter history, retained schedule, and reset/gap handling

C. Only equal output sample rates

D. Only a smooth magnitude spectrum

Answer: B. File adjacency does not prove preserved processing phase or state.

Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: Input timing, NCO evolution, filter history, retained schedule, and reset/gap handling.

Distinguishing consideration: compare this with option A, “Only contiguous file counters”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-018. A 9 MHz NCO at 48 MS/s is reset every 1000 input samples. What artifact can this create relative to continuous phase?

A. A guaranteed integer-cycle continuation

B. Alternating block sign reversal

C. An automatic reduction of tone amplitude by 1000

D. A change only in the file timestamp

Answer: B. Each block spans 187.5 NCO cycles; resetting discards a half-cycle progression and creates a phase discontinuity. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: Alternating block sign reversal.

Distinguishing consideration: compare this with option A, “A guaranteed integer-cycle continuation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-019. Why does a broadband channel comparison need more than one constant phase correction for retained-time offset?

A. Every retained-time offset is exactly a half cycle at all frequencies

B. Only amplitude calibration determines broadband timing

C. The offset's phase effect depends on frequency

D. A constant phase correction changes the sample clock

Answer: C. The same time displacement produces different phase shifts across frequency. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why the selected alternative fits: The offset's phase effect depends on frequency.

Distinguishing consideration: compare this with option A, “Every retained-time offset is exactly a half cycle at all frequencies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-MCQ-020. What remains unidentified even by a perfectly reproduced DDC sequence?

A. Which analog member of a prior sampling alias class produced the input samples

B. The specified filter coefficients

C. The declared decimation factor

D. The mixer sign actually used in the reference calculation

Answer: A. Digital processing begins after sampling and cannot supply missing analog admission evidence. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why the selected alternative fits: Which analog member of a prior sampling alias class produced the input samples.

Distinguishing consideration: compare this with option B, “The specified filter coefficients”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-MCQ-021. An eight-channel bank decimates by four. What is each channel's output sample rate?

A. Input rate divided by four

B. Input rate divided by eight

C. Input rate multiplied by eight

D. Input rate divided by thirty-two

Answer: A. Channel count and decimation are distinct quantities in Model 10C.

Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

Why the selected alternative fits: Input rate divided by four.

Distinguishing consideration: compare this with option B, “Input rate divided by eight”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10C for a polyphase analysis channelizer.

Review: Chapter 10 — Model 10C for a polyphase analysis channelizer.

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V011-C10-MCQ-022. What sets the signed channel-center grid spacing in the channelizer model?

A. Input sample rate divided only by the output record length

B. Output sample rate divided by filter length

C. The maximum window coefficient

D. Input sample rate divided by channel count

Answer: D. Grid spacing uses M channels; per-channel rate uses the distinct decimation D. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

Why the selected alternative fits: Input sample rate divided by channel count.

Distinguishing consideration: compare this with option A, “Input sample rate divided only by the output record length”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10C for a polyphase analysis channelizer.

Review: Chapter 10 — Model 10C for a polyphase analysis channelizer.

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V011-C10-MCQ-023. Why does the causal polyphase inner transform use a positive exponent?

A. Every inverse FFT has no normalization

B. The physical mixer changes to positive frequency translation

C. The decimation ratio is necessarily negative

D. Expanding the negative mixer at delayed samples leaves a positive lag-phase factor

Answer: D. The sign follows from the explicit lag convention, not the generic word FFT. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why the selected alternative fits: Expanding the negative mixer at delayed samples leaves a positive lag-phase factor.

Distinguishing consideration: compare this with option A, “Every inverse FFT has no normalization”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-MCQ-024. A normalized inverse DFT is used for the stated M-branch positive-exponent sum. What restoration is needed?

A. Multiply by the decimation D for every implementation

B. No restoration because all inverse transforms are unscaled

C. Divide by M again

D. Multiply by M

Answer: D. The defined inner sum is M times the normalized inverse DFT. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why the selected alternative fits: Multiply by M.

Distinguishing consideration: compare this with option A, “Multiply by the decimation D for every implementation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-MCQ-025. Why can a critically sampled implementation not be reused unchanged for D less than M?

A. The outer phase and branch-residue schedule generally change

B. The prototype coefficients alone force the old commutator schedule to remain correct

C. Oversampling only changes the displayed sample-rate label

D. All oversampled outer phases are one

Answer: A. The direct mixer-filter definition requires both correct timing and phase for oversampled outputs. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why the selected alternative fits: The outer phase and branch-residue schedule generally change.

Distinguishing consideration: compare this with option B, “The prototype coefficients alone force the old commutator schedule to remain correct”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-MCQ-026. A single tone lies at a channel boundary and appears strongly in two adjacent outputs. What is supported?

A. The outputs must have independent noise

B. Two emitters are established by the two traces

C. One source can produce both responses through the prototype

D. Adding their uncalibrated powers always gives exact input power

Answer: C. The full response vector and gain convention explain boundary duplication. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: One source can produce both responses through the prototype.

Distinguishing consideration: compare this with option A, “The outputs must have independent noise”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-027. Two different input tones give the same sequence in one retained channel. What may preserve their distinction?

A. The complete bank response when the specified bank is invertible

B. A smaller file format containing fewer channels

C. Repeated copies of that same single-channel sequence

D. The single-channel output frequency label alone

Answer: A. The chapter's rectangular-bank example retains distinctions across the full vector that one channel discards. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: The complete bank response when the specified bank is invertible.

Distinguishing consideration: compare this with option B, “A smaller file format containing fewer channels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-028. What does oversampling ratio $\frac{M}{D}$ establish by itself?

A. A flat calibrated channel passband

B. Aggregate output rate relative to input rate

C. Perfect reconstruction for every prototype

D. Statistical independence of output samples

Answer: B. Rate accounting alone says neither injectivity nor response quality.

Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why the selected alternative fits: Aggregate output rate relative to input rate.

Distinguishing consideration: compare this with option A, “A flat calibrated channel passband”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-MCQ-029. For 64 MS/s input, eight channels, D=4, and four bytes per complex sample, what is aggregate payload rate?

A. 128 MB/s

B. 64 MB/s

C. 256 MB/s

D. 512 MB/s in decimal units

Answer: D. Eight channels each emit 16 million samples per second, each stored in four bytes. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: 512 MB/s in decimal units.

Distinguishing consideration: compare this with option A, “128 MB/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-030. Does white input guarantee independent output channel streams?

A. Yes; different center labels guarantee independence

B. No; tap energies and overlapping histories can create correlation

C. Yes; zero mean alone establishes joint independence

D. Only critical sampling automatically makes every stream independent

Answer: B. Second-order whiteness is not full independence, and the bank can share weighted samples across channels and times. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: No; tap energies and overlapping histories can create correlation.

Distinguishing consideration: compare this with option A, "Yes; different center labels guarantee independence"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-031. A bank has diagonal same-frame covariance but overlapping frames. What may remain?

A. A universal single-record confidence interval

B. Guaranteed independence of all channel streams

C. Zero overlap in source indices

D. Correlation across output times

Answer: D. Same-frame decorrelation describes one slice; common samples can correlate adjacent frames. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: Correlation across output times.

Distinguishing consideration: compare this with option A, “A universal single-record confidence interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-032. Why can unit DC gain and critical aggregate rate fail to establish invertibility?

A. A zero coefficient has no effect on any input history

B. An input-index residue can be multiplied only by zero coefficients

C. Unit DC gain means every impulse is retained equally

D. Critical rate always adds independent missing information

Answer: B. The stated critical-bank counterexample has an entire blind residue despite those two favorable properties. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: An input-index residue can be multiplied only by zero coefficients.

Distinguishing consideration: compare this with option A, “A zero coefficient has no effect on any input history”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-033. What must be retained to apply the chapter's stated oversampled energy bound?

A. The exact coefficients and arithmetic, every channel, and all affected frames

B. Only frames wholly inside a truncated file

C. Only the strongest channel in each frame

D. Any oversampled prototype with the same rate ratio

Answer: A. The bound is configuration- and coverage-specific; omitted outputs can remove its premises. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: The exact coefficients and arithmetic, every channel, and all affected frames.

Distinguishing consideration: compare this with option B, “Only frames wholly inside a truncated file”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-034. What does a positive lower energy bound for the complete stated bank exclude?

A. All variation in energy gain with sample placement

B. A nonzero admissible finite-energy input with all outputs zero

C. Any need for voltage calibration

D. All numerical implementation error

Answer: B. A positive lower bound supports injectivity in that model while unequal bounds permit unequal energy weighting. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: A nonzero admissible finite-energy input with all outputs zero.

Distinguishing consideration: compare this with option A, “All variation in energy gain with sample placement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-035. Which test particularly exposes channel order and transform-sign mistakes?

A. A zero-only vector only

B. Equal amplitude in every output channel only

C. A magnitude plot that discards channel labels

D. A finite nonsymmetric input vector with predicted complex outputs

Answer: D. Asymmetric complex reference outputs discriminate permutations and sign conventions that symmetric tests can hide. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why the selected alternative fits: A finite nonsymmetric input vector with predicted complex outputs.

Distinguishing consideration: compare this with option A, “A zero-only vector only”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-MCQ-036. Why is total bit count insufficient to interpret a fixed-point channel value?

A. Every stored code is already volts

B. The recorded output exponent affects only storage size

C. Fractional bits, signedness, calibration, transform normalization, and scale also matter

D. All formats with equal width have equal steps

Answer: C. The numerical representation and physical conversion jointly define the value. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why the selected alternative fits: Fractional bits, signedness, calibration, transform normalization, and scale also matter.

Distinguishing consideration: compare this with option A, “Every stored code is already volts”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-MCQ-037. For signed S(W,F), what is the real code spacing?

A. W divided by F

B. One volt regardless of calibration

C. Two to the minus F

D. Two to the minus W for every F

Answer: C. Fractional-bit count sets the dimensionless grid; total width sets the signed range. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why the selected alternative fits: Two to the minus F.

Distinguishing consideration: compare this with option A, “W divided by F”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-MCQ-038. Does the half-step nearest-rounding error bound survive saturation?

A. Only when the saturation flag is omitted

B. Yes; if the final display is rescaled

C. Yes; clamping always reduces error below half a step

D. No; a separate range proof is required

Answer: D. The bound applies to an in-range unbounded rounded code, not an arbitrary clipped value. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why the selected alternative fits: No; a separate range proof is required.

Distinguishing consideration: compare this with option A, “Only when the saturation flag is omitted”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-MCQ-039. What makes the four-channel exact-transform example special?

A. Its every input is Gaussian

B. Weights are only plus/minus one and plus/minus j

C. Its coefficients cannot be quantized incorrectly

D. Its outputs need no accumulation width

Answer: B. Widened sums, sign changes, and component exchanges can implement these weights without irrational twiddle rounding. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why the selected alternative fits: Weights are only plus/minus one and plus/minus j.

Distinguishing consideration: compare this with option A, “Its every input is Gaussian”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-MCQ-040. Two implementations have identical quantized FIR coefficients but different outputs. Which explanation remains plausible?

A. Only their filenames can explain the result

B. The coefficients uniquely determine every finite-word computation regardless of architecture

C. Different conversion points, accumulation order, overflow rules, or state

D. Exact coefficients remove all need to check history

Answer: C. Finite-word behavior depends on the entire conversion and state schedule. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: Different conversion points, accumulation order, overflow rules, or state.

Distinguishing consideration: compare this with option A, “Only their filenames can explain the result”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-041. Why is restoring an output shift part of the error budget?

A. It recovers all discarded low bits

B. It changes only units without changing error magnitude

C. It eliminates earlier saturation

D. It magnifies stored output rounding error by the same scale factor

Answer: D. Scale restoration also restores the coarse spacing of the saved code grid. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: It magnifies stored output rounding error by the same scale factor.

Distinguishing consideration: compare this with option A, “It recovers all discarded low bits”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-042. Does nearest-even rounding establish a zero-mean white error process?

A. Yes; every tie rule creates independent errors

B. Only if output rescaling is applied

C. No; repeated inputs can produce deterministic bias

D. Yes; sufficiently many identical frames make error white

Answer: C. The deterministic rounding rule supplies no distribution or independence assumption. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: No; repeated inputs can produce deterministic bias.

Distinguishing consideration: compare this with option A, "Yes; every tie rule creates independent errors"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-043. What can a correct final value conceal in a wrapping accumulator?

A. Intermediate overflow that happens to cancel modulo the code range

B. A valid half-step error bound at every stage

C. A proof that saturation would give the same result

D. A guarantee that all intermediate values were in range

Answer: A. An accidentally correct modular endpoint does not establish the intended exact arithmetic. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: Intermediate overflow that happens to cancel modulo the code range.

Distinguishing consideration: compare this with option B, “A valid half-step error bound at every stage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-044. Why explicitly test the positive range endpoint of a two's-complement format?

A. It has one fewer positive code than the corresponding negative magnitude

B. Symmetric input bounds imply symmetric stored endpoints

C. The negative endpoint is never representable

D. Positive codes always have twice the resolution

Answer: A. Signed range asymmetry can make a product of two negative rails overflow positively. Source: §10.34 Range and error are separate obligations (p. 5728)

Why the selected alternative fits: It has one fewer positive code than the corresponding negative magnitude.

Distinguishing consideration: compare this with option B, “Symmetric input bounds imply symmetric stored endpoints”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Range and error are separate obligations.

Review: Chapter 10 — Range and error are separate obligations.

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V011-C10-MCQ-045. Two values of minus one multiply exactly to plus one. What happens if stored in S(7,6) with saturation?

A. It becomes zero

B. It becomes $\frac{63}{64}$

C. It remains exactly plus one

D. It becomes minus one under saturation

Answer: B. S(7,6) has maximum $\frac{63}{64}$; wrap would be a different operation returning minus one in this example. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: It becomes.

Distinguishing consideration: compare this with option A, “It becomes zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-046. Why can rounding each product differ from rounding once after their sum?

A. Rounding commutes with addition for every input

B. Intermediate quantization changes the values being accumulated

C. The tie rule forces both schedules to agree

D. Only the final fractional width matters

Answer: B. The chapter's two-product example has distinct errors and requires a separate budget for each schedule. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: Intermediate quantization changes the values being accumulated.

Distinguishing consideration: compare this with option A, “Rounding commutes with addition for every input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-047. Why can saturated addition depend on association?

A. Saturation preserves ordinary associativity for every operand

B. Adding more fractional bits always removes range overflow

C. An intermediate clamp irreversibly changes a partial sum

D. The final exact total determines all intermediate saturation

Answer: C. A later compensating term cannot recover the value discarded by an earlier clamp. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: An intermediate clamp irreversibly changes a partial sum.

Distinguishing consideration: compare this with option A, “Saturation preserves ordinary associativity for every operand”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-048. Coefficient rounding preserves DC gain in a test. What remains untested?

A. Response at other frequencies, including rejection

B. The observed DC gain in that case

C. The equality of the two coefficient sums

D. The arithmetic sum used for the DC test

Answer: A. Equal sums do not imply identical frequency weighting; the example changes the alternating-input response. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: Response at other frequencies, including rejection.

Distinguishing consideration: compare this with option B, “The observed DC gain in that case”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-049. What is the status of Model 10D's error envelope under its assumptions?

A. A conservative deterministic voltage bound

B. A sensitivity specification for the analog receiver

C. An exact false-alarm probability

D. A white-noise variance for every input

Answer: A. The bound uses magnitudes and no statistical error model; its arithmetic and range premises must hold. Source: §10.34 Range and error are separate obligations (p. 5728)

Why the selected alternative fits: A conservative deterministic voltage bound.

Distinguishing consideration: compare this with option B, “A sensitivity specification for the analog receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Range and error are separate obligations.

Review: Chapter 10 — Range and error are separate obligations.

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V011-C10-MCQ-050. A constant arithmetic error has zero variance about its own mean. What can remain nonzero?

A. Nothing, because zero variance proves exactness

B. Mean-square error relative to the intended value

C. The number of unknown code bits

D. Only the output sample rate

Answer: B. A constant bias has squared error even though its centered variance is zero. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why the selected alternative fits: Mean-square error relative to the intended value.

Distinguishing consideration: compare this with option A, “Nothing, because zero variance proves exactness”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-MCQ-051. Why can contiguous file placement fail to establish sample continuity?

A. A file sample offset always equals source identity

B. A parsed file necessarily preserves the original clock grid

C. Stored offsets can omit missing source positions

D. Every equal-length block is physically adjacent

Answer: C. Model 10E requires a mapping from retained positions to source indices. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why the selected alternative fits: Stored offsets can omit missing source positions.

Distinguishing consideration: compare this with option A, “A file sample offset always equals source identity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Source indices, stored offsets, and time anchors.

Review: Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-C10-MCQ-052. A first block starts at source 1000 and has 128 samples; the next starts at 1168. How many positions lie between these blocks?

A. 40

B. 168

C. 41

D. 128

Answer: A. The boundary discrepancy is 1168 minus (1000+128), or 40 missing positions if no accepted block supplies them. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

Why the selected alternative fits: 40.

Distinguishing consideration: compare this with option B, “168”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Application 10E.1: a file offset that conceals forty missing samples.

Review: Chapter 10 — Application 10E.1: a file offset that conceals forty missing samples.

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V011-C10-MCQ-053. For the chapter's overlapping two 64-sample blocks, what does discrepancy minus 32 establish before payload comparison?

A. Thirty-two trustworthy duplicate values automatically

B. An error-free reconstruction by averaging any conflicts

C. Thirty-two missing samples

D. Overlapping declared indices, not that the values agree

Answer: D. Index overlap and payload agreement are separate; a conflict remains unresolved until investigated. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

Why the selected alternative fits: Overlapping declared indices, not that the values agree.

Distinguishing consideration: compare this with option A, “Thirty-two trustworthy duplicate values automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

Review: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

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V011-C10-MCQ-054. May a lossless timestamped block boundary reset the FIR to rest automatically?

A. Yes; matching block lengths removes startup effects

B. No; the required state or equivalent history must continue

C. Yes; each timestamp proves zero prehistory

D. Only the oscillator needs continuity, never the filter

Answer: B. Block partitioning is not a physical startup and can create numerical transients even without lost input. Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)

Why the selected alternative fits: No; the required state or equivalent history must continue.

Distinguishing consideration: compare this with option A, "Yes; matching block lengths removes startup effects"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 10 — Application 10E.4: an ordinary block boundary preserves filter history.

Review: Chapter 10 — Application 10E.4: an ordinary block boundary preserves filter history.

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V011-C10-MCQ-055. When is a zero-filled output continuity-invalid?

A. Whenever any earlier sample anywhere in the file was once missing

B. Only when the computed output is visibly large

C. A nonzero coefficient depends on an absent or unresolved source value

D. Only when no numerical error bound can be stated

Answer: C. Computability and a small conditional error bound do not establish the missing dependency. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why the selected alternative fits: A nonzero coefficient depends on an absent or unresolved source value.

Distinguishing consideration: compare this with option A, “Whenever any earlier sample anywhere in the file was once missing”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-MCQ-056. A causal FIR has nonzero support exactly at lags 0 through 6. With missing source indices 10 through 12, output epoch 1, and decimation four, which retained source indices are affected?

A. 9 and 21

B. 13 and 17

C. Every subsequent output without finite recovery

D. 10, 11, and 12 only

Answer: B. The dependency interval is 10 through 18; intersecting the original retained grid leaves 13 and 17. Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)

Why the selected alternative fits: 13 and 17.

Distinguishing consideration: compare this with option A, “9 and 21”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Application 10E.8: decimation retains two outputs from a longer gap tail.

Review: Chapter 10 — Application 10E.8: decimation retains two outputs from a longer gap tail.

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V011-C10-MCQ-057. Why can an output between two invalid outputs remain valid for a sparse FIR?

A. The declared filter may be changed silently to clear the mask

B. An almost-zero coefficient removes dependency exactly

C. Its actual nonzero support may avoid the missing sample

D. Every interior output is valid by interpolation

Answer: C. The support mask, not nominal length alone, determines exact dependence. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

Why the selected alternative fits: Its actual nonzero support may avoid the missing sample.

Distinguishing consideration: compare this with option A, “The declared filter may be changed silently to clear the mask”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Application 10E.7: a zero coefficient changes the validity pattern.

Review: Chapter 10 — Application 10E.7: a zero coefficient changes the validity pattern.

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V011-C10-MCQ-058. When can one constant mixer rotation describe a compact-index error after a gap?

A. Whenever the sample count is an integer

B. Whenever the output magnitudes look smooth

C. Across every gap-crossing convolution automatically

D. When the source-to-stored deficit is constant across the whole contributing support

Answer: D. A support spanning different deficits also changes neighbors and cannot be repaired by one rotation alone. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

Why the selected alternative fits: When the source-to-stored deficit is constant across the whole contributing support.

Distinguishing consideration: compare this with option A, “Whenever the sample count is an integer”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Gap representations, phase, and the limits of timing claims.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-C10-MCQ-059. What does a valid continuity mask certify about clock accuracy and arithmetic overflow?

A. Neither; both need their own evidence

B. Both, because all sample dependencies exist

C. Absence of overflow only

D. Clock accuracy only

Answer: A. Dependency validity is a separate requirement from correct timing calibration and finite-word processing. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why the selected alternative fits: Neither; both need their own evidence.

Distinguishing consideration: compare this with option B, “Both, because all sample dependencies exist”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-MCQ-060. What should happen when overlapping source indices carry conflicting values?

A. Treat waveform resemblance as proof of identical source identity

B. Average them and call the result the original sample

C. Select whichever value makes the spectrum smoother

D. Investigate or mark them unresolved rather than manufacture agreement

Answer: D. Conflicting payloads at one declared source event do not resolve themselves through arithmetic blending. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

Why the selected alternative fits: Investigate or mark them unresolved rather than manufacture agreement.

Distinguishing consideration: compare this with option A, “Treat waveform resemblance as proof of identical source identity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

Review: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

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V011-C10-MCQ-061. What does zero filling preserve that deletion changes?

A. The original index grid, provided a separate validity mask is retained

B. The unknown physical values themselves

C. The original noise distribution at the missing samples

D. A guarantee that every processed output is valid

Answer: A. Deletion compresses chronology and changes filter neighbors, NCO phase, or retained grid; zero filling still lacks the missing values. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

Why the selected alternative fits: The original index grid, provided a separate validity mask is retained.

Distinguishing consideration: compare this with option B, “The unknown physical values themselves”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Gap representations, phase, and the limits of timing claims.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-C10-MCQ-062. With a gap of G missing samples, how many sampling intervals separate the two bounding retained samples?

A. G plus one

B. One regardless of G

C. G

D. G minus one

Answer: A. The missing positions lie between the endpoints; there is one additional interval joining the boundaries. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

Why the selected alternative fits: G plus one.

Distinguishing consideration: compare this with option B, “One regardless of G”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Gap representations, phase, and the limits of timing claims.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-C10-MCQ-063. What should be combined when several gaps have overlapping FIR dependency tails?

A. Only the first affected output

B. Only the longest gap's tail

C. The union of affected output sets

D. The raw sum of tail counts even when they overlap

Answer: C. A union avoids double-counting retained outputs influenced by more than one gap. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why the selected alternative fits: The union of affected output sets.

Distinguishing consideration: compare this with option A, “Only the first affected output”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-MCQ-064. Why does the finite FIR recovery rule not automatically cover recursive loops?

A. Every recursive filter has the same finite lag set

B. A valid file length resets all loop state

C. A zero-filled sample always restores a tracking loop immediately

D. Recursive or adaptive state can retain dependencies beyond finite tap support

Answer: D. IIR, AGC, adaptive, and phase-tracking recovery require their own state models. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why the selected alternative fits: Recursive or adaptive state can retain dependencies beyond finite tap support.

Distinguishing consideration: compare this with option A, “Every recursive filter has the same finite lag set”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-MCQ-065. A zero-filled missing constant-input sample produces responses in otherwise idle channels. What is the supported explanation in the constructed example?

A. A unit DC gain guarantees all idle channels remain zero

B. Three new transmitters must have appeared

C. The channel order alone proves external source multiplicity

D. The discontinuity breaks the bank's cancellation pattern

Answer: D. One missing input can affect all filters sharing that history and generate processing-induced spectral features. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

Why the selected alternative fits: The discontinuity breaks the bank's cancellation pattern.

Distinguishing consideration: compare this with option A, “A unit DC gain guarantees all idle channels remain zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Application 10E.10: one missing input appears in idle channels.

Review: Chapter 10 — Application 10E.10: one missing input appears in idle channels.

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V011-C10-MCQ-066. May a receive-only label automatically exclude every transmit-related requirement?

A. Yes; no further mode evidence can be relevant

B. No; applicability needs a criterion-specific rationale

C. Only if the inventory is signed, regardless of scope

D. Yes; unknown transmit behavior counts as disabled

Answer: B. Transmit performance may be outside scope while a requirement to establish disabled transmission can remain applicable. Source: §10.65 Define the case before testing (p. 5767)

Why the selected alternative fits: No; applicability needs a criterion-specific rationale.

Distinguishing consideration: compare this with option A, "Yes; no further mode evidence can be relevant"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 10 — Define the case before testing.

Review: Chapter 10 — Define the case before testing.

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V011-C10-MCQ-067. How do a verified digest mismatch and a missing authenticated digest differ?

A. Both prove malicious modification

B. The mismatch is weaker than no comparison and should be ignored

C. Both are satisfied if the filename matches

D. The mismatch contradicts the stated identity rule; missing evidence leaves it unresolved

Answer: D. These are different evidence states, neither of which alone identifies an actor or motive. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: The mismatch contradicts the stated identity rule; missing evidence leaves it unresolved.

Distinguishing consideration: compare this with option A, “Both prove malicious modification”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-068. Why can valid signature verification coexist with failed acceptance?

A. A successful signature erases contradictory tests

B. Only unsigned software can have defects

C. Signed content can violate build policy or functional criteria

D. A signature proves every numerical behavior

Answer: C. Identity and provenance evidence cannot replace the other mandatory applicable propositions. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why the selected alternative fits: Signed content can violate build policy or functional criteria.

Distinguishing consideration: compare this with option A, “A successful signature erases contradictory tests”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Separate signed artifacts from operating configurations.

Review: Chapter 10 — Separate signed artifacts from operating configurations.

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V011-C10-MCQ-069. What does an API sample-rate readback establish directly under the stated interface?

A. Absence of aliasing in every admitted band

B. The exact physical clock frequency without a reference

C. A guarantee that the requested rate was accepted unchanged

D. The reported configured rate, not an independent clock-accuracy measurement

Answer: D. Readback can expose coercion and support labeling; physical rate accuracy has a separate measurement criterion. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: The reported configured rate, not an independent clock-accuracy measurement.

Distinguishing consideration: compare this with option A, “Absence of aliasing in every admitted band”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-070. An allowed error interval is minus 0.50 through plus 0.50 dB inclusive. Estimate plus 0.32 with a deterministic half-width 0.18 is classified how under the stated rule?

A. Accepted only by converting the bound into a probability

B. Contradicted

C. Satisfied

D. Unresolved solely because an endpoint is reached

Answer: C. The complete interval is plus 0.14 through plus 0.50, within the inclusive allowed region. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: Satisfied.

Distinguishing consideration: compare this with option A, “Accepted only by converting the bound into a probability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-071. Does expected recording file size prove no samples were lost?

A. Only for two-channel files, because duplication is impossible there

B. Yes; if the disk write completed successfully

C. No; duplicated or padded values can preserve length

D. Yes; byte count uniquely identifies every sampling event

Answer: C. Length is a consistency condition, while source-index and state checks establish the actual chronology. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: No; duplicated or padded values can preserve length.

Distinguishing consideration: compare this with option A, “Only for two-channel files, because duplication is impossible there”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-072. When may an old result be reused after an update?

A. Whenever the updated component is not named in the old criterion

B. Whenever one favorable test is repeated

C. Whenever the release name changes only slightly

D. When its subject, conditions, and relevant dependencies remain demonstrably applicable

Answer: D. Dependency review determines which evidence survives; unresolved impact prevents automatic reuse. Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)

Why the selected alternative fits: When its subject, conditions, and relevant dependencies remain demonstrably applicable.

Distinguishing consideration: compare this with option A, “Whenever the updated component is not named in the old criterion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Choose evidence that can discriminate the required behavior.

Review: Chapter 10 — Choose evidence that can discriminate the required behavior.

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V011-C10-MCQ-073. Seven of eight mandatory criteria are satisfied and the eighth is unresolved. What is the case result?

A. The unresolved criterion counts as satisfied until disproved

B. An 87.5 percent pass automatically authorizes acceptance

C. Acceptance is not demonstrated

D. The case is contradicted solely because evidence is incomplete

Answer: C. Mandatory conjunction permits no fractional pass; unresolved differs from an observed breach. Source: §10.65 Define the case before testing (p. 5767)

Why the selected alternative fits: Acceptance is not demonstrated.

Distinguishing consideration: compare this with option A, "The unresolved criterion counts as satisfied until disproved"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 10 — Define the case before testing.

Review: Chapter 10 — Define the case before testing.

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V011-C10-MCQ-074. All listed tests pass, but the requirement set omits a relevant failure mode. What remains necessary?

A. Automatic acceptance of all possible configurations

B. Independent review of criterion completeness and relevance

C. Deleting the omitted concern because no listed test failed

D. A numerical confidence score computed from pass count

Answer: B. Aggregation of results cannot repair an inadequate acceptance specification. Source: §10.65 Define the case before testing (p. 5767)

Why the selected alternative fits: Independent review of criterion completeness and relevance.

Distinguishing consideration: compare this with option A, “Automatic acceptance of all possible configurations”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Define the case before testing.

Review: Chapter 10 — Define the case before testing.

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V011-C10-MCQ-075. A verified FPGA image exists in a download directory, but the loaded image is not associated with that file. What is unresolved?

A. Whether the downloaded file's digest was computed

B. Whether the filename can be displayed

C. Identity of the image used in the tested session

D. Every known behavior of all possible images

Answer: C. File verification and runtime/loading association are distinct propositions. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: Identity of the image used in the tested session.

Distinguishing consideration: compare this with option A, “Whether the downloaded file's digest was computed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-076. Why use asymmetric positive and negative integer vectors for a serialization test?

A. They can discriminate byte order, sign, and channel mapping errors

B. They prove all possible input values without range analysis

C. They measure analog noise figure directly

D. They make a shared library an independent oracle

Answer: A. Zero or symmetric test vectors can conceal permutations and representation errors. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: They can discriminate byte order, sign, and channel mapping errors.

Distinguishing consideration: compare this with option B, “They prove all possible input values without range analysis”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-077. A streaming benchmark discards buffers while the requirement names a disk writer. What is the recording result?

A. Satisfied if expected payload can be calculated

B. Contradicted merely because the benchmark did not write files

C. Satisfied because all endpoint behavior is equivalent

D. Unresolved until the actual recording endpoint is exercised

Answer: D. A test can pass within its scope while leaving the required recording path untested. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: Unresolved until the actual recording endpoint is exercised.

Distinguishing consideration: compare this with option A, “Satisfied if expected payload can be calculated”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-078. Two programs agree but use the same conversion library and map table. What does that agreement establish?

A. A reason to omit the analytical oracle

B. Reproducibility under a shared dependency, not the required independent check

C. Independent confirmation merely because application names differ

D. Proof that channel permutation is impossible

Answer: B. Known common dependencies limit independence; a discriminating external or analytical reference is still needed. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: Reproducibility under a shared dependency, not the required independent check.

Distinguishing consideration: compare this with option A, “A reason to omit the analytical oracle”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-079. A deterministic error interval overlaps the acceptance boundary. How is it classified under Framework 10F's stated conservative rule?

A. Unresolved

B. Satisfied whenever the center estimate is inside

C. Satisfied in proportion to the fraction of interval inside

D. Contradicted whenever any possible value is outside

Answer: A. The rule accepts only wholly inside and contradicts wholly outside intervals; overlap remains unresolved. Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)

Why the selected alternative fits: Unresolved.

Distinguishing consideration: compare this with option B, “Satisfied whenever the center estimate is inside”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Choose evidence that can discriminate the required behavior.

Review: Chapter 10 — Choose evidence that can discriminate the required behavior.

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V011-C10-MCQ-080. Does a valid component inventory establish provenance for an omitted FPGA image or calibration file?

A. No; omission proves those artifacts are defective

B. No; required omitted artifacts remain unresolved

C. Yes; firmware can always be excluded as hardware

D. Yes; the signed inventory implicitly covers every component

Answer: B. Inventory scope and acceptance requirements must be reconciled without inventing coverage or defects. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why the selected alternative fits: No; required omitted artifacts remain unresolved.

Distinguishing consideration: compare this with option A, “No; omission proves those artifacts are defective”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-MCQ-081. Why is sampling alias equivalence stronger than finite spectral overlap?

A. A narrower FFT window always identifies the analog member

B. Only display resolution causes alias ambiguity

C. Different analog signals can produce exactly identical samples for every integer index

D. Longer records always separate an alias class

Answer: C. The ambiguity exists algebraically before noise and finite-record limitations. Source: §10.81 Sampling equivalence, admissible bands, and receiver interpretation (p. 5789)

Why the selected alternative fits: Different analog signals can produce exactly identical samples for every integer index.

Distinguishing consideration: compare this with option A, “A narrower FFT window always identifies the analog member”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

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V011-C10-MCQ-082. Does sample rate greater than twice the desired baseband bandwidth reject every unwanted analog input?

A. No; the admitted spectral support must be independently justified

B. Yes; the desired bandwidth excludes all blockers physically

C. Only if the FFT has more than two bins

D. Yes; digital rate alone acts as an analog filter

Answer: A. The sufficient reconstruction condition assumes a band-limited signal class reaching the sampler. Source: §10.81 Sampling equivalence, admissible bands, and receiver interpretation (p. 5789)

Why the selected alternative fits: No; the admitted spectral support must be independently justified.

Distinguishing consideration: compare this with option B, “Yes; the desired bandwidth excludes all blockers physically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

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V011-C10-MCQ-083. Why do equal 10 MHz observations at 100 and 120 MS/s not uniquely establish a 10 MHz analog input in the example?

A. The longer rate always halves every RF frequency

B. Two sample rates can never distinguish any candidate inputs

C. A 110 MHz cosine maps identically by shift at one rate and reflection at the other

D. A stable feature must have been generated digitally

Answer: C. The stated phase-compatible alias survives both rates; an admitted-band restriction is additional evidence. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: A 110 MHz cosine maps identically by shift at one rate and reflection at the other.

Distinguishing consideration: compare this with option A, “The longer rate always halves every RF frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-084. Two fixed-phase analog tones alias to the same discrete frequency. How should their combination be treated?

A. Add their complex coefficients, allowing reinforcement or cancellation

B. Always select only the larger analog frequency

C. Always add their powers incoherently

D. Assume aliasing randomizes their relative phase

Answer: A. The chapter's coherent cancellation example has fixed phases; an incoherent power rule is unjustified. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: Add their complex coefficients, allowing reinforcement or cancellation.

Distinguishing consideration: compare this with option B, “Always select only the larger analog frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-085. What supports interpreting a complex channel's signed frequency physically?

A. The nominal sample rate without mixer sign

B. The presence of two stored numeric columns alone

C. A magnitude-only FFT image

D. I/Q convention, conversion plan, and actual quadrature/image-rejection behavior

Answer: D. Ideal complex coordinates retain sign, but physical implementation and conversion conventions need evidence. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: I/Q convention, conversion plan, and actual quadrature/image-rejection behavior.

Distinguishing consideration: compare this with option A, “The nominal sample rate without mixer sign”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-086. At exactly half the real sample rate, what can happen to a sine wave with quadrature phase?

A. Its frequency becomes uniquely reconstructible from zero samples

B. All samples can be zero despite nonzero analog amplitude

C. The signal automatically shifts to one-quarter rate

D. Every phase yields the same full peak amplitude

Answer: B. The samples depend on amplitude times cosine of phase; the strict baseband condition avoids this endpoint ambiguity. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: All samples can be zero despite nonzero analog amplitude.

Distinguishing consideration: compare this with option A, “Its frequency becomes uniquely reconstructible from zero samples”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-087. At 16 MS/s, what signed representative does an 11 MHz complex tone have?

A. Minus 5 MHz

B. Minus 11 MHz

C. Plus 5 MHz

D. Plus 11 MHz within the chosen interval

Answer: A. Reducing by one 16 MHz sample-rate period gives minus 5 MHz, distinct from plus 5 for complex samples. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: Minus 5 MHz.

Distinguishing consideration: compare this with option B, “Minus 11 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-088. Why can a narrow admitted band still fail an undersampling plan based only on twice its width?

A. The center frequency never affects folding

B. The band's location can cross a folding boundary and overlap itself

C. Complex phase always removes analog band overlap

D. Every narrow band is automatically a valid real baseband signal

Answer: B. The 29–31 MHz example at 20 MS/s folds both sides toward the same region. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: The band's location can cross a folding boundary and overlap itself.

Distinguishing consideration: compare this with option A, “The center frequency never affects folding”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-089. An interferer is minus 20 dBm and its allowed alias contribution is minus 90 dBm at the same plane. What attenuation is required under the stated linear model?

A. At least 70 dB at the interfering frequency

B. At least 60 dB because the desired signal is minus 80 dBm

C. At least 90 dB

D. At least 20 dB

Answer: A. The allowed contribution sets the required difference; earlier overload remains a separate limitation. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: At least 70 dB at the interfering frequency.

Distinguishing consideration: compare this with option B, “At least 60 dB because the desired signal is minus 80 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-090. Why specify which clock defines displayed hertz when studying a folded tone?

A. Every readback gives an independent true-rate measurement

B. A constant clock error cannot affect an aliased frequency

C. Folding removes all clock uncertainty

D. Physical-rate and nominal-rate labeling have different error dependence

Answer: D. The sampled coordinate and its conversion into hertz depend on the actual and declared rates. Source: §10.82 Ten worked sampling applications (p. 5792)

Why the selected alternative fits: Physical-rate and nominal-rate labeling have different error dependence.

Distinguishing consideration: compare this with option A, “Every readback gives an independent true-rate measurement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-MCQ-091. Does a deterministic half-code-step bound establish uniform quantization-error density?

A. Yes; the bound fixes every statistical moment

B. Only if the converter has more than eight bits

C. No; code-center and fixed-bias sequences satisfy the same bound

D. Yes; sufficiently many identical samples make the error uniform

Answer: C. A magnitude bound does not supply an error distribution, correlation, or spectrum. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: No; code-center and fixed-bias sequences satisfy the same bound.

Distinguishing consideration: compare this with option A, "Yes; the bound fixes every statistical moment"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-092. Why does a quarter-reference sine lose about 12.04 dB of ideal model SQNR at fixed code spacing?

A. Its power is sixteen times smaller while modeled error power is unchanged

B. Digital gain after conversion restores the lost ratio

C. Its amplitude is sixteen times smaller

D. Its code spacing becomes four times wider

Answer: A. The amplitude term is 20 $\log_{10}(\frac{1}{4})$; rescaling both signal and error does not undo it. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: Its power is sixteen times smaller while modeled error power is unchanged.

Distinguishing consideration: compare this with option B, “Digital gain after conversion restores the lost ratio”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-093. Which filter quantity belongs in the white quantization-error channel calculation?

A. Only the passband's center frequency

B. Equivalent noise bandwidth from squared magnitude at the declared reference gain

C. Only the decimation factor

D. The nominal 3 dB width without characterization

Answer: B. The integrated white-error power depends on the actual squared-response integral. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: Equivalent noise bandwidth from squared magnitude at the declared reference gain.

Distinguishing consideration: compare this with option A, “Only the passband's center frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-094. How can mean removal conceal an absolute conversion defect?

A. It reveals every DC error automatically

B. It makes all deterministic errors independent

C. It can remove constant error bias from a variance-style comparison

D. It restores the input's absolute level

Answer: C. Centered variance can be zero while mean-square error relative to the original level is nonzero. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: It can remove constant error bias from a variance-style comparison.

Distinguishing consideration: compare this with option A, “It reveals every DC error automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-095. What is missing from a claim that decimation alone adds effective bits?

A. A justified noise spectrum, filtering, gain, alias control, and defined metric

B. Nothing; bare deletion always reduces sample variance

C. Only a larger integer decimation label

D. Only a longer filename for the output

Answer: A. Process gain belongs to a suitable filtering/noise model, not sample deletion by itself. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: A justified noise spectrum, filtering, gain, alias control, and defined metric.

Distinguishing consideration: compare this with option B, “Nothing; bare deletion always reduces sample variance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-096. For independent white errors, what does keeping every fourth sample do to each retained sample's variance?

A. It makes variance zero

B. It divides variance by four

C. It divides variance by sixteen

D. It leaves the variance unchanged

Answer: D. Bare selection changes rate, not the marginal distribution; an averaging or filtering operation is different. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: It leaves the variance unchanged.

Distinguishing consideration: compare this with option A, “It makes variance zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-097. What does a deterministic code-center test with zero quantization error establish?

A. Absence of analog nonlinearity and jitter

B. The universal validity of the uniform-error variance

C. Zero error for the entire converter range

D. Exactness for those tested inputs, not all levels or an error distribution

Answer: D. The counterexample shows why bit count and one favorable sequence do not certify general performance. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: Exactness for those tested inputs, not all levels or an error distribution.

Distinguishing consideration: compare this with option A, “Absence of analog nonlinearity and jitter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-098. What additional premise permits channel-band process gain for quantization error?

A. A white error spectrum with actual anti-alias filtering and retained signal gain

B. Only an unsaturated half-step bound

C. Only a constant-error record

D. Only selecting a smaller output rate in software

Answer: A. The density integration requires a spectral model beyond the uniform marginal-error assumption. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why the selected alternative fits: A white error spectrum with actual anti-alias filtering and retained signal gain.

Distinguishing consideration: compare this with option B, “Only an unsaturated half-step bound”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-MCQ-099. Periodic broadband impulses coincide with overflow logs and disappear after changing storage destination. What is supported?

A. Converter certification of the complete chain

B. Proof that no environmental burst could coexist

C. A recording-path explanation requiring continuity review before environmental attribution

D. A guaranteed malicious transmitter at the overflow period

Answer: C. The controlled observation identifies a relevant recording mechanism but does not establish universal environmental absence. Source: §10.105 Hypothetical Case Adjudication: Software-Defined Radios, Sampling, Quantization, DDC, and Channelization (p. 5819)

Why the selected alternative fits: A recording-path explanation requiring continuity review before environmental attribution.

Distinguishing consideration: compare this with option A, “Converter certification of the complete chain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Hypothetical Case Adjudication: Software-Defined Radios, Sampling, Quantization, DDC, and Channelization.

Review: Chapter 10 — Hypothetical Case Adjudication: Software-Defined Radios, Sampling, Quantization, DDC, and Channelization.

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V011-C10-MCQ-100. Why does converter compliance alone not validate the complete SDR measurement?

A. A compliant converter makes all later software irrelevant

B. Front end, clock, DDC, firmware, transport, scaling, metadata, and analysis also contribute

C. Only the nominal bit count determines system dynamic range

D. A standard's title certifies every assembled receiver

Answer: B. The converter and complete recording/receiver systems have different validation boundaries. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

Why the selected alternative fits: Front end, clock, DDC, firmware, transport, scaling, metadata, and analysis also contribute.

Distinguishing consideration: compare this with option A, “A compliant converter makes all later software irrelevant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Converter and Waveform-Recorder Validation Boundary.

Review: Chapter 10 — Converter and Waveform-Recorder Validation Boundary.

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Fill-in-the-Blank Questions

V011-C10-FIB-001. The SDR record must identify where the analog path ends and where _____ are formed.

Answer: samples. The physical interpretation depends on the analog-digital boundary and subsequent processing. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

Why this term is required: “samples” completes the stated technical proposition.

Question context: The SDR record must identify where the analog path ends and where _____ are formed

Basis and qualification: Chapter 10 — SDR Boundary and Partitioning.

Review: Chapter 10 — SDR Boundary and Partitioning.

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V011-C10-FIB-002. Firmware, gateware, driver, host application, and analysis script all belong in the processing _____ record.

Answer: configuration. They can implement different parts of the measurement transformation. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

Why this term is required: “configuration” completes the stated technical proposition.

Question context: Firmware, gateware, driver, host application, and analysis script all belong in the processing _____ record

Basis and qualification: Chapter 10 — SDR Boundary and Partitioning.

Review: Chapter 10 — SDR Boundary and Partitioning.

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V011-C10-FIB-003. A generic I/Q rate label can conceal hidden _____ that changes actual channel bandwidth.

Answer: decimation. The nominal stream label alone does not specify the whole chain. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

Why this term is required: “decimation” completes the stated technical proposition.

Question context: A generic I/Q rate label can conceal hidden _____ that changes actual channel bandwidth

Basis and qualification: Chapter 10 — SDR Boundary and Partitioning.

Review: Chapter 10 — SDR Boundary and Partitioning.

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V011-C10-FIB-004. After ADC clipping, later digital scaling cannot recover the lost amplitude _____.

Answer: information. A plausible scaled waveform can still contain irreversible overload distortion. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

Why this term is required: “information” completes the stated technical proposition.

Question context: After ADC clipping, later digital scaling cannot recover the lost amplitude _____

Basis and qualification: Chapter 10 — Quantization, Clipping, and Converter Performance.

Review: Chapter 10 — Quantization, Clipping, and Converter Performance.

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V011-C10-FIB-005. In negative-exponential digital mixing, translated frequency is input frequency _____ NCO frequency.

Answer: minus. The sign convention must precede reconstruction of a physical frequency label. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why this term is required: “minus” completes the stated technical proposition.

Question context: In negative-exponential digital mixing, translated frequency is input frequency _____ NCO frequency

Basis and qualification: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-FIB-006. The DDC's output rate is input rate divided by its integer _____ factor.

Answer: decimation. The retained sample rule changes the clock on which the sequence is interpreted. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why this term is required: “decimation” completes the stated technical proposition.

Question context: The DDC's output rate is input rate divided by its integer _____ factor

Basis and qualification: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-FIB-007. At 48 MS/s with decimation eight, output rate is _____ MS/s.

Answer: 6. The ratio gives $\frac{48}{8}$ while tone gain remains separately specified. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “6” completes the stated technical proposition.

Question context: At 48 MS/s with decimation eight, output rate is _____ MS/s

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-008. The retained phase p in mM+p is an index _____, not an angle.

Answer: residue. It determines which input instants survive each decimation interval. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
Why this term is required: “residue” completes the stated technical proposition.
Question context: The retained phase p in mM+p is an index _____, not an angle
Basis and qualification: Chapter 10 — Model 10B for digital mixing filtering and decimation.
Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-FIB-009. For a settled tone, output amplitude includes the magnitude of the pre-decimation filter _____.

Answer: response. The response is evaluated at the translated frequency on that stage's input clock. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why this term is required: “response” completes the stated technical proposition.

Question context: For a settled tone, output amplitude includes the magnitude of the pre-decimation filter _____

Basis and qualification: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-FIB-010. Translated frequencies differing by an integer multiple of output rate can _____ after sample deletion.

Answer: alias. Once combined, their original coordinates are not separable by a later single-channel linear filter alone. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why this term is required: “alias” completes the stated technical proposition.

Question context: Translated frequencies differing by an integer multiple of output rate can _____ after sample deletion

Basis and qualification: Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-C10-FIB-011. For a real cosine, each complex-frequency coefficient has _____ the original peak amplitude.

Answer: half. Image selection and any reconstruction factor must be declared before comparing amplitudes. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “half” completes the stated technical proposition.

Question context: For a real cosine, each complex-frequency coefficient has _____ the original peak amplitude

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-012. A 30 dB stage rejection followed by 50 dB rejection along the actual blocker path totals _____ dB.

Answer: 80. Magnitude factors multiply, so logarithmic attenuation adds under the stated linear path. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “80” completes the stated technical proposition.

Question context: A 30 dB stage rejection followed by 50 dB rejection along the actual blocker path totals _____ dB

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-013. A filter zero at one frequency does not characterize an entire rejection _____.

Answer: band. Nearby alias-entry frequencies can have much larger response.

Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “band” completes the stated technical proposition.

Question context: A filter zero at one frequency does not characterize an entire rejection _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-014. For a symmetric 33-tap FIR, the center lag is _____ input samples.

Answer: 16. This is the ordinary linear-phase group delay away from response zeros. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “16” completes the stated technical proposition.

Question context: For a symmetric 33-tap FIR, the center lag is _____ input samples

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-015. Complete 33-tap history beginning at input zero first exists at retained input indices no smaller than _____.

Answer: 32. Startup support requires every nonzero lag, separately from group delay. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “32” completes the stated technical proposition.

Question context: Complete 33-tap history beginning at input zero first exists at retained input indices no smaller than _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-016. With decimation eight and retained phase three, the first retained index at least 32 is _____.

Answer: 35. The retained sequence is 3, 11, 19, 27, 35 and so on. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “35” completes the stated technical proposition.

Question context: With decimation eight and retained phase three, the first retained index at least 32 is _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-017. A retained-time offset of three samples at 48 MS/s equals _____ ns.

Answer: 62.5. Time displacement is three divided by 48 million seconds. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “62.5” completes the stated technical proposition.

Question context: A retained-time offset of three samples at 48 MS/s equals _____ ns

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-018. The ideal NCO's tuning grid is its input clock rate divided by two raised to accumulator bit _____.

Answer: width. Accumulator quantization is only one contributor to oscillator behavior. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “width” completes the stated technical proposition.

Question context: The ideal NCO's tuning grid is its input clock rate divided by two raised to accumulator bit _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-019. Constant frequency error accumulates into a linearly increasing phase _____ over elapsed time.

Answer: error. A small rate difference can matter in a long coherent comparison.

Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “error” completes the stated technical proposition.

Question context: Constant frequency error accumulates into a linearly increasing phase _____ over elapsed time

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-020. Exact polyphase regrouping preserves the same filter coefficients and input-output _____.

Answer: relation. Computational efficiency does not improve rejection by itself.

Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “relation” completes the stated technical proposition.

Question context: Exact polyphase regrouping preserves the same filter coefficients and input-output _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-021. A correct streaming DDC carries both NCO phase and FIR _____ across ordinary block boundaries.

Answer: history. Resetting either can create artifacts despite continuous source indices. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “history” completes the stated technical proposition.

Question context: A correct streaming DDC carries both NCO phase and FIR _____ across ordinary block boundaries

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-022. At 9 MHz on a 48 MS/s input, 1000 samples span _____ NCO cycles.

Answer: 187.5. The half-cycle remainder explains the alternating sign introduced by per-block reset. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

Why this term is required: “187.5” completes the stated technical proposition.

Question context: At 9 MHz on a 48 MS/s input, 1000 samples span _____ NCO cycles

Basis and qualification: Chapter 10 — Ten worked applications of Model 10B.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-FIB-023. A channelizer's number of channels M and decimation D are _____ parameters.

Answer: distinct. They separately determine center grid and per-channel output rate. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

Why this term is required: “distinct” completes the stated technical proposition.

Question context: A channelizer's number of channels M and decimation D are _____ parameters

Basis and qualification: Chapter 10 — Model 10C for a polyphase analysis channelizer.

Review: Chapter 10 — Model 10C for a polyphase analysis channelizer.

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V011-C10-FIB-024. For M channels, center-grid spacing is input sample rate divided by _____.

Answer: M. Per-channel output rate instead uses D. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

Why this term is required: “M” completes the stated technical proposition.

Question context: For M channels, center-grid spacing is input sample rate divided by _____

Basis and qualification: Chapter 10 — Model 10C for a polyphase analysis channelizer.

Review: Chapter 10 — Model 10C for a polyphase analysis channelizer.

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V011-C10-FIB-025. Critical sampling in this model means D equals _____.

Answer: M. The sum of channel output rates then equals input rate, without guaranteeing invertibility. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “M” completes the stated technical proposition.

Question context: Critical sampling in this model means D equals _____

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-026. Oversampling corresponds to D being _____ than M.

Answer: less. The aggregate output rate is then greater than input rate. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “less” completes the stated technical proposition.

Question context: Oversampling corresponds to D being _____ than M

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-027. The aggregate output-to-input rate ratio is M divided by _____.

Answer: D. This counts output samples, not independent environmental information. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “D” completes the stated technical proposition.

Question context: The aggregate output-to-input rate ratio is M divided by _____

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-028. The causal branch inner transform uses a _____ exponential sign.

Answer: positive. It follows from expanding the negative mixer at delayed input indices. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “positive” completes the stated technical proposition.

Question context: The causal branch inner transform uses a _____ exponential sign

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-029. A normalized inverse transform needs multiplication by _____ to realize the declared unscaled M-branch sum.

Answer: M. Its usual $\frac{1}{M}$ normalization otherwise changes voltage gain. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “M” completes the stated technical proposition.

Question context: A normalized inverse transform needs multiplication by _____ to realize the declared unscaled M-branch sum

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-030. Under oversampling, an outer channel _____ factor generally cannot be omitted.

Answer: phase. The direct definition fixes phase evolution even for center tones.

Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “phase” completes the stated technical proposition.

Question context: Under oversampling, an outer channel _____ factor generally cannot be omitted

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-031. The branch residue schedule repeats after M divided by the greatest common divisor of M and _____.

Answer: D. The commutator schedule changes when decimation differs from channel count. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “D” completes the stated technical proposition.

Question context: The branch residue schedule repeats after M divided by the greatest common divisor of M and _____

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-032. For M = 8 and D = 4, that schedule repeats every _____ output steps.

Answer: 2. The count is $\frac{8}{gcd(8,4)}$. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

Why this term is required: “2” completes the stated technical proposition.

Question context: For M = 8 and D = 4, that schedule repeats every _____ output steps

Basis and qualification: Chapter 10 — Causal polyphase grouping and the transform convention.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

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V011-C10-FIB-033. A boundary tone can appear in _____ adjacent channels without representing two sources.

Answer: two. The prototype response explains the related outputs. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “two” completes the stated technical proposition.

Question context: A boundary tone can appear in _____ adjacent channels without representing two sources

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-034. Signed channel center and residual frequency are both needed to reconstruct an input frequency _____.

Answer: label. A repeated residual label in two channels does not make their centers identical. Source: §10.20 Ten worked applications of Model 10C (p. 5709)
Why this term is required: “label” completes the stated technical proposition.
Question context: Signed channel center and residual frequency are both needed to reconstruct an input frequency _____
Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.
Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-035. At 64 MS/s with eight channels, the k = 6 signed center is _____ MHz.

Answer: minus 16. The positive grid value 48 MHz is represented as -16 MHz on the input interval. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “minus 16” completes the stated technical proposition.

Question context: At 64 MS/s with eight channels, the k = 6 signed center is _____ MHz

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-036. For that channel, a minus 13 MHz input has residual _____ MHz.

Answer: plus 3. The offset from the signed center is -13-(-16). Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “plus 3” completes the stated technical proposition.

Question context: For that channel, a minus 13 MHz input has residual _____ MHz

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-037. Four stored bytes per complex sample comprise two signed 16-bit _____ and Q components.

Answer: I. Storage accounting must include both components plus separate metadata overhead. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: "I" completes the stated technical proposition.

Question context: Four stored bytes per complex sample comprise two signed 16-bit _____ and Q components

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-038. At 512 MB/s, sixty seconds of payload requires _____ GB in decimal units.

Answer: 30.72. The product is 30,720 million bytes, before headers and continuity records. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “30.72” completes the stated technical proposition.

Question context: At 512 MB/s, sixty seconds of payload requires _____ GB in decimal units

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-039. White second-order input statistics do not automatically imply joint _____.

Answer: independence. A suitable distributional assumption is additional to covariance statements. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “independence” completes the stated technical proposition.

Question context: White second-order input statistics do not automatically imply joint _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-040. Same-frame diagonal covariance does not eliminate correlation between overlapping _____.

Answer: frames. Shared input samples can correlate different output times. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “frames” completes the stated technical proposition.

Question context: Same-frame diagonal covariance does not eliminate correlation between overlapping _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-041. The critical-bank counterexample loses a complete input-index _____ despite unit DC gain.

Answer: residue. Its only relevant coefficient for those sample positions is zero.

Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “residue” completes the stated technical proposition.

Question context: The critical-bank counterexample loses a complete input-index _____ despite unit DC gain

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-042. A positive complete-bank lower energy bound rules out an invisible nonzero input in the stated finite-_____ class.

Answer: energy. The exact bound requires all affected frames, channels, coefficients, and arithmetic assumptions. Source: §10.20 Ten worked applications of Model 10C (p. 5709)

Why this term is required: “energy” completes the stated technical proposition.

Question context: A positive complete-bank lower energy bound rules out an invisible nonzero input in the stated finite-_____ class

Basis and qualification: Chapter 10 — Ten worked applications of Model 10C.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-FIB-043. In S(W,F), W is total width and F is the number of _____ bits.

Answer: fractional. Both are needed to determine spacing and signed range. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “fractional” completes the stated technical proposition.

Question context: In S(W,F), W is total width and F is the number of _____ bits

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-044. The fixed-point code step is two to the power minus _____.

Answer: F. The code integer is scaled by this factor. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “F” completes the stated technical proposition.

Question context: The fixed-point code step is two to the power minus _____

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-045. A signed two's-complement range has one fewer positive _____ than the corresponding negative magnitude.

Answer: code. The asymmetric endpoint can cause positive overflow from two negative rails. Source: §10.33 Signed formats and explicit conversion points (p. 5725)
Why this term is required: “code” completes the stated technical proposition.
Question context: A signed two's-complement range has one fewer positive _____ than the corresponding negative magnitude
Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.
Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-046. The specified halfway rounding rule chooses the _____ integer code.

Answer: even. The tie rule is deterministic and does not establish a noise distribution. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “even” completes the stated technical proposition.

Question context: The specified halfway rounding rule chooses the _____ integer code

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-047. Clamping an out-of-range code is called _____.

Answer: saturation. It differs from modulo wrapping and invalidates the ordinary half-step bound. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “saturation” completes the stated technical proposition.

Question context: Clamping an out-of-range code is called _____

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-048. Modulo overflow can reverse the sign and is called _____.

Answer: wrapping. The retained code can conceal the original out-of-range result.

Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “wrapping” completes the stated technical proposition.

Question context: Modulo overflow can reverse the sign and is called _____

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-049. Full exact real-product fractional width is the _____ of input and coefficient fractional widths.

Answer: sum. The product grid contains both binary scale factors. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “sum” completes the stated technical proposition.

Question context: Full exact real-product fractional width is the _____ of input and coefficient fractional widths

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-050. The model rounds coefficients once and branch components once after exact _____.

Answer: accumulation. Rounding every product instead defines a different arithmetic schedule. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “accumulation” completes the stated technical proposition.

Question context: The model rounds coefficients once and branch components once after exact _____

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-051. Before using a rounding-error bound, establish that intermediate values remain within _____.

Answer: range. A precision bound is conditional on no overflow at the relevant conversions. Source: §10.34 Range and error are separate obligations (p. 5728)

Why this term is required: “range” completes the stated technical proposition.

Question context: Before using a rounding-error bound, establish that intermediate values remain within _____

Basis and qualification: Chapter 10 — Range and error are separate obligations.

Review: Chapter 10 — Range and error are separate obligations.

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V011-C10-FIB-052. A bound on each I and Q component is not the same as a bound on complex _____.

Answer: magnitude. Combining component errors introduces the appropriate Euclidean magnitude factor. Source: §10.34 Range and error are separate obligations (p. 5728)

Why this term is required: “magnitude” completes the stated technical proposition.

Question context: A bound on each I and Q component is not the same as a bound on complex _____

Basis and qualification: Chapter 10 — Range and error are separate obligations.

Review: Chapter 10 — Range and error are separate obligations.

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V011-C10-FIB-053. Restoring a stored shift s multiplies final rounding error by two to the power _____.

Answer: s. Display rescaling cannot recreate discarded precision. Source: §10.34 Range and error are separate obligations (p. 5728)

Why this term is required: “s” completes the stated technical proposition.

Question context: Restoring a stored shift s multiplies final rounding error by two to the power _____

Basis and qualification: Chapter 10 — Range and error are separate obligations.

Review: Chapter 10 — Range and error are separate obligations.

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V011-C10-FIB-054. For four-channel exact transforms, multiplication by j exchanges components and changes a _____.

Answer: sign. Weights limited to ±1 and ±j can be implemented with exact widened operations. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “sign” completes the stated technical proposition.

Question context: For four-channel exact transforms, multiplication by j exchanges components and changes a _____

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points.

Review: Chapter 10 — Signed formats and explicit conversion points.

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V011-C10-FIB-055. Rounding coefficients can preserve their sum while changing frequency _____.

Answer: response. A DC-only test misses differences at other offsets. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why this term is required: “response” completes the stated technical proposition.

Question context: Rounding coefficients can preserve their sum while changing frequency _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-FIB-056. The product of two negative unit rails is positive _____.

Answer: one. That value can exceed the positive endpoint of a narrowed fractional format. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why this term is required: “one” completes the stated technical proposition.

Question context: The product of two negative unit rails is positive _____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-FIB-057. In S(7,6), the largest positive value is _____ divided by 64.

Answer: 63. The positive code interval ends at 63 rather than 64. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why this term is required: “63” completes the stated technical proposition.

Question context: In S(7,6), the largest positive value is _____ divided by 64

Basis and qualification: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-FIB-058. Intermediate saturation can make ordinary addition non-_____.

Answer: associative. Different grouping can clamp different partial sums before later compensation. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why this term is required: “associative” completes the stated technical proposition.

Question context: Intermediate saturation can make ordinary addition non-_____

Basis and qualification: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-FIB-059. An exact code calculation can still have a channel phase or ordering _____ unrelated to precision.

Answer: error. More fractional bits do not repair omitted outer phase or transform-bin mapping. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

Why this term is required: “error” completes the stated technical proposition.

Question context: An exact code calculation can still have a channel phase or ordering _____ unrelated to precision

Basis and qualification: Chapter 10 — Ten worked applications of Model 10D.

Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-FIB-060. A constant error of minus one eighth volt has mean-square error _____ V squared relative to the intended value.

Answer: 1/64. Squaring the bias gives nonzero MSE even though its centered variance is zero. Source: §10.35 Ten worked applications of Model 10D (p. 5731)
Why this term is required: “1/64” completes the stated technical proposition.
Question context: A constant error of minus one eighth volt has mean-square error _____ V squared relative to the intended value
Basis and qualification: Chapter 10 — Ten worked applications of Model 10D.
Review: Chapter 10 — Ten worked applications of Model 10D.

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V011-C10-FIB-061. Model 10D's voltage envelope is deterministic rather than a noise _____.

Answer: variance. It uses magnitude bounds without a white or independent-error assumption. Source: §10.34 Range and error are separate obligations (p. 5728)

Why this term is required: “variance” completes the stated technical proposition.

Question context: Model 10D's voltage envelope is deterministic rather than a noise _____

Basis and qualification: Chapter 10 — Range and error are separate obligations.

Review: Chapter 10 — Range and error are separate obligations.

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V011-C10-FIB-062. Stored file position must be mapped to an original source _____ to establish chronology.

Answer: index. Contiguous bytes do not prove contiguous physical sampling events. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why this term is required: “index” completes the stated technical proposition.

Question context: Stored file position must be mapped to an original source _____ to establish chronology

Basis and qualification: Chapter 10 — Source indices, stored offsets, and time anchors.

Review: Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-C10-FIB-063. The source counter is tied to the sampling event rather than host-buffer _____.

Answer: arrival. Delivery time is a different event unless their relationship is established. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why this term is required: “arrival” completes the stated technical proposition.

Question context: The source counter is tied to the sampling event rather than host-buffer _____

Basis and qualification: Chapter 10 — Source indices, stored offsets, and time anchors.

Review: Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-C10-FIB-064. A clock reset or unresolved counter wrap ends the declared constant-clock _____.

Answer: segment. A new source/time mapping is then required. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why this term is required: “segment” completes the stated technical proposition.

Question context: A clock reset or unresolved counter wrap ends the declared constant-clock _____

Basis and qualification: Chapter 10 — Source indices, stored offsets, and time anchors.

Review: Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-C10-FIB-065. For adjacent ordered blocks, a positive boundary discrepancy indicates positions not covered by that _____ of blocks.

Answer: pair. Other accepted coverage must be resolved before declaring a global gap. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why this term is required: “pair” completes the stated technical proposition.

Question context: For adjacent ordered blocks, a positive boundary discrepancy indicates positions not covered by that _____ of blocks

Basis and qualification: Chapter 10 — Source indices, stored offsets, and time anchors.

Review: Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-C10-FIB-066. A negative boundary discrepancy indicates declared index _____.

Answer: overlap. Payload agreement and actual overlap extent still require examination. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)
Why this term is required: “overlap” completes the stated technical proposition.
Question context: A negative boundary discrepancy indicates declared index _____
Basis and qualification: Chapter 10 — Source indices, stored offsets, and time anchors.
Review: Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-C10-FIB-067. At 1 MS/s, forty missing sample positions create _____ microseconds between the bounding retained samples.

Answer: 41. There are forty missing positions and forty-one sampling intervals between the endpoints. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

Why this term is required: “41” completes the stated technical proposition.

Question context: At 1 MS/s, forty missing sample positions create _____ microseconds between the bounding retained samples

Basis and qualification: Chapter 10 — Application 10E.1: a file offset that conceals forty missing samples.

Review: Chapter 10 — Application 10E.1: a file offset that conceals forty missing samples.

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V011-C10-FIB-068. Two 64-sample blocks starting 32 indices apart cover _____ distinct indices when both complete intervals are considered.

Answer: 96. Their 32-index overlap means 128 stored values do not represent 128 unique events. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

Why this term is required: “96” completes the stated technical proposition.

Question context: Two 64-sample blocks starting 32 indices apart cover _____ distinct indices when both complete intervals are considered

Basis and qualification: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

Review: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

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V011-C10-FIB-069. Conflicting payloads at one source index must remain unresolved rather than be repaired by _____.

Answer: averaging. A third manufactured value does not identify the original sampling event. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

Why this term is required: “averaging” completes the stated technical proposition.

Question context: Conflicting payloads at one source index must remain unresolved rather than be repaired by _____

Basis and qualification: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

Review: Chapter 10 — Application 10E.2: overlap, duplicate indices, and conflicting payloads.

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V011-C10-FIB-070. The FIR validity mask uses only lags whose declared coefficients are _____.

Answer: nonzero. An exactly zero lag creates no dependency; a merely small coefficient still does. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “nonzero” completes the stated technical proposition.

Question context: The FIR validity mask uses only lags whose declared coefficients are _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-FIB-071. A dependency mask is a logical test, not a probability of _____.

Answer: correctness. It establishes availability of required inputs, not calibration, authenticity, or numerical accuracy. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “correctness” completes the stated technical proposition.

Question context: A dependency mask is a logical test, not a probability of _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-FIB-072. For nonzero FIR support of length L, a missing interval ending at b can affect source output indices through b plus L minus _____.

Answer: one. The last missing input remains in the finite history for that lag span.

Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “one” completes the stated technical proposition.

Question context: For nonzero FIR support of length L, a missing interval ending at b can affect source output indices through b plus L minus _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-FIB-073. The affected retained outputs are found by intersecting the dependency set with the original _____ grid.

Answer: decimation. The output epoch must be preserved when counting the intersection. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “decimation” completes the stated technical proposition.

Question context: The affected retained outputs are found by intersecting the dependency set with the original _____ grid

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-FIB-074. Several overlapping dependency tails must be combined by set _____.

Answer: union. Adding counts can double-count outputs affected by more than one missing interval. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “union” completes the stated technical proposition.

Question context: Several overlapping dependency tails must be combined by set _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-FIB-075. Zero filling needs a separate _____ mask to preserve which values are actually known.

Answer: validity. Numerical availability after filling does not restore the absent sample. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

Why this term is required: “validity” completes the stated technical proposition.

Question context: Zero filling needs a separate _____ mask to preserve which values are actually known

Basis and qualification: Chapter 10 — Gap representations, phase, and the limits of timing claims.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-C10-FIB-076. A finite missing-input error bound needs an independently justified amplitude _____.

Answer: bound. Without a bound on unknown inputs, the stated model supplies no finite error limit. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

Why this term is required: “bound” completes the stated technical proposition.

Question context: A finite missing-input error bound needs an independently justified amplitude _____

Basis and qualification: Chapter 10 — Gap representations, phase, and the limits of timing claims.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-C10-FIB-077. Deleting missing positions changes which physical samples become filter _____.

Answer: neighbors. It changes the operator unless the original source grid is reconstructed. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

Why this term is required: “neighbors” completes the stated technical proposition.

Question context: Deleting missing positions changes which physical samples become filter _____

Basis and qualification: Chapter 10 — Gap representations, phase, and the limits of timing claims.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-C10-FIB-078. Using compact indices for the mixer introduces a phase factor determined by the source-index _____.

Answer: deficit. The difference n-k controls the rotation when it is constant across the support. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

Why this term is required: “deficit” completes the stated technical proposition.

Question context: Using compact indices for the mixer introduces a phase factor determined by the source-index _____

Basis and qualification: Chapter 10 — Gap representations, phase, and the limits of timing claims.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-C10-FIB-079. After three deleted positions with mixer increment $\frac{\pi}{4}$ per sample, the constant rotation is _____ degrees where its assumptions hold.

Answer: 135. Three missing increments give $\frac{3\pi}{4}$; gap-crossing support and retained-grid changes need separate treatment. Source: §10.60 Application 10E.9: absolute phase survives three missing positions (p. 5762)

Why this term is required: “135” completes the stated technical proposition.

Question context: After three deleted positions with mixer increment per sample, the constant rotation is _____ degrees where its assumptions hold

Basis and qualification: Chapter 10 — Application 10E.9: absolute phase survives three missing positions.

Review: Chapter 10 — Application 10E.9: absolute phase survives three missing positions.

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V011-C10-FIB-080. A continuity-valid output can still be wrong because of clock error or arithmetic _____.

Answer: overflow. Dependency availability does not certify these separate properties. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “overflow” completes the stated technical proposition.

Question context: A continuity-valid output can still be wrong because of clock error or arithmetic _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-FIB-081. Framework 10F requires every mandatory applicable criterion to be _____.

Answer: satisfied. Favorable results cannot compensate for a required breach or missing evidence. Source: §10.65 Define the case before testing (p. 5767)

Why this term is required: “satisfied” completes the stated technical proposition.

Question context: Framework 10F requires every mandatory applicable criterion to be _____

Basis and qualification: Chapter 10 — Define the case before testing.

Review: Chapter 10 — Define the case before testing.

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V011-C10-FIB-082. Adequate evidence of a breach gives the criterion state _____.

Answer: contradicted. This differs from an invalid or incomplete test, which may leave the result unresolved. Source: §10.65 Define the case before testing (p. 5767)
Why this term is required: “contradicted” completes the stated technical proposition.
Question context: Adequate evidence of a breach gives the criterion state _____
Basis and qualification: Chapter 10 — Define the case before testing.
Review: Chapter 10 — Define the case before testing.

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V011-C10-FIB-083. Insufficient applicable evidence leaves a mandatory criterion _____.

Answer: unresolved. It is not assigned a fractional pass. Source: §10.65 Define the case before testing (p. 5767)

Why this term is required: “unresolved” completes the stated technical proposition.

Question context: Insufficient applicable evidence leaves a mandatory criterion _____

Basis and qualification: Chapter 10 — Define the case before testing.

Review: Chapter 10 — Define the case before testing.

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V011-C10-FIB-084. A criterion exclusion requires a recorded technical _____ tied to the declared case.

Answer: rationale. Scope labels cannot automatically discard difficult requirements.

Source: §10.65 Define the case before testing (p. 5767)

Why this term is required: “rationale” completes the stated technical proposition.

Question context: A criterion exclusion requires a recorded technical _____ tied to the declared case

Basis and qualification: Chapter 10 — Define the case before testing.

Review: Chapter 10 — Define the case before testing.

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V011-C10-FIB-085. A valid signature supports signed-content integrity and signing source under a stated trust _____.

Answer: policy. It is not a direct test of filter response, scaling, or functional correctness. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why this term is required: “policy” completes the stated technical proposition.

Question context: A valid signature supports signed-content integrity and signing source under a stated trust _____

Basis and qualification: Chapter 10 — Separate signed artifacts from operating configurations.

Review: Chapter 10 — Separate signed artifacts from operating configurations.

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V011-C10-FIB-086. A digest identifies examined _____ but does not by itself show they were loaded.

Answer: bytes. Loaded-image association is a distinct evidence obligation. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why this term is required: “bytes” completes the stated technical proposition.

Question context: A digest identifies examined _____ but does not by itself show they were loaded

Basis and qualification: Chapter 10 — Separate signed artifacts from operating configurations.

Review: Chapter 10 — Separate signed artifacts from operating configurations.

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V011-C10-FIB-087. The configuration manifest should retain actual values as well as requested _____.

Answer: values. A successful setting call may coerce the requested operating point.

Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why this term is required: “values” completes the stated technical proposition.

Question context: The configuration manifest should retain actual values as well as requested _____

Basis and qualification: Chapter 10 — Separate signed artifacts from operating configurations.

Review: Chapter 10 — Separate signed artifacts from operating configurations.

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V011-C10-FIB-088. A sample-rate readback is not an independent measurement of clock _____.

Answer: accuracy. That claim needs the separate reference and measurement conditions. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why this term is required: “accuracy” completes the stated technical proposition.

Question context: A sample-rate readback is not an independent measurement of clock _____

Basis and qualification: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-FIB-089. Host-memory, transport, and file serialization are separate format _____.

Answer: boundaries. I/Q order, signedness, byte order, scaling, and channel mapping must be fixed at each tested boundary. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why this term is required: “boundaries” completes the stated technical proposition.

Question context: Host-memory, transport, and file serialization are separate format _____

Basis and qualification: Chapter 10 — Separate signed artifacts from operating configurations.

Review: Chapter 10 — Separate signed artifacts from operating configurations.

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V011-C10-FIB-090. An independent test needs an expected result or _____ capable of exposing the proposed fault.

Answer: oracle. Shared implementation dependencies can make two agreeing outputs repeat the same error. Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)

Why this term is required: “oracle” completes the stated technical proposition.

Question context: An independent test needs an expected result or _____ capable of exposing the proposed fault

Basis and qualification: Chapter 10 — Choose evidence that can discriminate the required behavior.

Review: Chapter 10 — Choose evidence that can discriminate the required behavior.

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V011-C10-FIB-091. Under the inclusive limit ±0.50 dB, estimate +0.42 with deterministic half-width 0.18 is _____.

Answer: unresolved. The permitted +0.24 to +0.60 interval crosses the boundary under the stated conservative rule. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why this term is required: “unresolved” completes the stated technical proposition.

Question context: Under the inclusive limit ±0.50 dB, estimate +0.42 with deterministic half-width 0.18 is _____

Basis and qualification: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-FIB-092. A streaming pass that discards buffers does not validate the required disk-writing _____.

Answer: endpoint. The actual recording destination and workload must be exercised. Source: §10.68 Ten worked applications of Framework 10F (p. 5776)

Why this term is required: “endpoint” completes the stated technical proposition.

Question context: A streaming pass that discards buffers does not validate the required disk-writing _____

Basis and qualification: Chapter 10 — Ten worked applications of Framework 10F.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-FIB-093. Updates require review of each criterion's relevant _____ before reusing old evidence.

Answer: dependencies. Uncertain impact remains unresolved rather than presumed harmless. Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)

Why this term is required: “dependencies” completes the stated technical proposition.

Question context: Updates require review of each criterion's relevant _____ before reusing old evidence

Basis and qualification: Chapter 10 — Choose evidence that can discriminate the required behavior.

Review: Chapter 10 — Choose evidence that can discriminate the required behavior.

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V011-C10-FIB-094. Real sampling admits frequency candidates shifted by integer multiples of sample rate and by frequency _____.

Answer: reflection. The magnitude alias class includes plus and minus frequency representatives. Source: §10.81 Sampling equivalence, admissible bands, and receiver interpretation (p. 5789)

Why this term is required: “reflection” completes the stated technical proposition.

Question context: Real sampling admits frequency candidates shifted by integer multiples of sample rate and by frequency _____

Basis and qualification: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

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V011-C10-FIB-095. At exact half-rate, samples of a real sinusoid depend on amplitude times the _____ of phase.

Answer: cosine. A quadrature-phase input can produce all-zero samples despite nonzero amplitude. Source: §10.81 Sampling equivalence, admissible bands, and receiver interpretation (p. 5789)

Why this term is required: “cosine” completes the stated technical proposition.

Question context: At exact half-rate, samples of a real sinusoid depend on amplitude times the _____ of phase

Basis and qualification: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

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V011-C10-FIB-096. An admitted-band restriction supplies evidence needed to choose among otherwise identical sampled _____.

Answer: aliases. Longer observation alone does not break exact sequence equivalence. Source: §10.81 Sampling equivalence, admissible bands, and receiver interpretation (p. 5789)

Why this term is required: “aliases” completes the stated technical proposition.

Question context: An admitted-band restriction supplies evidence needed to choose among otherwise identical sampled _____

Basis and qualification: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

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V011-C10-FIB-097. For a real baseband limit B, the simple transition allowance to the nearest folding band is sample rate minus _____ B.

Answer: two. The chapter uses f_s-2B for the stated retained-band geometry, not a filter-order rule. Source: §10.82 Ten worked sampling applications (p. 5792)

Why this term is required: “two” completes the stated technical proposition.

Question context: For a real baseband limit B, the simple transition allowance to the nearest folding band is sample rate minus _____ B

Basis and qualification: Chapter 10 — Ten worked sampling applications.

Review: Chapter 10 — Ten worked sampling applications.

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V011-C10-FIB-098. For an ideal N-bit span F, interior quantizer step is F divided by two raised to _____.

Answer: N. The code-spacing formula does not establish an error distribution.

Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why this term is required: “N” completes the stated technical proposition.

Question context: For an ideal N-bit span F, interior quantizer step is F divided by two raised to _____

Basis and qualification: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-FIB-099. Uniform centered quantization error has modeled mean square equal to step squared divided by _____.

Answer: 12. This is a distributional assumption, not a consequence of the half-step bound alone. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)
Why this term is required: “12” completes the stated technical proposition.
Question context: Uniform centered quantization error has modeled mean square equal to step squared divided by _____
Basis and qualification: Chapter 10 — Quantization margin and channel bandwidth.
Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-FIB-100. White-error process gain requires actual filtering before _____, rather than bare deletion.

Answer: decimation. A lower retained rate alone does not reduce the variance of independent retained samples. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

Why this term is required: “decimation” completes the stated technical proposition.

Question context: White-error process gain requires actual filtering before _____, rather than bare deletion

Basis and qualification: Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C10-ESSAY-001. Derive the settled complex-tone output of the declared mixer, FIR, and decimator.

- Opening: Present a thesis that answers this precise question: Derive the settled complex-tone output of the declared mixer, FIR, and decimator. Identify which evidence would falsify the proposed conclusion Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Core terminology and scope: Define settled, complex-tone, output in the question's particular technical setting; explain how declared, mixer, decimator differ if that distinction would change the analysis of "Derive the settled complex-tone output of the declared mixer, FIR, and decimator" Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define input clock, signed input and NCO frequencies, initial phases, coefficient response, decimation, and retained residue Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the settled complex-tone output of the declared mixer, FIR, and decimator to the claimed result, following "Application 10C1 Signed channel centers and residual frequency"; name the intermediate states and measurable outputs Source: §10.21 Application 10C1 Signed channel centers and residual frequency (p. 5710)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the settled complex-tone output of the declared mixer, FIR, and decimator. Obtain translated response magnitude and phase at mM+p, and interpret frequency modulo output rate Source: §10.21 Application 10C1 Signed channel centers and residual frequency (p. 5710)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Interpretation and reproducibility of the channelized record” that resolves the question about the settled complex-tone output of the declared mixer, FIR, and decimator; derive the relevant result with units and stated validity conditions Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the settled complex-tone output of the declared mixer, FIR, and decimator. Explain the absence of an automatic voltage division by decimation and the inability to identify an earlier analog alias Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Worked application or illustrative case: Build a worked example of “the settled complex-tone output of the declared mixer, FIR, and decimator”, addressing this associated condition: Define input clock, signed input and NCO frequencies, initial phases, coefficient response, decimation, and.... Define input clock, signed input and NCO frequencies, initial phases, coefficient response, decimation, and retained residue Source: §10.21 Application 10C1 Signed channel centers and residual frequency (p. 5710)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the settled complex-tone output of the declared mixer, FIR, and decimator”. Using “Interpretation and reproducibility of the channelized record”, specify a discriminator and the result expected under each explanation Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the settled complex-tone output of the declared mixer, FIR, and decimator, including the effect of missing measurements and inconsistent operating conditions Source: §10.17 Interpretation of the DDC evidence (p. 5702)
- Scholarly synthesis and implications: Explain what the result about the settled complex-tone output of the declared mixer, FIR, and decimator authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Closing: Conclude by answering “Derive the settled complex-tone output of the declared mixer, FIR, and decimator” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

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V011-C10-ESSAY-002. Design a rejection test for a two-stage decimator that faces several blockers folding into the desired output.

- Opening: Present a thesis that answers this precise question: Design a rejection test for a two-stage decimator that faces several blockers folding into the desired output. Identify which evidence would falsify the proposed conclusion Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)
- Core terminology and scope: Define Design, rejection, test in the question's particular technical setting; explain how blockers, desired, output differ if that distinction would change the analysis of "Design a rejection test for a two-stage decimator that faces several blockers folding into the desired output" Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Trace each blocker on each stage's input clock, evaluate actual coefficient responses before deletion, combine stage attenuations, and compare each contribution with a common-plane limit Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a rejection test for a two-stage decimator that faces several blockers folding into the desired output to the claimed result, following "Application 10B3 An irreversible blocker combination"; name the intermediate states and measurable outputs Source: §10.9 Application 10B3 An irreversible blocker combination (p. 5694)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a rejection test for a two-stage decimator that faces several blockers folding into the desired output. Treat coherent combination separately from power addition and distinguish digital alias rejection from upstream analog overload Source: §10.9 Application 10B3 An irreversible blocker combination (p. 5694)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10B4 Allocate attenuation across actual stage frequencies” that resolves the question about a rejection test for a two-stage decimator that faces several blockers folding into the desired output; derive the relevant result with units and stated validity conditions Source: §10.10 Application 10B4 Allocate attenuation across actual stage frequencies (p. 5695)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a rejection test for a two-stage decimator that faces several blockers folding into the desired output. Avoid testing only one exact filter null Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)
- Worked application or illustrative case: Build a worked example of “a rejection test for a two-stage decimator that faces several blockers folding into the desired output”, addressing this associated condition: Trace each blocker on each stage's input clock, evaluate actual coefficient responses before deletion,.... Trace each blocker on each stage's input clock, evaluate actual coefficient responses

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before deletion, combine stage attenuations, and... Source: §10.9 Application 10B3 An irreversible blocker combination (p. 5694)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a rejection test for a two-stage decimator that faces several blockers folding into the desired output”. Using “Application 10B4 Allocate attenuation across actual stage frequencies”, specify a discriminator and the result expected under each explanation Source: §10.10 Application 10B4 Allocate attenuation across actual stage frequencies (p. 5695)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a rejection test for a two-stage decimator that faces several blockers folding into the desired output, including the effect of missing measurements and inconsistent operating conditions Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Scholarly synthesis and implications: Explain what the result about a rejection test for a two-stage decimator that faces several blockers folding into the desired output authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)
- Closing: Conclude by answering “Design a rejection test for a two-stage decimator that faces several blockers folding into the desired output” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

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V011-C10-ESSAY-003. Explain the difference between FIR group delay, complete startup history, and a retained output timestamp.

- Opening: Present a thesis that answers this precise question: Explain the difference between FIR group delay, complete startup history, and a retained output timestamp. Identify which evidence would falsify the proposed conclusion Source: §10.12 Application 10B6 Group delay and first complete filter history (p. 5697)
- Core terminology and scope: Define group, delay, startup in the question's particular technical setting; explain how history, retained, timestamp differ if that distinction would change the analysis of "Explain the difference between FIR group delay, complete startup history, and a retained output timestamp" Source: §10.12 Application 10B6 Group delay and first complete filter history (p. 5697)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the 33-tap symmetric example to distinguish center lag 16 from history requirement 32 Source: §10.12 Application 10B6 Group delay and first complete filter history (p. 5697)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the difference between FIR group delay, complete startup history, and a retained output timestamp to the claimed result, following "Application 10E.4: an ordinary block boundary preserves filter history"; name the intermediate states and measurable outputs Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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difference between FIR group delay, complete startup history, and a retained output timestamp. Map retained index mM+p to center time and identify the first complete retained history Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 10B for digital mixing filtering and decimation” that resolves the question about the difference between FIR group delay, complete startup history, and a retained output timestamp; derive the relevant result with units and stated validity conditions Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the difference between FIR group delay, complete startup history, and a retained output timestamp. Discuss initial-state assumptions, response zeros, error criterion, and why a single delay number does not define a discard interval Source: §10.12 Application 10B6 Group delay and first complete filter history (p. 5697)
- Worked application or illustrative case: Build a worked example of “the difference between FIR group delay, complete startup history, and a retained output timestamp”, addressing this associated condition: Use the 33-tap symmetric example to distinguish center lag 16 from history requirement 32. Use the 33-tap symmetric example to distinguish center lag 16 from history requirement 32 Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the difference between FIR group delay, complete startup history, and a retained output timestamp”. Using “Model 10B for digital mixing filtering and decimation”, specify a discriminator and the result expected under each explanation Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the difference between FIR group delay, complete startup history, and a retained output timestamp, including the effect of missing measurements and inconsistent operating conditions Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Scholarly synthesis and implications: Explain what the result about the difference between FIR group delay, complete startup history, and a retained output timestamp authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.12 Application 10B6 Group delay and first complete filter history (p. 5697)
- Closing: Conclude by answering “Explain the difference between FIR group delay, complete startup history, and a retained output timestamp” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.12 Application 10B6 Group delay and first complete filter history (p. 5697)

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V011-C10-ESSAY-004. Analyze a phase discontinuity introduced at file boundaries despite continuous source counters.

- Opening: Present a thesis that answers this precise question: Analyze a phase discontinuity introduced at file boundaries despite continuous source counters. Identify which evidence would falsify the proposed conclusion Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)
- Core terminology and scope: Define discontinuity, introduced, file in the question's particular technical setting; explain how boundaries, despite, counters differ if that distinction would change the analysis of "Analyze a phase discontinuity introduced at file boundaries despite continuous source counters" Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Track absolute input timing, continuous NCO phase, FIR history, and retained schedule Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a phase discontinuity introduced at file boundaries despite continuous source counters to the claimed result, following "Application 10B7 Retained phase creates a coherent offset"; name the intermediate states and measurable outputs Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a phase

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discontinuity introduced at file boundaries despite continuous source counters. Use the 9 MHz/48 MS/s/1000-sample example to explain alternating sign resets Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10E.4: an ordinary block boundary preserves filter history” that resolves the question about a phase discontinuity introduced at file boundaries despite continuous source counters; derive the relevant result with units and stated validity conditions Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a phase discontinuity introduced at file boundaries despite continuous source counters. Examine boundary convolution separately from settled block interiors and distinguish NCO reset from filter reset Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)
- Worked application or illustrative case: Build a worked example of “a phase discontinuity introduced at file boundaries despite continuous source counters”, addressing this associated condition: Track absolute input timing, continuous NCO phase, FIR history, and retained schedule. Track absolute input timing, continuous NCO phase, FIR history, and retained schedule Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a phase discontinuity introduced at file

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boundaries despite continuous source counters". Using "Application 10E.4: an ordinary block boundary preserves filter history", specify a discriminator and the result expected under each explanation Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a phase discontinuity introduced at file boundaries despite continuous source counters, including the effect of missing measurements and inconsistent operating conditions Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)
- Scholarly synthesis and implications: Explain what the result about a phase discontinuity introduced at file boundaries despite continuous source counters authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)
- Closing: Conclude by answering "Analyze a phase discontinuity introduced at file boundaries despite continuous source counters" using only the demonstrated evidence; state the remaining decisive verification step Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

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V011-C10-ESSAY-005. Derive the causal channelizer's polyphase transform convention from its direct mixer-filter sum.

- Opening: Present a thesis that answers this precise question: Derive the causal channelizer's polyphase transform convention from its direct mixer-filter sum. Identify which evidence would falsify the proposed conclusion Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)
- Core terminology and scope: Define causal, polyphase, transform in the question's particular technical setting; explain how convention, direct, mixer-filter differ if that distinction would change the analysis of "Derive the causal channelizer's polyphase transform convention from its direct mixer-filter sum" Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Group lag by channel count, derive the positive inner exponent, state inverse-DFT normalization and negative-FFT remapping, and retain the outer channel phase Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the causal channelizer's polyphase transform convention from its direct mixer-filter sum to the claimed result, following "Interpretation and reproducibility of the channelized record"; name the intermediate states and measurable outputs Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the causal channelizer's polyphase transform convention from its direct mixer-filter sum. Explain critical versus oversampled residue scheduling and why labels FFT or polyphase do not uniquely specify sign, order, or gain Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10C2 Transform sign and amplitude normalization” that resolves the question about the causal channelizer's polyphase transform convention from its direct mixer-filter sum; derive the relevant result with units and stated validity conditions Source: §10.22 Application 10C2 Transform sign and amplitude normalization (p. 5711)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the causal channelizer's polyphase transform convention from its direct mixer-filter sum. Explain critical versus oversampled residue scheduling and why labels FFT or polyphase do not uniquely specify sign, order, or gain Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)
- Worked application or illustrative case: Build a worked example of “the causal channelizer's polyphase transform convention from its direct mixer-filter sum”, addressing this associated condition: Group lag by channel count, derive the positive inner exponent, state inverse-DFT normalization and.... Group lag by channel count, derive the positive inner exponent, state inverse-DFT normalization and

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negative-FFT remapping, and retain the outer... Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the causal channelizer's polyphase transform convention from its direct mixer-filter sum”. Using “Application 10C2 Transform sign and amplitude normalization”, specify a discriminator and the result expected under each explanation Source: §10.22 Application 10C2 Transform sign and amplitude normalization (p. 5711)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the causal channelizer's polyphase transform convention from its direct mixer-filter sum, including the effect of missing measurements and inconsistent operating conditions Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)
- Scholarly synthesis and implications: Explain what the result about the causal channelizer's polyphase transform convention from its direct mixer-filter sum authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)
- Closing: Conclude by answering “Derive the causal channelizer's polyphase transform convention from its direct mixer-filter sum” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

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V011-C10-ESSAY-006. Evaluate whether two strong adjacent-channel traces establish two emitters.

- Opening: Present a thesis that answers this precise question: Evaluate whether two strong adjacent-channel traces establish two emitters. Identify which evidence would falsify the proposed conclusion Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Core terminology and scope: Define strong, adjacent-channel, traces in the question's particular technical setting; explain how emitters, measurement, evidence differ if that distinction would change the analysis of "Evaluate whether two strong adjacent-channel traces establish two emitters" Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the prototype response for a boundary tone, preserve signed centers and residual labels, and compare the full response vector Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting whether two strong adjacent-channel traces establish two emitters to the claimed result, following "Application 10C1 Signed channel centers and residual frequency"; name the intermediate states and measurable outputs Source: §10.21 Application 10C1 Signed channel centers and residual frequency (p. 5710)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for whether two strong adjacent-channel traces establish two emitters. Explain why one source can populate both channels and why unqualified power addition is not a calibrated input estimate Source: §10.21 Application 10C1 Signed channel centers and residual frequency (p. 5710)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10C3 One tone at a channel boundary” that resolves the question about whether two strong adjacent-channel traces establish two emitters; derive the relevant result with units and stated validity conditions Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)
- Evidence and method: Specify the native observations, control records and calculations that would resolve whether two strong adjacent-channel traces establish two emitters. Validate center and boundary tones with actual coefficients and arithmetic Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Worked application or illustrative case: Build a worked example of “whether two strong adjacent-channel traces establish two emitters”, addressing this associated condition: Use the prototype response for a boundary tone, preserve signed centers and residual labels, and compare the.... Use the prototype response for a boundary tone, preserve signed centers and residual labels, and compare the full response vector Source: §10.21 Application 10C1 Signed channel centers and residual frequency (p. 5710)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “whether two strong adjacent-channel traces establish two emitters”. Using “Application 10C3 One tone at a channel boundary”, specify a discriminator and the result expected under each explanation Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to whether two strong adjacent-channel traces establish two emitters, including the effect of missing measurements and inconsistent operating conditions Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)
- Scholarly synthesis and implications: Explain what the result about whether two strong adjacent-channel traces establish two emitters authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Closing: Conclude by answering “Evaluate whether two strong adjacent-channel traces establish two emitters” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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V011-C10-ESSAY-007. Explain why saving one channel can lose a distinction retained by the full channelizer.

- Opening: Present a thesis that answers this precise question: Explain why saving one channel can lose a distinction retained by the full channelizer. Identify which evidence would falsify the proposed conclusion Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)
- Core terminology and scope: Define saving, channel, lose in the question's particular technical setting; explain how distinction, retained, channelizer differ if that distinction would change the analysis of "Explain why saving one channel can lose a distinction retained by the full channelizer" Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Analyze the chapter's single-channel alias with adjusted complex coefficient and the particular complete rectangular bank's inverse Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why saving one channel can lose a distinction retained by the full channelizer to the claimed result, following "Interpretation and reproducibility of the channelized record"; name the intermediate states and measurable outputs Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why saving one channel can lose a distinction retained by the full channelizer. Identify which complete vector information distinguishes the inputs Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10C6 Oversampling and the complete recording rate” that resolves the question about why saving one channel can lose a distinction retained by the full channelizer; derive the relevant result with units and stated validity conditions Source: §10.26 Application 10C6 Oversampling and the complete recording rate (p. 5715)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why saving one channel can lose a distinction retained by the full channelizer. Limit perfect-reconstruction claims to the specified prototype, full channels, valid history, and retained frames; discuss recording-rate tradeoffs Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)
- Worked application or illustrative case: Build a worked example of “why saving one channel can lose a distinction retained by the full channelizer”, addressing this associated condition: Analyze the chapter's single-channel alias with adjusted complex coefficient and the particular complete.... Analyze the chapter's single-channel alias with adjusted complex coefficient and the particular complete rectangular bank's inverse Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “why saving one channel can lose a distinction retained by the full channelizer”. Using “Application 10C6 Oversampling and the complete recording rate”, specify a discriminator and the result expected under each explanation Source: §10.26 Application 10C6 Oversampling and the complete recording rate (p. 5715)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why saving one channel can lose a distinction retained by the full channelizer, including the effect of missing measurements and inconsistent operating conditions Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)
- Scholarly synthesis and implications: Explain what the result about why saving one channel can lose a distinction retained by the full channelizer authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)
- Closing: Conclude by answering “Explain why saving one channel can lose a distinction retained by the full channelizer” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

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V011-C10-ESSAY-008. Analyze statistical dependence across a channelizer's outputs under white input second moments.

- Opening: Present a thesis that answers this precise question: Analyze statistical dependence across a channelizer's outputs under white input second moments. Identify which evidence would falsify the proposed conclusion Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)
- Core terminology and scope: Define statistical, dependence, outputs in the question's particular technical setting; explain how white, second, moments differ if that distinction would change the analysis of "Analyze statistical dependence across a channelizer's outputs under white input second moments" Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Expand same-time covariance using tap energies and channel phase factors Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting statistical dependence across a channelizer's outputs under white input second moments to the claimed result, following "Application 10C7 White input can give correlated simultaneous channels"; name the intermediate states and measurable outputs Source: §10.27 Application 10C7 White input can give correlated simultaneous channels (p. 5717)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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statistical dependence across a channelizer's outputs under white input second moments. Explain correlated simultaneous channels from unequal energies, time correlation from overlapping frames, and why zero covariance is not independence without a suitable joint distribution Source: §10.27 Application 10C7 White input can give correlated simultaneous channels (p. 5717)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Interpretation and reproducibility of the channelized record” that resolves the question about statistical dependence across a channelizer's outputs under white input second moments; derive the relevant result with units and stated validity conditions Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Evidence and method: Specify the native observations, control records and calculations that would resolve statistical dependence across a channelizer's outputs under white input second moments. Keep prehistory assumptions explicit and reject counting every frame-channel pair as independent automatically Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)
- Worked application or illustrative case: Build a worked example of “statistical dependence across a channelizer's outputs under white input second moments”, addressing this associated condition: Expand same-time covariance using tap energies and channel phase factors. Expand same-time covariance using tap energies and channel phase factors Source: §10.27 Application 10C7 White input can give correlated simultaneous channels (p. 5717)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “statistical dependence across a channelizer's outputs under white input second moments”. Using “Interpretation and reproducibility of the channelized record”, specify a discriminator and the result expected under each explanation Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to statistical dependence across a channelizer's outputs under white input second moments, including the effect of missing measurements and inconsistent operating conditions Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)
- Scholarly synthesis and implications: Explain what the result about statistical dependence across a channelizer's outputs under white input second moments authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)
- Closing: Conclude by answering “Analyze statistical dependence across a channelizer's outputs under white input second moments” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

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V011-C10-ESSAY-009. Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility.

- Opening: Present a thesis that answers this precise question: Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility. Identify which evidence would falsify the proposed conclusion Source: §10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage (p. 5720)
- Core terminology and scope: Define oversampled, repair, examples in the question's particular technical setting; explain how claims, filter-bank, invertibility differ if that distinction would change the analysis of "Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility" Source: §10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage (p. 5720)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Show how the zero tap removes an entire residue at critical sampling despite unit DC gain and equal aggregate rate Source: §10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage (p. 5720)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility to the claimed result, following "Application 10C9 Critical sampling can retain a complete blind residue"; name the intermediate states and measurable outputs Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility. For the stated oversampled bank, retain every affected frame and channel and explain the positive lower energy bound and unequal energy weighting Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10C8 Same-frame decorrelation does not remove time overlap” that resolves the question about Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility; derive the relevant result with units and stated validity conditions Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility. Do not generalize this repair to every prototype or truncated record Source: §10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage (p. 5720)
- Worked application or illustrative case: Build a worked example of “Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility”, addressing this associated condition: Show how the zero tap removes an entire residue at critical sampling despite unit DC gain and equal aggregate.... Show how the zero tap removes an entire residue at critical sampling

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despite unit DC gain and equal aggregate rate Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility”. Using “Application 10C8 Same-frame decorrelation does not remove time overlap”, specify a discriminator and the result expected under each explanation Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility, including the effect of missing measurements and inconsistent operating conditions Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Scholarly synthesis and implications: Explain what the result about Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage (p. 5720)
- Closing: Conclude by answering “Use the blind-residue and oversampled repair examples to assess claims of filter-bank invertibility” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage (p. 5720)

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V011-C10-ESSAY-010. Construct a fixed-point representation specification sufficient to reproduce one channel output.

- Opening: Present a thesis that answers this precise question: Construct a fixed-point representation specification sufficient to reproduce one channel output. Identify which evidence would falsify the proposed conclusion Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Core terminology and scope: Define Construct, representation, specification in the question's particular technical setting; explain how sufficient, reproduce, channel differ if that distinction would change the analysis of "Construct a fixed-point representation specification sufficient to reproduce one channel output" Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State signed formats, total/fractional bits, physical voltage scale, quantized coefficients, product Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a fixed-point representation specification sufficient to reproduce one channel output to the claimed result, following "Signed formats and explicit conversion points"; name the intermediate states and measurable outputs Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a fixed-point representation specification sufficient to reproduce one

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channel output. Separate code correctness from physical calibration and include stage flags for intermediate overflow Source: §10.33 Signed formats and explicit conversion points (p. 5725)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 10D for fixed point channelizer arithmetic” that resolves the question about a fixed-point representation specification sufficient to reproduce one channel output; derive the relevant result with units and stated validity conditions Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a fixed-point representation specification sufficient to reproduce one channel output. Separate code correctness from physical calibration and include stage flags for intermediate overflow Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Worked application or illustrative case: Build a worked example of “a fixed-point representation specification sufficient to reproduce one channel output”, addressing this associated condition: State signed formats, total/fractional bits, physical voltage scale, quantized coefficients, product. State signed formats, total/fractional bits, physical voltage scale, quantized coefficients, product Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a fixed-point representation specification sufficient to reproduce one channel output”. Using “Model 10D for fixed point channelizer arithmetic”, specify a discriminator and the

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result expected under each explanation Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a fixed-point representation specification sufficient to reproduce one channel output, including the effect of missing measurements and inconsistent operating conditions Source: §10.34 Range and error are separate obligations (p. 5728)
- Scholarly synthesis and implications: Explain what the result about a fixed-point representation specification sufficient to reproduce one channel output authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Closing: Conclude by answering “Construct a fixed-point representation specification sufficient to reproduce one channel output” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.46 What the arithmetic comparison establishes (p. 5742)

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V011-C10-ESSAY-011. Derive an accumulator range from signed coefficient sums and input endpoints.

- Opening: Present a thesis that answers this precise question: Derive an accumulator range from signed coefficient sums and input endpoints. Identify which evidence would falsify the proposed conclusion Source: §10.34 Range and error are separate obligations (p. 5728)
- Core terminology and scope: Define accumulator, range, signed in the question's particular technical setting; explain how coefficient, sums, endpoints differ if that distinction would change the analysis of "Derive an accumulator range from signed coefficient sums and input endpoints" Source: §10.34 Range and error are separate obligations (p. 5728)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate positive and negative coefficient sums, choose endpoint inputs that minimize and maximize the branch, convert to full-product integer codes, and test both asymmetric code endpoints Source: §10.34 Range and error are separate obligations (p. 5728)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an accumulator range from signed coefficient sums and input endpoints to the claimed result, following "Application 10D2 Size a branch accumulator from its signed endpoints"; name the intermediate states and measurable outputs Source: §10.37 Application 10D2 Size a branch accumulator from its signed endpoints (p. 5733)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an

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accumulator range from signed coefficient sums and input endpoints. Explain when the interval protects direct partial sums and why transformed or feedback topologies require another intermediate analysis Source: §10.37 Application 10D2 Size a branch accumulator from its signed endpoints (p. 5733)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10D1 Coefficient rounding can preserve DC and change rejection” that resolves the question about an accumulator range from signed coefficient sums and input endpoints; derive the relevant result with units and stated validity conditions Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an accumulator range from signed coefficient sums and input endpoints. Explain when the interval protects direct partial sums and why transformed or feedback topologies require another intermediate analysis Source: §10.34 Range and error are separate obligations (p. 5728)
- Worked application or illustrative case: Build a worked example of “an accumulator range from signed coefficient sums and input endpoints”, addressing this associated condition: Separate positive and negative coefficient sums, choose endpoint inputs that minimize and maximize the.... Separate positive and negative coefficient sums, choose endpoint inputs that minimize and maximize the branch, convert to full-product integer codes, and test

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both... Source: §10.37 Application 10D2 Size a branch accumulator from its signed endpoints (p. 5733)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an accumulator range from signed coefficient sums and input endpoints”. Using “Application 10D1 Coefficient rounding can preserve DC and change rejection”, specify a discriminator and the result expected under each explanation Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an accumulator range from signed coefficient sums and input endpoints, including the effect of missing measurements and inconsistent operating conditions Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Scholarly synthesis and implications: Explain what the result about an accumulator range from signed coefficient sums and input endpoints authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.34 Range and error are separate obligations (p. 5728)
- Closing: Conclude by answering “Derive an accumulator range from signed coefficient sums and input endpoints” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.34 Range and error are separate obligations (p. 5728)

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V011-C10-ESSAY-012. Compare product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms.

- Opening: Present a thesis that answers this precise question: Compare product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms. Identify which evidence would falsify the proposed conclusion Source: §10.39 Application 10D4 Rounding once and rounding each product differ (p. 5735)
- Core terminology and scope: Define rounding, output, scaling in the question's particular technical setting; explain how distinct, error, mechanisms differ if that distinction would change the analysis of "Compare product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms" Source: §10.39 Application 10D4 Rounding once and rounding each product differ (p. 5735)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the two-product example to show noncommuting rounding and addition Source: §10.39 Application 10D4 Rounding once and rounding each product differ (p. 5735)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms to the claimed result, following "Model 10D for fixed point channelizer arithmetic"; name the intermediate states and measurable outputs Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for product-

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by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms. State the model's conversion schedule and no-overflow premises Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- Analytical framework: Identify the equation, calibration or evidential decision test in “What the arithmetic comparison establishes” that resolves the question about product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms; derive the relevant result with units and stated validity conditions Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Evidence and method: Specify the native observations, control records and calculations that would resolve product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms. Explain that scale restoration magnifies final rounding and does not restore low bits Source: §10.39 Application 10D4 Rounding once and rounding each product differ (p. 5735)
- Worked application or illustrative case: Build a worked example of “product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms”, addressing this associated condition: Use the two-product example to show noncommuting rounding and addition. Use the two-product example to show noncommuting rounding and addition Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms”.

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Using “What the arithmetic comparison establishes”, specify a discriminator and the result expected under each explanation Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms, including the effect of missing measurements and inconsistent operating conditions Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)
- Scholarly synthesis and implications: Explain what the result about product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.39 Application 10D4 Rounding once and rounding each product differ (p. 5735)
- Closing: Conclude by answering “Compare product-by-product rounding, once-per-branch rounding, and output scaling as distinct error mechanisms” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.39 Application 10D4 Rounding once and rounding each product differ (p. 5735)

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V011-C10-ESSAY-013. Explain how correct final codes can coexist with an invalid arithmetic implementation.

- Opening: Present a thesis that answers this precise question: Explain how correct final codes can coexist with an invalid arithmetic implementation. Identify which evidence would falsify the proposed conclusion Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)
- Core terminology and scope: Define final, codes, coexist in the question's particular technical setting; explain how invalid, arithmetic, implementation differ if that distinction would change the analysis of "Explain how correct final codes can coexist with an invalid arithmetic implementation" Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use intermediate wrapping or saturation examples and identify stage order and flags Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how correct final codes can coexist with an invalid arithmetic implementation to the claimed result, following "Application 10D5 Intermediate saturation makes association consequential"; name the intermediate states and measurable outputs Source: §10.40 Application 10D5 Intermediate saturation makes association consequential (p. 5736)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how

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correct final codes can coexist with an invalid arithmetic implementation. Discuss exact-phase/order mistakes that additional fractional bits cannot fix Source: §10.40 Application 10D5 Intermediate saturation makes association consequential (p. 5736)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Interpretation and reproducibility of the channelized record” that resolves the question about how correct final codes can coexist with an invalid arithmetic implementation; derive the relevant result with units and stated validity conditions Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how correct final codes can coexist with an invalid arithmetic implementation. Compare to the intended direct reference and test endpoint and nonsymmetric vectors; a coincidentally correct final result does not prove all internal ranges were valid Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)
- Worked application or illustrative case: Build a worked example of “how correct final codes can coexist with an invalid arithmetic implementation”, addressing this associated condition: Use intermediate wrapping or saturation examples and identify stage order and flags. Use intermediate wrapping or saturation examples and identify stage order and flags Source: §10.40 Application 10D5 Intermediate saturation makes association consequential (p. 5736)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how correct final codes can coexist with

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an invalid arithmetic implementation". Using "Interpretation and reproducibility of the channelized record", specify a discriminator and the result expected under each explanation Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how correct final codes can coexist with an invalid arithmetic implementation, including the effect of missing measurements and inconsistent operating conditions Source: §10.37 Application 10D2 Size a branch accumulator from its signed endpoints (p. 5733)
- Scholarly synthesis and implications: Explain what the result about how correct final codes can coexist with an invalid arithmetic implementation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)
- Closing: Conclude by answering "Explain how correct final codes can coexist with an invalid arithmetic implementation" using only the demonstrated evidence; state the remaining decisive verification step Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

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V011-C10-ESSAY-014. Develop a source-index map for a recording containing out-of-order blocks, overlaps, and gaps.

- Opening: Present a thesis that answers this precise question: Develop a source-index map for a recording containing out-of-order blocks, overlaps, and gaps. Identify which evidence would falsify the proposed conclusion Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)
- Core terminology and scope: Define source-index, recording, containing in the question's particular technical setting; explain how blocks, overlaps, gaps differ if that distinction would change the analysis of "Develop a source-index map for a recording containing out-of-order blocks, overlaps, and gaps" Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify stored starts, source starts, lengths, clock segment, and anchor Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a source-index map for a recording containing out-of-order blocks, overlaps, and gaps to the claimed result, following "Application 10E.2: overlap, duplicate indices, and conflicting payloads"; name the intermediate states and measurable outputs Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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source-index map for a recording containing out-of-order blocks, overlaps, and gaps. Reorder by declared source identity, resolve global coverage before declaring gaps, compare overlapping payloads, and distinguish repeated values from repeated indices Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Interpretation and continuation boundary for Model 10E” that resolves the question about a source-index map for a recording containing out-of-order blocks, overlaps, and gaps; derive the relevant result with units and stated validity conditions Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a source-index map for a recording containing out-of-order blocks, overlaps, and gaps. Preserve unresolved conflicts and show why continuous file offsets or total length do not establish chronology Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)
- Worked application or illustrative case: Build a worked example of “a source-index map for a recording containing out-of-order blocks, overlaps, and gaps”, addressing this associated condition: Identify stored starts, source starts, lengths, clock segment, and anchor. Identify stored starts, source starts, lengths, clock segment, and anchor Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a source-index map for a recording containing out-of-order blocks, overlaps, and gaps”. Using “Interpretation and continuation boundary for Model 10E”, specify a discriminator and the result expected under each explanation Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a source-index map for a recording containing out-of-order blocks, overlaps, and gaps, including the effect of missing measurements and inconsistent operating conditions Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)
- Scholarly synthesis and implications: Explain what the result about a source-index map for a recording containing out-of-order blocks, overlaps, and gaps authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)
- Closing: Conclude by answering “Develop a source-index map for a recording containing out-of-order blocks, overlaps, and gaps” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

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V011-C10-ESSAY-015. Derive the continuity mask for a finite filter and its intersection with a decimation grid.

- Opening: Present a thesis that answers this precise question: Derive the continuity mask for a finite filter and its intersection with a decimation grid. Identify which evidence would falsify the proposed conclusion Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)
- Core terminology and scope: Define continuity, mask, finite in the question's particular technical setting; explain how intersection, decimation, grid differ if that distinction would change the analysis of "Derive the continuity mask for a finite filter and its intersection with a decimation grid" Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use actual nonzero support and unique available source values Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the continuity mask for a finite filter and its intersection with a decimation grid to the claimed result, following "Application 10E.5: zero filling preserves the grid and exposes a finite tail"; name the intermediate states and measurable outputs Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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continuity mask for a finite filter and its intersection with a decimation grid. For contiguous support, form the gap tail and intersect it with the retained epoch using ceiling/floor bounds Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10E.7: a zero coefficient changes the validity pattern” that resolves the question about the continuity mask for a finite filter and its intersection with a decimation grid; derive the relevant result with units and stated validity conditions Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the continuity mask for a finite filter and its intersection with a decimation grid. Use set unions for multiple gaps Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)
- Worked application or illustrative case: Build a worked example of “the continuity mask for a finite filter and its intersection with a decimation grid”, addressing this associated condition: Use actual nonzero support and unique available source values. Use actual nonzero support and unique available source values Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the continuity mask for a finite filter and its intersection with a decimation grid”. Using “Application 10E.7: a zero coefficient changes the validity pattern”, specify a discriminator

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and the result expected under each explanation Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the continuity mask for a finite filter and its intersection with a decimation grid, including the effect of missing measurements and inconsistent operating conditions Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)
- Scholarly synthesis and implications: Explain what the result about the continuity mask for a finite filter and its intersection with a decimation grid authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)
- Closing: Conclude by answering “Derive the continuity mask for a finite filter and its intersection with a decimation grid” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)

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V011-C10-ESSAY-016. Compare zero filling and deleting one missing position through the same FIR.

- Opening: Present a thesis that answers this precise question: Compare zero filling and deleting one missing position through the same FIR. Identify which evidence would falsify the proposed conclusion Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Core terminology and scope: Define zero, filling, deleting in the question's particular technical setting; explain how missing, position, same differ if that distinction would change the analysis of "Compare zero filling and deleting one missing position through the same FIR" Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain the original grid and validity mask for zero filling, derive the missing-input error, and state a justified amplitude bound if available Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting zero filling and deleting one missing position through the same FIR to the claimed result, following "Gap representations, phase, and the limits of timing claims"; name the intermediate states and measurable outputs Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for zero filling and deleting one missing position through the same FIR. Explain deletion's changed neighbors, timestamps, oscillator indices, and retained grid Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10E.7: a zero coefficient changes the validity pattern” that resolves the question about zero filling and deleting one missing position through the same FIR; derive the relevant result with units and stated validity conditions Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)
- Evidence and method: Specify the native observations, control records and calculations that would resolve zero filling and deleting one missing position through the same FIR. Distinguish eventual finite-history recovery from restored chronology and preserve both as explicitly derived records Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Worked application or illustrative case: Build a worked example of “zero filling and deleting one missing position through the same FIR”, addressing this associated condition: Retain the original grid and validity mask for zero filling, derive the missing-input error, and state a.... Retain the original grid and validity mask for zero filling, derive the missing-input error, and state a justified amplitude bound if available Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “zero filling and deleting one missing position through the same FIR”. Using “Application 10E.7: a zero coefficient changes the validity pattern”, specify a discriminator and the result expected under each explanation Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to zero filling and deleting one missing position through the same FIR, including the effect of missing measurements and inconsistent operating conditions Source: §10.57 Application 10E.6: deleting the same gap changes a different operator (p. 5759)
- Scholarly synthesis and implications: Explain what the result about zero filling and deleting one missing position through the same FIR authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Closing: Conclude by answering “Compare zero filling and deleting one missing position through the same FIR” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

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V011-C10-ESSAY-017. Analyze the phase and decimation consequences of compact indexing after three missing samples.

- Opening: Present a thesis that answers this precise question: Analyze the phase and decimation consequences of compact indexing after three missing samples. Identify which evidence would falsify the proposed conclusion Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)
- Core terminology and scope: Define phase, decimation, consequences in the question's particular technical setting; explain how compact, missing, samples differ if that distinction would change the analysis of "Analyze the phase and decimation consequences of compact indexing after three missing samples" Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use source deficit three and mixer increment to obtain a 135-degree rotation only across constant-deficit support Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the phase and decimation consequences of compact indexing after three missing samples to the claimed result, following "Application 10E.9: absolute phase survives three missing positions"; name the intermediate states and measurable outputs Source: §10.60 Application 10E.9: absolute phase survives three missing positions (p. 5762)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the phase and decimation consequences of compact indexing after three missing samples. Explain the four intervals between bounding retained samples, gap-crossing convolution, and changed modulo-four retained source instants Source: §10.60 Application 10E.9: absolute phase survives three missing positions (p. 5762)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10E.8: decimation retains two outputs from a longer gap tail” that resolves the question about the phase and decimation consequences of compact indexing after three missing samples; derive the relevant result with units and stated validity conditions Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the phase and decimation consequences of compact indexing after three missing samples. Show why one phase factor cannot repair all consequences Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)
- Worked application or illustrative case: Build a worked example of “the phase and decimation consequences of compact indexing after three missing samples”, addressing this associated condition: Use source deficit three and mixer increment to obtain a 135-degree rotation only across constant-deficit.... Use source deficit three and mixer increment to obtain a 135-degree rotation only across

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constant-deficit support Source: §10.60 Application 10E.9: absolute phase survives three missing positions (p. 5762)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the phase and decimation consequences of compact indexing after three missing samples”. Using “Application 10E.8: decimation retains two outputs from a longer gap tail”, specify a discriminator and the result expected under each explanation Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the phase and decimation consequences of compact indexing after three missing samples, including the effect of missing measurements and inconsistent operating conditions Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)
- Scholarly synthesis and implications: Explain what the result about the phase and decimation consequences of compact indexing after three missing samples authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)
- Closing: Conclude by answering “Analyze the phase and decimation consequences of compact indexing after three missing samples” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

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V011-C10-ESSAY-018. Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument.

- Opening: Present a thesis that answers this precise question: Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument. Identify which evidence would falsify the proposed conclusion Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)
- Core terminology and scope: Define Separate, sample, continuity in the question's particular technical setting; explain how accuracy, acceptance, argument differ if that distinction would change the analysis of "Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument" Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State what the dependency mask establishes Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument to the claimed result, following "Model 10D for fixed point channelizer arithmetic"; name the intermediate states and measurable outputs Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Separate

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sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument. Add the constant-rate and anchor-error bound for timing, excluding unmodeled wander and resets, and apply the separate no-overflow/rounding contract for numerical values Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 10E for absolute sample continuity and retained processing state” that resolves the question about Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument; derive the relevant result with units and stated validity conditions Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument. Explain that valid dependencies are necessary candidates for usable observation but do not certify every signal or calibration property Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)
- Worked application or illustrative case: Build a worked example of “Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument”, addressing this associated condition: State what the dependency mask establishes. State what the dependency mask establishes Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument”. Using “Model 10E for absolute sample continuity and retained processing state”, specify a discriminator and the result expected under each explanation Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument, including the effect of missing measurements and inconsistent operating conditions Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)
- Scholarly synthesis and implications: Explain what the result about Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)
- Closing: Conclude by answering “Separate sample continuity, elapsed-time accuracy, and fixed-point accuracy in one acceptance argument” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

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V011-C10-ESSAY-019. Design a bounded SDR acceptance case for a named receive configuration and recording workload.

- Opening: Present a thesis that answers this precise question: Design a bounded SDR acceptance case for a named receive configuration and recording workload. Identify which evidence would falsify the proposed conclusion Source: §10.65 Define the case before testing (p. 5767)
- Core terminology and scope: Define Design, bounded, case in the question's particular technical setting; explain how named, recording, workload differ if that distinction would change the analysis of "Design a bounded SDR acceptance case for a named receive configuration and recording workload" Source: §10.65 Define the case before testing (p. 5767)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Declare plane, channels, bands, levels, gain/filter/clock states, sample formats, rates, processing, destination, and host conditions Source: §10.65 Define the case before testing (p. 5767)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a bounded SDR acceptance case for a named receive configuration and recording workload to the claimed result, following "Application 10F.10 An update closes a precisely bounded case"; name the intermediate states and measurable outputs Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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bounded SDR acceptance case for a named receive configuration and recording workload. Assign stable criteria with discriminating evidence and predeclared rules Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Framework 10F for bounded SDR acceptance” that resolves the question about a bounded SDR acceptance case for a named receive configuration and recording workload; derive the relevant result with units and stated validity conditions Source: §10.64 Framework 10F for bounded SDR acceptance (p. 5766)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a bounded SDR acceptance case for a named receive configuration and recording workload. Separate applicability from result, justify exclusions, and require all mandatory applicable criteria satisfied Source: §10.65 Define the case before testing (p. 5767)
- Worked application or illustrative case: Build a worked example of “a bounded SDR acceptance case for a named receive configuration and recording workload”, addressing this associated condition: Declare plane, channels, bands, levels, gain/filter/clock states, sample formats, rates, processing,.... Declare plane, channels, bands, levels, gain/filter/clock states, sample formats, rates, processing, destination, and host conditions Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a bounded SDR acceptance case for a

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named receive configuration and recording workload". Using "Framework 10F for bounded SDR acceptance", specify a discriminator and the result expected under each explanation Source: §10.64 Framework 10F for bounded SDR acceptance (p. 5766)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a bounded SDR acceptance case for a named receive configuration and recording workload, including the effect of missing measurements and inconsistent operating conditions Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)
- Scholarly synthesis and implications: Explain what the result about a bounded SDR acceptance case for a named receive configuration and recording workload authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.65 Define the case before testing (p. 5767)
- Closing: Conclude by answering "Design a bounded SDR acceptance case for a named receive configuration and recording workload" using only the demonstrated evidence; state the remaining decisive verification step Source: §10.65 Define the case before testing (p. 5767)

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V011-C10-ESSAY-020. Explain the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association.

- Opening: Present a thesis that answers this precise question: Explain the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association. Identify which evidence would falsify the proposed conclusion Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)
- Core terminology and scope: Define claims, digest, signature in the question's particular technical setting; explain how build, provenance, association differ if that distinction would change the analysis of "Explain the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association" Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Bind each documentary result to its actual subject and trust policy Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association to the claimed result, following "Application 10F.3 The verified image was never shown to be loaded"; name the intermediate states and measurable outputs Source: §10.71 Application 10F.3 The verified image was never shown to be loaded (p. 5779)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association. Distinguish same filename from same bytes, authenticated signing from permitted build expectations, and verified downloaded file from observed loaded image Source: §10.71 Application 10F.3 The verified image was never shown to be loaded (p. 5779)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10F.2 A valid signature with an unacceptable build claim” that resolves the question about the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association; derive the relevant result with units and stated validity conditions Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association. Identify limits of ordinary readbacks and version strings and retain narrower assurance rather than inventing runtime attestation Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)
- Worked application or illustrative case: Build a worked example of “the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association”, addressing this associated condition: Bind each documentary result to its actual

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subject and trust policy. Bind each documentary result to its actual subject and trust policy Source: §10.71 Application 10F.3 The verified image was never shown to be loaded (p. 5779)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association”. Using “Application 10F.2 A valid signature with an unacceptable build claim”, specify a discriminator and the result expected under each explanation Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association, including the effect of missing measurements and inconsistent operating conditions Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)
- Scholarly synthesis and implications: Explain what the result about the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)
- Closing: Conclude by answering “Explain the distinct claims supported by artifact digest, code signature, build provenance, and loaded-image association” using only the demonstrated evidence;

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state the remaining decisive verification step Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

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V011-C10-ESSAY-021. Construct a sample-format and channel-map test that can expose shared implementation faults.

- Opening: Present a thesis that answers this precise question: Construct a sample-format and channel-map test that can expose shared implementation faults. Identify which evidence would falsify the proposed conclusion Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)
- Core terminology and scope: Define Construct, sample-format, test in the question's particular technical setting; explain how expose, shared, implementation differ if that distinction would change the analysis of "Construct a sample-format and channel-map test that can expose shared implementation faults" Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use asymmetric signed integer codes, stated byte/IQ/channel order, and a declared boundary Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a sample-format and channel-map test that can expose shared implementation faults to the claimed result, following "Application 10F.8 Two agreeing programs share the same fault"; name the intermediate states and measurable outputs Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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sample-format and channel-map test that can expose shared implementation faults. Compare expected vectors from an analytically independent oracle with outputs, trace common libraries, and preserve scaling Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose evidence that can discriminate the required behavior” that resolves the question about a sample-format and channel-map test that can expose shared implementation faults; derive the relevant result with units and stated validity conditions Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a sample-format and channel-map test that can expose shared implementation faults. Explain why zeros, identical channel values, successful installation, or two programs sharing one map can conceal errors Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)
- Worked application or illustrative case: Build a worked example of “a sample-format and channel-map test that can expose shared implementation faults”, addressing this associated condition: Use asymmetric signed integer codes, stated byte/IQ/channel order, and a declared boundary. Use asymmetric signed integer codes, stated byte/IQ/channel order, and a declared boundary Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a sample-format and channel-map test

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that can expose shared implementation faults". Using "Choose evidence that can discriminate the required behavior", specify a discriminator and the result expected under each explanation Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a sample-format and channel-map test that can expose shared implementation faults, including the effect of missing measurements and inconsistent operating conditions Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Scholarly synthesis and implications: Explain what the result about a sample-format and channel-map test that can expose shared implementation faults authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)
- Closing: Conclude by answering "Construct a sample-format and channel-map test that can expose shared implementation faults" using only the demonstrated evidence; state the remaining decisive verification step Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)

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V011-C10-ESSAY-022. Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test.

- Opening: Present a thesis that answers this precise question: Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test. Identify which evidence would falsify the proposed conclusion Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)
- Core terminology and scope: Define Apply, rule, near in the question's particular technical setting; explain how boundary, incomplete, recording differ if that distinction would change the analysis of "Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test" Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use a justified deterministic interval with explicit inclusive endpoints, classify wholly inside, wholly outside, and overlap cases, and distinguish a coverage interval from a bound Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test to the claimed result, following "Application 10F.7 A streaming pass leaves the recording path unresolved"; name the intermediate states and measurable outputs

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Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test. For recording, require the named writer and workload plus source-index checks, not streaming-only success or expected file size Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10F.10 An update closes a precisely bounded case” that resolves the question about Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test; derive the relevant result with units and stated validity conditions Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test. Do not transfer a pass beyond tested scope Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)
- Worked application or illustrative case: Build a worked example of “Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test”, addressing this associated condition: Use a justified deterministic interval with

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explicit inclusive endpoints, classify wholly inside, wholly.... Use a justified deterministic interval with explicit inclusive endpoints, classify wholly inside, wholly outside,... Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test”. Using “Application 10F.10 An update closes a precisely bounded case”, specify a discriminator and the result expected under each explanation Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test, including the effect of missing measurements and inconsistent operating conditions Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)
- Scholarly synthesis and implications: Explain what the result about Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)
- Closing: Conclude by answering “Apply the three-state acceptance rule to an amplitude result near a stated boundary and to an incomplete recording test” using only the demonstrated evidence;

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state the remaining decisive verification step Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)

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V011-C10-ESSAY-023. Evaluate a rate-change alias challenge as candidate testing rather than a uniqueness theorem.

- Opening: Present a thesis that answers this precise question: Evaluate a rate-change alias challenge as candidate testing rather than a uniqueness theorem. Identify which evidence would falsify the proposed conclusion Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)
- Core terminology and scope: Define alias, challenge, candidate in the question's particular technical setting; explain how testing, uniqueness, theorem differ if that distinction would change the analysis of "Evaluate a rate-change alias challenge as candidate testing rather than a uniqueness theorem" Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the admitted analog bands and mixer plan, predict signed/folded mappings at each actual rate, and retain candidates with identical mappings Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a rate-change alias challenge as candidate testing rather than a uniqueness theorem to the claimed result, following "Sampling application 4 A useful rate change"; name the intermediate states and measurable outputs Source: §10.86 Sampling application 4 A useful rate change (p. 5796)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a rate-

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change alias challenge as candidate testing rather than a uniqueness theorem. Use the 10 MHz and 110 MHz two-rate counterexample and the half-rate phase ambiguity Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Sampling application 2 The half-rate phase failure” that resolves the question about a rate-change alias challenge as candidate testing rather than a uniqueness theorem; derive the relevant result with units and stated validity conditions Source: §10.84 Sampling application 2 The half-rate phase failure (p. 5794)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a rate-change alias challenge as candidate testing rather than a uniqueness theorem. Explain complex sign information and physical I/Q limits, plus why front-end admission evidence remains necessary Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)
- Worked application or illustrative case: Build a worked example of “a rate-change alias challenge as candidate testing rather than a uniqueness theorem”, addressing this associated condition: Define the admitted analog bands and mixer plan, predict signed/folded mappings at each actual rate, and.... Define the admitted analog bands and mixer plan, predict signed/folded mappings at each actual rate, and retain candidates with identical mappings Source: §10.86 Sampling application 4 A useful rate change (p. 5796)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a rate-change alias challenge as

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candidate testing rather than a uniqueness theorem". Using "Sampling application 2 The half-rate phase failure", specify a discriminator and the result expected under each explanation Source: §10.84 Sampling application 2 The half-rate phase failure (p. 5794)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a rate-change alias challenge as candidate testing rather than a uniqueness theorem, including the effect of missing measurements and inconsistent operating conditions Source: §10.85 Sampling application 3 A folded upper-zone tone (p. 5795)
- Scholarly synthesis and implications: Explain what the result about a rate-change alias challenge as candidate testing rather than a uniqueness theorem authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)
- Closing: Conclude by answering "Evaluate a rate-change alias challenge as candidate testing rather than a uniqueness theorem" using only the demonstrated evidence; state the remaining decisive verification step Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

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V011-C10-ESSAY-024. Derive the ideal quantization SQNR and filtered-error gain with their separate assumptions.

- Opening: Present a thesis that answers this precise question: Derive the ideal quantization SQNR and filtered-error gain with their separate assumptions. Identify which evidence would falsify the proposed conclusion Source: §10.101 Application 8 Mean-square error is not always variance (p. 5814)
- Core terminology and scope: Define ideal, quantization, filtered-error in the question's particular technical setting; explain how gain, separate, assumptions differ if that distinction would change the analysis of "Derive the ideal quantization SQNR and filtered-error gain with their separate assumptions" Source: §10.101 Application 8 Mean-square error is not always variance (p. 5814)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start with code spacing, distinguish half-step bound from uniform centered error, derive mean-square error Source: §10.101 Application 8 Mean-square error is not always variance (p. 5814)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the ideal quantization SQNR and filtered-error gain with their separate assumptions to the claimed result, following "Sampling, Aliasing, and Band Selection"; name the intermediate states and measurable outputs Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the ideal quantization SQNR and filtered-error gain with their separate

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assumptions. State actual equivalent bandwidth, anti-alias filtering, retained signal gain, endpoint/headroom limits, and why deletion or rescaling alone supplies no gain Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio” that resolves the question about the ideal quantization SQNR and filtered-error gain with their separate assumptions; derive the relevant result with units and stated validity conditions Source: §10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio (p. 5821)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the ideal quantization SQNR and filtered-error gain with their separate assumptions. State actual equivalent bandwidth, anti-alias filtering, retained signal gain, endpoint/headroom limits, and why deletion or rescaling alone supplies no gain Source: §10.101 Application 8 Mean-square error is not always variance (p. 5814)
- Worked application or illustrative case: Build a worked example of “the ideal quantization SQNR and filtered-error gain with their separate assumptions”, addressing this associated condition: Start with code spacing, distinguish half-step bound from uniform centered error, derive mean-square error. Start with code spacing, distinguish half-step bound from uniform centered error, derive mean-square error Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the ideal quantization SQNR and filtered-error gain with their separate assumptions”. Using “Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio”, specify a discriminator and the result expected under each explanation Source: §10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio (p. 5821)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the ideal quantization SQNR and filtered-error gain with their separate assumptions, including the effect of missing measurements and inconsistent operating conditions Source: §10.96 Application 3 Crest-factor headroom (p. 5809)
- Scholarly synthesis and implications: Explain what the result about the ideal quantization SQNR and filtered-error gain with their separate assumptions authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.101 Application 8 Mean-square error is not always variance (p. 5814)
- Closing: Conclude by answering “Derive the ideal quantization SQNR and filtered-error gain with their separate assumptions” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.101 Application 8 Mean-square error is not always variance (p. 5814)

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V011-C10-ESSAY-025. Assess a recording whose periodic impulses correlate with overflow and disappear after changing storage.

- Opening: Present a thesis that answers this precise question: Assess a recording whose periodic impulses correlate with overflow and disappear after changing storage. Identify which evidence would falsify the proposed conclusion Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)
- Core terminology and scope: Define recording, periodic, correlate in the question's particular technical setting; explain how overflow, disappear, storage differ if that distinction would change the analysis of "Assess a recording whose periodic impulses correlate with overflow and disappear after changing storage" Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Preserve original samples and logs, establish source-index gaps and processing-state effects, and compare capability and configuration across the destination change Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a recording whose periodic impulses correlate with overflow and disappear after changing storage to the claimed result, following "Model 10E for absolute sample continuity and retained processing state"; name the intermediate states and measurable outputs Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a recording whose periodic impulses correlate with overflow and disappear after changing storage. Treat the observations as support for a recording-path mechanism while checking affected records before environmental attribution Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10F.7 A streaming pass leaves the recording path unresolved” that resolves the question about a recording whose periodic impulses correlate with overflow and disappear after changing storage; derive the relevant result with units and stated validity conditions Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a recording whose periodic impulses correlate with overflow and disappear after changing storage. Avoid claiming the absence of all environmental bursts or future loss probability zero Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)
- Worked application or illustrative case: Build a worked example of “a recording whose periodic impulses correlate with overflow and disappear after changing storage”, addressing this associated condition: Preserve original samples and logs, establish source-index gaps and processing-state effects, and compare.... Preserve original samples and logs, establish source-index gaps and

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processing-state effects, and compare capability and configuration… Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a recording whose periodic impulses correlate with overflow and disappear after changing storage”. Using “Application 10F.7 A streaming pass leaves the recording path unresolved”, specify a discriminator and the result expected under each explanation Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a recording whose periodic impulses correlate with overflow and disappear after changing storage, including the effect of missing measurements and inconsistent operating conditions Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)
- Scholarly synthesis and implications: Explain what the result about a recording whose periodic impulses correlate with overflow and disappear after changing storage authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)
- Closing: Conclude by answering “Assess a recording whose periodic impulses correlate with overflow and disappear after changing storage” using only the demonstrated evidence; state the remaining

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decisive verification step Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C10-DISCUSSION-001. A team treats the SDR as software and proposes omitting analog input tests. How should the boundary be explained?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team treats the SDR as software and proposes omitting analog input tests. How should the boundary be explained?” Put this particular dispute to the panel: A team treats the SDR as software and proposes omitting analog input tests. How should the boundary be explained. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

- 02. Student A, terminology and scope: Agree the operational meanings of treats, software, omitting and analog, tests, boundary in “A team treats the SDR as software and proposes omitting analog input tests. How should the boundary be explained”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team treats the SDR as software and proposes omitting analog input tests; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Converter and Waveform-Recorder Validation Boundary”. Explain information lost before sampling and how digital settings depend on it Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team treats the SDR as software and proposes omitting analog input tests; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.63 SDR Acceptance and Supply-Chain Controls (p. 5765)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Converter and Waveform-Recorder Validation Boundary”. Explain information lost before sampling and how digital settings depend on it Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify protection, filters, gain, clock, and converter as parts of the same measurement chain Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A team treats the SDR as software and proposes omitting analog input tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team treats the SDR as software and proposes omitting analog input tests; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.63 SDR Acceptance and Supply-Chain Controls (p. 5765)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team treats the SDR as software and proposes omitting analog input tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team treats the SDR as software and proposes omitting analog input tests, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team treats the SDR as software and proposes omitting analog input tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team treats the SDR as software and proposes omitting analog input tests. Retain a configuration-bound acceptance plan spanning the relevant analog and digital functions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.63 SDR Acceptance and Supply-Chain Controls (p. 5765)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team treats the SDR as software and proposes omitting analog input tests, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team treats the SDR as software and proposes omitting analog input tests. Retain a configuration-bound

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acceptance plan spanning the relevant analog and digital functions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.63 SDR Acceptance and Supply-Chain Controls (p. 5765)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team treats the SDR as software and proposes omitting analog input tests and How should the boundary be explained; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team treats the SDR as software and proposes omitting analog input tests”, addressing “How should the boundary be explained”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team treats the SDR as software and proposes omitting analog input tests. How should the boundary be explained”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team treats the SDR as software and proposes omitting analog input tests. How should the boundary be explained”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

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V011-C10-DISCUSSION-002. Two DDC implementations agree in magnitude but disagree in phase. What evidence should guide review?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two DDC implementations agree in magnitude but disagree in phase. What evidence should guide review?” Put this particular dispute to the panel: Two DDC implementations agree in magnitude but disagree in phase. What evidence should guide review. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

- 02. Student A, terminology and scope: Agree the operational meanings of implementations, agree, magnitude and disagree, guide, review in “Two DDC implementations agree in magnitude but disagree in phase. What evidence should guide review”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two DDC implementations agree in magnitude but disagree in phase; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.7 Application 10B1 Mixer sign and the output frequency label (p. 5692)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10B1 Mixer sign and the output frequency label”. Magnitude agreement does not settle timing or phase meaning Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.7 Application 10B1 Mixer sign and the output frequency label (p. 5692)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two DDC implementations agree in magnitude but disagree in phase; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10B1 Mixer sign and the output frequency label”. Magnitude agreement does not settle timing or phase meaning Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.7 Application 10B1 Mixer sign and the output frequency label (p. 5692)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare mixer sign, NCO state, retained residue, filter delay/history, transform convention, and scaling using complex references Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two DDC implementations agree in magnitude but disagree in phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two DDC implementations agree in magnitude but disagree in phase; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two DDC implementations agree in magnitude but disagree in phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two DDC implementations agree in magnitude but disagree in phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.7 Application 10B1 Mixer sign and the output frequency label (p. 5692)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two DDC implementations agree in magnitude but disagree in phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two DDC implementations agree in magnitude but disagree in phase. Preserve exact input/output indices before attributing the difference to propagation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two DDC implementations agree in magnitude but disagree in phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.7 Application 10B1 Mixer sign and the output frequency label (p. 5692)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two DDC implementations agree in magnitude but disagree in phase. Preserve exact input/output indices before attributing the difference to propagation Respond point by point to

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Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.19 Causal polyphase grouping and the transform convention (p. 5707)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two DDC implementations agree in magnitude but disagree in phase and What evidence should guide review; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.12 Application 10B6 Group delay and first complete filter history (p. 5697)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two DDC implementations agree in magnitude but disagree in phase”, addressing “What evidence should guide review”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two DDC implementations agree in magnitude but disagree in phase. What evidence should guide review”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two DDC implementations agree in magnitude but disagree in phase. What evidence should guide review”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.17 Interpretation of the DDC evidence (p. 5702)

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V011-C10-DISCUSSION-003. Should a narrowband decimator be accepted after a perfect rejection measurement at one exact null?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a narrowband decimator be accepted after a perfect rejection measurement at one exact null?” Put this particular dispute to the panel: Should a narrowband decimator be accepted after a perfect rejection measurement at one exact null. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

- 02. Student A, terminology and scope: Agree the operational meanings of narrowband, decimator, accepted and perfect, rejection, null in “Should a narrowband decimator be accepted after a perfect rejection measurement at one exact null”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.10 Application 10B4 Allocate attenuation across actual stage frequencies (p. 5695)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10B4 Allocate attenuation across actual stage frequencies”. Require nearby and relevant band tests, range checks, and a declared allowable contribution Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.10 Application 10B4 Allocate attenuation across actual stage frequencies (p. 5695)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a narrowband decimator be accepted after a perfect rejection measurement at one

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exact null; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.65 Define the case before testing (p. 5767)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10B4 Allocate attenuation across actual stage frequencies”. Require nearby and relevant band tests, range checks, and a declared allowable contribution Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.10 Application 10B4 Allocate attenuation across actual stage frequencies (p. 5695)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss the admitted blocker bands and actual stage-frequency paths Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.65 Define the case before testing (p. 5767)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.10 Application 10B4 Allocate attenuation across actual stage frequencies (p. 5695)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the

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panel to retain, qualify or reject the conclusion. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null. A useful single-point result remains bounded and cannot replace rejection-band evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.65 Define the case before testing (p. 5767)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.10 Application 10B4 Allocate attenuation across actual stage frequencies (p. 5695)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null. A useful single-point result remains bounded and cannot replace rejection-band evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.65 Define the case before testing (p. 5767)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null and Discuss the admitted blocker bands and actual stage-frequency paths; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a narrowband decimator be accepted after a perfect rejection measurement at one exact null”, addressing “Discuss the admitted blocker bands and actual stage-

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frequency paths"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Should a narrowband decimator be accepted after a perfect rejection measurement at one exact null", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Should a narrowband decimator be accepted after a perfect rejection measurement at one exact null". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.11 Application 10B5 A moving-average null is not a rejection band (p. 5696)

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V011-C10-DISCUSSION-004. A programmer claims polyphase restructuring alone improved sensitivity. How should that claim be examined?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A programmer claims polyphase restructuring alone improved sensitivity. How should that claim be examined?” Put this particular dispute to the panel: A programmer claims polyphase restructuring alone improved sensitivity. How should that claim be examined. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 02. Student A, terminology and scope: Agree the operational meanings of claims, polyphase, restructuring and sensitivity, claim, examined in “A programmer claims polyphase restructuring alone improved sensitivity. How should that claim be examined”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A programmer claims polyphase restructuring alone improved sensitivity; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Acceptance as a reproducible technical argument”. Require comparable reference tests Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A programmer claims polyphase restructuring alone improved sensitivity; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §10.4 Digital Downconversion and Channelization (p. 5687)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Acceptance as a reproducible technical argument”. Require comparable reference tests Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish computational efficiency from unchanged exact filter response, then inspect arithmetic, scaling, timing, and actual changed coefficients Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A programmer claims polyphase restructuring alone improved sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A programmer claims polyphase restructuring alone improved sensitivity; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.4 Digital Downconversion and Channelization (p. 5687)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A programmer claims polyphase restructuring alone improved sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A programmer claims polyphase restructuring alone improved sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A programmer claims polyphase restructuring alone improved sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A programmer claims polyphase restructuring alone improved sensitivity. Attribute a measured difference to demonstrated changes rather than the architecture name alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.4 Digital Downconversion and Channelization (p. 5687)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A programmer claims polyphase restructuring alone improved sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A programmer claims polyphase restructuring alone improved sensitivity. Attribute a measured difference to

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demonstrated changes rather than the architecture name alone Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.4 Digital Downconversion and Channelization (p. 5687)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A programmer claims polyphase restructuring alone improved sensitivity and How should that claim be examined; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.15 Application 10B9 Polyphase computation preserves the specified filter (p. 5700)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A programmer claims polyphase restructuring alone improved sensitivity”, addressing “How should that claim be examined”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A programmer claims polyphase restructuring alone improved sensitivity. How should that claim be examined”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A programmer claims polyphase restructuring alone improved sensitivity. How should that claim be examined”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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V011-C10-DISCUSSION-005. A channelizer displays adjacent peaks that a report counts as separate emitters. What should reviewers request?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A channelizer displays adjacent peaks that a report counts as separate emitters. What should reviewers request?” Put this particular dispute to the panel: A channelizer displays adjacent peaks that a report counts as separate emitters. What should reviewers request. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

- 02. Student A, terminology and scope: Agree the operational meanings of channelizer, displays, adjacent and peaks, emitters, request in “A channelizer displays adjacent peaks that a report counts as separate emitters. What should reviewers request”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A channelizer displays adjacent peaks that a report counts as separate emitters; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpretation and reproducibility of the channelized record”. Consider one tone's split response and alias alternatives Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A channelizer displays adjacent peaks that a report counts as separate emitters; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpretation and reproducibility of the channelized record”. Consider one tone's split response and alias alternatives Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask for prototype, channel grid, complex response vectors, source records, and center/boundary reference tests Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A channelizer displays adjacent peaks that a report counts as separate emitters: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A channelizer displays adjacent peaks that a report counts as separate emitters; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A channelizer displays adjacent peaks that a report counts as separate emitters: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A channelizer displays adjacent peaks that a report counts as separate emitters, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A channelizer displays adjacent peaks that a report counts as separate emitters: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A channelizer displays adjacent peaks that a report counts as separate emitters. Revise source counting only to the multiplicity the complete evidence supports Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A channelizer displays adjacent peaks that a report counts as separate emitters, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A channelizer displays adjacent peaks that a

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report counts as separate emitters. Revise source counting only to the multiplicity the complete evidence supports Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A channelizer displays adjacent peaks that a report counts as separate emitters and What should reviewers request; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A channelizer displays adjacent peaks that a report counts as separate emitters”, addressing “What should reviewers request”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A channelizer displays adjacent peaks that a report counts as separate emitters. What should reviewers request”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A channelizer displays adjacent peaks that a report counts as separate emitters. What should reviewers request”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.23 Application 10C3 One tone at a channel boundary (p. 5712)

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V011-C10-DISCUSSION-006. The team can store only a subset of channels. How should it decide what information loss is acceptable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The team can store only a subset of channels. How should it decide what information loss is acceptable?” Put this particular dispute to the panel: The team can store only a subset of channels. How should it decide what information loss is acceptable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

- 02. Student A, terminology and scope: Agree the operational meanings of store, subset, channels and information, loss, acceptable in “The team can store only a subset of channels. How should it decide what information loss is acceptable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The team can store only a subset of channels; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpretation and reproducibility of the channelized record”. Account for actual payload and metadata, and state which distinctions complete-bank retention would preserve Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The team can store only a subset of channels; explain what each record can establish State

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what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.26 Application 10C6 Oversampling and the complete recording rate (p. 5715)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpretation and reproducibility of the channelized record”. Account for actual payload and metadata, and state which distinctions complete-bank retention would preserve Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Relate selected channels to the intended question, alias distinctions, boundaries, and inversion requirements Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The team can store only a subset of channels: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The team can store only a subset of channels; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.26 Application 10C6 Oversampling and the complete recording rate (p. 5715)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The team can store only a subset of channels: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The team can store only a subset of channels, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The team can store only a subset of channels: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The team can store only a subset of channels. Do not treat reduced rate as proof of independent or complete coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.26 Application 10C6 Oversampling and the complete recording rate (p. 5715)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The team can store only a subset of channels, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The team can store only a subset of channels. Do not treat reduced rate as proof of independent or complete coverage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §10.26 Application 10C6 Oversampling and the complete recording rate (p. 5715)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The team can store only a subset of channels and How should it decide what information loss is acceptable; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.34 Range and error are separate obligations (p. 5728)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The team can store only a subset of channels”, addressing “How should it decide what information loss is acceptable”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The team can store only a subset of channels. How should it decide what information loss is acceptable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The team can store only a subset of channels. How should it decide what information loss is acceptable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.24 Application 10C4 A single-channel alias and a distinguishable full bank (p. 5713)

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V011-C10-DISCUSSION-007. Does a doubled aggregate channelizer output rate mean twice as much independent information?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Does a doubled aggregate channelizer output rate mean twice as much independent information?” Put this particular dispute to the panel: Does a doubled aggregate channelizer output rate mean twice as much independent information. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

- 02. Student A, terminology and scope: Agree the operational meanings of aggregate, channelizer, mean and twice, independent, information in “Does a doubled aggregate channelizer output rate mean twice as much independent information”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Does a doubled aggregate channelizer output rate mean twice as much independent information; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 10C for a polyphase analysis channelizer”. Rate is a storage/processing count, while information and independence depend on the map and model Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does a doubled aggregate channelizer output rate mean twice as much independent

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information; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 10C for a polyphase analysis channelizer”. Rate is a storage/processing count, while information and independence depend on the map and model Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss redundant samples, prototype filtering, same-frame covariance, and overlapping histories Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Does a doubled aggregate channelizer output rate mean twice as much independent information: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Does a doubled aggregate channelizer output rate mean twice as much independent information; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Does a doubled aggregate channelizer output rate mean twice as much independent information: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Does a doubled aggregate channelizer output rate mean twice as much independent information, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Does a doubled aggregate channelizer output rate mean twice as much independent information: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Does a doubled aggregate channelizer output rate mean twice as much independent information. Require explicit claims for invertibility or statistical gains Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Does a doubled aggregate channelizer output rate mean twice as much independent information, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.18 Model 10C for a polyphase analysis channelizer (p. 5703)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Does a doubled aggregate channelizer output rate mean twice as much independent information. Require explicit claims for invertibility or statistical gains Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Does a doubled aggregate channelizer output rate mean twice as much independent information and Discuss redundant samples, prototype filtering, same-frame covariance, and overlapping histories; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Does a doubled aggregate channelizer output rate mean twice as much independent information”, addressing “Discuss redundant samples, prototype filtering, same-

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frame covariance, and overlapping histories"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Does a doubled aggregate channelizer output rate mean twice as much independent information", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Does a doubled aggregate channelizer output rate mean twice as much independent information". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

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V011-C10-DISCUSSION-008. A unit-DC-gain prototype passes a center-tone check. Is that sufficient for complete-bank acceptance?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A unit-DC-gain prototype passes a center-tone check. Is that sufficient for complete-bank acceptance?” Put this particular dispute to the panel: A unit-DC-gain prototype passes a center-tone check. Is that sufficient for complete-bank acceptance. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

- 02. Student A, terminology and scope: Agree the operational meanings of unit-DC-gain, prototype, passes and check, sufficient, acceptance in “A unit-DC-gain prototype passes a center-tone check. Is that sufficient for complete-bank acceptance”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A unit-DC-gain prototype passes a center-tone check; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10C9 Critical sampling can retain a complete blind residue”. Propose sparse impulses, nonsymmetric vectors, and actual response testing Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A unit-DC-gain prototype passes a center-tone check; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10C9 Critical sampling can retain a complete blind residue”. Propose sparse impulses, nonsymmetric vectors, and actual response testing Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use blind residue, boundary response, transform ordering, and finite history as separate mechanisms Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A unit-DC-gain prototype passes a center-tone check: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A unit-DC-gain prototype passes a center-tone check; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A unit-DC-gain prototype passes a center-tone check: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A unit-DC-gain prototype passes a center-tone check, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A unit-DC-gain prototype passes a center-tone check: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A unit-DC-gain prototype passes a center-tone check. Preserve the center-tone result without extending it to all inputs or reconstruction Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A unit-DC-gain prototype passes a center-tone check, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A unit-DC-gain prototype passes a center-tone check. Preserve the center-tone result without extending it to all inputs or reconstruction Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A unit-DC-gain prototype passes a center-tone check and Is that sufficient for complete-bank acceptance; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.30 Application 10C10 Oversampling repairs this blind residue with unequal energy coverage (p. 5720)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A unit-DC-gain prototype passes a center-tone check”, addressing “Is that sufficient for complete-bank acceptance”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A unit-DC-gain prototype passes a center-tone check. Is that sufficient for complete-bank acceptance”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A unit-DC-gain prototype passes a center-tone check. Is that sufficient for complete-bank acceptance”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

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V011-C10-DISCUSSION-009. A developer reports nearest-even rounding and concludes arithmetic error is white noise. How should the reviewer respond?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A developer reports nearest-even rounding and concludes arithmetic error is white noise. How should the reviewer respond?” Put this particular dispute to the panel: A developer reports nearest-even rounding and concludes arithmetic error is white noise. How should the reviewer respond. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

- 02. Student A, terminology and scope: Agree the operational meanings of reports, rounding, arithmetic and white, reviewer, respond in “A developer reports nearest-even rounding and concludes arithmetic error is white noise. How should the reviewer respond”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A developer reports nearest-even rounding and concludes arithmetic error is white noise; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.44 Application 10D9 A constant error does not become white noise (p. 5740)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10D9 A constant error does not become white noise”. Distinguish deterministic half-step bounds, no-overflow assumptions, and statistical models Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.44 Application 10D9 A constant error does not become white noise (p. 5740)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A developer reports nearest-

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even rounding and concludes arithmetic error is white noise; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10D9 A constant error does not become white noise”. Distinguish deterministic half-step bounds, no-overflow assumptions, and statistical models Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.44 Application 10D9 A constant error does not become white noise (p. 5740)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use code-center, periodic, and constant-bias counterexamples Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A developer reports nearest-even rounding and concludes arithmetic error is white noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A developer reports nearest-even rounding and concludes arithmetic error is white noise; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A developer reports nearest-even rounding and concludes arithmetic error is white noise: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A developer reports nearest-even rounding and concludes arithmetic error is white noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.44 Application 10D9 A constant error does not become white noise (p. 5740)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A developer reports nearest-even rounding and concludes arithmetic error is white noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A developer reports nearest-even rounding and concludes arithmetic error is white noise. Require evidence for any noise or independence claim instead of inferring it from the tie rule Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A developer reports nearest-even rounding and concludes arithmetic error is white noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.44 Application 10D9 A constant error does not become white noise (p. 5740)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A developer reports nearest-even rounding and concludes arithmetic error is white noise. Require evidence for any noise or independence claim instead of inferring it from the tie rule Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A developer reports nearest-even rounding and concludes arithmetic error is white noise and How should the reviewer respond; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.100 Application 7 A periodic error sequence (p. 5813)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A developer reports nearest-even rounding and concludes arithmetic error is white noise”, addressing “How should the reviewer respond”; specify the exact measurement or evidential gap on which the speakers still differ Require Students

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A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A developer reports nearest-even rounding and concludes arithmetic error is white noise. How should the reviewer respond”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A developer reports nearest-even rounding and concludes arithmetic error is white noise. How should the reviewer respond”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

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V011-C10-DISCUSSION-010. Is restoring the display scale enough to make two finite-word pipelines equivalent?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is restoring the display scale enough to make two finite-word pipelines equivalent?” Put this particular dispute to the panel: Is restoring the display scale enough to make two finite-word pipelines equivalent. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

- 02. Student A, terminology and scope: Agree the operational meanings of restoring, display, scale and make, pipelines, equivalent in “Is restoring the display scale enough to make two finite-word pipelines equivalent”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is

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restoring the display scale enough to make two finite-word pipelines equivalent; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications of Model 10D”. Lost low bits or saturation cannot be recreated by multiplication Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is restoring the display scale enough to make two finite-word pipelines equivalent; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would

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change your opinion. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications of Model 10D”. Lost low bits or saturation cannot be recreated by multiplication Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare conversion schedules, output step restoration, intermediate range, coefficient quantization, and state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Is restoring the display scale enough to make two finite-word pipelines equivalent: specify the altered receiver

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state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is restoring the display scale enough to make two finite-word pipelines equivalent; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is restoring the display scale enough to make two finite-word pipelines equivalent: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative

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that could survive the proposed test. Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is restoring the display scale enough to make two finite-word pipelines equivalent, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is restoring the display scale enough to make two finite-word pipelines equivalent: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is restoring the display scale enough to make two finite-word pipelines equivalent. Use exact finite vectors and declared voltage calibration to identify the actual difference Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is restoring the display scale enough to make two finite-word pipelines equivalent, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.35 Ten worked applications of Model 10D (p. 5731)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is restoring the display scale enough to make two finite-word pipelines equivalent. Use exact finite vectors and declared voltage calibration to identify the actual difference Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.93 Quantization margin and channel bandwidth (p. 5804)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is restoring the display scale enough to make two finite-word pipelines equivalent and Compare conversion schedules, output step restoration, intermediate range, coefficient quantization, and state; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio (p. 5821)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is restoring the display scale enough to make two finite-word pipelines equivalent”, addressing “Compare conversion schedules, output step restoration, intermediate range, coefficient quantization, and state”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement

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and the specific contested proposition that remains unresolved.

Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Is restoring the display scale enough to make two finite-word pipelines equivalent”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Is restoring the display scale enough to make two finite-word pipelines equivalent”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.45 Application 10D10 Audit a complete finite word output vector (p. 5741)

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V011-C10-DISCUSSION-011. A test's final value is correct despite an overflow flag. Should the flag be dismissed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A test's final value is correct despite an overflow flag. Should the flag be dismissed?” Put this particular dispute to the panel: A test's final value is correct despite an overflow flag. Should the flag be dismissed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- 02. Student A, terminology and scope: Agree the operational meanings of test's, final, value and despite, overflow, flag in “A test's final value is correct despite an overflow flag. Should the flag be dismissed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A test's

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final value is correct despite an overflow flag; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 10D for fixed point channelizer arithmetic”. Examine intermediate ranges, accumulation order, and boundary cases Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A test's final value is correct despite an overflow flag; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 10D for fixed point channelizer arithmetic”. Examine intermediate ranges, accumulation order, and boundary cases Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss modular cancellation and the intended exact arithmetic contract Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A test's final value is correct despite an overflow flag: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control

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condition and expected result, and identify how you would document an unexpected observation. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A test's final value is correct despite an overflow flag; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A test's final value is correct despite an overflow flag: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A test's final value is correct despite an overflow flag, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A test's final value is correct despite an overflow flag: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A test's final value is correct despite an overflow flag. A favorable final coincidence may be recorded but does not prove that the implementation meets its no-overflow requirement Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question

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cannot be settled by visual appearance or a single unqualified reading. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A test's final value is correct despite an overflow flag, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A test's final value is correct despite an overflow flag. A favorable final coincidence may be recorded but does not prove that the implementation meets its no-overflow requirement Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.43 Application 10D8 Exact codes still require phase order and history (p. 5739)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A test's final value is correct despite an overflow flag and Should the flag be dismissed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A test's final value is correct despite an overflow flag”, addressing “Should the flag be dismissed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A test's final value is correct despite an overflow flag. Should the flag be dismissed”, specifying the next test,

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responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A test's final value is correct despite an overflow flag. Should the flag be dismissed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

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V011-C10-DISCUSSION-012. A timestamped file has the expected length but conflicting overlap values. Can the team certify continuity?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A timestamped file has the expected length but conflicting overlap values. Can the team certify continuity?” Put this particular dispute to the panel: A timestamped file has the expected length but conflicting overlap values. Can the team certify continuity. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

- 02. Student A, terminology and scope: Agree the operational meanings of expected, length, conflicting and overlap, certify, continuity in “A timestamped file has the expected length but conflicting overlap values. Can the team certify continuity”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A timestamped file has the expected length but conflicting overlap values; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10E.2: overlap, duplicate indices, and conflicting payloads”. Resolve or mark conflicts rather than average them into a third value Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A timestamped file has the expected length but conflicting overlap values; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10E.2: overlap, duplicate indices, and conflicting payloads”. Resolve or mark conflicts rather than average them into a third value Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate timestamps, stored offsets, source identity, and payload agreement Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A timestamped file has the expected length but conflicting overlap values: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A timestamped file has the expected length but conflicting overlap values; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A timestamped file has the expected length but conflicting overlap values: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A timestamped file has the expected length but conflicting overlap values, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A timestamped file has the expected length but conflicting overlap values: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A timestamped file has the expected length but conflicting overlap values. Expected length is one consistency check, not a substitute for source-index evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A timestamped file has the expected length but conflicting overlap values, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.53 Application 10E.2: overlap, duplicate indices, and conflicting payloads (p. 5755)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A timestamped file has the expected length but conflicting overlap values. Expected length is one consistency check, not a substitute for source-index evidence Respond point by point to

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Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A timestamped file has the expected length but conflicting overlap values and Can the team certify continuity; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A timestamped file has the expected length but conflicting overlap values”, addressing “Can the team certify continuity”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A timestamped file has the expected length but conflicting overlap values. Can the team certify continuity”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A timestamped file has the expected length but conflicting overlap values. Can the team certify continuity”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

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V011-C10-DISCUSSION-013. The team wants to remove gaps so downstream software receives a continuous array. What conditions should govern that derived product?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The team wants to remove gaps so downstream software receives a continuous array. What conditions should govern that derived product?” Put this particular dispute to the panel: The team wants to remove gaps so downstream software receives a continuous array. What conditions should govern that derived product. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 02. Student A, terminology and scope: Agree the operational meanings of remove, gaps, downstream and array, govern, derived in “The team wants to remove gaps so downstream software receives a continuous array. What conditions should govern that derived product”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The team wants to remove gaps so downstream software receives a continuous array; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10E.10: one missing input appears in idle channels”. Explain changed convolution and timing Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The team wants to remove

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gaps so downstream software receives a continuous array; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10E.10: one missing input appears in idle channels”. Explain changed convolution and timing Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain the original data/map, document deletion or filling, carry validity masks, and preserve absolute phase/output epoch Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The team wants to remove gaps so downstream software receives a continuous array: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The team wants to remove gaps so downstream software receives a continuous array; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The team wants to remove gaps so downstream software receives a continuous array: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The team wants to remove gaps so downstream software receives a continuous array, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The team wants to remove gaps so downstream software receives a continuous array: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The team wants to remove gaps so downstream software receives a continuous array. A convenient array can be offered for a defined purpose without presenting it as the original continuous observation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The team wants to remove gaps so downstream software receives a continuous array, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The team wants to remove gaps so downstream software receives a continuous array. A convenient array can be offered for a defined purpose without presenting it as the original continuous observation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The team wants to remove gaps so downstream software receives a continuous array and What conditions should govern that derived product; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.60 Application 10E.9: absolute phase survives three missing positions (p. 5762)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The team wants to remove gaps so

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downstream software receives a continuous array", addressing "What conditions should govern that derived product"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "The team wants to remove gaps so downstream software receives a continuous array. What conditions should govern that derived product", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "The team wants to remove gaps so downstream software receives a continuous array. What conditions should govern that derived product". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

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V011-C10-DISCUSSION-014. Could an exactly zero coefficient justify keeping one output between invalid neighbors?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Could an exactly zero coefficient justify keeping one output between invalid neighbors?” Put this particular dispute to the panel: Could an exactly zero coefficient justify keeping one output between invalid neighbors. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 02. Student A, terminology and scope: Agree the operational meanings of exactly, zero, coefficient and keeping, output, invalid in “Could an exactly zero coefficient justify keeping one output between invalid neighbors”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Could an exactly zero coefficient justify keeping one output between invalid neighbors; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.69 Application 10F.1 A familiar filename with different bytes (p. 5777)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10F.1 A familiar filename with different bytes”. Retain the declared filter; do not change coefficients merely to clear invalidity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.69 Application 10F.1 A familiar filename with different bytes (p. 5777)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Could an exactly zero coefficient justify keeping one output between invalid neighbors;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10F.1 A familiar filename with different bytes”. Retain the declared filter; do not change coefficients merely to clear invalidity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.69 Application 10F.1 A familiar filename with different bytes (p. 5777)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Apply the actual support mask and distinguish an exact implemented zero from a small coefficient Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Could an exactly zero coefficient justify keeping one output between invalid neighbors: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Could an exactly zero coefficient justify keeping one output between invalid neighbors; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Could an exactly zero coefficient justify keeping one output between invalid neighbors: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Could an exactly zero coefficient justify keeping one output between invalid neighbors, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.69 Application 10F.1 A familiar filename with different bytes (p. 5777)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Could an exactly zero coefficient justify keeping one output between invalid neighbors: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Could an exactly zero coefficient justify keeping one output between invalid neighbors. Explain the local dependency result without claiming all intermediate samples are valid generally Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Could an exactly zero coefficient justify keeping one output between invalid neighbors, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.69 Application 10F.1 A familiar filename with different bytes (p. 5777)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Could an exactly zero coefficient justify keeping one output between invalid neighbors. Explain the local dependency result without claiming all intermediate samples are valid generally Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Could an exactly zero coefficient justify keeping one output between invalid neighbors and Apply the actual support mask and distinguish an exact implemented zero from a small coefficient; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Could an exactly zero coefficient justify keeping one output between invalid neighbors”, addressing “Apply the actual support mask and distinguish an exact implemented zero

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from a small coefficient"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Could an exactly zero coefficient justify keeping one output between invalid neighbors", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Could an exactly zero coefficient justify keeping one output between invalid neighbors". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

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V011-C10-DISCUSSION-015. A small missing-input error bound is available. Should a filled output be relabeled continuity-valid?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A small missing-input error bound is available. Should a filled output be relabeled continuity-valid?” Put this particular dispute to the panel: A small missing-input error bound is available. Should a filled output be relabeled continuity-valid. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 02. Student A, terminology and scope: Agree the operational meanings of error, bound, available and filled, output, relabeled in “A small missing-input error bound is available. Should a filled output be relabeled continuity-valid”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A small missing-input error bound is available; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10E.7: a zero coefficient changes the validity pattern”. Retain invalidity and the bound's assumptions while explaining possible limited uses Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A small missing-input error bound is available; explain what each record can establish State what the existing record establishes, what it does not establish, and

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which further measurement would change your opinion. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10E.7: a zero coefficient changes the validity pattern”. Retain invalidity and the bound's assumptions while explaining possible limited uses Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish conditional error magnitude from knowledge of the missing dependency Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A small missing-input error bound is available:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A small missing-input error bound is available; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A small missing-input error bound is available: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A small missing-input error bound is available, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A small missing-input error bound is available: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A small missing-input error bound is

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available. Do not convert a bounded numerical consequence into a claim that original samples exist Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A small missing-input error bound is available, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A small missing-input error bound is available. Do not convert a bounded numerical consequence into a claim that original samples exist Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that

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limits confidence. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A small missing-input error bound is available and Should a filled output be relabeled continuity-valid; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A small missing-input error bound is available”, addressing “Should a filled output be relabeled continuity-valid”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A small missing-input error bound is available. Should a filled output be relabeled continuity-valid”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A small missing-input error bound is available. Should a filled output be relabeled continuity-valid”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

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V011-C10-DISCUSSION-016. The record has no missing indices but timing disagrees with a reference. What hypotheses remain?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The record has no missing indices but timing disagrees with a reference. What hypotheses remain?” Put this particular dispute to the panel: The record has no missing indices but timing disagrees with a reference. What hypotheses remain. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

- 02. Student A, terminology and scope: Agree the operational meanings of record, missing, indices and timing, hypotheses, remain in “The record has no missing indices but timing disagrees with a reference. What hypotheses remain”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The record has no missing indices but timing disagrees with a reference; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 10E for absolute sample continuity and retained processing state”. Do not insert samples merely to force agreement Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The record has no missing indices but timing disagrees with a reference; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 10E for absolute sample continuity and retained processing state”. Do not insert samples merely to force agreement Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine constant rate error, anchor uncertainty, segment resets, and unmodeled wander separately from loss Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The record has no missing indices but timing disagrees with a reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The record has no missing indices but timing disagrees with a reference; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The record has no missing indices but timing disagrees with a reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The record has no missing indices but timing disagrees with a reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The record has no missing indices but timing disagrees with a reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The record has no missing indices but timing disagrees with a reference. Apply a justified timing model and preserve its scope alongside continuity evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The record has no missing indices but timing disagrees with a reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The record has no missing indices but timing disagrees with a reference. Apply a justified timing model and

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preserve its scope alongside continuity evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The record has no missing indices but timing disagrees with a reference and What hypotheses remain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The record has no missing indices but timing disagrees with a reference”, addressing “What hypotheses remain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The record has no missing indices but timing disagrees with a reference. What hypotheses remain”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The record has no missing indices but timing disagrees with a reference. What hypotheses remain”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.54 Application 10E.3: a continuous record with uncertain elapsed time (p. 5756)

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V011-C10-DISCUSSION-017. A signed software release produces a failed channel-map vector. Which evidence should determine acceptance?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A signed software release produces a failed channel-map vector. Which evidence should determine acceptance?” Put this particular dispute to the panel: A signed software release produces a failed channel-map vector. Which evidence should determine acceptance. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

- 02. Student A, terminology and scope: Agree the operational meanings of signed, software, release and produces, failed, vector in “A signed software release produces a failed channel-map vector. Which evidence should determine acceptance”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A signed software release produces a failed channel-map vector; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Separate signed artifacts from operating configurations”. A valid signature cannot compensate for a demonstrated mapping breach Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A signed software release produces a failed channel-map vector; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.64 Framework 10F for bounded SDR acceptance (p. 5766)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Separate signed artifacts from operating configurations”. A valid signature cannot compensate for a demonstrated mapping breach Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Keep signature integrity and functional behavior as separate criteria Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A signed software release produces a failed

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channel-map vector: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A signed software release produces a failed channel-map vector; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.64 Framework 10F for bounded SDR acceptance (p. 5766)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A signed software release produces a failed channel-map vector: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A signed software release produces a failed channel-map vector, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A signed software release produces a failed channel-map vector: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A signed software release produces a failed channel-map vector. Investigate the implementation without inferring malicious intent solely from the failure and retest the bounded corrected configuration Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.64 Framework 10F for bounded SDR acceptance (p. 5766)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A signed software release produces a failed channel-map vector, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A signed software release produces a failed channel-map vector. Investigate the implementation without inferring malicious intent solely from the failure and retest the

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bounded corrected configuration Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.64 Framework 10F for bounded SDR acceptance (p. 5766)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A signed software release produces a failed channel-map vector and Which evidence should determine acceptance; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A signed software release produces a failed channel-map vector”, addressing “Which evidence should determine acceptance”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A signed software release produces a failed channel-map vector. Which evidence should determine acceptance”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A signed software release produces a failed channel-map vector. Which evidence should determine acceptance”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

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V011-C10-DISCUSSION-018. A receive-only project wants to mark unknown transmission behavior nonapplicable. Is that legitimate?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A receive-only project wants to mark unknown transmission behavior nonapplicable. Is that legitimate?” Put this particular dispute to the panel: A receive-only project wants to mark unknown transmission behavior nonapplicable. Is that legitimate. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.65 Define the case before testing (p. 5767)

- 02. Student A, terminology and scope: Agree the operational meanings of project, mark, unknown and transmission, behavior, legitimate in “A receive-only project wants to mark unknown transmission behavior nonapplicable. Is that legitimate”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.65 Define the case before testing (p. 5767)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A receive-only project wants to mark unknown transmission behavior nonapplicable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10F.10 An update closes a precisely bounded case”. Unknown applicability is unresolved Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receive-only project wants to mark unknown transmission behavior nonapplicable; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10F.10 An update closes a precisely bounded case”. Unknown applicability is unresolved Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask which specific criterion is at issue: transmit spectral performance may be outside scope while disabled-transmission evidence may remain required Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.65 Define the case before testing (p. 5767)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A receive-only project wants to mark unknown transmission behavior nonapplicable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.65 Define the case before testing (p. 5767)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receive-only project wants to mark unknown transmission behavior nonapplicable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A receive-only project wants to mark unknown transmission behavior nonapplicable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.65 Define the case before testing (p. 5767)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A receive-only project wants to mark unknown transmission behavior nonapplicable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A receive-only project wants to mark unknown transmission behavior nonapplicable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.65 Define the case before testing (p. 5767)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A receive-only project wants to mark unknown transmission behavior nonapplicable. Require a defensible scope and rationale rather than relabeling difficult requirements after testing Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A receive-only project wants to mark unknown transmission behavior nonapplicable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A receive-only project wants to mark unknown

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transmission behavior nonapplicable. Require a defensible scope and rationale rather than relabeling difficult requirements after testing Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A receive-only project wants to mark unknown transmission behavior nonapplicable and Is that legitimate; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A receive-only project wants to mark unknown transmission behavior nonapplicable”, addressing “Is that legitimate”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §10.65 Define the case before testing (p. 5767)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A receive-only project wants to mark unknown transmission behavior nonapplicable. Is that legitimate”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A receive-only project wants to mark unknown transmission behavior nonapplicable. Is that legitimate”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.65 Define the case before testing (p. 5767)

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V011-C10-DISCUSSION-019. Two programs agree, but both rely on one conversion library. What value does the agreement still have?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two programs agree, but both rely on one conversion library. What value does the agreement still have?” Put this particular dispute to the panel: Two programs agree, but both rely on one conversion library. What value does the agreement still have. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 02. Student A, terminology and scope: Agree the operational meanings of programs, agree, conversion and library, value, agreement in “Two programs agree, but both rely on one conversion library. What value does the agreement still have”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two programs agree, but both rely on one conversion library; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpretation and reproducibility of the channelized record”. Discuss what it cannot independently verify and add a discriminating analytical or separately implemented oracle Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two programs agree, but both

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rely on one conversion library; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpretation and reproducibility of the channelized record”. Discuss what it cannot independently verify and add a discriminating analytical or separately implemented oracle Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It demonstrates reproducibility under that shared dependency Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two programs agree, but both rely on one conversion library: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two programs agree, but both rely on one conversion library; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two programs agree, but both rely on one conversion library: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two programs agree, but both rely on one conversion library, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two programs agree, but both rely on one conversion library: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two programs agree, but both rely on one conversion library. Avoid either discarding all agreement or overstating its independence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two programs agree, but both rely on one conversion library, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two programs agree, but both rely on one conversion library. Avoid either discarding all agreement or overstating its independence Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two programs agree, but both rely on one conversion library and What value does the agreement still have; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.58 Application 10E.7: a zero coefficient changes the validity pattern (p. 5760)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two programs agree, but both rely on one conversion library”, addressing “What value does the agreement still have”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two programs agree, but both rely on one conversion library. What value does the agreement still have”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two programs agree, but both rely on one conversion library. What value does the agreement still have”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

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V011-C10-DISCUSSION-020. The deadline arrives with seven mandatory passes and one unresolved item. What should the release statement say?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The deadline arrives with seven mandatory passes and one unresolved item. What should the release statement say?” Put this particular dispute to the panel: The deadline arrives with seven mandatory passes and one unresolved item. What should the release statement say. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 02. Student A, terminology and scope: Agree the operational meanings of arrives, seven, mandatory and passes, release, statement in “The deadline arrives with seven mandatory passes and one unresolved item. What should the release statement say”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The deadline arrives with seven mandatory passes and one unresolved item; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Acceptance as a reproducible technical argument”. Discuss a separately scoped useful case only with explicit requirements and justification Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The deadline arrives with

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seven mandatory passes and one unresolved item; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.65 Define the case before testing (p. 5767)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Acceptance as a reproducible technical argument”. Discuss a separately scoped useful case only with explicit requirements and justification Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Name the unsupported proposition and retain acceptance-not-demonstrated status under the declared conjunction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The deadline arrives with seven mandatory passes and one unresolved item: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The deadline arrives with seven mandatory passes and one unresolved item; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.65 Define the case before testing (p. 5767)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The deadline arrives with seven mandatory passes and one unresolved item: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The deadline arrives with seven mandatory passes and one unresolved item, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The deadline arrives with seven mandatory passes and one unresolved item: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The deadline arrives with seven mandatory passes and one unresolved item. Do not turn a pass fraction or schedule pressure into acceptance of the full case Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.65 Define the case before testing (p. 5767)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The deadline arrives with seven mandatory passes and one unresolved item, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The deadline arrives with seven mandatory passes and one unresolved item. Do not turn a pass fraction or

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schedule pressure into acceptance of the full case Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.65 Define the case before testing (p. 5767)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The deadline arrives with seven mandatory passes and one unresolved item and What should the release statement say; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.64 Framework 10F for bounded SDR acceptance (p. 5766)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The deadline arrives with seven mandatory passes and one unresolved item”, addressing “What should the release statement say”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement

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and the specific contested proposition that remains unresolved.

Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The deadline arrives with seven mandatory passes and one unresolved item. What should the release statement say”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The deadline arrives with seven mandatory passes and one unresolved item. What should the release statement say”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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V011-C10-DISCUSSION-021. An update changes only a serializer according to its release note. Which old tests should be reconsidered?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An update changes only a serializer according to its release note. Which old tests should be reconsidered?” Put this particular dispute to the panel: An update changes only a serializer according to its release note. Which old tests should be reconsidered. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 02. Student A, terminology and scope: Agree the operational meanings of update, changes, serializer and according, release, tests in “An update changes only a serializer according to its release note. Which old tests should be reconsidered”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An update changes only a serializer according to its release note; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10F.7 A streaming pass leaves the recording path unresolved”. Retain unaffected results only with documented applicability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An update changes only a serializer according to its release note; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10F.7 A streaming pass leaves the recording path unresolved”. Retain unaffected results only with documented applicability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Trace dependencies into sample representation, scaling, clipping, channel order, file chronology, and recording workload Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An update changes only a serializer according to its release note: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An update changes only a serializer according to its release note; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An update changes only a serializer according to its release note: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a

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rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An update changes only a serializer according to its release note, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An update changes only a serializer according to its release note: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An update changes only a serializer according to its release note. A release-note description is evidence to inspect, not a complete impact proof Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An update changes only a serializer according to its release note, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An update changes only a serializer according to its release note. A release-note description is evidence to inspect, not a complete impact proof Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An update changes only a serializer according to its release note and Which old tests should be reconsidered; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.70 Application 10F.2 A valid signature with an unacceptable build claim (p. 5778)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An update changes only a serializer according to its release note”, addressing “Which old tests should be reconsidered”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An update changes only a serializer according to its release note. Which old tests should be reconsidered”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An update changes only a serializer according to its release note. Which old tests should be reconsidered”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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V011-C10-DISCUSSION-022. A nominal rate request succeeded but readback differs. How should the capture be labeled and evaluated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A nominal rate request succeeded but readback differs. How should the capture be labeled and evaluated?” Put this particular dispute to the panel: A nominal rate request succeeded but readback differs. How should the capture be labeled and evaluated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

- 02. Student A, terminology and scope: Agree the operational meanings of request, readback, differs and capture, labeled, evaluated in “A nominal rate request succeeded but readback differs. How should the capture be labeled and evaluated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A nominal rate request succeeded but readback differs; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.92 Sampling application 10 Clock error shifts a folded result (p. 5802)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Sampling application 10 Clock error shifts a folded result”. Determine whether the actual rate lies inside the acceptance envelope Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.92 Sampling application 10 Clock error shifts a folded result (p. 5802)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A nominal rate request succeeded but readback differs; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Sampling application 10 Clock error shifts a folded result”. Determine whether the actual rate lies inside the acceptance envelope Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.92 Sampling application 10 Clock error shifts a folded result (p. 5802)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the established reported configuration consistently while separately measuring clock accuracy as required Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A nominal rate request succeeded but readback differs: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A nominal rate request succeeded but readback differs; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A nominal rate request succeeded but readback differs: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A nominal rate request succeeded but readback differs, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.92 Sampling application 10 Clock error shifts a folded result (p. 5802)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A nominal rate request succeeded but readback differs: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A nominal rate request succeeded but readback differs. A successful call cannot make the requested rate the true configuration Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A nominal rate request succeeded but readback differs, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.92 Sampling application 10 Clock error shifts a folded result (p. 5802)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A nominal rate request succeeded but readback differs. A successful call cannot make the requested rate the true configuration Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the

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missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.77 Application 10F.9 An inventory omits a required component (p. 5785)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A nominal rate request succeeded but readback differs and How should the capture be labeled and evaluated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.65 Define the case before testing (p. 5767)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A nominal rate request succeeded but readback differs”, addressing “How should the capture be labeled and evaluated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A nominal rate request succeeded but readback differs. How should the capture be labeled and evaluated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A nominal rate request succeeded but readback differs. How should the capture be labeled and evaluated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.72 Application 10F.4 A requested sample rate is not the established rate (p. 5780)

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V011-C10-DISCUSSION-023. Two rate-change captures show a stable feature. Does stability prove it was generated after sampling?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two rate-change captures show a stable feature. Does stability prove it was generated after sampling?” Put this particular dispute to the panel: Two rate-change captures show a stable feature. Does stability prove it was generated after sampling. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 02. Student A, terminology and scope: Agree the operational meanings of captures, stable, feature and stability, prove, generated in “Two rate-change captures show a stable feature. Does stability prove it was generated after sampling”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two rate-change captures show a stable feature; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Sampling, Aliasing, and Band Selection”. Stability can reject some explanations without selecting a unique origin Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two rate-change captures show a stable feature; explain what each record can establish State what the existing record establishes, what it does not establish, and

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which further measurement would change your opinion. Source: §10.85 Sampling application 3 A folded upper-zone tone (p. 5795)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Sampling, Aliasing, and Band Selection”. Stability can reject some explanations without selecting a unique origin Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Enumerate admitted analog candidates and their mappings, including the chapter's two-rate alias counterexample and automatic retuning Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two rate-change captures show a stable feature: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two rate-change captures show a stable feature; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.85 Sampling application 3 A folded upper-zone tone (p. 5795)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two rate-change captures show a stable feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two rate-change captures show a stable feature, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two rate-change captures show a stable feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two rate-change captures show a stable feature. Seek independent band and conversion evidence before attribution Explain the relevant statistical or calibration uncertainty,

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the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.85 Sampling application 3 A folded upper-zone tone (p. 5795)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two rate-change captures show a stable feature, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two rate-change captures show a stable feature. Seek independent band and conversion evidence before attribution Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.85 Sampling application 3 A folded upper-zone tone (p. 5795)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two rate-change captures show a stable feature and Does stability prove it was generated after sampling; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.99 Application 6 Exact code-center counterexample (p. 5812)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two rate-change captures show a stable feature”, addressing “Does stability prove it was generated after sampling”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two rate-change captures show a stable feature. Does stability prove it was generated after sampling”, specifying the next test, responsible measurement record and limit

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of the conclusion Summarise the strongest evidence for and against the resolution of “Two rate-change captures show a stable feature. Does stability prove it was generated after sampling”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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V011-C10-DISCUSSION-024. Should a converter be selected solely because the ideal bit formula exceeds a desired dynamic range?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a converter be selected solely because the ideal bit formula exceeds a desired dynamic range?” Put this particular dispute to the panel: Should a converter be selected solely because the ideal bit formula exceeds a desired dynamic range. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

- 02. Student A, terminology and scope: Agree the operational meanings of converter, ideal, formula and exceeds, dynamic, range in “Should a converter be selected solely because the ideal bit formula exceeds a desired dynamic range”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Quantization, Clipping, and Converter Performance”. Use the formula as conditional planning arithmetic Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range; explain what each record can establish State what

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the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio (p. 5821)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Quantization, Clipping, and Converter Performance”. Use the formula as conditional planning arithmetic Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss waveform amplitude and crest factor, quantizer distribution, jitter, noise, distortion, clipping, actual filter bandwidth, and full-chain tests Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a converter be selected solely

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because the ideal bit formula exceeds a desired dynamic range: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio (p. 5821)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings,

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controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range. Require measured performance in the intended configuration before accepting the system Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio (p. 5821)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a converter be selected solely because

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the ideal bit formula exceeds a desired dynamic range. Require measured performance in the intended configuration before accepting the system Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.107 Worked Example 10A.1. Ideal Quantization Signal-to-Noise Ratio (p. 5821)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range and Discuss waveform amplitude and crest factor, quantizer distribution, jitter, noise, distortion, clipping,…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a converter be selected solely because the ideal bit formula exceeds a desired dynamic range”, addressing “Discuss waveform amplitude and crest factor, quantizer distribution, jitter, noise, distortion, clipping,…”; specify the exact

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measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a converter be selected solely because the ideal bit formula exceeds a desired dynamic range”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a converter be selected solely because the ideal bit formula exceeds a desired dynamic range”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.96 Application 3 Crest-factor headroom (p. 5809)

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V011-C10-DISCUSSION-025. A storage change eliminates suspicious impulses. What is the strongest defensible report?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A storage change eliminates suspicious impulses. What is the strongest defensible report?” Put this particular dispute to the panel: A storage change eliminates suspicious impulses. What is the strongest defensible report. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 02. Student A, terminology and scope: Agree the operational meanings of storage, eliminates, suspicious and strongest, defensible, report in “A storage change eliminates suspicious impulses. What is the strongest defensible report”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A storage change eliminates suspicious impulses; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Data Transport, Gaps, and Reproducible Recording”. Preserve original and revised configurations and assess whether capability changed Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A storage change eliminates suspicious impulses; explain what each record can establish State what the existing record establishes, what it does not establish, and

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which further measurement would change your opinion. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Data Transport, Gaps, and Reproducible Recording”. Preserve original and revised configurations and assess whether capability changed Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Describe the controlled association, overflow/continuity evidence, and recording-path explanation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A storage change eliminates suspicious

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impulses: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A storage change eliminates suspicious impulses; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A storage change eliminates suspicious impulses: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A storage change eliminates suspicious impulses, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A storage change eliminates suspicious impulses: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A storage change eliminates suspicious

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impulses. State the limits of the environmental inference and avoid converting one corrected run into a guarantee of future loss-free behavior Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A storage change eliminates suspicious impulses, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A storage change eliminates suspicious impulses. State the limits of the environmental inference and avoid converting one corrected run into a guarantee of future loss-free behavior Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §10.75 Application 10F.7 A streaming pass leaves the recording path unresolved (p. 5783)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A storage change eliminates suspicious impulses and What is the strongest defensible report; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A storage change eliminates suspicious impulses”, addressing “What is the strongest defensible report”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A storage change eliminates suspicious impulses. What is the strongest defensible report”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A storage change eliminates suspicious impulses. What is the strongest defensible report”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.78 Application 10F.10 An update closes a precisely bounded case (p. 5786)

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Chapter 10 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C10-ESSAY-001 — Define input clock, signed input and NCO frequencies, initial phases, coefficient response, decimation, and retained residue. Obtain translated response magnitude and phase at mM+p, and interpret frequency modulo output rate. Explain the absence of an automatic voltage division by decimation and the inability to identify an earlier analog alias.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

V011-C10-ESSAY-002 — Trace each blocker on each stage's input clock, evaluate actual coefficient responses before deletion, combine stage attenuations, and compare each contribution with a common-plane limit. Treat coherent combination separately from power addition and distinguish digital alias rejection from upstream analog overload. Avoid testing only one exact filter null.

Review: Chapter 10 — Ten worked applications of Model 10B.

V011-C10-ESSAY-003 — Use the 33-tap symmetric example to distinguish center lag 16 from history requirement 32. Map retained index mM+p to center time and identify the first complete retained history. Discuss initial-state assumptions, response zeros, error criterion, and why a single delay number does not define a discard interval.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-ESSAY-004 — Track absolute input timing, continuous NCO phase, FIR history, and retained schedule. Use the 9 MHz/48 MS/s/1000-sample example to explain alternating sign resets. Examine boundary convolution separately from settled block interiors and distinguish NCO reset from filter reset. State the records needed to reproduce the correct stream.

Review: Chapter 10 — Ten worked applications of Model 10B.

V011-C10-ESSAY-005 — Group lag by channel count, derive the positive inner exponent, state inverse-DFT normalization and negative-FFT remapping, and retain the outer channel phase. Explain critical versus oversampled residue scheduling and why labels FFT or polyphase do not uniquely specify sign, order, or gain.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

V011-C10-ESSAY-006 — Use the prototype response for a boundary tone, preserve signed centers and residual labels, and compare the full response vector. Explain why one source can populate both channels and why unqualified power addition is not a calibrated input estimate. Validate center and boundary tones with actual coefficients and arithmetic.

Review: Chapter 10 — Ten worked applications of Model 10C.

V011-C10-ESSAY-007 — Analyze the chapter's single-channel alias with adjusted complex coefficient and the particular complete rectangular bank's inverse. Identify which complete vector information distinguishes the inputs. Limit perfect-reconstruction claims to the specified prototype, full channels, valid history, and retained frames; discuss recording-rate tradeoffs.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-ESSAY-008 — Expand same-time covariance using tap energies and channel phase factors. Explain correlated simultaneous channels from unequal energies, time correlation from overlapping frames, and why zero covariance is not independence without a suitable joint distribution. Keep prehistory assumptions explicit and reject counting every frame-channel pair as independent automatically.

Review: Chapter 10 — Ten worked applications of Model 10C.

V011-C10-ESSAY-009 — Show how the zero tap removes an entire residue at critical sampling despite unit DC gain and equal aggregate rate. For the stated oversampled bank, retain every affected frame and channel and explain the positive lower energy bound and unequal energy weighting. Do not generalize this repair to every prototype or truncated record.

Review: Chapter 10 — Ten worked applications of Model 10C.

V011-C10-ESSAY-010 — State signed formats, total/fractional bits, physical voltage scale, quantized coefficients, product and accumulator widths, conversion locations, tie rule, saturation/wrap policy, transform sign/order/normalization, shifts, and history. Separate code correctness from physical calibration and include stage flags for intermediate overflow.

Review: Chapter 10 — Signed formats and explicit conversion points.

V011-C10-ESSAY-011 — Separate positive and negative coefficient sums, choose endpoint inputs that minimize and maximize the branch, convert to full-product integer codes, and test both asymmetric code endpoints. Explain when the interval protects direct partial sums and why transformed or feedback topologies require another intermediate analysis.

Review: Chapter 10 — Range and error are separate obligations.

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V011-C10-ESSAY-012 — Use the two-product example to show noncommuting rounding and addition. State the model's conversion schedule and no-overflow premises. Explain that scale restoration magnifies final rounding and does not restore low bits. Distinguish deterministic bounds from assumed white-noise models and account separately for additional twiddle reductions.

Review: Chapter 10 — Ten worked applications of Model 10D.

V011-C10-ESSAY-013 — Use intermediate wrapping or saturation examples and identify stage order and flags. Discuss exact-phase/order mistakes that additional fractional bits cannot fix. Compare to the intended direct reference and test endpoint and nonsymmetric vectors; a coincidentally correct final result does not prove all internal ranges were valid.

Review: Chapter 10 — Ten worked applications of Model 10D.

V011-C10-ESSAY-014 — Identify stored starts, source starts, lengths, clock segment, and anchor. Reorder by declared source identity, resolve global coverage before declaring gaps, compare overlapping payloads, and distinguish repeated values from repeated indices. Preserve unresolved conflicts and show why continuous file offsets or total length do not establish chronology.

Review: Chapter 10 — Source indices, stored offsets, and time anchors.

V011-C10-ESSAY-015 — Use actual nonzero support and unique available source values. For contiguous support, form the gap tail and intersect it with the retained epoch using ceiling/floor bounds. Use set unions for multiple gaps. Explain sparse-support exceptions and the limits of finite recovery for recursive/adaptive state.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-ESSAY-016 — Retain the original grid and validity mask for zero filling, derive the missing-input error, and state a justified amplitude bound if available. Explain deletion's changed neighbors, timestamps, oscillator indices, and retained grid. Distinguish eventual finite-history recovery from restored chronology and preserve both as explicitly derived records.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

V011-C10-ESSAY-017 — Use source deficit three and mixer increment $\frac{\pi}{4}$ to obtain a 135-degree rotation only across constant-deficit support. Explain the four intervals between bounding retained samples, gap-crossing convolution, and changed modulo-four retained source instants. Show why one phase factor cannot repair all consequences.

Review: Chapter 10 — Application 10E.9: absolute phase survives three missing positions.

V011-C10-ESSAY-018 — State what the dependency mask establishes. Add the constant-rate and anchor-error bound for timing, excluding unmodeled wander and resets, and apply the separate no-overflow/rounding contract for numerical values. Explain that valid dependencies are necessary candidates for usable observation but do not certify every signal or calibration property.

Review: Chapter 10 — A continuity condition for finite filtering and decimation.

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V011-C10-ESSAY-019 — Declare plane, channels, bands, levels, gain/filter/clock states, sample formats, rates, processing, destination, and host conditions. Assign stable criteria with discriminating evidence and predeclared rules. Separate applicability from result, justify exclusions, and require all mandatory applicable criteria satisfied. Preserve contradictions and unresolved associations without scores.

Review: Chapter 10 — Define the case before testing.

V011-C10-ESSAY-020 — Bind each documentary result to its actual subject and trust policy. Distinguish same filename from same bytes, authenticated signing from permitted build expectations, and verified downloaded file from observed loaded image. Identify limits of ordinary readbacks and version strings and retain narrower assurance rather than inventing runtime attestation.

Review: Chapter 10 — Separate signed artifacts from operating configurations.

V011-C10-ESSAY-021 — Use asymmetric signed integer codes, stated byte/IQ/channel order, and a declared boundary. Compare expected vectors from an analytically independent oracle with outputs, trace common libraries, and preserve scaling. Explain why zeros, identical channel values, successful installation, or two programs sharing one map can conceal errors.

Review: Chapter 10 — Ten worked applications of Framework 10F.

V011-C10-ESSAY-022 — Use a justified deterministic interval with explicit inclusive endpoints, classify wholly inside, wholly outside, and overlap cases, and distinguish a coverage interval from a bound. For recording, require the named writer and workload plus source-index checks, not streaming-only success or expected file size. Do not transfer a pass beyond tested scope.

Review: Chapter 10 — Ten worked applications of Framework 10F.

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V011-C10-ESSAY-023 — Define the admitted analog bands and mixer plan, predict signed/folded mappings at each actual rate, and retain candidates with identical mappings. Use the 10 MHz and 110 MHz two-rate counterexample and the half-rate phase ambiguity. Explain complex sign information and physical I/Q limits, plus why front-end admission evidence remains necessary.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

V011-C10-ESSAY-024 — Start with code spacing, distinguish half-step bound from uniform centered error, derive mean-square error and the sinusoid amplitude term, then add the white-error density assumption for bandwidth integration. State actual equivalent bandwidth, anti-alias filtering, retained signal gain, endpoint/headroom limits, and why deletion or rescaling alone supplies no gain.

Review: Chapter 10 — Quantization margin and channel bandwidth.

V011-C10-ESSAY-025 — Preserve original samples and logs, establish source-index gaps and processing-state effects, and compare capability and configuration across the destination change. Treat the observations as support for a recording-path mechanism while checking affected records before environmental attribution. Avoid claiming the absence of all environmental bursts or future loss probability zero.

Review: Chapter 10 — Hypothetical Case Adjudication: Software-Defined Radios, Sampling, Quantization, DDC, and Channelization.

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Discussion Guidance

V011-C10-DISCUSSION-001 — Identify protection, filters, gain, clock, and converter as parts of the same measurement chain. Explain information lost before sampling and how digital settings depend on it. Retain a configuration-bound acceptance plan spanning the relevant analog and digital functions.

Review: Chapter 10 — SDR Boundary and Partitioning.

V011-C10-DISCUSSION-002 — Compare mixer sign, NCO state, retained residue, filter delay/history, transform convention, and scaling using complex references. Magnitude agreement does not settle timing or phase meaning. Preserve exact input/output indices before attributing the difference to propagation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation.

V011-C10-DISCUSSION-003 — Discuss the admitted blocker bands and actual stage-frequency paths. Require nearby and relevant band tests, range checks, and a declared allowable contribution. A useful single-point result remains bounded and cannot replace rejection-band evidence.

Review: Chapter 10 — Ten worked applications of Model 10B.

V011-C10-DISCUSSION-004 — Distinguish computational efficiency from unchanged exact filter response, then inspect arithmetic, scaling, timing, and actual changed coefficients. Require comparable reference tests. Attribute a measured difference to demonstrated changes rather than the architecture name alone.

Review: Chapter 10 — Ten worked applications of Model 10B.

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V011-C10-DISCUSSION-005 — Ask for prototype, channel grid, complex response vectors, source records, and center/boundary reference tests. Consider one tone's split response and alias alternatives. Revise source counting only to the multiplicity the complete evidence supports.

Review: Chapter 10 — Ten worked applications of Model 10C.

V011-C10-DISCUSSION-006 — Relate selected channels to the intended question, alias distinctions, boundaries, and inversion requirements. Account for actual payload and metadata, and state which distinctions complete-bank retention would preserve. Do not treat reduced rate as proof of independent or complete coverage.

Review: Chapter 10 — Ten worked applications of Model 10C.

V011-C10-DISCUSSION-007 — Discuss redundant samples, prototype filtering, same-frame covariance, and overlapping histories. Rate is a storage/processing count, while information and independence depend on the map and model. Require explicit claims for invertibility or statistical gains.

Review: Chapter 10 — Causal polyphase grouping and the transform convention.

V011-C10-DISCUSSION-008 — Use blind residue, boundary response, transform ordering, and finite history as separate mechanisms. Propose sparse impulses, nonsymmetric vectors, and actual response testing. Preserve the center-tone result without extending it to all inputs or reconstruction.

Review: Chapter 10 — Ten worked applications of Model 10C.

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V011-C10-DISCUSSION-009 — Use code-center, periodic, and constant-bias counterexamples. Distinguish deterministic half-step bounds, no-overflow assumptions, and statistical models. Require evidence for any noise or independence claim instead of inferring it from the tie rule.

Review: Chapter 10 — Ten worked applications of Model 10D.

V011-C10-DISCUSSION-010 — Compare conversion schedules, output step restoration, intermediate range, coefficient quantization, and state. Lost low bits or saturation cannot be recreated by multiplication. Use exact finite vectors and declared voltage calibration to identify the actual difference.

Review: Chapter 10 — Ten worked applications of Model 10D.

V011-C10-DISCUSSION-011 — Discuss modular cancellation and the intended exact arithmetic contract. Examine intermediate ranges, accumulation order, and boundary cases. A favorable final coincidence may be recorded but does not prove that the implementation meets its no-overflow requirement.

Review: Chapter 10 — Ten worked applications of Model 10D.

V011-C10-DISCUSSION-012 — Separate timestamps, stored offsets, source identity, and payload agreement. Resolve or mark conflicts rather than average them into a third value. Expected length is one consistency check, not a substitute for source-index evidence.

Review: Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-C10-DISCUSSION-013 — Retain the original data/map, document deletion or filling, carry validity masks, and preserve absolute phase/output epoch. Explain changed convolution and timing. A convenient array can be offered for a defined purpose without presenting it as the original continuous observation.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

V011-C10-DISCUSSION-014 — Apply the actual support mask and distinguish an exact implemented zero from a small coefficient. Retain the declared filter; do not change coefficients merely to clear invalidity. Explain the local dependency result without claiming all intermediate samples are valid generally.

Review: Chapter 10 — Application 10E.7: a zero coefficient changes the validity pattern.

V011-C10-DISCUSSION-015 — Distinguish conditional error magnitude from knowledge of the missing dependency. Retain invalidity and the bound's assumptions while explaining possible limited uses. Do not convert a bounded numerical consequence into a claim that original samples exist.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims.

V011-C10-DISCUSSION-016 — Examine constant rate error, anchor uncertainty, segment resets, and unmodeled wander separately from loss. Do not insert samples merely to force agreement. Apply a justified timing model and preserve its scope alongside continuity evidence.

Review: Chapter 10 — Application 10E.3: a continuous record with uncertain elapsed time.

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V011-C10-DISCUSSION-017 — Keep signature integrity and functional behavior as separate criteria. A valid signature cannot compensate for a demonstrated mapping breach. Investigate the implementation without inferring malicious intent solely from the failure and retest the bounded corrected configuration.

Review: Chapter 10 — Separate signed artifacts from operating configurations.

V011-C10-DISCUSSION-018 — Ask which specific criterion is at issue: transmit spectral performance may be outside scope while disabled-transmission evidence may remain required. Unknown applicability is unresolved. Require a defensible scope and rationale rather than relabeling difficult requirements after testing.

Review: Chapter 10 — Define the case before testing.

V011-C10-DISCUSSION-019 — It demonstrates reproducibility under that shared dependency. Discuss what it cannot independently verify and add a discriminating analytical or separately implemented oracle. Avoid either discarding all agreement or overstating its independence.

Review: Chapter 10 — Ten worked applications of Framework 10F.

V011-C10-DISCUSSION-020 — Name the unsupported proposition and retain acceptance-not-demonstrated status under the declared conjunction. Discuss a separately scoped useful case only with explicit requirements and justification. Do not turn a pass fraction or schedule pressure into acceptance of the full case.

Review: Chapter 10 — Define the case before testing.

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V011-C10-DISCUSSION-021 — Trace dependencies into sample representation, scaling, clipping, channel order, file chronology, and recording workload. Retain unaffected results only with documented applicability. A release-note description is evidence to inspect, not a complete impact proof.

Review: Chapter 10 — Choose evidence that can discriminate the required behavior.

V011-C10-DISCUSSION-022 — Use the established reported configuration consistently while separately measuring clock accuracy as required. Determine whether the actual rate lies inside the acceptance envelope. A successful call cannot make the requested rate the true configuration.

Review: Chapter 10 — Ten worked applications of Framework 10F.

V011-C10-DISCUSSION-023 — Enumerate admitted analog candidates and their mappings, including the chapter's two-rate alias counterexample and automatic retuning. Stability can reject some explanations without selecting a unique origin. Seek independent band and conversion evidence before attribution.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

V011-C10-DISCUSSION-024 — Discuss waveform amplitude and crest factor, quantizer distribution, jitter, noise, distortion, clipping, actual filter bandwidth, and full-chain tests. Use the formula as conditional planning arithmetic. Require measured performance in the intended configuration before accepting the system.

Review: Chapter 10 — Quantization margin and channel bandwidth.

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V011-C10-DISCUSSION-025 — Describe the controlled association, overflow/continuity evidence, and recording-path explanation. Preserve original and revised configurations and assess whether capability changed. State the limits of the environmental inference and avoid converting one corrected run into a guarantee of future loss-free behavior.

Review: Chapter 10 — Hypothetical Case Adjudication: Software-Defined Radios, Sampling, Quantization, DDC, and Channelization.

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Chapter Glossary

ABSOLUTE SAMPLE INDEX: Integer identity of a sampling event within a declared source segment, distinct from its retained file position.

ACCEPTANCE CASE: A bounded technical argument that a declared configuration satisfies specified applicable requirements using identified evidence and decision rules.

ADMITTED ANALOG BAND: The set of input frequencies allowed by an explicitly justified front-end and signal-class specification before sampling.

ALIASING: Indistinguishable mapping of spectral components caused by sampling without adequate band limitation or by intentional zone translation.

ANALYSIS CHANNELIZER: A bank that filters one sampled input into several indexed output streams with specified frequency translation and sample retention.

APPLICABILITY RATIONALE: The technical explanation establishing whether a criterion belongs to a declared acceptance case; an unknown relationship remains unresolved.

BINARY POINT SCALING: Representation in which an integer code is multiplied by a stated power of two; the fractional-bit count fixes the code step.

CHANNEL GRID: The signed center-frequency list and spacing assigned to a channelizer, distinct from each output stream’s sampling frequency.

CODE-CENTER TEST: A chosen input record exactly aligned with representable quantizer levels; its favorable error is not a distribution-wide guarantee.

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CONFIGURATION BINDING: The specified association among device, executable artifacts, loaded images, calibration data, and actual settings used by an examination.

CONTINUITY VALIDITY MASK: Binary dependency indicator identifying outputs whose nonzero filter terms all use resolved available samples or justified known prehistory.

CONVERSION SCHEDULE: Ordered locations and rules at which a numerical pipeline changes format, rounds, saturates, or wraps.

CRITICAL SAMPLING: Filter-bank rate condition in which the aggregate output sample rate equals the input rate; it does not by itself establish reconstruction.

DECIMATION PHASE: Retained input-index residue modulo the decimation factor, specifying output time origin and coherent phase.

DIGITAL DOWNCONVERTER: Digital mixer, filter, and decimator that translates and selects a sampled frequency band.

DUPLICATE SAMPLE INDEX: Repeated declaration of one source index in stored data; payload agreement and resolution remain separate questions.

EFFECTIVE NUMBER OF BITS: Converter-performance metric derived from measured noise and distortion relative to an ideal quantizer.

EVIDENCE APPLICABILITY: The demonstrated relationship between an observation or record and the subject, configuration, conditions, and proposition it is used to support.

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FIR STATE: Stored input history or equivalent realization state required to continue a finite impulse response filter across a processing boundary without changing the declared filter operation. The realization's delay-state coordinates need not be a raw list of prior input samples; transfer the compatible state or reconstruct the equivalent history.

FOLDED FREQUENCY: A representative nonnegative frequency in the first Nyquist interval for real-sample magnitude interpretation, without an implied analog-source identity.

GUARD BIT: Additional representation width retained to accommodate a proved intermediate range; its need depends on the actual operations and input bounds.

I/Q SAMPLES: Paired in-phase and quadrature values representing a complex analytic or translated signal.

MODULAR WRAPAROUND: An overflow rule that discards multiples of a format's code range and returns the corresponding representable signed code. An over-range positive result can therefore become negative. It differs from saturation and from ordinary rounding; restoring a later scale cannot recover the discarded range information or validate an earlier overflowed operation.

NEAREST EVEN ROUNDING: Selection of the nearest representable code, with an exact halfway case assigned to the even integer code.

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NONZERO COEFFICIENT SUPPORT: The set of declared filter lags whose implemented coefficients are nonzero. It determines which input samples can affect an output in Model 10E. An exactly zero tap creates no dependency, while a small nonzero tap still does; a justified amplitude bound can limit that dependence without making it absent.

NUMERICALLY CONTROLLED OSCILLATOR: Digital phase accumulator and waveform generator used for frequency translation or synthesis.

OVERSAMPLED CHANNELIZER: An analysis bank whose aggregate output sample rate exceeds its input sample rate under the stated channel count and decimation.

POLYPHASE COMMUTATOR: The sample-routing schedule that assigns input-index residues to coefficient branches; its phase and progression form part of the filter-bank definition.

POLYPHASE COMPONENT: A filter-coefficient subsequence selected by a fixed lag residue modulo an integer rate-change factor.

PROVENANCE VERIFICATION: Examination of an artifact and associated origin or build claims against defined integrity, identity, and policy expectations.

QUANTIZATION ERROR MEAN SQUARE: Average squared difference between a quantizer's output representation and its input; includes squared bias.

REGRESSION COVERAGE: The justified set of requirements reexamined after a change, based on affected subjects and dependencies rather than the change label alone.

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SAMPLE EPOCH: Fixed source-index reference establishing the retained output grid or oscillator phase convention within a declared segment.

SAMPLING EQUIVALENCE CLASS: Frequencies and phase conventions producing the same ideal uniformly sampled sequence.

SATURATING ARITHMETIC: A numerical operation that clamps an out-of-range code to the permitted endpoint of its declared signed format. Once clamping occurs, the ordinary half-step rounding-error bound no longer applies. Intermediate saturation can alter later results even when the final displayed value lies within range, so the conversion schedule and operation order remain part of the model.

SCALE RESTORATION: Reconstruction of a declared numerical or voltage scale from stored values and the associated exponent, without recovery of discarded precision.

STORED SAMPLE OFFSET: Integer position in the retained sample array, which need not equal the original source index after a gap or overlap.

TIME ANCHOR: An association between a specified source sample index and a time on a declared time scale. Together with a supported sample-rate model it permits other sample times to be calculated. A host-arrival or file-creation timestamp is not interchangeable with this sampling event, and anchor uncertainty remains distinct from continuity of sample indices.

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UNIFORM QUANTIZATION-ERROR MODEL: The stipulated probability model in which rounding error is uniformly distributed over one code-step interval centered on zero. It gives a mean-square error used in the ideal sine-wave estimate, but the half-step error bound alone does not establish this distribution. Predicting channel noise additionally requires the separate white-error premise.

WHITE-ERROR CHANNEL MODEL: A stipulated uncorrelated error model whose channel power is obtained by integrating its density against squared filter response.

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References and Works Cited

Advanced Micro Devices. Fast Fourier Transform LogiCORE IP Product Guide. PG109, version 9.1, July 17, 2026. Finite word length, rounding implementation, and fixed-point overflow sections. https://docs.amd.com/r/en-US/pg109-xfft/Finite-Word-Length-Considerations.

Annotation. Sections “Finite Word Length Considerations,” “Rounding Implementation,” and “Fixed-Point Data.” These are architecture-specific implementation conventions, not a universal FFT arithmetic specification or evidence that a receiver implements Model 10D. This implementation reference addresses fixed-point FFT scaling, finite word length, rounding choices and overflow behaviour inside a particular programmable logic design. The relevant engineering question is whether every butterfly stage has the width, scaling schedule and saturation policy assumed by the chapter’s worked model. Configuration and test vectors must be retained before the documented core behaviour can be attributed to a particular acquisition system. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

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Analog Devices. MT-085, "Fundamentals of Direct Digital Synthesis (DDS)." Rev. 0, October 2008, pp. 2–3. Phase-accumulator tuning relation and truncation distinction. https://www.analog.com/media/en/training-seminars/tutorials/MT-085.pdf.

Annotation. Printed pages 2–3, especially Equation 1 and the distinction between accumulator width and phase truncation. The chapter independently calculates the stated tuning example. The tutorial addresses numerical phase accumulation, frequency tuning and the effects of finite word length in a digital oscillator. The tuning equation, accumulator width, truncation position and reference clock are distinct quantities and must be documented separately. A theoretically possible output frequency or spur location is not proof that a deployed receiver produces it without measurements of clock quality and implementation. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Beavers, Ian. "Missing Half the Signal." Analog Dialogue, RAQ Issue 124. Analog Devices. NCO, FIR, and downsampling architecture; cited in Model 10B. https://www.analog.com/en/resources/analog-dialogue/raqs/raq-issue-124.html.

Annotation. The paragraphs on NCO mixing, FIR filtering and downsampling support the DDC architecture. Model 10B independently fixes its voltage normalization, sign convention and retained-sample rule;

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no unstated instrument dBFS convention is adopted. The article documents the constituent operations of digital downconversion: numerically controlled mixing, low-pass filtering and decimation. In-phase and quadrature sign conventions, sample-rate changes and filtering latency are necessary to interpret the retained digital signal. Vendor examples illustrate an architecture but do not certify the bit scaling, numerical precision or channel timing of a particular recorder. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

Cooper, David, et al. Security Considerations for Code Signing. NIST Cybersecurity White Paper. January 26, 2018. Sections 2, 3.4–3.5, and 5. https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.01262018.pdf.

Annotation. Sections 2, 3.4–3.5 and 5, printed pages 2, 4 and 7. Supports the bounded distinction between signed-content integrity/authenticity under policy and correct or benign executable behavior. The security guidance is relevant to establishing authenticity, build provenance and integrity of software or firmware used in the measurement chain. A valid signature can support a statement about which artifact was approved under a stated trust policy, but cannot independently demonstrate correct signal processing. Release evidence should connect signer identity, digest, build inputs, installed image and measured instrument configuration. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions.

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Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. "Configuring Devices and Streamers." Streaming arguments and formats. Accessed October 31, 2026. https://files.ettus.com/manual/page_configuration.html.

Annotation."Streaming Arguments," "CPU Data Format Specification," and "Over-the-wire Data Format Specification." These documented interfaces motivate explicit boundary contracts; they do not verify a deployed serializer or recording path. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. "Firmware and FPGA Images." Accessed October 31, 2026. https://files.ettus.com/manual/page_images.html.

Annotation."Images Overview," "UHD Images Downloader," and "Archive install." The chapter distinguishes downloaded bytes, selected image paths and the operating image using the applicable device-family loading

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mechanism. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “R&D Testing Procedures.” Development-test scope and FPGA functional verification. Accessed October 31, 2026. https://files.ettus.com/manual/page_rdtesting.html.

Annotation. Opening scope, “Devtests,” and “FPGA Functional Verification: Manual Test Procedure.” The source distinguishes development tests from manufacturing/production tests; a pass supports only the exercised conditions. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a

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different reader. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “uhd::rx_metadata_t Struct Reference.” Accessed October 31, 2026. https://files.ettus.com/manual/structuhd_1_1rx__metadata__t.html.

Annotation. Receive timing, fragmentation and error members, including the time of the first sample and out_of_sequence. Metadata interpretation does not establish that every declaration is physically correct or supply an exact missing-sample count from an error flag alone. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions.

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Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “uhd::usrp::multi_usrp.” Receive-rate, frequency, and gain setters. Accessed October 31, 2026. https://files.ettus.com/manual/classuhd_1_1usrp_1_1multi__usrp.html.

Annotation.set_rx_rate, set_rx_freq and set_rx_gain, including the requested-versus-resulting-value distinction. Actual configuration evidence is required before the chapter’s test case can be bound to an operating point. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

IEEE Standards Association. IEEE 1057-2017, IEEE Standard for Digitizing Waveform Recorders. Published January 26, 2018. Official status and scope checked November 1, 2026. https://standards.ieee.org/ieee/1057/5945/.

Annotation. Official public status and scope only, checked on the stated date. The complete paid standard was not read; no recorder certification

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or clause-level compliance claim follows from this listing. This standard record concerns terminology and testing of instruments that digitise and retain waveforms. Its public scope is useful for identifying the type of device and associated measured quantities, while acquisition errors require separate evidence from actual recordings. The reference listing itself does not establish clause-by-clause compliance, especially where the complete standard text has not been examined. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

IEEE Standards Association. IEEE 1241-2023, IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters. Published October 6, 2023. Official status and scope checked November 1, 2026. https://standards.ieee.org/ieee/1241/6797/.

Annotation. Official public status and scope only, checked on the stated date. No complete-standard access, clause-level compliance or validation of the entire SDR chain is claimed. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. The cited work is a methodological reference; the

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worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

Kester, Walt. MT-001, Taking the Mystery out of the Infamous Formula, “SNR = 6.02N + 1.76dB,” and Why You Should Care. Rev. A. Analog Devices, October 2008. Pages 1–7. https://www.analog.com/media/en/training-seminars/tutorials/MT-001.pdf.

Annotation. Printed pages 1–3, equations 1–10, support the ideal uniform-error and sine-wave treatment; pages 3–7 discuss process gain and correlation. Channel use retains the chapter’s white-error premise, and the hypothetical cases do not certify a physical converter. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions.

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Kester, Walt. MT-002, What the Nyquist Criterion Means to Your Sampled Data System Design. Rev. A. Analog Devices, October 2008. Pages 4–7 and 9–11. https://www.analog.com/media/en/training-seminars/tutorials/MT-002.pdf.

Annotation. Printed pages 4–7 and 9–11 support sampling images, analog filtering and band placement. The chapter independently derives its equivalence relation, clock effects and ten sampling applications. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

MathWorks. “Channelizer.” DSP HDL Toolbox, R2026b documentation. Description and Preserve channel phase parameter. Accessed October 31, 2026. https://www.mathworks.com/help/dsphdl/ref/channelizer.html.

Annotation. Description, “Preserve channel phase,” valid/reset inputs and Algorithms. This is a documented implementation comparison; the chapter’s causal convention and retained-state requirements are independently specified. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels.

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Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

MathWorks. “dsp.Channelizer.” R2026b documentation. Algorithms: polyphase implementation, maximally decimated channelizer, and non-maximally decimated or oversampled channelizer. Accessed October 31, 2026. https://www.mathworks.com/help/dsp/ref/dsp.channelizer-system-object.html.

Annotation. Algorithms, especially “Polyphase Implementation,” “Maximally decimated channelizer,” and “Non-maximally decimated or oversampled channelizer.” Supports architecture and rate distinctions; numerical examples are independently derived. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. The cited work is a methodological reference; the worked examples and

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the conclusions drawn from them remain separate authorial derivations requiring their own checks. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

MathWorks. “Fixed-Point Precision Rules for Avoiding Overflow in FIR Filters.” DSP System Toolbox. R2026b. Signed output intervals and full-precision accumulator settings. Accessed October 31, 2026. https://www.mathworks.com/help/dsp/ug/fixed-point-precision-rules-for-avoiding-overflow-in-fir-filters.html.

Annotation.“Output Limits for FIR Filters with Real Input and Real Coefficients” and “Full-Precision Accumulator Rule.” The chapter retains its own stated input interval and intermediate-operation assumptions. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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MathWorks. “Perform Fixed-Point Arithmetic.” Fixed-Point Designer. R2026b. Multiplication, assignment, and explicit conversion rules. Accessed October 31, 2026. https://www.mathworks.com/help/fixedpoint/ug/perform-fixed-point-arithmetic.html.

Annotation.“Multiplication,” “Assignment,” and “Quantize Results Explicitly.” Supports the need to specify representation and conversion points. Model 10D defines its own tie, saturation and wrap rules. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

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MIT OpenCourseWare. 6.341 Discrete-Time Signal Processing. Lecture 10, "Multirate Systems and Polyphase Structures," pp. 2–5; Lecture 2, "Background Review: Phase, Group Delay, and Generalized Linear Phase," pp. 4–5. OpenCourseWare 2006 notes for the Fall 2005 course. https://ocw.mit.edu/courses/6-341-discrete-time-signal-processing-fall-2005/d97506e5761422fd7bd49a2742247303_lec10.pdf; https://ocw.mit.edu/courses/6-341-discrete-time-signal-processing-fall-2005/c1e8402bc2d0d548fbdc34e3db8dbf0d_lec02.pdf.

Annotation. Lecture 10, pages 2–5, supports compression, polyphase equivalence and the restrictions on multirate identities; Lecture 2, pages 4–5, supports group-delay context. The finite sums and 33-tap startup example are independent chapter derivations. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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MIT OpenCourseWare. “Lecture 22: Modulated Filter Bank.” 6.341 Discrete-Time Signal Processing. OpenCourseWare 2006 notes for the Fall 2005 course, pp. 1–6. Modulated-bank and polyphase/DFT development; the causal convention in Model 10C is derived explicitly. https://ocw.mit.edu/courses/6-341-discrete-time-signal-processing-fall-2005/9bae63b4a7d9ac6bf534875e13c06ffd_lec22.pdf.

Annotation. Pages 1–6, especially 2–5. The lecture uses an advanced polyphase convention, while Model 10C explicitly derives its own causal lag convention; sign and phase factors are not transferred without that conversion. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

SciPy Community. SciPy v1.18.0 Manual. “scipy.signal.lfilter.” Initial and final delay state and difference-equation notes. Accessed October 31, 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.lfilter.html

Annotation. The zi parameter, zf return and Notes document initial/final delay state and the direct-form-II-transposed realization. Its state

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coordinates are not automatically a raw list of earlier input samples. The software reference provides an executable convention for signal processing calculations and the meaning of their input parameters. Filter initial conditions, complex conjugation, one-sided scaling and array length can change numerical results even when two calls appear mathematically similar. Documenting the exact version and configuration is necessary before treating a library result as reproducible evidence or equivalent to a physical receiver. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions.

SigMF Project. Signal Metadata Format Specification. Version 1.2.6. "Captures Array," sample_start, datetime, and global_index. Accessed October 31, 2026. https://sigmf.org/.

Annotation. Version 1.2.6 "Captures Array": sample_start, datetime and global_index. The decoding default for absent global_index does not establish loss-free physical acquisition; verified source-index declarations remain necessary. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

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SLSA. “Build: Verifying artifacts.” Specification version 1.2. “How to verify” and “Check expectations.” Accessed October 31, 2026. https://slsa.dev/spec/v1.2/verifying-artifacts.

Annotation. Version 1.2 “How to verify” and “Check expectations.” Supports artifact digest, attestation subject, provenance type, trusted-builder and expected-build checks. Their satisfaction is distinct from the receiver’s functional measurement performance. The security guidance is relevant to establishing authenticity, build provenance and integrity of software or firmware used in the measurement chain. A valid signature can support a statement about which artifact was approved under a stated trust policy, but cannot independently demonstrate correct signal processing. Release evidence should connect signer identity, digest, build inputs, installed image and measured instrument configuration. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

Souppaya, Murugiah, Karen Scarfone, and Donna Dodson. Secure Software Development Framework (SSDF) Version 1.1: Recommendations for Mitigating the Risk of Software Vulnerabilities. NIST SP 800-218. February 2022. Tasks PS.2.1 and PS.3.1–PS.3.2. https://doi.org/10.6028/NIST.SP.800-218.

Annotation. Version 1.1, page 10, tasks PS.2.1 and PS.3.1–PS.3.2. Supports release integrity, protected release material and component provenance. The inherited date-bound review treated version 1.2 as an

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initial public draft and did not substitute it for this cited edition. The security guidance is relevant to establishing authenticity, build provenance and integrity of software or firmware used in the measurement chain. A valid signature can support a statement about which artifact was approved under a stated trust policy, but cannot independently demonstrate correct signal processing. Release evidence should connect signer identity, digest, build inputs, installed image and measured instrument configuration. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

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Chapter 11. Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization

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11.1 Dynamic Range Is a Family of Conditions

Dynamic range is not one number. A receiver may have noise-limited dynamic range, instantaneous dynamic range, spurious-free dynamic range, blocking dynamic range, intermodulation dynamic range, display range, and digitizer range. Each uses a different lower limit, upper limit, bandwidth, spacing, detector, and test. Quoting the largest catalog value without its definition can overstate survey capability by tens of decibels.[1]

1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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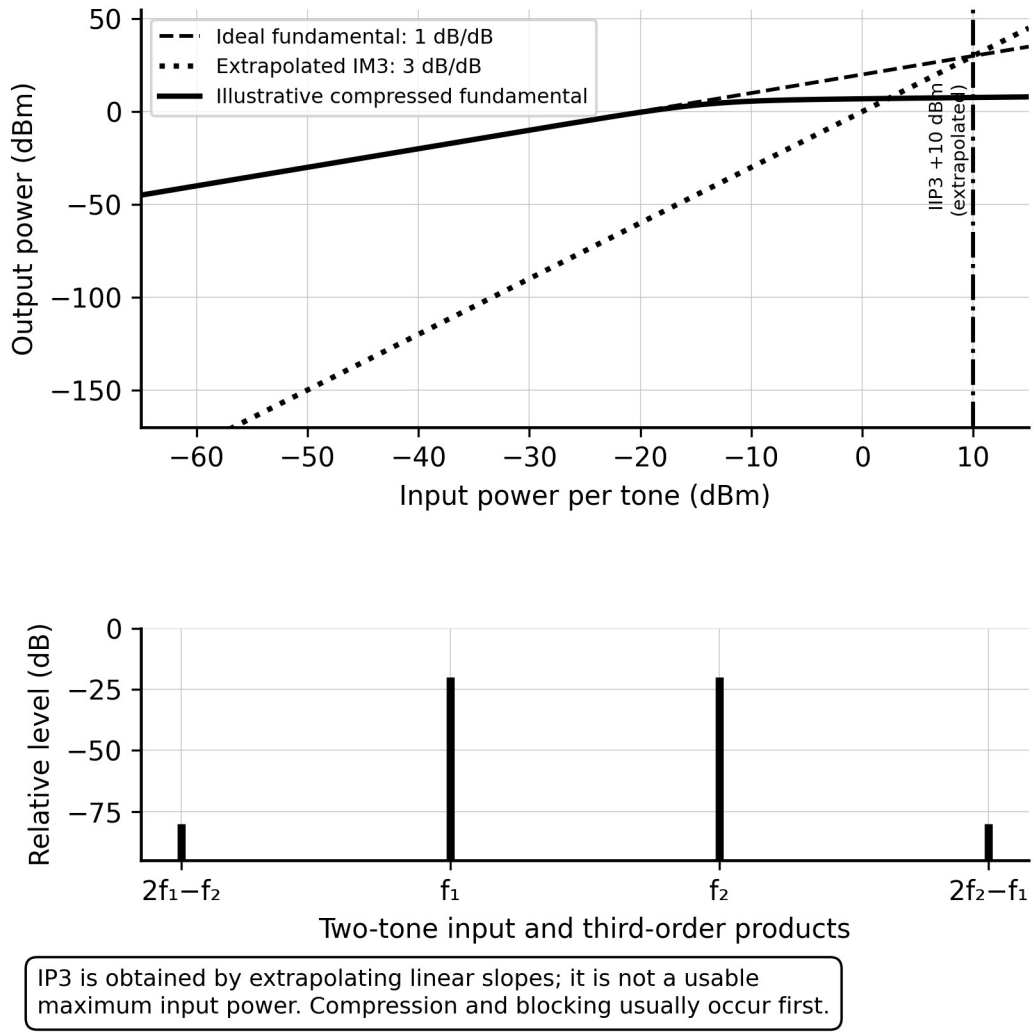

Figure 61. Two-tone intercept and intermodulation.

The practical question is whether the receiver can detect or measure a signal of interest while specified stronger signals are present. Total input power, individual carrier levels, spacing, modulation, crest factor, preselector state, and gain determine the answer. A receiver that is sensitive

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on a bench can be blind at a site because its front end, mixer, IF, ADC, or AGC is driven into a different operating state.

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11.2 Compression and Gain Change

Compression occurs when output no longer follows input with the expected incremental gain. The one-decibel compression point is a common benchmark, but subtle measurement errors can begin well below it. Filters, amplifiers, mixers, detectors, ADCs, and digital scaling can each compress or clip. A strong off-channel signal can reduce the indicated level of a weak on-channel signal without appearing in the displayed span.

Compression testing steps a calibrated input while monitoring desired output, gain state, total power, and overload indicators. For field challenge, input attenuation is changed and corrected traces are compared. If a component fails to change by the expected amount, the receiver may be compressed or the component may originate after the attenuator. Recovery after a pulse or strong carrier is also measured because temporary desensitization can create missed events.

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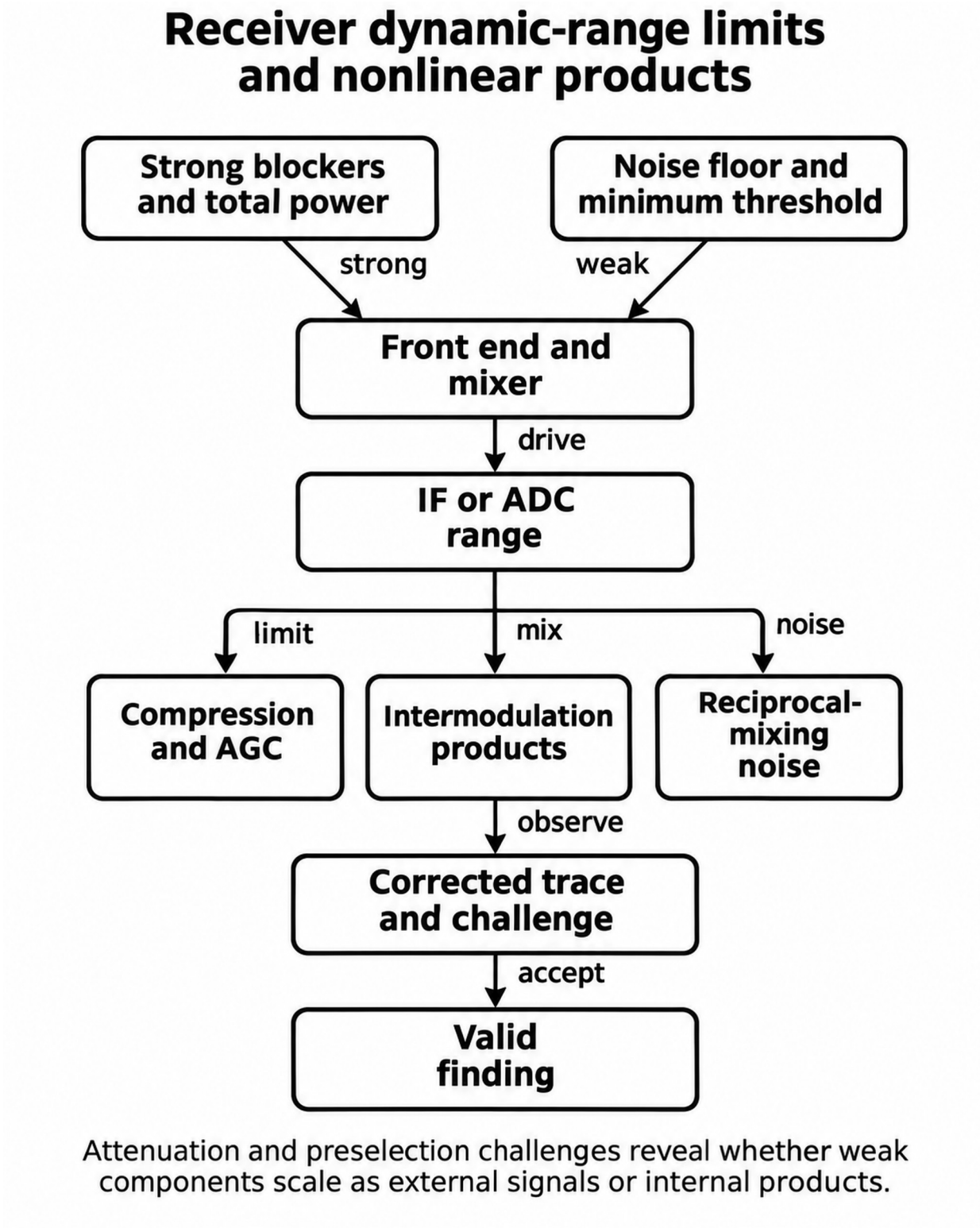

Figure 62. Receiver dynamic range and nonlinear products.

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11.3 Measure compression without confusing it with control action

A compression test needs a declared input quantity and a fixed receiver state. Step the intended stimulus through a bounded interval while measuring the desired output at the corresponding reference plane. Retain actual attenuation, gain, preselector, and detector states. If an automatic control changes during the sweep, the resulting curve describes the closed-loop receiver behavior, not the fixed-state transfer of one stage. Both may be useful, but they answer different questions and should be labeled separately.

Use an independent weak probe when the question is loss of sensitivity in the presence of a stronger signal. The blocker alone can produce an apparently plausible output while suppressing the probe or changing its estimator. Keep the probe level, frequency, modulation, and detection criterion controlled, then vary blocker level and offset. Observe desired gain, noise, products, and recovery together. A single displayed overload flag cannot establish the onset or absence of every relevant error.

After a strong pulse, measure the interval before the weak probe again meets its criterion. Model 5A supplies a bounded identified one-pole response when its assumptions apply, but limiting, saturation, detector storage, and control holdoff may produce other recovery histories. State the stimulus and prior state used to characterize recovery. The duration becomes an exclusion in the usable acquisition windows of Model 15A when the receiver cannot make valid observations during it.

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11.4 Intermodulation and Intercept Metrics

Nonlinear stages produce sums and differences of input frequencies. Third-order products are particularly troublesome because they can fall near desired signals and grow rapidly with input level. Input and output intercept points are extrapolated metrics, not actual operating points. They depend on tone spacing, frequency, gain, device state, and measurement range. Two-tone tests should be performed below compression with sources and combiners verified for their own intermodulation.

In a real survey, more than two strong signals may be present, including modulated carriers. Passive contacts, damaged connectors, preamplifiers, mixers, protection devices, and ADCs can all contribute. Changing one parent signal, adding attenuation, inserting preselection, or moving the receiver helps identify the generating path. A product that remains fixed while parent frequencies are changed requires a different explanation.

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11.5 Model 11A for cubic intermodulation and intercept metrics

A third-order intercept is useful only after the input quantity, output quantity, and extrapolation have been identified. A line on a spectrum display reports power in a selected observation band; it does not identify the nonlinear stage that generated that power. Model 11A derives a deliberately restricted voltage law, then follows its consequences through frequency placement, power conversion, unequal interferers, attenuation, and measurement uncertainty. This development supplies the assumptions behind the chapter's existing Equation 21 without replacing its summary or extending the separate Equation 22 noise-floor approximation.

The starting point is a memoryless third-order expansion around a fixed operating condition. Original circuit lectures distinguish this local description from the input and output filtering that may surround it, and distinguish the extrapolated intercept from large-signal compression. Here the coefficients describe loaded input and output voltages directly. Their numerical examples are constructed teaching cases, not measurements of any receiver. The model does not represent a complete SDR, an automatic-gain-control loop, a sampled-data converter, or an arbitrary frequency-converting mixer.[2]

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2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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11.6 Fix the voltage convention and operating domain

Let t denote time in seconds, and let f_1 and f_2 be positive frequencies in hertz with f_1 below f_2. Let A_1 and A_2 be positive peak voltages measured at the declared input reference plane, not open-circuit generator voltages. The two cosines have zero initial phase for this derivation. The input $x\backslash(t\backslash)$ and output $y\backslash(t\backslash)$ are real instantaneous voltages. Their variation with time is dynamic, although the model has no stored state: the output at a given instant depends only on the input at that instant. A fixed propagation delay could be accounted for separately without changing the power calculations.

Equation 21A Two tone voltage at the loaded input plane

$$x(t)=A_1\cos(2\pi f_1 t)+A_2\cos(2\pi f_2 t)$$

Equation 21B Declared odd cubic voltage law

$$y(t)=a_1 x(t)+a_3 x^3(t)$$

The constant a_1 is strictly positive and is a dimensionless voltage gain. The nonzero real constant a_3 has units of inverse square volts. A negative a_3 initially reduces a fundamental component; a positive a_3 initially increases it. Constant offset and even-order terms are set to zero as restrictions of this model, not because actual receiver hardware must have those properties. Bias, temperature, supply, loading, gain state, and fixture condition remain fixed during a comparison. A thermally drifting gain or a contact whose mechanical condition changes is outside this time-invariant coefficient description.

Let R_i and R_o be positive, real, frequency-independent input and output resistances in ohms. The output voltage is taken across R_o. The source is matched to R_i when available source power is identified with delivered input

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power; without that condition, record the delivered voltage and impedance rather than substituting a generator setting. For a cosine, mean-square voltage is half the squared peak amplitude. Thus the input power P_k of tone k is in watts, and the dimensionless small-signal power gain G_p includes both reference resistances.

Equation 21C Per tone power and small signal power gain

$$P_k = \frac{A_k^{\ 2}}{2 R_i}, G_p = \frac{a_1^{\ 2} R_i}{R_o}$$

Use distinct, nearby frequencies whose retained spectral products do not coincide. In particular, the two parent tones, their third harmonics, the mixed sum products, and the two close-in products must be separately identifiable, with both close-in frequencies positive. Degenerate frequency choices require the coincident complex amplitudes to be added before computing power. A frequency-independent polynomial also cannot predict how a real filter, matching network, or mixer weights those components. The present analysis refers all amplitudes to the same specified planes before introducing any separately declared attenuation.

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11.7 Derive the retained spectral amplitudes

Cubing the sum in Equation 21A yields two self-cubic terms and two mixed terms. The mixed term containing the square of the first tone occurs three times in the expansion, as does the mixed term containing the square of the second. The following identities expose the corresponding fundamental, harmonic, sum, and difference components. Here u and v are arbitrary dimensionless phase angles. Their substitution by the two time-dependent tone phases establishes the frequency locations; the factor of three from the polynomial expansion must still be retained.

Equation 21D Self cubic trigonometric identity

$$4\cos^3 u = 3\cos u + \cos 3u$$

Equation 21E Mixed cubic trigonometric identity

$$4\cos^2 u \cos v = 2\cos v + \cos(2u+v) + \cos(2u-v)$$

Write B_1 and B_2 for the signed peak coefficients at the two fundamental frequencies. Write C_{21} for the signed peak coefficient at twice f_1 minus f_2, and C_{12} for the coefficient at twice f_2 minus f_1. The mixed square term contributes both a component at the other fundamental and two intermodulation components. The self-cubic term contributes three quarters of its coefficient to its own fundamental and one quarter to its third harmonic. Collecting the coefficients gives the following results; the

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fractional coefficient agrees with the independent multinomial development of third-order mixing.[3]

Equation 21F First fundamental coefficient

$$B_1 = A_1\left[a_1 + \frac{3a_3}{4}\left(A_1^{\,2} + 2A_2^{\,2}\right)\right]$$

Equation 21G Second fundamental coefficient

$$B_2 = A_2\left[a_1 + \frac{3a_3}{4}\left(A_2^{\,2} + 2A_1^{\,2}\right)\right]$$

Equation 21H Close in third order coefficients

$$C_{21} = \frac{3a_3}{4}A_1^{\,2}A_2, C_{12} = \frac{3a_3}{4}A_1A_2^{\,2}$$

The signs of C_{21} and C_{12} preserve phase information relative to the specified cosines. Power measurement squares their magnitudes and discards that sign. Their associated sum-frequency coefficients have the same magnitudes in this memoryless model. The two third-harmonic coefficients are one quarter of a_3 times the cube of the corresponding peak input. Consequently, a clean third-harmonic observation is not interchangeable with a close-in two-tone measurement, even though both arise from the retained cubic term.

Define η_k as the magnitude of the cubic correction to fundamental k divided by its linear coefficient, with j denoting the other tone. Unless a later application is expressly an extrapolation exercise, use the declared working

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3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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condition η_1 and η_2 no greater than 0.05. This bounds each retained fundamental correction to five percent and keeps both signed fundamentals on the positive-gain branch. It does not bound omitted fifth-order terms, validate a physical receiver, or establish that temperature and state remained fixed. Those questions require evidence beyond the smallness of one retained coefficient.

Equation 21I Declared relative fundamental correction

$$\eta_k = \frac{3|a_3|}{4a_1}\left(A_k^{\,2} + 2A_j^{\,2}\right),\ j \neq k$$

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11.8 Construct the intercept from the linear asymptote

For equal peak amplitudes A, either close-in coefficient has magnitude three quarters of the magnitude of a_3 times A cubed. The intercept construction equates that magnitude to the linear fundamental a_1 times A, not to the full coefficient B_1. Define A_I as the positive peak input amplitude at this algebraic intersection, and P_I as the corresponding input power of one tone. Both are extrapolated parameters. A nonzero a_3 gives a finite value; as its magnitude tends to zero, the cubic intercept tends to infinity without establishing the absence of other distortion mechanisms.

Equation 21J Extrapolated input intercept in voltage and power

$$A_I^2 = \frac{4a_1}{3|a_3|}, P_I = \frac{A_I^2}{2R_i}$$

Substitution eliminates the unknown magnitude of a_3 from the intermodulation powers. Let P_{21} and P_{12} be the powers of the individual close-in products across R_o. These equations are exact for the declared polynomial and resistance conventions. They demonstrate why unequal interferers require separate calculations: one product contains the square of the first parent power, while the other contains the square of the second. A symmetric pair of product powers is predicted only when the parent powers are equal under these restrictions.

Equation 21K Unequal tone intermodulation powers

$$P_{21} = \frac{G_p P_1^2 P_2}{P_I^2}, P_{12} = \frac{G_p P_1 P_2^2}{P_I^2}$$

For logarithmic calculations, lower-case p_1, p_2, q, and s denote powers in dBm, defined as ten times the base-ten logarithm of watts divided by one

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milliwatt. Let g be ten times the base-ten logarithm of G_p, in decibels. Let I_3 and O_3 denote the input and output intercept levels in dBm. In an equal-tone case, p is the input level of one tone, q is its linear-asymptote output level, and s is one product level. A power gain is added as a difference in decibels, not as a power in dBm.

Equation 21L Equal tone logarithmic power law

$$q=p+g, s=3p+g-2I_3, O_3=I_3+g$$

Equation 21M Input and output intercept extraction

$$I_3=p+\frac{q-s}{2}, O_3=\frac{3q-s}{2}$$

The usual separation rule therefore uses one fundamental and one associated intermodulation product. Summing the two parent powers first introduces an inappropriate three-decibel change for equal tones. Instrument documentation also distinguishes low-side, high-side, and averaged tone results; an average of logarithmic levels is not the total power of their sum. Preserve the individual measurements and state the selected convention rather than allowing a display label to decide which quantity entered Equation 21M.[4]

If the measured fundamental includes a finite cubic correction, its level differs from q by a gain change δg. Using that measured value in the input extraction formula introduces half that gain change into the intercept

4 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers” (June 14, 2013), “Baseline Case: Cascade of Linear Circuit Blocks” and “Noise Temperature,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and synthetic cases are stated in Model 2B.

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estimate; using it in both occurrences of the output extraction formula introduces three halves. These are algebraic biases within this model, separate from calibration uncertainty. A fitted low-level linear asymptote or an explicitly bounded correction is needed when the requested precision makes those differences material.

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11.9 Ten worked applications of Model 11A

Applications 11A.1 through 11A.10 use synthetic values and the same bounded polynomial argument. They vary the inference, not merely the numerical setting. Where logarithmic straight-line examples are used, q denotes the linear asymptote as defined above. No example authorizes a stimulus level, establishes instrument safety, or substitutes for the applicable measurement configuration. The formal compression calculation is explicitly distinguished from the working domain.

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11.10 Application 11A.1 Locate the products before measuring their powers

Choose f_1 equal to 100 MHz and f_2 equal to 101 MHz, with frequency spacing of 1 MHz. Twice the first frequency minus the second is 99 MHz; twice the second minus the first is 102 MHz. The mixed sum frequencies are 301 and 302 MHz, and the self-cubic harmonics are 300 and 303 MHz. These six generated positive frequencies are distinct from both fundamentals, so no coefficient addition caused by frequency coincidence is needed. A receiver examining a narrow band around 99 MHz could therefore encounter a polynomial product even though neither parent lies in that narrow observation band.

Now increase only the first parent by 0.20 MHz while retaining the second. The lower product moves from 99 to 99.40 MHz, and the upper product moves from 102 to 101.80 MHz. The two-to-one and opposite one-to-one shifts follow from their respective frequency expressions. This intervention supplies a discriminating prediction, provided the observation path follows the appropriate frequencies and does not change state. A matching movement is compatible with the model, but does not locate the generating component. A fixed feature contradicts this particular parent-product association only if frequency accuracy, detectability, and stable configuration are adequate.

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11.11 Application 11A.2 Evaluate the cubic amplitudes and extraction bias

Set a_1 to 10, a_3 to minus 100 inverse square volts, both resistances to 50 ohms, and both input peak amplitudes to 0.020 V. Each input power is 0.000004 W, or minus 23.979400 dBm. The linear output coefficient is 0.200 V peak. The equal-tone cubic correction subtracts 0.001800 V, leaving B_1 and B_2 at 0.198200 V. Each close-in signed coefficient is minus 0.000600 V peak. The relative fundamental correction is 0.009, within the stated 0.05 limit.

Squaring 0.198200 V and dividing by 100 ohms gives a fundamental power of 0.0003928324 W, or minus 4.057927 dBm. The corresponding product power is 0.0000000036 W, or minus 54.436975 dBm. Equation 21J gives an input intercept of 1.249387 dBm; the small-signal gain is 20 dB, giving an output intercept of 21.249387 dBm. The actual fundamental gain change is minus 0.078527 dB. If its finite-power level is used instead of the linear asymptote, the input estimate becomes 1.210124 dBm and the output estimate becomes 21.131597 dBm. Neither discrepancy is a calibration defect; both are caused by applying an asymptotic extraction to a corrected fundamental.

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11.12 Application 11A.3 Resolve unequal parent amplitudes

Retain the same coefficients and resistances, but set A_1 to 0.040 V and A_2 to 0.010 V. Their powers are minus 17.958800 and minus 30.000000 dBm. Equation 21H gives C_{21} equal to minus 0.001200 V peak and C_{12} equal to minus 0.000300 V peak. Their magnitude ratio is four, so their power ratio is sixteen and their logarithmic separation is 12.041200 dB. Direct conversion gives minus 48.416375 and minus 60.457575 dBm. Replacing both parents by their average would erase the very asymmetry the calculation predicts.

The fundamentals also differ in their relative correction. Equations 21F and 21G give 0.394600 and 0.097525 V peak. Relative to the respective linear coefficients of 0.400 and 0.100 V, the gain changes are minus 0.118058 and minus 0.217681 dB. The weak second tone experiences the larger fractional correction because its gain contains the squared amplitude of the stronger first tone. Both correction magnitudes remain below five percent. If only the first parent power is increased by one decibel within the model domain, the lower product rises two decibels and the upper product rises one, rather than both following the equal-tone three-decibel rule.

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11.13 Application 11A.4 Keep each tone separate in the intercept calculation

Consider an equal-tone low-level asymptote with input p equal to minus 25 dBm, linear output q equal to minus 5 dBm, and one product s equal to minus 65 dBm. The separation is 60 dB. Half that separation is 30 dB, producing I_3 equal to 5 dBm and O_3 equal to 25 dBm. Increasing each input by 2 dB makes the linear fundamental minus 3 dBm and the cubic product minus 59 dBm. The new separation is 56 dB; adding half to the new input level of minus 23 dBm again gives 5 dBm.

The total input power of the two original equal tones is minus 21.989700 dBm. Substituting this total for p while retaining the single-tone separation gives the wrong input intercept, 8.010300 dBm. The error is exactly the logarithm of two expressed in decibels. Adding the two fundamental powers creates the analogous problem at the output. A record should therefore identify the per-tone level, chosen product, frequencies, reference planes, and gain state. The numerical constancy of two intercept estimates tests a necessary slope relationship here; it does not demonstrate that the source, combiner, and measurement receiver contributed no product.

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11.14 Application 11A.5 Recover a coefficient without confusing voltage and power gain

Let R_i be 50 ohms, R_o be 200 ohms, and a_1 be 10. Equation 21C gives G_p equal to 25, or 13.979400 dB, rather than 20 dB. Suppose the inferred input intercept is 5 dBm. Its power is 0.003162278 W, and twice R_i times that power is 0.316227766 square volts. Rearranging Equation 21J gives the magnitude of a_3 as 42.163702 inverse square volts. The output intercept is 18.979400 dBm. Omitting the resistance ratio would overstate it by 6.020600 dB.

Power-only intermodulation data do not choose the sign of this coefficient. To see the consequence, apply equal peaks of 0.050 V. With a negative coefficient, each fundamental is 0.488141459 V peak; with a positive coefficient, it is 0.511858541 V peak. Their gain changes are minus 0.208486 and plus 0.203599 dB relative to the 0.500 V linear coefficient. The product magnitudes are identical in both cases. Both have a correction magnitude of approximately 0.023717, within the declared bound. A signed or gain-sensitive observation supplies information that the two product powers alone have discarded.

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11.15 Application 11A.6 Test the slope over a declared power interval

Use the asymptotic case from Application 11A.4. Reduce each input from minus 25 to minus 31 dBm without changing any coefficient or reference plane. The linear output falls from minus 5 to minus 11 dBm, whereas the product falls from minus 65 to minus 83 dBm. Thus a 6 dB parent-power reduction produces an 18 dB product-power reduction and improves the fundamental-to-product separation from 60 to 72 dB. Applying Equation 21M at the new point still gives the same 5 dBm input intercept.

Suppose a constructed comparison instead places the product at minus 77 dBm while the linear fundamental remains minus 11 dBm. That product moved only 12 dB, giving an apparent input intercept of 2 dBm. The two values cannot both describe the same exact fixed-coefficient cubic-only case under the stated measurements. Plausible departures include another coherent contribution, a noise-limited reading, a state change, frequency-dependent response, or higher-order behavior. The slope mismatch identifies the failure of the proposed description; it does not select one departure uniquely. An observed floor also prevents extrapolating indefinitely to weaker products merely because the formula continues to produce a number.

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11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage

Place an ideal, matched, frequency-flat attenuator with power loss L equal to 10 dB either before or after the modeled stage. Its voltage transmission k is ten raised to minus L divided by twenty. Before the stage, substitution replaces the effective first coefficient by k times a_1 and the cubic coefficient by k cubed times a_3. After the stage, both coefficients are multiplied by k. The physical location therefore changes the input-referred nonlinearity even when the overall small-signal gain is the same.[5]

Equation 21N Input attenuation coefficient transformation

$$a_{1,pre} = k\,a_1,\; a_{3,pre} = k^3 a_3$$

Equation 21O Output attenuation coefficient transformation

$$a_{1,post} = k\,a_1,\; a_{3,post} = k\,a_3$$

Take an input intercept of 0 dBm, gain of 20 dB, and equal inputs of minus 20 dBm per tone at the original plane. The linear fundamentals are 0 dBm and the products are minus 40 dBm. Pre-attenuation yields fundamentals of minus 10 dBm and products of minus 70 dBm. Post-attenuation also yields fundamentals of minus 10 dBm, but products of minus 50 dBm. Referenced to the new external input plane, pre-attenuation raises I_3 to 10 dBm and leaves O_3 at 20 dBm; post-attenuation leaves I_3 at 0 dBm and lowers O_3 to 10 dBm. Noise, mismatch, attenuator distortion, and sensitivity are absent from

5 H. T. Friis, “Noise Figures of Radio Receivers,” Proceedings of the IRE 32, no. 7 (July 1944): 419–22, https://doi.org/10.1109/JRPROC.1944.232049. The publisher’s abstract was read for the historical network, component, mismatch, and measurement framing. The full paper was not accessed; Model 2B supplies its own stated derivation and working conventions.

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this calculation, so it supplies no unconditional signal-to-noise or usable-dynamic-range improvement.

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11.17 Application 11A.8 Separate formal compression from the working domain

This application deliberately examines the extrapolation boundary of the truncated polynomial. Assume a negative a_3 and remain on the positive fundamental branch. A one-decibel power-gain reduction corresponds to a voltage ratio r equal to ten raised to minus one twentieth, approximately 0.891250938. With one input tone, the cubic fundamental correction is three quarters of a_3 times its peak cubed. With two equal tones, it is nine quarters. Let P_{c1} be the single-tone input power at the formal reduction, and P_{c2} the per-tone input power for two equal tones.

Equation 21P Formal cubic compression powers

$$P_{c1}=P_I(1-r), P_{c2}=\frac{P_I(1-r)}{3}$$

The resulting ratios are 0.108749062 and 0.036249687 times P_I. Their logarithmic offsets below I_3 are 9.635745 dB and 14.406957 dB, respectively. For an input intercept of 5 dBm, the formal levels are minus 4.635745 dBm for one tone and minus 9.406957 dBm per tone for two. The second result cannot be substituted for the first or interpreted as total two-tone power. Both require a 10.874906 percent fundamental correction and therefore exceed this treatment's five-percent working bound. Higher-order terms can alter actual compression, as the original circuit treatment explicitly warns. These numbers demonstrate a model-specific algebraic relation, not a receiver compression specification.[6]

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6 International Electrotechnical Commission, CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus, 5th ed. (May 22, 2019), official

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11.18 Application 11A.9 Propagate calibration bounds with their dependencies

Return to p equal to minus 25 dBm, q equal to minus 5 dBm, and s equal to minus 65 dBm. Suppose independent bounded-error coordinates permit departures of at most u_p equal to 0.2 dB, u_q equal to 0.3 dB, and u_s equal to 0.5 dB in either direction. Independent here means the admissible set is the full rectangular set of error values; no probability distribution or confidence level is assigned. Let u_I and u_O denote the maximum absolute errors in the input and output intercept levels, respectively, in decibels. Because the intercept expressions are affine in these logarithmic coordinates, their extrema occur at the appropriate corners.

Equation 21Q Worst case intercept error bounds

$$u_I = u_p + \frac{u_q + u_s}{2}, u_O = \frac{3u_q + u_s}{2}$$

The input bound is 0.2 plus half the sum of 0.3 and 0.5, which is 0.6 dB. Thus I_3 lies from 4.4 to 5.6 dBm. The output bound is one and a half times 0.3 plus half of 0.5, or 0.7 dB, giving 24.3 to 25.7 dBm. Now change the error model: suppose the only output error is a common additive offset b bounded by 0.3 dB, while p is exact. Adding b to both q and s cancels it from their difference. The input intercept remains exactly 5 dBm under that restricted error model, whereas the output intercept becomes 25 dBm plus b. Treating the

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publication scope, https://webstore.iec.ch/en/publication/60774, checked November 1, 2026. The public scope identifies the 9 kHz–18 GHz apparatus range and EMI receivers and spectrum analyzers. No access to or clause-by-clause compliance review of the complete standard is claimed.

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shared offset as two freely varying errors would misdescribe the available information.

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11.19 Application 11A.10 Bound a coherent contaminating product

Add a declared observation model at one product frequency. Let U_{m} be the measured root-mean-square phasor magnitude, U_{c} the magnitude attributable to the modeled stage, and E a nonnegative bound on an additive coherent contaminating phasor at the same reference plane. The contaminant phase is unknown. The triangle and reverse-triangle inequalities, rather than subtraction of powers, give the permitted interval for U_{c}. This extension describes uncertainty in observing the polynomial product; it introduces no additional receiver dynamics.

Equation 21R Magnitude enclosure for coherent contamination

$$max\left(0, U_m - E\right) \leq U_c \leq U_m + E$$

Choose U_{m} equal to 1.000 mV rms, E equal to 0.100 mV rms, and R_o equal to 50 ohms. The permitted stage magnitude is 0.900 through 1.100 mV rms. Squaring those endpoints and dividing by 50 gives product powers from minus 47.904850 to minus 46.161846 dBm. With p equal to minus 20 dBm and q equal to 0 dBm, Equation 21M reverses the interval order and gives I_3 from 3.080923 to 3.952425 dBm. Ignoring the contamination would give 3.494850 dBm. If E reaches U_{m}, the observation enclosure includes zero. The stipulated nonzero cubic coefficient excludes an exactly zero stage product, but permits arbitrarily small positive magnitudes, so no finite upper intercept bound follows. Source isolation, source-harmonic suppression,

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and measurement-receiver checks are therefore substantive parts of a defensible test, not decorations around a computed intercept.[7]

7 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers,” June 14, 2013, “Baseline Case: Cascade of Linear Circuit Blocks,” “A Heterodyne Receiver,” “Noise Temperature,” and “Y-Factor,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html. The scalar derivation and numerical cases here are original and explicitly exclude unmodeled image contributions.

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11.20 Carry the conditions into receiver interpretation

A power sweep can support the local cubic description only over the observed interval and declared operating state. Repeat the relevant frequency and level conditions when the interpretation depends on them, preserve the separate low and high products, and characterize the complete path to the chosen reference planes. Frequency-selective memory, automatic gain, thermal history, mismatch, modulation envelopes, and higher orders can defeat a single real coefficient. The sign and phase of a contaminating contribution can also make a small displayed spur compatible with a larger stage-generated product.

Do not transfer this analog intercept construction automatically to a digitizer or entire SDR chain. The manufacturer tutorial on converter intermodulation distinguishes the usual analog power-law extrapolation from converter distortion and clipping behavior. For the complete receiver, the data and acceptance case must establish which portion of the path supports a local model and which behavior requires direct characterization. Chapter 10 retains responsibility for sampling, numerical representation, continuity, and configuration identity; this section supplies a conditional analog-stage calculation without closing those separate requirements.[8]

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8 Keysight Technologies, Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide, part N9069-90001, edition 1 (March 2016), 10–11, 73–81, especially “Using Loss Compensation” and “Setting Temperature of Loss,” https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf. This identified edition supports the stated measurement controls, not a claim about every current analyzer.

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11.21 Blocking and Reciprocal Mixing

Blocking is the reduction of sensitivity or accuracy caused by a strong signal separated from the desired channel. It can arise from front-end compression, AGC, filter leakage, mixer or IF overload, ADC range occupation, or control-state changes. The blocker may be outside the instrument's selected span. Testing requires a calibrated desired signal and one or more blockers at defined offsets and modulation.

Reciprocal mixing occurs when local-oscillator phase noise around a strong signal raises the apparent noise near the tuned frequency. The result can resemble environmental broadband noise or a cluster of weak signals. Better preselection may not help if the blocker is within the admitted band, while a lower-phase-noise LO or different tuning plan can. The receiver noise floor should be measured as a function of blocker level and offset.

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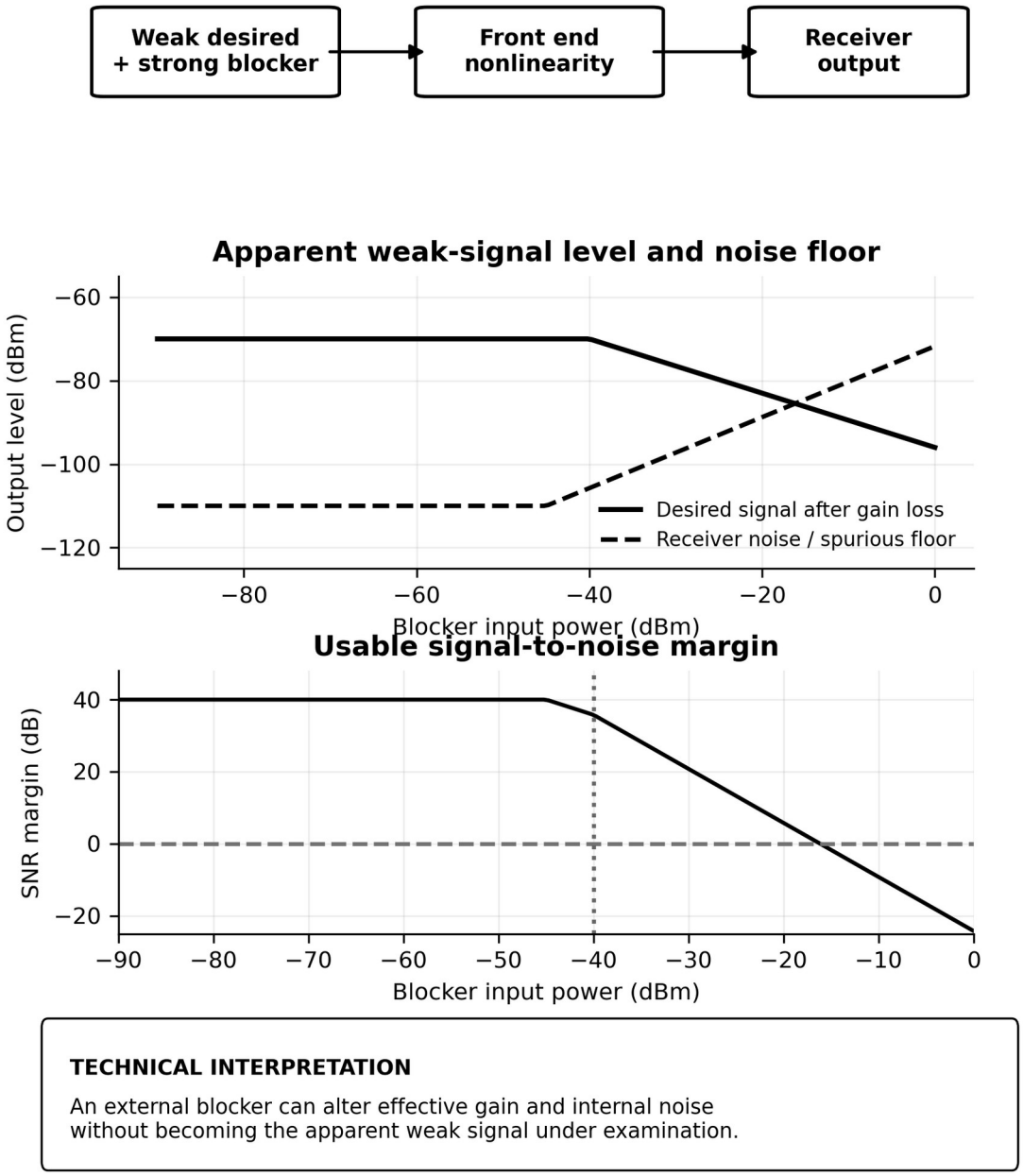

TECHNICAL INTERPRETATION

An external blocker can alter effective gain and internal noise without becoming the apparent weak signal under examination.

Figure 63. Strong-signal blocking and desensitisation.

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11.22 Model 11B for reciprocal mixing and admitted noise

A strong carrier can degrade a weak-signal measurement without producing the discrete intermodulation products developed in Model 11A. Phase fluctuations in the receiving local oscillator spread a translated copy of the blocker around its nominal intermediate frequency. Part of that spread can enter the desired observation channel even when the blocker carrier lies outside it. A displayed noise increase is consequently compatible with an internally generated contribution. Its magnitude depends on the admitted blocker power, the oscillator spectrum at the relevant offsets, and the weighting of the observation channel. None of those three quantities can be replaced safely by an unspecified catalog number.

Model 11B develops that mechanism under fixed conversion gain and a small-phase expansion. It makes the phase-noise convention explicit, derives the weighted integration, and carries the result through reference-plane changes, noise-rise limits, several blockers, measurement subtraction, and a bound on the omitted term. Equations 22A through 22T belong to this local development. The chapter's existing standalone Equation 22 remains the separate spurious-free-dynamic-range approximation. Every numerical case below is synthetic; no displayed result is an observation of a particular receiver, oscillator, site, or emitter.

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11.23 Define the phase spectrum before converting decibels

Let t denote time in seconds and $\varphi(t)$ the real oscillator phase fluctuation in radians after removal of the nominal carrier phase. For the retained linear calculation, assume a zero-mean, wide-sense stationary process with finite variance. Its two-sided power spectral density is $S_{\varphi,2}(f)$, in square radians per hertz, with signed Fourier frequency f in hertz. Real phase makes that spectrum even. Assume an ordinary density over the offsets being integrated; a discrete phase spur instead contributes a spectral line that must be integrated as such. A close-in asymptote cannot be extended to zero or infinity if doing so gives infinite total phase variance.

NIST defines the single-sideband phase-noise quantity as one half of the one-sided phase spectral density. Accordingly, for a positive offset f, define $\ell(f)$ as the linear single-sideband density and $L(f)$ as its logarithmic value in dBc/Hz. The two-sided phase density has the same numerical value as ℓ at that positive offset. The factor of two is already included in this convention.[9]

Equation 22A Single sideband and phase spectrum convention

$$\ell(f)=S_{\varphi,2}(f)=\frac{S_{\varphi,1}(f)}{2}=10^{\frac{L(f)}{10}}\ Hz^{-1}, f>0$$

Here $S_{\varphi,1}$ denotes the one-sided phase spectral density. Radians are dimensionless in the power conversion, so ℓ has units of inverse hertz. The

9 James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. Its historical radiometer thresholds are not adopted as acceptance limits for the present constructed receiver.

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logarithm in Equation 22A applies to the density expressed relative to one inverse hertz. The later formulas use ℓ, not the logarithmic number L, inside an integral. Adding dBc/Hz samples or averaging them arithmetically does not perform a power-density integration. The distinction matters whenever one portion of the admitted offset interval carries substantially more noise than another.

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11.24 Translate one blocker through the fluctuating oscillator

Let the desired channel center be v equal to zero in a complex intermediate-frequency representation, with signed frequency v measured in hertz. Let Δ be the blocker's signed offset from that center. P_{B} is its positive power in watts at the mixer input after all preceding frequency-selective gain or loss. It is not automatically the generator setting or the power at an antenna connector. Normalize the complex envelope so that its squared magnitude represents power; the known conversion gain is removed at this stage. The unmodulated blocker envelope is the first two factors in Equation 22B.

The phase Θ_{B} is uniform over one full cycle and independent of φ. This ensemble convention leaves the blocker power unchanged and permits stationary power calculations for its modulated remainder. It is not a claim that an actual carrier randomly resets on each observation. A deterministic phase gives the same retained single-blocker spectrum because φ has zero mean and stationary covariance. The uniform-phase convention becomes useful when stronger stationarity assumptions are imposed for the nonlinear error bound.

Equation 22B Power normalized translated blocker envelope

$$z_B(t)=\sqrt{P_B}e^{j(2\pi\Delta t+\Theta_B)}e^{-j\varphi(t)}$$

Expand only the oscillator phase factor. The complex number j is the square root of minus one, and $r\backslash(t\backslash)$ is defined by the exact identity in Equation 22C. The retained perturbation $u_1\backslash(t\backslash)$ is minus j times $\varphi\backslash(t\backslash)$ times the unmodulated blocker envelope. It has units of square root watts. Multiplication by the carrier exponential translates the phase spectrum by Δ, while multiplication by the blocker amplitude scales its density by P_{B}. Thus

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no independent phase-noise source needs to be invented at the desired frequency.

Equation 22C Retained phase term and exact remainder

$$e^{-j\varphi(t)}=1-j\varphi(t)+r(t)$$

Equation 22D Spectrum of the retained blocker perturbation

$$S_{u1}(v)=P_B S_{\varphi,2}(v-\Delta)=P_B \ell(\,|\,\Delta-v\,|\,)$$

Equation 22D has units of watts per hertz. The use of an absolute offset inside ℓ follows from the even spectrum of a real phase process; it does not make a signed blocker offset interchangeable when the observation filter is asymmetric. The nominal blocker carrier is a separate spectral line. Require that its direct leakage through the observation path be negligible or independently characterized. The reciprocal-mixing calculation alone neither predicts that leakage nor excludes gain compression, an automatic-gain-control response, digitizer clipping, or a contribution from the blocker source itself.

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11.25 Integrate the channel that actually produces the reported value

Let $H(v)$ be the dimensionless complex response of the fixed observation filter, normalized at the desired center so that $H(0)$ equals one. Set $W(v)$ equal to its squared magnitude. For this treatment, require zero through unity power weighting and finite integral. This peak-normalized condition is also used later in the remainder bound; a filter with gain above unity after this normalization requires a revised bound. B_{eff} is the equivalent noise bandwidth in hertz. The mathematical filter may represent a declared digital channel as well as an analog response, provided its power weighting and normalization are established.

Equation 22E Power weighting and equivalent noise bandwidth

$$W(v)=|H(v)|^2, B_{eff}=\int_{-\infty}^{\infty} W(v)\,dv$$

An instrument's resolution-bandwidth label does not by itself specify this integral. Keysight's 89600 VSA help defines its RBW as equivalent noise bandwidth and distinguishes that convention from the 3 dB width generally used by swept analyzers. The relevant specification must therefore be checked for the actual instrument and processing path. A detector, averaging rule, window correction, or logarithmic display transformation must not be silently substituted for a linear power integral.[10]

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10 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf; MACOM, “Designing with Diodes: Protecting Sensitive Components” (September 2, 2022), receiver-protector operation and recovery discussion, https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting. These are identified examples of preselection, gain placement, and protection, not a universal front-end architecture or an instrument-independent limit.

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Define the dimensionless overlap factor K_Δ by weighting the translated single-sideband spectrum over the entire channel. This notation separates three questions: which blocker power reached the mixer, which oscillator offsets intersect the channel, and how the observation path weights them. The frequencies with nonzero W are assumed to stay away from the blocker carrier and any excluded zero-offset singularity. Where the response has small tails, their omitted contribution needs a bound rather than an unrecorded truncation.

Equation 22F Weighted oscillator and channel overlap

$$K_\Delta = \int_{-\infty}^{\infty} W(v)\,\ell(\,|\,\Delta - v\,|\,)\,dv$$

Equation 22G Input equivalent and output reciprocal mixing powers

$$N_{RM} = P_B K_\Delta, N_{out} = G\,N_{RM}$$

N_{RM} is the retained reciprocal-mixing power referred to the mixer input, in watts. G is the fixed positive dimensionless power gain from that plane to the reported output, after accounting for the normalized channel response. N_{out} is the corresponding output contribution. Both quantities describe the same added component at different planes. If conversion gain varies appreciably across the admitted noise spectrum, incorporate that frequency dependence into the weighting and revise the normalization; a single G is then insufficient. For a real mixer with another admitted image or conversion path, that path also requires explicit treatment.

When ℓ is constant over every offset carrying significant weight, K_Δ equals that constant times B_{eff}. Replacing it by the value at the center offset is an approximation when the spectrum varies. If lower and upper linear densities bound the entire weighted region, multiplying each bound by B_{eff} encloses

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K_{Δ}. A single tabulated center value supplies no such enclosure without information about the shape. This is particularly important on a sloping spectrum, near a phase spur, or when the desired channel occupies a substantial fraction of the blocker separation.

Equation 22H Flat spectrum special case

$$N_{RM} = P_B \ell(|\Delta|) B_{eff}(flat\ \ell)$$

Equation 22I Logarithmic form of the flat spectrum result

$$n_{RM} = p_B + L(|\Delta|) + 10\log_{10}\left(\frac{B_{eff}}{1\,Hz}\right)$$

In Equation 22I, p_{B} and n_{RM} are the blocker and added-noise levels in dBm, each defined relative to one milliwatt. L is in dBc/Hz, and the bandwidth ratio is dimensionless. The manufacturer mixer treatment gives the same blocker-power, phase-density, and bandwidth product under a flat-spectrum assumption. Its oscillator-driver discussion also shows why an external oscillator specification need not describe all phase noise present inside the conversion path. The relevant quantity is the effective phase spectrum seen by the admitted blocker.[11]

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11 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf. The manual identifies firmware 3.20 and higher; the cited architecture is a specific instrument example.

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11.26 Convert added power into a conditional noise-rise limit

Let N_0 be the positive baseline noise power referred to the same mixer-input plane, integrated by the same W, with the same conversion gain and processing. Assume its cross power with the retained reciprocal-mixing contribution is zero, so their powers add. Define R as the rise in total noise level in decibels. A finite permissible rise $R_{\max}$, also in decibels and nonnegative, then bounds the allowed added power. This compares noise powers; it does not directly establish detection probability for an unknown waveform or a particular decision rule.

Equation 22J Noise rise from an added uncorrelated contribution

$$R = 10\log_{10}\left(1 + \frac{N_{RM}}{N_0}\right)$$

Equation 22K Reciprocal mixing allowance for a specified rise

$$N_{RM} \le N_0\left(10^{\frac{R_{max}}{10}} - 1\right)$$

The allowance tends to zero as the permissible rise tends to zero. It depends on the baseline: the same added watts produce a larger rise in a quieter receiver. A high initial noise floor can consequently make a blocker appear less damaging by this metric without making weak signals easier to detect. If a blocker changes gain, bandwidth, or baseline noise, the observed on/off ratio no longer isolates Equation 22J. Signal transfer and receiver state must then be measured alongside the apparent floor.

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11.27 Ten worked applications of Model 11B

Applications 11B.1 through 11B.10 use constructed data and the stated conventions. They test distinct decisions: an ordinary estimate, inversion of an allowance, bandwidth normalization, nonuniform spectral integration, signed offsets, reference-plane translation, multiple blockers, linear subtraction, bounded uncertainty, and the validity of the retained expansion. Except where a failure is expressly examined, gain and filter remain fixed, the blocker carrier is excluded, and baseline and added-noise cross powers vanish. Values are rounded only for presentation; the calculation records retain unrounded quantities.

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11.28 Application 11B.1 Compute the added noise and its consequence

Take a mixer-input blocker level of minus 30 dBm, equal to 0.000001 W. Let the relevant oscillator density be flat at minus 140 dBc/Hz, so ℓ equals 10 to the minus fourteenth per hertz, across a channel with B_{eff} equal to 200,000 Hz. Multiplication gives K_{Δ} equal to 0.000000002 and N_{RM} equal to 2.000000 times 10 to the minus fifteenth W. The corresponding level is minus 116.989700 dBm. Equivalently, adding minus 30, minus 140, and 53.010300 dB gives the same result.

A baseline of minus 114 dBm is 3.981072 times 10 to the minus fifteenth W. The added-to-baseline ratio is 0.502377, giving a rise of 1.767790 dB. The weaker numerical level of the added component does not make it negligible: it adds approximately half the original noise power. If a fixed output gain of 20 dB were used, both baseline and added powers would rise by that gain and their ratio would remain unchanged. Comparing an output noise level directly with the input-equivalent baseline would instead introduce a false gain factor.

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11.29 Application 11B.2 Invert a one decibel allowance

Retain the minus 114 dBm baseline and 200,000 Hz bandwidth, but require a noise rise no greater than 1 dB. Ten to the power 0.1 minus one is 0.258925. The allowed added power is therefore 1.030801 times 10 to the minus fifteenth W, or minus 119.868253 dBm. For a minus 30 dBm blocker and the flat-spectrum model, subtracting the blocker level and the 53.010300 dB bandwidth term gives a maximum density of minus 142.878553 dBc/Hz. A more positive density would exceed the allowance.

Alternatively, hold the density at minus 140 dBc/Hz and solve for blocker level. The maximum is minus 32.878553 dBm at the mixer input. This is 2.878553 dB below the original blocker, whereas the original noise rise exceeded the target by only 0.767790 dB. The two differences are not equal because the requirement is on total noise, including N_0. The algebra supplies a conditional allocation. It does not establish that adding an attenuator will achieve it, because an attenuator may also alter desired-signal transfer, input-referred baseline noise, mismatch, or receiver state.

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11.30 Application 11B.3 Distinguish filter width from noise bandwidth

Construct a finite channel with W equal to one between minus 50 and plus 50 kHz, equal to 0.1 in the two adjoining intervals out to minus and plus 100 kHz, and zero elsewhere. The width of the region at or above half the peak power response is 100 kHz. Its equivalent noise bandwidth is instead 100 kHz plus 0.1 times the combined 100 kHz in the skirts, giving 110 kHz. The abrupt steps are an idealized integration exercise, not a proposed realizable filter shape.

With the minus 30 dBm blocker and flat minus 140 dBc/Hz density over the relevant finite offsets, N_{RM} is 1.100000 times 10 to the minus fifteenth W, or minus 119.586073 dBm. Using 100 kHz would predict minus 120 dBm, an underestimate of 0.413927 dB. No globally white phase process is assumed: the density is declared flat only where this finite filter samples it, with a finite-variance continuation elsewhere. The example isolates the area error. It does not infer the skirts of an unknown filter from a single reported width.

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11.31 Application 11B.4 Integrate a nonuniform oscillator spectrum

Place a minus 30 dBm blocker at Δ equal to plus 1 MHz and use unit weighting over ν from minus 100 to plus 100 kHz. The oscillator offsets sampled are 900 through 1,100 kHz. Define the density as minus 130 dBc/Hz from 900 to 950 kHz, minus 140 from 950 to 1,050 kHz, and minus 150 from 1,050 to 1,100 kHz. The three linear overlap contributions are respectively 0.000000005, 0.000000001, and 0.00000000005. Their sum is K_{Δ} equal to 0.00000000605.

The resulting added power is 6.050000 times 10 to the minus fifteenth W, or minus 112.182446 dBm. Using only the minus 140 dBc/Hz value at the center offset with the full 200 kHz bandwidth would give minus 116.989700 dBm, underestimating the contribution by 4.807254 dB. Against the minus 114 dBm baseline, the correctly integrated noise rise is 4.013473 dB. The noisiest 50 kHz portion dominates despite occupying only one quarter of the bandwidth. Averaging the three logarithmic density labels would assign a different and unjustified weighting.

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11.32 Application 11B.5 Preserve the sign of the blocker offset

Use an asymmetric unit-weight channel from v equal to zero through 100 kHz, with zero weight elsewhere. On the offset ranges encountered, let ℓ\(f\) equal C divided by f squared, where C equals 0.01 Hz. This local law has units of inverse hertz; a finite-variance continuation is assumed outside those ranges. Keep P_{B} at minus 30 dBm. For Δ equal to plus 1 MHz, integration gives C times the difference between the reciprocal of 900,000 Hz and the reciprocal of 1,000,000 Hz. Thus K_{Δ} is 1.111111 times 10 to the minus ninth.

For Δ equal to minus 1 MHz, the same observation channel samples offsets from 1,000,000 to 1,100,000 Hz. The integral is C times the difference between their reciprocals, giving 9.090909 times 10 to the minus tenth. The corresponding noise levels are minus 119.542425 and minus 120.413927 dBm. Their 0.871502 dB separation comes from channel asymmetry, although the underlying real-phase spectrum is even. Replacing both signed offsets by a positive number before applying W would erase this distinction. A symmetric filter would remove this particular difference for the stated even spectrum.

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11.33 Application 11B.6 Move both blocker and desired reference planes

Let $P_{\mathrm{B,ext}}$ be blocker power at an external connector, and let A_B be the positive power transfer from that connector to the mixer at the blocker frequency. Let A_D be the corresponding power transfer for a narrow desired signal at the desired center. Both are dimensionless and can include gain or loss. The desired-external-input-equivalent reciprocal noise is the mixer-input-equivalent noise divided by A_D. Consequently, the blocker rejection relevant to desired-signal comparison is the ratio A_B to A_D.

Equation 22L Blocker transfer and desired input reference

$$P_B = A_B P_{B,ext}$$
$$N_{ext} = \frac{N_{RM}}{A_D} = P_{B,ext} \frac{A_B}{A_D} K_\Delta$$

Take an external blocker of minus 5 dBm, blocker transfer of minus 25 dB, and desired-center transfer of minus 2 dB. The mixer sees minus 30 dBm. With the density and bandwidth of Application 11B.1, its reciprocal contribution remains minus 116.989700 dBm at the mixer-input-equivalent plane. Dividing by the desired power transfer raises the externally referred value to minus 114.989700 dBm. The differential rejection is 23 dB, not the 25 dB blocker loss alone.

This scalar reference conversion applies to the declared narrow desired signal or an adequate constant-transfer approximation across its spectrum. A broad desired waveform requires the frequency-dependent desired transfer and its signal weighting; A_D at one center frequency is not sufficient to refer the entire waveform. Nor does the 23 dB differential figure establish the change in total sensitivity. Noise generated ahead of and behind the

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selective element and any change in mismatch or gain must be included in the baseline comparison. The example establishes the reference transformation of this one generated contribution.

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11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition

Let m be a positive integer number of blockers, with index k running from one through m. Each $P_{\mathrm{B},k}$ is a mixer-input blocker power and each Δ_k its signed offset. Sum their reciprocal contributions only if the admitted cross powers vanish under the declared ensemble or averaging procedure. Independent uniform carrier phases, independent also of the phase-noise process, are one sufficient ensemble condition. A shared local oscillator alone does not imply independent contributions. Distinct deterministic carriers can produce cyclostationary cross terms before a justified time average; coincident coherent carriers require field addition.

Equation 22M Multiple blocker power sum under zero cross powers

$$N_{\Sigma}=\sum_{k=1}^{m} P_{B,k} K_{\Delta k}$$

For an explicitly uncorrelated three-contribution case, use 200 kHz effective bandwidth and flat densities over each relevant region. The respective pairs of blocker level and density are minus 30 dBm with minus 140 dBc/Hz, minus 40 dBm with minus 130 dBc/Hz, and minus 35 dBm with minus 145 dBc/Hz. The resulting powers are 2.000000, 2.000000, and 0.200000 times 10 to the minus fifteenth W. Their sum is 4.200000 times 10 to the minus fifteenth W, or minus 113.767507 dBm.

Against the minus 114 dBm baseline, the noise rise is 3.128102 dB. The second blocker is ten decibels weaker than the first, but its phase-noise density is ten decibels higher at the applicable offset; their contributions are equal. The third contributes only one tenth as much. Summing blocker

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powers before selecting an oscillator offset would hide these differences. If the three admitted contributions have nonzero cross powers, their complex covariance terms must be retained and the numerical sum above is not the applicable model.

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11.35 Application 11B.8 Infer an effective density from linear subtraction

Suppose the output noise is minus 112 dBm with a blocker absent and minus 107 dBm with it present. Let fixed power gain G be 100, or 20 dB, and B_{eff} be 100 kHz. The mixer-input blocker is minus 20 dBm. Define N_{off} and N_{on} as the two output noise powers in watts. Under unchanged baseline, filter, and gain, and after excluding or bounding other added contributions, their difference is the output reciprocal-mixing power. A negative or unresolved difference cannot support a positive density estimate.

Equation 22N Conditional on and off power subtraction

$$N_{RM} = \frac{N_{on} - N_{off}}{G}$$

Equation 22O Flat effective density inferred from the added power

$$\hat{\ell} = \frac{N_{on} - N_{off}}{G\, P_B B_{eff}}$$

The two output powers are 6.309573 times 10 to the minus fifteenth W and 1.995262 times 10 to the minus fourteenth W. Subtracting in watts gives 1.364305 times 10 to the minus fourteenth W. Dividing by G gives 1.364305 times 10 to the minus sixteenth W, or minus 128.650885 dBm, at the mixer-input-equivalent plane. Division by the blocker power and bandwidth gives an inferred density of minus 158.650885 dBc/Hz. The observed 5 dB rise is a ratio of totals; it is not the added power in either dBm or dBc/Hz.

This inference is attributable to receiver reciprocal mixing only when the other conditions are supported. Analog Devices' single-tone desensitization discussion explicitly includes phase noise from the jammer generator as

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another route into the measurement. Qualify the stimulus spectrum at the relevant offset, including its path to the receiver, and characterize changes in gain and baseline. Otherwise the inferred number is an effective aggregate under the assumed subtraction model. A quiet source specification at a different offset or reference plane does not resolve the attribution.[12]

12 MACOM, "Designing with Diodes: Protecting Sensitive Components," September 2, 2022, receiver-protector limiter operation and recovery paragraphs, https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting. The discussion is used for the stated PIN-limiter mechanism, not as a universal quantitative recovery law.

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11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise

Suppose the flat-spectrum inputs are known only within a full rectangular set of deterministic bounds: blocker level from minus 30.5 to minus 29.5 dBm, density from minus 142 to minus 138 dBc/Hz, bandwidth from 190 to 210 kHz, and baseline from minus 114.3 to minus 113.7 dBm. A rectangular set means every combination within these limits is admitted. It does not assign statistical independence, a probability distribution, or a coverage probability. Denote the lower and upper blocker levels by p_{minus} and p_{plus}, density limits by L_{minus} and L_{plus}, and bandwidth limits by B_{minus} and B_{plus}.

Equation 22P Monotone bounds for the flat added noise level

$$n_{minus} = p_{minus} + L_{minus} + 10\log_{10}\left(\frac{B_{minus}}{1\,Hz}\right)$$
$$n_{plus} = p_{plus} + L_{plus} + 10\log_{10}\left(\frac{B_{plus}}{1\,Hz}\right)$$

Equation 22P gives added-noise levels from minus 119.712464 to minus 114.277807 dBm, equivalent to 1.068449 through 3.734387 times 10 to the minus fifteenth W. The smallest rise combines the smallest added power with the largest baseline, producing 0.970729 dB. The largest combines the largest added power with the smallest baseline, producing 3.021411 dB. These extrema follow from monotonicity, not from adding logarithmic rise uncertainties. Correlated calibration errors or a restricted feasible set could narrow the interval, but that requires a justified dependency model. Calling this deterministic enclosure a 95 percent interval would add information the premises do not contain.

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11.37 Application 11B.10 Bound the omitted phase term in the selected channel

A small phase variance motivates the retained approximation but does not alone quantify its error in a narrow selected channel. For any real value of φ, the integral form of the exponential remainder gives the pointwise inequality in Equation 22Q. Squaring and taking expectation gives the second inequality at each time for which the fourth moment exists. Neither inequality requires stationarity. The NIST treatment supplies the small-phase interpretation of single-sideband power and a sinusoidal-modulation benchmark; the bounds here are a separate derivation for the declared stochastic model.[13]

Equation 22Q Pointwise remainder and fourth moment enclosure

$$\left|r(t)\right| \le \frac{\varphi^2(t)}{2}$$
$$E\left[\left|r(t)\right|^2\right] \le \frac{E\left[\varphi^4(t)\right]}{4}$$

To apply a stationary filtered-power bound to the nonlinear remainder, now strengthen the assumptions: φ must be strictly stationary with a finite fourth moment, and Θ_{B} retains its independent uniform distribution. Wide-sense stationarity alone is sufficient for the earlier retained linear spectrum, but does not generally make a nonlinear function of φ stationary. Let P_r be the mean power after filtering the omitted envelope term, and let N_{exact} be the

13 Analog Devices, ADL8201: DC to 30 GHz, RF Limiter, data sheet, rev. 0 (January 2026), tables 1–6, 3–5, https://www.analog.com/media/en/technical-documentation/data-sheets/adl8201.pdf. Device performance, survivability, and absolute maximum ratings have separate conditions; no numerical device rating is transferred to the synthetic front-end cases.

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filtered power of the full perturbation obtained by subtracting the unmodulated blocker envelope from Equation 22B. These definitions keep direct carrier leakage outside the comparison.

Equation 22R Filtered omitted power under stronger stationarity

$$P_r \leq \frac{P_B E\left[\varphi^4(t)\right]}{4}$$

The filter cannot increase this stationary remainder power because its power weighting is everywhere at most one. The exact perturbation is the sum of retained and omitted envelopes, which need not be uncorrelated. Applying the Cauchy-Schwarz inequality to their filtered cross power yields Equation 22S. Dropping that cross term would give an unjustifiably optimistic error bound. This is an absolute bound on the selected perturbation power, not a claim about the actual sign of the correction.

Equation 22S Selected power error including the cross term

$$\left|N_{exact} - N_{RM}\right| \leq 2\sqrt{N_{RM} P_r} + P_r$$

For a numerical evaluation, additionally give the strictly stationary process a zero-mean Gaussian marginal with standard deviation σ_φ in radians. The fourth moment then has the value in Equation 22T. This marginal condition supplies the moment, not the required stationarity or a particular oscillator spectrum. Retain a minus 30 dBm blocker and a selected first-order power N_{RM} of 2.000000 times 10 to the minus fifteenth W. These values are compatible with many different out-of-channel phase spectra.

Equation 22T Fourth moment of the declared Gaussian marginal

$$E\left[\varphi^4(t)\right] = 3\sigma_\varphi^{\ 4}$$

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With σ_φ equal to 0.001 rad, the fourth moment is 3.000000 times 10 to the minus twelfth. Equation 22R bounds P_r by 7.500000 times 10 to the minus nineteenth W. Equation 22S then bounds the selected absolute power error by 7.820967 times 10 to the minus seventeenth W, or 3.910483 percent of the retained result. The corresponding upper change in level is 0.166594 dB. This enclosure includes an unknown cross-term sign; the upper logarithmic change is not a symmetric uncertainty interval in decibels.

Increase σ_φ to 0.03 rad while keeping the same selected first-order power by allowing more phase variance elsewhere. The omitted-power bound becomes 6.075000 times 10 to the minus thirteenth W, and the selected absolute-error bound becomes 6.772137 times 10 to the minus thirteenth W. That is 338.606850 times the retained result, permitting an upper level change of 25.309764 dB. The bound is now uninformative for precise channel prediction, although 0.03 rad still appears small as a total rms phase. A loose global bound does not prove a large actual error. It shows that total variance and a fourth moment alone do not localize the omitted spectrum sufficiently.

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11.38 Use the model to design discriminating receiver observations

The mechanism predicts a retained noise contribution proportional to blocker power while the effective phase spectrum and observation path remain fixed. A one-decibel blocker change therefore changes that contribution by one decibel, but generally changes the total displayed noise by less because baseline power remains. Offset variation probes the weighted oscillator spectrum; bandwidth variation probes its integral. Those interventions provide distinct checks. A fitted line obtained while automatic gain, filter selection, or numerical scaling changes does not test the fixed-state prediction. Record the state and input/output planes alongside each power, not after the fit has been interpreted.

A useful normalization check comes from a small sinusoidal phase modulation of peak β radians. Each first-order sideband has power relative to the carrier of β squared divided by four. Their combined power is β squared divided by two, equal to the phase variance. Thus a single selected sideband uses the single-sideband convention without an additional doubling. This constructed benchmark checks a calculation or implementation; a measured discrete spur still needs its own line-power treatment.[14]

For a survey receiver, the practical result is a conditional operating envelope. Preselection changes admitted blocker power; retuning changes

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14 Walt Kester, MT-080, Mixers and Modulators, rev. 0 (Analog Devices, October 2008), 1–2 and 5, including the multiplier model and “Image Response,” https://www.analog.com/media/en/training-seminars/tutorials/mt-080.pdf. The ideal product identities are developed in Model 4A; its candidate spur locations do not establish the amplitudes of real mixer products.

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the oscillator offsets sampled by a fixed channel; another oscillator or conversion path can change the effective phase spectrum. Each intervention must also preserve or remeasure desired-signal transfer and baseline noise. A reduced apparent floor alone cannot establish improved weak-signal detectability if the desired response has fallen as well. The following field-desensitization section therefore requires known references and controlled receiver configurations. Model 11B explains one contribution that such observations can separate, while leaving the full detection and state-response problem open.

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11.39 Desensitization Tests in Operational Environments

Field desensitization is assessed with known references placed near the search frequency while the site's strong emitters remain present. The reference can be radiated under controlled conditions or injected through a coupler. Its level is stepped, and detection probability or measured amplitude is recorded across receiver settings. Preselection, attenuation, antenna orientation, and location are varied to find a configuration that restores reliable observation.

These tests must not interfere with authorized services or create an unaccounted signal. Coupling, shielding, power, frequency, and timing are controlled. The reference is clearly marked in data and removed before final searches where appropriate. A sensitivity claim without strong-signal context is inadequate for a TSCM survey conducted in a dense RF environment.

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11.40 Distinguish strong-signal mechanisms through paired interventions

Cubic intermodulation and reciprocal mixing can both obscure a weak component, but their developed models predict different dependencies. Model 11A connects specified parent tones to discrete products under a fixed memoryless cubic law. Model 11B connects admitted blocker power and effective phase-noise density to weighted added noise. Neither model alone covers every desensitization mechanism. Compression, AGC, switching transients, and broadband interference remain alternatives to examine when the observations do not follow the proposed dependence.

Choose an intervention that changes one modeled cause while keeping the observation channel interpretable. Moving a parent frequency tests a product location. Changing admitted blocker power tests a noise contribution. Inserting a preselector changes blocker admission but may also alter desired loss and noise, so preserve its measured transfer and use the appropriate reference-plane correction. A smaller displayed floor after filtering is not automatically an improvement in input-referred sensitivity unless the desired transfer and baseline noise are also accounted for.

An attenuation challenge has a location. Attenuation before a nonlinear stage changes its drive; attenuation after that stage scales an already generated product together with other downstream signals. Model 11A develops this distinction explicitly. Input attenuation can also change a control loop or cause the receiver to choose another gain range. Record those effects and compare the corrected desired reference, not only the

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unexplained component. An apparent slope that mixes several state transitions is not a clean estimate of nonlinear order.

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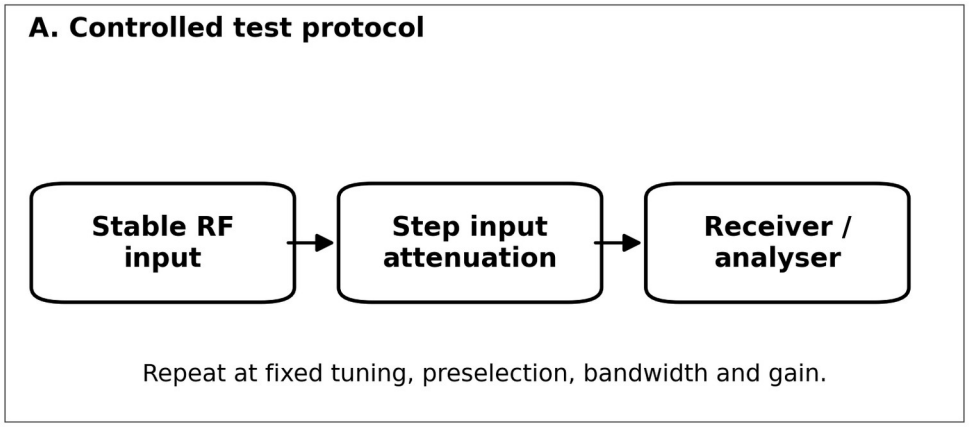

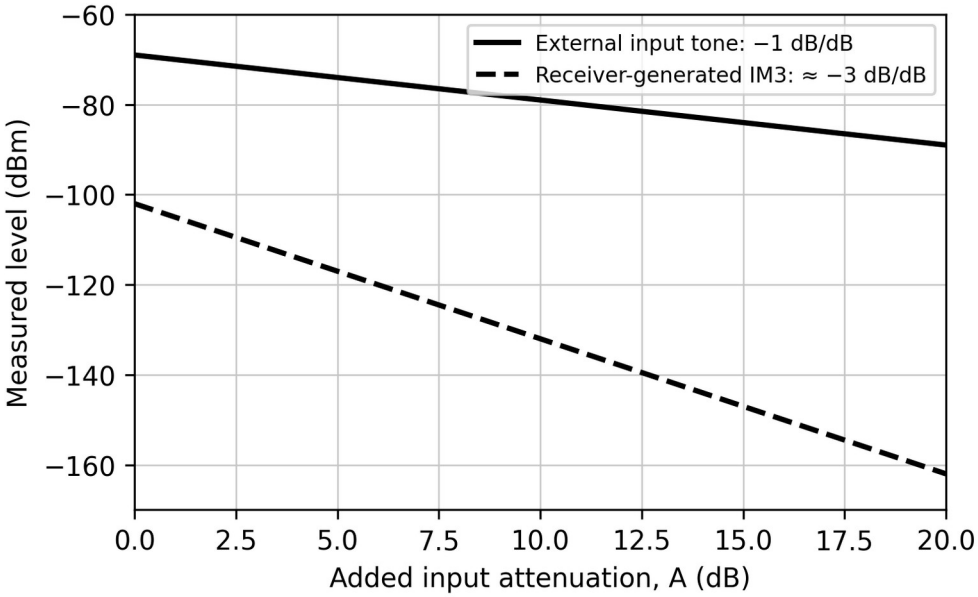

Interpretation is conditional: predicted slopes assume nonlinearity follows the input attenuator and no AGC or noise-floor limitation.

Figure 64. Attenuation challenge for signal origin.

Use off-state and on-state measurements through the same gain and weighting when estimating added noise. Subtract powers in linear units and retain the uncertainty of both measurements. Model 11B shows why a small difference can be poorly determined and why a coherent contaminant

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cannot be removed by an uncorrelated-power subtraction. If the two states alter the desired transfer, correct that change or redesign the experiment before interpreting the difference as one new noise mechanism.

The synthetic calculations in this chapter provide predictions that can be challenged, not substitute acceptance data. Build the actual receiver matrix around the bands, external paths, blocker environments, signal classes, and recovery intervals expected in use. Include boundary conditions where a procedure must switch configuration or declare insufficient capability. A documented limitation can guide a successful survey; an unqualified dynamic-range number cannot tell the operator which weak observations remain trustworthy.

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11.41 Dynamic-Range Acceptance Matrix

An operational receiver is accepted against a matrix of weak references, blockers, tone spacings, modulation types, preselector states, gain settings, and recovery intervals. The objective is not to reproduce one catalog number but to establish the safe and useful region for the complete field configuration. Tests extend to band edges, automatic-state changes, and the external preamplifier or splitter paths actually deployed.

Known limitations are encoded in the survey procedure. An instrument may be approved for occupancy search in one band while requiring external preselection or reduced gain in another. Acceptance records include parent signals and products so that field observations can be screened against known residual families.

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11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization

Equation 1. Third-order input intercept estimate

$$\mathrm{IIP3}_{\mathrm{dBm}} = P_{\mathrm{in,dBm}} + \frac{P_{\mathrm{fund,dBm}} - P_{\mathrm{IM3,dBm}}}{2}$$

For a two-tone test in the linear small-signal region, input third-order intercept is estimated from tone input power and the output separation between fundamentals and third-order products. The sources, combiner, and measurement receiver must contribute negligible products.

Equation 21 is the small-signal, per-tone intercept relation derived in Model 11A and Applications 11A.1–11A.10. A fitted intercept extrapolates the local cubic trend. It is not an operating input power and does not establish source purity, compression behavior, or immunity to a different blocker mechanism.

Equation 2. Spurious-free dynamic range approximation

$$\mathrm{SFDR}_{\mathrm{dB}} \approx \frac{2}{3}\left(\mathrm{IIP3}_{\mathrm{dBm}} - N_{\mathrm{floor,dBm}}\right)$$

For a third-order-limited system with compatible bandwidth and input-referred quantities, spurious-free dynamic range is approximately two thirds of the difference between IIP3 and noise floor. The relation is a simplified planning model and excludes blockers, higher-order effects, compression, and nonwhite noise.

Equation 22 follows directly from the local equal-tone cubic law rather than introducing a separate receiver mechanism. Let p be the numerical input power of either tone in dBm, I the numerical IIP3 at that same plane, and N the input-equivalent noise power in dBm integrated over the declared

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observation bandwidth. The input-equivalent third-order product level is $3p-2I$. Set that level equal to N and solve for the permitted per-tone level; subtracting N then gives the stated planning range.

Derived form of Equation 22. Equal-tone cubic intersection with the declared noise floor

$$p_{\mathrm{IM3}}=3p-2I,\ p_{\max}=\frac{N+2I}{3},\ p_{\max}-N=\frac{2}{3}(I-N)$$

For the hypothetical values $I=-20\ \mathrm{dBm}$ and $N=-125\ \mathrm{dBm}$, the intersection is $p=-55\ \mathrm{dBm}$ per tone and the difference is 70 dB. The calculation is useful only if the cubic law remains adequate up to that level, the required signal and product bandwidths and planes agree, and compression, phase noise, other spurs, and the desired decision margin do not impose a tighter limit. A nonpositive range, or an intersection outside the characterized cubic interval, supplies no usable operating claim.

Table 1. Chapter 11 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Compression	Input level, gain, output, total power, attenuation state, and recovery	Identifies departure from linear response	Errors can begin before the nominal 1 dB point
Intermodulation	Parent frequencies, levels, spacing, source purity, products, and level slope	Tests nonlinear product generation	The test source or combiner can create the same products

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Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Blocking	Desired reference, blocker level and offset, modulation, sensitivity change, and AGC state	Measures strong-signal desensitization	The blocker may be outside the displayed span
Reciprocal mixing	LO phase noise, blocker offset, floor rise, tuning plan, and preselection	Explains close-in noise elevation	Can resemble environmental noise or dense weak signals

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11.43 Hypothetical Applied Calculation: Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization

Two equal input tones at -45 dBm each produce fundamentals at -20 dBm and third-order products at -70 dBm. The 50 dB output separation gives an estimated IIP3 of -20 dBm. If the input-referred noise floor is -125 dBm in the measurement bandwidth, the simplified third-order SFDR estimate is about 70 dB.

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11.44 Hypothetical Case Adjudication: Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization

A receiver appears unable to detect a calibrated -110 dBm reference near 450 MHz at a city site. A 100 kW broadcast transmitter at a much lower frequency is outside the displayed span but drives the broadband preamplifier. Removing the preamplifier and inserting a high-pass filter restores detection. The failed search configuration is documented as desensitized.

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11.45 Memory-dependent intermodulation and the limits of static intercept-point inference

A familiar two-tone third-order-intercept model describes a bounded small-signal region of a nonlinear device. It should not be converted into a universal prediction for an antenna-connected receiver whose gain control, bias conditions and protection network have memory. A memoryless cubic relation $y(t) = a_1 x(t) + a_3 x(t)^3$ can explain third-order products near $2f_1 - f_2$ and $2f_2 - f_1$ for two inputs, but the coefficients may depend on drive level, frequency, temperature and history. More elaborate models require convolution or state variables because a carrier arriving immediately after a strong blocker may experience different gain than the same carrier arriving in a settled state. A high intercept figure measured on a static two-tone laboratory fixture cannot certify transient detection performance under arbitrary pulsed interferers.

For a hypothetical two-tone equal-level test, suppose the fundamental output increases by 1 dB when each input rises by 1 dB, while a third-order product rises by 3 dB over the demonstrated local region. If the measured fundamental exceeds its extrapolated third-order product by 42 dB at a given input level, then a straight-line output intercept estimate lies 21 dB above that input level in the same coordinate convention. This is an extrapolation of two local slopes, not proof that hardware can physically accept that much power without compression or damage. If a bias loop changes between steps, the slope is not the one stipulated by the elementary construction. The report should retain the input levels,

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measured slopes, uncertainties and conditions that justify using that straight-line model.

A more discriminating experiment varies tone separation and stimulus order. Certain bias and thermal effects become apparent when the tones are moved or the duty factor changes while their total mean power is kept nominally fixed. Record whether the product appears at the external reference plane, within a combiner, after a gain stage or only after downstream sampling and processing. A simple input attenuation test can offer evidence about location but is not conclusive when the attenuator simultaneously changes automatic gain state. A suitable reference measurement independently bounds source harmonics and combiner intermodulation. Without that control the receiver may be blamed for products already generated in the test apparatus, thereby producing a reproducible but incorrect system diagnosis.

Report compression, blocking, desensitisation, reciprocal mixing and discrete intermodulation as different outcomes. Compression concerns changed transfer for the desired signal; blocking can reduce gain or operation even without a new spectral line; reciprocal mixing can raise local noise; intermodulation can produce discrete frequencies. One event may induce several concurrently. A forensic record should include the affected weak-reference response and its recovery interval, rather than merely counting visible products. This is especially important when the questioned phenomenon is intermittent and the system's recovery behaviour determines whether the next emission could have been observed at all.

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11.46 Advanced technical expansion. Memory-dependent nonlinearities and multicarrier stress

A receiver's large-signal response cannot always be described by a single third-order intercept point. Input intercept and output intercept are useful approximations for a bounded two-tone test conducted in a small enough region that the corresponding polynomial terms dominate. Under operational multicarrier exposure, amplifier bias, thermal feedback, automatic control and memory in filters or protection elements may change the response dynamically. An architecture can pass a continuous-wave two-tone test yet produce transient desensitisation or spectral regrowth when subjected to a high-crest-factor waveform. The appropriate model begins by defining the waveforms, their instantaneous amplitude distribution and the operating states of all vulnerable elements. It is not enough to add average powers and assume that the sum defines the worst instantaneous condition.

A memoryless polynomial model $y = a_1x + a_3x^3$ can identify the frequencies of some third-order products, but a Volterra-type representation allows output at one time to depend on combinations of earlier inputs. Such models are powerful precisely because they distinguish instantaneous amplitude from waveform history. Their coefficients cannot be inferred from a single intercept figure, and their use must be limited by the experiments that identify them. If a device under test has a gain-control loop, bias network or thermal time constant, a long burst and a short burst with equal peak level can have different distortion and recovery behaviour. The examiner must therefore preserve burst duration and duty factor as

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independent test dimensions. Results obtained at one temperature or repetition rate are conditional, not blanket device ratings.

The crest factor of a waveform is the ratio of its peak magnitude to its RMS magnitude under an explicitly stated averaging interval. A 12-dB peak-to-average power ratio corresponds to a peak power approximately 15.85 times the average. Thus a multicarrier signal with mean power -20 dBm can, under that stipulated ratio, reach a peak power near -8 dBm even before gain changes are considered. These values do not prove compression in a particular amplifier. They demonstrate why the stage-level peak must be compared with an experimentally supported input envelope rather than an attractive average-power budget. A limiter may respond to peaks, while a slowly adapting AGC responds to a different statistic and timescale. Their combined behaviour can create a weak-event blind interval extending beyond the duration of the principal blocker.

Reciprocal mixing adds another dependency. Phase noise around an oscillator can mix the energy of a strong blocker into the weak desired channel, even though a narrow final display excludes the blocker itself. A prediction based on phase-noise density requires the blocker power at the relevant conversion plane, oscillator spectrum under the actual state, and the filter weighting of the desired channel. Integrating phase-noise density over an offset band yields different results from using its value at one representative offset. A broad blocker whose own modulation creates in-band sidebands requires an additional source-path noise measurement, or a reciprocal-mixing conclusion may be confounded by the blocker source's actual spectrum. Changing LO conditions while maintaining comparable wanted-signal sensitivity is a useful discriminating experiment.

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The most informative acceptance protocol combines a calibrated weak reference with one or more controlled blockers. It first measures the quiet weak-reference response and noise; it then introduces blockers one at a time, followed by combined conditions, while retaining raw IF or complex samples and all gain states. Measure compression, intermodulation, noise-floor displacement, recovery duration and false detections as separate outputs. Repeat with the front-end attenuation and preselection changes that the competing hypotheses predict should matter. If the weak reference vanishes because a changed filter rejected it, the trial does not demonstrate improved blocking immunity. If a nonlinear line disappears only after a generator combiner is changed, the observed mechanism may not be in the receiver at all. A valid operating envelope must follow the physical paths and actual experimental controls, not merely the most favourable trace.

A resulting survey report should distinguish a measured blocker response from an extrapolation to unknown environmental signals. State the source levels, modulation, crest factor, temperature, reference plane, receiver path and tested duration range. Explain which waveform families were challenged and which remain outside the accepted envelope. A gain-corrected display that returns to its initial level does not establish that all intermediate samples were valid. Preserve bad intervals, overload indicators and subsequent closing checks. This produces a useful technical conclusion even when a receiver architecture is found to be unsuitable for a particular strong-signal environment: the constraint is established, bounded and reproducible rather than hidden inside a nominal dynamic-range specification.

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11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture

Simultaneous wideband acquisition exposes a receiver to an unusually large set of possible blockers. The required input protection depends on the power which reaches each vulnerable stage, not on the amplitude of a narrow detected line after GPU channelisation. Forty gigahertz of nominal coverage can be partitioned into many independently preselected slices, but each slice must have measured rejection outside its intended passband and sufficient headroom for the local electromagnetic environment. A high-gain front end chosen only to reach minus-170-dBm/Hz noise density may be driven into compression by an unrelated broadcast or radar signal. Once a mixer, amplifier or ADC clips, no subsequent fine-resolution FFT can restore the lost weak signal, even though the resulting software spectrum may look remarkably clean.

The aggregate spectral display also has a correlated-error problem. A common clock harmonic may create apparent emissions in many slices. A spur from an FPGA lane or power supply may repeat at regular frequency offsets. Frequency translation can mirror an unwanted tone into a nominally empty band. When two independent antennas reveal the same feature, the conclusion is stronger only if they also change relevant system-error paths. A useful acceptance test injects a deliberately placed weak reference near a strong blocker and verifies its recovery while varying input attenuation, preselection and conversion state. The experiment should measure not only recovered tone amplitude but also spectral products, noise-floor elevation, missed bursts and recovery time.

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The fundamental objective is a map of valid operating conditions. At every frequency slice and gain state, document the maximum admitted signal envelope, noise density, measured spurious-free dynamic range, conversion image rejection, timing coherence and frequency-dependent calibration uncertainty. A low-level signal that is measurable in a quiet terminated-input test may be unmeasurable during a strong event. The valid finding should therefore specify frequency, observation time, event class and interference envelope instead of expressing dynamic range as a single catalogue number. That approach makes the forty-gigahertz design technically testable and enables engineering decisions about front-end allocation, isolation, attenuator placement and whether additional analogue preselection is needed.

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Chapter Summary

Receiver capability is determined by noise and strong-signal behavior together. Compression, intermodulation, blocking, reciprocal mixing, and recovery tests define whether a weak observation is credible in the actual environment.

Model 11A starts from loaded voltages and a fixed memoryless cubic law. It distinguishes per-tone powers, unequal products, reference resistances and linear-asymptote intercepts. Measured fundamentals can carry a finite correction, and a small observed product can hide coherent contamination. The resulting spurious-free-range estimate remains conditional on the same local model and noise definition.

Model 11B instead integrates translated oscillator phase noise through the actual observation-channel weighting. Admitted blocker power, signed offset, gain and baseline remain explicit. Power subtraction, deterministic bounds and omitted-term analysis preserve their different assumptions. A flat-density shortcut or a small total phase variance does not automatically justify a precise narrow-channel result.

Useful challenges retain a controlled weak reference while changing a predicted cause. Recheck desired transfer and receiver state when adding attenuation, preselection or retuning. Characterize recovery as an observation exclusion where needed. The acceptance matrix records the tested configurations and limitations, allowing later findings to remain within demonstrated capability rather than a generic dynamic-range label.

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Chapter 11 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C11-MCQ-001. Why cannot one catalog dynamic-range number establish survey capability?

A. Display range always equals usable weak-signal range

B. Digitizer range automatically determines analog blocking

C. Different definitions use different limits, bandwidths, spacings, detectors, and tests

D. The largest quoted number includes every strong-signal mechanism

Answer: C. The relevant capability is configuration- and signal-condition-specific.

Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

Why the selected alternative fits: Different definitions use different limits, bandwidths, spacings, detectors, and tests.

Distinguishing consideration: compare this with option A, “Display range always equals usable weak-signal range”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Dynamic Range Is a Family of Conditions.

Review: Chapter 11 — Dynamic Range Is a Family of Conditions.

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V011-C11-MCQ-002. What is the practical strong-signal question for a receiver?

A. Whether the display can draw a large amplitude interval

B. Whether a catalog intercept exceeds the nominal input level

C. Whether a specified weak signal can be detected or measured with stated stronger signals present

D. Whether one bench sensitivity value is numerically small

Answer: C. The required weak observation, environment, and receiver state define the useful test. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

Why the selected alternative fits: Whether a specified weak signal can be detected or measured with stated stronger signals present.

Distinguishing consideration: compare this with option A, “Whether the display can draw a large amplitude interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Dynamic Range Is a Family of Conditions.

Review: Chapter 11 — Dynamic Range Is a Family of Conditions.

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V011-C11-MCQ-003. Why retain an independent weak probe while varying a blocker?

A. The probe makes all receiver stages linear

B. The blocker alone uniquely measures every detection threshold

C. A weak probe guarantees unchanged AGC state

D. The blocker output can remain plausible while weak-signal capability degrades

Answer: D. Controlled desired-signal response reveals loss of the capability the blocker can obscure. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

Why the selected alternative fits: The blocker output can remain plausible while weak-signal capability degrades.

Distinguishing consideration: compare this with option A, “The probe makes all receiver stages linear”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Measure compression without confusing it with control action.

Review: Chapter 11 — Measure compression without confusing it with control action.

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V011-C11-MCQ-004. An AGC state changes during an input sweep. What does the resulting curve describe?

A. Only the calibrated source output

B. A pure fixed-coefficient compression curve by definition

C. Closed-loop receiver behavior rather than a fixed-state stage transfer alone

D. A universal intercept independent of control state

Answer: C. State changes can alter gain separately from fixed-stage compression and must be labeled. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

Why the selected alternative fits: Closed-loop receiver behavior rather than a fixed-state stage transfer alone.

Distinguishing consideration: compare this with option A, “Only the calibrated source output”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Measure compression without confusing it with control action.

Review: Chapter 11 — Measure compression without confusing it with control action.

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V011-C11-MCQ-005. After a strong pulse, what determines the recovery exclusion for a weak observation?

A. A universal one-pole constant for every receiver

B. When the controlled weak probe again meets its stated criterion under the tested prior state

C. The time at which the strong pulse's screen trace disappears alone

D. The nominal sweep duration regardless of gain recovery

Answer: B. Recovery is mechanism- and state-dependent; invalid intervals bound usable observation. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

Why the selected alternative fits: When the controlled weak probe again meets its stated criterion under the tested prior state.

Distinguishing consideration: compare this with option A, “A universal one-pole constant for every receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Measure compression without confusing it with control action.

Review: Chapter 11 — Measure compression without confusing it with control action.

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V011-C11-MCQ-006. Can a blocker outside the displayed span reduce weak in-span sensitivity?

A. Yes, it can stress earlier stages or control behavior

B. No, the final display span physically rejects it at the antenna

C. Only when the receiver has no preamplifier

D. Only if its carrier appears in the final RBW

Answer: A. Final span does not define all energy admitted to earlier stages. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

Why the selected alternative fits: Yes, it can stress earlier stages or control behavior.

Distinguishing consideration: compare this with option B, “No, the final display span physically rejects it at the antenna”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Blocking and Reciprocal Mixing.

Review: Chapter 11 — Blocking and Reciprocal Mixing.

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V011-C11-MCQ-007. Why define the model's input amplitudes at the loaded reference plane?

A. Peak voltage can be used as RMS without conversion

B. A generator's open-circuit voltage always equals the load voltage

C. Loaded and available powers agree for every mismatch

D. Delivered voltage and resistance determine power; open-circuit settings need not equal them

Answer: D. The matched condition permits available and delivered powers to coincide; otherwise establish the actual loaded quantity. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why the selected alternative fits: Delivered voltage and resistance determine power; open-circuit settings need not equal them.

Distinguishing consideration: compare this with option A, “Peak voltage can be used as RMS without conversion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-MCQ-008. Does the declared odd cubic law predict second-order sum and difference products?

A. Only if the two input powers are equal

B. Yes; every cubic coefficient automatically includes a square term

C. No; those require an omitted term or another mechanism

D. Yes; every observed product validates the odd-only restriction

Answer: C. The restriction is mathematical, not a claim that actual hardware lacks even-order behavior. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why the selected alternative fits: No; those require an omitted term or another mechanism.

Distinguishing consideration: compare this with option A, “Only if the two input powers are equal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-MCQ-009. What are the units of the cubic voltage coefficient a_3?

A. Watts

B. Inverse square volts

C. Dimensionless power gain

D. Volts squared

Answer: B. Multiplying a_3 by voltage cubed must yield output voltage. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why the selected alternative fits: Inverse square volts.

Distinguishing consideration: compare this with option A, “Watts”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-MCQ-010. For voltage gain a1, what is the small-signal power gain with loaded resistances R_i and R_o?

A. a1 squared for all impedance choices

B. a1 divided by two

C. a1 times R_o divided by R_i

D. a1 squared times R_i divided by R_o

Answer: D. Power conversion includes both reference resistances; equal-resistance simplification is conditional. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why the selected alternative fits: a1 squared times divided by.

Distinguishing consideration: compare this with option A, “a1 squared for all impedance choices”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-MCQ-011. What information is lost when a signed intermodulation coefficient is converted to power?

A. Its sign or referenced phase

B. The chosen product frequency label

C. Its magnitude squared

D. The output resistance used for conversion

Answer: A. Power-only data cannot distinguish opposite cubic coefficient signs with equal magnitude. Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why the selected alternative fits: Its sign or referenced phase.

Distinguishing consideration: compare this with option B, “The chosen product frequency label”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-MCQ-012. What does the declared five-percent fundamental-correction bound establish?

A. A small retained cubic correction on the positive-gain branch

B. Measured validity of a physical receiver at all levels

C. A complete noise and blocker immunity specification

D. A bound on every omitted higher-order term

Answer: A. The local working condition does not validate omitted physics or changing state. Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why the selected alternative fits: A small retained cubic correction on the positive-gain branch.

Distinguishing consideration: compare this with option B, “Measured validity of a physical receiver at all levels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-MCQ-013. Which input combination governs the lower close-in product's voltage magnitude in the model?

A. First-tone peak squared times second-tone peak

B. The average of the two tone powers only

C. The sum of the two peak voltages only

D. First-tone peak times second-tone peak squared

Answer: A. The coefficient at twice f1 minus f2 contains A1 squared times A2.

Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why the selected alternative fits: First-tone peak squared times second-tone peak.

Distinguishing consideration: compare this with option B, “The average of the two tone powers only”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-MCQ-014. Increasing only the first parent power by 2 dB produces what product-power changes in the valid fixed cubic model?

A. Lower product plus 2 dB and upper product plus 4 dB

B. Both products plus 2 dB

C. Lower product plus 4 dB and upper product plus 2 dB

D. Both products plus 6 dB

Answer: C. The unequal-tone laws contain P1 squared P2 and P1 P2 squared, respectively. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: Lower product plus 4 dB and upper product plus 2 dB.

Distinguishing consideration: compare this with option A, “Lower product plus 2 dB and upper product plus 4 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-MCQ-015. Can equal observed product powers determine the sign of a_3?

A. Yes; equal powers require negative a_3

B. No; power discards the signed coefficient

C. Only if input powers are equal, regardless of phase evidence

D. Yes; equal powers require positive a_3

Answer: B. Fundamental gain change or appropriately referenced phase is needed to distinguish the constructed signs. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: No; power discards the signed coefficient.

Distinguishing consideration: compare this with option A, "Yes; equal powers require negative"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-016. How is the third-order intercept defined?

A. An intersection of extrapolated linear-fundamental and cubic-product terms

B. The noise floor at zero input

C. The point where all higher orders vanish

D. The actual input where the device must be operated until both outputs match

Answer: A. Driving to the formal intersection leaves the small-correction domain and may invoke other mechanisms. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: An intersection of extrapolated linear-fundamental and cubic-product terms.

Distinguishing consideration: compare this with option B, “The noise floor at zero input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-MCQ-017. Which fundamental level belongs in the exact asymptotic extraction?

A. The total of both parent output powers

B. An arbitrary compressed fundamental without accounting for its correction

C. The fitted linear-asymptote output level

D. The largest spur level in the display

Answer: C. Finite cubic correction biases an extraction that substitutes the measured fundamental for its linear asymptote. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: The fitted linear-asymptote output level.

Distinguishing consideration: compare this with option A, “The total of both parent output powers”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-MCQ-018. If the measured fundamental differs from its linear asymptote by delta g dB, what bias enters the input-intercept estimate using that one value?

A. Twice delta g

B. All of delta g

C. One half of delta g

D. Three halves of delta g

Answer: C. Input extraction contains one half of the fundamental-to-product level difference. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: One half of delta g.

Distinguishing consideration: compare this with option A, “Twice delta g”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-MCQ-019. If that measured value is used in the output-intercept formula, what is the resulting gain-change bias?

A. Zero for every gain change

B. Three halves of delta g

C. Minus all of delta g

D. One half of delta g

Answer: B. The output formula gives the fundamental level coefficient three halves.

Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: Three halves of delta g.

Distinguishing consideration: compare this with option A, “Zero for every gain change”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-MCQ-020. Why must equal-tone input power remain per tone in the intercept calculation?

A. Total and per-tone powers are identical in dBm

B. Using the total of both tones adds an inappropriate 3.0103 dB

C. Averaging dBm levels always gives summed watts

D. The total power is always lower than one tone's power

Answer: B. The separation formula is derived for one parent and its associated product. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: Using the total of both tones adds an inappropriate 3.0103 dB.

Distinguishing consideration: compare this with option A, “Total and per-tone powers are identical in dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-MCQ-021. Equal per-tone input is minus 25 dBm, linear output minus 5 dBm, and one product minus 65 dBm. What is IIP3?

A. 8.0103 dBm

B. 25 dBm

C. Minus 5 dBm

D. 5 dBm

Answer: D. Input plus half the 60 dB separation is -25+30 = 5 dBm. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: 5 dBm.

Distinguishing consideration: compare this with option A, “8.0103 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-022. For that same fully specified case, what is OIP3?

A. Minus 25 dBm

B. 25 dBm

C. 28.0103 dBm

D. 5 dBm

Answer: B. The linear output level plus half its separation from the product is -5+30 = 25 dBm. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: 25 dBm.

Distinguishing consideration: compare this with option A, “Minus 25 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-023. At f1 = 100 MHz and f2 = 101 MHz, where are the close-in third-order products?

A. 300 and 303 MHz

B. 99 and 102 MHz

C. 201 and 1 MHz

D. 100 and 101 MHz

Answer: B. Twice each parent minus the other gives the two close-in locations; third harmonics are different terms. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: 99 and 102 MHz.

Distinguishing consideration: compare this with option A, “300 and 303 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-024. Increasing only f1 by 0.20 MHz moves the lower and upper products how?

A. Lower minus 0.20 MHz, upper plus 0.40 MHz

B. Neither changes if amplitudes are fixed

C. Lower plus 0.40 MHz, upper minus 0.20 MHz

D. Both plus 0.20 MHz

Answer: C. The frequency expressions give coefficients two and minus one for changes of f1. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: Lower plus 0.40 MHz, upper minus 0.20 MHz.

Distinguishing consideration: compare this with option A, “Lower minus 0.20 MHz, upper plus 0.40 MHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-025. Does matching product movement identify the generating component uniquely?

A. No; it is compatible with the parent-product relation but does not locate the stage

B. Yes; it proves the ADC generated the product

C. Yes; it proves the product is environmental

D. Only when both tones have equal power, irrespective of the path

Answer: A. Location needs separate controlled path evidence and comparable detection conditions. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: No; it is compatible with the parent-product relation but does not locate the stage.

Distinguishing consideration: compare this with option B, "Yes; it proves the ADC generated the product"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-026. With unequal parents, why is replacing both by their average unsafe?

A. The smaller tone contributes nothing to either product

B. Unequal inputs cannot generate close-in products

C. It erases the predicted unequal product amplitudes

D. Both products depend only on total input power

Answer: C. The two cubic products weight the parent powers differently. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: It erases the predicted unequal product amplitudes.

Distinguishing consideration: compare this with option A, “The smaller tone contributes nothing to either product”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-027. For a1 = 10, R_i = 50 ohms, and R_o = 200 ohms, what is power gain?

A. 25, about 13.98 dB

B. 400, about 26.02 dB

C. 100, exactly 20 dB

D. 10, exactly 10 dB

Answer: A. The resistance ratio is one quarter, so a1 squared times $\frac{R_i}{R_o}$ is 25. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: 25, about 13.98 dB.

Distinguishing consideration: compare this with option B, “400, about 26.02 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-028. Both parent powers fall 6 dB within the same cubic regime. How much does a product power fall?

A. 18 dB

B. 12 dB

C. 36 dB

D. 6 dB

Answer: A. Equal-tone product power is cubic in each common input-power scale.

Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: 18 dB.

Distinguishing consideration: compare this with option B, “12 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-029. A product instead falls only 12 dB during that controlled 6 dB parent reduction. What follows?

A. The lower product reading proves improved linearity at every level

B. The original intercept remains exact by definition

C. The source of the discrepancy is uniquely identified as AGC

D. The exact fixed cubic-only description does not fit both observations

Answer: D. A slope mismatch identifies a model departure without selecting its cause. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: The exact fixed cubic-only description does not fit both observations.

Distinguishing consideration: compare this with option A, “The lower product reading proves improved linearity at every level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-030. How does ideal matched output attenuation affect input-referred IIP3 in the stated model?

A. It lowers IIP3 by three times the attenuation

B. It leaves IIP3 unchanged while lowering OIP3

C. It raises IIP3 by the attenuation in every case

D. It removes all cubic distortion

Answer: B. Output attenuation scales generated fundamental and product equally.

Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: It leaves IIP3 unchanged while lowering OIP3.

Distinguishing consideration: compare this with option A, “It lowers IIP3 by three times the attenuation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-031. How does 10 dB ideal matched input attenuation change cubic product power compared with the same loss after the stage for unchanged external parents?

A. Both reduce the product 10 dB

B. Pre-attenuation reduces it 10 dB; post-attenuation reduces it 30 dB

C. Both reduce the product 30 dB

D. Pre-attenuation reduces the product 30 dB; post-attenuation reduces it 10 dB

Answer: D. The drive reduction acts cubically before generation, while a later loss scales the already generated signal. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: Pre-attenuation reduces the product 30 dB; post-attenuation reduces it 10 dB.

Distinguishing consideration: compare this with option A, “Both reduce the product 10 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-032. Why is that pre-attenuation calculation not an unconditional sensitivity improvement?

A. Input attenuation necessarily improves every weak-signal result

B. The input-referred intercept is the only required metric

C. The desired signal is unaffected by matched attenuation

D. It omits noise, mismatch, attenuator distortion, and control-state consequences

Answer: D. Linearity benefit and usable weak-signal performance need a complete chain comparison. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: It omits noise, mismatch, attenuator distortion, and control-state consequences.

Distinguishing consideration: compare this with option A, “Input attenuation necessarily improves every weak-signal result”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-033. What is the status of the model's formal one-decibel compression calculation?

A. A proof that all higher-order terms are negligible

B. A recommended operating input level

C. An extrapolation outside its declared five-percent working bound

D. A certified receiver compression specification

Answer: C. The formal correction is about 10.875 percent, exceeding the local working restriction. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: An extrapolation outside its declared five-percent working bound.

Distinguishing consideration: compare this with option A, “A proof that all higher-order terms are negligible”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-034. Why does common output calibration offset cancel from IIP3 but not OIP3?

A. Only input power has units, so output offsets cannot matter

B. A common offset always doubles in IIP3

C. Both formulas discard all output calibration automatically

D. IIP3 uses the q-minus-s difference; OIP3 retains one net copy of the offset

Answer: D. The result depends on a demonstrated shared error, not two merely similar uncertainty labels. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: IIP3 uses the q-minus-s difference; OIP3 retains one net copy of the offset.

Distinguishing consideration: compare this with option A, “Only input power has units, so output offsets cannot matter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-035. A coherent contaminant bound equals the measured spur magnitude. What happens to an upper intercept bound under this observation model?

A. The contaminant power may simply be subtracted as independent noise

B. No finite upper bound follows because arbitrarily small positive stage products remain possible

C. The intercept is exactly zero dBm

D. The measured spur becomes an exact stage-power estimate

Answer: B. The phasor enclosure reaches zero; the nonzero cubic coefficient does not provide a positive measured lower magnitude. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: No finite upper bound follows because arbitrarily small positive stage products remain possible.

Distinguishing consideration: compare this with option A, “The contaminant power may simply be subtracted as independent noise”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-036. Which mechanism can raise apparent channel noise around a strong blocker without discrete cubic products?

A. Only the ideal quantizer bit count

B. Only a wider display amplitude range

C. Only third-harmonic generation

D. Reciprocal mixing through oscillator phase noise

Answer: D. The blocker translates oscillator phase fluctuations into the observation channel. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

Why the selected alternative fits: Reciprocal mixing through oscillator phase noise.

Distinguishing consideration: compare this with option A, “Only the ideal quantizer bit count”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Blocking and Reciprocal Mixing.

Review: Chapter 11 — Blocking and Reciprocal Mixing.

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V011-C11-MCQ-037. What does blocker power in Model 11B refer to?

A. The final displayed carrier level regardless of gain

B. Power at the mixer input after preceding gain and selection

C. Always the signal generator's setting

D. Always the antenna-connector power without correction

Answer: B. The admitted power and its plane are essential to the generated-noise prediction. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

Why the selected alternative fits: Power at the mixer input after preceding gain and selection.

Distinguishing consideration: compare this with option A, “The final displayed carrier level regardless of gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Translate one blocker through the fluctuating oscillator.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-MCQ-038. Why is the two-sided phase density not doubled again in the reciprocal-mixing integral?

A. The phase process is complex rather than real

B. The observation filter automatically halves all powers

C. Every two-sided density contains no negative frequencies

D. At positive offset it already equals the declared single-sideband density

Answer: D. The one-sided phase density is twice this value; another factor of two would double-count under the defined convention. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why the selected alternative fits: At positive offset it already equals the declared single-sideband density.

Distinguishing consideration: compare this with option A, “The phase process is complex rather than real”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-MCQ-039. What stationarity suffices for the retained linear phase-noise spectrum?

A. No second-order stationarity or finite variance

B. Zero-mean wide-sense stationarity with finite variance

C. Only a deterministic sinusoid with no noise

D. Strict stationarity with Gaussian marginals is always necessary at this first step

Answer: B. The stronger nonlinear-remainder conditions are separate from the retained second-order spectrum. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why the selected alternative fits: Zero-mean wide-sense stationarity with finite variance.

Distinguishing consideration: compare this with option A, “No second-order stationarity or finite variance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-MCQ-040. How should dBc/Hz values enter a weighted power-density integral?

A. Average the logarithmic labels without bandwidth weights

B. Convert each to its linear inverse-hertz density first

C. Add the dBc/Hz numbers directly across frequency

D. Treat each dBc/Hz label as a discrete line power

Answer: B. The integral sums linear density times bandwidth weighting; logarithmic labels cannot be integrated as powers directly. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why the selected alternative fits: Convert each to its linear inverse-hertz density first.

Distinguishing consideration: compare this with option A, “Average the logarithmic labels without bandwidth weights”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-MCQ-041. How should a discrete oscillator phase spur be handled?

A. As a density value multiplied by arbitrary one-hertz bins

B. As zero because the ordinary-density model excludes it

C. By averaging its dBc label with the continuous floor

D. As a spectral line with its own integrated power contribution

Answer: D. A line and an ordinary density have different representations; the defined density assumption does not erase spurs. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why the selected alternative fits: As a spectral line with its own integrated power contribution.

Distinguishing consideration: compare this with option A, “As a density value multiplied by arbitrary one-hertz bins”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-MCQ-042. Which phase-spectrum extension is inadmissible in the stated finite-variance model?

A. Extending a divergent close-in law to zero or infinity without a valid continuation

B. Using an even real-phase density over the specified offsets

C. Integrating a finite admitted offset band

D. Bounding omitted filter-tail contributions

Answer: A. A density whose integral diverges contradicts the assumed finite phase variance. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why the selected alternative fits: Extending a divergent close-in law to zero or infinity without a valid continuation.

Distinguishing consideration: compare this with option B, “Using an even real-phase density over the specified offsets”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-MCQ-043. What translates the oscillator phase spectrum to a blocker's neighborhood?

A. The logarithmic display axis

B. Multiplication by the blocker carrier exponential

C. The nominal RBW label alone

D. A universal additive broadband source independent of blocker power

Answer: B. Frequency translation and blocker amplitude scaling produce the retained perturbation spectrum. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

Why the selected alternative fits: Multiplication by the blocker carrier exponential.

Distinguishing consideration: compare this with option A, “The logarithmic display axis”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Translate one blocker through the fluctuating oscillator.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-MCQ-044. Which contribution remains separate from the reciprocal-mixing calculation?

A. The retained phase-noise sidebands

B. Direct leakage of the nominal blocker carrier

C. The admitted blocker level used in the model

D. The specified observation-channel weighting

Answer: B. Carrier leakage must be negligible or independently characterized; the perturbation model does not predict it. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

Why the selected alternative fits: Direct leakage of the nominal blocker carrier.

Distinguishing consideration: compare this with option A, “The retained phase-noise sidebands”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Translate one blocker through the fluctuating oscillator.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-MCQ-045. What is the observation filter's power weighting W?

A. Its nominal bandwidth label

B. Its complex phase alone

C. Squared magnitude of its complex response

D. Its voltage response without squaring

Answer: C. The integrated power uses the actual squared response and the stated normalization. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why the selected alternative fits: Squared magnitude of its complex response.

Distinguishing consideration: compare this with option A, “Its nominal bandwidth label”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-MCQ-046. Why require the center response to equal one in this model?

A. To make every filter's bandwidth one hertz

B. To force all phase noise to be white

C. To guarantee the blocker carrier is removed

D. To define gain and input-equivalent power consistently

Answer: D. The desired-center normalization separates a fixed gain from channel weighting. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why the selected alternative fits: To define gain and input-equivalent power consistently.

Distinguishing consideration: compare this with option A, “To make every filter's bandwidth one hertz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-MCQ-047. When is using only center-offset phase-noise density exact?

A. Whenever the RBW label is available

B. When the density is flat over all significantly weighted offsets

C. Whenever the blocker is one megahertz away

D. Whenever a log plot looks smooth

Answer: B. Otherwise the shortcut needs a justified approximation or spectral bounds over the weighted region. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why the selected alternative fits: When the density is flat over all significantly weighted offsets.

Distinguishing consideration: compare this with option A, “Whenever the RBW label is available”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-MCQ-048. Does equal blocker separation above and below the center guarantee equal added noise?

A. No, an asymmetric observation filter can weight different offsets

B. Only the sign of the receiver gain determines the answer

C. Yes, even phase density makes every signed translation identical

D. Yes, because only absolute blocker frequency matters

Answer: A. Even phase spectrum does not remove signed-offset effects relative to asymmetric W. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: No, an asymmetric observation filter can weight different offsets.

Distinguishing consideration: compare this with option B, “Only the sign of the receiver gain determines the answer”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-049. What filter quantity replaces a nominal width in the flat-density added-noise expression?

A. Equivalent noise bandwidth from the integral of W

B. Only the 3 dB width for every implementation

C. The number of output channels

D. The entire RF tuning range

Answer: A. Actual area under the power weighting determines admitted flat-density noise. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why the selected alternative fits: Equivalent noise bandwidth from the integral of W.

Distinguishing consideration: compare this with option B, “Only the 3 dB width for every implementation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-MCQ-050. A filter has unit power weight over 100 kHz and weight 0.1 over another total 100 kHz. What is its equivalent noise bandwidth?

A. 110 kHz

B. 200 kHz

C. 10 kHz

D. 100 kHz

Answer: A. The weighted area is 100 plus 0.1 times 100 kHz. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: 110 kHz.

Distinguishing consideration: compare this with option B, “200 kHz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-051. Under the flat-density model, blocker level is minus 30 dBm, density minus 140 dBc/Hz, and bandwidth 200 kHz. What added level follows?

A. Minus 170 dBm

B. Minus 110 dBm

C. About minus 116.99 dBm

D. About minus 113.98 dBm

Answer: C. Add the blocker, density, and 53.0103 dB bandwidth term without an extra sideband factor. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: About minus 116.99 dBm.

Distinguishing consideration: compare this with option A, “Minus 170 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-052. Which ratio controls externally referred reciprocal noise relative to a narrow desired signal?

A. Blocker transfer divided by desired transfer

B. Desired transfer divided by blocker transfer

C. The product of the two transfers without referral

D. Blocker transfer alone

Answer: A. The mixer contribution must be divided by desired transfer to refer it to the external desired-input plane. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: Blocker transfer divided by desired transfer.

Distinguishing consideration: compare this with option B, “Desired transfer divided by blocker transfer”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-053. Blocker loss is 25 dB and desired loss is 2 dB. What differential rejection enters that reference comparison?

A. 2 dB

B. 27 dB

C. 25 dB

D. 23 dB

Answer: D. The blocker-to-desired power-transfer ratio contains the difference of losses. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: 23 dB.

Distinguishing consideration: compare this with option A, “2 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-054. Why is one center-frequency desired transfer insufficient for a broad waveform?

A. Broad signals have no input reference plane

B. The desired loss is always frequency-independent

C. A broad waveform automatically removes phase-noise contributions

D. Its frequency-dependent signal weighting may matter

Answer: D. The scalar referral is valid for a narrow signal or a justified constant-transfer approximation. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: Its frequency-dependent signal weighting may matter.

Distinguishing consideration: compare this with option A, “Broad signals have no input reference plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-055. May several blocker contributions be power-summed merely because they share one LO?

A. Only if all blockers have equal power, regardless of phase

B. Yes; distinct carriers never have cross terms

C. No; admitted cross powers must vanish under a justified ensemble or averaging

D. Yes; a common LO ensures independence

Answer: C. Shared phase processes do not establish uncorrelated contributions; coherent cases can require field addition. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: No; admitted cross powers must vanish under a justified ensemble or averaging.

Distinguishing consideration: compare this with option A, “Only if all blockers have equal power, regardless of phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-056. What condition allows baseline and added reciprocal-noise powers to add in the rise formula?

A. The blocker is outside the displayed span

B. Zero cross power with unchanged gain and weighting

C. The baseline is expressed in dBm

D. The total noise image is visually smooth

Answer: B. The formula is conditional on compatible quantities and an uncorrelated-power decomposition. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why the selected alternative fits: Zero cross power with unchanged gain and weighting.

Distinguishing consideration: compare this with option A, “The blocker is outside the displayed span”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-MCQ-057. If added power equals half the positive baseline, what is total noise rise?

A. Minus 3.010 dB

B. 0.5 dB

C. About 1.761 dB

D. 3.010 dB

Answer: C. The total-to-baseline ratio is 1.5, whose ten-times logarithm is about 1.761 dB. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why the selected alternative fits: About 1.761 dB.

Distinguishing consideration: compare this with option A, “Minus 3.010 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-MCQ-058. For a one-decibel rise limit, the permitted added power is approximately what fraction of baseline?

A. 0.1

B. 1

C. 0.2589

D. 1.2589

Answer: C. The allowance is ten to 0.1 minus one, not the total ratio itself. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why the selected alternative fits: 0.2589.

Distinguishing consideration: compare this with option A, “0.1”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-MCQ-059. Why can the same added watts give a smaller rise in a noisier receiver?

A. The added-to-baseline ratio is smaller

B. The noise-rise formula ignores baseline

C. Added power becomes negative in a noisy receiver

D. The higher baseline improves weak-signal detectability automatically

Answer: A. A smaller relative rise need not mean better absolute sensitivity. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why the selected alternative fits: The added-to-baseline ratio is smaller.

Distinguishing consideration: compare this with option B, “The noise-rise formula ignores baseline”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-MCQ-060. Why is a five-decibel on/off increase not five dBm of added noise?

A. The on value alone is the added component

B. The off value should be subtracted from blocker frequency

C. It is a ratio of totals; subtract compatible linear powers first

D. Decibel differences always equal added watts

Answer: C. Refer the positive difference through fixed gain and exclude other changed contributions before inferring a density. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: It is a ratio of totals; subtract compatible linear powers first.

Distinguishing consideration: compare this with option A, “The on value alone is the added component”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-061. What does the deterministic rise interval from a full rectangular set of input bounds establish?

A. Statistical independence of calibration errors

B. An automatic 95 percent confidence interval

C. An enclosure for all admitted combinations, with no coverage probability

D. A probability distribution inferred from endpoint counts

Answer: C. Hard bounds and stochastic uncertainty claims require different premises. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: An enclosure for all admitted combinations, with no coverage probability.

Distinguishing consideration: compare this with option A, “Statistical independence of calibration errors”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-062. Which combination produces the largest rise within independent rectangular power bounds?

A. Midpoint of every input range

B. Largest added power and largest baseline

C. Smallest added power and smallest baseline

D. Largest added power and smallest baseline

Answer: D. Noise rise increases with the added-to-baseline ratio. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: Largest added power and smallest baseline.

Distinguishing consideration: compare this with option A, “Midpoint of every input range”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-063. A one-decibel blocker change in a fixed model changes which level by one decibel?

A. The retained reciprocal contribution, not generally the total noise

B. The baseline alone

C. The desired signal automatically

D. The total floor by exactly one decibel under every baseline

Answer: A. The contribution is proportional to blocker power, while unchanged baseline dilutes the total-level change. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

Why the selected alternative fits: The retained reciprocal contribution, not generally the total noise.

Distinguishing consideration: compare this with option B, “The baseline alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Use the model to design discriminating receiver observations.

Review: Chapter 11 — Use the model to design discriminating receiver observations.

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V011-C11-MCQ-064. What happens if a blocker changes AGC or filter state during an on/off comparison?

A. The state change cancels because both readings use dBm

B. The ratio no longer isolates the fixed-state noise-rise model

C. The comparison still proves reciprocal mixing uniquely

D. Only the reported clock time is affected

Answer: B. Desired transfer, weighting, and baseline must remain compatible or be recharacterized. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why the selected alternative fits: The ratio no longer isolates the fixed-state noise-rise model.

Distinguishing consideration: compare this with option A, “The state change cancels because both readings use dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-MCQ-065. Why qualify the blocker source's spectrum at the actual offset and plane?

A. The source's carrier power alone bounds every sideband

B. Source phase noise can also contribute to the measured increase

C. A source specification at any offset is interchangeable

D. Every measured added watt must originate in the receiver LO

Answer: B. An effective inferred density is not uniquely receiver-attributable without excluding or bounding stimulus contributions. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why the selected alternative fits: Source phase noise can also contribute to the measured increase.

Distinguishing consideration: compare this with option A, “The source's carrier power alone bounds every sideband”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-MCQ-066. What is the pointwise bound on the omitted exponential phase term r for real phase phi?

A. Magnitude of r no greater than phi squared divided by two

B. Magnitude of r no greater than phi cubed for all signs

C. Magnitude of r always equals phase variance

D. r is exactly zero whenever RMS phase is below one radian

Answer: A. The remainder identity supplies a pointwise bound independently of stationarity. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: Magnitude of r no greater than phi squared divided by two.

Distinguishing consideration: compare this with option B, “Magnitude of r no greater than phi cubed for all signs”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-MCQ-067. Which assumptions support the stationary filtered nonlinear-remainder bound beyond the retained linear model?

A. A Gaussian marginal alone without stationarity

B. Wide-sense stationarity alone for every nonlinear function

C. Only a small displayed noise rise

D. Strict stationarity, finite fourth moment, and the declared independent uniform carrier phase

Answer: D. A nonlinear function need not be stationary from wide-sense stationarity alone; moment and carrier assumptions remain distinct. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: Strict stationarity, finite fourth moment, and the declared independent uniform carrier phase.

Distinguishing consideration: compare this with option A, “A Gaussian marginal alone without stationarity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-MCQ-068. What does a zero-mean Gaussian marginal supply for the fourth moment?

A. Strict stationarity automatically

B. The full oscillator spectrum at every offset

C. A proof of independent phase samples

D. Three times the fourth power of phase standard deviation

Answer: D. The marginal moment does not determine time dependence or replace other assumptions. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: Three times the fourth power of phase standard deviation.

Distinguishing consideration: compare this with option A, “Strict stationarity automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-MCQ-069. Why must the retained and omitted filtered terms' cross power be bounded?

A. The carrier phase makes every nonlinear term independent

B. They need not be uncorrelated

C. All cross powers are always zero by construction

D. The omitted term has no amplitude units

Answer: B. Dropping an unknown cross term understates the possible selected-power error. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: They need not be uncorrelated.

Distinguishing consideration: compare this with option A, “The carrier phase makes every nonlinear term independent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-MCQ-070. For retained power N and omitted power bound P, what error enclosure is used?

A. P alone in every case

B. Two times N plus P as an exact error

C. Two times sqrt(NP) plus P

D. N minus P regardless of phase

Answer: C. Cauchy–Schwarz bounds the cross term and the omitted power adds separately. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: Two times sqrt(NP) plus P.

Distinguishing consideration: compare this with option A, “P alone in every case”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-MCQ-071. Why can a small total phase RMS fail to justify a precise narrow-channel prediction?

A. Every narrow filter makes the omitted term vanish

B. Small RMS necessarily implies large actual selected error

C. The global omitted-power bound may be large relative to the selected first-order power

D. The fourth moment uniquely locates its spectrum

Answer: C. A loose bound is uninformative, not proof of a large error; localization needs more evidence. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: The global omitted-power bound may be large relative to the selected first-order power.

Distinguishing consideration: compare this with option A, “Every narrow filter makes the omitted term vanish”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-MCQ-072. What does peak-normalized W no greater than one permit in the remainder argument?

A. The filter cannot increase stationary omitted power under the model

B. The filter must have zero delay

C. The filter guarantees zero direct carrier leakage

D. The filter makes the remainder independent of the retained term

Answer: A. The power gain bound is a distinct premise used to carry global remainder power into the selected channel. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: The filter cannot increase stationary omitted power under the model.

Distinguishing consideration: compare this with option B, “The filter must have zero delay”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-MCQ-073. For small sinusoidal phase modulation of peak beta, what is each first-order sideband's carrier-relative power?

A. Beta squared divided by two

B. Two beta squared

C. Beta squared

D. Beta squared divided by four

Answer: D. The two sidebands together have beta squared divided by two, matching phase variance under this benchmark. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

Why the selected alternative fits: Beta squared divided by four.

Distinguishing consideration: compare this with option A, “Beta squared divided by two”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Use the model to design discriminating receiver observations.

Review: Chapter 11 — Use the model to design discriminating receiver observations.

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V011-C11-MCQ-074. What distinguishes the predictions of Models 11A and 11B?

A. The cubic model covers every AGC transient while reciprocal mixing covers all clipping

B. Both predict only fixed noise independent of blocker level

C. Both provide the same universal detector-probability formula

D. Discrete parent-dependent cubic products versus weighted blocker-induced phase-noise contribution

Answer: D. Each conditional mechanism leaves other strong-signal failures open.

Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Discrete parent-dependent cubic products versus weighted blocker-induced phase-noise contribution.

Distinguishing consideration: compare this with option A, “The cubic model covers every AGC transient while reciprocal mixing covers all clipping”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-MCQ-075. When can off/on subtraction be interpreted as one added uncorrelated contribution?

A. Whenever the blocker carrier is not visible

B. Compatible transfer, weighting, planes, justified cross-power condition, and retained uncertainty

C. Whenever two dBm numbers can be subtracted

D. Whenever the on trace is higher, regardless of state

Answer: B. Subtract linear powers; a valid difference requires the measurement and decomposition assumptions. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Compatible transfer, weighting, planes, justified cross-power condition, and retained uncertainty.

Distinguishing consideration: compare this with option A, “Whenever the blocker carrier is not visible”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-MCQ-076. What is a useful intervention for testing a proposed cubic parent-product frequency association?

A. Move one parent frequency while preserving detectable output and receiver state

B. Only lower the screen's trace reference without changing the input

C. Only increase the display averaging count

D. Change every gain and filter simultaneously

Answer: A. The model predicts specific product-frequency movements that a controlled test can challenge. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Move one parent frequency while preserving detectable output and receiver state.

Distinguishing consideration: compare this with option B, “Only lower the screen's trace reference without changing the input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-MCQ-077. What must be rechecked after inserting preselection to reduce a displayed noise floor?

A. Only the number of visible peaks

B. Desired transfer, baseline noise, and actual receiver state

C. Only the nominal filter name

D. Nothing if the floor decreased

Answer: B. The filter can also attenuate the desired signal or change the chain, so floor alone is not input-referred sensitivity. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Desired transfer, baseline noise, and actual receiver state.

Distinguishing consideration: compare this with option A, “Only the number of visible peaks”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-MCQ-078. Why record the physical location of an attenuation challenge?

A. Only the attenuator's label affects the outcome

B. A matched attenuator cannot change stage drive

C. All attenuation locations are equivalent after display correction

D. Attenuation before and after generation has different effects

Answer: D. A pre-stage loss alters nonlinear drive; a post-stage loss scales already generated signals. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Attenuation before and after generation has different effects.

Distinguishing consideration: compare this with option A, “Only the attenuator's label affects the outcome”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-MCQ-079. What can a fitted slope spanning automatic gain transitions misrepresent?

A. A purely algebraic definition of decibels

B. Nonlinear order of one fixed stage

C. The literal number of recorded points

D. The presence of the written gain settings

Answer: B. The observations combine state-dependent transfer and cannot be read as one fixed-coefficient power law. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Nonlinear order of one fixed stage.

Distinguishing consideration: compare this with option A, “A purely algebraic definition of decibels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-MCQ-080. Which dimension belongs in an operational dynamic-range acceptance matrix?

A. Only one maximum catalog range

B. Only one terminated-input trace

C. Weak references, blocker levels/spacings/modulation, gain/preselection states, and recovery

D. Only nominal ADC bit depth

Answer: C. The matrix demonstrates capability in the actual relevant configurations and environments. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

Why the selected alternative fits: Weak references, blocker levels/spacings/modulation, gain/preselection states, and recovery.

Distinguishing consideration: compare this with option A, “Only one maximum catalog range”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Dynamic-Range Acceptance Matrix.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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V011-C11-MCQ-081. Why include band edges and external preamplifier paths in acceptance?

A. One center-frequency test validates all external paths

B. Band edges always have identical gain and rejection

C. Their responses can impose limitations absent from a central bench setting

D. External accessories cannot change receiver overload

Answer: C. Acceptance must cover the deployed chain and configuration boundaries. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

Why the selected alternative fits: Their responses can impose limitations absent from a central bench setting.

Distinguishing consideration: compare this with option A, “One center-frequency test validates all external paths”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Dynamic-Range Acceptance Matrix.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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V011-C11-MCQ-082. What should a known band-specific limitation change operationally?

A. The allowed configuration or procedure for that band

B. The mathematical definition of a watt

C. Nothing if another band passed

D. Only the document's marketing description

Answer: A. Some uses may require preselection, reduced gain, or a bounded scope while others remain acceptable. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

Why the selected alternative fits: The allowed configuration or procedure for that band.

Distinguishing consideration: compare this with option B, “The mathematical definition of a watt”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Dynamic-Range Acceptance Matrix.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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V011-C11-MCQ-083. What does a product remain-fixed observation contradict most directly when one proposed parent is moved under adequate controls?

A. That particular predicted parent-product association

B. All environmental sources at the site

C. Every possible intermodulation mechanism anywhere

D. The existence of receiver noise

Answer: A. Stable configuration, frequency accuracy, and detectability are needed for this bounded contradiction. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

Why the selected alternative fits: That particular predicted parent-product association.

Distinguishing consideration: compare this with option B, “All environmental sources at the site”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Intermodulation and Intercept Metrics.

Review: Chapter 11 — Intermodulation and Intercept Metrics.

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V011-C11-MCQ-084. Why verify sources and combiner for their own products in an intercept test?

A. Their errors cancel from every intercept estimate

B. Source products always have a different frequency from receiver products

C. A matched source guarantees perfect spectral purity

D. They can create a coherent contribution at the same observed product frequency

Answer: D. Small displayed products can include constructive or destructive contamination, limiting attribution. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

Why the selected alternative fits: They can create a coherent contribution at the same observed product frequency.

Distinguishing consideration: compare this with option A, “Their errors cancel from every intercept estimate”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Intermodulation and Intercept Metrics.

Review: Chapter 11 — Intermodulation and Intercept Metrics.

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V011-C11-MCQ-085. For a measured spur phasor contaminated by an unknown-phase phasor of RMS magnitude at most E, what bounds the uncontaminated stage-spur RMS magnitude?

A. From max(0, measured minus E) to measured plus E

B. Exactly measured minus E for every phase

C. Only the upper value, with no possible lower ambiguity

D. Measured power minus E power only

Answer: A. Triangle and reverse-triangle inequalities apply to phasors, not incoherent power subtraction. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: From max(0, measured minus E) to measured plus E.

Distinguishing consideration: compare this with option B, “Exactly measured minus E for every phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-086. A common calibration offset is known to affect q and s equally. Why should it not be treated as two freely varying bounded errors?

A. Equal-looking numerical bounds always prove the dependency

B. The feasible error set has a dependency that changes intercept bounds

C. All correlated errors vanish from all formulas

D. The input level becomes irrelevant

Answer: B. Bound propagation must follow the justified dependency model rather than an invented rectangular set. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: The feasible error set has a dependency that changes intercept bounds.

Distinguishing consideration: compare this with option A, “Equal-looking numerical bounds always prove the dependency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-087. What does a noise-limited product reading prevent?

A. Indefinite extrapolation of a measured cubic trend to weaker products

B. Every possible higher-level measurement

C. The existence of a formal polynomial coefficient

D. Any use of the original reference-plane labels

Answer: A. Below the observation floor, numerical predictions are not validated product observations. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: Indefinite extrapolation of a measured cubic trend to weaker products.

Distinguishing consideration: compare this with option B, “Every possible higher-level measurement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-MCQ-088. Which behavior lies outside a fixed real memoryless cubic coefficient description?

A. A stated constant loaded resistance

B. A bounded retained fundamental correction

C. Separately identifiable nearby parent tones

D. Changing thermal history, frequency-selective memory, or AGC state

Answer: D. Those effects can require a richer model or direct characterization rather than transfer of the simple coefficient. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

Why the selected alternative fits: Changing thermal history, frequency-selective memory, or AGC state.

Distinguishing consideration: compare this with option A, “A stated constant loaded resistance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Carry the conditions into receiver interpretation.

Review: Chapter 11 — Carry the conditions into receiver interpretation.

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V011-C11-MCQ-089. Why not transfer this analog intercept construction automatically to an ADC or complete SDR?

A. Converter distortion, clipping, and digital behavior need their own demonstrated model

B. A digital output guarantees absence of analog distortion

C. A nominal bit count supplies the analog cubic coefficient

D. Every ADC necessarily follows the same cubic slopes

Answer: A. The chapter's local voltage law has a defined boundary, not universal system applicability. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

Why the selected alternative fits: Converter distortion, clipping, and digital behavior need their own demonstrated model.

Distinguishing consideration: compare this with option B, “A digital output guarantees absence of analog distortion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Carry the conditions into receiver interpretation.

Review: Chapter 11 — Carry the conditions into receiver interpretation.

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V011-C11-MCQ-090. Under the compatible equal-tone cubic planning model, how is SFDR obtained?

A. Equate total input power to the noise floor

B. Use OIP3 minus output display range with any bandwidth

C. Subtract the two parent powers directly

D. Find the per-tone level where input-equivalent IM3 reaches the stated noise floor, then subtract that floor

Answer: D. The resulting two-thirds relation depends on common planes, bandwidths, and a valid cubic interval. Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why the selected alternative fits: Find the per-tone level where input-equivalent IM3 reaches the stated noise floor, then subtract that floor.

Distinguishing consideration: compare this with option A, “Equate total input power to the noise floor”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-MCQ-091. For input IIP3 minus 20 dBm and input-equivalent noise minus 125 dBm, what is the cubic intersection per tone?

A. Minus 20 dBm

B. Minus 70 dBm

C. Minus 90 dBm

D. Minus 55 dBm

Answer: D. The intersection is (noise + two times IIP3)/3 = $\frac{(-125-40)}{3}$. Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why the selected alternative fits: Minus 55 dBm.

Distinguishing consideration: compare this with option A, “Minus 20 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-MCQ-092. What is the corresponding simplified SFDR in that same case?

A. 70 dB

B. 55 dB

C. 105 dB

D. 35 dB

Answer: A. The intersection minus the -125 dBm floor is 70 dB, equal to two thirds of 105 dB. Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why the selected alternative fits: 70 dB.

Distinguishing consideration: compare this with option B, “55 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-MCQ-093. If the cubic-noise intersection lies outside the characterized cubic interval, what follows?

A. The model is validated by its algebraic intersection

B. A positive numerical range overrides compression tests

C. It supplies no validated usable operating claim

D. The receiver must be safe up to IIP3

Answer: C. The planning relation cannot establish behavior beyond its demonstrated domain or tighter mechanisms. Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why the selected alternative fits: It supplies no validated usable operating claim.

Distinguishing consideration: compare this with option A, “The model is validated by its algebraic intersection”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-MCQ-094. A preamplifier removal and high-pass insertion restore a calibrated weak reference in the stated city-site case. What is supported?

A. Every preamplifier is unsuitable for all surveys

B. The original configuration was desensitized under those site conditions

C. The site had no unwanted emitters

D. The receiver's bench noise figure was necessarily false

Answer: B. The intervention restores measured capability in a specific strong-signal environment. Source: §11.44 Hypothetical Case Adjudication: Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6430)

Why the selected alternative fits: The original configuration was desensitized under those site conditions.

Distinguishing consideration: compare this with option A, “Every preamplifier is unsuitable for all surveys”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Hypothetical Case Adjudication: Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Hypothetical Case Adjudication: Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-MCQ-095. What should follow when a strong-signal experiment fails to match either developed mechanism?

A. Conclude all observations are invalid regardless of retained evidence

B. Choose the closest equation and declare it proven

C. Examine compression, control action, leakage, source effects, and other alternatives

D. Average until the discrepancy disappears

Answer: C. Models provide discriminating predictions, not an exhaustive taxonomy that forces every result into one mechanism. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Examine compression, control action, leakage, source effects, and other alternatives.

Distinguishing consideration: compare this with option A, “Conclude all observations are invalid regardless of retained evidence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-MCQ-096. Why mark a field test reference in the retained data?

A. To turn it into an environmental finding

B. To eliminate its coupling uncertainty

C. To distinguish deliberate injected or radiated stimulus from survey observations

D. To exclude every receiver limitation automatically

Answer: C. The reference's level, path, timing, and role belong in a reproducible controlled test record. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

Why the selected alternative fits: To distinguish deliberate injected or radiated stimulus from survey observations.

Distinguishing consideration: compare this with option A, “To turn it into an environmental finding”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Desensitization Tests in Operational Environments.

Review: Chapter 11 — Desensitization Tests in Operational Environments.

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V011-C11-MCQ-097. What is the central criterion for credibility of a weak field observation?

A. The absence of an overload icon alone

B. A single prior catalog sensitivity value

C. Demonstrated noise and strong-signal capability in the actual chain and environment

D. The largest display dynamic-range setting

Answer: C. Receiver state, external path, blockers, and recovery together bound what the observation supports. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

Why the selected alternative fits: Demonstrated noise and strong-signal capability in the actual chain and environment.

Distinguishing consideration: compare this with option A, “The absence of an overload icon alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Dynamic-Range Acceptance Matrix.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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V011-C11-MCQ-098. Conversion gain varies materially across the admitted reciprocal-noise spectrum. How should the model be adapted?

A. Include that frequency dependence in weighting and revise normalization

B. Use the center gain as an exact scalar for every spectrum

C. Ignore the variation whenever the blocker carrier is excluded

D. Apply a universal extra 3 dB to the result

Answer: A. A single fixed gain is insufficient when relevant frequencies experience different transfer. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why the selected alternative fits: Include that frequency dependence in weighting and revise normalization.

Distinguishing consideration: compare this with option B, “Use the center gain as an exact scalar for every spectrum”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-MCQ-099. A real mixer admits an additional image or conversion path. What does the chapter require?

A. Automatic doubling of the single-path result in every case

B. Explicit treatment of that path and its admitted contributions

C. Ignoring the path because a complex representation was used

D. Replacing both paths by one nominal bandwidth label

Answer: B. The declared path model does not silently account for another admitted image; its transfer and contributions need evidence. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why the selected alternative fits: Explicit treatment of that path and its admitted contributions.

Distinguishing consideration: compare this with option A, “Automatic doubling of the single-path result in every case”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-MCQ-100. An absolute selected-power enclosure yields a stated upper change in decibel level. What should the report avoid inferring automatically?

A. Dependence on retained power and omitted-term bound

B. A conditional upper level change under the stated bound

C. The need to retain the unknown cross-term sign

D. A symmetric decibel uncertainty interval or a coverage probability

Answer: D. A nonlinear log conversion and a hard enclosure do not establish symmetric or probabilistic uncertainty. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why the selected alternative fits: A symmetric decibel uncertainty interval or a coverage probability.

Distinguishing consideration: compare this with option A, “Dependence on retained power and omitted-term bound”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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Fill-in-the-Blank Questions

V011-C11-FIB-001. Dynamic range must specify both a lower limit and an _____ limit under a defined test.

Answer: upper. Different noise, blocking, spur, and display measures use different boundaries. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

Why this term is required: “upper” completes the stated technical proposition.

Question context: Dynamic range must specify both a lower limit and an _____ limit under a defined test

Basis and qualification: Chapter 11 — Dynamic Range Is a Family of Conditions.

Review: Chapter 11 — Dynamic Range Is a Family of Conditions.

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V011-C11-FIB-002. The amount by which a waveform's peak exceeds its RMS level is its crest _____.

Answer: factor. Strong-signal behavior depends on peaks as well as total or individual carrier powers. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

Why this term is required: “factor” completes the stated technical proposition.

Question context: The amount by which a waveform's peak exceeds its RMS level is its crest _____

Basis and qualification: Chapter 11 — Dynamic Range Is a Family of Conditions.

Review: Chapter 11 — Dynamic Range Is a Family of Conditions.

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V011-C11-FIB-003. A fixed-stage compression test must retain a fixed receiver _____.

Answer: state. Automatic control transitions produce a different closed-loop transfer question. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

Why this term is required: “state” completes the stated technical proposition.

Question context: A fixed-stage compression test must retain a fixed receiver _____

Basis and qualification: Chapter 11 — Measure compression without confusing it with control action.

Review: Chapter 11 — Measure compression without confusing it with control action.

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V011-C11-FIB-004. An independent weak _____ tests the desired capability while a stronger blocker is varied.

Answer: probe. The strong signal can look normal while suppressing the weak response. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

Why this term is required: “probe” completes the stated technical proposition.

Question context: An independent weak _____ tests the desired capability while a stronger blocker is varied

Basis and qualification: Chapter 11 — Measure compression without confusing it with control action.

Review: Chapter 11 — Measure compression without confusing it with control action.

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V011-C11-FIB-005. Recovery intervals that fail the weak-signal criterion become observation _____.

Answer: exclusions. Usable coverage must omit periods of unvalidated sensitivity after the tested strong event. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

Why this term is required: “exclusions” completes the stated technical proposition.

Question context: Recovery intervals that fail the weak-signal criterion become observation _____

Basis and qualification: Chapter 11 — Measure compression without confusing it with control action.

Review: Chapter 11 — Measure compression without confusing it with control action.

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V011-C11-FIB-006. A displayed overload flag alone cannot establish the onset or absence of every measurement _____.

Answer: error. Desired gain, noise, products, and recovery need observation as appropriate. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

Why this term is required: “error” completes the stated technical proposition.

Question context: A displayed overload flag alone cannot establish the onset or absence of every measurement _____

Basis and qualification: Chapter 11 — Measure compression without confusing it with control action.

Review: Chapter 11 — Measure compression without confusing it with control action.

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V011-C11-FIB-007. Intermodulation products involve sums and _____ of parent frequencies.

Answer: differences. Their placement can be challenged by moving a parent under controlled conditions. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)
Why this term is required: “differences” completes the stated technical proposition.
Question context: Intermodulation products involve sums and _____ of parent frequencies
Basis and qualification: Chapter 11 — Intermodulation and Intercept Metrics.
Review: Chapter 11 — Intermodulation and Intercept Metrics.

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V011-C11-FIB-008. An intercept is an extrapolated metric, not an actual operating _____.

Answer: point. The small-signal asymptotes can intersect outside the valid physical or model regime. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “point” completes the stated technical proposition.

Question context: An intercept is an extrapolated metric, not an actual operating _____

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-009. The cubic model uses input peak voltages at a declared _____ plane.

Answer: loaded. Open-circuit generator settings need a justified conversion to delivered quantities. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “loaded” completes the stated technical proposition.

Question context: The cubic model uses input peak voltages at a declared _____ plane

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-010. Available and delivered source powers coincide under the stated _____ condition.

Answer: matched. Without matching, establish delivered voltage and impedance explicitly. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “matched” completes the stated technical proposition.

Question context: Available and delivered source powers coincide under the stated _____ condition

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-011. For a real cosine averaged over complete cycles, mean-square voltage is peak squared divided by _____.

Answer: two. This converts the defined peak amplitude to power across the stated resistance. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “two” completes the stated technical proposition.

Question context: For a real cosine averaged over complete cycles, mean-square voltage is peak squared divided by _____

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-012. The linear coefficient a1 is dimensionless voltage _____.

Answer: gain. Its conversion to power gain also depends on the input and output resistances. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)
Why this term is required: “gain” completes the stated technical proposition.
Question context: The linear coefficient a1 is dimensionless voltage _____
Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.
Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-013. The cubic coefficient a_3 has units inverse volts _____.

Answer: squared. Those units make a_3 times voltage cubed an output voltage.

Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “squared” completes the stated technical proposition.

Question context: The cubic coefficient has units inverse volts _____

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-014. A negative a_3 initially reduces a fundamental, while a positive value initially produces gain _____.

Answer: expansion. Power-only product magnitudes do not identify that sign.

Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “expansion” completes the stated technical proposition.

Question context: A negative initially reduces a fundamental, while a positive value initially produces gain _____

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-015. The model deliberately omits constant offset and _____-order terms.

Answer: even. Their omission is a restriction, not a universal property of receiver hardware. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “even” completes the stated technical proposition.

Question context: The model deliberately omits constant offset and _____-order terms

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-016. Coincident generated frequencies require adding their complex _____ before computing power.

Answer: amplitudes. The separate-product formulas assume distinguishable spectral locations. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “amplitudes” completes the stated technical proposition.

Question context: Coincident generated frequencies require adding their complex _____ before computing power

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-017. The first close-in product occurs at twice f1 _____ f2.

Answer: minus. Its parent dependence differs from the other close-in product.

Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why this term is required: “minus” completes the stated technical proposition.

Question context: The first close-in product occurs at twice f1 _____ f2

Basis and qualification: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-FIB-018. The second close-in product occurs at twice f2 _____ f1.

Answer: minus. The two nearby frequency expressions support distinct movement tests. Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why this term is required: “minus” completes the stated technical proposition.

Question context: The second close-in product occurs at twice f2 _____ f1

Basis and qualification: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-FIB-019. For parents at 90 and 91 MHz, the lower close-in product is _____ MHz.

Answer: 89. Twice 90 minus 91 gives 89 MHz under the stated association. Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why this term is required: “89” completes the stated technical proposition.

Question context: For parents at 90 and 91 MHz, the lower close-in product is _____ MHz

Basis and qualification: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-FIB-020. For those same parents, the upper close-in product is _____ MHz.

Answer: 92. Twice 91 minus 90 gives 92 MHz. Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why this term is required: “92” completes the stated technical proposition.

Question context: For those same parents, the upper close-in product is _____ MHz

Basis and qualification: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-FIB-021. The coefficient at twice f1 minus f2 contains A1 to the power _____.

Answer: two. It also contains one factor of A2 and the three-quarters cubic coefficient. Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why this term is required: “two” completes the stated technical proposition.

Question context: The coefficient at twice f1 minus f2 contains A1 to the power _____

Basis and qualification: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-FIB-022. The lower product power contains P1 squared times _____.

Answer: P2. It is not determined solely by the average of parent powers. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “P2” completes the stated technical proposition.

Question context: The lower product power contains P1 squared times _____

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-023. The upper product power contains P1 times P2 _____.

Answer: squared. Unequal parent powers therefore generally give unequal product powers. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “squared” completes the stated technical proposition.

Question context: The upper product power contains P1 times P2 _____

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-024. The declared maximum retained relative fundamental correction is _____ percent.

Answer: five. This is the local working condition, not a bound on omitted higher orders. Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

Why this term is required: “five” completes the stated technical proposition.

Question context: The declared maximum retained relative fundamental correction is _____ percent

Basis and qualification: Chapter 11 — Derive the retained spectral amplitudes.

Review: Chapter 11 — Derive the retained spectral amplitudes.

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V011-C11-FIB-025. At equal peak inputs, the generated close-in cubic-product voltage amplitude scales with input amplitude _____.

Answer: cubed. Its power therefore has the stated equal-tone three-to-one logarithmic slope. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “cubed” completes the stated technical proposition.

Question context: At equal peak inputs, the generated close-in cubic-product voltage amplitude scales with input amplitude _____

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-026. The intercept compares the cubic product with the _____ fundamental asymptote.

Answer: linear. Using a finite corrected fundamental introduces an extraction bias.

Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “linear” completes the stated technical proposition.

Question context: The intercept compares the cubic product with the _____ fundamental asymptote

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-027. Input intercept power is defined per _____ in the equal-tone construction.

Answer: tone. Summing both parents before applying the separation rule adds the wrong three-decibel term. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “tone” completes the stated technical proposition.

Question context: Input intercept power is defined per _____ in the equal-tone construction

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-028. Output intercept in dBm equals input intercept plus small-signal power _____ in dB.

Answer: gain. The reference-plane conversion must use power gain, including resistance ratio. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “gain” completes the stated technical proposition.

Question context: Output intercept in dBm equals input intercept plus small-signal power _____ in dB

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-029. For one input tone p, linear output q, and product s, IIP3 equals p plus one _____ of q minus s.

Answer: half. The level separation enters with coefficient one half. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “half” completes the stated technical proposition.

Question context: For one input tone p, linear output q, and product s, IIP3 equals p plus one _____ of q minus s

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-030. The output-intercept expression weights q by three _____.

Answer: halves. Its output calibration and finite-gain-correction sensitivity differ from IIP3. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
Why this term is required: “halves” completes the stated technical proposition.
Question context: The output-intercept expression weights q by three _____
Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.
Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-031. If both equal parent powers increase 3 dB in the same cubic regime, product power increases _____ dB.

Answer: 9. The common input-power level enters the product law with coefficient three. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “9” completes the stated technical proposition.

Question context: If both equal parent powers increase 3 dB in the same cubic regime, product power increases _____ dB

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-032. If only the second parent power increases 3 dB, the lower product rises _____ dB.

Answer: 3. The lower product contains one factor of P2 while the upper contains its square. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “3” completes the stated technical proposition.

Question context: If only the second parent power increases 3 dB, the lower product rises _____ dB

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-033. Under that same one-parent change, the upper product rises _____ dB.

Answer: 6. The upper-product power has two factors of P2. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why this term is required: “6” completes the stated technical proposition.

Question context: Under that same one-parent change, the upper product rises _____ dB

Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-FIB-034. A 60 dB fundamental-to-product separation contributes _____ dB to the per-tone intercept extraction.

Answer: 30. The separation is halved before addition to input or linear output level.

Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “30” completes the stated technical proposition.

Question context: A 60 dB fundamental-to-product separation contributes _____ dB to the per-tone intercept extraction

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-035. Two equal powers total _____ dB above either one, to four decimal places.

Answer: 3.0103. That total must not replace the per-tone level in the intercept formula. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “3.0103” completes the stated technical proposition.

Question context: Two equal powers total _____ dB above either one, to four decimal places

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-036. With voltage gain ten and equal resistances, small-signal power gain is _____ dB.

Answer: 20. Power gain is 100 when the resistance ratio is one. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

Why this term is required: “20” completes the stated technical proposition.

Question context: With voltage gain ten and equal resistances, small-signal power gain is _____ dB

Basis and qualification: Chapter 11 — Fix the voltage convention and operating domain.

Review: Chapter 11 — Fix the voltage convention and operating domain.

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V011-C11-FIB-037. With the same voltage gain and $\frac{R_i}{R_o}$ = one quarter, power gain is _____ as a linear ratio.

Answer: 25. The resistance ratio changes the voltage-to-power conversion. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “25” completes the stated technical proposition.

Question context: With the same voltage gain and = one quarter, power gain is _____ as a linear ratio

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-038. A one-decibel fundamental gain reduction corresponds to voltage ratio ten to minus one divided by _____.

Answer: 20. Voltage and power logarithmic conversions differ by the square relationship. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “20” completes the stated technical proposition.

Question context: A one-decibel fundamental gain reduction corresponds to voltage ratio ten to minus one divided by _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-039. The formal one-decibel cubic compression correction is about 10.875 percent, which _____ the five-percent working bound.

Answer: exceeds. The calculation is a declared extrapolation, not a validated operating prediction. Source: §11.9 Ten worked applications of Model 11A (p. 6376)
Why this term is required: “exceeds” completes the stated technical proposition.
Question context: The formal one-decibel cubic compression correction is about 10.875 percent, which _____ the five-percent working bound
Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.
Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-040. An ideal output attenuator scales fundamental and already generated product _____.

Answer: equally. It leaves input-referred IIP3 unchanged in the stated matched model. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “equally” completes the stated technical proposition.

Question context: An ideal output attenuator scales fundamental and already generated product _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-041. Before the nonlinear stage, attenuator voltage transmission k scales the generated cubic-product voltage amplitude by k _____.

Answer: cubed. Input reduction changes product generation differently from downstream scaling. Source: §11.9 Ten worked applications of Model 11A (p. 6376)
Why this term is required: “cubed” completes the stated technical proposition.
Question context: Before the nonlinear stage, attenuator voltage transmission k scales the generated cubic-product voltage amplitude by k _____
Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.
Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-042. After the stage, the same transmission scales both voltage coefficients by _____.

Answer: k. The generated output is multiplied uniformly under the ideal attenuator assumptions. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “k” completes the stated technical proposition.

Question context: After the stage, the same transmission scales both voltage coefficients by _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-043. A common additive output calibration offset cancels from the q minus s _____.

Answer: difference. That cancellation supports IIP3 only when the shared-error dependency is justified. Source: §11.9 Ten worked applications of Model 11A (p. 6376)
Why this term is required: “difference” completes the stated technical proposition.
Question context: A common additive output calibration offset cancels from the q minus s _____
Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.
Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-044. Under the same common offset, OIP3 retains _____ copy of that error.

Answer: one. Its coefficients three halves and minus one half sum to one. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “one” completes the stated technical proposition.

Question context: Under the same common offset, OIP3 retains _____ copy of that error

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-045. Unknown coherent contamination is bounded with triangle inequalities applied to _____.

Answer: phasors. Incoherent power subtraction is not generally valid for an unknown coherent phase. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “phasors” completes the stated technical proposition.

Question context: Unknown coherent contamination is bounded with triangle inequalities applied to _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-046. For measured spur magnitude 1.0 mV RMS and contaminant bound 0.1 mV RMS, the minimum permitted stage magnitude is _____ mV RMS.

Answer: 0.9. The reverse-triangle lower bound is measured magnitude minus the bound, floored at zero. Source: §11.9 Ten worked applications of Model 11A (p. 6376) Why this term is required: “0.9” completes the stated technical proposition. Question context: For measured spur magnitude 1.0 mV RMS and contaminant bound 0.1 mV RMS, the minimum permitted stage magnitude is _____ mV RMS Basis and qualification: Chapter 11 — Ten worked applications of Model 11A. Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-047. For that same observation, the maximum permitted stage magnitude is _____ mV RMS.

Answer: 1.1. The triangle upper bound adds the two magnitudes. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why this term is required: “1.1” completes the stated technical proposition.

Question context: For that same observation, the maximum permitted stage magnitude is _____ mV RMS

Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-048. A product slope inconsistent with the declared cubic law indicates a model _____ without uniquely identifying its cause.

Answer: departure. Noise floor, coherent contamination, state changes, or higher orders are alternatives. Source: §11.9 Ten worked applications of Model 11A (p. 6376)
Why this term is required: “departure” completes the stated technical proposition.
Question context: A product slope inconsistent with the declared cubic law indicates a model _____ without uniquely identifying its cause
Basis and qualification: Chapter 11 — Ten worked applications of Model 11A.
Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-FIB-049. A frequency-selective memory effect is outside a fixed _____ cubic law.

Answer: memoryless. The model's output depends only on the present input with fixed coefficients. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

Why this term is required: “memoryless” completes the stated technical proposition.

Question context: A frequency-selective memory effect is outside a fixed _____ cubic law

Basis and qualification: Chapter 11 — Carry the conditions into receiver interpretation.

Review: Chapter 11 — Carry the conditions into receiver interpretation.

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V011-C11-FIB-050. Blocking is degradation caused by a strong signal separated from the desired _____.

Answer: channel. The blocker can lie outside the selected display while affecting earlier stages. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

Why this term is required: “channel” completes the stated technical proposition.

Question context: Blocking is degradation caused by a strong signal separated from the desired _____

Basis and qualification: Chapter 11 — Blocking and Reciprocal Mixing.

Review: Chapter 11 — Blocking and Reciprocal Mixing.

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V011-C11-FIB-051. Reciprocal mixing translates local-oscillator phase _____ around an admitted blocker.

Answer: noise. Its weighted contribution can resemble environmental broadband noise. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

Why this term is required: “noise” completes the stated technical proposition.

Question context: Reciprocal mixing translates local-oscillator phase _____ around an admitted blocker

Basis and qualification: Chapter 11 — Blocking and Reciprocal Mixing.

Review: Chapter 11 — Blocking and Reciprocal Mixing.

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V011-C11-FIB-052. The blocker power used in Model 11B is measured at the mixer _____ plane.

Answer: input. Preceding frequency-selective gains and losses must already be included. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

Why this term is required: “input” completes the stated technical proposition.

Question context: The blocker power used in Model 11B is measured at the mixer _____ plane

Basis and qualification: Chapter 11 — Translate one blocker through the fluctuating oscillator.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-FIB-053. The phase process in the retained linear model has zero mean and finite _____.

Answer: variance. Those second-order assumptions support the stated spectrum.

Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why this term is required: “variance” completes the stated technical proposition.

Question context: The phase process in the retained linear model has zero mean and finite _____

Basis and qualification: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-FIB-054. A real phase process has an _____ two-sided phase spectrum.

Answer: even. This does not remove signed-offset effects with an asymmetric observation filter. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why this term is required: “even” completes the stated technical proposition.

Question context: A real phase process has an _____ two-sided phase spectrum

Basis and qualification: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-FIB-055. The linear single-sideband density equals _____ of the one-sided phase spectral density.

Answer: half. At positive offset it also equals the two-sided phase density numerically. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why this term is required: “half” completes the stated technical proposition.

Question context: The linear single-sideband density equals _____ of the one-sided phase spectral density

Basis and qualification: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-FIB-056. The logarithmic phase-noise density unit used in this model is dBc per _____.

Answer: hertz. It must be converted to linear inverse-hertz density before power integration. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why this term is required: “hertz” completes the stated technical proposition.

Question context: The logarithmic phase-noise density unit used in this model is dBc per _____

Basis and qualification: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-FIB-057. To convert L dBc/Hz to linear density, raise ten to L divided by _____.

Answer: 10. The logarithmic quantity represents a power-density ratio. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why this term is required: “10” completes the stated technical proposition.

Question context: To convert L dBc/Hz to linear density, raise ten to L divided by _____

Basis and qualification: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-FIB-058. An ordinary-density integral must treat a discrete phase _____ separately as a line.

Answer: spur. Its contribution is not a point density multiplied by an arbitrary bandwidth. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

Why this term is required: “spur” completes the stated technical proposition.

Question context: An ordinary-density integral must treat a discrete phase _____ separately as a line

Basis and qualification: Chapter 11 — Define the phase spectrum before converting decibels.

Review: Chapter 11 — Define the phase spectrum before converting decibels.

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V011-C11-FIB-059. The retained small-phase term in the oscillator exponential is minus j times _____.

Answer: phi. The exact remainder is defined after retaining one minus j phi. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

Why this term is required: “phi” completes the stated technical proposition.

Question context: The retained small-phase term in the oscillator exponential is minus j times _____

Basis and qualification: Chapter 11 — Translate one blocker through the fluctuating oscillator.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-FIB-060. The retained translated-noise density scales directly with blocker _____.

Answer: power. At fixed phase spectrum and weighting, a blocker-level change produces the same change in that contribution. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

Why this term is required: “power” completes the stated technical proposition.

Question context: The retained translated-noise density scales directly with blocker _____

Basis and qualification: Chapter 11 — Translate one blocker through the fluctuating oscillator.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-FIB-061. Direct carrier _____ must be negligible or characterized separately from reciprocal mixing.

Answer: leakage. The perturbation calculation does not establish carrier rejection or other strong-signal mechanisms. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

Why this term is required: “leakage” completes the stated technical proposition.

Question context: Direct carrier _____ must be negligible or characterized separately from reciprocal mixing

Basis and qualification: Chapter 11 — Translate one blocker through the fluctuating oscillator.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-FIB-062. The channel power weighting is the magnitude _____ of its complex response.

Answer: squared. Power integration requires the squared response magnitude, not the voltage response alone. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “squared” completes the stated technical proposition.

Question context: The channel power weighting is the magnitude _____ of its complex response

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-FIB-063. The observation response is normalized to unity at the desired channel _____.

Answer: center. This separates channel weighting from the declared fixed conversion gain. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “center” completes the stated technical proposition.

Question context: The observation response is normalized to unity at the desired channel _____

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-FIB-064. The area under the channel power weighting is its equivalent noise _____.

Answer: bandwidth. A nominal width need not equal this integral. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “bandwidth” completes the stated technical proposition.

Question context: The area under the channel power weighting is its equivalent noise _____

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-FIB-065. The weighted overlap factor K is _____ under the chapter's unit conventions.

Answer: dimensionless. Inverse-hertz density integrated over hertz gives a dimensionless power ratio. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “dimensionless” completes the stated technical proposition.

Question context: The weighted overlap factor K is _____ under the chapter's unit conventions

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-FIB-066. Input-equivalent reciprocal noise equals blocker power multiplied by the overlap _____.

Answer: factor. The factor includes oscillator spectrum and actual observation weighting. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “factor” completes the stated technical proposition.

Question context: Input-equivalent reciprocal noise equals blocker power multiplied by the overlap _____

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-FIB-067. The center-density shortcut is exact when that density is _____ over the relevant weighted offsets.

Answer: flat. A center point alone cannot prove the needed spectral condition.

Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “flat” completes the stated technical proposition.

Question context: The center-density shortcut is exact when that density is _____ over the relevant weighted offsets

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-FIB-068. Filter tails omitted from an integration need a justified contribution _____.

Answer: bound. Unrecorded truncation can omit significant admitted noise. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “bound” completes the stated technical proposition.

Question context: Filter tails omitted from an integration need a justified contribution _____

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-C11-FIB-069. An asymmetric filter can distinguish positive and negative signed blocker _____.

Answer: offsets. The even phase spectrum is sampled through differently translated weighting regions. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “offsets” completes the stated technical proposition.

Question context: An asymmetric filter can distinguish positive and negative signed blocker _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-070. With equal fixed gain on baseline and added noise, the added-to-baseline _____ is unchanged between those planes.

Answer: ratio. Mixing planes without the same gain would introduce an artificial factor. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “ratio” completes the stated technical proposition.

Question context: With equal fixed gain on baseline and added noise, the added-to-baseline _____ is unchanged between those planes

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-071. Referring mixer noise to an external desired-input plane requires division by desired power _____.

Answer: transfer. Blocker rejection alone omits the desired-path reference conversion. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “transfer” completes the stated technical proposition.

Question context: Referring mixer noise to an external desired-input plane requires division by desired power _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-072. Twenty-five dB blocker loss and two dB desired loss give _____ dB differential rejection.

Answer: 23. The relevant logarithmic difference is 25 minus 2. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “23” completes the stated technical proposition.

Question context: Twenty-five dB blocker loss and two dB desired loss give _____ dB differential rejection

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-073. Several blocker contributions can be added as powers only when their admitted cross powers _____.

Answer: vanish. A common local oscillator alone does not establish this condition.

Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “vanish” completes the stated technical proposition.

Question context: Several blocker contributions can be added as powers only when their admitted cross powers _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-074. Coincident coherent blockers require complex _____ addition.

Answer: field. Their relative phases can reinforce or cancel before power is computed. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “field” completes the stated technical proposition.

Question context: Coincident coherent blockers require complex _____ addition

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-075. The noise-rise formula uses one plus added power divided by positive _____ power.

Answer: baseline. The total-to-baseline ratio determines the decibel increase.

Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why this term is required: “baseline” completes the stated technical proposition.

Question context: The noise-rise formula uses one plus added power divided by positive _____ power

Basis and qualification: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-FIB-076. If added power equals baseline, total noise rises approximately _____ dB.

Answer: 3.0103. The total power doubles under the stated zero-cross-power condition. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why this term is required: “3.0103” completes the stated technical proposition.

Question context: If added power equals baseline, total noise rises approximately _____ dB

Basis and qualification: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-FIB-077. A zero permissible noise rise allows _____ added power under the unchanged-baseline model.

Answer: zero. The allowance N0 times (10 to $\frac{R}{10}$ minus one) tends to zero with R.

Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why this term is required: “zero” completes the stated technical proposition.

Question context: A zero permissible noise rise allows _____ added power under the unchanged-baseline model

Basis and qualification: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-FIB-078. The same added watts cause a larger relative rise in a _____ baseline receiver.

Answer: quieter. The ratio increases as positive baseline power decreases. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why this term is required: “quieter” completes the stated technical proposition.

Question context: The same added watts cause a larger relative rise in a _____ baseline receiver

Basis and qualification: Chapter 11 — Convert added power into a conditional noise-rise limit.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-FIB-079. A 5 dB on/off increase is a ratio of totals, not an added power expressed in _____.

Answer: dBm. Subtract compatible linear powers before conversion back to a logarithmic level. Source: §11.27 Ten worked applications of Model 11B (p. 6402)
Why this term is required: “dBm” completes the stated technical proposition.
Question context: A 5 dB on/off increase is a ratio of totals, not an added power expressed in _____
Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.
Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-080. The inferred receiver density must exclude or bound phase noise from the blocker _____.

Answer: source. A stimulus contribution can contaminate the same on/off observation. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “source” completes the stated technical proposition.

Question context: The inferred receiver density must exclude or bound phase noise from the blocker _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-081. A negative or unresolved on-minus-off power difference cannot support a positive effective-density _____.

Answer: estimate. Uncertainty and compatible unchanged conditions must be retained. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “estimate” completes the stated technical proposition.

Question context: A negative or unresolved on-minus-off power difference cannot support a positive effective-density _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-082. A full rectangular set of hard bounds supplies an enclosure without a coverage _____.

Answer: probability. No statistical distribution follows from deterministic limits alone. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “probability” completes the stated technical proposition.

Question context: A full rectangular set of hard bounds supplies an enclosure without a coverage _____

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-083. For largest possible rise, combine largest added power with the _____ baseline.

Answer: smallest. This maximizes the added-to-baseline ratio under the declared feasible set. Source: §11.27 Ten worked applications of Model 11B (p. 6402)

Why this term is required: “smallest” completes the stated technical proposition.

Question context: For largest possible rise, combine largest added power with the _____ baseline

Basis and qualification: Chapter 11 — Ten worked applications of Model 11B.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-FIB-084. The pointwise remainder bound does not require _____.

Answer: stationarity. It holds for each real phase value; expectation additionally needs the relevant moment. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why this term is required: “stationarity” completes the stated technical proposition.

Question context: The pointwise remainder bound does not require _____

Basis and qualification: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-FIB-085. The expected-square remainder bound requires a finite _____ moment of phase.

Answer: fourth. Squaring the pointwise quadratic bound introduces phase to the fourth power. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why this term is required: “fourth” completes the stated technical proposition.

Question context: The expected-square remainder bound requires a finite _____ moment of phase

Basis and qualification: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-FIB-086. The stationary filtered nonlinear bound strengthens wide-sense to _____ stationarity.

Answer: strict. Wide-sense stationarity alone need not be inherited by a nonlinear function. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why this term is required: “strict” completes the stated technical proposition.

Question context: The stationary filtered nonlinear bound strengthens wide-sense to _____ stationarity

Basis and qualification: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-FIB-087. For a zero-mean Gaussian marginal, the fourth moment is _____ times sigma to the fourth power.

Answer: three. This moment statement does not establish stationarity or a spectrum. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why this term is required: “three” completes the stated technical proposition.

Question context: For a zero-mean Gaussian marginal, the fourth moment is _____ times sigma to the fourth power

Basis and qualification: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-FIB-088. The selected-power error enclosure retains an unknown filtered _____ term.

Answer: cross. Retained and omitted contributions need not be uncorrelated.

Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why this term is required: “cross” completes the stated technical proposition.

Question context: The selected-power error enclosure retains an unknown filtered _____ term

Basis and qualification: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-FIB-089. A loose global omitted-term bound does not prove a large _____ error.

Answer: actual. It can be uninformative because it does not locate omitted spectral power precisely. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

Why this term is required: “actual” completes the stated technical proposition.

Question context: A loose global omitted-term bound does not prove a large _____ error

Basis and qualification: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-FIB-090. For small sinusoidal phase modulation, the two first-order sidebands together have power ratio beta squared divided by _____.

Answer: two. Each has beta squared over four; their sum matches the phase variance in this benchmark. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

Why this term is required: “two” completes the stated technical proposition.

Question context: For small sinusoidal phase modulation, the two first-order sidebands together have power ratio beta squared divided by _____

Basis and qualification: Chapter 11 — Use the model to design discriminating receiver observations.

Review: Chapter 11 — Use the model to design discriminating receiver observations.

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V011-C11-FIB-091. Changing blocker level tests proportionality, while changing offset probes the weighted oscillator _____.

Answer: spectrum. The interventions test distinct aspects of the reciprocal-mixing mechanism. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

Why this term is required: “spectrum” completes the stated technical proposition.

Question context: Changing blocker level tests proportionality, while changing offset probes the weighted oscillator _____

Basis and qualification: Chapter 11 — Use the model to design discriminating receiver observations.

Review: Chapter 11 — Use the model to design discriminating receiver observations.

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V011-C11-FIB-092. A lower displayed floor is not improved input-referred sensitivity unless desired _____ is preserved or remeasured.

Answer: transfer. A filter can reduce both noise indication and the wanted signal.

Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why this term is required: “transfer” completes the stated technical proposition.

Question context: A lower displayed floor is not improved input-referred sensitivity unless desired _____ is preserved or remeasured

Basis and qualification: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-FIB-093. The location of an attenuator determines whether it changes nonlinear drive or scales an already generated _____.

Answer: product. Pre- and post-stage losses are different interventions. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
Why this term is required: “product” completes the stated technical proposition.
Question context: The location of an attenuator determines whether it changes nonlinear drive or scales an already generated _____
Basis and qualification: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.
Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-FIB-094. A dynamic-range acceptance matrix includes recovery intervals and automatic-state _____.

Answer: changes. These can create boundaries of valid weak-signal observation.

Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

Why this term is required: “changes” completes the stated technical proposition.

Question context: A dynamic-range acceptance matrix includes recovery intervals and automatic-state _____

Basis and qualification: Chapter 11 — Dynamic-Range Acceptance Matrix.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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V011-C11-FIB-095. Known test references should be clearly _____ in retained field data.

Answer: marked. Their controlled role must remain distinguishable from environmental findings. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

Why this term is required: “marked” completes the stated technical proposition.

Question context: Known test references should be clearly _____ in retained field data

Basis and qualification: Chapter 11 — Desensitization Tests in Operational Environments.

Review: Chapter 11 — Desensitization Tests in Operational Environments.

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V011-C11-FIB-096. For the local equal-tone cubic law, the input-equivalent product level is three p minus two _____.

Answer: I. Here p is per-tone input dBm and I is input intercept at the same plane.

Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why this term is required: "I" completes the stated technical proposition.

Question context: For the local equal-tone cubic law, the input-equivalent product level is three p minus two _____

Basis and qualification: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-FIB-097. Equating that product to noise floor N gives per-tone intersection (N plus two I) divided by _____.

Answer: three. The relation is a conditional planning result under compatible bandwidth and model validity. Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why this term is required: “three” completes the stated technical proposition.

Question context: Equating that product to noise floor N gives per-tone intersection (N plus two I) divided by _____

Basis and qualification: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-FIB-098. The simplified third-order SFDR is _____ thirds of the input-intercept-minus-noise-floor difference.

Answer: two. It excludes tighter limits from other mechanisms and invalid extrapolation. Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why this term is required: “two” completes the stated technical proposition.

Question context: The simplified third-order SFDR is _____ thirds of the input-intercept-minus-noise-floor difference

Basis and qualification: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-FIB-099. A cubic-noise intersection outside the characterized domain does not establish a usable operating _____.

Answer: range. A positive numerical result alone cannot override the model's applicability limits. Source: §11.42 Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization (p. 6426)

Why this term is required: “range” completes the stated technical proposition.

Question context: A cubic-noise intersection outside the characterized domain does not establish a usable operating _____

Basis and qualification: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-FIB-100. Weak-signal credibility depends on the actual external path, blockers, receiver state, and demonstrated _____.

Answer: capability. A generic range label cannot substitute for configuration-bound acceptance evidence. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
Why this term is required: “capability” completes the stated technical proposition.
Question context: Weak-signal credibility depends on the actual external path, blockers, receiver state, and demonstrated _____
Basis and qualification: Chapter 11 — Dynamic-Range Acceptance Matrix.
Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C11-ESSAY-001. Develop a compression test that distinguishes fixed-stage transfer from automatic receiver control action.

- Opening: Present a thesis that answers this precise question: Develop a compression test that distinguishes fixed-stage transfer from automatic receiver control action. Identify which evidence would falsify the proposed conclusion Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Core terminology and scope: Define compression, distinguishes, transfer in the question's particular technical setting; explain how automatic, control, action differ if that distinction would change the analysis of "Develop a compression test that distinguishes fixed-stage transfer from automatic receiver control action" Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define input/output planes and stimulus interval, retain actual gain/attenuation/filter/detector states, and identify transitions Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a compression test that distinguishes fixed-stage transfer from automatic receiver control action to the claimed result, following "Compression and Gain Change"; name the intermediate states and measurable outputs Source: §11.2 Compression and Gain Change (p. 6363)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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compression test that distinguishes fixed-stage transfer from automatic receiver control action. Use an independent controlled weak probe for sensitivity loss Source: §11.2 Compression and Gain Change (p. 6363)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 11A for cubic intermodulation and intercept metrics” that resolves the question about a compression test that distinguishes fixed-stage transfer from automatic receiver control action; derive the relevant result with units and stated validity conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a compression test that distinguishes fixed-stage transfer from automatic receiver control action. Measure recovery after a specified pulse/prior state and define observation exclusions Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Worked application or illustrative case: Build a worked example of “a compression test that distinguishes fixed-stage transfer from automatic receiver control action”, addressing this associated condition: Define input/output planes and stimulus interval, retain actual gain/attenuation/filter/detector states, and.... Define input/output planes and stimulus interval, retain actual gain/attenuation/filter/detector states, and identify transitions Source: §11.2 Compression and Gain Change (p. 6363)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a compression test that distinguishes fixed-stage transfer from automatic receiver control action”. Using “Model 11A for cubic intermodulation and intercept metrics”, specify a discriminator and the result expected under each explanation Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a compression test that distinguishes fixed-stage transfer from automatic receiver control action, including the effect of missing measurements and inconsistent operating conditions Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Scholarly synthesis and implications: Explain what the result about a compression test that distinguishes fixed-stage transfer from automatic receiver control action authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Closing: Conclude by answering “Develop a compression test that distinguishes fixed-stage transfer from automatic receiver control action” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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V011-C11-ESSAY-002. Derive the close-in coefficients of the stated two-tone odd cubic voltage law.

- Opening: Present a thesis that answers this precise question: Derive the close-in coefficients of the stated two-tone odd cubic voltage law. Identify which evidence would falsify the proposed conclusion Source: §11.7 Derive the retained spectral amplitudes (p. 6370)
- Core terminology and scope: Define close-in, coefficients, stated in the question's particular technical setting; explain how two-tone, cubic, voltage differ if that distinction would change the analysis of "Derive the close-in coefficients of the stated two-tone odd cubic voltage law" Source: §11.7 Derive the retained spectral amplitudes (p. 6370)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State loaded peak-voltage and resistance conventions, fixed coefficients, distinct frequencies, and the absence of even terms Source: §11.7 Derive the retained spectral amplitudes (p. 6370)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the close-in coefficients of the stated two-tone odd cubic voltage law to the claimed result, following "Construct the intercept from the linear asymptote"; name the intermediate states and measurable outputs Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the close-in coefficients of the stated two-tone odd cubic voltage law. Expand the self and mixed cubic terms to obtain the three-quarters

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coefficients with unequal amplitude powers Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 11A for cubic intermodulation and intercept metrics” that resolves the question about the close-in coefficients of the stated two-tone odd cubic voltage law; derive the relevant result with units and stated validity conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the close-in coefficients of the stated two-tone odd cubic voltage law. Preserve signs before power conversion and explain coincident-frequency and higher-order limitations Source: §11.7 Derive the retained spectral amplitudes (p. 6370)
- Worked application or illustrative case: Build a worked example of “the close-in coefficients of the stated two-tone odd cubic voltage law”, addressing this associated condition: State loaded peak-voltage and resistance conventions, fixed coefficients, distinct frequencies, and the.... State loaded peak-voltage and resistance conventions, fixed coefficients, distinct frequencies, and the absence of even terms Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the close-in coefficients of the stated two-tone odd cubic voltage law”. Using “Model 11A for cubic intermodulation and intercept metrics”, specify a discriminator and

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the result expected under each explanation Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the close-in coefficients of the stated two-tone odd cubic voltage law, including the effect of missing measurements and inconsistent operating conditions Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)
- Scholarly synthesis and implications: Explain what the result about the close-in coefficients of the stated two-tone odd cubic voltage law authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.7 Derive the retained spectral amplitudes (p. 6370)
- Closing: Conclude by answering “Derive the close-in coefficients of the stated two-tone odd cubic voltage law” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.7 Derive the retained spectral amplitudes (p. 6370)

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V011-C11-ESSAY-003. Derive input and output intercept formulas and explain why they use a linear asymptote and per-tone powers.

- Opening: Present a thesis that answers this precise question: Derive input and output intercept formulas and explain why they use a linear asymptote and per-tone powers. Identify which evidence would falsify the proposed conclusion Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Core terminology and scope: Define input, output, intercept in the question's particular technical setting; explain how linear, asymptote, powers differ if that distinction would change the analysis of "Derive input and output intercept formulas and explain why they use a linear asymptote and per-tone powers" Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Equate the equal-tone cubic magnitude with the linear fundamental, convert through and and obtain the logarithmic separation rules Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting input and output intercept formulas and explain why they use a linear asymptote and per-tone powers to the claimed result, following "Application 11A.4 Keep each tone separate in the intercept calculation"; name the intermediate states and measurable outputs Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for input and output intercept formulas and explain why they use a linear asymptote and per-tone powers. Distinguish extrapolated intercept from operating point Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 11A for cubic intermodulation and intercept metrics” that resolves the question about input and output intercept formulas and explain why they use a linear asymptote and per-tone powers; derive the relevant result with units and stated validity conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Evidence and method: Specify the native observations, control records and calculations that would resolve input and output intercept formulas and explain why they use a linear asymptote and per-tone powers. Show the 3.0103 dB error from total two-tone substitution and the half versus three-halves gain-correction bias Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Worked application or illustrative case: Build a worked example of “input and output intercept formulas and explain why they use a linear asymptote and per-tone powers”, addressing this associated condition: Equate the equal-tone cubic magnitude with the linear fundamental, convert through and and obtain the.... Equate the equal-tone cubic magnitude with the linear fundamental, convert

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through and and obtain the logarithmic separation rules Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “input and output intercept formulas and explain why they use a linear asymptote and per-tone powers”. Using “Model 11A for cubic intermodulation and intercept metrics”, specify a discriminator and the result expected under each explanation Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to input and output intercept formulas and explain why they use a linear asymptote and per-tone powers, including the effect of missing measurements and inconsistent operating conditions Source: §11.11 Application 11A.2 Evaluate the cubic amplitudes and extraction bias (p. 6378)
- Scholarly synthesis and implications: Explain what the result about input and output intercept formulas and explain why they use a linear asymptote and per-tone powers authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Closing: Conclude by answering “Derive input and output intercept formulas and explain why they use a linear asymptote and per-tone powers” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

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V011-C11-ESSAY-004. Design a parent-frequency and parent-power intervention for a suspected close-in cubic product.

- Opening: Present a thesis that answers this precise question: Design a parent-frequency and parent-power intervention for a suspected close-in cubic product. Identify which evidence would falsify the proposed conclusion Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Core terminology and scope: Define Design, parent-power, intervention in the question's particular technical setting; explain how suspected, cubic, product differ if that distinction would change the analysis of "Design a parent-frequency and parent-power intervention for a suspected close-in cubic product" Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Predict both product locations and their shifts when one frequency moves Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a parent-frequency and parent-power intervention for a suspected close-in cubic product to the claimed result, following "Distinguish strong-signal mechanisms through paired interventions"; name the intermediate states and measurable outputs Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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parent-frequency and parent-power intervention for a suspected close-in cubic product. Vary one parent power to distinguish unequal-tone slopes, then vary both under fixed state Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 11A.6 Test the slope over a declared power interval” that resolves the question about a parent-frequency and parent-power intervention for a suspected close-in cubic product; derive the relevant result with units and stated validity conditions Source: §11.15 Application 11A.6 Test the slope over a declared power interval (p. 6382)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a parent-frequency and parent-power intervention for a suspected close-in cubic product. Preserve detectability and source purity Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Worked application or illustrative case: Build a worked example of “a parent-frequency and parent-power intervention for a suspected close-in cubic product”, addressing this associated condition: Predict both product locations and their shifts when one frequency moves. Predict both product locations and their shifts when one frequency moves Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a parent-frequency and parent-power intervention for a suspected close-in cubic product”. Using

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"Application 11A.6 Test the slope over a declared power interval", specify a discriminator and the result expected under each explanation Source: §11.15 Application 11A.6 Test the slope over a declared power interval (p. 6382)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a parent-frequency and parent-power intervention for a suspected close-in cubic product, including the effect of missing measurements and inconsistent operating conditions Source: §11.10 Application 11A.1 Locate the products before measuring their powers (p. 6377)
- Scholarly synthesis and implications: Explain what the result about a parent-frequency and parent-power intervention for a suspected close-in cubic product authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Closing: Conclude by answering "Design a parent-frequency and parent-power intervention for a suspected close-in cubic product" using only the demonstrated evidence; state the remaining decisive verification step Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

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V011-C11-ESSAY-005. Analyze unequal parent levels without replacing them by an average.

- Opening: Present a thesis that answers this precise question: Analyze unequal parent levels without replacing them by an average. Identify which evidence would falsify the proposed conclusion Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)
- Core terminology and scope: Define unequal, parent, levels in the question's particular technical setting; explain how replacing, them, average differ if that distinction would change the analysis of "Analyze unequal parent levels without replacing them by an average" Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the separate amplitude and power laws for the two products and separate fundamental corrections Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting unequal parent levels without replacing them by an average to the claimed result, following "Construct the intercept from the linear asymptote"; name the intermediate states and measurable outputs Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for unequal parent levels without replacing them by an average. Explain how the

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stronger parent can cause a larger fractional correction of the weaker fundamental Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 11A.4 Keep each tone separate in the intercept calculation” that resolves the question about unequal parent levels without replacing them by an average; derive the relevant result with units and stated validity conditions Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Evidence and method: Specify the native observations, control records and calculations that would resolve unequal parent levels without replacing them by an average. Keep individual measured products, reference planes, and correction bounds; show why equal-tone shortcuts erase informative asymmetry Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)
- Worked application or illustrative case: Build a worked example of “unequal parent levels without replacing them by an average”, addressing this associated condition: Use the separate amplitude and power laws for the two products and separate fundamental corrections. Use the separate amplitude and power laws for the two products and separate fundamental corrections Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “unequal parent levels without replacing them by an average”. Using “Application 11A.4 Keep each tone separate in the intercept calculation”, specify a discriminator and the

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result expected under each explanation Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to unequal parent levels without replacing them by an average, including the effect of missing measurements and inconsistent operating conditions Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)
- Scholarly synthesis and implications: Explain what the result about unequal parent levels without replacing them by an average authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)
- Closing: Conclude by answering “Analyze unequal parent levels without replacing them by an average” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

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V011-C11-ESSAY-006. Explain why voltage gain and power gain differ when input and output resistances differ.

- Opening: Present a thesis that answers this precise question: Explain why voltage gain and power gain differ when input and output resistances differ. Identify which evidence would falsify the proposed conclusion Source: §11.6 Fix the voltage convention and operating domain (p. 6368)
- Core terminology and scope: Define voltage, gain, power in the question's particular technical setting; explain how differ, output, resistances differ if that distinction would change the analysis of "Explain why voltage gain and power gain differ when input and output resistances differ" Source: §11.6 Fix the voltage convention and operating domain (p. 6368)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start from delivered peak voltages and cycle-mean cosine power, derive a1 squared and evaluate the 10, 50-ohm, 200-ohm case Source: §11.6 Fix the voltage convention and operating domain (p. 6368)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why voltage gain and power gain differ when input and output resistances differ to the claimed result, following "Application 11A.5 Recover a coefficient without confusing voltage and power gain"; name the intermediate states and measurable outputs Source: §11.14 Application 11A.5 Recover a coefficient without confusing voltage and power gain (p. 6381)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why voltage gain and power gain differ when input and output resistances differ. Carry the gain into OIP3 and coefficient recovery Source: §11.14 Application 11A.5 Recover a coefficient without confusing voltage and power gain (p. 6381)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 11A.2 Evaluate the cubic amplitudes and extraction bias” that resolves the question about why voltage gain and power gain differ when input and output resistances differ; derive the relevant result with units and stated validity conditions Source: §11.11 Application 11A.2 Evaluate the cubic amplitudes and extraction bias (p. 6378)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why voltage gain and power gain differ when input and output resistances differ. Explain matching assumptions and why power-only product data cannot recover the sign of Source: §11.6 Fix the voltage convention and operating domain (p. 6368)
- Worked application or illustrative case: Build a worked example of “why voltage gain and power gain differ when input and output resistances differ”, addressing this associated condition: Start from delivered peak voltages and cycle-mean cosine power, derive a1 squared and evaluate the 10,.... Start from delivered peak voltages and cycle-mean cosine power, derive a1 squared and evaluate the 10, 50-ohm, 200-ohm case Source: §11.14 Application 11A.5 Recover a coefficient without confusing voltage and power gain (p. 6381)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “why voltage gain and power gain differ when input and output resistances differ”. Using “Application 11A.2 Evaluate the cubic amplitudes and extraction bias”, specify a discriminator and the result expected under each explanation Source: §11.11 Application 11A.2 Evaluate the cubic amplitudes and extraction bias (p. 6378)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why voltage gain and power gain differ when input and output resistances differ, including the effect of missing measurements and inconsistent operating conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Scholarly synthesis and implications: Explain what the result about why voltage gain and power gain differ when input and output resistances differ authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.6 Fix the voltage convention and operating domain (p. 6368)
- Closing: Conclude by answering “Explain why voltage gain and power gain differ when input and output resistances differ” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

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V011-C11-ESSAY-007. Compare ideal matched attenuation before and after the modeled nonlinear stage.

- Opening: Present a thesis that answers this precise question: Compare ideal matched attenuation before and after the modeled nonlinear stage. Identify which evidence would falsify the proposed conclusion Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)
- Core terminology and scope: Define ideal, matched, attenuation in the question's particular technical setting; explain how modeled, nonlinear, stage differ if that distinction would change the analysis of "Compare ideal matched attenuation before and after the modeled nonlinear stage" Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Substitute voltage transmission into linear and cubic coefficients for each location Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting ideal matched attenuation before and after the modeled nonlinear stage to the claimed result, following "Distinguish strong-signal mechanisms through paired interventions"; name the intermediate states and measurable outputs Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for ideal

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matched attenuation before and after the modeled nonlinear stage. Track fundamental/product changes, IIP3 and OIP3 reference planes, and equal overall small-signal gain Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 11A for cubic intermodulation and intercept metrics” that resolves the question about ideal matched attenuation before and after the modeled nonlinear stage; derive the relevant result with units and stated validity conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Evidence and method: Specify the native observations, control records and calculations that would resolve ideal matched attenuation before and after the modeled nonlinear stage. State the absent noise, mismatch, distortion, and control consequences that prevent claiming universal sensitivity improvement Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)
- Worked application or illustrative case: Build a worked example of “ideal matched attenuation before and after the modeled nonlinear stage”, addressing this associated condition: Substitute voltage transmission into linear and cubic coefficients for each location. Substitute voltage transmission into linear and cubic coefficients for each location Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “ideal matched attenuation before and after the modeled nonlinear stage”. Using “Model 11A for cubic

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intermodulation and intercept metrics", specify a discriminator and the result expected under each explanation Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to ideal matched attenuation before and after the modeled nonlinear stage, including the effect of missing measurements and inconsistent operating conditions Source: §11.11 Application 11A.2 Evaluate the cubic amplitudes and extraction bias (p. 6378)
- Scholarly synthesis and implications: Explain what the result about ideal matched attenuation before and after the modeled nonlinear stage authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)
- Closing: Conclude by answering "Compare ideal matched attenuation before and after the modeled nonlinear stage" using only the demonstrated evidence; state the remaining decisive verification step Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)

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V011-C11-ESSAY-008. Assess the formal relation between cubic intercept and one-decibel compression.

- Opening: Present a thesis that answers this precise question: Assess the formal relation between cubic intercept and one-decibel compression. Identify which evidence would falsify the proposed conclusion Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)
- Core terminology and scope: Define formal, relation, cubic in the question's particular technical setting; explain how intercept, one-decibel, compression differ if that distinction would change the analysis of "Assess the formal relation between cubic intercept and one-decibel compression" Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish one tone from two equal tones and per-tone from total power Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the formal relation between cubic intercept and one-decibel compression to the claimed result, following "Application 11A.4 Keep each tone separate in the intercept calculation"; name the intermediate states and measurable outputs Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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formal relation between cubic intercept and one-decibel compression. Convert one-decibel gain reduction into a voltage ratio, identify the formal powers, and compare the required correction with the five-percent working bound Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Memory-dependent intermodulation and the limits of static intercept-point inference” that resolves the question about the formal relation between cubic intercept and one-decibel compression; derive the relevant result with units and stated validity conditions Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the formal relation between cubic intercept and one-decibel compression. Explain why omitted terms and actual device behavior prevent treating the extrapolation as a receiver specification Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)
- Worked application or illustrative case: Build a worked example of “the formal relation between cubic intercept and one-decibel compression”, addressing this associated condition: Distinguish one tone from two equal tones and per-tone from total power. Distinguish one tone from two equal tones and per-tone from total power Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the formal relation between cubic intercept and one-decibel compression”. Using “Memory-dependent intermodulation and the limits of static intercept-point inference”, specify a discriminator and the result expected under each explanation Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the formal relation between cubic intercept and one-decibel compression, including the effect of missing measurements and inconsistent operating conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Scholarly synthesis and implications: Explain what the result about the formal relation between cubic intercept and one-decibel compression authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)
- Closing: Conclude by answering “Assess the formal relation between cubic intercept and one-decibel compression” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

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V011-C11-ESSAY-009. Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset.

- Opening: Present a thesis that answers this precise question: Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset. Identify which evidence would falsify the proposed conclusion Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)
- Core terminology and scope: Define Propagate, intercept, bounded in the question's particular technical setting; explain how coordinates, shared, offset differ if that distinction would change the analysis of "Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset" Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use affine logarithmic formulas and rectangular corner bounds for p, q, and s Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset to the claimed result, following "Application 11B.9 Carry hard bounds through the nonlinear noise rise"; name the intermediate states and measurable outputs Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset. Then impose a common additive output error and demonstrate cancellation from IIP3 but one surviving copy in OIP3 Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Construct the intercept from the linear asymptote” that resolves the question about Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset; derive the relevant result with units and stated validity conditions Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset. Keep hard bounds separate from coverage probabilities and justify the dependency model rather than choosing it for a smaller interval Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)
- Worked application or illustrative case: Build a worked example of “Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset”, addressing this associated condition: Use affine logarithmic formulas and rectangular corner bounds for p, q, and s. Use affine logarithmic formulas and rectangular corner bounds for p, q, and s Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset”. Using “Construct the intercept from the linear asymptote”, specify a discriminator and the result expected under each explanation Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset, including the effect of missing measurements and inconsistent operating conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Scholarly synthesis and implications: Explain what the result about Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)
- Closing: Conclude by answering “Propagate intercept uncertainty for both independent bounded coordinates and a shared output offset” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

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V011-C11-ESSAY-010. Bound a stage-generated spur when a coherent contaminating phasor is present.

- Opening: Present a thesis that answers this precise question: Bound a stage-generated spur when a coherent contaminating phasor is present. Identify which evidence would falsify the proposed conclusion Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)
- Core terminology and scope: Define Bound, spur, coherent in the question's particular technical setting; explain how contaminating, phasor, present differ if that distinction would change the analysis of "Bound a stage-generated spur when a coherent contaminating phasor is present" Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Apply triangle and reverse-triangle magnitude bounds, convert endpoints to power at the same resistance, and propagate through the decreasing dependence of intercept on product level Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Bound a stage-generated spur when a coherent contaminating phasor is present to the claimed result, following "Construct the intercept from the linear asymptote"; name the intermediate states and measurable outputs Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Bound a stage-generated spur when a coherent contaminating phasor is present. Discuss loss of a finite upper intercept bound when contamination can cancel the observed magnitude Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 11A for cubic intermodulation and intercept metrics” that resolves the question about Bound a stage-generated spur when a coherent contaminating phasor is present; derive the relevant result with units and stated validity conditions Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Bound a stage-generated spur when a coherent contaminating phasor is present. Specify source/combiner/isolation checks and reject simple incoherent subtraction Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)
- Worked application or illustrative case: Build a worked example of “Bound a stage-generated spur when a coherent contaminating phasor is present”, addressing this associated condition: Apply triangle and reverse-triangle magnitude bounds, convert endpoints to power at the same resistance, and.... Apply triangle and reverse-triangle magnitude bounds, convert endpoints to power at the same resistance, and propagate through the decreasing dependence... Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Bound a stage-generated spur when a coherent contaminating phasor is present”. Using “Model 11A for cubic intermodulation and intercept metrics”, specify a discriminator and the result expected under each explanation Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Bound a stage-generated spur when a coherent contaminating phasor is present, including the effect of missing measurements and inconsistent operating conditions Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)
- Scholarly synthesis and implications: Explain what the result about Bound a stage-generated spur when a coherent contaminating phasor is present authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)
- Closing: Conclude by answering “Bound a stage-generated spur when a coherent contaminating phasor is present” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

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V011-C11-ESSAY-011. Derive the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope.

- Opening: Present a thesis that answers this precise question: Derive the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope. Identify which evidence would falsify the proposed conclusion Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)
- Core terminology and scope: Define retained, reciprocal-mixing, spectrum in the question's particular technical setting; explain how phase-modulated, blocker, envelope differ if that distinction would change the analysis of "Derive the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope" Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define mixer-input blocker power, signed offset, real zero-mean phase process, density convention, and first-order exponential expansion Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope to the claimed result, following "Application 11B.7 Sum blockers only under an explicit cross-power condition"; name the intermediate states and measurable outputs Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope. Show spectrum translation and amplitude scaling, retaining units Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Define the phase spectrum before converting decibels” that resolves the question about the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope; derive the relevant result with units and stated validity conditions Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope. Separate direct carrier leakage and other strong-signal mechanisms, and explain why no extra sideband factor is inserted Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)
- Worked application or illustrative case: Build a worked example of “the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope”, addressing this associated condition: Define mixer-input blocker power, signed offset, real zero-mean phase process, density convention, and.... Define mixer-input blocker power, signed offset, real zero-mean phase process, density convention, and first-order exponential expansion Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope”. Using “Define the phase spectrum before converting decibels”, specify a discriminator and the result expected under each explanation Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope, including the effect of missing measurements and inconsistent operating conditions Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Scholarly synthesis and implications: Explain what the result about the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)
- Closing: Conclude by answering “Derive the retained reciprocal-mixing spectrum from the phase-modulated blocker envelope” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

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V011-C11-ESSAY-012. Construct the actual observation-channel integral and assess the flat-density shortcut.

- Opening: Present a thesis that answers this precise question: Construct the actual observation-channel integral and assess the flat-density shortcut. Identify which evidence would falsify the proposed conclusion Source: §11.30 Application 11B.3 Distinguish filter width from noise bandwidth (p. 6405)
- Core terminology and scope: Define Construct, observation-channel, integral in the question's particular technical setting; explain how flat-density, shortcut, measurement differ if that distinction would change the analysis of "Construct the actual observation-channel integral and assess the flat-density shortcut" Source: §11.30 Application 11B.3 Distinguish filter width from noise bandwidth (p. 6405)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define normalized H and W, equivalent noise bandwidth, signed translated offsets, and overlap factor Source: §11.30 Application 11B.3 Distinguish filter width from noise bandwidth (p. 6405)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the actual observation-channel integral and assess the flat-density shortcut to the claimed result, following "Integrate the channel that actually produces the reported value"; name the intermediate states and measurable outputs Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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actual observation-channel integral and assess the flat-density shortcut. Integrate linear density rather than logarithmic labels Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Define the phase spectrum before converting decibels” that resolves the question about the actual observation-channel integral and assess the flat-density shortcut; derive the relevant result with units and stated validity conditions Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the actual observation-channel integral and assess the flat-density shortcut. State exact flat-spectrum conditions, bounds for varying density, treatment of tails and lines, and the need for frequency-dependent gain when one scalar is insufficient Source: §11.30 Application 11B.3 Distinguish filter width from noise bandwidth (p. 6405)
- Worked application or illustrative case: Build a worked example of “the actual observation-channel integral and assess the flat-density shortcut”, addressing this associated condition: Define normalized H and W, equivalent noise bandwidth, signed translated offsets, and overlap factor. Define normalized H and W, equivalent noise bandwidth, signed translated offsets, and overlap factor Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the actual observation-channel integral and assess the flat-density shortcut”. Using “Define the phase

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spectrum before converting decibels", specify a discriminator and the result expected under each explanation Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the actual observation-channel integral and assess the flat-density shortcut, including the effect of missing measurements and inconsistent operating conditions Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Scholarly synthesis and implications: Explain what the result about the actual observation-channel integral and assess the flat-density shortcut authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.30 Application 11B.3 Distinguish filter width from noise bandwidth (p. 6405)
- Closing: Conclude by answering "Construct the actual observation-channel integral and assess the flat-density shortcut" using only the demonstrated evidence; state the remaining decisive verification step Source: §11.30 Application 11B.3 Distinguish filter width from noise bandwidth (p. 6405)

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V011-C11-ESSAY-013. Analyze an asymmetric channel with blockers at equal positive and negative separations.

- Opening: Present a thesis that answers this precise question: Analyze an asymmetric channel with blockers at equal positive and negative separations. Identify which evidence would falsify the proposed conclusion Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Core terminology and scope: Define asymmetric, channel, blockers in the question's particular technical setting; explain how equal, positive, negative differ if that distinction would change the analysis of "Analyze an asymmetric channel with blockers at equal positive and negative separations" Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Preserve signed blocker translation while using the even real-phase density Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an asymmetric channel with blockers at equal positive and negative separations to the claimed result, following "Application 11B.5 Preserve the sign of the blocker offset"; name the intermediate states and measurable outputs Source: §11.32 Application 11B.5 Preserve the sign of the blocker offset (p. 6407)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an

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asymmetric channel with blockers at equal positive and negative separations. Identify the different offset intervals sampled by the one-sided channel, integrate the stated local inverse-square law, and explain why a symmetric filter removes this particular asymmetry Source: §11.32 Application 11B.5 Preserve the sign of the blocker offset (p. 6407)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 11B.7 Sum blockers only under an explicit cross-power condition” that resolves the question about an asymmetric channel with blockers at equal positive and negative separations; derive the relevant result with units and stated validity conditions Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an asymmetric channel with blockers at equal positive and negative separations. Do not infer global finite variance from a local divergent law without continuation Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Worked application or illustrative case: Build a worked example of “an asymmetric channel with blockers at equal positive and negative separations”, addressing this associated condition: Preserve signed blocker translation while using the even real-phase density. Preserve signed blocker translation while using the even real-phase density Source: §11.32 Application 11B.5 Preserve the sign of the blocker offset (p. 6407)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “an asymmetric channel with blockers at equal positive and negative separations”. Using “Application 11B.7 Sum blockers only under an explicit cross-power condition”, specify a discriminator and the result expected under each explanation Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an asymmetric channel with blockers at equal positive and negative separations, including the effect of missing measurements and inconsistent operating conditions Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)
- Scholarly synthesis and implications: Explain what the result about an asymmetric channel with blockers at equal positive and negative separations authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Closing: Conclude by answering “Analyze an asymmetric channel with blockers at equal positive and negative separations” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

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V011-C11-ESSAY-014. Refer reciprocal-mixing power from an external connector through selective blocker and desired paths.

- Opening: Present a thesis that answers this precise question: Refer reciprocal-mixing power from an external connector through selective blocker and desired paths. Identify which evidence would falsify the proposed conclusion Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)
- Core terminology and scope: Define Refer, connector, selective in the question's particular technical setting; explain how blocker, desired, paths differ if that distinction would change the analysis of "Refer reciprocal-mixing power from an external connector through selective blocker and desired paths" Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify blocker transfer into the mixer and divide generated noise by desired transfer for narrow-signal external equivalence Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Refer reciprocal-mixing power from an external connector through selective blocker and desired paths to the claimed result, following "Blocking and Reciprocal Mixing"; name the intermediate states and measurable outputs Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Refer

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reciprocal-mixing power from an external connector through selective blocker and desired paths. Derive the transfer ratio and 23 dB differential example Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Convert added power into a conditional noise-rise limit” that resolves the question about Refer reciprocal-mixing power from an external connector through selective blocker and desired paths; derive the relevant result with units and stated validity conditions Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Refer reciprocal-mixing power from an external connector through selective blocker and desired paths. Explain broad-waveform weighting and why total sensitivity also requires baseline noise, mismatch, and gain-state accounting Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)
- Worked application or illustrative case: Build a worked example of “Refer reciprocal-mixing power from an external connector through selective blocker and desired paths”, addressing this associated condition: Identify blocker transfer into the mixer and divide generated noise by desired transfer for narrow-signal.... Identify blocker transfer into the mixer and divide generated noise by desired transfer for narrow-signal external equivalence Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Refer reciprocal-mixing power from an external connector through selective blocker and desired paths”. Using “Convert added power into a conditional noise-rise limit”, specify a discriminator and the result expected under each explanation Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Refer reciprocal-mixing power from an external connector through selective blocker and desired paths, including the effect of missing measurements and inconsistent operating conditions Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)
- Scholarly synthesis and implications: Explain what the result about Refer reciprocal-mixing power from an external connector through selective blocker and desired paths authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)
- Closing: Conclude by answering “Refer reciprocal-mixing power from an external connector through selective blocker and desired paths” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)

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V011-C11-ESSAY-015. Derive a permissible added-noise allocation from a total noise-rise requirement.

- Opening: Present a thesis that answers this precise question: Derive a permissible added-noise allocation from a total noise-rise requirement. Identify which evidence would falsify the proposed conclusion Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Core terminology and scope: Define permissible, added-noise, allocation in the question's particular technical setting; explain how total, noise-rise, requirement differ if that distinction would change the analysis of "Derive a permissible added-noise allocation from a total noise-rise requirement" Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State compatible baseline, gain, weighting, plane, and zero cross power Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a permissible added-noise allocation from a total noise-rise requirement to the claimed result, following "Application 11B.2 Invert a one decibel allowance"; name the intermediate states and measurable outputs Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a permissible added-noise allocation from a total noise-rise

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requirement. Invert the total-to-baseline logarithm, evaluate the one-decibel fraction, and explain why required blocker reduction differs from excess total rise Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 11B.1 Compute the added noise and its consequence” that resolves the question about a permissible added-noise allocation from a total noise-rise requirement; derive the relevant result with units and stated validity conditions Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a permissible added-noise allocation from a total noise-rise requirement. Discuss quieter versus noisier baselines and why the metric alone does not give detection probability Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Worked application or illustrative case: Build a worked example of “a permissible added-noise allocation from a total noise-rise requirement”, addressing this associated condition: State compatible baseline, gain, weighting, plane, and zero cross power. State compatible baseline, gain, weighting, plane, and zero cross power Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a permissible added-noise allocation from a total noise-rise requirement”. Using “Application 11B.1 Compute the added noise and its consequence”, specify a

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discriminator and the result expected under each explanation Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a permissible added-noise allocation from a total noise-rise requirement, including the effect of missing measurements and inconsistent operating conditions Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Scholarly synthesis and implications: Explain what the result about a permissible added-noise allocation from a total noise-rise requirement authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Closing: Conclude by answering “Derive a permissible added-noise allocation from a total noise-rise requirement” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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V011-C11-ESSAY-016. Evaluate when several blockers may be combined as powers in a reciprocal-mixing estimate.

- Opening: Present a thesis that answers this precise question: Evaluate when several blockers may be combined as powers in a reciprocal-mixing estimate. Identify which evidence would falsify the proposed conclusion Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Core terminology and scope: Define several, blockers, combined in the question's particular technical setting; explain how powers, reciprocal-mixing, estimate differ if that distinction would change the analysis of "Evaluate when several blockers may be combined as powers in a reciprocal-mixing estimate" Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State each admitted blocker power, signed offset, and weighted overlap Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting when several blockers may be combined as powers in a reciprocal-mixing estimate to the claimed result, following "Blocking and Reciprocal Mixing"; name the intermediate states and measurable outputs Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for when several blockers may be combined as powers in a reciprocal-mixing

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estimate. Require zero admitted cross powers through a justified ensemble or averaging rule Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 11B for reciprocal mixing and admitted noise” that resolves the question about when several blockers may be combined as powers in a reciprocal-mixing estimate; derive the relevant result with units and stated validity conditions Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)
- Evidence and method: Specify the native observations, control records and calculations that would resolve when several blockers may be combined as powers in a reciprocal-mixing estimate. Explain shared-LO dependence, coincident coherent carriers, and differing density offsets Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Worked application or illustrative case: Build a worked example of “when several blockers may be combined as powers in a reciprocal-mixing estimate”, addressing this associated condition: State each admitted blocker power, signed offset, and weighted overlap. State each admitted blocker power, signed offset, and weighted overlap Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “when several blockers may be combined as powers in a reciprocal-mixing estimate”. Using “Model 11B for reciprocal mixing and admitted noise”, specify a discriminator and

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the result expected under each explanation Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to when several blockers may be combined as powers in a reciprocal-mixing estimate, including the effect of missing measurements and inconsistent operating conditions Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Scholarly synthesis and implications: Explain what the result about when several blockers may be combined as powers in a reciprocal-mixing estimate authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Closing: Conclude by answering “Evaluate when several blockers may be combined as powers in a reciprocal-mixing estimate” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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V011-C11-ESSAY-017. Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution.

- Opening: Present a thesis that answers this precise question: Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution. Identify which evidence would falsify the proposed conclusion Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)
- Core terminology and scope: Define Infer, effective, density in the question's particular technical setting; explain how data, overstating, attribution differ if that distinction would change the analysis of "Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution" Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Convert both compatible output levels to watts, subtract with uncertainty, divide through fixed gain, blocker power, and justified bandwidth Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution to the claimed result, following "Use the model to design discriminating receiver observations"; name the intermediate states and measurable outputs Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution. Require unchanged baseline/state and exclude or bound stimulus phase noise, leakage, and other mechanisms Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Distinguish strong-signal mechanisms through paired interventions” that resolves the question about Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution; derive the relevant result with units and stated validity conditions Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution. Treat negative or unresolved differences appropriately and describe an aggregate effective density when attribution remains incomplete Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)
- Worked application or illustrative case: Build a worked example of “Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution”, addressing this associated condition: Convert both compatible output levels to watts, subtract with uncertainty, divide through fixed gain, blocker.... Convert both

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compatible output levels to watts, subtract with uncertainty, divide through fixed gain, blocker power, and... Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution”. Using “Distinguish strong-signal mechanisms through paired interventions”, specify a discriminator and the result expected under each explanation Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution, including the effect of missing measurements and inconsistent operating conditions Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)
- Scholarly synthesis and implications: Explain what the result about Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)
- Closing: Conclude by answering “Infer an effective phase-noise density from blocker-on and blocker-off data without overstating attribution” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)

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V011-C11-ESSAY-018. Carry deterministic input bounds through the nonlinear noise-rise calculation.

- Opening: Present a thesis that answers this precise question: Carry deterministic input bounds through the nonlinear noise-rise calculation. Identify which evidence would falsify the proposed conclusion Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Core terminology and scope: Define Carry, deterministic, input in the question's particular technical setting; explain how bounds, nonlinear, calculation differ if that distinction would change the analysis of "Carry deterministic input bounds through the nonlinear noise-rise calculation" Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the feasible set and distinguish rectangular freedom from statistical independence Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Carry deterministic input bounds through the nonlinear noise-rise calculation to the claimed result, following "Convert added power into a conditional noise-rise limit"; name the intermediate states and measurable outputs Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Carry

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deterministic input bounds through the nonlinear noise-rise calculation. Use monotonic extrema for added power and combine largest added with smallest baseline for maximum rise Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 11B.2 Invert a one decibel allowance” that resolves the question about Carry deterministic input bounds through the nonlinear noise-rise calculation; derive the relevant result with units and stated validity conditions Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Carry deterministic input bounds through the nonlinear noise-rise calculation. Explain how justified dependencies could narrow the interval and why a hard enclosure has no automatic confidence percentage Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Worked application or illustrative case: Build a worked example of “Carry deterministic input bounds through the nonlinear noise-rise calculation”, addressing this associated condition: Define the feasible set and distinguish rectangular freedom from statistical independence. Define the feasible set and distinguish rectangular freedom from statistical independence Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Carry deterministic input bounds through the nonlinear noise-rise calculation”. Using “Application

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11B.2 Invert a one decibel allowance", specify a discriminator and the result expected under each explanation Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Carry deterministic input bounds through the nonlinear noise-rise calculation, including the effect of missing measurements and inconsistent operating conditions Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)
- Scholarly synthesis and implications: Explain what the result about Carry deterministic input bounds through the nonlinear noise-rise calculation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)
- Closing: Conclude by answering "Carry deterministic input bounds through the nonlinear noise-rise calculation" using only the demonstrated evidence; state the remaining decisive verification step Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

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V011-C11-ESSAY-019. Explain the separate assumptions at each stage of the omitted-phase-term bound.

- Opening: Present a thesis that answers this precise question: Explain the separate assumptions at each stage of the omitted-phase-term bound. Identify which evidence would falsify the proposed conclusion Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)
- Core terminology and scope: Define separate, assumptions, stage in the question's particular technical setting; explain how omitted-phase-term, bound, measurement differ if that distinction would change the analysis of "Explain the separate assumptions at each stage of the omitted-phase-term bound" Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish pointwise remainder, expected square requiring a fourth moment, retained linear WSS spectrum, Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the separate assumptions at each stage of the omitted-phase-term bound to the claimed result, following "Application 11A.10 Bound a coherent contaminating product"; name the intermediate states and measurable outputs Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the separate assumptions at each stage of the omitted-phase-term bound. Retain W no greater than one, unknown cross power, and the Gaussian marginal moment only where invoked Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Define the phase spectrum before converting decibels” that resolves the question about the separate assumptions at each stage of the omitted-phase-term bound; derive the relevant result with units and stated validity conditions Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the separate assumptions at each stage of the omitted-phase-term bound. Explain why small global RMS alone need not yield a useful selected-channel error bound Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)
- Worked application or illustrative case: Build a worked example of “the separate assumptions at each stage of the omitted-phase-term bound”, addressing this associated condition: Distinguish pointwise remainder, expected square requiring a fourth moment, retained linear WSS spectrum,. Distinguish pointwise remainder, expected square requiring a fourth moment, retained linear WSS spectrum, Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the separate assumptions at each stage of the omitted-phase-term bound”. Using “Define the phase spectrum before converting decibels”, specify a discriminator and the result expected under each explanation Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the separate assumptions at each stage of the omitted-phase-term bound, including the effect of missing measurements and inconsistent operating conditions Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Scholarly synthesis and implications: Explain what the result about the separate assumptions at each stage of the omitted-phase-term bound authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)
- Closing: Conclude by answering “Explain the separate assumptions at each stage of the omitted-phase-term bound” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

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V011-C11-ESSAY-020. Design paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization.

- Opening: Present a thesis that answers this precise question: Design paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization. Identify which evidence would falsify the proposed conclusion Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Core terminology and scope: Define Design, paired, interventions in the question's particular technical setting; explain how cubic, reciprocal, desensitization differ if that distinction would change the analysis of "Design paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization" Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Choose parent-frequency movement, blocker-power/offset changes, and controlled weak-probe response as distinct tests Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization to the claimed result, following "Measure compression without confusing it with control action"; name the intermediate states and measurable outputs Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization. Hold or record relevant gain and weighting states, characterize preselector transfer, and examine recovery Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Blocking and Reciprocal Mixing” that resolves the question about paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization; derive the relevant result with units and stated validity conditions Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Evidence and method: Specify the native observations, control records and calculations that would resolve paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization. Preserve alternative mechanisms where predictions fail rather than force one explanation from a lower floor or apparent slope Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Worked application or illustrative case: Build a worked example of “paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization”, addressing this associated condition: Choose parent-frequency movement, blocker-power/offset changes, and controlled weak-probe response as.... Choose parent-frequency movement, blocker-power/offset changes,

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and controlled weak-probe response as distinct tests Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization”. Using “Blocking and Reciprocal Mixing”, specify a discriminator and the result expected under each explanation Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization, including the effect of missing measurements and inconsistent operating conditions Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)
- Scholarly synthesis and implications: Explain what the result about paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Closing: Conclude by answering “Design paired interventions to distinguish cubic products, reciprocal mixing, and control-induced desensitization” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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V011-C11-ESSAY-021. Build an operational acceptance matrix for a receiver with an external preamplifier and splitter.

- Opening: Present a thesis that answers this precise question: Build an operational acceptance matrix for a receiver with an external preamplifier and splitter. Identify which evidence would falsify the proposed conclusion Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Core terminology and scope: Define Build, acceptance, matrix in the question's particular technical setting; explain how external, preamplifier, splitter differ if that distinction would change the analysis of "Build an operational acceptance matrix for a receiver with an external preamplifier and splitter" Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Include weak reference classes, blocker levels/spacings/modulation, band edges, installed paths, gain/preselection states, and recovery intervals Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Build an operational acceptance matrix for a receiver with an external preamplifier and splitter to the claimed result, following "Measure compression without confusing it with control action"; name the intermediate states and measurable outputs Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Build an

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operational acceptance matrix for a receiver with an external preamplifier and splitter. Test actual deployed configurations and define transitions or limitations Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Dynamic Range Is a Family of Conditions” that resolves the question about Build an operational acceptance matrix for a receiver with an external preamplifier and splitter; derive the relevant result with units and stated validity conditions Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Build an operational acceptance matrix for a receiver with an external preamplifier and splitter. Retain parent/product families and encode band-specific procedural requirements without extrapolating one catalog number Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Worked application or illustrative case: Build a worked example of “Build an operational acceptance matrix for a receiver with an external preamplifier and splitter”, addressing this associated condition: Include weak reference classes, blocker levels/spacings/modulation, band edges, installed paths,.... Include weak reference classes, blocker levels/spacings/modulation, band edges, installed paths, gain/preselection states, and recovery intervals Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Build an operational acceptance matrix for a receiver with an external preamplifier and splitter”. Using “Dynamic Range Is a Family of Conditions”, specify a discriminator and the result expected under each explanation Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Build an operational acceptance matrix for a receiver with an external preamplifier and splitter, including the effect of missing measurements and inconsistent operating conditions Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)
- Scholarly synthesis and implications: Explain what the result about Build an operational acceptance matrix for a receiver with an external preamplifier and splitter authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Closing: Conclude by answering “Build an operational acceptance matrix for a receiver with an external preamplifier and splitter” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

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V011-C11-ESSAY-022. Derive the simplified equal-tone third-order spurious-free range and identify its failure boundaries.

- Opening: Present a thesis that answers this precise question: Derive the simplified equal-tone third-order spurious-free range and identify its failure boundaries. Identify which evidence would falsify the proposed conclusion Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Core terminology and scope: Define simplified, third-order, spurious-free in the question's particular technical setting; explain how range, failure, boundaries differ if that distinction would change the analysis of "Derive the simplified equal-tone third-order spurious-free range and identify its failure boundaries" Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Refer IIP3 and integrated noise to the same input plane and compatible bandwidth Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the simplified equal-tone third-order spurious-free range and identify its failure boundaries to the claimed result, following "Memory-dependent intermodulation and the limits of static intercept-point inference"; name the intermediate states and measurable outputs Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the simplified equal-tone third-order spurious-free range and identify its failure boundaries. Set the cubic product level 3p-2I equal to noise N, solve for p, and subtract N Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Dynamic Range Is a Family of Conditions” that resolves the question about the simplified equal-tone third-order spurious-free range and identify its failure boundaries; derive the relevant result with units and stated validity conditions Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the simplified equal-tone third-order spurious-free range and identify its failure boundaries. Check the characterized cubic interval and tighter compression, phase-noise, spur, or decision-margin limits Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Worked application or illustrative case: Build a worked example of “the simplified equal-tone third-order spurious-free range and identify its failure boundaries”, addressing this associated condition: Refer IIP3 and integrated noise to the same input plane and compatible bandwidth. Refer IIP3 and integrated noise to the same input plane and compatible bandwidth Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the simplified equal-tone third-order spurious-free range and identify its failure boundaries”. Using “Dynamic Range Is a Family of Conditions”, specify a discriminator and the result expected under each explanation Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the simplified equal-tone third-order spurious-free range and identify its failure boundaries, including the effect of missing measurements and inconsistent operating conditions Source: §11.11 Application 11A.2 Evaluate the cubic amplitudes and extraction bias (p. 6378)
- Scholarly synthesis and implications: Explain what the result about the simplified equal-tone third-order spurious-free range and identify its failure boundaries authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)
- Closing: Conclude by answering “Derive the simplified equal-tone third-order spurious-free range and identify its failure boundaries” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

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V011-C11-ESSAY-023. Assess a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering.

- Opening: Present a thesis that answers this precise question: Assess a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering. Identify which evidence would falsify the proposed conclusion Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)
- Core terminology and scope: Define field, detection, restored in the question's particular technical setting; explain how preamplifier, removal, filtering differ if that distinction would change the analysis of "Assess a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering" Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Document before/after source, reference, chain, gain, and capability Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering to the claimed result, following "Dynamic-Range Acceptance Matrix"; name the intermediate states and measurable outputs Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a field

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observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering. Explain the demonstrated desensitization of the original configuration while distinguishing which individual change remains causally unresolved if both changed Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Memory-dependent intermodulation and the limits of static intercept-point inference” that resolves the question about a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering; derive the relevant result with units and stated validity conditions Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering. Require a suitable reference and state limits on environmental absence and transfer to other bands Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)
- Worked application or illustrative case: Build a worked example of “a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering”, addressing this associated condition: Document before/after source, reference, chain, gain, and capability. Document before/after source, reference, chain, gain, and capability Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering”. Using “Memory-dependent intermodulation and the limits of static intercept-point inference”, specify a discriminator and the result expected under each explanation Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering, including the effect of missing measurements and inconsistent operating conditions Source: §11.2 Compression and Gain Change (p. 6363)
- Scholarly synthesis and implications: Explain what the result about a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)
- Closing: Conclude by answering “Assess a field observation whose weak-reference detection is restored by preamplifier removal and high-pass filtering” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

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V011-C11-ESSAY-024. Explain why a small measured intermodulation product can conceal a larger underlying stage contribution.

- Opening: Present a thesis that answers this precise question: Explain why a small measured intermodulation product can conceal a larger underlying stage contribution. Identify which evidence would falsify the proposed conclusion Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Core terminology and scope: Define intermodulation, conceal, larger in the question's particular technical setting; explain how underlying, stage, contribution differ if that distinction would change the analysis of "Explain why a small measured intermodulation product can conceal a larger underlying stage contribution" Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use coherent phasor cancellation and uncertainty about source/combiner/receiver products, retaining reference phase and planes Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a small measured intermodulation product can conceal a larger underlying stage contribution to the claimed result, following "Application 11A.10 Bound a coherent contaminating product"; name the intermediate states and measurable outputs Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a small measured intermodulation product can conceal a larger underlying stage contribution. Contrast a power-only reading with signed or controlled path evidence Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Construct the intercept from the linear asymptote” that resolves the question about why a small measured intermodulation product can conceal a larger underlying stage contribution; derive the relevant result with units and stated validity conditions Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a small measured intermodulation product can conceal a larger underlying stage contribution. Explain the consequence for intercept bounds and why more averaging does not necessarily remove deterministic contamination Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Worked application or illustrative case: Build a worked example of “why a small measured intermodulation product can conceal a larger underlying stage contribution”, addressing this associated condition: Use coherent phasor cancellation and uncertainty about source/combiner/receiver products, retaining reference.... Use coherent phasor cancellation and uncertainty about source/combiner/receiver products, retaining reference phase and

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planes Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a small measured intermodulation product can conceal a larger underlying stage contribution”. Using “Construct the intercept from the linear asymptote”, specify a discriminator and the result expected under each explanation Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a small measured intermodulation product can conceal a larger underlying stage contribution, including the effect of missing measurements and inconsistent operating conditions Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)
- Scholarly synthesis and implications: Explain what the result about why a small measured intermodulation product can conceal a larger underlying stage contribution authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)
- Closing: Conclude by answering “Explain why a small measured intermodulation product can conceal a larger underlying stage contribution” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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V011-C11-ESSAY-025. Write a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity.

- Opening: Present a thesis that answers this precise question: Write a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity. Identify which evidence would falsify the proposed conclusion Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Core terminology and scope: Define release, findings, remain in the question's particular technical setting; explain how useful, universal, immunity differ if that distinction would change the analysis of "Write a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity" Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Tie each finding to signal class, bandwidth, reference planes, gain/filter states, blockers, and recovery Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity to the claimed result, following "Dynamic Range Is a Family of Conditions"; name the intermediate states and measurable outputs Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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release justification for dynamic-range findings that remain useful without claiming universal receiver immunity. State which local model was tested and what alternatives remain Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture” that resolves the question about a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity; derive the relevant result with units and stated validity conditions Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity. Preserve raw/reference observations, uncertainty and exclusions, and translate demonstrated limits into procedures for credible weak observations Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Worked application or illustrative case: Build a worked example of “a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity”, addressing this associated condition: Tie each finding to signal class, bandwidth, reference planes, gain/filter states, blockers, and recovery. Tie each finding to signal class, bandwidth, reference planes, gain/filter states, blockers, and recovery Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity”. Using “Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture”, specify a discriminator and the result expected under each explanation Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity, including the effect of missing measurements and inconsistent operating conditions Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)
- Scholarly synthesis and implications: Explain what the result about a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Closing: Conclude by answering “Write a release justification for dynamic-range findings that remain useful without claiming universal receiver immunity” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C11-DISCUSSION-001. Two suppliers quote different dynamic-range definitions. How should a survey team compare them?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two suppliers quote different dynamic-range definitions. How should a survey team compare them?” Put this particular dispute to the panel: Two suppliers quote different dynamic-range definitions. How should a survey team compare them. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 02. Student A, terminology and scope: Agree the operational meanings of suppliers, quote, dynamic-range and definitions, survey, them in “Two suppliers quote different dynamic-range definitions. How should a survey team compare them”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two suppliers quote different dynamic-range definitions; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Dynamic-Range Acceptance Matrix”. Then compare relevant installed configurations with weak references and blockers Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two suppliers quote different dynamic-range definitions; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Dynamic-Range Acceptance Matrix”. Then compare relevant installed configurations with weak references and blockers Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. First align lower/upper limits, bandwidth, detector, spacing, signal class, and reference planes Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two suppliers quote different dynamic-range definitions: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two suppliers quote different dynamic-range definitions; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two suppliers quote different dynamic-range definitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two suppliers quote different dynamic-range definitions, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two suppliers quote different dynamic-range definitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two suppliers quote different dynamic-range definitions. The largest number alone cannot rank capability for the actual task Explain the relevant statistical or calibration

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uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two suppliers quote different dynamic-range definitions, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two suppliers quote different dynamic-range definitions. The largest number alone cannot rank capability for the actual task Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two suppliers quote different dynamic-range definitions and How should a survey team compare them; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two suppliers quote different dynamic-range definitions”, addressing “How should a survey team compare them”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two suppliers quote different dynamic-range definitions. How should a survey team compare them”, specifying

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the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two suppliers quote different dynamic-range definitions. How should a survey team compare them”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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V011-C11-DISCUSSION-002. An operator wants to stop compression testing because no overload icon appeared. What should a reviewer ask for?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An operator wants to stop compression testing because no overload icon appeared. What should a reviewer ask for?” Put this particular dispute to the panel: An operator wants to stop compression testing because no overload icon appeared. What should a reviewer ask for. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 02. Student A, terminology and scope: Agree the operational meanings of operator, wants, compression and testing, overload, reviewer in “An operator wants to stop compression testing because no overload icon appeared. What should a reviewer ask for”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An operator wants to stop compression testing because no overload icon appeared; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.2 Compression and Gain Change (p. 6363)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Compression and Gain Change”. An icon is one observation and may not mark every relevant error Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.2 Compression and Gain Change (p. 6363)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An operator wants to stop compression testing because no overload icon appeared; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Compression and Gain Change”. An icon is one observation and may not mark every relevant error Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.2 Compression and Gain Change (p. 6363)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Request desired gain, weak-probe criterion, noise/product response, actual control states, and recovery under the intended stimulus Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An operator wants to stop compression testing because no overload icon appeared: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An operator wants to stop compression testing because no overload icon appeared; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An operator wants to stop compression testing because no overload icon appeared: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An operator wants to stop compression testing because no overload icon appeared, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.2 Compression and Gain Change (p. 6363)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An operator wants to stop compression testing because no overload icon appeared: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An operator wants to stop compression testing because no overload icon appeared. Keep a bounded conclusion tied to demonstrated capability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An operator wants to stop compression testing because no overload icon appeared, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.2 Compression and Gain Change (p. 6363)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An operator wants to stop compression testing because no overload icon appeared. Keep a bounded conclusion

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tied to demonstrated capability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An operator wants to stop compression testing because no overload icon appeared and What should a reviewer ask for; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An operator wants to stop compression testing because no overload icon appeared”, addressing “What should a reviewer ask for”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An operator wants to stop compression testing because no overload icon appeared. What should a reviewer ask for”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An operator wants to stop compression testing because no overload icon appeared. What should a reviewer ask for”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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V011-C11-DISCUSSION-003. A gain curve has several smooth knees that coincide with AGC transitions. Can it be called one stage's compression characteristic?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A gain curve has several smooth knees that coincide with AGC transitions. Can it be called one stage's compression characteristic?” Put this particular dispute to the panel: A gain curve has several smooth knees that coincide with AGC transitions. Can it be called one stage's compression characteristic. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 02. Student A, terminology and scope: Agree the operational meanings of curve, smooth, coincide and transitions, called, characteristic in “A gain curve has several smooth knees that coincide with AGC transitions. Can it be called one stage's compression characteristic”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A gain curve has several smooth knees that coincide with AGC transitions; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 11A.7 Compare attenuation before and after the nonlinear stage”. Discuss whether the operational question concerns automatic behavior or local stage nonlinearity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A gain curve has several smooth knees that coincide with AGC transitions; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 11A.7 Compare attenuation before and after the nonlinear stage”. Discuss whether the operational question concerns automatic behavior or local stage nonlinearity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate closed-loop behavior from fixed-state transfer and retain the transition record Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A gain curve has several smooth knees that coincide with AGC transitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A gain curve has several smooth knees that coincide with AGC transitions; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A gain curve has several smooth knees that coincide with AGC transitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A gain curve has several smooth knees that coincide with AGC transitions, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A gain curve has several smooth knees that coincide with AGC

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transitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A gain curve has several smooth knees that coincide with AGC transitions. Do not fit one polynomial slope across states without evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A gain curve has several smooth knees that coincide with AGC transitions, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A gain curve has several smooth knees that coincide with AGC transitions. Do not fit one polynomial slope across states without evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A gain curve has several smooth knees that coincide with AGC transitions and Can it be called one stage's compression characteristic; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A gain curve has several smooth knees that coincide with AGC transitions”, addressing “Can it be called one stage's compression characteristic”; specify the exact measurement

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or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A gain curve has several smooth knees that coincide with AGC transitions. Can it be called one stage's compression characteristic”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A gain curve has several smooth knees that coincide with AGC transitions. Can it be called one stage's compression characteristic”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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V011-C11-DISCUSSION-004. A product tracks a predicted parent-frequency change. How far should the source-location claim go?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A product tracks a predicted parent-frequency change. How far should the source-location claim go?” Put this particular dispute to the panel: A product tracks a predicted parent-frequency change. How far should the source-location claim go. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 02. Student A, terminology and scope: Agree the operational meanings of product, tracks, predicted and parent-frequency, source-location, claim in “A product tracks a predicted parent-frequency change. How far should the source-location claim go”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A product tracks a predicted parent-frequency change; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Intermodulation and Intercept Metrics”. Receiver, source, combiner, or external nonlinear contacts can share the frequency relation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A product tracks a predicted parent-frequency change; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Intermodulation and Intercept Metrics”. Receiver, source, combiner, or external nonlinear contacts can share the frequency relation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Recognize compatibility with the association, then test candidate generating paths under comparable detectability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A product tracks a predicted parent-frequency

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change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A product tracks a predicted parent-frequency change; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A product tracks a predicted parent-frequency change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A product tracks a predicted parent-frequency change, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A product tracks a predicted parent-frequency change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A product tracks a predicted parent-

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frequency change. Preserve alternatives until an intervention discriminates them Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A product tracks a predicted parent-frequency change, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A product tracks a predicted parent-frequency change. Preserve alternatives until an intervention discriminates them Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A product tracks a predicted parent-frequency change and How far should the source-location claim go; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.16 Application 11A.7 Compare attenuation before and after the nonlinear stage (p. 6383)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A product tracks a predicted parent-frequency change”, addressing “How far should the source-location claim go”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A product tracks a predicted parent-frequency change. How far should the source-location claim go”, specifying the

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next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A product tracks a predicted parent-frequency change. How far should the source-location claim go”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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V011-C11-DISCUSSION-005. Should the team combine two unequal parent levels into one average before reporting IIP3?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should the team combine two unequal parent levels into one average before reporting IIP3?” Put this particular dispute to the panel: Should the team combine two unequal parent levels into one average before reporting IIP3. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 02. Student A, terminology and scope: Agree the operational meanings of combine, unequal, parent and average, reporting, IIP3 in “Should the team combine two unequal parent levels into one average before reporting IIP3”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether the team combine two unequal parent levels into one average before reporting IIP3; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 11A.4 Keep each tone separate in the intercept calculation”. If an equal-tone metric is desired, establish that test condition explicitly Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether the team combine two unequal parent levels into one average before reporting IIP3;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 11A.4 Keep each tone separate in the intercept calculation”. If an equal-tone metric is desired, establish that test condition explicitly Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss the unequal product laws and separate low/high results Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether the team combine two unequal parent levels into one average before reporting IIP3: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether the team combine two unequal parent levels into one average before reporting IIP3; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether the team combine two unequal parent levels into one average before reporting IIP3: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether the team combine two unequal parent levels into one average before reporting IIP3, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether the team combine two unequal parent levels into one average before reporting IIP3: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether the team combine two unequal parent levels into one average before reporting IIP3. Avoid using averaged logs or total powers to conceal asymmetry or imply a convention not actually measured Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether the team combine two unequal parent levels into one average before reporting IIP3, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether the team combine two unequal parent levels into one average before reporting IIP3. Avoid using averaged logs or total powers to conceal asymmetry or imply a convention not actually measured Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether the team combine two unequal parent levels into one average before reporting IIP3 and Discuss the unequal product laws and separate low/high results; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether the team combine two unequal

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parent levels into one average before reporting IIP3", addressing "Discuss the unequal product laws and separate low/high results"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Should the team combine two unequal parent levels into one average before reporting IIP3", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Should the team combine two unequal parent levels into one average before reporting IIP3". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

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V011-C11-DISCUSSION-006. A small spur gives an attractive intercept number, but source isolation is weak. Is the result conservative?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A small spur gives an attractive intercept number, but source isolation is weak. Is the result conservative?” Put this particular dispute to the panel: A small spur gives an attractive intercept number, but source isolation is weak. Is the result conservative. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 02. Student A, terminology and scope: Agree the operational meanings of spur, attractive, intercept and number, isolation, conservative in “A small spur gives an attractive intercept number, but source isolation is weak. Is the result conservative”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A small spur gives an attractive intercept number, but source isolation is weak; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. Require phasor bounds or controlled isolation evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A small spur gives an attractive intercept number, but source isolation is weak; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change

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your opinion. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. Require phasor bounds or controlled isolation evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain that coherent contamination can either reinforce or cancel the stage contribution, so a small observed spur need not be conservative Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A small spur gives an attractive intercept

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number, but source isolation is weak: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A small spur gives an attractive intercept number, but source isolation is weak; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A small spur gives an attractive intercept number, but source isolation is weak: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A small spur gives an attractive intercept number, but source isolation is weak, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A small spur gives an attractive intercept number, but source isolation is weak: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A small spur gives an attractive intercept number, but source isolation is weak. Report the resulting interval and nonidentifiability rather than the preferred point estimate alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A small spur gives an attractive intercept number, but source isolation is weak, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A small spur gives an attractive intercept number, but source isolation is weak. Report the resulting interval and nonidentifiability rather than the preferred point estimate alone Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A small spur gives an attractive intercept number, but source isolation is weak and Is the result conservative; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A small spur gives an attractive intercept number, but source isolation is weak”, addressing “Is the result conservative”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A small spur gives an attractive intercept number, but source isolation is weak. Is the result conservative”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A small spur gives an attractive intercept number, but source isolation is weak. Is the result conservative”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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V011-C11-DISCUSSION-007. An input attenuator improves the apparent product separation but weak-reference detection worsens. Is the observation inconsistent?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An input attenuator improves the apparent product separation but weak-reference detection worsens. Is the observation inconsistent?” Put this particular dispute to the panel: An input attenuator improves the apparent product separation but weak-reference detection worsens. Is the observation inconsistent. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 02. Student A, terminology and scope: Agree the operational meanings of attenuator, improves, apparent and separation, detection, inconsistent in “An input attenuator improves the apparent product separation but weak-reference detection worsens. Is the observation inconsistent”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An input attenuator improves the apparent product separation but weak-reference detection worsens; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture”. Record state, transfer, and baseline and compare the actual detection criterion Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of An input attenuator improves the apparent product separation but weak-reference detection worsens; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture”. Record state, transfer, and baseline and compare the actual detection criterion Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate nonlinear drive reduction from noise and desired-signal loss Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An input attenuator improves the apparent product separation but weak-reference detection worsens: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An input attenuator improves the apparent product separation but weak-reference detection worsens; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An input attenuator improves the apparent product separation but weak-reference detection worsens: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An input attenuator improves the apparent product separation but weak-reference detection worsens, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An input attenuator improves the apparent product separation but weak-reference detection worsens: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An input attenuator improves the apparent product separation but weak-reference detection worsens. A higher input-referred intercept does not automatically improve all useful dynamic-range measures Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An input attenuator improves the apparent product separation but weak-reference detection worsens, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An input attenuator improves the apparent product separation but weak-reference detection worsens. A higher input-referred intercept does not automatically improve all useful dynamic-range measures Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An input attenuator improves the apparent product separation but weak-reference detection worsens and Is the observation inconsistent; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An input attenuator improves the apparent product separation but weak-reference detection

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worsens", addressing "Is the observation inconsistent"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "An input attenuator improves the apparent product separation but weak-reference detection worsens. Is the observation inconsistent", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "An input attenuator improves the apparent product separation but weak-reference detection worsens. Is the observation inconsistent". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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V011-C11-DISCUSSION-008. The formal cubic compression calculation lies beyond the working domain. Should it be removed or treated as measured performance?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The formal cubic compression calculation lies beyond the working domain. Should it be removed or treated as measured performance?” Put this particular dispute to the panel: The formal cubic compression calculation lies beyond the working domain. Should it be removed or treated as measured performance. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 02. Student A, terminology and scope: Agree the operational meanings of formal, cubic, working and domain, removed, treated in “The formal cubic compression calculation lies beyond the working domain. Should it be removed or treated as measured performance”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The formal cubic compression calculation lies beyond the working domain; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 11A for cubic intermodulation and intercept metrics”. Distinguish it from an acceptance test or operating recommendation, and explain the additional terms and measurements needed for actual compression behavior Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The formal cubic compression calculation lies beyond the working domain; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 11A for cubic intermodulation and intercept metrics”. Distinguish it from an acceptance test or operating recommendation, and explain the additional terms and measurements needed for actual compression behavior Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Keep it as the explicitly bounded teaching extrapolation that demonstrates a limitation Put two specific questions to Student D about the stated

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competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The formal cubic compression calculation lies beyond the working domain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The formal cubic compression calculation lies beyond the working domain; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The formal cubic compression calculation lies beyond the working domain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The formal cubic compression calculation lies beyond the working domain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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The formal cubic compression calculation lies beyond the working domain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The formal cubic compression calculation lies beyond the working domain. Distinguish it from an acceptance test or operating recommendation, and explain the additional terms and measurements needed for actual compression behavior Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The formal cubic compression calculation lies beyond the working domain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The formal cubic compression calculation lies beyond the working domain. Distinguish it from an acceptance test or operating recommendation, and explain the additional terms and measurements needed for actual compression behavior Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The formal cubic compression calculation lies beyond the working domain and Should it be removed or treated as measured performance; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The formal cubic compression calculation lies beyond the working domain”, addressing “Should it be removed or treated as measured performance”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The formal cubic compression calculation lies beyond the working domain. Should it be removed or treated as measured performance”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The formal cubic compression calculation lies beyond the working domain. Should it be removed or treated as measured performance”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

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V011-C11-DISCUSSION-009. Two calibration errors have identical numerical limits. Can reviewers treat them as one common offset to obtain a tighter bound?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two calibration errors have identical numerical limits. Can reviewers treat them as one common offset to obtain a tighter bound?” Put this particular dispute to the panel: Two calibration errors have identical numerical limits. Can reviewers treat them as one common offset to obtain a tighter bound. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 02. Student A, terminology and scope: Agree the operational meanings of errors, identical, numerical and limits, treat, obtain in “Two calibration errors have identical numerical limits. Can reviewers treat them as one common offset to obtain a tighter bound”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two calibration errors have identical numerical limits; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. Similar labels alone do not establish common error Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two calibration errors have identical numerical limits; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. Similar labels alone do not establish common error Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require evidence of a shared physical/calibration dependency Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two calibration errors have identical numerical

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limits: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two calibration errors have identical numerical limits; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two calibration errors have identical numerical limits: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two calibration errors have identical numerical limits, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two calibration errors have identical numerical limits: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two calibration errors have identical

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numerical limits. Compare the feasible sets and retain a defensible bound without assigning an unsupported probability or cancellation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two calibration errors have identical numerical limits, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two calibration errors have identical numerical limits. Compare the feasible sets and retain a defensible bound without assigning an unsupported probability or cancellation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two calibration errors have identical numerical limits and Can reviewers treat them as one common offset to obtain a tighter bound; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two calibration errors have identical numerical limits”, addressing “Can reviewers treat them as one common offset to obtain a tighter bound”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two calibration errors have identical numerical limits. Can reviewers treat them as one common offset to obtain a tighter bound”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two calibration errors have identical numerical limits. Can reviewers treat them as one common offset to obtain a tighter bound”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

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V011-C11-DISCUSSION-010. A blocker raises the floor but produces no visible close-in discrete products. Which mechanisms remain plausible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A blocker raises the floor but produces no visible close-in discrete products. Which mechanisms remain plausible?” Put this particular dispute to the panel: A blocker raises the floor but produces no visible close-in discrete products. Which mechanisms remain plausible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 02. Student A, terminology and scope: Agree the operational meanings of raises, floor, produces and visible, discrete, mechanisms in “A blocker raises the floor but produces no visible close-in discrete products. Which mechanisms remain plausible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A blocker raises the floor but produces no visible close-in discrete products; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Use controlled weak probes and blocker offset/level changes Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A blocker raises the floor but produces no visible close-in discrete products; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Use controlled weak probes and blocker offset/level changes Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider reciprocal mixing, source phase noise, gain/control changes, direct leakage, ADC occupation, and other broadband effects Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A blocker raises the floor but produces no visible close-in discrete products: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A blocker raises the floor but produces no visible close-in discrete products; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A blocker raises the floor but produces no visible close-in discrete products: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A blocker raises the floor but produces no visible close-in discrete products, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A blocker raises the floor but produces no visible close-in discrete products: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A blocker raises the floor but produces no visible close-in discrete products. Absence of one product family does not establish one alternative uniquely Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A blocker raises the floor but produces no visible close-in discrete products, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A blocker raises the floor but produces no visible close-in discrete products. Absence of one product family does not establish one alternative uniquely Respond point by point

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to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A blocker raises the floor but produces no visible close-in discrete products and Which mechanisms remain plausible; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A blocker raises the floor but produces no visible close-in discrete products”, addressing “Which mechanisms remain plausible”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A blocker raises the floor but produces no visible close-in discrete products. Which mechanisms remain plausible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A blocker raises the floor but produces no visible close-in discrete products. Which mechanisms remain plausible”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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V011-C11-DISCUSSION-011. Should a catalog LO phase-noise value at one offset be used across a wide observation channel?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a catalog LO phase-noise value at one offset be used across a wide observation channel?” Put this particular dispute to the panel: Should a catalog LO phase-noise value at one offset be used across a wide observation channel. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 02. Student A, terminology and scope: Agree the operational meanings of catalog, value, offset and used, wide, observation in “Should a catalog LO phase-noise value at one offset be used across a wide observation channel”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether a catalog LO phase-noise value at one offset be used across a wide observation channel; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Define the phase spectrum before converting decibels”. Use an integral or justified envelope Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a catalog LO phase-noise value at one offset be used across a wide observation channel; explain what each record can establish State what the existing

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record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Define the phase spectrum before converting decibels”. Use an integral or justified envelope Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Assess spectral variation over every weighted offset, actual LO path, filter response, and omitted tails or lines Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a catalog LO phase-noise value at one

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offset be used across a wide observation channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a catalog LO phase-noise value at one offset be used across a wide observation channel; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a catalog LO phase-noise value at one offset be used across a wide observation channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable,

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expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a catalog LO phase-noise value at one offset be used across a wide observation channel, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a catalog LO phase-noise value at one offset be used across a wide observation channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a catalog LO phase-noise value at one offset be used across a wide observation channel. A convenient center value is an exact shortcut only under its flat-density condition Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a catalog LO phase-noise value at one offset be used across a wide observation channel, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a catalog LO phase-noise value at one offset be used across a wide observation channel. A convenient

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center value is an exact shortcut only under its flat-density condition Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a catalog LO phase-noise value at one offset be used across a wide observation channel and Assess spectral variation over every weighted offset, actual LO path, filter response, and omitted tails or…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a catalog LO phase-noise value at one offset be used across a wide observation channel”, addressing “Assess spectral variation over every weighted offset, actual LO path, filter response, and omitted tails or…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a catalog LO phase-noise value at one offset be used across a wide observation channel”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a catalog LO phase-noise value at one offset be used across a wide observation channel”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

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V011-C11-DISCUSSION-012. Why might equal blockers above and below a channel produce different apparent noise?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Why might equal blockers above and below a channel produce different apparent noise?” Put this particular dispute to the panel: Why might equal blockers above and below a channel produce different apparent noise. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 02. Student A, terminology and scope: Agree the operational meanings of equal, blockers, channel and produce, apparent, noise in “Why might equal blockers above and below a channel produce different apparent noise”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Why might equal blockers above and below a channel produce different apparent noise; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Use the model to design discriminating receiver observations”. Retain desired transfer and gain Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Why might equal blockers above and below a channel produce different apparent noise; explain what each record can establish State what the existing

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record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Use the model to design discriminating receiver observations”. Retain desired transfer and gain Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine signed translation relative to asymmetric weighting before inferring different source powers or instrument faults Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Why might equal blockers above and below a

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channel produce different apparent noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Why might equal blockers above and below a channel produce different apparent noise; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Why might equal blockers above and below a channel produce different apparent noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable,

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expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Why might equal blockers above and below a channel produce different apparent noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Why might equal blockers above and below a channel produce different apparent noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Why might equal blockers above and below a channel produce different apparent noise. The model's even real-phase spectrum does not make every asymmetric observation symmetric Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Why might equal blockers above and below a channel produce different apparent noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Why might equal blockers above and below a channel produce different apparent noise. The model's even real-

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phase spectrum does not make every asymmetric observation symmetric Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Why might equal blockers above and below a channel produce different apparent noise and Examine signed translation relative to asymmetric weighting before inferring different source powers or…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Why might equal blockers above and below a channel produce different apparent noise”, addressing “Examine signed translation relative to asymmetric weighting before inferring different source powers or…”; specify the exact measurement or evidential gap on which the speakers still differ

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Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Why might equal blockers above and below a channel produce different apparent noise”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Why might equal blockers above and below a channel produce different apparent noise”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

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V011-C11-DISCUSSION-013. A preselector lowers the displayed floor by 5 dB. What additional evidence is needed before claiming a 5 dB sensitivity improvement?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A preselector lowers the displayed floor by 5 dB. What additional evidence is needed before claiming a 5 dB sensitivity improvement?” Put this particular dispute to the panel: A preselector lowers the displayed floor by 5 dB. What additional evidence is needed before claiming a 5 dB sensitivity improvement. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 02. Student A, terminology and scope: Agree the operational meanings of preselector, lowers, displayed and floor, additional, improvement in “A preselector lowers the displayed floor by 5 dB. What additional evidence is needed before claiming a 5 dB sensitivity improvement”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A preselector lowers the displayed floor by 5 dB; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. The same filter may attenuate wanted energy or alter noise/gain Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A preselector lowers the displayed floor by 5 dB; explain what each record can establish State

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what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. The same filter may attenuate wanted energy or alter noise/gain Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Measure desired transfer, input-referred baseline, receiver state, and actual weak-reference performance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A preselector lowers the displayed floor by 5

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dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A preselector lowers the displayed floor by 5 dB; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A preselector lowers the displayed floor by 5 dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A preselector lowers the displayed floor by 5 dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A preselector lowers the displayed floor by 5 dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A preselector lowers the displayed floor by

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5 dB. Report the demonstrated improvement in the stated criterion rather than equating display floor with capability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A preselector lowers the displayed floor by 5 dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A preselector lowers the displayed floor by 5 dB. Report the demonstrated improvement in the stated criterion rather than equating display floor with capability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or

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uncertainty term that limits confidence. Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A preselector lowers the displayed floor by 5 dB and What additional evidence is needed before claiming a 5 dB sensitivity improvement; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A preselector lowers the displayed floor by 5 dB”, addressing “What additional evidence is needed before claiming a 5 dB sensitivity improvement”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A preselector lowers the displayed floor by 5 dB. What additional evidence is needed before claiming a 5 dB sensitivity improvement”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A preselector lowers the displayed floor by 5 dB. What additional evidence is needed before claiming a 5 dB sensitivity improvement”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

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V011-C11-DISCUSSION-014. A common LO is used for three blocker tests. Can their measured powers be added without examining cross terms?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A common LO is used for three blocker tests. Can their measured powers be added without examining cross terms?” Put this particular dispute to the panel: A common LO is used for three blocker tests. Can their measured powers be added without examining cross terms. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

- 02. Student A, terminology and scope: Agree the operational meanings of used, powers, added and examining, cross, terms in “A common LO is used for three blocker tests. Can their measured powers be added without examining cross terms”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A common LO is used for three blocker tests; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Shared phase noise may create dependence, while coincident coherent components require field addition Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A common LO is used for three

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blocker tests; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Shared phase noise may create dependence, while coincident coherent components require field addition Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Discuss the ensemble or time average and whether admitted contributions are uncorrelated Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A common LO is used for three blocker tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A common LO is used for three blocker tests; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A common LO is used for three blocker tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled

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variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A common LO is used for three blocker tests, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A common LO is used for three blocker tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A common LO is used for three blocker tests. Retain covariance or declare limits if the sum premise is unproven Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A common LO is used for three blocker tests, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A common LO is used for three blocker tests. Retain covariance or declare limits if the sum premise is unproven Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A common LO is used for three blocker tests and Can their measured powers be added without examining cross terms; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A common LO is used for three blocker tests”, addressing “Can their measured powers be added without examining cross terms”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A common LO is used for three blocker tests. Can their measured powers be added without examining cross terms”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A common LO is used for three blocker tests. Can their measured powers be added without examining cross terms”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)

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V011-C11-DISCUSSION-015. A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. How should it be corrected?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. How should it be corrected?” Put this particular dispute to the panel: A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. How should it be corrected. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 02. Student A, terminology and scope: Agree the operational meanings of subtracts, readings, calls and difference, added, corrected in “A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. How should it be corrected”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 11B.1 Compute the added noise and its consequence”. Check source noise and other changes before attribution Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team subtracts on/off dBm

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readings and calls the difference added reciprocal-noise power; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 11B.1 Compute the added noise and its consequence”. Check source noise and other changes before attribution Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Preserve both original readings, convert to compatible watts, subtract with uncertainty, and refer through fixed gain Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. The dB rise remains a ratio of totals, not the added power itself Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. The dB rise remains a ratio of totals, not the added power itself Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power and How should it be corrected; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power”, addressing “How should it be corrected”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and

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I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. How should it be corrected”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team subtracts on/off dBm readings and calls the difference added reciprocal-noise power. How should it be corrected”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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V011-C11-DISCUSSION-016. One receiver shows a smaller noise rise than another but starts with a much higher floor. Which is better for the weak target?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One receiver shows a smaller noise rise than another but starts with a much higher floor. Which is better for the weak target?” Put this particular dispute to the panel: One receiver shows a smaller noise rise than another but starts with a much higher floor. Which is better for the weak target. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 02. Student A, terminology and scope: Agree the operational meanings of smaller, rise, starts and higher, better, target in “One receiver shows a smaller noise rise than another but starts with a much higher floor. Which is better for the weak target”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One receiver shows a smaller noise rise than another but starts with a much higher floor; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 11B.9 Carry hard bounds through the nonlinear noise rise”. The higher baseline can mask a given added wattage in the relative metric Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One receiver shows a smaller

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noise rise than another but starts with a much higher floor; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 11B.9 Carry hard bounds through the nonlinear noise rise”. The higher baseline can mask a given added wattage in the relative metric Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare actual desired signal transfer and absolute noise/detection criterion, not rise alone Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving One receiver shows a smaller noise rise than another but starts with a much higher floor: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One receiver shows a smaller noise rise than another but starts with a much higher floor; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One receiver shows a smaller noise rise than another but starts with a much higher floor: specify

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the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One receiver shows a smaller noise rise than another but starts with a much higher floor, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One receiver shows a smaller noise rise than another but starts with a much higher floor: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One receiver shows a smaller noise rise than another but starts with a much higher floor. Use the required configuration and target class to make the decision Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One receiver shows a smaller noise rise than another but starts with a much higher floor, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One receiver shows a smaller noise rise than another but starts with a much higher floor. Use the required configuration and target class to make the decision Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.29 Application 11B.2 Invert a one decibel allowance (p. 6404)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One receiver shows a smaller noise rise than another but starts with a much higher floor and Which is better for the weak target; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One receiver shows a smaller noise rise than another but starts with a much higher floor”, addressing “Which is better for the weak target”; specify the exact measurement or evidential gap on which the speakers still differ Require Students

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A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved.

Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One receiver shows a smaller noise rise than another but starts with a much higher floor. Which is better for the weak target”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One receiver shows a smaller noise rise than another but starts with a much higher floor. Which is better for the weak target”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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V011-C11-DISCUSSION-017. Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative?” Put this particular dispute to the panel: Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 02. Student A, terminology and scope: Agree the operational meanings of deterministic, interval, advertised and percent, confidence, conservative in “Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 11A.9 Propagate calibration bounds with their dependencies”. Discuss what hard bounds actually cover, dependencies, and their adequacy Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a deterministic reciprocal-

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noise interval be advertised as 95 percent confidence because it seems conservative; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 11A.9 Propagate calibration bounds with their dependencies”. Discuss what hard bounds actually cover, dependencies, and their adequacy Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No probability follows without a distributional or coverage model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would

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lead the panel to retain, qualify or reject the conclusion. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative. Keep an enclosure useful on its own terms rather than adding a numerical confidence label Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.18 Application 11A.9 Propagate calibration bounds with their dependencies (p. 6386)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative. Keep an enclosure useful on its own terms rather than adding a numerical confidence label Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative and ; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems

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conservative", addressing ""; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Can a deterministic reciprocal-noise interval be advertised as 95 percent confidence because it seems conservative". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.36 Application 11B.9 Carry hard bounds through the nonlinear noise rise (p. 6414)

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V011-C11-DISCUSSION-018. The phase RMS is small but the remainder bound is much larger than the selected first-order result. What conclusion is warranted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The phase RMS is small but the remainder bound is much larger than the selected first-order result. What conclusion is warranted?” Put this particular dispute to the panel: The phase RMS is small but the remainder bound is much larger than the selected first-order result. What conclusion is warranted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 02. Student A, terminology and scope: Agree the operational meanings of phase, remainder, bound and larger, conclusion, warranted in “The phase RMS is small but the remainder bound is much larger than the selected first-order result. What conclusion is warranted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The phase RMS is small but the remainder bound is much larger than the selected first-order result; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integrate the channel that actually produces the reported value”. Seek information about omitted spectral localization or a stronger direct comparison Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of The phase RMS is small but the remainder bound is much larger than the selected first-order result; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integrate the channel that actually produces the reported value”. Seek information about omitted spectral localization or a stronger direct comparison Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The available global bound is insufficient for a precise channel claim, not proof that the actual error is large Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The phase RMS is small but the remainder bound is much larger than the selected first-order result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The phase RMS is small but the remainder bound is much larger than the selected first-order result; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The phase RMS is small but the

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remainder bound is much larger than the selected first-order result: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The phase RMS is small but the remainder bound is much larger than the selected first-order result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The phase RMS is small but the remainder bound is much larger than the selected first-order result: specify the altered receiver state

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or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The phase RMS is small but the remainder bound is much larger than the selected first-order result. Preserve the retained model's limited prediction and explicit uncertainty Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The phase RMS is small but the remainder bound is much larger than the selected first-order result, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The phase RMS is small but the remainder bound is much larger than the selected first-order result. Preserve the retained model's limited prediction and explicit uncertainty Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The phase RMS is small but the remainder bound is much larger than the selected first-order result and What conclusion is warranted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The phase RMS is small but the remainder

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bound is much larger than the selected first-order result", addressing "What conclusion is warranted"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "The phase RMS is small but the remainder bound is much larger than the selected first-order result. What conclusion is warranted", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "The phase RMS is small but the remainder bound is much larger than the selected first-order result. What conclusion is warranted". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

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V011-C11-DISCUSSION-019. Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis?” Put this particular dispute to the panel: Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 02. Student A, terminology and scope: Agree the operational meanings of Gaussian, phase, histogram and step, nonlinear-remainder, analysis in “Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integrate the channel that actually produces the reported value”. A histogram can support only part of the required evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integrate the channel that actually produces the reported value”. A histogram can support only part of the required evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate marginal fourth moment from strict stationarity, temporal dependence, carrier-phase assumptions, and filter gain bound Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis. Do not substitute one favorable statistic for the full model premises Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis. Do not substitute one favorable statistic for the full model premises Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis and Separate marginal fourth moment from strict stationarity, temporal dependence, carrier-phase assumptions, and…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Is a Gaussian phase histogram enough to

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justify every step of the nonlinear-remainder analysis", addressing "Separate marginal fourth moment from strict stationarity, temporal dependence, carrier-phase assumptions, and…"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Is a Gaussian phase histogram enough to justify every step of the nonlinear-remainder analysis". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.37 Application 11B.10 Bound the omitted phase term in the selected channel (p. 6415)

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V011-C11-DISCUSSION-020. How should a test be revised when added-noise slope changes at a gain-range transition?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a test be revised when added-noise slope changes at a gain-range transition?” Put this particular dispute to the panel: How should a test be revised when added-noise slope changes at a gain-range transition. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 02. Student A, terminology and scope: Agree the operational meanings of test, revised, slope and changes, gain-range, transition in “How should a test be revised when added-noise slope changes at a gain-range transition”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a test be revised when added-noise slope changes at a gain-range transition; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Fit only a fixed-state comparison appropriate to the proposed mechanism or explicitly report closed-loop behavior Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a test be revised

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when added-noise slope changes at a gain-range transition; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Fit only a fixed-state comparison appropriate to the proposed mechanism or explicitly report closed-loop behavior Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Record the transition, separate states, and remeasure desired transfer and baseline Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a test be revised when added-noise slope changes at a gain-range transition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a test be revised when added-noise slope changes at a gain-range transition; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a test be revised

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when added-noise slope changes at a gain-range transition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a test be revised when added-noise slope changes at a gain-range transition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a test be revised when added-noise slope changes at a gain-range transition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a test be revised when added-noise slope changes at a gain-range transition. Avoid interpreting a mixed-state slope as a clean nonlinear order Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a test be revised when added-noise slope changes at a gain-range transition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a test be revised when added-noise slope changes at a gain-range transition. Avoid interpreting a mixed-state slope as a clean nonlinear order Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a test be revised when added-noise slope changes at a gain-range transition and Record the transition, separate states, and remeasure desired transfer and baseline; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.28 Application 11B.1 Compute the added noise and its consequence (p. 6403)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a test be revised when added-noise slope changes at a gain-range transition”, addressing “Record

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the transition, separate states, and remeasure desired transfer and baseline"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "How should a test be revised when added-noise slope changes at a gain-range transition", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "How should a test be revised when added-noise slope changes at a gain-range transition". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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V011-C11-DISCUSSION-021. A failed configuration is documented for one dense RF site. Does that disqualify the receiver everywhere?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A failed configuration is documented for one dense RF site. Does that disqualify the receiver everywhere?” Put this particular dispute to the panel: A failed configuration is documented for one dense RF site. Does that disqualify the receiver everywhere. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

- 02. Student A, terminology and scope: Agree the operational meanings of failed, configuration, documented and dense, site, receiver in “A failed configuration is documented for one dense RF site. Does that disqualify the receiver everywhere”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A failed configuration is documented for one dense RF site; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. A specific limitation can guide use without universal condemnation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A failed configuration is documented for one dense RF site; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. A specific limitation can guide use without universal condemnation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Describe the tested blockers, chain, state, and failed criterion, then identify corrected or bounded configurations Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A failed configuration is documented for one dense RF site: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A failed configuration is documented for one dense RF site; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A failed configuration is documented for one dense RF site: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A failed configuration is documented for one dense RF site, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A failed configuration is documented for one dense RF site: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A failed configuration is documented for one dense RF site. Acceptance elsewhere needs applicable evidence rather than assuming either universal failure or universal success

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Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A failed configuration is documented for one dense RF site, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A failed configuration is documented for one dense RF site. Acceptance elsewhere needs applicable evidence rather than assuming either universal failure or universal success Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A failed configuration is documented for one dense RF site and Does that disqualify the receiver everywhere; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A failed configuration is documented for one dense RF site”, addressing “Does that disqualify the receiver everywhere”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A failed configuration is documented for one dense RF site. Does that disqualify the receiver everywhere”,

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specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A failed configuration is documented for one dense RF site. Does that disqualify the receiver everywhere”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

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V011-C11-DISCUSSION-022. How should band-specific acceptance limitations reach the operator?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should band-specific acceptance limitations reach the operator?” Put this particular dispute to the panel: How should band-specific acceptance limitations reach the operator. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 02. Student A, terminology and scope: Agree the operational meanings of band-specific, acceptance, limitations and reach, operator, measurement in “How should band-specific acceptance limitations reach the operator”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how

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should band-specific acceptance limitations reach the operator; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Dynamic-Range Acceptance Matrix”. Retain the supporting matrix and reference observations Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should band-specific acceptance limitations reach the operator; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Dynamic-Range Acceptance Matrix”. Retain the supporting matrix and reference observations Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Translate them into explicit configuration and procedural requirements, including preselection, gain, paths, and recovery exclusions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 08. Student D, answer to Student E: Design a discriminating experiment involving how should band-specific acceptance limitations reach the operator: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the

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independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should band-specific acceptance limitations reach the operator; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should band-specific acceptance limitations reach the operator: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should band-specific acceptance limitations reach the operator, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should band-specific acceptance limitations reach the operator: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should band-specific acceptance limitations reach the operator. A caveat buried behind one dynamic-range number is insufficient for reproducible use Explain the relevant statistical or calibration uncertainty, the range of defensible

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claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should band-specific acceptance limitations reach the operator, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should band-specific acceptance limitations reach the operator. A caveat buried behind one dynamic-range number is insufficient for reproducible use Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should band-specific acceptance limitations reach the operator and Translate them into explicit configuration and procedural requirements, including preselection, gain, paths,…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.24 Translate one blocker through the fluctuating oscillator (p. 6396)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should band-specific acceptance limitations reach the operator”, addressing “Translate them into explicit configuration and procedural requirements, including preselection, gain, paths,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should band-specific acceptance

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limitations reach the operator", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "How should band-specific acceptance limitations reach the operator". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

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V011-C11-DISCUSSION-023. Should a positive cubic SFDR calculation override a lower measured blocking limit?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should a positive cubic SFDR calculation override a lower measured blocking limit?” Put this particular dispute to the panel: Should a positive cubic SFDR calculation override a lower measured blocking limit. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 02. Student A, terminology and scope: Agree the operational meanings of positive, cubic, calculation and lower, blocking, limit in “Should a positive cubic SFDR calculation override a lower measured blocking limit”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of

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whether a positive cubic SFDR calculation override a lower measured blocking limit; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. Explain the compatible-plane cubic planning calculation while retaining blocking, phase noise, compression, and decision margins Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a positive cubic SFDR calculation override a lower measured blocking limit; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would

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change your opinion. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Dynamic Range Is a Family of Conditions”. Explain the compatible-plane cubic planning calculation while retaining blocking, phase noise, compression, and decision margins Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The operational limit must respect the tighter demonstrated mechanism and model domain Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether a positive cubic SFDR calculation

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override a lower measured blocking limit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether a positive cubic SFDR calculation override a lower measured blocking limit; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether a positive cubic SFDR calculation override a lower measured blocking limit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative

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that could survive the proposed test. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether a positive cubic SFDR calculation override a lower measured blocking limit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether a positive cubic SFDR calculation override a lower measured blocking limit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether a positive cubic SFDR calculation

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override a lower measured blocking limit. Do not use one model to erase contrary applicable evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether a positive cubic SFDR calculation override a lower measured blocking limit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether a positive cubic SFDR calculation override a lower measured blocking limit. Do not use one model to erase contrary applicable evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or

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uncertainty term that limits confidence. Source: §11.45 Memory-dependent intermodulation and the limits of static intercept-point inference (p. 6431)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether a positive cubic SFDR calculation override a lower measured blocking limit and The operational limit must respect the tighter demonstrated mechanism and model domain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether a positive cubic SFDR calculation override a lower measured blocking limit”, addressing “The operational limit must respect the tighter demonstrated mechanism and model domain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should a positive cubic SFDR calculation override a lower measured blocking limit”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should a positive cubic SFDR calculation override a lower measured blocking limit”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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V011-C11-DISCUSSION-024. An intervention changes both preamplifier and filter and restores a reference. What causal claim is justified immediately?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An intervention changes both preamplifier and filter and restores a reference. What causal claim is justified immediately?” Put this particular dispute to the panel: An intervention changes both preamplifier and filter and restores a reference. What causal claim is justified immediately. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 02. Student A, terminology and scope: Agree the operational meanings of intervention, preamplifier, restores and causal, justified, immediately in “An intervention changes both preamplifier and filter and restores a reference. What causal claim is justified immediately”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An intervention changes both preamplifier and filter and restores a reference; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Isolating which change mattered requires further controlled comparison Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An intervention changes both

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preamplifier and filter and restores a reference; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Distinguish strong-signal mechanisms through paired interventions”. Isolating which change mattered requires further controlled comparison Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The original configuration was inadequate and the combined revised configuration restored the criterion under the test Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An intervention changes both preamplifier and filter and restores a reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An intervention changes both preamplifier and filter and restores a reference; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An intervention changes both preamplifier and filter and restores a reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An intervention changes both preamplifier and filter and restores a reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An intervention changes both preamplifier and filter and restores a reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An intervention changes both preamplifier and filter and restores a reference. Preserve both useful capability results without pretending the combined intervention uniquely localized the mechanism Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An intervention changes both preamplifier and filter and restores a reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An intervention changes both preamplifier and filter and restores a reference. Preserve both useful capability results without pretending the combined intervention uniquely localized the mechanism Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An intervention changes both preamplifier and filter and restores a reference and What causal claim is justified immediately; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.39 Desensitization Tests in Operational Environments (p. 6420)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An intervention changes both preamplifier and filter and restores a reference”, addressing “What causal claim is justified immediately”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and

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I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An intervention changes both preamplifier and filter and restores a reference. What causal claim is justified immediately”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An intervention changes both preamplifier and filter and restores a reference. What causal claim is justified immediately”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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V011-C11-DISCUSSION-025. What should a second reviewer find in a complete strong-signal evidence package?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should a second reviewer find in a complete strong-signal evidence package?” Put this particular dispute to the panel: What should a second reviewer find in a complete strong-signal evidence package. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 02. Student A, terminology and scope: Agree the operational meanings of second, reviewer, find and complete, strong-signal, package in “What should a second reviewer find in a complete strong-signal evidence package”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What

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should a second reviewer find in a complete strong-signal evidence package; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measure compression without confusing it with control action”. The report should show bounded findings and unresolved alternatives so credibility does not depend on operator recollection Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a second reviewer find in a complete strong-signal evidence package; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measure compression without confusing it with control action”. The report should show bounded findings and unresolved alternatives so credibility does not depend on operator recollection Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The weak-reference criterion, parents/blockers, levels/frequencies/modulation, planes, gains, filters, external paths, raw observations, calibration Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should a second reviewer find in a complete strong-signal evidence package: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a second reviewer find in a complete strong-signal evidence package; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should a second reviewer find in a complete strong-signal evidence package: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should a second reviewer find in a complete strong-signal evidence package, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should a second reviewer find in a complete strong-signal evidence package: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should a second reviewer find in a complete strong-signal evidence package. The report should show bounded findings and unresolved alternatives so credibility does not depend on operator recollection Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should a second reviewer find in a complete strong-signal evidence package, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should a second reviewer find in a

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complete strong-signal evidence package. The report should show bounded findings and unresolved alternatives so credibility does not depend on operator recollection Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should a second reviewer find in a complete strong-signal evidence package and The weak-reference criterion, parents/blockers, levels/frequencies/modulation, planes, gains, filters,…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should a second reviewer find in a complete strong-signal evidence package”, addressing “The weak-reference criterion, parents/blockers, levels/frequencies/modulation, planes, gains, filters,…”; specify the exact measurement or evidential gap on which the speakers still

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differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should a second reviewer find in a complete strong-signal evidence package”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should a second reviewer find in a complete strong-signal evidence package”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)

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Chapter 11 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C11-ESSAY-001 — Define input/output planes and stimulus interval, retain actual gain/attenuation/filter/detector states, and identify transitions. Use an independent controlled weak probe for sensitivity loss. Measure recovery after a specified pulse/prior state and define observation exclusions. Label fixed-state and closed-loop results separately and avoid relying on one overload flag.

Review: Chapter 11 — Measure compression without confusing it with control action.

V011-C11-ESSAY-002 — State loaded peak-voltage and resistance conventions, fixed coefficients, distinct frequencies, and the absence of even terms. Expand the self and mixed cubic terms to obtain the three-quarters coefficients with unequal amplitude powers. Preserve signs before power conversion and explain coincident-frequency and higher-order limitations.

Review: Chapter 11 — Derive the retained spectral amplitudes.

V011-C11-ESSAY-003 — Equate the equal-tone cubic magnitude with the linear fundamental, convert through R_i and R_o, and obtain the logarithmic separation rules. Distinguish extrapolated intercept from operating point. Show the 3.0103 dB error from total two-tone substitution and the half versus three-halves gain-correction bias.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

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V011-C11-ESSAY-004 — Predict both product locations and their shifts when one frequency moves. Vary one parent power to distinguish unequal-tone slopes, then vary both under fixed state. Preserve detectability and source purity. Interpret agreement as compatibility with the association, not unique localization, and investigate departures without selecting a cause from slope alone.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-ESSAY-005 — Use the separate amplitude and power laws for the two products and separate fundamental corrections. Explain how the stronger parent can cause a larger fractional correction of the weaker fundamental. Keep individual measured products, reference planes, and correction bounds; show why equal-tone shortcuts erase informative asymmetry.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-ESSAY-006 — Start from delivered peak voltages and cycle-mean cosine power, derive a1 squared $\frac{R_i}{R_o}$, and evaluate the 10, 50-ohm, 200-ohm case. Carry the gain into OIP3 and coefficient recovery. Explain matching assumptions and why power-only product data cannot recover the sign of a_3.

Review: Chapter 11 — Fix the voltage convention and operating domain.

V011-C11-ESSAY-007 — Substitute voltage transmission into linear and cubic coefficients for each location. Track fundamental/product changes, IIP3 and OIP3 reference planes, and equal overall small-signal gain. State the absent noise, mismatch, distortion, and control consequences that prevent claiming universal sensitivity improvement.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-ESSAY-008 — Distinguish one tone from two equal tones and per-tone from total power. Convert one-decibel gain reduction into a voltage ratio, identify the formal powers, and compare the required correction with the five-percent working bound. Explain why omitted terms and actual device behavior prevent treating the extrapolation as a receiver specification.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-ESSAY-009 — Use affine logarithmic formulas and rectangular corner bounds for p, q, and s. Then impose a common additive output error and demonstrate cancellation from IIP3 but one surviving copy in OIP3. Keep hard bounds separate from coverage probabilities and justify the dependency model rather than choosing it for a smaller interval.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-ESSAY-010 — Apply triangle and reverse-triangle magnitude bounds, convert endpoints to power at the same resistance, and propagate through the decreasing dependence of intercept on product level. Discuss loss of a finite upper intercept bound when contamination can cancel the observed magnitude. Specify source/combiner/isolation checks and reject simple incoherent subtraction.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-ESSAY-011 — Define mixer-input blocker power, signed offset, real zero-mean phase process, density convention, and first-order exponential expansion. Show spectrum translation and amplitude scaling, retaining units. Separate direct carrier leakage and other strong-signal mechanisms, and explain why no extra sideband factor is inserted.

Review: Chapter 11 — Translate one blocker through the fluctuating oscillator.

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V011-C11-ESSAY-012 — Define normalized H and W, equivalent noise bandwidth, signed translated offsets, and overlap factor. Integrate linear density rather than logarithmic labels. State exact flat-spectrum conditions, bounds for varying density, treatment of tails and lines, and the need for frequency-dependent gain when one scalar is insufficient.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

V011-C11-ESSAY-013 — Preserve signed blocker translation while using the even real-phase density. Identify the different offset intervals sampled by the one-sided channel, integrate the stated local inverse-square law, and explain why a symmetric filter removes this particular asymmetry. Do not infer global finite variance from a local divergent law without continuation.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-ESSAY-014 — Identify blocker transfer into the mixer and divide generated noise by desired transfer for narrow-signal external equivalence. Derive the transfer ratio and 23 dB differential example. Explain broad-waveform weighting and why total sensitivity also requires baseline noise, mismatch, and gain-state accounting.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-ESSAY-015 — State compatible baseline, gain, weighting, plane, and zero cross power. Invert the total-to-baseline logarithm, evaluate the one-decibel fraction, and explain why required blocker reduction differs from excess total rise. Discuss quieter versus noisier baselines and why the metric alone does not give detection probability.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

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V011-C11-ESSAY-016 — State each admitted blocker power, signed offset, and weighted overlap. Require zero admitted cross powers through a justified ensemble or averaging rule. Explain shared-LO dependence, coincident coherent carriers, and differing density offsets. Preserve covariance terms when the power-sum premise fails.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-ESSAY-017 — Convert both compatible output levels to watts, subtract with uncertainty, divide through fixed gain, blocker power, and justified bandwidth. Require unchanged baseline/state and exclude or bound stimulus phase noise, leakage, and other mechanisms. Treat negative or unresolved differences appropriately and describe an aggregate effective density when attribution remains incomplete.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-ESSAY-018 — Define the feasible set and distinguish rectangular freedom from statistical independence. Use monotonic extrema for added power and combine largest added with smallest baseline for maximum rise. Explain how justified dependencies could narrow the interval and why a hard enclosure has no automatic confidence percentage.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-ESSAY-019 — Distinguish pointwise remainder, expected square requiring a fourth moment, retained linear WSS spectrum, and stationary nonlinear filtered bound requiring strict stationarity and carrier-phase assumptions. Retain W no greater than one, unknown cross power, and the Gaussian marginal moment only where invoked. Explain why small global RMS alone need not yield a useful selected-channel error bound.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

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V011-C11-ESSAY-020 — Choose parent-frequency movement, blocker-power/offset changes, and controlled weak-probe response as distinct tests. Hold or record relevant gain and weighting states, characterize preselector transfer, and examine recovery. Preserve alternative mechanisms where predictions fail rather than force one explanation from a lower floor or apparent slope.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

V011-C11-ESSAY-021 — Include weak reference classes, blocker levels/spacings/modulation, band edges, installed paths, gain/preselection states, and recovery intervals. Test actual deployed configurations and define transitions or limitations. Retain parent/product families and encode band-specific procedural requirements without extrapolating one catalog number.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

V011-C11-ESSAY-022 — Refer IIP3 and integrated noise to the same input plane and compatible bandwidth. Set the cubic product level 3p-2I equal to noise N, solve for p, and subtract N. Check the characterized cubic interval and tighter compression, phase-noise, spur, or decision-margin limits. A nonpositive or inapplicable intersection provides no usable claim.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

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V011-C11-ESSAY-023 — Document before/after source, reference, chain, gain, and capability. Explain the demonstrated desensitization of the original configuration while distinguishing which individual change remains causally unresolved if both changed. Require a suitable reference and state limits on environmental absence and transfer to other bands.

Review: Chapter 11 — Hypothetical Case Adjudication: Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

V011-C11-ESSAY-024 — Use coherent phasor cancellation and uncertainty about source/combiner/receiver products, retaining reference phase and planes. Contrast a power-only reading with signed or controlled path evidence. Explain the consequence for intercept bounds and why more averaging does not necessarily remove deterministic contamination.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-ESSAY-025 — Tie each finding to signal class, bandwidth, reference planes, gain/filter states, blockers, and recovery. State which local model was tested and what alternatives remain. Preserve raw/reference observations, uncertainty and exclusions, and translate demonstrated limits into procedures for credible weak observations.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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Discussion Guidance

V011-C11-DISCUSSION-001 — First align lower/upper limits, bandwidth, detector, spacing, signal class, and reference planes. Then compare relevant installed configurations with weak references and blockers. The largest number alone cannot rank capability for the actual task.

Review: Chapter 11 — Dynamic Range Is a Family of Conditions.

V011-C11-DISCUSSION-002 — Request desired gain, weak-probe criterion, noise/product response, actual control states, and recovery under the intended stimulus. An icon is one observation and may not mark every relevant error. Keep a bounded conclusion tied to demonstrated capability.

Review: Chapter 11 — Measure compression without confusing it with control action.

V011-C11-DISCUSSION-003 — Separate closed-loop behavior from fixed-state transfer and retain the transition record. Discuss whether the operational question concerns automatic behavior or local stage nonlinearity. Do not fit one polynomial slope across states without evidence.

Review: Chapter 11 — Measure compression without confusing it with control action.

V011-C11-DISCUSSION-004 — Recognize compatibility with the association, then test candidate generating paths under comparable detectability. Receiver, source, combiner, or external nonlinear contacts can share the frequency relation. Preserve alternatives until an intervention discriminates them.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-DISCUSSION-005 — Discuss the unequal product laws and separate low/high results. If an equal-tone metric is desired, establish that test condition explicitly. Avoid using averaged logs or total powers to conceal asymmetry or imply a convention not actually measured.

Review: Chapter 11 — Construct the intercept from the linear asymptote.

V011-C11-DISCUSSION-006 — Explain that coherent contamination can either reinforce or cancel the stage contribution, so a small observed spur need not be conservative. Require phasor bounds or controlled isolation evidence. Report the resulting interval and nonidentifiability rather than the preferred point estimate alone.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-DISCUSSION-007 — Separate nonlinear drive reduction from noise and desired-signal loss. Record state, transfer, and baseline and compare the actual detection criterion. A higher input-referred intercept does not automatically improve all useful dynamic-range measures.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-DISCUSSION-008 — Keep it as the explicitly bounded teaching extrapolation that demonstrates a limitation. Distinguish it from an acceptance test or operating recommendation, and explain the additional terms and measurements needed for actual compression behavior.

Review: Chapter 11 — Ten worked applications of Model 11A.

V011-C11-DISCUSSION-009 — Require evidence of a shared physical/calibration dependency. Similar labels alone do not establish common error. Compare the feasible sets and retain a defensible bound without assigning an unsupported probability or cancellation.

Review: Chapter 11 — Ten worked applications of Model 11A.

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V011-C11-DISCUSSION-010 — Consider reciprocal mixing, source phase noise, gain/control changes, direct leakage, ADC occupation, and other broadband effects. Use controlled weak probes and blocker offset/level changes. Absence of one product family does not establish one alternative uniquely.

Review: Chapter 11 — Blocking and Reciprocal Mixing.

V011-C11-DISCUSSION-011 — Assess spectral variation over every weighted offset, actual LO path, filter response, and omitted tails or lines. Use an integral or justified envelope. A convenient center value is an exact shortcut only under its flat-density condition.

Review: Chapter 11 — Integrate the channel that actually produces the reported value.

V011-C11-DISCUSSION-012 — Examine signed translation relative to asymmetric weighting before inferring different source powers or instrument faults. Retain desired transfer and gain. The model's even real-phase spectrum does not make every asymmetric observation symmetric.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-DISCUSSION-013 — Measure desired transfer, input-referred baseline, receiver state, and actual weak-reference performance. The same filter may attenuate wanted energy or alter noise/gain. Report the demonstrated improvement in the stated criterion rather than equating display floor with capability.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-C11-DISCUSSION-014 — Discuss the ensemble or time average and whether admitted contributions are uncorrelated. Shared phase noise may create dependence, while coincident coherent components require field addition. Retain covariance or declare limits if the sum premise is unproven.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-DISCUSSION-015 — Preserve both original readings, convert to compatible watts, subtract with uncertainty, and refer through fixed gain. Check source noise and other changes before attribution. The dB rise remains a ratio of totals, not the added power itself.

Review: Chapter 11 — Ten worked applications of Model 11B.

V011-C11-DISCUSSION-016 — Compare actual desired signal transfer and absolute noise/detection criterion, not rise alone. The higher baseline can mask a given added wattage in the relative metric. Use the required configuration and target class to make the decision.

Review: Chapter 11 — Convert added power into a conditional noise-rise limit.

V011-C11-DISCUSSION-017 — No probability follows without a distributional or coverage model. Discuss what hard bounds actually cover, dependencies, and their adequacy. Keep an enclosure useful on its own terms rather than adding a numerical confidence label.

Review: Chapter 11 — Ten worked applications of Model 11B.

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V011-C11-DISCUSSION-018 — The available global bound is insufficient for a precise channel claim, not proof that the actual error is large. Seek information about omitted spectral localization or a stronger direct comparison. Preserve the retained model's limited prediction and explicit uncertainty.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

V011-C11-DISCUSSION-019 — Separate marginal fourth moment from strict stationarity, temporal dependence, carrier-phase assumptions, and filter gain bound. A histogram can support only part of the required evidence. Do not substitute one favorable statistic for the full model premises.

Review: Chapter 11 — Application 11B.10 Bound the omitted phase term in the selected channel.

V011-C11-DISCUSSION-020 — Record the transition, separate states, and remeasure desired transfer and baseline. Fit only a fixed-state comparison appropriate to the proposed mechanism or explicitly report closed-loop behavior. Avoid interpreting a mixed-state slope as a clean nonlinear order.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

V011-C11-DISCUSSION-021 — Describe the tested blockers, chain, state, and failed criterion, then identify corrected or bounded configurations. A specific limitation can guide use without universal condemnation. Acceptance elsewhere needs applicable evidence rather than assuming either universal failure or universal success.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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V011-C11-DISCUSSION-022 — Translate them into explicit configuration and procedural requirements, including preselection, gain, paths, and recovery exclusions. Retain the supporting matrix and reference observations. A caveat buried behind one dynamic-range number is insufficient for reproducible use.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

V011-C11-DISCUSSION-023 — The operational limit must respect the tighter demonstrated mechanism and model domain. Explain the compatible-plane cubic planning calculation while retaining blocking, phase noise, compression, and decision margins. Do not use one model to erase contrary applicable evidence.

Review: Chapter 11 — Quantitative Model for Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

V011-C11-DISCUSSION-024 — The original configuration was inadequate and the combined revised configuration restored the criterion under the test. Isolating which change mattered requires further controlled comparison. Preserve both useful capability results without pretending the combined intervention uniquely localized the mechanism.

Review: Chapter 11 — Hypothetical Case Adjudication: Dynamic Range, Compression, Blocking, Intermodulation, and Desensitization.

V011-C11-DISCUSSION-025 — The weak-reference criterion, parents/blockers, levels/frequencies/modulation, planes, gains, filters, external paths, raw observations, calibration and uncertainty, source-purity checks, state transitions, and recovery. The report should show bounded findings and unresolved alternatives so credibility does not depend on operator recollection.

Review: Chapter 11 — Dynamic-Range Acceptance Matrix.

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Chapter Glossary

ADMITTED BLOCKER POWER: The power of a specified interfering carrier at the conversion-stage input after preceding gain, loss, and frequency selection, at a declared reference plane.

BLOCKER OFFSET: The signed frequency separation between an admitted interfering carrier and the declared desired-channel center. Model 11B uses it to identify which oscillator phase-noise frequencies enter the weighted channel. An even phase spectrum does not make positive and negative blocker offsets interchangeable when the observation filter is asymmetric.

BLOCKING: Loss of sensitivity or accuracy caused by a strong signal outside or beside the desired channel.

COHERENT CONTAMINATION: An unwanted complex amplitude at the same observed frequency whose phase-dependent addition can raise or lower the magnitude attributed to the modeled source.

COMPRESSION: Reduction of incremental gain as a stage approaches nonlinear or limiting operation.

CROSS POWER: The contribution arising from the joint product of two admitted signal components when their combined mean power is formed. Its sign and magnitude depend on their relationship. Model 11B retains a bound on the cross term between the kept and omitted phase contributions instead of assuming their powers add without interaction.

CUBIC INTERMODULATION MODEL: A bounded memoryless voltage relation retaining linear and third-order terms under explicit amplitude, loading, frequency, and fixed-state assumptions.

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DESENSITIZATION: Degradation of receiver sensitivity caused by overload, control action, noise elevation, or other strong-signal effects.

DESIRED INPUT EQUIVALENCE: Referral of an internally generated disturbance to the desired-signal input using the declared desired transfer; a center-frequency scalar requires a narrow signal or a justified constant-transfer approximation.

DYNAMIC-RANGE ACCEPTANCE MATRIX: A structured set of receiver tests spanning the weak references, blockers, tone spacings, modulation, gain states, external paths and recovery conditions relevant to the declared use. Its results establish a bounded operating region and known exclusions. One favorable catalog number cannot replace this configuration-dependent evidence.

EFFECTIVE PHASE NOISE: The phase-fluctuation spectrum experienced by a blocker in the actual conversion path, including relevant oscillator and driver contributions under a specified operating state.

FLAT-SPECTRUM APPROXIMATION: Replacement of a varying linear spectral density by one constant over the frequency region carrying significant filter weight. It is exact for the stated constant-density case and requires justification otherwise. A center-frequency phase-noise value alone does not establish the integrated noise when other admitted offsets have different densities.

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FOURTH MOMENT: The expectation of the fourth power of a stated real random quantity, when finite. Model 11B uses the phase fourth moment to bound omitted nonlinear power. A zero-mean Gaussian marginal supplies a particular moment relation, but that marginal condition alone establishes neither strict stationarity nor a specific phase spectrum.

FUNDAMENTAL CORRECTION: The contribution of retained nonlinear terms to the amplitude at a parent frequency, distinct from a newly generated intermodulation component.

INPUT INTERCEPT LEVEL: The input-referred extrapolated level at which a declared nonlinear-product law meets its associated linear asymptote. Model 11A defines it per tone at the loaded input plane. Its usefulness depends on the local model and measured interval; it is not an attainable operating level or a total multi-tone input power.

INTERCEPT EXTRAPOLATION: The procedure of extending specified low-level fundamental and nonlinear-product laws to their algebraic intersection. In Model 11A it equates the linear fundamental asymptote to a selected cubic-product magnitude, retaining per-tone powers and reference planes. A measured fundamental with finite nonlinear correction requires a fitted asymptote or an explicitly bounded correction.

INTERCEPT POINT: The extrapolated input or output level at which a specified nonlinear product and reference fundamental asymptote have equal power under the declared test convention. It is a parameter of those response laws, not an attainable operating level or a compression threshold. The input and output values differ by the declared power gain expressed in decibels.

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LOADED VOLTAGE GAIN: The ratio of output voltage across its declared load to input voltage at its declared loaded plane; power gain additionally depends on both resistances.

MEMORYLESS NONLINEARITY: A relation in which the output at an instant depends on the input at that instant without an internal stored state. The fixed cubic law can produce new frequency components even though it has no memory. Thermal history, control-loop dynamics and frequency-selective storage require a different or extended description.

NOISE RISE ALLOWANCE: The additional uncorrelated noise power permitted by a stated rise relative to a fixed baseline measured through the same gain, weighting, and reference plane.

NORMALIZED FILTER POWER RESPONSE: The squared magnitude of the declared observation filter after its reference gain has been specified. It weights the noise admitted at each frequency. Model 11B additionally requires this weighting to remain between zero and one for its remainder bound; center normalization alone would not establish that peak constraint.

ONE-DECIBEL COMPRESSION POINT: A specified stimulus level at which the measured response is one decibel below its declared small-signal linear extrapolation under fixed test conditions. It is a benchmark, not a universal threshold for all measurement error. Automatic gain changes, different stimuli and recovery behavior require separate characterization.

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OUTPUT INTERCEPT LEVEL: The output-referred extrapolated intersection associated with the declared input intercept and small-signal power gain. The input and output planes and resistance conventions must be compatible. Substituting a compressed measured fundamental for the linear asymptote can bias the extraction, even before ordinary calibration uncertainty is considered.

PER-TONE POWER: The power assigned to one specified sinusoidal component, distinct from the sum of the powers in a multi-tone stimulus.

PHASE REMAINDER BOUND: An enclosure for terms omitted from a declared small-phase expansion, with moment and stationarity requirements stated separately from the retained linear model.

POWER GAIN: The ratio of output power to input power under declared reference-plane, loading and signal conventions. For the chapter’s loaded sinusoidal voltages, both the squared voltage ratio and the input/output resistance ratio enter. A voltage-gain number is therefore insufficient when the reference resistances differ.

PRODUCT COLLISION: Coincidence of two generated or existing spectral components at one frequency, requiring their complex amplitudes to be combined before calculating power.

RECIPROCAL MIXING: Noise produced when local-oscillator phase noise mixes a strong nearby signal into the observation band.

RECIPROCAL MIXING OVERLAP: The dimensionless integral of translated linear single-sideband phase density weighted by the observation channel's normalized power response.

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RECOVERY EXCLUSION: An interval after a stimulus or state change during which the receiver has not yet met the declared criterion for valid observation.

SINGLE-SIDEBAND PHASE DENSITY: The linear phase-noise quantity equal to one half of the one-sided phase spectral density and, at positive offsets, to the two-sided phase density.

SMALL-SIGNAL ASYMPTOTE: The linear response extrapolated from the declared low-level behavior of a stage. It supplies the fundamental reference for the chapter's intercept construction, rather than the full finite-level fundamental including its cubic correction. Confusing those quantities changes the inferred intercept and can obscure the limits of the approximation.

SOURCE-GENERATED INTERMODULATION: Nonlinear products produced in a stimulus source, combiner, connector or other test-path component before the receiver contribution is isolated. Such products can contaminate an intercept measurement and can combine coherently with receiver-generated amplitudes. Source isolation and harmonic filtering are therefore part of the validity argument, not merely setup details.

SPECTRAL LINE: A discrete-frequency contribution with finite integrated power, distinct from an ordinary continuous spectral density. A carrier or discrete phase-modulation spur must be included through its line contribution and the observation response. Assigning it an arbitrary per-hertz value or treating it as a flat density can misstate admitted power.

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SPURIOUS-FREE DYNAMIC RANGE: A range defined by specified desired-signal, noise and spur conditions at compatible reference planes and bandwidths. The chapter's third-order planning expression finds where the equal-tone cubic product meets the stated noise floor. Compression, reciprocal mixing, other products or model breakdown can impose a smaller usable range.

STRICT STATIONARITY: Invariance of all finite-dimensional probability distributions under a common shift of time. Model 11B invokes this stronger premise, with a finite fourth moment and its stated blocker-phase convention, when bounding the filtered nonlinear remainder. The weaker covariance premise sufficient for the retained linear spectrum does not automatically provide it.

UNEQUAL-TONE INTERMODULATION: The nonlinear-product behavior produced when the two parent tones have different stated amplitudes or powers. In the retained cubic model, each close-in product weights one parent twice and the other once in power. The two products therefore need separate calculations; symmetry cannot be inferred from their frequency placement alone.

WEAK-PROBE CHALLENGE: A strong-signal test that retains a controlled weaker desired reference to measure changes in useful observation capability.

WIDE-SENSE STATIONARITY: A second-order condition with constant mean and covariance determined by time separation. It supports the chapter's retained linear phase-spectrum treatment when variance is finite. It does not generally make a nonlinear function of the phase stationary, so it cannot silently replace the stronger premise used for the remainder-power bound.

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ZERO CROSS-POWER CONDITION: A specified ensemble or averaging condition under which the cross terms between admitted contributions vanish and their mean powers may be added.

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References and Works Cited

Keysight Technologies. Optimizing RF and Microwave Spectrum Analyzer Dynamic Range. Application note 5968-4545E. December 1, 2017. Pages 2 and 4–8. https://www.keysight.com/zz/en/assets/7018-06813/application-notes/5968-4545.pdf.

Annotation. Printed pages 2 and 4–8 distinguish measurement/display range, mixer compression, internal distortion, noise and uncertainty. Model-specific performance figures are not transferred to an unspecified receiver; the chapter derives its own bounded SFDR relation. The publication explains analyser operation and measurement settings governing spectral detection, resolution and transient capture. Resolution bandwidth, video filtering, detector mode and acquisition duty cycle can alter a displayed spectrum without changing the external transmitter. A manufacturer's application note supports stated instrument behaviour but does not certify that a particular survey captured every possible short-duration event. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions.

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Perrott, Michael H. Lecture 8, Noise Figure, Impact of Amplifier Nonlinearities. 6.976 High Speed Communication Circuits and Systems. MIT OpenCourseWare, 2003. Slides 22–35. https://ocw.mit.edu/courses/6-976-high-speed-communication-circuits-and-systems-spring-2003/a3bae9358da0286076b42f98b9dafc20_lec8.pdf.

Annotation. Slides 22–23, 26 and 31–35 support the local nonlinearity, intercept and compression distinctions. Model 11A fixes its own loaded-voltage and resistance conventions; its formal truncated-polynomial compression offsets are independently calculated. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

Niknejad, Ali M. Effect of Feedback on Distortion. EECS 142. University of California, Berkeley. Version dated March 30, 2025. Slides 9 and 27. https://rfic.eecs.berkeley.edu/courses/ee142/pdf/module16_distofb.pdf.

Annotation. Slides 9 and 27 support the attenuation and polynomial-distortion context. The unequal-tone coefficients and pre/post-attenuation comparison follow from the chapter’s displayed

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trigonometric expansion and substitution. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

Keysight Technologies. Swept IMD and IM Spectrum Concepts. E5080B VNA Help. Tone Power Parameters, Intermodulation Distortion Parameters, and Intercept Point Parameters. Accessed November 1, 2026. https://helpfiles.keysight.com/csg/e5080b/Applications/Swept_IMD_and_IM_Spectrum_Concepts.htm.

Annotation. Tone Power Parameters, Intermodulation Distortion Parameters and Intercept Point Parameters. Supports preservation of individual-tone and product conventions rather than interpreting an averaged logarithmic level as total power. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. The cited work is a methodological

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reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

Keysight Technologies. Third Order Intermodulation Distortion Performance Test. N7875A help. Source isolation and source-harmonic filtering. Accessed November 1, 2026. https://helpfiles.keysight.com/calsoft/N7875A/Help/Content/Performance/TOI_PV.htm.

Annotation. Source isolation and harmonic-filtering procedure. The coherent-magnitude interval and numerical enclosure are original applications of triangle inequalities, not reproduced performance-test results. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Kester, Walt. MT-012, Intermodulation Distortion Considerations for ADCs. Rev. A. Analog Devices, October 2008. Pages 1–4. https://www.analog.com/media/en/training-seminars/tutorials/mt-012.pdf.

Annotation. Printed pages 1–4 distinguish converter distortion from the usual analog intercept extrapolation. The chapter does not assert a universal converter intercept law. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

Hati, Archita, Craig Nelson, Neil Ashby, and David Howe. Calibration Uncertainty for the NIST PM/AM Noise Standards. NIST Special Publication 250-90. July 2012. Sections 2.1–2.2.2, pages 2–4. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=909758.

Annotation. Section 2.1, pages 2–3, equations (3)–(4), and sections 2.1–2.2.2, pages 3–4, equations (7)–(12), support phase-noise conventions and the small sinusoidal-modulation benchmark. Model 11B independently derives its weighted integral, pointwise remainder, fourth-moment enclosure and cross-term bound. The reference supplies a

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technical framework for interpreting oscillator stability or correlated phase-noise measurements. Observation interval, averaging statistic, timebase origin and common-clock correlation should be specified before translating a frequency statistic into arrival-time or phase evidence. A nominally stable source can still have an offset or transient recovery event, and averaging may suppress or distort correlated components. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

Keysight Technologies. About Resolution Bandwidth. 89600 VSA Help. Opening definition and comparison of swept analyzers with the 89600 VSA. 2026 Update 2.0. Accessed November 1, 2026. https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/gui/content/rbw_about_rbw.htm.

Annotation. Opening definition and comparison with swept-analyzer RBW conventions. This implementation-specific definition does not establish the actual filter response of an unspecified instrument. The publication explains analyser operation and measurement settings governing spectral detection, resolution and transient capture. Resolution bandwidth, video filtering, detector mode and acquisition duty cycle can alter a displayed spectrum without changing the external transmitter. A manufacturer’s application note supports stated instrument behaviour but does not certify that a particular survey captured every possible short-duration event. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their

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own checks. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

Analog Devices. Specifications and Measurement of Local Oscillator Noise in Integrated Circuit Base Station Mixers. June 18, 2003. Mixer Noise Model and Effective Noise Floor of LO Driver. https://www.analog.com/en/resources/technical-articles/2022/07/16/08/18/specifications-and-measurement-of-local-oscillator-noise-in-integrated-circuit-base-station-mixers.html.

Annotation."Mixer Noise Model," equation (2), and "Effective Noise Floor of LO Driver." The chapter's generalized weighting, reference-plane analysis and applications are independently developed under explicit premises. The technical treatment concerns the conversion of strong off-channel energy and local-oscillator phase noise into receiver degradation. An apparent rise in the noise floor can reflect oscillator-sideband mixing rather than increased external thermal noise or a new transmitter. Conclusions require blocker level, frequency offset, preselection, instrument state and phase-noise conditions at specified reference planes. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Analog Devices. Measuring Single-Tone Desensitization for CDMA Receivers. May 26, 2006. Reciprocal Mixing subsection. https://www.analog.com/en/resources/technical-articles/2022/07/16/09/37/measuring-singletone-desensitization-for-cdma-receivers.html.

Annotation."Reciprocal Mixing" subsection identifies jammer-generator phase noise as a measurement contribution. No cellular-system test limit or commercial receiver capability is adopted. The technical treatment concerns the conversion of strong off-channel energy and local-oscillator phase noise into receiver degradation. An apparent rise in the noise floor can reflect oscillator-sideband mixing rather than increased external thermal noise or a new transmitter. Conclusions require blocker level, frequency offset, preselection, instrument state and phase-noise conditions at specified reference planes. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

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Chapter 12. Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing

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12.1 Frequency Reference and Tuning Accuracy

Receiver frequency accuracy depends on its reference oscillator, synthesizer, dividers, numerical tuning, temperature, aging, supply state, and calibration. A displayed center frequency can be numerically exact while the physical tuning is offset. The error may be constant, proportional to frequency, band dependent, or state dependent. Frequency measurements should be checked against traceable references at several points rather than corrected from one tone.[1]

Reference sources include internal crystal oscillators, oven-controlled oscillators, disciplined oscillators, external 10 MHz standards, network time and frequency, and specialized atomic or satellite-referenced systems. Their labels do not establish present performance. Lock status, holdover, antenna condition, phase steps, distribution delay, and cabling must be recorded. A degraded disciplined oscillator can remain close on average while exhibiting short-term noise or excursions.

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1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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12.2 Model 12A: connect clock reading, frequency and phase

Clock accuracy is meaningful only relative to a defined time and frequency reference. Model 12A defines the clock reading as ideal time plus a time error. Positive error means that the clock is advanced. Its derivative is fractional frequency error, and multiplying time error by two pi times nominal carrier frequency gives relative unwrapped phase. This convention follows the time-error and fractional-frequency relationship used in the NIST frequency-stability handbook. It is kept explicit because a physical propagation delay has the opposite transfer-phase sign.[2]

Equation 23A. Clock reading and time-error convention

$$c(t)=t+x(t),\ x(t)>0 \text{ means an advanced clock}$$

Equation 23B. Frequency and phase from time error

$$y(t)=\frac{dx}{dt},\ f(t)=f_0[1+y(t)]$$
$$\varphi_{rel}(t)=2\pi f_0 x(t),\ f_0>0$$

The ideal time t, clock reading c and time error x are in seconds. Nominal frequency f_0 is in hertz; fractional frequency y is dimensionless; relative phase is in radians. In the local drift law, d is fractional-frequency change per second. A physical delay τ is in seconds. The nonnegative bounds b_0, b_y and b_d have the units of time error, fractional frequency and fractional-frequency drift, respectively. The tolerance φ_{tol} is a positive phase magnitude in radians, and its equivalent time tolerance follows by division by $2\pi f_0$.

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2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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The model is deterministic over a declared interval. An initial epoch error, a constant fractional frequency error, and a local linear frequency drift integrate into a constant, linear, and quadratic time-error term. They answer different questions. A clock can have correct average frequency while its epoch is displaced, or it can begin at the correct epoch and then accumulate substantial error. Neither a frequency-lock indicator nor a plausible timestamp establishes all three terms.

Equation 23C. Local linear fractional-frequency drift

$$y(t) = y_0 + dt$$
$$x(t) = x_0 + y_0 t + \frac{d}{2} t^2$$

The interval matters because a fitted drift law need not persist through warmup, environmental change, holdover, a power interruption, or reacquisition of a reference. Segment the record at such events. Within a segment, state whether the coefficients are calibrated values, estimates from observed phase, or conservative bounds. A polynomial fit can summarize an observed trend without proving the mechanism that will govern the next interval.

A positive physical delay acts differently from an advanced clock. Delaying a sinusoid produces a negative transfer phase proportional to frequency. A nondispersive delay can therefore be inferred from an unwrapped phase slope, but a single wrapped phase value admits many possible delays. Frequency-dependent filters add phase curvature, in which case one constant delay cannot describe the whole path. The delay calibration must use the frequency range and channel state needed by the later inference.

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Equation 23D. Physical delay and its transfer-phase sign

$$H(f)=\exp(-j2\pi f\tau)$$
$$\theta(f)=-2\pi f\tau \text{ on the declared unwrapped branch}$$

Equation 23E. Delay from unwrapped phase slope

$$\tau=-\frac{1}{2\pi}\frac{d\theta}{df}$$
$$\tau=-\frac{\theta_2-\theta_1}{2\pi(f_2-f_1)} \text{ for a nondispersive path}$$

Two separated tones can constrain delay, but their wrapped phase difference leaves an ambiguity related to the tone spacing. A prior delay range, an additional frequency pattern, or an independently established unwrap is required to choose among the alternatives. The example below uses a pure delay with compatible absolute phase, making two different delays produce the same wrapped pair. This is a measurement ambiguity, not a numerical precision problem.

Equation 23F. Two-tone delay ambiguity

$$\tau_m=\tau_0+\frac{m}{\Delta f}, m\in\mathbb{Z}, \Delta f>0$$
$$\text{Wrapped difference repeats every } \frac{1}{\Delta \mathrm{f}} \text{ in delay.}$$

Two epoch measurements also provide an average fractional-frequency estimate over their separation. If the endpoint errors are given as deterministic bounds, propagate them as bounds rather than converting them into standard deviations without a distribution. A statistical uncertainty calculation belongs to the measurement model in Chapter 14. Either approach should retain the reference time interval and any correlation between the endpoint measurements.

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Equation 23G. Average frequency from endpoint time errors

$$y_{avg} = \frac{x_2 - x_1}{t_2 - t_1}$$
$$|\delta y_{avg}| \le \frac{b_1 + b_2}{t_2 - t_1} \, if \; |\delta x_i| \le b_i$$

A reset or retune can insert a phase step. A finite difference that crosses that step includes it, while the continuous derivative on either side may remain unchanged. Do not fit one smooth drift law through a documented discontinuity. Preserve the event time and separate segment phases. Coherent comparison across the event requires a measured deterministic relationship, not merely the fact that both segments use the same nominal sample rate.

Equation 23H. Phase reset as an explicit segment event

$$\varphi(t_r^{+¿}) - \varphi(t_r^{-}) = \Delta\varphi_r ¿ \; cross-reset\ average = continuous-segment\ average + \frac{\Delta\varphi_r}{2\pi\Delta t}$$

The sample clock controls both elapsed-time labels and discrete-frequency labels. If the actual rate differs from the nominal rate by a fractional amount, the elapsed time for a fixed number of actual sample intervals changes inversely. Scaling a normalized discrete frequency with the nominal rate produces a corresponding frequency error. This reuses the sample-index and continuity conventions in Model 10E. Count intervals carefully: a record containing N endpoint samples spans $N-1$ intervals between its first and last sample.

Equation 23I. Actual sample-clock time and frequency scaling

$$f_{s,true} = f_{s,nom}(1+\varepsilon) > 0$$
$$T_{true} = \frac{N}{f_{s,true}}, f_{label} = \frac{f_{true}}{1+\varepsilon}$$
$$N\ sample\ intervals\ have\ N+1\ endpoint\ samples.$$

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For two channels, subtract their time errors before converting to relative phase. Common contributions can cancel, but unequal distribution paths, resets, aperture delays, or processing offsets remain. The shared reference is only one element of the timing system. A common-signal calibration should traverse the actual analog and digital paths and be repeated after any state change that can alter their relationship.

Equation 23J. Relative channel timing and phase

$$x_{AB} = x_A - x_B$$
$$\varphi_{AB} = 2\pi f_0 x_{AB}$$

A calibration interval can be chosen from justified bounds on initial time error, fractional-frequency error, and drift. Their worst-case accumulated envelope is monotone for nonnegative bounds and nonnegative elapsed time. Compare it with the time error corresponding to the allowed phase error at the stated carrier. If the initial bound already exceeds the limit, no positive waiting interval is feasible. If it equals the limit and a drift bound is nonzero, only the initial instant qualifies. If both frequency and drift bounds vanish, the initial bound alone decides the interval.

Equation 23K. Deterministic accumulated-error envelope

$$|\, x(t) \,| \le b_0 + b_y t + \frac{b_d}{2} t^2$$
$$b_0, b_y, b_d \ge 0, t \ge 0$$

Equation 23L. Finite calibration interval for a positive drift bound

$$B = \frac{\varphi_{tol}}{2\pi f_0} - b_0 > 0$$
$$t_{max} = \frac{2B}{b_y + \sqrt{b_y^2 + 2 b_d B}} \; if \; b_d > 0$$
$$t_{max} = \frac{B}{b_y} \; if \; b_d = 0 \text{ and } b_y > 0$$

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12.3 Worked applications with hypothetical inputs

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12.4 Application 12A.1: Accumulate a constant fractional frequency offset

A clock has constant fractional frequency error +0.2 parts per million and begins with zero time error. Over 86,400 seconds it advances by 0.01728 s, or 17.28 ms. At a nominal 10 MHz, its frequency error is +2 Hz and its relative unwrapped phase accumulates 172,800 cycles. A wrapped phase display cannot retain that cycle count by itself.

The daily result assumes the offset stays constant for the entire day. If the reference is disciplined or its environment changes, use the measured or bounded time-dependent error instead. A small-looking fractional specification can produce a large epoch error over a long interval, while the same offset can be unimportant for a short amplitude-only observation. The acceptable limit follows from the intended timing or coherence decision.

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12.5 Application 12A.2: Integrate a linear fractional-frequency drift

Start with a +2 μs epoch error, fractional frequency -10^{-8}, and a linear fractional-frequency drift of 2×10^{-12} per second. After 3,600 s, the time error is -21.040000 μs and fractional frequency is -2.8×10^{-9}. At 10 MHz the unwrapped relative phase is -210.400000 cycles.

The positive drift partly offsets the initially negative frequency error, but the accumulated time error remains negative. Reading only the final frequency would miss the history represented by the integral. This constructed polynomial is valid only over its stipulated interval. A holdover claim needs evidence that the coefficient bounds or model remain applicable under the relevant temperature, supply, and prior-lock conditions.

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12.6 Application 12A.3: Separate an epoch offset from a frequency offset

A clock is advanced by 0.75 μs but has zero fractional frequency error. At 10 MHz, its phase is advanced by 7.5 cycles, represented as −180 degrees in the chosen principal interval from −180 inclusive to +180 exclusive. At 4 million samples per second, the epoch error is three sample intervals. Its frequency error remains zero.

Frequency agreement therefore does not establish aligned samples. A timestamp and a sample index need an explicit relationship to the actual aperture or equivalent sample event. If a transport packet is stamped later, its timestamp may describe a software or interface event instead. Calibrate the required timing point and preserve that definition with the channel record.

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12.7 Application 12A.4: Keep physical delay and clock-error signs separate

A physical delay of 12.5 ns produces −450 degrees transfer phase at 100 MHz, which wraps to −90 degrees. At 400 MHz it produces −1,800 degrees, which wraps to zero. The second tone can therefore appear phase aligned even though the path delay is unchanged and nonzero.

An acceptance rule that compares only one wrapped phase could pass the delayed channel at 400 MHz and fail it at 100 MHz without explaining why. Use an unwrapped frequency response or a justified delay prior when delay is the measurand. Cable substitution and channel reversal can help distinguish a fixed path delay from a phase-reference offset, provided the changed configuration is itself characterized.

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12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity

Two declared unwrapped phases are −72 degrees at 100 MHz and −86.4 degrees at 120 MHz. Their slope gives a 2 ns delay. The 20 MHz spacing creates a 50 ns wrapped-delay ambiguity period: a pure delay of 52 ns gives the same two wrapped phases. The unwrapped pair, or an independent bound selecting its branch, is therefore essential to the 2 ns conclusion.

Adding decimal places to the two phase readings cannot distinguish those branches. A wider or differently spaced set of calibrated tones can provide additional information, but its ambiguity and constant-phase model must be worked out explicitly. If the path is dispersive, fit or retain its frequency-dependent response instead of forcing a single delay through points that do not support it.

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12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements

Time-error observations of 1 and 7 μs are separated by 600 s. The central average fractional-frequency estimate is 10^{-8}, corresponding to 0.1 Hz at 10 MHz. If each endpoint has an absolute error bound of 0.1 μs, the difference can range from 5.8 to 6.2 μs. The resulting fractional-frequency interval has approximate endpoints $9.66666667 \times 10^{-9}$ through $1.03333333 \times 10^{-8}$.

This is a worst-case interval because the endpoint errors can take opposite signs. It is not a confidence interval. If the endpoint errors share a common calibration contribution, a statistical analysis may treat their covariance differently, but that requires additional information. The central estimate alone does not show whether a tolerance boundary is resolved.

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12.10 Application 12A.7: Recognize a phase reset in a finite difference

A phase record has a steady 20 Hz slope and then a 90-degree reset. A 10 μs difference interval crossing the reset reports 20 plus one quarter cycle divided by 10 μs, or 25,020 Hz. Intervals that do not cross the reset continue to report 20 Hz. The large number describes the reset-containing difference, not a persistent oscillator offset.

A derivative is not finite at the idealized phase jump used here. A real instrument may slew rapidly instead, in which case a resolved transient model is needed. In either case, the event must be retained rather than smoothed into a misleading long-term frequency estimate. Splitting the record also prevents a subsequent coherent integration from joining incompatible phase histories without correction.

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12.11 Application 12A.8: Apply the actual sample clock to elapsed time and frequency labels

A nominal 2 MHz sample clock is actually 25 parts per million high, giving 2000050 samples per second. Two million actual sample intervals occupy 0.999975000625 s, which is -24.999375 μs less than the nominal second. A true 100 kHz tone labeled using the nominal clock appears at 99997.500062 Hz.

The example counts two million intervals, so a record including both endpoints contains two million and one samples. The frequency result also presumes the correct admitted alias class. A wrong clock scale and a wrong alias choice are separate errors and need different challenges. Record the clock estimate and the frequency-axis convention together so that later reprocessing can apply a consistent correction.

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12.12 Application 12A.9: Form a relative channel phase from two time-error laws

Channel A begins at +100 ns and has fractional frequency $+2\times10^{-9}$. Channel B begins at −50 ns and has fractional frequency -10^{-9}. After 10 s, their relative time error A minus B is 180 ns. At 10 MHz that is 648 degrees unwrapped, or −72 degrees in the principal interval.

These are independently identified channel residuals. A common nominal reference does not make them vanish, because distribution, aperture and processing terms can differ. The appropriate calibration observes a common signal through the paths actually used for the later comparison. If a channel reset or a missing-sample event occurs afterward, the previous relative phase result no longer applies automatically to the successor segment.

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12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds

At 10 MHz, allow no more than 45 degrees phase error, equivalent to 12.5 ns time error. Suppose justified bounds are 2 ns initially, 10^{-11} in fractional frequency, and 10^{-14} per second in fractional-frequency drift. Solving the quadratic bound gives a maximum interval of approximately 760.681686 s. Substituting the unrounded endpoint returns the 12.5 ns limit.

The result is an engineering interval conditional on those bounds, not a universal recalibration schedule. A changed temperature range, reference source, distribution path, or reset history can invalidate it. Repeat or update the bound when those conditions change. If the initial calibration uncertainty alone exceeds the allowed time error, shortening the interval cannot solve the problem; the initial measurement must improve or the intended claim must change.

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12.14 Phase Noise and Close-In Observation

Phase noise spreads oscillator energy around a carrier and limits the receiver's ability to see weak signals near strong ones. Contributions arise from the reference, synthesizer, multipliers, local oscillators, clocks, power supplies, and mechanical sensitivity. The analyzer or receiver used to measure phase noise must have lower residual noise or use correlation and reference techniques that separate instrument noise.

Integrated phase noise can be related to timing jitter over a specified offset band, but the integration limits and carrier frequency matter. Close-in flicker, spurs, and far-out white phase noise affect communications, radar, coherent integration, and reciprocal mixing differently. A single jitter number cannot replace the phase-noise spectrum when receiver selectivity is the issue.

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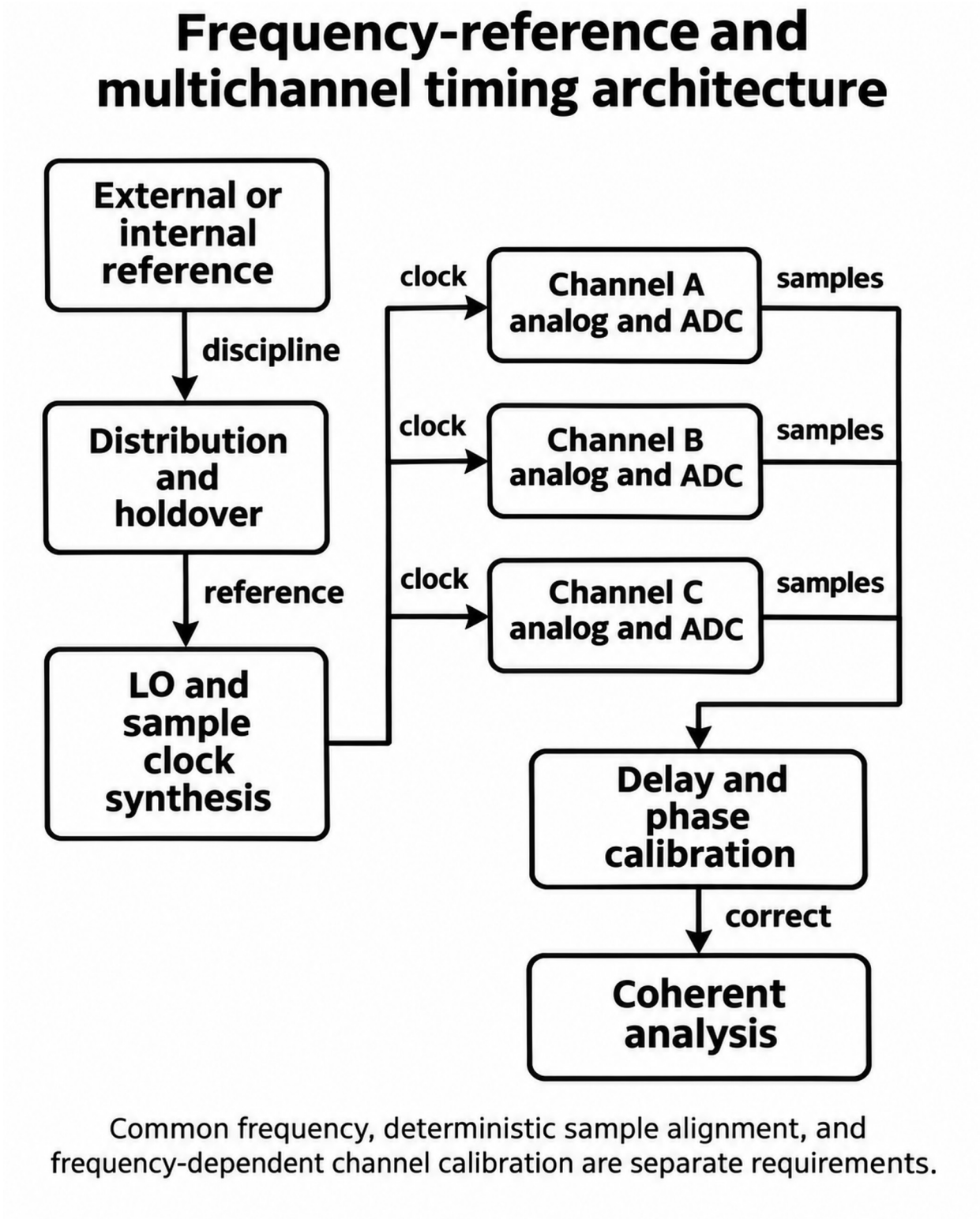

Figure 65. Multichannel frequency-reference architecture.

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12.15 Clock Jitter and Sampling Uncertainty

Sampling-clock jitter creates voltage error proportional to signal slope. At high input frequency, a small timing uncertainty can limit effective converter performance even when quantization is excellent. Clock distribution adds skew, additive jitter, duty-cycle distortion, crosstalk, and common-mode coupling. Different digitizers advertised as synchronized may share frequency but not deterministic phase or sample alignment.

Jitter tests use known high-frequency inputs, phase-noise measurements, time-interval instruments, or cross-channel comparison. The measurement distinguishes random and deterministic components where practical. Temperature, cable movement, reference switching, and holdover can change results. For short bursts, trigger and timestamp uncertainty may dominate long-term clock accuracy.

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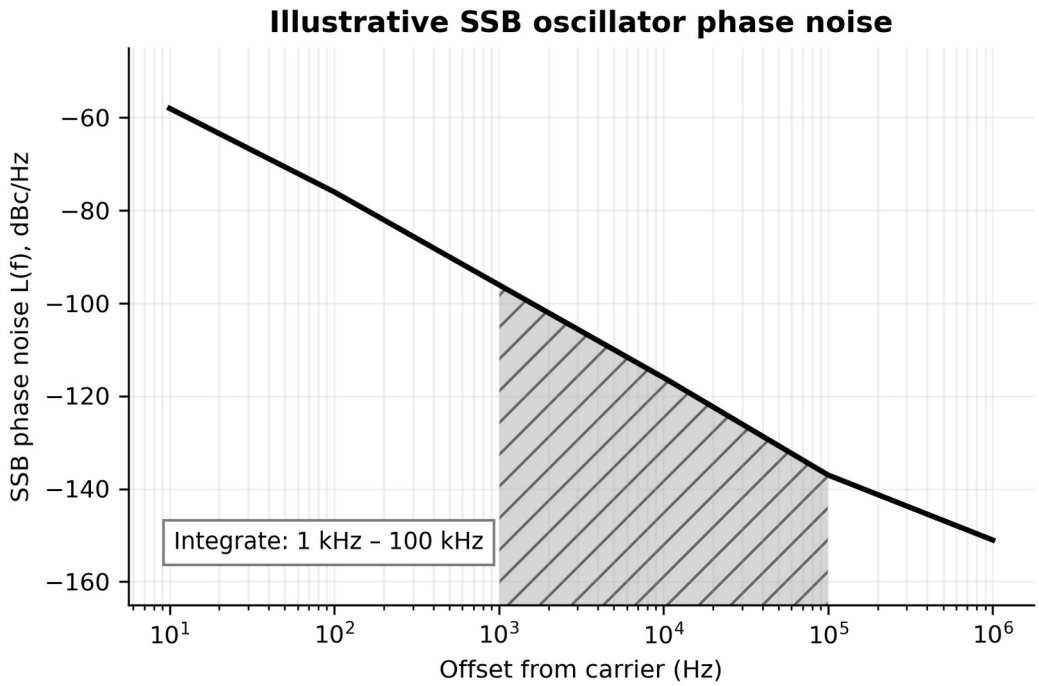

$$\sigma_\phi^2 \simeq 2\int_{f_1}^{f_2} 10^{L(f)/10}\, df$$

$\sigma_t = \sigma_\phi/(2\pi f_c)$; example $f_c = 1$ GHz: 0.11 ps

TECHNICAL INTERPRETATION

Integrated jitter depends on the oscillator spectrum AND declared offset integration limits; a single phase-noise point is insufficient.

Figure 66. Phase-noise integration and timing jitter.

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12.16 Model 12B: finite-band jitter and coherent signal power

A single RMS jitter value compresses a spectral distribution into one number. That can be useful for a defined timing calculation, but it cannot preserve the offset-dependent receiver consequences of the original phase noise. Model 12B reuses Model 11B's linear single-sideband phase-density convention and states an explicit positive-offset integration band. The corresponding real phase process has equal positive and negative spectral contributions, producing the factor two in its variance. The carrier frequency then converts radians to seconds.

Equation 24A. Linear SSB density and finite-band phase variance

$$\ell(f)=10^{\frac{L_{dBc/Hz}(f)}{10}}$$
$$\sigma_\varphi^2=2\int_F \ell(f)\,df\,,F\subset(0,\infty)\,\textit{is the stated band}$$

Equation 24B. Band-limited phase-to-time conversion

$$\sigma_t=\frac{\sigma_\varphi}{2\pi f_0}\,,f_0>0$$

The phase RMS σ_φ is in radians and timing RMS σ_t is in seconds. Linear SSB density ℓ has reciprocal-hertz units under the adopted radian convention; its logarithmic representation L is reported in dBc/Hz relative to the carrier. The integration set F contains the declared positive offset bands in hertz. Covariance C and increment variance D are in squared radians. In the finite-vector calculation, μ_k is a mean phase and C_{ij} is the covariance of samples i and j; N is their positive integer count.

Integrate linear density, not decibel ordinates. Adjacent bands can be integrated separately and their variance contributions added. A local power-

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law fit must remain local unless its continuation has been justified and is integrable. A discrete modulation or reference line has a line power rather than a density independent of resolution bandwidth. Analog Devices' MT-008 illustrates linear integration and the phase-to-time conversion; the integration limits in this chapter are chosen explicitly for each constructed case rather than inherited from a generic clock example.[3]

The covariance of the band-limited phase component follows from the cosine transform of its even two-sided spectrum. The phase-difference variance between two instants is twice the variance minus twice their covariance. These are second-order relationships for the stated finite-variance stationary component. They show why two phase-noise distributions with equal integrated variance can affect a given time separation differently: the increment weighting contains one minus the cosine of offset frequency times separation.

Equation 24C. Covariance of the stated phase component

$$C(\tau)=2\int_F \ell(f)\cos(2\pi f\tau)\,df$$

Equation 24D. Phase-increment variance and its spectral weighting

$$D(\tau)=E\left[\left(\varphi(t+\tau)-\varphi(t)\right)^2\right]=2\left[C(0)-C(\tau)\right]$$
$$¿\,4\int_F \ell(f)\left[1-\cos(2\pi f\tau)\right]df$$

Independent timing contributions can have their variances added, but a shared source or coupled path can make them correlated. Retain the

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3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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covariance or cross-spectral information needed by the calculation. The sign matters: positively correlated errors reinforce when added, while negatively correlated errors can partly cancel. For a difference between channels, the same common contribution can cancel instead of reinforcing. Define the time-error quantity before deciding how to combine its components.

Equation 24E. Two timing contributions with covariance

$$\sigma_{\text{sum}}^2 = \sigma_1^2 + \sigma_2^2 + 2\rho\sigma_1\sigma_2, -1 \le \rho \le 1$$

A PSD alone supplies second-order information. It does not determine every nonlinear phase function. To calculate the exact mean of a complex phase exponential, the next part of the model explicitly assumes a finite jointly Gaussian phase vector with specified mean and covariance. The variance of a phase difference is the sum of the two marginal variances minus twice their covariance. The Gaussian characteristic function then gives the exponential of minus one half that difference variance, multiplied by the deterministic mean-phase factor. This distributional assumption is additional to stationarity or a measured RMS value.

Equation 24F. Finite Gaussian phase-vector differences

$$\varphi \; jointly \; Gaussian : E\varphi = \mu, Cov(\varphi) = C$$
$$D_{ij} = C_{ii} + C_{jj} - 2C_{ij} \ge 0$$

Equation 24G. Gaussian phase-difference characteristic function

$$E\left[\exp\left(j(\varphi_i - \varphi_j)\right)\right] = \exp\left(j(\mu_i - \mu_j)\right)\exp\left(-\frac{D_{ij}}{2}\right)$$

The exponential identity follows by applying the characteristic function of a real normal variable to the phase difference. Integrating its complex exponential against a normal density, or differentiating that Gaussian integral and fixing its value at zero, gives the mean-phase exponential times

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the exponential of minus one half the variance. A linear combination of a jointly Gaussian vector is normal, so the difference has the required law. Merely knowing the variance of a non-Gaussian difference does not supply this step.

Normalize an equal-weight coherent sum by its positive integer sample count. Expanding its squared magnitude produces every pair of sample phasors, including the diagonal self terms. Taking expectations with the stated Gaussian relation gives mean coherent signal power. Conjugate off-diagonal pairs make the result real. This is not a complete signal-to-noise improvement calculation: additive noise, amplitude variation, and any estimated phase corrections would need their own justified treatment.

Equation 24H. Expected normalized coherent signal power

$$q=\frac{1}{N}\sum_{k=1}^{N}\exp\left(j\varphi_k\right),N\in\mathbb{Z}_{¿0}$$

$$E\left|q\right|^2=\frac{1}{N}+\frac{2}{N^2}\sum_{1\le i<j\le N}\exp\left(-\frac{D_{ij}}{2}\right)\cos\left(\mu_i-\mu_j\right)$$

A common random phase rotates every sample together. It can reduce the magnitude of the ensemble-mean phasor while leaving the coherent power within every record unchanged. Independent sample phases instead create relative rotations and cancellation, with a finite-sample diagonal contribution that remains in the expected power. Equation 24I compares a common Gaussian phase with independent Gaussian phases having the same mean phase and common variance. The shared mean may be taken as zero without changing either power result. Different deterministic mean phases remain in Equations 24H and 24K. These two cases have the same marginal phase variance but different coherence. The Gaussian-vector applications start from stipulated covariance, so they do not rely on

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interpreting a large measured RF sideband through a small-phase approximation.

Equation 24I. Common Gaussian phase and independent Gaussian phases

$$common\,\varphi : E|q|^2 = 1,\ |\ E\,q\ | = \exp\left(-\frac{\sigma^2}{2}\right)$$
$$independent\ phases : E|q|^2 = \frac{1}{N} + \left(1 - \frac{1}{N}\right)\exp\left(-\sigma^2\right)$$

For a stationary Gaussian vector with equal marginal variance, a specified lag covariance can be substituted directly into the pair sum. It is the increment variance, not the marginal RMS alone, that determines the pair coherence. A proposed covariance matrix must be positive semidefinite to describe a possible joint vector. The geometric lag example below satisfies that condition; an arbitrary table of pairwise correlations might not.

Equation 24J. Equal-variance covariance specified by lag

$$C_{ij} = \sigma^2 \rho^{|i-j|},\ |\ \rho\ | < 1, \mu_k = 0$$
$$D_k = 2\sigma^2[1 - \rho^k]$$
$$E|q|^2 = \frac{1}{N} + \frac{2}{N^2}\sum_{k=1}^{N-1}(N-k)\exp\left(-\sigma^2\left(1-\rho^k\right)\right)$$

Deterministic frequency rotation can be combined with independent Gaussian phase errors by keeping the deterministic phasor sum and the random diagonal contribution separate. Evaluate the finite sum directly at special frequencies where a trigonometric closed form would have a removable zero-over-zero expression. State the actual sample times: N samples separated by a fixed interval have an endpoint span of $N-1$ intervals, even though the geometric-sum numerator involves N times that interval.

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Equation 24K. Deterministic rotation plus independent phase error

$$\varphi_k = \theta_k + \varepsilon_k, \varepsilon_k \, independent \, N(0, \sigma^2)$$
$$E|q|^2 = \exp(-\sigma^2) \left| \frac{1}{N} \sum_{k=1}^{N} \exp(j\theta_k) \right|^2 + \frac{1 - \exp(-\sigma^2)}{N}$$

Unmeasured phase noise should remain visible as an unmeasured contribution. If a justified upper density bound exists over a finite extra band, integrate it to obtain a variance bound and then convert the interval to timing RMS. Without such a bound, extending a plotted floor is an assumption, not measured evidence. Frequencies outside the declared combined bands remain outside the result, and an RMS number should be labeled accordingly.

Equation 24L. Bound a finite additional offset band

$$0 \le V_{extra} \le 2\ell_{max}(f_H - f_L)$$
$$\frac{\sqrt{V_{meas}}}{2\pi f_0} \le \sigma_{t,combined} \le \frac{\sqrt{V_{meas} + 2\ell_{max}(f_H - f_L)}}{2\pi f_0}$$

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12.17 Worked applications with hypothetical inputs

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12.18 Application 12B.1: Integrate a flat SSB density over a declared band

A flat SSB density of −120 dBc/Hz is stipulated from 1 kHz through 1 MHz at a 100 MHz carrier. Its linear density is 10^{-12} per hertz. Multiplying the 999,000 Hz width by twice that density gives $1.998 \times 10^{-6}\ \mathrm{rad}^2$. Phase RMS is 0.001413506 radian, and timing RMS is 2.249665 ps.

The result belongs only to the stated offset band. It does not include a close-in drift or an unmeasured high-offset floor. A comparison with another jitter number is meaningful only after aligning carrier frequency, offset limits, weights and line treatment. Equal numerical picoseconds can otherwise hide very different definitions.

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12.19 Application 12B.2: Add density bands in linear units

Use −110 dBc/Hz from 1 to 10 kHz and −135 dBc/Hz from 10 kHz to 1 MHz. The two phase-variance contributions are 1.8×10^{-7} and $6.26130977 \times 10^{-8}\ \mathrm{rad}^2$. Their sum is $2.42613098 \times 10^{-7}\ \mathrm{rad}^2$, giving 0.783930 ps at 100 MHz.

The narrower band can contribute strongly because its density is much higher. Averaging the two decibel levels would not integrate either band and would lose their different widths. Keep the contribution table with the result when a design or measurement change affects only one offset region. It then remains clear which part of the noise changed and which part was merely omitted.

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12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion

The same 0.02 radian phase RMS corresponds to 318.309886 ps at 10 MHz and 3.183099 ps at 1 GHz. Conversely, a fixed 1 ps timing RMS corresponds to 0.000062832 and 0.006283185 radian at those two carriers.

Neither comparison shows that one oscillator is better without specifying which physical quantity and observation band are being held fixed. A timing error produces more phase error at a higher carrier. A fixed phase error converts to fewer seconds at that carrier. Preserve the carrier and reference plane whenever phase noise or jitter is transferred between a clock, LO, and sampled-signal calculation.

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12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin

A deterministic 20 kHz phase-modulation line has peak phase 0.01 radian on a 100 MHz carrier. Over complete modulation periods, its phase variance is $5\times10^{-5}\ \mathrm{rad}^2$ and its timing RMS is 11.253954 ps. The first-order RF sideband power is 2.5×10^{-5} on each side, or -46.020600 dBc relative to an unmodulated carrier.

The line power is not a density independent of the analysis bandwidth. A reported dBc/Hz value for the line requires a stated bandwidth convention. Its RMS phase also does not make it a Gaussian phase process. Use its deterministic trajectory when calculating coherence, or state a separate random-phase model if that is the actual experiment. Applying the Gaussian exponential formula solely from this RMS value is unjustified.

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12.22 Application 12B.5: Include covariance when combining timing contributions

Two additive timing-error contributions have RMS values 2 and 3 ps. Correlation coefficients +0.5, zero, and −0.5 give combined RMS values 4.358899, 3.605551, and 2.645751 ps. The familiar root-sum-square result is only the zero-covariance middle case.

A shared reference can create correlation, but its magnitude and sign still depend on the transfer paths and the defined error quantity. For a relative-channel difference, common-mode timing may cancel instead. Measure or justify the relevant covariance rather than labeling every contribution independent because it has a separate component name. The individual RMS values do not supply that missing information.

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12.23 Application 12B.6: Distinguish a common random phase from lost coherent power

Eight samples in each record share exactly one zero-mean Gaussian phase with RMS 0.4 radian. The magnitude of the ensemble-mean phasor is 0.92311635, and its square is 0.85214379. Nevertheless, the normalized coherent sum has power one in every record, so its mean power is one.

All eight phasors rotate together and therefore do not cancel within the record. This does not establish their absolute phase relative to an external reference. It establishes that common random rotation and relative phase decorrelation are different effects. The distinction is essential when a measured loss in an ensemble-averaged complex trace is interpreted as a loss of recoverable signal energy.

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12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases

Now make the eight zero-mean Gaussian phases independent, each still with RMS 0.4 radian. The exact model gives mean normalized coherent power of approximately 0.87062582, or -0.601685 dB relative to unity. Its infinite-sample limit is 0.85214379, but the finite record retains its diagonal self-power contribution.

The marginal RMS is unchanged from Application 12B.6, while the covariance structure is completely different. A single jitter number cannot select between the two results. The independent-phase model may be useful for a stipulated sampled process, but adjacent samples from a narrowband physical phase-noise process are generally not automatically independent. Their actual covariance must support that approximation.

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12.25 Application 12B.8: Use a specified correlated Gaussian phase vector

Keep eight jointly Gaussian phase samples with 0.4 radian RMS, but specify covariance at lag k as $0.16 \times 0.8^{|k|}$. Substituting those pair differences into Equation 24H gives mean normalized coherent power 0.93937987, or -0.271588 dB. The positive correlation preserves more relative alignment than the independent case.

This covariance is a valid geometric-lag model, not a covariance estimated from an undisclosed instrument record. A measured application would preserve the estimation interval, mean removal, and evidence supporting joint Gaussianity if the exact exponential result were used. Second-order covariance alone can still describe phase differences without establishing that distributional step.

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12.26 Application 12B.9: Combine deterministic rotation with independent phase errors

Use 100 samples at 100 μs spacing with deterministic residual frequency 50 Hz. Their normalized deterministic coherent power is 0.40531807. Add independent zero-mean Gaussian phase errors with RMS 0.1 radian; expected coherent power becomes 0.40138459, or -3.964393 dB.

Most of the loss here comes from the deterministic rotation, so improving random phase noise alone does not restore coherent integration. The first-to-last sample span is 9.9 ms, while the finite geometric-sum expression uses the 100-sample count. A justified frequency correction can address the rotation, but fitting it to the same weak record introduces an estimation issue that must be evaluated separately.

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12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution

A measured band contributes $2\times10^{-6}\ \mathrm{rad}^2$. A separate justified upper SSB density bound of 10^{-15} per hertz applies only from 1 to 20 MHz. That finite band can add at most $3.8\times10^{-8}\ \mathrm{rad}^2$. At a 100 MHz carrier, the combined timing-RMS interval has endpoints of approximately 2.250791 and 2.272073 ps.

The upper bound is useful because its domain is explicit. It says nothing about lower offsets excluded from the measured band or offsets above 20 MHz. An unlimited extension of a nonzero white floor would have divergent variance and would contradict the finite-variance premise. A complete timing specification must identify the physical filtering or other evidence that defines its meaningful bandwidth.

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12.28 Coherent Integration and Phase Preservation

Coherent integration adds complex samples with preserved phase, increasing a stable signal more rapidly than uncorrelated noise. It requires frequency and phase stability over the integration interval. Motion, multipath, modulation, clock error, propagation change, and source instability limit coherence time. Extending integration beyond that time can reduce rather than improve the result.

The practitioner estimates coherence from repeated phase measurements, cross-correlation, or model residuals and validates on a known reference. Phase corrections derived from the signal under test can overfit noise or create artificial coherence. The correction method and degrees of freedom are retained. A weak component revealed only after extensive phase alignment is reported with the processing dependency.

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12.29 Multichannel Synchronization and Delay Calibration

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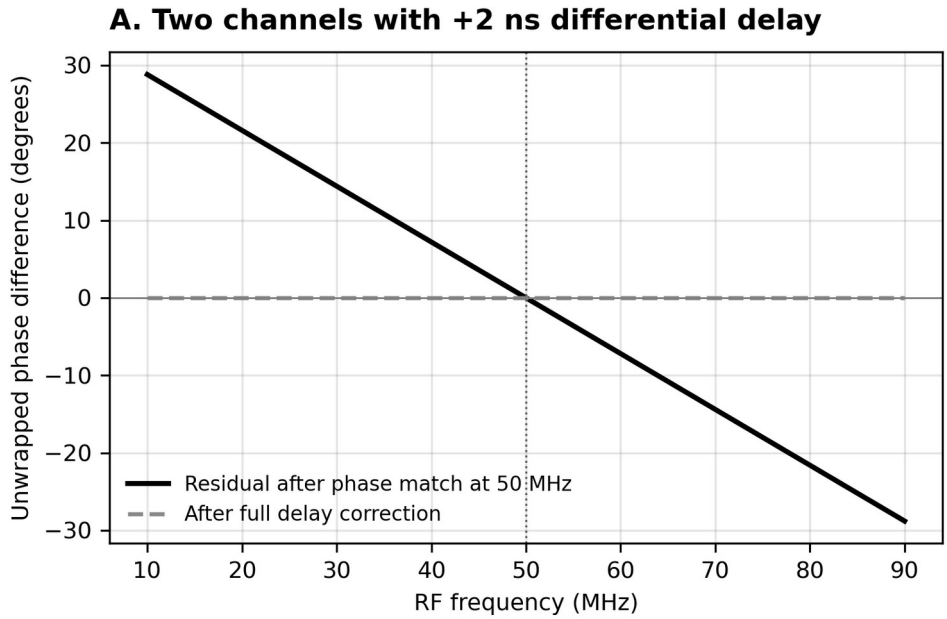

B. Delay produces a phase slope

$\Delta\phi(f) = -360^\circ (f - f_{ref})\Delta\tau$ for f in Hz

$\Delta\tau = 2$ ns gives -0.72°/MHz phase slope.

A common sampling clock does not remove unequal cable, filter, aperture or processing delays. Calibrate phase across the operating bandwidth and document residual frequency-dependent uncertainty.

Figure 67. Phase offset versus broadband delay calibration.

Direction finding, TDOA, phase comparison, and cross-spectral analysis require known channel timing and phase. Shared sampling clocks are not enough if trigger paths, analog filters, cables, ADC apertures, digital pipelines, and packet transport have unequal delays. Calibration uses a common signal injected or radiated into all channels through known

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geometry and repeated across frequency. The broadband phase-delay distinction is illustrated in Figure 53.

Delay can vary with frequency because of filters and cables. A single time offset may not correct broadband data. Channel swaps and reversal tests help separate sensor geometry from electronics. Missing samples and asynchronous packet timing are monitored. The final uncertainty combines calibration residual, clock stability, location, geometry, interpolation, and signal bandwidth.

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12.30 Accept coherence at the required boundary and state

Treat reference distribution as a measured network. A common oscillator can feed paths with different cable delays, additive noise, termination sensitivity, power-up behavior, and deterministic phase resets. Identify the clock or LO port, analog aperture, sample index, trigger, and timestamp points used by the intended comparison. A calibration at a convenient reference connector does not automatically establish the relationship at the stored sample boundary.

Use a common injected signal to compare channel amplitude and phase over the required band, then change one element at a time to localize residuals. Channel swaps test whether the error follows a path or a channel. Cable substitution tests delay and sensitivity to installation. Retune, trigger, and restart sequences test whether the phase relation is preserved or must be re-established. Repeat after environmental or configuration changes that can alter the accepted state.

A coherence time should be reported as an interval meeting a specified operation and error criterion. A phase tolerance for beamforming, a coherent tone sum, a cross-spectrum, and a timestamp correlation may lead to different intervals. Model 12B supplies one conditional coherent-power calculation; Model 12A supplies deterministic accumulated-error bounds. Neither replaces actual observation of a system whose reference changes state or whose signal path is not stationary.

Retain the original phase and timing records alongside any correction. A fitted delay, frequency trend, or phase trajectory can improve alignment while concealing the instability being investigated. Verify the correction on a

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known reference and, where possible, on an interval not used for fitting. If a discontinuity prevents coherent comparison across part of the record, state that boundary and limit the claim to the valid segments instead of forcing a continuous interpretation.

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12.31 Reference Distribution Acceptance

The reference-distribution system is accepted as a network. Tests include frequency offset, phase noise, additive jitter, channel skew, warmup, holdover, relock, power interruption, cable substitution, and environmental change. Each output is identified and measured at the installed termination, because distribution amplifiers and long cables can dominate performance after the primary reference.

Reference changes during an engagement are logged as configuration events and linked to affected captures. The receiver is not assumed coherent across a retune, trigger reset, firmware restart, or loss of lock unless deterministic phase behavior has been demonstrated. When absolute phase cannot be preserved, the analysis is limited to quantities supported by relative timing or magnitude.

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12.32 Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing

Equation 1. Fractional frequency error

$$\varepsilon_f = \frac{f_{\text{meas}} - f_{\text{ref}}}{f_{\text{ref}}}$$

Fractional frequency error ε_f is the difference between measured and reference frequency divided by reference frequency. It is dimensionless and can be expressed in parts per million or smaller units. The observation interval and reference uncertainty must be stated.

Equation 2. Time jitter from phase noise

$$\sigma_t = \frac{\sigma_\varphi}{2\pi f_c}$$

Root-mean-square time jitter σ_t is related to RMS phase fluctuation σ_φ in radians at carrier frequency f_c when the phase variance has been integrated over a specified offset band. The conversion does not retain the spectral distribution of the noise.

Equations 23 and 24 use the conventions developed in Models 12A and 12B and their respective ten applications. The reference frequency and carrier frequency are positive. Phase-to-time conversion retains the stated offset band and phase convention; it does not establish a broadband physical path delay from one scalar jitter value.

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Table 1. Chapter 12 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Frequency reference	Type, identity, lock, holdover, distribution, calibration, and uncertainty	Supports tuning and measurement accuracy	A lock indicator does not prove short-term purity
Phase noise	Carrier, offset range, residual instrument noise, spurs, and integration limits	Limits close-in sensitivity and coherent processing	One integrated jitter number hides spectral location
Clock and trigger	Sample clock, skew, jitter, trigger path, timestamp, and missing samples	Defines timing of digitized records	Frequency synchronization does not guarantee phase alignment
Multichannel calibration	Common signal, cable and filter delay, frequency dependence, swaps, and residuals	Supports phase, delay, and direction estimates	A single narrowband offset cannot correct a wideband system

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12.33 Hypothetical Applied Calculation: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing

A 1.000000000 GHz reference is measured 120 Hz high. The fractional error is 1.2×10^{-7}, or 0.12 parts per million. If the measurement receiver's reference uncertainty is 0.2 parts per million, the observed difference is not sufficient to claim that the source is out of tolerance.

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12.34 Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing

Three remote SDR channels share a disciplined 10 MHz source but use independent packet triggers. A TDOA estimate suggests an impossible location until calibration shows packet-alignment variations of several samples. Adding a deterministic trigger and per-channel delay calibration resolves the geometry. Shared frequency alone had not provided synchronized sampling.

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12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation

A nominal common frequency reference is not sufficient to claim simultaneous RF observation. Multichannel receivers also require knowledge of sample-aperture phase, clock distribution delay, trigger alignment, counter semantics and periods when a disciplined reference was lost. In a simplified clock model, local time $t_i = a_i t_{ref} + b_i + \epsilon_i(t)$, a_i represents scale or rate error, b_i the epoch offset, and ϵ_i time-dependent deviation. Estimating these parameters from a shared reference pulse can align observed events but must include reference-pulse propagation, antenna geometry, analogue group delay, detector latency and timestamp definition. A host file-creation time need not represent a converter aperture even when the host operating system is synchronised to a trusted time service.

Holdover error grows after loss of discipline according to the underlying oscillator's frequency instability and any applied drift model. If a clock has a constant fractional frequency error $y = 2$ parts per million after the last confirmed reference event, then after 90 seconds its idealised accumulated time offset is y multiplied by 90 s, or 180 microseconds. That is a deterministic illustrative drift, not a bound for every oscillator; temperature and random-walk frequency noise can make the actual deviation vary with elapsed time. An instrument that reports a syntactically precise timestamp to the nearest nanosecond may nevertheless possess hundreds of microseconds of uncertainty under such conditions. Stated time digits, absolute accuracy and phase coherence must be treated as distinct claims.

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A correct multi-receiver timing uncertainty calculation is covariance aware. If two channel time estimates have variances u_1 squared and u_2 squared and covariance c_12, the variance of their difference is u_1 squared + u_2 squared - 2c_12. A shared reference offset may cancel in a difference, while a common clock-distribution transient may affect all channels and defeat independent corroboration. For a location inference, correlations of arrival-time errors can determine the shape of the feasible spatial region. Assuming zero covariance without evidence may make a calculated error ellipse look implausibly narrow. The acquisition plan should record which inputs are common, which are independently disciplined and where clocks are rederived or resampled.

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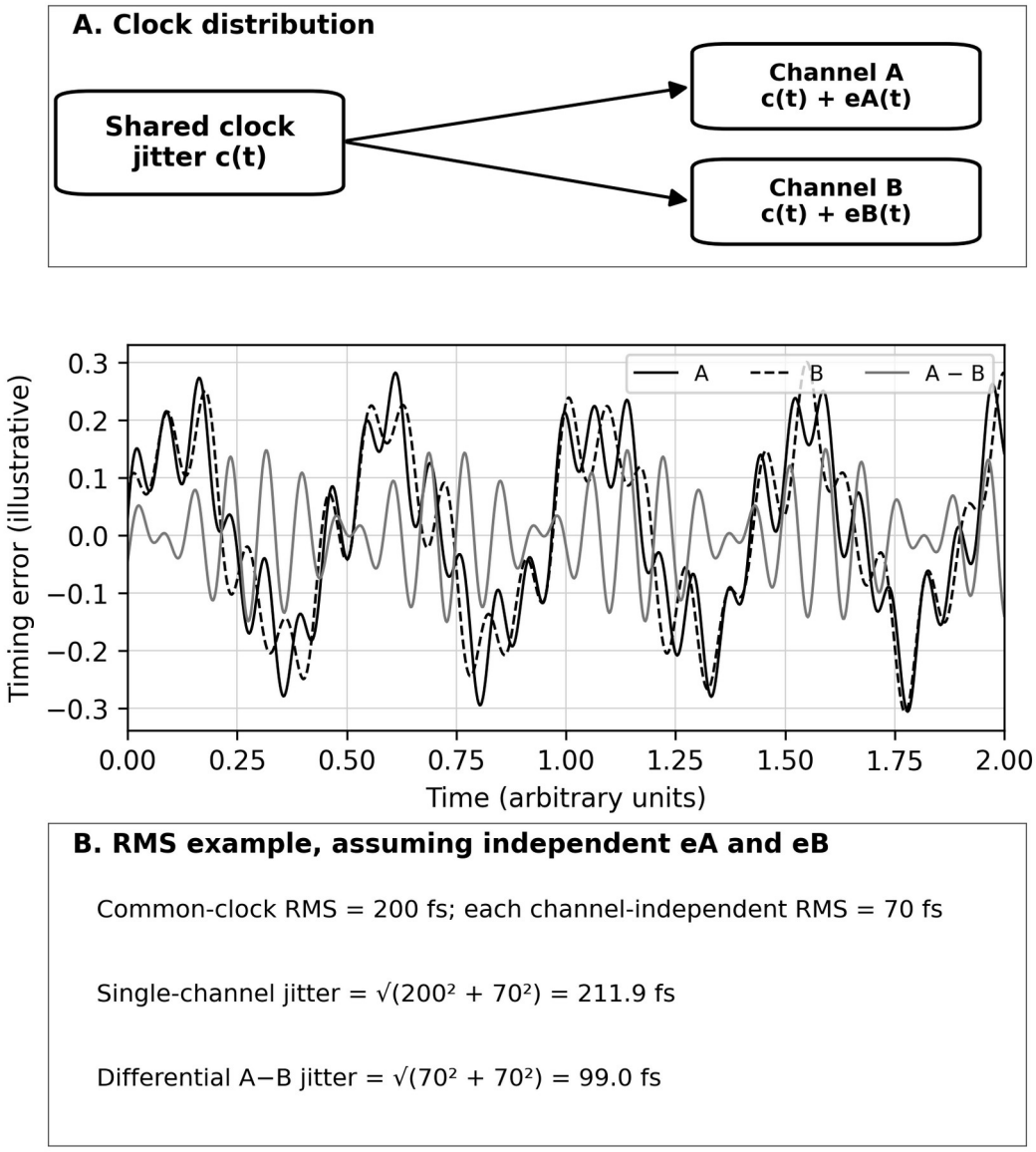

A common reference does not automatically guarantee coherence; path delays and independent timing noise still require calibration.

Figure 68. Common and independent clock jitter.

The integrity record should preserve original sample counters and clock-state events before fitting a common time coordinate. A sample counter can remain continuous through a host writing delay, while a temporary device-buffer overflow can remove samples even if file timestamps are regularly

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spaced. Partition the record into acquisition epochs separated by resets, loss of lock, counter discontinuities or unvalidated state changes. Timing corrections and interpolation belong to derivative products, with the raw counter sequence still available. Cross-correlation of two received signals is useful only after accounting for their possible shared interference and source content, and is not a substitute for demonstrating that the recorded waveform belonged to the claimed physical event.

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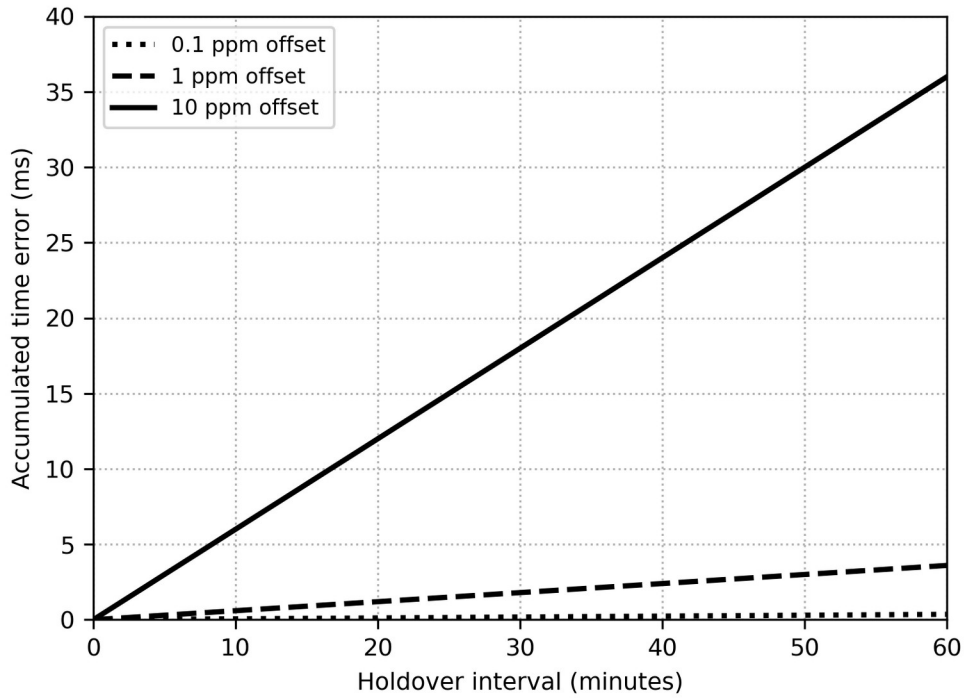

$\Delta t \approx \varepsilon\, t$ (ε: fractional frequency error)

Uncompensated constant-offset model; real oscillators also have drift and noise.

Figure 69. Clock-holdover error and frequency offset.

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12.36 Advanced technical expansion. Shared clocks, holdover uncertainty and coherent-channel covariance

Frequency accuracy and coherent timing involve several quantities that must not be collapsed into one clock specification. A stable reference frequency, short-term phase fluctuations, long-term drift, synchronisation offset, transport asymmetry and sample-aperture timing are connected but different. A converter can have an accurate nominal sample rate while individual aperture times vary enough to damage high-frequency coherent measurement. Conversely, multiple receivers may appear synchronised because they share one reference, yet the same reference fault can affect every channel and create misleadingly consistent results. The measurement record should identify where each timestamp is generated and which event it denotes, rather than assigning all recorded dates the evidential strength of an actual sample-aperture measurement.

For a reference oscillator with nominal frequency f_0 and fractional frequency error y(t), accumulated time error x(t) follows the integral of y(t) over elapsed time under the selected sign convention. A constant fractional error of 1 part in 10^9 causes approximately 1 microsecond of accumulated time error over 1,000 seconds if no correction is applied. A constant error is a simple illustrative model; real holdover includes drift, stochastic noise, temperature sensitivity and retraining after reference acquisition. A user who reports a single 'clock accuracy' value without its averaging interval or holdover duration has not specified the quantity needed for coherent reconstruction. The uncertainty of a time interval may increase substantially

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when the external reference is lost, even while the receiver continues to emit plausible timestamps.

Short-term stability must be described at a relevant observation interval and with an estimator compatible with the noise process. Allan variance and related stability statistics can help distinguish characteristic oscillator-noise behaviours, but their interpretation depends on sampling, dead time, estimator and the span of available data. A plotted stability curve is not a universal upper bound on future holdover performance. If receiver channels share power supplies, enclosure temperature and common reference distribution, they also share components of the timing error. A multichannel uncertainty budget should therefore include common-mode covariance instead of claiming that averaging the channels creates independently timed evidence. Independence requires a physical argument about fault and noise mechanisms, not just separate channel identifiers.

Relative phase error becomes particularly important as RF frequency rises. For a pure sinusoid of frequency f, a time-offset error delta_t corresponds to phase difference delta_phi = 2 pi f delta_t. A 200-ps relative timing uncertainty at 1 GHz corresponds to approximately 1.257 radians, or 72 degrees. For a phase-coherent array, that is potentially consequential even though the same time error appears negligible on a millisecond-level event log. The error can also be frequency dependent because cable and distribution-network group delays vary across the band. A calibration at one tone therefore does not prove phase agreement for every captured waveform. The installed network, connector state and temperature must be part of the calibration evidence.

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A distributed receiving system requires separate validation of common time, sample indexing and signal propagation delay. A timestamp assigned when a packet arrives at a computer is not interchangeable with the time of the ADC aperture; network transport, buffering and retransmission can introduce delays uncorrelated with the RF event itself. A hardware trigger may mark one event but not prove that all downstream samples were retained. Record source-clock identity, synchronisation status, reference transitions, per-channel sample counters, measured phase offsets, and the actual delay correction model. On loss of reference lock, partition the record into controlled, transition and holdover intervals; release time-based findings only within the applicable uncertainty of each interval.

An independent challenge should vary reference conditions and use a controlled coherent source of known phase relationship, ideally with separate corroboration of the source path. Inject or observe the reference at multiple frequencies, temperatures and gain states, and measure the residual phase and timing after the exact corrections used in subsequent analysis. Repeat after a reference interruption, because reacquisition may produce a phase discontinuity even when the indicated frequency has returned to nominal. The final assurance can then state what relative coherence was demonstrated, for which duration and bandwidth, and what uncertainty remains. It should not convert agreement of two instruments that shared the same faulty clock into proof of physical source identity or precise arrival-time geometry.

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12.37 A stochastic and deterministic state description for clocks used in coherent receiving

Frequency accuracy, frequency stability and phase coherence are distinct properties. Accuracy concerns agreement with a stated reference over a declared interval; stability concerns changes in the frequency process as observation time varies; coherence concerns the relative phase behaviour of the quantities actually compared. An oscillator can exhibit excellent short-interval stability while maintaining a substantial fixed frequency offset. Two channels sharing one inaccurate reference can nevertheless retain excellent relative phase coherence, whereas independently accurate oscillators can have poorly controlled relative short-term phase. These distinctions become consequential in RF surveys because the same numerical time stamp may be asked to support carrier-frequency measurement, pulse association, direction finding and an assertion that two receivers observed the same physical event.

Let $x_i(t)$ denote time error of clock i, expressed in seconds relative to the declared reference epoch, and let $y_i(t)=dx_i(t)/dt$ denote instantaneous fractional frequency error where the derivative exists. A useful local deterministic model is $x_i(t)=x_i(0)+y_i(0)t+(1/2)d_i t^2+w_i(t)$, in which $x_i(0)$ is the initial time offset in seconds, $y_i(0)$ is dimensionless fractional-frequency offset, d_i is its local rate of change per second, and $w_i(t)$ represents an explicitly characterised stochastic or unmodelled contribution in seconds. This quadratic model is not a general physical guarantee. A reference reacquisition, cycle slip, counter reset or software correction can introduce discontinuities for which a single differentiable law is

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inappropriate. Such occurrences require separate state intervals and explicit transition records.

For an RF sinusoid with frequency f_c hertz, the time error x_i produces carrier phase perturbation $\varphi_i(t)=2\pi f_c x_i(t)$ radians under the chosen positive-exponential convention. The phase difference relevant to coherent combination is $\varphi_1-\varphi_2$, not simply the largest individual clock error quoted on a datasheet. Thus uncertainty in the relative time error $\Delta x=x_1-x_2$ must be calculated with its covariance: $\mathrm{Var}(\Delta x)=\mathrm{Var}(x_1)+\mathrm{Var}(x_2)-2\mathrm{Cov}(x_1,x_2)$. Positive common-mode correlation can make relative error much smaller than either absolute uncertainty. Conversely, a shared hidden clock jump can bias every channel and leave relative coherence apparently intact while corrupting absolute event time. A clocking architecture therefore needs independent tests for relative coherence and external time traceability.

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12.38 Characterising short- and long-term stability without confusing one statistic for another

The ordinary standard deviation of a free-running clock's frequency measurements may depend strongly on record length when drift and low-frequency noise are present. Allan deviation instead characterises differences between adjacent fractional-frequency averages over a specified averaging time τ. For M consecutive non-overlapping averages ybar_k of equal duration τ, define σ_y^2(τ)=[1/(2(M-1))] sum from k=1 to M-1 of (ybar_(k+1)-ybar_k)^2. The definition requires that sampling, gaps and data preprocessing be stated. It is not a prediction of every future time error; that prediction also needs the noise class, deterministic drift, environment, initial state and relevant forecast horizon. Modified Allan deviation and time deviation address related but distinct aspects of noise and timing performance, and the analyst must choose the statistic that answers the instrument's coherence or timestamp requirement.

Noise classes influence extrapolation. White frequency noise can average differently from flicker frequency noise or frequency random walk. Environmental temperature cycles, vibration-induced stress, reference-distribution faults and oscillator ageing may produce deterministic structure not represented adequately by a stationary random process. A log-log plot of a stability statistic can help diagnose a regime, but a short record and an attractive straight line are not proof of a particular power-law noise mechanism. Identify the measurement bandwidth and counter dead time, estimate confidence from the actual number of independent differences, and compare candidate models against held-out data. A stability figure at

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τ=1 s should not be transferred unqualified to a two-day holdover prediction.

A responsible holdover bound has three layers. First account for the known starting phase and frequency state, including their covariance. Second propagate any supported deterministic frequency slope or temperature response. Third add the random forecast error appropriate to the identified noise process, without assuming samples separated by τ are independent unless the evidence supports that. If the time-scale reference disappears, a receiver can preserve its own sample continuity while losing traceable absolute time. If the internal sampling oscillator also changes or relocks, frequency mapping and sample-aperture spacing may change. These are different failures and should have different flags in the acquisition manifest.

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12.39 The measurement chain of a distributed reference

A laboratory reference output does not instantaneously become the same phase at every receiver connector. Distribution amplifiers introduce propagation and group delay; coaxial or optical runs respond to temperature and mechanical displacement; connectors, power supplies and multipliers can add their own phase disturbances. Define the actual reference plane at which timing is claimed. For each branch measure fixed delay, its temperature coefficient and any residual stochastic phase difference. A disciplined two-channel test measures a common stable RF source through matched input paths and compares the channels after their separate distribution paths. A subsequent channel swap can help separate receiver-specific effects from fixture or source effects, provided the swap itself is recorded and does not change the physical question.

A 10 MHz reference, a 1-pulse-per-second epoch signal, and an ADC sample clock have different jobs. A locked 10 MHz reference can control long-term frequency without establishing the absolute sample epoch. A 1-PPS edge can mark a nominal epoch without establishing that each sampled edge occurs at the commanded aperture instant. An FPGA packet timestamp may describe a buffer event rather than the first analogue sample. The validation record must link counter states and hardware sample indexes to the epoch mapping. An apparent one-sample disagreement may indicate a dropped sample, an initial alignment error or a genuine propagation-time difference. These mechanisms cannot be identified from nominal reference frequency alone.

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Timestamp and phase offsets may also be frequency dependent. If a common observation passes through different analogue filters, equal sample-clock epochs need not imply equal group delay of the retained waveform. The appropriate composite delay is the sum of cable propagation, analogue-filter group delay, converter and digital-filter latency, buffering where applicable, and any algorithmic timestamp convention. Some terms are deterministic within a state, others random, and some depend on the signal spectrum. Delay correction must refer to the same feature and observation band as the reported event. A wideband pulse-edge timestamp and a narrowband carrier-phase timestamp need not shift by the same amount.

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12.40 Reference transitions, cycle slips and false continuity

A receiver that is disciplined to an external reference may encounter a transition to holdover or another reference during collection. The frequency may stay approximately continuous while the phase jumps, or the phase may be steered continuously while the instantaneous frequency deviates during the correction. Both affect a coherent record. Phase unwrapping can conceal a true integer-cycle slip if the tracking algorithm automatically chooses the nearest phase continuation. Conversely, a low-SNR observation may introduce a false slip where the hardware clock never changed. Test for slips with independent counter or status events, a stable reference injection and alternate phase unwrapping parameters. Do not resolve physical ambiguity merely by choosing the smoothest reconstructed phase curve.

A digital resampler can compensate modest sample-rate mismatch and produce a useful common-rate analysis stream, but that is a derived representation. Its interpolation kernel, group delay, edge handling and treatment of gaps must be retained; the result is not evidence that the original converter sampled at a different physical rate. When two receivers are aligned by cross-correlation, the peak can reflect propagation delay, repeated waveform structure or an ambiguous periodic modulation, not necessarily a unique clock offset. Correlation is a measurement of the selected signal and model. A short event with unknown source location cannot generally establish both the emission time and each receiver's absolute clock offset from the same observed arrival times.

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12.41 Coherence under stochastic phase error

For N equal-amplitude analytic phasors, define the normalised coherent sum $z=(1/N)\sum_{k=1}^{N}\exp(j\varphi_k)$. If the residual phases are independent, zero-mean Gaussian with common variance σ_φ^2, then $E|z|^2=1/N+(1-1/N)\exp(-\sigma_\varphi^2)$. This result depends on the stated distribution and independence. If every φ_k is the same random common phase, $|z|^2=1$ for each realisation and there is no relative coherent-power loss, although an external absolute phase estimate may remain uncertain. A mixed covariance matrix produces a different result. Thus the correct input to multichannel coherence analysis is the pairwise phase-difference structure, not the list of independent oscillator specifications.

Phase-noise spectra must be integrated in linear units over a physically declared Fourier-offset band. A single-sideband level expressed in dBc/Hz is logarithmic and cannot simply be summed across bands as an ordinary power. Discrete spurs require a line-power treatment rather than being treated as a density multiplied by an arbitrary resolution bin. The integrated phase variance depends on high- and low-offset bounds, filters and the definition of the measurement channel. Unmeasured phase-noise regions cannot be assigned zero contribution merely because the displayed plot does not extend to them. At high carrier frequencies even a small time uncertainty may become substantial relative phase, while common-mode cancellation may preserve coherence when both channels share the same disturbance.

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12.42 Ten numerical applications, each with stipulated assumptions

Application 12C.1. Take a free-running oscillator with a fixed fractional frequency error $y_0=2.0\times10^{-9}$ and no drift or random term during 6 hours. The accumulated time error is $x=y_0\,t=(2.0\times10^{-9})(21{,}600\text{ s})=43.2$ microseconds. This is not the expected error of a disciplined clock; it is a conditional demonstration that an apparently small fractional offset accumulates. At a carrier frequency of 100 MHz, the corresponding raw carrier phase represents 4,320 complete cycles. A phase display confined to $\pm\pi$ cannot recover the number of missed turns from that final sample alone.

Application 12C.2. Let the residual fractional frequency drift rate be $d=4\times10^{-14}\text{ s}^{-1}$ over 4 hours, with zero initial time and frequency error and no stochastic contribution. The quadratic term is $x=(1/2)d\,t^2=0.5\times4\times10^{-14}\times14{,}400^2=4.1472$ microseconds. A straight-line extrapolation from the initial frequency would predict zero and fail. The calculation is a hypothetical model over its declared interval; temperature steps or drift-rate changes require separate segments.

Application 12C.3. Two receiver channels have standard time errors of 2 ns and 3 ns and covariance of +3 ns^2. The differential variance is $4+9-2\times3=7\text{ ns}^2$; the standard deviation is $\sqrt{7}=2.646$ ns. If independence were asserted, the value would be $\sqrt{13}=3.606$ ns. Neither result is automatically an empirical clock specification; covariance must be determined for the actual distribution and shared physical path.

Application 12C.4. A 2 GHz sinusoid observed at two channels has a residual relative delay of 50 ps. The phase is $2\pi\times2\times10^9\times50\times10^{-12}=0.628319$ rad, or

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36 degrees. An uncorrected 50 ps delay matters greatly at 2 GHz even though it may be negligible for a slow envelope timestamp. The relevant value is the differential delay at the actual RF or coherent baseband phase reference, including analogue and digital path contributions.

Application 12C.5. At 1 GHz input frequency, assume uncorrelated Gaussian sampling-aperture jitter of 1 ps rms and that this source dominates the relevant noise mechanism. The familiar small-jitter sinusoidal bound is $SNR \approx -20\log10(2\pi f \sigma_t) = -20\log10(0.006283) = 44.04$ dB. It is an ideal jitter-limited bound, not a total ADC SINAD or ENOB measurement. Correlated jitter, analogue source phase noise and other converter errors require another model.

Application 12C.6. A hypothetical channel has measured phase standard deviation $\sigma_\varphi = 0.20$ rad, with independent Gaussian phase error across N=8 equal phasors. The expected normalised coherent power is $1/8+(7/8)\exp(-0.04)=0.96569$, corresponding to about -0.152 dB. Replacing those phases with one common random phase of the same marginal variance yields $|z|^2=1$. The example exposes why marginal phase statistics do not determine array coherence.

Application 12C.7. A link of 100 m has propagation velocity 2.0×10^8 m/s under a stipulated effective cable model. Its one-way delay is 500 ns. Two unequal cables differing by 0.40 m contribute an approximate 2.0 ns relative delay. Calibration must determine actual electrical length, dispersion and temperature, not merely tape-measured physical length; the example is an illustration of scale, not a cable-specific certificate.

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Application 12C.8. A clock-status log shows the last trusted epoch at t=0 and the first detected relock at 1,200 s, while a saved RF segment spans 1,150–1,250 s. Without a trustworthy transition time inside that window, the segment cannot be assigned one uninterrupted clock state. It may be partitioned only if independent evidence supports the boundary; assigning the relock to the log-receipt instant would assume zero telemetry latency and a particular timestamp convention.

Application 12C.9. Four successive fractional-frequency averages in units of 10^-9 are 1, 2, 1 and 3, each lasting 10 s without gap. Their adjacent differences are 1, -1 and 2 in those units. Allan variance at τ=10 s is $(1^2+(-1)^2+2^2)/(2\times3)\times10^{-18}=1\times10^{-18}$ and Allan deviation is 1×10^-9. This is a sample statistic for the stipulated four averages. It provides no justified confidence band without the relevant noise model and estimator treatment.

Application 12C.10. A source is observed at t_A=10.000000150 s and t_B=10.000000390 s. Independently calibrated channel delays are 100 ns and 280 ns. Corrected arrivals are therefore t_A'=10.000000050 s and t_B'=10.000000110 s, differing by 60 ns. That residual could arise from different propagation paths, clock error or event-picking uncertainty. It does not by itself identify a source position. To infer geometry, specify sensor positions, propagation medium, synchronisation errors and the event feature used to assign each timestamp.

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12.43 Controlled acceptance of a multichannel timing network

A practical acceptance campaign must cover ordinary locked operation, warm start, cold start, source substitution, reference dropout, holdover, relock, thermal excursions, and the loss or corruption of packet metadata. For every condition retain the source configuration, oscillator and synthesiser states, branch delays, sample indexes, time scales and phase observations. Use at least one common injected reference to test relative coherence and a separately traceable epoch test to establish absolute timing. Where the channels share hardware, document the resulting covariance rather than claiming independence. A control programme must also examine the failure path: a receiver may continue writing plausible timestamps during reference loss even if those times have lost their claimed accuracy.

The final timing report should provide explicit validity intervals, an uncertainty budget for absolute epoch and for relative channel delay, stated carrier and observation bandwidths, and the test evidence supporting any correction. It should preserve separate estimates for deterministic drift, stochastic stability, reference-distribution delay and software timestamp latency. Where the data do not determine one of those quantities, retain that limitation instead of absorbing it into a conveniently enlarged generic error bar. The result is a usable coherence assurance: it shows what phase or timing inference is supported, for which channels, over what interval, and under which equipment states.

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12.44 Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands

A phase-locked or frequency-disciplined oscillator provides a controlled relation between a local oscillator and a reference, but its precision must be described at the timescales on which RF samples are compared. The reference may discipline long-term frequency while a local quartz or microwave oscillator dominates short-term phase noise. A ten-megahertz reference delivered to many receivers is not equivalent to proof that their converter apertures open on the same sample edge, or that their microwave translation oscillators have identical phase. A common one-pulse-per-second event may align counters without determining the fractional sample delay or the initial mixer phase. The three separate requirements are rate accuracy, epoch alignment and relative phase calibration. Only their combination, with uncertainty records, can support strong claims about coherent array processing.

For an RF sinusoid of frequency f, a relative time error δt produces phase error $\delta\varphi=2\pi f\delta t$ in radians when the error is referred to the original RF waveform. At 40 GHz, one picosecond corresponds to 0.2513 rad or 14.4 degrees; keeping this particular phase error under one degree would require $|\delta t|<1/(360f)$, approximately 69.4 femtoseconds. This is an explanatory bound, not a universal converter clock specification. A superheterodyne chain may translate the desired signal to a much lower IF before the ADC, while uncertainty in the LO phase persists as a separate contribution. The phase relationship of the original RF input to each channel

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must be reconstructed from the complete chain; using the downstream sample rate alone can grossly misstate cross-channel coherence.

A convenient channel model is $z_k[n]=g_k s(t_n-\tau_k)\exp(j\varphi_k[n])+\eta_k[n]$, where g_k is complex gain, τ_k is the calibrated path delay, $\varphi_k[n]$ includes residual LO and sampling-reference phase errors, and η_k comprises channel-specific and shared noise. If several channels share a distributed reference, some errors can be correlated. The variance of the relative phase $\varphi_i-\varphi_j$ equals $\mathrm{Var}(\varphi_i)+\mathrm{Var}(\varphi_j)-2\mathrm{Cov}(\varphi_i,\varphi_j)$; omitting the covariance misstates how much common-reference noise cancels in an interferometric comparison. Conversely, assuming perfect cancellation can be worse when branch-specific PLLs amplify different phase-noise bands or a reference splitter introduces time-varying skew. The covariance needs measurement over the chosen integration time and RF offset, not merely a wiring diagram.

A phase-locked loop changes, rather than eliminates, phase noise. Within a suitable loop bandwidth, output phase may track reference fluctuations plus divider and loop noise; beyond that range the voltage-controlled oscillator and other circuit contributions can dominate. Loop transfer functions, reference multiplication, frequency dividers and mixer stages all alter phase-noise spectral density. The designer should measure integrated phase variance in the bands actually used by coherent processing, as well as Allan deviation or an appropriate frequency-stability statistic over millisecond, second and four-hour timescales. A reference that looks excellent at one-second averaging time might drift badly during a long holdover interval, and the inverse is equally possible. NIST explicitly distinguishes oscillator stability from frequency correctness; both belong in a complete receiver acceptance case.

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Phase coherence can be validated with a distributed known reference signal injected at a clearly defined electrical or radiated plane. Record complex channel phase against the common reference before and after long acquisitions, while logging clock-lock state, reference-source changes, synthesiser relock, temperature, cable movement and converter lane resets. Detect phase discontinuities with unwrapped phase residuals while guarding against false cycle slips at low amplitude. For a moving antenna or array, geometry can also create real path-dependent phase changes. Report the inferred electronic phase drift separately from actual propagation phase. A single calibration at boot cannot certify every phase relationship for four hours when environmental temperature and system load vary.

The acceptance protocol must include induced clock faults and independent witness timing. Test loss and restoration of the reference, short phase hits, reference switching, deliberate frequency offset, FPGA sample-counter resets, and distributed timestamp jitter. Inject a reference whose timing can be measured by an independent time-interval counter, not solely by the same PLL whose behaviour is in question. If an event falls during an uncertain holdover transition, retain the native samples and mark the interval as phase-uncertain instead of silently phase-rotating it to agree with a preferred hypothesis. Some amplitude or energy conclusions may survive phase uncertainty; source location inferred by interferometry may not.

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12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system

Application C12.1. A relative delay of 1 ps at 40 GHz yields 360×40×10^9×10^-12=14.4 degrees of RF phase. At 10 GHz the same delay gives 3.6 degrees. Stated in degrees, the answer depends on the original signal frequency to which delay is referred and does not prove that the converter samples directly at that frequency.

Application C12.2. The delay corresponding to one degree at 40 GHz is 1/(360×40×10^9)=69.44 femtoseconds. At 1 GHz it is 2.778 picoseconds. The result is a phase requirement for that particular signal, not a prescription that every individual hardware clock must have such jitter under every measurement purpose.

Application C12.3. With independent random phase-error standard deviations of 0.04 and 0.03 radians for two channels, the relative standard deviation is sqrt(0.04^2+0.03^2)=0.05 radians. If their covariance is +0.0006 radian squared, the relative variance is 0.0016+0.0009−0.0012=0.0013 radian squared, giving about 0.0361 radians. The assumed covariance must be documented rather than inferred from common wiring.

Application C12.4. For sample-clock aperture jitter σ_t=100 femtoseconds and a directly sampled tone at 10 GHz, the sinusoidal jitter-limited SNR is approximately −20 log10(2π×10^10×10^-13)=44.04 dB. At 1 GHz under otherwise identical assumptions it is 64.04 dB. This simplified relation assumes small, uncorrelated timing error and excludes amplitude noise, fixed skew and other distortion.

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Application C12.5. A common nominal sample rate of 100 MS/s gives 10 ns sample spacing, but synchronising two receive start commands to within 100 ns only locates their epochs within ten sample intervals. A valid coherent comparison requires sample-index alignment, residual fractional-delay calibration and the relevant LO phase relation.

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Chapter Summary

Frequency and phase integrity are separate from nominal tuning. Reference state, phase noise, jitter, trigger, delay, and coherence determine whether precision spectral and multichannel inferences are valid.

Model 12A distinguishes initial epoch error, fractional-frequency offset and local drift. Integrating them gives time error; a declared carrier converts it to clock phase. Physical delay has the opposite transfer-phase sign. Wrapped observations, phase resets and sample-clock scale errors retain their own ambiguity or segment boundaries. Calibration intervals follow from stated bounds and the required tolerance.

Model 12B integrates phase-noise density in linear units over explicit offset bands and handles lines separately. Carrier frequency controls conversion to timing RMS. Coherent signal power additionally depends on relative phase and covariance. Its exact Gaussian-vector calculation retains finite-sample self terms and deterministic rotation; neither one RMS number nor a spectrum alone establishes all those distributional assumptions.

Accept the installed reference network at the actual acquisition and stored-sample boundaries. Use common signals, channel swaps and state changes to test residual relationships. Preserve original timing records and validate fitted corrections beyond their fitting interval. When phase continuity is not demonstrated, limit comparisons to the supported segments and quantities.

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Chapter 12 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C12-MCQ-001. What does positive clock time error mean in Model 12A?

A. The clock frequency must be permanently high

B. A physical propagation path necessarily has positive transfer phase

C. The sample rate must be lower than nominal

D. The clock is advanced relative to ideal reference time

Answer: D. The convention defines clock reading as ideal time plus time error; its derivative determines fractional frequency. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: The clock is advanced relative to ideal reference time.

Distinguishing consideration: compare this with option A, “The clock frequency must be permanently high”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-002. Why can correct frequency coexist with incorrect sample alignment?

A. Zero frequency error implies zero time error at all epochs

B. Frequency agreement fixes every aperture delay

C. A shared rate necessarily aligns every trigger

D. A constant epoch error has zero derivative but shifts timing

Answer: D. Initial epoch and frequency offset are distinct terms in the time-error model. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: A constant epoch error has zero derivative but shifts timing.

Distinguishing consideration: compare this with option A, “Zero frequency error implies zero time error at all epochs”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-003. How does positive physical delay differ from positive clock advance in the stated conventions?

A. Delay changes only amplitude, not phase

B. Delay gives negative transfer phase; advance gives positive relative clock phase

C. Both always give the same positive phase

D. Both always give negative phase independent of definition

Answer: B. The transfer exponential and clock-error convention have opposite signs and must not be conflated. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Delay gives negative transfer phase; advance gives positive relative clock phase.

Distinguishing consideration: compare this with option A, “Delay changes only amplitude, not phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-004. What can resolve the two-tone wrapped-delay ambiguity?

A. The fact that both tones are detected

B. More decimal places in the same wrapped readings alone

C. A justified unwrap, compatible delay prior, or additional calibrated frequency information

D. A common nominal frequency label alone

Answer: C. Branch selection requires additional information, not numerical precision alone. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: A justified unwrap, compatible delay prior, or additional calibrated frequency information.

Distinguishing consideration: compare this with option A, “The fact that both tones are detected”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-005. Why are bounded endpoint time errors not automatically standard uncertainties?

A. Their signs are always independent Gaussian variables

B. Bounds specify permitted values without a probability distribution

C. A sufficiently long interval makes all error models equivalent

D. Every bound is exactly one standard deviation

Answer: B. Statistical uncertainty needs justified distribution and dependency information beyond the bounds. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Bounds specify permitted values without a probability distribution.

Distinguishing consideration: compare this with option A, “Their signs are always independent Gaussian variables”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-006. How many endpoint samples are required to span N actual sample intervals?

A. N plus one

B. N minus one

C. N

D. Two N

Answer: A. A count of samples differs by one from the count of intervals between first and last endpoints. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: N plus one.

Distinguishing consideration: compare this with option B, “N minus one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-007. If the true sample clock is high and software labels a valid alias-class tone using the lower nominal rate, what happens?

A. The label is true frequency divided by one plus fractional rate error

B. The label always equals the true frequency

C. The alias class becomes uniquely known from the clock correction

D. The label is necessarily higher by exactly the rate error in hertz

Answer: A. Frequency-axis scaling and alias identification are separate requirements. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: The label is true frequency divided by one plus fractional rate error.

Distinguishing consideration: compare this with option B, “The label always equals the true frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-008. When is a positive waiting interval infeasible under the deterministic calibration envelope?

A. The frequency and drift bounds are small but positive with available margin

B. The time tolerance is expressed in nanoseconds rather than seconds

C. The initial error bound already exceeds the tolerance

D. The initial bound is below tolerance and both growth bounds are zero

Answer: C. Shortening the interval cannot repair an initial uncertainty already outside the allowed region. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: The initial error bound already exceeds the tolerance.

Distinguishing consideration: compare this with option A, “The frequency and drift bounds are small but positive with available margin”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-009. What derivative connects time error to fractional-frequency error?

A. The derivative of displayed amplitude

B. The second derivative of phase divided by sample count

C. The time error itself without a derivative

D. The first derivative of time error with respect to ideal time

Answer: D. The model defines fractional frequency as dx/dt; local drift is its derivative. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: The first derivative of time error with respect to ideal time.

Distinguishing consideration: compare this with option A, “The derivative of displayed amplitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-010. A constant positive fractional-frequency error starts from zero epoch error. How does time error evolve?

A. Linearly upward with elapsed time

B. It remains zero because the initial epoch was correct

C. It changes only at trigger edges

D. It decreases quadratically for every positive error

Answer: A. Integrating a constant frequency offset produces a linear time-error accumulation. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Linearly upward with elapsed time.

Distinguishing consideration: compare this with option B, “It remains zero because the initial epoch was correct”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-011. A local fractional-frequency drift is constant. Which time-error term does it produce?

A. A linear term equal to drift without time units

B. A quadratic term with one-half the drift coefficient

C. Only a constant epoch offset

D. A logarithmic term independent of initial state

Answer: B. Integrating a linear fractional-frequency law yields the stated quadratic time term. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: A quadratic term with one-half the drift coefficient.

Distinguishing consideration: compare this with option A, “A linear term equal to drift without time units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-012. What units belong to fractional-frequency drift d in Model 12A?

A. Hertz squared for every carrier

B. Radians alone

C. Seconds

D. Per second

Answer: D. Fractional frequency is dimensionless, so its time derivative has inverse-time units. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Per second.

Distinguishing consideration: compare this with option A, “Hertz squared for every carrier”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-013. Which event can invalidate extrapolating a fitted drift law through the next interval?

A. Warmup, holdover, reference reacquisition, or a power interruption

B. A stated unchanged reference plane

C. An additional copy of the same calibration file

D. A consistent unit conversion

Answer: A. The polynomial is local to a declared segment and operating conditions.

Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Warmup, holdover, reference reacquisition, or a power interruption.

Distinguishing consideration: compare this with option B, “A stated unchanged reference plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-014. What does a lock indicator fail to establish by itself?

A. That a lock status was reported

B. The nominal reference label

C. Epoch alignment, short-term purity, and all drift behavior

D. The presence of a recorded status field

Answer: C. Status is evidence of a reported condition, not a full timing or noise characterization. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

Why the selected alternative fits: Epoch alignment, short-term purity, and all drift behavior.

Distinguishing consideration: compare this with option A, “That a lock status was reported”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Frequency Reference and Tuning Accuracy.

Review: Chapter 12 — Frequency Reference and Tuning Accuracy.

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V011-C12-MCQ-015. Why measure frequency response at several reference points?

A. A numerically exact tuning command guarantees physical accuracy

B. One tone mathematically fixes every synthesizer error

C. Errors can be constant, proportional, band-dependent, or state-dependent

D. Every oscillator error is a single constant offset

Answer: C. A multi-point, state-aware check distinguishes error forms that one correction cannot cover. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

Why the selected alternative fits: Errors can be constant, proportional, band-dependent, or state-dependent.

Distinguishing consideration: compare this with option A, “A numerically exact tuning command guarantees physical accuracy”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Frequency Reference and Tuning Accuracy.

Review: Chapter 12 — Frequency Reference and Tuning Accuracy.

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V011-C12-MCQ-016. A clock at nominal 10 MHz has constant fractional error plus 0.2 ppm. What is frequency error?

A. Minus 2 Hz

B. Plus 20 Hz

C. Plus 2 Hz

D. Plus 0.2 Hz

Answer: C. Multiplying 10 million hertz by 0.2 millionths gives 2 Hz. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: Plus 2 Hz.

Distinguishing consideration: compare this with option A, “Minus 2 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-017. Under that constant offset for 86400 seconds from zero time error, what epoch advance accumulates?

A. 17.28 microseconds

B. 172.8 seconds

C. 17.28 ms

D. 0.2 ms

Answer: C. Time error is fractional error times elapsed time; constancy over the full interval is essential. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 17.28 ms.

Distinguishing consideration: compare this with option A, “17.28 microseconds”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-018. A constant epoch advance of 0.75 microseconds with zero frequency error represents how many 10 MHz cycles?

A. 0.75 cycles

B. 7.5 cycles

C. 75 cycles

D. Zero cycles

Answer: B. Phase advance in cycles is nominal frequency times time error, independent of its zero derivative. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 7.5 cycles.

Distinguishing consideration: compare this with option A, “0.75 cycles”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-019. Why can a nonzero physical delay appear phase aligned at one frequency?

A. Its phase can wrap by an integer number of cycles

B. The receiver's amplitude calibration cancels all delay

C. Zero wrapped phase proves zero delay

D. Delay disappears when frequency increases

Answer: A. Wrapped phase retains no unique cycle count without additional evidence. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: Its phase can wrap by an integer number of cycles.

Distinguishing consideration: compare this with option B, “The receiver's amplitude calibration cancels all delay”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-020. For a nondispersive path, how is delay obtained from unwrapped phase slope?

A. Minus the slope divided by two pi

B. The slope multiplied by carrier amplitude

C. The inverse of one wrapped phase reading

D. Plus the slope divided by two pi under the declared delay convention

Answer: A. The negative transfer-phase convention fixes the slope sign; dispersion requires a richer response. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Minus the slope divided by two pi.

Distinguishing consideration: compare this with option B, “The slope multiplied by carrier amplitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-021. Two tones separated by 20 MHz produce a wrapped-delay ambiguity period of what?

A. 500 ns

B. 50 ns

C. 5 ns

D. 20 ns

Answer: B. The difference-phase ambiguity repeats after one divided by tone spacing. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 50 ns.

Distinguishing consideration: compare this with option A, “500 ns”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-022. What does phase curvature across frequency suggest for delay correction?

A. Only epoch error can create any frequency dependence

B. A perfect frequency-independent time shift is proven

C. All phase measurements must be invalid

D. One constant nondispersive delay may be insufficient

Answer: D. Frequency-dependent filters can require retaining or fitting their actual response. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: One constant nondispersive delay may be insufficient.

Distinguishing consideration: compare this with option A, “Only epoch error can create any frequency dependence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-023. Time-error observations increase from 1 to 7 microseconds over 600 seconds. What average fractional-frequency estimate follows?

A. Six times ten to the minus six

B. One times ten to the minus six

C. One times ten to the minus ten

D. One times ten to the minus eight

Answer: D. The six-microsecond difference divided by 600 seconds gives 10^{-8}.

Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: One times ten to the minus eight.

Distinguishing consideration: compare this with option A, “Six times ten to the minus six”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-024. If each endpoint has a freely signed hard error bound 0.1 microsecond, what is the difference-error bound?

A. 0.2 microsecond

B. Zero because both bounds have the same size

C. 0.1 microsecond

D. About 0.1414 microsecond as a deterministic maximum

Answer: A. Opposite endpoint errors can add in the difference; RSS would need a different model. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 0.2 microsecond.

Distinguishing consideration: compare this with option B, “Zero because both bounds have the same size”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-025. A 90-degree phase reset lies inside a 10-microsecond difference interval with continuous 20 Hz phase slope. What apparent average frequency results?

A. 9020 Hz

B. 20 Hz

C. 25020 Hz

D. 2500 Hz

Answer: C. One quarter cycle over 10 microseconds adds 25000 Hz to the continuous slope. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 25020 Hz.

Distinguishing consideration: compare this with option A, “9020 Hz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-026. Why not fit one smooth drift through a documented phase reset?

A. The derivative remains finite at an ideal instantaneous jump

B. A reset is always Gaussian phase noise

C. The finite difference includes a discontinuity absent from either continuous segment

D. Equal nominal rates prove the phases join continuously

Answer: C. Retain event time and separate phase segments; a real slew needs its own resolved model. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: The finite difference includes a discontinuity absent from either continuous segment.

Distinguishing consideration: compare this with option A, “The derivative remains finite at an ideal instantaneous jump”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-027. Two million sample intervals at actual rate 2000050 per second occupy what time approximately?

A. 1.000025 seconds

B. 0.999950 seconds

C. 0.999975 seconds

D. Exactly one second

Answer: C. Elapsed time varies inversely with actual clock rate; the nominal second is too long here. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 0.999975 seconds.

Distinguishing consideration: compare this with option A, “1.000025 seconds”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-028. What remains necessary after correcting the sample-clock scale of an observed tone?

A. Assume the lowest possible analog frequency automatically

B. Discard the original clock estimate

C. Treat the corrected label as proof of source identity

D. Establish the admitted alias class and conversion convention

Answer: D. Clock-axis correction cannot resolve an independent sampling alias ambiguity. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: Establish the admitted alias class and conversion convention.

Distinguishing consideration: compare this with option A, “Assume the lowest possible analog frequency automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-029. How should relative timing of channels A and B be computed before phase conversion?

A. Assume zero difference because they share a reference label

B. Convert only the larger channel error

C. Subtract their time errors, then multiply by the stated carrier's two pi frequency

D. Add their absolute time errors regardless of the target quantity

Answer: C. The defined relative quantity determines which common terms cancel and which unequal paths remain. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Subtract their time errors, then multiply by the stated carrier's two pi frequency.

Distinguishing consideration: compare this with option A, “Assume zero difference because they share a reference label”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-030. Channels begin at plus 100 ns and minus 50 ns, with fractional errors plus 2e-9 and minus 1e-9. After 10 seconds, what is A-minus-B time error?

A. 120 ns

B. 30 ns

C. 180 ns

D. 150 ns

Answer: C. Initial difference is 150 ns and differential drift accumulates another 30 ns. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 180 ns.

Distinguishing consideration: compare this with option A, “120 ns”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-031. At 10 MHz, what phase tolerance corresponds to 12.5 ns time error?

A. 45 degrees

B. 4.5 degrees

C. 12.5 degrees

D. 450 degrees

Answer: A. The cycle fraction is 10 million times 12.5 nanoseconds = 0.125. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: 45 degrees.

Distinguishing consideration: compare this with option B, “4.5 degrees”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-032. If initial bound equals tolerance and a positive growth bound exists, which elapsed times satisfy the monotone envelope?

A. Every sufficiently short positive interval

B. All times until the first full cycle

C. Only the initial instant

D. No time including the initial instant

Answer: C. At zero elapsed time equality holds; any positive growth exceeds the bound afterward. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: Only the initial instant.

Distinguishing consideration: compare this with option A, “Every sufficiently short positive interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-033. If initial error is within tolerance and both frequency/drift bounds vanish, what determines the calibration interval under this model?

A. The number of displayed digits

B. A universal one-day interval

C. The nominal carrier period alone

D. The initial bound alone, with no finite growth-imposed limit

Answer: D. Without growth terms the envelope is constant, subject to continued applicability of the assumptions. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: The initial bound alone, with no finite growth-imposed limit.

Distinguishing consideration: compare this with option A, “The number of displayed digits”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-034. Why is the derived maximum calibration interval not a universal schedule?

A. A tighter initial bound cannot affect the interval

B. Only the model's chapter number determines the schedule

C. It depends on justified bounds, carrier, tolerance, and operating conditions

D. Every oscillator requires the same 760.68-second interval

Answer: C. Changing environment, path, or reference state can invalidate the conditional envelope. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: It depends on justified bounds, carrier, tolerance, and operating conditions.

Distinguishing consideration: compare this with option A, “A tighter initial bound cannot affect the interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-035. What is distinct about an aperture timestamp versus a packet-arrival timestamp?

A. A shared frequency automatically calibrates transport latency

B. Packet delivery always occurs at the sampling instant

C. They are interchangeable when their units are seconds

D. They describe different events unless a relationship is established

Answer: D. The timing boundary must match the measurand and source-index mapping. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why the selected alternative fits: They describe different events unless a relationship is established.

Distinguishing consideration: compare this with option A, “A shared frequency automatically calibrates transport latency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-MCQ-036. Why is the single-sideband density integrated with factor two for real-phase variance?

A. Every phase-noise line is Gaussian

B. The carrier frequency is counted twice

C. The symmetric negative-offset phase band contributes equal variance

D. Every jitter calculation must double an already integrated RMS

Answer: C. The positive-offset SSB density equals the two-sided phase density under the adopted convention. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: The symmetric negative-offset phase band contributes equal variance.

Distinguishing consideration: compare this with option A, “Every phase-noise line is Gaussian”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-037. Why state the jitter integration band?

A. A jitter RMS automatically includes every unmeasured offset

B. Changing limits leaves RMS unchanged

C. All clocks have the same universal integration limits

D. The result includes only the declared phase component and separately treated lines

Answer: D. Unmeasured regions remain outside the claim unless characterized or bounded. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: The result includes only the declared phase component and separately treated lines.

Distinguishing consideration: compare this with option A, “A jitter RMS automatically includes every unmeasured offset”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-038. Do the phase covariance and increment-variance identities require Gaussianity?

A. No; they are second-order relations under the stated spectral/covariance assumptions

B. Yes; all covariance arithmetic requires a Gaussian vector

C. Only when the carrier is exactly 100 MHz

D. No; no finite variance or stationarity is needed for the stated spectral identities

Answer: A. The exact nonlinear exponential result later requires a separate distributional assumption. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: No; they are second-order relations under the stated spectral/covariance assumptions.

Distinguishing consideration: compare this with option B, “Yes; all covariance arithmetic requires a Gaussian vector”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-039. Why can a common random phase leave normalized coherent power unchanged within each record?

A. All sample phasors rotate together without relative cancellation

B. Random phase is always equivalent to no absolute phase uncertainty

C. Its ensemble-mean complex phasor must retain unit magnitude

D. Each sample acquires an independent compensating rotation

Answer: A. Common rotation and relative decorrelation have different effects on record power. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

Why the selected alternative fits: All sample phasors rotate together without relative cancellation.

Distinguishing consideration: compare this with option B, “Random phase is always equivalent to no absolute phase uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

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V011-C12-MCQ-040. Can one marginal RMS phase or jitter value determine finite-record coherent power?

A. Yes; every vector with that RMS has the same sum power

B. Only when the RMS is expressed in radians rather than seconds

C. Yes; only sample count supplies the missing distribution

D. No; covariance and deterministic phase differences also matter

Answer: D. Common, independent, and correlated vectors can have equal marginal RMS but different coherence. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: No; covariance and deterministic phase differences also matter.

Distinguishing consideration: compare this with option A, “Yes; every vector with that RMS has the same sum power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-041. What term remains in the finite independent-Gaussian-phase coherent-power result?

A. Only the infinite-record exponential term

B. A mandatory zero for all finite records

C. The diagonal self-power contribution one over N

D. The sample-rate label without phase variance

Answer: C. Omitting self terms substitutes an infinite-N limit for the exact finite result. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why the selected alternative fits: The diagonal self-power contribution one over N.

Distinguishing consideration: compare this with option A, “Only the infinite-record exponential term”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-MCQ-042. May a deterministic PM line use the Gaussian coherent-power formula solely because its RMS is known?

A. Only if its frequency is an integer number of kilohertz

B. No; use its trajectory or justify a separate random model

C. Yes; the RMS fixes its entire characteristic function

D. Yes; every sinusoid is jointly Gaussian

Answer: B. A line's deterministic phase law does not establish the Gaussian-vector premise. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

Why the selected alternative fits: No; use its trajectory or justify a separate random model.

Distinguishing consideration: compare this with option A, “Only if its frequency is an integer number of kilohertz”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

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V011-C12-MCQ-043. What does a finite upper density bound over an additional band establish?

A. An upper bound over all offsets to infinity

B. The exact noise spectrum within the unmeasured band

C. A full oscillator acceptance certificate

D. A bound on that band's variance and the combined band-limited timing RMS

Answer: D. The result remains bounded to the declared union of measured and constrained bands. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

Why the selected alternative fits: A bound on that band's variance and the combined band-limited timing RMS.

Distinguishing consideration: compare this with option A, “An upper bound over all offsets to infinity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

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V011-C12-MCQ-044. How should adjacent phase-noise bands be combined?

A. Integrate linear densities over their widths and add variances

B. Add their RMS jitters directly whenever bands are named separately

C. Average their dBc/Hz labels arithmetically

D. Use the wider band's center value for both

Answer: A. The logarithmic labels and different bandwidths must be converted into compatible power contributions. Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)

Why the selected alternative fits: Integrate linear densities over their widths and add variances.

Distinguishing consideration: compare this with option B, “Add their RMS jitters directly whenever bands are named separately”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.2: Add density bands in linear units.

Review: Chapter 12 — Application 12B.2: Add density bands in linear units.

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V011-C12-MCQ-045. For fixed phase RMS, what happens to timing RMS when carrier frequency increases tenfold?

A. It increases tenfold

B. It decreases by the square root of ten

C. It decreases tenfold

D. It is unchanged

Answer: C. Timing RMS is phase RMS divided by two pi times carrier frequency.

Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

Why the selected alternative fits: It decreases tenfold.

Distinguishing consideration: compare this with option A, “It increases tenfold”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

Review: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

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V011-C12-MCQ-046. For fixed timing RMS, what happens to phase RMS when carrier frequency increases tenfold?

A. It increases tenfold

B. It decreases one hundredfold

C. It is unchanged

D. It decreases tenfold

Answer: A. The physical quantity being held fixed must be stated when comparing carriers. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

Why the selected alternative fits: It increases tenfold.

Distinguishing consideration: compare this with option B, “It decreases one hundredfold”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

Review: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

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V011-C12-MCQ-047. Flat SSB density 1e-12 per hertz over width 999000 Hz gives what real-phase variance?

A. 9.99e-7 radian squared

B. 1.998e-6 radian squared

C. 0.999 radian squared

D. 1.998e-12 radian squared

Answer: B. The positive-band integral is doubled under the real-phase convention.

Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

Why the selected alternative fits: 1.998e-6 radian squared.

Distinguishing consideration: compare this with option A, “9.99e-7 radian squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.1: Integrate a flat SSB density over a declared band.

Review: Chapter 12 — Application 12B.1: Integrate a flat SSB density over a declared band.

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V011-C12-MCQ-048. Why can a narrower offset band contribute more variance than a wider one?

A. Only width controls every phase-variance contribution

B. Its linear density can be sufficiently higher

C. Decibel labels may be added without weights

D. Every narrow band contains exactly one line

Answer: B. The contribution is the density integral, not bandwidth alone. Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)

Why the selected alternative fits: Its linear density can be sufficiently higher.

Distinguishing consideration: compare this with option A, “Only width controls every phase-variance contribution”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.2: Add density bands in linear units.

Review: Chapter 12 — Application 12B.2: Add density bands in linear units.

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V011-C12-MCQ-049. A sinusoidal PM line has peak phase 0.01 radian. Over complete periods, what is its phase variance?

A. 5e-5 radian squared

B. 2.5e-5 radian squared

C. 1e-4 radian squared

D. Zero because it is deterministic

Answer: A. The mean is zero and the sinusoidal mean square is peak squared divided by two over complete periods. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

Why the selected alternative fits: 5e-5 radian squared.

Distinguishing consideration: compare this with option B, “2.5e-5 radian squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

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V011-C12-MCQ-050. What must accompany a reported dBc/Hz value for a discrete line?

A. An assumption that the line vanishes as RBW narrows

B. A stated analysis-bandwidth convention

C. A Gaussianity statement inferred solely from RMS

D. A claim that line power is independent density at every resolution

Answer: B. Line power does not become a resolution-independent ordinary density merely by relabeling it. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

Why the selected alternative fits: A stated analysis-bandwidth convention.

Distinguishing consideration: compare this with option A, “An assumption that the line vanishes as RBW narrows”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

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V011-C12-MCQ-051. What spectral weighting governs phase-difference variance at separation tau?

A. Only the unweighted total RMS

B. Only the carrier's nominal frequency label

C. The negative of every density value

D. One minus cosine of two pi offset frequency times tau

Answer: D. Different offset distributions with equal variance can give different increments at a chosen separation. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: One minus cosine of two pi offset frequency times tau.

Distinguishing consideration: compare this with option A, “Only the unweighted total RMS”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-052. What is the increment variance at zero time separation?

A. Undefined for every stationary process

B. The full phase variance

C. Twice the total phase variance

D. Zero

Answer: D. The two phases are the same random variable, so their difference and its variance vanish. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Zero.

Distinguishing consideration: compare this with option A, “Undefined for every stationary process”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-053. For the stated stationary phase component, how is increment variance related to covariance?

A. C(0) plus C(tau) without factors

B. The square root of C(tau)

C. C(tau) divided by C(0)

D. Twice C(0) minus twice C(tau)

Answer: D. The difference variance retains both marginal terms and the cross covariance. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Twice C(0) minus twice C(tau).

Distinguishing consideration: compare this with option A, “C(0) plus C(tau) without factors”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-054. Why is root-sum-square addition of timing RMS conditional?

A. Every sum has the same RMS as the largest component

B. It assumes zero covariance between the additive contributions

C. All shared references force negative correlation

D. Distinct component names prove zero covariance

Answer: B. The covariance term can reinforce or partially cancel the sum. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why the selected alternative fits: It assumes zero covariance between the additive contributions.

Distinguishing consideration: compare this with option A, “Every sum has the same RMS as the largest component”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-MCQ-055. Two additive zero-mean timing contributions have RMS 2 and 3 ps and correlation plus 0.5. What is combined RMS?

A. Square root of 19 ps, about 4.359 ps

B. 1 ps

C. Square root of 13 ps, about 3.606 ps

D. 5 ps

Answer: A. Variance is 4+9+2 times 0.5 times 2 times 3 = 19 square picoseconds.

Source: §12.22 Application 12B.5: Include covariance when combining timing contributions

(p. 6982)

Why the selected alternative fits: Square root of 19 ps, about 4.359 ps.

Distinguishing consideration: compare this with option B, “1 ps”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-MCQ-056. For a relative-channel difference, what can happen to an exactly common timing contribution?

A. It cancels

B. It changes only amplitude units

C. It necessarily doubles as in a sum

D. It becomes independent by subtraction

Answer: A. The defined error quantity determines the covariance sign; common terms behave differently in sums and differences. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why the selected alternative fits: It cancels.

Distinguishing consideration: compare this with option B, “It changes only amplitude units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-MCQ-057. What information does a PSD alone generally fail to determine?

A. The declared integrated phase variance

B. Every nonlinear phase-exponential expectation

C. Its own second-order spectral distribution

D. The stated covariance transform

Answer: B. The exact nonlinear characteristic function needs an additional distributional model. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Every nonlinear phase-exponential expectation.

Distinguishing consideration: compare this with option A, “The declared integrated phase variance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-058. Which distributional assumption supports the chapter's exact pair-phasor exponential identity?

A. Second-order whiteness without any joint law

B. A finite jointly Gaussian phase vector with stated means and covariance

C. A small RMS value without a distribution

D. Gaussian marginal histograms alone for every possible joint dependence

Answer: B. Joint Gaussianity ensures each phase difference is normal with the specified mean and variance. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: A finite jointly Gaussian phase vector with stated means and covariance.

Distinguishing consideration: compare this with option A, “Second-order whiteness without any joint law”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-059. What property must a proposed covariance matrix have to represent a possible phase vector?

A. Every correlation exactly zero

B. Positive semidefiniteness

C. Only symmetry, with no further restriction

D. Every entry strictly positive

Answer: B. A table of individually plausible pair correlations may still fail joint feasibility. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Positive semidefiniteness.

Distinguishing consideration: compare this with option A, “Every correlation exactly zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-060. In the Gaussian pair identity, what quantity enters the negative one-half exponent?

A. The signed covariance without marginal terms

B. The carrier frequency in hertz

C. The sum of the phase means alone

D. Variance of the phase difference

Answer: D. The difference variance combines both marginals minus twice covariance. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Variance of the phase difference.

Distinguishing consideration: compare this with option A, “The signed covariance without marginal terms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-061. What factor retains deterministic phase differences in coherent-power calculation?

A. A mandatory zero mean for all phase records

B. Cosine of each pair's mean-phase difference in the real pair sum

C. The nominal ADC bit count

D. Only the marginal RMS

Answer: B. Deterministic rotation and random decorrelation are distinct effects in the finite sum. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Cosine of each pair's mean-phase difference in the real pair sum.

Distinguishing consideration: compare this with option A, “A mandatory zero mean for all phase records”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-062. For N = 1 normalized unit phasor, what is coherent power regardless of phase?

A. One

B. Zero for any random phase

C. One half

D. The exponential of minus marginal variance

Answer: A. A single unit phasor has unit magnitude; the finite formula's self term preserves that identity. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: One.

Distinguishing consideration: compare this with option B, “Zero for any random phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-063. For independent Gaussian phases of common mean and variance sigma squared, what is the infinite-N mean-power limit?

A. One for every nonzero variance

B. Exp(minus sigma squared)

C. Zero for every finite variance

D. Exp(minus sigma squared divided by two)

Answer: B. The finite self contribution tends to zero, leaving the off-diagonal factor.

Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why the selected alternative fits: Exp(minus sigma squared).

Distinguishing consideration: compare this with option A, “One for every nonzero variance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-MCQ-064. Eight independent zero-mean Gaussian phases have RMS 0.4 radian. Which is the exact-model mean normalized coherent power approximately?

A. 0.852144 exactly at finite N

B. 1

C. 0.870626

D. 0.923116

Answer: C. The finite expression adds the $\frac{1}{8}$ self term to seven-eighths times exp(-0.16). Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why the selected alternative fits: 0.870626.

Distinguishing consideration: compare this with option A, “0.852144 exactly at finite N”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-MCQ-065. The same eight marginal phases are perfectly common instead. What is mean record coherent power?

A. 0.852144

B. 0.870626

C. One eighth

D. One

Answer: D. Common rotation preserves every record sum magnitude, despite a smaller ensemble-mean phasor. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

Why the selected alternative fits: One.

Distinguishing consideration: compare this with option A, “0.852144”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

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V011-C12-MCQ-066. Why can the squared magnitude of an ensemble-mean phasor differ from mean record power?

A. A phase histogram uniquely gives the complete time record

B. Random common phase changes only sample rate

C. Expectation and squared magnitude do not generally commute

D. Every expectation is equal to one

Answer: C. The common-phase example has diminished mean complex phasor but unit power in each record. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

Why the selected alternative fits: Expectation and squared magnitude do not generally commute.

Distinguishing consideration: compare this with option A, “A phase histogram uniquely gives the complete time record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

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V011-C12-MCQ-067. In the stated positive geometric-correlation example, why is coherent power greater than in the independent case with equal RMS?

A. The marginal phase variance is secretly zero

B. The record has acquired additional samples

C. Relative phase increments are smaller on average

D. Positive correlation always doubles physical signal power

Answer: C. Coherence depends on differences and their covariance, not marginal RMS alone. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

Why the selected alternative fits: Relative phase increments are smaller on average.

Distinguishing consideration: compare this with option A, “The marginal phase variance is secretly zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

Review: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

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V011-C12-MCQ-068. What must be justified before applying an independent-phase model to adjacent samples of physical narrowband phase noise?

A. A smooth average spectrum alone

B. A large sample count alone

C. Their actual covariance supports that approximation

D. The fact that all samples are stored separately

Answer: C. Narrowband processes can correlate nearby phases; the independence assumption is not automatic. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why the selected alternative fits: Their actual covariance supports that approximation.

Distinguishing consideration: compare this with option A, “A smooth average spectrum alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-MCQ-069. A deterministic residual frequency produces substantial coherent-sum loss. What does reducing random phase noise alone fail to do?

A. Preserve the original deterministic phase record

B. Reduce the random contribution under its model

C. Remove the deterministic rotation

D. Change the stated marginal random variance

Answer: C. The mean-phase trajectory remains unless a justified correction addresses it. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

Why the selected alternative fits: Remove the deterministic rotation.

Distinguishing consideration: compare this with option A, “Preserve the original deterministic phase record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

Review: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

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V011-C12-MCQ-070. For 100 samples separated by 100 microseconds, what is first-to-last span?

A. 10 ms

B. 0.1 ms

C. 100 ms

D. 9.9 ms

Answer: D. There are 99 intervals between 100 endpoint samples, even when a geometric sum contains N. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

Why the selected alternative fits: 9.9 ms.

Distinguishing consideration: compare this with option A, “10 ms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

Review: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

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V011-C12-MCQ-071. Why assess a frequency correction fitted to the same weak record separately?

A. A deterministic correction can never improve alignment

B. Fitting can overfit noise or create artificial coherence

C. A larger number of fit parameters guarantees external source truth

D. All fitted corrections are necessarily invalid

Answer: B. The method, degrees of freedom, and validation outside the fit matter to interpretation. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

Why the selected alternative fits: Fitting can overfit noise or create artificial coherence.

Distinguishing consideration: compare this with option A, “A deterministic correction can never improve alignment”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Coherent Integration and Phase Preservation.

Review: Chapter 12 — Coherent Integration and Phase Preservation.

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V011-C12-MCQ-072. What should happen at a removable zero-over-zero form in a finite geometric-sum expression?

A. Replace the value with zero by default

B. Evaluate the finite sum or its correct limit

C. Declare the physical coherent power undefined automatically

D. Discard the diagonal terms

Answer: B. A closed-form singular representation need not be a singular finite sum.

Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Evaluate the finite sum or its correct limit.

Distinguishing consideration: compare this with option A, “Replace the value with zero by default”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-073. What is the effect of extending a nonzero flat phase-noise floor to infinite offset without a physical limit?

A. A finite universal jitter independent of bandwidth

B. Automatic conversion of lines into Gaussian noise

C. A guaranteed upper bound on every oscillator

D. Divergent variance, contrary to the finite-variance premise

Answer: D. The domain of an assumed spectrum matters; finite measured or bounded bands must remain explicit. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

Why the selected alternative fits: Divergent variance, contrary to the finite-variance premise.

Distinguishing consideration: compare this with option A, “A finite universal jitter independent of bandwidth”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

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V011-C12-MCQ-074. A density bound 1e-15 per hertz applies from 1 to 20 MHz. What is the maximum additional phase variance?

A. 3.8e-6 radian squared

B. 3.8e-8 radian squared

C. 2e-15 radian squared

D. 1.9e-8 radian squared

Answer: B. Twice density times 19 million hertz gives the finite extra-band bound.

Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

Why the selected alternative fits: 3.8e-8 radian squared.

Distinguishing consideration: compare this with option A, “3.8e-6 radian squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

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V011-C12-MCQ-075. How are measured and bounded extra-band contributions combined into timing RMS bounds?

A. Use the upper bound as an exact measured spectrum

B. Add all RMS values as though phases were identical

C. Add variance bounds, take square roots, then divide by two pi carrier

D. Average logarithmic density labels first

Answer: C. The combined result remains band-limited and interval-valued. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

Why the selected alternative fits: Add variance bounds, take square roots, then divide by two pi carrier.

Distinguishing consideration: compare this with option A, “Use the upper bound as an exact measured spectrum”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

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V011-C12-MCQ-076. What can limit coherent integration besides receiver clock noise?

A. Only the display's nominal center frequency

B. Motion, multipath, modulation, propagation change, and source instability

C. Only the final stored sample count

D. Only numerical tuning-word resolution

Answer: B. Coherence is a property of the whole measured signal/path over the interval. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

Why the selected alternative fits: Motion, multipath, modulation, propagation change, and source instability.

Distinguishing consideration: compare this with option A, “Only the display's nominal center frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Coherent Integration and Phase Preservation.

Review: Chapter 12 — Coherent Integration and Phase Preservation.

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V011-C12-MCQ-077. What can happen when integration extends beyond the demonstrated coherence time?

A. All noise becomes independent automatically

B. A frequency label proves unlimited coherence

C. Signal must improve monotonically with every added sample

D. The coherent result can decrease rather than improve

Answer: D. Relative phases can cancel, so longer is not universally better. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

Why the selected alternative fits: The coherent result can decrease rather than improve.

Distinguishing consideration: compare this with option A, “All noise becomes independent automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Coherent Integration and Phase Preservation.

Review: Chapter 12 — Coherent Integration and Phase Preservation.

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V011-C12-MCQ-078. Why is shared sampling frequency insufficient for multichannel alignment?

A. Triggers, apertures, filters, cables, pipelines, and transport can have unequal delays

B. Equal frequency makes every sample simultaneous

C. Calibration at any connector automatically reaches stored samples

D. Only antenna geometry can cause relative phase

Answer: A. The relevant boundary is the actual measured path and sample relationship. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

Why the selected alternative fits: Triggers, apertures, filters, cables, pipelines, and transport can have unequal delays.

Distinguishing consideration: compare this with option B, “Equal frequency makes every sample simultaneous”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Multichannel Synchronization and Delay Calibration.

Review: Chapter 12 — Multichannel Synchronization and Delay Calibration.

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V011-C12-MCQ-079. Which calibration best addresses the channels used in the later inference?

A. Only a shared oscillator model number

B. Only the reference-source output connector

C. Only equal sample-rate requests

D. A common signal traversing the actual analog and digital paths across the needed band

Answer: D. Installed path delays and state behavior can remain after a common frequency reference. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: A common signal traversing the actual analog and digital paths across the needed band.

Distinguishing consideration: compare this with option A, “Only a shared oscillator model number”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-MCQ-080. What does a channel-swap test help distinguish?

A. Every possible source location uniquely

B. A universal absence of clock noise

C. Residuals following a path or a channel

D. A constant physical delay from all frequency-dependent effects without further tests

Answer: C. The controlled interchange supplies diagnostic evidence about which component carries a discrepancy. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: Residuals following a path or a channel.

Distinguishing consideration: compare this with option A, “Every possible source location uniquely”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-MCQ-081. Why test retune, restart, and trigger sequences explicitly?

A. They may preserve, reset, or change the phase relation

B. Only long-term frequency aging matters

C. A shared clock makes resets irrelevant

D. Every device preserves deterministic phase across all such events

Answer: A. Coherence across state changes requires demonstrated deterministic behavior, not assumption. Source: §12.31 Reference Distribution Acceptance (p. 6994)

Why the selected alternative fits: They may preserve, reset, or change the phase relation.

Distinguishing consideration: compare this with option B, “Only long-term frequency aging matters”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Reference Distribution Acceptance.

Review: Chapter 12 — Reference Distribution Acceptance.

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V011-C12-MCQ-082. At what termination should distribution outputs be tested for installed acceptance?

A. Any convenient unloaded connector without qualification

B. A nominal 50-ohm label regardless of deployed load

C. Only the primary oscillator before distribution

D. The actual installed termination

Answer: D. Distribution amplifiers and cables can dominate performance after the primary reference. Source: §12.31 Reference Distribution Acceptance (p. 6994)

Why the selected alternative fits: The actual installed termination.

Distinguishing consideration: compare this with option A, “Any convenient unloaded connector without qualification”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Reference Distribution Acceptance.

Review: Chapter 12 — Reference Distribution Acceptance.

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V011-C12-MCQ-083. Why preserve original timing records alongside fitted corrections?

A. Corrected plots automatically contain every original discontinuity

B. Corrections can conceal the instability being investigated

C. Original records are redundant once a phase fit converges

D. A fitted trend is always the physical mechanism

Answer: B. A reviewer needs both the observation and the transformation to assess validity and overfitting. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: Corrections can conceal the instability being investigated.

Distinguishing consideration: compare this with option A, “Corrected plots automatically contain every original discontinuity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-MCQ-084. What defines a reported coherence time meaningfully?

A. One universal scalar valid for beamforming and timestamping alike

B. An interval meeting a specified operation and error criterion

C. The longest available recording file

D. The oscillator manufacturer's nominal lock time

Answer: B. Different operations tolerate different phase, timing, and modeling errors. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: An interval meeting a specified operation and error criterion.

Distinguishing consideration: compare this with option A, “One universal scalar valid for beamforming and timestamping alike”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-MCQ-085. If absolute phase cannot be preserved across a restart, what is the appropriate analysis scope?

A. Assumption of phase continuity from the same filename

B. Quantities and segments supported by demonstrated relative timing or magnitude

C. A forced continuous phase trajectory without evidence

D. Universal rejection of every magnitude observation

Answer: B. Limit the claim to preserved relationships rather than inventing a cross-event phase association. Source: §12.31 Reference Distribution Acceptance (p. 6994)

Why the selected alternative fits: Quantities and segments supported by demonstrated relative timing or magnitude.

Distinguishing consideration: compare this with option A, “Assumption of phase continuity from the same filename”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Reference Distribution Acceptance.

Review: Chapter 12 — Reference Distribution Acceptance.

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V011-C12-MCQ-086. A measured 1 GHz reference is 120 Hz high while measurement-reference uncertainty is 0.2 ppm. What is justified from that difference alone?

A. The measurement reference must be exact because its label is 1 GHz

B. The source frequency is necessarily correct

C. It is insufficient to claim the source is out of tolerance

D. The source is proven 0.12 ppm out of every possible tolerance

Answer: C. The observed 0.12 ppm difference must be interpreted with reference uncertainty and a stated tolerance rule. Source: §12.32 Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing (p. 6995)

Why the selected alternative fits: It is insufficient to claim the source is out of tolerance.

Distinguishing consideration: compare this with option A, "The measurement reference must be exact because its label is 1 GHz"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 12 — Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

Review: Chapter 12 — Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

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V011-C12-MCQ-087. What explains the impossible TDOA location in the chapter's remote-channel case?

A. Packet-trigger alignment differed despite a shared frequency reference

B. The geometry necessarily proved multiple sources

C. All common references are unusable for timing

D. A shared 10 MHz input guaranteed aperture simultaneity

Answer: A. Deterministic triggering and channel-delay calibration resolved a sample-alignment problem. Source: §12.34 Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing (p. 6998)

Why the selected alternative fits: Packet-trigger alignment differed despite a shared frequency reference.

Distinguishing consideration: compare this with option B, “The geometry necessarily proved multiple sources”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

Review: Chapter 12 — Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

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V011-C12-MCQ-088. What should a clock-reference change during a capture be logged as?

A. A harmless annotation unrelated to phase

B. A configuration event linked to affected records

C. An automatic correction to all prior timestamps

D. Proof that every sample remained coherent

Answer: B. The change can alter phase, timing, or noise and requires applicable segment evidence. Source: §12.31 Reference Distribution Acceptance (p. 6994)

Why the selected alternative fits: A configuration event linked to affected records.

Distinguishing consideration: compare this with option A, “A harmless annotation unrelated to phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Reference Distribution Acceptance.

Review: Chapter 12 — Reference Distribution Acceptance.

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V011-C12-MCQ-089. Why is a single integrated jitter number insufficient for close-in selectivity assessment?

A. Every offset contributes identically to every receiver decision

B. The number contains the complete PSD by definition

C. Jitter is unrelated to phase noise under all models

D. It discards where phase noise lies relative to a blocker and channel

Answer: D. Offset-dependent mechanisms require spectral information that one integral compresses. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

Why the selected alternative fits: It discards where phase noise lies relative to a blocker and channel.

Distinguishing consideration: compare this with option A, “Every offset contributes identically to every receiver decision”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Phase Noise and Close-In Observation.

Review: Chapter 12 — Phase Noise and Close-In Observation.

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V011-C12-MCQ-090. Why must a phase-noise measurement consider the measuring instrument's residual noise?

A. Only the source's nominal frequency sets the reading

B. The observed spectrum can include the measurement chain's contribution

C. Every analyzer has zero phase noise after calibration

D. Correlation automatically removes all systematic errors

Answer: B. A quieter reference or justified correlation technique is needed to separate instrument limits. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

Why the selected alternative fits: The observed spectrum can include the measurement chain's contribution.

Distinguishing consideration: compare this with option A, “Only the source's nominal frequency sets the reading”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Phase Noise and Close-In Observation.

Review: Chapter 12 — Phase Noise and Close-In Observation.

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V011-C12-MCQ-091. What makes high-frequency sampled inputs more sensitive to a given timing jitter?

A. The clock must lose every other sample

B. Every jitter value becomes a deterministic delay

C. Their voltage slope can be larger for the same amplitude

D. Quantization spacing necessarily increases with input frequency

Answer: C. Timing displacement creates voltage error through signal slope. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

Why the selected alternative fits: Their voltage slope can be larger for the same amplitude.

Distinguishing consideration: compare this with option A, “The clock must lose every other sample”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Clock Jitter and Sampling Uncertainty.

Review: Chapter 12 — Clock Jitter and Sampling Uncertainty.

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V011-C12-MCQ-092. For short bursts, what may dominate long-term frequency accuracy in the timing budget?

A. Trigger and timestamp uncertainty

B. The mean frequency averaged over a year

C. The number of oscillator aging digits alone

D. Only the nominal reference frequency

Answer: A. The relevant event boundary and short-time alignment can dominate a brief observation. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

Why the selected alternative fits: Trigger and timestamp uncertainty.

Distinguishing consideration: compare this with option B, “The mean frequency averaged over a year”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Clock Jitter and Sampling Uncertainty.

Review: Chapter 12 — Clock Jitter and Sampling Uncertainty.

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V011-C12-MCQ-093. Which statement correctly relates covariance information and exact Gaussian coherent-power claims?

A. Covariance can describe second-order differences without proving the required joint Gaussian law

B. A PSD makes all nonlinear expectations unique

C. A covariance matrix always proves Gaussianity

D. Gaussian marginal RMS alone proves every pair law

Answer: A. The exact exponential identity requires the declared distributional step in addition to second-order information. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Covariance can describe second-order differences without proving the required joint Gaussian law.

Distinguishing consideration: compare this with option B, “A PSD makes all nonlinear expectations unique”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-094. Why distinguish a nominal center-frequency command from actual tuning?

A. Every reference error is removed by entering more digits

B. Digital commands cannot represent any frequency

C. A known sample count makes the LO exact

D. Physical reference and synthesis errors can remain despite an exact numerical command

Answer: D. Command precision and physical accuracy are different properties.

Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

Why the selected alternative fits: Physical reference and synthesis errors can remain despite an exact numerical command.

Distinguishing consideration: compare this with option A, “Every reference error is removed by entering more digits”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Frequency Reference and Tuning Accuracy.

Review: Chapter 12 — Frequency Reference and Tuning Accuracy.

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V011-C12-MCQ-095. What is the strongest general timing acceptance claim supported by this chapter's approach?

A. Configuration-bound accuracy and coherence at the actual acquisition and stored-sample boundaries

B. Universal synchronization from a common clock cable

C. Absolute source location from one wrapped phase pair

D. An unlimited integration interval from one RMS value

Answer: A. The claim rests on calibrated paths, state tests, defined quantities, and retained limits. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: Configuration-bound accuracy and coherence at the actual acquisition and stored-sample boundaries.

Distinguishing consideration: compare this with option B, “Universal synchronization from a common clock cable”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-MCQ-096. Under a deterministic envelope, initial time bound is 2 ns, frequency-error bound is 1e-11, drift bound is zero, and tolerance is 12 ns. What is the maximum interval while these bounds remain applicable?

A. 200 seconds

B. 1200 seconds

C. 100 seconds

D. 1000 seconds

Answer: D. The available 10 ns margin divided by the dimensionless frequency bound 1e-11 gives 1000 seconds. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: 1000 seconds.

Distinguishing consideration: compare this with option A, “200 seconds”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-MCQ-097. What additional analysis is needed before calling the normalized coherent signal-power result a complete SNR improvement?

A. A justified treatment of additive noise, amplitude variation, and any estimated corrections

B. Only increasing N beyond the displayed record length

C. Only changing its unit label to decibels

D. No further analysis because signal power and SNR are identical

Answer: A. The derived phasor sum concerns signal power; it deliberately leaves other SNR contributors outside that calculation. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: A justified treatment of additive noise, amplitude variation, and any estimated corrections.

Distinguishing consideration: compare this with option B, “Only increasing N beyond the displayed record length”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-098. A disciplined reference stays close in long-term average frequency. What can still impair a short observation?

A. Short-term phase noise, excursions, or state transitions

B. No timing defect because discipline guarantees every timescale

C. Only the numerical precision of the center-frequency entry

D. Only a constant frequency offset equal to the average

Answer: A. The reference label and average behavior do not establish present short-time performance. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

Why the selected alternative fits: Short-term phase noise, excursions, or state transitions.

Distinguishing consideration: compare this with option B, “No timing defect because discipline guarantees every timescale”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Frequency Reference and Tuning Accuracy.

Review: Chapter 12 — Frequency Reference and Tuning Accuracy.

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V011-C12-MCQ-099. For a stationary zero-mean phase component, C(0) is 0.04 radian squared and C(tau) is 0.01 radian squared. What is phase-increment variance at that separation?

A. 0.05 radian squared

B. 0.06 radian squared

C. 0.02 radian squared

D. 0.03 radian squared

Answer: B. The second-order relation gives 2[0.04-0.01] = 0.06; Gaussianity is not needed for this variance calculation. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: 0.06 radian squared.

Distinguishing consideration: compare this with option A, “0.05 radian squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-MCQ-100. Two equal-weight unit phasors have deterministic phases zero and pi, with no random phase error. What is their normalized coherent power?

A. Zero

B. One half

C. One

D. Two

Answer: A. Their opposite deterministic phases cancel exactly. Zero random jitter alone does not establish a coherently aligned sum. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: Zero.

Distinguishing consideration: compare this with option B, “One half”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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Fill-in-the-Blank Questions

V011-C12-FIB-001. The clock model writes its reading as ideal time plus time _____.

Answer: error. The sign convention defines positive error as an advanced clock.

Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “error” completes the stated technical proposition.

Question context: The clock model writes its reading as ideal time plus time _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-002. Fractional-frequency error is the first time _____ of clock time error.

Answer: derivative. A constant epoch offset therefore has zero fractional-frequency error. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
Why this term is required: “derivative” completes the stated technical proposition.
Question context: Fractional-frequency error is the first time _____ of clock time error
Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.
Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-003. A constant fractional-frequency offset integrates to a _____ time-error term.

Answer: linear. The initial epoch is a separate constant term. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “linear” completes the stated technical proposition.

Question context: A constant fractional-frequency offset integrates to a _____ time-error term

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-004. A local linear fractional-frequency drift contributes a _____ time-error term.

Answer: quadratic. Integration introduces one half of drift times elapsed time squared. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “quadratic” completes the stated technical proposition.

Question context: A local linear fractional-frequency drift contributes a _____ time-error term

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-005. The fractional-frequency quantity is

_____.

Answer: dimensionless. It may be reported in ppm while retaining its reference and observation interval. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “dimensionless” completes the stated technical proposition.

Question context: The fractional-frequency quantity is _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-006. The local drift coefficient has units per

_____.

Answer: second. It is the rate of change of dimensionless fractional-frequency error. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “second” completes the stated technical proposition.

Question context: The local drift coefficient has units per _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-007. Clock advance is converted to relative unwrapped phase using two pi times nominal carrier _____.

Answer: frequency. The carrier must be positive and the time-error convention retained. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “frequency” completes the stated technical proposition.

Question context: Clock advance is converted to relative unwrapped phase using two pi times nominal carrier _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-008. A positive physical delay has a _____ transfer-phase slope under the stated exponential convention.

Answer: negative. It differs in sign from the chapter's advanced-clock relative phase. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “negative” completes the stated technical proposition.

Question context: A positive physical delay has a _____ transfer-phase slope under the stated exponential convention

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-009. A single wrapped phase cannot retain the integer _____ count.

Answer: cycle. Several delays or epochs can share the same principal phase. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “cycle” completes the stated technical proposition.

Question context: A single wrapped phase cannot retain the integer _____ count

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-010. For a nondispersive path, delay is minus unwrapped phase slope divided by two _____.

Answer: pi. The slope is with respect to frequency, with phase in radians. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “pi” completes the stated technical proposition.

Question context: For a nondispersive path, delay is minus unwrapped phase slope divided by two _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-011. The two-tone wrapped-delay ambiguity period is one divided by tone _____.

Answer: spacing. Additional calibrated information or a prior selects among branches. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “spacing” completes the stated technical proposition.

Question context: The two-tone wrapped-delay ambiguity period is one divided by tone _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-012. At a 10 MHz tone spacing, that ambiguity period is _____ ns.

Answer: 100. One divided by ten million hertz is 100 nanoseconds. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “100” completes the stated technical proposition.

Question context: At a 10 MHz tone spacing, that ambiguity period is _____ ns

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-013. A phase curve with frequency-dependent curvature may require a _____ path model rather than one constant delay.

Answer: dispersive. Filters can have a frequency-dependent group delay. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “dispersive” completes the stated technical proposition.

Question context: A phase curve with frequency-dependent curvature may require a _____ path model rather than one constant delay

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-014. Two epoch-error observations provide an _____ fractional-frequency estimate over their separation.

Answer: average. They do not alone reveal every change inside the interval. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “average” completes the stated technical proposition.

Question context: Two epoch-error observations provide an _____ fractional-frequency estimate over their separation

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-015. Freely signed deterministic endpoint bounds add in the worst-case difference rather than combine by root-sum-_____.

Answer: square. RSS would require an appropriate statistical model and dependencies. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “square” completes the stated technical proposition.

Question context: Freely signed deterministic endpoint bounds add in the worst-case difference rather than combine by root-sum-_____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-016. A phase reset must be retained as a segment _____.

Answer: event. A smooth drift fit should not conceal a documented discontinuity.

Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “event” completes the stated technical proposition.

Question context: A phase reset must be retained as a segment _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-017. A finite difference across a reset includes the phase jump divided by two pi times interval _____.

Answer: duration. That term is not necessarily a persistent oscillator-frequency offset. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
Why this term is required: “duration” completes the stated technical proposition.
Question context: A finite difference across a reset includes the phase jump divided by two pi times interval _____
Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.
Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-018. N endpoint samples span N minus _____ sample intervals.

Answer: one. Careful interval counting is needed for elapsed time and phase calculations. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “one” completes the stated technical proposition.

Question context: N endpoint samples span N minus _____ sample intervals

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-019. At fixed sample-interval count, elapsed time is inversely proportional to actual sample _____.

Answer: rate. A faster true clock produces a shorter physical interval. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “rate” completes the stated technical proposition.

Question context: At fixed sample-interval count, elapsed time is inversely proportional to actual sample _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-020. Using nominal rate for frequency labeling divides true tone frequency by one plus fractional clock _____.

Answer: error. The relation presumes the correct admitted alias class. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “error” completes the stated technical proposition.

Question context: Using nominal rate for frequency labeling divides true tone frequency by one plus fractional clock _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-021. For relative channel phase, first form the _____ of channel time errors.

Answer: difference. Common timing contributions may cancel while unequal paths remain. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “difference” completes the stated technical proposition.

Question context: For relative channel phase, first form the _____ of channel time errors

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-022. An initial timing bound exceeding tolerance cannot be repaired merely by shortening the calibration _____.

Answer: interval. The initial measurement or claimed tolerance must change.

Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “interval” completes the stated technical proposition.

Question context: An initial timing bound exceeding tolerance cannot be repaired merely by shortening the calibration _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-023. If initial bound equals tolerance with positive growth, only elapsed time _____ qualifies.

Answer: zero. The nonnegative envelope grows beyond the boundary immediately afterward. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “zero” completes the stated technical proposition.

Question context: If initial bound equals tolerance with positive growth, only elapsed time _____ qualifies

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-024. With zero frequency and drift bounds, the timing envelope is _____ over time within the valid segment.

Answer: constant. Its initial value alone determines compliance under that model.

Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “constant” completes the stated technical proposition.

Question context: With zero frequency and drift bounds, the timing envelope is _____ over time within the valid segment

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-025. The allowed time error corresponding to a phase tolerance decreases as carrier frequency _____.

Answer: increases. The conversion divides phase tolerance by two pi carrier. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “increases” completes the stated technical proposition.

Question context: The allowed time error corresponding to a phase tolerance decreases as carrier frequency _____

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-026. At 10 MHz, one complete cycle corresponds to _____ ns.

Answer: 100. The period is the reciprocal of the frequency. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “100” completes the stated technical proposition.

Question context: At 10 MHz, one complete cycle corresponds to _____ ns

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-027. At that carrier, a 25 ns clock advance gives _____ degrees relative phase.

Answer: 90. It is one quarter of a 100 ns cycle. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “90” completes the stated technical proposition.

Question context: At that carrier, a 25 ns clock advance gives _____ degrees relative phase

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-028. A plus 1 ppm constant fractional-frequency error accumulates _____ microseconds of time advance in one second.

Answer: 1. The time-error change equals fractional error times duration. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “1” completes the stated technical proposition.

Question context: A plus 1 ppm constant fractional-frequency error accumulates _____ microseconds of time advance in one second

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-FIB-029. A 0.75 microsecond epoch offset at 4 MS/s equals _____ sample intervals.

Answer: 3. The interval is 0.25 microsecond even when frequency error is zero.

Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “3” completes the stated technical proposition.

Question context: A 0.75 microsecond epoch offset at 4 MS/s equals _____ sample intervals

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-030. A 12.5 ns physical delay produces _____ degrees unwrapped phase at 100 MHz.

Answer: minus 450. The delay represents 1.25 cycles with the negative transfer sign. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “minus 450” completes the stated technical proposition.

Question context: A 12.5 ns physical delay produces _____ degrees unwrapped phase at 100 MHz

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-031. At 400 MHz, that same delay wraps to _____ degrees despite remaining nonzero.

Answer: zero. Five complete cycles are lost in the wrapped representation. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “zero” completes the stated technical proposition.

Question context: At 400 MHz, that same delay wraps to _____ degrees despite remaining nonzero

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-032. The unwrapped phase change from minus 72 to minus 86.4 degrees over 20 MHz implies _____ ns delay.

Answer: 2. The negative 14.4-degree slope corresponds to two nanoseconds.

Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “2” completes the stated technical proposition.

Question context: The unwrapped phase change from minus 72 to minus 86.4 degrees over 20 MHz implies _____ ns delay

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-033. The 52 ns alternative in that example differs by one wrapped-delay ambiguity _____.

Answer: period. The 20 MHz spacing leaves 50 ns between compatible branches.

Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “period” completes the stated technical proposition.

Question context: The 52 ns alternative in that example differs by one wrapped-delay ambiguity _____

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-034. A 6 microsecond time-error change over 600 seconds gives fractional error one times ten to the power minus _____.

Answer: eight. Dividing time error by elapsed ideal time yields a dimensionless ratio. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “eight” completes the stated technical proposition.

Question context: A 6 microsecond time-error change over 600 seconds gives fractional error one times ten to the power minus _____

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-035. At 10 MHz, that fractional error corresponds to _____ Hz frequency offset.

Answer: 0.1. Ten million times 10^{-8} equals 0.1 Hz. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “0.1” completes the stated technical proposition.

Question context: At 10 MHz, that fractional error corresponds to _____ Hz frequency offset

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-036. A 90-degree reset equals one _____ of a cycle.

Answer: quarter. Its contribution to a finite difference depends on the interval containing it. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “quarter” completes the stated technical proposition.

Question context: A 90-degree reset equals one _____ of a cycle

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-037. An ideal instantaneous phase jump has no finite ordinary _____ at the jump.

Answer: derivative. A real resolved slew needs a transient model rather than the ideal discontinuity. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)
Why this term is required: “derivative” completes the stated technical proposition.
Question context: An ideal instantaneous phase jump has no finite ordinary _____ at the jump
Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.
Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-038. Two million actual intervals require two million plus _____ endpoint samples.

Answer: one. This differs from a record containing exactly two million samples.

Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “one” completes the stated technical proposition.

Question context: Two million actual intervals require two million plus _____ endpoint samples

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-039. The example A-minus-B timing after ten seconds is 180 ns, or _____ unwrapped cycles at 10 MHz.

Answer: 1.8. Multiplying frequency by relative time gives the cycle advance. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “1.8” completes the stated technical proposition.

Question context: The example A-minus-B timing after ten seconds is 180 ns, or _____ unwrapped cycles at 10 MHz

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-040. That 1.8-cycle phase is _____ degrees in the stated principal interval.

Answer: minus 72. 648 degrees reduced to [-180,180) is -72 degrees. Source: §12.3 Worked applications with hypothetical inputs (p. 6956)

Why this term is required: “minus 72” completes the stated technical proposition.

Question context: That 1.8-cycle phase is _____ degrees in the stated principal interval

Basis and qualification: Chapter 12 — Worked applications with hypothetical inputs.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-FIB-041. Phase-noise integration must use _____ density values, not decibel ordinates.

Answer: linear. Variance is a power-like sum over weighted bandwidth. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “linear” completes the stated technical proposition.

Question context: Phase-noise integration must use _____ density values, not decibel ordinates

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-042. The SSB density is doubled for real-phase variance because the negative offset spectrum is _____.

Answer: symmetric. The positive and negative bands contribute equally under the adopted convention. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “symmetric” completes the stated technical proposition.

Question context: The SSB density is doubled for real-phase variance because the negative offset spectrum is _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-043. The positive offset integration set excludes zero unless a valid continuation supports the intended _____.

Answer: model. A divergent local law cannot be extended indiscriminately. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “model” completes the stated technical proposition.

Question context: The positive offset integration set excludes zero unless a valid continuation supports the intended _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-044. Phase RMS is converted to timing RMS by dividing by two pi times carrier _____.

Answer: frequency. The stated offset band remains part of the result. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “frequency” completes the stated technical proposition.

Question context: Phase RMS is converted to timing RMS by dividing by two pi times carrier _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-045. Phase RMS has units _____; timing RMS has units seconds.

Answer: radians. The carrier conversion changes the physical quantity while retaining band scope. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “radians” completes the stated technical proposition.

Question context: Phase RMS has units _____; timing RMS has units seconds

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-046. Adjacent disjoint density bands contribute additive phase _____.

Answer: variances. One integrates each linear density over its width before summing. Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)
Why this term is required: “variances” completes the stated technical proposition.
Question context: Adjacent disjoint density bands contribute additive phase _____
Basis and qualification: Chapter 12 — Application 12B.2: Add density bands in linear units.
Review: Chapter 12 — Application 12B.2: Add density bands in linear units.

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V011-C12-FIB-047. A discrete phase-modulation line has line _____ rather than a resolution-independent density.

Answer: power. Any dBc/Hz representation requires a bandwidth convention.

Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

Why this term is required: “power” completes the stated technical proposition.

Question context: A discrete phase-modulation line has line _____ rather than a resolution-independent density

Basis and qualification: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

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V011-C12-FIB-048. Over complete periods, a sinusoidal phase of peak beta has variance beta squared divided by _____.

Answer: two. The deterministic sinusoid is not made Gaussian by this RMS value.

Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin

(p. 6981)

Why this term is required: “two” completes the stated technical proposition.

Question context: Over complete periods, a sinusoidal phase of peak beta has variance beta squared divided by _____

Basis and qualification: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

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V011-C12-FIB-049. The first-order RF power in each PM sideband is beta squared divided by _____.

Answer: four. The two together match the phase variance in the small-modulation benchmark. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

Why this term is required: “four” completes the stated technical proposition.

Question context: The first-order RF power in each PM sideband is beta squared divided by _____

Basis and qualification: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

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V011-C12-FIB-050. Equal integrated phase variance can have different covariance at a given time _____.

Answer: separation. The cosine spectral weighting retains offset-location information. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “separation” completes the stated technical proposition.

Question context: Equal integrated phase variance can have different covariance at a given time _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-051. The phase covariance uses a _____ transform of the even density.

Answer: cosine. The stated spectrum is real and even for a real stationary phase component. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “cosine” completes the stated technical proposition.

Question context: The phase covariance uses a _____ transform of the even density

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-052. Increment variance equals twice total variance minus twice the lag _____.

Answer: covariance. It is a second-order relationship independent of Gaussianity.

Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “covariance” completes the stated technical proposition.

Question context: Increment variance equals twice total variance minus twice the lag _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-053. At zero separation, the phase increment variance is _____.

Answer: zero. Identical phase samples have no difference. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “zero” completes the stated technical proposition.

Question context: At zero separation, the phase increment variance is _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-054. The spectral increment weighting contains one minus the _____ of offset phase advance.

Answer: cosine. This makes the result depend on noise location as well as its total area. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “cosine” completes the stated technical proposition.

Question context: The spectral increment weighting contains one minus the _____ of offset phase advance

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-055. The RMS of a sum of timing contributions depends on their cross _____.

Answer: covariance. Separate component names do not justify independence.

Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why this term is required: “covariance” completes the stated technical proposition.

Question context: The RMS of a sum of timing contributions depends on their cross _____

Basis and qualification: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-FIB-056. For zero covariance, two timing RMS values combine by root-sum-_____.

Answer: square. Nonzero covariance adds a signed cross term. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why this term is required: “square” completes the stated technical proposition.

Question context: For zero covariance, two timing RMS values combine by root-sum-_____

Basis and qualification: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-FIB-057. For equal common errors in a relative-channel difference, the common contribution _____.

Answer: cancels. The sign of combination follows the defined measurement quantity. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why this term is required: “cancels” completes the stated technical proposition.

Question context: For equal common errors in a relative-channel difference, the common contribution _____

Basis and qualification: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-FIB-058. Two additive RMS values 2 and 3 ps with zero covariance combine to square root of _____ ps.

Answer: 13. The variance is 4+9 square picoseconds. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why this term is required: “13” completes the stated technical proposition.

Question context: Two additive RMS values 2 and 3 ps with zero covariance combine to square root of _____ ps

Basis and qualification: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-FIB-059. With correlation minus 0.5, those values combine to square root of _____ ps.

Answer: 7. The cross term subtracts 6 from the sum of 13. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why this term is required: “7” completes the stated technical proposition.

Question context: With correlation minus 0.5, those values combine to square root of _____ ps

Basis and qualification: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-C12-FIB-060. The exact Gaussian phasor result assumes a _____ Gaussian vector, not merely known marginal RMS values.

Answer: jointly. A linear phase difference must have the required normal law.

Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “jointly” completes the stated technical proposition.

Question context: The exact Gaussian phasor result assumes a _____ Gaussian vector, not merely known marginal RMS values

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-061. The variance of a phase difference equals two marginal variances' sum minus twice their _____.

Answer: covariance. This difference variance controls pair coherence in the Gaussian identity. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “covariance” completes the stated technical proposition.

Question context: The variance of a phase difference equals two marginal variances' sum minus twice their _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-062. A covariance matrix representing a possible joint vector must be positive _____.

Answer: semidefinite. Pairwise correlations alone can be inconsistent as a full matrix. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
Why this term is required: “semidefinite” completes the stated technical proposition.
Question context: A covariance matrix representing a possible joint vector must be positive _____
Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.
Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-063. The exponential pair-coherence factor contains minus one _____ of difference variance.

Answer: half. The Gaussian characteristic function supplies this factor. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “half” completes the stated technical proposition.

Question context: The exponential pair-coherence factor contains minus one _____ of difference variance

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-064. The real coherent-power pair sum retains cosine of deterministic mean-phase _____.

Answer: differences. Mean rotation is not captured by random marginal variance alone. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
Why this term is required: “differences” completes the stated technical proposition.
Question context: The real coherent-power pair sum retains cosine of deterministic mean-phase _____
Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.
Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-065. The normalized coherent sum uses equal weight one divided by sample count _____.

Answer: N. The formula includes all sample pairs and diagonal self terms. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “N” completes the stated technical proposition.

Question context: The normalized coherent sum uses equal weight one divided by sample count _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-066. The diagonal self-power contribution is one divided by _____.

Answer: N. It remains in the exact finite independent-phase result. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why this term is required: “N” completes the stated technical proposition.

Question context: The diagonal self-power contribution is one divided by _____

Basis and qualification: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-FIB-067. A common random phase preserves within-record phasor _____ because all samples rotate together.

Answer: alignment. It can reduce the ensemble-mean complex phasor without reducing each record's power. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

Why this term is required: “alignment” completes the stated technical proposition.

Question context: A common random phase preserves within-record phasor _____ because all samples rotate together

Basis and qualification: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

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V011-C12-FIB-068. For a single normalized unit phasor, power equals _____ regardless of its phase distribution.

Answer: one. This is an exact finite-sample identity. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “one” completes the stated technical proposition.

Question context: For a single normalized unit phasor, power equals _____ regardless of its phase distribution

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-069. For common Gaussian phase variance sigma squared, the ensemble-mean phasor magnitude is exp of minus sigma squared divided by _____.

Answer: two. Its squared magnitude is distinct from mean record power. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

Why this term is required: “two” completes the stated technical proposition.

Question context: For common Gaussian phase variance sigma squared, the ensemble-mean phasor magnitude is exp of minus sigma squared divided by _____

Basis and qualification: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

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V011-C12-FIB-070. Independent common-mean Gaussian phases have limiting mean coherent power exp of minus phase _____.

Answer: variance. The finite-N formula additionally retains its diagonal term. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why this term is required: “variance” completes the stated technical proposition.

Question context: Independent common-mean Gaussian phases have limiting mean coherent power exp of minus phase _____

Basis and qualification: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-FIB-071. Eight independent phases retain a diagonal term of one _____.

Answer: eighth. The remaining seven-eighths is weighted by the off-diagonal exponential factor. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why this term is required: “eighth” completes the stated technical proposition.

Question context: Eight independent phases retain a diagonal term of one _____

Basis and qualification: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-FIB-072. Equal marginal RMS does not distinguish common, independent, and _____ phase vectors.

Answer: correlated. Their different increments produce different coherent power.

Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

Why this term is required: “correlated” completes the stated technical proposition.

Question context: Equal marginal RMS does not distinguish common, independent, and _____ phase vectors

Basis and qualification: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

Review: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

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V011-C12-FIB-073. In a geometric lag model, covariance is sigma squared times rho raised to absolute lag _____.

Answer: index. The chapter's stated model supplies a valid covariance structure for its Gaussian calculation. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

Why this term is required: “index” completes the stated technical proposition.

Question context: In a geometric lag model, covariance is sigma squared times rho raised to absolute lag _____

Basis and qualification: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

Review: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

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V011-C12-FIB-074. Positive correlation in the stated example preserves more relative alignment than the _____ case.

Answer: independent. This is a result for the specified covariance, not a universal claim based only on an RMS value. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

Why this term is required: “independent” completes the stated technical proposition.

Question context: Positive correlation in the stated example preserves more relative alignment than the _____ case

Basis and qualification: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

Review: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

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V011-C12-FIB-075. Adjacent samples of narrowband phase noise need not be _____.

Answer: independent. Their actual covariance must support any approximation used. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

Why this term is required: “independent” completes the stated technical proposition.

Question context: Adjacent samples of narrowband phase noise need not be _____

Basis and qualification: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

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V011-C12-FIB-076. Deterministic residual frequency creates a systematic phase _____ through the record.

Answer: rotation. Improving random noise alone leaves this coherent-sum effect.

Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

Why this term is required: “rotation” completes the stated technical proposition.

Question context: Deterministic residual frequency creates a systematic phase _____ through the record

Basis and qualification: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

Review: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

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V011-C12-FIB-077. One hundred samples at 100 microsecond spacing span _____ ms between endpoints.

Answer: 9.9. There are 99 intervals, even though the finite sum contains 100 terms.

Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

Why this term is required: “9.9” completes the stated technical proposition.

Question context: One hundred samples at 100 microsecond spacing span _____ ms between endpoints

Basis and qualification: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

Review: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

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V011-C12-FIB-078. A removable zero-over-zero geometric expression should be evaluated by its finite _____ or correct limit.

Answer: sum. The underlying finite coherent sum can be well defined. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “sum” completes the stated technical proposition.

Question context: A removable zero-over-zero geometric expression should be evaluated by its finite _____ or correct limit

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-FIB-079. Phase corrections fitted from the tested signal can overfit _____ and create artificial coherence.

Answer: noise. The fitting method and degrees of freedom must remain visible.

Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

Why this term is required: “noise” completes the stated technical proposition.

Question context: Phase corrections fitted from the tested signal can overfit _____ and create artificial coherence

Basis and qualification: Chapter 12 — Coherent Integration and Phase Preservation.

Review: Chapter 12 — Coherent Integration and Phase Preservation.

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V011-C12-FIB-080. A correction should be checked where possible on an interval not used for _____.

Answer: fitting. Held-out comparison helps expose tuning to the original noise or state. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “fitting” completes the stated technical proposition.

Question context: A correction should be checked where possible on an interval not used for _____

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-FIB-081. A finite unmeasured band with density at most ℓ_{max} contributes at most twice ℓ_{max} times band _____.

Answer: width. The bound is limited to that stated interval. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

Why this term is required: “width” completes the stated technical proposition.

Question context: A finite unmeasured band with density at most contributes at most twice times band _____

Basis and qualification: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

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V011-C12-FIB-082. A constant nonzero floor extended to infinite offset has divergent phase _____.

Answer: variance. A finite-variance model needs a justified physical or mathematical bandwidth limit. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

Why this term is required: “variance” completes the stated technical proposition.

Question context: A constant nonzero floor extended to infinite offset has divergent phase _____

Basis and qualification: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

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V011-C12-FIB-083. Unmeasured regions outside the declared band union remain outside the timing-RMS _____.

Answer: result. A finite upper bound does not create global spectral knowledge.

Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

Why this term is required: “result” completes the stated technical proposition.

Question context: Unmeasured regions outside the declared band union remain outside the timing-RMS _____

Basis and qualification: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

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V011-C12-FIB-084. At fixed phase RMS, multiplying carrier by ten divides timing RMS by _____.

Answer: ten. The conversion is inversely proportional to carrier frequency. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

Why this term is required: “ten” completes the stated technical proposition.

Question context: At fixed phase RMS, multiplying carrier by ten divides timing RMS by _____

Basis and qualification: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

Review: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

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V011-C12-FIB-085. At fixed timing RMS, multiplying carrier by ten multiplies phase RMS by _____.

Answer: ten. The phase consequence of a given timing displacement grows with frequency. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

Why this term is required: “ten” completes the stated technical proposition.

Question context: At fixed timing RMS, multiplying carrier by ten multiplies phase RMS by _____

Basis and qualification: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

Review: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

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V011-C12-FIB-086. Sampling jitter produces voltage error through the input signal's _____.

Answer: slope. High-frequency inputs can therefore be sensitive even with excellent quantization. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

Why this term is required: “slope” completes the stated technical proposition.

Question context: Sampling jitter produces voltage error through the input signal's _____

Basis and qualification: Chapter 12 — Clock Jitter and Sampling Uncertainty.

Review: Chapter 12 — Clock Jitter and Sampling Uncertainty.

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V011-C12-FIB-087. A common frequency reference does not guarantee deterministic sample _____.

Answer: alignment. Aperture, trigger, path, and processing delays remain relevant.

Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

Why this term is required: “alignment” completes the stated technical proposition.

Question context: A common frequency reference does not guarantee deterministic sample _____

Basis and qualification: Chapter 12 — Multichannel Synchronization and Delay Calibration.

Review: Chapter 12 — Multichannel Synchronization and Delay Calibration.

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V011-C12-FIB-088. Shared clocks can coexist with unequal analog-filter and digital-pipeline _____.

Answer: delays. Calibration must traverse the actual measurement path. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

Why this term is required: “delays” completes the stated technical proposition.

Question context: Shared clocks can coexist with unequal analog-filter and digital-pipeline _____

Basis and qualification: Chapter 12 — Multichannel Synchronization and Delay Calibration.

Review: Chapter 12 — Multichannel Synchronization and Delay Calibration.

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V011-C12-FIB-089. A calibration at a clock connector does not automatically establish timing at the stored-_____ boundary.

Answer: sample. The chosen reference point must match the intended comparison.

Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “sample” completes the stated technical proposition.

Question context: A calibration at a clock connector does not automatically establish timing at the stored-_____ boundary

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-FIB-090. Channel swaps can reveal whether an error follows an electronic channel or a physical _____.

Answer: path. The controlled interchange helps localize residuals. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “path” completes the stated technical proposition.

Question context: Channel swaps can reveal whether an error follows an electronic channel or a physical _____

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-FIB-091. Cable substitution tests delay and sensitivity to the actual _____.

Answer: installation. Distribution performance depends on deployed components and termination. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “installation” completes the stated technical proposition.

Question context: Cable substitution tests delay and sensitivity to the actual _____

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-FIB-092. Retune, trigger, and restart tests examine whether phase relations are preserved or must be re-_____.

Answer: established. A nominal common rate does not guarantee cross-event continuity. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
Why this term is required: “established” completes the stated technical proposition.
Question context: Retune, trigger, and restart tests examine whether phase relations are preserved or must be re-_____
Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.
Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-FIB-093. Reference-distribution outputs should be measured at installed _____.

Answer: terminations. Loading and distribution paths can dominate residual performance. Source: §12.31 Reference Distribution Acceptance (p. 6994)

Why this term is required: “terminations” completes the stated technical proposition.

Question context: Reference-distribution outputs should be measured at installed _____

Basis and qualification: Chapter 12 — Reference Distribution Acceptance.

Review: Chapter 12 — Reference Distribution Acceptance.

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V011-C12-FIB-094. Holdover, relock, warmup, and power interruption are relevant reference _____ changes.

Answer: state. They may invalidate a previously identified timing law or phase relation. Source: §12.31 Reference Distribution Acceptance (p. 6994)

Why this term is required: “state” completes the stated technical proposition.

Question context: Holdover, relock, warmup, and power interruption are relevant reference _____ changes

Basis and qualification: Chapter 12 — Reference Distribution Acceptance.

Review: Chapter 12 — Reference Distribution Acceptance.

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V011-C12-FIB-095. A coherence time is defined against a specified operation and error _____.

Answer: criterion. Different uses can support different valid intervals. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “criterion” completes the stated technical proposition.

Question context: A coherence time is defined against a specified operation and error _____

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-FIB-096. When absolute phase is unavailable, restrict analysis to supported segments and relative timing or _____.

Answer: magnitude. Do not manufacture continuous phase relationships across unresolved events. Source: §12.31 Reference Distribution Acceptance (p. 6994)

Why this term is required: “magnitude” completes the stated technical proposition.

Question context: When absolute phase is unavailable, restrict analysis to supported segments and relative timing or _____

Basis and qualification: Chapter 12 — Reference Distribution Acceptance.

Review: Chapter 12 — Reference Distribution Acceptance.

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V011-C12-FIB-097. A 120 Hz offset at 1 GHz equals

_____ ppm.

Answer: 0.12. The dimensionless ratio is 1.2e-7 before conversion to parts per million. Source: §12.32 Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing (p. 6995)

Why this term is required: “0.12” completes the stated technical proposition.

Question context: A 120 Hz offset at 1 GHz equals _____ ppm

Basis and qualification: Chapter 12 — Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

Review: Chapter 12 — Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

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V011-C12-FIB-098. The chapter's remote-SDR case was resolved by deterministic triggering and per-channel delay _____.

Answer: calibration. Shared frequency alone had not aligned the sampling events.

Source: §12.34 Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing (p. 6998)

Why this term is required: “calibration” completes the stated technical proposition.

Question context: The chapter's remote-SDR case was resolved by deterministic triggering and per-channel delay _____

Basis and qualification: Chapter 12 — Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

Review: Chapter 12 — Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

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V011-C12-FIB-099. Original timing records should be preserved alongside every fitted _____.

Answer: correction. A transformation can improve alignment while concealing the instability under study. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “correction” completes the stated technical proposition.

Question context: Original timing records should be preserved alongside every fitted _____

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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V011-C12-FIB-100. Precision timing acceptance belongs to the actual boundary and receiver _____ used for the inference.

Answer: state. The reference label alone does not establish installed measurement behavior. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “state” completes the stated technical proposition.

Question context: Precision timing acceptance belongs to the actual boundary and receiver _____ used for the inference

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C12-ESSAY-001. Derive the relation among clock reading, time error, fractional frequency, and unwrapped phase.

- Opening: Present a thesis that answers this precise question: Derive the relation among clock reading, time error, fractional frequency, and unwrapped phase. Identify which evidence would falsify the proposed conclusion Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Core terminology and scope: Define relation, clock, reading in the question's particular technical setting; explain how error, fractional, unwrapped differ if that distinction would change the analysis of "Derive the relation among clock reading, time error, fractional frequency, and unwrapped phase" Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define positive time error as advance, differentiate to obtain fractional frequency, and multiply by the positive nominal carrier for phase Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the relation among clock reading, time error, fractional frequency, and unwrapped phase to the claimed result, following "Application 12A.2: Integrate a linear fractional-frequency drift"; name the intermediate states and measurable outputs Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the relation among clock reading, time error, fractional frequency, and unwrapped phase. Integrate a constant offset and local linear drift with separate initial epoch Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12A.1: Accumulate a constant fractional frequency offset” that resolves the question about the relation among clock reading, time error, fractional frequency, and unwrapped phase; derive the relevant result with units and stated validity conditions Source: §12.4 Application 12A.1: Accumulate a constant fractional frequency offset (p. 6957)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the relation among clock reading, time error, fractional frequency, and unwrapped phase. State units and interval boundaries, and explain why correct frequency need not imply aligned sample epochs Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Worked application or illustrative case: Build a worked example of “the relation among clock reading, time error, fractional frequency, and unwrapped phase”, addressing this associated condition: Define positive time error as advance, differentiate to obtain fractional frequency, and multiply by the.... Define positive time error as advance, differentiate to obtain fractional frequency, and multiply by

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the positive nominal carrier for phase Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the relation among clock reading, time error, fractional frequency, and unwrapped phase”. Using “Application 12A.1: Accumulate a constant fractional frequency offset”, specify a discriminator and the result expected under each explanation Source: §12.4 Application 12A.1: Accumulate a constant fractional frequency offset (p. 6957)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the relation among clock reading, time error, fractional frequency, and unwrapped phase, including the effect of missing measurements and inconsistent operating conditions Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Scholarly synthesis and implications: Explain what the result about the relation among clock reading, time error, fractional frequency, and unwrapped phase authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Closing: Conclude by answering “Derive the relation among clock reading, time error, fractional frequency, and unwrapped phase” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

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V011-C12-ESSAY-002. Compare physical propagation delay with clock advance using the declared phase conventions.

- Opening: Present a thesis that answers this precise question: Compare physical propagation delay with clock advance using the declared phase conventions. Identify which evidence would falsify the proposed conclusion Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)
- Core terminology and scope: Define physical, propagation, delay in the question's particular technical setting; explain how clock, declared, conventions differ if that distinction would change the analysis of "Compare physical propagation delay with clock advance using the declared phase conventions" Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Write the negative transfer exponential and derive delay from unwrapped frequency slope Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting physical propagation delay with clock advance using the declared phase conventions to the claimed result, following "Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity"; name the intermediate states and measurable outputs Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for physical

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propagation delay with clock advance using the declared phase conventions. Contrast positive clock-error phase, account for wrapping, and show how a nonzero delay can appear aligned at a selected frequency Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Accept coherence at the required boundary and state” that resolves the question about physical propagation delay with clock advance using the declared phase conventions; derive the relevant result with units and stated validity conditions Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Evidence and method: Specify the native observations, control records and calculations that would resolve physical propagation delay with clock advance using the declared phase conventions. Require calibrated path state and treat dispersion separately from constant delay Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)
- Worked application or illustrative case: Build a worked example of “physical propagation delay with clock advance using the declared phase conventions”, addressing this associated condition: Write the negative transfer exponential and derive delay from unwrapped frequency slope. Write the negative transfer exponential and derive delay from unwrapped frequency slope Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “physical propagation delay with clock

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advance using the declared phase conventions". Using "Accept coherence at the required boundary and state", specify a discriminator and the result expected under each explanation Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to physical propagation delay with clock advance using the declared phase conventions, including the effect of missing measurements and inconsistent operating conditions Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Scholarly synthesis and implications: Explain what the result about physical propagation delay with clock advance using the declared phase conventions authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)
- Closing: Conclude by answering "Compare physical propagation delay with clock advance using the declared phase conventions" using only the demonstrated evidence; state the remaining decisive verification step Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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V011-C12-ESSAY-003. Analyze a two-tone delay estimate that has only wrapped phase measurements.

- Opening: Present a thesis that answers this precise question: Analyze a two-tone delay estimate that has only wrapped phase measurements. Identify which evidence would falsify the proposed conclusion Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Core terminology and scope: Define two-tone, delay, estimate in the question's particular technical setting; explain how wrapped, phase, measurements differ if that distinction would change the analysis of "Analyze a two-tone delay estimate that has only wrapped phase measurements" Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Derive the ambiguity period from tone spacing and identify compatible branches Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a two-tone delay estimate that has only wrapped phase measurements to the claimed result, following "Application 12A.4: Keep physical delay and clock-error signs separate"; name the intermediate states and measurable outputs Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a two-

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tone delay estimate that has only wrapped phase measurements. Explain the 2 ns versus 52 ns example and why added numerical precision cannot select one Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- Analytical framework: Identify the equation, calibration or evidential decision test in "Ten numerical applications, each with stipulated assumptions" that resolves the question about a two-tone delay estimate that has only wrapped phase measurements; derive the relevant result with units and stated validity conditions Source: §12.42 Ten numerical applications, each with stipulated assumptions (p. 7015)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a two-tone delay estimate that has only wrapped phase measurements. State what a prior, extra calibrated frequencies, or established unwrap contributes and retain any constant-phase/dispersion assumptions Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Worked application or illustrative case: Build a worked example of "a two-tone delay estimate that has only wrapped phase measurements", addressing this associated condition: Derive the ambiguity period from tone spacing and identify compatible branches. Derive the ambiguity period from tone spacing and identify compatible branches Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)
- Alternative explanations and failure modes: Construct two plausible technical explanations for "a two-tone delay estimate that has only wrapped phase measurements". Using "Ten numerical applications,

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each with stipulated assumptions", specify a discriminator and the result expected under each explanation Source: §12.42 Ten numerical applications, each with stipulated assumptions (p. 7015)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a two-tone delay estimate that has only wrapped phase measurements, including the effect of missing measurements and inconsistent operating conditions Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Scholarly synthesis and implications: Explain what the result about a two-tone delay estimate that has only wrapped phase measurements authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Closing: Conclude by answering "Analyze a two-tone delay estimate that has only wrapped phase measurements" using only the demonstrated evidence; state the remaining decisive verification step Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

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V011-C12-ESSAY-004. Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds.

- Opening: Present a thesis that answers this precise question: Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds. Identify which evidence would falsify the proposed conclusion Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Core terminology and scope: Define fractional, epoch, propagate in the question's particular technical setting; explain how hard, endpoint, bounds differ if that distinction would change the analysis of "Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds" Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the ideal-time separation and difference of epoch errors, compute the central ratio, and use the sum of freely signed endpoint bounds for the maximum departure Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds to the claimed result, following "Application 12A.10: Choose a calibration interval from deterministic error bounds"; name the intermediate states and measurable outputs Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds. Distinguish shared calibration dependencies and statistical covariance from rectangular hard bounds Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12A.2: Integrate a linear fractional-frequency drift” that resolves the question about Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds; derive the relevant result with units and stated validity conditions Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds. State that the estimate does not reveal all within-interval behavior Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Worked application or illustrative case: Build a worked example of “Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds”, addressing this associated condition: Define the ideal-time separation and difference of epoch errors, compute the central ratio, and use the sum.... Define the ideal-time separation and difference of epoch errors, compute the

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central ratio, and use the sum of freely signed endpoint... Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds”. Using “Application 12A.2: Integrate a linear fractional-frequency drift”, specify a discriminator and the result expected under each explanation Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds, including the effect of missing measurements and inconsistent operating conditions Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)
- Scholarly synthesis and implications: Explain what the result about Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Closing: Conclude by answering “Estimate average fractional frequency from two epoch errors and propagate hard endpoint bounds” using only the demonstrated evidence; state the remaining

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decisive verification step Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

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V011-C12-ESSAY-005. Explain how a phase reset can imitate a large frequency estimate in a finite difference.

- Opening: Present a thesis that answers this precise question: Explain how a phase reset can imitate a large frequency estimate in a finite difference. Identify which evidence would falsify the proposed conclusion Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)
- Core terminology and scope: Define reset, imitate, large in the question's particular technical setting; explain how estimate, finite, difference differ if that distinction would change the analysis of "Explain how a phase reset can imitate a large frequency estimate in a finite difference" Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate continuous slope and reset contribution, evaluate the 90-degree/10-microsecond case, and distinguish an ideal jump from a resolved real slew Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how a phase reset can imitate a large frequency estimate in a finite difference to the claimed result, following "Application 12A.6: Bound a frequency estimate from two epoch measurements"; name the intermediate states and measurable outputs Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how a phase reset can imitate a large frequency estimate in a finite difference. Preserve the event and segment phases Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.10: Bound a finite unmeasured high-offset contribution” that resolves the question about how a phase reset can imitate a large frequency estimate in a finite difference; derive the relevant result with units and stated validity conditions Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how a phase reset can imitate a large frequency estimate in a finite difference. Do not fit one drift law or coherently join segments without a measured relationship Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)
- Worked application or illustrative case: Build a worked example of “how a phase reset can imitate a large frequency estimate in a finite difference”, addressing this associated condition: Separate continuous slope and reset contribution, evaluate the 90-degree/10-microsecond case, and distinguish.... Separate continuous slope and reset contribution, evaluate the 90-degree/10-microsecond case, and distinguish an ideal jump from a resolved real slew Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “how a phase reset can imitate a large frequency estimate in a finite difference”. Using “Application 12B.10: Bound a finite unmeasured high-offset contribution”, specify a discriminator and the result expected under each explanation Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how a phase reset can imitate a large frequency estimate in a finite difference, including the effect of missing measurements and inconsistent operating conditions Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Scholarly synthesis and implications: Explain what the result about how a phase reset can imitate a large frequency estimate in a finite difference authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)
- Closing: Conclude by answering “Explain how a phase reset can imitate a large frequency estimate in a finite difference” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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V011-C12-ESSAY-006. Develop a consistent correction for true versus nominal sample-clock scaling.

- Opening: Present a thesis that answers this precise question: Develop a consistent correction for true versus nominal sample-clock scaling. Identify which evidence would falsify the proposed conclusion Source: §12.11 Application 12A.8: Apply the actual sample clock to elapsed time and frequency labels (p. 6964)
- Core terminology and scope: Define consistent, correction, true in the question's particular technical setting; explain how nominal, sample-clock, scaling differ if that distinction would change the analysis of "Develop a consistent correction for true versus nominal sample-clock scaling" Source: §12.11 Application 12A.8: Apply the actual sample clock to elapsed time and frequency labels (p. 6964)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Count actual sample intervals and endpoint samples, use inverse actual rate for elapsed time, and derive nominal frequency labeling for the selected alias class Source: §12.11 Application 12A.8: Apply the actual sample clock to elapsed time and frequency labels (p. 6964)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a consistent correction for true versus nominal sample-clock scaling to the claimed result, following "Application 12A.3: Separate an epoch offset from a frequency offset"; name the intermediate states and measurable outputs Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a consistent correction for true versus nominal sample-clock scaling. Apply the 25 ppm example with clear sign Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system” that resolves the question about a consistent correction for true versus nominal sample-clock scaling; derive the relevant result with units and stated validity conditions Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a consistent correction for true versus nominal sample-clock scaling. Separate clock correction from analog alias identification and preserve source-index and anchor definitions Source: §12.11 Application 12A.8: Apply the actual sample clock to elapsed time and frequency labels (p. 6964)
- Worked application or illustrative case: Build a worked example of “a consistent correction for true versus nominal sample-clock scaling”, addressing this associated condition: Count actual sample intervals and endpoint samples, use inverse actual rate for elapsed time, and derive.... Count actual sample intervals and endpoint samples, use inverse actual rate for elapsed time, and derive nominal frequency labeling for the selected alias class Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a consistent correction for true versus nominal sample-clock scaling”. Using “Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system”, specify a discriminator and the result expected under each explanation Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a consistent correction for true versus nominal sample-clock scaling, including the effect of missing measurements and inconsistent operating conditions Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Scholarly synthesis and implications: Explain what the result about a consistent correction for true versus nominal sample-clock scaling authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.11 Application 12A.8: Apply the actual sample clock to elapsed time and frequency labels (p. 6964)
- Closing: Conclude by answering “Develop a consistent correction for true versus nominal sample-clock scaling” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.11 Application 12A.8: Apply the actual sample clock to elapsed time and frequency labels (p. 6964)

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V011-C12-ESSAY-007. Form a relative-channel phase model from two independently identified time-error laws.

- Opening: Present a thesis that answers this precise question: Form a relative-channel phase model from two independently identified time-error laws. Identify which evidence would falsify the proposed conclusion Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Core terminology and scope: Define Form, phase, model in the question's particular technical setting; explain how independently, identified, laws differ if that distinction would change the analysis of "Form a relative-channel phase model from two independently identified time-error laws" Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Subtract epoch and frequency/drift terms before multiplying by the carrier Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Form a relative-channel phase model from two independently identified time-error laws to the claimed result, following "Application 12A.2: Integrate a linear fractional-frequency drift"; name the intermediate states and measurable outputs Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Form a

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relative-channel phase model from two independently identified time-error laws. Use the chapter's 180 ns/10 MHz example, distinguish wrapped and unwrapped phase, and identify common terms that cancel Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 12A: connect clock reading, frequency and phase” that resolves the question about Form a relative-channel phase model from two independently identified time-error laws; derive the relevant result with units and stated validity conditions Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Form a relative-channel phase model from two independently identified time-error laws. Require calibration through actual paths and new applicability review after reset, missing samples, or configuration change Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Worked application or illustrative case: Build a worked example of “Form a relative-channel phase model from two independently identified time-error laws”, addressing this associated condition: Subtract epoch and frequency/drift terms before multiplying by the carrier. Subtract epoch and frequency/drift terms before multiplying by the carrier Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Form a relative-channel phase model from two independently identified time-error laws”. Using “Model 12A: connect clock reading, frequency and phase”, specify a discriminator and the result expected under each explanation Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Form a relative-channel phase model from two independently identified time-error laws, including the effect of missing measurements and inconsistent operating conditions Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)
- Scholarly synthesis and implications: Explain what the result about Form a relative-channel phase model from two independently identified time-error laws authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Closing: Conclude by answering “Form a relative-channel phase model from two independently identified time-error laws” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)

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V011-C12-ESSAY-008. Choose a calibration interval from deterministic initial, frequency, and drift bounds.

- Opening: Present a thesis that answers this precise question: Choose a calibration interval from deterministic initial, frequency, and drift bounds. Identify which evidence would falsify the proposed conclusion Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)
- Core terminology and scope: Define calibration, interval, deterministic in the question's particular technical setting; explain how initial, drift, bounds differ if that distinction would change the analysis of "Choose a calibration interval from deterministic initial, frequency, and drift bounds" Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Construct the monotone accumulated-error envelope, convert phase tolerance to time tolerance, and solve the positive-root or zero-drift case Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Choose a calibration interval from deterministic initial, frequency, and drift bounds to the claimed result, following "Application 12A.2: Integrate a linear fractional-frequency drift"; name the intermediate states and measurable outputs Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Choose a calibration interval from deterministic initial, frequency, and drift bounds. Address initial bound above/equal/below tolerance and zero growth Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Accept coherence at the required boundary and state” that resolves the question about Choose a calibration interval from deterministic initial, frequency, and drift bounds; derive the relevant result with units and stated validity conditions Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Choose a calibration interval from deterministic initial, frequency, and drift bounds. State the environmental and state assumptions and avoid presenting the computed interval as a universal schedule Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)
- Worked application or illustrative case: Build a worked example of “Choose a calibration interval from deterministic initial, frequency, and drift bounds”, addressing this associated condition: Construct the monotone accumulated-error envelope, convert phase tolerance to time tolerance, and solve the.... Construct the monotone accumulated-error envelope, convert phase tolerance to time tolerance, and solve the positive-root or zero-drift case Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Choose a calibration interval from deterministic initial, frequency, and drift bounds”. Using “Accept coherence at the required boundary and state”, specify a discriminator and the result expected under each explanation Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Choose a calibration interval from deterministic initial, frequency, and drift bounds, including the effect of missing measurements and inconsistent operating conditions Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Scholarly synthesis and implications: Explain what the result about Choose a calibration interval from deterministic initial, frequency, and drift bounds authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)
- Closing: Conclude by answering “Choose a calibration interval from deterministic initial, frequency, and drift bounds” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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V011-C12-ESSAY-009. Design a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors.

- Opening: Present a thesis that answers this precise question: Design a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors. Identify which evidence would falsify the proposed conclusion Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)
- Core terminology and scope: Define Design, calibration, offset in the question's particular technical setting; explain how scale, state-dependent, errors differ if that distinction would change the analysis of "Design a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors" Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use traceable references at several points and relevant gain/tuning states, retain reference uncertainty, lock/holdover, temperature, aging, and conversion settings Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors to the claimed result, following "Reference Distribution Acceptance"; name the intermediate states and measurable outputs Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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reference-frequency calibration that can distinguish offset, scale, and state-dependent errors. Explain why one tone or a numerically exact command cannot characterize all errors Source: §12.31 Reference Distribution Acceptance (p. 6994)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12A.6: Bound a frequency estimate from two epoch measurements” that resolves the question about a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors; derive the relevant result with units and stated validity conditions Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors. Tie the result to the intended observation interval and installed chain Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)
- Worked application or illustrative case: Build a worked example of “a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors”, addressing this associated condition: Use traceable references at several points and relevant gain/tuning states, retain reference uncertainty,.... Use traceable references at several points and relevant gain/tuning states, retain reference uncertainty, lock/holdover, temperature,... Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a reference-frequency calibration that

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can distinguish offset, scale, and state-dependent errors". Using "Application 12A.6: Bound a frequency estimate from two epoch measurements", specify a discriminator and the result expected under each explanation Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors, including the effect of missing measurements and inconsistent operating conditions Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Scholarly synthesis and implications: Explain what the result about a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)
- Closing: Conclude by answering "Design a reference-frequency calibration that can distinguish offset, scale, and state-dependent errors" using only the demonstrated evidence; state the remaining decisive verification step Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

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V011-C12-ESSAY-010. Derive finite-band timing RMS from an SSB phase-noise spectrum.

- Opening: Present a thesis that answers this precise question: Derive finite-band timing RMS from an SSB phase-noise spectrum. Identify which evidence would falsify the proposed conclusion Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Core terminology and scope: Define finite-band, timing, phase-noise in the question's particular technical setting; explain how spectrum, measurement, evidence differ if that distinction would change the analysis of "Derive finite-band timing RMS from an SSB phase-noise spectrum" Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the real-phase side convention, positive offset set, linear density conversion, factor two, variance integration, square root, and carrier division Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting finite-band timing RMS from an SSB phase-noise spectrum to the claimed result, following "Model 12B: finite-band jitter and coherent signal power"; name the intermediate states and measurable outputs Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for finite-band timing RMS from an SSB phase-noise spectrum. Treat disjoint

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bands and discrete lines separately Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.1: Integrate a flat SSB density over a declared band” that resolves the question about finite-band timing RMS from an SSB phase-noise spectrum; derive the relevant result with units and stated validity conditions Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)
- Evidence and method: Specify the native observations, control records and calculations that would resolve finite-band timing RMS from an SSB phase-noise spectrum. Preserve unmeasured offsets and avoid extending local laws beyond an integrable justified domain Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Worked application or illustrative case: Build a worked example of “finite-band timing RMS from an SSB phase-noise spectrum”, addressing this associated condition: State the real-phase side convention, positive offset set, linear density conversion, factor two, variance.... State the real-phase side convention, positive offset set, linear density conversion, factor two, variance integration, square root, and carrier division Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “finite-band timing RMS from an SSB phase-noise spectrum”. Using “Application 12B.1: Integrate a flat SSB density over a declared band”, specify a discriminator and the

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result expected under each explanation Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to finite-band timing RMS from an SSB phase-noise spectrum, including the effect of missing measurements and inconsistent operating conditions Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Scholarly synthesis and implications: Explain what the result about finite-band timing RMS from an SSB phase-noise spectrum authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Closing: Conclude by answering “Derive finite-band timing RMS from an SSB phase-noise spectrum” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

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V011-C12-ESSAY-011. Compare equal jitter numbers obtained at different carrier frequencies or integration bands.

- Opening: Present a thesis that answers this precise question: Compare equal jitter numbers obtained at different carrier frequencies or integration bands. Identify which evidence would falsify the proposed conclusion Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Core terminology and scope: Define jitter, numbers, obtained in the question's particular technical setting; explain how frequencies, integration, bands differ if that distinction would change the analysis of "Compare equal jitter numbers obtained at different carrier frequencies or integration bands" Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify which phase or timing quantity is held fixed, align offset limits, weighting, line handling, and reference planes, and show the inverse carrier conversion Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting equal jitter numbers obtained at different carrier frequencies or integration bands to the claimed result, following "Application 12B.1: Integrate a flat SSB density over a declared band"; name the intermediate states and measurable outputs Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for equal jitter numbers obtained at different carrier frequencies or integration bands. Explain why a scalar RMS can conceal noise location and cannot rank oscillators or predict close-in receiver performance without the definitions Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.3: Keep carrier frequency in the phase-to-time conversion” that resolves the question about equal jitter numbers obtained at different carrier frequencies or integration bands; derive the relevant result with units and stated validity conditions Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)
- Evidence and method: Specify the native observations, control records and calculations that would resolve equal jitter numbers obtained at different carrier frequencies or integration bands. Explain why a scalar RMS can conceal noise location and cannot rank oscillators or predict close-in receiver performance without the definitions Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Worked application or illustrative case: Build a worked example of “equal jitter numbers obtained at different carrier frequencies or integration bands”, addressing this associated condition: Identify which phase or timing quantity is held fixed, align offset limits, weighting, line handling, and.... Identify which phase or timing quantity is held fixed, align offset limits, weighting, line handling,

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and reference planes, and show the inverse... Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “equal jitter numbers obtained at different carrier frequencies or integration bands”. Using “Application 12B.3: Keep carrier frequency in the phase-to-time conversion”, specify a discriminator and the result expected under each explanation Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to equal jitter numbers obtained at different carrier frequencies or integration bands, including the effect of missing measurements and inconsistent operating conditions Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
- Scholarly synthesis and implications: Explain what the result about equal jitter numbers obtained at different carrier frequencies or integration bands authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Closing: Conclude by answering “Compare equal jitter numbers obtained at different carrier frequencies or integration bands” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

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V011-C12-ESSAY-012. Derive covariance and phase-increment variance from the stated band-limited density.

- Opening: Present a thesis that answers this precise question: Derive covariance and phase-increment variance from the stated band-limited density. Identify which evidence would falsify the proposed conclusion Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Core terminology and scope: Define covariance, phase-increment, variance in the question's particular technical setting; explain how stated, band-limited, density differ if that distinction would change the analysis of "Derive covariance and phase-increment variance from the stated band-limited density" Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the even spectrum's cosine transform, then expand the variance of a phase difference Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting covariance and phase-increment variance from the stated band-limited density to the claimed result, following "Application 12B.10: Bound a finite unmeasured high-offset contribution"; name the intermediate states and measurable outputs Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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covariance and phase-increment variance from the stated band-limited density. Identify the one-minus-cosine weighting and demonstrate why equal integrated variance need not imply equal increments Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin” that resolves the question about covariance and phase-increment variance from the stated band-limited density; derive the relevant result with units and stated validity conditions Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Evidence and method: Specify the native observations, control records and calculations that would resolve covariance and phase-increment variance from the stated band-limited density. State second-order stationarity and finite-variance conditions without introducing unnecessary Gaussian assumptions Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Worked application or illustrative case: Build a worked example of “covariance and phase-increment variance from the stated band-limited density”, addressing this associated condition: Use the even spectrum's cosine transform, then expand the variance of a phase difference. Use the even spectrum's cosine transform, then expand the variance of a phase difference Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “covariance and phase-increment

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variance from the stated band-limited density". Using "Application 12B.4: Treat a phase-modulation line as a line, not a density bin", specify a discriminator and the result expected under each explanation Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to covariance and phase-increment variance from the stated band-limited density, including the effect of missing measurements and inconsistent operating conditions Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)
- Scholarly synthesis and implications: Explain what the result about covariance and phase-increment variance from the stated band-limited density authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Closing: Conclude by answering "Derive covariance and phase-increment variance from the stated band-limited density" using only the demonstrated evidence; state the remaining decisive verification step Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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V011-C12-ESSAY-013. Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference, retaining each stated covariance condition.

- Opening: Present a thesis that answers this precise question: Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference, retaining each stated covariance condition. Identify which evidence would falsify the proposed conclusion Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)
- Core terminology and scope: Define combine, contributions, difference in the question's particular technical setting; explain how retaining, covariance, condition differ if that distinction would change the analysis of "Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference, retaining each stated covariance condition" Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain covariance and its sign, calculate the 2 ps/3 ps cases, and explain the zero-covariance RSS condition Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,… to the claimed result,

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following “Application 12B.3: Keep carrier frequency in the phase-to-time conversion”; name the intermediate states and measurable outputs Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,…. Discuss a common reference's possible cancellation in a difference and its reinforcement in a sum Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.9: Combine deterministic rotation with independent phase errors” that resolves the question about Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,…; derive the relevant result with units and stated validity conditions Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,…. Require evidence for the relevant transfer and correlation rather than infer independence from component names Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

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- Worked application or illustrative case: Build a worked example of “Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,…”, addressing this associated condition: Retain covariance and its sign, calculate the 2 ps/3 ps cases, and explain the zero-covariance RSS condition. Retain covariance and its sign, calculate the 2 ps/3 ps cases, and explain the zero-covariance RSS… Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,…”. Using “Application 12B.9: Combine deterministic rotation with independent phase errors”, specify a discriminator and the result expected under each explanation Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,…, including the effect of missing measurements and inconsistent operating conditions Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)
- Scholarly synthesis and implications: Explain what the result about Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference,… authorises the investigator or engineer to claim, and what stronger

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proposition remains unsupported Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- Closing: Conclude by answering “Using Application 12B.5, combine its 2 ps and 3 ps RMS timing contributions for both a sum and a relative-channel difference, retaining each stated covariance condition” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

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V011-C12-ESSAY-014. Derive the finite Gaussian pair-phasor expectation and coherent-power sum.

- Opening: Present a thesis that answers this precise question: Derive the finite Gaussian pair-phasor expectation and coherent-power sum. Identify which evidence would falsify the proposed conclusion Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Core terminology and scope: Define finite, Gaussian, pair-phasor in the question's particular technical setting; explain how expectation, coherent-power, measurement differ if that distinction would change the analysis of "Derive the finite Gaussian pair-phasor expectation and coherent-power sum" Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State joint Gaussian mean/covariance, form each difference variance, apply the Gaussian characteristic function, and retain deterministic mean differences Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the finite Gaussian pair-phasor expectation and coherent-power sum to the claimed result, following "Application 12B.6: Distinguish a common random phase from lost coherent power"; name the intermediate states and measurable outputs Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the finite Gaussian pair-phasor expectation and coherent-power sum. Expand the normalized squared sum including diagonal terms and conjugate pairs Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases” that resolves the question about the finite Gaussian pair-phasor expectation and coherent-power sum; derive the relevant result with units and stated validity conditions Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the finite Gaussian pair-phasor expectation and coherent-power sum. Require a positive-semidefinite covariance matrix and distinguish this signal-power result from a complete SNR calculation Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Worked application or illustrative case: Build a worked example of “the finite Gaussian pair-phasor expectation and coherent-power sum”, addressing this associated condition: State joint Gaussian mean/covariance, form each difference variance, apply the Gaussian characteristic.... State joint Gaussian mean/covariance, form each difference variance, apply the Gaussian characteristic function, and

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retain deterministic mean differences Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the finite Gaussian pair-phasor expectation and coherent-power sum”. Using “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases”, specify a discriminator and the result expected under each explanation Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the finite Gaussian pair-phasor expectation and coherent-power sum, including the effect of missing measurements and inconsistent operating conditions Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Scholarly synthesis and implications: Explain what the result about the finite Gaussian pair-phasor expectation and coherent-power sum authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Closing: Conclude by answering “Derive the finite Gaussian pair-phasor expectation and coherent-power sum” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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V011-C12-ESSAY-015. Explain the difference between common random phase and independent sample phase errors with equal marginal RMS.

- Opening: Present a thesis that answers this precise question: Explain the difference between common random phase and independent sample phase errors with equal marginal RMS. Identify which evidence would falsify the proposed conclusion Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Core terminology and scope: Define difference, common, random in the question's particular technical setting; explain how independent, errors, marginal differ if that distinction would change the analysis of "Explain the difference between common random phase and independent sample phase errors with equal marginal RMS" Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compare within-record phasor alignment, ensemble-mean phasor, and mean record power Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the difference between common random phase and independent sample phase errors with equal marginal RMS to the claimed result, following "Application 12B.7: Compute finite-sample coherence for independent Gaussian phases"; name the intermediate states and

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measurable outputs Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the difference between common random phase and independent sample phase errors with equal marginal RMS. Use the eight-sample 0.4-radian cases to show unit common-phase power versus the finite independent result Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.9: Combine deterministic rotation with independent phase errors” that resolves the question about the difference between common random phase and independent sample phase errors with equal marginal RMS; derive the relevant result with units and stated validity conditions Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the difference between common random phase and independent sample phase errors with equal marginal RMS. Explain why marginal RMS alone cannot choose the appropriate covariance model or establish absolute phase Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Worked application or illustrative case: Build a worked example of “the difference between common random phase and independent sample phase errors with equal marginal RMS”, addressing this

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associated condition: Compare within-record phasor alignment, ensemble-mean phasor, and mean record power. Compare within-record phasor alignment, ensemble-mean phasor, and mean record power Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the difference between common random phase and independent sample phase errors with equal marginal RMS”. Using “Application 12B.9: Combine deterministic rotation with independent phase errors”, specify a discriminator and the result expected under each explanation Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the difference between common random phase and independent sample phase errors with equal marginal RMS, including the effect of missing measurements and inconsistent operating conditions Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Scholarly synthesis and implications: Explain what the result about the difference between common random phase and independent sample phase errors with equal marginal RMS authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Closing: Conclude by answering “Explain the difference between common random phase and independent sample phase errors with

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equal marginal RMS" using only the demonstrated evidence; state the remaining decisive verification step Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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V011-C12-ESSAY-016. Assess a geometric-covariance Gaussian model for finite coherent integration.

- Opening: Present a thesis that answers this precise question: Assess a geometric-covariance Gaussian model for finite coherent integration. Identify which evidence would falsify the proposed conclusion Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Core terminology and scope: Define geometric-covariance, Gaussian, model in the question's particular technical setting; explain how finite, coherent, integration differ if that distinction would change the analysis of "Assess a geometric-covariance Gaussian model for finite coherent integration" Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the valid covariance and lag increment variance, substitute the finite multiplicities into the pair sum, and compare the stated correlated and independent outcomes Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a geometric-covariance Gaussian model for finite coherent integration to the claimed result, following "Application 12B.7: Compute finite-sample coherence for independent Gaussian phases"; name the intermediate states and measurable outputs Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a geometric-covariance Gaussian model for finite coherent integration. Distinguish a stipulated teaching covariance from an estimated physical one and preserve evidence for joint Gaussianity if the exact exponential result is claimed Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 12B.9: Combine deterministic rotation with independent phase errors" that resolves the question about a geometric-covariance Gaussian model for finite coherent integration; derive the relevant result with units and stated validity conditions Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a geometric-covariance Gaussian model for finite coherent integration. Distinguish a stipulated teaching covariance from an estimated physical one and preserve evidence for joint Gaussianity if the exact exponential result is claimed Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Worked application or illustrative case: Build a worked example of "a geometric-covariance Gaussian model for finite coherent integration", addressing this associated condition: Define the valid covariance and lag increment variance, substitute the finite multiplicities into the pair.... Define the valid covariance and lag

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increment variance, substitute the finite multiplicities into the pair sum, and compare the stated correlated and independent... Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a geometric-covariance Gaussian model for finite coherent integration”. Using “Application 12B.9: Combine deterministic rotation with independent phase errors”, specify a discriminator and the result expected under each explanation Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a geometric-covariance Gaussian model for finite coherent integration, including the effect of missing measurements and inconsistent operating conditions Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Scholarly synthesis and implications: Explain what the result about a geometric-covariance Gaussian model for finite coherent integration authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Closing: Conclude by answering “Assess a geometric-covariance Gaussian model for finite coherent integration” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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V011-C12-ESSAY-017. Combine deterministic residual frequency with independent Gaussian phase errors.

- Opening: Present a thesis that answers this precise question: Combine deterministic residual frequency with independent Gaussian phase errors. Identify which evidence would falsify the proposed conclusion Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Core terminology and scope: Define Combine, deterministic, residual in the question's particular technical setting; explain how independent, Gaussian, errors differ if that distinction would change the analysis of "Combine deterministic residual frequency with independent Gaussian phase errors" Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Keep the deterministic finite phasor sum and random diagonal contribution separate Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Combine deterministic residual frequency with independent Gaussian phase errors to the claimed result, following "Application 12B.6: Distinguish a common random phase from lost coherent power"; name the intermediate states and measurable outputs Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Combine deterministic residual frequency with independent Gaussian phase errors. State actual sample times and endpoint span, evaluate special-frequency limits correctly, and explain why reducing random phase noise does not remove deterministic cancellation Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin” that resolves the question about Combine deterministic residual frequency with independent Gaussian phase errors; derive the relevant result with units and stated validity conditions Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Combine deterministic residual frequency with independent Gaussian phase errors. Assess separately a correction estimated from the same weak data Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Worked application or illustrative case: Build a worked example of “Combine deterministic residual frequency with independent Gaussian phase errors”, addressing this associated condition: Keep the deterministic finite phasor sum and random diagonal contribution separate. Keep the deterministic finite phasor sum and

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random diagonal contribution separate Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Combine deterministic residual frequency with independent Gaussian phase errors”. Using “Application 12B.4: Treat a phase-modulation line as a line, not a density bin”, specify a discriminator and the result expected under each explanation Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Combine deterministic residual frequency with independent Gaussian phase errors, including the effect of missing measurements and inconsistent operating conditions Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)
- Scholarly synthesis and implications: Explain what the result about Combine deterministic residual frequency with independent Gaussian phase errors authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Closing: Conclude by answering “Combine deterministic residual frequency with independent Gaussian phase errors” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

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V011-C12-ESSAY-018. Analyze a deterministic phase-modulation line without misusing a Gaussian jitter model.

- Opening: Present a thesis that answers this precise question: Analyze a deterministic phase-modulation line without misusing a Gaussian jitter model. Identify which evidence would falsify the proposed conclusion Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Core terminology and scope: Define deterministic, phase-modulation, line in the question's particular technical setting; explain how Gaussian, jitter, model differ if that distinction would change the analysis of "Analyze a deterministic phase-modulation line without misusing a Gaussian jitter model" Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use complete-period sinusoidal phase variance and the small-modulation sideband convention, state line power and any bandwidth representation, and retain the deterministic trajectory for... Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a deterministic phase-modulation line without misusing a Gaussian jitter model to the claimed result, following "Application 12B.7: Compute finite-sample coherence for independent Gaussian phases"; name the intermediate states and measurable outputs Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a deterministic phase-modulation line without misusing a Gaussian jitter model. Explain why RMS equivalence does not establish a Gaussian process or resolution-independent density Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Model 12B: finite-band jitter and coherent signal power" that resolves the question about a deterministic phase-modulation line without misusing a Gaussian jitter model; derive the relevant result with units and stated validity conditions Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a deterministic phase-modulation line without misusing a Gaussian jitter model. Explain why RMS equivalence does not establish a Gaussian process or resolution-independent density Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Worked application or illustrative case: Build a worked example of "a deterministic phase-modulation line without misusing a Gaussian jitter model", addressing this associated condition: Use complete-period sinusoidal phase variance and the small-modulation sideband convention, state line power.... Use complete-period sinusoidal phase variance and the small-modulation sideband convention, state line power and any bandwidth representation,

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and... Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a deterministic phase-modulation line without misusing a Gaussian jitter model”. Using “Model 12B: finite-band jitter and coherent signal power”, specify a discriminator and the result expected under each explanation Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a deterministic phase-modulation line without misusing a Gaussian jitter model, including the effect of missing measurements and inconsistent operating conditions Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Scholarly synthesis and implications: Explain what the result about a deterministic phase-modulation line without misusing a Gaussian jitter model authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Closing: Conclude by answering “Analyze a deterministic phase-modulation line without misusing a Gaussian jitter model” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

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V011-C12-ESSAY-019. Bound a finite unmeasured offset band and report the resulting timing-RMS interval.

- Opening: Present a thesis that answers this precise question: Bound a finite unmeasured offset band and report the resulting timing-RMS interval. Identify which evidence would falsify the proposed conclusion Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Core terminology and scope: Define Bound, unmeasured, offset in the question's particular technical setting; explain how band, report, resulting differ if that distinction would change the analysis of "Bound a finite unmeasured offset band and report the resulting timing-RMS interval" Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Integrate a justified upper SSB density over only the stated extra band with the factor two, add to measured variance, and convert lower/upper totals through square root and carrier Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Bound a finite unmeasured offset band and report the resulting timing-RMS interval to the claimed result, following "Application 12B.1: Integrate a flat SSB density over a declared band"; name the intermediate states and measurable outputs Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Bound a finite unmeasured offset band and report the resulting timing-RMS interval. Identify excluded offsets and physical bandwidth assumptions Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin” that resolves the question about Bound a finite unmeasured offset band and report the resulting timing-RMS interval; derive the relevant result with units and stated validity conditions Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Bound a finite unmeasured offset band and report the resulting timing-RMS interval. Do not describe extrapolated floors as measurements or extend a nonzero density to infinity Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Worked application or illustrative case: Build a worked example of “Bound a finite unmeasured offset band and report the resulting timing-RMS interval”, addressing this associated condition: Integrate a justified upper SSB density over only the stated extra band with the factor two, add to measured.... Integrate a justified upper SSB density over only the stated extra band with the factor two, add to

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measured variance, and convert lower/upper… Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Bound a finite unmeasured offset band and report the resulting timing-RMS interval”. Using “Application 12B.4: Treat a phase-modulation line as a line, not a density bin”, specify a discriminator and the result expected under each explanation Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Bound a finite unmeasured offset band and report the resulting timing-RMS interval, including the effect of missing measurements and inconsistent operating conditions Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)
- Scholarly synthesis and implications: Explain what the result about Bound a finite unmeasured offset band and report the resulting timing-RMS interval authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)
- Closing: Conclude by answering “Bound a finite unmeasured offset band and report the resulting timing-RMS interval” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

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V011-C12-ESSAY-020. Design a multichannel delay calibration for broadband phase or TDOA inference.

- Opening: Present a thesis that answers this precise question: Design a multichannel delay calibration for broadband phase or TDOA inference. Identify which evidence would falsify the proposed conclusion Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Core terminology and scope: Define Design, multichannel, delay in the question's particular technical setting; explain how broadband, TDOA, inference differ if that distinction would change the analysis of "Design a multichannel delay calibration for broadband phase or TDOA inference" Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use a common signal through the actual analog, aperture, trigger, digital, and stored-sample paths across frequency Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a multichannel delay calibration for broadband phase or TDOA inference to the claimed result, following "Accept coherence at the required boundary and state"; name the intermediate states and measurable outputs Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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multichannel delay calibration for broadband phase or TDOA inference. Retain geometry, skew, frequency-dependent delay, missing samples, and interpolation residuals Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Reference Distribution Acceptance” that resolves the question about a multichannel delay calibration for broadband phase or TDOA inference; derive the relevant result with units and stated validity conditions Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a multichannel delay calibration for broadband phase or TDOA inference. Use swaps and cable changes to localize error, and demonstrate phase behavior after retune/restart rather than assuming shared frequency is enough Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Worked application or illustrative case: Build a worked example of “a multichannel delay calibration for broadband phase or TDOA inference”, addressing this associated condition: Use a common signal through the actual analog, aperture, trigger, digital, and stored-sample paths across.... Use a common signal through the actual analog, aperture, trigger, digital, and stored-sample paths across frequency Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a multichannel delay calibration for

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broadband phase or TDOA inference". Using "Reference Distribution Acceptance", specify a discriminator and the result expected under each explanation Source: §12.31 Reference Distribution Acceptance (p. 6994)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a multichannel delay calibration for broadband phase or TDOA inference, including the effect of missing measurements and inconsistent operating conditions Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Scholarly synthesis and implications: Explain what the result about a multichannel delay calibration for broadband phase or TDOA inference authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Closing: Conclude by answering "Design a multichannel delay calibration for broadband phase or TDOA inference" using only the demonstrated evidence; state the remaining decisive verification step Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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V011-C12-ESSAY-021. Define a coherence-time acceptance criterion for a specific operation.

- Opening: Present a thesis that answers this precise question: Define a coherence-time acceptance criterion for a specific operation. Identify which evidence would falsify the proposed conclusion Source: §12.41 Coherence under stochastic phase error (p. 7014)
- Core terminology and scope: Define Define, coherence-time, acceptance in the question's particular technical setting; explain how criterion, specific, operation differ if that distinction would change the analysis of "Define a coherence-time acceptance criterion for a specific operation" Source: §12.41 Coherence under stochastic phase error (p. 7014)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Choose the operation and allowed phase/timing or coherent-power error, identify deterministic drift and stochastic covariance contributions, and validate with a known reference Source: §12.41 Coherence under stochastic phase error (p. 7014)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Define a coherence-time acceptance criterion for a specific operation to the claimed result, following "Coherent Integration and Phase Preservation"; name the intermediate states and measurable outputs Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Define a coherence-time acceptance criterion for a specific operation. Include

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motion, propagation, source instability, and state changes where relevant Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Accept coherence at the required boundary and state” that resolves the question about Define a coherence-time acceptance criterion for a specific operation; derive the relevant result with units and stated validity conditions Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Define a coherence-time acceptance criterion for a specific operation. Report an interval under those conditions rather than one universal coherence number Source: §12.41 Coherence under stochastic phase error (p. 7014)
- Worked application or illustrative case: Build a worked example of “Define a coherence-time acceptance criterion for a specific operation”, addressing this associated condition: Choose the operation and allowed phase/timing or coherent-power error, identify deterministic drift and.... Choose the operation and allowed phase/timing or coherent-power error, identify deterministic drift and stochastic covariance contributions, and validate with a known... Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Define a coherence-time acceptance criterion for a specific operation”. Using “Accept coherence at the required boundary and state”, specify a discriminator and the result

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expected under each explanation Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Define a coherence-time acceptance criterion for a specific operation, including the effect of missing measurements and inconsistent operating conditions Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Scholarly synthesis and implications: Explain what the result about Define a coherence-time acceptance criterion for a specific operation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.41 Coherence under stochastic phase error (p. 7014)
- Closing: Conclude by answering “Define a coherence-time acceptance criterion for a specific operation” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.41 Coherence under stochastic phase error (p. 7014)

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V011-C12-ESSAY-022. Evaluate a phase-alignment algorithm that reveals a weak component only after many fitted corrections.

- Opening: Present a thesis that answers this precise question: Evaluate a phase-alignment algorithm that reveals a weak component only after many fitted corrections. Identify which evidence would falsify the proposed conclusion Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Core terminology and scope: Define algorithm, reveals, weak in the question's particular technical setting; explain how component, fitted, corrections differ if that distinction would change the analysis of "Evaluate a phase-alignment algorithm that reveals a weak component only after many fitted corrections" Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain raw timing/phase records, correction model, degrees of freedom, fitting interval, and uncertainty Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a phase-alignment algorithm that reveals a weak component only after many fitted corrections to the claimed result, following "Accept coherence at the required boundary and state"; name the intermediate states and measurable outputs Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a phase-

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alignment algorithm that reveals a weak component only after many fitted corrections. Challenge on known and held-out signals, assess overfitting and artificial coherence, and state the processing dependency Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin” that resolves the question about a phase-alignment algorithm that reveals a weak component only after many fitted corrections; derive the relevant result with units and stated validity conditions Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a phase-alignment algorithm that reveals a weak component only after many fitted corrections. Do not treat a fitted trajectory as proof of the physical mechanism that produced the original data Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Worked application or illustrative case: Build a worked example of “a phase-alignment algorithm that reveals a weak component only after many fitted corrections”, addressing this associated condition: Retain raw timing/phase records, correction model, degrees of freedom, fitting interval, and uncertainty. Retain raw timing/phase records, correction model, degrees of freedom, fitting interval, and uncertainty Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a phase-alignment algorithm that reveals a weak component only after many fitted corrections”. Using “Application 12B.4: Treat a phase-modulation line as a line, not a density bin”, specify a discriminator and the result expected under each explanation Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a phase-alignment algorithm that reveals a weak component only after many fitted corrections, including the effect of missing measurements and inconsistent operating conditions Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Scholarly synthesis and implications: Explain what the result about a phase-alignment algorithm that reveals a weak component only after many fitted corrections authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)
- Closing: Conclude by answering “Evaluate a phase-alignment algorithm that reveals a weak component only after many fitted corrections” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

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V011-C12-ESSAY-023. Construct acceptance tests for an installed reference-distribution network.

- Opening: Present a thesis that answers this precise question: Construct acceptance tests for an installed reference-distribution network. Identify which evidence would falsify the proposed conclusion Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Core terminology and scope: Define Construct, acceptance, tests in the question's particular technical setting; explain how installed, reference-distribution, network differ if that distinction would change the analysis of "Construct acceptance tests for an installed reference-distribution network" Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify outputs, termination, cabling, reference identity, frequency/phase noise, additive jitter, skew, warmup, holdover, relock, interruption, and environmental conditions Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting acceptance tests for an installed reference-distribution network to the claimed result, following "Accept coherence at the required boundary and state"; name the intermediate states and measurable outputs Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for acceptance tests for an installed reference-distribution network.

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Measure at the required boundary and log changes to affected captures Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Clock Jitter and Sampling Uncertainty” that resolves the question about acceptance tests for an installed reference-distribution network; derive the relevant result with units and stated validity conditions Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)
- Evidence and method: Specify the native observations, control records and calculations that would resolve acceptance tests for an installed reference-distribution network. Separate absolute phase claims from supported relative or magnitude quantities Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Worked application or illustrative case: Build a worked example of “acceptance tests for an installed reference-distribution network”, addressing this associated condition: Identify outputs, termination, cabling, reference identity, frequency/phase noise, additive jitter, skew,…. Identify outputs, termination, cabling, reference identity, frequency/phase noise, additive jitter, skew, warmup, holdover, relock, interruption, and environmental… Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “acceptance tests for an installed reference-distribution network”. Using “Clock Jitter and Sampling Uncertainty”, specify a discriminator and the result expected under each explanation Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to acceptance tests for an installed reference-distribution network, including the effect of missing measurements and inconsistent operating conditions Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Scholarly synthesis and implications: Explain what the result about acceptance tests for an installed reference-distribution network authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Closing: Conclude by answering “Construct acceptance tests for an installed reference-distribution network” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.31 Reference Distribution Acceptance (p. 6994)

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V011-C12-ESSAY-024. Assess the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry.

- Opening: Present a thesis that answers this precise question: Assess the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry. Identify which evidence would falsify the proposed conclusion Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Core terminology and scope: Define TDOA, case, shared in the question's particular technical setting; explain how source, impossible, geometry differ if that distinction would change the analysis of "Assess the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry" Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain how common frequency differs from deterministic trigger and sample alignment Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry to the claimed result, following "Accept coherence at the required boundary and state"; name the intermediate states and measurable outputs Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry. Use per-channel common-signal delay calibration and packet/source timing evidence to test the discrepancy Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12A.9: Form a relative channel phase from two time-error laws” that resolves the question about the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry; derive the relevant result with units and stated validity conditions Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry. Preserve original records and revised configuration, and avoid assigning the impossible location to a physical source before timing validity is established Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Worked application or illustrative case: Build a worked example of “the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry”, addressing this associated condition: Explain how common frequency differs from deterministic trigger and sample alignment. Explain how common frequency differs from deterministic trigger and sample alignment Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry”. Using “Application 12A.9: Form a relative channel phase from two time-error laws”, specify a discriminator and the result expected under each explanation Source: §12.12 Application 12A.9: Form a relative channel phase from two time-error laws (p. 6965)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry, including the effect of missing measurements and inconsistent operating conditions Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)
- Scholarly synthesis and implications: Explain what the result about the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Closing: Conclude by answering “Assess the remote-SDR TDOA case where a shared 10 MHz source coexists with impossible geometry” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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V011-C12-ESSAY-025. Write a precision-frequency finding that respects reference uncertainty and temporal scope.

- Opening: Present a thesis that answers this precise question: Write a precision-frequency finding that respects reference uncertainty and temporal scope. Identify which evidence would falsify the proposed conclusion Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Core terminology and scope: Define finding, respects, reference in the question's particular technical setting; explain how uncertainty, temporal, scope differ if that distinction would change the analysis of "Write a precision-frequency finding that respects reference uncertainty and temporal scope" Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Calculate fractional difference with units and ppm conversion, identify reference uncertainty and tolerance rule, and state observation interval and operating state Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a precision-frequency finding that respects reference uncertainty and temporal scope to the claimed result, following "The measurement chain of a distributed reference"; name the intermediate states and measurable outputs Source: §12.39 The measurement chain of a distributed reference (p. 7011)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a precision-frequency finding that respects reference uncertainty and temporal scope. Use the 120 Hz at 1 GHz example to distinguish an observed difference from a proven out-of-tolerance source Source: §12.39 The measurement chain of a distributed reference (p. 7011)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Accept coherence at the required boundary and state" that resolves the question about a precision-frequency finding that respects reference uncertainty and temporal scope; derive the relevant result with units and stated validity conditions Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a precision-frequency finding that respects reference uncertainty and temporal scope. Preserve the calibration chain and avoid extending one measurement to all conditions Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Worked application or illustrative case: Build a worked example of "a precision-frequency finding that respects reference uncertainty and temporal scope", addressing this associated condition: Calculate fractional difference with units and ppm conversion, identify reference uncertainty and tolerance.... Calculate fractional difference with units and ppm conversion, identify reference uncertainty and tolerance rule, and state observation interval... Source: §12.39 The measurement chain of a distributed reference (p. 7011)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a precision-frequency finding that respects reference uncertainty and temporal scope”. Using “Accept coherence at the required boundary and state”, specify a discriminator and the result expected under each explanation Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a precision-frequency finding that respects reference uncertainty and temporal scope, including the effect of missing measurements and inconsistent operating conditions Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Scholarly synthesis and implications: Explain what the result about a precision-frequency finding that respects reference uncertainty and temporal scope authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)
- Closing: Conclude by answering “Write a precision-frequency finding that respects reference uncertainty and temporal scope” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C12-DISCUSSION-001. A system shows the correct average frequency but channels are several samples apart. How should the discrepancy be approached?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A system shows the correct average frequency but channels are several samples apart. How should the discrepancy be approached?” Put this particular dispute to the panel: A system shows the correct average frequency but channels are several samples apart. How should the discrepancy be approached. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 02. Student A, terminology and scope: Agree the operational meanings of shows, average, frequency and channels, samples, discrepancy in “A system shows the correct average frequency but channels are several samples apart. How should the discrepancy be approached”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A system shows the correct average frequency but channels are several samples apart; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation”. Use common-signal calibration at the actual stored-sample boundary Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A system shows the correct average frequency but channels are several samples apart; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation”. Use common-signal calibration at the actual stored-sample boundary Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate epoch, aperture, trigger, distribution, and processing delays from frequency offset Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A system shows the correct average frequency but channels are several samples apart: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A system shows the correct average frequency but channels are several samples apart; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A system shows the correct average frequency but channels are several samples apart: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A system shows the correct average frequency but channels are several samples apart, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A system shows the correct average frequency but channels are

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several samples apart: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A system shows the correct average frequency but channels are several samples apart. Equal frequency is useful evidence but cannot establish alignment by itself Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A system shows the correct average frequency but channels are several samples apart, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A system shows the correct average frequency but channels are several samples apart. Equal frequency is useful evidence but cannot establish alignment by itself Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A system shows the correct average frequency but channels are several samples apart and How should the discrepancy be approached; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.4 Application 12A.1: Accumulate a constant fractional frequency offset (p. 6957)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A system shows the correct average frequency but channels are several samples apart”, addressing “How should the discrepancy be approached”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A system shows the correct average frequency but channels are several samples apart. How should the discrepancy be approached”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A system shows the correct average frequency but channels are several samples apart. How should the discrepancy be approached”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

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V011-C12-DISCUSSION-002. Two wrapped tone phases are reported with many decimal places and one claimed delay. What should a reviewer request?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two wrapped tone phases are reported with many decimal places and one claimed delay. What should a reviewer request?” Put this particular dispute to the panel: Two wrapped tone phases are reported with many decimal places and one claimed delay. What should a reviewer request. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 02. Student A, terminology and scope: Agree the operational meanings of wrapped, decimal, places and claimed, reviewer, request in “Two wrapped tone phases are reported with many decimal places and one claimed delay. What should a reviewer request”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two wrapped tone phases are reported with many decimal places and one claimed delay; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12A.4: Keep physical delay and clock-error signs separate”. Precision within one branch does not select among branches Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Two wrapped tone phases are reported with many decimal places and one claimed delay; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12A.4: Keep physical delay and clock-error signs separate”. Precision within one branch does not select among branches Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask for unwrap, delay prior, additional calibrated frequencies, phase convention, and dispersion model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two wrapped tone phases are reported with many decimal places and one claimed delay: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two wrapped tone phases are reported with many decimal places and one claimed delay; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two wrapped tone phases are

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reported with many decimal places and one claimed delay: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two wrapped tone phases are reported with many decimal places and one claimed delay, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two wrapped tone phases are reported with many decimal places and one claimed delay: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two wrapped tone phases are reported with many decimal places and one claimed delay. Report unresolved ambiguity rather than manufacture a unique delay Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two wrapped tone phases are reported with many decimal places and one claimed delay, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two wrapped tone phases are reported with many decimal places and one claimed delay. Report unresolved ambiguity rather than manufacture a unique delay Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two wrapped tone phases are reported with many decimal places and one claimed delay and What should a reviewer request; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two wrapped tone phases are reported with many decimal places and one claimed delay”, addressing “What should a reviewer request”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two wrapped tone phases are reported with many decimal places and one claimed delay. What should a reviewer request”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two wrapped tone phases are reported with many decimal places and one claimed delay. What should a reviewer request”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

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V011-C12-DISCUSSION-003. A fitted drift extrapolates well on one warm laboratory interval. Should it govern holdover after power interruption?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A fitted drift extrapolates well on one warm laboratory interval. Should it govern holdover after power interruption?” Put this particular dispute to the panel: A fitted drift extrapolates well on one warm laboratory interval. Should it govern holdover after power interruption. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

- 02. Student A, terminology and scope: Agree the operational meanings of fitted, warm, laboratory and govern, holdover, interruption in “A fitted drift extrapolates well on one warm laboratory interval. Should it govern holdover after power interruption”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A fitted drift extrapolates well on one warm laboratory interval; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Reference Distribution Acceptance”. A local fit describes observations without proving future mechanism Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A fitted drift extrapolates well on one warm laboratory interval; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Reference Distribution Acceptance”. A local fit describes observations without proving future mechanism Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine the changed segment, environment, prior lock, and coefficient bounds Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A fitted drift extrapolates well on one warm

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laboratory interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A fitted drift extrapolates well on one warm laboratory interval; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A fitted drift extrapolates well on one warm laboratory interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A fitted drift extrapolates well on one warm laboratory interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A fitted drift extrapolates well on one warm laboratory interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A fitted drift extrapolates well on one warm laboratory interval. Establish new applicability or retain an explicit unresolved holdover limitation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A fitted drift extrapolates well on one warm laboratory interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A fitted drift extrapolates well on one warm laboratory interval. Establish new applicability or retain an explicit unresolved holdover limitation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A fitted drift extrapolates well on one warm laboratory interval and Should it govern holdover after power interruption; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A fitted drift extrapolates well on one warm laboratory interval”, addressing “Should it govern holdover after power interruption”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A fitted drift extrapolates well on one warm laboratory interval. Should it govern holdover after power interruption”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A fitted drift extrapolates well on one warm laboratory interval. Should it govern holdover after power interruption”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

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V011-C12-DISCUSSION-004. One team calls positive phase a delay and another calls it a clock advance. How can the disagreement be resolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One team calls positive phase a delay and another calls it a clock advance. How can the disagreement be resolved?” Put this particular dispute to the panel: One team calls positive phase a delay and another calls it a clock advance. How can the disagreement be resolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 02. Student A, terminology and scope: Agree the operational meanings of calls, positive, delay and clock, disagreement, resolved in “One team calls positive phase a delay and another calls it a clock advance. How can the disagreement be resolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One team calls positive phase a delay and another calls it a clock advance; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12A.6: Bound a frequency estimate from two epoch measurements”. Opposite signs can be consistent conventions, while an undocumented sign can reverse a delay inference Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One team calls positive phase

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a delay and another calls it a clock advance; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12A.6: Bound a frequency estimate from two epoch measurements”. Opposite signs can be consistent conventions, while an undocumented sign can reverse a delay inference Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Write the signal and clock conventions explicitly, identify conjugation/transfer definitions and reference direction, then compare physical quantities Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 08. Student D, answer to Student E: Design a discriminating experiment involving One team calls positive phase a delay and another calls it a clock advance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One team calls positive phase a delay and another calls it a clock advance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One team calls positive phase a delay and another calls it a clock advance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One team calls positive phase a delay and another calls it a clock advance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One team calls positive phase a delay and another calls it a clock

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advance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One team calls positive phase a delay and another calls it a clock advance. Opposite signs can be consistent conventions, while an undocumented sign can reverse a delay inference Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One team calls positive phase a delay and another calls it a clock advance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source:

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§12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One team calls positive phase a delay and another calls it a clock advance. Opposite signs can be consistent conventions, while an undocumented sign can reverse a delay inference Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One team calls positive phase a delay and another calls it a clock advance and How can the disagreement be resolved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One team calls positive phase a delay and another calls it a clock advance”, addressing “How can the disagreement be resolved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One team calls positive phase a delay and another calls it a clock advance. How can the disagreement be resolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One team calls positive phase a delay and another calls it a clock advance. How can the disagreement be resolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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V011-C12-DISCUSSION-005. Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table?” Put this particular dispute to the panel: Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 02. Student A, terminology and scope: Agree the operational meanings of deterministic, converted, deviation and just, preferred, table in “Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Controlled acceptance of a multichannel timing network”. Preserve the hard bound if no such evidence exists Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a deterministic timing bound be converted to a standard deviation just to fit a preferred

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uncertainty table; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Controlled acceptance of a multichannel timing network”. Preserve the hard bound if no such evidence exists Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require a justified distribution and dependency model for that conversion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table. Distinguish maximum-error acceptance from a probabilistic statement rather than relabeling numbers for convenience Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table. Distinguish maximum-error acceptance from a probabilistic statement rather than relabeling numbers for convenience Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table and Require a justified distribution and dependency model for that conversion; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table”, addressing “Require a justified distribution and dependency model for that conversion”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Can a deterministic timing bound be converted to a standard deviation just to fit a preferred uncertainty table”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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V011-C12-DISCUSSION-006. An initial calibration bound already exceeds the required phase tolerance. What useful options remain?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An initial calibration bound already exceeds the required phase tolerance. What useful options remain?” Put this particular dispute to the panel: An initial calibration bound already exceeds the required phase tolerance. What useful options remain. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 02. Student A, terminology and scope: Agree the operational meanings of initial, bound, exceeds and tolerance, options, remain in “An initial calibration bound already exceeds the required phase tolerance. What useful options remain”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An initial calibration bound already exceeds the required phase tolerance; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. A shorter recalibration interval cannot solve an initial violation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An initial calibration bound

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already exceeds the required phase tolerance; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. A shorter recalibration interval cannot solve an initial violation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Improve the initial measurement/path, change justified operating conditions, or narrow the intended claim Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An initial calibration bound already exceeds the required phase tolerance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An initial calibration bound already exceeds the required phase tolerance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An initial calibration bound already exceeds the required phase tolerance: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An initial calibration bound already exceeds the required phase tolerance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An initial calibration bound already exceeds the required phase tolerance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An initial calibration bound already exceeds the required phase tolerance. Explain the conditional requirement without inventing a universal schedule Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An initial calibration bound already exceeds the required phase tolerance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An initial calibration bound already exceeds the required phase tolerance. Explain the conditional requirement without inventing a universal schedule Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An initial calibration bound already exceeds the required phase tolerance and What useful options remain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An initial calibration bound already exceeds the required phase tolerance”, addressing “What useful options remain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An initial calibration bound already exceeds the required phase tolerance. What useful options remain”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An initial calibration bound already exceeds the required phase tolerance. What useful options remain”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

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V011-C12-DISCUSSION-007. A reset produces a large apparent frequency spike. Should it be averaged away as an outlier?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reset produces a large apparent frequency spike. Should it be averaged away as an outlier?” Put this particular dispute to the panel: A reset produces a large apparent frequency spike. Should it be averaged away as an outlier. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 02. Student A, terminology and scope: Agree the operational meanings of reset, produces, large and apparent, averaged, away in “A reset produces a large apparent frequency spike. Should it be averaged away as an outlier”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reset produces a large apparent frequency spike; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “A stochastic and deterministic state description for clocks used in coherent receiving”. The spike may be a valid finite-difference description while misleading as persistent offset Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reset produces a large

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apparent frequency spike; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “A stochastic and deterministic state description for clocks used in coherent receiving”. The spike may be a valid finite-difference description while misleading as persistent offset Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain the event, distinguish a true phase step or slew from continuous frequency behavior, and segment the analysis Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A reset produces a large apparent frequency spike: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reset produces a large apparent frequency spike; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reset produces a large apparent frequency spike: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reset produces a large apparent frequency spike, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A reset produces a large apparent frequency spike: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reset produces a large apparent frequency spike. Coherent joining needs an established cross-event relationship Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reset produces a large apparent frequency spike, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reset produces a large apparent frequency spike. Coherent joining needs an established cross-event relationship Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the

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missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reset produces a large apparent frequency spike and Should it be averaged away as an outlier; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reset produces a large apparent frequency spike”, addressing “Should it be averaged away as an outlier”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reset produces a large apparent frequency spike. Should it be averaged away as an outlier”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reset produces a large apparent frequency spike. Should it be averaged away as an outlier”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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V011-C12-DISCUSSION-008. Should two jitter specifications be ranked by their picosecond values alone?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should two jitter specifications be ranked by their picosecond values alone?” Put this particular dispute to the panel: Should two jitter specifications be ranked by their picosecond values alone. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 02. Student A, terminology and scope: Agree the operational meanings of jitter, specifications, ranked and picosecond, values, alone in “Should two jitter specifications be ranked by their picosecond values alone”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of

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whether two jitter specifications be ranked by their picosecond values alone; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.3: Keep carrier frequency in the phase-to-time conversion”. Discuss offset-dependent receiver consequences and the physical quantity held fixed Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether two jitter specifications be ranked by their picosecond values alone; explain what each record can establish State what the existing record establishes, what it does not establish, and which further

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measurement would change your opinion. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.3: Keep carrier frequency in the phase-to-time conversion”. Discuss offset-dependent receiver consequences and the physical quantity held fixed Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Align carrier, integration bands, spectral weighting, line treatment, and reference plane first Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 08. Student D, answer to Student E: Design a discriminating experiment involving whether two jitter specifications be ranked by

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their picosecond values alone: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether two jitter specifications be ranked by their picosecond values alone; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether two jitter specifications be ranked by their picosecond values alone: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether two jitter specifications be ranked by their picosecond values alone, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether two jitter specifications be ranked by their picosecond values alone: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether two jitter specifications be ranked by their picosecond values alone. Equal or smaller scalar values can describe different questions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether two jitter specifications be ranked by their picosecond values alone, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.20 Application 12B.3: Keep carrier frequency in the phase-to-time conversion (p. 6980)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether two jitter specifications be ranked by their picosecond values alone. Equal or smaller scalar values can describe different questions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether two jitter specifications be ranked by their picosecond values alone and Align carrier, integration bands, spectral weighting, line treatment, and reference plane first; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether two jitter specifications be ranked by their picosecond values alone”, addressing “Align carrier, integration bands, spectral weighting, line treatment, and reference plane first”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should two jitter specifications be ranked by their picosecond values alone”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should two jitter specifications be ranked by their picosecond values alone”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

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V011-C12-DISCUSSION-009. A measured plot ends at 20 MHz offset. May its final floor be extended indefinitely to complete a jitter total?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A measured plot ends at 20 MHz offset. May its final floor be extended indefinitely to complete a jitter total?” Put this particular dispute to the panel: A measured plot ends at 20 MHz offset. May its final floor be extended indefinitely to complete a jitter total. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 02. Student A, terminology and scope: Agree the operational meanings of plot, ends, floor and extended, indefinitely, jitter in “A measured plot ends at 20 MHz offset. May its final floor be extended indefinitely to complete a jitter total”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A measured plot ends at 20 MHz offset; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 12B: finite-band jitter and coherent signal power”. An infinite nonzero floor gives divergent variance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A measured plot ends at 20 MHz offset; explain what each record can establish State what the existing record establishes, what it does not establish, and which

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further measurement would change your opinion. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 12B: finite-band jitter and coherent signal power”. An infinite nonzero floor gives divergent variance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Keep unmeasured frequencies explicit and seek justified finite bandwidth or bounds Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A measured plot ends at 20 MHz offset: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A measured plot ends at 20 MHz offset; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A measured plot ends at 20 MHz offset: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A measured plot ends at 20 MHz offset, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A measured plot ends at 20 MHz offset: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A measured plot ends at 20 MHz offset. A conditional extrapolation must remain labeled as an assumption within its stated domain Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question

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cannot be settled by visual appearance or a single unqualified reading. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A measured plot ends at 20 MHz offset, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A measured plot ends at 20 MHz offset. A conditional extrapolation must remain labeled as an assumption within its stated domain Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A measured plot ends at 20 MHz offset and May its final floor be extended indefinitely to complete a jitter total; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A measured plot ends at 20 MHz offset”, addressing “May its final floor be extended indefinitely to complete a jitter total”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A measured plot ends at 20 MHz offset. May its final floor be extended indefinitely to complete a jitter total”, specifying the next test, responsible measurement record and limit

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of the conclusion Summarise the strongest evidence for and against the resolution of “A measured plot ends at 20 MHz offset. May its final floor be extended indefinitely to complete a jitter total”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

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V011-C12-DISCUSSION-010. A deterministic PM spur and Gaussian noise have the same RMS phase. Are their coherence effects interchangeable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A deterministic PM spur and Gaussian noise have the same RMS phase. Are their coherence effects interchangeable?” Put this particular dispute to the panel: A deterministic PM spur and Gaussian noise have the same RMS phase. Are their coherence effects interchangeable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 02. Student A, terminology and scope: Agree the operational meanings of deterministic, spur, Gaussian and coherence, effects, interchangeable in “A deterministic PM spur and Gaussian noise have the same RMS phase. Are their coherence effects interchangeable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A deterministic PM spur and Gaussian noise have the same RMS phase; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases”. RMS alone does not determine nonlinear phasor expectations Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A deterministic PM spur and Gaussian noise have the same RMS phase; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases”. RMS alone does not determine nonlinear phasor expectations Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use their actual trajectory or joint law and covariance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A deterministic PM spur and Gaussian noise have the same RMS phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A deterministic PM spur and Gaussian noise have the same RMS phase; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A deterministic PM spur and Gaussian noise have the same RMS phase: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A deterministic PM spur and Gaussian noise have the same RMS phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A deterministic PM spur and Gaussian noise have the same RMS phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A deterministic PM spur and Gaussian noise have the same RMS phase. Treat line power and continuous density separately and reject a Gaussian formula justified only by matching RMS Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A deterministic PM spur and Gaussian noise have the same RMS phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A deterministic PM spur and Gaussian noise have the same RMS phase. Treat line power and continuous density separately and reject a Gaussian formula justified only by matching RMS Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A deterministic PM spur and Gaussian noise have the same RMS phase and Are their coherence effects interchangeable; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A deterministic PM spur and Gaussian noise have the same RMS phase”, addressing “Are their coherence effects interchangeable”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A deterministic PM spur and Gaussian noise have the same RMS phase. Are their coherence effects interchangeable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A deterministic PM spur and Gaussian noise have the same RMS phase. Are their coherence effects interchangeable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

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V011-C12-DISCUSSION-011. Separate component datasheets give RMS jitter but no covariance. What should the system calculation do?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Separate component datasheets give RMS jitter but no covariance. What should the system calculation do?” Put this particular dispute to the panel: Separate component datasheets give RMS jitter but no covariance. What should the system calculation do. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 02. Student A, terminology and scope: Agree the operational meanings of Separate, component, jitter and covariance, system, calculation in “Separate component datasheets give RMS jitter but no covariance. What should the system calculation do”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Separate component datasheets give RMS jitter but no covariance; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 12B: finite-band jitter and coherent signal power”. RSS is a conditional model rather than an automatic consequence of different component names Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Separate component

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datasheets give RMS jitter but no covariance; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 12B: finite-band jitter and coherent signal power”. RSS is a conditional model rather than an automatic consequence of different component names Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Define whether the relevant quantity is a sum or difference, investigate shared sources and transfer paths, and retain uncertainty about covariance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Separate component datasheets give RMS jitter but no covariance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Separate component datasheets give RMS jitter but no covariance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Separate component datasheets give RMS jitter but no covariance: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Separate component datasheets give RMS jitter but no covariance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Separate component datasheets give RMS jitter but no covariance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Separate component datasheets give RMS jitter but no covariance. RSS is a conditional model rather than an automatic consequence of different component names Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Separate component datasheets give RMS jitter but no covariance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Separate component datasheets give RMS jitter but no covariance. RSS is a conditional model rather than an automatic consequence of different component names Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Separate component datasheets give RMS jitter but no covariance and What should the system calculation do; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Separate component datasheets give RMS jitter but no covariance”, addressing “What should the system calculation do”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Separate component datasheets give RMS jitter but no covariance. What should the system calculation do”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Separate component datasheets give RMS jitter but no covariance. What should the system calculation do”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

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V011-C12-DISCUSSION-012. A common phase rotation lowers an ensemble-averaged complex trace. Does that prove signal energy was lost inside each record?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A common phase rotation lowers an ensemble-averaged complex trace. Does that prove signal energy was lost inside each record?” Put this particular dispute to the panel: A common phase rotation lowers an ensemble-averaged complex trace. Does that prove signal energy was lost inside each record. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 02. Student A, terminology and scope: Agree the operational meanings of rotation, lowers, trace and prove, lost, inside in “A common phase rotation lowers an ensemble-averaged complex trace. Does that prove signal energy was lost inside each record”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A common phase rotation lowers an ensemble-averaged complex trace; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. Common rotation can preserve record power while losing absolute reference alignment Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A common phase rotation lowers an ensemble-averaged complex trace; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. Common rotation can preserve record power while losing absolute reference alignment Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare magnitude of the mean with mean magnitude squared and inspect relative phases Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A common phase rotation lowers an ensemble-averaged complex trace: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A common phase rotation lowers an ensemble-averaged complex trace; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A common phase rotation lowers an ensemble-averaged complex trace: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A common phase rotation lowers an ensemble-averaged complex trace, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A common phase rotation lowers an ensemble-averaged complex

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trace: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A common phase rotation lowers an ensemble-averaged complex trace. State which quantity was measured before interpreting a loss Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A common phase rotation lowers an ensemble-averaged complex trace, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A common phase rotation lowers an ensemble-averaged complex trace. State which quantity was measured before interpreting a loss Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A common phase rotation lowers an ensemble-averaged complex trace and Does that prove signal energy was lost inside each record; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A common phase rotation lowers an ensemble-averaged complex trace”, addressing “Does that prove signal energy was lost inside each record”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A common phase rotation lowers an ensemble-averaged complex trace. Does that prove signal energy was lost inside each record”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A common phase rotation lowers an ensemble-averaged complex trace. Does that prove signal energy was lost inside each record”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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V011-C12-DISCUSSION-013. The same RMS phase yields different coherent results in two models. Is that evidence of an error?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The same RMS phase yields different coherent results in two models. Is that evidence of an error?” Put this particular dispute to the panel: The same RMS phase yields different coherent results in two models. Is that evidence of an error. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 02. Student A, terminology and scope: Agree the operational meanings of phase, yields, coherent and results, models, error in “The same RMS phase yields different coherent results in two models. Is that evidence of an error”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The same RMS phase yields different coherent results in two models; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases”. The common, independent, and correlated examples intentionally differ Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The same RMS phase yields different coherent results in two models; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases”. The common, independent, and correlated examples intentionally differ Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare covariance, mean trajectories, sample count, and joint distribution Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The same RMS phase yields different coherent results in two models: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The same RMS phase yields different coherent results in two models; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The same RMS phase yields different coherent results in two models: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The same RMS phase yields different coherent results in two models, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The same RMS phase yields different coherent results in two models: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The same RMS phase yields different coherent results in two models. Require model applicability rather than force one scalar RMS to determine all outcomes Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The same RMS phase yields different coherent results in two models, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The same RMS phase yields different coherent results in two models. Require model applicability rather than force

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one scalar RMS to determine all outcomes Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The same RMS phase yields different coherent results in two models and Is that evidence of an error; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The same RMS phase yields different coherent results in two models”, addressing “Is that evidence of an error”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The same RMS phase yields different coherent results in two models. Is that evidence of an error”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The same RMS phase yields different coherent results in two models. Is that evidence of an error”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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V011-C12-DISCUSSION-014. Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance?” Put this particular dispute to the panel: Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 02. Student A, terminology and scope: Agree the operational meanings of arbitrary, table, pairwise and accepted, phase-vector, covariance in “Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation”. Individually plausible pair values may be inconsistent together Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation”. Individually plausible pair values may be inconsistent together Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check symmetry, variances, and positive-semidefinite joint feasibility, then assess empirical support Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance. Keep the exact Gaussian calculation conditional on a valid justified joint model Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance. Keep the exact Gaussian calculation conditional on a valid justified joint model Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance and Check symmetry, variances, and positive-semidefinite joint feasibility, then assess empirical support; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Can an arbitrary table of pairwise

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correlations be accepted as a phase-vector covariance", addressing "Check symmetry, variances, and positive-semidefinite joint feasibility, then assess empirical support"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Can an arbitrary table of pairwise correlations be accepted as a phase-vector covariance". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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V011-C12-DISCUSSION-015. An engineer omits the finite diagonal term because the asymptotic formula is simpler. When is that acceptable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An engineer omits the finite diagonal term because the asymptotic formula is simpler. When is that acceptable?” Put this particular dispute to the panel: An engineer omits the finite diagonal term because the asymptotic formula is simpler. When is that acceptable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 02. Student A, terminology and scope: Agree the operational meanings of omits, diagonal, asymptotic and formula, simpler, acceptable in “An engineer omits the finite diagonal term because the asymptotic formula is simpler. When is that acceptable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An engineer omits the finite diagonal term because the asymptotic formula is simpler; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases”. At small N the self term can matter substantially, and N=1 must retain unit phasor power Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An engineer omits the finite

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diagonal term because the asymptotic formula is simpler; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.38 Characterising short- and long-term stability without confusing one statistic for another (p. 7009)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.7: Compute finite-sample coherence for independent Gaussian phases”. At small N the self term can matter substantially, and N=1 must retain unit phasor power Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Quantify the finite-N difference relative to the required accuracy and label any approximation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An engineer omits the finite diagonal term because the asymptotic formula is simpler: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An engineer omits the finite diagonal term because the asymptotic formula is simpler; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.38 Characterising short- and long-term stability without confusing one statistic for another (p. 7009)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An engineer omits the finite diagonal term because the asymptotic formula is simpler: specify

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the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An engineer omits the finite diagonal term because the asymptotic formula is simpler, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An engineer omits the finite diagonal term because the asymptotic formula is simpler: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An engineer omits the finite diagonal term because the asymptotic formula is simpler. Simplicity does not justify changing an exact finite claim silently Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.38 Characterising short- and long-term stability without confusing one statistic for another (p. 7009)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An engineer omits the finite diagonal term because the asymptotic formula is simpler, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An engineer omits the finite diagonal term because the asymptotic formula is simpler. Simplicity does not justify changing an exact finite claim silently Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.38 Characterising short- and long-term stability without confusing one statistic for another (p. 7009)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An engineer omits the finite diagonal term because the asymptotic formula is simpler and When is that acceptable; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An engineer omits the finite diagonal term because the asymptotic formula is simpler”, addressing “When is that acceptable”; specify the exact measurement or evidential gap

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on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An engineer omits the finite diagonal term because the asymptotic formula is simpler. When is that acceptable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An engineer omits the finite diagonal term because the asymptotic formula is simpler. When is that acceptable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.10 Application 12A.7: Recognize a phase reset in a finite difference (p. 6963)

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V011-C12-DISCUSSION-016. Random phase noise improves but coherent integration still performs poorly. What should be investigated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Random phase noise improves but coherent integration still performs poorly. What should be investigated?” Put this particular dispute to the panel: Random phase noise improves but coherent integration still performs poorly. What should be investigated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 02. Student A, terminology and scope: Agree the operational meanings of Random, improves, integration and performs, poorly, investigated in “Random phase noise improves but coherent integration still performs poorly. What should be investigated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Random phase noise improves but coherent integration still performs poorly; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. A random-noise improvement does not remove deterministic cancellation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Random phase noise improves

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but coherent integration still performs poorly; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. A random-noise improvement does not remove deterministic cancellation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Inspect deterministic residual frequency, mean phase trajectory, motion/propagation, modulation, and source instability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Random phase noise improves but coherent integration still performs poorly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Random phase noise improves but coherent integration still performs poorly; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Random phase noise improves but coherent integration still performs poorly: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Random phase noise improves but coherent integration still performs poorly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Random phase noise improves but coherent integration still performs poorly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Random phase noise improves but coherent integration still performs poorly. Validate any correction separately from its fitted record Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Random phase noise improves but coherent integration still performs poorly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Random phase noise improves but coherent integration still performs poorly. Validate any correction separately from its fitted record Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Random phase noise improves but coherent integration still performs poorly and What should be investigated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Random phase noise improves but coherent integration still performs poorly”, addressing “What should be investigated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before

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voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Random phase noise improves but coherent integration still performs poorly. What should be investigated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Random phase noise improves but coherent integration still performs poorly. What should be investigated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

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V011-C12-DISCUSSION-017. A phase-fitting algorithm aligns every weak record almost perfectly. What evidence would prevent overclaiming?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A phase-fitting algorithm aligns every weak record almost perfectly. What evidence would prevent overclaiming?” Put this particular dispute to the panel: A phase-fitting algorithm aligns every weak record almost perfectly. What evidence would prevent overclaiming. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 02. Student A, terminology and scope: Agree the operational meanings of phase-fitting, algorithm, weak and record, perfectly, prevent in “A phase-fitting algorithm aligns every weak record almost perfectly. What evidence would prevent overclaiming”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A phase-fitting algorithm aligns every weak record almost perfectly; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. Examine whether noise was fitted or selection manufactured coherence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A phase-fitting algorithm

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aligns every weak record almost perfectly; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. Examine whether noise was fitted or selection manufactured coherence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain degrees of freedom, raw phase, fitting/held-out intervals, known-reference tests, and uncertainty Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A phase-fitting algorithm aligns every weak record almost perfectly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A phase-fitting algorithm aligns every weak record almost perfectly; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A phase-fitting algorithm aligns every weak record almost perfectly: specify the altered receiver state

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or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A phase-fitting algorithm aligns every weak record almost perfectly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A phase-fitting algorithm aligns every weak record almost perfectly: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what

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observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A phase-fitting algorithm aligns every weak record almost perfectly. Report the transformation-dependent result rather than an unsupported stable-source claim Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A phase-fitting algorithm aligns every weak record almost perfectly, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A phase-fitting algorithm aligns every weak record almost perfectly. Report the transformation-dependent result rather than an unsupported stable-source claim Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A phase-fitting algorithm aligns every weak record almost perfectly and What evidence would prevent overclaiming; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A phase-fitting algorithm aligns every weak record almost perfectly”, addressing “What evidence would prevent overclaiming”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and

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I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A phase-fitting algorithm aligns every weak record almost perfectly. What evidence would prevent overclaiming”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A phase-fitting algorithm aligns every weak record almost perfectly. What evidence would prevent overclaiming”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

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V011-C12-DISCUSSION-018. A reference connector is calibrated accurately. Does that certify timing at the saved I/Q samples?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reference connector is calibrated accurately. Does that certify timing at the saved I/Q samples?” Put this particular dispute to the panel: A reference connector is calibrated accurately. Does that certify timing at the saved I/Q samples. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 02. Student A, terminology and scope: Agree the operational meanings of connector, calibrated, certify and timing, saved, samples in “A reference connector is calibrated accurately. Does that certify timing at the saved I/Q samples”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reference connector is calibrated accurately; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. Calibrate through actual paths and states Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reference connector is calibrated accurately; explain what each record can establish State what the existing record establishes, what it does not establish, and

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which further measurement would change your opinion. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. Calibrate through actual paths and states Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Trace distribution, aperture, trigger, pipelines, packet alignment, and source-index association Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A reference connector is calibrated accurately: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reference connector is calibrated accurately; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reference connector is calibrated accurately: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reference connector is calibrated accurately, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A reference connector is calibrated accurately: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reference connector is calibrated accurately. Connector performance is one boundary result, not automatic end-to-end timing evidence Explain the relevant statistical

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or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reference connector is calibrated accurately, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reference connector is calibrated accurately. Connector performance is one boundary result, not automatic end-to-end timing evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.31 Reference Distribution Acceptance (p. 6994)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reference connector is calibrated accurately and Does that certify timing at the saved I/Q samples; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reference connector is calibrated accurately”, addressing “Does that certify timing at the saved I/Q samples”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reference connector is calibrated accurately. Does that certify timing at the saved I/Q samples”, specifying the next test, responsible measurement record and limit of the

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conclusion Summarise the strongest evidence for and against the resolution of “A reference connector is calibrated accurately. Does that certify timing at the saved I/Q samples”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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V011-C12-DISCUSSION-019. How should a receiver team decide whether it can compare phase across retunes?

- 01. Moderator, opening proposition: Introduce the exact dispute, “How should a receiver team decide whether it can compare phase across retunes?” Put this particular dispute to the panel: How should a receiver team decide whether it can compare phase across retunes. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 02. Student A, terminology and scope: Agree the operational meanings of receiver, phase, retunes and discussion, Terminology, interpretations in “How should a receiver team decide whether it can compare phase across retunes”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of how should a receiver team decide whether it can compare phase across retunes; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.44 Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands (p. 7019)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands”. If continuity is unresolved, restrict phase comparison to valid segments and use supported magnitude or timing quantities elsewhere Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.44 Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands (p. 7019)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of how should a receiver team decide whether it can compare phase across retunes; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands”. If continuity is unresolved, restrict phase comparison to valid segments and use supported magnitude or timing quantities elsewhere Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.44 Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands (p. 7019)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Test deterministic behavior with common references through the relevant retune sequence, retain resets and states, and establish any repeatable correction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 08. Student D, answer to Student E: Design a discriminating experiment involving how should a receiver team decide whether it can compare phase across retunes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of how should a receiver team decide whether it can compare phase across retunes; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.31 Reference Distribution Acceptance (p. 6994)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving how should a receiver team decide whether it can compare phase across retunes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving how should a receiver team decide whether it can compare phase across retunes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.44 Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands (p. 7019)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving how should a receiver team decide whether it can compare phase

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across retunes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for how should a receiver team decide whether it can compare phase across retunes. If continuity is unresolved, restrict phase comparison to valid segments and use supported magnitude or timing quantities elsewhere Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving how should a receiver team decide whether it can compare phase across retunes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §12.44 Clock discipline, common references and why coherent SDR channels require more than simultaneous start commands (p. 7019)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for how should a receiver team decide whether it can compare phase across retunes. If continuity is unresolved, restrict phase comparison to valid segments and use supported magnitude or timing quantities elsewhere Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about how should a receiver team decide whether it can compare phase across retunes and Test deterministic behavior with common references through the relevant retune sequence, retain resets and…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “how should a receiver team decide whether it can compare phase across retunes”, addressing “Test deterministic behavior with common references through the relevant retune sequence, retain resets and…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “How should a receiver team decide whether it can compare phase across retunes”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “How should a receiver team decide whether it can compare phase across retunes”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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V011-C12-DISCUSSION-020. One constant delay correction fixes a narrowband test but not broadband data. What should be done?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One constant delay correction fixes a narrowband test but not broadband data. What should be done?” Put this particular dispute to the panel: One constant delay correction fixes a narrowband test but not broadband data. What should be done. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 02. Student A, terminology and scope: Agree the operational meanings of constant, delay, fixes and narrowband, broadband, data in “One constant delay correction fixes a narrowband test but not broadband data. What should be done”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One constant delay correction fixes a narrowband test but not broadband data; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. Use the required band and state, retain residuals, and avoid forcing a single offset through inconsistent points Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One constant delay correction

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fixes a narrowband test but not broadband data; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. Use the required band and state, retain residuals, and avoid forcing a single offset through inconsistent points Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Measure frequency-dependent response and distinguish dispersion from an epoch shift Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving One constant delay correction fixes a narrowband test but not broadband data: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One constant delay correction fixes a narrowband test but not broadband data; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One constant delay correction fixes a narrowband test but not broadband data: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One constant delay correction fixes a narrowband test but not broadband data, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One constant delay correction fixes a narrowband test but not broadband data: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One constant delay correction fixes a narrowband test but not broadband data. Revalidate corrections outside the fitting interval Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One constant delay correction fixes a narrowband test but not broadband data, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One constant delay correction fixes a narrowband test but not broadband data. Revalidate corrections outside the fitting interval Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One constant delay correction fixes a narrowband test but not broadband data and What should be done; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.4 Application 12A.1: Accumulate a constant fractional frequency offset (p. 6957)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One constant delay correction fixes a narrowband test but not broadband data”, addressing “What should be done”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond

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to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One constant delay correction fixes a narrowband test but not broadband data. What should be done”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One constant delay correction fixes a narrowband test but not broadband data. What should be done”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.8 Application 12A.5: Use an unwrapped phase slope while declaring delay ambiguity (p. 6961)

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V011-C12-DISCUSSION-021. A shared-reference installation changes one cable. Is previous timing acceptance automatically preserved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A shared-reference installation changes one cable. Is previous timing acceptance automatically preserved?” Put this particular dispute to the panel: A shared-reference installation changes one cable. Is previous timing acceptance automatically preserved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 02. Student A, terminology and scope: Agree the operational meanings of installation, cable, previous and acceptance, automatically, preserved in “A shared-reference installation changes one cable. Is previous timing acceptance automatically preserved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A shared-reference installation changes one cable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Reference Distribution Acceptance”. Repeat appropriate common-signal and state tests Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A shared-reference installation changes one cable; explain what each record can establish State what the existing record establishes, what it does not establish, and

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which further measurement would change your opinion. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Reference Distribution Acceptance”. Repeat appropriate common-signal and state tests Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Assess delay, termination sensitivity, additive noise, and channel relationships affected by that path Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A shared-reference installation changes one cable: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A shared-reference installation changes one cable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A shared-reference installation changes one cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A shared-reference installation changes one cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A shared-reference installation changes one cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A shared-reference installation changes one

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cable. Retain unaffected evidence only when its applicability is demonstrated Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A shared-reference installation changes one cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.31 Reference Distribution Acceptance (p. 6994)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A shared-reference installation changes one cable. Retain unaffected evidence only when its applicability is demonstrated Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits

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confidence. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A shared-reference installation changes one cable and Is previous timing acceptance automatically preserved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A shared-reference installation changes one cable”, addressing “Is previous timing acceptance automatically preserved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A shared-reference installation changes one cable. Is previous timing acceptance automatically preserved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A shared-reference installation changes one cable. Is previous timing acceptance automatically preserved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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V011-C12-DISCUSSION-022. Should coherence time be identical for beamforming, a tone sum, and timestamp correlation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Should coherence time be identical for beamforming, a tone sum, and timestamp correlation?” Put this particular dispute to the panel: Should coherence time be identical for beamforming, a tone sum, and timestamp correlation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 02. Student A, terminology and scope: Agree the operational meanings of coherence, identical, beamforming and tone, timestamp, correlation in “Should coherence time be identical for beamforming, a tone sum, and timestamp correlation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of whether coherence time be identical for beamforming, a tone sum, and timestamp correlation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Coherence under stochastic phase error”. Different deterministic and stochastic requirements can produce different valid intervals Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether coherence time be identical for beamforming, a tone sum, and timestamp correlation;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Coherence under stochastic phase error”. Different deterministic and stochastic requirements can produce different valid intervals Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Define each operation's error criterion and relevant boundary first Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving whether coherence time be identical for beamforming, a tone sum, and timestamp correlation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of whether coherence time be identical for beamforming, a tone sum, and timestamp correlation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving whether coherence time be identical for beamforming, a tone sum, and timestamp correlation: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving whether coherence time be identical for beamforming, a tone sum, and timestamp correlation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving whether coherence time be identical for beamforming, a tone sum, and timestamp correlation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for whether coherence time be identical for beamforming, a tone sum, and timestamp correlation. A single universal number conceals those distinctions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving whether coherence time be identical for beamforming, a tone sum, and timestamp correlation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.41 Coherence under stochastic phase error (p. 7014)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for whether coherence time be identical for beamforming, a tone sum, and timestamp correlation. A single universal number conceals those distinctions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about whether coherence time be identical for beamforming, a tone sum, and timestamp correlation and Define each operation's error criterion and relevant boundary first; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “whether coherence time be identical for beamforming, a tone sum, and timestamp correlation”, addressing “Define each operation's error criterion and relevant boundary first”;

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specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Should coherence time be identical for beamforming, a tone sum, and timestamp correlation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Should coherence time be identical for beamforming, a tone sum, and timestamp correlation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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V011-C12-DISCUSSION-023. An impossible TDOA location disappears after deterministic trigger calibration. How should the original finding be described?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An impossible TDOA location disappears after deterministic trigger calibration. How should the original finding be described?” Put this particular dispute to the panel: An impossible TDOA location disappears after deterministic trigger calibration. How should the original finding be described. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 02. Student A, terminology and scope: Agree the operational meanings of impossible, TDOA, location and disappears, finding, described in “An impossible TDOA location disappears after deterministic trigger calibration. How should the original finding be described”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An impossible TDOA location disappears after deterministic trigger calibration; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. The shared clock did not alone synchronize sampling Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An impossible TDOA location

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disappears after deterministic trigger calibration; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. The shared clock did not alone synchronize sampling Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Explain the prior alignment defect and the calibrated successor result while preserving evidence and configuration Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An impossible TDOA location disappears after deterministic trigger calibration: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An impossible TDOA location disappears after deterministic trigger calibration; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An impossible TDOA location disappears after deterministic trigger calibration: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An impossible TDOA location disappears after deterministic trigger calibration, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An impossible TDOA location disappears after deterministic trigger calibration: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An impossible TDOA location disappears after deterministic trigger calibration. Avoid attributing the original impossible geometry to a physical source without valid timing Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An impossible TDOA location disappears after deterministic trigger calibration, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An impossible TDOA location disappears after deterministic trigger calibration. Avoid attributing the original

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impossible geometry to a physical source without valid timing Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An impossible TDOA location disappears after deterministic trigger calibration and How should the original finding be described; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An impossible TDOA location disappears after deterministic trigger calibration”, addressing “How should the original finding be described”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An impossible TDOA location disappears after deterministic trigger calibration. How should the original finding be described”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An impossible TDOA location disappears after deterministic trigger calibration. How should the original finding be described”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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V011-C12-DISCUSSION-024. A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. What should a report claim?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. What should a report claim?” Put this particular dispute to the panel: A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. What should a report claim. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

- 02. Student A, terminology and scope: Agree the operational meanings of observed, difference, smaller and stated, report, claim in “A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. What should a report claim”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.39 The measurement chain of a distributed reference (p. 7011)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “The measurement chain of a distributed reference”. Do not declare the source out of tolerance from the difference alone Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.39 The measurement chain of a distributed reference (p. 7011)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm

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uncertainty; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “The measurement chain of a distributed reference”. Do not declare the source out of tolerance from the difference alone Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.39 The measurement chain of a distributed reference (p. 7011)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the observed difference, reference uncertainty, interval, and decision rule Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a

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repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.39 The measurement chain of a distributed reference (p. 7011)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. Additional reference evidence or a better measurement may resolve the required comparison Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.39 The measurement chain of a distributed reference (p. 7011)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. Additional reference evidence or a better measurement may resolve the required comparison Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.35 Clock holdover, phase-reference lineage and covariance-aware receiver synchronisation (p. 6999)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty and What should a report claim; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.13 Application 12A.10: Choose a calibration interval from deterministic error bounds (p. 6966)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty”, addressing “What should a report claim”; specify the exact

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measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. What should a report claim”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A 0.12 ppm observed frequency difference is smaller than the reference's stated 0.2 ppm uncertainty. What should a report claim”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.15 Clock Jitter and Sampling Uncertainty (p. 6969)

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V011-C12-DISCUSSION-025. What should a reviewer be able to reconstruct from a timing and coherence package?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should a reviewer be able to reconstruct from a timing and coherence package?” Put this particular dispute to the panel: What should a reviewer be able to reconstruct from a timing and coherence package. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, able, reconstruct and timing, coherence, package in “What should a reviewer be able to reconstruct from a timing and coherence package”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should a reviewer be able to reconstruct from a timing and coherence package; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Coherence under stochastic phase error”. Each precision claim should remain tied to its operation and error criterion Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a reviewer be able to reconstruct from a timing and coherence package; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Coherence under stochastic phase error”. Each precision claim should remain tied to its operation and error criterion Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. the specific operating conditions identified in the accompanying guidance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should a reviewer be able to reconstruct from a timing and coherence package: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should a reviewer be able to reconstruct from a timing and coherence package; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should a reviewer be able to reconstruct from a timing and coherence package: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should a reviewer be able to reconstruct from a timing and coherence package, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should a reviewer be able to reconstruct from a timing and coherence package: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should a reviewer be able to reconstruct from a timing and coherence package. Each precision claim should remain tied to its operation and error criterion Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should a reviewer be able to reconstruct from a timing and coherence package, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should a reviewer be able to reconstruct from a timing and coherence package. Each precision claim should

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remain tied to its operation and error criterion Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should a reviewer be able to reconstruct from a timing and coherence package and the specific operating conditions identified in the accompanying guidance; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.5 Application 12A.2: Integrate a linear fractional-frequency drift (p. 6958)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should a reviewer be able to reconstruct from a timing and coherence package”, addressing “the specific operating conditions identified in the accompanying guidance”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should a reviewer be able to reconstruct from a timing and coherence package”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should a reviewer be able to reconstruct from a timing and coherence package”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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Chapter 12 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C12-ESSAY-001 — Define positive time error as advance, differentiate to obtain fractional frequency, and multiply by the positive nominal carrier for phase. Integrate a constant offset and local linear drift with separate initial epoch. State units and interval boundaries, and explain why correct frequency need not imply aligned sample epochs.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-ESSAY-002 — Write the negative transfer exponential and derive delay from unwrapped frequency slope. Contrast positive clock-error phase, account for wrapping, and show how a nonzero delay can appear aligned at a selected frequency. Require calibrated path state and treat dispersion separately from constant delay.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-ESSAY-003 — Derive the ambiguity period from tone spacing and identify compatible branches. Explain the 2 ns versus 52 ns example and why added numerical precision cannot select one. State what a prior, extra calibrated frequencies, or established unwrap contributes and retain any constant-phase/dispersion assumptions.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-ESSAY-004 — Define the ideal-time separation and difference of epoch errors, compute the central ratio, and use the sum of freely signed endpoint bounds for the maximum departure. Distinguish shared calibration dependencies and statistical covariance from rectangular hard bounds. State that the estimate does not reveal all within-interval behavior.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-ESSAY-005 — Separate continuous slope and reset contribution, evaluate the 90-degree/10-microsecond case, and distinguish an ideal jump from a resolved real slew. Preserve the event and segment phases. Do not fit one drift law or coherently join segments without a measured relationship.

Review: Chapter 12 — Worked applications with hypothetical inputs.

V011-C12-ESSAY-006 — Count actual sample intervals and endpoint samples, use inverse actual rate for elapsed time, and derive nominal frequency labeling for the selected alias class. Apply the 25 ppm example with clear sign. Separate clock correction from analog alias identification and preserve source-index and anchor definitions.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-ESSAY-007 — Subtract epoch and frequency/drift terms before multiplying by the carrier. Use the chapter's 180 ns/10 MHz example, distinguish wrapped and unwrapped phase, and identify common terms that cancel. Require calibration through actual paths and new applicability review after reset, missing samples, or configuration change.

Review: Chapter 12 — Worked applications with hypothetical inputs.

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V011-C12-ESSAY-008 — Construct the monotone accumulated-error envelope, convert phase tolerance to time tolerance, and solve the positive-root or zero-drift case. Address initial bound above/equal/below tolerance and zero growth. State the environmental and state assumptions and avoid presenting the computed interval as a universal schedule.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-ESSAY-009 — Use traceable references at several points and relevant gain/tuning states, retain reference uncertainty, lock/holdover, temperature, aging, and conversion settings. Explain why one tone or a numerically exact command cannot characterize all errors. Tie the result to the intended observation interval and installed chain.

Review: Chapter 12 — Frequency Reference and Tuning Accuracy.

V011-C12-ESSAY-010 — State the real-phase side convention, positive offset set, linear density conversion, factor two, variance integration, square root, and carrier division. Treat disjoint bands and discrete lines separately. Preserve unmeasured offsets and avoid extending local laws beyond an integrable justified domain.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

V011-C12-ESSAY-011 — Identify which phase or timing quantity is held fixed, align offset limits, weighting, line handling, and reference planes, and show the inverse carrier conversion. Explain why a scalar RMS can conceal noise location and cannot rank oscillators or predict close-in receiver performance without the definitions.

Review: Chapter 12 — Application 12B.3: Keep carrier frequency in the phase-to-time conversion.

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V011-C12-ESSAY-012 — Use the even spectrum's cosine transform, then expand the variance of a phase difference. Identify the one-minus-cosine weighting and demonstrate why equal integrated variance need not imply equal increments. State second-order stationarity and finite-variance conditions without introducing unnecessary Gaussian assumptions.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

V011-C12-ESSAY-013 — Retain covariance and its sign, calculate the 2 ps/3 ps cases, and explain the zero-covariance RSS condition. Discuss a common reference's possible cancellation in a difference and its reinforcement in a sum. Require evidence for the relevant transfer and correlation rather than infer independence from component names.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

V011-C12-ESSAY-014 — State joint Gaussian mean/covariance, form each difference variance, apply the Gaussian characteristic function, and retain deterministic mean differences. Expand the normalized squared sum including diagonal terms and conjugate pairs. Require a positive-semidefinite covariance matrix and distinguish this signal-power result from a complete SNR calculation.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-ESSAY-015 — Compare within-record phasor alignment, ensemble-mean phasor, and mean record power. Use the eight-sample 0.4-radian cases to show unit common-phase power versus the finite independent result. Explain why marginal RMS alone cannot choose the appropriate covariance model or establish absolute phase.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

V011-C12-ESSAY-016 — Define the valid covariance and lag increment variance, substitute the finite multiplicities into the pair sum, and compare the stated correlated and independent outcomes. Distinguish a stipulated teaching covariance from an estimated physical one and preserve evidence for joint Gaussianity if the exact exponential result is claimed.

Review: Chapter 12 — Application 12B.8: Use a specified correlated Gaussian phase vector.

V011-C12-ESSAY-017 — Keep the deterministic finite phasor sum and random diagonal contribution separate. State actual sample times and endpoint span, evaluate special-frequency limits correctly, and explain why reducing random phase noise does not remove deterministic cancellation. Assess separately a correction estimated from the same weak data.

Review: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

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V011-C12-ESSAY-018 — Use complete-period sinusoidal phase variance and the small-modulation sideband convention, state line power and any bandwidth representation, and retain the deterministic trajectory for coherence. Explain why RMS equivalence does not establish a Gaussian process or resolution-independent density.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

V011-C12-ESSAY-019 — Integrate a justified upper SSB density over only the stated extra band with the factor two, add to measured variance, and convert lower/upper totals through square root and carrier. Identify excluded offsets and physical bandwidth assumptions. Do not describe extrapolated floors as measurements or extend a nonzero density to infinity.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

V011-C12-ESSAY-020 — Use a common signal through the actual analog, aperture, trigger, digital, and stored-sample paths across frequency. Retain geometry, skew, frequency-dependent delay, missing samples, and interpolation residuals. Use swaps and cable changes to localize error, and demonstrate phase behavior after retune/restart rather than assuming shared frequency is enough.

Review: Chapter 12 — Multichannel Synchronization and Delay Calibration.

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V011-C12-ESSAY-021 — Choose the operation and allowed phase/timing or coherent-power error, identify deterministic drift and stochastic covariance contributions, and validate with a known reference. Include motion, propagation, source instability, and state changes where relevant. Report an interval under those conditions rather than one universal coherence number.

Review: Chapter 12 — Accept coherence at the required boundary and state.

V011-C12-ESSAY-022 — Retain raw timing/phase records, correction model, degrees of freedom, fitting interval, and uncertainty. Challenge on known and held-out signals, assess overfitting and artificial coherence, and state the processing dependency. Do not treat a fitted trajectory as proof of the physical mechanism that produced the original data.

Review: Chapter 12 — Coherent Integration and Phase Preservation.

V011-C12-ESSAY-023 — Identify outputs, termination, cabling, reference identity, frequency/phase noise, additive jitter, skew, warmup, holdover, relock, interruption, and environmental conditions. Measure at the required boundary and log changes to affected captures. Separate absolute phase claims from supported relative or magnitude quantities.

Review: Chapter 12 — Reference Distribution Acceptance.

V011-C12-ESSAY-024 — Explain how common frequency differs from deterministic trigger and sample alignment. Use per-channel common-signal delay calibration and packet/source timing evidence to test the discrepancy. Preserve original records and revised configuration, and avoid assigning the impossible location to a physical source before timing validity is established.

Review: Chapter 12 — Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

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V011-C12-ESSAY-025 — Calculate fractional difference with units and ppm conversion, identify reference uncertainty and tolerance rule, and state observation interval and operating state. Use the 120 Hz at 1 GHz example to distinguish an observed difference from a proven out-of-tolerance source. Preserve the calibration chain and avoid extending one measurement to all conditions.

Review: Chapter 12 — Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

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Discussion Guidance

V011-C12-DISCUSSION-001 — Separate epoch, aperture, trigger, distribution, and processing delays from frequency offset. Use common-signal calibration at the actual stored-sample boundary. Equal frequency is useful evidence but cannot establish alignment by itself.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-DISCUSSION-002 — Ask for unwrap, delay prior, additional calibrated frequencies, phase convention, and dispersion model. Precision within one branch does not select among branches. Report unresolved ambiguity rather than manufacture a unique delay.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-DISCUSSION-003 — Examine the changed segment, environment, prior lock, and coefficient bounds. A local fit describes observations without proving future mechanism. Establish new applicability or retain an explicit unresolved holdover limitation.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-DISCUSSION-004 — Write the signal and clock conventions explicitly, identify conjugation/transfer definitions and reference direction, then compare physical quantities. Opposite signs can be consistent conventions, while an undocumented sign can reverse a delay inference.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-C12-DISCUSSION-005 — Require a justified distribution and dependency model for that conversion. Preserve the hard bound if no such evidence exists. Distinguish maximum-error acceptance from a probabilistic statement rather than relabeling numbers for convenience.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-DISCUSSION-006 — Improve the initial measurement/path, change justified operating conditions, or narrow the intended claim. A shorter recalibration interval cannot solve an initial violation. Explain the conditional requirement without inventing a universal schedule.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-C12-DISCUSSION-007 — Retain the event, distinguish a true phase step or slew from continuous frequency behavior, and segment the analysis. The spike may be a valid finite-difference description while misleading as persistent offset. Coherent joining needs an established cross-event relationship.

Review: Chapter 12 — Worked applications with hypothetical inputs.

V011-C12-DISCUSSION-008 — Align carrier, integration bands, spectral weighting, line treatment, and reference plane first. Discuss offset-dependent receiver consequences and the physical quantity held fixed. Equal or smaller scalar values can describe different questions.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-C12-DISCUSSION-009 — Keep unmeasured frequencies explicit and seek justified finite bandwidth or bounds. An infinite nonzero floor gives divergent variance. A conditional extrapolation must remain labeled as an assumption within its stated domain.

Review: Chapter 12 — Application 12B.10: Bound a finite unmeasured high-offset contribution.

V011-C12-DISCUSSION-010 — Use their actual trajectory or joint law and covariance. RMS alone does not determine nonlinear phasor expectations. Treat line power and continuous density separately and reject a Gaussian formula justified only by matching RMS.

Review: Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

V011-C12-DISCUSSION-011 — Define whether the relevant quantity is a sum or difference, investigate shared sources and transfer paths, and retain uncertainty about covariance. RSS is a conditional model rather than an automatic consequence of different component names.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

V011-C12-DISCUSSION-012 — Compare magnitude of the mean with mean magnitude squared and inspect relative phases. Common rotation can preserve record power while losing absolute reference alignment. State which quantity was measured before interpreting a loss.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power.

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V011-C12-DISCUSSION-013 — Compare covariance, mean trajectories, sample count, and joint distribution. The common, independent, and correlated examples intentionally differ. Require model applicability rather than force one scalar RMS to determine all outcomes.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

V011-C12-DISCUSSION-014 — Check symmetry, variances, and positive-semidefinite joint feasibility, then assess empirical support. Individually plausible pair values may be inconsistent together. Keep the exact Gaussian calculation conditional on a valid justified joint model.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

V011-C12-DISCUSSION-015 — Quantify the finite-N difference relative to the required accuracy and label any approximation. At small N the self term can matter substantially, and N=1 must retain unit phasor power. Simplicity does not justify changing an exact finite claim silently.

Review: Chapter 12 — Application 12B.7: Compute finite-sample coherence for independent Gaussian phases.

V011-C12-DISCUSSION-016 — Inspect deterministic residual frequency, mean phase trajectory, motion/propagation, modulation, and source instability. A random-noise improvement does not remove deterministic cancellation. Validate any correction separately from its fitted record.

Review: Chapter 12 — Application 12B.9: Combine deterministic rotation with independent phase errors.

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V011-C12-DISCUSSION-017 — Retain degrees of freedom, raw phase, fitting/held-out intervals, known-reference tests, and uncertainty. Examine whether noise was fitted or selection manufactured coherence. Report the transformation-dependent result rather than an unsupported stable-source claim.

Review: Chapter 12 — Coherent Integration and Phase Preservation.

V011-C12-DISCUSSION-018 — Trace distribution, aperture, trigger, pipelines, packet alignment, and source-index association. Calibrate through actual paths and states. Connector performance is one boundary result, not automatic end-to-end timing evidence.

Review: Chapter 12 — Accept coherence at the required boundary and state.

V011-C12-DISCUSSION-019 — Test deterministic behavior with common references through the relevant retune sequence, retain resets and states, and establish any repeatable correction. If continuity is unresolved, restrict phase comparison to valid segments and use supported magnitude or timing quantities elsewhere.

Review: Chapter 12 — Reference Distribution Acceptance.

V011-C12-DISCUSSION-020 — Measure frequency-dependent response and distinguish dispersion from an epoch shift. Use the required band and state, retain residuals, and avoid forcing a single offset through inconsistent points. Revalidate corrections outside the fitting interval.

Review: Chapter 12 — Multichannel Synchronization and Delay Calibration.

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V011-C12-DISCUSSION-021 — Assess delay, termination sensitivity, additive noise, and channel relationships affected by that path. Repeat appropriate common-signal and state tests. Retain unaffected evidence only when its applicability is demonstrated.

Review: Chapter 12 — Reference Distribution Acceptance.

V011-C12-DISCUSSION-022 — Define each operation's error criterion and relevant boundary first. Different deterministic and stochastic requirements can produce different valid intervals. A single universal number conceals those distinctions.

Review: Chapter 12 — Accept coherence at the required boundary and state.

V011-C12-DISCUSSION-023 — Explain the prior alignment defect and the calibrated successor result while preserving evidence and configuration. The shared clock did not alone synchronize sampling. Avoid attributing the original impossible geometry to a physical source without valid timing.

Review: Chapter 12 — Hypothetical Case Adjudication: Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

V011-C12-DISCUSSION-024 — State the observed difference, reference uncertainty, interval, and decision rule. Do not declare the source out of tolerance from the difference alone. Additional reference evidence or a better measurement may resolve the required comparison.

Review: Chapter 12 — Quantitative Model for Frequency Accuracy, Phase Noise, Clocks, Coherence, and Multichannel Timing.

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V011-C12-DISCUSSION-025 — The defined time/phase convention, actual rates and sample intervals, reference identity/state, calibration paths, raw records, corrections, integration bands, covariance/distribution assumptions, resets, and valid segments. Each precision claim should remain tied to its operation and error criterion.

Review: Chapter 12 — Accept coherence at the required boundary and state.

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Chapter Glossary

APERTURE DELAY: The timing displacement associated with when a converter actually samples its input relative to the declared timing reference. Unequal channel apertures contribute to relative timing alongside analog paths and digital processing. A calibration of a convenient clock connector does not automatically measure this acquisition-boundary contribution.

BAND-LIMITED PHASE VARIANCE: The phase variance contributed by a stated finite set of offset bands and line measures under an explicit spectral normalization.

CALIBRATION ERROR ENVELOPE: A justified deterministic bound on accumulated time or phase error over a declared interval after calibration.

CALIBRATION INTERVAL: The elapsed interval over which a declared error criterion remains satisfied under justified initial-error, frequency-error and drift bounds. Model 12A compares their accumulated envelope with a carrier-dependent phase tolerance. The admissible interval can be zero, finite or unrestricted within the assumed model; a schedule alone does not establish those bounds.

CHANNEL-SWAP TEST: A controlled interchange of channels or paths used to test whether an observed timing or phase residual follows the electronics, the path or the measurement geometry. Its interpretation requires preserving the other relevant conditions and recording the swap. It supports localization without making one successful comparison a universal calibration.

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CHARACTERISTIC FUNCTION: The expected complex exponential of a real random quantity at a specified argument. Model 12B evaluates it for a Gaussian phase difference to obtain a mean-phase factor and a variance-dependent attenuation factor. Applying that identity to a non-Gaussian difference requires its actual distribution, not merely a matching variance.

CLOCK TIME ERROR: The difference between a clock's reading and ideal reference time, positive for an advanced clock in the adopted convention.

COHERENCE TIME: Interval over which relative phase remains sufficiently stable for a specified coherent operation.

COHERENT PHASOR SUM: A complex sum that preserves the relative phases of its declared contributions. Its squared magnitude contains self and cross terms, so common rotation and relative rotation have different consequences. The chapter's normalized signal-power result does not by itself include additive noise, amplitude variation or uncertainty introduced by estimated phase corrections.

COMMON PHASE ROTATION: A phase contribution shared by every sample in a record, which can alter ensemble complex phase without causing relative cancellation within that record.

COVARIANCE MATRIX VALIDITY: The requirement that a proposed covariance matrix describe a possible joint random vector, including symmetry and positive semidefiniteness. Individually plausible pairwise correlations do not guarantee that the complete matrix meets this condition. Model 12B uses a specified valid geometric lag structure before evaluating the coherent-power sum.

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DETERMINISTIC PHASE ROTATION: A specified progression of mean phase across the actual sample times, such as that produced by a frequency offset. Model 12B keeps its finite phasor sum separate from independent random phase errors. Special frequencies are evaluated by the finite sum instead of an indeterminate trigonometric quotient.

ENDPOINT TIME COMPARISON: An estimate of average fractional-frequency error obtained from two time-error observations divided by their reference-time separation. Deterministic endpoint-error limits propagate as a bound on that average. They do not become standard deviations without an additional statistical model, and the interval must not conceal an unmodeled reset.

EPOCH OFFSET: The time-reading error at a declared reference instant. It is the initial condition in Model 12A and is distinct from subsequent fractional-frequency error or drift. Correct average frequency does not remove an existing epoch offset, while a correct initial epoch does not prevent later accumulated error.

FINITE-SAMPLE SELF TERM: The diagonal contribution obtained when the squared magnitude of a finite coherent phasor sum is expanded. Each unit-magnitude phasor contributes its own power before cross terms are considered. This produces the finite-count contribution in Model 12B and prevents replacing expected coherent power by the squared ensemble-mean phasor.

FRACTIONAL FREQUENCY ERROR: Frequency difference normalized to a reference frequency.

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FREQUENCY DRIFT: A change of fractional frequency with elapsed time under a declared local model. A constant drift coefficient gives a quadratic contribution to accumulated time error. Its fitted value and validity interval must remain explicit; the same law need not survive warmup, reference loss, restart or environmental change.

FREQUENCY SYNCHRONIZATION: Agreement of specified frequency rates or their controlled relationship over a declared interval. It can coexist with unknown epoch, trigger or channel-phase offsets. Sharing a reference oscillator therefore does not establish the sample alignment or deterministic phase relationship required for every multichannel inference.

HOLDOVER: Operation of a disciplined clock after loss of its external reference using its internal oscillator and stored model.

JOINT GAUSSIAN PHASE MODEL: An explicit distributional model in which every linear combination of the finite phase vector is normally distributed, allowing degenerate cases. The declared mean and covariance then determine the characteristic function used in Model 12B. Stationarity, marginal RMS values or a measured power spectrum alone do not establish this additional assumption.

MEAN COHERENT SIGNAL POWER: The expectation of the squared magnitude of a declared coherent signal sum, distinct from the squared ensemble-mean phasor and from a complete SNR calculation.

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NONDISPERSIVE DELAY: A delay that is constant over the frequency region used in the model, producing a linear unwrapped transfer-phase dependence on frequency. A slope estimate can identify it within the selected branch. Phase curvature from filters or other path behavior means that one constant delay may be inadequate for broadband correction.

OFFSET INTEGRATION BAND: The specified set of positive frequency offsets included in a phase-noise variance calculation. Its limits and any separately included lines form part of the result. Noise outside the set is not measured by the resulting RMS value, and extrapolating a displayed floor requires an additional justified assumption or bound.

OUT-OF-FIT VALIDATION: Evaluation of a fitted timing, phase or delay correction on observations not used to select that correction. It helps reveal overfitting and retained instability that an apparently aligned fitting record can conceal. The original records and correction method remain available so that processing-dependent conclusions can be examined.

PHASE COVARIANCE: The second-order relationship between phase deviations at two specified times or sample positions. Together with the marginal variances, it determines the variance of their difference. Equal marginal RMS values can therefore produce different coherent behavior when the covariance differs; the required relationship cannot be inferred from a scalar jitter number alone.

PHASE-INCREMENT VARIANCE: The variance of the difference between two phase samples, determined by their individual variances and covariance.

PHASE NOISE: Random phase fluctuation represented as spectral density around a carrier or reference.

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PHASE RESET: A discrete change in phase associated with an identified event such as retuning, triggering or restarting. A finite difference crossing the event includes the step even if the continuous frequency behavior is unchanged on either side. Segment boundaries and any measured cross-event relationship must therefore be preserved.

REFERENCE DISTRIBUTION NETWORK: The installed paths carrying a reference to the devices and boundaries that depend on it. Distribution amplifiers, cables, terminations and state changes can add delay or noise after the primary source. Acceptance therefore identifies and tests the actual outputs rather than relying only on the source's nominal accuracy or lock indication.

RELATIVE CHANNEL PHASE: The phase relationship between specified channels at a stated frequency and observation boundary. Model 12A obtains it from the difference of their time errors. A common contribution can cancel, but unequal analog paths, apertures, resets and processing delays remain unless measured or otherwise accounted for.

RMS TIMING JITTER: The root-mean-square timing fluctuation associated with a declared phase component and positive carrier frequency. Model 12B obtains it from that component's RMS phase by the stated phase-to-time conversion. The scalar retains neither the detailed offset distribution nor a complete account of deterministic delay, trigger error or sample alignment.

SAMPLE ALIGNMENT: The established relationship between sample indices and the corresponding acquisition instants across channels. Trigger paths, aperture times, digital pipelines and missing data can affect it even when the channels share frequency. The required relationship must be verified at the stored-data boundary used by the analysis.

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SAMPLE-CLOCK SCALE ERROR: A discrepancy between the actual and nominal sample rates that changes both elapsed-time labels and the frequency scale attached to normalized discrete data. For a fixed interval count, true elapsed time depends inversely on actual rate. Correcting one displayed frequency does not by itself establish correct timestamps or continuity.

SAMPLE-INTERVAL COUNT: The number of elapsed intervals between sample endpoints; a span of N intervals contains N plus one endpoint samples.

SINGLE-SIDEBAND PHASE-NOISE DENSITY: The carrier-referred noise-density convention used for one positive offset side of the phase spectrum, expressed linearly per hertz or logarithmically in dBc/Hz. Model 12B states the small-phase convention explicitly and includes both symmetric contributions when obtaining real-phase variance. A discrete spur requires a separate line treatment.

TIMING SKEW: Relative delay between nominally simultaneous channels, triggers, or signal paths.

TRANSFER PHASE: The phase difference imposed by a specified input-to-output path at a stated frequency. With the chapter's sinusoidal convention, a positive physical delay gives negative transfer phase. This sign must not be interchanged with the positive relative phase assigned to an advanced clock in Model 12A.

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UNMEASURED SPECTRAL CONTRIBUTION: A phase-noise contribution outside the directly evaluated spectral region. Model 12B bounds a specified finite extra band only when a justified upper density limit is supplied. Without that information, extending a plot or quoting the measured-band RMS as a complete jitter value would add unsupported evidence.

UNWRAPPED PHASE: A phase trajectory represented on a declared continuous branch rather than reduced at each observation to a principal angular interval. Its slope can support frequency or delay calculations when the model applies. Choosing the branch requires evidence; numerical precision alone cannot resolve an integer-cycle ambiguity.

WRAPPED-DELAY AMBIGUITY: The family of delays compatible with specified wrapped phase observations until additional phase, frequency or prior-range information selects a branch.

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References and Works Cited

Riley, W. J. Handbook of Frequency Stability Analysis. NIST Special Publication 1065. July 2008. https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication1065.pdf.

Annotation. Printed page 5, “Definitions and Terminology,” and section 3.1, “Noise Model,” equations (1)–(4), support the stated time-error, fractional-frequency and phase conventions. The deterministic drift envelope, interval selection, sample-clock examples and multistate acceptance procedure are the chapter’s original applications under declared premises. The reference supplies a technical framework for interpreting oscillator stability or correlated phase-noise measurements. Observation interval, averaging statistic, timebase origin and common-clock correlation should be specified before translating a frequency statistic into arrival-time or phase evidence. A nominally stable source can still have an offset or transient recovery event, and averaging may suppress or distort correlated components. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

Analog Devices. MT-085, "Fundamentals of Direct Digital Synthesis (DDS)." Rev. 0, October 2008, pp. 2–3. Phase-accumulator tuning relation and truncation distinction. https://www.analog.com/media/en/training-seminars/tutorials/MT-085.pdf.

Annotation. Printed pages 2–3 explain numerical tuning relative to a clock. This bounded citation does not establish the actual accuracy,

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phase continuity or trigger behavior of an unspecified receiver or reference network. The tutorial addresses numerical phase accumulation, frequency tuning and the effects of finite word length in a digital oscillator. The tuning equation, accumulator width, truncation position and reference clock are distinct quantities and must be documented separately. A theoretically possible output frequency or spur location is not proof that a deployed receiver produces it without measurements of clock quality and implementation. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

Kester, Walt. MT-008, Converting Oscillator Phase Noise to Time Jitter. Rev. A. Analog Devices, October 2008. https://www.analog.com/media/en/training-seminars/tutorials/MT-008.pdf.

Annotation. Printed pages 3–4, especially “Converting Phase Noise to Jitter” and equations (2)–(3), support linear phase-noise integration and the carrier-dependent phase-to-time conversion. The chapter selects its own finite bands and independently develops the covariance and Gaussian-vector coherent-power results; it does not adopt illustrative integration limits as universal requirements. This source informs the distinction between deterministic sampling-time displacement and random timing uncertainty. The effect of timing uncertainty depends on input frequency, the integration limits for phase noise and correlation between parallel sampling paths. Ideal jitter-limited SNR formulae are bounds under specified models, not measured effective number of bits

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or evidence that parallel ADCs create a wider word. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions.

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Chapter 13. Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration

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13.1 Measurement Chain Ownership

A receiver measurement is only as interpretable as the components ahead of its declared input plane. Antennas convert fields to terminal quantities according to pattern, polarization, impedance, effective aperture, and installation. Cables, adapters, splitters, filters, attenuators, bias networks, preamplifiers, and switches then alter amplitude, phase, noise, mode content, and dynamic range. These elements are not accessories outside the receiver problem; they are part of the measured transfer function.[1]

Ownership is divided deliberately across the series. V010 and V093 govern antenna and probe theory, V087 governs cables and connectors, V016 governs EMC and common-mode paths, and V011 governs how those elements are integrated and corrected in the receiver chain. The local treatment is sufficient to define reference planes, gain and loss, switching state, and measurement uncertainty without duplicating the full design theory of each component.

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1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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13.2 Define a complete path at named planes

An external receiving path should be specified as an ordered assembly. Name the antenna terminal plane, the remote-amplifier input and output if present, the ends of each cable, the switching or filtering planes, and the receiver connector. This turns an informal list of accessories into a measurement model. It also determines ownership of corrections. If the antenna calibration already includes a particular adapter, that adapter must not be corrected a second time; if the receiver calibration stops at its front connector, a field cable remains outside that calibration.

Keep three related records. The assembly record identifies physical components and their order. The state record identifies switch positions, gain, attenuation, bias, temperature, and receiver configuration during an observation. The correction record identifies the measured transfers, their reference planes, frequency grids, interpolation, uncertainty, and serial applicability. A photograph can help reconstruct the assembly, but it cannot replace the state or correction record. Conversely, a list of calibration certificates cannot prove that the listed components were connected in the intended order.

The two orders in Application 2B.2 are an instructive example. Their total desired-signal gain is identical, but their input noise temperatures differ greatly. A record containing only total gain would allow an analyst to miss the difference. For the remote-amplifier order, moving the reported plane from the antenna terminal to the receiver connector also removes the amplifier and cable from the reported receiver contribution. Both results

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may be useful, provided the plane is explicit. A comparison must return them to the same physical question before declaring an improvement.

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13.3 Antennas and Field-to-Terminal Conversion

An antenna terminal voltage or power depends on incident field, polarization, direction, near- or far-field condition, impedance, loading, and surrounding structure. Antenna factor, effective height, and effective aperture provide different conversion relationships under defined assumptions. Indoors, multipath and reactive coupling can make a nominal free-space calibration an incomplete description. A field-strength result should therefore identify the antenna, geometry, calibration basis, cable, and uncertainty.

Orientation changes are an analytical control as well as a search technique. A genuine polarized field should respond consistently with antenna pattern and geometry, while common-mode cable pickup or receiver enclosure leakage may respond differently. Antenna substitution can reveal frequency-dependent calibration errors or local near-field coupling. Measurements made with unknown active antennas or built-in automatic gain should not be converted to field strength without characterization.

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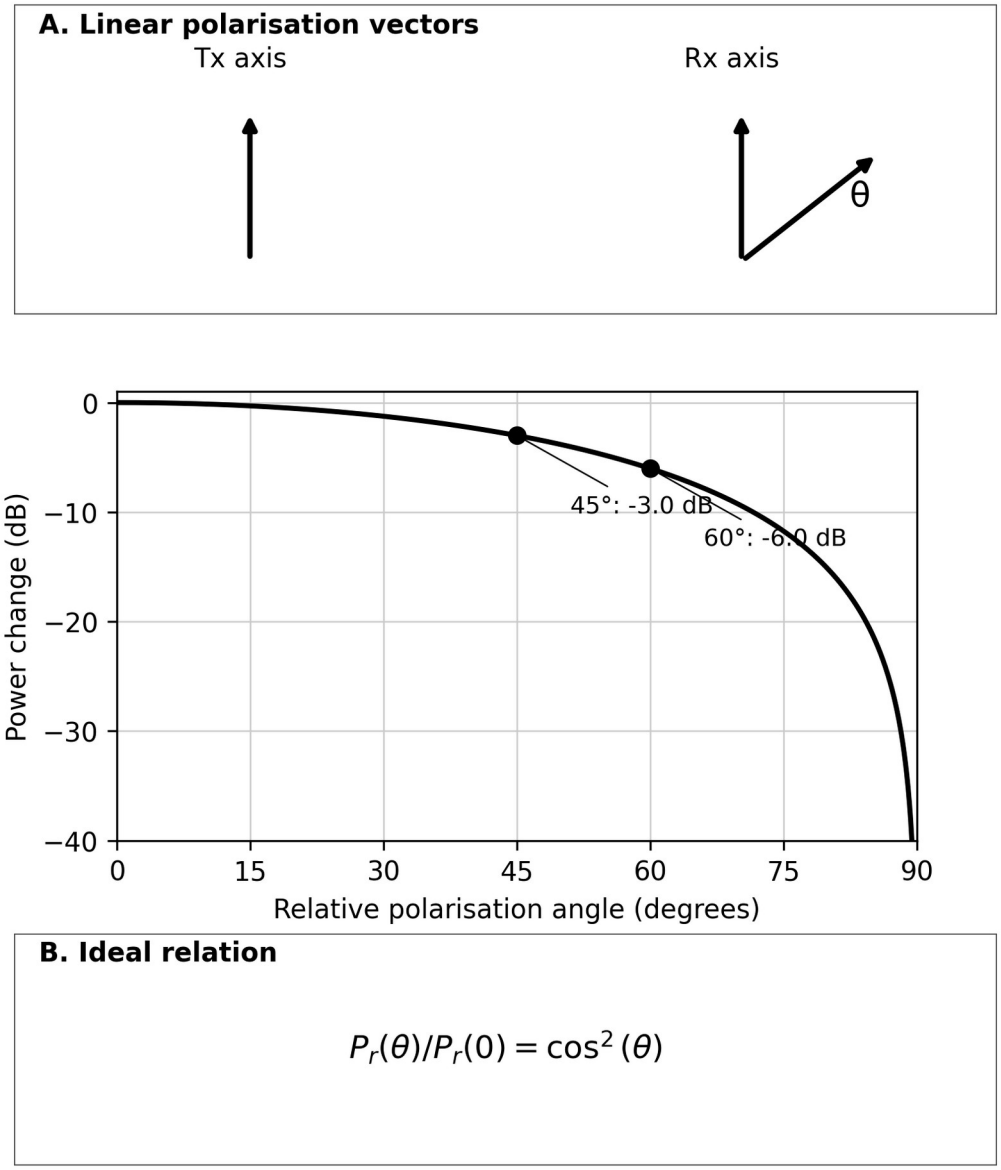

Ideal matched linear polarisations; real antenna cross-polar discrimination, multipath and orientation may prevent a perfect null.

Figure 70. Antenna polarisation mismatch.

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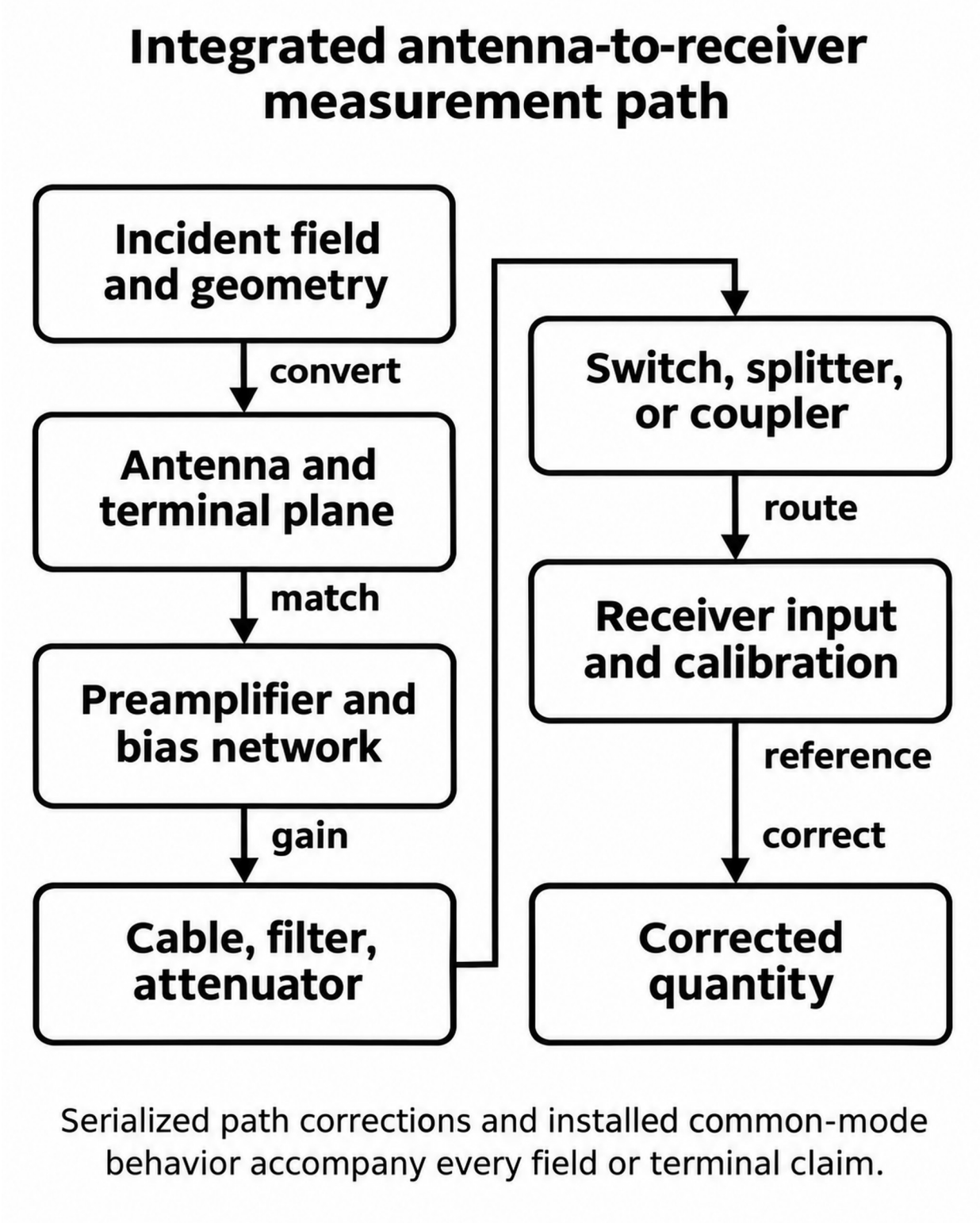

Figure 71. Integrated antenna-to-receiver measurement path.

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13.4 Keep field conversion separate from terminal power

An antenna-terminal measurement and a field estimate are different measurands. The terminal result can be supported by a calibrated conducted injection at that terminal plane. A field estimate additionally depends on the antenna response, polarization, direction, environment, and geometry. Equation 25 gives the ideal available-power relation for its stated aperture assumptions. It should not be used to convert an arbitrary near-field probe reading into a plane-wave power density. When only a comparative survey indication is supported, retain that interpretation instead of adding a field-strength unit that suggests a broader calibration.

Antenna factor is usually applied to a specified terminal voltage and load condition. A receiver that reports power requires a consistent voltage-power conversion at that impedance before the field conversion is applied. Available power, delivered power, open-circuit voltage, and loaded voltage are not interchangeable. A factor calibrated for a loaded 50-ohm voltage should not be applied directly to an open-circuit voltage estimate. Keeping the quantities and units in the correction record prevents an apparently constant offset from concealing a factor-of-two voltage error.

NPL's antenna guide distinguishes the uncertainty of an antenna calibration from additional uncertainty when the antenna is used in an emission measurement. It discusses mutual coupling, pattern, phase center, mounting, and feed-cable effects, and gives a rod-antenna example in which cable common-mode current makes layout consequential. These passages support a bounded conclusion: a certificate for the antenna does not, by itself, characterize every installed arrangement. The guide's historical EMC

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geometries and numerical examples are not adopted here as general limits for an indoor survey.[2]

For an installed comparison, hold antenna position, orientation, and nearby conductors as stable as the purpose requires. If the aim is to map spatial variation, movement is intentional and belongs in the record. If the aim is to compare two receiver states, unintended movement is a confounding variable. A small antenna rotation can change polarization coupling while an altered cable route changes the installed response. The resulting level change may be real at the receiver terminal without representing a change in the external source. Record the controlled question before interpreting the change.

2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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13.5 External Preamplifiers, Bias, and Stability

External preamplifiers are placed near the antenna to overcome cable loss and receiver noise. Their gain, noise figure, compression, intercept, reverse isolation, input protection, bias state, and stability determine whether they improve the system. Bias tees and remote power introduce conducted paths that can carry switching noise, oscillation, or common-mode current. A preamplifier can also reradiate local-oscillator leakage from the receiver through inadequate reverse isolation.

Stability tests include terminated input, output loading, supply variation, cable-length variation, temperature, strong-signal exposure, and spectrum observation over the amplifier's full response. Gain should be measured rather than assumed from a label. If the amplifier is switched or remote-controlled, its state and transition time are logged. Field recordings with different amplifier states are corrected and kept distinct.

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13.6 Remote amplification requires electrical and installed checks

A remote preamplifier can overcome the noise penalty of a long cable, as Application 2B.2 shows. Its input is also where the external spectrum first meets an active device. A narrow downstream receiver channel does not protect it from signals elsewhere in its own passband. Establish the desired and blocker transfers up to the remote input, then apply the front-end analysis of Chapter 3. If preselection is added ahead of the remote amplifier, repeat the noise calculation with its actual loss and physical temperature. The improved rejection and the increased input-equivalent noise are both consequences of the new assembly.

Bias delivery is part of the state. Record the power source, bias tee or separate feed, nominal operating conditions, and any monitoring available at the remote unit. A voltage measured at the supply does not establish the voltage at the amplifier after a resistive cable or protection element. A battery substitution can be a useful comparison, but it can change both supply noise and the conductive path to other equipment. If the observation changes, those alternatives remain until a more selective test separates them.

Stability should be checked in the configurations that the assembly can actually encounter. A remote amplifier may behave differently with an antenna, a matched termination, an open switch branch, or a long cable. A narrow unexpected line, a raised baseline, or a gain change can indicate oscillation or another instability, but those observations are not unique to it. Terminated-input and alternate-load comparisons, bias monitoring, and an

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independent observation of the amplifier output can constrain the explanation. Perform such tests within the component's documented operating conditions.

A stable bench assembly can still be a poor installed measurement system if its temperature, supply, or mechanical state drifts during use. Retain a reference before and after the observation and after consequential changes such as reconnection, relocation, or a gain-state change. If a reference fails, investigate the affected time interval rather than silently applying a single correction to all earlier records. A measured drift may support a bounded correction when its evolution is understood; an intermittent or unexplained change generally requires a more limited interpretation.

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13.7 Attenuators, Filters, Splitters, and Switches

Attenuators provide level control, impedance improvement, and linearity challenge. Filters restrict admitted energy. Splitters and couplers distribute signals while introducing loss, isolation limits, amplitude or phase imbalance, and unused-port requirements. Switches add path-dependent loss, repeatability, leakage, and switching transients. These components can enable controlled multichannel comparison, but they also create hidden differences if their paths are assumed identical.

Acceptance measurements use a network analyzer or calibrated source and receiver across the relevant frequency range and power level. High-power, pulsed, or nonlinear behavior may require separate tests. Unused ports are terminated as specified. Mechanical torque, connector condition, path labels, and temperature are controlled. A correction file is linked to the exact serialized path rather than to a generic component model.

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13.8 Treat connections and unused branches as part of the network

A switch selects a path but does not make every other path disappear. Finite isolation can admit a strong signal from an unused branch, and an unterminated branch can alter the impedance presented through the switch. A splitter likewise changes delivered power and can couple its output loads. The matched scalar cascade is appropriate only when the effective transfer and added-noise behavior of the selected assembly satisfy its assumptions. If changing an unused termination changes the observed result, the system needs a multiport or empirical description that includes that branch.

Insertion loss measured with a network analyzer is valuable, but the result is tied to its calibration planes, source and load conditions, frequency, and signal level. A connector that is reassembled after calibration can introduce a different reflection or loss. Mechanical strain can make that difference intermittent. Retain the identity of adapters and cables, use the relevant connector practices, and verify the complete selected path after assembly. A nominal cable type is not a substitute for a measured transfer when the required accuracy makes individual variation consequential.

Mismatch can affect a noise measurement in two ways: it changes delivered source power and can change the receiver's own gain and noise response to the source impedance. Weatherspoon and colleagues explicitly separate these effects in their vector-corrected noise-temperature work. Their method uses receiver noise parameters and measured reflection coefficients. This is why a generic scalar mismatch allowance or a single

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insertion-loss correction cannot always repair a high-accuracy hot/cold measurement. Model 2B deliberately assumes matching; moving outside that boundary requires the additional characterization.[3]

An attenuator can reduce the influence of reflections while adding thermal noise and lowering signal level. Its usefulness depends on which uncertainty or failure dominates. For a strong reference calibration, the improved match may be valuable. For a weak field observation, the same pad may make the signal undetectable. The correct comparison uses the complete uncertainty and sensitivity at the selected plane, with the pad's loss and temperature included. Do not treat improved return loss as a free improvement in every other measurement property.

3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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13.9 Common-Mode Current and Installed-Path Effects

Coaxial and shielded paths can carry external common-mode current on their outer surfaces even when the internal transmission mode is well matched. Cable routing, shield termination, grounding, ferrites, equipment bonding, and nearby structures affect pickup and radiation. A receiver connected through a long cable can detect the cable as an antenna, making the nominal sensing element less important than the installed path.

Common-mode challenges include changing cable route, adding or moving ferrites, bonding the enclosure, using optical isolation, operating from battery, and comparing a short local cable. These changes must be interpreted carefully because they also alter impedance and environment. The report identifies whether the observation is referred to the intended antenna terminals or to the complete installed receiving structure.

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13.10 Separate the intended coaxial path from installed coupling

The intended coaxial signal is associated with the field between the center conductor and the inside of the shield. Current on the outside of the shield can participate in a different coupling path involving the antenna, enclosure, ground, and nearby conductors. A matched two-port measurement of the intended path does not fully describe that installed path. This distinction explains why an excellent conducted insertion-loss result can coexist with a receiver indication that changes when a cable is moved.

A useful installed comparison preserves the desired observation geometry while deliberately changing one coupling opportunity. Examples include rerouting a defined cable segment, changing a permitted bonding arrangement, or introducing a characterized common-mode treatment. Record the exact change and remeasure the intended-path transfer when it could be affected. A ferrite comparison is evidence of sensitivity to that intervention; it is not, by itself, proof of a unique current distribution or external source. The treatment may also move the cable or alter its impedance.

A battery-powered optical link can remove a conductive cable path, but it introduces its own gain, noise, bandwidth, timing, and power-state behavior. Its result becomes an independent comparison only after those properties are understood well enough for the question. If the optical configuration has much less sensitivity, the disappearance of a weak feature is inconclusive. If it preserves the desired reference while an anomalous

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feature changes, the comparison is stronger. Preserve both observations and the reference evidence that makes them comparable.

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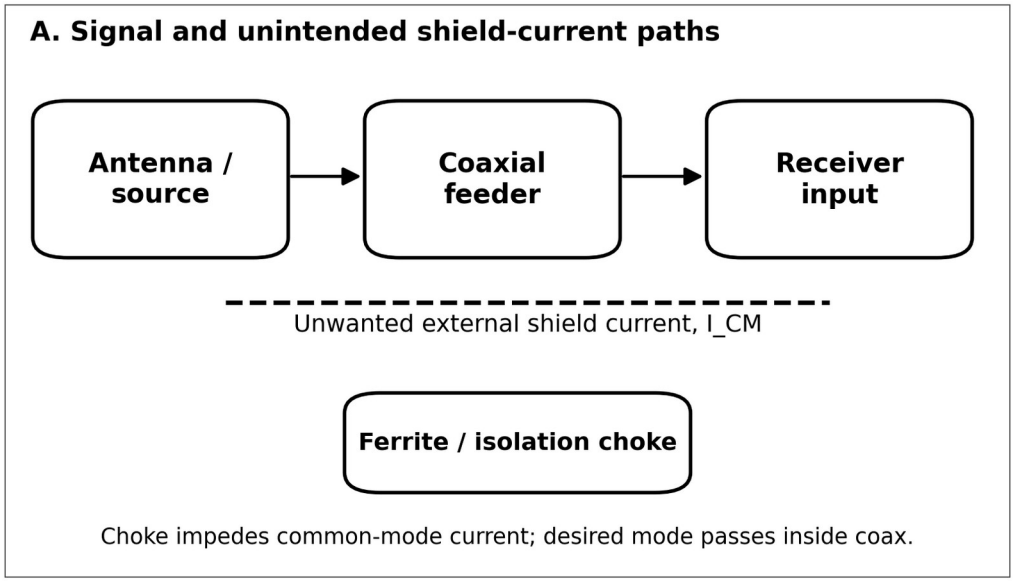

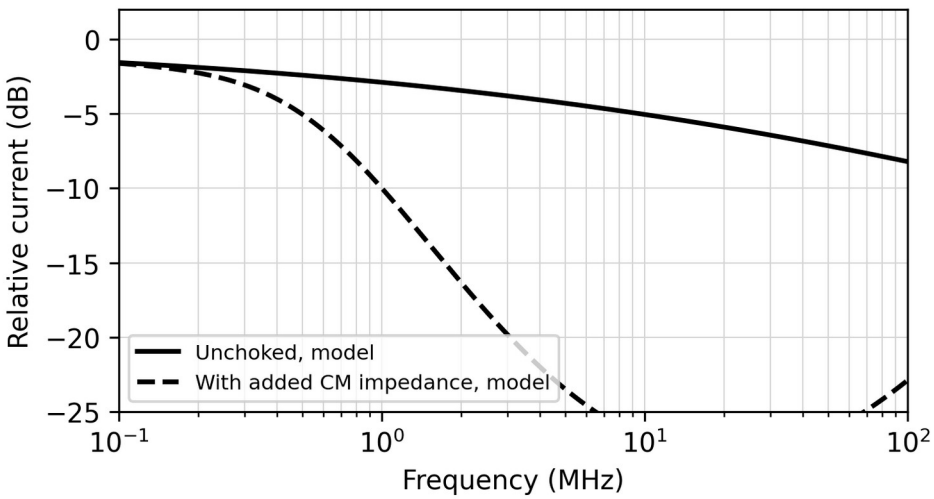

Model curves are conceptual; measure current and coupling with the actual cable, grounding, termination and choke impedance.

Figure 72. Coaxial common-mode coupling.

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13.11 Integrated Path Acceptance

The full path is accepted as a serialized assembly with measured response, configuration control, torque, labels, cable route, bias state, and environmental range. Calibration is repeated after any accessory substitution or relocation that changes loss, phase, balance, or common-mode behavior. Reference sweeps include the active antennas and remote preamplifiers under the same power and control state used during deployment.

Field checks compare a stable reference through short and installed paths, alternate antennas, and battery or isolated operation. Disagreement is resolved before environmental data is interpreted. The path record provides both corrections and limitations, including frequencies where gain, match, common-mode rejection, or dynamic range do not support quantitative conclusions.

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13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration

Equation 1. Available power from effective aperture

$$P_r = S_{\text{inc}} A_e$$

For a matched receiving antenna in the far field with polarization accounted for, available received power P_r equals incident power density S_{inc} times effective aperture A_e. Near-field coupling, mismatch, loss, and multipath require additional treatment.

Equation 2. Cascaded corrected level

$$P_{\text{ref,dBm}} = P_{\text{ind,dBm}} + \sum_i L_{\text{i,dB}} - \sum_j G_{\text{j,dB}}$$

Equation 25 is the bounded antenna-to-terminal interface stated for this chapter; antenna pattern, polarization, field region, and matching remain part of its conditions. Equation 26 reuses the scalar path correction from Model 2B. The full signed correction chain and its uncertainty are worked in Chapter 14 rather than inferred from a catalog sum.

Power at a chosen upstream reference plane equals indicated power plus downstream passive losses and minus downstream gains, using signed frequency- and state-dependent corrections. Mismatch and uncertainty are separate terms.

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Table 1. Chapter 13 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Antenna conversion	Pattern, polarization, geometry, calibration, impedance, and field region	Supports field or terminal interpretation	Indoor and near-field conditions can invalidate free-space assumptions
External preamplifier	Gain, noise figure, intercept, compression, bias, stability, and reverse isolation	Can overcome cable and receiver noise	Can oscillate, overload, or reradiate receiver leakage
Passive path	Loss, return loss, isolation, imbalance, power rating, and serialized correction	Provides controlled level and routing	Generic model data may not describe the installed path
Installed common mode	Cable route, shield termination, bonds, ferrites, enclosure, and battery comparison	Separates intended antenna response from cable pickup	Changing the route can also change the environmental field

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13.13 Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration

A calibrated antenna delivers -92.0 dBm at its terminals. The path contains 6.4 dB cable and switch loss and a preamplifier with 20.1 dB gain. The receiver should indicate about -78.3 dBm before mismatch and calibration uncertainty. An actual -70 dBm indication is inconsistent by 8.3 dB and requires checking gain state, correction file, overload, and common-mode pickup.

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13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration

A weak component disappears when the remote preamplifier is replaced by a passive through path, but it also remains when the antenna input is terminated. Changing the bias cable length shifts the component. These observations implicate the installed active and bias path. Self-oscillation is one hypothesis, alongside conducted or radiated pickup, reference leakage, and other network-dependent responses. Separately observing the amplifier output and controlling the bias and load conditions would help discriminate those mechanisms while checking that the comparison retains the required detection capability.

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13.15 A constructed acceptance case for the assembled chain

Consider the remote-amplifier order in Application 2B.2, operated in its declared linear state. Its desired-signal gain from the antenna terminal to the receiver output is 44 dB. A conducted reference of −112 dBm at that terminal should therefore produce −68 dBm at the stated output. This prediction is a transfer check, separate from the noise calculation. A reference injected only at the receiver connector bypasses the remote amplifier and cable, so it cannot verify their contribution even if the final displayed level is correct.

Build the acceptance record around that distinction. First verify the receiver alone at its own connector. Then verify the assembled conducted path at the antenna-terminal plane, retaining the raw output and all corrections. Finally perform an installed reference observation with the antenna in its documented geometry if a field-based conclusion is required. Each step extends the tested scope. Passing the first step cannot be described as passing the third, and a failure in the third does not immediately identify the receiver as the cause.

Table 13A. Minimum information for the constructed integrated path

Record	Required content	Reason
Assembly	Serial components, order, connectors, unused ports	Reconstructs the actual network
State	Gain, attenuation, filter, bias, temperature, time	Identifies the valid transfer and noise law
Desired transfer	Frequency, reference planes, gain, uncertainty	Supports terminal-level correction
Blocker transfer	Blocker frequencies and admitted levels	Tests loading before vulnerable stages

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Record	Required content	Reason
Installed geometry	Antenna orientation, mounting, cable route	Bounds field and common-mode interpretation
Closure	Before/after references and changes	Bounds the interval of demonstrated validity

Now introduce the declared blocker through a controlled path and retain the desired reference. If desired gain remains consistent while the noise rises, inspect the source spectrum and the reciprocal-mixing prediction. If desired gain changes, test gain control or compression before trusting the quiet-state noise budget. If an apparent product changes with cable routing while the conducted reference remains stable, examine installed coupling. These outcomes route the investigation toward different mechanisms; they do not require an invented single score for overall receiver quality.

The closing report should state which plane and configuration were accepted, the frequencies and signal conditions actually challenged, the reference uncertainty, and any interval in which state was unknown. Component certificates belong in the supporting record, while the acceptance conclusion belongs to the assembled measurement that was performed. This distinction allows the same hardware to support a strong conclusion for a bounded conducted measurement and a more cautious conclusion for an installation whose field coupling was only partially characterized.

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13.16 Integrated reference-plane analysis and system-level acceptance

An antenna, a feeder, a filter, an attenuator, a protective device and a receiver should be treated as a single measurement chain only after each relevant reference plane has been declared. The incident field at the antenna location is an electromagnetic quantity whose connection to terminal power depends upon antenna factor, effective aperture, polarisation, orientation, impedance and environmental coupling. The available power at an antenna port is not necessarily the power delivered to a particular load through a real transmission line. Every claim of received power therefore identifies whether it refers to the antenna's nominal available power, the conducted power at a connector, the receiver input after a passive network, or a detector output reconstructed through a calibrated transfer function. Without this declaration, two perfectly reproducible measurements can appear to disagree while describing different measurands.

The system's linear response can be described locally through a frequency-dependent transducer gain, but the validity of that response must be established for the source and load impedances under which it is used. The commonly employed decibel correction is useful for matched, small-signal comparisons where reflections are negligible or included in the calibration. If the antenna has a complex source impedance and the cable or preselector has substantial reflections, a scalar loss measured against a matched laboratory source may not reproduce the in-situ transfer. A rigorous approach retains complex scattering parameters, cable length, temperature, connector condition and uncertainty associated with the actual source/load

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match. The decision to use a simpler model is itself an engineering judgement, and its possible error should be bounded rather than concealed.

The measurement chain also has a spatial boundary. In a room with near-field coupling or significant reflections, antenna factor derived from a far-field plane-wave calibration may not faithfully convert a detected voltage into local electric-field strength. An antenna orientation change may alter its coupling to the source, the building's conducting surfaces and the cable's common-mode path. The investigator should distinguish a change in the incident environment from a change in effective antenna transfer. Repositioning an antenna or retorquing a connector may be useful as a challenge test, but the altered geometry means that a subsequent signal-level difference cannot automatically be attributed to source variability. Where the aim is to compare observations, record a repeatable geometry and an independent reference whenever practicable.

A dedicated preamplifier close to the antenna may improve the sensitivity of a long-cable arrangement, yet it shifts the vulnerability to out-of-band blockers nearer the antenna. The operator must evaluate both the input noise budget and the absolute power arriving at that amplifier. A downstream attenuator cannot protect an earlier amplifier from overload. Conversely a high-isolation preselector placed before a low-noise amplifier may suppress powerful interferers but incur enough insertion loss to harm sensitivity to a legitimate low-level test signal. An effective design balances these constraints at the actual antenna location. Catalogued noise figure, gain and compression values are starting hypotheses for validation, not final statements of system performance after installation.

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13.17 Electromagnetic return paths, cables and the risk of false spatial inference

Coaxial systems are often represented as a clean TEM transmission line with current on the inner conductor and the interior surface of the screen. Real installations can also carry common-mode current on the exterior conductor. That current may be excited by nearby fields, grounding differences, power-supply noise or conductive structures connected to the cable. Consequently the cable itself can become part of the receiving structure. A spectrum feature that changes when a cable is moved or rerouted may reflect such a coupling path, rather than a change in the true field at the intended antenna. This should be tested using appropriate isolation and common-mode suppression arrangements, not inferred from the colour or direction of a waterfall trace.

A connector defect can be both a linear and a nonlinear problem. Loose contacts and corroded junctions alter return loss and insertion loss; under powerful excitations, a nonlinear contact may mix frequencies and create a new component that appears to originate at another location. Mechanical strain can make that component intermittent. The investigator should preserve a baseline transfer measurement of the assembled cable, use consistent connector cleaning and torque procedures appropriate to the hardware, and repeat controlled tests after suspected mechanical movement. Avoid defeating protective bonding or altering safety arrangements merely to pursue a lower-noise measurement; any diagnostic configuration change must remain within electrical-safety and lawful operational limits.

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The route of a cable changes more than its nominal attenuation. Temperature and bending can alter phase delay, particularly when a receiver network depends upon coherence. A cable showing acceptable magnitude response may have drifted enough in phase or group delay to invalidate a timing or direction-finding conclusion. For ordinary occupancy surveys this may be immaterial, but for coherent arrays it becomes a direct source of uncertainty. Accordingly the chapter's reference-plane register should distinguish amplitude corrections from phase and timing corrections. It should also specify whether calibration was performed with the actual in-situ assembled path or a nominally similar replacement. Substituting accessories without updating their records can destroy traceability even when the displayed spectrum appears stable.

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13.18 Ten worked examples in integrated antenna-to-receiver measurements

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13.18.1 Example 13.X1. Conducted power transferred across a measured feeder

Suppose an antenna-terminal reference signal has available power -67.0 dBm under matched conditions. The selected feeder has measured loss 4.2 dB and a protective filter adds 1.3 dB at the frequency of interest. Ignoring mismatch and nonlinearity, the receiver input power is -67.0-4.2-1.3=-72.5 dBm. If a preamplifier with 16.0 dB calibrated gain is installed ahead of the feeder, the receiver input would nominally be -56.5 dBm, provided the amplifier remains linear and the filter position is unchanged. These figures are not field-strength estimates. They refer to power conventions at defined conducted planes. A frequency-dependent antenna factor or effective-aperture model and a suitable propagation assumption would be required to relate a free-space field to the original available power. The gain intervention can improve a noise budget without validating a claim of additional information about the outside emitter.

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13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude

A connectorised system is measured to have return loss 14.0 dB at one test frequency. On the conventional definition, $|\Gamma|=10^{(-RL/20)}=10^{(-14/20)}=0.1995$. Its reflected-power fraction is $|\Gamma|^2=0.0398$, approximately 4 percent. The mismatch-only power reduction in a simplified one-interface model is $-10 \log_{10}(1-0.0398)=0.176$ dB. That is not a universally valid end-to-end power correction. If source and load are both mismatched, their complex reflection coefficients and phase interactions contribute to mismatch uncertainty. Thus the 0.176 dB estimate is a diagnostic scale, not a replacement for a proper transducer-gain assessment. At frequencies where the cable becomes electrically longer, small mechanical changes can alter those phase relationships and require recalibration.

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13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model

For a receiving antenna with linear gain G=2.0 at a free-space wavelength lambda=0.30 m, the ideal effective aperture is A_e = G lambda^2/(4 pi) = 2(0.09)/12.566=0.01432 square metres. If an assumed incident plane-wave power flux density is 1.0 microwatt per square metre and polarisation is perfectly matched, the ideal available antenna power is 1.432 times 10^(-8) W, approximately -48.44 dBm. This calculation assumes far-field illumination, a suitable gain convention, correct matching and a plane-wave relation between the incident flux and antenna response. Near metalwork or a local source, those assumptions may be false. The number should therefore be labelled an ideal reference computation rather than a measured field or an attribution to any particular emitter.

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13.18.4 Example 13.X4. Polarisation mismatch of orthogonal linearly polarised antennas

For two ideal linearly polarised antennas with polarisation axes separated by theta degrees, the received power ratio from polarisation alone is cos^2(theta). At theta=60 degrees the fraction is 0.25, corresponding to 10 log10(0.25)=-6.02 dB. At 90 degrees the ideal model predicts zero coupling, but real antennas have finite cross-polar response, environmental depolarisation and near-field effects. A negative result from one antenna orientation does not establish that no RF energy was present. The operator should report the orientation, antenna characteristics and uncertainty, and test other polarisations where the survey question requires adequate coverage. This computation concerns one polarisation mechanism and cannot explain the entire amplitude variation in a complex room.

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13.18.5 Example 13.X5. Selecting a remote preamplifier with a long feeder

A receiver has a nominal noise figure of 6 dB, and a matched 8 dB cable precedes it. Under reference-temperature assumptions, the cable has a linear loss of 6.31, so the system's input noise figure referred ahead of the cable is roughly 14 dB when no other elements are present. Introduce a near-antenna amplifier with 20 dB available gain and 2 dB noise figure. The combined noise factor is approximately $F_{amp}+(F_{cableReceiver}-1)/G_{amp}$, where $F_{amp}=1.585$, $G_{amp}=100$, and $F_{cableReceiver}=10^{(14/10)}=25.12$. Thus $F_{total}\approx1.585+0.2412=1.826$, giving $NF_{total}\approx2.61$ dB. This idealised improvement is substantial, but the amplifier now confronts the full antenna environment. A blocker or lightning-protection requirement may make the seemingly better sensitivity configuration inappropriate without additional filtering and safe installation measures.

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13.18.6 Example 13.X6. Coherence loss from uncorrected cable delay

A phase-coherent receiver pair has an unmodelled relative time-delay change of 0.5 ns between calibration and measurement. At a 1 GHz carrier, the corresponding phase shift is phi=360 degrees times frequency times delay, giving phi=360(10^9)(0.5 x 10^(-9))=180 degrees. A naive coherent combination could therefore subtract what should add. The exact effect depends on the algorithm, signal frequency and whether differential delay was estimated during acquisition, but the scale demonstrates why an amplitude-only cable calibration is insufficient for array processing. For a broadband waveform, group-delay variation and sample timing must also be considered. The example does not imply that the installation physically moved by a fixed distance; dielectric and temperature changes can create differential electrical delay without an equivalent visible movement.

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13.18.7 Example 13.X7. Loss and system noise from a protective filter

A protective input filter adds 1.8 dB passband insertion loss and rejects a stipulated off-band blocker by 35 dB. In a matched reference-temperature cascade, placing it before a sufficiently good first amplifier will ordinarily worsen the intrinsic input noise figure by approximately its insertion loss. Nevertheless the filter may be essential if it prevents an otherwise saturating blocker from reaching the amplifier. Suppose a blocker arrives at -4 dBm. After 35 dB rejection it reaches the vulnerable amplifier at approximately -39 dBm, an enormous reduction compared with the unfiltered -4 dBm condition. The passband noise penalty and blocker suppression should both be reported. It would be erroneous to describe the 35 dB rejection as a 35 dB improvement in sensitivity. Instead the result is increased validity in the specified strong-signal environment, subject to testing the filter's finite transition band and power handling.

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13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement

A receiver reports -82.0 dBm at its input plane. A calibrated feeder loss of 3.2 dB and filter loss of 1.5 dB are added to refer the result back to the antenna port, giving -77.3 dBm under the adopted sign convention. If the independent standard uncertainties of displayed level, feeder loss and filter loss are 0.4, 0.2 and 0.3 dB respectively, the root-sum-square uncertainty is sqrt(0.4^2+0.2^2+0.3^2)=0.5385 dB. A nominal expansion factor of two yields about 1.08 dB under the approximation, but whether a formal coverage interval is justified depends on distribution assumptions, degrees of freedom and correlation. If the losses were established against the same calibration source, treating them as independent may not be defensible. A report should list the contributing terms, their correlations and the exact reference plane.

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13.18.9 Example 13.X9. Intermittent common-mode cable response

A controlled laboratory source at fixed level is monitored by an antenna and cable assembly. With the cable on its normal route the apparent component is -75 dBm; after a deliberate safe rerouting with the antenna position unchanged it becomes -64 dBm. The 11 dB difference demonstrates a configuration dependence of the measured system, not by itself a change in the laboratory source. A common-mode current path on the feeder is one hypothesis; changes in connector impedance, cable microphonics or the electromagnetic geometry are alternatives. The proper follow-up uses a second calibrated and physically distinct receiving arrangement, measured common-mode suppression where appropriate and a configuration ledger. One must not apply an unexplained 11 dB correction to the original evidence or describe the rerouted state as necessarily closer to the truth. Both are observed states whose physical causes still need resolution.

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13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone

Suppose a receiver input indicates -90 dBm of conducted power. A direct conversion to incident electric-field strength is impossible without an antenna transfer model and valid environmental assumptions. If the associated antenna has a calibrated antenna factor AF=20 dB per metre in a suitable far-field arrangement and a measurement at its terminal corresponds to 20 dB microvolts, the ideal indicated electric-field strength would be 40 dB microvolts per metre by E_dBuV/m = V_dBuV + AF_dB/m. Yet the original -90 dBm is not automatically equal to 20 dB microvolts at a mismatched port. Voltage and power conversion require the reference impedance and appropriate delivered-power convention. The numerical field-strength result is therefore conditional on measured voltage at the antenna terminal, calibration geometry and proper polarisation correction. This distinction prevents an attractive number from disguising a missing physical premise.

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13.19 Verification, records and the interpretation of negative observations

An installation acceptance record should identify the antenna type and serial identifier, orientation, fixture position, cable path, connector condition, filter and preamplifier state, protection components, instrument input state, calibration interval, temperature and relevant frequency span. Each important transfer correction should have a provenance link to the test equipment, procedure and reference standard used to determine it. The record distinguishes a component datasheet value from an actual system calibration. A nominal gain figure measured at room temperature cannot automatically be transferred to a sunlit roof installation or a concealed cable routed through a fluctuating thermal environment. The technical burden is proportional to the intended inference. Simple occupancy screening may need less detailed phase calibration than coherent source localisation, but it still needs truthful documentation of its uncertainty.

The survey report should specify how the receiving chain could have missed a relevant signal. Blind intervals, antenna pattern nulls, polarisation mismatch, preselector rejection, weak-signal sensitivity, overload recovery and operator-selected frequency coverage all limit negative claims. Multiple receiver chains provide stronger corroboration only when their failure modes are sufficiently independent. Two instruments sharing the same compromised antenna splitter or reference clock do not become independent simply because their displays resemble one another. The final assessment must account for the installation's actual physical pathways and not merely the nominal specifications of its individual modules. The strongest defensible negative statement describes the tested frequencies,

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observation intervals, configurations and decision thresholds under which no qualifying event was detected.

The governing documentation should permit a second examiner to reconstruct the measurement corrections and understand why the selected geometry, reference planes and component states were appropriate. It should separate raw conducted measurements from derived field values, and measured timing from inferred location. Any disputed result should remain traceable to the relevant recording, calibration record and instrument state. Worked computations in this section are hypothetical demonstrations of method rather than measurements of a real installation. Their accuracy under the stated assumptions must still be confirmed for the user's actual instruments and source geometry before they are used as evidential findings.

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13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane

An antenna and receiver connected by a cable form an interacting network, not a succession of ideal scalar decibel corrections. The available power from an antenna depends on its Thevenin equivalent and source impedance, while delivered power depends on the receiving input impedance and the intervening network. When an antenna is reactive or the receiver's input match changes with gain state, a calibrated insertion loss between nominally matched ports is insufficient to predict the installed transducer gain. The complete relation requires reflection coefficients, transmission coefficients and a declared plane. A scalar path correction remains useful where mismatch effects have been measured, bounded or shown negligible, but the engineer should not confuse the convenience of dBm arithmetic with universal applicability of the model.

Let reflection coefficient Gamma = (Z - Z0)/(Z + Z0), where Z is the complex port impedance and Z0 is the real positive reference impedance. The reflected-power fraction is |Gamma| squared for the corresponding power-wave convention. A source with |Gamma| = 0.3 has reflected fraction 0.09, or nine percent, under the stated reference, whereas a second state with magnitude 0.1 reflects one percent. These figures do not by themselves establish the network's net transducer gain, because phase, multiple reflections and cable electrical length can change the result. A reported change in power after cable substitution may arise from the new mismatch geometry even if the cable's matched-port insertion loss appears

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unchanged. Measuring only one cable loss number would leave an ambiguity that cannot be removed by a later scalar correction.

Antenna factor introduces a second conversion: an electric field strength in volts per metre is related to the voltage at a specifically defined antenna port under specified frequency, polarisation, geometry and loading. Applying an antenna factor without checking those conditions can turn a receiver input-voltage reading into an unsupported environmental field claim. For a simple hypothetical calibration, suppose a port voltage of 10 microvolts is related to a plane-wave field through an applicable antenna factor of 20 per metre. The field magnitude is then 200 microvolts per metre before other stated corrections. This result assumes the chosen calibration definition and the same installed orientation and reference plane. If the antenna is used in a reactive near field rather than the calibration geometry, the same factor may not apply and the true vector field cannot be inferred from one scalar reading.

The appropriate acceptance record uses actual cable routing, connector identity, torque or installation method, bias tees, protective elements and preselector states. Each substitution should be accompanied by a closing reference test at the new configuration. Calibration of the antenna alone and calibration of the receiver alone do not automatically compose into a traceable installed-system result. The uncertainty budget must distinguish repeated connection variation, systematic antenna-factor uncertainty, mismatch, environmental coupling and the applicability of the far-field model. A signal disappearing after a probe has been moved is useful evidence of changed coupling; it is not necessarily the physical position of a particular transmitting apparatus.

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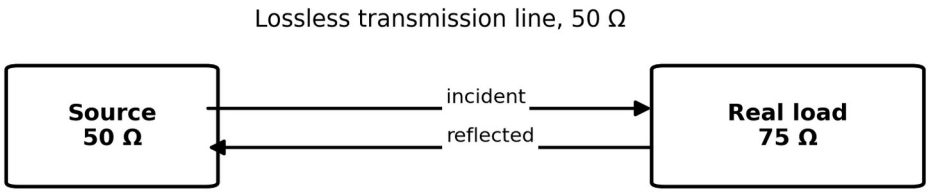

$$\Gamma = (Z_L - Z_0)/(Z_L + Z_0) = 0.20$$

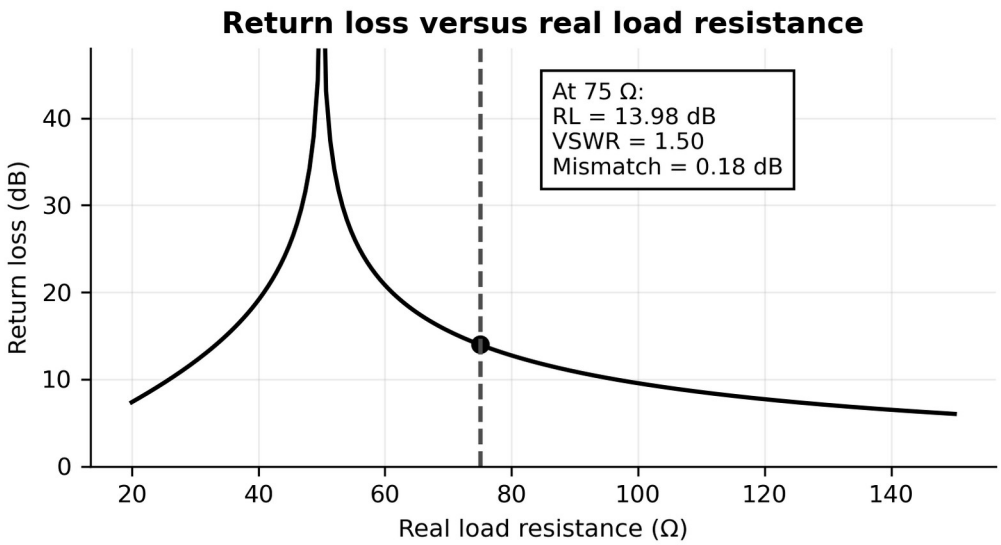

TECHNICAL INTERPRETATION

A mismatched receiver input reflects RF power; return loss, VSWR and mismatch loss are distinct metrics with explicit assumptions.

Figure 73. Transmission-line impedance mismatch.

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13.21 Vector reference-plane transport and installed-path uncertainty at antennas and cables

An antenna, cable and receiver comprise a coupled network rather than a list of independent scalar attenuation labels. If a generator measures a nominal cable insertion loss using matched reference impedances, that result does not automatically describe the power accepted when the cable is attached to a reactive antenna or a receiver whose input return loss changes with attenuator state. Reflection coefficients at both ends affect delivered power, and standing-wave patterns can change with cable length, bending, temperature and connector condition. A rigorous measurement record distinguishes available source power, incident travelling-wave power and delivered load power. Treating all of them as dBm at an unspecified plane can give an arithmetically smooth but physically incorrect correction.

For a single transmission line with propagation constant gamma = alpha + j beta and length ell, the forward travelling-wave coefficient is exp(-gamma ell) under the chosen normalisation. An additional reflection term depends on the source and load reflection coefficients and the phase accumulated along the path. If the product of reflection magnitudes is small, scalar insertion loss may be an acceptable approximation with a bounded mismatch allowance. If the product is appreciable, the delivered transfer changes with electrical length, and replacing the path by a single loss value conceals frequency-dependent ripple. A vector network analyser can characterise the ports when its calibration planes and connector repeatability are controlled, but a VNA calibration alone does not establish

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the antenna's environmental effective aperture or the geometry of a later field installation.

Mismatch uncertainty has a physically interpretable range. Suppose the magnitudes of effective source and load reflection coefficients are 0.2 and 0.3 under a simplified two-reflection model. Their product is 0.06. The factor in delivered transfer arising from the denominator |1 - Gamma_s Gamma_l exp(-j phi)| squared lies between 1/(1.06)^2 and 1/(0.94)^2 as unknown relative phase phi varies. The corresponding gain difference between these extremes is 20 log10(1.06/0.94), approximately 1.04 dB. This is a bounded variation within the stated model, not a normally distributed uncertainty or an empirical calibration certificate. Any correction using a measured complex reflection state can reduce the range, but its own frequency, temperature and connector repeatability conditions must then be recorded.

Antenna factor and effective aperture require careful treatment of polarisation and field region. A calibrated receiving antenna used in a known plane-wave far field can support a relation between incident field and terminal voltage with a stipulated orientation and load. Indoors, the spatial distribution may include reflections, near fields and strongly varying polarisation, so a single manufacturer's far-field antenna factor can be inappropriate for precise source-field inference. An antenna's gain pattern measured in an anechoic chamber also need not describe its installed response near metallic furniture, cable supports or shielded structures. The useful defensive measurement may remain terminal power or a comparative signal level without claiming absolute field strength at the unknown emitter.

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Common-mode currents along coaxial shields can create a reception path that is distinct from the nominal antenna terminals. The cable itself may participate in the effective receiving structure and alter apparent direction, polarisation and spatial response. A diagnostic can compare ferrite treatment, shield routing, balun or choke configuration, and physically different cable paths while maintaining a calibrated desired reference. These are interventions with their own transfer consequences; a reduction in a suspect signal after a choke is added does not alone prove where it originated. Examine whether the choke also changed the desired signal and whether an alternative RF input path remained available.

Vector calibration and uncertainty can be organised around a chain of measured complex ratios. State each reference plane, frequency grid, calibration standard, connector sequence, temperature range and processing convention. Keep a covariance-aware model for shared calibration terms; when several measurement paths rely upon the same calibration kit or power reference, their uncertainties cannot be treated as independent merely because files were exported separately. For a distributed receiving array, phase and timing errors must also be linked to the actual clock state. The final report should distinguish a locally valid relative comparison from an absolute field or source-power inference that the experiment did not establish.

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13.22 Additional study: vector reference planes, mismatch and multiport calibration in an installed receiving path

The phrase cable loss frequently disguises an extensive chain of electromagnetic assumptions. A measurement made at a receiver connector may be related to an antenna terminal through a set of adapters, a mechanically stressed feeder, a preselector, a switch, a limiter and an external amplifier. The forward transfer can depend on the source impedance, frequency, input power, temperature, cable configuration and the state of every unterminated or imperfectly terminated branch. In general, the transducer power gain of an assembled two-port is not obtained by adding individually measured matched insertion-loss values in decibels. That scalar approximation is useful within a declared mismatch allowance, but it omits coherent multiple reflections and any common-mode coupling that bypasses the intended differential or coaxial route. A vector treatment makes the limitations of a simple correction explicit.

For a linear two-port network referenced to a real impedance Z_0, let a_1 and a_2 denote incident power waves and b_1 and b_2 the corresponding outgoing waves. The scattering relation is $[b_1, b_2]^T = S[a_1, a_2]^T$, where S is a 2-by-2 complex matrix with entries S_{11}, S_{12}, S_{21} and S_{22}. The numerical magnitudes are defined under a stated power-wave convention and common reference impedance, and the squared magnitude $|S_{21}|^2$ is the forward delivered-power ratio only under the specified matched-port conditions. For a passive reciprocal device within its linear range, S_{21} and S_{12} may be equal under consistent normalisation, but reciprocity does not establish zero reflection, unchanging temperature or the absence of

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installation-specific common-mode effects. An amplifier can be nonreciprocal and can add noise and distortion even where its small-signal scattering matrix is correctly calibrated.

The receiving source and load are usually not ideal matches. Introduce source and load reflection coefficients Γ_S and Γ_L, both complex and dimensionless, at their declared reference planes. The corresponding transducer power gain is $G_T = [(1-|\Gamma_S|^2)|S_{21}|^2(1-|\Gamma_L|^2)] / |(1-S_{11}\Gamma_S)(1-S_{22}\Gamma_L)-S_{12}S_{21}\Gamma_S\Gamma_L|^2$ for a general linear two-port under the conventional source-available-to-load-delivered power definition. This relation requires a passive or active stable operating state in which the adopted small-signal S parameters apply. It is not a proof that an amplifier stays linear under a strong adjacent transmitter. The denominator shows why a product of matched scalar losses can misrepresent the assembled transfer when reflections interact coherently. The phase of each reflection coefficient matters; two networks with the same individual return-loss magnitudes can produce different composite transfer functions.

An antenna referenced to environmental field strength demands further care. For a plane wave incident in the antenna's characterised far-field regime, an effective-height or antenna-factor model can relate a specified field component to a terminal quantity. That relation depends on polarisation, direction, receiving pattern, loading and frequency. It does not automatically apply in the reactive near field of a device hidden within building materials or in strong coupling with a cable sheath. The antenna may be electrically small, spatially nonuniformly illuminated or oriented so that the field direction changes materially across its aperture. A single antenna factor measured in one laboratory geometry cannot guarantee

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absolute field measurement accuracy under arbitrary installed conditions. For a TSCM survey it may still support useful relative observations, provided those conclusions are explicitly bounded by the tested geometry and transfer paths.

Mismatch uncertainty should be distinguished from unknown connection state. If all component reflection coefficients are characterised vectorially, the corresponding transducer gain can be calculated within the adopted calibration model. If only magnitudes of return losses are known, the unknown phases can cause a range of possible gains. The conservative task is then to bound the transfer over the permitted phase combinations instead of assuming random, independent reflections without evidence. If a cable or switch changes during the survey, even the earlier bounded model may no longer describe the new configuration. Its significance should be established by a new measurement or a demonstrated state-invariance argument, not by retaining the previous correction file because the connector types are unchanged.

Multiport devices reveal a different error. A splitter's unused output may appear irrelevant to the main connection, but its termination can alter input match and isolation. In a switching matrix, imperfect isolation can admit another antenna, a calibration generator or a locally generated source into the monitored path. A terminated reference-plane measurement may therefore fail to reproduce a survey condition in which another port was connected to an active device. An advanced acceptance protocol should characterise not only the selected signal route but also the influence of plausible states at other ports. A complete description can use a larger scattering matrix, or measured state-dependent transfer coefficients where

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a full multiport model is impractical. Whichever representation is chosen, the evidential claim must identify which configurations were actually examined.

Common-mode currents are especially consequential when observing weak RF signals in buildings. The intended measurement may involve a differential signal between a coaxial inner conductor and the inside of its shield, yet the outside of that shield can carry current excited by nearby electronics or building wiring. That current can couple into the receiver through connectors, chassis structures or imperfect balance. A cable movement may change the observed trace by changing the antenna pattern of the entire installation rather than the apparent free-space source. An attenuation or termination test inside the nominal signal route may not suppress this separate path in the predicted way. The useful response is a controlled physical perturbation and an independent observation of the common-mode route, with attention to safety and the applicable connection geometry.

A hypothetical matched-reference example uses an installed passive chain whose measured forward coefficient has magnitude 0.50 at one frequency. Under matched source and load, $|S_{21}|^2 = 0.25$, equivalent to a -6.0206 dB power transfer. If the reflection conditions change, that number is not automatically the delivered-power ratio at the receiver. As an elementary one-interface illustration, let the source voltage reflection coefficient have magnitude 0.20 and the load magnitude 0.30. Their product magnitude is 0.06; depending on relative phase, a simple single-reflection correction denominator $|1-\Gamma_S \Gamma_L|^2$ ranges between $(1-0.06)^2$ and $(1+0.06)^2$. The corresponding gain multiplier can lie between approximately 0.890 and

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1.132. This ±-like range is illustrative and does not replace the full network relation above. It shows how a small-looking reflection product can create a consequential calibration difference without a change in the nominal cable attenuation.

A second constructed example concerns a known 50-ohm passive termination at the far end of a line with return-loss magnitude 20 dB. The corresponding reflection magnitude is $|\Gamma| = 10^{(-20/20)} = 0.1$, and the reflected fraction of incident power is $|\Gamma|^2 = 0.01$, or one percent. Reporting a 20 dB return loss as though twenty percent of power were reflected confuses logarithmic amplitude and power. It also obscures where the measurement was made: the reflection coefficient referred to a different plane acquires phase through the connecting line. That phase is useful for location and mismatch analysis, but it cannot be treated as a property of the remote termination alone without accounting for the line.

A third constructed example uses a line velocity factor of 0.66 relative to the speed of light and physical length ten metres. With speed of light c = 299,792,458 metres per second, propagation velocity is approximately 1.97863×10^8 metres per second, and one-way delay is about 50.54 ns. A phase-sensitive multichannel comparison that ignores this delay can accumulate a phase difference of $2\pi f \tau$ at frequency f. At 10 MHz the phase is approximately 181.94 degrees, modulo a full cycle. A calibration valid for amplitude alone cannot eliminate that timing error. If the coaxial dielectric temperature changes the velocity factor or length sufficiently, phase drift may require repeated calibration even though the measured insertion loss remains nearly unchanged.

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13.23 Controlled qualification of the installed network

The acceptance procedure starts by declaring the source and destination planes, the electrical reference impedance, the installed topology and the permitted operating states. First, characterise individual components with calibrated fixtures and recorded connector condition. Secondly, measure the assembled path without assuming that the separate measurements multiply exactly. Thirdly, vary plausible antenna loading, switch states, bias conditions and temperatures to identify the actual transfer envelope. The observed deviations should be compared with an uncertainty model containing source match, load match, connection repeatability, instrument calibration, common references and the possible influence of other ports. A single vector-network-analyser pass is not complete assurance of the arrangement after transport or reconnection.

For a field observation, retain both native receiver quantities and the corrections that refer them to the chosen plane. A terminal-power result is not a free-space field-strength result without an applicable antenna model, nor is it the emitted power of an alleged source. A movement experiment may support a spatial inference only after the antenna pattern, coupling and receiver states changed by the movement have been considered. In particular, moving a long cable can alter common-mode coupling while the antenna tip remains at the same physical location. An observation that depends on cable route is a reason to examine installation effects, not automatic proof of a concealed transmitter hidden along the route.

A fourth synthetic case illustrates a cable-reconnection effect. Two independent passes show the same installed source and receiver but a

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corrected component level changes by 0.8 dB after the cable and adapter are reconnected. If the repeatability budget for that connection is only 0.2 dB standard uncertainty, the difference merits investigation. It is not legitimate to dismiss the 0.8 dB solely because each individual instrument calibration certificate remains current. Conversely, the level difference does not establish the external source changed; load mismatch, cable bending, connector contact and common-mode current are plausible alternatives. The appropriate controlled test restores the connection geometry, measures vector match and repeats the source reference without cherry-picking a favourable trace.

A fifth example involves multiport isolation. Suppose an unselected antenna path leaks into the selected receiver route at −45 dB relative to its input, while the unselected path carries a −10 dBm local signal. In the small-signal scalar approximation, that leakage can produce a −55 dBm contribution at the selected output reference plane before any other gain or loss. A desired weak component at −105 dBm may be completely obscured, despite the switch being marked as selecting the proper antenna. The calculation is a warning about the need to know the actual isolation and loading. It is not a claim that every switch behaves this way. An end-to-end test with the unselected port deliberately and safely driven can reveal the path, but the test must not inject unauthorised interference into the environment.

The scientific output is an installed-path transfer dossier. It should identify the frequency-specific complex transfer where supported, mismatch and thermal limits, calibration data, state changes, branch isolation, common-mode observations and all circumstances in which the scalar correction is known to be inadequate. The dossier supports calibrated receiver readings

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but does not expand the legitimate inference beyond what the network and antenna measurements establish. Its strength is that a later reviewer can reconstruct why a measured component was assigned to the environment, the measurement system or an unresolved mixture of the two.

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13.24 Advanced technical expansion. Vector reference-plane transfer in a mismatched installed path

An installed RF path cannot always be corrected by adding cable insertion loss and subtracting amplifier gain. Such scalar treatment assumes a particular relationship among source, load and calibration impedances, usually under conditions sufficiently close to the matched reference model. An antenna may present a complex impedance that varies strongly with frequency and position, while a receiver input changes its reflection coefficient with attenuation or preselector state. Multiple reflections then modify the voltage and power actually delivered to the first active device. A quoted matched-port insertion loss may remain a valid component specification while being an incomplete description of the installed transfer. The analyst should distinguish available source power, incident travelling-wave power, accepted power and any estimated field quantity rather than using one unqualified dBm label for all four.

Scattering parameters offer a systematic language for this problem. In a two-port network, complex incident travelling-wave amplitudes a_1 and a_2 and reflected amplitudes b_1 and b_2 are related by $[b_1,b_2]^T = S[a_1,a_2]^T$ in an explicitly normalised wave convention. The parameters S_{11} and S_{22} describe reflection at the defined ports; S_{21} describes forward transfer under the specified reference conditions; S_{12} describes reverse coupling. Their values are complex functions of frequency and usually of configuration and temperature. Converting an S_{21} magnitude alone into a universal field-strength correction is unjustified when antenna mismatch, loading and polarisation remain uncharacterised. A useful receiver system model treats

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each calibrated network section as a multiport and connects them using a consistent wave or impedance representation, retaining the source and load states.

Consider a hypothetical antenna with reflection coefficient magnitude 0.3 at a 50-ohm reference, and a receiver input with coefficient magnitude 0.2. Even before propagation through a cable is considered, the product of the reflection magnitudes is 0.06, so a simple geometric series of round-trip voltage contributions can be sensitive to relative reflection phase. The exact transmitted power depends on the complex coefficients, electrical length and the power-wave convention. It is inappropriate to convert 0.06 directly into an exact loss or uncertainty without the full network relation. The example shows why a system using nominally 50-ohm connectors can still exhibit consequential mismatch uncertainty: connector labels provide the chosen reference impedance, not proof of matching under the installed operating condition.

Vector calibration and de-embedding are necessary when phase or coherent timing is part of the measurand. A cable may have acceptable insertion loss but substantial temperature-dependent electrical length. The phase of its transfer depends on frequency, path length and environmental conditions; a mechanically flexed lead can also couple an unwanted common-mode signal through its shield or nearby structures. For a one-metre illustrative change in electrical path length and propagation velocity 2.0×10^8 m/s, the corresponding pure propagation delay change is 5 ns. At 100 MHz that delay represents half a cycle of phase. Such a large change is intentionally illustrative, not a likely small thermal perturbation. It demonstrates that a calibration expressed solely in decibels does not supply a coherent phase

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correction. Smaller physical changes can be consequential at sufficiently high carrier frequency.

Antenna factors introduce another measurement boundary. Converting terminal voltage to electric-field strength requires the antenna's applicable factor, polarisation, environment, geometry and reference convention. A field calibration performed in an appropriate radiating arrangement may not apply unaltered to the reactive near field of an unknown installation. For a source close to metallic structures or cable routing, local current distribution can change the measured coupling in ways not captured by a free-space far-field approximation. The examiner should not infer transmitter power from a received level without a justified propagation model. A useful report can preserve calibrated terminal or receiver-input power when source-power inference remains underdetermined. Precision in the receiver readout cannot restore the missing field geometry.

The laboratory procedure must separately characterise small-signal multiport transfer, source and load reflections, path switching, noise contribution, nonlinear overload and temperature drift. Record reference-plane identities, calibration kit and its validity interval, instrument correction data, accessory serial numbers, installed cable route and antenna orientation. Conduct a repeat measurement after reconnecting the path to estimate connection repeatability, and perform a controlled common-mode challenge when shield currents could explain an unexpected component. A vector network analyser test alone does not establish large-signal behaviour of an active preamplifier or limiter, and a later connector continuity test does not prove that a field signal used the assumed path. Release each

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correction within its measured frequency, temperature and physical-configuration domain.

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Chapter Summary

The antenna-to-receiver path is one calibrated structure. Field conversion, external gain, passive corrections, switching state, and common-mode behavior must remain traceable to serialized components and installed geometry.

The assembly, state and correction records answer different questions. Name every relevant plane and assign each correction once. Antenna-terminal power and field strength remain distinct measurands: field conversion adds polarization, pattern, loading, geometry and installation conditions. A conducted reference verifies only the path it traverses; an antenna certificate does not establish every installed arrangement.

Remote gain can overcome cable and receiver noise while increasing exposure to blockers, bias coupling or instability. Passive networks add loss, reflection and branch interactions. Their selected and unused ports belong to the model. When source impedance changes the receiver’s own response, a matched scalar cascade may require additional vector or empirical characterization.

Use controlled comparisons to separate intended transfer from installed coupling. Recheck desired response when changing cables, terminations, bias or isolation, and retain the observations that establish comparable sensitivity. Accept the serialized arrangement at named planes and states, with tested conditions and unknown intervals stated. A changed indication directs further discrimination; it does not uniquely identify an external source or fault.

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Chapter 13 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C13-MCQ-001. An assembly record lists all component serial numbers but omits their order. What remains unreconstructable even if total desired gain is known?

A. The sum of the listed component gains alone

B. Placement-dependent noise and loading exposure

C. The nominal model number of each component

D. Whether the total gain file contains the stated sum

Answer: B. Equal total gain does not establish equal input-equivalent noise or the level reaching each vulnerable stage. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: Placement-dependent noise and loading exposure.

Distinguishing consideration: compare this with option A, “The sum of the listed component gains alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-002. What is established by a conducted reference injected only at the receiver connector?

A. The cable's terminal-to-connector correction

B. The complete antenna field-conversion chain

C. The remote amplifier's installed stability

D. The downstream response from that named plane

Answer: D. Upstream components and field conversion are bypassed by the injection. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: The downstream response from that named plane.

Distinguishing consideration: compare this with option A, “The cable's terminal-to-connector correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-003. Why can an antenna factor certificate fail to establish an installed field estimate?

A. A terminal measurement eliminates polarization dependence

B. The factor is valid only when expressed in linear units

C. The installed geometry and coupling may differ from the calibration conditions

D. The receiver calibration necessarily includes all cable effects

Answer: C. Applicability depends on loading, geometry, polarization and installed coupling, not merely possession of a certificate. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: The installed geometry and coupling may differ from the calibration conditions.

Distinguishing consideration: compare this with option A, “A terminal measurement eliminates polarization dependence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-004. A battery substitution removes a line from a remote amplifier measurement. Which conclusion is justified?

A. Supply ripple has uniquely been identified

B. The receiver's conducted amplitude calibration has been disproved

C. The antenna must have stopped receiving the external source

D. The line is sensitive to that intervention, which changed possible supply and conductive paths

Answer: D. Battery operation can alter grounding and conductive coupling as well as supply noise; a selective follow-up is needed. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why the selected alternative fits: The line is sensitive to that intervention, which changed possible supply and conductive paths.

Distinguishing consideration: compare this with option A, “Supply ripple has uniquely been identified”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-MCQ-005. Why can a nominally unused switch port change the selected-path measurement?

A. Finite isolation and impedance coupling make its termination consequential

B. Unused ports contribute only a fixed temperature-independent loss

C. A selected switch path is always an isolated two-port

D. Only the selected port's connector torque matters

Answer: A. The unused branch can admit energy or change impedance; its state belongs in the assembly model. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why the selected alternative fits: Finite isolation and impedance coupling make its termination consequential.

Distinguishing consideration: compare this with option B, “Unused ports contribute only a fixed temperature-independent loss”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-MCQ-006. Which pair of effects makes source mismatch important in receiver noise measurements?

A. Changed delivered source noise and changed receiver gain or added noise

B. Changed displayed units and changed reference impedance label only

C. Changed receiver gain only, with delivered source noise necessarily fixed

D. Changed source noise only, with receiver response necessarily fixed

Answer: A. A scalar insertion-loss correction need not capture the receiver's impedance-dependent noise response. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why the selected alternative fits: Changed delivered source noise and changed receiver gain or added noise.

Distinguishing consideration: compare this with option B, “Changed displayed units and changed reference impedance label only”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-MCQ-007. A cable reroute changes an anomalous indication while the conducted desired transfer stays stable. What is the appropriate next hypothesis to test?

A. A uniquely identified external transmitter moving in frequency

B. Installed coupling involving the exterior shield and surrounding structure

C. A required error in the receiver frequency reference

D. A necessary change in the calibrated internal coaxial loss

Answer: B. Stable conducted transfer narrows one explanation but does not uniquely identify the installed coupling mechanism. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: Installed coupling involving the exterior shield and surrounding structure.

Distinguishing consideration: compare this with option A, “A uniquely identified external transmitter moving in frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-008. In the constructed example, what does a terminal reference of −112 dBm producing −68 dBm establish under the stated linear conditions?

A. The 44 dB desired transfer between those planes

B. The complete noise budget and blocker validity

C. The antenna's free-space field conversion

D. The absence of common-mode pickup in every installation

Answer: A. The difference tests desired transfer; the other claims require separate evidence. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: The 44 dB desired transfer between those planes.

Distinguishing consideration: compare this with option B, “The complete noise budget and blocker validity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-009. A receiver's factory calibration ends at its front connector. Which downstream-file choice correctly refers an indication to the antenna terminals?

A. A generic cable model without the installed switches

B. The antenna gain alone, independent of cable and active stages

C. A second copy of the receiver's internal correction

D. A correction for the actual external path between the two named planes

Answer: D. Correction scope follows the physical path and plane boundaries. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: A correction for the actual external path between the two named planes.

Distinguishing consideration: compare this with option A, “A generic cable model without the installed switches”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-010. An adapter is included in a measured cable-and-adapter correction and is also entered separately. What error is introduced?

A. Double application of the adapter correction

B. Automatic correction of mismatch

C. Cancellation of all cable uncertainty

D. A change only to the receiver-connector reference plane

Answer: A. Each included element must have one correction owner. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: Double application of the adapter correction.

Distinguishing consideration: compare this with option B, “Automatic correction of mismatch”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-011. Which record identifies whether a transfer file applies to a particular remote amplifier setting?

A. The state record including gain, bias and filter configuration

B. A component certificate without setting information

C. A list of prior calibration dates alone

D. A photograph showing the amplifier enclosure only

Answer: A. The response can depend on the actual electrical state and environment. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: The state record including gain, bias and filter configuration.

Distinguishing consideration: compare this with option B, “A component certificate without setting information”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-012. Which information is specific to the correction record rather than merely the assembly inventory?

A. Gain-switch position and ambient temperature without measured transfer

B. Reference planes, frequency grid, interpolation and uncertainty

C. Component order and connector identities without measured transfer

D. Gain-switch position and remote bias voltage only

Answer: B. A correction needs its numerical applicability and interpolation rule as well as hardware identity. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: Reference planes, frequency grid, interpolation and uncertainty.

Distinguishing consideration: compare this with option A, “Gain-switch position and ambient temperature without measured transfer”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-013. Why is a photograph of the connected chain insufficient by itself?

A. It proves all connectors have the specified torque

B. It automatically contradicts serialized calibration

C. It cannot establish any component identity

D. It does not establish hidden state settings or correction applicability

Answer: D. Visible assembly evidence does not fully establish electrical state and corrections. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: It does not establish hidden state settings or correction applicability.

Distinguishing consideration: compare this with option A, “It proves all connectors have the specified torque”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-014. Moving the reporting plane upstream across a lossy cable changes which interpretation?

A. No numerical or uncertainty term can change

B. The cable contribution and correction included in the reported result

C. Only the uncertainty label with no change in included path

D. Only the receiver's internal sample rate

Answer: B. A reference plane defines which transfer and noise contributions belong between it and the indication. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: The cable contribution and correction included in the reported result.

Distinguishing consideration: compare this with option A, “No numerical or uncertainty term can change”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-015. Which measurand is directly supported by a suitable conducted antenna-terminal injection?

A. Plane-wave power density in an arbitrary near field

B. The antenna's installed polarization response

C. Terminal-level response of the downstream chain

D. Incident field strength for every antenna orientation

Answer: C. Conducted injection does not exercise the antenna-to-field conversion.

Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: Terminal-level response of the downstream chain.

Distinguishing consideration: compare this with option A, “Plane-wave power density in an arbitrary near field”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-016. Which set is needed before converting antenna-terminal power to field strength?

A. Receiver attenuation setting and display units alone

B. Antenna conversion convention, geometry, polarization, loading and field region

C. Cable loss and room temperature alone

D. Antenna serial number and nominal frequency alone

Answer: B. The field-to-terminal relation has conditions beyond the receiver's conducted calibration. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: Antenna conversion convention, geometry, polarization, loading and field region.

Distinguishing consideration: compare this with option A, “Receiver attenuation setting and display units alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-017. Why should a near-field probe reading not automatically be reported as plane-wave power density?

A. The receiver gain becomes irrelevant in the near field

B. The probe output cannot be expressed as voltage

C. Any near-field measurement has exactly zero uncertainty

D. The plane-wave field relation may not describe the local field

Answer: D. The conversion must use a model appropriate to the field region and probe response. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

Why the selected alternative fits: The plane-wave field relation may not describe the local field.

Distinguishing consideration: compare this with option A, “The receiver gain becomes irrelevant in the near field”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Antennas and Field-to-Terminal Conversion.

Review: Chapter 13 — Antennas and Field-to-Terminal Conversion.

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V011-C13-MCQ-018. A factor calibrated for voltage across a 50 ohm load is applied to an open-circuit voltage estimate. What must be checked first?

A. Whether the indicated and correction levels use the same logarithmic reference

B. Whether the calibration uncertainty is reported as standard or expanded

C. Whether the downstream frequency response is adequately sampled

D. Whether the voltage convention and loading match the factor definition

Answer: D. Loaded and open-circuit voltages are different measurands; an ideal matched-source case can differ by a factor of two. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: Whether the voltage convention and loading match the factor definition.

Distinguishing consideration: compare this with option A, “Whether the indicated and correction levels use the same logarithmic reference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-019. Which distinction is essential when applying an antenna conversion?

A. Peak voltage versus RMS voltage only

B. Available power versus delivered power at the actual load

C. Mean power versus the number of report pages

D. Absolute frequency versus carrier offset only

Answer: B. Mismatch and loading determine whether available and delivered quantities coincide. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: Available power versus delivered power at the actual load.

Distinguishing consideration: compare this with option A, “Peak voltage versus RMS voltage only”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-020. Antenna rotation changes terminal power during a receiver-setting comparison. What has been confounded?

A. Receiver-state response with an unavoidable frequency-unit conversion

B. Only the antenna certificate date

C. Receiver-state response with polarization and geometry changes

D. Only the receiver's output impedance

Answer: C. Geometry must be held or documented when the purpose is to compare receiver states. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: Receiver-state response with polarization and geometry changes.

Distinguishing consideration: compare this with option A, “Receiver-state response with an unavoidable frequency-unit conversion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-021. For an intentional spatial field map, what is the appropriate treatment of antenna movement?

A. Treat every movement as an invalid experiment

B. Apply one undocumented orientation correction afterward

C. Record the position and orientation as part of each observation

D. Discard geometry once terminal power is known

Answer: C. Movement can be the experimental variable, but its state must remain traceable. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: Record the position and orientation as part of each observation.

Distinguishing consideration: compare this with option A, “Treat every movement as an invalid experiment”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-022. Why may placing a preamplifier near the antenna improve sensitivity through a long cable?

A. Its gain can reduce the input-equivalent influence of subsequent cable and receiver noise

B. It makes antenna mismatch irrelevant

C. It removes the cable's physical loss entirely

D. It prevents every blocker from entering the first active stage

Answer: A. Remote gain changes the downstream noise weighting but does not erase loss or loading limits. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why the selected alternative fits: Its gain can reduce the input-equivalent influence of subsequent cable and receiver noise.

Distinguishing consideration: compare this with option B, “It makes antenna mismatch irrelevant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-MCQ-023. A narrow channel filter is located after a broadband remote amplifier. Which risk remains?

A. The amplifier can respond only within the final channel bandwidth

B. The amplifier sees only the displayed in-channel power

C. The filter necessarily protects every upstream stage

D. Out-of-channel signals can overload the remote amplifier before filtering

Answer: D. The first active element sees signals admitted before the downstream filter. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why the selected alternative fits: Out-of-channel signals can overload the remote amplifier before filtering.

Distinguishing consideration: compare this with option A, “The amplifier can respond only within the final channel bandwidth”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-MCQ-024. Which amplifier property matters when receiver local-oscillator leakage could reach the antenna?

A. Forward gain alone

B. Reverse isolation

C. The amplifier's forward small-signal gain

D. Output display resolution alone

Answer: B. Limited reverse isolation can allow leakage to propagate backward and reradiate. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why the selected alternative fits: Reverse isolation.

Distinguishing consideration: compare this with option A, “Forward gain alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-MCQ-025. Adding a lossy preselector before a remote amplifier improves blocker rejection. What else must be reassessed?

A. The assembly's noise and desired-signal response including the preselector's loss and temperature

B. No other property because rejection improved

C. Only the final channel center-frequency correction

D. Only the downstream amplifier's catalog gain

Answer: A. The preceding passive loss can degrade sensitivity while reducing loading. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why the selected alternative fits: The assembly's noise and desired-signal response including the preselector's loss and temperature.

Distinguishing consideration: compare this with option B, “No other property because rejection improved”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-MCQ-026. Why is the supply voltage measured at a base unit insufficient to establish amplifier bias?

A. Cable resistance and protection elements can change the voltage at the remote device

B. The nominal supply voltage already includes every cable drop

C. A correct receiver supply guarantees the remote device voltage

D. RF gain uniquely determines the device's DC voltage

Answer: A. The device's actual electrical state must be verified at the relevant location. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why the selected alternative fits: Cable resistance and protection elements can change the voltage at the remote device.

Distinguishing consideration: compare this with option B, “The nominal supply voltage already includes every cable drop”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-MCQ-027. Which test extends bench stability evidence toward installed operation?

A. Comparing catalog gain values without connecting the assembly

B. Checking actual antenna, cable, load, bias and environmental states

C. Repeating only the original matched bench termination

D. Checking only the receiver-connector amplitude reference

Answer: B. Installation-dependent impedances and supply paths can change stability. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why the selected alternative fits: Checking actual antenna, cable, load, bias and environmental states.

Distinguishing consideration: compare this with option A, “Comparing catalog gain values without connecting the assembly”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-MCQ-028. A line appears after a remote amplifier is installed. Which observation alone proves self-oscillation?

A. A change in gain alone

B. The presence of a narrow line alone

C. None; alternate-load, bias and output observations are needed to discriminate causes

D. A changed baseline alone

Answer: C. Pickup, leakage and network-dependent responses can produce similar observations. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why the selected alternative fits: None; alternate-load, bias and output observations are needed to discriminate causes.

Distinguishing consideration: compare this with option A, “A change in gain alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-MCQ-029. Why retain a reference before and after a consequential assembly change?

A. To ensure every intervening defect can be corrected with one constant

B. To establish the external source identity

C. To bound demonstrated validity and detect changes affecting the observation interval

D. To eliminate the need for configuration records

Answer: C. Reference closure tests stability of the measurement path, not all possible mechanisms. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why the selected alternative fits: To bound demonstrated validity and detect changes affecting the observation interval.

Distinguishing consideration: compare this with option A, “To ensure every intervening defect can be corrected with one constant”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-MCQ-030. A closing reference fails after an unexplained intermittent event. Which action is supported?

A. Investigate and bound the affected interval before asserting validity

B. Apply the latest correction to every earlier observation automatically

C. Delete the failed reference because the opening one passed

D. Assume drift was linear without evidence

Answer: A. An unknown evolution cannot be repaired by an unsupported uniform correction. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why the selected alternative fits: Investigate and bound the affected interval before asserting validity.

Distinguishing consideration: compare this with option B, “Apply the latest correction to every earlier observation automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-MCQ-031. When may a drift correction across an interval be defensible?

A. Only when the receiver has no external components

B. Whenever two endpoints have different readings

C. When its evolution is understood and the correction is bounded with uncertainty

D. Whenever the operator expects slow drift

Answer: C. A model of the evolution is needed; endpoints alone do not establish arbitrary intervening behavior. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why the selected alternative fits: When its evolution is understood and the correction is bounded with uncertainty.

Distinguishing consideration: compare this with option A, “Only when the receiver has no external components”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-MCQ-032. What is one useful role of an attenuator in an assembled path?

A. Removing thermal noise from the path

B. Managing level and improving match while adding loss and thermal noise

C. Making amplifier compression impossible at all powers

D. Replacing all vector mismatch characterization

Answer: B. Its benefits and costs must be evaluated together. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why the selected alternative fits: Managing level and improving match while adding loss and thermal noise.

Distinguishing consideration: compare this with option A, “Removing thermal noise from the path”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-MCQ-033. What does a filter's admission characteristic primarily determine for a following vulnerable stage?

A. The antenna's certified polarization pattern

B. The identity of every interfering source

C. The exact internal waveform of every admitted burst

D. Which frequency-dependent signal levels reach that stage

Answer: D. Filter placement and rejection affect the stage's loading. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why the selected alternative fits: Which frequency-dependent signal levels reach that stage.

Distinguishing consideration: compare this with option A, “The antenna's certified polarization pattern”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-MCQ-034. Which splitter property can make one output load affect another output?

A. An unlimited power rating

B. Finite interport isolation

C. The printed nominal power ratio alone

D. Perfectly independent output ports

Answer: B. A real multiport network can couple its branches. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why the selected alternative fits: Finite interport isolation.

Distinguishing consideration: compare this with option A, “An unlimited power rating”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-MCQ-035. Which switch characteristic matters immediately after changing paths?

A. Only the previous path's noise floor

B. Only steady-state insertion loss

C. Only the nominal isolation in the unselected state

D. Transient behavior and settling, as well as path response

Answer: D. A valid measurement must account for state transitions rather than assume instantaneous settled response. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why the selected alternative fits: Transient behavior and settling, as well as path response.

Distinguishing consideration: compare this with option A, “Only the previous path's noise floor”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-MCQ-036. A passive network was characterized at low continuous-wave power. Which extrapolation needs separate evidence?

A. Its stated matched test planes

B. Its validity for high-power or pulsed operation

C. Its low-power frequency grid

D. Its recorded connector identities

Answer: B. Power dependence and nonlinear or transient behavior may exceed the characterized regime. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why the selected alternative fits: Its validity for high-power or pulsed operation.

Distinguishing consideration: compare this with option A, “Its stated matched test planes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-MCQ-037. A correction file describes a cable model but not the installed serialized cable and switches. What is missing?

A. Only the intended terminal reference impedance

B. A proof that decibels cannot be added

C. A requirement that every cable be lossless

D. Evidence that the correction represents this actual path

Answer: D. Nominal model data may not describe unit-specific or assembled behavior. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: Evidence that the correction represents this actual path.

Distinguishing consideration: compare this with option A, “Only the intended terminal reference impedance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-038. What does a network-analyzer insertion-loss measurement describe directly?

A. The measured path under its named source, load, planes, frequency and level conditions

B. Every installed common-mode coupling path

C. The receiver's added noise for all source impedances

D. The antenna's near-field conversion

Answer: A. A conducted two-port result has a bounded scope. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why the selected alternative fits: The measured path under its named source, load, planes, frequency and level conditions.

Distinguishing consideration: compare this with option B, “Every installed common-mode coupling path”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-MCQ-039. Why reverify transfer after reassembling nominally identical connectors?

A. Reassembly changes only the filename

B. Calibration files automatically measure every new connection

C. Changed reflection, torque, damage or strain can alter the actual path

D. Serialization guarantees exactly invariant response

Answer: C. Mechanical assembly can have electrical consequences. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why the selected alternative fits: Changed reflection, torque, damage or strain can alter the actual path.

Distinguishing consideration: compare this with option A, “Reassembly changes only the filename”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-MCQ-040. A pad improves return loss but reduces desired level. Which assessment is appropriate?

A. Declare unconditional improvement in every metric

B. Recalculate sensitivity and uncertainty including pad loss and physical temperature

C. Treat desired signal attenuation as an increase in sensitivity

D. Ignore pad noise because matching improved

Answer: B. A match improvement has costs that can matter to the total measurement. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why the selected alternative fits: Recalculate sensitivity and uncertainty including pad loss and physical temperature.

Distinguishing consideration: compare this with option A, “Declare unconditional improvement in every metric”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-MCQ-041. Where does intended coaxial transmission principally reside in the chapter's distinction?

A. Uniformly in every nearby conductor

B. Only on the exterior surface of the shield

C. Between the center conductor and the inside of the shield

D. Only through the equipment's protective earth

Answer: C. Exterior shield current can participate in a separate installed coupling path. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: Between the center conductor and the inside of the shield.

Distinguishing consideration: compare this with option A, “Uniformly in every nearby conductor”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-042. Why can excellent conducted insertion loss coexist with cable-movement sensitivity?

A. A matched cable cannot be part of an antenna structure

B. The conducted internal path and exterior installed coupling are different mechanisms

C. Good insertion loss proves the external field changed

D. A coaxial shield eliminates all outside current

Answer: B. A two-port match does not fully characterize the complete receiving structure. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: The conducted internal path and exterior installed coupling are different mechanisms.

Distinguishing consideration: compare this with option A, “A matched cable cannot be part of an antenna structure”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-043. What should accompany a common-mode treatment when it might change the desired path?

A. Immediate deletion of the untreated result

B. A declaration that all changed features are external transmissions

C. A remeasurement of intended-path transfer

D. An assumption that desired gain is unchanged

Answer: C. The intervention's effect on the desired response must be separated from other changes. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: A remeasurement of intended-path transfer.

Distinguishing consideration: compare this with option A, “Immediate deletion of the untreated result”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-044. A ferrite intervention changes a feature. Which statement is appropriately bounded?

A. The receiver's internal noise has been proved zero

B. The external emitter has been uniquely located

C. The exact current distribution has been uniquely measured

D. The feature is sensitive to the intervention, with impedance and geometry changes still possible

Answer: D. The treatment is evidence of sensitivity, not a unique mechanism proof.

Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: The feature is sensitive to the intervention, with impedance and geometry changes still possible.

Distinguishing consideration: compare this with option A, “The receiver's internal noise has been proved zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-045. Why is optical isolation not automatically an equivalent comparison?

A. It eliminates all need for reference observations

B. The optical path has its own gain, noise, bandwidth, timing and power-state behavior

C. It guarantees unchanged sensitivity at every frequency

D. Optical paths cannot carry any measurement information

Answer: B. Comparison strength depends on demonstrated capability for the question. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: The optical path has its own gain, noise, bandwidth, timing and power-state behavior.

Distinguishing consideration: compare this with option A, “It eliminates all need for reference observations”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-046. A weak feature disappears after replacing a conductive link with a much noisier optical path. What is the main limitation?

A. The disappearance uniquely proves conductive pickup

B. The antenna's field pattern must have become isotropic

C. The new path may lack detection capability for that feature

D. The optical path proves the original cable was defective

Answer: C. A disappearance under reduced sensitivity is inconclusive without capability matching. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: The new path may lack detection capability for that feature.

Distinguishing consideration: compare this with option A, “The disappearance uniquely proves conductive pickup”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-047. Which optical-isolation observation provides stronger discrimination?

A. No reference is measured in either configuration

B. Only the optical link's nominal bandwidth is recorded

C. The desired reference remains detectable and consistent while the anomalous feature changes

D. Both desired reference and feature disappear into a raised noise floor

Answer: C. Preserved relevant capability makes the intervention more informative.

Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: The desired reference remains detectable and consistent while the anomalous feature changes.

Distinguishing consideration: compare this with option A, “No reference is measured in either configuration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-048. What is accepted under the chapter's integrated-path approach?

A. A serialized assembly at stated planes, states and tested conditions

B. All future substitutions with equal catalog gain

C. The antenna independently of cable route and mounting

D. Every possible arrangement of the same component models

Answer: A. Acceptance scope follows the tested assembled measurement. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: A serialized assembly at stated planes, states and tested conditions.

Distinguishing consideration: compare this with option B, “All future substitutions with equal catalog gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-049. An accessory substitution changes phase response. What should happen before quantitative use?

A. Retain the old correction solely because connector types match

B. Recharacterize the affected path and its applicable correction

C. Change only the inventory list

D. Assume amplitude calibration also guarantees phase

Answer: B. A consequential substitution changes the scope of the existing calibration. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: Recharacterize the affected path and its applicable correction.

Distinguishing consideration: compare this with option A, “Retain the old correction solely because connector types match”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-050. Why should remote amplifiers be powered in the deployment state during reference sweeps?

A. A powered sweep eliminates every possible overload

B. The receiver correction file otherwise becomes a field factor

C. Their response can depend on the actual bias and control state

D. Active circuits are necessarily state independent

Answer: C. Acceptance should reproduce the relevant operating conditions. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: Their response can depend on the actual bias and control state.

Distinguishing consideration: compare this with option A, “A powered sweep eliminates every possible overload”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-051. Short-path and installed-path reference measurements disagree beyond their supported bounds. What comes first?

A. Attribute the difference immediately to a new external source

B. Average the two values and assign the mean as truth

C. Delete the short-path result

D. Resolve the path discrepancy before interpreting environmental observations

Answer: D. Unresolved measurement-path validity undermines the environmental inference. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: Resolve the path discrepancy before interpreting environmental observations.

Distinguishing consideration: compare this with option A, “Attribute the difference immediately to a new external source”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-052. At frequencies where installed match or dynamic range is inadequate, what belongs in the path record?

A. A statement that the instrument model guarantees validity

B. Explicit limitations on quantitative conclusions

C. Only the favorable parts of the frequency sweep

D. A uniform correction asserted without evidence

Answer: B. Acceptance must identify the frequency and condition boundaries.

Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: Explicit limitations on quantitative conclusions.

Distinguishing consideration: compare this with option A, “A statement that the instrument model guarantees validity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-053. Under Equation 25's matched far-field assumptions, what is available received power for 2 $\frac{mW}{m^2}$ incident density and 0.05 m^2 effective aperture?

A. 40 mW

B. 0.1 W

C. 10 mW

D. 0.1 mW

Answer: D. Multiplication gives 0.002 $\frac{W}{m^2}$ times 0.05 m^2 = 0.0001 W. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: 0.1 mW.

Distinguishing consideration: compare this with option A, “40 mW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-054. Which condition is explicitly required when using received power equals incident density times effective aperture as stated?

A. Unknown antenna loading with no mismatch allowance

B. Arbitrary near-field geometry without a probe model

C. Far-field matching with polarization accounted for

D. Any indoor multipath arrangement with a single scalar guarantee

Answer: C. The simple aperture relation is bounded by the stated antenna and field conditions. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: Far-field matching with polarization accounted for.

Distinguishing consideration: compare this with option A, “Unknown antenna loading with no mismatch allowance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-055. An indication is −80 dBm, downstream losses total 7 dB and downstream gains total 18 dB. What is the upstream corrected level?

A. −69 dBm

B. −91 dBm

C. −55 dBm

D. −105 dBm

Answer: B. The upstream level is indicated power plus loss minus gain: −80 + 7 − 18. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: −91 dBm.

Distinguishing consideration: compare this with option A, "−69 dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-056. Why are upstream correction terms frequency dependent?

A. Serialized identity alone establishes the response at unmeasured frequencies

B. A single-frequency calibration necessarily represents every nearby filter transition

C. The receiver's internal correction includes every external response

D. Path loss and gain can vary across frequency and state

Answer: D. The correction must describe the response at the measurement frequency and state. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: Path loss and gain can vary across frequency and state.

Distinguishing consideration: compare this with option A, “Serialized identity alone establishes the response at unmeasured frequencies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-057. Which term is not automatically removed by the scalar signed gain-and-loss correction?

A. The included calibrated amplifier gain

B. The included calibrated switch loss

C. Mismatch and its uncertainty

D. The included calibrated cable loss

Answer: C. Equation 26 does not silently solve all mismatch effects. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: Mismatch and its uncertainty.

Distinguishing consideration: compare this with option A, “The included calibrated amplifier gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-058. The chapter's antenna terminal is −92.0 dBm, loss is 6.4 dB and gain is 20.1 dB. What receiver indication is predicted?

A. −78.3 dBm

B. −65.5 dBm

C. −105.7 dBm

D. −118.5 dBm

Answer: A. Forward propagation subtracts loss and adds gain: −92.0 − 6.4 + 20.1.

Source: §13.13 Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7557)

Why the selected alternative fits: −78.3 dBm.

Distinguishing consideration: compare this with option B, "−65.5 dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-059. For a predicted −78.3 dBm indication and observed −70.0 dBm, what is the signed observed-minus-predicted discrepancy?

A. −8.3 dB

B. +8.3 dB

C. −13.7 dB

D. +13.7 dB

Answer: B. The observed reading is 8.3 dB higher, prompting investigation of the path and state. Source: §13.13 Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7557)

Why the selected alternative fits: +8.3 dB.

Distinguishing consideration: compare this with option A, "−8.3 dB"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-060. Which response best follows an unexplained 8.3 dB excess over the modeled indication?

A. Assign the full excess immediately to antenna gain

B. Check state, correction, overload and installed coupling

C. Report it as proof of a stronger external source

D. Subtract it permanently as a known calibration offset

Answer: B. The discrepancy identifies a validation problem, not a unique cause.

Source: §13.13 Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7557)

Why the selected alternative fits: Check state, correction, overload and installed coupling.

Distinguishing consideration: compare this with option A, “Assign the full excess immediately to antenna gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-061. A line remains with the antenna input terminated and shifts when bias-cable length changes. Which scope is first implicated?

A. A uniquely established self-oscillation mode

B. The installed active and bias path

C. Only the calibrated antenna field factor

D. Only the intended antenna's far-field reception

Answer: B. The controls implicate the path but leave multiple mechanisms to discriminate. Source: §13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7558)

Why the selected alternative fits: The installed active and bias path.

Distinguishing consideration: compare this with option A, “A uniquely established self-oscillation mode”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-062. Which follow-up is most useful for the chapter's bias-cable case?

A. Observe amplifier output separately while controlling load and bias

B. Apply a free-space antenna factor to the terminated input

C. Assume termination excludes all radiated pickup

D. Change the report's reference plane without new measurements

Answer: A. Independent output and selective electrical controls can separate competing mechanisms. Source: §13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7558)

Why the selected alternative fits: Observe amplifier output separately while controlling load and bias.

Distinguishing consideration: compare this with option B, “Apply a free-space antenna factor to the terminated input”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-063. What is the first stage of the constructed acceptance sequence?

A. Accept the complete path from total catalog gain

B. Verify the receiver at its own connector

C. Challenge common mode without checking desired response

D. Declare field calibration from component certificates

Answer: B. The sequence builds scope from receiver to assembled conducted path to installed field observation. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Verify the receiver at its own connector.

Distinguishing consideration: compare this with option A, “Accept the complete path from total catalog gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-064. After receiver-only verification, which test extends coverage to the remote amplifier and cable?

A. A second injection at the receiver connector

B. A conducted reference at the antenna-terminal plane

C. A software correction applied without a reference

D. A photograph of the active antenna

Answer: B. The reference must traverse the components being verified. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: A conducted reference at the antenna-terminal plane.

Distinguishing consideration: compare this with option A, “A second injection at the receiver connector”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-065. Which additional step is needed when a field-based conclusion is required?

A. A list of amplifier serial numbers alone

B. An installed reference observation with documented antenna geometry

C. A connector-level reference alone

D. A second calculation of total gain alone

Answer: B. The field conversion and installed geometry are not exercised by conducted checks alone. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: An installed reference observation with documented antenna geometry.

Distinguishing consideration: compare this with option A, “A list of amplifier serial numbers alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-066. A receiver-only reference passes but an installed field comparison fails. What follows?

A. The receiver pass does not isolate the failure to the receiver

B. The receiver must be the sole cause

C. The entire installed chain is accepted

D. The antenna certificate must be fraudulent

Answer: A. Each test covers a different scope; the failure requires localization.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: The receiver pass does not isolate the failure to the receiver.

Distinguishing consideration: compare this with option B, “The receiver must be the sole cause”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-067. What does the constructed record's blocker-transfer entry establish?

A. Only total integrated display noise

B. Only the gain at the desired signal frequency

C. Admitted levels at blocker frequencies before vulnerable stages

D. The identity of every blocker transmitter

Answer: C. Loading depends on the blocker path, which may differ from desired transfer. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Admitted levels at blocker frequencies before vulnerable stages.

Distinguishing consideration: compare this with option A, “Only total integrated display noise”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-068. A blocker raises measured noise while desired gain remains consistent. Which investigation is supported?

A. Inspect source spectrum and the reciprocal-mixing prediction

B. Treat all added noise as externally radiated at the desired frequency

C. Discard the unchanged gain reference

D. Assume gain compression has been uniquely proved

Answer: A. Stable gain and increased noise favor a different test route from gain-change cases. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Inspect source spectrum and the reciprocal-mixing prediction.

Distinguishing consideration: compare this with option B, “Treat all added noise as externally radiated at the desired frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-069. A blocker changes desired gain. What should be checked before trusting a quiet-state noise budget?

A. Gain control or compression

B. Only antenna polarization

C. The antenna's loaded-voltage convention

D. Only the passive cable's catalog temperature coefficient

Answer: A. The chain may no longer be in the linear state assumed by the noise budget. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Gain control or compression.

Distinguishing consideration: compare this with option B, “Only antenna polarization”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-070. Why retain raw output as well as applied corrections during assembly acceptance?

A. Because raw output and corrected input necessarily have equal numerical values

B. Because a corrected result cannot have a defined reference plane

C. To replace every independent input reference with a correction file

D. To allow the transfer calculation and correction ownership to be reconstructed

Answer: D. Both raw measurement and transformation are needed for an auditable result. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: To allow the transfer calculation and correction ownership to be reconstructed.

Distinguishing consideration: compare this with option A, “Because raw output and corrected input necessarily have equal numerical values”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-071. Which closure statement is strongest and justified?

A. One passing tone proves all noise and blocker conditions

B. All component certificates collectively prove every assembled behavior

C. Acceptance specifies tested planes, configuration, frequency and signal conditions

D. The same hardware is universally accepted for any installation

Answer: C. The conclusion must follow the actual tests and their bounded scope.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Acceptance specifies tested planes, configuration, frequency and signal conditions.

Distinguishing consideration: compare this with option A, “One passing tone proves all noise and blocker conditions”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-072. An installed configuration was unknown for one observation interval. How should the report treat it?

A. Identify the interval and limit claims depending on that state

B. Erase the interval from the configuration history

C. Assign the nearest known state without evidence

D. Treat unknown state as zero uncertainty

Answer: A. State uncertainty can prevent a quantitative claim even when later references pass. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Identify the interval and limit claims depending on that state.

Distinguishing consideration: compare this with option B, “Erase the interval from the configuration history”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-073. Why should a catalog sum not be treated as an assembled acceptance measurement?

A. Decibel arithmetic cannot represent cascade gain

B. Catalog data always overestimate every loss

C. A measurement is valid only when no components are passive

D. It does not test actual connections, states, loading or installed coupling

Answer: D. The numerical sum is a model whose applicability needs evidence.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: It does not test actual connections, states, loading or installed coupling.

Distinguishing consideration: compare this with option A, “Decibel arithmetic cannot represent cascade gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-074. A measured path includes a switch in position A; the experiment uses position B. What is required?

A. A second copy of the receiver's correction

B. A correction and validation applicable to position B

C. An assumption of equal phase because gain is similar

D. The position-A file with only its label changed

Answer: B. Switch paths can have distinct loss, phase, isolation and repeatability.

Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why the selected alternative fits: A correction and validation applicable to position B.

Distinguishing consideration: compare this with option A, “A second copy of the receiver's correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-MCQ-075. Why record connector torque in integrated acceptance?

A. Torque directly determines external field strength

B. Correct torque cancels all mismatch mathematically

C. Torque removes the need for reference sweeps

D. Connection state can affect repeatability and response

Answer: D. Mechanical connection control supports reproducible electrical behavior. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: Connection state can affect repeatability and response.

Distinguishing consideration: compare this with option A, “Torque directly determines external field strength”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-076. What comparison helps distinguish a long installed cable's contribution?

A. Two recordings with unknown amplifier states

B. Only two cable catalog loss curves

C. Unrelated environmental signals at different times

D. A suitable stable reference through short and installed paths with scope controlled

Answer: D. The comparison should retain a common reference and known configuration. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: A suitable stable reference through short and installed paths with scope controlled.

Distinguishing consideration: compare this with option A, “Two recordings with unknown amplifier states”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-077. How should antenna-terminal and installed-structure results be distinguished?

A. Use antenna-terminal wording regardless of cable pickup

B. Remove geometry from the report because it is inconvenient

C. Treat all cable response as known antenna gain

D. State which physical receiving structure and reference plane the observation represents

Answer: D. Installed conductors can contribute to reception beyond the intended sensing element. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

Why the selected alternative fits: State which physical receiving structure and reference plane the observation represents.

Distinguishing consideration: compare this with option A, “Use antenna-terminal wording regardless of cable pickup”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Common-Mode Current and Installed-Path Effects.

Review: Chapter 13 — Common-Mode Current and Installed-Path Effects.

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V011-C13-MCQ-078. An optical link removes a conductive return path but changes timing. Which claim needs fresh validation?

A. Any time-sensitive comparison relying on the original path delay or clock behavior

B. The passive assembly serial-number record

C. The previous path's connector-only loss

D. Only the previously accepted steady-state amplitude correction

Answer: A. Isolation does not preserve every metrological property automatically.

Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: Any time-sensitive comparison relying on the original path delay or clock behavior.

Distinguishing consideration: compare this with option B, “The passive assembly serial-number record”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-079. For a matched 50 ohm antenna convention, why could an open-circuit voltage substitution cause a 6.02 dB voltage-level discrepancy?

A. A factor-of-two voltage difference corresponds to 20 log10(2)

B. Open-circuit voltage is necessarily zero

C. The decibel convention changes from logarithmic to linear

D. A factor-of-two voltage difference is always 3.01 dB

Answer: A. This illustrates why voltage loading conventions must match; it is not a universal correction for unknown impedance. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: A factor-of-two voltage difference corresponds to 20 log10(2).

Distinguishing consideration: compare this with option B, “Open-circuit voltage is necessarily zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-MCQ-080. Under the stated aperture model, doubling incident density at fixed effective aperture does what?

A. Leaves received power unchanged

B. Halves effective aperture automatically

C. Quadruples available received power

D. Doubles available received power

Answer: D. The model is linear in incident power density at fixed conditions. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: Doubles available received power.

Distinguishing consideration: compare this with option A, “Leaves received power unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-081. An upstream level is −100 dBm, with 12 dB loss and 25 dB gain downstream. What indication follows in the linear scalar model?

A. −137 dBm

B. −63 dBm

C. −87 dBm

D. −113 dBm

Answer: C. Forward transfer adds gain and subtracts loss, giving a net +13 dB.

Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: −87 dBm.

Distinguishing consideration: compare this with option A, "−137 dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-082. Why should correction interpolation be recorded?

A. Interpolation makes calibration uncertainty identically zero

B. All response curves are exactly straight between measured frequencies

C. Only the number of stored decimal places matters

D. The frequency-specific correction depends on the chosen interpolation of measured data

Answer: D. The correction transformation must be reconstructable and appropriate to the sampled response. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: The frequency-specific correction depends on the chosen interpolation of measured data.

Distinguishing consideration: compare this with option A, “Interpolation makes calibration uncertainty identically zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-MCQ-083. Which effect can a bias tee introduce besides delivering DC?

A. An additional conductive or noise-coupling path

B. Elimination of remote supply variation

C. Automatic antenna impedance matching

D. Guaranteed suppression of every oscillator leakage path

Answer: A. Bias infrastructure is part of the installed electrical network. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why the selected alternative fits: An additional conductive or noise-coupling path.

Distinguishing consideration: compare this with option B, “Elimination of remote supply variation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-MCQ-084. Why can replacing a preamplifier with a passive through path be an ambiguous challenge?

A. It tests only the antenna's polarization

B. It changes desired gain and sensitivity as well as removing the active element

C. It necessarily leaves all noise and bandwidth unchanged

D. It proves all terminated-input lines are amplifier oscillations

Answer: B. A comparison must account for multiple properties changed by the substitution. Source: §13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7558)

Why the selected alternative fits: It changes desired gain and sensitivity as well as removing the active element.

Distinguishing consideration: compare this with option A, “It tests only the antenna's polarization”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-085. Why distinguish desired transfer from blocker transfer in the assembly record?

A. Every chain has identical gain at all frequencies

B. Desired gain alone specifies every upstream loading condition

C. Frequency-selective elements can pass the desired signal and blocker very differently

D. Blocker level matters only after the final channel filter

Answer: C. The levels reaching vulnerable stages require their own frequency-specific path analysis. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Frequency-selective elements can pass the desired signal and blocker very differently.

Distinguishing consideration: compare this with option A, “Every chain has identical gain at all frequencies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-086. What makes a conducted reference suitable for an acceptance test?

A. Known input at a named plane with uncertainty and applicable state control

B. A calibration file applied twice to obtain agreement

C. A signal whose level is guessed from the final indication

D. Any detectable environmental carrier with unknown variation

Answer: A. A reference must support the particular transfer claim independently of the measured output. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Known input at a named plane with uncertainty and applicable state control.

Distinguishing consideration: compare this with option B, “A calibration file applied twice to obtain agreement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-087. Which result can the same hardware legitimately support with different confidence?

A. A field conclusion stronger than all supporting geometry evidence

B. An unconditional universal receiver-quality score

C. A well-bounded conducted level and a more limited installed field estimate

D. Identical confidence for every measurand by hardware identity alone

Answer: C. The evidence and model applicability differ by measurand and tested scope. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: A well-bounded conducted level and a more limited installed field estimate.

Distinguishing consideration: compare this with option A, “A field conclusion stronger than all supporting geometry evidence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-088. If an accessory relocation changes common-mode behavior while nominal coaxial loss is unchanged, what follows?

A. The old installed acceptance necessarily remains complete

B. No field-based claim can ever be made again

C. Only the passive two-port correction needs review

D. The installed acceptance may need renewal despite similar conducted loss

Answer: D. Installed coupling is a separate relevant property of the configuration.

Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: The installed acceptance may need renewal despite similar conducted loss.

Distinguishing consideration: compare this with option A, “The old installed acceptance necessarily remains complete”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-089. Why preserve both untreated and treated observations in a common-mode comparison?

A. The untreated measurement can be reconstructed exactly from memory

B. Only the treated result is ever scientifically relevant

C. They document the actual intervention effect and support later alternative explanations

D. Keeping both automatically proves a unique source

Answer: C. The evidence is the bounded comparison, including its references and limitations. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: They document the actual intervention effect and support later alternative explanations.

Distinguishing consideration: compare this with option A, “The untreated measurement can be reconstructed exactly from memory”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-090. In a field-based acceptance report, which missing record most directly prevents reconstruction of the receiving geometry?

A. Antenna orientation, mounting and cable route

B. The receiver-connector correction uncertainty

C. The total number of calibration files

D. The remote amplifier's nominal output impedance

Answer: A. These geometric states affect field conversion and installed coupling.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Antenna orientation, mounting and cable route.

Distinguishing consideration: compare this with option B, “The receiver-connector correction uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-091. What separates a component certificate from an assembled acceptance conclusion?

A. The certificate supports a component's stated conditions; acceptance follows the tested arrangement

B. The acceptance conclusion can ignore component applicability

C. The certificate automatically validates every connected component

D. A component certificate is always irrelevant to uncertainty

Answer: A. Certificates contribute evidence but do not replace the assembled test.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: The certificate supports a component's stated conditions; acceptance follows the tested arrangement.

Distinguishing consideration: compare this with option B, “The acceptance conclusion can ignore component applicability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-092. Which response is appropriate when an acceptance challenge changes desired gain and an anomalous feature simultaneously?

A. Ignore the reference because only the anomaly matters

B. Assume equal detection capability from equal receiver model numbers

C. First account for the changed transfer and loading before interpreting the anomaly's disappearance

D. Conclude that the original anomaly was definitely an external signal

Answer: C. A changed reference exposes a confound in the challenge. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: First account for the changed transfer and loading before interpreting the anomaly's disappearance.

Distinguishing consideration: compare this with option A, “Ignore the reference because only the anomaly matters”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-093. What does a controlled cable-route intervention ideally preserve?

A. The desired observation geometry and a verified intended-path response

B. Every possible coupling path unchanged

C. An unrecorded position and unknown antenna orientation

D. Only the receiver's display scale

Answer: A. A useful selective comparison changes a defined opportunity while controlling the relevant response. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: The desired observation geometry and a verified intended-path response.

Distinguishing consideration: compare this with option B, “Every possible coupling path unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-094. Why is a single overall receiver-quality score not required by the constructed acceptance case?

A. All measured outcomes are interchangeable

B. One gain measurement determines every receiver property

C. Different reference outcomes direct mechanism-specific investigations with explicit scope

D. The chapter excludes numerical measurements

Answer: C. Desired gain, noise and route sensitivity answer different questions and should retain that distinction. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: Different reference outcomes direct mechanism-specific investigations with explicit scope.

Distinguishing consideration: compare this with option A, “All measured outcomes are interchangeable”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-095. An accepted arrangement is later used outside its tested environmental range. What is the appropriate conclusion?

A. Serialization alone guarantees identical response

B. All previous measurements become automatically invalid

C. The prior acceptance does not by itself establish validity in the new range

D. The original correction becomes exactly zero

Answer: C. The boundary of tested conditions must be respected and extended by evidence. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why the selected alternative fits: The prior acceptance does not by itself establish validity in the new range.

Distinguishing consideration: compare this with option A, “Serialization alone guarantees identical response”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-MCQ-096. Why include a before-and-after reference closure entry alongside an assembly inventory?

A. Reference timing is irrelevant once serial numbers are known

B. Inventory and closure are interchangeable records

C. A closure entry proves all external signals were stationary

D. It bounds when demonstrated transfer validity held, whereas inventory identifies what was connected

Answer: D. Hardware identity and temporal validity answer different reconstruction questions. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: It bounds when demonstrated transfer validity held, whereas inventory identifies what was connected.

Distinguishing consideration: compare this with option A, “Reference timing is irrelevant once serial numbers are known”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-097. In a linear scalar path, the receiver indicates −60 dBm and the net downstream gain is 44 dB. What is the upstream level?

A. −104 dBm

B. −44 dBm

C. −16 dBm

D. +104 dBm

Answer: A. Referring upstream subtracts the net downstream gain from the indication. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: −104 dBm.

Distinguishing consideration: compare this with option B, "−44 dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-MCQ-098. What must be retained when a path is accepted only for a bounded conducted measurement?

A. A universal zero-mismatch assumption

B. A claim that every field conversion is also accepted

C. The named plane, tested state, reference uncertainty and stated limitations

D. Only the nominal receiver bandwidth

Answer: C. A bounded conducted claim can be strong without implying untested installed behavior. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why the selected alternative fits: The named plane, tested state, reference uncertainty and stated limitations.

Distinguishing consideration: compare this with option A, “A universal zero-mismatch assumption”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-MCQ-099. Which evidence would strengthen a claim that an optical comparison preserved the relevant weak-signal capability?

A. An unchanged cable label

B. The optical link's advertised maximum data rate alone

C. A strong saturated reference visible in both paths

D. A known weak reference measured with compatible bandwidth, gain and noise in both paths

Answer: D. The reference should test the capability pertinent to the feature, not merely gross connectivity. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: A known weak reference measured with compatible bandwidth, gain and noise in both paths.

Distinguishing consideration: compare this with option A, “An unchanged cable label”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-MCQ-100. What is the role of the chapter's antenna and path equations in acceptance?

A. They establish unique causes for every discrepancy

B. They replace all state and uncertainty records

C. They make installed geometry irrelevant

D. They provide bounded predictions to test against configured measurements

Answer: D. Model predictions aid acceptance only with the declared assumptions and supporting tests. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why the selected alternative fits: They provide bounded predictions to test against configured measurements.

Distinguishing consideration: compare this with option A, “They establish unique causes for every discrepancy”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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Fill-in-the-Blank Questions

V011-C13-FIB-001. The record of serialized components and their order is the _____ record.

Answer: assembly. It reconstructs the actual connected network, distinct from state and numerical correction records. Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “assembly” completes the stated technical proposition.

Question context: The record of serialized components and their order is the _____ record

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-002. Gain, attenuation, filter and bias settings belong to the _____ record.

Answer: state. The transfer and noise law can depend on these operating conditions. Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “state” completes the stated technical proposition.

Question context: Gain, attenuation, filter and bias settings belong to the _____ record

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-003. The correction record must name the upstream and downstream reference _____.

Answer: planes. A correction's scope is defined by the physical boundaries it spans.

Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “planes” completes the stated technical proposition.

Question context: The correction record must name the upstream and downstream reference _____

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-004. An adapter already included in an assembly calibration must not be corrected a _____ time.

Answer: second. Duplicating a correction assigns the same physical contribution twice. Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “second” completes the stated technical proposition.

Question context: An adapter already included in an assembly calibration must not be corrected a _____ time

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-005. Equal total desired gain does not guarantee equal input-equivalent _____ when component order changes.

Answer: noise. Gain order changes the weighting of subsequent noise contributions. Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “noise” completes the stated technical proposition.

Question context: Equal total desired gain does not guarantee equal input-equivalent _____ when component order changes

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-006. A calibration ending at the receiver connector does not include the external _____ path.

Answer: antenna-to-receiver. The upstream cables, accessories and remote active stages need their own applicable evidence. Source: §13.1 Measurement Chain Ownership (p. 7536)

Why this term is required: “antenna-to-receiver” completes the stated technical proposition.

Question context: A calibration ending at the receiver connector does not include the external _____ path

Basis and qualification: Chapter 13 — Measurement Chain Ownership.

Review: Chapter 13 — Measurement Chain Ownership.

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V011-C13-FIB-007. The rule used to obtain corrections between measured frequency points is the _____ rule.

Answer: interpolation. It is part of the reconstructable numerical transformation.

Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “interpolation” completes the stated technical proposition.

Question context: The rule used to obtain corrections between measured frequency points is the _____ rule

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-008. A photograph can show assembly geometry but cannot alone establish electrical _____ settings.

Answer: state. Hidden gain, bias or switch conditions may not be visually recoverable. Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “state” completes the stated technical proposition.

Question context: A photograph can show assembly geometry but cannot alone establish electrical _____ settings

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-009. Changing a reporting plane changes which downstream transfer and noise _____ are included.

Answer: contributions. The result is defined relative to a physical boundary. Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “contributions” completes the stated technical proposition.

Question context: Changing a reporting plane changes which downstream transfer and noise _____ are included

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-010. Terminal power and incident field strength are different _____.

Answer: measurands. Field conversion requires antenna and geometric conditions in addition to conducted response. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “measurands” completes the stated technical proposition.

Question context: Terminal power and incident field strength are different _____

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-011. A voltage antenna factor must use the same loading _____ as the voltage to which it is applied.

Answer: convention. Loaded and open-circuit voltages are not interchangeable.

Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “convention” completes the stated technical proposition.

Question context: A voltage antenna factor must use the same loading _____ as the voltage to which it is applied

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-012. The field-conversion conditions include antenna pattern and wave _____.

Answer: polarization. Orientation and polarization determine coupling to the antenna. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

Why this term is required: “polarization” completes the stated technical proposition.

Question context: The field-conversion conditions include antenna pattern and wave _____

Basis and qualification: Chapter 13 — Antennas and Field-to-Terminal Conversion.

Review: Chapter 13 — Antennas and Field-to-Terminal Conversion.

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V011-C13-FIB-013. Near-field probe data cannot automatically use a _____-wave power-density relation.

Answer: plane. The local electric and magnetic field relation may differ from the assumed far-field model. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

Why this term is required: “plane” completes the stated technical proposition.

Question context: Near-field probe data cannot automatically use a _____-wave power-density relation

Basis and qualification: Chapter 13 — Antennas and Field-to-Terminal Conversion.

Review: Chapter 13 — Antennas and Field-to-Terminal Conversion.

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V011-C13-FIB-014. For a matched source, open-circuit voltage can be _____ times the loaded voltage.

Answer: two. This illustrates the loading convention difference; actual mismatched conditions need their own treatment. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “two” completes the stated technical proposition.

Question context: For a matched source, open-circuit voltage can be _____ times the loaded voltage

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-015. An antenna certificate's applicability must be checked against installed mounting and nearby _____.

Answer: conductors. The surroundings can alter coupling and response. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “conductors” completes the stated technical proposition.

Question context: An antenna certificate's applicability must be checked against installed mounting and nearby _____

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-016. During a receiver-state comparison, antenna position and orientation should be held or _____.

Answer: documented. Otherwise geometry changes can confound the receiver comparison. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “documented” completes the stated technical proposition.

Question context: During a receiver-state comparison, antenna position and orientation should be held or _____

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-017. During intentional spatial mapping, position is a recorded experimental _____.

Answer: variable. Movement is legitimate when it is part of the defined measurement. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “variable” completes the stated technical proposition.

Question context: During intentional spatial mapping, position is a recorded experimental _____

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-018. Available antenna power equals delivered load power only under the relevant _____ condition.

Answer: matching. Mismatch affects the delivered fraction and may require additional characterization. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “matching” completes the stated technical proposition.

Question context: Available antenna power equals delivered load power only under the relevant _____ condition

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-019. The antenna-to-terminal conversion depends on whether the observation is in the near or far _____ region.

Answer: field. A conversion must fit the physical field regime. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

Why this term is required: “field” completes the stated technical proposition.

Question context: The antenna-to-terminal conversion depends on whether the observation is in the near or far _____ region

Basis and qualification: Chapter 13 — Antennas and Field-to-Terminal Conversion.

Review: Chapter 13 — Antennas and Field-to-Terminal Conversion.

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V011-C13-FIB-020. Conducted injection at the antenna terminals bypasses the antenna's _____ conversion.

Answer: field-to-terminal. It tests downstream electrical response rather than the receiving geometry itself. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “field-to-terminal” completes the stated technical proposition.

Question context: Conducted injection at the antenna terminals bypasses the antenna's _____ conversion

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-021. Remote preamplifier gain can reduce the input-equivalent influence of downstream cable and receiver _____.

Answer: noise. It does not remove their physical noise or loss, but changes their referred weighting. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
Why this term is required: “noise” completes the stated technical proposition.
Question context: Remote preamplifier gain can reduce the input-equivalent influence of downstream cable and receiver _____
Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.
Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-022. A filter after the remote amplifier cannot protect that amplifier against all _____-of-channel signals.

Answer: out. Upstream loading occurs before the later frequency selection. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why this term is required: “out” completes the stated technical proposition.

Question context: A filter after the remote amplifier cannot protect that amplifier against all _____-of-channel signals

Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-023. The amplifier property limiting backward propagation of receiver leakage is reverse _____.

Answer: isolation. Finite reverse isolation can permit reradiation or coupling toward the antenna. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why this term is required: “isolation” completes the stated technical proposition.

Question context: The amplifier property limiting backward propagation of receiver leakage is reverse _____

Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-024. A lossy preselector ahead of an amplifier adds thermal noise associated with its physical _____.

Answer: temperature. The complete noise and signal budget must be reconsidered.

Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why this term is required: “temperature” completes the stated technical proposition.

Question context: A lossy preselector ahead of an amplifier adds thermal noise associated with its physical _____

Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-025. Remote amplifier bias must be checked after cable resistance and protection-element voltage _____.

Answer: drops. The local supply indication may not equal the device voltage. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why this term is required: “drops” completes the stated technical proposition.

Question context: Remote amplifier bias must be checked after cable resistance and protection-element voltage _____

Basis and qualification: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-FIB-026. A battery substitution can alter supply noise and conductive or grounding _____.

Answer: paths. A changed line does not uniquely identify ripple as its source. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why this term is required: “paths” completes the stated technical proposition.

Question context: A battery substitution can alter supply noise and conductive or grounding _____

Basis and qualification: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-FIB-027. The stability of an installed amplifier depends partly on the actual load _____.

Answer: impedance. Matched bench evidence does not cover every installed termination. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why this term is required: “impedance” completes the stated technical proposition.

Question context: The stability of an installed amplifier depends partly on the actual load _____

Basis and qualification: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-FIB-028. Before-and-after reference observations help bound the interval of demonstrated measurement _____.

Answer: validity. They reveal consequential transfer changes, though not every intermediate behavior. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why this term is required: “validity” completes the stated technical proposition.

Question context: Before-and-after reference observations help bound the interval of demonstrated measurement _____

Basis and qualification: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-FIB-029. An unexplained intermittent reference failure prevents assuming a simple _____ drift correction.

Answer: linear. The evolution must be supported, not inferred solely from a preferred model. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

Why this term is required: “linear” completes the stated technical proposition.

Question context: An unexplained intermittent reference failure prevents assuming a simple _____ drift correction

Basis and qualification: Chapter 13 — Remote amplification requires electrical and installed checks.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

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V011-C13-FIB-030. A bias tee adds a DC feed but also becomes part of the installed electrical _____.

Answer: network. Its coupling and noise behavior can affect the measurement.

Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why this term is required: “network” completes the stated technical proposition.

Question context: A bias tee adds a DC feed but also becomes part of the installed electrical _____

Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-031. Attenuation can improve match while reducing wanted signal and adding _____ noise.

Answer: thermal. The sensitivity cost accompanies the matching benefit. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why this term is required: “thermal” completes the stated technical proposition.

Question context: Attenuation can improve match while reducing wanted signal and adding _____ noise

Basis and qualification: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-FIB-032. A splitter's finite interport _____ allows branch interactions.

Answer: isolation. One output's load or energy can affect another output. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why this term is required: “isolation” completes the stated technical proposition.

Question context: A splitter's finite interport _____ allows branch interactions

Basis and qualification: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-FIB-033. For a switch, path changes may require time for transients to _____.

Answer: settle. The measurement must be taken in the valid operating state. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why this term is required: “settle” completes the stated technical proposition.

Question context: For a switch, path changes may require time for transients to _____

Basis and qualification: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-FIB-034. Unused network ports require the specified _____.

Answer: terminations. Their impedance can affect the selected-path response.

Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why this term is required: “terminations” completes the stated technical proposition.

Question context: Unused network ports require the specified _____

Basis and qualification: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-FIB-035. High-power or pulsed operation can fall outside a low-power _____ characterization.

Answer: continuous-wave. Power and transient behavior need evidence appropriate to the use case. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why this term is required: “continuous-wave” completes the stated technical proposition.

Question context: High-power or pulsed operation can fall outside a low-power _____ characterization

Basis and qualification: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-FIB-036. A correction tied only to a component model may fail to describe the actual _____ assembly.

Answer: serialized. Unit identity, order, connections and states matter. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why this term is required: “serialized” completes the stated technical proposition.

Question context: A correction tied only to a component model may fail to describe the actual _____ assembly

Basis and qualification: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-FIB-037. Connection torque and mechanical strain can affect electrical response and _____.

Answer: repeatability. Nominally identical reconnection need not reproduce exactly the same path. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why this term is required: “repeatability” completes the stated technical proposition.

Question context: Connection torque and mechanical strain can affect electrical response and _____

Basis and qualification: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-FIB-038. A network-analyzer insertion-loss result applies at its named source, load and reference _____.

Answer: planes. Those conditions define the directly characterized conducted path.

Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why this term is required: “planes” completes the stated technical proposition.

Question context: A network-analyzer insertion-loss result applies at its named source, load and reference _____

Basis and qualification: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-FIB-039. Source mismatch can change delivered noise and the receiver's own gain and added _____.

Answer: noise. The second effect can require vector or empirical receiver characterization. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why this term is required: “noise” completes the stated technical proposition.

Question context: Source mismatch can change delivered noise and the receiver's own gain and added _____

Basis and qualification: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-FIB-040. When unused-port loading changes the selected reading, the network may need a _____-port description.

Answer: multi. A fixed independent two-port assumption is then insufficient. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why this term is required: “multi” completes the stated technical proposition.

Question context: When unused-port loading changes the selected reading, the network may need a _____-port description

Basis and qualification: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-FIB-041. The intended coaxial field lies between the center conductor and the _____ of the shield.

Answer: inside. Exterior shield current belongs to a separate installed coupling opportunity. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “inside” completes the stated technical proposition.

Question context: The intended coaxial field lies between the center conductor and the _____ of the shield

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-042. Current on the _____ of the shield can make the cable part of the receiving structure.

Answer: outside. The installed network can respond beyond the nominal antenna element. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “outside” completes the stated technical proposition.

Question context: Current on the _____ of the shield can make the cable part of the receiving structure

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-043. A good internal insertion-loss result does not fully characterize installed _____-mode coupling.

Answer: common. Exterior current paths and surrounding conductors are not exhausted by the conducted test. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

Why this term is required: “common” completes the stated technical proposition.

Question context: A good internal insertion-loss result does not fully characterize installed _____-mode coupling

Basis and qualification: Chapter 13 — Common-Mode Current and Installed-Path Effects.

Review: Chapter 13 — Common-Mode Current and Installed-Path Effects.

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V011-C13-FIB-044. A ferrite intervention demonstrates sensitivity to the intervention, not a uniquely known current _____.

Answer: distribution. It can also change impedance, cable placement and environment. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “distribution” completes the stated technical proposition.

Question context: A ferrite intervention demonstrates sensitivity to the intervention, not a uniquely known current _____

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-045. After a potentially consequential common-mode treatment, remeasure the intended-path _____.

Answer: transfer. The desired response may have changed along with the anomaly.

Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “transfer” completes the stated technical proposition.

Question context: After a potentially consequential common-mode treatment, remeasure the intended-path _____

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-046. An optical link introduces its own gain, noise, bandwidth and _____ behavior.

Answer: timing. Electrical isolation does not preserve every measurement property automatically. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “timing” completes the stated technical proposition.

Question context: An optical link introduces its own gain, noise, bandwidth and _____ behavior

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-047. A weak feature's disappearance is inconclusive if the comparison path has inadequate detection _____.

Answer: capability. The path may simply be unable to reveal the feature. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “capability” completes the stated technical proposition.

Question context: A weak feature's disappearance is inconclusive if the comparison path has inadequate detection _____

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-048. An isolation comparison is stronger when a relevant desired _____ remains consistent.

Answer: reference. The reference supports comparable capability during the intervention. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “reference” completes the stated technical proposition.

Question context: An isolation comparison is stronger when a relevant desired _____ remains consistent

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-049. Installed acceptance includes the antenna orientation, mounting and cable _____.

Answer: route. Geometry affects field conversion and common-mode behavior.

Source: §13.11 Integrated Path Acceptance (p. 7554)

Why this term is required: “route” completes the stated technical proposition.

Question context: Installed acceptance includes the antenna orientation, mounting and cable _____

Basis and qualification: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-FIB-050. A consequential accessory substitution requires renewed characterization of the affected _____.

Answer: path. The previous correction and acceptance covered a different arrangement. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why this term is required: “path” completes the stated technical proposition.

Question context: A consequential accessory substitution requires renewed characterization of the affected _____

Basis and qualification: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-FIB-051. In the stated matched far-field model, received power equals incident power density times effective _____.

Answer: aperture. Equation 25 relates available power to the antenna's effective collecting area under bounded conditions. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: “aperture” completes the stated technical proposition.

Question context: In the stated matched far-field model, received power equals incident power density times effective _____

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-052. For 4 $\frac{\mu W}{m^2}$ incident density and 0.25 m^2 aperture, available power is _____ μW.

Answer: 1. The product is 4 times 0.25 = 1 μW under the stated model. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: "1" completes the stated technical proposition.

Question context: For 4 incident density and 0.25 aperture, available power is _____ μW

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-053. In the upstream correction equation, passive loss in dB is _____ to indicated dBm.

Answer: added. Loss is undone when referring a downstream reading upstream.

Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: “added” completes the stated technical proposition.

Question context: In the upstream correction equation, passive loss in dB is _____ to indicated dBm

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-054. In the same upstream correction, downstream gain in dB is _____ from indicated dBm.

Answer: subtracted. The downstream amplification is removed from the referred input level. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: “subtracted” completes the stated technical proposition.

Question context: In the same upstream correction, downstream gain in dB is _____ from indicated dBm

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-055. An indication of −72 dBm with 4 dB loss and 15 dB gain refers upstream to _____ dBm.

Answer: −83. Compute −72 + 4 − 15. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: "−83" completes the stated technical proposition.

Question context: An indication of −72 dBm with 4 dB loss and 15 dB gain refers upstream to _____ dBm

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-056. A −90 dBm input with 3 dB loss and 18 dB gain produces _____ dBm in the linear scalar model.

Answer: −75. Forward propagation gives −90 − 3 + 18. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: "−75" completes the stated technical proposition.

Question context: A −90 dBm input with 3 dB loss and 18 dB gain produces _____ dBm in the linear scalar model

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-057. The chapter's −92.0 dBm terminal, 6.4 dB loss and 20.1 dB gain predict _____ dBm.

Answer: −78.3. This is the stated hypothetical forward-transfer calculation. Source: §13.13 Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7557)

Why this term is required: "−78.3" completes the stated technical proposition.

Question context: The chapter's −92.0 dBm terminal, 6.4 dB loss and 20.1 dB gain predict _____ dBm

Basis and qualification: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-058. Observed −70.0 dBm minus predicted −78.3 dBm equals a discrepancy of _____ dB.

Answer: 8.3. The observed value is higher than the prediction. Source: §13.13 Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7557)

Why this term is required: “8.3” completes the stated technical proposition.

Question context: Observed −70.0 dBm minus predicted −78.3 dBm equals a discrepancy of _____ dB

Basis and qualification: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-059. Scalar gain-and-loss correction does not automatically remove _____.

Answer: mismatch. The chapter treats mismatch and uncertainty separately. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: “mismatch” completes the stated technical proposition.

Question context: Scalar gain-and-loss correction does not automatically remove _____

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-060. Gain and loss corrections must be appropriate to frequency and operating _____.

Answer: state. A valid file for another state or path is not automatically transferable.

Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: “state” completes the stated technical proposition.

Question context: Gain and loss corrections must be appropriate to frequency and operating _____

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-061. The constructed terminal-to-output desired gain is _____ dB.

Answer: 44. The −112 dBm to −68 dBm example defines that transfer. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “44” completes the stated technical proposition.

Question context: The constructed terminal-to-output desired gain is _____ dB

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-062. A −112 dBm reference followed by 44 dB gain predicts _____ dBm.

Answer: −68. The sum is −112 + 44. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: "−68" completes the stated technical proposition.

Question context: A −112 dBm reference followed by 44 dB gain predicts _____ dBm

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-063. A −60 dBm output behind 44 dB net gain refers to _____ dBm upstream.

Answer: −104. The input is output minus net gain. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: "−104" completes the stated technical proposition.

Question context: A −60 dBm output behind 44 dB net gain refers to _____ dBm upstream

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-064. Receiver-connector injection _____ the remote amplifier and cable.

Answer: bypasses. It cannot directly verify those upstream contributions. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “bypasses” completes the stated technical proposition.

Question context: Receiver-connector injection _____ the remote amplifier and cable

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-065. The three acceptance scopes progress from receiver, to assembled conducted path, to installed _____ observation.

Answer: field. Each step exercises additional parts of the measurement model.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “field” completes the stated technical proposition.

Question context: The three acceptance scopes progress from receiver, to assembled conducted path, to installed _____ observation

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-066. The assembled path reference should enter at the selected antenna-_____ plane.

Answer: terminal. That injection traverses the remote path being accepted. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “terminal” completes the stated technical proposition.

Question context: The assembled path reference should enter at the selected antenna-_____ plane

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-067. In the acceptance table, blocker transfer records levels admitted before _____ stages.

Answer: vulnerable. The stage sees the blocker after the applicable upstream transfer. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “vulnerable” completes the stated technical proposition.

Question context: In the acceptance table, blocker transfer records levels admitted before _____ stages

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-068. Noise rising with unchanged desired gain motivates checking source spectrum and reciprocal _____.

Answer: mixing. This outcome differs from a demonstrated gain change. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “mixing” completes the stated technical proposition.

Question context: Noise rising with unchanged desired gain motivates checking source spectrum and reciprocal _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-069. Desired gain changing under a blocker motivates tests of gain control or _____.

Answer: compression. The quiet linear-state noise budget may no longer apply.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “compression” completes the stated technical proposition.

Question context: Desired gain changing under a blocker motivates tests of gain control or _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-070. A cable-route-sensitive anomaly with stable conducted reference motivates examining installed _____.

Answer: coupling. The observation does not uniquely establish an external source.

Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “coupling” completes the stated technical proposition.

Question context: A cable-route-sensitive anomaly with stable conducted reference motivates examining installed _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-071. The closing report names frequencies and signal conditions actually _____.

Answer: challenged. Acceptance must follow the scope of performed tests. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “challenged” completes the stated technical proposition.

Question context: The closing report names frequencies and signal conditions actually _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-072. Unknown configuration intervals should be explicitly _____ in the report.

Answer: identified. Claims requiring known state must be limited for those intervals. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “identified” completes the stated technical proposition.

Question context: Unknown configuration intervals should be explicitly _____ in the report

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-073. Component certificates support the record, but acceptance belongs to the assembled _____ performed.

Answer: measurement. A component certificate is not an automatic assembled-path conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “measurement” completes the stated technical proposition.

Question context: Component certificates support the record, but acceptance belongs to the assembled _____ performed

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-074. In the bias-cable case, antenna-input termination still leaves the anomalous component _____.

Answer: present. That observation implicates alternatives to normal antenna-terminal reception. Source: §13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7558)

Why this term is required: “present” completes the stated technical proposition.

Question context: In the bias-cable case, antenna-input termination still leaves the anomalous component _____

Basis and qualification: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-075. Changing bias cable length shifts the component, implicating the active and _____ path.

Answer: bias. Multiple network-dependent mechanisms remain possible. Source: §13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7558)

Why this term is required: “bias” completes the stated technical proposition.

Question context: Changing bias cable length shifts the component, implicating the active and _____ path

Basis and qualification: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-076. Separate observation of the amplifier _____ can help discriminate the case's mechanisms.

Answer: output. It adds evidence outside the original receiver indication. Source: §13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7558)

Why this term is required: “output” completes the stated technical proposition.

Question context: Separate observation of the amplifier _____ can help discriminate the case's mechanisms

Basis and qualification: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-077. Removing a preamplifier changes sensitivity, so an anomaly's disappearance alone may be _____.

Answer: inconclusive. A reduction in detection capability can produce the same observation. Source: §13.14 Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7558)

Why this term is required: “inconclusive” completes the stated technical proposition.

Question context: Removing a preamplifier changes sensitivity, so an anomaly's disappearance alone may be _____

Basis and qualification: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-078. For a field-based result, an installed reference must retain documented antenna _____.

Answer: geometry. Orientation, mounting and surrounding conductors affect the conversion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “geometry” completes the stated technical proposition.

Question context: For a field-based result, an installed reference must retain documented antenna _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-079. The Table 13A record of before-and-after references is the _____ entry.

Answer: closure. It bounds the interval of demonstrated transfer validity. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “closure” completes the stated technical proposition.

Question context: The Table 13A record of before-and-after references is the _____ entry

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-080. A switched-path correction must identify the selected switch _____.

Answer: position. Different paths can have different loss, phase and isolation.

Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

Why this term is required: “position” completes the stated technical proposition.

Question context: A switched-path correction must identify the selected switch _____

Basis and qualification: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

Review: Chapter 13 — Attenuators, Filters, Splitters, and Switches.

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V011-C13-FIB-081. If a splitter branch termination changes, the corresponding network _____ has changed.

Answer: state. The selected path can depend on the consequential unused branches. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why this term is required: “state” completes the stated technical proposition.

Question context: If a splitter branch termination changes, the corresponding network _____ has changed

Basis and qualification: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-FIB-082. For a hypothetical matched loading convention, a factor-two voltage difference is approximately _____ dB.

Answer: 6.02. Voltage-level ratios use 20 log10 of the ratio. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “6.02” completes the stated technical proposition.

Question context: For a hypothetical matched loading convention, a factor-two voltage difference is approximately _____ dB

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-FIB-083. With 0.5 mW available received power and 0.1 m^2 effective aperture, the stated aperture model implies _____ $\frac{mW}{m^2}$ incident density.

Answer: 5. Divide available received power by aperture under the model conditions.

Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: "5" completes the stated technical proposition.

Question context: With 0.5 mW available received power and 0.1 effective aperture, the stated aperture model implies _____ incident density

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-084. At fixed aperture, a threefold incident power density produces a _____ increase in available received power.

Answer: threefold. Equation 25 is linear in density for unchanged conditions. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: “threefold” completes the stated technical proposition.

Question context: At fixed aperture, a threefold incident power density produces a _____ increase in available received power

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-085. An upstream −100 dBm input through 12 dB loss and 25 dB gain gives a net gain of _____ dB.

Answer: 13. The net desired transfer is 25 − 12. Source: §13.12 Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration (p. 7555)

Why this term is required: “13” completes the stated technical proposition.

Question context: An upstream −100 dBm input through 12 dB loss and 25 dB gain gives a net gain of _____ dB

Basis and qualification: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-FIB-086. Calibration of intended coaxial transmission does not by itself calibrate the complete installed receiving _____.

Answer: structure. External shield and nearby conductors can participate in reception. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

Why this term is required: “structure” completes the stated technical proposition.

Question context: Calibration of intended coaxial transmission does not by itself calibrate the complete installed receiving _____

Basis and qualification: Chapter 13 — Common-Mode Current and Installed-Path Effects.

Review: Chapter 13 — Common-Mode Current and Installed-Path Effects.

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V011-C13-FIB-087. Any branch that measurably changes the selected result belongs to the network's applicable _____ conditions.

Answer: boundary. Treating it as absent would omit an observed dependency.

Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

Why this term is required: “boundary” completes the stated technical proposition.

Question context: Any branch that measurably changes the selected result belongs to the network's applicable _____ conditions

Basis and qualification: Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-FIB-088. A preselector's blocker benefit should be assessed together with its desired-signal _____ cost.

Answer: loss. Rejection improvement is not a free sensitivity improvement. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why this term is required: “loss” completes the stated technical proposition.

Question context: A preselector's blocker benefit should be assessed together with its desired-signal _____ cost

Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-089. Remote amplifier input protection, compression and intercept describe aspects of its level-handling _____.

Answer: limits. Gain and noise figure alone do not characterize loading robustness.

Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why this term is required: “limits” completes the stated technical proposition.

Question context: Remote amplifier input protection, compression and intercept describe aspects of its level-handling _____

Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-090. Gain corrections cannot establish an unknown amplifier _____ state.

Answer: compression. A linear correction assumes a valid transfer regime; it cannot repair unknown nonlinear behavior. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “compression” completes the stated technical proposition.

Question context: Gain corrections cannot establish an unknown amplifier _____ state

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-091. For a useful cable-route comparison, the changed cable segment should be explicitly _____.

Answer: defined. Selective intervention requires a reconstructable physical change.

Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “defined” completes the stated technical proposition.

Question context: For a useful cable-route comparison, the changed cable segment should be explicitly _____

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-092. An optical path's advertised bandwidth alone does not establish its weak-signal _____.

Answer: sensitivity. Noise and gain also determine capability. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “sensitivity” completes the stated technical proposition.

Question context: An optical path's advertised bandwidth alone does not establish its weak-signal _____

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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V011-C13-FIB-093. Where the installed match or dynamic range is inadequate, the correction record should state quantitative _____.

Answer: limitations. A numerical correction cannot justify every condition. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why this term is required: “limitations” completes the stated technical proposition.

Question context: Where the installed match or dynamic range is inadequate, the correction record should state quantitative _____

Basis and qualification: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-FIB-094. An antenna-terminal conducted claim can be strong while the installed field claim remains more _____.

Answer: limited. The second measurand depends on additional geometry and coupling evidence. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “limited” completes the stated technical proposition.

Question context: An antenna-terminal conducted claim can be strong while the installed field claim remains more _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-095. An acceptance report must include the reference measurement's _____.

Answer: uncertainty. The comparison has finite evidential precision. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “uncertainty” completes the stated technical proposition.

Question context: An acceptance report must include the reference measurement's _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-096. The assembly order is needed to reconstruct noise weighting and stage _____.

Answer: loading. Equal aggregate desired gain does not supply this information.

Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “loading” completes the stated technical proposition.

Question context: The assembly order is needed to reconstruct noise weighting and stage _____

Basis and qualification: Chapter 13 — Define a complete path at named planes.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-FIB-097. Receiver-only verification followed by an installed failure does not uniquely locate the _____.

Answer: cause. The scopes differ and additional localization is required. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

Why this term is required: “cause” completes the stated technical proposition.

Question context: Receiver-only verification followed by an installed failure does not uniquely locate the _____

Basis and qualification: Chapter 13 — A constructed acceptance case for the assembled chain.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-FIB-098. A broadband remote amplifier can be exposed to energy rejected by the later narrow channel _____.

Answer: filter. The rejection occurs after the vulnerable stage. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

Why this term is required: “filter” completes the stated technical proposition.

Question context: A broadband remote amplifier can be exposed to energy rejected by the later narrow channel _____

Basis and qualification: Chapter 13 — External Preamplifiers, Bias, and Stability.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-FIB-099. Applying an old correction after a consequential component change requires evidence of its continued _____.

Answer: applicability. A matching filename or model number is insufficient. Source: §13.11 Integrated Path Acceptance (p. 7554)

Why this term is required: “applicability” completes the stated technical proposition.

Question context: Applying an old correction after a consequential component change requires evidence of its continued _____

Basis and qualification: Chapter 13 — Integrated Path Acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-FIB-100. A controlled common-mode comparison should retain both observations and supporting _____ evidence.

Answer: reference. The reference makes the capability and transfer comparison assessable. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “reference” completes the stated technical proposition.

Question context: A controlled common-mode comparison should retain both observations and supporting _____ evidence

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C13-ESSAY-001. Design a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish.

- Opening: Present a thesis that answers this precise question: Design a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish. Identify which evidence would falsify the proposed conclusion Source: §13.2 Define a complete path at named planes (p. 7537)
- Core terminology and scope: Define Design, traceable, three-part in the question's particular technical setting; explain how record, assembly, part differ if that distinction would change the analysis of "Design a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish" Source: §13.2 Define a complete path at named planes (p. 7537)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify assembly serials and order; electrical and environmental state; correction planes, frequency grid, interpolation and uncertainty Source: §13.2 Define a complete path at named planes (p. 7537)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish to the claimed result, following "13. Ten worked examples in integrated antenna-to-receiver measurements"; name the intermediate states and measurable outputs Source: §13.18 Ten worked examples in integrated antenna-to-receiver measurements (p. 7565)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish. Explain why a photograph or certificate alone cannot substitute for all three and show how a correction is assigned once Source: §13.18 Ten worked examples in integrated antenna-to-receiver measurements (p. 7565)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Remote amplification requires electrical and installed checks” that resolves the question about a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish; derive the relevant result with units and stated validity conditions Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish. Explain why a photograph or certificate alone cannot substitute for all three and show how a correction is assigned once Source: §13.2 Define a complete path at named planes (p. 7537)
- Worked application or illustrative case: Build a worked example of “a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish”, addressing this associated condition: Identify assembly serials and order; electrical and environmental state; correction planes, frequency grid,....

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Identify assembly serials and order; electrical and environmental state; correction planes, frequency grid,... Source: §13.18 Ten worked examples in integrated antenna-to-receiver measurements (p. 7565)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish”. Using “Remote amplification requires electrical and installed checks”, specify a discriminator and the result expected under each explanation Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish, including the effect of missing measurements and inconsistent operating conditions Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Scholarly synthesis and implications: Explain what the result about a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.2 Define a complete path at named planes (p. 7537)
- Closing: Conclude by answering “Design a traceable three-part record for an antenna-to-receiver assembly and explain what each part can and cannot establish” using only the demonstrated

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evidence; state the remaining decisive verification step Source: §13.2

Define a complete path at named planes (p. 7537)

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V011-C13-ESSAY-002. Explain how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior.

- Opening: Present a thesis that answers this precise question: Explain how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior. Identify which evidence would falsify the proposed conclusion Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Core terminology and scope: Define orders, desired, usable in the question's particular technical setting; explain how sensitivity, blocker, behavior differ if that distinction would change the analysis of "Explain how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior" Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate aggregate transfer from stage-dependent noise weighting and admitted levels Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior to the claimed result, following "A constructed acceptance case for the assembled chain"; name the intermediate states and measurable outputs Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how two

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component orders can have equal desired gain yet different usable sensitivity and blocker behavior. Discuss cable before versus after remote amplification, identify vulnerable stages, and require actual linear-state evidence rather than infer sensitivity from gain equality Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 13.X5. Selecting a remote preamplifier with a long feeder” that resolves the question about how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior; derive the relevant result with units and stated validity conditions Source: §13.18.5 Example 13.X5. Selecting a remote preamplifier with a long feeder (p. 7570)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior. Discuss cable before versus after remote amplification, identify vulnerable stages, and require actual linear-state evidence rather than infer sensitivity from gain equality Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Worked application or illustrative case: Build a worked example of “how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior”, addressing this associated condition: Separate aggregate transfer from stage-dependent noise weighting and admitted levels. Separate aggregate transfer from stage-dependent noise weighting and admitted levels Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior”. Using “Example 13.X5. Selecting a remote preamplifier with a long feeder”, specify a discriminator and the result expected under each explanation Source: §13.18.5 Example 13.X5. Selecting a remote preamplifier with a long feeder (p. 7570)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior, including the effect of missing measurements and inconsistent operating conditions Source: §13.2 Define a complete path at named planes (p. 7537)
- Scholarly synthesis and implications: Explain what the result about how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Closing: Conclude by answering “Explain how two component orders can have equal desired gain yet different usable sensitivity and blocker behavior” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-C13-ESSAY-003. Develop a field-strength reporting plan from antenna-terminal measurements.

- Opening: Present a thesis that answers this precise question: Develop a field-strength reporting plan from antenna-terminal measurements. Identify which evidence would falsify the proposed conclusion Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Core terminology and scope: Define field-strength, reporting, antenna-terminal in the question's particular technical setting; explain how measurements, measurement, evidence differ if that distinction would change the analysis of "Develop a field-strength reporting plan from antenna-terminal measurements" Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define terminal voltage or power convention, antenna factor or aperture, matching, polarization, direction, field region and installation Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a field-strength reporting plan from antenna-terminal measurements to the claimed result, following "Antennas and Field-to-Terminal Conversion"; name the intermediate states and measurable outputs Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a field-

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strength reporting plan from antenna-terminal measurements. Separate conducted downstream validation from field conversion and give limits for near-field or altered mounting conditions Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 13.X10. Why field strength cannot be inferred from connector power alone” that resolves the question about a field-strength reporting plan from antenna-terminal measurements; derive the relevant result with units and stated validity conditions Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a field-strength reporting plan from antenna-terminal measurements. Separate conducted downstream validation from field conversion and give limits for near-field or altered mounting conditions Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Worked application or illustrative case: Build a worked example of “a field-strength reporting plan from antenna-terminal measurements”, addressing this associated condition: Define terminal voltage or power convention, antenna factor or aperture, matching, polarization, direction,.... Define terminal voltage or power convention, antenna factor or aperture, matching, polarization, direction, field region and installation Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a field-strength reporting plan from antenna-terminal measurements”. Using “Example 13.X10. Why field strength cannot be inferred from connector power alone”, specify a discriminator and the result expected under each explanation Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a field-strength reporting plan from antenna-terminal measurements, including the effect of missing measurements and inconsistent operating conditions Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)
- Scholarly synthesis and implications: Explain what the result about a field-strength reporting plan from antenna-terminal measurements authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Closing: Conclude by answering “Develop a field-strength reporting plan from antenna-terminal measurements” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-C13-ESSAY-004. Analyze the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate.

- Opening: Present a thesis that answers this precise question: Analyze the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate. Identify which evidence would falsify the proposed conclusion Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Core terminology and scope: Define consequences, antenna, factor in the question's particular technical setting; explain how open-circuit, voltage, estimate differ if that distinction would change the analysis of "Analyze the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate" Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the two quantities and the source/load conditions Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate to the claimed result, following "13. Integrated reference-plane analysis and system-level acceptance"; name the intermediate states and measurable outputs Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate. Explain the possible factor-two voltage discrepancy in a matched case, its approximately 6.02 dB level effect, and why an unknown impedance cannot be repaired by assuming that factor universally Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Transducer gain, mismatch and antenna calibration at the installed measurement plane” that resolves the question about the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate; derive the relevant result with units and stated validity conditions Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate. Explain the possible factor-two voltage discrepancy in a matched case, its approximately 6.02 dB level effect, and why an unknown impedance cannot be repaired by assuming that factor universally Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Worked application or illustrative case: Build a worked example of “the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate”, addressing this associated condition: Define the two quantities and the source/load conditions. Define the

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two quantities and the source/load conditions Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate”. Using “Transducer gain, mismatch and antenna calibration at the installed measurement plane”, specify a discriminator and the result expected under each explanation Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate, including the effect of missing measurements and inconsistent operating conditions Source: §13.23 Controlled qualification of the installed network (p. 7589)
- Scholarly synthesis and implications: Explain what the result about the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Closing: Conclude by answering “Analyze the consequences of using a loaded-voltage antenna factor with an open-circuit voltage estimate” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-C13-ESSAY-005. Evaluate a proposal to add remote amplification ahead of a long cable.

- Opening: Present a thesis that answers this precise question: Evaluate a proposal to add remote amplification ahead of a long cable. Identify which evidence would falsify the proposed conclusion Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Core terminology and scope: Define proposal, remote, amplification in the question's particular technical setting; explain how ahead, long, cable differ if that distinction would change the analysis of "Evaluate a proposal to add remote amplification ahead of a long cable" Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain downstream-noise weighting, exposure of the first active stage to blockers, reverse leakage, gain and compression limits, bias and stability Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a proposal to add remote amplification ahead of a long cable to the claimed result, following "Remote amplification requires electrical and installed checks"; name the intermediate states and measurable outputs Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a proposal to add remote amplification ahead of a long cable. Compare preselection benefits with its loss and thermal-noise cost

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and identify the required assembled tests Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- Analytical framework: Identify the equation, calibration or evidential decision test in “A constructed acceptance case for the assembled chain” that resolves the question about a proposal to add remote amplification ahead of a long cable; derive the relevant result with units and stated validity conditions Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a proposal to add remote amplification ahead of a long cable. Compare preselection benefits with its loss and thermal-noise cost and identify the required assembled tests Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Worked application or illustrative case: Build a worked example of “a proposal to add remote amplification ahead of a long cable”, addressing this associated condition: Explain downstream-noise weighting, exposure of the first active stage to blockers, reverse leakage, gain and.... Explain downstream-noise weighting, exposure of the first active stage to blockers, reverse leakage, gain and compression limits, bias and stability Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a proposal to add remote amplification ahead of a long cable”. Using “A constructed acceptance case for the assembled chain”, specify a discriminator and the result expected

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under each explanation Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a proposal to add remote amplification ahead of a long cable, including the effect of missing measurements and inconsistent operating conditions Source: §13.18.5 Example 13.X5. Selecting a remote preamplifier with a long feeder (p. 7570)
- Scholarly synthesis and implications: Explain what the result about a proposal to add remote amplification ahead of a long cable authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Closing: Conclude by answering “Evaluate a proposal to add remote amplification ahead of a long cable” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

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V011-C13-ESSAY-006. Construct a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation.

- Opening: Present a thesis that answers this precise question: Construct a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation. Identify which evidence would falsify the proposed conclusion Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Core terminology and scope: Define Construct, discriminating, line in the question's particular technical setting; explain how appears, remote, battery differ if that distinction would change the analysis of "Construct a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation" Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Problem statement and purpose: Frame the actual measurement or decision in the question. List supply ripple, conductive coupling, instability and leakage as alternatives Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation to the claimed result, following "Define a complete path at named planes"; name the intermediate states and measurable outputs Source: §13.2 Define a complete path at named planes (p. 7537)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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discriminating test plan for a line that appears with a remote amplifier and changes during battery operation. Use selective bias and load controls, independent output observation and maintained desired references Source: §13.2 Define a complete path at named planes (p. 7537)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Separate the intended coaxial path from installed coupling” that resolves the question about a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation; derive the relevant result with units and stated validity conditions Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation. Explain why disappearance after a multi-property substitution is not a unique cause determination Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Worked application or illustrative case: Build a worked example of “a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation”, addressing this associated condition: List supply ripple, conductive coupling, instability and leakage as alternatives. List supply ripple, conductive coupling, instability and leakage as alternatives Source: §13.2 Define a complete path at named planes (p. 7537)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation”. Using “Separate the intended coaxial path from installed coupling”, specify a discriminator and the result expected under each explanation Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation, including the effect of missing measurements and inconsistent operating conditions Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Scholarly synthesis and implications: Explain what the result about a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Closing: Conclude by answering “Construct a discriminating test plan for a line that appears with a remote amplifier and changes during battery operation” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-C13-ESSAY-007. Specify an installed stability and drift acceptance plan for a remote amplifier.

- Opening: Present a thesis that answers this precise question: Specify an installed stability and drift acceptance plan for a remote amplifier. Identify which evidence would falsify the proposed conclusion Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Core terminology and scope: Define Specify, installed, stability in the question's particular technical setting; explain how drift, remote, amplifier differ if that distinction would change the analysis of "Specify an installed stability and drift acceptance plan for a remote amplifier" Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Include actual antenna and cable impedances, supply at the remote device, temperature and mechanical states Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Specify an installed stability and drift acceptance plan for a remote amplifier to the claimed result, following "External Preamplifiers, Bias, and Stability"; name the intermediate states and measurable outputs Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Specify

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an installed stability and drift acceptance plan for a remote amplifier. Use opening and closing references and consequential-change checks Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Define a complete path at named planes” that resolves the question about Specify an installed stability and drift acceptance plan for a remote amplifier; derive the relevant result with units and stated validity conditions Source: §13.2 Define a complete path at named planes (p. 7537)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Specify an installed stability and drift acceptance plan for a remote amplifier. Distinguish bounded understood drift correction from unexplained intermittent failures and identify affected intervals Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Worked application or illustrative case: Build a worked example of “Specify an installed stability and drift acceptance plan for a remote amplifier”, addressing this associated condition: Include actual antenna and cable impedances, supply at the remote device, temperature and mechanical states. Include actual antenna and cable impedances, supply at the remote device, temperature and mechanical states Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Specify an installed stability and drift acceptance plan for a remote amplifier”. Using “Define a complete path at named planes”, specify a discriminator and the result

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expected under each explanation Source: §13.2 Define a complete path at named planes (p. 7537)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Specify an installed stability and drift acceptance plan for a remote amplifier, including the effect of missing measurements and inconsistent operating conditions Source: §13.18.9 Example 13.X9. Intermittent common-mode cable response (p. 7574)
- Scholarly synthesis and implications: Explain what the result about Specify an installed stability and drift acceptance plan for a remote amplifier authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Closing: Conclude by answering “Specify an installed stability and drift acceptance plan for a remote amplifier” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-C13-ESSAY-008. Explain why a splitter or switch assembly may require more than independent scalar two-port corrections.

- Opening: Present a thesis that answers this precise question: Explain why a splitter or switch assembly may require more than independent scalar two-port corrections. Identify which evidence would falsify the proposed conclusion Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Core terminology and scope: Define splitter, switch, assembly in the question's particular technical setting; explain how require, scalar, corrections differ if that distinction would change the analysis of "Explain why a splitter or switch assembly may require more than independent scalar two-port corrections" Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Discuss finite isolation, unused terminations, reflections and branch loading Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a splitter or switch assembly may require more than independent scalar two-port corrections to the claimed result, following "Remote amplification requires electrical and installed checks"; name the intermediate states and measurable outputs Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a

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splitter or switch assembly may require more than independent scalar two-port corrections. Propose tests changing one termination while preserving intended response, record network state, and identify when vector or empirical multiport characterization is warranted Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Attenuators, Filters, Splitters, and Switches” that resolves the question about why a splitter or switch assembly may require more than independent scalar two-port corrections; derive the relevant result with units and stated validity conditions Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a splitter or switch assembly may require more than independent scalar two-port corrections. Propose tests changing one termination while preserving intended response, record network state, and identify when vector or empirical multiport characterization is warranted Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Worked application or illustrative case: Build a worked example of “why a splitter or switch assembly may require more than independent scalar two-port corrections”, addressing this associated condition: Discuss finite isolation, unused terminations, reflections and branch loading. Discuss finite isolation, unused terminations, reflections and branch loading Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a splitter or switch assembly may require more than independent scalar two-port corrections”. Using “Attenuators, Filters, Splitters, and Switches”, specify a discriminator and the result expected under each explanation Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a splitter or switch assembly may require more than independent scalar two-port corrections, including the effect of missing measurements and inconsistent operating conditions Source: §13.22 Additional study: vector reference planes, mismatch and multiport calibration in an installed receiving path (p. 7584)
- Scholarly synthesis and implications: Explain what the result about why a splitter or switch assembly may require more than independent scalar two-port corrections authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Closing: Conclude by answering “Explain why a splitter or switch assembly may require more than independent scalar two-port corrections” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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V011-C13-ESSAY-009. Evaluate a pad inserted to improve the receiver's input match.

- Opening: Present a thesis that answers this precise question: Evaluate a pad inserted to improve the receiver's input match. Identify which evidence would falsify the proposed conclusion Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Core terminology and scope: Define inserted, improve, receiver's in the question's particular technical setting; explain how input, match, measurement differ if that distinction would change the analysis of "Evaluate a pad inserted to improve the receiver's input match" Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Account for desired loss, physical-temperature noise and altered source impedance Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a pad inserted to improve the receiver's input match to the claimed result, following "Treat connections and unused branches as part of the network"; name the intermediate states and measurable outputs Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a pad inserted to improve the receiver's input match. Explain possible

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improvements in match and possible deterioration of sensitivity; require a complete uncertainty and noise comparison rather than a universal improvement claim Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Attenuators, Filters, Splitters, and Switches” that resolves the question about a pad inserted to improve the receiver's input match; derive the relevant result with units and stated validity conditions Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a pad inserted to improve the receiver's input match. Explain possible improvements in match and possible deterioration of sensitivity; require a complete uncertainty and noise comparison rather than a universal improvement claim Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Worked application or illustrative case: Build a worked example of “a pad inserted to improve the receiver's input match”, addressing this associated condition: Account for desired loss, physical-temperature noise and altered source impedance. Account for desired loss, physical-temperature noise and altered source impedance Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a pad inserted to improve the receiver's input match”. Using “Attenuators, Filters, Splitters, and Switches”,

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specify a discriminator and the result expected under each explanation Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a pad inserted to improve the receiver's input match, including the effect of missing measurements and inconsistent operating conditions Source: §13.2 Define a complete path at named planes (p. 7537)
- Scholarly synthesis and implications: Explain what the result about a pad inserted to improve the receiver's input match authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Closing: Conclude by answering “Evaluate a pad inserted to improve the receiver's input match” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

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V011-C13-ESSAY-010. Compare intended coaxial transmission with installed common-mode reception.

- Opening: Present a thesis that answers this precise question: Compare intended coaxial transmission with installed common-mode reception. Identify which evidence would falsify the proposed conclusion Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Core terminology and scope: Define intended, coaxial, transmission in the question's particular technical setting; explain how installed, common-mode, reception differ if that distinction would change the analysis of "Compare intended coaxial transmission with installed common-mode reception" Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Describe inside-shield fields and exterior-shield current paths involving antenna, enclosure and nearby conductors Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting intended coaxial transmission with installed common-mode reception to the claimed result, following "Common-Mode Current and Installed-Path Effects"; name the intermediate states and measurable outputs Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for intended

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coaxial transmission with installed common-mode reception. Explain why a matched insertion-loss result can coexist with route sensitivity, and design a controlled intervention with reference-transfer checks Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- Analytical framework: Identify the equation, calibration or evidential decision test in “13. Electromagnetic return paths, cables and the risk of false spatial inference” that resolves the question about intended coaxial transmission with installed common-mode reception; derive the relevant result with units and stated validity conditions Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)
- Evidence and method: Specify the native observations, control records and calculations that would resolve intended coaxial transmission with installed common-mode reception. Explain why a matched insertion-loss result can coexist with route sensitivity, and design a controlled intervention with reference-transfer checks Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Worked application or illustrative case: Build a worked example of “intended coaxial transmission with installed common-mode reception”, addressing this associated condition: Describe inside-shield fields and exterior-shield current paths involving antenna, enclosure and nearby.... Describe inside-shield fields and exterior-shield current paths involving antenna, enclosure and nearby conductors Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “intended coaxial transmission with installed common-mode reception”. Using “13. Electromagnetic return paths, cables and the risk of false spatial inference”, specify a discriminator and the result expected under each explanation Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to intended coaxial transmission with installed common-mode reception, including the effect of missing measurements and inconsistent operating conditions Source: §13.11 Integrated Path Acceptance (p. 7554)
- Scholarly synthesis and implications: Explain what the result about intended coaxial transmission with installed common-mode reception authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Closing: Conclude by answering “Compare intended coaxial transmission with installed common-mode reception” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-ESSAY-011. Assess a ferrite comparison offered as proof of a particular external source.

- Opening: Present a thesis that answers this precise question: Assess a ferrite comparison offered as proof of a particular external source. Identify which evidence would falsify the proposed conclusion Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Core terminology and scope: Define ferrite, offered, proof in the question's particular technical setting; explain how particular, external, source differ if that distinction would change the analysis of "Assess a ferrite comparison offered as proof of a particular external source" Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain which intervention sensitivity is observed and which alternative impedance, geometry and coupling changes remain Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a ferrite comparison offered as proof of a particular external source to the claimed result, following "Remote amplification requires electrical and installed checks"; name the intermediate states and measurable outputs Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a ferrite

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comparison offered as proof of a particular external source. Require recorded placement, preserved desired response and further selective evidence; state a bounded conclusion without claiming unique current distribution or source identity Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Keep field conversion separate from terminal power” that resolves the question about a ferrite comparison offered as proof of a particular external source; derive the relevant result with units and stated validity conditions Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a ferrite comparison offered as proof of a particular external source. Require recorded placement, preserved desired response and further selective evidence; state a bounded conclusion without claiming unique current distribution or source identity Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Worked application or illustrative case: Build a worked example of “a ferrite comparison offered as proof of a particular external source”, addressing this associated condition: Explain which intervention sensitivity is observed and which alternative impedance, geometry and coupling.... Explain which intervention sensitivity is observed and which alternative impedance, geometry and coupling changes remain Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a ferrite comparison offered as proof of a particular external source”. Using “Keep field conversion separate from terminal power”, specify a discriminator and the result expected under each explanation Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a ferrite comparison offered as proof of a particular external source, including the effect of missing measurements and inconsistent operating conditions Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)
- Scholarly synthesis and implications: Explain what the result about a ferrite comparison offered as proof of a particular external source authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Closing: Conclude by answering “Assess a ferrite comparison offered as proof of a particular external source” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-ESSAY-012. Develop a capability-matched optical-isolation comparison.

- Opening: Present a thesis that answers this precise question: Develop a capability-matched optical-isolation comparison. Identify which evidence would falsify the proposed conclusion Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Core terminology and scope: Define capability-matched, optical-isolation, terminology in the question's particular technical setting; explain how computational, relationships, theory differ if that distinction would change the analysis of "Develop a capability-matched optical-isolation comparison" Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Characterize optical gain, noise, bandwidth, timing and power state Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a capability-matched optical-isolation comparison to the claimed result, following "Common-Mode Current and Installed-Path Effects"; name the intermediate states and measurable outputs Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a capability-matched optical-isolation comparison. Use a relevant weak reference in both configurations, preserve untreated data and

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compare the anomaly Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- Analytical framework: Identify the equation, calibration or evidential decision test in “13. Verification, records and the interpretation of negative observations” that resolves the question about a capability-matched optical-isolation comparison; derive the relevant result with units and stated validity conditions Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a capability-matched optical-isolation comparison. Explain why a noisier path losing both reference and anomaly offers little discrimination Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Worked application or illustrative case: Build a worked example of “a capability-matched optical-isolation comparison”, addressing this associated condition: Characterize optical gain, noise, bandwidth, timing and power state. Characterize optical gain, noise, bandwidth, timing and power state Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a capability-matched optical-isolation comparison”. Using “13. Verification, records and the interpretation of negative observations”, specify a discriminator and the result expected under each explanation Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a capability-matched optical-isolation comparison, including the effect of missing measurements and inconsistent operating conditions Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Scholarly synthesis and implications: Explain what the result about a capability-matched optical-isolation comparison authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Closing: Conclude by answering “Develop a capability-matched optical-isolation comparison” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-ESSAY-013. Build an integrated path acceptance procedure that covers conducted and field-based claims separately.

- Opening: Present a thesis that answers this precise question: Build an integrated path acceptance procedure that covers conducted and field-based claims separately. Identify which evidence would falsify the proposed conclusion Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Core terminology and scope: Define Build, integrated, procedure in the question's particular technical setting; explain how covers, conducted, claims differ if that distinction would change the analysis of "Build an integrated path acceptance procedure that covers conducted and field-based claims separately" Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Progress from receiver connector to assembled antenna-terminal reference to installed antenna observation Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Build an integrated path acceptance procedure that covers conducted and field-based claims separately to the claimed result, following "Integrated Path Acceptance"; name the intermediate states and measurable outputs Source: §13.11 Integrated Path Acceptance (p. 7554)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Build an

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integrated path acceptance procedure that covers conducted and field-based claims separately. Define planes, serialized network, geometry, state, uncertainty and limits Source: §13.11 Integrated Path Acceptance (p. 7554)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Define a complete path at named planes” that resolves the question about Build an integrated path acceptance procedure that covers conducted and field-based claims separately; derive the relevant result with units and stated validity conditions Source: §13.2 Define a complete path at named planes (p. 7537)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Build an integrated path acceptance procedure that covers conducted and field-based claims separately. Explain why passing a narrower stage does not accept all broader scopes Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Worked application or illustrative case: Build a worked example of “Build an integrated path acceptance procedure that covers conducted and field-based claims separately”, addressing this associated condition: Progress from receiver connector to assembled antenna-terminal reference to installed antenna observation. Progress from receiver connector to assembled antenna-terminal reference to installed antenna observation Source: §13.11 Integrated Path Acceptance (p. 7554)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Build an integrated path acceptance

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procedure that covers conducted and field-based claims separately". Using "Define a complete path at named planes", specify a discriminator and the result expected under each explanation Source: §13.2 Define a complete path at named planes (p. 7537)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Build an integrated path acceptance procedure that covers conducted and field-based claims separately, including the effect of missing measurements and inconsistent operating conditions Source: §13.23 Controlled qualification of the installed network (p. 7589)
- Scholarly synthesis and implications: Explain what the result about Build an integrated path acceptance procedure that covers conducted and field-based claims separately authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Closing: Conclude by answering "Build an integrated path acceptance procedure that covers conducted and field-based claims separately" using only the demonstrated evidence; state the remaining decisive verification step Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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V011-C13-ESSAY-014. Derive and apply the signed scalar upstream correction for a chain containing loss and gain.

- Opening: Present a thesis that answers this precise question: Derive and apply the signed scalar upstream correction for a chain containing loss and gain. Identify which evidence would falsify the proposed conclusion Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)
- Core terminology and scope: Define apply, signed, scalar in the question's particular technical setting; explain how upstream, chain, containing differ if that distinction would change the analysis of "Derive and apply the signed scalar upstream correction for a chain containing loss and gain" Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain why losses are added and gains subtracted when referring an indication upstream Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting and apply the signed scalar upstream correction for a chain containing loss and gain to the claimed result, following "Define a complete path at named planes"; name the intermediate states and measurable outputs Source: §13.2 Define a complete path at named planes (p. 7537)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for and

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apply the signed scalar upstream correction for a chain containing loss and gain. Use a fully specified hypothetical case, identify frequency and state applicability, and keep mismatch and correction uncertainty explicit rather than absorbed into an unexplained residual Source: §13.2 Define a complete path at named planes (p. 7537)

- Analytical framework: Identify the equation, calibration or evidential decision test in “13. Verification, records and the interpretation of negative observations” that resolves the question about and apply the signed scalar upstream correction for a chain containing loss and gain; derive the relevant result with units and stated validity conditions Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Evidence and method: Specify the native observations, control records and calculations that would resolve and apply the signed scalar upstream correction for a chain containing loss and gain. Use a fully specified hypothetical case, identify frequency and state applicability, and keep mismatch and correction uncertainty explicit rather than absorbed into an unexplained residual Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)
- Worked application or illustrative case: Build a worked example of “and apply the signed scalar upstream correction for a chain containing loss and gain”, addressing this associated condition: Explain why losses are added and gains subtracted when referring an indication upstream. Explain why losses are added and gains

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subtracted when referring an indication upstream Source: §13.2 Define a complete path at named planes (p. 7537)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “and apply the signed scalar upstream correction for a chain containing loss and gain”. Using “13. Verification, records and the interpretation of negative observations”, specify a discriminator and the result expected under each explanation Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to and apply the signed scalar upstream correction for a chain containing loss and gain, including the effect of missing measurements and inconsistent operating conditions Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Scholarly synthesis and implications: Explain what the result about and apply the signed scalar upstream correction for a chain containing loss and gain authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)
- Closing: Conclude by answering “Derive and apply the signed scalar upstream correction for a chain containing loss and gain” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)

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V011-C13-ESSAY-015. Explain the bounded use of effective aperture to infer received power.

- Opening: Present a thesis that answers this precise question: Explain the bounded use of effective aperture to infer received power. Identify which evidence would falsify the proposed conclusion Source: §13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model (p. 7568)
- Core terminology and scope: Define bounded, effective, aperture in the question's particular technical setting; explain how infer, received, power differ if that distinction would change the analysis of "Explain the bounded use of effective aperture to infer received power" Source: §13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model (p. 7568)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the far-field, matching and polarization conditions for power density times aperture Source: §13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model (p. 7568)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the bounded use of effective aperture to infer received power to the claimed result, following "Antennas and Field-to-Terminal Conversion"; name the intermediate states and measurable outputs Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the bounded use of effective aperture to infer received power. Include a

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dimensional calculation, distinguish available from delivered power, and explain why near fields, multipath and changed geometry may require further treatment Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Keep field conversion separate from terminal power” that resolves the question about the bounded use of effective aperture to infer received power; derive the relevant result with units and stated validity conditions Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the bounded use of effective aperture to infer received power. Include a dimensional calculation, distinguish available from delivered power, and explain why near fields, multipath and changed geometry may require further treatment Source: §13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model (p. 7568)
- Worked application or illustrative case: Build a worked example of “the bounded use of effective aperture to infer received power”, addressing this associated condition: State the far-field, matching and polarization conditions for power density times aperture. State the far-field, matching and polarization conditions for power density times aperture Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the bounded use of effective aperture to infer received power”. Using “Keep field conversion separate from

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terminal power", specify a discriminator and the result expected under each explanation Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the bounded use of effective aperture to infer received power, including the effect of missing measurements and inconsistent operating conditions Source: §13.1 Measurement Chain Ownership (p. 7536)
- Scholarly synthesis and implications: Explain what the result about the bounded use of effective aperture to infer received power authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model (p. 7568)
- Closing: Conclude by answering "Explain the bounded use of effective aperture to infer received power" using only the demonstrated evidence; state the remaining decisive verification step Source: §13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model (p. 7568)

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V011-C13-ESSAY-016. Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication.

- Opening: Present a thesis that answers this precise question: Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication. Identify which evidence would falsify the proposed conclusion Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Core terminology and scope: Define Adjudicate, prediction, indication in the question's particular technical setting; explain how terminology, computational, relationships differ if that distinction would change the analysis of "Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication" Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Reconstruct −92.0 − 6.4 + 20.1 dBm and the +8.3 dB discrepancy Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication to the claimed result, following "13. Verification, records and the interpretation of negative observations"; name the intermediate states and measurable outputs Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication. Investigate gain state, correction ownership, overload and installed coupling with independent references Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Example 13.X8. Converting a correction uncertainty into a confidence statement” that resolves the question about Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication; derive the relevant result with units and stated validity conditions Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication. Do not turn the residual into an unconditional correction or source attribution Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Worked application or illustrative case: Build a worked example of “Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication”, addressing this associated condition: Reconstruct −92.0 − 6.4 + 20.1 dBm and the +8.3 dB discrepancy. Reconstruct −92.0 − 6.4 + 20.1 dBm and the +8.3 dB discrepancy Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication”. Using “Example 13.X8. Converting a correction uncertainty into a confidence statement”,

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specify a discriminator and the result expected under each explanation Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication, including the effect of missing measurements and inconsistent operating conditions Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Scholarly synthesis and implications: Explain what the result about Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Closing: Conclude by answering “Adjudicate the chapter's −78.3 dBm prediction versus −70.0 dBm indication” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-ESSAY-017. Analyze the terminated-input, bias-cable-dependent component in the hypothetical case.

- Opening: Present a thesis that answers this precise question: Analyze the terminated-input, bias-cable-dependent component in the hypothetical case. Identify which evidence would falsify the proposed conclusion Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Core terminology and scope: Define terminated-input, bias-cable-dependent, component in the question's particular technical setting; explain how hypothetical, case, measurement differ if that distinction would change the analysis of "Analyze the terminated-input, bias-cable-dependent component in the hypothetical case" Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain what termination and cable-length sensitivity constrain Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the terminated-input, bias-cable-dependent component in the hypothetical case to the claimed result, following "Remote amplification requires electrical and installed checks"; name the intermediate states and measurable outputs Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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terminated-input, bias-cable-dependent component in the hypothetical case. Retain competing active, conductive, radiated and leakage hypotheses; propose independent amplifier-output and controlled-load observations with adequate sensitivity Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- Analytical framework: Identify the equation, calibration or evidential decision test in “13. Verification, records and the interpretation of negative observations” that resolves the question about the terminated-input, bias-cable-dependent component in the hypothetical case; derive the relevant result with units and stated validity conditions Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the terminated-input, bias-cable-dependent component in the hypothetical case. State the strongest conclusion before those follow-ups Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Worked application or illustrative case: Build a worked example of “the terminated-input, bias-cable-dependent component in the hypothetical case”, addressing this associated condition: . Explain what termination and cable-length sensitivity constrain Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the terminated-input, bias-cable-dependent component in the hypothetical case”. Using “13. Verification, records and the interpretation of negative

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observations", specify a discriminator and the result expected under each explanation Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the terminated-input, bias-cable-dependent component in the hypothetical case, including the effect of missing measurements and inconsistent operating conditions Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)
- Scholarly synthesis and implications: Explain what the result about the terminated-input, bias-cable-dependent component in the hypothetical case authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Closing: Conclude by answering "Analyze the terminated-input, bias-cable-dependent component in the hypothetical case" using only the demonstrated evidence; state the remaining decisive verification step Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

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V011-C13-ESSAY-018. Develop an acceptance record for the −112 dBm to −68 dBm constructed transfer example.

- Opening: Present a thesis that answers this precise question: Develop an acceptance record for the −112 dBm to −68 dBm constructed transfer example. Identify which evidence would falsify the proposed conclusion Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Core terminology and scope: Define acceptance, record, constructed in the question's particular technical setting; explain how transfer, example, measurement differ if that distinction would change the analysis of "Develop an acceptance record for the −112 dBm to −68 dBm constructed transfer example" Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the 44 dB linear desired transfer and named planes Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an acceptance record for the −112 dBm to −68 dBm constructed transfer example to the claimed result, following "Define a complete path at named planes"; name the intermediate states and measurable outputs Source: §13.2 Define a complete path at named planes (p. 7537)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an acceptance record for the −112 dBm to −68 dBm constructed

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transfer example. Preserve input, output, correction and uncertainty; then separately address noise, blocker transfer and installed geometry Source: §13.2 Define a complete path at named planes (p. 7537)

- Analytical framework: Identify the equation, calibration or evidential decision test in “13. Verification, records and the interpretation of negative observations” that resolves the question about an acceptance record for the −112 dBm to −68 dBm constructed transfer example; derive the relevant result with units and stated validity conditions Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an acceptance record for the −112 dBm to −68 dBm constructed transfer example. Explain why receiver-connector injection bypasses the remote path Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Worked application or illustrative case: Build a worked example of “an acceptance record for the −112 dBm to −68 dBm constructed transfer example”, addressing this associated condition: Identify the 44 dB linear desired transfer and named planes. Identify the 44 dB linear desired transfer and named planes Source: §13.2 Define a complete path at named planes (p. 7537)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “an acceptance record for the −112 dBm to −68 dBm constructed transfer example”. Using “13. Verification, records and the interpretation of negative observations”, specify a

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discriminator and the result expected under each explanation Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an acceptance record for the −112 dBm to −68 dBm constructed transfer example, including the effect of missing measurements and inconsistent operating conditions Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)
- Scholarly synthesis and implications: Explain what the result about an acceptance record for the −112 dBm to −68 dBm constructed transfer example authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Closing: Conclude by answering “Develop an acceptance record for the −112 dBm to −68 dBm constructed transfer example” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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V011-C13-ESSAY-019. Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence.

- Opening: Present a thesis that answers this precise question: Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence. Identify which evidence would falsify the proposed conclusion Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Core terminology and scope: Define outcomes, constructed, case in the question's particular technical setting; explain how design, diagnostic, sequence differ if that distinction would change the analysis of "Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence" Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Problem statement and purpose: Frame the actual measurement or decision in the question. For unchanged gain with increased noise, inspect source spectrum and reciprocal mixing Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence to the claimed result, following "Remote amplification requires electrical and installed checks"; name the intermediate states and measurable outputs Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Use the

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three blocker-challenge outcomes in the constructed case to design a diagnostic sequence. Keep each conclusion conditional and preserve measured evidence Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Treat connections and unused branches as part of the network” that resolves the question about Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence; derive the relevant result with units and stated validity conditions Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence. Keep each conclusion conditional and preserve measured evidence Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Worked application or illustrative case: Build a worked example of “Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence”, addressing this associated condition: For unchanged gain with increased noise, inspect source spectrum and reciprocal mixing. For unchanged gain with increased noise, inspect source spectrum and reciprocal mixing Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Use the three blocker-challenge

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outcomes in the constructed case to design a diagnostic sequence". Using "Treat connections and unused branches as part of the network", specify a discriminator and the result expected under each explanation Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence, including the effect of missing measurements and inconsistent operating conditions Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)
- Scholarly synthesis and implications: Explain what the result about Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Closing: Conclude by answering "Use the three blocker-challenge outcomes in the constructed case to design a diagnostic sequence" using only the demonstrated evidence; state the remaining decisive verification step Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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V011-C13-ESSAY-020. Explain how a closing reference failure changes the report for an earlier observation interval.

- Opening: Present a thesis that answers this precise question: Explain how a closing reference failure changes the report for an earlier observation interval. Identify which evidence would falsify the proposed conclusion Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Core terminology and scope: Define closing, failure, changes in the question's particular technical setting; explain how report, earlier, observation differ if that distinction would change the analysis of "Explain how a closing reference failure changes the report for an earlier observation interval" Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish a known modeled drift from an unexplained failure, identify the interval and states at risk, and retain both reference observations Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how a closing reference failure changes the report for an earlier observation interval to the claimed result, following "Treat connections and unused branches as part of the network"; name the intermediate states and measurable outputs Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how a closing reference failure changes the report for an earlier observation interval. Discuss bounded corrections only where justified and avoid silently extending later calibration to unknown earlier conditions Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Remote amplification requires electrical and installed checks” that resolves the question about how a closing reference failure changes the report for an earlier observation interval; derive the relevant result with units and stated validity conditions Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how a closing reference failure changes the report for an earlier observation interval. Discuss bounded corrections only where justified and avoid silently extending later calibration to unknown earlier conditions Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Worked application or illustrative case: Build a worked example of “how a closing reference failure changes the report for an earlier observation interval”, addressing this associated condition: Distinguish a known modeled drift from an unexplained failure, identify the interval and states at risk, and.... Distinguish a known modeled drift from an unexplained failure, identify the interval and

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states at risk, and retain both reference observations Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how a closing reference failure changes the report for an earlier observation interval”. Using “Remote amplification requires electrical and installed checks”, specify a discriminator and the result expected under each explanation Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how a closing reference failure changes the report for an earlier observation interval, including the effect of missing measurements and inconsistent operating conditions Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Scholarly synthesis and implications: Explain what the result about how a closing reference failure changes the report for an earlier observation interval authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Closing: Conclude by answering “Explain how a closing reference failure changes the report for an earlier observation interval” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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V011-C13-ESSAY-021. Design a correction-file selection and change-control process for switched external paths.

- Opening: Present a thesis that answers this precise question: Design a correction-file selection and change-control process for switched external paths. Identify which evidence would falsify the proposed conclusion Source: §13.2 Define a complete path at named planes (p. 7537)
- Core terminology and scope: Define Design, selection, process in the question's particular technical setting; explain how switched, external, paths differ if that distinction would change the analysis of "Design a correction-file selection and change-control process for switched external paths" Source: §13.2 Define a complete path at named planes (p. 7537)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Key files to serial assembly, selected path, gain and bias state, temperature range, planes and frequency grid Source: §13.2 Define a complete path at named planes (p. 7537)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a correction-file selection and change-control process for switched external paths to the claimed result, following "Integrated Path Acceptance"; name the intermediate states and measurable outputs Source: §13.11 Integrated Path Acceptance (p. 7554)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a correction-file selection and change-control process for switched external paths. Record interpolation and uncertainty, prevent

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duplicate accessory corrections, and require renewed verification after consequential substitutions Source: §13.11 Integrated Path Acceptance (p. 7554)

- Analytical framework: Identify the equation, calibration or evidential decision test in “13. Verification, records and the interpretation of negative observations” that resolves the question about a correction-file selection and change-control process for switched external paths; derive the relevant result with units and stated validity conditions Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a correction-file selection and change-control process for switched external paths. Record interpolation and uncertainty, prevent duplicate accessory corrections, and require renewed verification after consequential substitutions Source: §13.2 Define a complete path at named planes (p. 7537)
- Worked application or illustrative case: Build a worked example of “a correction-file selection and change-control process for switched external paths”, addressing this associated condition: Key files to serial assembly, selected path, gain and bias state, temperature range, planes and frequency grid. Key files to serial assembly, selected path, gain and bias state, temperature range, planes and frequency grid Source: §13.11 Integrated Path Acceptance (p. 7554)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a correction-file selection and change-control process for switched external paths”. Using “13. Verification,

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records and the interpretation of negative observations", specify a discriminator and the result expected under each explanation Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a correction-file selection and change-control process for switched external paths, including the effect of missing measurements and inconsistent operating conditions Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Scholarly synthesis and implications: Explain what the result about a correction-file selection and change-control process for switched external paths authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.2 Define a complete path at named planes (p. 7537)
- Closing: Conclude by answering "Design a correction-file selection and change-control process for switched external paths" using only the demonstrated evidence; state the remaining decisive verification step Source: §13.2 Define a complete path at named planes (p. 7537)

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V011-C13-ESSAY-022. Evaluate the statement that a complete set of component certificates is equivalent to assembled calibration.

- Opening: Present a thesis that answers this precise question: Evaluate the statement that a complete set of component certificates is equivalent to assembled calibration. Identify which evidence would falsify the proposed conclusion Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Core terminology and scope: Define statement, complete, component in the question's particular technical setting; explain how certificates, equivalent, assembled differ if that distinction would change the analysis of "Evaluate the statement that a complete set of component certificates is equivalent to assembled calibration" Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain the certificates' real supporting role and gaps from connections, order, operating state, loading and installed coupling Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the statement that a complete set of component certificates is equivalent to assembled calibration to the claimed result, following "13. Controlled qualification of the installed network"; name the intermediate states and measurable outputs Source: §13.23 Controlled qualification of the installed network (p. 7589)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the statement that a complete set of component certificates is equivalent to assembled calibration. Define an assembled reference test whose conclusion is limited to the performed measurement and uncertainty Source: §13.23 Controlled qualification of the installed network (p. 7589)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Separate the intended coaxial path from installed coupling” that resolves the question about the statement that a complete set of component certificates is equivalent to assembled calibration; derive the relevant result with units and stated validity conditions Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the statement that a complete set of component certificates is equivalent to assembled calibration. Define an assembled reference test whose conclusion is limited to the performed measurement and uncertainty Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Worked application or illustrative case: Build a worked example of “the statement that a complete set of component certificates is equivalent to assembled calibration”, addressing this associated condition: Explain the certificates' real supporting role and gaps from connections, order, operating state, loading and.... Explain the certificates' real supporting role and gaps from connections, order,

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operating state, loading and installed coupling Source: §13.23 Controlled qualification of the installed network (p. 7589)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the statement that a complete set of component certificates is equivalent to assembled calibration”. Using “Separate the intended coaxial path from installed coupling”, specify a discriminator and the result expected under each explanation Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the statement that a complete set of component certificates is equivalent to assembled calibration, including the effect of missing measurements and inconsistent operating conditions Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)
- Scholarly synthesis and implications: Explain what the result about the statement that a complete set of component certificates is equivalent to assembled calibration authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Closing: Conclude by answering “Evaluate the statement that a complete set of component certificates is equivalent to assembled calibration” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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V011-C13-ESSAY-023. Explain how changing the reporting reference plane changes the meaning of a receiver result.

- Opening: Present a thesis that answers this precise question: Explain how changing the reporting reference plane changes the meaning of a receiver result. Identify which evidence would falsify the proposed conclusion Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Core terminology and scope: Define changing, reporting, reference in the question's particular technical setting; explain how plane, changes, meaning differ if that distinction would change the analysis of "Explain how changing the reporting reference plane changes the meaning of a receiver result" Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Track which gain, loss and noise contributions lie downstream of each plane, distinguish raw output from referred input, and show one hypothetical correction Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how changing the reporting reference plane changes the meaning of a receiver result to the claimed result, following "A constructed acceptance case for the assembled chain"; name the intermediate states and measurable outputs Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how changing the reporting reference plane changes the meaning of a receiver result. Discuss why field conversion is a separate additional model rather than merely another arbitrary plane label Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Analytical framework: Identify the equation, calibration or evidential decision test in "13. Integrated reference-plane analysis and system-level acceptance" that resolves the question about how changing the reporting reference plane changes the meaning of a receiver result; derive the relevant result with units and stated validity conditions Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how changing the reporting reference plane changes the meaning of a receiver result. Discuss why field conversion is a separate additional model rather than merely another arbitrary plane label Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Worked application or illustrative case: Build a worked example of "how changing the reporting reference plane changes the meaning of a receiver result", addressing this associated condition: Track which gain, loss and noise contributions lie downstream of each plane, distinguish raw output from.... Track which gain, loss and noise contributions lie downstream of each plane, distinguish raw

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output from referred input, and show one hypothetical... Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how changing the reporting reference plane changes the meaning of a receiver result”. Using “13. Integrated reference-plane analysis and system-level acceptance”, specify a discriminator and the result expected under each explanation Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how changing the reporting reference plane changes the meaning of a receiver result, including the effect of missing measurements and inconsistent operating conditions Source: §13.21 Vector reference-plane transport and installed-path uncertainty at antennas and cables (p. 7581)
- Scholarly synthesis and implications: Explain what the result about how changing the reporting reference plane changes the meaning of a receiver result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Closing: Conclude by answering “Explain how changing the reporting reference plane changes the meaning of a receiver result” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-C13-ESSAY-024. Develop a reporting approach for frequencies where the installed path has inadequate match or dynamic range.

- Opening: Present a thesis that answers this precise question: Develop a reporting approach for frequencies where the installed path has inadequate match or dynamic range. Identify which evidence would falsify the proposed conclusion Source: §13.11 Integrated Path Acceptance (p. 7554)
- Core terminology and scope: Define reporting, approach, installed in the question's particular technical setting; explain how inadequate, match, dynamic differ if that distinction would change the analysis of "Develop a reporting approach for frequencies where the installed path has inadequate match or dynamic range" Source: §13.11 Integrated Path Acceptance (p. 7554)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify tested ranges, state-specific limitations and the effect on quantitative claims Source: §13.11 Integrated Path Acceptance (p. 7554)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reporting approach for frequencies where the installed path has inadequate match or dynamic range to the claimed result, following "13. Verification, records and the interpretation of negative observations"; name the intermediate states and measurable outputs Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a reporting approach for frequencies where the installed path has inadequate match or dynamic range. Retain usable bounded results, avoid unsupported correction extrapolation, and describe what new characterization would be needed to extend acceptance Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Transducer gain, mismatch and antenna calibration at the installed measurement plane" that resolves the question about a reporting approach for frequencies where the installed path has inadequate match or dynamic range; derive the relevant result with units and stated validity conditions Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reporting approach for frequencies where the installed path has inadequate match or dynamic range. Retain usable bounded results, avoid unsupported correction extrapolation, and describe what new characterization would be needed to extend acceptance Source: §13.11 Integrated Path Acceptance (p. 7554)
- Worked application or illustrative case: Build a worked example of "a reporting approach for frequencies where the installed path has inadequate match or dynamic range", addressing this associated condition: Identify tested ranges, state-specific limitations and the effect on quantitative claims. Identify tested ranges, state-specific

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limitations and the effect on quantitative claims Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a reporting approach for frequencies where the installed path has inadequate match or dynamic range”. Using “Transducer gain, mismatch and antenna calibration at the installed measurement plane”, specify a discriminator and the result expected under each explanation Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reporting approach for frequencies where the installed path has inadequate match or dynamic range, including the effect of missing measurements and inconsistent operating conditions Source: §13.23 Controlled qualification of the installed network (p. 7589)
- Scholarly synthesis and implications: Explain what the result about a reporting approach for frequencies where the installed path has inadequate match or dynamic range authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.11 Integrated Path Acceptance (p. 7554)
- Closing: Conclude by answering “Develop a reporting approach for frequencies where the installed path has inadequate match or dynamic range” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.11 Integrated Path Acceptance (p. 7554)

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V011-C13-ESSAY-025. Explain why a successful desired-transfer test alone cannot close the full assembled-path acceptance.

- Opening: Present a thesis that answers this precise question: Explain why a successful desired-transfer test alone cannot close the full assembled-path acceptance. Identify which evidence would falsify the proposed conclusion Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Core terminology and scope: Define successful, desired-transfer, test in the question's particular technical setting; explain how close, full, acceptance differ if that distinction would change the analysis of "Explain why a successful desired-transfer test alone cannot close the full assembled-path acceptance" Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate desired transfer, noise, blocker loading, state stability and field coupling Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a successful desired-transfer test alone cannot close the full assembled-path acceptance to the claimed result, following "13. Integrated reference-plane analysis and system-level acceptance"; name the intermediate states and measurable outputs Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a

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successful desired-transfer test alone cannot close the full assembled-path acceptance. Use the constructed acceptance table to assign evidence to each and identify what an otherwise correct displayed reference cannot establish Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Antennas and Field-to-Terminal Conversion” that resolves the question about why a successful desired-transfer test alone cannot close the full assembled-path acceptance; derive the relevant result with units and stated validity conditions Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a successful desired-transfer test alone cannot close the full assembled-path acceptance. Use the constructed acceptance table to assign evidence to each and identify what an otherwise correct displayed reference cannot establish Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Worked application or illustrative case: Build a worked example of “why a successful desired-transfer test alone cannot close the full assembled-path acceptance”, addressing this associated condition: Separate desired transfer, noise, blocker loading, state stability and field coupling. Separate desired transfer, noise, blocker loading, state stability and field coupling Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a successful desired-transfer test alone cannot close the full assembled-path acceptance”. Using “Antennas and Field-to-Terminal Conversion”, specify a discriminator and the result expected under each explanation Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a successful desired-transfer test alone cannot close the full assembled-path acceptance, including the effect of missing measurements and inconsistent operating conditions Source: §13.11 Integrated Path Acceptance (p. 7554)
- Scholarly synthesis and implications: Explain what the result about why a successful desired-transfer test alone cannot close the full assembled-path acceptance authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Closing: Conclude by answering “Explain why a successful desired-transfer test alone cannot close the full assembled-path acceptance” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C13-DISCUSSION-001. A team wants to accept an installed chain because every component has an in-date certificate. What assembled evidence should you request?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team wants to accept an installed chain because every component has an in-date certificate. What assembled evidence should you request?” Put this particular dispute to the panel: A team wants to accept an installed chain because every component has an in-date certificate. What assembled evidence should you request. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 02. Student A, terminology and scope: Agree the operational meanings of accept, installed, chain and certificate, assembled, request in “A team wants to accept an installed chain because every component has an in-date certificate. What assembled evidence should you request”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.23 Controlled qualification of the installed network (p. 7589)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team wants to accept an installed chain because every component has an in-date certificate; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Explain connection, loading and coupling gaps; retain the certificates as support while limiting acceptance to tested conditions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team wants to accept an installed chain because every component has an in-date certificate; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Explain connection, loading and coupling gaps; retain the certificates as support while limiting acceptance to tested conditions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Ask for the actual serial order, electrical state, correction ownership and named-plane reference measurements Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A team wants to accept an installed chain because every component has an in-date certificate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team wants to accept an installed chain because every component has an in-date certificate; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team wants to accept an installed chain because every component has an in-date certificate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team wants to accept an installed chain because every component has an in-date certificate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team wants to accept an installed chain because every component

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has an in-date certificate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team wants to accept an installed chain because every component has an in-date certificate. Explain connection, loading and coupling gaps; retain the certificates as support while limiting acceptance to tested conditions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team wants to accept an installed chain because every component has an in-date certificate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team wants to accept an installed chain because every component has an in-date certificate. Explain connection, loading and coupling gaps; retain the certificates as support while limiting acceptance to tested conditions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team wants to accept an installed chain because every component has an in-date certificate and What assembled evidence should you request; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team wants to accept an installed chain because every component has an in-date certificate”, addressing “What assembled evidence should you request”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team wants to accept an installed chain because every component has an in-date certificate. What assembled evidence should you request”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team wants to accept an installed chain because every component has an in-date certificate. What assembled evidence should you request”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.23 Controlled qualification of the installed network (p. 7589)

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V011-C13-DISCUSSION-002. Two technicians propose different component orders with the same catalog gain. How should the choice be evaluated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two technicians propose different component orders with the same catalog gain. How should the choice be evaluated?” Put this particular dispute to the panel: Two technicians propose different component orders with the same catalog gain. How should the choice be evaluated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 02. Student A, terminology and scope: Agree the operational meanings of component, orders, catalog and gain, choice, evaluated in “Two technicians propose different component orders with the same catalog gain. How should the choice be evaluated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two technicians propose different component orders with the same catalog gain; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “External Preamplifiers, Bias, and Stability”. Avoid deciding solely from the equal gain sum; identify preselection and remote-bias tradeoffs Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two technicians propose different component orders with the same catalog gain; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “External Preamplifiers, Bias, and Stability”. Avoid deciding solely from the equal gain sum; identify preselection and remote-bias tradeoffs Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare noise weighting and blocker levels at vulnerable stages, then verify actual desired transfer and linear state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two technicians propose different component orders with the same catalog gain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two technicians propose different component orders with the same catalog gain; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two technicians propose different component orders with the same catalog gain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two technicians propose different component orders with the same catalog gain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two technicians propose different component orders with the same catalog gain: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two technicians propose different component orders with the same catalog gain. Avoid deciding solely from the equal gain sum; identify preselection and remote-bias tradeoffs Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two technicians propose different component orders with the same catalog gain, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two technicians propose different component orders with the same catalog gain. Avoid deciding solely from the equal gain sum; identify preselection and remote-bias tradeoffs

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Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two technicians propose different component orders with the same catalog gain and How should the choice be evaluated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.2 Define a complete path at named planes (p. 7537)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two technicians propose different component orders with the same catalog gain”, addressing “How should the choice be evaluated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two technicians propose different component orders with the same catalog gain. How should the choice be evaluated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two technicians propose different component orders with the same catalog gain. How should the choice be evaluated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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V011-C13-DISCUSSION-003. A field map changes after the antenna cable is rerouted. How would you separate an environmental change from installed-path sensitivity?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A field map changes after the antenna cable is rerouted. How would you separate an environmental change from installed-path sensitivity?” Put this particular dispute to the panel: A field map changes after the antenna cable is rerouted. How would you separate an environmental change from installed-path sensitivity. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 02. Student A, terminology and scope: Agree the operational meanings of field, antenna, cable and rerouted, environmental, sensitivity in “A field map changes after the antenna cable is rerouted. How would you separate an environmental change from installed-path sensitivity”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A field map changes after the antenna cable is rerouted; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Separate the intended coaxial path from installed coupling”. Recognize that routing itself can alter the local environment and avoid unique attribution Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A field map changes after the

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antenna cable is rerouted; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Separate the intended coaxial path from installed coupling”. Recognize that routing itself can alter the local environment and avoid unique attribution Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reproduce a documented route intervention while retaining intended geometry and reference response, preserve both observations, and check exterior-shield coupling Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A field map changes after the antenna cable is rerouted: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A field map changes after the antenna cable is rerouted; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A field map changes after the antenna cable is rerouted: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A field map changes after the antenna cable is rerouted, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A field map changes after the antenna cable is rerouted: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A field map changes after the antenna cable is rerouted. Recognize that routing itself can alter the local environment and avoid unique attribution Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A field map changes after the antenna cable is rerouted, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A field map changes after the antenna cable is rerouted. Recognize that routing itself can alter the local environment and avoid unique attribution Respond point by point to

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Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A field map changes after the antenna cable is rerouted and How would you separate an environmental change from installed-path sensitivity; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A field map changes after the antenna cable is rerouted”, addressing “How would you separate an environmental change from installed-path sensitivity”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that

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remains unresolved. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A field map changes after the antenna cable is rerouted. How would you separate an environmental change from installed-path sensitivity”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A field map changes after the antenna cable is rerouted. How would you separate an environmental change from installed-path sensitivity”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

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V011-C13-DISCUSSION-004. An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. How would you resolve the result?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. How would you resolve the result?” Put this particular dispute to the panel: An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. How would you resolve the result. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 02. Student A, terminology and scope: Agree the operational meanings of applies, loaded, inferred and open, circuit, resolve in “An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. How would you resolve the result”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 13.X10. Why field strength cannot be inferred from connector power alone”. Discuss the possible factor-two example without assuming it for an arbitrary source/load combination Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 13.X10. Why field strength cannot be inferred from connector power alone”. Discuss the possible factor-two example without assuming it for an arbitrary source/load combination Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Recover definitions and impedance conditions, correct only under the supported loading model, and recompute uncertainty Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would

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discriminate between them without changing the measurand. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An operator applies a 50 ohm loaded antenna factor to a voltage

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inferred as open circuit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. Discuss the possible factor-two example without assuming it for an arbitrary source/load combination Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. Discuss the possible factor-two example without assuming it for an arbitrary source/load combination Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit and How would you resolve the result; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit”, addressing “How would you resolve the result”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. How would you resolve the result”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An operator applies a 50 ohm loaded antenna factor to a voltage inferred as open circuit. How would you resolve the result”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-C13-DISCUSSION-005. A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. What follow-up matters?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. What follow-up matters?” Put this particular dispute to the panel: A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. What follow-up matters. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 02. Student A, terminology and scope: Agree the operational meanings of preamplifier, improves, quiet and floor, creates, matters in “A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. What follow-up matters”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Consider nonlinear or reciprocal-mixing mechanisms and maintain capability when comparing passive and active configurations Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A preamplifier improves the

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quiet noise floor but creates lines near a strong out-of-band carrier; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Consider nonlinear or reciprocal-mixing mechanisms and maintain capability when comparing passive and active configurations Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Measure admitted blocker levels before the active stage, desired gain under loading, preselection and bias behavior Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. Consider nonlinear or reciprocal-mixing mechanisms and maintain capability when comparing passive and active configurations Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.11 Integrated Path Acceptance (p. 7554)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. Consider nonlinear or reciprocal-mixing mechanisms and maintain capability when comparing passive and active configurations Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier and What follow-up matters; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier”, addressing “What follow-up matters”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. What follow-up matters”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A preamplifier improves the quiet noise floor but creates lines near a strong out-of-band carrier. What follow-up matters”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-C13-DISCUSSION-006. A battery removes an anomaly and the team wants to report supply ripple as proved. What evidence is still missing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A battery removes an anomaly and the team wants to report supply ripple as proved. What evidence is still missing?” Put this particular dispute to the panel: A battery removes an anomaly and the team wants to report supply ripple as proved. What evidence is still missing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 02. Student A, terminology and scope: Agree the operational meanings of battery, removes, report and supply, ripple, missing in “A battery removes an anomaly and the team wants to report supply ripple as proved. What evidence is still missing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A battery removes an anomaly and the team wants to report supply ripple as proved; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Separate the intended coaxial path from installed coupling”. Propose selective controls and independent output observations, preserve the successful intervention, and state only its demonstrated sensitivity until alternatives are separated Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A battery removes an anomaly and the team wants to report supply ripple as proved; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Separate the intended coaxial path from installed coupling”. Propose selective controls and independent output observations, preserve the successful intervention, and state only its demonstrated sensitivity until alternatives are separated Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify changed conductive and ground paths as well as supply spectrum Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A battery removes an anomaly and the team wants to report supply ripple as proved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A battery removes an anomaly and the team wants to report supply ripple as proved; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A battery removes an anomaly and the team wants to report supply ripple as proved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A battery removes an anomaly and the team wants to report supply ripple as proved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A battery removes an anomaly and the team wants to report supply

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ripple as proved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A battery removes an anomaly and the team wants to report supply ripple as proved. Propose selective controls and independent output observations, preserve the successful intervention, and state only its demonstrated sensitivity until alternatives are separated Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A battery removes an anomaly and the team wants to report supply ripple as proved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request

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an explicit statement of what evidence would reverse the conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A battery removes an anomaly and the team wants to report supply ripple as proved. Propose selective controls and independent output observations, preserve the successful intervention, and state only its demonstrated sensitivity until alternatives are separated Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A battery removes an anomaly and the team wants to report supply ripple as proved and What evidence is still missing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.11 Integrated Path Acceptance (p. 7554)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A battery removes an anomaly and the team wants to report supply ripple as proved”, addressing “What evidence is still missing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A battery removes an anomaly and the team wants to report supply ripple as proved. What evidence is still missing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A battery removes an anomaly and the team wants to report supply ripple as proved. What evidence is still missing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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V011-C13-DISCUSSION-007. The closing reference is wrong but all environmental recordings look plausible. How should the interval be handled?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The closing reference is wrong but all environmental recordings look plausible. How should the interval be handled?” Put this particular dispute to the panel: The closing reference is wrong but all environmental recordings look plausible. How should the interval be handled. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 02. Student A, terminology and scope: Agree the operational meanings of closing, wrong, environmental and recordings, look, interval in “The closing reference is wrong but all environmental recordings look plausible. How should the interval be handled”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The closing reference is wrong but all environmental recordings look plausible; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Apply corrections only when a supported evolution model exists Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The closing reference is wrong but all environmental recordings look plausible; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Apply corrections only when a supported evolution model exists Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Treat appearance as insufficient validity evidence; identify unknown state and drift history, bound affected records and repeat or qualify where necessary Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The closing reference is wrong but all environmental recordings look plausible: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The closing reference is wrong but all environmental recordings look plausible; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The closing reference is wrong but all environmental recordings look plausible: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The closing reference is wrong but all environmental recordings look plausible, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The closing reference is wrong but all environmental recordings look plausible: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The closing reference is wrong but all environmental recordings look plausible. Apply corrections only when a supported evolution model exists Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The closing reference is wrong but all environmental recordings look plausible, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The closing reference is wrong but all environmental recordings look plausible. Apply corrections only

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when a supported evolution model exists Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The closing reference is wrong but all environmental recordings look plausible and How should the interval be handled; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The closing reference is wrong but all environmental recordings look plausible”, addressing “How should the interval be handled”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The closing reference is wrong but all environmental recordings look plausible. How should the interval be handled”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The closing reference is wrong but all environmental recordings look plausible. How should the interval be handled”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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V011-C13-DISCUSSION-008. A switch's unused port is left open because it is not selected. What acceptance comparison would settle whether this matters?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A switch's unused port is left open because it is not selected. What acceptance comparison would settle whether this matters?” Put this particular dispute to the panel: A switch's unused port is left open because it is not selected. What acceptance comparison would settle whether this matters. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 02. Student A, terminology and scope: Agree the operational meanings of unused, port, open and acceptance, settle, matters in “A switch's unused port is left open because it is not selected. What acceptance comparison would settle whether this matters”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A switch's unused port is left open because it is not selected; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Attenuators, Filters, Splitters, and Switches”. Use the actual multiport state if consequential Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A switch's unused port is left open because it is not selected; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Attenuators, Filters, Splitters, and Switches”. Use the actual multiport state if consequential Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare required termination and open state with a stable desired reference, measure changed loss or noise, and record finite isolation and branch coupling Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A switch's unused port is left open because it is not selected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A switch's unused port is left open because it is not selected; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A switch's unused port is left open because it is not selected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A switch's unused port is left open because it is not selected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A switch's unused port is left open because it is not selected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A switch's unused port is left open because it is not selected. Use the actual multiport state if consequential Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A switch's unused port is left open because it is not selected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.7 Attenuators, Filters, Splitters, and Switches (p. 7547)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A switch's unused port is left open because it is not selected. Use the actual multiport state if consequential Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A switch's unused port is left open because it is not selected and What acceptance comparison would settle whether this matters; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.18.7 Example 13.X7. Loss and system noise from a protective filter (p. 7572)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A switch's unused port is left open because it is not selected”, addressing “What acceptance comparison would settle whether this matters”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A switch's unused port is left open because it is not selected. What acceptance comparison would settle whether this matters”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A switch's unused port is left open because it is not selected. What acceptance comparison would settle whether this matters”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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V011-C13-DISCUSSION-009. A ferrite improves a weak-feature measurement. How would you avoid overstating what the improvement means?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A ferrite improves a weak-feature measurement. How would you avoid overstating what the improvement means?” Put this particular dispute to the panel: A ferrite improves a weak-feature measurement. How would you avoid overstating what the improvement means. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 02. Student A, terminology and scope: Agree the operational meanings of ferrite, improves, avoid and overstating, improvement, means in “A ferrite improves a weak-feature measurement. How would you avoid overstating what the improvement means”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A ferrite improves a weak-feature measurement; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. Distinguish a useful mitigation from a unique causal explanation or external-source identification Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A ferrite improves a weak-feature measurement; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. Distinguish a useful mitigation from a unique causal explanation or external-source identification Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check intended-path response, geometry and sensitivity, and document the exact intervention Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A ferrite improves a weak-feature measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A ferrite improves a weak-feature measurement; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A ferrite improves a weak-feature measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion

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Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A ferrite improves a weak-feature measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A ferrite improves a weak-feature measurement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A ferrite improves a weak-feature measurement. Distinguish a useful mitigation from a unique causal explanation or external-source identification Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A ferrite improves a weak-feature measurement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A ferrite improves a weak-feature measurement. Distinguish a useful mitigation from a unique causal explanation or external-source identification Respond point by point

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to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A ferrite improves a weak-feature measurement and How would you avoid overstating what the improvement means; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A ferrite improves a weak-feature measurement”, addressing “How would you avoid overstating what the improvement means”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A ferrite improves a weak-feature measurement. How would you avoid overstating what the improvement means”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A ferrite improves a weak-feature measurement. How would you avoid overstating what the improvement means”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-DISCUSSION-010. An optical link loses an anomalous line but also raises the noise floor by 15 dB. How should the result be discussed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An optical link loses an anomalous line but also raises the noise floor by 15 dB. How should the result be discussed?” Put this particular dispute to the panel: An optical link loses an anomalous line but also raises the noise floor by 15 dB. How should the result be discussed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 02. Student A, terminology and scope: Agree the operational meanings of optical, link, loses and line, raises, floor in “An optical link loses an anomalous line but also raises the noise floor by 15 dB. How should the result be discussed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An optical link loses an anomalous line but also raises the noise floor by 15 dB; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. Treat disappearance as inconclusive if capability is inadequate Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An optical link loses an anomalous line but also raises the noise floor by 15 dB; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. Treat disappearance as inconclusive if capability is inadequate Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Evaluate whether the original feature would remain detectable, use an appropriate weak reference, and characterize gain, bandwidth and timing Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An optical link loses an anomalous line but also raises the noise floor by 15 dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An optical link loses an anomalous line but also raises the noise floor by 15 dB; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An optical link loses an anomalous line but also raises the noise floor by 15 dB: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An optical link loses an anomalous line but also raises the noise floor by 15 dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An optical link loses an anomalous line but also raises the noise floor by 15 dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An optical link loses an anomalous line but also raises the noise floor by 15 dB. Treat disappearance as inconclusive if capability is inadequate Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An optical link loses an anomalous line but also raises the noise floor by 15 dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An optical link loses an anomalous line but also raises the noise floor by 15 dB. Treat disappearance as inconclusive if capability is inadequate Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An optical link loses an anomalous line but also raises the noise floor by 15 dB and How should the result be discussed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An optical link loses an anomalous line but also raises the noise floor by 15 dB”, addressing “How should the result be discussed”; specify the exact measurement or evidential

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gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An optical link loses an anomalous line but also raises the noise floor by 15 dB. How should the result be discussed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An optical link loses an anomalous line but also raises the noise floor by 15 dB. How should the result be discussed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-DISCUSSION-011. Receiver-only acceptance passes while antenna-terminal transfer fails. How would you localize the problem?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Receiver-only acceptance passes while antenna-terminal transfer fails. How would you localize the problem?” Put this particular dispute to the panel: Receiver-only acceptance passes while antenna-terminal transfer fails. How would you localize the problem. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.2 Define a complete path at named planes (p. 7537)

- 02. Student A, terminology and scope: Agree the operational meanings of acceptance, passes, transfer and fails, localize, problem in “Receiver-only acceptance passes while antenna-terminal transfer fails. How would you localize the problem”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Receiver-only acceptance passes while antenna-terminal transfer fails; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Avoid blaming the receiver or antenna from the broad failure alone Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Receiver-only acceptance passes while antenna-terminal transfer fails; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Avoid blaming the receiver or antenna from the broad failure alone Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Keep the receiver pass scoped to its connector, then inspect remote gain, cable, adapters, switch state and correction ownership with intermediate planes or substitutions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Receiver-only acceptance passes while antenna-terminal transfer fails: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.2 Define a complete path at named planes (p. 7537)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Receiver-only acceptance passes while antenna-terminal transfer fails; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Receiver-only acceptance passes while antenna-terminal transfer fails: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.2 Define a complete path at named planes (p. 7537)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Receiver-only acceptance passes while antenna-terminal transfer fails, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Receiver-only acceptance passes while antenna-terminal transfer fails: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Receiver-only acceptance passes while antenna-terminal transfer fails. Avoid blaming the receiver or antenna from the broad failure alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Receiver-only acceptance passes while antenna-terminal transfer fails, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Receiver-only acceptance passes while antenna-terminal transfer fails. Avoid blaming the receiver or antenna from the broad failure alone Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Receiver-only acceptance passes while antenna-terminal transfer fails and How would you localize the problem; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Receiver-only acceptance passes while antenna-terminal transfer fails”, addressing “How would you localize the problem”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Receiver-only acceptance passes while antenna-terminal transfer fails. How would you localize the problem”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Receiver-only acceptance passes while antenna-terminal transfer fails. How would you localize the problem”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.2 Define a complete path at named planes (p. 7537)

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V011-C13-DISCUSSION-012. A terminal reference agrees exactly after two independently maintained correction files are combined. What audit would you perform?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A terminal reference agrees exactly after two independently maintained correction files are combined. What audit would you perform?” Put this particular dispute to the panel: A terminal reference agrees exactly after two independently maintained correction files are combined. What audit would you perform. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 02. Student A, terminology and scope: Agree the operational meanings of terminal, independently, files and combined, audit, perform in “A terminal reference agrees exactly after two independently maintained correction files are combined. What audit would you perform”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A terminal reference agrees exactly after two independently maintained correction files are combined; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measurement Chain Ownership”. Agreement alone can result from compensating errors and is not proof of correct ownership Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A terminal reference agrees

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exactly after two independently maintained correction files are combined; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.2 Define a complete path at named planes (p. 7537)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measurement Chain Ownership”. Agreement alone can result from compensating errors and is not proof of correct ownership Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check whether any adapter, switch or gain term was included twice, compare raw output against independently known input, and verify plane boundaries Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A terminal reference agrees exactly after two independently maintained correction files are combined: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A terminal reference agrees exactly after two independently maintained correction files are combined; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.2 Define a complete path at named planes (p. 7537)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A terminal reference agrees exactly after two independently maintained correction files are

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combined: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A terminal reference agrees exactly after two independently maintained correction files are combined, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.1 Measurement Chain Ownership (p. 7536)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A terminal reference agrees exactly after two independently maintained correction files are combined: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead

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the panel to retain, qualify or reject the conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A terminal reference agrees exactly after two independently maintained correction files are combined. Agreement alone can result from compensating errors and is not proof of correct ownership Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.2 Define a complete path at named planes (p. 7537)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A terminal reference agrees exactly after two independently maintained correction files are combined, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.1 Measurement Chain Ownership (p. 7536)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A terminal reference agrees exactly after two independently maintained correction files are combined. Agreement alone can result from compensating errors and is not proof of correct ownership Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.2 Define a complete path at named planes (p. 7537)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A terminal reference agrees exactly after two independently maintained correction files are combined and What audit would you perform; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A terminal reference agrees exactly after two independently maintained correction files are combined”, addressing “What audit would you perform”; specify the exact

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measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A terminal reference agrees exactly after two independently maintained correction files are combined. What audit would you perform”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A terminal reference agrees exactly after two independently maintained correction files are combined. What audit would you perform”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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V011-C13-DISCUSSION-013. An antenna certificate is used beside a large metal structure absent from calibration. What claim can be defended?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An antenna certificate is used beside a large metal structure absent from calibration. What claim can be defended?” Put this particular dispute to the panel: An antenna certificate is used beside a large metal structure absent from calibration. What claim can be defended. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 02. Student A, terminology and scope: Agree the operational meanings of certificate, large, metal and structure, absent, defended in “An antenna certificate is used beside a large metal structure absent from calibration. What claim can be defended”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An antenna certificate is used beside a large metal structure absent from calibration; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Antennas and Field-to-Terminal Conversion”. Report terminal results separately from any more uncertain field conversion Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An antenna certificate is used beside a large metal structure absent from calibration; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Antennas and Field-to-Terminal Conversion”. Report terminal results separately from any more uncertain field conversion Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain certified behavior only within its conditions, assess changed pattern and coupling, and seek installed reference evidence Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An antenna certificate is used beside a large

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metal structure absent from calibration: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An antenna certificate is used beside a large metal structure absent from calibration; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An antenna certificate is used beside a large metal structure absent from calibration: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative

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that could survive the proposed test. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An antenna certificate is used beside a large metal structure absent from calibration, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An antenna certificate is used beside a large metal structure absent from calibration: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An antenna certificate is used beside a large metal structure absent from calibration. Report terminal results separately from any more uncertain field conversion Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An antenna certificate is used beside a large metal structure absent from calibration, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An antenna certificate is used beside a large metal structure absent from calibration. Report terminal results separately from any more uncertain field conversion Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An antenna certificate is used beside a large metal structure absent from calibration and What claim can be defended; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An antenna certificate is used beside a large metal structure absent from calibration”, addressing “What claim can be defended”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An antenna certificate is used beside a large metal structure absent from calibration. What claim can be defended”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An antenna certificate is used beside a large metal structure absent from calibration. What claim can be defended”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-C13-DISCUSSION-014. A pad improves return loss but hides the weakest desired signal. How should the engineering tradeoff be judged?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A pad improves return loss but hides the weakest desired signal. How should the engineering tradeoff be judged?” Put this particular dispute to the panel: A pad improves return loss but hides the weakest desired signal. How should the engineering tradeoff be judged. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

- 02. Student A, terminology and scope: Agree the operational meanings of improves, return, hides and desired, engineering, tradeoff in “A pad improves return loss but hides the weakest desired signal. How should the engineering tradeoff be judged”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A pad improves return loss but hides the weakest desired signal; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Treat connections and unused branches as part of the network”. Use the measurement's required detection and uncertainty goals rather than declare the pad universally beneficial Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A pad improves return loss but hides the weakest desired signal; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Treat connections and unused branches as part of the network”. Use the measurement's required detection and uncertainty goals rather than declare the pad universally beneficial Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Combine match improvement with added loss, thermal noise and input-equivalent sensitivity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A pad improves return loss but hides the weakest desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A pad improves return loss but hides the weakest desired signal; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A pad improves return loss but hides the weakest desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A pad improves return loss but hides the weakest desired signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A pad improves return loss but hides the weakest desired signal: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A pad improves return loss but hides the weakest desired signal. Use the measurement's required detection and uncertainty goals rather than declare the pad universally beneficial Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A pad improves return loss but hides the weakest desired signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A pad improves return loss but hides the weakest desired signal. Use the measurement's required detection and uncertainty goals rather than declare the pad universally beneficial Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.18.8 Example 13.X8. Converting a correction uncertainty into a confidence statement (p. 7573)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A pad improves return loss but hides the weakest desired signal and How should the engineering tradeoff be judged; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A pad improves return loss but hides the weakest desired signal”, addressing “How should the engineering tradeoff be judged”; specify the exact measurement or evidential

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gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A pad improves return loss but hides the weakest desired signal. How should the engineering tradeoff be judged”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A pad improves return loss but hides the weakest desired signal. How should the engineering tradeoff be judged”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.18.2 Example 13.X2. Converting measured return loss to reflection magnitude (p. 7567)

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V011-C13-DISCUSSION-015. An amplifier is stable on a matched bench load and unstable with one installed antenna. What does the evidence suggest testing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An amplifier is stable on a matched bench load and unstable with one installed antenna. What does the evidence suggest testing?” Put this particular dispute to the panel: An amplifier is stable on a matched bench load and unstable with one installed antenna. What does the evidence suggest testing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 02. Student A, terminology and scope: Agree the operational meanings of bench, load, unstable and installed, suggest, testing in “An amplifier is stable on a matched bench load and unstable with one installed antenna. What does the evidence suggest testing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An amplifier is stable on a matched bench load and unstable with one installed antenna; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “External Preamplifiers, Bias, and Stability”. The bench result remains valid for its scope but does not establish installed stability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An amplifier is stable on a

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matched bench load and unstable with one installed antenna; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.21 Vector reference-plane transport and installed-path uncertainty at antennas and cables (p. 7581)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “External Preamplifiers, Bias, and Stability”. The bench result remains valid for its scope but does not establish installed stability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check actual source/load impedances, cable length, bias voltage, temperature and independent output Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An amplifier is stable on a matched bench load and unstable with one installed antenna: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An amplifier is stable on a matched bench load and unstable with one installed antenna; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.21 Vector reference-plane transport and installed-path uncertainty at antennas and cables (p. 7581)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An amplifier is stable on a matched bench load and unstable with one installed antenna: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable,

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authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An amplifier is stable on a matched bench load and unstable with one installed antenna, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An amplifier is stable on a matched bench load and unstable with one installed antenna: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An amplifier is stable on a matched bench load and unstable with one installed antenna. The bench result remains valid for its scope but does not establish installed stability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.21 Vector reference-plane transport and installed-path uncertainty at antennas and cables (p. 7581)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An amplifier is stable on a matched bench load and unstable with one installed antenna, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An amplifier is stable on a matched bench load

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and unstable with one installed antenna. The bench result remains valid for its scope but does not establish installed stability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.21 Vector reference-plane transport and installed-path uncertainty at antennas and cables (p. 7581)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An amplifier is stable on a matched bench load and unstable with one installed antenna and What does the evidence suggest testing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An amplifier is stable on a matched bench load and unstable with one installed antenna”, addressing “What does the evidence suggest testing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by

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another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An amplifier is stable on a matched bench load and unstable with one installed antenna. What does the evidence suggest testing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An amplifier is stable on a matched bench load and unstable with one installed antenna. What does the evidence suggest testing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-C13-DISCUSSION-016. A reference at the receiver connector passes and the report calls the whole field chain calibrated. How should that conclusion be revised?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reference at the receiver connector passes and the report calls the whole field chain calibrated. How should that conclusion be revised?” Put this particular dispute to the panel: A reference at the receiver connector passes and the report calls the whole field chain calibrated. How should that conclusion be revised. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 02. Student A, terminology and scope: Agree the operational meanings of connector, passes, report and calls, conclusion, revised in “A reference at the receiver connector passes and the report calls the whole field chain calibrated. How should that conclusion be revised”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reference at the receiver connector passes and the report calls the whole field chain calibrated; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Explain precisely which remote and field-conversion elements were bypassed Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A reference at the receiver connector passes and the report calls the whole field chain calibrated; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Explain precisely which remote and field-conversion elements were bypassed Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the tested downstream scope and add antenna-terminal and installed geometry checks for broader claims Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A reference at the receiver connector passes and the report calls the whole field chain calibrated: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reference at the receiver connector passes and the report calls the whole field chain calibrated; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reference at the receiver connector passes and the report calls the whole field chain calibrated: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reference at the receiver connector passes and the report calls the whole field chain calibrated, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A reference at the receiver connector passes and the report calls the

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whole field chain calibrated: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reference at the receiver connector passes and the report calls the whole field chain calibrated. Explain precisely which remote and field-conversion elements were bypassed Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reference at the receiver connector passes and the report calls the whole field chain calibrated, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reference at the receiver connector passes and the report calls the whole field chain calibrated. Explain precisely which remote and field-conversion elements were bypassed Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reference at the receiver connector passes and the report calls the whole field chain calibrated and How should that conclusion be revised; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reference at the receiver connector passes and the report calls the whole field chain calibrated”, addressing “How should that conclusion be revised”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reference at the receiver connector passes and the report calls the whole field chain calibrated. How should that conclusion be revised”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reference at the receiver connector passes and the report calls the whole field chain calibrated. How should that conclusion be revised”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-C13-DISCUSSION-017. Under a blocker, desired gain stays stable but noise rises. Which competing explanations and records matter?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Under a blocker, desired gain stays stable but noise rises. Which competing explanations and records matter?” Put this particular dispute to the panel: Under a blocker, desired gain stays stable but noise rises. Which competing explanations and records matter. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 02. Student A, terminology and scope: Agree the operational meanings of stays, stable, rises and competing, explanations, matter in “Under a blocker, desired gain stays stable but noise rises. Which competing explanations and records matter”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Under a blocker, desired gain stays stable but noise rises; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “External Preamplifiers, Bias, and Stability”. Avoid diagnosing compression solely from a noise increase Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Under a blocker, desired gain stays stable but noise rises; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “External Preamplifiers, Bias, and Stability”. Avoid diagnosing compression solely from a noise increase Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Inspect blocker source spectrum and predicted reciprocal mixing, verify actual admitted levels and stable state, and keep noise and gain observations distinct Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Under a blocker, desired gain stays stable but

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noise rises: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Under a blocker, desired gain stays stable but noise rises; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Under a blocker, desired gain stays stable but noise rises: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Under a blocker, desired gain stays stable but noise rises, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Under a blocker, desired gain stays stable but noise rises: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Under a blocker, desired gain stays stable

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but noise rises. Avoid diagnosing compression solely from a noise increase Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Under a blocker, desired gain stays stable but noise rises, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Under a blocker, desired gain stays stable but noise rises. Avoid diagnosing compression solely from a noise increase Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Under a blocker, desired gain stays stable but noise rises and Which competing explanations and records matter; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Under a blocker, desired gain stays stable but noise rises”, addressing “Which competing explanations and records matter”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Under a blocker, desired gain stays stable but

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noise rises. Which competing explanations and records matter", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Under a blocker, desired gain stays stable but noise rises. Which competing explanations and records matter". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-C13-DISCUSSION-018. Under the same controlled blocker challenge, desired gain falls. How does the investigation change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Under the same controlled blocker challenge, desired gain falls. How does the investigation change?” Put this particular dispute to the panel: Under the same controlled blocker challenge, desired gain falls. How does the investigation change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 02. Student A, terminology and scope: Agree the operational meanings of controlled, blocker, challenge and desired, falls, investigation in “Under the same controlled blocker challenge, desired gain falls. How does the investigation change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Under the same controlled blocker challenge, desired gain falls; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Record the reference and operating state, and identify the linearity boundary rather than correcting the loss as ordinary cable attenuation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Under the same controlled blocker challenge, desired gain falls; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Record the reference and operating state, and identify the linearity boundary rather than correcting the loss as ordinary cable attenuation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine gain control or compression and stage loading before using a quiet-state noise budget Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Under the same controlled blocker challenge, desired gain falls: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Under the same controlled blocker challenge, desired gain falls; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Under the same controlled blocker challenge, desired gain falls: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Under the same controlled blocker challenge, desired gain falls, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Under the same controlled blocker challenge, desired gain falls: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Under the same controlled blocker challenge, desired gain falls. Record the reference and operating state, and identify the linearity boundary rather than correcting the loss as ordinary cable attenuation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Under the same controlled blocker challenge, desired gain falls, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Under the same controlled blocker challenge, desired gain falls. Record the reference and operating state, and identify the linearity boundary rather than correcting the loss as

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ordinary cable attenuation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Under the same controlled blocker challenge, desired gain falls and How does the investigation change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Under the same controlled blocker challenge, desired gain falls”, addressing “How does the investigation change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Under the same controlled blocker challenge, desired gain falls. How does the investigation change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Under the same controlled blocker challenge, desired gain falls. How does the investigation change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

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V011-C13-DISCUSSION-019. A line follows bias-cable length even with antenna termination. What conclusion should appear in a preliminary report?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A line follows bias-cable length even with antenna termination. What conclusion should appear in a preliminary report?” Put this particular dispute to the panel: A line follows bias-cable length even with antenna termination. What conclusion should appear in a preliminary report. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 02. Student A, terminology and scope: Agree the operational meanings of line, follows, length and termination, conclusion, appear in “A line follows bias-cable length even with antenna termination. What conclusion should appear in a preliminary report”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A line follows bias-cable length even with antenna termination; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Common-Mode Current and Installed-Path Effects”. Avoid a unique source or oscillation diagnosis Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A line follows bias-cable length even with antenna termination; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Common-Mode Current and Installed-Path Effects”. Avoid a unique source or oscillation diagnosis Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Report sensitivity to the installed active and bias path, list plausible instability, pickup and leakage mechanisms, and propose independent output and selective-load checks Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A line follows bias-cable length even with antenna termination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A line follows bias-cable length even with antenna termination; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A line follows bias-cable length even with antenna termination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A line follows bias-cable length even with antenna termination, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A line follows bias-cable length even with antenna termination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A line follows bias-cable length even with antenna termination. Avoid a unique source or oscillation diagnosis Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A line follows bias-cable length even with antenna termination, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A line follows bias-cable length even with antenna termination. Avoid a unique source or oscillation diagnosis Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A line follows bias-cable length even with antenna termination and What conclusion should appear in a preliminary report; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.21 Vector reference-plane transport and installed-path uncertainty at antennas and cables (p. 7581)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A line follows bias-cable length even with antenna termination”, addressing “What conclusion should appear in a preliminary report”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A line follows bias-cable length even with antenna termination. What conclusion should appear in a preliminary report”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A line follows bias-cable length even with antenna termination. What conclusion should appear in a preliminary report”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-C13-DISCUSSION-020. Two field crews use the same hardware but different cable routes and mounting. May one acceptance file cover both?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two field crews use the same hardware but different cable routes and mounting. May one acceptance file cover both?” Put this particular dispute to the panel: Two field crews use the same hardware but different cable routes and mounting. May one acceptance file cover both. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 02. Student A, terminology and scope: Agree the operational meanings of field, hardware, routes and mounting, file, cover in “Two field crews use the same hardware but different cable routes and mounting. May one acceptance file cover both”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.11 Integrated Path Acceptance (p. 7554)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two field crews use the same hardware but different cable routes and mounting; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Separate the intended coaxial path from installed coupling”. Equal hardware identity alone is insufficient Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two field crews use the same hardware but different cable routes and mounting; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Separate the intended coaxial path from installed coupling”. Equal hardware identity alone is insufficient Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare whether the changed geometry affects desired transfer or common mode, preserve serialized and state records, and obtain installed evidence for each consequential configuration Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.11 Integrated Path Acceptance (p. 7554)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two field crews use the same hardware but different cable routes and mounting: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two field crews use the same hardware but different cable routes and mounting; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two field crews use the same hardware but different cable routes and mounting: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two field crews use the same hardware but different cable routes and mounting, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two field crews use the same hardware but different cable routes and mounting: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.11 Integrated Path Acceptance (p. 7554)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two field crews use the same hardware but different cable routes and mounting. Equal hardware identity alone is insufficient Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two field crews use the same hardware but different cable routes and mounting, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two field crews use the same hardware but different cable routes and mounting. Equal hardware identity alone is insufficient Respond point by point to Student J. Distinguish a

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verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two field crews use the same hardware but different cable routes and mounting and May one acceptance file cover both; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two field crews use the same hardware but different cable routes and mounting”, addressing “May one acceptance file cover both”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.11 Integrated Path Acceptance (p. 7554)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two field crews use the same hardware but different cable routes and mounting. May one acceptance file cover both”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two field crews use the same hardware but different cable routes and mounting. May one acceptance file cover both”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.11 Integrated Path Acceptance (p. 7554)

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V011-C13-DISCUSSION-021. An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. How would you respond?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. How would you respond?” Put this particular dispute to the panel: An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. How would you respond. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 02. Student A, terminology and scope: Agree the operational meanings of operator, number, overall and quality, constructed, respond in “An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. How would you respond”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An operator wants a single number to rank overall receiver quality from the constructed acceptance tests; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Relate each to intended use and uncertainty rather than invent an unsupported aggregate score Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of An operator wants a single number to rank overall receiver quality from the constructed acceptance tests; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “A constructed acceptance case for the assembled chain”. Relate each to intended use and uncertainty rather than invent an unsupported aggregate score Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain separate results for desired transfer, noise, blocker response and installed coupling because they support different claims Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An operator wants a single number to rank overall receiver quality from the constructed acceptance tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An operator wants a single number to rank overall receiver quality from the constructed acceptance tests; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An operator wants a single

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number to rank overall receiver quality from the constructed acceptance tests: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An operator wants a single number to rank overall receiver quality from the constructed acceptance tests, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An operator wants a single number to rank overall receiver quality from the constructed acceptance tests: specify the altered receiver

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state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. Relate each to intended use and uncertainty rather than invent an unsupported aggregate score Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An operator wants a single number to rank overall receiver quality from the constructed acceptance tests, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. Relate each to intended use and uncertainty rather than invent an unsupported aggregate score Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An operator wants a single number to rank overall receiver quality from the constructed acceptance tests and How would you respond; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.23 Controlled qualification of the installed network (p. 7589)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An operator wants a single number to rank overall receiver quality from the constructed acceptance tests”, addressing “How would you respond”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. How would you respond”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An operator wants a single number to rank overall receiver quality from the constructed acceptance tests. How would you respond”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-DISCUSSION-022. A correction is interpolated across a sharp filter transition. What should the reviewer ask?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A correction is interpolated across a sharp filter transition. What should the reviewer ask?” Put this particular dispute to the panel: A correction is interpolated across a sharp filter transition. What should the reviewer ask. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.2 Define a complete path at named planes (p. 7537)

- 02. Student A, terminology and scope: Agree the operational meanings of correction, interpolated, sharp and filter, transition, reviewer in “A correction is interpolated across a sharp filter transition. What should the reviewer ask”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A correction is interpolated across a sharp filter transition; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. Do not infer an exact response from sparse data or smooth plotting Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A correction is interpolated across a sharp filter transition; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. Do not infer an exact response from sparse data or smooth plotting Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Request the measured grid, interpolation method, state applicability and uncertainty near the transition, and seek finer characterization if needed Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A correction is interpolated across a sharp filter transition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.2 Define a complete path at named planes (p. 7537)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A correction is interpolated across a sharp filter transition; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A correction is interpolated across a sharp filter transition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.2 Define a complete path at named planes (p. 7537)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A correction is interpolated across a sharp filter transition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A correction is interpolated across a sharp filter transition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A correction is interpolated across a sharp filter transition. Do not infer an exact response from sparse data or smooth plotting Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A correction is interpolated across a sharp filter transition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A correction is interpolated across a sharp filter transition. Do not infer an exact response from sparse data or smooth plotting Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the

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missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A correction is interpolated across a sharp filter transition and What should the reviewer ask; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A correction is interpolated across a sharp filter transition”, addressing “What should the reviewer ask”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.2 Define a complete path at named planes (p. 7537)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A correction is interpolated across a sharp filter transition. What should the reviewer ask”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A correction is interpolated across a sharp filter transition. What should the reviewer ask”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.2 Define a complete path at named planes (p. 7537)

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V011-C13-DISCUSSION-023. An accessory was relocated without changing measured coaxial loss, but a field result changed. How should change control apply?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An accessory was relocated without changing measured coaxial loss, but a field result changed. How should change control apply?” Put this particular dispute to the panel: An accessory was relocated without changing measured coaxial loss, but a field result changed. How should change control apply. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 02. Student A, terminology and scope: Agree the operational meanings of accessory, changing, coaxial and field, control, apply in “An accessory was relocated without changing measured coaxial loss, but a field result changed. How should change control apply”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An accessory was relocated without changing measured coaxial loss, but a field result changed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Stable scalar loss does not settle the installed field response Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An accessory was relocated

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without changing measured coaxial loss, but a field result changed; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Stable scalar loss does not settle the installed field response Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Treat relocation as potentially consequential to installed coupling, examine geometry and common mode, and renew applicable acceptance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An accessory was relocated without changing measured coaxial loss, but a field result changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An accessory was relocated without changing measured coaxial loss, but a field result changed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An accessory was relocated without changing measured coaxial loss, but a field result changed:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An accessory was relocated without changing measured coaxial loss, but a field result changed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An accessory was relocated without changing measured coaxial loss, but a field result changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An accessory was relocated without changing measured coaxial loss, but a field result changed. Stable scalar loss does not settle the installed field response Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An accessory was relocated without changing measured coaxial loss, but a field result changed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.11 Integrated Path Acceptance (p. 7554)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An accessory was relocated without changing measured coaxial loss, but a field result changed. Stable scalar loss does not settle the installed field response Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An accessory was relocated without changing measured coaxial loss, but a field result changed and How should change control apply; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.9 Common-Mode Current and Installed-Path Effects (p. 7550)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An accessory was relocated without changing measured coaxial loss, but a field result changed”, addressing “How should change control apply”; specify the exact measurement or evidential gap on which the speakers still differ

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Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An accessory was relocated without changing measured coaxial loss, but a field result changed. How should change control apply”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An accessory was relocated without changing measured coaxial loss, but a field result changed. How should change control apply”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-C13-DISCUSSION-024. A component certificate has expired but a recent assembled reference passes. How should the evidence be weighed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A component certificate has expired but a recent assembled reference passes. How should the evidence be weighed?” Put this particular dispute to the panel: A component certificate has expired but a recent assembled reference passes. How should the evidence be weighed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 02. Student A, terminology and scope: Agree the operational meanings of component, certificate, recent and assembled, reference, passes in “A component certificate has expired but a recent assembled reference passes. How should the evidence be weighed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A component certificate has expired but a recent assembled reference passes; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. State the bounded current evidence and unresolved limits without either discarding the reference or claiming it establishes every certificate property Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A component certificate has expired but a recent assembled reference passes; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “13. Verification, records and the interpretation of negative observations”. State the bounded current evidence and unresolved limits without either discarding the reference or claiming it establishes every certificate property Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish demonstrated assembled transfer at tested conditions from unverified component properties and formal applicability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A component certificate has expired but a recent assembled reference passes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A component certificate has expired but a recent assembled reference passes; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.23 Controlled qualification of the installed network (p. 7589)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A component certificate has expired but a recent assembled reference passes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A component certificate has expired but a recent assembled reference passes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A component certificate has expired but a recent assembled

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reference passes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A component certificate has expired but a recent assembled reference passes. State the bounded current evidence and unresolved limits without either discarding the reference or claiming it establishes every certificate property Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A component certificate has expired but a recent assembled reference passes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A component certificate has expired but a recent assembled reference passes. State the bounded current evidence and unresolved limits without either discarding the reference or claiming it establishes every certificate property Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.23 Controlled qualification of the installed network (p. 7589)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A component certificate has expired but a recent assembled reference passes and How should the evidence be weighed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A component certificate has expired but a recent assembled reference passes”, addressing “How should the evidence be weighed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A component certificate has expired but a recent assembled reference passes. How should the evidence be weighed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A component certificate has expired but a recent assembled reference passes. How should the evidence be weighed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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V011-C13-DISCUSSION-025. The final report must include a strong conducted claim and a tentative field claim from the same hardware. How should they be written?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The final report must include a strong conducted claim and a tentative field claim from the same hardware. How should they be written?” Put this particular dispute to the panel: The final report must include a strong conducted claim and a tentative field claim from the same hardware. How should they be written. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 02. Student A, terminology and scope: Agree the operational meanings of final, report, conducted and claim, hardware, written in “The final report must include a strong conducted claim and a tentative field claim from the same hardware. How should they be written”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The final report must include a strong conducted claim and a tentative field claim from the same hardware; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 13.X10. Why field strength cannot be inferred from connector power alone”. Explain why different evidential strength is appropriate and avoid extending the stronger conducted result into untested field conditions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The final report must include a strong conducted claim and a tentative field claim from the same hardware; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 13.X10. Why field strength cannot be inferred from connector power alone”. Explain why different evidential strength is appropriate and avoid extending the stronger conducted result into untested field conditions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Name separate measurands, planes, states, uncertainty and supporting tests; identify the field-geometry and coupling limits Put two specific

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questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The final report must include a strong conducted claim and a tentative field claim from the same hardware: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The final report must include a strong conducted claim and a tentative field claim from the same hardware; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The final report must include a strong conducted claim and a tentative field claim from the same hardware: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The final report must include a strong conducted claim and a tentative field claim from the same hardware, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The final report must include a strong conducted claim and a tentative field claim from the same hardware: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The final report must include a strong conducted claim and a tentative field claim from the same hardware. Explain why different evidential strength is appropriate and avoid extending the stronger conducted result into untested field conditions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The final report must include a strong conducted claim and a tentative field claim from the same hardware, formulate an instrumental artifact or confounding

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alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The final report must include a strong conducted claim and a tentative field claim from the same hardware. Explain why different evidential strength is appropriate and avoid extending the stronger conducted result into untested field conditions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The final report must include a strong conducted claim and a tentative field claim from the same hardware and How should they be written; exclude protections irrelevant to the scenario Question Student F about the custody and

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reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The final report must include a strong conducted claim and a tentative field claim from the same hardware”, addressing “How should they be written”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The final report must include a strong conducted claim and a tentative field claim from the same hardware. How should they be written”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The final report must include a strong conducted claim and a tentative field claim from the same hardware. How should they be

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written". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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Chapter 13 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C13-ESSAY-001 — Identify assembly serials and order; electrical and environmental state; correction planes, frequency grid, interpolation and uncertainty. Explain why a photograph or certificate alone cannot substitute for all three and show how a correction is assigned once.

Review: Chapter 13 — Define a complete path at named planes.

V011-C13-ESSAY-002 — Separate aggregate transfer from stage-dependent noise weighting and admitted levels. Discuss cable before versus after remote amplification, identify vulnerable stages, and require actual linear-state evidence rather than infer sensitivity from gain equality.

Review: Chapter 13 — Define a complete path at named planes.

V011-C13-ESSAY-003 — Define terminal voltage or power convention, antenna factor or aperture, matching, polarization, direction, field region and installation. Separate conducted downstream validation from field conversion and give limits for near-field or altered mounting conditions.

Review: Chapter 13 — Keep field conversion separate from terminal power.

V011-C13-ESSAY-004 — Define the two quantities and the source/load conditions. Explain the possible factor-two voltage discrepancy in a matched case, its approximately 6.02 dB level effect, and why an unknown impedance cannot be repaired by assuming that factor universally.

Review: Chapter 13 — Keep field conversion separate from terminal power.

V011-C13-ESSAY-005 — Explain downstream-noise weighting, exposure of the first active stage to blockers, reverse leakage, gain and compression limits, bias and stability. Compare preselection benefits with its loss and thermal-noise cost and identify the required assembled tests.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

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V011-C13-ESSAY-006 — List supply ripple, conductive coupling, instability and leakage as alternatives. Use selective bias and load controls, independent output observation and maintained desired references. Explain why disappearance after a multi-property substitution is not a unique cause determination.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

V011-C13-ESSAY-007 — Include actual antenna and cable impedances, supply at the remote device, temperature and mechanical states. Use opening and closing references and consequential-change checks. Distinguish bounded understood drift correction from unexplained intermittent failures and identify affected intervals.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

V011-C13-ESSAY-008 — Discuss finite isolation, unused terminations, reflections and branch loading. Propose tests changing one termination while preserving intended response, record network state, and identify when vector or empirical multiport characterization is warranted.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

V011-C13-ESSAY-009 — Account for desired loss, physical-temperature noise and altered source impedance. Explain possible improvements in match and possible deterioration of sensitivity; require a complete uncertainty and noise comparison rather than a universal improvement claim.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-ESSAY-010 — Describe inside-shield fields and exterior-shield current paths involving antenna, enclosure and nearby conductors. Explain why a matched insertion-loss result can coexist with route sensitivity, and design a controlled intervention with reference-transfer checks.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

V011-C13-ESSAY-011 — Explain which intervention sensitivity is observed and which alternative impedance, geometry and coupling changes remain. Require recorded placement, preserved desired response and further selective evidence; state a bounded conclusion without claiming unique current distribution or source identity.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

V011-C13-ESSAY-012 — Characterize optical gain, noise, bandwidth, timing and power state. Use a relevant weak reference in both configurations, preserve untreated data and compare the anomaly. Explain why a noisier path losing both reference and anomaly offers little discrimination.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

V011-C13-ESSAY-013 — Progress from receiver connector to assembled antenna-terminal reference to installed antenna observation. Define planes, serialized network, geometry, state, uncertainty and limits. Explain why passing a narrower stage does not accept all broader scopes.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-ESSAY-014 — Explain why losses are added and gains subtracted when referring an indication upstream. Use a fully specified hypothetical case, identify frequency and state applicability, and keep mismatch and correction uncertainty explicit rather than absorbed into an unexplained residual.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

V011-C13-ESSAY-015 — State the far-field, matching and polarization conditions for power density times aperture. Include a dimensional calculation, distinguish available from delivered power, and explain why near fields, multipath and changed geometry may require further treatment.

Review: Chapter 13 — Quantitative Model for Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

V011-C13-ESSAY-016 — Reconstruct −92.0 − 6.4 + 20.1 dBm and the +8.3 dB discrepancy. Investigate gain state, correction ownership, overload and installed coupling with independent references. Do not turn the residual into an unconditional correction or source attribution.

Review: Chapter 13 — Hypothetical Applied Calculation: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

V011-C13-ESSAY-017 — Explain what termination and cable-length sensitivity constrain. Retain competing active, conductive, radiated and leakage hypotheses; propose independent amplifier-output and controlled-load observations with adequate sensitivity. State the strongest conclusion before those follow-ups.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

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V011-C13-ESSAY-018 — Identify the 44 dB linear desired transfer and named planes. Preserve input, output, correction and uncertainty; then separately address noise, blocker transfer and installed geometry. Explain why receiver-connector injection bypasses the remote path.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-ESSAY-019 — For unchanged gain with increased noise, inspect source spectrum and reciprocal mixing; for changed gain, examine gain control or compression; for route-sensitive anomaly with stable reference, examine installed coupling. Keep each conclusion conditional and preserve measured evidence.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-ESSAY-020 — Distinguish a known modeled drift from an unexplained failure, identify the interval and states at risk, and retain both reference observations. Discuss bounded corrections only where justified and avoid silently extending later calibration to unknown earlier conditions.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

V011-C13-ESSAY-021 — Key files to serial assembly, selected path, gain and bias state, temperature range, planes and frequency grid. Record interpolation and uncertainty, prevent duplicate accessory corrections, and require renewed verification after consequential substitutions.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-ESSAY-022 — Explain the certificates' real supporting role and gaps from connections, order, operating state, loading and installed coupling. Define an assembled reference test whose conclusion is limited to the performed measurement and uncertainty.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-ESSAY-023 — Track which gain, loss and noise contributions lie downstream of each plane, distinguish raw output from referred input, and show one hypothetical correction. Discuss why field conversion is a separate additional model rather than merely another arbitrary plane label.

Review: Chapter 13 — Define a complete path at named planes.

V011-C13-ESSAY-024 — Identify tested ranges, state-specific limitations and the effect on quantitative claims. Retain usable bounded results, avoid unsupported correction extrapolation, and describe what new characterization would be needed to extend acceptance.

Review: Chapter 13 — Integrated Path Acceptance.

V011-C13-ESSAY-025 — Separate desired transfer, noise, blocker loading, state stability and field coupling. Use the constructed acceptance table to assign evidence to each and identify what an otherwise correct displayed reference cannot establish.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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Discussion Guidance

V011-C13-DISCUSSION-001 — Ask for the actual serial order, electrical state, correction ownership and named-plane reference measurements. Explain connection, loading and coupling gaps; retain the certificates as support while limiting acceptance to tested conditions.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-DISCUSSION-002 — Compare noise weighting and blocker levels at vulnerable stages, then verify actual desired transfer and linear state. Avoid deciding solely from the equal gain sum; identify preselection and remote-bias tradeoffs.

Review: Chapter 13 — Define a complete path at named planes.

V011-C13-DISCUSSION-003 — Reproduce a documented route intervention while retaining intended geometry and reference response, preserve both observations, and check exterior-shield coupling. Recognize that routing itself can alter the local environment and avoid unique attribution.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

V011-C13-DISCUSSION-004 — Recover definitions and impedance conditions, correct only under the supported loading model, and recompute uncertainty. Discuss the possible factor-two example without assuming it for an arbitrary source/load combination.

Review: Chapter 13 — Keep field conversion separate from terminal power.

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V011-C13-DISCUSSION-005 — Measure admitted blocker levels before the active stage, desired gain under loading, preselection and bias behavior. Consider nonlinear or reciprocal-mixing mechanisms and maintain capability when comparing passive and active configurations.

Review: Chapter 13 — External Preamplifiers, Bias, and Stability.

V011-C13-DISCUSSION-006 — Identify changed conductive and ground paths as well as supply spectrum. Propose selective controls and independent output observations, preserve the successful intervention, and state only its demonstrated sensitivity until alternatives are separated.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

V011-C13-DISCUSSION-007 — Treat appearance as insufficient validity evidence; identify unknown state and drift history, bound affected records and repeat or qualify where necessary. Apply corrections only when a supported evolution model exists.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

V011-C13-DISCUSSION-008 — Compare required termination and open state with a stable desired reference, measure changed loss or noise, and record finite isolation and branch coupling. Use the actual multiport state if consequential.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

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V011-C13-DISCUSSION-009 — Check intended-path response, geometry and sensitivity, and document the exact intervention. Distinguish a useful mitigation from a unique causal explanation or external-source identification.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

V011-C13-DISCUSSION-010 — Evaluate whether the original feature would remain detectable, use an appropriate weak reference, and characterize gain, bandwidth and timing. Treat disappearance as inconclusive if capability is inadequate.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling.

V011-C13-DISCUSSION-011 — Keep the receiver pass scoped to its connector, then inspect remote gain, cable, adapters, switch state and correction ownership with intermediate planes or substitutions. Avoid blaming the receiver or antenna from the broad failure alone.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-DISCUSSION-012 — Check whether any adapter, switch or gain term was included twice, compare raw output against independently known input, and verify plane boundaries. Agreement alone can result from compensating errors and is not proof of correct ownership.

Review: Chapter 13 — Define a complete path at named planes.

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V011-C13-DISCUSSION-013 — Retain certified behavior only within its conditions, assess changed pattern and coupling, and seek installed reference evidence. Report terminal results separately from any more uncertain field conversion.

Review: Chapter 13 — Keep field conversion separate from terminal power.

V011-C13-DISCUSSION-014 — Combine match improvement with added loss, thermal noise and input-equivalent sensitivity. Use the measurement's required detection and uncertainty goals rather than declare the pad universally beneficial.

Review: Chapter 13 — Treat connections and unused branches as part of the network.

V011-C13-DISCUSSION-015 — Check actual source/load impedances, cable length, bias voltage, temperature and independent output. The bench result remains valid for its scope but does not establish installed stability.

Review: Chapter 13 — Remote amplification requires electrical and installed checks.

V011-C13-DISCUSSION-016 — State the tested downstream scope and add antenna-terminal and installed geometry checks for broader claims. Explain precisely which remote and field-conversion elements were bypassed.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-DISCUSSION-017 — Inspect blocker source spectrum and predicted reciprocal mixing, verify actual admitted levels and stable state, and keep noise and gain observations distinct. Avoid diagnosing compression solely from a noise increase.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-DISCUSSION-018 — Examine gain control or compression and stage loading before using a quiet-state noise budget. Record the reference and operating state, and identify the linearity boundary rather than correcting the loss as ordinary cable attenuation.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-DISCUSSION-019 — Report sensitivity to the installed active and bias path, list plausible instability, pickup and leakage mechanisms, and propose independent output and selective-load checks. Avoid a unique source or oscillation diagnosis.

Review: Chapter 13 — Hypothetical Case Adjudication: Antenna, Preamplifier, Attenuator, Filter, Cable, and Reference-Plane Integration.

V011-C13-DISCUSSION-020 — Compare whether the changed geometry affects desired transfer or common mode, preserve serialized and state records, and obtain installed evidence for each consequential configuration. Equal hardware identity alone is insufficient.

Review: Chapter 13 — Integrated Path Acceptance.

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V011-C13-DISCUSSION-021 — Retain separate results for desired transfer, noise, blocker response and installed coupling because they support different claims. Relate each to intended use and uncertainty rather than invent an unsupported aggregate score.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

V011-C13-DISCUSSION-022 — Request the measured grid, interpolation method, state applicability and uncertainty near the transition, and seek finer characterization if needed. Do not infer an exact response from sparse data or smooth plotting.

Review: Chapter 13 — Define a complete path at named planes.

V011-C13-DISCUSSION-023 — Treat relocation as potentially consequential to installed coupling, examine geometry and common mode, and renew applicable acceptance. Stable scalar loss does not settle the installed field response.

Review: Chapter 13 — Integrated Path Acceptance.

V011-C13-DISCUSSION-024 — Distinguish demonstrated assembled transfer at tested conditions from unverified component properties and formal applicability. State the bounded current evidence and unresolved limits without either discarding the reference or claiming it establishes every certificate property.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-C13-DISCUSSION-025 — Name separate measurands, planes, states, uncertainty and supporting tests; identify the field-geometry and coupling limits. Explain why different evidential strength is appropriate and avoid extending the stronger conducted result into untested field conditions.

Review: Chapter 13 — A constructed acceptance case for the assembled chain.

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Chapter Glossary

ANTENNA FACTOR: Frequency-dependent relationship used to convert antenna-terminal voltage to incident electric-field strength under stated conditions.

ANTENNA TERMINAL PLANE: The declared electrical boundary between an antenna and the receiving path. A conducted reference applied there can test the downstream chain under the stated loading. It does not by itself characterize the antenna's conversion from an incident field, which also depends on direction, polarization, geometry and environment.

ASSEMBLY RECORD: Identification and order of the physical components, connections, and terminations that form a measurement path.

AVAILABLE POWER: The power a source can make available under the applicable matching convention. The chapter's ideal effective-aperture relation uses this quantity for the stated receiving-antenna conditions. It must not be interchanged with power actually delivered to an arbitrary load, particularly when mismatch or an installed coupling path is significant.

BIAS DELIVERY: The actual supply path and operating state used to power a remote active component. Cable resistance, protection elements and coupling to other equipment can make the remote condition differ from the source-terminal indication. Record the feed arrangement and available monitoring rather than inferring the amplifier's state from supply voltage alone.

BIAS TEE: Network combining or separating direct-current power and RF on a common conductor.

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BLOCKER-TRANSFER VERIFICATION: Characterization of the interfering-signal levels admitted up to the vulnerable stages under the stated assembly and state. It complements desired-signal transfer because a narrow downstream channel does not protect every earlier component. Retaining the desired reference during a blocker challenge helps distinguish changed gain from a raised noise contribution.

CALIBRATION BOUNDARY: The part of a measurement path and its stated conditions covered by a calibration. Components or effects outside that scope require additional treatment. An adapter included in an antenna calibration must not be corrected again, while a field cable beyond a receiver's calibrated connector remains outside the receiver calibration.

COMMON-MODE CURRENT: Current flowing on conductors together with respect to an external reference or surrounding structure.

CONDUCTED REFERENCE: Known signal applied at a specified electrical port to verify the transfer or response of the downstream path.

CONNECTOR REPEATABILITY: The consistency of a connection's electrical response when it is assembled again under controlled conditions. Reconnection, torque, contamination or mechanical strain can alter loss or reflection. A previous calibration remains relevant only to the extent that the resulting installed connection satisfies the required transfer and uncertainty conditions.

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CORRECTION OWNERSHIP: The assignment of each gain, loss or conversion to the calibration or processing step responsible for it. Explicit boundaries prevent omission and double correction when antenna, accessory and receiver records overlap. The correct assignment follows the actual measured assembly and quantity, not merely the presence of a certificate or file.

CORRECTION RECORD: The record identifying a correction's measured transfer, reference planes, frequency grid, interpolation, uncertainty and serialized applicability. It establishes which measured path and state the correction describes. It must distinguish corrections already applied from those still required and retain raw observations where needed to reconstruct the result.

DELIVERED POWER: The power transferred into the specified load under the actual source and load conditions. It can differ from available power when impedances are mismatched. A receiver indication and a calibration factor must refer to compatible loading before a terminal or field conversion is assigned.

DESIRED-TRANSFER VERIFICATION: A check of the response to a known desired signal between stated planes in the relevant configuration. It establishes the traversed path at the check time and supports comparisons whose detection capability is retained. An injection at the receiver connector bypasses upstream components and cannot verify their contribution.

EFFECTIVE APERTURE: Equivalent receiving area relating incident power density to available antenna power.

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EFFECTIVE HEIGHT: A receiving-antenna conversion quantity relating incident electric field to a specified terminal-voltage response under declared direction, polarization and loading conventions. It answers a voltage question, unlike effective aperture's power-density relationship. Its use requires the applicable antenna convention and field conditions rather than treating all antenna conversion factors as interchangeable.

FIELD-TO-TERMINAL CONVERSION: The relationship between an incident field and the electrical quantity at an antenna's terminals under stated conditions. Pattern, polarization, field region, loading and installation affect its applicability. A sound terminal-power measurement therefore does not automatically support an equally sound field-strength estimate in an uncharacterized environment.

INSERTION LOSS: The reduction in transferred signal associated with inserting a specified path under declared calibration planes, source and load conditions, frequency and level. Its measured value is conditional on those arrangements. Reconnection, strain, mismatch or a different selected branch can change the installed transfer.

INSTALLED RESPONSE: Behavior of the receiving assembly in its actual mounting, cable, grounding, and environmental arrangement.

LOAD-DEPENDENT STABILITY: The dependence of an active assembly's stable behavior on the impedance and network connected to it. An amplifier may respond differently to an antenna, matched termination, switch branch or cable. Stability evidence therefore covers the configurations actually tested and does not follow solely from one favorable bench arrangement.

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LOADED VOLTAGE: The terminal voltage under a declared connected load. Antenna factors and voltage-to-power conversions must use the compatible impedance and calibration convention. A nominal impedance label does not remove the need to state whether the calibration describes loaded voltage, open-circuit voltage, available power or delivered power.

NOISE PARAMETERS: A set of quantities used to describe how a device's noise behavior varies with source impedance under a specified model and reference plane. The cited vector-corrected method uses such characterization with measured reflections. Their role marks a boundary of the matched scalar cascade, whose simpler assumptions cannot silently supply them.

OPEN-CIRCUIT VOLTAGE: The terminal voltage defined with no load drawing current in the stated antenna or source model. It is not the same as the voltage across a specified receiver load. Applying a calibration intended for a loaded voltage to an open-circuit estimate can introduce a systematic conversion error.

OPTICAL ISOLATION COMPARISON: A controlled comparison in which an optical link removes a particular conductive path while its own gain, noise, bandwidth, timing and power state are characterized. Disappearance of a weak feature is inconclusive if the replacement lacks adequate sensitivity. A preserved desired reference makes the comparison more informative but does not identify every mechanism uniquely.

PATH CORRECTION: Measured gain or loss assigned to a specific serialized signal path and state.

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POLARIZATION COUPLING: The dependence of antenna response on the relationship between incident-field polarization and the antenna's receiving orientation. Rotation can change terminal level without a change in source strength. An installed comparison must therefore retain or deliberately vary orientation according to the stated measurement question.

REFERENCE PLANE: A named physical or modeled boundary at which a signal quantity, transfer or noise contribution is specified. Changing the reporting plane changes which downstream components belong to the correction. Two results must address compatible planes and quantities before their difference can be interpreted as improved measurement performance.

REMOTE PREAMPLIFIER: An active gain stage installed near the sensing element to reduce the effect of downstream cable loss and receiver noise. Its input is also exposed to signals throughout its admitted band. Gain, noise, blocker transfer, bias, protection and stability must therefore be assessed together in the installed arrangement.

RETURN LOSS: A logarithmic indication of reflection at a specified port and reference impedance, conventionally larger for a smaller reflected fraction. Improved matching can reduce some reflection effects, but an attenuator used to obtain it also lowers desired signal and adds thermal noise. The full measurement consequence must therefore be evaluated.

REVERSE ISOLATION: The limitation on signal transfer from a device's output side back toward its input under stated conditions. In a remote receiving assembly, insufficient isolation can allow downstream leakage to propagate toward the antenna. A forward-gain measurement alone does not establish this reverse-path behavior.

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SCALAR CASCADE: Ordered power-transfer and noise model with one effective channel per stage and explicitly bounded matching, state, and correlation assumptions.

SOURCE-IMPEDANCE DEPENDENCE: The change in a receiver's transfer or added-noise response when the impedance driving its input changes. Mismatch can therefore affect both delivered source power and the receiver contribution. A single scalar loss adjustment may be inadequate when the required noise-measurement accuracy depends on this interaction.

SPLITTER ISOLATION: The degree to which a signal or load change at one splitter branch is prevented from affecting another under stated port conditions. Finite isolation and coupled output loads can make unused branches consequential. Selected-path gain alone does not establish the behavior of the complete multiport assembly.

STATE RECORD: The record of the switch, gain, attenuation, bias, temperature and receiver settings relevant to an observation. It connects an assembled path to the transfer and noise behavior applicable at that time. Physical component identities alone cannot establish this state, especially across switching, warmup or remote-control transitions.

SUPPLY-PATH CONFOUNDING: Ambiguity introduced when a power-source comparison changes more than the noise on the supply. Replacing a supply with a battery can also alter conductive coupling and grounding. A changed receiver indication supports sensitivity to the intervention, but a more selective test is needed to identify which changed mechanism caused it.

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SWITCH LEAKAGE: Signal coupling through a nominally unselected switch path under specified conditions. A strong signal on an unused branch may remain observable despite selection of another branch. The switch state, port terminations and relevant isolation must therefore be included in the path model and acceptance record.

TERMINATED-INPUT TEST: An observation made with a specified load replacing the usual input source or antenna. It can constrain hypotheses about pickup, leakage or instability, but it also changes the source impedance and installed coupling. The comparison must retain the detection capability and operating conditions needed by the question.

UNUSED-PORT TERMINATION: Load condition at a nonselected network port that can affect leakage, matching, or coupling into the selected path.

VECTOR NOISE CORRECTION: A noise-measurement treatment that retains the relevant impedance and receiver-noise relationships rather than reducing all mismatch effects to one scalar loss. The cited method separates delivered source power from changes in receiver response. Applying such a method requires its additional characterization; citing it does not make that information available for an unmeasured assembly.

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Annotation. Introduction and sections 3.3, 4.1 and 9.10, printed pages 2, 9, 11–13 and 64. The cited antenna, mounting, feed-cable, coupling and use-uncertainty limitations support the distinction between calibration and installation. Historical EMC geometries, standards references and numerical examples are not asserted as current universal survey requirements. This measurement guide places antenna calibration in the context of the test environment, mounting geometry, cable paths and frequency-dependent response. A receiver comparison should track antenna factors, mismatch and phase-centre conventions at the declared reference plane rather than regard an antenna reading as a direct field value. Any extrapolation from laboratory calibration to a different installation requires documented geometry and uncertainty. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

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Weatherspoon, Mark H., Lawrence P. Dunleavy, Ali Boudiaf, and James P. Randa. “Vector Corrected Noise Temperature Measurements.” 2002 IEEE MTT-S International Microwave Symposium Digest (2002): 2253–56. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=954.

Annotation. Sections II–IV and equations (1)–(7), printed pages 2253–2256. The four-page NIST-hosted scan supports the distinction between mismatch effects on delivered source power and on receiver gain/noise response. The chapter cites the vector method to identify the boundary of Model 2B’s matched scalar approximation; it does not claim the additional receiver parameters were measured for an unspecified installation. The cited work treats receiver noise as a gain- and bandwidth-dependent measurement problem, including equivalent input noise or cascaded stages. Input and output reference planes, source temperature, impedance match, receiver gain and effective detector bandwidth must all be stated. Noise-figure figures from a particular test setup do not establish minimum detectable signals or calibrated sensitivity in every field installation. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

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Chapter 14. Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty

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14.1 Calibration Model and Traceability

Calibration relates receiver indication to reference quantities under stated configurations. It does not certify every possible frequency, level, bandwidth, detector, gain, modulation, or environmental condition. A calibration certificate should identify the instrument, option set, firmware where relevant, standards, methods, results, uncertainties, and dates. The practitioner determines whether the intended measurement lies within that scope.[1]

Traceability is a documented chain of comparisons with stated uncertainties, not a label attached to an instrument. External cables, filters, preamplifiers, antennas, digitizers, and software corrections extend the measurement chain beyond the calibrated receiver. Their characterization and stability must be included. A field check with a known source verifies present function but does not replace a full calibration.

1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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14.2 Attach calibration to a stated measurement result

A calibration plan begins with the quantity to be reported. Receiver-terminal power, antenna-terminal power, field strength, carrier frequency, relative channel phase, noise figure, and detection probability require different evidence. They may share hardware and reference standards, but they do not share one universal correction. Write the measurement equation first, identify the inputs that materially affect it, and then select the calibrations and checks that support those inputs. This order prevents a collection of certificates from being mistaken for a complete argument about the final result.

The VIM defines calibration through the relation between standards, indications, and their uncertainties, and distinguishes it from adjustment and verification. It defines metrological traceability as a property of a result supported by a documented calibration chain, with uncertainty contributed along that chain. It also cautions that traceability alone does not ensure adequate uncertainty or freedom from mistakes. These distinctions are directly relevant to a receiver whose calibrated components may be used in an unverified assembly.[2]

A calibration scope should therefore be read as a set of conditions. Identify the instrument serial, options, firmware or processing version where relevant, frequency range, level range, gain and attenuation states,

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2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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bandwidths, detector or data reduction, reference planes, and environmental limits. Determine which corrections are already applied by the instrument and which remain external. A certificate can be entirely valid while omitting the particular state used in a survey. In that case, characterize the missing state or narrow the reported claim; do not imply coverage by association.

Traceability records and configuration records answer complementary questions. The first links numerical values to references and uncertainties. The second establishes which values belong to the observation. A precisely calibrated cable correction applied to the wrong cable is a configuration error, not a small uncertainty contribution to be hidden in a budget. Likewise, a software sign error can invalidate a corrected level even when every calibration input is excellent. Independent recomputation of a small set of representative records is a useful way to reveal such implementation mistakes.

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A. An illustrative 50-Ω receiver chain

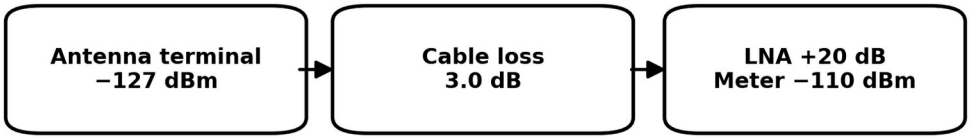

Reference plane: the antenna terminals, not the receiver display.

B. Corrections and uncertainty

$$P_{antenna} = P_{meter} + L_{cable} - G_{LNA}$$

$$= -110 + 3 - 20 = -127\,\text{dBm}$$

$$u_c = \sqrt{0.5^2 + 0.2^2 + 0.4^2} = 0.67\,\text{dB}$$

C. Traceability checks

Preserve frequency, attenuation, gain state, uncertainty and calibration dates.

The uncertainty example assumes uncorrelated standard uncertainties in dB; correlation and systematic effects require separate treatment.

Figure 74. Calibrated receiver reference plane.

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14.3 Amplitude Response and Linearity

Amplitude calibration covers frequency response, input attenuation, preamplifier gain, reference level, detector, IF bandwidth, impedance, and display scaling. Measurements at one level do not prove linearity across the range. Verification uses multiple levels and frequencies, including points near band boundaries and gain-state transitions. The source path and power sensor must have better or independently understood accuracy.

Mismatch introduces frequency-dependent error through reflections among source, cable, accessories, and receiver. Adding attenuation can improve match while changing noise and level. Vector correction may be necessary for high-accuracy work. At low levels, noise and detector statistics dominate; at high levels, compression and intermodulation dominate. The uncertainty model should change accordingly.

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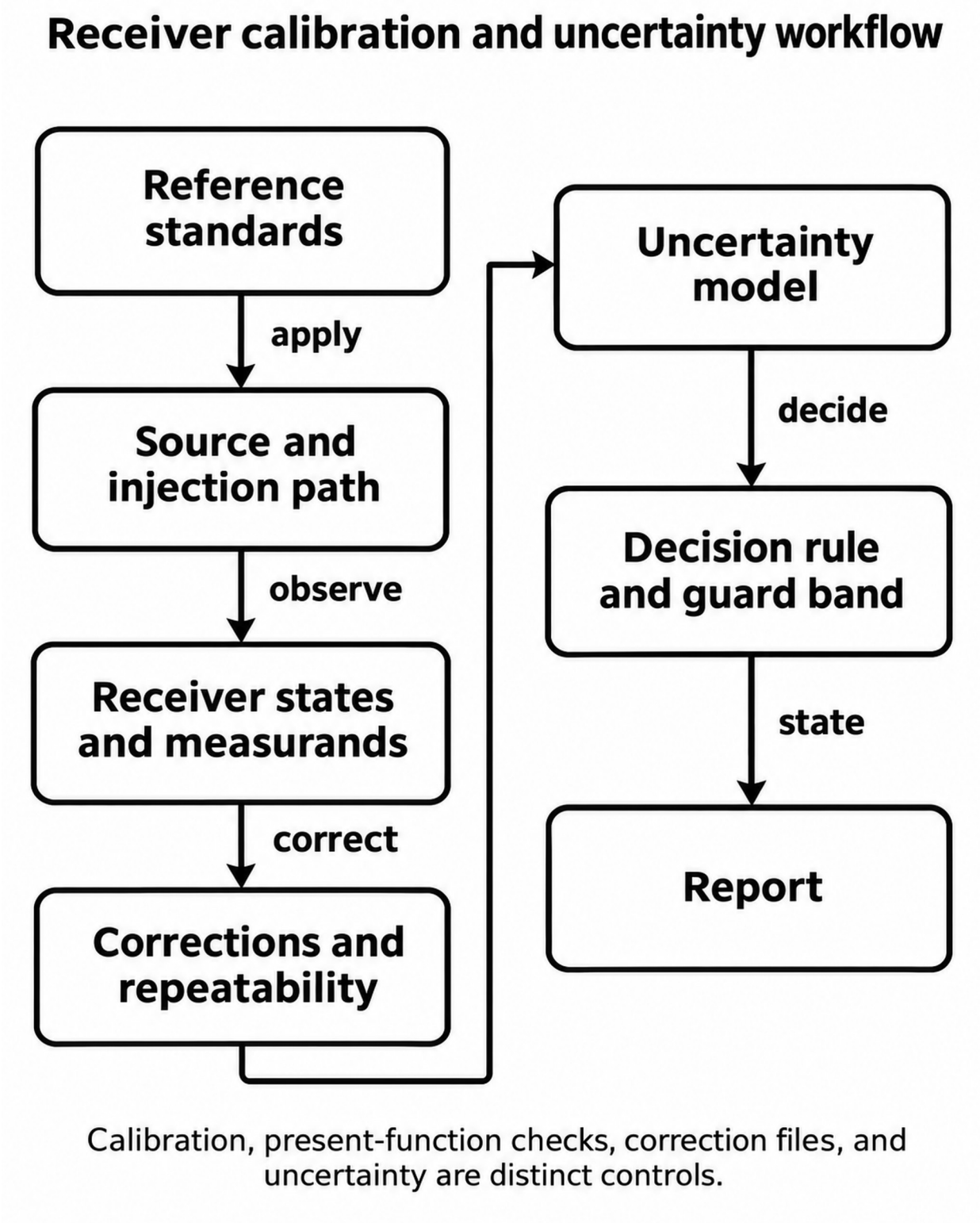

Figure 75. Receiver calibration and uncertainty workflow.

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14.4 Build a correction chain with signs that can be checked

Use the level-transfer relation in Equation 26 to move a measurement to an earlier plane. Loss is added when referring a downstream reading backward, and gain is subtracted. This sign rule follows from the physical forward path. It should be verified by predicting a downstream reading from a known upstream reference, then reversing the calculation. The forward check is particularly useful when a correction file mixes positive loss entries with signed gain entries or when instrument software already applies one of the corrections.

Consider a constructed conducted measurement at 915 MHz. The raw receiver indication is −72.60 dBm. The receiver's residual amplitude correction is +0.20 dB. Ahead of it are a 2.40 dB cable loss, a 17.80 dB external amplifier gain, and a 1.10 dB input-filter loss, all defined for the selected assembly and frequency. Referring the result to the filter input gives $-72.60+0.20+2.40-17.80+1.10$, or −86.70 dBm. The same model predicts a receiver-plane power of −72.40 dBm from that upstream value, agreeing with the corrected indication.

This example is a calculation record, not an actual calibrated result. A real record would need the measured values and uncertainty statements for those exact components, evidence that the receiver and amplifier were linear at the applied levels, and the matching or mismatch treatment appropriate to the interfaces. A filter or amplifier measured at another bias, temperature, or switch state may require a different correction. When a correction is interpolated between calibration frequencies, the interpolation

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method and any unresolved response structure belong in the measurement model.

Calibrate amplitude over the level range that matters, not only at a convenient strong reference. A level sequence can reveal compression near the upper end and noise or detector bias near the lower end. Repeat relevant points across attenuator and preamplifier transitions. The desired outcome is a response whose residual behavior is understood within the claimed range. A straight line fitted across a compressed region can produce small average residuals while misrepresenting the weak-signal and strong-signal endpoints. Retain the individual observations and the rationale for the accepted range.

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14.5 Frequency and Phase Calibration

Frequency calibration compares receiver tuning or measured components with a reference whose uncertainty and stability are known over the observation interval. Phase calibration includes channel delay, filter response, cable phase, converter phase, clock alignment, and any phase resets. A receiver can have accurate average frequency while losing deterministic phase after each retune or trigger.

Multichannel phase calibration is performed over frequency and repeated after cable or configuration changes. Phase unwrapping, interpolation, and reference-plane movement are documented. A single calibration tone cannot establish broadband group delay or phase matching. When only relative phase is required, the reference and stability requirement are stated explicitly.

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14.6 Frequency, phase, and delay require their own observables

Frequency calibration concerns the relation between an observed frequency and an appropriate reference over a stated interval. The reference's calibration, stability, distribution path, and the receiver's estimation process can all matter. A reference input labeled as locked establishes a state indication; it does not alone quantify the residual error of a measured carrier. Compare a known signal using the actual observation duration and estimator, and retain the reference source and timing conditions. If the reference is shared by source and receiver, identify the errors that cancel and those that remain common.

Phase calibration has a different scope. Relative phase between channels requires a defined simultaneous input relationship and a repeatable reference plane for each channel. Cable delay, filter phase, conversion phase, and digitizer alignment all contribute. A single tone tests the phase relation at one frequency. It cannot establish broadband delay or distinguish all phase ambiguities. A frequency-dependent characterization is needed when a waveform spans a band, and the analysis must preserve the phase-unwrapping and interpolation conventions used to obtain the correction.

A receiver may return to the same amplitude after a retune while its conversion phase changes. Triggering, reference reacquisition, sample-rate changes, or a reset can likewise alter the relationship between records. Test repeatability across the actual operations that precede a measurement. If only within-record phase is reproducible, state that limit and avoid treating separately acquired records as a single coherent observation. Chapter 12

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develops timing and coherence in detail; the calibration record here identifies the state changes for which its corrections have been demonstrated.

Separate instrument delay from an event's arrival time. A known signal introduced at the receiver connector tests a different path from a signal introduced at an antenna or remote converter. Moving a timing reference plane requires accounting for the intervening path and its uncertainty. If that path can change with temperature or routing, a one-time correction has a limited scope. A time stamp in a file is useful only with its relation to the sampled signal, trigger, and reference clock documented well enough for the intended comparison.

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14.7 Noise Figure and System Sensitivity Calibration

Noise-figure calibration requires a known noise source or alternative method, stable bandwidth and gain, and linear response. Loss between the source and receiver is corrected at the reference plane. A preamplifier, switch, or filter changes the cascade and may require a new system measurement. Noise-source excess-noise ratio and receiver hot/cold readings contribute to uncertainty.

System sensitivity verification can use a calibrated coherent signal at several levels and detection statistics. This approach tests the complete path and decision rule, although it does not by itself separate noise contributions. In field configurations, a portable reference source and coupler can reveal drift or wrong correction files. The test must be arranged so that the reference does not radiate outside the controlled path or mask the environmental measurement.

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14.8 Calibrate noise without confusing it with detection

Applications 2B.8 through 2B.10 show the entire scalar hot/cold calculation, a gain-state failure, and a local uncertainty propagation. A practical implementation should preserve the same structure. Record both output powers, not only the computed noise figure; retain the source temperatures at the receiver plane, the source calibration, and the loss corrections that produced those temperatures. This permits an independent calculation and reveals impossible ratios, incorrect logarithmic conversion, or a change in the assumed cold temperature.

A useful sequence includes enough repeated source states to reveal drift and switching behavior. Settling time should be established from the observed response rather than assumed from a software delay alone. A receiver that changes gain after the source switches invalidates the simple ratio even when it eventually settles. The measurement may still be possible with a more complete state-dependent model, but the equal-gain inversion cannot be used until its conditions are demonstrated. Check the highest noise-power state for compression, since the cold-state response can remain apparently normal.

Mismatch deserves a separate decision. If the hot and cold source impedances differ materially, their delivered powers and the receiver's noise response can differ as well. A matched attenuator may reduce this sensitivity at a noise cost; vector characterization may support a more complete correction. The choice depends on the target uncertainty and available characterization. The vector noise-temperature work cited in Chapter 13 establishes why both source and receiver mismatch can matter. It does not

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authorize applying a vector correction without the required measured parameters.

A sensitivity verification then asks a different question: whether the complete system and its decision rule detect the intended reference under stated conditions. Use a calibrated signal with defined waveform, duration, frequency, and level at the selected plane. Retain detections and misses, including the receiver's observation schedule. A noise-figure result helps explain performance, but it cannot substitute for this verification when acquisition timing, interference, modulation, or threshold behavior matters. Conversely, a successful detection trial does not uniquely identify the receiver's equivalent noise temperature.

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14.9 Uncertainty Budgets and Decision Rules

An uncertainty budget begins with a measurement model and identifies quantities that affect the result. Typical terms include calibration, frequency response, attenuator and preamplifier state, cable loss, antenna conversion, mismatch, detector statistics, repeatability, temperature, bandwidth, clock, geometry, and analysis. Sensitivity coefficients express how each input changes the measurand. Correlation is considered where terms share a calibration or physical mechanism.

Expanded uncertainty and coverage factor are reported with the result when appropriate. Detection and compliance decisions may use guard bands so that uncertainty near a limit is not ignored. A result can be indeterminate rather than forced into pass or fail. The report distinguishes measured value, correction, standard uncertainty, expanded uncertainty, decision rule, and residual limitations.

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14.10 Use covariance and model sensitivity deliberately

Equation 27 expresses a first-order uncertainty propagation. Its sensitivity coefficients carry the signs and units of the measurement function; they are not always one. The JCGM guidance distinguishes uncorrelated inputs from inputs sharing a calibration or influence, and requires significant covariance to be retained. Common influences can alternatively be represented as explicit inputs to the measurement function. This is useful because a shared error may cancel in a difference but reinforce in a sum. The signs come from the model, not from a preference for a larger or smaller reported uncertainty.[3]

Return to the constructed −86.70 dBm correction chain. Assign standard uncertainties of 0.12 dB to the indication, 0.20 dB to the residual receiver correction, 0.10 dB to the cable loss, 0.18 dB to the amplifier gain, and 0.08 dB to the filter loss. With zero covariances, the variance is $0.0144 + 0.0400 + 0.0100 + 0.0324 + 0.0064$ equal to 0.1032 square decibel, giving 0.321 dB combined standard uncertainty. The amplifier coefficient is minus one; its squared contribution is still positive.

Now stipulate, for a second version of the same constructed budget, a correlation coefficient of +0.60 between the residual receiver correction and the measured amplifier gain. Their standard uncertainties remain 0.20 and 0.18 dB. Because their coefficients have opposite signs, the covariance term

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3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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is −2 times 0.20 times 0.18 times 0.60, or −0.0432 square decibel. The total variance becomes 0.0600 square decibel and the standard uncertainty becomes 0.245 dB. This reduction is justified only if that positive correlation is supported by the actual calibration model or evidence. Choosing a favorable correlation without support is not uncertainty evaluation.

The numerical example also shows why a budget should not count a common reference uncertainty twice as independent while separately adding a covariance for it. Either represent the common reference explicitly in the measurement equation or use a consistent covariance matrix for the derived inputs. Inspect whether the same correction has already been included in an instrument specification or calibration statement. A complete-looking table can otherwise exaggerate or understate the result through double counting, even when every individual number has a legitimate source.

NIST's uncertainty guidance emphasizes that the measurement function must represent the measurement process, including significant corrections and influences. It also distinguishes uncertainty in an applied correction from the error that the correction addresses. For this receiver case, known significant offsets should be corrected with their uncertainty retained. Enlarging an uncertainty interval to conceal an unapplied correction would make the reported central value less informative and could change a decision near a limit.[4]

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4 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers” (June 14, 2013), “Baseline Case: Cascade of Linear Circuit Blocks” and “Noise Temperature,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and

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First-order propagation needs a local adequacy check. In Application 2B.10, the inversion is evaluated well away from Y equal to one, and the stipulated uncertainties are small enough to motivate a local calculation. Near the singular boundary, symmetric input uncertainty can produce a strongly asymmetric output distribution. Use an appropriate nonlinear propagation method when the linear approximation does not represent the problem, and state the input distributions and dependencies that method requires. A simulation can propagate assumptions accurately while the assumptions themselves remain unsupported.

synthetic cases are stated in Model 2B.

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14.11 Declare the decision rule before seeing the result

Expanded uncertainty adds a coverage convention to the standard uncertainty, as Equation 28 states. A factor of two is often convenient, but its interpretation depends on the output distribution and the uncertainty estimate. NIST's guidance gives the approximately normal, adequately known standard-uncertainty case in which it corresponds to about 95 percent coverage. Report the factor and the basis for its use. A coverage statement for a measured level is also distinct from a false-alarm or detection probability for a search procedure.[5]

5 H. T. Friis, “Noise Figures of Radio Receivers,” Proceedings of the IRE 32, no. 7 (July 1944): 419–22, https://doi.org/10.1109/JRPROC.1944.232049. The publisher’s abstract was read for the historical network, component, mismatch, and measurement framing. The full paper was not accessed; Model 2B supplies its own stated derivation and working conventions.

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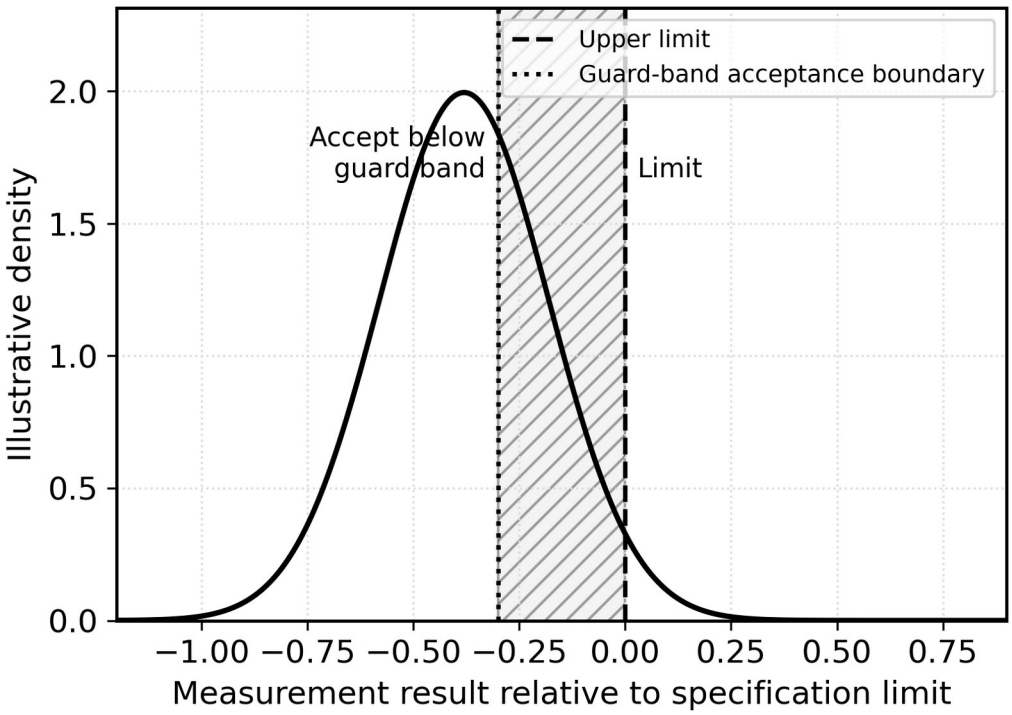

A defensible decision rule names the measurand, uncertainty, coverage assumptions and consequences of a false acceptance.

Figure 76. Uncertainty guard bands and acceptance risk.

For a constructed decision example, let the upper permitted input level be −86.50 dBm. Predeclare three outcomes: accept when the interval's upper end is no greater than the limit, reject when its lower end is greater than the limit, and otherwise report indeterminate. Using the correlated budget

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above with an illustrative factor of two gives −86.70 dBm with an expanded uncertainty of about 0.49 dB. Its upper end is −86.21 dBm, so the result does not meet the acceptance condition even though the central value is below the limit. The interval overlaps the limit; the stipulated rule yields an indeterminate outcome, not evidence that the actual level necessarily exceeds the limit.

The response to an indeterminate result should follow the measurement purpose. A better characterized path, a more suitable reference, or repeated observations addressing the dominant random contribution may reduce uncertainty. Repeating the same measurements does not reduce an unchanged calibration uncertainty, and moving the limit after observing the result defeats the declared decision rule. Retain the original result and the reason for any additional measurement. If a different rule is adopted for a later decision, identify it as a different rule rather than rewriting the earlier outcome.

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14.12 Calibration Lifecycle and Change Control

Calibration intervals are determined by stability, use, transport, environment, repair history, measurement consequence, and observed drift rather than by calendar alone. Intermediate checks use independent references selected to reveal likely failures in frequency, amplitude, attenuation, noise, phase, and sample continuity. A failed check quarantines affected data back to the last valid verification unless evidence supports a narrower interval.

Correction files and calibration constants are controlled as configuration items. Their version, serial applicability, units, interpolation, uncertainty, and software implementation are reviewed before use. A firmware update, option change, repair, or accessory replacement can invalidate prior corrections even when the receiver passes a basic self-test.

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14.13 Quantitative Model for Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty

Equation 1. Combined standard uncertainty

$$u_c(y)=\sqrt{\sum_i (c_i u_i)^2+2\sum_{i<j} c_i c_j u_i u_j r_{ij}}$$

Combined standard uncertainty u_c includes sensitivity coefficients c_i, input standard uncertainties u_i, and correlation coefficients r_{ij}. The model should reflect the actual measurement equation and distributions.

Equation 2. Expanded uncertainty

$$U=k_{\mathrm{cov}} u_c$$

Expanded uncertainty U equals combined standard uncertainty u_c multiplied by coverage factor k_{cov} selected for the stated coverage convention and effective degrees of freedom. The factor should not be assumed without justification.

Model 14B below distinguishes exact affine covariance propagation from the local approximation represented by Equation 27 and links ten worked applications of that same relation. Equation 28 adds a declared coverage factor; it does not independently establish a coverage probability or an acceptance decision.

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14.14 Model 14B: exact covariance and local uncertainty propagation

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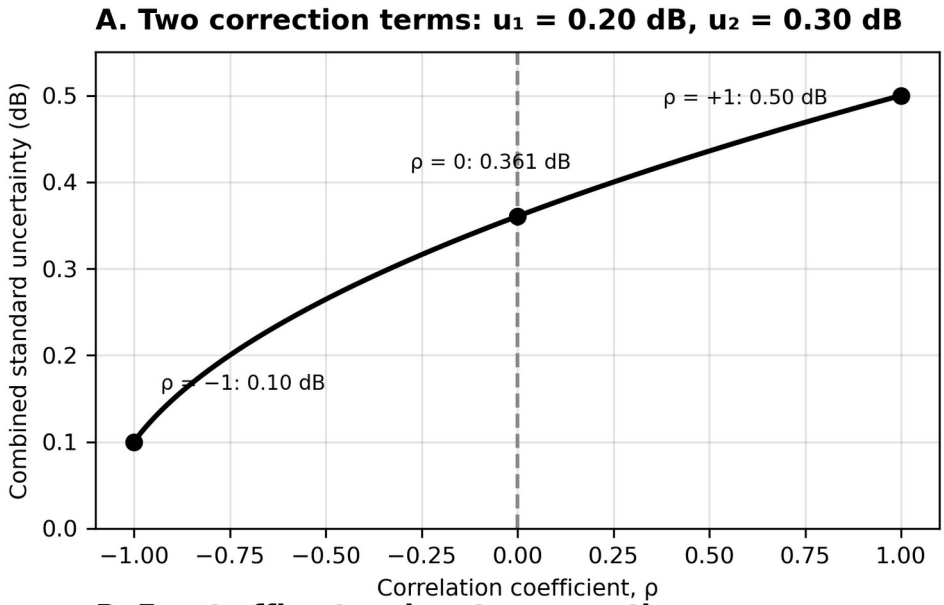

B. Exact affine two-input propagation

$$u_c^2 = u_1^2 + u_2^2 + 2\rho u_1 u_2$$

Same marginal uncertainties, different covariance, different result.

Shared standards and common calibration chains can produce correlated errors. Root-sum-square is valid only after relevant covariances are justified as negligible; sign conventions in the measurement function matter.

Figure 77. Correlated uncertainty in two-term corrections.

The uncertainty law in Equation 27 connects the preceding calibration cases. Its domain deserves the same care as a receiver gain or noise model. Let X be a finite vector of real input quantities, with finite second moments, mean vector μ, and covariance matrix Σ. Each component retains its own unit. A superscript T denotes transpose. The covariance entry Σ_{ij} has the product of

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the units of X_i and X_j. A physically admissible covariance matrix is symmetric and positive semidefinite; independently plausible pairwise correlations do not by themselves guarantee that a whole proposed matrix is admissible. The effect of covariance is illustrated in Figure 63.

For an affine measurement function $Y = a + c^{\mathrm{T}} X$, the constant a has the output unit and each coefficient c_i has the output unit divided by the corresponding input unit. Subtract the mean and expand the square of c^{T}\($X - \mu$ \). Linearity of expectation yields Equation 27A exactly. Independence and a normal distribution are unnecessary. Zero covariance removes a cross term, while a shared input can cancel or reinforce according to its signed coefficients.[6]

Equation 27A. Exact affine mean and covariance

$$Y = a + c^{\mathrm{T}} X, \mathrm{E}[Y] = a + c^{\mathrm{T}} \mu$$
$$\mathrm{Var}(Y) = c^{\mathrm{T}} \Sigma c$$

A nonlinear function g requires a different statement. At an input estimate x, use the gradient J, with component J_i equal to the partial derivative of g with respect to x_i. The linearized output is g\(x \)$+ J$\($X - x$ \), and its variance is $J \Sigma J^{\mathrm{T}}$. Treating that variance as the uncertainty of g\(X \) requires the neglected nonlinear remainder to be adequately small for the intended result. A derivative can vanish while curvature remains consequential.

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6 International Electrotechnical Commission, CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus, 5th ed. (May 22, 2019), official publication scope, https://webstore.iec.ch/en/publication/60774, checked November 1, 2026. The public scope identifies the 9 kHz–18 GHz apparatus range and EMI receivers and spectrum analyzers. No access to or clause-by-clause compliance review of the complete standard is claimed.

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Equations 27A and 27B therefore distinguish a mathematical identity from a local approximation.[7]

Equation 27B. Local nonlinear propagation

$$Y_{\text{lin}} = g(x) + J(X - x)$$
$$J_i = \frac{\partial g}{\partial x_i}, u_{\text{lin}}{}^2 = J \Sigma J^{\text{T}}$$

Standard uncertainty describes dispersion under the stated input information. It is not a maximum error bound. An expanded interval additionally needs the factor, distributional or coverage justification, and decision rule discussed earlier under “Declare the decision rule before seeing the result.” A calibration input does not become independent merely because it occupies a separate row of a budget, and repetition does not remove a common correction uncertainty. The examples below state such dependencies explicitly.

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7 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers,” June 14, 2013, “Baseline Case: Cascade of Linear Circuit Blocks,” “A Heterodyne Receiver,” “Noise Temperature,” and “Y-Factor,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html. The scalar derivation and numerical cases here are original and explicitly exclude unmodeled image contributions.

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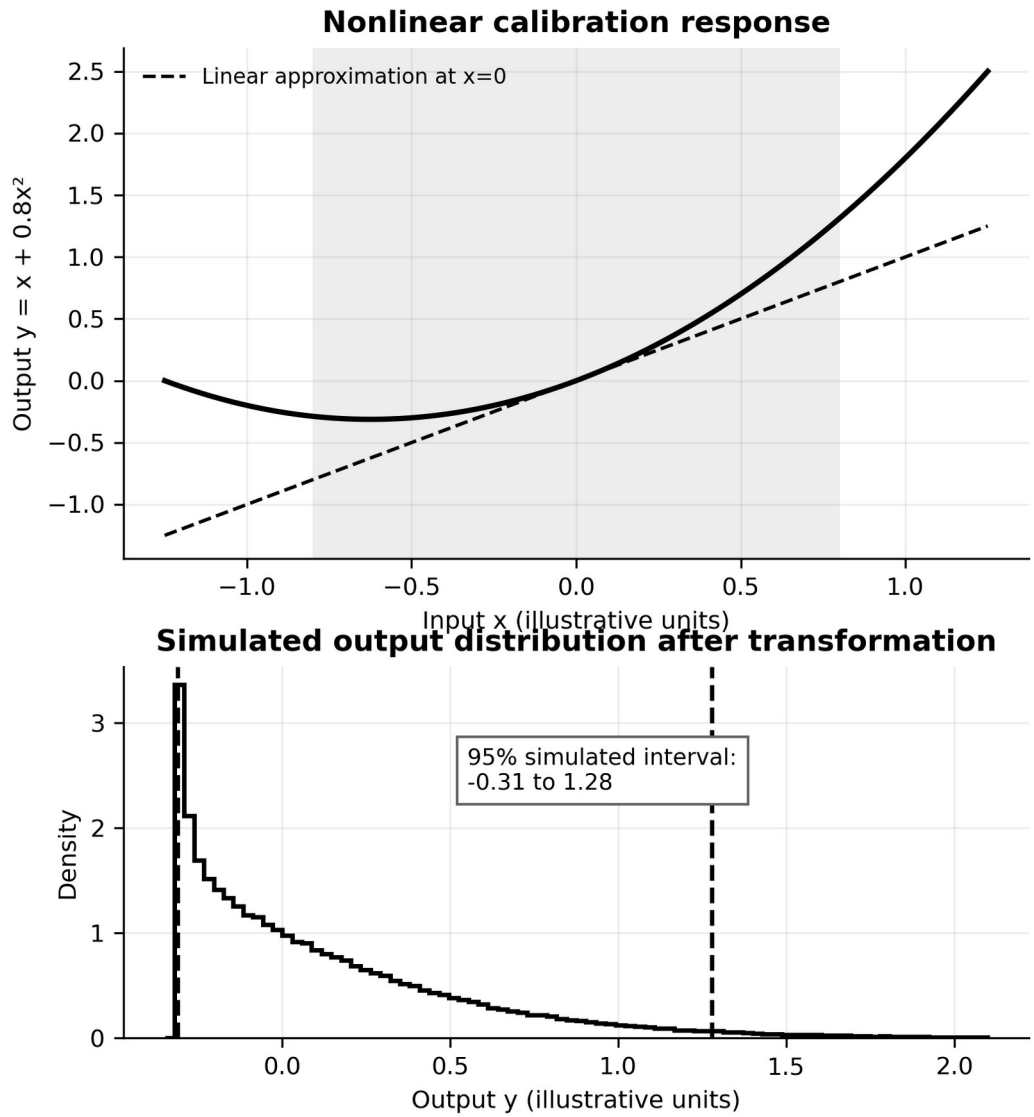

TECHNICAL INTERPRETATION

A symmetric input uncertainty may yield a skewed output interval after a nonlinear calibration. Linearized uncertainty may misdescribe coverage.

Figure 78. Nonlinear measurement-uncertainty propagation.

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14.14.1 Four worked applications already developed in the calibration chain

Application 14B.1 is the signed correction chain in “Build a correction chain with signs that can be checked” and its independent budget in “Use covariance and model sensitivity deliberately.” The five terms give −86.70 dBm; their squared standard-uncertainty contributions sum to 0.1032 dB^2, giving 0.321248 dB. This is exact affine propagation under the declared zero covariances. The negative amplifier coefficient changes the central correction sign while its individual variance contribution remains positive.

Application 14B.2 is the correlated version immediately following that budget. A +0.60 correlation between the +0.20 dB correction uncertainty and the subtracted 0.18 dB gain uncertainty contributes −0.0432 dB^2. The remaining 0.0600 dB^2 gives 0.244949 dB. The following decision example uses this same result. The covariance is an input to be supported by the calibration method, not a free adjustment chosen to obtain acceptance.

Application 14B.3 is the four-component RSS screen under this chapter’s hypothetical applied calculation. Its terms 0.35, 0.25, 0.20, and 0.15 dB give 0.2475 dB^2 and 0.497494 dB. The expanded value at the stipulated factor of two is 0.994987 dB. This simpler screening budget isolates independent additive contributions and rounding; the stated factor alone does not create a probability guarantee.

Application 14B.4 is Application 2B.10, “Propagate the local calibration uncertainty.” Equations 4N–4P retain the signs and units of the hot/cold inversion sensitivities. The displayed 266.54, 1.19, and 12.84 K^2 contributions give approximately 16.75 K, followed locally by 0.0921 dB noise-figure

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standard uncertainty. Unlike the preceding affine budgets, this calculation is local and can fail near the inversion's $Y = 1$ singularity. Its original inputs, derivation, and coverage limitation remain in Chapter 2.

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14.14.2 Worked applications with hypothetical inputs

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14.14.3 Application 14B.5: cancel a shared phase reference correctly

Two calibrated channels report phases of 34° and 11° on one explicitly unwrapped branch. Their difference is 23°. Stipulate mutually uncorrelated residual channel errors with standard uncertainties 0.30° and 0.40°, and an identical additive reference contribution with standard uncertainty 0.80° in both channels. Subtraction cancels that common input exactly. The remaining variance is \($0.30^2 + 0.40^2$ \) $\text{degree}^2 = 0.25\ \text{degree}^2$, and the standard uncertainty is 0.50°.

The same answer follows from the channel covariance matrix. Its diagonal entries are $0.30^2 + 0.80^2 = 0.73$ and $0.40^2 + 0.80^2 = 0.80$ degree squared, and the off-diagonal entry is $0.80^2 = 0.64$ degree squared. Applying coefficients +1 and −1 gives $0.73 + 0.80 - 2$ \(0.64 \) $= 0.25$. Treating the two marginal channel uncertainties as independent instead gives 1.23693°, which double counts the common contribution. Cancellation depends on the identical coupling and shared state; different reference paths or an unresolved phase branch invalidate that simplification.

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14.14.4 Application 14B.6: propagate phase-slope delay uncertainty

For a characterized constant-delay path, define Φ as phase at the lower frequency minus phase at the higher frequency, on the established unwrapped branch, in degrees. Let Δf be the positive frequency separation in hertz. Then $\tau = \frac{\Phi}{360\,\Delta f}$ in seconds. Stipulate $\Phi = 36.0^{\circ}$, $\Delta f = 100\ \text{MHz}$, standard uncertainties 0.20° and 10 kHz, and zero covariance. The delay estimate is 1.000 ns. The signed sensitivity coefficients are $\frac{1}{360\,\Delta f} \approx 2.77778 \times 10^{-11}\ \text{s/degree}$ and $-\frac{\Phi}{360\,\backslash(\Delta f\,\backslash)^2} = -1.00000 \times 10^{-17}\ \text{s/Hz}$.

Equation 27C. Local uncertainty of an unwrapped phase-slope delay

$$c_{\Phi} = \frac{1}{360\,\Delta f},\ c_{\Delta f} = -\frac{\Phi}{360\,(\Delta f)^2}$$

$$u_{\tau}^{2} \approx c_{\Phi}^{2} u_{\Phi}^{2} + c_{\Delta f}^{2} u_{\Delta f}^{2} + 2\,c_{\Phi}\,c_{\Delta f}\,\mathrm{Cov}(\Phi, \Delta f)$$

The uncertainty contributions before squaring are +5.55556 ps and −0.10000 ps. Their squared sum gives a standard uncertainty of 5.55646 ps. The frequency-separation relative standard uncertainty is only 0.0001 in this constructed case, supporting a local denominator approximation; the phase-to-delay map is already linear in Φ. Neither the calculation nor a small result chooses the phase branch, proves a constant delay across a wider band, or establishes the receiver’s phase-repeatability after retuning. Those conditions require the timing checks developed in Chapter 12.

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14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation

A correction file has values of +0.60 and +1.00 dB at adjacent frequencies. At a fixed fractional position $w = 0.25$ between them, linear interpolation gives $[0.75 \backslash (0.60 \backslash) + 0.25 \backslash (1.00 \backslash)]\ \mathrm{dB} = +0.70\ \mathrm{dB}$. Stipulate endpoint standard uncertainties 0.15 and 0.20 dB, correlation +0.40, and a separately characterized zero-mean interpolation residual with standard uncertainty 0.08 dB, uncorrelated with both endpoints. Denote the resulting correction by C, the endpoint standard uncertainties by u_0 and u_1, their correlation by r, and the residual standard uncertainty by u_{res}. The residual represents imperfect interpolation of the physical response; the formula alone does not establish its size.

Equation 27D. Correlated interpolation with a separate response residual

$$u_C{}^2 = (1-w)^2 u_0{}^2 + w^2 u_1{}^2 + 2\,w\,(1-w)\,r\,u_0 u_1 + u_{\mathrm{res}}{}^2$$

The two endpoint variance terms are 0.01265625 and 0.00250000 dB². Their covariance contribution is +0.00450000 dB², so the endpoint-only standard uncertainty is 0.140201 dB. Adding $0.08^2\ \mathrm{dB}^2$ for the residual gives 0.02605625 dB² and 0.161419 dB. The result shows why endpoint uncertainty and response-model inadequacy answer different questions. A dense enough characterization or an independently supported smoothness bound is needed to justify the residual term. If w is uncertain or extrapolation is used, the measurement equation must include that changed condition.

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14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove

Let a corrected level be the arithmetic mean of n readings in dBm plus one common calibration correction. Stipulate independent zero-mean reading errors with standard deviation 0.40 dB and a zero-mean common correction uncertainty of 0.30 dB independent of those errors. Use σ_{rep} for the reading-error standard deviation and u_{cal} for the common calibration standard uncertainty. The calibration contribution is the same random input in every corrected reading. For $n=16$, a mean indication of −80.20 dBm and a +0.15 dB correction give −80.05 dBm.

Equation 27E. Mean variance with a common calibration contribution

$$\mathrm{Var}\left(Y_{\mathrm{mean}}\right)=u_{\mathrm{cal}}{}^{2}+\frac{\sigma_{\mathrm{rep}}{}^{2}}{n}$$

The variance is \(0.30^2+\frac{0.40^2}{16} \) $\mathrm{dB}^2=0.1000\ \mathrm{dB}^2$, so the standard uncertainty is 0.316228 dB. Increasing the count to 64 gives 0.0925 dB² and 0.304138 dB. As the positive integer n grows, the standard uncertainty approaches 0.30 dB. The same result follows from a full reading covariance matrix: distinct corrected readings share covariance 0.09 dB². Averaging removes neither that common term nor an unrecognized bias. Correlated reading errors, drifting corrections, or averaging powers before logarithmic conversion require a different model; Chapter 8 distinguishes the last operation from a mean of levels.

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14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm

Under the fixed-transfer and additive-power conditions of Model 11B, suppose paired on-state and off-state estimates are 1.30 and 1.00 nW. Their standard uncertainties u_{on} and u_{off} are 0.04 and 0.03 nW, with correlation +0.80 justified here by an explicit constructed joint law. Let Z_1 and Z_2 be independent uniform variables on $[-\sqrt{3}, \sqrt{3}]$, each with zero mean and unit variance. Set the off estimate to $\backslash(1.00 + 0.030\, Z_1 \backslash)\ \text{nW}$ and the on estimate to $\backslash(1.30 + 0.032\, Z_1 + 0.024\, Z_2 \backslash)\ \text{nW}$. These definitions give the stated variances and covariance 0.00096 nW².

Equation 27F. Exact power-difference variance and local logarithmic sensitivity

$$D = P_{\text{on}} - P_{\text{off}}, u_D{}^2 = u_{\text{on}}{}^2 + u_{\text{off}}{}^2 - 2\,\text{Cov}\left(P_{\text{on}}, P_{\text{off}}\right)$$

$$L_{\text{dBm}} = 10 \log_{10}\left(\frac{D}{1\ \text{mW}}\right), \frac{\partial L}{\partial D} = \frac{10}{\ln(10)\, D}$$

The estimated additional power is 0.300 nW. Its exact affine variance is $[0.04^2 + 0.03^2 - 2\backslash(0.00096\backslash)]\ \text{nW}^2 = 0.00058\ \text{nW}^2$, giving 0.0240832 nW standard uncertainty. More strongly, its complete stipulated support is $[0.300 \pm \sqrt{3}\backslash(0.002 + 0.024\backslash)]\ \text{nW}$, with approximate endpoints [0.254967, 0.345033] nW. Every value is positive, so a logarithmic transform is defined throughout this particular input domain. That property comes from the joint law, not merely from the positive central estimate.

Converting 0.300 nW to dBm gives −65.228787 dBm. The local logarithmic coefficient is $\frac{10}{\ln\backslash(10\backslash) \times 0.300}\ \text{dB/nW} \approx 14.476483\ \text{dB/nW}$, giving approximately 0.348640 dB standard uncertainty. This is a local propagation, not the exact standard deviation of the transformed distribution. The exact transformed

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support has approximate endpoints [−65.935166, −64.621390] dBm and is asymmetric around the transformed central value. No coverage probability is assigned to a multiple of the local standard uncertainty. If a different on/off budget admits zero or negative differences, this logarithmic result cannot be carried across that boundary; retain the linear difference and resolve its interpretation first.

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14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law

Consider the static power quantity $P=\frac{X^2}{R}$ for an exactly known positive resistance $R=50\ \Omega$. Stipulate a Gaussian voltage quantity X with mean μ and standard deviation $\sigma=1.00\ \mathrm{mV}$. This is an uncertainty example for a nonlinear transformation, not a specification of a temporal noise process. Write $X=\mu+\varepsilon$, where the Gaussian centered moments are $\mathrm{E}[\varepsilon]=0$, $\mathrm{E}[\varepsilon^2]=\sigma^2$, $\mathrm{E}[\varepsilon^3]=0$, and $\mathrm{E}[\varepsilon^4]=3\sigma^4$. Expanding X^2 and X^4 gives the exact mean and variance in Equation 27G.

Equation 27G. Exact squared-Gaussian moments and the retained local term

$$\mathrm{E}[P]=\frac{\mu^2+\sigma^2}{R}$$
$$\mathrm{Var}(P)=\frac{4\mu^2\sigma^2+2\sigma^4}{R^2}$$
$$u_{\mathrm{lin}}{}^2=\left(\frac{2\mu}{R}\right)^2\sigma^2$$

At $\mu=10.0\ \mathrm{mV}$, evaluating the power function at the mean gives 2.000 μW, whereas the expected power is 2.020 μW. The local standard uncertainty is 0.400000 μW; the standard uncertainty from the exact model is approximately 0.400999 μW. The additional 0.020 μW mean shift and the small variance correction arise from curvature. Whether they may be neglected depends on the required result, not on the apparent precision of the input estimate.

At $\mu=0$ with the same σ and R, the derivative $\frac{2\mu}{R}$ vanishes and first-order propagation returns zero. Yet the exact mean power is 20.0 nW and the

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exact model gives a standard deviation of approximately 28.2843 nW. The exact variance is $8.00 \times 10^{-16}\ \mathrm{W}^2$. This counterexample identifies the missing term rather than treating a zero derivative as a perfect measurement. A nonlinear expectation is generally different from the function evaluated at the input expectation. The same warning applies near receiver calibration singularities, physical boundaries, and strongly curved transformations.

Table 1. Chapter 14 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Calibration scope	Instrument, options, firmware, ranges, bandwidths, methods, standards, and uncertainties	Defines where traceability applies	A valid certificate may not cover the selected configuration
Amplitude and linearity	Frequency points, levels, gain states, detector, match, and compression check	Supports corrected power or voltage	One-level calibration does not establish linearity
Phase and timing	Reference, channel delay, filters, cables, retune state, and repeatability	Supports coherence, delay, and DF measurements	A narrowband tone cannot define broadband phase
Uncertainty and rule	Model, inputs, distributions, correlation, coverage, guard band, and decision	Makes the conclusion quantitatively reviewable	A point result near a limit can be indeterminate

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14.15 Hypothetical Applied Calculation: Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty

A hypothetical corrected signal level is −82.4 dBm. Stipulate independent additive standard-uncertainty contributions of 0.35 dB calibration, 0.25 dB path correction, 0.20 dB repeatability, and 0.15 dB detector statistics. Their variance sum is $0.1225+0.0625+0.0400+0.0225\ \mathrm{dB}^2=0.2475\ \mathrm{dB}^2$, giving 0.497494 dB, or about 0.50 dB. An illustrative coverage factor of two gives 0.994987 dB, rounded to 1.0 dB, so the stated expanded result is −82.4 dBm ±1.0 dB. This is Application 14B.3. A 95 percent interpretation additionally requires a justified output distribution and uncertainty estimate; it does not follow from multiplication alone.

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14.16 Hypothetical Case Adjudication: Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty

Two analyzers disagree by 2.8 dB on a weak signal. Review shows that one trace uses an external preamplifier correction measured at room temperature, while the outdoor preamplifier has warmed by 35 degrees Celsius and changed gain. A temperature-characterized correction reduces the difference to 0.6 dB, within the combined uncertainty.

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14.17 System-Level Vector Calibration and Uncertainty

Published experimental example. In a 2025 study, Kast and colleagues calibrated a 28 GHz VSA over a 160 MHz measurement band using a traceably characterized sampling oscilloscope. They derived complex corrections with a multisine and tested a 64-QAM waveform, carrying magnitude, phase, mismatch, cable, and repeatability contributions through a Monte Carlo calculation that retained correlations. The reported mean EVM decreased from about 3.2% to below 0.7% after calibration. Including calibration uncertainty also widened the distribution relative to the repeatability-only result.[8]

The experiment gives Models 7A and 14B a concrete calibration setting. Repeatability alone did not represent the full measurement uncertainty. The same oscilloscope served as calibration and comparison receiver, so agreement could retain common reference errors. The reported correction was linear and depended on the instrument state. For an installed survey chain, the corresponding questions are whether the reference, correction, covariance, and processing apply to that exact state, and whether a remaining nonlinear response has been separately bounded. The published result supports this method; it does not validate the hypothetical receiver configurations used elsewhere in this volume.

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8 Keysight Technologies, Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide, part N9069-90001, edition 1 (March 2016), 10–11, 73–81, especially “Using Loss Compensation” and “Setting Temperature of Loss,” https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf. This identified edition supports the stated measurement controls, not a claim about every current analyzer.

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Receiver-chain state	Minimum record	Adverse inference if missing
RF input	Attenuation, preselection, protection, reference plane	Overload or external loss is mistaken for environment
Frequency conversion	LO state, image plan, spur table, mixer level	An image or internal product is reported as a signal
Digitization	Sample rate, clock, bit depth, scaling, clipping	Quantization or aliasing is treated as source behavior
DSP	DDC, filters, windows, averaging, detector, software version	A processing artifact is represented as raw evidence
Recording	Trigger, pretrigger, gaps, native format, hashes, time source	A screenshot is mistaken for a complete evidence object

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14.18 Close the calibration record across the working interval

The validity of a correction extends through a period and a configuration, not indefinitely through possession of a certificate. Identify changes that can alter the model: repair, firmware or processing changes, a replaced cable or adapter, a moved reference plane, a different gain state, or a changed remote power arrangement. The consequence may be a targeted recharacterization rather than a complete recalibration, but that choice requires evidence about which quantities changed. A self-test that checks internal function does not necessarily verify an external path or its correction file.

Intermediate references are most useful when they challenge likely failure modes independently. A reference that passes through the same incorrect correction file as the measurement may reproduce the error. Retain a raw comparison and an independent calculation at selected points. Before and after checks can bound a working interval, while checks after consequential changes can narrow the period affected by a failure. If a closing reference is inconsistent, preserve the affected data and investigate the last demonstrated valid state before assigning a correction retrospectively.

A complete release record links the raw observation, configuration, correction values, source certificates, uncertainty calculation, decision rule, and final reported result. For the constructed amplitude example, another analyst should be able to reproduce −86.70 dBm, identify why the amplifier term is subtracted, calculate either stated uncertainty case, and see why the conservative decision remains indeterminate. For a noise result, the same analyst should be able to reconstruct Y from the linear powers and check its

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physical domain. Reproducibility at that level is the practical connection between calibration and defensible receiver evidence.

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14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology

Many receiver corrections are affine in logarithmic units only within a fixed physical model. Real metrological inference frequently contains nonlinear steps: inversion of a hot/cold noise ratio, correction of power near a zero-subtraction boundary, conversion from measured voltage to power, nonlinear phase unwrapping and geometrical inversion of timing differences into position. An expression for combined standard uncertainty obtained from first derivatives is a local approximation. When the measurement function has appreciable curvature over the uncertainty region, the output distribution can be asymmetric or can encounter a region where the inverse ceases to exist. The 2026 amendment to JCGM 100 explicitly addresses nonlinearity in measurement models; its applicability should be evaluated using the official text and a model-specific argument rather than inferred from the existence of a publication date alone.

A simple inverse example establishes the issue without relying on equipment-specific data. Let $z = 1/(Y - 1)$ for Y greater than one. At nominal $Y = 1.10$, $z = 10$. If Y is constrained instead to the interval [1.05, 1.15], then the exact transformed interval is approximately [6.667, 20], strongly asymmetric about ten. The first derivative at the central value is -100 per unit Y; multiplying it by a symmetric input half-width of 0.05 would suggest a local variation of five, producing [5,15], which does not enclose the true upper bound. The example shows that apparently prudent linear propagation can misrepresent an ill-conditioned inverse. It does not supply a probability

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distribution or an expanded uncertainty without additional assumptions about the input quantities.

A useful RF uncertainty dossier begins by specifying the measurand, actual observation state, all input variables, known dependencies, the validity domain and numerical processing. For compatible uncertainties, the first-order covariance propagation u_y squared = g transpose C g uses a vector g of sensitivities and a covariance matrix C, but may need nonlinear propagation or a distributional method where g changes substantially across the relevant region. An interval obtained from worst-case parameter bounds is not equivalent to a confidence or coverage interval. Conversely, a Monte Carlo distribution propagated through a model cannot repair an unmeasured amplifier state or a missing sample interval, because those are problems of missing physical evidence or model adequacy, not simply numerical propagation.

Documentation must preserve uncertainty from both laboratory calibration and field installation. Correlated corrections should not be double counted as independent contributions; several traces depending on the same cable calibration share part of their uncertainty. For a bounded source attribution, the final inference may be a set of physically compatible locations or receiver-origin hypotheses, not a single point estimate with a misleading number of digits. The report should distinguish conditional metrological uncertainty, alternative model structures and what was never observed. This is essential for claims whose legal or operational consequence exceeds the precision of the underlying receiver indication.

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14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands

The conventional first-order propagation formula is a local approximation to a measurement function, not a guarantee that all resulting uncertainty intervals are symmetric or well represented by one standard deviation. Consider a derived quantity y = f(x_1,...,x_n), with estimates x, covariance matrix U and gradient vector g of sensitivity coefficients. For sufficiently small input uncertainty over a region where f is adequately differentiable, u_y squared is approximately g transposed U g. A source-to-output physical model must still be valid: covariance propagation cannot rescue a frequency conversion with the wrong image branch, a clipped ADC record or an unspecified antenna calibration plane. Inverse models may also be ill conditioned, especially where two measured powers nearly cancel or where a denominator approaches zero. These limitations belong in the released uncertainty statement before any confidence percentage is supplied.

The 2026 JCGM amendment on nonlinear measurement models makes especially relevant the distinction between first-order estimates and methods that account for curvature. For an illustrative positive random quantity X with mean mu and variance sigma squared, the expectation of f(X) may differ from f(mu); the leading curvature correction is approximately one half f''(mu) sigma squared when the assumptions of a sufficiently local expansion apply. Such a correction is not a universal fix. Non-Gaussian, truncated or multimodal input distributions, discontinuous instrument-state changes and substantial model uncertainty may require direct numerical propagation or explicit feasible-set methods. One should document the

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chosen distribution, parameter dependence, sampling convergence, admissible domain and handling of physically impossible draws. A Monte Carlo output histogram is only as trustworthy as the input model supplied to it.

A numerical example illustrates asymmetric bounds. Suppose the calibrated measured power P is known only to lie between 9 and 11 arbitrary linear power units. Reported level is $L = 10 \log10(P/P_0)$, where $P_0 = 1$ power unit. The level interval is [9.5424, 10.4139] dB. The logarithm of the midpoint power is 10 dB, but the lower and upper deviations are -0.4576 and +0.4139 dB, respectively. The asymmetry is entirely due to the nonlinear transformation. It is not justified to convert a symmetric ±1-unit input bound into a symmetric dB interval without checking the transformation. Nor may the bounded result be described as a standard uncertainty or 95 per cent interval without further probability information.

Calibration terms shared across devices require covariance rather than independent root-sum-square bookkeeping. Two instruments calibrated by one reference source inherit some common amplitude error. Their difference can cancel a common offset, while their average retains it. If one estimates an absolute field level from their average and treats the shared calibration as independent, the uncertainty may appear to shrink artificially. If one estimates the difference and instead adds the shared error twice, the uncertainty may be overstated. The correct direction follows from explicit sensitivities with signed covariance terms. Repeated observations under an unchanged calibration state do not average away that shared component, and a more sophisticated numerical propagation method cannot substitute for correct dependency identification.

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Decision guard bands connect metrology to operational release. Suppose a receiver test requires a measured error not to exceed threshold T. With uncertainty around the reported error, treating every central estimate just below T as an unconditional pass can create unacceptable false acceptance. A guard-band rule can define an acceptance region strictly inside the tolerance, with risk treatment based on a stated distribution or conservative bound. The chosen decision rule is part of the intended claim: an interval overlapping the threshold may require retest or a qualified result rather than a forced pass/fail. The laboratory should state which quantities were corrected, which effects remained systematic or unmodelled, and the relationship between uncertainty and the acceptance criterion.

A complete uncertainty section should compare linear propagation, nonlinear numerical propagation and deterministic enclosure on the same synthetic examples, exposing where and why they disagree. It should not label a convenient output range as a standard uncertainty or infer a precise coverage probability from a coverage factor alone. Retain the measurement function, calibrated input datasets, dependencies and processing revision so that a later independent reviewer can reproduce the reported uncertainty, challenge one assumption and see how the final conclusion changes.

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14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation

A calibration calculation is not necessarily a reliable measurement equation merely because each of its input quantities has an assigned uncertainty. Many RF reductions combine logarithms, ratios, positive-power differences, complex magnitudes, phase unwrapping and the inverse of a nonlinear transfer law. Such functions can be nearly linear over one operating region and badly conditioned near a boundary. The familiar first-order uncertainty formula is valuable when the local derivatives provide an adequate approximation over the plausible input range. It is not a universal guarantee that output uncertainty is symmetric, Gaussian or fully described by one standard deviation. Postgraduate receiver metrology must distinguish input uncertainty, measurement-model adequacy, computational approximation and decision consequences as separate questions.

Let the measurand Y be defined by a model $f(X_1, \ldots, X_n)$, where each X_i is an input quantity with declared units, estimates and relevant dependence. A first-order local approximation near x gives output variance $u_Y^2 \approx J\,U\,J^T$, with J the row vector of sensitivities $\partial f/\partial X_i$ and U the input covariance matrix. This is the full covariance form, not the simplified independent-input sum. It can be exact for an affine model with finite second moments even when inputs are non-Gaussian. For a nonlinear model it is a local approximation. It may perform poorly near a singularity, a discontinuous phase wrapper, the boundary of positive power or a decision threshold. Reporting the value of u_Y without examining the model's operating domain

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can give false assurance about the validity of the uncertainty calculation itself.

Consider a corrected level $y = p + l - g$, where p is the indicated dBm value, l is a passive loss in dB and g is an applicable gain in dB. This relation is affine in those logarithmic coordinates. When p, l and g have finite covariance under the stated model, the variance given by the signed sensitivities is exact: $var(y) = var(p)+var(l)+var(g)+2cov(p,l)-2cov(p,g)-2cov(l,g)$. Correlated calibration terms may cancel or reinforce one another according to their signs. Applying the same common gain correction to two measured levels can cancel that common uncertainty in their difference, but not in each absolute level. Conversely, treating a shared correction as independent on every occasion can understate or overstate the uncertainty of a derived comparison. The covariance structure is a statement about physical and documentary common causes, not a discretionary numerical adjustment.

Now consider a measured power difference $P_{sig} = P_{total} - P_{background}$, where both inputs are in watts. Its arithmetic difference is affine and may have a well-defined variance, yet the subsequent level $y = 10 \log10(P_{sig}/1\ mW)$ is nonlinear and defined only for positive P_{sig}. If the plausible difference includes zero or negative values, a standard uncertainty in dBm derived by evaluating a derivative at a small positive central difference can become enormous or misleading. A clipped negative difference set to an arbitrary epsilon before taking the logarithm does not create physical evidence of a weak positive signal. The appropriate result may be an upper bound, a one-sided interval, or an explicit inconclusive inference under a stated noise model. It cannot be repaired by reporting more digits in the logarithmic display.

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A similar issue arises when a phase measurement is represented by arg(z) for a complex phasor z. Far from the origin and with a well-separated phase distribution, a local approximation may be adequate. Near zero complex amplitude, phase becomes poorly identified, and the distribution of the estimated angle can become nearly uniform. The mathematical discontinuity at ±π radians is a representation convention, not necessarily a physical phase step. Unwrapping requires a validated continuity assumption; a pulse gap or lost samples can invalidate that assumption. Therefore amplitude and phase uncertainties should be evaluated jointly where both are used to infer time delay, channel coherence or direction. The corresponding covariance cannot be reconstructed from two independent error bars if the original complex observations have been discarded.

JCGM 100:2008 Amendment 1:2026 addresses nonlinearity in measurement models, while JCGM 101 describes propagation of distributions by Monte Carlo simulation. The published guidance supports considering higher-order terms or distribution propagation where local linearisation is inadequate; it does not certify a particular RF calibration simply because software draws a Monte Carlo histogram. The analyst must define the joint input distribution, including dependence, truncation and constraints, justify that description from calibration and measurement evidence, and ensure that the numerical algorithm reproduces the chosen function and its domain. A simulation with a million draws from an unjustified distribution is a precise computation of an unsupported model.

A suitable validation procedure begins with dimension and range checks. Confirm that logarithms act on dimensionless ratios, that positive physical powers are not represented by negative watts, and that calibration

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parameters refer to the actual receiver state. Next calculate the output with the nominal inputs, determine the local sensitivities, and inspect their variation over an interval supported by calibration. If the sensitivities change materially or the model has a nearby boundary, retain a more complete method. Propagation of distributions can then sample the joint input model, evaluate the actual nonlinear function, and report the output distribution or a suitable interval. Every rejected or undefined realisation must be counted and explained; silently discarding it will condition the result on a more favourable population.

A constructed example makes the issue concrete. Let total measured power be 2.00 ± 0.05 pW and background power be 1.90 ± 0.05 pW, with independent Gaussian measurement errors for this demonstration. The nominal difference is 0.10 pW. The standard uncertainty of the difference is $\mathrm{sqrt}(0.05^2+0.05^2) = 0.07071$ pW. Although the nominal ratio to its uncertainty is approximately 1.414, a substantial lower tail of the Gaussian difference model lies at or below zero. A normal cumulative approximation gives $P(P_sig \leq 0) \approx \Phi(-1.414) \approx 0.07865$. Thus a log-power calculation is undefined on approximately 7.9 percent of this stipulated input distribution. Reporting a symmetric dBm interval obtained by differentiating the logarithm at 0.10 pW would hide that domain failure. A physically more complete model could constrain the latent signal power and estimate it from the observations, but that requires explicit additional assumptions rather than clipping the observed difference.

A second synthetic example concerns two correlated level corrections. Let an indicated level have standard uncertainty 0.20 dB, a loss correction 0.15 dB and a gain correction 0.15 dB. Suppose the loss and gain corrections

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share calibration information with correlation coefficient +0.8, and the indication is independent of both. The output variance is $0.20^2 + 0.15^2 + 0.15^2 - 2(0.8)(0.15)(0.15) = 0.0490\ \text{dB}^2$, giving u_y = 0.22136 dB. A calculation that discards the covariance obtains sqrt(0.0850) = 0.29155 dB. The difference illustrates cancellation through opposite signs. If the same covariance entered two corrections with the same sensitivity sign, it would instead increase uncertainty. A claim of zero covariance requires evidence about shared instruments, common calibration data and processing, not the mere fact that inputs appear in separate spreadsheet cells.

A third example examines a nonlinearity that does not have a singularity. Suppose a detector amplitude calibration is locally $y = a\,x^2$ with a known positive coefficient a, x positive, and x is a normally distributed input with mean μ and standard deviation σ. The exact mean is $E[y] = a(\mu^2+\sigma^2)$, while a naive plug-in value gives $a\mu^2$. The difference $a\sigma^2$ is a second-order bias under this stipulated distribution. If μ = 2.0 V, σ = 0.2 V and a = 0.5 V^{-1}, the plug-in result is 2.00 V, whereas the exact expected output is 2.02 V. The first-order sensitivity is 2aμ = 2 in dimensionless output/input terms, so its predicted standard uncertainty is 0.40 V; the exact variance for Gaussian x is $a^2(4\mu^2\sigma^2+2\sigma^4)$, giving standard deviation approximately 0.400998 V. The central-value bias is small but real. Near smaller μ relative to σ the discrepancy grows, and a physically positive-only calibration input might require a truncated rather than unrestricted normal model.

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14.22 Decision rules, calibration applicability and publication evidence

A tolerance decision asks a different question from reporting an estimate. Suppose a device is acceptable only when a quantity lies below limit L. A measured estimate y with uncertainty does not by itself prescribe an acceptance probability or a guard band. The rule must identify which risk is being controlled, the distributional or bounded model used, and the consequence of false acceptance and false rejection. A guard band can reduce false acceptance at the expense of false rejection; this trade-off is not a universal numerical constant. When the calibration is used in forensic reporting rather than manufacturing conformity, a conclusion should additionally distinguish instrument performance assurance from attribution of a particular external signal.

A constructed guarded-decision illustration assumes a one-sided upper tolerance of 10.0 dB for an error quantity, a reported estimate of 9.6 dB, and a valid normally distributed standard uncertainty of 0.3 dB. The probability that the true error exceeds 10.0 dB under this assumed posterior-style normal model is $1-\Phi((10.0-9.6)/0.3)$, approximately 0.0912. This number is model-dependent and is not automatically a frequentist probability for a fixed unknown quantity merely because the uncertainty was labelled standard. If the adopted policy requires an estimated exceedance risk below 0.05 under the declared probabilistic model, this observation would not meet that policy. A different evidence model or calibrated guard band could change the decision. The method and chosen risk convention must be recorded before inspecting an attractive result.

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A second decision illustration avoids an invented probability distribution. Let the true response error be known only to lie within a deterministically bounded interval [9.1, 10.2] dB. A rule requiring error no greater than 10.0 dB cannot certify that requirement from these bounds because a valid endpoint exceeds the limit. It also cannot conclude definite nonconformity because a valid endpoint is below the limit. The appropriate category under an interval-only policy is indeterminate, unless an explicit decision rule authorises a different treatment of overlapping bounds. Assigning the midpoint 9.65 dB as an exact value or assuming a uniform distribution within the interval would introduce information not present in the bound.

Calibration applicability requires a state-space ledger. The measured system may change preselector, gain, detector, temperature, clock reference, sample rate or firmware. A correction derived under one combination may be transferable to another if its physical dependence and uncertainty have been demonstrated, but not merely because the instrument retains the same model number. A practical ledger lists the nominal model, the measurements supporting it, the operating range, applicable calibration files, software version, untested transitions, and any resulting invalid intervals. It also records whether corrections have already been embedded in an export. Applying a cable loss or gain correction twice is a bookkeeping failure that can remain invisible when all reported numbers have plausible units.

Finally, an independently reviewable uncertainty statement should retain the original observations, the exact measurement function, parameter estimates, covariance model or joint distribution, numerical code revision, simulation seed where relevant, rejected-realisation policy, and the interval

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or decision rule. Where a correction is subsequently revised, the original derived report should remain reproducible from the earlier input and code, while the new estimate receives its own version identity. Reproducibility does not by itself guarantee scientific correctness; it makes incorrect assumptions discoverable and enables their correction without erasing evidence. This is the standard by which an advanced receiver calibration becomes defensible rather than simply numerically elaborate.

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14.23 Advanced technical expansion. Nonlinear uncertainty propagation and decision risk

Uncertainty analysis must begin with an explicit measurement function, not a spreadsheet of convenient percentages. A scalar level correction may be approximately affine in decibels under a known linear path, but a frequency-dependent vector calibration, noise-temperature inversion or source-location estimate can be strongly nonlinear. Let the output vector y be computed from input quantities x by y = f(x); a first-order covariance approximation uses $J \Sigma_x J^T$, where J is the Jacobian of f evaluated at the stated input estimate. This formula is only as good as the local linear approximation and the input covariance matrix. It does not create a probability distribution or rescue a measurement equation whose physical state is invalid. The NIST Technical Note 1297 framework explicitly includes covariance among input quantities, and that dependence is essential when several corrections share the same calibration source or time reference.

An illustrative positive-power conversion demonstrates a difficulty hidden by logarithmic notation. Suppose a receiver output contains 2.0 pW total power, while an independently measured additive contribution is 1.8 pW under conditions permitting linear-power subtraction. The inferred signal-only power is 0.2 pW. If both estimates have standard uncertainty 0.15 pW and are provisionally uncorrelated, the uncertainty of their difference is about 0.212 pW, comparable to or larger than the inferred signal. A symmetric Gaussian approximation for that difference assigns nonzero probability to physically negative signal power. Simply taking the logarithm of the central 0.2 pW and reporting a symmetric dB uncertainty would

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disguise the boundary. A more defensible result may preserve the linear-power measurement and a constrained interval or detection decision, while explicitly explaining the limits of the additive-noise model and the chosen statistical treatment. The numbers are invented for metrological illustration.

Monte Carlo propagation can be valuable when a local Jacobian cannot represent the plausible input range, but simulation alone does not establish reliable uncertainty. One must specify each input distribution, the dependence between inputs, constraints imposed by physical states, and the rule for treating simulated points outside the model's domain. If a Y-factor inversion becomes singular as hot and cold powers approach equality, a simulation may generate extremely broad or asymmetric output values. Silently deleting such outcomes and renormalising the remaining sample set is an analytical selection that can be material to the result. The model should distinguish a conditional estimate valid within a restricted state from evidence that the state itself was never established. Simulated uncertainty describes the stipulated inputs and model; it does not certify that the laboratory actually measured them.

Complex amplitude and phase require covariance-aware reporting. An RF transfer function H(f) has real and imaginary components, or equivalently magnitude and phase under a locally valid transformation. Uncertainty in cable delay and receiver frequency reference can rotate the same complex phasor, coupling the resulting amplitude and phase estimates when nonlinear operations are involved. A phase near the wrap boundary is not well represented by an ordinary symmetric interval without attention to circular statistics. Repeatedly measuring a reference derived from the same oscillator may produce very low short-term scatter while leaving common

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systematic phase error unchanged. If coherent channel comparisons matter, the report should include the relevant cross-channel covariance and the physical source of shared calibration uncertainty.

Decision rules require another distinction. A measurement result of 9.9 dB against a requirement of at least 10 dB is not a pass simply because the value rounds to 10 dB; neither is a result of 10.1 dB automatically an unqualified pass if relevant uncertainty straddles the boundary. Guard bands and conditional acceptance rules allocate the risk of accepting a deficient condition or rejecting a compliant one. Their choice depends on the decision context and the stated measurement capability, and must not be disguised as a property of the instrument alone. A technical-security report should identify the acceptance rule selected before testing, the applicable uncertainty model, and any inconclusive state. An examiner who changes the decision threshold after seeing the most favourable reading creates an additional selection bias outside the numerical calibration calculation.

A reproducible uncertainty budget includes original estimates and units, probability or bound interpretations, sensitivity coefficients, covariances, correlations, state-validity evidence, numerical method, significant digits and results of independent arithmetic checks. For source-supported statements about reporting conventions, identify the actual edition of the guidance consulted and the material accessible to the reviewer. Do not describe the public summary of a closed standard as though a complete clause-by-clause review had been performed. The strongest engineering conclusion is one that states precisely which tested domain is supported and

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what additional observation would be needed to narrow the remaining uncertainty.

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Chapter Summary

Calibration supports a defined configuration, not the receiver in the abstract. Amplitude, phase, noise, and timing corrections must be connected to the complete chain and expressed through an uncertainty-aware decision rule.

Begin with the intended quantity and its measurement equation. Calibration, adjustment and verification serve different purposes, and traceability belongs to a supported result. Signed corrections must follow the actual path, state and applied processing. Independent forward and reverse calculations can reveal wrong planes, duplicate corrections or software mistakes that an uncertainty budget cannot repair.

Model 14B makes covariance explicit. For a fixed affine relation, propagation of finite second moments is exact. For a nonlinear relation, gradients provide a local approximation whose adequacy depends on curvature, boundaries and the input domain. Common references can cancel or reinforce, while repeated readings do not remove an unchanged calibration contribution. Preserve those dependencies rather than selecting favorable correlations.

Report standard uncertainty, the chosen coverage convention and the predeclared decision rule separately. An interval overlapping a limit can support an indeterminate outcome. Noise calibration and sensitivity verification likewise answer different questions. Maintain configuration and correction records across changes, retain raw checks, and investigate inconsistent closing references before extending validity to earlier observations.

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Chapter 14 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C14-MCQ-001. Does exact affine variance propagation require Gaussian inputs?

A. No; finite second moments and the stated covariance suffice

B. Yes; all inputs must be independent Gaussians

C. Yes; every marginal must be symmetric

D. No; even infinite input variances always give finite output variance

Answer: A. For an affine function the covariance identity follows by expansion; coverage claims require additional information. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: No; finite second moments and the stated covariance suffice.

Distinguishing consideration: compare this with option B, “Yes; all inputs must be independent Gaussians”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-002. Why does the shared phase-reference contribution cancel in Application 14B.5?

A. Phase errors cancel whenever both channels have equal gain

B. The reference uncertainty is numerically smaller than both residuals

C. Any two standards called common are statistically independent

D. It is the same additive input with equal coupling and opposite coefficients in the difference

Answer: D. Cancellation follows the actual measurement equation and shared state, not a label. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why the selected alternative fits: It is the same additive input with equal coupling and opposite coefficients in the difference.

Distinguishing consideration: compare this with option A, “Phase errors cancel whenever both channels have equal gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-MCQ-003. Can the calculated 5.55646 ps local delay uncertainty select the correct unwrapped phase branch?

A. No; the estimate and propagation are conditional on an established branch

B. No; delay uncertainty can never be calculated from phase

C. Yes; the smallest uncertainty always selects the physical branch

D. Yes; positive frequency spacing removes all integer ambiguity

Answer: A. The branch is a model input requiring separate evidence. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why the selected alternative fits: No; the estimate and propagation are conditional on an established branch.

Distinguishing consideration: compare this with option B, “No; delay uncertainty can never be calculated from phase”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-MCQ-004. Why retain an interpolation residual beyond endpoint calibration uncertainties?

A. It removes the need to specify the frequency location

B. It is always exactly zero for linear arithmetic

C. It represents inadequacy of the between-point response model

D. It is a second copy of the same endpoint calibration uncertainty

Answer: C. Endpoint values and physical response between them are different uncertainty questions. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why the selected alternative fits: It represents inadequacy of the between-point response model.

Distinguishing consideration: compare this with option A, “It removes the need to specify the frequency location”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-MCQ-005. What establishes positivity throughout the power-difference domain in Application 14B.9?

A. The fact that dBm is a logarithmic unit

B. The positive central difference alone

C. A positive local estimate minus two standard uncertainties for any distribution

D. The explicit bounded joint input law

Answer: D. The complete stipulated support stays above zero; arbitrary positive estimates do not prove this. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why the selected alternative fits: The explicit bounded joint input law.

Distinguishing consideration: compare this with option A, “The fact that dBm is a logarithmic unit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-MCQ-006. Why is zero local uncertainty inadequate for squared Gaussian voltage at zero mean?

A. A zero mean voltage necessarily implies zero expected power

B. The first derivative vanishes but quadratic randomness remains

C. A larger coverage factor recovers all omitted curvature

D. The voltage variance must also be zero

Answer: B. The exact second and fourth moments retain nonzero power mean and variance. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why the selected alternative fits: The first derivative vanishes but quadratic randomness remains.

Distinguishing consideration: compare this with option A, “A zero mean voltage necessarily implies zero expected power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-MCQ-007. Why does metrological traceability attach to a measurement result?

A. It depends on the actual model, configuration and documented comparison chain with uncertainties

B. It is a permanent property of an instrument regardless of use

C. It follows solely from an unexpired certificate date

D. It guarantees adequate uncertainty for every decision

Answer: A. A component certificate alone does not establish the final assembled result. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why the selected alternative fits: It depends on the actual model, configuration and documented comparison chain with uncertainties.

Distinguishing consideration: compare this with option B, “It is a permanent property of an instrument regardless of use”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-MCQ-008. Why is amplifier gain subtracted when a receiver indication is referred upstream?

A. Amplifier power gain is a passive loss

B. The gain increased the downstream level and must be removed

C. All calibrated corrections are subtracted by convention

D. Gain uncertainty is always negative

Answer: B. The sign follows reversal of the physical forward transfer. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why the selected alternative fits: The gain increased the downstream level and must be removed.

Distinguishing consideration: compare this with option A, “Amplifier power gain is a passive loss”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-MCQ-009. What can a single phase-calibration tone establish directly?

A. Every cable's temperature coefficient

B. Broadband group delay without ambiguity

C. Phase repeatability after every retune

D. The phase relationship at that frequency under the tested state

Answer: D. A broadband or changed-state claim needs additional frequency and repeatability evidence. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: The phase relationship at that frequency under the tested state.

Distinguishing consideration: compare this with option A, “Every cable's temperature coefficient”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-010. Why preserve hot and cold powers alongside reported noise figure?

A. They permit independent ratio, domain, state and conversion checks

B. They eliminate all mismatch corrections

C. They make source temperature calibration unnecessary

D. They guarantee equal gain in both source states

Answer: A. The final scalar result conceals important inputs and validity conditions.

Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why the selected alternative fits: They permit independent ratio, domain, state and conversion checks.

Distinguishing consideration: compare this with option B, “They eliminate all mismatch corrections”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-MCQ-011. When can positive input correlation reduce output variance?

A. When the relevant sensitivity coefficients have opposite signs

B. Whenever the inputs appear in separate budget rows

C. Whenever the desired decision is acceptance

D. Only when all individual variances are negative

Answer: A. The cross term includes the product of the signed coefficients and supported covariance. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why the selected alternative fits: When the relevant sensitivity coefficients have opposite signs.

Distinguishing consideration: compare this with option B, “Whenever the inputs appear in separate budget rows”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-MCQ-012. Does multiplying standard uncertainty by two always create 95 percent coverage?

A. Yes; covariance automatically makes every output Gaussian

B. Yes; the multiplier alone defines the probability

C. No; expanded uncertainty can never carry a coverage statement

D. No; interpretation depends on distribution and uncertainty information

Answer: D. The chosen factor and its justification must be stated separately. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: No; interpretation depends on distribution and uncertainty information.

Distinguishing consideration: compare this with option A, "Yes; covariance automatically makes every output Gaussian"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-MCQ-013. For −86.70 dBm ±0.49 dB and an upper limit of −86.50 dBm, what does the chapter's predeclared three-outcome rule give?

A. Accept because the central value is below the limit

B. Indeterminate

C. Reject because the interval upper end exceeds the limit

D. Accept because the uncertainty is less than 1 dB

Answer: B. The interval overlaps the limit; neither full acceptance nor full rejection condition holds. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: Indeterminate.

Distinguishing consideration: compare this with option A, “Accept because the central value is below the limit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-MCQ-014. A closing reference fails after cable replacement. What is the appropriate treatment of earlier records?

A. Preserve them and establish the last valid state and consequential-change time

B. Discard the failed check if the instrument self-test passes

C. Treat the replacement as irrelevant when connector types match

D. Apply the new correction uniformly to every prior record

Answer: A. Evidence may bound a narrower affected interval; retrospective correction requires support. Source: §14.18 Close the calibration record across the working interval (p. 8147)

Why the selected alternative fits: Preserve them and establish the last valid state and consequential-change time.

Distinguishing consideration: compare this with option B, “Discard the failed check if the instrument self-test passes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Close the calibration record across the working interval.

Review: Chapter 14 — Close the calibration record across the working interval.

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V011-C14-MCQ-015. What should a calibration plan identify before choosing certificates?

A. The largest number of calibrated accessories

B. The instrument with the longest certificate

C. The smallest available uncertainty regardless of scope

D. The intended measurand and its measurement equation

Answer: D. The equation identifies which inputs and conditions require supporting evidence. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why the selected alternative fits: The intended measurand and its measurement equation.

Distinguishing consideration: compare this with option A, “The largest number of calibrated accessories”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-MCQ-016. A precisely calibrated correction is applied to the wrong cable. How should this be classified?

A. A small random term automatically covered by RSS

B. A harmless consequence of traceability

C. A covariance benefit

D. A configuration error to resolve

Answer: D. A budget cannot legitimize using the wrong physical input. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why the selected alternative fits: A configuration error to resolve.

Distinguishing consideration: compare this with option A, “A small random term automatically covered by RSS”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-MCQ-017. What distinguishes a present-function field check from full calibration?

A. It establishes all long-term stability

B. It replaces all traceability records

C. It proves all range and state corrections

D. It verifies selected current behavior within a limited scope

Answer: D. The check is useful but does not cover every calibration quantity and condition. Source: §14.1 Calibration Model and Traceability (p. 8104)

Why the selected alternative fits: It verifies selected current behavior within a limited scope.

Distinguishing consideration: compare this with option A, “It establishes all long-term stability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibration Model and Traceability.

Review: Chapter 14 — Calibration Model and Traceability.

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V011-C14-MCQ-018. An instrument certificate is valid but omits the gain state used in a survey. What is supported?

A. Characterize the missing state or narrow the claim

B. Add an arbitrary uncertainty until acceptance occurs

C. Apply the nearest state correction without stating the substitution

D. Assume every gain state is covered by the same serial number

Answer: A. Calibration scope is conditional, not universal by association. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why the selected alternative fits: Characterize the missing state or narrow the claim.

Distinguishing consideration: compare this with option B, “Add an arbitrary uncertainty until acceptance occurs”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-MCQ-019. Why independently recompute representative corrected records?

A. To expose implementation errors such as signs or wrong correction ownership

B. To eliminate physical calibration uncertainty

C. To infer source identity from arithmetic agreement

D. To prove all untested frequencies are valid

Answer: A. Excellent calibrated inputs can still be implemented incorrectly. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why the selected alternative fits: To expose implementation errors such as signs or wrong correction ownership.

Distinguishing consideration: compare this with option B, “To eliminate physical calibration uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-MCQ-020. What is the difference between a known correction and its uncertainty?

A. The uncertainty should replace every nonzero correction

B. The correction addresses a known offset; uncertainty describes remaining information about that correction

C. They are interchangeable numbers with opposite signs

D. A correction removes all residual uncertainty

Answer: B. A significant known offset should be corrected with its uncertainty retained. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why the selected alternative fits: The correction addresses a known offset; uncertainty describes remaining information about that correction.

Distinguishing consideration: compare this with option A, "The uncertainty should replace every nonzero correction"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-MCQ-021. What must amplitude verification vary to assess linearity?

A. Levels as well as relevant frequencies and gain states

B. Only one convenient strong signal

C. Only the number of repeated measurements at one point

D. Only the display's reference label

Answer: A. A single level cannot establish response across a range or state transition. Source: §14.3 Amplitude Response and Linearity (p. 8108)

Why the selected alternative fits: Levels as well as relevant frequencies and gain states.

Distinguishing consideration: compare this with option B, “Only one convenient strong signal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Amplitude Response and Linearity.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-MCQ-022. Why can a straight-line fit through compressed data be misleading?

A. Averaging fit residuals removes the physical compression

B. Compression changes only phase, never amplitude

C. Any straight-line fit proves local linearity everywhere

D. Small average residuals can hide invalid weak- and strong-level endpoints

Answer: D. Individual observations and accepted range limits must be retained.

Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why the selected alternative fits: Small average residuals can hide invalid weak- and strong-level endpoints.

Distinguishing consideration: compare this with option A, “Averaging fit residuals removes the physical compression”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-MCQ-023. Which effect tends to dominate amplitude uncertainty at very low levels?

A. Strong-signal compression alone

B. Noise and detector statistics

C. Intermodulation from the desired signal alone

D. A constant calibration term necessarily dominating every case

Answer: B. The model changes across operating regimes; low-level statistics differ from high-level nonlinearity. Source: §14.3 Amplitude Response and Linearity (p. 8108)

Why the selected alternative fits: Noise and detector statistics.

Distinguishing consideration: compare this with option A, “Strong-signal compression alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Amplitude Response and Linearity.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-MCQ-024. What is the corrected upstream value for the chapter's −72.60+0.20+2.40−17.80+1.10 dBm chain?

A. −87.10 dBm

B. −86.70 dBm

C. −79.70 dBm

D. −51.10 dBm

Answer: B. The signs remove gain and restore upstream losses after the receiver residual correction. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why the selected alternative fits: −86.70 dBm.

Distinguishing consideration: compare this with option A, "−87.10 dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-MCQ-025. What corrected receiver-plane value follows from raw −72.60 dBm and residual +0.20 dB?

A. −72.80 dBm

B. −55.00 dBm

C. −86.70 dBm

D. −72.40 dBm

Answer: D. The receiver's residual correction is added before external plane movement. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why the selected alternative fits: −72.40 dBm.

Distinguishing consideration: compare this with option A, “−72.80 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-MCQ-026. Why perform a forward prediction after computing an upstream correction?

A. It supplies missing component calibration values

B. It guarantees that the amplifier stayed linear

C. It proves mismatch is absent

D. It checks the physical sign and plane convention independently

Answer: D. A reverse/forward arithmetic closure tests implementation, while physical assumptions need separate evidence. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why the selected alternative fits: It checks the physical sign and plane convention independently.

Distinguishing consideration: compare this with option A, “It supplies missing component calibration values”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-MCQ-027. What is required if a gain correction was measured at a different bias or temperature?

A. An assumption that gain is unchanged because the amplifier model matches

B. Only the same frequency label

C. Evidence of applicability or a state-appropriate correction

D. A larger averaging count at the original state

Answer: C. Correction scope follows actual operating state. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why the selected alternative fits: Evidence of applicability or a state-appropriate correction.

Distinguishing consideration: compare this with option A, “An assumption that gain is unchanged because the amplifier model matches”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-MCQ-028. Which mismatch claim is valid for precision amplitude work?

A. A pad always removes all mismatch uncertainty without cost

B. Vector correction may be needed when scalar treatment is inadequate

C. Mismatch affects only phase and never delivered power

D. Receiver calibration alone necessarily covers all source reflections

Answer: B. Reflections among source, path and receiver can create frequency-dependent error. Source: §14.3 Amplitude Response and Linearity (p. 8108)

Why the selected alternative fits: Vector correction may be needed when scalar treatment is inadequate.

Distinguishing consideration: compare this with option A, “A pad always removes all mismatch uncertainty without cost”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Amplitude Response and Linearity.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-MCQ-029. What should a calibration source path and sensor provide?

A. Only a higher output power

B. Only a manufacturer specification with no applicability check

C. Exactly the same unexamined errors as the receiver

D. Better or independently understood accuracy for the intended comparison

Answer: D. The reference must support the uncertainty and scope of the calibration result. Source: §14.3 Amplitude Response and Linearity (p. 8108)

Why the selected alternative fits: Better or independently understood accuracy for the intended comparison.

Distinguishing consideration: compare this with option A, “Only a higher output power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Amplitude Response and Linearity.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-MCQ-030. Why test around attenuator and preamplifier transitions?

A. All switches have identical loss at every position

B. Transition points are automatically more accurate

C. One high-level calibration fixes every lower gain state

D. The response and correction can change with gain state

Answer: D. A valid range includes consequential state boundaries. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why the selected alternative fits: The response and correction can change with gain state.

Distinguishing consideration: compare this with option A, “All switches have identical loss at every position”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-MCQ-031. A reference input reports locked. What does that indication alone establish?

A. A state indication, not quantified residual carrier-measurement error

B. Deterministic phase after every trigger

C. Zero frequency error for every estimator

D. A complete time-stamp uncertainty budget

Answer: A. Actual reference, distribution, duration and estimation behavior still require verification. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: A state indication, not quantified residual carrier-measurement error.

Distinguishing consideration: compare this with option B, “Deterministic phase after every trigger”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-032. Source and receiver share a frequency reference. What must the analysis identify?

A. A universal factor-two uncertainty reduction

B. Zero absolute error from apparent agreement

C. Errors that cancel and errors that remain common

D. Automatic independence of the two instruments

Answer: C. Common reference errors can be hidden by comparison. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: Errors that cancel and errors that remain common.

Distinguishing consideration: compare this with option A, “A universal factor-two uncertainty reduction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-033. Why test phase after retune, trigger and sample-rate changes?

A. One continuous record proves every future reset state

B. A shared clock forbids all conversion-phase resets

C. Amplitude repeatability guarantees phase repeatability

D. Those operations can alter inter-record phase relationships

Answer: D. The correction's scope must include actual preparatory operations.

Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: Those operations can alter inter-record phase relationships.

Distinguishing consideration: compare this with option A, “One continuous record proves every future reset state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-034. If phase is reproducible only within each record, what should be avoided?

A. Computing any within-record spectrum

B. Using simultaneous samples within the valid record

C. Reporting any terminal power

D. Treating separate acquisitions as one coherent observation without further evidence

Answer: D. Inter-record coherence is a stronger condition than within-record phase stability. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: Treating separate acquisitions as one coherent observation without further evidence.

Distinguishing consideration: compare this with option A, “Computing any within-record spectrum”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-035. Moving a timing reference plane upstream requires what?

A. Using frequency accuracy as a complete delay calibration

B. Assuming every cable has zero delay

C. Accounting for intervening delay and its uncertainty

D. Changing only the time-stamp label

Answer: C. The event arrival and instrument-path delay are distinct quantities.

Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: Accounting for intervening delay and its uncertainty.

Distinguishing consideration: compare this with option A, “Using frequency accuracy as a complete delay calibration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-036. Why document phase unwrapping in a broadband calibration?

A. Unwrapping removes all measurement uncertainty

B. The branch convention affects the inferred phase slope and delay

C. A small local uncertainty selects the correct branch

D. Phase is always confined to one unique physical turn

Answer: B. A frequency-dependent correction requires a supported branch and interpolation convention. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: The branch convention affects the inferred phase slope and delay.

Distinguishing consideration: compare this with option A, “Unwrapping removes all measurement uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-037. What makes a file timestamp useful for timing comparison?

A. A known relation to samples, trigger and reference clock

B. Its presence as a date string alone

C. A correct filename sequence

D. An accurate average carrier frequency alone

Answer: A. Timing evidence must locate the relevant sample events within the stated clock model. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why the selected alternative fits: A known relation to samples, trigger and reference clock.

Distinguishing consideration: compare this with option B, “Its presence as a date string alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-MCQ-038. Which condition invalidates the simple hot/cold equal-gain inversion?

A. Both output powers are stored in linear units

B. Gain changes between source states

C. The hot state is checked for compression

D. The source temperatures are known at the receiver plane

Answer: B. The ratio model assumes the same transfer in both states. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why the selected alternative fits: Gain changes between source states.

Distinguishing consideration: compare this with option A, “Both output powers are stored in linear units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-MCQ-039. Why check compression at the highest noise-power state?

A. The hot state may be nonlinear while the cold state appears normal

B. Only the cold state can overload

C. A known ENR guarantees receiver linearity

D. Thermal noise cannot cause gain change

Answer: A. The highest loading is a necessary part of model validation. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why the selected alternative fits: The hot state may be nonlinear while the cold state appears normal.

Distinguishing consideration: compare this with option B, “Only the cold state can overload”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-MCQ-040. How should source-state settling time be established?

A. Only from a nominal software delay

B. From the detector's display update label alone

C. By assuming equal settling after every change

D. From the observed response and relevant state behavior

Answer: D. A delay value is not evidence that the measured system has settled.

Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why the selected alternative fits: From the observed response and relevant state behavior.

Distinguishing consideration: compare this with option A, “Only from a nominal software delay”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-MCQ-041. What does successful sensitivity verification test directly?

A. Every possible modulation and duty cycle

B. The full path and decision rule under stated waveform, level and schedule

C. Noise figure independently of acquisition timing

D. A unique decomposition of receiver equivalent noise temperature

Answer: B. Detection tests and noise calibration answer different questions. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why the selected alternative fits: The full path and decision rule under stated waveform, level and schedule.

Distinguishing consideration: compare this with option A, “Every possible modulation and duty cycle”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-MCQ-042. What records are essential in sensitivity trials?

A. Only the successful screenshots

B. Only the maximum detected signal level

C. Detections and misses plus signal conditions and observation schedule

D. Only average noise figure

Answer: C. The trial and exposure information is necessary to interpret detection performance. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why the selected alternative fits: Detections and misses plus signal conditions and observation schedule.

Distinguishing consideration: compare this with option A, “Only the successful screenshots”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-MCQ-043. If hot and cold source impedances differ materially, what may change?

A. Nothing once source ENR is known

B. Only the displayed source temperature label

C. Delivered noise and receiver noise response

D. Only the uncertainty units

Answer: C. A scalar matched inversion may need more complete characterization.

Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why the selected alternative fits: Delivered noise and receiver noise response.

Distinguishing consideration: compare this with option A, “Nothing once source ENR is known”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-MCQ-044. For a covariance matrix of real finite-variance inputs, which property is required?

A. Symmetry and positive semidefiniteness

B. Every diagonal entry must equal one

C. All off-diagonal entries must be positive

D. Every pairwise correlation must be zero

Answer: A. A physically admissible matrix must give nonnegative variance for every linear combination. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: Symmetry and positive semidefiniteness.

Distinguishing consideration: compare this with option B, “Every diagonal entry must equal one”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-045. Do individually plausible pairwise correlations guarantee an admissible whole matrix?

A. No; joint positive semidefiniteness must also hold

B. Yes; positive correlations cannot conflict

C. Yes; each lying between −1 and +1 is sufficient

D. No; covariance matrices are never useful for mixed units

Answer: A. Pairwise bounds alone do not ensure global consistency. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: No; joint positive semidefiniteness must also hold.

Distinguishing consideration: compare this with option B, "Yes; positive correlations cannot conflict"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-046. For an affine result $Y = a + c^T X$, what is its exact variance?

A. The sum of standard deviations without coefficients

B. $a + c^T \mu$

C. $c^T \Sigma c$

D. The square of the mean

Answer: C. The constant drops out and covariance propagates through the signed coefficients. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: option C contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-047. What units does a sensitivity coefficient carry?

A. The input unit divided by the output unit

B. Output unit divided by the corresponding input unit

C. Always dimensionless

D. Always the squared output unit

Answer: B. Units must make each coefficient times input perturbation an output perturbation. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: Output unit divided by the corresponding input unit.

Distinguishing consideration: compare this with option A, “The input unit divided by the output unit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-048. What is the local nonlinear variance approximation at a stated input estimate?

A. The exact variance for every nonlinear function

B. $J \Sigma J^T$

C. The square of the zero-order output estimate

D. The function evaluated at the input variance alone

Answer: B. The gradient expression is conditional on neglected remainder terms being sufficiently small. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: option B contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-049. What does a zero first derivative establish by itself?

A. Only that the first-order contribution vanishes at that point

B. That the output is nonrandom

C. That all higher derivatives vanish

D. That the uncertainty is a strict maximum-error bound

Answer: A. Curvature can remain consequential. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: Only that the first-order contribution vanishes at that point.

Distinguishing consideration: compare this with option B, “That the output is nonrandom”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-050. Is standard uncertainty generally a maximum error bound?

A. No; it describes dispersion under the stated information

B. Yes; all outcomes must lie inside one standard uncertainty

C. Yes; unless covariance is nonzero

D. No; it is merely the applied correction

Answer: A. A hard support bound and a standard deviation are different claims.

Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: No; it describes dispersion under the stated information.

Distinguishing consideration: compare this with option B, “Yes; all outcomes must lie inside one standard uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-MCQ-051. In the five-term independent budget, what variance follows from 0.12, 0.20, 0.10, 0.18 and 0.08 dB standard uncertainties?

A. 0.68 dB^2

B. 0.1032 dB^2

C. 0.01032 dB^2

D. 0.0600 dB^2

Answer: B. The squared terms add under the stated zero covariances. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

Why the selected alternative fits: 0.1032.

Distinguishing consideration: compare this with option A, “0.68”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Four worked applications already developed in the calibration chain.

Review: Chapter 14 — Four worked applications already developed in the calibration chain.

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V011-C14-MCQ-052. With +0.60 correlation between +0.20 dB correction and subtracted 0.18 dB gain errors, what covariance contribution occurs?

A. +0.0432 dB^2

B. +0.0600 dB^2

C. −0.0432 dB^2

D. −0.0216 dB^2

Answer: C. The term is 2 times +1 times −1 times 0.20 times 0.18 times 0.60. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why the selected alternative fits: −0.0432.

Distinguishing consideration: compare this with option A, "+0.0432"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-MCQ-053. What is the correlated five-term budget's standard uncertainty when variance is 0.0600 dB^2?

A. Approximately 0.321248 dB

B. 0.0600 dB

C. Approximately 0.244949 dB

D. Approximately 0.489898 dB

Answer: C. Standard uncertainty is the square root; 0.489898 dB would use a factor of two. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

Why the selected alternative fits: Approximately 0.244949 dB.

Distinguishing consideration: compare this with option A, “Approximately 0.321248 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Four worked applications already developed in the calibration chain.

Review: Chapter 14 — Four worked applications already developed in the calibration chain.

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V011-C14-MCQ-054. Why may a common reference be represented either explicitly or by covariance, but not inconsistently both?

A. The numerical units of the reference become arbitrary

B. Covariance representation always removes calibration uncertainty

C. Otherwise the same contribution can be counted twice

D. Explicit inputs are necessarily independent

Answer: C. The alternatives must describe the same underlying dependency without duplication. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why the selected alternative fits: Otherwise the same contribution can be counted twice.

Distinguishing consideration: compare this with option A, “The numerical units of the reference become arbitrary”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-MCQ-055. What supports a favorable correlation used to reduce uncertainty?

A. The need to pass a limit

B. The smallest possible variance over all correlations

C. The order of rows in the budget

D. The actual calibration model or evidence

Answer: D. Correlation is input information, not a decision-adjustment parameter.

Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why the selected alternative fits: The actual calibration model or evidence.

Distinguishing consideration: compare this with option A, “The need to pass a limit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-MCQ-056. Near the hot/cold inversion's Y=1 boundary, what becomes problematic?

A. Every uncertainty vanishes because Y is dimensionless

B. Local symmetric propagation can misrepresent a strongly nonlinear output

C. The inversion becomes exactly affine

D. The output must be Gaussian by averaging

Answer: B. The singular denominator can magnify asymmetry and domain issues.

Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why the selected alternative fits: Local symmetric propagation can misrepresent a strongly nonlinear output.

Distinguishing consideration: compare this with option A, “Every uncertainty vanishes because Y is dimensionless”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-MCQ-057. What does a nonlinear propagation simulation establish?

A. Consequences of its stated input distributions and dependencies

B. The truth of those assumptions automatically

C. Independence of all inputs by construction of a computer model

D. A universal exact confidence level without a probability model

Answer: A. Accurate propagation cannot repair unsupported input assumptions.

Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why the selected alternative fits: Consequences of its stated input distributions and dependencies.

Distinguishing consideration: compare this with option B, “The truth of those assumptions automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-MCQ-058. For phases 34° and 11° on one established branch, with independent residual uncertainties 0.30° and 0.40° and an identical common 0.80° input, what is difference uncertainty?

A. 1.50°

B. 0.50°

C. 1.23693°

D. 0.80°

Answer: B. The common input cancels; residual variance is 0.09+0.16=0.25 degree squared. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why the selected alternative fits: 0.50°.

Distinguishing consideration: compare this with option A, "1.50°"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-MCQ-059. In that shared-reference example, what is the off-diagonal covariance?

A. 0.12 degree squared

B. 0.64 degree squared

C. 0 degree squared

D. 0.80 degree squared

Answer: B. The shared additive reference contributes its variance 0.80 squared.

Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why the selected alternative fits: 0.64 degree squared.

Distinguishing consideration: compare this with option A, “0.12 degree squared”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-MCQ-060. If common-reference couplings differ between channels, what changes?

A. The residuals automatically become Gaussian

B. The reference always cancels because its source is shared

C. Exact cancellation can fail and the remaining coefficient must be modeled

D. Only the nominal channel gain needs updating

Answer: C. Cancellation requires equal effective coupling in the difference. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why the selected alternative fits: Exact cancellation can fail and the remaining coefficient must be modeled.

Distinguishing consideration: compare this with option A, “The residuals automatically become Gaussian”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-MCQ-061. For phase difference 36° and positive separation 100 MHz in the constant-delay model, what is delay?

A. 10.000 ns

B. 0.360 ns

C. 1.000 ns

D. 0.100 ns

Answer: C. Delay equals 36 divided by 360 times 100 million, in seconds. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why the selected alternative fits: 1.000 ns.

Distinguishing consideration: compare this with option A, “10.000 ns”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-MCQ-062. What is the sign of delay sensitivity to frequency separation for positive phase difference?

A. Undefined at all positive separations

B. Positive

C. Negative

D. Zero at every nonzero separation

Answer: C. At fixed phase, increasing separation reduces the inferred delay. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why the selected alternative fits: Negative.

Distinguishing consideration: compare this with option A, “Undefined at all positive separations”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-MCQ-063. What are the two signed uncertainty contributions in Application 14B.6 before squaring?

A. +1 ps and −1 ps

B. +5.55556 ps and −0.10000 ps

C. +5.55556 ns and −0.10000 ns

D. +0.20 ps and +10 ps

Answer: B. They are each sensitivity coefficient times the stipulated input standard uncertainty. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why the selected alternative fits: +5.55556 ps and −0.10000 ps.

Distinguishing consideration: compare this with option A, “+1 ps and −1 ps”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-MCQ-064. What is the local standard uncertainty from those zero-covariance contributions?

A. About 5.65556 ps

B. About 5.55646 ps

C. Exactly 1.000 ns

D. About 5.45556 ps

Answer: B. Independent variance contributions add as squares, not signed standard deviations. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why the selected alternative fits: About 5.55646 ps.

Distinguishing consideration: compare this with option A, “About 5.65556 ps”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-MCQ-065. What does a small delay uncertainty not establish?

A. The stated local calculation's units

B. The gradient at the stipulated input point

C. The numerical frequency separation used

D. Constant delay across an untested wider band

Answer: D. Calibration uncertainty does not prove untested model applicability.

Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why the selected alternative fits: Constant delay across an untested wider band.

Distinguishing consideration: compare this with option A, “The stated local calculation's units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-MCQ-066. At fixed interpolation fraction 0.25 between +0.60 and +1.00 dB, what correction results?

A. +0.85 dB

B. +0.80 dB

C. +0.70 dB

D. +0.40 dB

Answer: C. The weights are 0.75 and 0.25. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why the selected alternative fits: +0.70 dB.

Distinguishing consideration: compare this with option A, "+0.85 dB"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-MCQ-067. For that interpolation with endpoint uncertainties 0.15 and 0.20 dB and correlation 0.40, what is the covariance term?

A. +0.0045 dB^2

B. +0.0090 dB^2

C. +0.0120 dB^2

D. −0.0045 dB^2

Answer: A. It is 2 times 0.75 times 0.25 times 0.40 times 0.15 times 0.20. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why the selected alternative fits: +0.0045.

Distinguishing consideration: compare this with option B, “+0.0090”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-MCQ-068. Adding an independent 0.08 dB residual to endpoint variance 0.01965625 dB^2 gives what total variance?

A. 0.0064 dB^2

B. 0.01325625 dB^2

C. 0.02605625 dB^2

D. 0.09965625 dB^2

Answer: C. The residual contributes its square, 0.0064 dB^2. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why the selected alternative fits: 0.02605625.

Distinguishing consideration: compare this with option A, “0.0064”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-MCQ-069. What must change if the interpolation fraction itself is uncertain?

A. The residual must be set to zero

B. The fixed-weight equation remains complete without change

C. The endpoint covariance must become -1

D. The measurement equation must include that additional input and dependencies

Answer: D. The original expression stipulated a fixed fractional position. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why the selected alternative fits: The measurement equation must include that additional input and dependencies.

Distinguishing consideration: compare this with option A, “The residual must be set to zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-MCQ-070. What would justify the interpolation residual's magnitude?

A. The number of decimal places in the correction file

B. Automatic equality to endpoint uncertainty

C. Exact arithmetic alone

D. Adequate response characterization or a supported smoothness bound

Answer: D. The residual concerns actual between-point response, not numerical interpolation precision. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why the selected alternative fits: Adequate response characterization or a supported smoothness bound.

Distinguishing consideration: compare this with option A, “The number of decimal places in the correction file”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-MCQ-071. For 16 independent reading errors with SD 0.40 dB and common independent calibration uncertainty 0.30 dB, what is mean variance?

A. 0.005625 dB^2

B. 0.1000 dB^2

C. 0.25 dB^2

D. 0.015625 dB^2

Answer: B. The common term remains 0.09 and the reading term is $\frac{0.16}{16}$=0.01.

Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why the selected alternative fits: 0.1000.

Distinguishing consideration: compare this with option A, “0.005625”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-MCQ-072. As the reading count grows in Application 14B.8, what standard-uncertainty floor remains?

A. Zero

B. 0.70 dB

C. 0.40 dB

D. 0.30 dB

Answer: D. Averaging does not remove the common correction uncertainty. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why the selected alternative fits: 0.30 dB.

Distinguishing consideration: compare this with option A, “Zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-MCQ-073. What covariance do distinct corrected readings share in the stated common-calibration model?

A. 0.25 dB^2

B. 0.16 dB^2

C. 0.09 dB^2

D. Zero

Answer: C. The same calibration input appears in every corrected reading. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why the selected alternative fits: 0.09.

Distinguishing consideration: compare this with option A, “0.25”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-MCQ-074. Why is the mean-of-levels model not automatically applicable to averaged powers followed by a logarithm?

A. The common calibration term always vanishes after a logarithm

B. All logarithms commute with arithmetic averaging

C. Power averages are necessarily independent

D. The operations define different nonlinear estimators

Answer: D. The measurement function must reflect the actual processing order.

Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why the selected alternative fits: The operations define different nonlinear estimators.

Distinguishing consideration: compare this with option A, “The common calibration term always vanishes after a logarithm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-MCQ-075. A mean indication is −80.20 dBm and correction +0.15 dB. What is the corrected mean?

A. −80.20 dBm

B. −80.35 dBm

C. −79.90 dBm

D. −80.05 dBm

Answer: D. The common additive correction changes the central level once. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why the selected alternative fits: −80.05 dBm.

Distinguishing consideration: compare this with option A, "−80.20 dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-MCQ-076. For on/off estimates 1.30 and 1.00 nW, what is the added linear power?

A. 1.13943 dB

B. 2.300 nW

C. 0.300 nW

D. 1.300 nW

Answer: C. Physical subtraction precedes any logarithmic conversion. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why the selected alternative fits: 0.300 nW.

Distinguishing consideration: compare this with option A, “1.13943 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-MCQ-077. Given on/off standard uncertainties 0.04 and 0.03 nW and covariance 0.00096 nW^2, what is difference variance?

A. 0.00442 nW^2

B. 0.00058 nW^2

C. 0.0025 nW^2

D. 0.00154 nW^2

Answer: B. Compute 0.0016+0.0009−2 times 0.00096. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why the selected alternative fits: 0.00058.

Distinguishing consideration: compare this with option A, “0.00442”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-MCQ-078. What is the level of 0.300 nW relative to 1 mW?

A. Approximately −95.228787 dBm

B. Approximately −5.228787 dBm

C. Approximately −65.228787 dBm

D. Approximately −60.000000 dBm

Answer: C. 0.300 nW is 3 times 10 to the minus seven mW. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why the selected alternative fits: Approximately −65.228787 dBm.

Distinguishing consideration: compare this with option A, “Approximately −95.228787 dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-MCQ-079. At positive difference D, what is the derivative of its dBm level with respect to D?

A. 10 divided by ln(10) times D in the denominator

B. 1 divided by D with no logarithmic scale factor

C. 10 times ln(10) times D

D. D divided by 10 ln(10)

Answer: A. Differentiating 10 log 10(D/1 mW) gives $\frac{10}{[\ln(10)D]}$. Source: §14.14.7

Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why the selected alternative fits: 10 divided by ln(10) times D in the denominator.

Distinguishing consideration: compare this with option B, “1 divided by D with no logarithmic scale factor”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-MCQ-080. If a different on/off uncertainty domain includes zero or negative differences, what should be retained first?

A. The linear difference and its interpretation

B. A fixed extra 3 dB correction

C. The positive central logarithm as valid for the whole domain

D. A logarithm of the absolute difference without qualification

Answer: A. The logarithmic map cannot be extended through the nonpositive boundary by assertion. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why the selected alternative fits: The linear difference and its interpretation.

Distinguishing consideration: compare this with option B, “A fixed extra 3 dB correction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-MCQ-081. For Gaussian X with mean μ, SD σ and known positive R, what is $E[\frac{X^2}{R}]$?

A. $\frac{(\mu^2+\sigma^2)}{R}$

B. $\frac{\sigma}{R}$

C. $\frac{\mu^2}{R}$

D. $\frac{(\mu+\sigma)^2}{R}$

Answer: A. Curvature adds the variance contribution to the expected squared quantity. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why the selected alternative fits: option A contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-MCQ-082. For the same model, what term is omitted by first-order power variance propagation?

A. $\frac{\mu^2}{R}$

B. $\frac{4\mu^2\sigma^2}{R^2}$

C. $\frac{2\sigma^4}{R^2}$

D. $\frac{2\mu}{R}$

Answer: C. The exact variance includes both the linear sensitivity term and this curvature term. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why the selected alternative fits: option C contains the mathematical expression shown in the question; its interpretation depends on the stated equation and units.

Distinguishing consideration: evaluate the other displayed alternatives against the original formula and its operating assumptions; no equivalence is established by the answer letter alone.

Basis and limitation: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-MCQ-083. At μ=0, σ=1 mV and R=50 ohms, what is expected power?

A. 0 nW

B. 20 μW

C. 20 nW

D. 2 nW

Answer: C. $\frac{\sigma^2}{R}$ equals 10 to the minus six divided by 50 watts. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why the selected alternative fits: 20 nW.

Distinguishing consideration: compare this with option A, “0 nW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-MCQ-084. At that zero-mean point, what is exact power standard deviation?

A. 20 nW

B. 40 nW

C. About 28.2843 nW

D. 0 nW

Answer: C. The standard deviation is square root of two times $\frac{\sigma^2}{R}$. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why the selected alternative fits: About 28.2843 nW.

Distinguishing consideration: compare this with option A, “20 nW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-MCQ-085. At μ=10 mV with σ=1 mV and R=50 ohms, what distinguishes expected power from power at the mean voltage?

A. 2.000 μW versus 2.020 μW

B. 2.020 μW versus 2.000 μW

C. Both exactly 2.000 μW

D. 20 nW versus zero

Answer: B. The nonlinear expectation includes the 0.020 μW curvature shift. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why the selected alternative fits: 2.020 μW versus 2.000 μW.

Distinguishing consideration: compare this with option A, "2.000 μW versus 2.020 μW"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-MCQ-086. Under the declared upper-limit rule, when is a result accepted?

A. Whenever any part of the interval is below the limit

B. Whenever the interval width is less than 1 dB

C. When the interval upper end is no greater than the limit

D. Whenever the central value is below the limit

Answer: C. The rule uses the full interval and was declared before observing the result. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: When the interval upper end is no greater than the limit.

Distinguishing consideration: compare this with option A, “Whenever any part of the interval is below the limit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-MCQ-087. Under that rule, when is a result rejected?

A. When the interval lower end is greater than the limit

B. Whenever the upper end exceeds the limit

C. Whenever the central value equals the limit

D. Whenever uncertainty is nonzero

Answer: A. An overlapping interval is indeterminate rather than necessarily rejected. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: When the interval lower end is greater than the limit.

Distinguishing consideration: compare this with option B, “Whenever the upper end exceeds the limit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-MCQ-088. What is the role of repeated observations after an indeterminate outcome?

A. They can reduce a dominant random term if the model supports it

B. They prove the original result was wrong

C. They authorize moving the limit afterward

D. They necessarily remove common calibration uncertainty

Answer: A. The response should address actual uncertainty sources while retaining the original record. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: They can reduce a dominant random term if the model supports it.

Distinguishing consideration: compare this with option B, “They prove the original result was wrong”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-MCQ-089. Which statement about an expanded level interval and a search false-alarm probability is correct?

A. They are identical whenever the coverage factor is two

B. The search false-alarm rate determines every calibration correction

C. They are different probabilistic claims requiring their respective models

D. The level interval supplies the search false-alarm rate automatically

Answer: C. Coverage of a measured quantity is distinct from decision behavior in a search procedure. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: They are different probabilistic claims requiring their respective models.

Distinguishing consideration: compare this with option A, “They are identical whenever the coverage factor is two”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-MCQ-090. What should happen if a later decision adopts a different rule?

A. Use whichever rule produces the desired decision without disclosure

B. Rewrite the earlier outcome as though the new rule always applied

C. Identify the new rule and preserve the original outcome

D. Delete the earlier uncertainty calculation

Answer: C. Decision-rule changes are part of the record. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: Identify the new rule and preserve the original outcome.

Distinguishing consideration: compare this with option A, “Use whichever rule produces the desired decision without disclosure”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-MCQ-091. What should determine calibration intervals besides calendar time?

A. Only the instrument purchase price

B. Only the number of stored screenshots

C. Only the previous certificate's page count

D. Stability, use, transport, environment, repairs and consequence

Answer: D. Observed drift and likely failure mechanisms inform the lifecycle. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

Why the selected alternative fits: Stability, use, transport, environment, repairs and consequence.

Distinguishing consideration: compare this with option A, “Only the instrument purchase price”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibration Lifecycle and Change Control.

Review: Chapter 14 — Calibration Lifecycle and Change Control.

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V011-C14-MCQ-092. Why can a firmware update require renewed correction review?

A. A passing self-test proves all external corrections unchanged

B. It may change processing or state behavior covered by prior calibration

C. Only hardware replacements can change calibration scope

D. Software cannot affect calibrated measurements

Answer: B. Correction applicability depends on the implemented measurement chain. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

Why the selected alternative fits: It may change processing or state behavior covered by prior calibration.

Distinguishing consideration: compare this with option A, “A passing self-test proves all external corrections unchanged”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Calibration Lifecycle and Change Control.

Review: Chapter 14 — Calibration Lifecycle and Change Control.

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V011-C14-MCQ-093. What makes an intermediate reference genuinely informative about implementation errors?

A. Only confirming the file exists

B. Using the same correction path twice and calling agreement independent

C. Only checking the final reported value

D. A raw comparison and independent recomputation that do not simply repeat the same faulty correction

Answer: D. Shared implementation errors can survive repeated self-comparisons.

Source: §14.18 Close the calibration record across the working interval (p. 8147)

Why the selected alternative fits: A raw comparison and independent recomputation that do not simply repeat the same faulty correction.

Distinguishing consideration: compare this with option A, “Only confirming the file exists”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Close the calibration record across the working interval.

Review: Chapter 14 — Close the calibration record across the working interval.

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V011-C14-MCQ-094. What did the published vector-calibration example illustrate about repeatability-only uncertainty?

A. It always overestimates complete uncertainty

B. It removes common-reference concerns

C. It omitted calibration contributions that widened the full uncertainty distribution

D. It is automatically identical to traceable calibration uncertainty

Answer: C. The chapter uses the example to distinguish repeatability from the wider calibration model. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

Why the selected alternative fits: It omitted calibration contributions that widened the full uncertainty distribution.

Distinguishing consideration: compare this with option A, “It always overestimates complete uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — System-Level Vector Calibration and Uncertainty.

Review: Chapter 14 — System-Level Vector Calibration and Uncertainty.

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V011-C14-MCQ-095. Why can agreement with the same oscilloscope used for calibration retain common errors?

A. The comparison and calibration share a reference contribution

B. A vector correction always removes all nonlinear response

C. Repeated measurements make all reference errors independent

D. Every oscilloscope has zero uncertainty

Answer: A. Common dependence must remain visible when interpreting agreement. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

Why the selected alternative fits: The comparison and calibration share a reference contribution.

Distinguishing consideration: compare this with option B, “A vector correction always removes all nonlinear response”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — System-Level Vector Calibration and Uncertainty.

Review: Chapter 14 — System-Level Vector Calibration and Uncertainty.

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V011-C14-MCQ-096. Does a linear vector correction establish absence of receiver nonlinearity?

A. Yes; complex coefficients can represent any state-dependent nonlinearity

B. No; residual nonlinear behavior requires separate bounding

C. No; linear corrections are never useful

D. Yes; improved modulation error proves every level is linear

Answer: B. The correction has a linear, state-dependent scope. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

Why the selected alternative fits: No; residual nonlinear behavior requires separate bounding.

Distinguishing consideration: compare this with option A, “Yes; complex coefficients can represent any state-dependent nonlinearity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — System-Level Vector Calibration and Uncertainty.

Review: Chapter 14 — System-Level Vector Calibration and Uncertainty.

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V011-C14-MCQ-097. What did the temperature-dependent preamplifier case demonstrate?

A. Room-temperature correction is always valid outdoors

B. An applicable state correction can resolve much of an analyzer disagreement

C. The initial 2.8 dB difference uniquely identified either analyzer as defective

D. Within-uncertainty agreement proves exact equality

Answer: B. The gain state changed with temperature; the updated correction reduced the discrepancy to 0.6 dB within combined uncertainty. Source: §14.16 Hypothetical Case Adjudication: Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty (p. 8144)

Why the selected alternative fits: An applicable state correction can resolve much of an analyzer disagreement.

Distinguishing consideration: compare this with option A, “Room-temperature correction is always valid outdoors”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Hypothetical Case Adjudication: Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty.

Review: Chapter 14 — Hypothetical Case Adjudication: Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty.

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V011-C14-MCQ-098. What belongs in a complete release record?

A. Only the uncertainty total without the model

B. Raw observation, configuration, corrections, certificates, uncertainty, decision rule and result

C. Only the corrected central value and certificate date

D. Only successful calibration screenshots

Answer: B. The chain lets another analyst reconstruct both calculation and scope.

Source: §14.18 Close the calibration record across the working interval (p. 8147)

Why the selected alternative fits: Raw observation, configuration, corrections, certificates, uncertainty, decision rule and result.

Distinguishing consideration: compare this with option A, “Only the uncertainty total without the model”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Close the calibration record across the working interval.

Review: Chapter 14 — Close the calibration record across the working interval.

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V011-C14-MCQ-099. When can targeted recharacterization be justified instead of complete recalibration after a change?

A. When evidence identifies which quantities were affected and bounds the unchanged scope

B. Whenever the self-test passes

C. Whenever the new component has the same connector type

D. Whenever a full calibration would be inconvenient

Answer: A. The decision must follow the actual model consequences of the change.

Source: §14.18 Close the calibration record across the working interval (p. 8147)

Why the selected alternative fits: When evidence identifies which quantities were affected and bounds the unchanged scope.

Distinguishing consideration: compare this with option B, “Whenever the self-test passes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Close the calibration record across the working interval.

Review: Chapter 14 — Close the calibration record across the working interval.

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V011-C14-MCQ-100. Why is a simulation with an unsupported covariance matrix not a valid uncertainty solution?

A. More trials remove covariance inconsistency

B. Simulation automatically projects every matrix onto the correct calibration law

C. The resulting histogram alone establishes the input truth

D. Numerical propagation cannot make inconsistent or unjustified input dependence physical

Answer: D. Model validity precedes numerical propagation accuracy. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why the selected alternative fits: Numerical propagation cannot make inconsistent or unjustified input dependence physical.

Distinguishing consideration: compare this with option A, “More trials remove covariance inconsistency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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Fill-in-the-Blank Questions

V011-C14-FIB-001. Calibration should begin with the quantity to be reported and its measurement _____.

Answer: equation. The equation identifies material inputs and applicable calibrations. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
Why this term is required: “equation” completes the stated technical proposition.
Question context: Calibration should begin with the quantity to be reported and its measurement _____
Basis and qualification: Chapter 14 — Attach calibration to a stated measurement result.
Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-FIB-002. Metrological traceability is a property of a supported measurement _____.

Answer: result. It requires a documented comparison chain with uncertainties and applicable configuration. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why this term is required: “result” completes the stated technical proposition.

Question context: Metrological traceability is a property of a supported measurement _____

Basis and qualification: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-FIB-003. Applying the right numeric correction to the wrong cable is a _____ error.

Answer: configuration. It must be resolved rather than hidden as a small uncertainty term. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why this term is required: “configuration” completes the stated technical proposition.

Question context: Applying the right numeric correction to the wrong cable is a _____ error

Basis and qualification: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-FIB-004. A field check verifies selected present function but does not replace full _____.

Answer: calibration. Its scope is narrower than a complete calibration relation.

Source: §14.1 Calibration Model and Traceability (p. 8104)

Why this term is required: “calibration” completes the stated technical proposition.

Question context: A field check verifies selected present function but does not replace full _____

Basis and qualification: Chapter 14 — Calibration Model and Traceability.

Review: Chapter 14 — Calibration Model and Traceability.

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V011-C14-FIB-005. The calibration certificate's frequency, level, state and environmental conditions define its _____.

Answer: scope. A valid certificate need not cover every intended use. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why this term is required: “scope” completes the stated technical proposition.

Question context: The calibration certificate's frequency, level, state and environmental conditions define its _____

Basis and qualification: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-FIB-006. Calibration, adjustment and verification are distinct metrological _____.

Answer: operations. Their purposes should not be conflated when assessing a result. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why this term is required: “operations” completes the stated technical proposition.

Question context: Calibration, adjustment and verification are distinct metrological _____

Basis and qualification: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-FIB-007. The uncertainty of an applied correction remains after the known offset has been _____.

Answer: corrected. Removing a known central offset does not create perfect knowledge. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
Why this term is required: “corrected” completes the stated technical proposition.
Question context: The uncertainty of an applied correction remains after the known offset has been _____
Basis and qualification: Chapter 14 — Use covariance and model sensitivity deliberately.
Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-FIB-008. Independent recomputation can reveal a software correction _____ error.

Answer: sign. Traceable input numbers can be implemented with the wrong physical direction. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

Why this term is required: “sign” completes the stated technical proposition.

Question context: Independent recomputation can reveal a software correction _____ error

Basis and qualification: Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 14 — Attach calibration to a stated measurement result.

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V011-C14-FIB-009. Amplitude linearity requires checks at more than one signal _____.

Answer: level. One point does not establish response across the dynamic range.

Source: §14.3 Amplitude Response and Linearity (p. 8108)

Why this term is required: “level” completes the stated technical proposition.

Question context: Amplitude linearity requires checks at more than one signal _____

Basis and qualification: Chapter 14 — Amplitude Response and Linearity.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-FIB-010. Near gain-state transitions, repeat relevant amplitude _____ points.

Answer: verification. A correction may change when attenuation or preamplification changes. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)
Why this term is required: “verification” completes the stated technical proposition.
Question context: Near gain-state transitions, repeat relevant amplitude _____ points
Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.
Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-011. When referring downstream power upstream, passive loss is _____.

Answer: added. The forward path reduced level by that loss. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why this term is required: “added” completes the stated technical proposition.

Question context: When referring downstream power upstream, passive loss is _____

Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-012. When referring the same reading upstream, amplifier gain is _____.

Answer: subtracted. The forward amplification must be removed. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why this term is required: “subtracted” completes the stated technical proposition.

Question context: When referring the same reading upstream, amplifier gain is _____

Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-013. The chapter's signed 915 MHz chain gives _____ dBm at the filter input.

Answer: −86.70. Compute −72.60+0.20+2.40−17.80+1.10. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why this term is required: "−86.70" completes the stated technical proposition.

Question context: The chapter's signed 915 MHz chain gives _____ dBm at the filter input

Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-014. Raw −72.60 dBm plus a +0.20 dB receiver correction gives _____ dBm.

Answer: −72.40. This is the corrected receiver-plane indication. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why this term is required: "−72.40" completes the stated technical proposition.

Question context: Raw −72.60 dBm plus a +0.20 dB receiver correction gives _____ dBm

Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-015. For the stated chain, total external gain minus losses is _____ dB.

Answer: 14.30. 17.80−2.40−1.10=14.30 dB. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why this term is required: “14.30” completes the stated technical proposition.

Question context: For the stated chain, total external gain minus losses is _____ dB

Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-016. Forward calculation from the upstream result is an independent check on correction _____ and planes.

Answer: signs. It follows the physical transfer direction. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why this term is required: “signs” completes the stated technical proposition.

Question context: Forward calculation from the upstream result is an independent check on correction _____ and planes

Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-017. At weak levels, detector statistics and _____ may dominate amplitude uncertainty.

Answer: noise. The uncertainty model should change with operating regime. Source: §14.3 Amplitude Response and Linearity (p. 8108)

Why this term is required: “noise” completes the stated technical proposition.

Question context: At weak levels, detector statistics and _____ may dominate amplitude uncertainty

Basis and qualification: Chapter 14 — Amplitude Response and Linearity.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-FIB-018. At high levels, compression and _____ can dominate instead.

Answer: intermodulation. Strong-signal behavior can violate a linear calibration model. Source: §14.3 Amplitude Response and Linearity (p. 8108)

Why this term is required: “intermodulation” completes the stated technical proposition.

Question context: At high levels, compression and _____ can dominate instead

Basis and qualification: Chapter 14 — Amplitude Response and Linearity.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-FIB-019. A line fitted through compressed response can hide invalid endpoint _____ behavior.

Answer: linearity. Small mean residuals do not prove validity over the range. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

Why this term is required: “linearity” completes the stated technical proposition.

Question context: A line fitted through compressed response can hide invalid endpoint _____ behavior

Basis and qualification: Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

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V011-C14-FIB-020. A frequency reference marked locked does not alone quantify residual measurement _____.

Answer: error. Actual estimator and reference-path behavior still matter. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why this term is required: “error” completes the stated technical proposition.

Question context: A frequency reference marked locked does not alone quantify residual measurement _____

Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-021. Relative channel phase requires a defined simultaneous input _____ and channel reference planes.

Answer: relationship. The calibration must establish what phase relation is being compared. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why this term is required: “relationship” completes the stated technical proposition.

Question context: Relative channel phase requires a defined simultaneous input _____ and channel reference planes

Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-022. A single tone tests phase at one frequency, not broadband group _____.

Answer: delay. Frequency-dependent characterization is needed. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why this term is required: “delay” completes the stated technical proposition.

Question context: A single tone tests phase at one frequency, not broadband group _____

Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-023. Phase correction across a band must document its _____ convention.

Answer: unwrapping. Different branches can imply different slopes and delays.

Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why this term is required: “unwrapping” completes the stated technical proposition.

Question context: Phase correction across a band must document its _____ convention

Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-024. Retuning can preserve amplitude while changing conversion _____.

Answer: phase. Amplitude repeatability does not establish coherent record linkage.

Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why this term is required: “phase” completes the stated technical proposition.

Question context: Retuning can preserve amplitude while changing conversion _____

Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-025. If only within-record phase repeats, separate records should not automatically be treated as _____.

Answer: coherent. Inter-record state changes can alter phase. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why this term is required: “coherent” completes the stated technical proposition.

Question context: If only within-record phase repeats, separate records should not automatically be treated as _____

Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-026. Moving a timing plane requires accounting for the intervening path's _____.

Answer: delay. The associated uncertainty and state dependence also belong in the model. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
Why this term is required: “delay” completes the stated technical proposition.
Question context: Moving a timing plane requires accounting for the intervening path's _____
Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.
Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-027. A timestamp must be related to the samples, trigger and reference _____.

Answer: clock. A date field alone does not establish event timing. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

Why this term is required: “clock” completes the stated technical proposition.

Question context: A timestamp must be related to the samples, trigger and reference _____

Basis and qualification: Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-FIB-028. Noise-figure calculation should retain both hot and cold output _____.

Answer: powers. They permit independent ratio and validity checks. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why this term is required: “powers” completes the stated technical proposition.

Question context: Noise-figure calculation should retain both hot and cold output _____

Basis and qualification: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-FIB-029. The simple hot/cold inversion assumes equal _____ between the two states.

Answer: gain. A source-state gain change invalidates that ratio model. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why this term is required: “gain” completes the stated technical proposition.

Question context: The simple hot/cold inversion assumes equal _____ between the two states

Basis and qualification: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-FIB-030. The highest source-noise state must be checked for _____.

Answer: compression. The cold state can appear normal while the hot state is nonlinear. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)
Why this term is required: “compression” completes the stated technical proposition.
Question context: The highest source-noise state must be checked for _____
Basis and qualification: Chapter 14 — Calibrate noise without confusing it with detection.
Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-FIB-031. Source-state settling must be established from observed _____.

Answer: response. A software delay alone is not measurement evidence. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why this term is required: “response” completes the stated technical proposition.

Question context: Source-state settling must be established from observed _____

Basis and qualification: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-FIB-032. Sensitivity verification tests the full path and its decision _____.

Answer: rule. It is distinct from separating receiver noise contributions. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why this term is required: “rule” completes the stated technical proposition.

Question context: Sensitivity verification tests the full path and its decision _____

Basis and qualification: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-FIB-033. Detection trials must retain misses as well as _____.

Answer: detections. Successful examples alone do not describe trial performance.

Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why this term is required: “detections” completes the stated technical proposition.

Question context: Detection trials must retain misses as well as _____

Basis and qualification: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-FIB-034. A hot/cold source-impedance change can alter both delivered power and receiver noise _____.

Answer: response. A scalar source-power correction may be insufficient. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

Why this term is required: “response” completes the stated technical proposition.

Question context: A hot/cold source-impedance change can alter both delivered power and receiver noise _____

Basis and qualification: Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-FIB-035. Sensitivity coefficients carry signs and _____ from the measurement function.

Answer: units. They need not be dimensionless or unity. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why this term is required: “units” completes the stated technical proposition.

Question context: Sensitivity coefficients carry signs and _____ from the measurement function

Basis and qualification: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-FIB-036. An affine variance identity requires finite second _____.

Answer: moments. Gaussian inputs or independence are unnecessary for that identity. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: “moments” completes the stated technical proposition.

Question context: An affine variance identity requires finite second _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-037. A valid covariance matrix is symmetric and positive _____.

Answer: semidefinite. Every linear combination must have nonnegative variance.

Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: “semidefinite” completes the stated technical proposition.

Question context: A valid covariance matrix is symmetric and positive _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-038. The covariance entry for two inputs has the product of their _____.

Answer: units. Mixed-unit input vectors still have a consistent covariance law.

Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: “units” completes the stated technical proposition.

Question context: The covariance entry for two inputs has the product of their _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-039. For $Y = a + c^T X$, the mean is a plus c^T times the input mean _____.

Answer: vector. Linearity of expectation gives the affine mean exactly. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: "vector" completes the stated technical proposition.

Question context: For the mean is a plus times the input mean _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-040. The exact affine variance is _____ .

Answer: $c^T \Sigma c$. The coefficient signs determine cancellation or reinforcement of covariance. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: "The coefficient signs determine cancellation or reinforcement of covariance" completes the stated technical proposition.

Question context: The exact affine variance is _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-041. For a nonlinear function, the first-order coefficient vector is its local _____.

Answer: gradient. It is evaluated at the stated input estimate. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: “gradient” completes the stated technical proposition.

Question context: For a nonlinear function, the first-order coefficient vector is its local _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-042. The local nonlinear variance expression is

_____ .

Answer: $J \Sigma J^T$. Its adequacy depends on the neglected remainder. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: "Its adequacy depends on the neglected remainder" completes the stated technical proposition.

Question context: The local nonlinear variance expression is _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-043. Zero covariance removes a cross term but does not generally imply statistical _____.

Answer: independence. The affine variance identity does not require that stronger condition. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: “independence” completes the stated technical proposition.

Question context: Zero covariance removes a cross term but does not generally imply statistical _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-044. A vanishing first derivative can coexist with consequential _____.

Answer: curvature. Higher-order terms can preserve output randomness. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why this term is required: “curvature” completes the stated technical proposition.

Question context: A vanishing first derivative can coexist with consequential _____

Basis and qualification: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-FIB-045. Standard uncertainty describes dispersion, not necessarily a maximum-error _____.

Answer: bound. Support and standard deviation are different information. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: “bound” completes the stated technical proposition.

Question context: Standard uncertainty describes dispersion, not necessarily a maximum-error _____

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-FIB-046. The independent five-term amplitude budget has variance _____ dB^2.

Answer: 0.1032. The squares of 0.12,0.20,0.10,0.18 and 0.08 add to this value.

Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

Why this term is required: “0.1032” completes the stated technical proposition.

Question context: The independent five-term amplitude budget has variance _____

Basis and qualification: Chapter 14 — Four worked applications already developed in the calibration chain.

Review: Chapter 14 — Four worked applications already developed in the calibration chain.

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V011-C14-FIB-047. The square root of that variance is approximately _____ dB.

Answer: 0.321248. This is combined standard uncertainty before any coverage factor. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

Why this term is required: “0.321248” completes the stated technical proposition.

Question context: The square root of that variance is approximately _____ dB

Basis and qualification: Chapter 14 — Four worked applications already developed in the calibration chain.

Review: Chapter 14 — Four worked applications already developed in the calibration chain.

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V011-C14-FIB-048. The signed covariance contribution for 0.20 and 0.18 dB errors at correlation +0.60 with opposite coefficients is _____ dB^2.

Answer: −0.0432. The cross term is −2×0.20×0.18×0.60. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why this term is required: "−0.0432" completes the stated technical proposition.

Question context: The signed covariance contribution for 0.20 and 0.18 dB errors at correlation +0.60 with opposite coefficients is _____

Basis and qualification: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-FIB-049. The resulting correlated budget variance is

_____ dB^2.

Answer: 0.0600. Subtract 0.0432 from 0.1032. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

Why this term is required: “0.0600” completes the stated technical proposition.

Question context: The resulting correlated budget variance is _____

Basis and qualification: Chapter 14 — Four worked applications already developed in the calibration chain.

Review: Chapter 14 — Four worked applications already developed in the calibration chain.

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V011-C14-FIB-050. Its standard uncertainty is approximately _____ dB.

Answer: 0.244949. Take the square root of 0.0600. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

Why this term is required: “0.244949” completes the stated technical proposition.

Question context: Its standard uncertainty is approximately _____ dB

Basis and qualification: Chapter 14 — Four worked applications already developed in the calibration chain.

Review: Chapter 14 — Four worked applications already developed in the calibration chain.

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V011-C14-FIB-051. A factor of two gives expanded uncertainty approximately _____ dB for that correlated budget.

Answer: 0.489898. The factor is stipulated; coverage probability requires additional justification. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: “0.489898” completes the stated technical proposition.

Question context: A factor of two gives expanded uncertainty approximately _____ dB for that correlated budget

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-FIB-052. The interval around −86.70 dBm with ±0.49 dB has upper end _____ dBm.

Answer: −86.21. Add the expanded uncertainty to the central value. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: "−86.21" completes the stated technical proposition.

Question context: The interval around −86.70 dBm with ±0.49 dB has upper end _____ dBm

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-FIB-053. Against −86.50 dBm, that overlapping interval is _____ under the chapter's rule.

Answer: indeterminate. Neither the full interval-below nor interval-above condition holds. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: “indeterminate” completes the stated technical proposition.

Question context: Against −86.50 dBm, that overlapping interval is _____ under the chapter's rule

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-FIB-054. The acceptance condition for the upper limit requires the interval's _____ end to be no greater than the limit.

Answer: upper. The rule was declared before seeing the data. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: “upper” completes the stated technical proposition.

Question context: The acceptance condition for the upper limit requires the interval's _____ end to be no greater than the limit

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-FIB-055. Under the chapter's declared three-outcome upper-limit interval rule, rejection requires the interval's lower end to be _____ than the limit.

Answer: greater. An overlap alone is not the rejection condition. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: “greater” completes the stated technical proposition.

Question context: Under the chapter's declared three-outcome upper-limit interval rule, rejection requires the interval's lower end to be _____ than the limit

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-FIB-056. A multiplier of two does not by itself establish a _____ percent interval.

Answer: 95. Distribution and uncertainty information support the coverage interpretation. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: “95” completes the stated technical proposition.

Question context: A multiplier of two does not by itself establish a _____ percent interval

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-FIB-057. Repeating readings does not remove an unchanged common calibration _____.

Answer: uncertainty. Only appropriate random contributions decrease with count.

Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why this term is required: “uncertainty” completes the stated technical proposition.

Question context: Repeating readings does not remove an unchanged common calibration _____

Basis and qualification: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-FIB-058. A common reference may cancel in a difference but _____ in a sum.

Answer: reinforce. The measurement coefficients determine its effect. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why this term is required: “reinforce” completes the stated technical proposition.

Question context: A common reference may cancel in a difference but _____ in a sum

Basis and qualification: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-FIB-059. Representing a shared uncertainty explicitly and inconsistently again through covariance risks _____ counting.

Answer: double. The dependency must be represented once in a coherent model.

Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why this term is required: “double” completes the stated technical proposition.

Question context: Representing a shared uncertainty explicitly and inconsistently again through covariance risks _____ counting

Basis and qualification: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-FIB-060. Near Y=1, the hot/cold inversion has a _____ boundary.

Answer: singular. Local symmetric propagation can become inadequate. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

Why this term is required: “singular” completes the stated technical proposition.

Question context: Near Y=1, the hot/cold inversion has a _____ boundary

Basis and qualification: Chapter 14 — Use covariance and model sensitivity deliberately.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-FIB-061. The shared-reference phase example gives a phase difference of _____ degrees.

Answer: 23. The branch is stipulated and 34−11=23. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why this term is required: “23” completes the stated technical proposition.

Question context: The shared-reference phase example gives a phase difference of _____ degrees

Basis and qualification: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-FIB-062. Its independent residual variance is

_____ degree squared.

Answer: 0.25. $0.30^2+0.40^2$=0.25. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why this term is required: “0.25” completes the stated technical proposition.

Question context: Its independent residual variance is _____ degree squared

Basis and qualification: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-FIB-063. The resulting phase-difference standard uncertainty is _____ degrees.

Answer: 0.50. The shared identical additive reference cancels. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why this term is required: “0.50” completes the stated technical proposition.

Question context: The resulting phase-difference standard uncertainty is _____ degrees

Basis and qualification: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-FIB-064. The common 0.80° reference contributes channel covariance _____ degree squared.

Answer: 0.64. The covariance is the common-input variance. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why this term is required: “0.64” completes the stated technical proposition.

Question context: The common 0.80° reference contributes channel covariance _____ degree squared

Basis and qualification: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-FIB-065. Exact common-reference cancellation requires identical effective _____.

Answer: coupling. Different paths or states can leave a residual contribution. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

Why this term is required: “coupling” completes the stated technical proposition.

Question context: Exact common-reference cancellation requires identical effective _____

Basis and qualification: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-C14-FIB-066. For phase difference Φ in degrees and positive spacing Δf in hertz, delay is Φ divided by _____.

Answer: $360\,\Delta f$. The result is in seconds under the constant-delay model. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: "The result is in seconds under the constant-delay model" completes the stated technical proposition.

Question context: For phase difference in degrees and positive spacing in hertz, delay is divided by _____

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-067. At Φ=36° and Δf=100 MHz, the delay is

_____ ns.

Answer: 1.000. 36/(360×100 million)=10 to the minus nine seconds. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: “1.000” completes the stated technical proposition.

Question context: At =36° and =100 MHz, the delay is _____ ns

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-068. The sensitivity of delay to Φ is

_____ .

Answer: $\frac{1}{(360\,\Delta f)}$. Its units are seconds per degree. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: "Its units are seconds per degree" completes the stated technical proposition.

Question context: The sensitivity of delay to is _____

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-069. For $\tau = \frac{\Phi}{(360\,\Delta f)}$, with Φ in degrees and nonzero Δf in hertz, the sensitivity of delay to Δf is _____ .

Answer: $\frac{-\Phi}{[360(\Delta f)^2]}$. The derivative is negative for positive phase difference.

Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: "The derivative is negative for positive phase difference" completes the stated technical proposition.

Question context: For with in degrees and nonzero in hertz, the sensitivity of delay to is _____

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-070. The 0.20° phase uncertainty contributes approximately _____ ps before squaring.

Answer: 5.55556. Multiply 0.20° by 2.77778×10 to the minus eleven seconds per degree. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: “5.55556” completes the stated technical proposition.

Question context: The 0.20° phase uncertainty contributes approximately _____ ps before squaring

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-071. The 10 kHz frequency-spacing uncertainty contributes _____ ps before squaring in the stated example.

Answer: −0.10000. The signed coefficient is −1.00000×10 to the minus seventeen seconds per hertz. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: "−0.10000" completes the stated technical proposition.

Question context: The 10 kHz frequency-spacing uncertainty contributes _____ ps before squaring in the stated example

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-072. Their zero-covariance RSS gives approximately _____ ps.

Answer: 5.55646. Square, add and take the square root. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: “5.55646” completes the stated technical proposition.

Question context: Their zero-covariance RSS gives approximately _____ ps

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-073. A local delay uncertainty cannot choose an unresolved phase _____.

Answer: branch. Branch identification is prior model evidence. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

Why this term is required: “branch” completes the stated technical proposition.

Question context: A local delay uncertainty cannot choose an unresolved phase _____

Basis and qualification: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

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V011-C14-FIB-074. At fractional position w=0.25, the lower endpoint interpolation weight is _____.

Answer: 0.75. The two affine weights are 1−w and w. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why this term is required: “0.75” completes the stated technical proposition.

Question context: At fractional position w=0.25, the lower endpoint interpolation weight is _____

Basis and qualification: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-FIB-075. Interpolating +0.60 and +1.00 dB at that position gives _____ dB.

Answer: +0.70. 0.75×0.60+0.25×1.00=0.70. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why this term is required: "+0.70" completes the stated technical proposition.

Question context: Interpolating +0.60 and +1.00 dB at that position gives _____ dB

Basis and qualification: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-FIB-076. The endpoint covariance term in Application 14B.7 is _____ dB^2.

Answer: 0.0045. Use 2w(1−w)r u0u1 with the stipulated values. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why this term is required: “0.0045” completes the stated technical proposition.

Question context: The endpoint covariance term in Application 14B.7 is _____

Basis and qualification: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-FIB-077. The independent 0.08 dB interpolation residual contributes variance _____ dB^2.

Answer: 0.0064. Its standard uncertainty is squared. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why this term is required: "0.0064" completes the stated technical proposition.

Question context: The independent 0.08 dB interpolation residual contributes variance _____

Basis and qualification: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-FIB-078. The complete interpolation variance is

_____ dB^2.

Answer: 0.02605625. This adds the two weighted endpoint variances, covariance and residual variance. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why this term is required: "0.02605625" completes the stated technical proposition.

Question context: The complete interpolation variance is _____

Basis and qualification: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-FIB-079. The corresponding standard uncertainty is approximately _____ dB.

Answer: 0.161419. It is the square root of the complete variance. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why this term is required: “0.161419” completes the stated technical proposition.

Question context: The corresponding standard uncertainty is approximately _____ dB

Basis and qualification: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-FIB-080. If interpolation fraction w is uncertain, it becomes an additional model _____.

Answer: input. The fixed-weight expression is no longer complete. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

Why this term is required: “input” completes the stated technical proposition.

Question context: If interpolation fraction w is uncertain, it becomes an additional model _____

Basis and qualification: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-FIB-081. For n=16, reading SD 0.40 dB and common uncertainty 0.30 dB, mean variance is _____ dB^2.

Answer: 0.1000. $0.30^2+\frac{0.40^2}{16}$=0.10. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why this term is required: "0.1000" completes the stated technical proposition.

Question context: For n=16, reading SD 0.40 dB and common uncertainty 0.30 dB, mean variance is _____

Basis and qualification: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-FIB-082. At n=64 with the same conditions, mean variance is _____ dB^2.

Answer: 0.0925. The random contribution is $\frac{0.16}{64}$=0.0025. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why this term is required: “0.0925” completes the stated technical proposition.

Question context: At n=64 with the same conditions, mean variance is _____

Basis and qualification: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-FIB-083. For Application 14B.8's independent readings with a common 0.30 dB calibration standard uncertainty, the mean's standard uncertainty tends as n grows to _____ dB.

Answer: 0.30. The common calibration contribution remains. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why this term is required: “0.30” completes the stated technical proposition.

Question context: For Application 14B.8's independent readings with a common 0.30 dB calibration standard uncertainty, the mean's standard uncertainty tends as n grows to _____ dB

Basis and qualification: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-FIB-084. Distinct corrected readings in that model share covariance _____ dB^2.

Answer: 0.09. The shared calibration variance is 0.30^2. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why this term is required: “0.09” completes the stated technical proposition.

Question context: Distinct corrected readings in that model share covariance _____

Basis and qualification: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-FIB-085. The corrected mean of −80.20 dBm with +0.15 dB correction is _____ dBm.

Answer: −80.05. The common correction is added once to the mean. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why this term is required: "−80.05" completes the stated technical proposition.

Question context: The corrected mean of −80.20 dBm with +0.15 dB correction is _____ dBm

Basis and qualification: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-FIB-086. The on/off power estimates 1.30 and 1.00 nW have difference _____ nW.

Answer: 0.300. Subtract linear powers before taking a logarithm. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: “0.300” completes the stated technical proposition.

Question context: The on/off power estimates 1.30 and 1.00 nW have difference _____ nW

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-087. Their stated covariance is _____ nW^2.

Answer: 0.00096. 0.04×0.03×0.80=0.00096. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: “0.00096” completes the stated technical proposition.

Question context: Their stated covariance is _____

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-088. The difference variance is _____ nW^2.

Answer: 0.00058. $0.04^2 + 0.03^2 - 2 \times 0.00096$. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: "0.00058" completes the stated technical proposition.

Question context: The difference variance is _____

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-089. The difference standard uncertainty is approximately _____ nW.

Answer: 0.0240832. It is the square root of 0.00058. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: “0.0240832” completes the stated technical proposition.

Question context: The difference standard uncertainty is approximately _____ nW

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-090. The stipulated difference support has lower endpoint about _____ nW.

Answer: 0.254967. $0.300 - \sqrt{3}(0.002 + 0.024)$ remains positive. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: "0.254967" completes the stated technical proposition.

Question context: The stipulated difference support has lower endpoint about _____ nW

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-091. The level of 0.300 nW is approximately _____ dBm.

Answer: −65.228787. Use 10 log 10 of 0.300 nW divided by 1 mW. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: "−65.228787" completes the stated technical proposition.

Question context: The level of 0.300 nW is approximately _____ dBm

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-092. The local log sensitivity at 0.300 nW is approximately _____ dB/nW.

Answer: 14.476483. It is $\frac{10}{[\ln(10) \times 0.300]}$. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: "14.476483" completes the stated technical proposition.

Question context: The local log sensitivity at 0.300 nW is approximately _____ dB/nW

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-093. The resulting local standard uncertainty is approximately _____ dB.

Answer: 0.348640. Multiply the local sensitivity by 0.0240832 nW. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: “0.348640” completes the stated technical proposition.

Question context: The resulting local standard uncertainty is approximately _____ dB

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-094. The complete positive support follows from the explicit joint input _____, not the point estimate alone.

Answer: law. The constructed bounded uniforms establish the full domain. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

Why this term is required: “law” completes the stated technical proposition.

Question context: The complete positive support follows from the explicit joint input _____, not the point estimate alone

Basis and qualification: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-C14-FIB-095. For Gaussian voltage X, the exact mean of X^2 includes the squared mean plus the _____.

Answer: variance. $E[X^2]=\mu^2+\sigma^2$. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why this term is required: "variance" completes the stated technical proposition.

Question context: For Gaussian voltage X, the exact mean of includes the squared mean plus the _____

Basis and qualification: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-FIB-096. For $P=\frac{X^2}{R}$, the exact variance contains the curvature term _____ .

Answer: $\frac{2\sigma^4}{R^2}$. This survives when the mean voltage and first derivative vanish.

Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why this term is required: "This survives when the mean voltage and first derivative vanish" completes the stated technical proposition.

Question context: For the exact variance contains the curvature term _____

Basis and qualification: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-FIB-097. At zero mean, σ=1 mV and R=50 ohms, exact expected power is _____ nW.

Answer: 20.0. The squared voltage SD divided by resistance is nonzero. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why this term is required: “20.0” completes the stated technical proposition.

Question context: At zero mean, =1 mV and R=50 ohms, exact expected power is _____ nW

Basis and qualification: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-FIB-098. At that point, exact power variance is

_____ W^2.

Answer: 8.00×10^{-16}. Use $\frac{2\sigma^4}{R^2}$. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why this term is required: “8” completes the stated technical proposition.

Question context: At that point, exact power variance is _____

Basis and qualification: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-FIB-099. At μ=10 mV, the curvature contribution to mean power is _____ μW.

Answer: 0.020. It is $\frac{\sigma^2}{R}$, added to the 2.000 μW power at the mean voltage. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why this term is required: "0.020" completes the stated technical proposition.

Question context: At =10 mV, the curvature contribution to mean power is _____ μW

Basis and qualification: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-C14-FIB-100. A full release record links raw data, configuration, corrections, uncertainty and the decision _____.

Answer: rule. Another analyst must be able to reconstruct both arithmetic and the stated conclusion. Source: §14.18 Close the calibration record across the working interval (p. 8147)

Why this term is required: “rule” completes the stated technical proposition.

Question context: A full release record links raw data, configuration, corrections, uncertainty and the decision _____

Basis and qualification: Chapter 14 — Close the calibration record across the working interval.

Review: Chapter 14 — Close the calibration record across the working interval.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C14-ESSAY-001. Explain why calibration should be designed around a reported measurand rather than an instrument label.

- Opening: Present a thesis that answers this precise question: Explain why calibration should be designed around a reported measurand rather than an instrument label. Identify which evidence would falsify the proposed conclusion Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Core terminology and scope: Define calibration, designed, reported in the question's particular technical setting; explain how measurand, instrument, label differ if that distinction would change the analysis of "Explain why calibration should be designed around a reported measurand rather than an instrument label" Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the measurement equation and required inputs for two distinct results, such as terminal power and relative phase Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why calibration should be designed around a reported measurand rather than an instrument label to the claimed result, following "Calibration Model and Traceability"; name the intermediate states and measurable outputs Source: §14.1 Calibration Model and Traceability (p. 8104)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why

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calibration should be designed around a reported measurand rather than an instrument label. Distinguish calibration, adjustment and verification, and explain traceability scope, configuration applicability and uncertainty without claiming traceability guarantees correctness Source: §14.1 Calibration Model and Traceability (p. 8104)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Frequency and Phase Calibration” that resolves the question about why calibration should be designed around a reported measurand rather than an instrument label; derive the relevant result with units and stated validity conditions Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why calibration should be designed around a reported measurand rather than an instrument label. Distinguish calibration, adjustment and verification, and explain traceability scope, configuration applicability and uncertainty without claiming traceability guarantees correctness Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Worked application or illustrative case: Build a worked example of “why calibration should be designed around a reported measurand rather than an instrument label”, addressing this associated condition: Define the measurement equation and required inputs for two distinct results, such as terminal power and.... Define the measurement equation and required inputs for two distinct results,

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such as terminal power and relative phase Source: §14.1 Calibration Model and Traceability (p. 8104)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why calibration should be designed around a reported measurand rather than an instrument label”. Using “Frequency and Phase Calibration”, specify a discriminator and the result expected under each explanation Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why calibration should be designed around a reported measurand rather than an instrument label, including the effect of missing measurements and inconsistent operating conditions Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Scholarly synthesis and implications: Explain what the result about why calibration should be designed around a reported measurand rather than an instrument label authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Closing: Conclude by answering “Explain why calibration should be designed around a reported measurand rather than an instrument label” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

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V011-C14-ESSAY-002. Audit the chapter's constructed 915 MHz signed correction chain.

- Opening: Present a thesis that answers this precise question: Audit the chapter's constructed 915 MHz signed correction chain. Identify which evidence would falsify the proposed conclusion Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)
- Core terminology and scope: Define Audit, constructed, signed in the question's particular technical setting; explain how correction, chain, measurement differ if that distinction would change the analysis of "Audit the chapter's constructed 915 MHz signed correction chain" Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Reproduce −86.70 dBm, identify the +0.20 residual and each loss/gain sign, predict the −72.40 dBm corrected receiver plane, and state linearity, mismatch and state assumptions Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Audit the chapter's constructed 915 MHz signed correction chain to the claimed result, following "Close the calibration record across the working interval"; name the intermediate states and measurable outputs Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Audit

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the chapter's constructed 915 MHz signed correction chain. Explain how wrong-plane or duplicate corrections can survive valid component certificates Source: §14.18 Close the calibration record across the working interval (p. 8147)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Four worked applications already developed in the calibration chain” that resolves the question about Audit the chapter's constructed 915 MHz signed correction chain; derive the relevant result with units and stated validity conditions Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Audit the chapter's constructed 915 MHz signed correction chain. Explain how wrong-plane or duplicate corrections can survive valid component certificates Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)
- Worked application or illustrative case: Build a worked example of “Audit the chapter's constructed 915 MHz signed correction chain”, addressing this associated condition: Reproduce −86.70 dBm, identify the +0.20 residual and each loss/gain sign, predict the −72.40 dBm corrected.... Reproduce −86.70 dBm, identify the +0.20 residual and each loss/gain sign, predict the −72.40 dBm corrected receiver plane, and state linearity, mismatch and state... Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Audit the chapter's constructed 915 MHz

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signed correction chain". Using "Four worked applications already developed in the calibration chain", specify a discriminator and the result expected under each explanation Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Audit the chapter's constructed 915 MHz signed correction chain, including the effect of missing measurements and inconsistent operating conditions Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Scholarly synthesis and implications: Explain what the result about Audit the chapter's constructed 915 MHz signed correction chain authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)
- Closing: Conclude by answering "Audit the chapter's constructed 915 MHz signed correction chain" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

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V011-C14-ESSAY-003. Design an amplitude calibration covering weak-signal and strong-signal use.

- Opening: Present a thesis that answers this precise question: Design an amplitude calibration covering weak-signal and strong-signal use. Identify which evidence would falsify the proposed conclusion Source: §14.3 Amplitude Response and Linearity (p. 8108)
- Core terminology and scope: Define Design, amplitude, calibration in the question's particular technical setting; explain how covering, weak-signal, strong-signal differ if that distinction would change the analysis of "Design an amplitude calibration covering weak-signal and strong-signal use" Source: §14.3 Amplitude Response and Linearity (p. 8108)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Specify levels, frequencies, band and gain-state boundaries, independently characterized source path, detector and bandwidth Source: §14.3 Amplitude Response and Linearity (p. 8108)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an amplitude calibration covering weak-signal and strong-signal use to the claimed result, following "Application 14B.7: retain endpoint covariance in a correction interpolation"; name the intermediate states and measurable outputs Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an amplitude calibration covering weak-signal and strong-signal use. Distinguish low-level statistical effects from

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compression/intermodulation and explain why fitting a single line does not validate every endpoint Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Frequency, phase, and delay require their own observables” that resolves the question about an amplitude calibration covering weak-signal and strong-signal use; derive the relevant result with units and stated validity conditions Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an amplitude calibration covering weak-signal and strong-signal use. Distinguish low-level statistical effects from compression/intermodulation and explain why fitting a single line does not validate every endpoint Source: §14.3 Amplitude Response and Linearity (p. 8108)
- Worked application or illustrative case: Build a worked example of “an amplitude calibration covering weak-signal and strong-signal use”, addressing this associated condition: Specify levels, frequencies, band and gain-state boundaries, independently characterized source path,.... Specify levels, frequencies, band and gain-state boundaries, independently characterized source path, detector and bandwidth Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “an amplitude calibration covering weak-signal and strong-signal use”. Using “Frequency, phase, and delay

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require their own observables", specify a discriminator and the result expected under each explanation Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an amplitude calibration covering weak-signal and strong-signal use, including the effect of missing measurements and inconsistent operating conditions Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)
- Scholarly synthesis and implications: Explain what the result about an amplitude calibration covering weak-signal and strong-signal use authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.3 Amplitude Response and Linearity (p. 8108)
- Closing: Conclude by answering "Design an amplitude calibration covering weak-signal and strong-signal use" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.3 Amplitude Response and Linearity (p. 8108)

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V011-C14-ESSAY-004. Develop a calibration plan for multichannel phase through retuning and triggering.

- Opening: Present a thesis that answers this precise question: Develop a calibration plan for multichannel phase through retuning and triggering. Identify which evidence would falsify the proposed conclusion Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Core terminology and scope: Define calibration, multichannel, phase in the question's particular technical setting; explain how retuning, triggering, measurement differ if that distinction would change the analysis of "Develop a calibration plan for multichannel phase through retuning and triggering" Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define simultaneous input relationship, reference planes, phase branch, frequency sweep and delay model Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a calibration plan for multichannel phase through retuning and triggering to the claimed result, following "Frequency and Phase Calibration"; name the intermediate states and measurable outputs Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a calibration plan for multichannel phase through retuning and

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triggering. Test actual reset/retune/sample-rate operations and distinguish within-record from inter-record repeatability Source: §14.5 Frequency and Phase Calibration (p. 8112)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Attach calibration to a stated measurement result” that resolves the question about a calibration plan for multichannel phase through retuning and triggering; derive the relevant result with units and stated validity conditions Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a calibration plan for multichannel phase through retuning and triggering. Include cable and reference-path uncertainty Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Worked application or illustrative case: Build a worked example of “a calibration plan for multichannel phase through retuning and triggering”, addressing this associated condition: Define simultaneous input relationship, reference planes, phase branch, frequency sweep and delay model. Define simultaneous input relationship, reference planes, phase branch, frequency sweep and delay model Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a calibration plan for multichannel phase through retuning and triggering”. Using “Attach calibration to a stated measurement result”, specify a discriminator and the result

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expected under each explanation Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a calibration plan for multichannel phase through retuning and triggering, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Scholarly synthesis and implications: Explain what the result about a calibration plan for multichannel phase through retuning and triggering authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Closing: Conclude by answering “Develop a calibration plan for multichannel phase through retuning and triggering” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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V011-C14-ESSAY-005. Compare noise-figure calibration with system sensitivity verification.

- Opening: Present a thesis that answers this precise question: Compare noise-figure calibration with system sensitivity verification. Identify which evidence would falsify the proposed conclusion Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)
- Core terminology and scope: Define noise-figure, calibration, system in the question's particular technical setting; explain how sensitivity, verification, measurement differ if that distinction would change the analysis of "Compare noise-figure calibration with system sensitivity verification" Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Describe hot/cold inputs, raw powers, equal gain, settling, compression and mismatch requirements Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting noise-figure calibration with system sensitivity verification to the claimed result, following "Calibrate noise without confusing it with detection"; name the intermediate states and measurable outputs Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for noise-figure calibration with system sensitivity verification. Contrast with waveform-specific detection/miss trials and acquisition schedules,

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explaining why neither result uniquely substitutes for the other Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Attach calibration to a stated measurement result” that resolves the question about noise-figure calibration with system sensitivity verification; derive the relevant result with units and stated validity conditions Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Evidence and method: Specify the native observations, control records and calculations that would resolve noise-figure calibration with system sensitivity verification. Contrast with waveform-specific detection/miss trials and acquisition schedules, explaining why neither result uniquely substitutes for the other Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)
- Worked application or illustrative case: Build a worked example of “noise-figure calibration with system sensitivity verification”, addressing this associated condition: Describe hot/cold inputs, raw powers, equal gain, settling, compression and mismatch requirements. Describe hot/cold inputs, raw powers, equal gain, settling, compression and mismatch requirements Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “noise-figure calibration with system sensitivity verification”. Using “Attach calibration to a stated measurement result”, specify a discriminator and the result

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expected under each explanation Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to noise-figure calibration with system sensitivity verification, including the effect of missing measurements and inconsistent operating conditions Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Scholarly synthesis and implications: Explain what the result about noise-figure calibration with system sensitivity verification authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)
- Closing: Conclude by answering “Compare noise-figure calibration with system sensitivity verification” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

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V011-C14-ESSAY-006. Derive exact affine mean and covariance propagation for finite-variance inputs.

- Opening: Present a thesis that answers this precise question: Derive exact affine mean and covariance propagation for finite-variance inputs. Identify which evidence would falsify the proposed conclusion Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Core terminology and scope: Define affine, mean, covariance in the question's particular technical setting; explain how propagation, finite-variance, inputs differ if that distinction would change the analysis of "Derive exact affine mean and covariance propagation for finite-variance inputs" Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start from centered inputs and expand the squared linear combination Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting exact affine mean and covariance propagation for finite-variance inputs to the claimed result, following "14. Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation"; name the intermediate states and measurable outputs Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for exact affine mean and covariance propagation for finite-variance inputs. Retain signed cross terms, units and covariance admissibility Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Four worked applications already developed in the calibration chain” that resolves the question about exact affine mean and covariance propagation for finite-variance inputs; derive the relevant result with units and stated validity conditions Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Evidence and method: Specify the native observations, control records and calculations that would resolve exact affine mean and covariance propagation for finite-variance inputs. Explain why Gaussian assumptions and independence are unnecessary for the identity but may matter to separate coverage claims Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Worked application or illustrative case: Build a worked example of “exact affine mean and covariance propagation for finite-variance inputs”, addressing this associated condition: Start from centered inputs and expand the squared linear combination. Start from centered inputs and expand the squared linear combination Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “exact affine mean and covariance

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propagation for finite-variance inputs". Using "Four worked applications already developed in the calibration chain", specify a discriminator and the result expected under each explanation Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to exact affine mean and covariance propagation for finite-variance inputs, including the effect of missing measurements and inconsistent operating conditions Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Scholarly synthesis and implications: Explain what the result about exact affine mean and covariance propagation for finite-variance inputs authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Closing: Conclude by answering "Derive exact affine mean and covariance propagation for finite-variance inputs" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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V011-C14-ESSAY-007. Derive the local nonlinear propagation expression and state its adequacy conditions.

- Opening: Present a thesis that answers this precise question: Derive the local nonlinear propagation expression and state its adequacy conditions. Identify which evidence would falsify the proposed conclusion Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Core terminology and scope: Define local, nonlinear, propagation in the question's particular technical setting; explain how expression, adequacy, conditions differ if that distinction would change the analysis of "Derive the local nonlinear propagation expression and state its adequacy conditions" Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the gradient at the input estimate and the linearized output, propagate covariance, and identify the neglected remainder Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the local nonlinear propagation expression and state its adequacy conditions to the claimed result, following "Nonlinear measurement models and defensible uncertainty intervals in RF metrology"; name the intermediate states and measurable outputs Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the local nonlinear propagation expression and state its adequacy conditions. Discuss curvature, singularities and domain boundaries; distinguish an exact affine identity from an approximate nonlinear uncertainty Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 14B.9: subtract paired powers before propagating a logarithm” that resolves the question about the local nonlinear propagation expression and state its adequacy conditions; derive the relevant result with units and stated validity conditions Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the local nonlinear propagation expression and state its adequacy conditions. Discuss curvature, singularities and domain boundaries; distinguish an exact affine identity from an approximate nonlinear uncertainty Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Worked application or illustrative case: Build a worked example of “the local nonlinear propagation expression and state its adequacy conditions”, addressing this associated condition: Define the gradient at the input estimate and the linearized output, propagate covariance, and identify the.... Define the gradient at the input estimate and the linearized output, propagate covariance, and

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identify the neglected remainder Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the local nonlinear propagation expression and state its adequacy conditions”. Using “Application 14B.9: subtract paired powers before propagating a logarithm”, specify a discriminator and the result expected under each explanation Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the local nonlinear propagation expression and state its adequacy conditions, including the effect of missing measurements and inconsistent operating conditions Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Scholarly synthesis and implications: Explain what the result about the local nonlinear propagation expression and state its adequacy conditions authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Closing: Conclude by answering “Derive the local nonlinear propagation expression and state its adequacy conditions” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

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V011-C14-ESSAY-008. Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result.

- Opening: Present a thesis that answers this precise question: Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result. Identify which evidence would falsify the proposed conclusion Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Core terminology and scope: Define Reconstruct, both, uncertainty in the question's particular technical setting; explain how budgets, measurement, evidence differ if that distinction would change the analysis of "Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result" Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compute 0.1032 and 0.321248 dB under zero covariances, then the −0.0432 covariance term and 0.244949 dB result Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result to the claimed result, following "Four worked applications already developed in the calibration chain"; name the intermediate states and measurable outputs Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Reconstruct both uncertainty budgets for the chapter's −86.70 dBm

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result. Explain the amplifier coefficient sign, evidence needed for correlation, and prevention of shared-reference double counting Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 14B.8: identify the uncertainty that averaging cannot remove” that resolves the question about Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result; derive the relevant result with units and stated validity conditions Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result. Explain the amplifier coefficient sign, evidence needed for correlation, and prevention of shared-reference double counting Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Worked application or illustrative case: Build a worked example of “Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result”, addressing this associated condition: Compute 0.1032 and 0.321248 dB under zero covariances, then the −0.0432 covariance term and 0.244949 dB result. Compute 0.1032 and 0.321248 dB under zero covariances, then the −0.0432 covariance term and 0.244949 dB result Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result”. Using “Application 14B.8: identify the uncertainty that averaging cannot remove”, specify a discriminator and the result expected under each explanation Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result, including the effect of missing measurements and inconsistent operating conditions Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)
- Scholarly synthesis and implications: Explain what the result about Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Closing: Conclude by answering “Reconstruct both uncertainty budgets for the chapter's −86.70 dBm result” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

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V011-C14-ESSAY-009. Explain shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms.

- Opening: Present a thesis that answers this precise question: Explain shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms. Identify which evidence would falsify the proposed conclusion Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Core terminology and scope: Define shared-reference, cancellation, Application in the question's particular technical setting; explain how explicit-input, covariance, forms differ if that distinction would change the analysis of "Explain shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms" Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use 34°−11°, independent 0.30°/0.40° residuals and common 0.80° contribution Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms to the claimed result, following "Application 14B.8: identify the uncertainty that averaging cannot remove"; name the intermediate states and measurable outputs Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for shared-

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reference cancellation using Application 14B.5 in both explicit-input and covariance forms. Show 0.50° uncertainty by cancellation and by $0.73+0.80-2\times0.64$ Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 14B.6: propagate phase-slope delay uncertainty" that resolves the question about shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms; derive the relevant result with units and stated validity conditions Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Evidence and method: Specify the native observations, control records and calculations that would resolve shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms. State equal-coupling, common-state and unwrapped-branch conditions Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Worked application or illustrative case: Build a worked example of "shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms", addressing this associated condition: Use 34°−11°, independent 0.30°/0.40° residuals and common 0.80° contribution. Use 34°−11°, independent 0.30°/0.40° residuals and common 0.80° contribution Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Alternative explanations and failure modes: Construct two plausible technical explanations for "shared-reference cancellation using

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Application 14B.5 in both explicit-input and covariance forms". Using "Application 14B.6: propagate phase-slope delay uncertainty", specify a discriminator and the result expected under each explanation Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Scholarly synthesis and implications: Explain what the result about shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Closing: Conclude by answering "Explain shared-reference cancellation using Application 14B.5 in both explicit-input and covariance forms" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

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V011-C14-ESSAY-010. Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish.

- Opening: Present a thesis that answers this precise question: Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish. Identify which evidence would falsify the proposed conclusion Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Core terminology and scope: Define Propagate, uncertainty, phase-slope in the question's particular technical setting; explain how delay, example, cannot differ if that distinction would change the analysis of "Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish" Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use 36°,100 MHz,0.20° and 10 kHz; derive signed sensitivities and 5.55646 ps Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish to the claimed result, following "Frequency, phase, and delay require their own observables"; name the intermediate states and measurable outputs Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish. Explain the small denominator uncertainty, branch assumption, constant-delay scope and need for independent phase-repeatability evidence Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Frequency and Phase Calibration” that resolves the question about Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish; derive the relevant result with units and stated validity conditions Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish. Explain the small denominator uncertainty, branch assumption, constant-delay scope and need for independent phase-repeatability evidence Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Worked application or illustrative case: Build a worked example of “Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish”, addressing this associated condition: Use 36°,100 MHz,0.20° and 10 kHz; derive signed sensitivities and 5.55646 ps. Use 36°,100 MHz,0.20° and 10 kHz; derive signed sensitivities and 5.55646 ps Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish”. Using “Frequency and Phase Calibration”, specify a discriminator and the result expected under each explanation Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish, including the effect of missing measurements and inconsistent operating conditions Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Scholarly synthesis and implications: Explain what the result about Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Closing: Conclude by answering “Propagate uncertainty in the phase-slope delay example and discuss what the small result cannot establish” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

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V011-C14-ESSAY-011. Develop the correlated interpolation budget in Application 14B.7.

- Opening: Present a thesis that answers this precise question: Develop the correlated interpolation budget in Application 14B.7. Identify which evidence would falsify the proposed conclusion Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)
- Core terminology and scope: Define correlated, interpolation, budget in the question's particular technical setting; explain how Application, measurement, evidence differ if that distinction would change the analysis of "Develop the correlated interpolation budget in Application 14B.7" Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Calculate the +0.70 dB correction and weighted endpoint variances, covariance and residual Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the correlated interpolation budget in Application 14B.7 to the claimed result, following "Four worked applications already developed in the calibration chain"; name the intermediate states and measurable outputs Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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correlated interpolation budget in Application 14B.7. Explain the 0.161419 dB uncertainty, evidence for the residual, and changes needed for uncertain fraction or extrapolation Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 14B.8: identify the uncertainty that averaging cannot remove” that resolves the question about the correlated interpolation budget in Application 14B.7; derive the relevant result with units and stated validity conditions Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the correlated interpolation budget in Application 14B.7. Explain the 0.161419 dB uncertainty, evidence for the residual, and changes needed for uncertain fraction or extrapolation Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)
- Worked application or illustrative case: Build a worked example of “the correlated interpolation budget in Application 14B.7”, addressing this associated condition: Calculate the +0.70 dB correction and weighted endpoint variances, covariance and residual. Calculate the +0.70 dB correction and weighted endpoint variances, covariance and residual Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the correlated interpolation budget in Application 14B.7”. Using “Application 14B.8: identify the uncertainty

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that averaging cannot remove", specify a discriminator and the result expected under each explanation Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the correlated interpolation budget in Application 14B.7, including the effect of missing measurements and inconsistent operating conditions Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Scholarly synthesis and implications: Explain what the result about the correlated interpolation budget in Application 14B.7 authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)
- Closing: Conclude by answering "Develop the correlated interpolation budget in Application 14B.7" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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V011-C14-ESSAY-012. Derive the common-calibration uncertainty floor in Application 14B.8.

- Opening: Present a thesis that answers this precise question: Derive the common-calibration uncertainty floor in Application 14B.8. Identify which evidence would falsify the proposed conclusion Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Core terminology and scope: Define common-calibration, uncertainty, floor in the question's particular technical setting; explain how Application, measurement, evidence differ if that distinction would change the analysis of "Derive the common-calibration uncertainty floor in Application 14B.8" Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Represent independent reading errors and one shared correction input, derive compute n = 16 and 64, and show the 0.30 dB limit Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the common-calibration uncertainty floor in Application 14B.8 to the claimed result, following "Four worked applications already developed in the calibration chain"; name the intermediate states and measurable outputs Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the common-calibration uncertainty floor in Application 14B.8. Explain why correlated readings, drift or averaging powers require a different model Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Analytical framework: Identify the equation, calibration or evidential decision test in “System-Level Vector Calibration and Uncertainty” that resolves the question about the common-calibration uncertainty floor in Application 14B.8; derive the relevant result with units and stated validity conditions Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the common-calibration uncertainty floor in Application 14B.8. Explain why correlated readings, drift or averaging powers require a different model Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Worked application or illustrative case: Build a worked example of “the common-calibration uncertainty floor in Application 14B.8”, addressing this associated condition: Represent independent reading errors and one shared correction input, derive compute n = 16 and 64, and show.... Represent independent reading errors and one shared correction input, derive compute n = 16 and 64, and show the 0.30 dB limit Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the common-calibration uncertainty floor in Application 14B.8”. Using “System-Level Vector Calibration and Uncertainty”, specify a discriminator and the result expected under each explanation Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the common-calibration uncertainty floor in Application 14B.8, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Scholarly synthesis and implications: Explain what the result about the common-calibration uncertainty floor in Application 14B.8 authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Closing: Conclude by answering “Derive the common-calibration uncertainty floor in Application 14B.8” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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V011-C14-ESSAY-013. Analyze the paired-power example from the explicit joint law to the local logarithmic result.

- Opening: Present a thesis that answers this precise question: Analyze the paired-power example from the explicit joint law to the local logarithmic result. Identify which evidence would falsify the proposed conclusion Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Core terminology and scope: Define paired-power, example, explicit in the question's particular technical setting; explain how joint, local, logarithmic differ if that distinction would change the analysis of "Analyze the paired-power example from the explicit joint law to the local logarithmic result" Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Derive covariance and 0.00058 difference variance; use bounded uniforms to establish positive support Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the paired-power example from the explicit joint law to the local logarithmic result to the claimed result, following "Model 14B: exact covariance and local uncertainty propagation"; name the intermediate states and measurable outputs Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the paired-power example from the explicit joint law to the local logarithmic result. Calculate −65.228787 dBm and 0.348640 dB local uncertainty Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Analytical framework: Identify the equation, calibration or evidential decision test in "14. Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation" that resolves the question about the paired-power example from the explicit joint law to the local logarithmic result; derive the relevant result with units and stated validity conditions Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the paired-power example from the explicit joint law to the local logarithmic result. Distinguish exact affine difference, exact transformed support and approximate log dispersion Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Worked application or illustrative case: Build a worked example of "the paired-power example from the explicit joint law to the local logarithmic result", addressing this associated condition: Derive covariance and 0.00058 difference variance; use bounded uniforms to establish positive support. Derive covariance and 0.00058 difference variance; use bounded uniforms to establish positive

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support Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the paired-power example from the explicit joint law to the local logarithmic result”. Using “14. Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation”, specify a discriminator and the result expected under each explanation Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the paired-power example from the explicit joint law to the local logarithmic result, including the effect of missing measurements and inconsistent operating conditions Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Scholarly synthesis and implications: Explain what the result about the paired-power example from the explicit joint law to the local logarithmic result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Closing: Conclude by answering “Analyze the paired-power example from the explicit joint law to the local logarithmic result” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

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V011-C14-ESSAY-014. Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning.

- Opening: Present a thesis that answers this precise question: Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning. Identify which evidence would falsify the proposed conclusion Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)
- Core terminology and scope: Define squared-Gaussian, example, failure in the question's particular technical setting; explain how zero-sensitivity, reasoning, measurement differ if that distinction would change the analysis of "Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning" Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Derive E[P] and Var(P) from Gaussian moments, compare μ10 mV and μ0 with σ1 mV,R50 ohms, and identify the omitted curvature term Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning to the claimed result, following "Uncertainty Budgets and Decision Rules"; name the intermediate states and measurable outputs Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Use the

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squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning. Explain why multiplying a zero local uncertainty by a coverage factor cannot restore information Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 14B: exact covariance and local uncertainty propagation” that resolves the question about Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning; derive the relevant result with units and stated validity conditions Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning. Explain why multiplying a zero local uncertainty by a coverage factor cannot restore information Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)
- Worked application or illustrative case: Build a worked example of “Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning”, addressing this associated condition: Derive E[P] and Var(P) from Gaussian moments, compare μ10 mV and μ0 with σ1 mV,R50 ohms, and identify the.... Derive E[P] and Var(P) from Gaussian moments, compare μ10 mV and μ0 with σ1 mV,R50 ohms, and identify the omitted curvature term Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning”. Using “Model 14B: exact covariance and local uncertainty propagation”, specify a discriminator and the result expected under each explanation Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning, including the effect of missing measurements and inconsistent operating conditions Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Scholarly synthesis and implications: Explain what the result about Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)
- Closing: Conclude by answering “Use the squared-Gaussian example to demonstrate failure of zero-sensitivity reasoning” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

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V011-C14-ESSAY-015. Evaluate the declared three-outcome decision rule for the constructed upper-level limit.

- Opening: Present a thesis that answers this precise question: Evaluate the declared three-outcome decision rule for the constructed upper-level limit. Identify which evidence would falsify the proposed conclusion Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Core terminology and scope: Define declared, decision, rule in the question's particular technical setting; explain how constructed, upper-level, limit differ if that distinction would change the analysis of "Evaluate the declared three-outcome decision rule for the constructed upper-level limit" Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use −86.70±0.49 dBm and −86.50 dBm to establish overlap and indeterminacy Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the declared three-outcome decision rule for the constructed upper-level limit to the claimed result, following "Uncertainty Budgets and Decision Rules"; name the intermediate states and measurable outputs Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the declared three-outcome decision rule for the constructed upper-

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level limit. Distinguish central estimate, uncertainty, coverage and decision, and describe legitimate follow-up without shifting the limit retrospectively Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- Analytical framework: Identify the equation, calibration or evidential decision test in “14. Decision rules, calibration applicability and publication evidence” that resolves the question about the declared three-outcome decision rule for the constructed upper-level limit; derive the relevant result with units and stated validity conditions Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the declared three-outcome decision rule for the constructed upper-level limit. Distinguish central estimate, uncertainty, coverage and decision, and describe legitimate follow-up without shifting the limit retrospectively Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Worked application or illustrative case: Build a worked example of “the declared three-outcome decision rule for the constructed upper-level limit”, addressing this associated condition: Use −86.70±0.49 dBm and −86.50 dBm to establish overlap and indeterminacy. Use −86.70±0.49 dBm and −86.50 dBm to establish overlap and indeterminacy Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the declared three-outcome decision rule for the constructed upper-level limit”. Using “14. Decision rules,

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calibration applicability and publication evidence", specify a discriminator and the result expected under each explanation Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the declared three-outcome decision rule for the constructed upper-level limit, including the effect of missing measurements and inconsistent operating conditions Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Scholarly synthesis and implications: Explain what the result about the declared three-outcome decision rule for the constructed upper-level limit authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Closing: Conclude by answering "Evaluate the declared three-outcome decision rule for the constructed upper-level limit" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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V011-C14-ESSAY-016. Explain how calibration covariance should be documented and checked.

- Opening: Present a thesis that answers this precise question: Explain how calibration covariance should be documented and checked. Identify which evidence would falsify the proposed conclusion Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Core terminology and scope: Define calibration, covariance, documented in the question's particular technical setting; explain how checked, measurement, evidence differ if that distinction would change the analysis of "Explain how calibration covariance should be documented and checked" Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Discuss explicit shared inputs versus derived covariance, signed coefficients, unit consistency, symmetry and positive semidefiniteness Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how calibration covariance should be documented and checked to the claimed result, following "Use covariance and model sensitivity deliberately"; name the intermediate states and measurable outputs Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how

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calibration covariance should be documented and checked. Explain why individually plausible pairwise correlations and a favorable final total are insufficient evidence Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Worked applications with hypothetical inputs” that resolves the question about how calibration covariance should be documented and checked; derive the relevant result with units and stated validity conditions Source: §14.14.2 Worked applications with hypothetical inputs (p. 8134)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how calibration covariance should be documented and checked. Explain why individually plausible pairwise correlations and a favorable final total are insufficient evidence Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Worked application or illustrative case: Build a worked example of “how calibration covariance should be documented and checked”, addressing this associated condition: Discuss explicit shared inputs versus derived covariance, signed coefficients, unit consistency, symmetry and.... Discuss explicit shared inputs versus derived covariance, signed coefficients, unit consistency, symmetry and positive semidefiniteness Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how calibration covariance should be

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documented and checked". Using "Worked applications with hypothetical inputs", specify a discriminator and the result expected under each explanation Source: §14.14.2 Worked applications with hypothetical inputs (p. 8134)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how calibration covariance should be documented and checked, including the effect of missing measurements and inconsistent operating conditions Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Scholarly synthesis and implications: Explain what the result about how calibration covariance should be documented and checked authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Closing: Conclude by answering "Explain how calibration covariance should be documented and checked" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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V011-C14-ESSAY-017. Compare a standard uncertainty, an expanded interval and a hard support bound.

- Opening: Present a thesis that answers this precise question: Compare a standard uncertainty, an expanded interval and a hard support bound. Identify which evidence would falsify the proposed conclusion Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Core terminology and scope: Define standard, uncertainty, expanded in the question's particular technical setting; explain how hard, support, bound differ if that distinction would change the analysis of "Compare a standard uncertainty, an expanded interval and a hard support bound" Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the power-difference or Gaussian-square examples to distinguish dispersion, coverage convention and possible-domain statements Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a standard uncertainty, an expanded interval and a hard support bound to the claimed result, following "Uncertainty Budgets and Decision Rules"; name the intermediate states and measurable outputs Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a standard uncertainty, an expanded interval and a hard support

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bound. Explain why factor two and positive central estimates do not establish universal coverage or positivity Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 14B.9: subtract paired powers before propagating a logarithm” that resolves the question about a standard uncertainty, an expanded interval and a hard support bound; derive the relevant result with units and stated validity conditions Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a standard uncertainty, an expanded interval and a hard support bound. Explain why factor two and positive central estimates do not establish universal coverage or positivity Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Worked application or illustrative case: Build a worked example of “a standard uncertainty, an expanded interval and a hard support bound”, addressing this associated condition: Use the power-difference or Gaussian-square examples to distinguish dispersion, coverage convention and.... Use the power-difference or Gaussian-square examples to distinguish dispersion, coverage convention and possible-domain statements Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a standard uncertainty, an expanded

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interval and a hard support bound". Using "Application 14B.9: subtract paired powers before propagating a logarithm", specify a discriminator and the result expected under each explanation Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a standard uncertainty, an expanded interval and a hard support bound, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Scholarly synthesis and implications: Explain what the result about a standard uncertainty, an expanded interval and a hard support bound authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Closing: Conclude by answering "Compare a standard uncertainty, an expanded interval and a hard support bound" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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V011-C14-ESSAY-018. Design a lifecycle and change-control plan for a receiver with external accessories and processing updates.

- Opening: Present a thesis that answers this precise question: Design a lifecycle and change-control plan for a receiver with external accessories and processing updates. Identify which evidence would falsify the proposed conclusion Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Core terminology and scope: Define Design, lifecycle, external in the question's particular technical setting; explain how accessories, processing, updates differ if that distinction would change the analysis of "Design a lifecycle and change-control plan for a receiver with external accessories and processing updates" Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Record correction versions, serial applicability, units, interpolation and uncertainty Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a lifecycle and change-control plan for a receiver with external accessories and processing updates to the claimed result, following "Close the calibration record across the working interval"; name the intermediate states and measurable outputs Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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lifecycle and change-control plan for a receiver with external accessories and processing updates. Tie checks to likely failures and consequential changes, distinguish targeted recharacterization from full recalibration, and define treatment of a failed closing reference Source: §14.18 Close the calibration record across the working interval (p. 8147)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Attach calibration to a stated measurement result” that resolves the question about a lifecycle and change-control plan for a receiver with external accessories and processing updates; derive the relevant result with units and stated validity conditions Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a lifecycle and change-control plan for a receiver with external accessories and processing updates. Tie checks to likely failures and consequential changes, distinguish targeted recharacterization from full recalibration, and define treatment of a failed closing reference Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Worked application or illustrative case: Build a worked example of “a lifecycle and change-control plan for a receiver with external accessories and processing updates”, addressing this associated condition: Record correction versions, serial applicability, units, interpolation and uncertainty. Record correction versions, serial applicability, units, interpolation and uncertainty Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a lifecycle and change-control plan for a receiver with external accessories and processing updates”. Using “Attach calibration to a stated measurement result”, specify a discriminator and the result expected under each explanation Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a lifecycle and change-control plan for a receiver with external accessories and processing updates, including the effect of missing measurements and inconsistent operating conditions Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Scholarly synthesis and implications: Explain what the result about a lifecycle and change-control plan for a receiver with external accessories and processing updates authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Closing: Conclude by answering “Design a lifecycle and change-control plan for a receiver with external accessories and processing updates” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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V011-C14-ESSAY-019. Assess the role of independent references in closing a working interval.

- Opening: Present a thesis that answers this precise question: Assess the role of independent references in closing a working interval. Identify which evidence would falsify the proposed conclusion Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Core terminology and scope: Define role, independent, references in the question's particular technical setting; explain how closing, working, interval differ if that distinction would change the analysis of "Assess the role of independent references in closing a working interval" Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain how a shared faulty correction can reproduce its own error, retain raw comparisons and independent recomputation, and use opening, closing and change-point checks Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the role of independent references in closing a working interval to the claimed result, following "Calibration Lifecycle and Change Control"; name the intermediate states and measurable outputs Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the role of independent references in closing a working interval. Preserve

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affected data and justify any retrospective correction by evidence Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Attach calibration to a stated measurement result” that resolves the question about the role of independent references in closing a working interval; derive the relevant result with units and stated validity conditions Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the role of independent references in closing a working interval. Preserve affected data and justify any retrospective correction by evidence Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Worked application or illustrative case: Build a worked example of “the role of independent references in closing a working interval”, addressing this associated condition: Explain how a shared faulty correction can reproduce its own error, retain raw comparisons and independent.... Explain how a shared faulty correction can reproduce its own error, retain raw comparisons and independent recomputation, and use opening, closing and change-point... Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the role of independent references in closing a working interval”. Using “Attach calibration to a stated measurement result”, specify a discriminator and the result

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expected under each explanation Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the role of independent references in closing a working interval, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Scholarly synthesis and implications: Explain what the result about the role of independent references in closing a working interval authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Closing: Conclude by answering “Assess the role of independent references in closing a working interval” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.18 Close the calibration record across the working interval (p. 8147)

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V011-C14-ESSAY-020. Analyze the temperature-dependent preamplifier disagreement case.

- Opening: Present a thesis that answers this precise question: Analyze the temperature-dependent preamplifier disagreement case. Identify which evidence would falsify the proposed conclusion Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Core terminology and scope: Define temperature-dependent, preamplifier, disagreement in the question's particular technical setting; explain how case, measurement, evidence differ if that distinction would change the analysis of "Analyze the temperature-dependent preamplifier disagreement case" Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain why a room-temperature correction may not apply after 35°C warming Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the temperature-dependent preamplifier disagreement case to the claimed result, following "Uncertainty Budgets and Decision Rules"; name the intermediate states and measurable outputs Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the temperature-dependent preamplifier disagreement case. Explain

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why a room-temperature correction may not apply after 35°C warming Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Close the calibration record across the working interval” that resolves the question about the temperature-dependent preamplifier disagreement case; derive the relevant result with units and stated validity conditions Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the temperature-dependent preamplifier disagreement case. Explain why a room-temperature correction may not apply after 35°C warming Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Worked application or illustrative case: Build a worked example of “the temperature-dependent preamplifier disagreement case”, addressing this associated condition: Explain why a room-temperature correction may not apply after 35°C warming. Explain why a room-temperature correction may not apply after 35°C warming Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the temperature-dependent preamplifier disagreement case”. Using “Close the calibration record across the working interval”, specify a discriminator and the result expected under each explanation Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the temperature-dependent preamplifier disagreement case, including the effect of missing measurements and inconsistent operating conditions Source: §14.3 Amplitude Response and Linearity (p. 8108)
- Scholarly synthesis and implications: Explain what the result about the temperature-dependent preamplifier disagreement case authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Closing: Conclude by answering “Analyze the temperature-dependent preamplifier disagreement case” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

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V011-C14-ESSAY-021. Explain what the published vector-calibration example contributes to the chapter's uncertainty argument.

- Opening: Present a thesis that answers this precise question: Explain what the published vector-calibration example contributes to the chapter's uncertainty argument. Identify which evidence would falsify the proposed conclusion Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Core terminology and scope: Define published, vector-calibration, example in the question's particular technical setting; explain how contributes, uncertainty, argument differ if that distinction would change the analysis of "Explain what the published vector-calibration example contributes to the chapter's uncertainty argument" Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish complex linear correction, repeatability and calibration uncertainty, shared calibration/comparison reference, and remaining nonlinear scope Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting what the published vector-calibration example contributes to the chapter's uncertainty argument to the claimed result, following "Worked applications with hypothetical inputs"; name the intermediate states and measurable outputs Source: §14.14.2 Worked applications with hypothetical inputs (p. 8134)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for what the published vector-calibration example contributes to the chapter's uncertainty argument. Do not claim the study validates hypothetical configurations elsewhere in the book Source: §14.14.2 Worked applications with hypothetical inputs (p. 8134)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Four worked applications already developed in the calibration chain” that resolves the question about what the published vector-calibration example contributes to the chapter's uncertainty argument; derive the relevant result with units and stated validity conditions Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Evidence and method: Specify the native observations, control records and calculations that would resolve what the published vector-calibration example contributes to the chapter's uncertainty argument. Do not claim the study validates hypothetical configurations elsewhere in the book Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Worked application or illustrative case: Build a worked example of “what the published vector-calibration example contributes to the chapter's uncertainty argument”, addressing this associated condition: Distinguish complex linear correction, repeatability and calibration uncertainty, shared.... Distinguish complex linear correction, repeatability and calibration uncertainty, shared

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calibration/comparison reference, and remaining nonlinear scope Source: §14.14.2 Worked applications with hypothetical inputs (p. 8134)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “what the published vector-calibration example contributes to the chapter's uncertainty argument”. Using “Four worked applications already developed in the calibration chain”, specify a discriminator and the result expected under each explanation Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to what the published vector-calibration example contributes to the chapter's uncertainty argument, including the effect of missing measurements and inconsistent operating conditions Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)
- Scholarly synthesis and implications: Explain what the result about what the published vector-calibration example contributes to the chapter's uncertainty argument authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Closing: Conclude by answering “Explain what the published vector-calibration example contributes to the chapter's uncertainty argument” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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V011-C14-ESSAY-022. Develop a review protocol for a simulation-based nonlinear uncertainty result.

- Opening: Present a thesis that answers this precise question: Develop a review protocol for a simulation-based nonlinear uncertainty result. Identify which evidence would falsify the proposed conclusion Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Core terminology and scope: Define review, protocol, simulation-based in the question's particular technical setting; explain how nonlinear, uncertainty, measurement differ if that distinction would change the analysis of "Develop a review protocol for a simulation-based nonlinear uncertainty result" Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Require the measurement function, input domains, distributions, dependence and admissible covariance Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a review protocol for a simulation-based nonlinear uncertainty result to the claimed result, following "Nonlinear measurement models and defensible uncertainty intervals in RF metrology"; name the intermediate states and measurable outputs Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a review protocol for a simulation-based nonlinear uncertainty result. Examine boundaries and curvature, compare simple analytic checks where available, and explain that numerical precision does not establish the assumptions Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 14B: exact covariance and local uncertainty propagation” that resolves the question about a review protocol for a simulation-based nonlinear uncertainty result; derive the relevant result with units and stated validity conditions Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a review protocol for a simulation-based nonlinear uncertainty result. Examine boundaries and curvature, compare simple analytic checks where available, and explain that numerical precision does not establish the assumptions Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Worked application or illustrative case: Build a worked example of “a review protocol for a simulation-based nonlinear uncertainty result”, addressing this associated condition: Require the measurement function, input domains, distributions, dependence and admissible covariance. Require the measurement function, input domains, distributions, dependence and admissible covariance Source: §14.19

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Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a review protocol for a simulation-based nonlinear uncertainty result”. Using “Model 14B: exact covariance and local uncertainty propagation”, specify a discriminator and the result expected under each explanation Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a review protocol for a simulation-based nonlinear uncertainty result, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)
- Scholarly synthesis and implications: Explain what the result about a review protocol for a simulation-based nonlinear uncertainty result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Closing: Conclude by answering “Develop a review protocol for a simulation-based nonlinear uncertainty result” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

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V011-C14-ESSAY-023. Explain why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty.

- Opening: Present a thesis that answers this precise question: Explain why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty. Identify which evidence would falsify the proposed conclusion Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Core terminology and scope: Define correction, errors, configuration in the question's particular technical setting; explain how mistakes, concealed, uncertainty differ if that distinction would change the analysis of "Explain why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty" Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish an applied correction's residual uncertainty from a wrong cable, wrong sign or unapplied offset Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty to the claimed result, following "Close the calibration record across the working interval"; name the intermediate states and measurable outputs Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why

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known correction errors and configuration mistakes should not be concealed by enlarging uncertainty. Use a decision-near-limit case to show the effect on central value and identify independent reconstruction checks Source: §14.18 Close the calibration record across the working interval (p. 8147)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Nonlinear measurement models and defensible uncertainty intervals in RF metrology” that resolves the question about why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty; derive the relevant result with units and stated validity conditions Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty. Use a decision-near-limit case to show the effect on central value and identify independent reconstruction checks Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Worked application or illustrative case: Build a worked example of “why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty”, addressing this associated condition: Distinguish an applied correction's residual uncertainty from a wrong cable, wrong sign or unapplied offset. Distinguish an applied correction's residual uncertainty from a

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wrong cable, wrong sign or unapplied offset Source: §14.18 Close the calibration record across the working interval (p. 8147)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty”. Using “Nonlinear measurement models and defensible uncertainty intervals in RF metrology”, specify a discriminator and the result expected under each explanation Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Scholarly synthesis and implications: Explain what the result about why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Closing: Conclude by answering “Explain why known correction errors and configuration mistakes should not be concealed by enlarging uncertainty” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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V011-C14-ESSAY-024. Construct a complete release record for both a corrected level and a noise-figure result.

- Opening: Present a thesis that answers this precise question: Construct a complete release record for both a corrected level and a noise-figure result. Identify which evidence would falsify the proposed conclusion Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Core terminology and scope: Define Construct, complete, release in the question's particular technical setting; explain how record, corrected, level differ if that distinction would change the analysis of "Construct a complete release record for both a corrected level and a noise-figure result" Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Problem statement and purpose: Frame the actual measurement or decision in the question. For level, link raw indication, planes, state, correction terms, certificates, covariance, coverage and rule Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a complete release record for both a corrected level and a noise-figure result to the claimed result, following "Calibrate noise without confusing it with detection"; name the intermediate states and measurable outputs Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a complete release record for both a corrected level and a noise-

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figure result. For noise, retain linear hot/cold powers and temperatures, ratio/domain and gain checks Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Noise Figure and System Sensitivity Calibration” that resolves the question about a complete release record for both a corrected level and a noise-figure result; derive the relevant result with units and stated validity conditions Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a complete release record for both a corrected level and a noise-figure result. Make another analyst able to reproduce the arithmetic and its validity conditions Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Worked application or illustrative case: Build a worked example of “a complete release record for both a corrected level and a noise-figure result”, addressing this associated condition: For level, link raw indication, planes, state, correction terms, certificates, covariance, coverage and rule. For level, link raw indication, planes, state, correction terms, certificates, covariance, coverage and rule Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a complete release record for both a corrected level and a noise-figure result”. Using “Noise Figure and System Sensitivity Calibration”, specify a discriminator and the result

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expected under each explanation Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a complete release record for both a corrected level and a noise-figure result, including the effect of missing measurements and inconsistent operating conditions Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Scholarly synthesis and implications: Explain what the result about a complete release record for both a corrected level and a noise-figure result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Closing: Conclude by answering “Construct a complete release record for both a corrected level and a noise-figure result” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.18 Close the calibration record across the working interval (p. 8147)

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V011-C14-ESSAY-025. Compare common-reference effects in a phase difference, an averaged level and a calibration comparison.

- Opening: Present a thesis that answers this precise question: Compare common-reference effects in a phase difference, an averaged level and a calibration comparison. Identify which evidence would falsify the proposed conclusion Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Core terminology and scope: Define effects, phase, difference in the question's particular technical setting; explain how averaged, level, calibration differ if that distinction would change the analysis of "Compare common-reference effects in a phase difference, an averaged level and a calibration comparison" Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain equal-coupling cancellation in the difference, persistence in an average, and hidden common error in apparent agreement Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting common-reference effects in a phase difference, an averaged level and a calibration comparison to the claimed result, following "System-Level Vector Calibration and Uncertainty"; name the intermediate states and measurable outputs Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for common-reference effects in a phase difference, an averaged level and a calibration comparison. Use signed measurement equations and stated dependencies rather than treating every shared reference as either always helpful or always harmful Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Frequency, phase, and delay require their own observables” that resolves the question about common-reference effects in a phase difference, an averaged level and a calibration comparison; derive the relevant result with units and stated validity conditions Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Evidence and method: Specify the native observations, control records and calculations that would resolve common-reference effects in a phase difference, an averaged level and a calibration comparison. Use signed measurement equations and stated dependencies rather than treating every shared reference as either always helpful or always harmful Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Worked application or illustrative case: Build a worked example of “common-reference effects in a phase difference, an averaged level and a calibration comparison”, addressing this associated condition: Explain equal-coupling cancellation in the difference, persistence in an average, and hidden common error in.... Explain equal-coupling

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cancellation in the difference, persistence in an average, and hidden common error in apparent agreement Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “common-reference effects in a phase difference, an averaged level and a calibration comparison”. Using “Frequency, phase, and delay require their own observables”, specify a discriminator and the result expected under each explanation Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to common-reference effects in a phase difference, an averaged level and a calibration comparison, including the effect of missing measurements and inconsistent operating conditions Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Scholarly synthesis and implications: Explain what the result about common-reference effects in a phase difference, an averaged level and a calibration comparison authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Closing: Conclude by answering “Compare common-reference effects in a phase difference, an averaged level and a calibration comparison” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C14-DISCUSSION-001. A certificate covers the receiver but not the selected gain state. How should a reviewer respond?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A certificate covers the receiver but not the selected gain state. How should a reviewer respond?” Put this particular dispute to the panel: A certificate covers the receiver but not the selected gain state. How should a reviewer respond. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 02. Student A, terminology and scope: Agree the operational meanings of certificate, covers, receiver and gain, reviewer, respond in “A certificate covers the receiver but not the selected gain state. How should a reviewer respond”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A certificate covers the receiver but not the selected gain state; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Do not hide the gap under an arbitrary uncertainty allowance or infer coverage from serial identity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A certificate covers the receiver but not the selected gain state; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Do not hide the gap under an arbitrary uncertainty allowance or infer coverage from serial identity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the omitted scope, request targeted characterization or narrow the claim, and retain the valid covered calibration Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A certificate covers the receiver but not the

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selected gain state: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A certificate covers the receiver but not the selected gain state; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A certificate covers the receiver but not the selected gain state: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A certificate covers the receiver but not the selected gain state, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A certificate covers the receiver but not the selected gain state: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A certificate covers the receiver but not the selected gain state. Do not hide the gap under an arbitrary uncertainty allowance or infer coverage from serial identity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A certificate covers the receiver but not the selected gain state, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A certificate covers the receiver but not the selected gain state. Do not hide the gap under an arbitrary uncertainty allowance or infer coverage from serial identity Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A certificate covers the receiver but not the selected gain state and How should a reviewer respond; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A certificate covers the receiver but not the selected gain state”, addressing “How should a reviewer respond”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A certificate covers the receiver but not the selected gain state. How should a reviewer respond”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A certificate covers the receiver but not the selected gain state. How should a reviewer respond”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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V011-C14-DISCUSSION-002. A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. What should be fixed first?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. What should be fixed first?” Put this particular dispute to the panel: A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. What should be fixed first. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 02. Student A, terminology and scope: Agree the operational meanings of reports, excellent, total and uses, wrong, file in “A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. What should be fixed first”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A spreadsheet reports an excellent uncertainty total but uses the wrong cable file; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Nonlinear uncertainty propagation, model uncertainty and decision guard bands”. Explain why a precise uncertainty propagation cannot repair the wrong measurement equation or input identity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A spreadsheet reports an

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excellent uncertainty total but uses the wrong cable file; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Nonlinear uncertainty propagation, model uncertainty and decision guard bands”. Explain why a precise uncertainty propagation cannot repair the wrong measurement equation or input identity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Resolve the configuration mismatch and recompute with applicable data Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A spreadsheet reports an excellent uncertainty total but uses the wrong cable file: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A spreadsheet reports an excellent uncertainty total but uses the wrong cable file; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A spreadsheet reports an excellent uncertainty total but uses the wrong cable file: specify the

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altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A spreadsheet reports an excellent uncertainty total but uses the wrong cable file, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A spreadsheet reports an excellent uncertainty total but uses the wrong cable file: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. Explain why a precise uncertainty propagation cannot repair the wrong measurement equation or input identity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A spreadsheet reports an excellent uncertainty total but uses the wrong cable file, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. Explain why a precise uncertainty propagation cannot repair the wrong measurement equation or input identity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A spreadsheet reports an excellent uncertainty total but uses the wrong cable file and What should be fixed first; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A spreadsheet reports an excellent

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uncertainty total but uses the wrong cable file", addressing "What should be fixed first"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. What should be fixed first", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A spreadsheet reports an excellent uncertainty total but uses the wrong cable file. What should be fixed first". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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V011-C14-DISCUSSION-003. The forward and reverse level calculations do not close. What would you inspect?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The forward and reverse level calculations do not close. What would you inspect?” Put this particular dispute to the panel: The forward and reverse level calculations do not close. What would you inspect. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

- 02. Student A, terminology and scope: Agree the operational meanings of forward, reverse, level and calculations, close, inspect in “The forward and reverse level calculations do not close. What would you inspect”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The

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forward and reverse level calculations do not close; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Amplitude Response and Linearity”. Keep physical linearity and mismatch checks separate from arithmetic closure Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The forward and reverse level calculations do not close; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Amplitude Response and Linearity”. Keep physical linearity and mismatch checks separate from arithmetic closure Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check correction signs, planes, instrument-applied terms, units and duplicate ownership against raw data Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The forward and reverse level calculations do not close: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control

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condition and expected result, and identify how you would document an unexpected observation. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The forward and reverse level calculations do not close; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The forward and reverse level calculations do not close: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The forward and reverse level calculations do not close, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The forward and reverse level calculations do not close: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The forward and reverse level calculations do not close. Keep physical linearity and mismatch checks separate from arithmetic closure Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified

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reading. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The forward and reverse level calculations do not close, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The forward and reverse level calculations do not close. Keep physical linearity and mismatch checks separate from arithmetic closure Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The forward and reverse level calculations do not close and What would you inspect; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The forward and reverse level calculations do not close”, addressing “What would you inspect”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The forward and reverse level calculations do not close. What would you inspect”, specifying the next test, responsible measurement record and limit of the conclusion

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Summarise the strongest evidence for and against the resolution of “The forward and reverse level calculations do not close. What would you inspect”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

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V011-C14-DISCUSSION-004. A linear fit gives small average residuals despite visible endpoint compression. May the full range be accepted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A linear fit gives small average residuals despite visible endpoint compression. May the full range be accepted?” Put this particular dispute to the panel: A linear fit gives small average residuals despite visible endpoint compression. May the full range be accepted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 02. Student A, terminology and scope: Agree the operational meanings of residuals, despite, visible and endpoint, compression, accepted in “A linear fit gives small average residuals despite visible endpoint compression. May the full range be accepted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A linear fit gives small average residuals despite visible endpoint compression; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Amplitude Response and Linearity”. Explain that an average fit statistic can conceal systematic endpoint behavior relevant to the intended measurement Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A linear fit gives small average

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residuals despite visible endpoint compression; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Amplitude Response and Linearity”. Explain that an average fit statistic can conceal systematic endpoint behavior relevant to the intended measurement Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Inspect individual data and define a supported range; test boundaries and state transitions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A linear fit gives small average residuals despite visible endpoint compression: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A linear fit gives small average residuals despite visible endpoint compression; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A linear fit gives small average residuals despite visible endpoint compression: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A linear fit gives small average residuals despite visible endpoint compression, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A linear fit gives small average residuals despite visible endpoint compression: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A linear fit gives small average residuals despite visible endpoint compression. Explain that an average fit statistic can conceal systematic endpoint behavior relevant to the intended measurement Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A linear fit gives small average residuals despite visible endpoint compression, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A linear fit gives small average residuals despite visible endpoint compression. Explain that an average fit statistic

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can conceal systematic endpoint behavior relevant to the intended measurement Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A linear fit gives small average residuals despite visible endpoint compression and May the full range be accepted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A linear fit gives small average residuals despite visible endpoint compression”, addressing “May the full range be accepted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A linear fit gives small average residuals despite visible endpoint compression. May the full range be accepted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A linear fit gives small average residuals despite visible endpoint compression. May the full range be accepted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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V011-C14-DISCUSSION-005. Two channels agree at one tone after calibration but disagree on a wideband waveform. What is missing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two channels agree at one tone after calibration but disagree on a wideband waveform. What is missing?” Put this particular dispute to the panel: Two channels agree at one tone after calibration but disagree on a wideband waveform. What is missing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 02. Student A, terminology and scope: Agree the operational meanings of channels, agree, disagree and wideband, waveform, missing in “Two channels agree at one tone after calibration but disagree on a wideband waveform. What is missing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.3 Amplitude Response and Linearity (p. 8108)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two channels agree at one tone after calibration but disagree on a wideband waveform; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frequency and Phase Calibration”. Acknowledge the valid single-frequency result while limiting its broader implication Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two channels agree at one tone after calibration but disagree on a wideband waveform; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frequency and Phase Calibration”. Acknowledge the valid single-frequency result while limiting its broader implication Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Frequency-dependent phase/amplitude response, branch and interpolation, delay model and state repeatability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two channels agree at one tone after

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calibration but disagree on a wideband waveform: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two channels agree at one tone after calibration but disagree on a wideband waveform; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two channels agree at one tone after calibration but disagree on a wideband waveform: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative

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that could survive the proposed test. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two channels agree at one tone after calibration but disagree on a wideband waveform, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two channels agree at one tone after calibration but disagree on a wideband waveform: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.3 Amplitude Response and Linearity (p. 8108)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two channels agree at one tone after

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calibration but disagree on a wideband waveform. Acknowledge the valid single-frequency result while limiting its broader implication Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two channels agree at one tone after calibration but disagree on a wideband waveform, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two channels agree at one tone after calibration but disagree on a wideband waveform. Acknowledge the valid single-frequency result while limiting its broader implication Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two channels agree at one tone after calibration but disagree on a wideband waveform and What is missing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two channels agree at one tone after calibration but disagree on a wideband waveform”, addressing “What is missing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.3 Amplitude Response and Linearity (p. 8108)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two channels agree at one tone after calibration but disagree on a wideband waveform. What is missing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two channels agree at one tone after calibration but disagree on a wideband waveform. What is missing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.3 Amplitude Response and Linearity (p. 8108)

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V011-C14-DISCUSSION-006. Two receivers sharing one reference agree in frequency. What absolute accuracy claim is warranted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two receivers sharing one reference agree in frequency. What absolute accuracy claim is warranted?” Put this particular dispute to the panel: Two receivers sharing one reference agree in frequency. What absolute accuracy claim is warranted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 02. Student A, terminology and scope: Agree the operational meanings of receivers, sharing, agree and absolute, accuracy, claim in “Two receivers sharing one reference agree in frequency. What absolute accuracy claim is warranted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two receivers sharing one reference agree in frequency; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 14B.8: identify the uncertainty that averaging cannot remove”. Agreement constrains relative behavior but can retain common absolute error Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two receivers sharing one reference agree in frequency; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 14B.8: identify the uncertainty that averaging cannot remove”. Agreement constrains relative behavior but can retain common absolute error Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify common and canceling reference errors and compare against an independent suitable standard where needed Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two receivers sharing one reference agree in

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frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two receivers sharing one reference agree in frequency; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two receivers sharing one reference agree in frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two receivers sharing one reference agree in frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two receivers sharing one reference agree in frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two receivers sharing one reference agree

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in frequency. Agreement constrains relative behavior but can retain common absolute error Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two receivers sharing one reference agree in frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two receivers sharing one reference agree in frequency. Agreement constrains relative behavior but can retain common absolute error Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two receivers sharing one reference agree in frequency and What absolute accuracy claim is warranted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two receivers sharing one reference agree in frequency”, addressing “What absolute accuracy claim is warranted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two receivers sharing one reference agree in

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frequency. What absolute accuracy claim is warranted", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Two receivers sharing one reference agree in frequency. What absolute accuracy claim is warranted". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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V011-C14-DISCUSSION-007. A receiver locks after every retune but restarts with random phase. What correction scope should be reported?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A receiver locks after every retune but restarts with random phase. What correction scope should be reported?” Put this particular dispute to the panel: A receiver locks after every retune but restarts with random phase. What correction scope should be reported. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 02. Student A, terminology and scope: Agree the operational meanings of locks, retune, restarts and random, scope, reported in “A receiver locks after every retune but restarts with random phase. What correction scope should be reported”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A receiver locks after every retune but restarts with random phase; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Attach calibration to a stated measurement result”. Require actual reset-state phase tests before combining acquisitions coherently Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver locks after every retune but restarts with random phase; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Attach calibration to a stated measurement result”. Require actual reset-state phase tests before combining acquisitions coherently Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State demonstrated frequency lock and within-record behavior separately from absent inter-record coherence Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A receiver locks after every retune but restarts

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with random phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver locks after every retune but restarts with random phase; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A receiver locks after every retune but restarts with random phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A receiver locks after every retune but restarts with random phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A receiver locks after every retune but restarts with random phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A receiver locks after every retune but restarts with random phase. Require actual reset-state phase tests before combining acquisitions coherently Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A receiver locks after every retune but restarts with random phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A receiver locks after every retune but restarts with random phase. Require actual reset-state phase tests before combining acquisitions coherently Respond point by point to Student J. Distinguish a verified observation from a conditional

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inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A receiver locks after every retune but restarts with random phase and What correction scope should be reported; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A receiver locks after every retune but restarts with random phase”, addressing “What correction scope should be reported”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A receiver locks after every retune but restarts with random phase. What correction scope should be reported”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A receiver locks after every retune but restarts with random phase. What correction scope should be reported”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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V011-C14-DISCUSSION-008. Hot/cold readings settle to repeatable values but the receiver changes gain between them. Is the simple inversion valid?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Hot/cold readings settle to repeatable values but the receiver changes gain between them. Is the simple inversion valid?” Put this particular dispute to the panel: Hot/cold readings settle to repeatable values but the receiver changes gain between them. Is the simple inversion valid. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 02. Student A, terminology and scope: Agree the operational meanings of readings, settle, repeatable and values, simple, inversion in “Hot/cold readings settle to repeatable values but the receiver changes gain between them. Is the simple inversion valid”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Hot/cold readings settle to repeatable values but the receiver changes gain between them; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Noise Figure and System Sensitivity Calibration”. Preserve raw states, characterize the transfer or use a supported expanded model, and check hot-state compression and mismatch Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Hot/cold readings settle to repeatable values but the receiver changes gain between them;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Noise Figure and System Sensitivity Calibration”. Preserve raw states, characterize the transfer or use a supported expanded model, and check hot-state compression and mismatch Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; repeatability does not supply equal gain Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Hot/cold readings settle to repeatable values but the receiver changes gain between them: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Hot/cold readings settle to repeatable values but the receiver changes gain between them; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Hot/cold readings settle to repeatable values but the receiver changes gain between them: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Hot/cold readings settle to repeatable values but the receiver changes gain between them, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Hot/cold readings settle to repeatable values but the receiver changes gain between them: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Hot/cold readings settle to repeatable values but the receiver changes gain between them. Preserve raw states, characterize the transfer or use a supported expanded model, and check hot-state compression and mismatch Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Hot/cold readings settle to repeatable values but the receiver changes gain between them, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Hot/cold readings settle to repeatable values but the receiver changes gain between them. Preserve raw states, characterize the transfer or use a supported expanded model, and check hot-state compression and mismatch Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Hot/cold readings settle to repeatable values but the receiver changes gain between them and Is the simple inversion valid; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Hot/cold readings settle to repeatable values but the receiver changes gain between them”, addressing “Is the simple inversion valid”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Hot/cold readings settle to repeatable values but the receiver changes gain between them. Is the simple inversion valid”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Hot/cold readings settle to repeatable values but the receiver changes gain between them. Is the simple inversion valid”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

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V011-C14-DISCUSSION-009. A system has a good noise figure but misses brief signals. How would you investigate?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A system has a good noise figure but misses brief signals. How would you investigate?” Put this particular dispute to the panel: A system has a good noise figure but misses brief signals. How would you investigate. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 02. Student A, terminology and scope: Agree the operational meanings of good, noise, figure and misses, brief, signals in “A system has a good noise figure but misses brief signals. How would you investigate”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A system has a good noise figure but misses brief signals; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Distinguish acquisition opportunity and decision behavior from the noise budget Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A system has a good noise figure but misses brief signals; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Distinguish acquisition opportunity and decision behavior from the noise budget Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Test the actual waveform, duration, threshold and observation schedule, retaining misses and detections Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A system has a good noise figure but misses

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brief signals: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A system has a good noise figure but misses brief signals; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A system has a good noise figure but misses brief signals: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A system has a good noise figure but misses brief signals, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A system has a good noise figure but misses brief signals: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A system has a good noise figure but

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misses brief signals. Distinguish acquisition opportunity and decision behavior from the noise budget Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A system has a good noise figure but misses brief signals, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A system has a good noise figure but misses brief signals. Distinguish acquisition opportunity and decision behavior from the noise budget Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A system has a good noise figure but misses brief signals and How would you investigate; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A system has a good noise figure but misses brief signals”, addressing “How would you investigate”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A system has a good noise figure but misses

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brief signals. How would you investigate", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A system has a good noise figure but misses brief signals. How would you investigate". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

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V011-C14-DISCUSSION-010. A budget selects correlation +0.9 solely because it achieves acceptance. What evidence is required?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A budget selects correlation +0.9 solely because it achieves acceptance. What evidence is required?” Put this particular dispute to the panel: A budget selects correlation +0.9 solely because it achieves acceptance. What evidence is required. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 02. Student A, terminology and scope: Agree the operational meanings of budget, selects, correlation and because, achieves, acceptance in “A budget selects correlation +0.9 solely because it achieves acceptance. What evidence is required”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A budget selects correlation +0.9 solely because it achieves acceptance; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Four worked applications already developed in the calibration chain”. Recompute with supported assumptions; uncertainty is not optimized to obtain a preferred decision Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A budget selects correlation +0.9 solely because it achieves acceptance; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Four worked applications already developed in the calibration chain”. Recompute with supported assumptions; uncertainty is not optimized to obtain a preferred decision Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Request the actual shared calibration model or measured dependency and check matrix admissibility Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A budget selects correlation +0.9 solely because it achieves acceptance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A budget selects correlation +0.9 solely because it achieves acceptance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A budget selects correlation +0.9 solely because it achieves acceptance: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A budget selects correlation +0.9 solely because it achieves acceptance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A budget selects correlation +0.9 solely because it achieves acceptance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A budget selects correlation +0.9 solely because it achieves acceptance. Recompute with supported assumptions; uncertainty is not optimized to obtain a preferred decision Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A budget selects correlation +0.9 solely because it achieves acceptance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A budget selects correlation +0.9 solely because it achieves acceptance. Recompute with supported assumptions;

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uncertainty is not optimized to obtain a preferred decision Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A budget selects correlation +0.9 solely because it achieves acceptance and What evidence is required; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A budget selects correlation +0.9 solely because it achieves acceptance”, addressing “What evidence is required”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A budget selects correlation +0.9 solely because it achieves acceptance. What evidence is required”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A budget selects correlation +0.9 solely because it achieves acceptance. What evidence is required”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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V011-C14-DISCUSSION-011. Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. How should it be treated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. How should it be treated?” Put this particular dispute to the panel: Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. How should it be treated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 02. Student A, terminology and scope: Agree the operational meanings of proposed, matrix, yields and variance, combination, treated in “Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. How should it be treated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 14B: exact covariance and local uncertainty propagation”. Pairwise bounds are necessary but not sufficient Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 14B: exact covariance and local uncertainty propagation”. Pairwise bounds are necessary but not sufficient Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reject the inconsistent joint covariance description, identify conflicting dependencies and reconstruct a physical model Put two specific

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questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source:

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§14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. Pairwise bounds are necessary but not sufficient Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Several pairwise correlations lie within −1 to

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+1, but the proposed matrix yields negative variance for one combination, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. Pairwise bounds are necessary but not sufficient Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination and How should it be treated; exclude protections irrelevant to the scenario Question Student F about the custody and

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reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination”, addressing “How should it be treated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. How should it be treated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Several pairwise correlations lie within −1 to +1, but the proposed matrix yields negative variance for one combination. How should it

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be treated". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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V011-C14-DISCUSSION-012. An analyst counts a common reference as two independent rows and then adds covariance from that same reference. What is the risk?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An analyst counts a common reference as two independent rows and then adds covariance from that same reference. What is the risk?” Put this particular dispute to the panel: An analyst counts a common reference as two independent rows and then adds covariance from that same reference. What is the risk. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, counts, common and adds, covariance, risk in “An analyst counts a common reference as two independent rows and then adds covariance from that same reference. What is the risk”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An analyst counts a common reference as two independent rows and then adds covariance from that same reference; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Use covariance and model sensitivity deliberately”. Check signed coefficients and compare both formulations as an audit Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst counts a common

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reference as two independent rows and then adds covariance from that same reference; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Use covariance and model sensitivity deliberately”. Check signed coefficients and compare both formulations as an audit Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Show the double counting and rebuild either explicit common-input or consistent derived-covariance representation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An analyst counts a common reference as two independent rows and then adds covariance from that same reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst counts a common reference as two independent rows and then adds covariance from that same reference; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An analyst counts a common reference as two independent rows and then adds covariance from that same reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An analyst counts a common reference as two independent rows and then adds covariance from that same reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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An analyst counts a common reference as two independent rows and then adds covariance from that same reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An analyst counts a common reference as two independent rows and then adds covariance from that same reference. Check signed coefficients and compare both formulations as an audit Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An analyst counts a common reference as two independent rows and then adds covariance from that same reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible

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instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An analyst counts a common reference as two independent rows and then adds covariance from that same reference. Check signed coefficients and compare both formulations as an audit Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An analyst counts a common reference as two independent rows and then adds covariance from that same reference and What is the risk; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An analyst counts a common reference as two independent rows and then adds covariance from that same reference”, addressing “What is the risk”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An analyst counts a common reference as two independent rows and then adds covariance from that same reference. What is the risk”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An analyst counts a common reference as two independent rows and then adds covariance from that same reference. What is the risk”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

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V011-C14-DISCUSSION-013. A phase-difference uncertainty is small, but the unwrap branch is unresolved. Is the delay result ready?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A phase-difference uncertainty is small, but the unwrap branch is unresolved. Is the delay result ready?” Put this particular dispute to the panel: A phase-difference uncertainty is small, but the unwrap branch is unresolved. Is the delay result ready. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- 02. Student A, terminology and scope: Agree the operational meanings of uncertainty, unwrap, branch and unresolved, delay, ready in “A phase-difference uncertainty is small, but the unwrap branch is unresolved. Is the delay result ready”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A phase-difference uncertainty is small, but the unwrap branch is unresolved; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frequency and Phase Calibration”. Separate branch ambiguity from local dispersion, establish the branch with suitable frequency/continuity evidence, and preserve the conditional result without claiming the uncertainty chooses… Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A phase-difference uncertainty is small, but the unwrap branch is unresolved; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frequency and Phase Calibration”. Separate branch ambiguity from local dispersion, establish the branch with suitable frequency/continuity evidence, and preserve the conditional result without claiming the uncertainty chooses… Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate branch ambiguity from local dispersion, establish the branch with suitable frequency/continuity evidence, and preserve the conditional result without claiming the uncertainty chooses… Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A phase-difference uncertainty is small, but the unwrap branch is unresolved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A phase-difference uncertainty is small, but the unwrap branch is unresolved; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A phase-difference uncertainty is small, but the unwrap branch is unresolved: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A phase-difference uncertainty is small, but the unwrap branch is unresolved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A phase-difference uncertainty is small, but the unwrap branch is unresolved: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A phase-difference uncertainty is small, but the unwrap branch is unresolved. Separate branch ambiguity from local dispersion, establish the branch with suitable frequency/continuity evidence, and preserve the conditional result without claiming the uncertainty chooses… Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A phase-difference uncertainty is small, but the unwrap branch is unresolved, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.5 Frequency and Phase Calibration (p. 8112)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A phase-difference uncertainty is small, but the unwrap branch is unresolved. Separate branch ambiguity from local dispersion, establish the branch with suitable frequency/continuity evidence, and preserve the conditional result without claiming the uncertainty chooses… Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A phase-difference uncertainty is small, but the unwrap branch is unresolved and Is the delay result ready; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A phase-difference uncertainty is small,

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but the unwrap branch is unresolved", addressing "Is the delay result ready"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A phase-difference uncertainty is small, but the unwrap branch is unresolved. Is the delay result ready", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A phase-difference uncertainty is small, but the unwrap branch is unresolved. Is the delay result ready". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

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V011-C14-DISCUSSION-014. The interpolation arithmetic is exact, so a team sets model residual to zero. What should a reviewer ask?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The interpolation arithmetic is exact, so a team sets model residual to zero. What should a reviewer ask?” Put this particular dispute to the panel: The interpolation arithmetic is exact, so a team sets model residual to zero. What should a reviewer ask. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 02. Student A, terminology and scope: Agree the operational meanings of interpolation, arithmetic, sets and residual, zero, reviewer in “The interpolation arithmetic is exact, so a team sets model residual to zero. What should a reviewer ask”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The interpolation arithmetic is exact, so a team sets model residual to zero; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “System-Level Vector Calibration and Uncertainty”. Distinguish endpoint calibration uncertainty from response-model inadequacy and consider uncertain frequency position or extrapolation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The interpolation arithmetic is exact, so a team sets model residual to zero; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “System-Level Vector Calibration and Uncertainty”. Distinguish endpoint calibration uncertainty from response-model inadequacy and consider uncertain frequency position or extrapolation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Request measured between-point response or a supported smoothness bound Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The interpolation arithmetic is exact, so a team sets model residual to zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The interpolation arithmetic is exact, so a team sets model residual to zero; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The interpolation arithmetic is exact, so a team sets model residual to zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The interpolation arithmetic is exact, so a team sets model residual to zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The interpolation arithmetic is exact, so a team sets model residual to zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The interpolation arithmetic is exact, so a team sets model residual to zero. Distinguish endpoint calibration uncertainty from response-model inadequacy and consider uncertain frequency position or extrapolation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The interpolation arithmetic is exact, so a team sets model residual to zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The interpolation arithmetic is exact, so a team

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sets model residual to zero. Distinguish endpoint calibration uncertainty from response-model inadequacy and consider uncertain frequency position or extrapolation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.5 Frequency and Phase Calibration (p. 8112)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The interpolation arithmetic is exact, so a team sets model residual to zero and What should a reviewer ask; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The interpolation arithmetic is exact, so a team sets model residual to zero”, addressing “What should a reviewer ask”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before

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voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The interpolation arithmetic is exact, so a team sets model residual to zero. What should a reviewer ask”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The interpolation arithmetic is exact, so a team sets model residual to zero. What should a reviewer ask”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.5 Application 14B.7: retain endpoint covariance in a correction interpolation (p. 8137)

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V011-C14-DISCUSSION-015. Increasing averages from 16 to 64 barely changes uncertainty. Is the measurement broken?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Increasing averages from 16 to 64 barely changes uncertainty. Is the measurement broken?” Put this particular dispute to the panel: Increasing averages from 16 to 64 barely changes uncertainty. Is the measurement broken. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 02. Student A, terminology and scope: Agree the operational meanings of Increasing, averages, barely and changes, uncertainty, broken in “Increasing averages from 16 to 64 barely changes uncertainty. Is the measurement broken”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Increasing averages from 16 to 64 barely changes uncertainty; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Use covariance and model sensitivity deliberately”. Determine whether a better reference or correction would address the dominant term rather than merely repeating readings Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Increasing averages from 16 to 64 barely changes uncertainty; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Use covariance and model sensitivity deliberately”. Determine whether a better reference or correction would address the dominant term rather than merely repeating readings Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the common-calibration model to explain 0.316228 to 0.304138 dB and the 0.30 dB floor Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Increasing averages from 16 to 64 barely

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changes uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Increasing averages from 16 to 64 barely changes uncertainty; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Increasing averages from 16 to 64 barely changes uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Increasing averages from 16 to 64 barely changes uncertainty, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Increasing averages from 16 to 64 barely changes uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Increasing averages from 16 to 64 barely changes uncertainty. Determine whether a better reference or correction would address the dominant term rather than merely repeating readings Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Increasing averages from 16 to 64 barely changes uncertainty, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Increasing averages from 16 to 64 barely changes uncertainty. Determine whether a better reference or correction would address the dominant term rather than merely repeating readings Respond point by point to Student J. Distinguish

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a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Increasing averages from 16 to 64 barely changes uncertainty and Is the measurement broken; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Increasing averages from 16 to 64 barely changes uncertainty”, addressing “Is the measurement broken”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Increasing averages from 16 to 64 barely changes uncertainty. Is the measurement broken”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Increasing averages from 16 to 64 barely changes uncertainty. Is the measurement broken”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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V011-C14-DISCUSSION-016. An on/off difference is positive, but its possible domain crosses zero. How should the logarithmic result be reported?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An on/off difference is positive, but its possible domain crosses zero. How should the logarithmic result be reported?” Put this particular dispute to the panel: An on/off difference is positive, but its possible domain crosses zero. How should the logarithmic result be reported. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 02. Student A, terminology and scope: Agree the operational meanings of difference, possible, domain and crosses, logarithmic, reported in “An on/off difference is positive, but its possible domain crosses zero. How should the logarithmic result be reported”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An on/off difference is positive, but its possible domain crosses zero; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 14B.9: subtract paired powers before propagating a logarithm”. Do not use an absolute-value transform or a central positive log to hide the boundary Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An on/off difference is positive,

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but its possible domain crosses zero; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 14B.9: subtract paired powers before propagating a logarithm”. Do not use an absolute-value transform or a central positive log to hide the boundary Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain the linear difference and investigate model and interpretation before assigning a log-domain uncertainty Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An on/off difference is positive, but its possible domain crosses zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An on/off difference is positive, but its possible domain crosses zero; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An on/off difference is positive,

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but its possible domain crosses zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An on/off difference is positive, but its possible domain crosses zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An on/off difference is positive, but its possible domain crosses zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what

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observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An on/off difference is positive, but its possible domain crosses zero. Do not use an absolute-value transform or a central positive log to hide the boundary Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An on/off difference is positive, but its possible domain crosses zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An on/off difference is positive, but its possible domain crosses zero. Do not use an absolute-value transform or a central positive log to hide the boundary Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An on/off difference is positive, but its possible domain crosses zero and How should the logarithmic result be reported; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An on/off difference is positive, but its possible domain crosses zero”, addressing “How should the logarithmic result be reported”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An on/off difference is positive, but its possible domain crosses zero. How should the logarithmic result be reported”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An on/off difference is positive, but its possible domain crosses zero. How should the logarithmic result be reported”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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V011-C14-DISCUSSION-017. A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. How do you challenge it?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. How do you challenge it?” Put this particular dispute to the panel: A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. How do you challenge it. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

- 02. Student A, terminology and scope: Agree the operational meanings of Gaussian, voltage, produces and calculated, propagation, challenge in “A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. How do you challenge it”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Nonlinear uncertainty propagation, model uncertainty and decision guard bands”. Identify the missing curvature term and require a suitable nonlinear treatment Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Nonlinear uncertainty propagation, model uncertainty and decision guard bands”. Identify the missing curvature term and require a suitable nonlinear treatment Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the exact squared-Gaussian moments to show 20 nW mean and 28.2843nWSD for 1 mV/50 ohms Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask

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which setting or observation would discriminate between them without changing the measurand. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. Identify the missing curvature term and require a suitable nonlinear treatment Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts.

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Request an explicit statement of what evidence would reverse the conclusion. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. Identify the missing curvature term and require a suitable nonlinear treatment Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation and How do you challenge it; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation”, addressing “How do you challenge it”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. How do you challenge it”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A zero-mean Gaussian voltage produces a calculated zero power uncertainty by first-order propagation. How do you challenge it”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

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V011-C14-DISCUSSION-018. A user wants to call every factor-two interval a 95 percent interval. What should the report state?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A user wants to call every factor-two interval a 95 percent interval. What should the report state?” Put this particular dispute to the panel: A user wants to call every factor-two interval a 95 percent interval. What should the report state. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 02. Student A, terminology and scope: Agree the operational meanings of user, wants, factor-two and interval, percent, report in “A user wants to call every factor-two interval a 95 percent interval. What should the report state”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A user wants to call every factor-two interval a 95 percent interval; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Uncertainty Budgets and Decision Rules”. State the factor and distribution/uncertainty justification explicitly, distinguish adequate normal approximations from other domains, and avoid assigning unsupported coverage Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A user wants to call every factor-two interval a 95 percent interval; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Uncertainty Budgets and Decision Rules”. State the factor and distribution/uncertainty justification explicitly, distinguish adequate normal approximations from other domains, and avoid assigning unsupported coverage Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the factor and distribution/uncertainty justification explicitly, distinguish adequate normal approximations from other domains, and avoid assigning unsupported coverage Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A user wants to call every factor-two interval a 95 percent interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A user wants to call every factor-two interval a 95 percent interval; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A user wants to call every factor-two interval a 95 percent interval: specify the altered receiver

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state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A user wants to call every factor-two interval a 95 percent interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A user wants to call every factor-two interval a 95 percent interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A user wants to call every factor-two interval a 95 percent interval. State the factor and distribution/uncertainty justification explicitly, distinguish adequate normal approximations from other domains, and avoid assigning unsupported coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A user wants to call every factor-two interval a 95 percent interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A user wants to call every factor-two interval a 95 percent interval. State the factor and distribution/uncertainty justification explicitly, distinguish adequate normal approximations from other domains, and avoid assigning unsupported coverage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A user wants to call every factor-two interval a 95 percent interval and What should the report state; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A user wants to call every factor-two interval a 95 percent interval”, addressing “What should the report

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state"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A user wants to call every factor-two interval a 95 percent interval. What should the report state", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A user wants to call every factor-two interval a 95 percent interval. What should the report state". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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V011-C14-DISCUSSION-019. An interval overlaps an upper limit but its center is below it. How should the declared three-outcome rule be applied?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An interval overlaps an upper limit but its center is below it. How should the declared three-outcome rule be applied?” Put this particular dispute to the panel: An interval overlaps an upper limit but its center is below it. How should the declared three-outcome rule be applied. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 02. Student A, terminology and scope: Agree the operational meanings of overlaps, upper, limit and center, rule, applied in “An interval overlaps an upper limit but its center is below it. How should the declared three-outcome rule be applied”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An interval overlaps an upper limit but its center is below it; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Nonlinear measurement models and defensible uncertainty intervals in RF metrology”. Do not equate overlap with proof of exceedance or silently switch to a central-value rule Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An interval overlaps an upper limit but its center is below it; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Nonlinear measurement models and defensible uncertainty intervals in RF metrology”. Do not equate overlap with proof of exceedance or silently switch to a central-value rule Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Calculate both endpoints, report indeterminate, preserve the result and explain follow-up targeting dominant uncertainty Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An interval overlaps an upper limit but its center is below it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An interval overlaps an upper limit but its center is below it; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An interval overlaps an upper limit but its center is below it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An interval overlaps an upper limit but its center is below it, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An interval overlaps an upper limit but its center is below it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An interval overlaps an upper limit but its center is below it. Do not equate overlap with proof of exceedance or silently switch to a central-value rule Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An interval overlaps an upper limit but its center is below it, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An interval overlaps an upper limit but its center is below it. Do not equate overlap with proof of exceedance or silently switch to a central-value rule Respond point by point to Student J. Distinguish a verified observation from a conditional

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inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An interval overlaps an upper limit but its center is below it and How should the declared three-outcome rule be applied; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An interval overlaps an upper limit but its center is below it”, addressing “How should the declared three-outcome rule be applied”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An interval overlaps an upper limit but its center is below it. How should the declared three-outcome rule be applied”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An interval overlaps an upper limit but its center is below it. How should the declared three-outcome rule be applied”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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V011-C14-DISCUSSION-020. After seeing an indeterminate result, a team proposes moving the limit. How should the decision history be preserved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “After seeing an indeterminate result, a team proposes moving the limit. How should the decision history be preserved?” Put this particular dispute to the panel: After seeing an indeterminate result, a team proposes moving the limit. How should the decision history be preserved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 02. Student A, terminology and scope: Agree the operational meanings of seeing, indeterminate, moving and limit, history, preserved in “After seeing an indeterminate result, a team proposes moving the limit. How should the decision history be preserved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of After seeing an indeterminate result, a team proposes moving the limit; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Uncertainty Budgets and Decision Rules”. Additional measurements should address the measurement purpose rather than rewrite the original decision Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of After seeing an indeterminate result, a team proposes moving the limit; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Uncertainty Budgets and Decision Rules”. Additional measurements should address the measurement purpose rather than rewrite the original decision Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Keep the original rule and outcome; any later rule must be explicitly new with its rationale Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving After seeing an indeterminate result, a team proposes moving the limit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of After seeing an indeterminate result, a team proposes moving the limit; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving After seeing an indeterminate result, a team proposes moving the limit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving After seeing an indeterminate result, a team proposes moving the limit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving After seeing an indeterminate result, a team proposes moving the limit: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for After seeing an indeterminate result, a team proposes moving the limit. Additional measurements should address the measurement purpose rather than rewrite the original decision Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving After seeing an indeterminate result, a team proposes moving the limit, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for After seeing an indeterminate result, a team proposes moving the limit. Additional measurements should address the measurement purpose rather than rewrite the original

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decision Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about After seeing an indeterminate result, a team proposes moving the limit and How should the decision history be preserved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “After seeing an indeterminate result, a team proposes moving the limit”, addressing “How should the decision history be preserved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “After seeing an indeterminate result, a team proposes moving the limit. How should the decision history be preserved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “After seeing an indeterminate result, a team proposes moving the limit. How should the decision history be preserved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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V011-C14-DISCUSSION-021. A firmware change passes self-test. Can all external correction files be reused automatically?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A firmware change passes self-test. Can all external correction files be reused automatically?” Put this particular dispute to the panel: A firmware change passes self-test. Can all external correction files be reused automatically. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 02. Student A, terminology and scope: Agree the operational meanings of firmware, passes, external and correction, files, automatically in “A firmware change passes self-test. Can all external correction files be reused automatically”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A firmware change passes self-test; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Close the calibration record across the working interval”. Self-test has a narrower scope Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A firmware change passes self-test; explain what each record can establish State what the existing record establishes, what it does not establish, and which further

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measurement would change your opinion. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Close the calibration record across the working interval”. Self-test has a narrower scope Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Review affected processing and state scope, check representative raw and independently recomputed results, and retain or update files only with applicability evidence Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A firmware change passes self-test: specify the

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altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A firmware change passes self-test; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A firmware change passes self-test: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A firmware change passes self-test, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A firmware change passes self-test: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A firmware change passes self-test. Self-test has a narrower scope Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question

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cannot be settled by visual appearance or a single unqualified reading. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A firmware change passes self-test, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A firmware change passes self-test. Self-test has a narrower scope Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A firmware change passes self-test and Can

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all external correction files be reused automatically; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A firmware change passes self-test”, addressing “Can all external correction files be reused automatically”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A firmware change passes self-test. Can all external correction files be reused automatically”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A firmware change passes self-test. Can all external correction files be reused automatically”. Allocate the next

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measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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V011-C14-DISCUSSION-022. A closing reference fails after a known accessory replacement. How can the affected interval be bounded?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A closing reference fails after a known accessory replacement. How can the affected interval be bounded?” Put this particular dispute to the panel: A closing reference fails after a known accessory replacement. How can the affected interval be bounded. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 02. Student A, terminology and scope: Agree the operational meanings of closing, fails, accessory and replacement, affected, bounded in “A closing reference fails after a known accessory replacement. How can the affected interval be bounded”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A closing reference fails after a known accessory replacement; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “14. Decision rules, calibration applicability and publication evidence”. Avoid uniform retrospective reassignment Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A closing reference fails after a known accessory replacement; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “14. Decision rules, calibration applicability and publication evidence”. Avoid uniform retrospective reassignment Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the last valid check and documented change time, retain all data, and investigate whether evidence supports a narrower interval or bounded correction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A closing reference fails after a known accessory replacement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A closing reference fails after a known accessory replacement; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A closing reference fails after a known accessory replacement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A closing reference fails after a known accessory replacement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A closing reference fails after a known accessory replacement: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A closing reference fails after a known accessory replacement. Avoid uniform retrospective reassignment Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A closing reference fails after a known accessory replacement, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A closing reference fails after a known accessory replacement. Avoid uniform retrospective reassignment Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test

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or uncertainty term that limits confidence. Source: §14.1 Calibration Model and Traceability (p. 8104)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A closing reference fails after a known accessory replacement and How can the affected interval be bounded; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A closing reference fails after a known accessory replacement”, addressing “How can the affected interval be bounded”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A closing reference fails after a known accessory replacement. How can the affected interval be bounded”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A closing reference fails after a known accessory replacement. How can the affected interval be bounded”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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V011-C14-DISCUSSION-023. A calibration and comparison both use the same reference oscilloscope. How should agreement be interpreted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A calibration and comparison both use the same reference oscilloscope. How should agreement be interpreted?” Put this particular dispute to the panel: A calibration and comparison both use the same reference oscilloscope. How should agreement be interpreted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 02. Student A, terminology and scope: Agree the operational meanings of calibration, same, reference and oscilloscope, agreement, interpreted in “A calibration and comparison both use the same reference oscilloscope. How should agreement be interpreted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A calibration and comparison both use the same reference oscilloscope; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 14B.8: identify the uncertainty that averaging cannot remove”. Agreement is useful within its dependencies Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A calibration and comparison

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both use the same reference oscilloscope; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 14B.8: identify the uncertainty that averaging cannot remove”. Agreement is useful within its dependencies Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify shared errors and retained covariance, distinguish repeatability from full uncertainty, and seek independent evidence for claims requiring absolute validation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A calibration and comparison both use the same reference oscilloscope: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A calibration and comparison both use the same reference oscilloscope; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A calibration and comparison both use the same reference oscilloscope: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A calibration and comparison both use the same reference oscilloscope, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A calibration and comparison both use the same reference oscilloscope: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A calibration and comparison both use the same reference oscilloscope. Agreement is useful within its dependencies Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A calibration and comparison both use the same reference oscilloscope, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A calibration and comparison both use the same reference oscilloscope. Agreement is useful within its dependencies Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A calibration and comparison both use the same reference oscilloscope and How should agreement be interpreted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A calibration and comparison both use the same reference oscilloscope”, addressing “How should agreement be interpreted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before

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voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A calibration and comparison both use the same reference oscilloscope. How should agreement be interpreted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A calibration and comparison both use the same reference oscilloscope. How should agreement be interpreted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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V011-C14-DISCUSSION-024. A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. What remains unresolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. What remains unresolved?” Put this particular dispute to the panel: A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. What remains unresolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 02. Student A, terminology and scope: Agree the operational meanings of Monte, Carlo, smooth and precise, assumed, sharing in “A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. What remains unresolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Use covariance and model sensitivity deliberately”. More trials improve numerical propagation but do not cure incorrect assumptions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Use covariance and model sensitivity deliberately”. More trials improve numerical propagation but do not cure incorrect assumptions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The input dependence model is unsupported; reconstruct the common contribution and rerun if necessary Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A Monte Carlo calculation looks smooth and precise but uses

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assumed independent inputs sharing a standard: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. More trials improve numerical propagation but do not cure incorrect assumptions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §14.10 Use covariance and model sensitivity deliberately (p. 8119)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. More trials improve numerical propagation but do not cure incorrect assumptions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard and What remains unresolved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard”, addressing “What remains unresolved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. What remains unresolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A Monte Carlo calculation looks smooth and precise but uses assumed independent inputs sharing a standard. What remains unresolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.17 System-Level Vector Calibration and Uncertainty (p. 8145)

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V011-C14-DISCUSSION-025. What would make the chapter's calibration record independently reproducible by another analyst?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What would make the chapter's calibration record independently reproducible by another analyst?” Put this particular dispute to the panel: What would make the chapter's calibration record independently reproducible by another analyst. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 02. Student A, terminology and scope: Agree the operational meanings of make, calibration, record and independently, reproducible, analyst in “What would make the chapter's calibration record independently reproducible by another analyst”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What would make the chapter's calibration record independently reproducible by another analyst; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Declare the decision rule before seeing the result”. Require reconstruction of both arithmetic and validity rather than only matching the final number Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What would make the chapter's calibration record independently reproducible by another

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analyst; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Declare the decision rule before seeing the result”. Require reconstruction of both arithmetic and validity rather than only matching the final number Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Provide raw observations, actual state and planes, correction values and versions, source certificates, covariance and domains, coverage convention, rule and result Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What would make the chapter's calibration record independently reproducible by another analyst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What would make the chapter's calibration record independently reproducible by another analyst; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What would make the chapter's calibration record independently reproducible by another analyst:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What would make the chapter's calibration record independently reproducible by another analyst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What would make the chapter's calibration record independently reproducible by another analyst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What would make the chapter's calibration record independently reproducible by another analyst. Require reconstruction of both arithmetic and validity rather than only matching the final number Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What would make the chapter's calibration record independently reproducible by another analyst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What would make the chapter's calibration record independently reproducible by another analyst. Require reconstruction of both arithmetic and validity rather than only matching the final number Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What would make the chapter's calibration record independently reproducible by another analyst and Provide raw observations, actual state and planes, correction values and versions, source certificates,...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.4 Build a correction chain with signs that can be checked (p. 8110)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What would make the chapter's calibration record independently reproducible by another analyst”, addressing “Provide raw observations, actual state and planes, correction values and versions, source certificates,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.18 Close the calibration record across the working interval (p. 8147)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What would make the chapter's calibration record independently reproducible by another analyst”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What would make the chapter's calibration record independently reproducible by another analyst”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.18 Close the calibration record across the working interval (p. 8147)

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Chapter 14 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C14-ESSAY-001 — Define the measurement equation and required inputs for two distinct results, such as terminal power and relative phase. Distinguish calibration, adjustment and verification, and explain traceability scope, configuration applicability and uncertainty without claiming traceability guarantees correctness.

Review: Chapter 14 — Attach calibration to a stated measurement result.

V011-C14-ESSAY-002 — Reproduce −86.70 dBm, identify the +0.20 residual and each loss/gain sign, predict the −72.40 dBm corrected receiver plane, and state linearity, mismatch and state assumptions. Explain how wrong-plane or duplicate corrections can survive valid component certificates.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

V011-C14-ESSAY-003 — Specify levels, frequencies, band and gain-state boundaries, independently characterized source path, detector and bandwidth. Distinguish low-level statistical effects from compression/intermodulation and explain why fitting a single line does not validate every endpoint.

Review: Chapter 14 — Amplitude Response and Linearity.

V011-C14-ESSAY-004 — Define simultaneous input relationship, reference planes, phase branch, frequency sweep and delay model. Test actual reset/retune/sample-rate operations and distinguish within-record from inter-record repeatability. Include cable and reference-path uncertainty.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-C14-ESSAY-005 — Describe hot/cold inputs, raw powers, equal gain, settling, compression and mismatch requirements. Contrast with waveform-specific detection/miss trials and acquisition schedules, explaining why neither result uniquely substitutes for the other.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

V011-C14-ESSAY-006 — Start from centered inputs and expand the squared linear combination. Retain signed cross terms, units and covariance admissibility. Explain why Gaussian assumptions and independence are unnecessary for the identity but may matter to separate coverage claims.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

V011-C14-ESSAY-007 — Define the gradient at the input estimate and the linearized output, propagate covariance, and identify the neglected remainder. Discuss curvature, singularities and domain boundaries; distinguish an exact affine identity from an approximate nonlinear uncertainty.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

V011-C14-ESSAY-008 — Compute 0.1032 dB^2 and 0.321248 dB under zero covariances, then the -0.0432 covariance term and 0.244949 dB result. Explain the amplifier coefficient sign, evidence needed for correlation, and prevention of shared-reference double counting.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-ESSAY-009 — Use 34°−11°, independent 0.30°/0.40° residuals and common 0.80° contribution. Show 0.50° uncertainty by cancellation and by 0.73+0.80−2×0.64. State equal-coupling, common-state and unwrapped-branch conditions.

Review: Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

V011-C14-ESSAY-010 — Use 36°,100 MHz,0.20° and 10 kHz; derive signed sensitivities and 5.55646 ps. Explain the small denominator uncertainty, branch assumption, constant-delay scope and need for independent phase-repeatability evidence.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

V011-C14-ESSAY-011 — Calculate the +0.70 dB correction and weighted endpoint variances, covariance and residual. Explain the 0.161419 dB uncertainty, evidence for the residual, and changes needed for uncertain fraction or extrapolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

V011-C14-ESSAY-012 — Represent independent reading errors and one shared correction input, derive $0.30^2+\frac{0.40^2}{n}$, compute n = 16 and 64, and show the 0.30 dB limit. Explain why correlated readings, drift or averaging powers require a different model.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-C14-ESSAY-013 — Derive covariance and 0.00058 nW^2 difference variance; use bounded uniforms to establish positive support. Calculate −65.228787 dBm and 0.348640 dB local uncertainty. Distinguish exact affine difference, exact transformed support and approximate log dispersion.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

V011-C14-ESSAY-014 — Derive E[P] and Var(P) from Gaussian moments, compare μ10 mV and μ0 with σ1 mV,R50 ohms, and identify the omitted curvature term. Explain why multiplying a zero local uncertainty by a coverage factor cannot restore information.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

V011-C14-ESSAY-015 — Use −86.70±0.49 dBm and −86.50 dBm to establish overlap and indeterminacy. Distinguish central estimate, uncertainty, coverage and decision, and describe legitimate follow-up without shifting the limit retrospectively.

Review: Chapter 14 — Declare the decision rule before seeing the result.

V011-C14-ESSAY-016 — Discuss explicit shared inputs versus derived covariance, signed coefficients, unit consistency, symmetry and positive semidefiniteness. Explain why individually plausible pairwise correlations and a favorable final total are insufficient evidence.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-C14-ESSAY-017 — Use the power-difference or Gaussian-square examples to distinguish dispersion, coverage convention and possible-domain statements. Explain why factor two and positive central estimates do not establish universal coverage or positivity.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

V011-C14-ESSAY-018 — Record correction versions, serial applicability, units, interpolation and uncertainty. Tie checks to likely failures and consequential changes, distinguish targeted recharacterization from full recalibration, and define treatment of a failed closing reference.

Review: Chapter 14 — Calibration Lifecycle and Change Control.

V011-C14-ESSAY-019 — Explain how a shared faulty correction can reproduce its own error, retain raw comparisons and independent recomputation, and use opening, closing and change-point checks. Preserve affected data and justify any retrospective correction by evidence.

Review: Chapter 14 — Close the calibration record across the working interval.

V011-C14-ESSAY-020 — Explain why a room-temperature correction may not apply after 35°C warming, how a characterized correction can reduce 2.8 dB discrepancy to 0.6 dB, and why agreement within combined uncertainty is a bounded consistency result rather than proof of exact identity.

Review: Chapter 14 — Hypothetical Case Adjudication: Calibration, Gain, Amplitude and Phase Accuracy, Noise Figure, and Uncertainty.

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V011-C14-ESSAY-021 — Distinguish complex linear correction, repeatability and calibration uncertainty, shared calibration/comparison reference, and remaining nonlinear scope. Do not claim the study validates hypothetical configurations elsewhere in the book.

Review: Chapter 14 — System-Level Vector Calibration and Uncertainty.

V011-C14-ESSAY-022 — Require the measurement function, input domains, distributions, dependence and admissible covariance. Examine boundaries and curvature, compare simple analytic checks where available, and explain that numerical precision does not establish the assumptions.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

V011-C14-ESSAY-023 — Distinguish an applied correction's residual uncertainty from a wrong cable, wrong sign or unapplied offset. Use a decision-near-limit case to show the effect on central value and identify independent reconstruction checks.

Review: Chapter 14 — Attach calibration to a stated measurement result.

V011-C14-ESSAY-024 — For level, link raw indication, planes, state, correction terms, certificates, covariance, coverage and rule. For noise, retain linear hot/cold powers and temperatures, ratio/domain and gain checks. Make another analyst able to reproduce the arithmetic and its validity conditions.

Review: Chapter 14 — Close the calibration record across the working interval.

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V011-C14-ESSAY-025 — Explain equal-coupling cancellation in the difference, persistence in an average, and hidden common error in apparent agreement. Use signed measurement equations and stated dependencies rather than treating every shared reference as either always helpful or always harmful.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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Discussion Guidance

V011-C14-DISCUSSION-001 — Identify the omitted scope, request targeted characterization or narrow the claim, and retain the valid covered calibration. Do not hide the gap under an arbitrary uncertainty allowance or infer coverage from serial identity.

Review: Chapter 14 — Attach calibration to a stated measurement result.

V011-C14-DISCUSSION-002 — Resolve the configuration mismatch and recompute with applicable data. Explain why a precise uncertainty propagation cannot repair the wrong measurement equation or input identity.

Review: Chapter 14 — Attach calibration to a stated measurement result.

V011-C14-DISCUSSION-003 — Check correction signs, planes, instrument-applied terms, units and duplicate ownership against raw data. Keep physical linearity and mismatch checks separate from arithmetic closure.

Review: Chapter 14 — Build a correction chain with signs that can be checked.

V011-C14-DISCUSSION-004 — Inspect individual data and define a supported range; test boundaries and state transitions. Explain that an average fit statistic can conceal systematic endpoint behavior relevant to the intended measurement.

Review: Chapter 14 — Amplitude Response and Linearity.

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V011-C14-DISCUSSION-005 — Frequency-dependent phase/amplitude response, branch and interpolation, delay model and state repeatability. Acknowledge the valid single-frequency result while limiting its broader implication.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

V011-C14-DISCUSSION-006 — Identify common and canceling reference errors and compare against an independent suitable standard where needed. Agreement constrains relative behavior but can retain common absolute error.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

V011-C14-DISCUSSION-007 — State demonstrated frequency lock and within-record behavior separately from absent inter-record coherence. Require actual reset-state phase tests before combining acquisitions coherently.

Review: Chapter 14 — Frequency, phase, and delay require their own observables.

V011-C14-DISCUSSION-008 — No; repeatability does not supply equal gain. Preserve raw states, characterize the transfer or use a supported expanded model, and check hot-state compression and mismatch.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

V011-C14-DISCUSSION-009 — Test the actual waveform, duration, threshold and observation schedule, retaining misses and detections. Distinguish acquisition opportunity and decision behavior from the noise budget.

Review: Chapter 14 — Calibrate noise without confusing it with detection.

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V011-C14-DISCUSSION-010 — Request the actual shared calibration model or measured dependency and check matrix admissibility. Recompute with supported assumptions; uncertainty is not optimized to obtain a preferred decision.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

V011-C14-DISCUSSION-011 — Reject the inconsistent joint covariance description, identify conflicting dependencies and reconstruct a physical model. Pairwise bounds are necessary but not sufficient.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

V011-C14-DISCUSSION-012 — Show the double counting and rebuild either explicit common-input or consistent derived-covariance representation. Check signed coefficients and compare both formulations as an audit.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

V011-C14-DISCUSSION-013 — Separate branch ambiguity from local dispersion, establish the branch with suitable frequency/continuity evidence, and preserve the conditional result without claiming the uncertainty chooses the branch.

Review: Chapter 14 — Application 14B.6: propagate phase-slope delay uncertainty.

V011-C14-DISCUSSION-014 — Request measured between-point response or a supported smoothness bound. Distinguish endpoint calibration uncertainty from response-model inadequacy and consider uncertain frequency position or extrapolation.

Review: Chapter 14 — Application 14B.7: retain endpoint covariance in a correction interpolation.

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V011-C14-DISCUSSION-015 — Use the common-calibration model to explain 0.316228 to 0.304138 dB and the 0.30 dB floor. Determine whether a better reference or correction would address the dominant term rather than merely repeating readings.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

V011-C14-DISCUSSION-016 — Retain the linear difference and investigate model and interpretation before assigning a log-domain uncertainty. Do not use an absolute-value transform or a central positive log to hide the boundary.

Review: Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

V011-C14-DISCUSSION-017 — Use the exact squared-Gaussian moments to show 20 nW mean and 28.2843nWSD for 1 mV/50 ohms. Identify the missing curvature term and require a suitable nonlinear treatment.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

V011-C14-DISCUSSION-018 — State the factor and distribution/uncertainty justification explicitly, distinguish adequate normal approximations from other domains, and avoid assigning unsupported coverage.

Review: Chapter 14 — Declare the decision rule before seeing the result.

V011-C14-DISCUSSION-019 — Calculate both endpoints, report indeterminate, preserve the result and explain follow-up targeting dominant uncertainty. Do not equate overlap with proof of exceedance or silently switch to a central-value rule.

Review: Chapter 14 — Declare the decision rule before seeing the result.

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V011-C14-DISCUSSION-020 — Keep the original rule and outcome; any later rule must be explicitly new with its rationale. Additional measurements should address the measurement purpose rather than rewrite the original decision.

Review: Chapter 14 — Declare the decision rule before seeing the result.

V011-C14-DISCUSSION-021 — Review affected processing and state scope, check representative raw and independently recomputed results, and retain or update files only with applicability evidence. Self-test has a narrower scope.

Review: Chapter 14 — Calibration Lifecycle and Change Control.

V011-C14-DISCUSSION-022 — Use the last valid check and documented change time, retain all data, and investigate whether evidence supports a narrower interval or bounded correction. Avoid uniform retrospective reassignment.

Review: Chapter 14 — Close the calibration record across the working interval.

V011-C14-DISCUSSION-023 — Identify shared errors and retained covariance, distinguish repeatability from full uncertainty, and seek independent evidence for claims requiring absolute validation. Agreement is useful within its dependencies.

Review: Chapter 14 — System-Level Vector Calibration and Uncertainty.

V011-C14-DISCUSSION-024 — The input dependence model is unsupported; reconstruct the common contribution and rerun if necessary. More trials improve numerical propagation but do not cure incorrect assumptions.

Review: Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-C14-DISCUSSION-025 — Provide raw observations, actual state and planes, correction values and versions, source certificates, covariance and domains, coverage convention, rule and result. Require reconstruction of both arithmetic and validity rather than only matching the final number.

Review: Chapter 14 — Close the calibration record across the working interval.

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Chapter Glossary

ADJUSTMENT: An intervention intended to change a measuring system's response to the required relation. It is distinct from calibration, which establishes a relationship and its uncertainty, and verification, which checks a stated requirement. A changed response can require new characterization before previous corrections or uncertainty statements are used.

AFFINE MEASUREMENT FUNCTION: A measurement relation consisting of a constant plus a fixed linear combination of the input quantities. Its output mean and variance follow exactly from the input mean and covariance when the required second moments exist. Neither independence nor normality is required for that identity; the coefficients retain their signs and units.

AFFINE UNCERTAINTY PROPAGATION: Exact evaluation of output variance for a fixed affine measurement function from finite input second moments and their covariance.

CALIBRATION: An operation establishing, under specified conditions, the relationship between reference values and indications with their associated uncertainties, enabling a measurement result to be obtained from an indication. It is distinct from changing instrument settings or checking a requirement. Its relevance depends on the particular quantity, state, range and reference plane being reported.

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CALIBRATION CHANGE CONTROL: The identification and evaluation of changes that may invalidate a correction or its uncertainty statement. Firmware, processing, accessories, reference planes, gain states and remote power arrangements can alter applicability. Evidence about the affected quantities determines whether targeted recharacterization suffices; an unchanged certificate or successful self-test is not enough by itself.

CALIBRATION SCOPE: Quantities, ranges, states, reference planes, and conditions for which calibration results and uncertainties apply.

COMBINED STANDARD UNCERTAINTY: The standard uncertainty assigned to the measurement result after the relevant input contributions and dependencies have been propagated through the measurement model. The chapter's affine variance relation is exact under its finite-moment premises; using the same form for a nonlinear function additionally requires a justified local approximation.

COMMON CALIBRATION CONTRIBUTION: An input uncertainty shared across several observations, whose effect depends on its coupling and the signed coefficients of the reported quantity.

CORRECTION COVARIANCE: Joint uncertainty between correction inputs, retained with the signs of their measurement sensitivity coefficients.

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CORRECTION INTERPOLATION: Estimation of a correction between characterized points using a stated model and position. Endpoint uncertainty and covariance are distinct from the residual between the physical response and that interpolation model. An uncertain position, extrapolation or unresolved response structure changes the measurement equation and cannot be omitted merely because the file provides a smooth curve.

CORRELATION COEFFICIENT: A dimensionless normalized measure of covariance between quantities with nonzero standard deviations. Its contribution to output variance also depends on the signs of the measurement sensitivities. A favorable coefficient must be supported by the joint calibration model or evidence; it cannot be chosen to obtain a desired uncertainty or decision.

COVARIANCE MATRIX: The matrix of pairwise covariances of a specified input vector, with each entry carrying the product of the corresponding input units. A physically admissible matrix is symmetric and positive semidefinite. Separate plausible pairwise correlations need not form a valid complete matrix, so the joint model must be checked.

COVERAGE FACTOR: Multiplier applied to combined standard uncertainty to obtain an expanded uncertainty under a stated convention.

COVERAGE PROBABILITY: The probability assigned to an interval under a justified output-distribution and uncertainty interpretation. Multiplying standard uncertainty by two does not independently establish a universal probability. Such interval coverage is also distinct from the false-alarm or detection probabilities of a receiver search procedure.

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CURVATURE BIAS: The difference arising when the expected output of a nonlinear transformation differs from the transformation evaluated at the expected input. The squared-voltage example exhibits this mean shift explicitly. It is a model consequence, not evidence of an instrument fault, and its significance depends on the intended accuracy of the reported result.

DECISION RULE: The declared procedure translating a measurement result and its uncertainty into an outcome relative to a requirement. It can specify acceptance, rejection and an indeterminate region. The rule should be selected before observing the result and retained with it; changing the rule later creates a different decision rather than revising the earlier evidence.

DETERMINISTIC ERROR BOUND: A justified limit on the magnitude or allowed set of an error under specified conditions. It differs from a standard deviation, which describes dispersion under an uncertainty model. Converting one into the other requires additional information; a multiple of standard uncertainty is not automatically a worst-case enclosure.

EXPANDED UNCERTAINTY: Combined standard uncertainty multiplied by a stated coverage factor, with the basis of the associated coverage interpretation identified.

GRADIENT: The set of first partial derivatives of a scalar measurement function at a declared input point. These signed, dimensioned sensitivities define its local linear approximation. They can propagate input covariance locally, but a small or zero derivative does not show that curvature or a nearby domain boundary is negligible.

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GUARD BAND: Decision margin used to account for uncertainty near an acceptance or compliance limit.

INDETERMINATE RESULT: An outcome in which the supplied evidence does not meet the stated conditions for either acceptance or rejection. In the chapter's constructed rule, an uncertainty interval overlapping the upper limit has this status. It neither proves compliance nor proves that the actual quantity exceeds the limit.

INDICATION: The value supplied by the measuring system before any additional external corrections needed for the stated result. Its quantity, units, detector and processing state must be identified. A numerically plausible indication can still be inconsistent with the intended reference plane or already contain a correction that should not be applied again.

INPUT SUPPORT: The complete set of values permitted by the stipulated joint input model. It can determine whether a nonlinear operation is defined throughout the problem. The paired-power example proves a positive difference over its full support before applying a logarithm; a positive central estimate alone would not establish that property.

INTERMEDIATE CHECK: Reference observation between calibrations used to test continued validity for a stated quantity and configuration.

INTERPOLATION RESIDUAL: Difference between a physical response and the adopted interpolation model, characterized separately from uncertainty in the endpoint values.

LOCAL PROPAGATION ADEQUACY: Suitability of a first-order uncertainty approximation for the stated input domain and intended output, including the effect of neglected curvature and boundaries.

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LOGARITHMIC UNCERTAINTY PROPAGATION: Propagation through a logarithmic transformation of a strictly positive quantity using the appropriate model and sensitivity. The chapter separates exact variance of a linear power difference from the local variance of its logarithm. Exact transformed limits can be asymmetric, and a domain admitting zero or negative power differences requires a different treatment.

MEASURAND: The quantity selected for measurement and reporting, with the conditions needed to distinguish it from related quantities. Receiver-terminal power, field strength, relative phase and detection probability require different models. Defining that intended result before selecting corrections and calibrations prevents the available instrument display from silently determining the measurement question.

MEASUREMENT CORRECTION: A compensation applied for an identified effect in the measurement model. Its sign follows the physical relationship and its uncertainty remains in the result. A known significant offset should not be concealed merely by widening an uncertainty interval, and a correction already applied by the instrument must not be counted twice.

MEASUREMENT MODEL: Equation or functional relationship connecting the measurand to input quantities.

MISMATCH UNCERTAINTY: Uncertainty caused by unknown or varying phase relationships among reflected waves at imperfectly matched interfaces.

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NONLINEAR REMAINDER: The part of a nonlinear measurement response omitted by its local linear approximation. The suitability of first-order propagation depends on whether that omitted behavior matters over the actual input domain. Near a singularity, boundary or zero derivative, it can change the output dispersion or shape even when the central calculation is finite.

REFERENCE CANCELLATION: Removal of a shared contribution by the signed structure of a reported difference when its coupling is genuinely identical in both observations. The phase example obtains the same result by an explicit common input or a consistent covariance matrix. Unequal paths, changed states or unresolved phase branches invalidate automatic cancellation.

REPEATABILITY CONTRIBUTION: The uncertainty contribution associated with variation among observations made under the declared repeated conditions. Averaging can reduce a suitable independent reading-error contribution, but not an unchanged shared calibration input. A repeatability-only estimate can therefore understate the uncertainty of a corrected system-level result.

SENSITIVITY COEFFICIENT: Local derivative of the measurement function with respect to an input quantity, carrying the units and sign needed for uncertainty propagation.

STANDARD UNCERTAINTY: An uncertainty expressed in the form of a standard deviation under the stated input information and model. It describes dispersion rather than a guaranteed maximum error. Its numerical value alone does not define a coverage probability, a detection probability or an acceptance decision.

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SYSTEM-LEVEL VECTOR CALIBRATION: Calibration of the relevant complex response of an assembled measurement system, retaining amplitude, phase and their uncertainty relationships. The cited experiment combines multiple correction contributions and correlations. Its success illustrates a method under the published conditions, without certifying another receiver configuration or bounding that configuration's remaining nonlinear behavior.

TRACEABILITY: Property of a measurement result relating it to references through a documented, unbroken chain of calibrations with stated uncertainties.

UNCERTAINTY BUDGET: An organized account of the input quantities, uncertainty information, sensitivities and dependencies relevant to a specified result. The table follows the measurement model rather than replacing it. Shared references, unapplied corrections, interpolation residuals and configuration mistakes must be treated according to their actual roles instead of being assigned arbitrary independent rows.

VERIFICATION: A check that specified requirements are met using appropriate evidence for the quantity, configuration and time concerned. A field reference can verify present function within its traversed scope without replacing a full calibration. Successful internal checks do not automatically establish external-path transfer, file correctness or uninterrupted validity over an earlier interval.

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References and Works Cited

Joint Committee for Guides in Metrology. International Vocabulary of Metrology: Basic and General Concepts and Associated Terms (VIM). JCGM 200:2012. 3rd ed., 2008 version with minor corrections, 2012. https://www.bipm.org/documents/20126/2071204/JCGM_200_2012.pdf.

Annotation. Sections 2.39–2.44, especially section 2.41 notes 4–5, printed pages 28–30. Supports the distinction among calibration, adjustment and verification and the result-based meaning and limits of metrological traceability. The chapter's specific receiver configuration and release records are application requirements. This institutional vocabulary establishes conventional relationships among measurands, measurement results, calibration, uncertainty and traceability. Its role is terminological rather than an instrument-specific proof: the survey must still state the actual measurement model, reference plane and uncertainty evidence. A correct definition cannot compensate for an uncalibrated observation or justify conflating detection, classification and transmitter attribution. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

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Joint Committee for Guides in Metrology. Evaluation of Measurement Data: Guide to the Expression of Uncertainty in Measurement. JCGM 100:2008. Corrected version 2010. https://www.bipm.org/en/doi/10.59161/jcgm100-2008e.

Annotation. Sections 4.1, 5.1–5.2 and 6.2–6.3, especially equations (13)–(16), sections 5.2.4–5.2.5, and the note to section 5.1.2. Supports covariance propagation and the distinction between first-order approximation and consequential nonlinear terms. The receiver examples and squared-Gaussian counterexample are independently derived. This metrological guidance concerns the evaluation and reporting of measurement uncertainty, including propagation through a measurement model. Covariance, shared calibration terms, nonlinear transformations and declared coverage factors require attention when evidence from multiple receiver channels is combined. An uncertainty budget is meaningful only for a specified measurand and operating condition; it does not itself certify the authenticity of the underlying acquisition. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions.

Taylor, Barry N., and Chris E. Kuyatt. Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results. NIST Technical Note 1297. 1994 ed. https://www.nist.gov/pml/nist-technical-note-1297.

Annotation. Section 5 and appendix A, A.1–A.5, address the measurement function and propagation of uncertainty; section 6.1–6.5

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addresses expanded uncertainty. Model 14B derives its exact affine identity from covariance. The illustrative factor of two and constructed decision rule do not independently establish a universal coverage probability. This metrological guidance concerns the evaluation and reporting of measurement uncertainty, including propagation through a measurement model. Covariance, shared calibration terms, nonlinear transformations and declared coverage factors require attention when evidence from multiple receiver channels is combined. An uncertainty budget is meaningful only for a specified measurand and operating condition; it does not itself certify the authenticity of the underlying acquisition. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

Kast, Joshua M., Paritosh Manurkar, Kate A. Remley, Dylan F. Williams, and Robert D. Horansky. “System-Level Calibration of a Millimeter-Wave Vector Signal Analyzer with Uncertainties.” IEEE Transactions on Microwave Theory and Techniques 73, no. 11 (November 2025): 9085–95. https://doi.org/10.1109/TMTT.2025.3597240. NIST-hosted manuscript, pages 1–9, especially sections II–III: https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=959731.

Annotation.NIST-hosted manuscript pages 1–9, especially sections II–III; method and results text were read. The slightly different means in the introduction and section III.B are retained only at their common coarse precision. No figure was independently digitized, and the published experiment does not certify this volume’s constructed configurations.

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The research concerns complex-vector calibration or noise-temperature measurement where amplitude, phase and uncertainty propagate through the measurement chain. Reference-plane consistency, added cable paths and calibration-state changes are material to a repeatable comparison. Published experimental results cannot automatically be transferred to a different apparatus or treated as certification of the book’s constructed numerical examples. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

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Chapter 15. Triggering, Burst Capture, Recording, Metadata, and Reproducibility

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15.1 Probability of Intercept and Observation Strategy

An intermittent signal can be missed by a receiver that is sufficiently sensitive but observes the wrong time, frequency, antenna, or state. Probability of intercept depends on signal duty cycle, dwell, revisit time, instantaneous bandwidth, trigger threshold, number of sensors, and search schedule. A sweep that covers a wide span slowly may have poor probability for short bursts, while a wideband recorder can preserve the event at the cost of data rate and dynamic range.[9]

The survey plan matches observation architecture to the hypothesized signal behavior. Continuous carriers, periodic bursts, frequency hopping, wake-up transmissions, event-triggered devices, and remotely illuminated responses require different strategies. Controlled state changes, repeated occupancy windows, and synchronized external observations improve efficiency. Missed observations are interpreted within the coverage model rather than as proof of absence.

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9 James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. Its historical radiometer thresholds are not adopted as acceptance limits for the present constructed receiver.

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15.2 Model 15A: calculate conditional event coverage from usable windows

An observation schedule should be expressed in intervals during which the required data are actually usable. A tuning command, an illuminated acquisition indicator, and a saved record can describe different intervals. Frequency settling, filter memory, AGC recovery, trigger rearming, transfer pauses, and invalid sample flags can shorten the usable part of a nominal dwell. The event criterion then states how much contiguous signal must be present in one valid record. Detecting that a burst occurred, measuring its steady amplitude, estimating its modulation, and preserving its complete startup can require different lengths from the same event.

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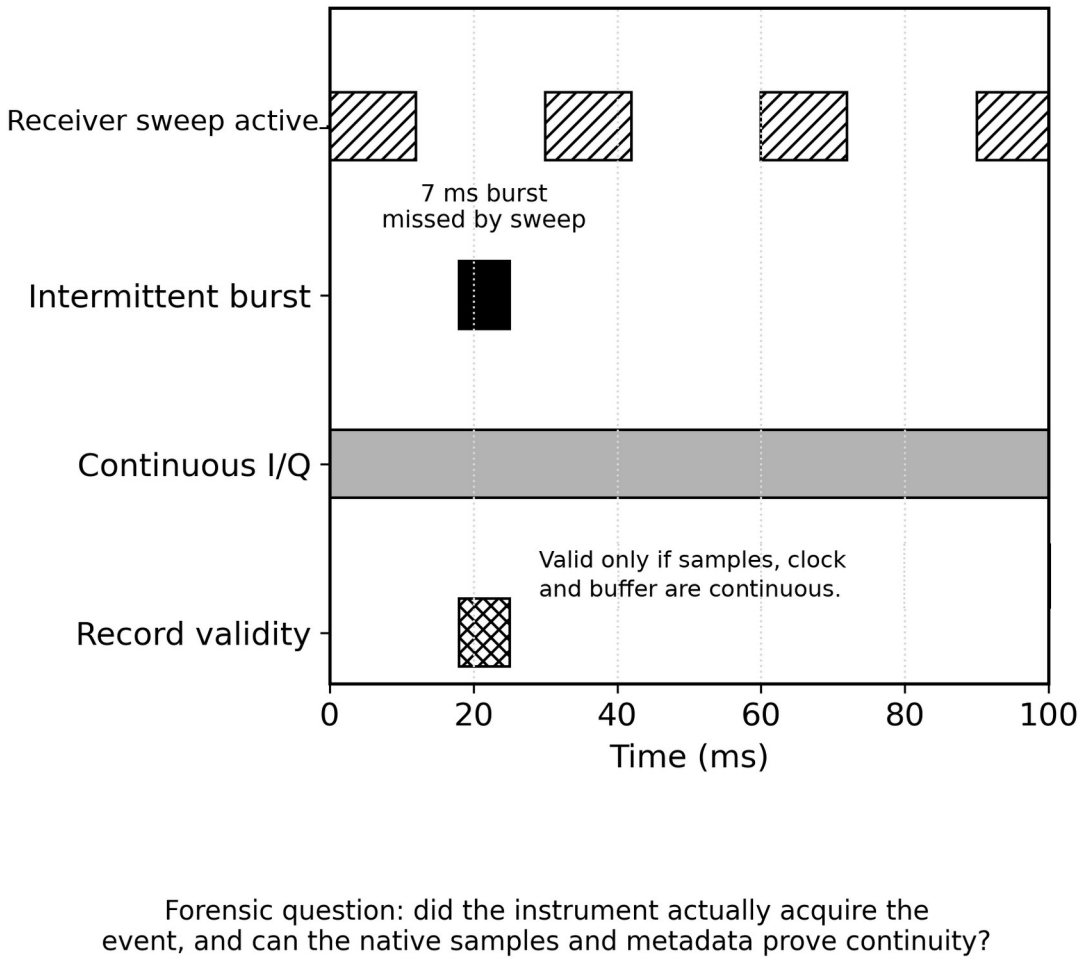

Figure 79. Burst timing and missed observation windows.

Model 15A isolates this timing geometry. It does not infer a detector threshold, false-alarm rate, signal-to-noise ratio, or ability to recognize the waveform. Those are prerequisites established by separate receiver tests. The model assumes that an event meeting those prerequisites is

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successfully available whenever one usable record overlaps it for at least the specified positive duration. Calling the result conditional capture probability keeps the geometric claim separate from an untested detection claim. Real-time analyzer descriptions likewise tie transient capture to acquisition bandwidth, processing continuity, event duration, and the quantity being measured.[10]

Equation 30A. Periodic usable-window and event definitions

$$T>0, 0<b<T, 0<D_j<T, r>0$$
$$W_j=[a_j, a_j+D_j], event=[s, s+b]$$

All times and durations in one calculation use the same unit, seconds or explicitly converted milliseconds. Index j labels a usable window W_j with start a_j and length D_j. The set E_j contains its eligible event starts, π_T reduces starts modulo the period, and A is the merged eligible-start set within one period. Its length is a duration, so length divided by T is a dimensionless probability. The random start phase S is distinct from the deterministic trial start s.

Let the observation schedule repeat with positive period T. Each declared usable window is a single contiguous acquisition interval with length strictly between zero and T. An event has length b strictly between zero and T. Its start phase S is considered modulo T, and the required contiguous overlap r is positive. Windows may cross the arbitrary period origin. Keep such a

10 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf; MACOM, “Designing with Diodes: Protecting Sensitive Components” (September 2, 2022), receiver-protector operation and recovery discussion, https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting. These are identified examples of preselection, gain placement, and protection, not a universal front-end architecture or an instrument-independent limit.

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record intact on an unfolded time axis before reducing its eligible event starts modulo T. Two files are not one continuous record merely because their timestamps appear adjacent; continuity must be established before joining them.

For one usable window from a to a plus D, consider an event from s to s plus b. Their intersection length is the positive part of the smaller ending time minus the larger starting time. Requiring at least r seconds of overlap is impossible when either the event or window is shorter than r. Otherwise the event must start no earlier than a plus r minus b and no later than a plus D minus r. These two inequalities give the complete eligible-start interval. They are derived on the unfolded axis, where the meaning of one contiguous overlap is unambiguous.

Equation 30B. Contiguous intersection length

$$O(s)=max(0,min(s+b,a+D)-max(s,a))$$

Equation 30C. Eligible starts for one contiguous window

$$E_j=[a_j+r-b,a_j+D_j-r]\,if\ r\leq min(b,D_j)$$
$$E_j=\varnothing\ otherwise$$

For a periodic schedule, reduce each eligible-start interval modulo T and take their union. When an interval crosses zero, its two pieces on the displayed period still represent one set of eligible starts. Measure the union only after overlapping pieces have been merged. Adding the lengths of individual windows or their eligible-start sets can count the same event phase more than once. The union calculation also handles windows that differ in length or are separated by acquisition dead time.

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Equation 30D. Capture-start union on one schedule period

$$A = \bigcup_j \pi_T(E_j)$$

$$\pi_T(s) = s - T\lfloor \frac{s}{T} \rfloor, A \subset ¿$$

¿

If the event start is uniformly distributed over one period, conditional capture probability is the length of that union divided by T. Uniformity is a model of the event phase relative to the schedule, not a consequence of ignorance about it. A synchronized device, a periodic telemetry source, or a common clock can produce a concentrated or fixed phase. In those circumstances use the actual phase distribution or a deterministic coverage statement. A plausible average over hypothetical start phases does not establish the outcome at the phase encountered in a particular survey.

Equation 30E. Uniform-start conditional capture probability

$$S \sim Uniform ¿$$

¿

For one window, the eligible interval has length D plus b minus twice r when the overlap requirement is feasible. Reduction modulo T caps its union length at T. The resulting compact expression is useful, but only with the stated domain. In particular, setting r equal to zero would make an empty intersection satisfy an unhelpful greater-than-or-equal test. A point observation is treated separately: an ideal instantaneous event must fall within a usable window. Its probability is D divided by T for one window, which is also the appropriate short-event limit when the entire shrinking event is required.

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Equation 30F. Single-window result with its feasibility condition

$$p = min\left(1, \frac{D + b - 2r}{T}\right) if\ 0 < r \leq min(b, D)$$
$$p = 0\ if\ r > min(b, D)$$

Equation 30G. Ideal point observation as a separate limit

$$p_{point} = \frac{D}{T}, instantaneous\ event\ inside\ the\ usable\ window$$

The strict window-length condition excludes a continuously usable acquisition represented as repeated touching pieces. If acquisition genuinely continues through each period boundary, merge those pieces and evaluate the actual continuous record. If a real rearm gap exists, preserve the gap. This distinction is material when the criterion requires one uninterrupted portion of a burst: two short pieces on either side of a gap do not become one longer observation by adding their durations.

Repeated trials require a second, separate probability assumption. If event phases are independent and identically distributed with single-trial probability p, the probability of at least one capture is one minus the probability that all trials miss. Independence must concern the relevant event phase and usable schedule, not merely the number of files. A periodic event at a fixed phase can miss the same window indefinitely. Changing the schedule, observing continuously, or introducing justified independent phase variation changes that experiment; repeating the original schedule does not.

Equation 30H. Independent repeated trials

$$P_{\geq 1} = 1 - (1 - p)^n$$
$$n \in \mathbb{Z}_{\geq 1}, trials\ independent\ with\ common\ p$$

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For a desired probability strictly between zero and one and a single-trial probability strictly between zero and one, solving the complement inequality gives an integer minimum trial count. Round upward and verify the preceding integer so the boundary is explicit. If p is zero, no finite positive count reaches a positive target. If p is one, one valid trial suffices. A target of exactly one is unattainable in finitely many independent trials when p remains strictly between zero and one. These endpoint statements prevent a logarithmic formula from being applied outside its domain.

Equation 30I. Minimum independent trial count for an interior target

$$n_{min} = \lceil \frac{\ln(1-q)}{\ln(1-p)} \rceil$$
$$0 < p < 1, 0 < q < 1$$

Independent trials with different known probabilities use the product of their individual miss probabilities. This extension can represent a deliberately varied schedule only if the corresponding independence assumptions remain justified. Correlated trials require their joint distribution, or a defensible bound, rather than the same product with new labels. The practical record should preserve the schedule and event model so a reviewer can distinguish a calculated coverage probability from a count of observations.

Equation 30J. Independent trials with unequal probabilities

$$P_{\geq 1} = 1 - \prod_{i=1}^{n} (1 - p_i), \textit{independent trials}$$

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15.3 Worked applications with hypothetical inputs

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15.4 Application 15A.1: Distinguish a point observation from full capture of a short event

A schedule repeats every 100 ms and has one usable window from 10 through 30 ms. An ideal point event with uniform start phase is captured with probability $\frac{20}{100}$, or 0.20. A finite 0.1 ms event that must be captured completely instead has eligible starts from 10 through 29.9 ms. Its conditional probability is 0.199. The small difference comes from the trailing edge of the complete-event requirement.

This example distinguishes a point limit from a finite record criterion. It does not set an actual receiver minimum pulse width. A detector, channel filter, or amplitude estimator may need a much longer signal than 0.1 ms. Establish that prerequisite first, then use the corresponding usable interval and event requirement in the geometry. Endpoints have zero probability under the stipulated continuous uniform distribution, although an exact deterministic start still needs a consistent boundary convention.

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15.5 Application 15A.2: Capture a burst when only part of it is required

Keep the 100 ms period and the 10–30 ms usable window, but use a 5 ms event and require only one contiguous millisecond. Equation 30C gives starts from $10+1-5$ ms $=6$ ms through $30-1$ ms $=29$ ms. The eligible interval is 23 ms long, so conditional capture probability is 0.23. An event may begin before the window and still provide the required observed tail.

The increase beyond the 0.20 point-event probability does not mean the receiver observes longer than its 20 ms dwell. The finite burst can overlap the dwell even when its start lies outside it. The calculation is appropriate only if the stipulated one millisecond is sufficient for the intended observation and any leading transient or settling requirement has already been accounted for. It does not establish complete-event recording.

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15.6 Application 15A.3: Require the whole burst

Now require the whole 5 ms event in the same 10–30 ms window. Eligible starts run from 10 through 25 ms, giving probability 0.15. Compared with Application 15A.2, the event and schedule are unchanged; only the evidence requirement has changed. Capturing an identifiable fragment and preserving the entire burst are therefore different coverage claims.

A report should state which claim its probability describes. If a later analysis needs startup timing, pulse count, or a complete modulation frame, a survey planned only for a short fragment may not provide it. Preserve incomplete records as observations, but do not relabel them as complete captures after seeing a recognizable pattern. A prospective criterion makes both the success and the limitation reviewable.

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15.7 Application 15A.4: Reject an impossible overlap requirement

A 100 ms schedule contains a usable interval from 10 through 14 ms. The event lasts 2 ms, while the requested contiguous observation is 3 ms. Since the event itself is shorter than the requirement, the eligible-start set is empty and conditional probability is zero. A longer dwell or more repetitions cannot create a third millisecond within that event.

The appropriate response is to reconsider the measurement question or acquire a different kind of evidence. Combining separate events might support an estimator under an additional repeatability model, but it would no longer meet the stated one-event contiguous criterion. Treat that as a new justified analysis, not a successful application of the impossible original requirement.

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15.8 Application 15A.5: Remove settling and closing guards from nominal dwell

A nominal 0–30 ms dwell in a 100 ms schedule loses its first 4 ms to verified settling and its last 3 ms to a verified closing exclusion. The usable interval is 4–27 ms. For an 8 ms event requiring 2 ms of contiguous overlap, the unfolded eligible starts are −2 through 25 ms. Modulo the schedule period, they are 98–100 and 0–25 ms, giving probability 0.27. Ignoring the guards would give 0.34.

The guard lengths are stipulated measured exclusions, not assumed properties of every receiver. Test them with the actual tuning, gain, bandwidth, trigger, and recording path. A command log alone establishes when a change was requested, not when the data became valid. If settling depends on the previous state or signal level, retain the relevant transition class rather than applying one optimistic guard to every dwell.

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15.9 Application 15A.6: Take the union of overlapping capture-start sets

Use two usable windows, 10–25 and 28–43 ms, in a 100 ms schedule. A 20 ms event needs 5 ms of contiguous overlap in either single window. The first eligible-start interval is −5 through 20 ms and the second is 13 through 38 ms. Their union modulo 100 ms is 95–100 together with 0–38 ms, totaling 43 ms. Conditional capture probability is 0.43, while adding the two separate probabilities would incorrectly give 0.50.

The overlap from 13 through 20 ms corresponds to starts that can satisfy either window. Each is one event phase, so it contributes once to the probability of any qualifying record. The rule still does not add a short overlap in the first window to a short overlap in the second. If the scientific objective permits combining separated pieces, its coherence, repeatability, and estimator assumptions must be stated in a different record criterion.

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15.10 Application 15A.7: Keep a deterministic repeated miss deterministic

A 5 ms event always begins at phase 50 ms of the same 100 ms schedule. A usable window at 10–30 ms misses it on every repetition. One hundred events produce zero captures, despite the nonzero uniform-phase probability calculated for a different experiment in Application 15A.2. Moving the usable window to 49–69 ms gives a full 5 ms overlap and captures all one hundred stipulated events.

Neither count is a random estimate in this deterministic example. The fixed relationship between event and schedule controls the result. A survey that repeatedly observes a commensurate miss needs a changed timing strategy or a justified distribution of relative phases. More repetitions are useful only when they add coverage or evidence; the independence formula cannot convert identical geometric misses into new opportunities.

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15.11 Application 15A.8: Preserve one contiguous window across the period origin

A single continuous acquisition runs from 90 through 110 ms across the origin of a 100 ms schedule. The event lasts 15 ms and needs 12 contiguous milliseconds. Keeping the window intact gives eligible starts from 87 through 98 ms and probability 0.11. An event starting at phase 95 ms has a 15 ms overlap and qualifies. One starting at phase zero has only a 10 ms overlap with the relevant record and fails.

Splitting the acquisition at the displayed zero would incorrectly turn one 20 ms record into two 10 ms pieces, neither long enough to satisfy the 12 ms requirement. Conversely, joining records across a genuine acquisition gap would falsely create continuity. Period coordinates, file boundaries, and physical continuity are separate concepts. The metadata must identify which boundaries are merely representational and which interrupt the samples.

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15.12 Application 15A.9: Calculate repeated capture only under independent start phases

Under independent uniform start phases, use the single-trial probability 0.23 from Application 15A.2 for ten trials. The all-miss probability is 0.77 to the tenth power, or 0.073266805. The probability of at least one qualifying capture is 0.926733195. This is a conditional result for the declared timing and signal-validity assumptions.

Independence could be established by the event-generation protocol in a controlled test. It should not be inferred from a field log containing ten timestamps. Shared triggers, periodic operation, and synchronized observation can correlate those starts. If the trial structure changes after a missed event, preserve the adaptive rule and analyze the resulting experiment instead of reporting the original fixed-trial expression without qualification.

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15.13 Application 15A.10: Solve for a conditional trial count and check the boundary

For independent trials with probability 0.23, require at least 0.99 probability of one capture. Equation 30I gives a minimum of 18 trials. Their probability is 0.990946155; 17 trials give only 0.988241760. Checking both integers verifies the upward rounding at the acceptance boundary.

Eighteen trials are not a universal receiver-search prescription. They solve this particular conditional model with its stated event length, usable window, overlap requirement, and independent phase law. A different event population or a detector failure changes the inputs or invalidates the model. Preserve those conditions beside the number so a later reader can evaluate whether the trial count applies to the actual observation.

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15.14 Trigger Types and Pretrigger Context

Receivers may trigger on level, frequency mask, pulse width, edge, pattern, external event, time, GPS or network schedule, or software statistic. Each trigger has latency, dead time, hysteresis, false-alarm behavior, and a specific location in the chain. A trigger after narrow filtering cannot respond to out-of-band precursors; a trigger after AGC can be delayed or suppressed by control behavior.

Pretrigger memory preserves the context before the event and is essential for identifying startup transients, causal sequences, or preceding interference. Record length must include settling and recovery after the event. Trigger and acquisition clocks may differ, producing timestamp uncertainty. A trigger test with a known burst verifies latency, pretrigger depth, and missed-event behavior.

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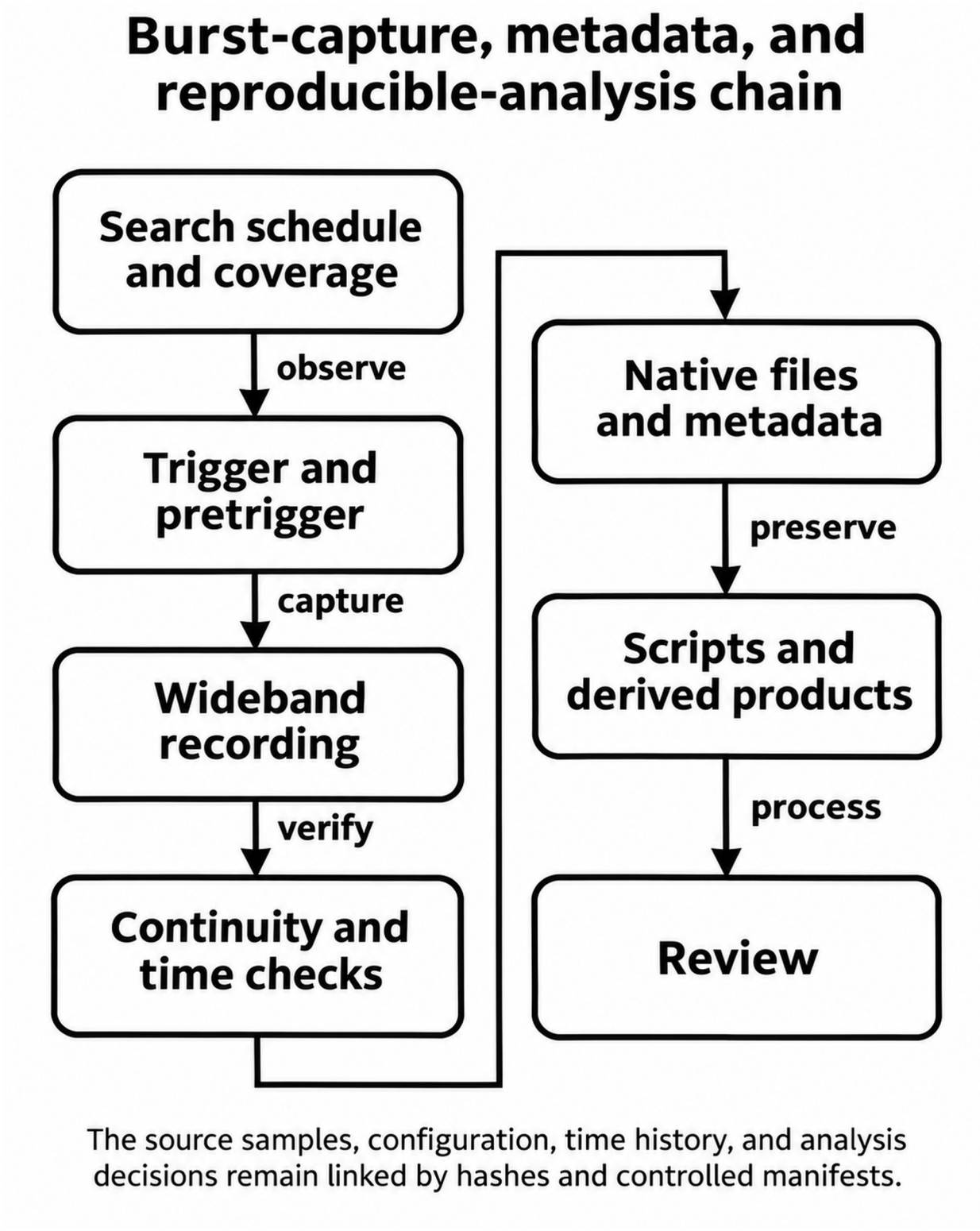

Figure 80. Burst capture and reproducible analysis.

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15.15 Verify the trigger at its actual signal-path location

A trigger is an estimator operating somewhere in the receiver chain. Identify whether it sees the full-rate digitized signal, a decimated channel, a filtered detector, or a software statistic. Its bandwidth and latency can differ from those of the saved waveform. A brief event may pass through the recorder while failing the trigger, or satisfy a detector before enough valid waveform samples are available. The documented distinction between full-rate and decimated trigger paths in real-time instruments illustrates why a trigger label alone does not establish this relationship.[11]

Characterize trigger timing with a known stimulus that includes the relevant leading edge, duration, level, modulation, and prior quiet interval. Record the stimulus reference and the actual sample interval around the trigger. Vary pretrigger allocation and total record length while keeping the event definition fixed. Then examine retrigger, holdoff, and rearm behavior using event pairs at controlled separations. A successful isolated pulse does not test the second pulse that arrives during recovery.

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11 Rohde & Schwarz, R&S ESW EMI Test Receiver User Manual, 1177.6298.02, version 18 (2025), §§9.7.1.2–9.7.1.3, 193–94, https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf. The manual identifies firmware 3.20 and higher; the cited architecture is a specific instrument example.

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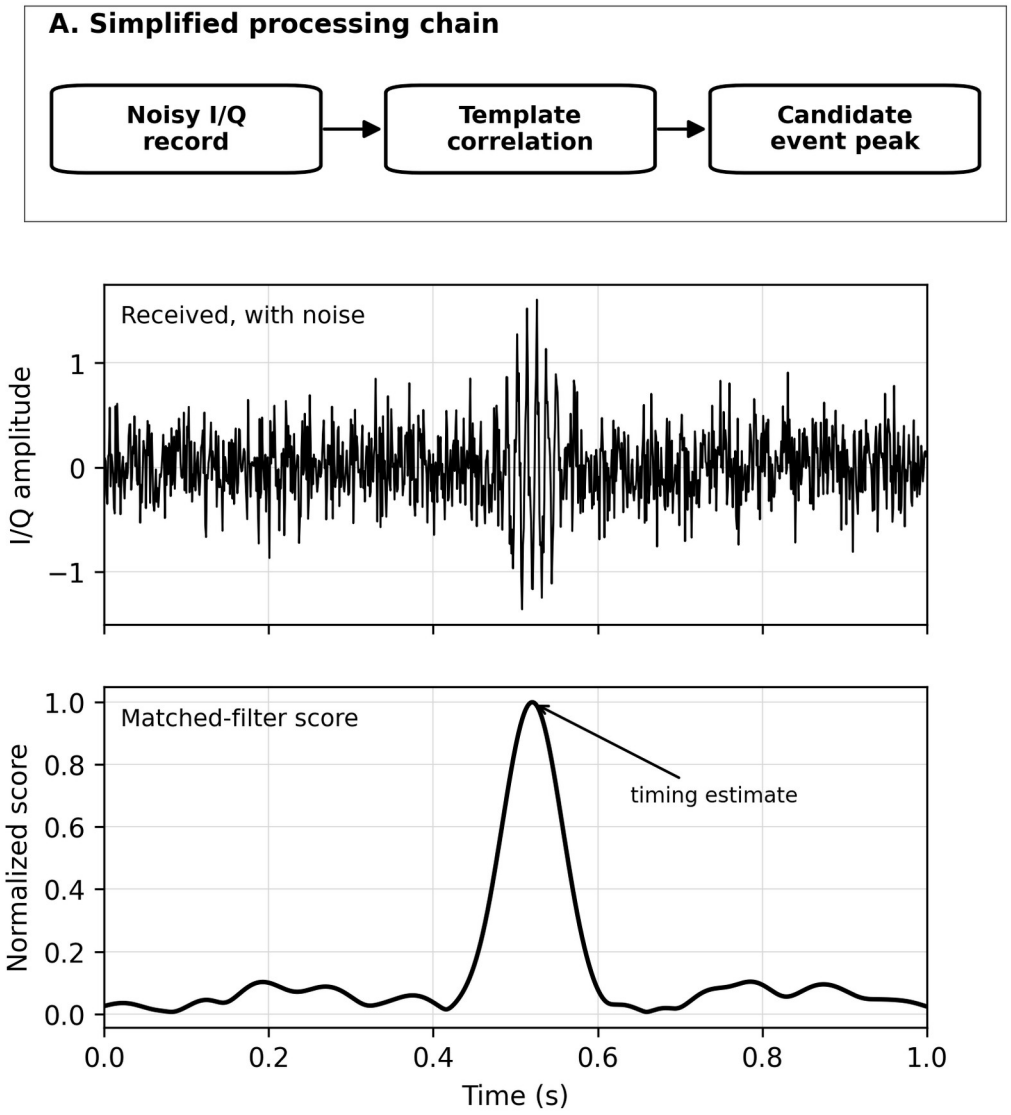

Matched filtering assumes a known template and a suitable noise model; the peak is not proof of an external source.

Figure 81. Matched filtering for burst detection.

Pretrigger depth protects causal context only when the buffer contains valid samples from the same accepted configuration. A tuning or gain change inside that interval can make the early data incomparable with the event. Retain state-transition timestamps and validity flags. If the trigger

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timestamp refers to a comparator, packet, or software event rather than a sample aperture, establish its relation to the stored samples through Model 12A and the measured trigger path.

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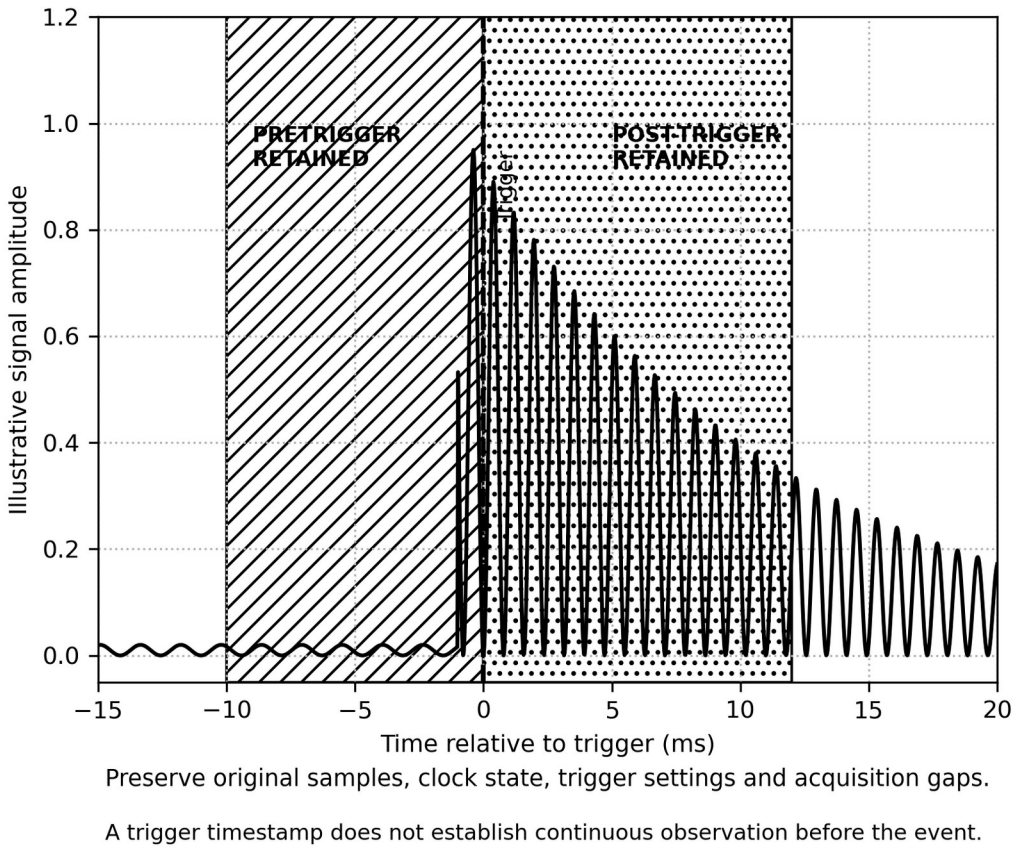

Figure 82. Pretrigger buffering and event boundaries.

Table 15A. Match the capture claim to the retained evidence

Claim	Required record and check	Limit to preserve
A qualifying fragment was observed	One valid contiguous interval meeting the declared duration and detector condition	The unobserved beginning and end remain unknown

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Claim	Required record and check	Limit to preserve
The complete event was captured	Event boundaries and required context lie within one verified continuous record	A trigger-centered display alone does not prove both boundaries
The observation schedule had stated coverage	Usable intervals, guards, rearm gaps, and the declared event-phase model	Conditional geometry does not establish detector performance
The result can be reproduced	Native samples, continuity evidence, metadata, calibration, and exact processing parameters	A derived image cannot restore discarded samples

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15.16 Wideband Recording and Data Integrity

Wideband recording preserves flexible analysis but generates high data rates. Bit depth, sample rate, channel count, data type, headers, time stamps, compression, and storage performance determine file size and continuity. The recording path is monitored for dropped samples, overruns, packet loss, repeated blocks, clock unlock, thermal throttling, and file rollover. A hash is calculated for stable files after closure.

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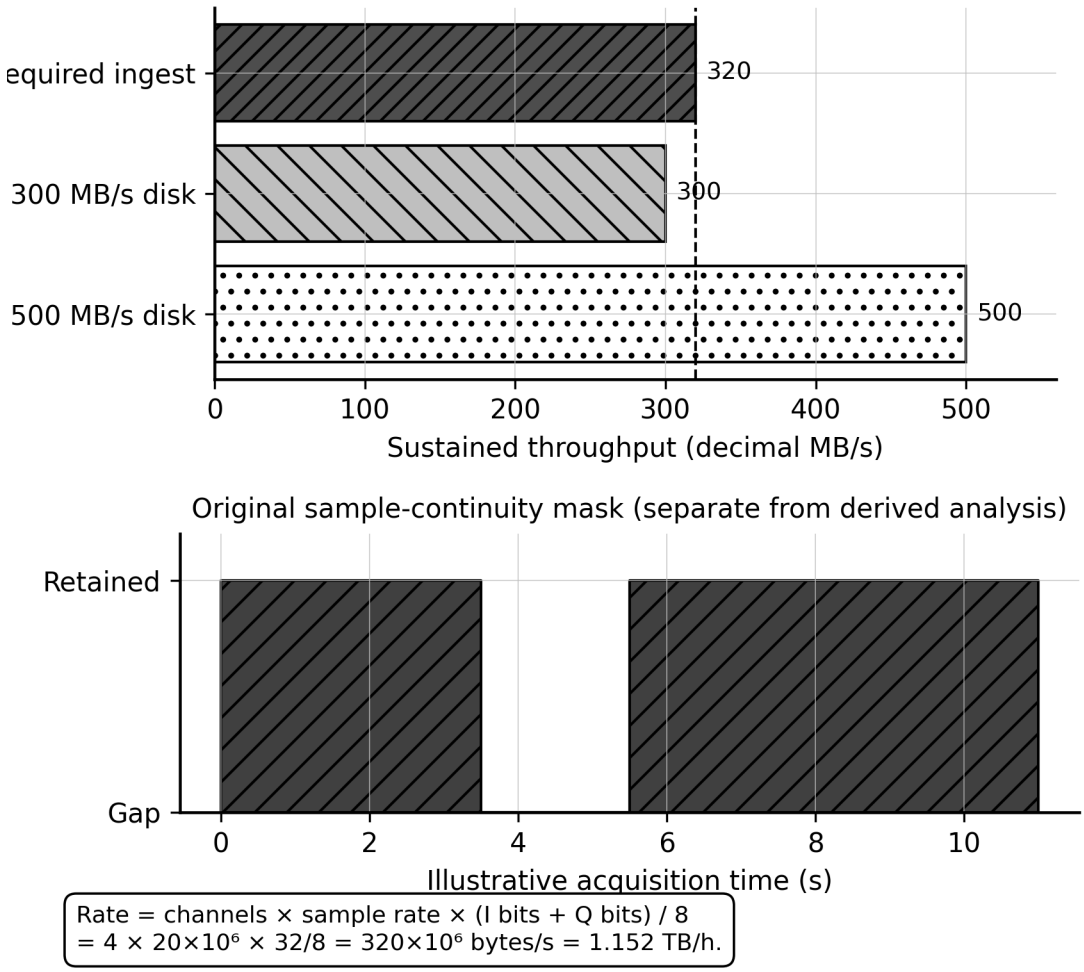

Figure 83. I/Q bandwidth, bit depth and recording duration.

Segmented acquisition can reduce storage by capturing only triggered intervals, but it can bias occupancy and omit context. Continuous circular buffers with triggered extraction offer a compromise. File formats should preserve center frequency, sample rate, scaling, time reference, device

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identity, gain and filter states, and any processing. If metadata is stored separately, binding hashes or a controlled manifest maintain the relationship.

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15.17 Metadata, Time, and Site Context

Technical metadata includes instrument serial number, software and driver versions, antenna and path, calibration files, coordinates, orientation, height, operator, authority, environment, trigger settings, clock source, time uncertainty, and state of relevant systems. Human-readable notes explain why settings changed and identify unexpected conditions. Automated logs capture rapid configuration changes that an operator may not notice.

Absolute time can be less important than relative timing for some surveys, but the requirement should be explicit. Correlation with access-control events, device operation, power switching, network logs, or other sensors needs a common time basis and known uncertainty. Time-zone, leap-second, daylight-saving, and clock-correction behavior are documented. A timestamp without a clock history is not a complete timing measurement.

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15.18 Reproducible Analysis and Derived Products

Analysis scripts, software versions, parameters, calibration inputs, excluded intervals, and manual decisions are preserved. Derived spectra, audio, decodes, images, and tables identify the source file and processing chain. Where proprietary software prevents complete export, setup files, screenshots, command histories, and independent checks provide additional context.

Reproducibility is tested by rerunning the analysis on the same source, using a second implementation where practical, and applying the method to reference and noise-only data. Results sensitive to one threshold or one window are reported as such. Data minimization and access controls apply to the preserved records, especially where incidental communications content or personally identifiable information could be present.

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15.19 Bind sample continuity, storage accounting and derived results

Use Equation 29 with the stored representation, not only the converter resolution printed on a specification sheet. A nominal 12-bit component may occupy a 16-bit container; an integer format and a floating-point export can have different byte rates for the same sample sequence. State whether samples are real or complex, how channels are interleaved, the byte order, signedness, scaling, and any packing. Headers, padding, timestamps, compression, and rollover records require additional accounting beyond the payload equation.

Test sustained writing for the planned duration and configuration. Short benchmark bursts can be absorbed by buffers and conceal a slower steady storage path. Monitor sequence numbers, sample counters, block lengths, overrun indicators, and clock status. A file hash proves that the preserved bytes have not changed relative to that hash; it does not prove that the acquisition originally contained every intended sample. Continuity evidence must be produced by the acquisition and checked before spectral or timing interpretations depend on it.

Treat gaps and repeats as explicit sample-domain events. A missing block changes the relationship between index and elapsed time, while concatenating the remaining bytes can create a false discontinuity or erase the true interval. Model 10E provides the sample-index and phase-continuity framework, and Model 12A supplies the time-reference relationship. Preserve a gap map or equivalent sequence record and restrict analyses to

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valid segments when the estimator assumes uniform uninterrupted sampling.

A derived result should identify its source record, selected interval, channel, calibration, receiver state, sample scale, and processing parameters. Windowing and spectral normalization belong to Chapter 9; mixing and decimation belong to Chapter 10; modulation alignment belongs to Chapters 6 and 7. Record these decisions as part of the result rather than expecting a screenshot to convey them. A second implementation can then reproduce the same declared quantity and expose a convention mismatch instead of merely generating a visually similar plot.

Before releasing a negative coverage statement, reconcile what was planned, what was commanded, what the receiver marked valid, and what was successfully preserved. Report excluded intervals and untested event classes. A clean recording of one band cannot support a claim about a band outside the instantaneous passband, and a high capture probability for one event model does not establish absence of all other emissions. The useful conclusion is bounded by the actual acquisition and the question it was configured to answer.

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15.20 Coverage Review and Storage Governance

Coverage and storage plans are reviewed before deployment against expected event duration, revisit interval, trigger dead time, channel count, sample format, storage write speed, retention, and access restrictions. The plan includes reserve capacity and a response to lost packets or device failure. Long captures are divided through controlled rollover so that files remain manageable without losing chronology.

Data disposition is linked to the authorized purpose. Native records needed for evidence or later verification are preserved with access controls, while incidental or unnecessary content is minimized according to policy. Derived products do not silently replace the native capture, and deletion or migration events are documented.

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15.21 Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility

Equation 3. Uncompressed I/Q data rate

$$R_{\text{data}} = \frac{f_s N_{\text{ch}} N_{\text{comp}} N_{\text{bits}}}{8}$$

Uncompressed byte rate R_{data} equals sample rate f_s times number of channels N_{ch}, components per channel N_{comp}, and bits per component N_{bits}, divided by eight. Headers, packet overhead, compression, and file-system behavior change the actual storage rate.

Equation 4. Independent-window intercept probability

$$P_{\text{intercept}} = 1 - \left(1 - p_{\text{hit}}\right)^{N_{\text{obs}}}$$

If N_{obs} observation windows are independent and each has probability p_{hit} of overlapping a signal event, total intercept probability follows the complement relation. Real revisit schedules and periodic signals often violate independence and require a specific timing model.

Equation 29 is byte accounting for the declared uncompressed format, including both I and Q when the component count is two. Its throughput must be verified against the actual recording path. Equation 30 is the independent-trial special case examined in Model 15A and Applications 15A.1–15A.10; correlated or phase-locked observation opportunities require their own timing calculation.

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Table 2. Chapter 15 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Search coverage	Instantaneous bandwidth, dwell, revisit, duty cycle, sensors, and state windows	Quantifies probability of observing an intermittent signal	No observation outside the covered windows does not establish absence
Trigger	Location, statistic, threshold, latency, dead time, pretrigger, and test burst	Preserves relevant events and context	Trigger logic can miss or distort the event
Recording integrity	Rate, depth, packet sequence, overrun, clock, file rollover, storage, and hashes	Supports continuous and reproducible samples	Dropped samples can create false transients and spectral splatter
Metadata and analysis	Site, time, configuration, calibration, script, parameters, and derived-file lineage	Connects the data to a defensible method	A derived image without its source and settings is weak evidence

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15.22 Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility

A two-channel complex recorder samples at 40 MS/s with 16-bit I and 16-bit Q components. The uncompressed data rate is 320 MB/s. A 30-minute continuous capture requires about 576 GB before headers and file-system overhead, so storage margin and sustained-write testing are part of the survey plan.

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15.23 Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility

A triggered receiver captures several unexplained bursts but omits the preceding 2 ms. Increasing pretrigger depth reveals that every burst follows a relay transition in the receiver's own antenna switch. The additional record establishes temporal order and supports a switch-related transient hypothesis. It does not yet distinguish that mechanism from a real signal newly admitted by the switch or another shared control. A matched-reference comparison with the switch held static or bypassed would test the explanation. The corrected configuration preserves both events and the unresolved attribution.

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15.24 Acquisition provenance, loss masks and portable complex-sample metadata

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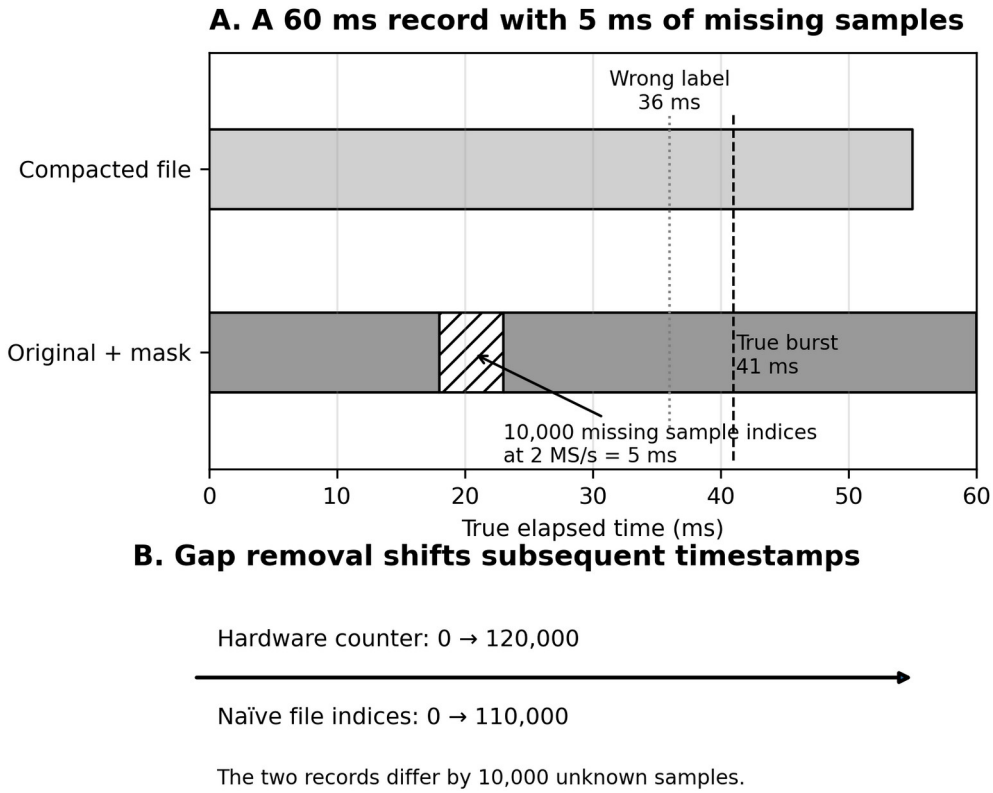

The missing-data interval is unknown, not a run of zero-amplitude measurements. Preserve counter discontinuities, epoch, sample rate, state changes and an explicit sample-validity mask before spectral estimation.

Figure 84. Missing I/Q samples and false time labels.

Native I/Q samples cannot be understood independently of their numeric representation and acquisition-state history. A complex-sample stream has at minimum a declared signedness or floating-point datatype, endian convention, I/Q ordering, channel count, sample rate, centre frequency, scale and clock reference. An identical byte array can be interpreted as a

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radically different waveform if its manifest changes, even when a cryptographic digest of the sample payload remains unchanged. The SigMF v1.2.6 specification supplies a useful public vocabulary for recording metadata alongside datasets, including global recording information, capture segments and annotations. Conformance to a metadata syntax, however, is not a substitute for calibrated proof that the recorded analogue input represented a particular electromagnetic event. The missing-sample timeline example is illustrated in Figure 70.

A capture manifest should contain state transitions as separate entries where they affect the data. The fields describing a later retune, gain change or receiver selection cannot silently be inherited when the specification requires explicit capture metadata. Record the actual start sample index, actual frequency and rate as known from instrument status, and any uncertain transition boundaries. File creation time, acquisition start and sample aperture time are not generally interchangeable. A simple time estimate for contiguous uniform samples is $t_k = t_0 + k/f_s$, with t_0 a defined aperture reference and f_s the established acquisition rate. When samples were lost, concatenating the surviving bytes and applying the same expression to the new ordinal index shifts the subsequent physical-time mapping. A gap mask or original acquisition counter is needed to retain the missing duration.

As a synthetic continuity exercise, a receiver nominally generates 2 million complex samples per second. A verified hardware-counter discontinuity of 10,000 acquisition indices represents 5 ms of missing nominal sample time if the counter semantics and rate remained valid. If an exported file conceals that gap, a later 50 ms burst may appear five milliseconds earlier relative to

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subsequent records. An analyst should not fill the missing samples with zeros and then describe the added zeros as measured silence. A derivative file may use placeholders for computational convenience, but the validity mask, original byte digest and transformation record must make their status unmistakable. If the hardware-counter interpretation is uncertain, the gap duration must be reported conditionally rather than asserted as a measured fact.

A robust chain of custody maintains separate digests for the original sample object, the appropriate manifest and the custody ledger or signed event history. It identifies the algorithm used for each digest, the custodian, the acquisition device and the point in time at which the trusted reference digest was created. A successful later hash comparison supports byte continuity relative to that reference; it does not prove that the receiver was calibrated, that the acquisition was lawful, or that the clock was correct. Preserve minimally necessary original records under applicable access controls, and document any decimation, compression, filtering or redaction as an explicit derivative. A complete evidential package allows a sceptical reviewer to reconstruct the processing while still respecting the authorised limits of collection and disclosure.

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15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput

A digital RF recording should be interpreted as a time-indexed sequence of actual acquisitions, not a file whose nominal size happens to equal an expected number of bytes. The physical sample count, sample aperture timing, sample format and declared validity must be connected. Buffered acquisition can overwrite records, duplicate blocks, reorder network packets or insert placeholder values while a downstream writer still produces a syntactically valid binary file. A cryptographic digest proves that the retained bytes have not changed since a specified digest was computed; it does not show that those bytes represent continuous samples acquired without loss. Forensic reproducibility therefore requires both data integrity and acquisition-state evidence, including sample counters and buffer-overrun records where the hardware exposes them.

The throughput budget is a necessary design calculation. Let f_s be complex samples per second, n_b be total stored bits per complex sample including both components, and R be the continuous payload rate in bytes per second. Then $R = f_s n_b/8$. For a complex stream of 50 million samples per second represented by two 16-bit signed integers, $n_b = 32$ bits per complex sample and the payload rate is 200 million bytes per second, approximately 190.7 MiB/s. For eight such independent streams, aggregate payload alone reaches 1.6 GB/s. Metadata, file-system overhead, buffering, concurrent readers, thermal throttling and occasional storage pauses add additional demands. A disk briefly achieving the nominal aggregate throughput in a synthetic benchmark has not proved that it can sustain acquisition for a full

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operational interval, especially while an analysis process competes for input/output resources.

A defensible continuity protocol uses monotonically increasing hardware or driver sample counters that identify any gaps between accepted blocks. For every acquisition transition record the commanded state, actual sample rate, time-reference state and whether any samples were discarded during filter settling or buffer resets. If the acquisition lacks a trustworthy sample counter, record that limitation and use independent hardware reference events where feasible; software file timestamps are not equivalent to sample-aperture timestamps. Clock drift requires a separately characterised mapping from index to physical time, and a step discontinuity should split the record into state intervals. Inserting zeros into a gap may be a useful explicitly labelled processing choice, but the zeros are synthetic values rather than observations of zero input energy.

A hypothetical continuity check illustrates the distinction. A recorder asserts an effective complex sample rate of 20 MS/s over a nominal 30-second interval, so 600 million complex sample positions are expected if that rate and interval are valid. Suppose hardware counters identify a missing span of 100,000 positions. The lost duration is 100,000 divided by 20 million, or 5 ms. A file whose application has filled that span with zeros may retain the expected byte length, yet actual observation covers only 29.995 seconds under the stated time mapping. A burst wholly inside the five-millisecond gap remains unobserved. An uncertainty statement about burst detection must preserve that gap rather than converting storage completeness into physical coverage.

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A portable metadata representation such as SigMF can document sample format, sample rate, acquisition context and capture boundaries. It should be treated as a metadata schema rather than a guarantee of scientific accuracy or comprehensive chain of custody. The laboratory may need extensions or companion records for sample-counter gaps, calibration, clock holdover, equipment serials, legal minimisation controls, digest lineage and software transformations. Preserve a manifest connecting original sample files to their metadata, segment validity maps and later derived spectra. If a corrected file is made, preserve the original and document the script version, parameters, input digests, output digests and rejected or censored intervals. Hashing the output without retaining those elements does not demonstrate how the result was produced.

Triggering introduces additional non-observation intervals. Pretrigger buffers may silently wrap before a candidate event is recognised, trigger comparators may have latency and hysteresis, and acquisition systems may rearm after a finite dead time. The trigger threshold must therefore be validated against weak and short reference events under the receiver's actual gain and filter state. A claimed five-second recording interval after a trigger may contain a shorter valid pre-event history than its user interface suggests. Acquisition testing should include controlled bursts placed near buffer boundaries and saturation recovery periods, with a separate reference clock or known event source to examine alignment. The final evidential report states the temporal and spectral support of the samples actually retained, not merely the duration printed in a filename.

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15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time

A recorder that writes a syntactically valid file has not necessarily captured a continuous RF interval. Between the analogue-to-digital converter and persistent storage, samples may traverse FPGA buffers, DMA transfers, device-driver queues, network links, operating-system caches and user-space applications. At each boundary, an overload or backpressure condition can discard, repeat or reorder observations while preserving the appearance of a smoothly increasing file offset. A forensic description of recorded RF must therefore prove which physical sample instants correspond to each stored representation, or explicitly identify the intervals for which that correspondence is unknown. A checksum can certify that bytes have not changed after the checksum was computed; it cannot establish that the acquisition hardware sampled the expected physical waveform in the first place.

Let f_s denote the realised sample rate in complex samples per second and n an integer sample counter tied to acquisition hardware. Under constant-rate operation with a declared epoch t_0, ideal sample times satisfy $t_n = t_0 + n/f_s$. This relation is meaningful only while the counter represents actual ADC apertures and the rate is applicable. A host-generated file index or displayed timestamp cannot substitute automatically for a hardware count if samples can be omitted before the host receives them. When the clock changes or is disciplined, the time law may require a piecewise mapping or a measured phase/time correction. An abrupt rate change should create a

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new configuration interval in the evidence record, not a silent reinterpretation of all older samples using the latest nominal rate.

The data-rate calculation is a necessary but insufficient feasibility check. If each complex sample contains b_I bits for the in-phase component and b_Q bits for the quadrature component, the nominal uncompressed payload rate is $R_{bits} = f_s(b_I+b_Q)$. With the common symmetric case $b_I=b_Q=b$, the rate is $2bf_s$ bits per second. This is the rate of packed useful samples, before framing, timestamps, headers, transport overhead, storage allocation and error-correction or retransmission. A sample stream with sixteen-bit I and Q components at 100 million complex samples per second carries 3.2 gigabits per second, or 400 million payload bytes per second. A ten-minute uninterrupted capture would therefore require 240 gigabytes of payload under decimal units, before overhead. The calculation assumes the full stream is retained and that no channel decimation or compression changes the representation.

Peak write capability must be distinguished from sustained recording capability. An SSD benchmark showing a short-lived throughput above 400 MB/s does not establish that a specific computer, file system and temperature state can sustain the required rate over ten minutes. Internal garbage collection, wear management, background tasks, thermal throttling, encryption overhead and file-rotation behaviour can create pauses. Buffering can conceal a temporary write shortfall but cannot eliminate an indefinite rate mismatch. A useful acceptance test deliberately extends beyond the expected longest acquisition interval, monitors actual buffer occupancy and hardware lost-sample counters, and repeats under realistic computational and environmental loading. Successful copying of an

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existing file at high speed is not equivalent to simultaneous sampling, processing and writing from the receiver chain.

For a finite queue with capacity C bytes, incoming rate R_in and service rate R_out, the simplest fluid approximation while nonempty is dQ/dt = R_in−R_out, where Q is bytes and rates are bytes per second. If R_in exceeds R_out by constant positive ΔR, a previously empty queue fills in time C/ΔR. That time is a bound only for the stipulated deterministic rates; real storage systems have variable service and burst traffic. A correct engineering design needs a margin for the distribution of service interruptions and for the maximum input burst, not merely equality of average rates. When a queue saturates, the acquisition architecture must specify whether it discards oldest samples, newest samples, whole packets or simply blocks upstream flow. Each policy creates a different evidential gap and must be included in the file's continuity metadata.

A deliberately synthetic calculation assumes a 400 MB/s payload stream, 32 GB of free buffering and a sustained storage service rate of 360 MB/s. The deficit is 40 MB/s, so even the initially empty buffer fills after 32,000 MB divided by 40 MB/s, or 800 seconds, about 13 minutes and 20 seconds, ignoring all overhead. A 20-minute recording cannot be made continuous by that buffer under the stipulated constant rates. Increasing the buffer to 64 GB delays failure but does not resolve the negative long-term throughput margin. The correct architectural remedy is to increase sustained service rate, reduce stored throughput through valid acquisition changes, or formally limit recording duration, rather than treating the transient benchmark peak as proof of an unlimited capture.

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The loss record should distinguish three levels of certainty. A hardware counter discontinuity can establish that sample indices are absent; a validated frame sequence may reveal packet loss after acquisition; and a processing check can establish that a derived file omitted samples despite their presence in the native record. Each observation supports a different reconstruction question. A file with no detectable counter gaps may still contain overwritten samples if the device counter itself was reset, duplicated or not exposed. Two identical waveform buffers do not prove duplication when a truly periodic source could produce equal samples, but repeated buffers with identical hardware sequence identifiers and incompatible timestamps are strong evidence of a transport or software fault. The reviewer should examine both numerical content and acquisition metadata before drawing a conclusion.

A recording gap must remain a gap in subsequent time-frequency analysis. Concatenating two surviving buffers and assigning consecutive nominal times compresses the physical timeline, potentially converting two separate bursts into an apparent longer event or shifting the phase of an oscillator. Zero-padding preserves index positions and can be appropriate for some displays, but the inserted zeros are not measurements of zero incident voltage. Interpolation can support an explicitly model-dependent estimate, yet it does not restore directly observed RF data and may be especially unreliable around a transient or changing receiver state. For evidential purposes, the missing-sample mask should be retained alongside any repaired derivative and carried through every analysis that depends on timing or phase.

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A second hypothetical example considers a missing segment of 24,000 complex samples at an actual sampling rate of 48 million samples per second. The physical gap is 24,000/48,000,000 = 0.0005 seconds, or 0.5 ms. At a carrier-offset frequency of 20 kHz in complex baseband, the unobserved phase evolution across that interval is 2π times 20,000 times 0.0005 = 20π radians, ten full cycles. Its modulo-2π endpoint phase appears unchanged under the stipulated constant-frequency model, but that equality does not prove signal continuity or exclude a transient within the gap. A different unknown frequency excursion could add additional phase. A coherent phase estimate crossing the gap must disclose reliance on the assumed frequency model and the uncertainty of the missing interval.

A third example concerns random loss versus systematic gaps. If a recorder drops exactly one buffer at every file rollover, repeated test runs may show excellent average throughput while leaving a periodic observation blind spot. The lost samples are not independent random events. A probability-of-capture calculation that multiplies an assumed per-buffer survival rate across repeated sweeps would be invalid without evidence for that model. A source whose bursts are synchronised to file rollover could repeatedly coincide with the gap, creating systematic nondetection. A qualification test should therefore vary event start phase against rollover, queue flushes, gain transitions and other recurring operational cycles.

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15.27 Evidence-grade metadata and reproducible processing

A portable complex-sample representation requires more than an extension identifying the file as I/Q data. The metadata should state sample type, endianness, number of bits, actual sample rate, applicable centre frequency, acquisition epoch, sample-offset conventions, capture segments, device identity and consequential settings. The SigMF project provides an openly documented metadata approach for signal recordings, but a correctly formatted metadata document is only as reliable as the underlying observations that supplied its fields. A false timestamp or stale gain state remains false when encoded in valid JSON. The recorder must tie metadata to actual device status and calibration evidence, and note where such evidence is unavailable.

Data provenance has a sequence. First preserve the earliest useful native representation and its acquisition-state record, preferably with a contemporaneous integrity digest and restricted write access. Next produce a derivative for analysis without replacing the original. Record the processing code version, parameter values, selected intervals, calibration files, missing-data masks and any changes in time or frequency coordinates. Finally retain the scientific finding separately from the derived plot or classifier output. A cryptographic hash proves equality to the bytes hashed, not authenticity of the originating RF event, correctness of the receiver clock, or legal authority for the acquisition. These distinctions prevent a sophisticated chain-of-custody mechanism from being asked to support a proposition it cannot logically establish.

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A fourth constructed example uses a sixteen-channel architecture, each retaining a 2 MHz complex stream with sixteen-bit I and sixteen-bit Q. The total payload rate is 16×2,000,000×4 bytes/s = 128 MB/s. A forty-five-minute acquisition carries 345.6 GB of payload before metadata and storage overhead. If a nominal 512 GB volume has only 300 GB actually available and no channel is reduced, the recording cannot hold the complete requested duration. A software status that displays available disk capacity in gibibytes should not be directly compared with decimal gigabytes without conversion. The design must calculate actual free bytes, reserved space and validated sustainable write capacity rather than rely on the drive's advertised nominal size.

A fifth synthetic example illustrates timestamp ambiguity. Two streams show event marks separated by 1.0 ms. The first timestamp is established as the ADC sample aperture with ±10 μs uncertainty; the second is a host file-write time with variable latency between 0.2 and 2.0 ms. Without a measured second-stream latency, the apparent millisecond separation cannot be interpreted as a source propagation delay or precise simultaneity. The second mark may refer to a different physical instant entirely. Calibrating the storage or transport path can narrow that uncertainty, but a common wall-clock display by itself cannot do so. Any triangulation or coherent array claim based on such times would exceed the supported evidence.

The final acceptance requires an end-to-end known-event test. Inject an authorised, time-labelled RF test pattern while simultaneously monitoring hardware counters, buffers, device status, derived file indices and persistent storage. Include test events before and after deliberate file rollover, high

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disk load, gain changes, receiver restart and temporary network impairment. Compare the independently known event schedule with the retained native record. Record failed and partial captures, not solely successful files. The release dossier should provide the set of physically observed intervals, the missing-sample masks, validated rate and time mappings, and the exact storage representation. Only then can an analyst responsibly describe a captured interval as continuous within the stated uncertainty and operating conditions.

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15.28 Advanced technical expansion. Continuity proofs for burst-triggered I/Q evidence

A digital file can be internally well formed while failing to represent continuous acquisition of the intended RF channel. The distinction between sample indexing, physical aperture time, trigger time, buffering, transport and storage must therefore be maintained in the recording model. Let a converter sample at a realised rate f_s in complex samples per second and let each retained complex sample occupy b bytes in the selected format. The uncompacted minimum payload rate is $R = f_s b$ bytes per second, before packet headers, metadata, file-system overhead or redundancy. For a hypothetical single complex channel at 20 million samples per second stored as two 16-bit signed integers, b = 4 and the raw payload rate is 80 MB/s in decimal units. Eight such channels need 640 MB/s, or approximately 2.304 TB per hour, before storage overhead. These are capacity-planning results; they do not prove that a particular host or disk can sustain the rate without lost data.

A trigger introduces a second time base. The threshold crossing occurs at some physical or digital decision stage; the software notification and file-write start may occur later. If the desired report needs the first microseconds of a brief pulse, a pretrigger buffer must contain valid samples acquired before the trigger and must retain their sample indexes. A buffer of L complex samples at sample rate f_s contains L/f_s seconds of nominal pretrigger history. For example, 262,144 samples at 20 MS/s represent approximately 13.1072 ms. That figure is not an independent guarantee that the buffer was correctly aligned with the event or that the

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earliest samples survived subsequent backpressure. Verification requires a known reference with an independently marked onset and a record of the trigger-comparator and sample-counter relationship.

Missing or repeated buffers can be particularly treacherous because an application may export a file with the expected number of samples after inserting, omitting or reordering data. A file-length check alone does not establish acquisition continuity. Use monotonic hardware sample counters or another independently validated continuity mechanism, link transport sequence numbers to original acquisition indexes where available, and record discontinuities as explicit gaps rather than silently concatenating the fragments. A checksum proves the exported bytes have not changed since a specified reference; it does not prove that the bytes were a complete representation of the earlier analogue event. Similarly, an unchanged timestamp written by software may reflect a reconstructed clock rather than each actual sample aperture. The provenance record should distinguish measured hardware time from derived time.

Recording performance should be tested under the worst credible sustained workload, not only by copying a previously captured file. Real-time acquisition involves interface transfer, buffers, operating-system scheduling, metadata production and storage flush behaviour that do not appear in a synthetic disk write benchmark. Test with the intended sample format, channel count and maximum recording duration, while independently monitoring source identity and sample continuity. Include cases where the processor is busy, the storage subsystem approaches full capacity, a device changes gain or preselector state, and a network link experiences bounded delay. Preserve every failure and the exact condition that produced it. A

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successful ten-second recording cannot by itself establish uninterrupted eight-hour operation, especially when thermals and write amplification change over time.

SigMF provides a concrete public metadata framework for linking sample files with descriptions of format, sample rate, captures and annotations. It does not replace the investigator's legal authority, calibration records or proof of physical continuity. An acquisition package should include explicit complex-data type and endianness, declared and verified sample rate, time and frequency references, capture start indexes, channel identifiers, processing revisions and gap annotations. If the underlying format uses a global sample rate but the receiver changed rates during a recording, either partition into separate valid records or provide an explicitly supported representation that preserves each actual time basis. Misrepresenting mixed-rate data as one uniform sequence can corrupt every subsequent frequency and timing inference.

End-to-end assurance must also preserve transformed outputs without confusing them with original measurements. Retain the raw I/Q stream where authorised, a cryptographic digest, a manifest linking auxiliary metadata and recorded files, the immutable configuration-state ledger and separate analysis products. Each derived waterfall or decoded feature should identify its input ranges, algorithm, coefficients and numerical environment sufficiently for independent reproduction. A scientifically useful retention policy may preserve technical subsets rather than unrelated communication content, but the minimisation decision and its consequences for possible reanalysis must be stated. An absent sample or

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discarded band remains absent, regardless of how carefully the surviving bytes are signed or archived.

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15.29 Event-driven capture without treating quiet intervals as proof that no emission existed

A massively parallel receiver should not be forced to choose between archiving every byte for four hours and storing only attractive events displayed by one detector. Full-rate continuous spectral analysis is a computational service, whereas full-rate raw I/Q retention is a separate storage policy. A rational architecture runs both a fast event detector and a narrowband spectral estimator from the same calibrated acquisition path, with a rolling pretrigger buffer in each frequency slice. Candidate events cause selected intervals to be retained at the finest available representation needed for the task, while the system continuously records coverage status, detector configuration, valid-gain state, overload flags and sample continuity across every band. That arrangement can reduce the long-term volume greatly, but it cannot guarantee retention of emissions which all active detectors miss. Its assurance must be defined empirically for stipulated event classes.

The front-end FPGA should attach a monotone sample counter to blocks before sending them to host software or GPU memory. The block manifest includes channel identity, sample-rate epoch, RF tuning, calibration identifier, gain and preselection state, reference-clock lock, packet serial, first and last sample indices, and checksum or authenticated digest as appropriate. If consecutive received blocks have noncontiguous counters, the storage record contains an explicit hole, even if the application writes a file that appears continuous. Placeholder zero samples can help preserve time axes for some processing, but they must be distinguished from actual

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acquired zeros. Decimation and channelisation outputs retain the source block range and filter group delay. The original ADC-derived I/Q, when preserved, must not be silently replaced by a corrected or denoised copy.

A multi-resolution detection cascade begins with coarse wideband power, impulsive change measures, and narrow frequency-cell statistics appropriate to their respective waveform families. A fast detector may inspect overlapping short windows to preserve microsecond transients; a slow estimator may integrate tens of milliseconds to resolve a persistent carrier near the 30 Hz RBW requirement. A trigger can be raised by energy, cyclostationary structure, matched-filter correlation against an authorised test waveform, or a validated machine-learning anomaly score. These triggers have different observation domains. A threshold calibrated with isolated tones cannot automatically detect chirped pulses, frequency-hopping events or emissions adjacent to a large blocker. Fusing their scores requires explicit dependence and false-alarm modelling, not treating four correlated triggers as four independent confirmations.

Event windows must be sized relative to trigger latency and instrument recovery. If the detector recognises a burst after L seconds and the rolling buffer holds B seconds before the current write index, retaining the complete burst leading edge requires adequate B relative to L plus any additional pipeline and classification delay, with uncertainty and queueing variation. A nominal ten-millisecond ring buffer can lose a short event if trigger decisions are delayed longer by a GPU queue, a storage flush or an expensive classifier. Backpressure therefore requires active monitoring, admission control and a priority path that can preserve the earliest candidate samples. A report should state when the recorder continued

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collecting but could not persist triggered data, rather than presenting the missing event as undetected by the RF channel.

Avoiding so-called dead-air recording must not erase the statistical denominator of a negative finding. A system can preserve lightweight background summaries with timestamps, spectral-noise estimates, threshold versions, coverage masks, observed dropouts and periodic random challenge snippets. A small prespecified fraction of noise-only raw windows can be retained as an audit sample, where authorised, so that an independent examiner can test whether the event detector had become biased by adaptive baselines or unexpectedly structured interference. Unselected intervals may contain below-threshold transmissions. They are properly called unretained, not demonstrated empty. An operator who silently removes them from the history cannot later calculate probability of missed events or explain why no I/Q was saved in a relevant band.

Signal-identification products are a directed acyclic graph of derivatives linked to original samples. A detected event receives a unique identifier, one or more source chunk hashes and exact source sample intervals. Processing nodes may generate a narrow I/Q extraction, a carrier offset estimate, a constellation or modulation feature, a spectrogram, a pulse interval list or legally authorised content recovery. Each derived item retains its processing version, filter passband, time mapping and classification uncertainty. A spectral line which survives a change of software cannot be claimed independent corroboration when both outputs derive from the same raw buffer. The appropriate challenge uses a sufficiently independent measurement path or explicitly acknowledges shared-error structure.

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Validation should include blind inserted events in noise-only stretches, weak pulses of unknown starting phase, frequency-agile emissions crossing slice boundaries, overlapping waveforms, and strong blockers which stress gain and digitiser headroom. Predeclare event-detection and extraction acceptance criteria by waveform class, frequency region, level, duration and operating state. Record both successes and misses. A four-hour observation should be represented by a time-frequency coverage grid and a separate event ledger; the absence of a saved raw file in a grid cell is not itself proof of signal absence. Storage savings, lawful minimisation and evidential integrity are compatible only when the decision to retain or discard samples remains reconstructable and bounded by a disclosed detector capability.

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15.30 Massive I/Q ingestion, GPU scheduling and four-hour storage accounting

Forty gigahertz of genuinely simultaneous useful RF passband is a federation of receiver front ends, converters, frequency translations and channelisers unless a particular instrument independently proves direct acquisition at the required aggregate throughput. The term aggregate is essential. If four hundred nominal hundred-megahertz complex slices cover adjacent, nonoverlapping bands, the ideal complex sample rate totals forty billion samples per second. Practical spectral guard regions, filter transition bands and duplicated overlap must be added if the required useful coverage is still forty gigahertz. Each slice must have a well-defined centre frequency, sign convention and calibrated overlap correction. A stitched 40 GHz heat map assembled from disjoint times does not satisfy the instantaneous requirement, no matter how smooth it looks.

At an ideal forty billion complex samples per second, sixteen-bit I and sixteen-bit Q ingest at 160 decimal GB/s. A 100 millisecond rolling buffer across all slices requires 16 GB of payload in this representation. One second requires 160 GB and thirty seconds 4.8 TB, before headers or replication. The resources can be distributed among receiver nodes with local memory rather than forced into one GPU, but the total cannot be wished away by choosing a smaller FFT bin. A packed fourteen-bit stream requires 140 GB/s of ideal source payload; if each complex pair is padded into two sixteen-bit words before transmission, it requires 160 GB/s on that path. A twenty-four-bit representation requires 240 GB/s and more than 3

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PB if continuously archived for four hours. The source converter's effective number of bits does not improve simply because the storage type is wider.

NVIDIA's cuFFT supplies planned GPU transforms and batched execution, while GPUDirect RDMA can reduce unnecessary host-memory movement on supported device topologies. Neither creates a performance guarantee for an unspecified video card. The system must benchmark achievable sustained samples per second after including frequency translation, channel filters, overlapping FFT windows, scaling, trigger classification, source-to-buffer transfer, event copying, metadata and durable storage. The CPU, FPGA, GPU, NIC and NVMe stages require queue-occupancy and missed-deadline counters. Fixed FFT plan buffers and well-designed asynchronous streams can improve predictability, but shared accelerator memory bandwidth or simultaneous storage traffic may still become the limiting resource.

The fine-resolution branch is particularly expensive if all spectral bins are emitted continuously. Forty gigahertz divided by thirty hertz is approximately 1.333 billion nominal frequency cells. A single four-byte float per cell occupies about 5.333 GB for one complete-resolution spectral image. Twenty such full images per second would constitute about 106.7 GB/s of output, even before metadata or multiple detector estimates. Therefore the spectral engine should create hierarchical products: coarse continuously updated occupancy, targeted fine-resolution bins, sparse peak tables, selected narrowband complex extracts, and independently sampled quality-control tiles. If every full fine-resolution image is still required, the budget must include its output rate just as rigorously as the ADC input rate.

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An FFT calculation is not free merely because the raw IQ was not written to disk.

The observation duration of four hours places a separate demand upon system health. Verify that oscillators remain in qualified states, memory and disk pools do not exhaust, GPU temperatures do not cause unrecorded throttling, and all receiver slices remain aligned. Run controlled known-signal challenges at predeclared intervals without contaminating unrelated survey evidence, and mark calibration-pulse intervals in metadata. Accumulate per-slice coverage, invalid-state time, event retention volume, dropped-block counts and monitoring interruptions. The final report should give these measures alongside detected signals; it should not describe the intended four-hour programme as four hours of valid simultaneous observation if some slices were unavailable or uncalibrated.

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15.31 Archiving policies for fifteen minutes to seventy-two hours of instantaneous forty-gigahertz observation

A receiving installation can claim continuous observation over a specified duration only when its acquisition paths, timestamps, gain states and processing validity remain sufficiently documented throughout that interval. The length of the requested observation is not a cosmetic report field. Fifteen minutes may expose the response to a controlled short laboratory stimulus; sixty minutes may cover several cycles of a periodic building system; four hours may span shifts in local radio occupancy; eight or twelve hours may reveal daypart-related activity; twenty-four and thirty hours may disclose one complete daily pattern plus transition behaviour; and seventy-two hours may expose variations across successive working periods. These are possibilities to test, not reasons to assume that an unobserved transmitter must reveal itself eventually. A three-day observation with a blind frequency region can provide weaker evidence about that region than a ten-minute correctly configured test. The aim of this section is to separate time coverage, spectral detail, preserved waveform content and conclusions defensible from each record.

Adopt the author's system requirement of forty gigahertz of instantaneous aggregate useful receiver bandwidth, continuously analysed by distributed GPU-enabled SDR nodes. Let B denote the summed complex-sampled useful bandwidth, set nominally to 40,000,000,000 hertz, and let R_c denote the corresponding ideal aggregate complex sample rate in sample pairs per second. For a collection of independent complex slices whose usable widths sum to B, the ideal one-sample-per-hertz complex representation has R_c

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approximately equal to B. This is an accounting simplification: oversampling, nonrectangular anti-alias transition bands, overlapping receiver slices and duplicated recording may require a higher actual aggregate data rate. It is not a claim that one commercially specified converter samples a contiguous forty-gigahertz band, nor a claim that usable sensitivity or a four-decibel noise figure holds at every frequency. Each receiver lane must be independently calibrated for its selected preselector, analogue conversion, clock and reference plane.

If b is the stored number of bits for EACH I and Q component, an ideal packed complex pair contains 2b bits. The payload rate R_bytes in bytes per second is R_c times 2b divided by 8. Over an observation of T seconds, uncompressed data volume V_bytes equals R_bytes times T. Both expressions are exact under the stated packed, continuous-sample accounting. Decimal gigabytes and petabytes mean 10^9 and 10^15 bytes, respectively. This avoids the often unnoticed factor-of-two error in calculations that count only I, and the factor-of-eight error in calculations that confuse bits and bytes. It also prevents a 24-bit output container from being described as 24-bit analogue resolution. The acquisition equipment must separately demonstrate actual useful ENOB, bandwidth, signal handling and sample continuity.

The reference cases used here are 8-, 12-, 14-, 16- and 24-bit representations for each component. Their ideal packed payload rates are respectively 80, 120, 140, 160 and 240 decimal gigabytes per second. Real data interfaces frequently pad twelve- and fourteen-bit signed samples to sixteen-bit words, producing the same sixteen-bit transport budget even though the ADC provides fewer nominal bits. Some systems represent twenty-four-bit values

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as thirty-two-bit integers or floating-point words, which similarly increases traffic to 320 decimal gigabytes per second. No storage model should claim the packed saving until the device output, direct-memory-access descriptors, driver, GPU input and archived on-disk format have all been shown to retain the shorter representation. Conversion on ingestion can enlarge the live memory footprint even when the eventual archive is packed.

At fifteen minutes, the requested observation spans 900 seconds; at sixty minutes, 3,600 seconds; at four hours, 14,400 seconds; at eight hours, 28,800 seconds; at twelve hours, 43,200 seconds; at twenty-four hours, 86,400 seconds; at thirty hours, 108,000 seconds; and at seventy-two hours, 259,200 seconds. Each interval is a separate acceptance case, with the acquisition-state ledger required to establish that the receiver was actually observing during that interval rather than merely remaining powered on. A timestamp on a file written after an interruption does not bridge the missing interval, and a checksum on an internally consistent partial file cannot recover samples that never reached the host.

The following complete uncompressed payload matrix is calculated at nominal R_c = 40 billion complex sample pairs per second, using tightly packed I and Q components. For fifteen minutes, the volumes for 8, 12, 14, 16 and 24 bits per component are respectively 0.072, 0.108, 0.126, 0.144 and 0.216 decimal petabytes. For sixty minutes they are 0.288, 0.432, 0.504, 0.576 and 0.864 petabytes. For four hours they are 1.152, 1.728, 2.016, 2.304 and 3.456 petabytes. For eight hours they are 2.304, 3.456, 4.032, 4.608 and 6.912 petabytes. For twelve hours they are 3.456, 5.184, 6.048, 6.912 and 10.368 petabytes. The duration scaling is linear because this example holds aggregate sample rate, precision, and recording duty fraction fixed.

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For twenty-four hours, the same ordered 8-, 12-, 14-, 16- and 24-bit volumes become 6.912, 10.368, 12.096, 13.824 and 20.736 petabytes. For thirty hours they become 8.640, 12.960, 15.120, 17.280 and 25.920 petabytes. For seventy-two hours they become 20.736, 31.104, 36.288, 41.472 and 62.208 petabytes. These values exclude equipment redundancy, filesystem protection, transport encapsulation, storage parity, reanalysis duplicates, logging, receiver-band overlap and uncompressed temporary GPU representations. Their purpose is to define the size of the problem before a product proposal says that the network will simply record all I/Q. A four-hour 16-bit archive is over two petabytes of ideal payload, and a seventy-two-hour archive of the same kind is over forty-one petabytes. Neither figure is a measured system performance result.

The word archive must be qualified by representation. A continuous low-rate occupancy journal can cover the full observation duration while storing only per-band calibration state, selected power statistics and sparse event descriptors. A continuous frequency-time spectral archive can retain high-resolution channel energies, averaged and maximum statistics, occupancy masks, local noise estimates and validity flags, but generally cannot reconstruct the original complex waveform after magnitude formation. A triggered raw-I/Q archive can retain full complex samples in selected frequency-time windows, provided its trigger, ring buffer and export channel actually preserve the relevant precursor and end of the event. Finally, a full-rate raw-I/Q archive preserves the original data representation continuously but requires the extreme throughputs calculated above. These four categories must never be conflated in promotional language or in an evidential report.

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At thirty-hertz nominal bin spacing, forty gigahertz spans about 1.333 billion frequency bins across the distributed receiver slices. A hypothetical single snapshot storing one unsigned sixteen-bit scalar per frequency bin therefore contains about 2.667 decimal gigabytes before timestamps, uncertainty or state metadata. If such full-frequency snapshots are archived once per second for seventy-two hours, the ideal store would contain 691.2 decimal terabytes. If they are archived once every ten seconds, it falls to 69.12 terabytes, but transient persistence within those ten-second intervals cannot be reconstructed from the decimated records. More aggressive quantisation or hierarchical aggregation can reduce this volume further only by surrendering information and documenting exactly which statistics survive. Bin spacing alone does not establish a thirty-hertz equivalent noise bandwidth: the actual window ENBW and overlap processing must also be specified.

Thirty-hertz spectral resolution does not demand a thirty-hertz ADC, nor does it grant thirty-hertz time resolution. The transform input must retain enough observation time for the selected FFT window, and the continuous receiver must simultaneously preserve the fast transient path for pulses whose duration is much shorter than one over thirty seconds. For a fixed complex sample rate f_s per channel and an N-point transform, the nominal spacing is f_s divided by N hertz; the effective noise bandwidth depends upon the selected window and its squared weight. Nonoverlapped thirty-hertz frames cannot describe exactly when a microsecond pulse occurred, even if energy from the pulse influences some of the resulting bins. Use a parallel wideband short-window event detector, a narrow high-resolution

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spectral estimator and a rolling pretrigger waveform buffer, each with an explicit purpose and compatible sample index lineage.

The storage-saving proposition is not to stop observing empty space. It is to stop routinely retaining the most expensive raw representation whenever the authorised measurement objective permits a less informative summary. The full receiver must still monitor all nominal frequency slices throughout the chosen fifteen-minute to seventy-two-hour interval. For each valid slice, record the start and end sample counters, actual sample rate, receiver gain, frequency reference, reference-clock lock, FFT and detector settings, overload condition, packet-loss information, dynamic threshold state and whether the event-preservation pathway was available. A discarded raw interval should be recorded as observed but not waveform-retained only if the corresponding monitoring capability and data quality were demonstrated. A detector failing to identify a low-power or unmodelled signal does not create proof that no signal was present.

Define a retained-bandwidth-time fraction q as the sum over stored event segments of their useful archived bandwidth multiplied by their retained duration, divided by the product of forty gigahertz and the total observation duration. This dimensionless quantity is helpful for first-order payload budgeting only if event segments are nonoverlapping in their underlying source sample intervals and stored at a common precision. Real systems often retain overlapping pretrigger intervals, adjacent filter-guard regions, multiple signal representations or repeated exports, so the actual byte ledger is authoritative. At sixteen bits per I or Q component and a nominal q of 0.1 percent, average retained raw payload would be 160 megabytes per second, equal to approximately 2.304 terabytes over four hours or 41.472

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terabytes over seventy-two hours. At q of one percent, those figures rise tenfold. Those are illustrative duty fractions, not forecasts of actual RF occupancy; an installation surrounded by strong transmitters may spend much longer in triggered preservation.

The retention fraction must never be used to size the shortest-term buffers. A dense simultaneous burst across all monitored bands could require the raw input path to accept the full 80 to 240 gigabytes per second, even if long-term average retention is one-thousandth of that rate. A resilient architecture puts independent, bounded ring buffers near each acquisition node, assigns fast local triggering responsibility to FPGA or host logic, and moves candidate segments to slower durable storage asynchronously. Every transition between memory, GPU and disk has an explicit queue-depth limit and overflow policy. At nominal sixteen-bit complex precision, a five-second pretrigger archive for a one-gigahertz complex slice requires twenty decimal gigabytes before overhead. Forty such slices would need eight hundred gigabytes if the same five-second history were retained simultaneously across the full forty gigahertz. The system must demonstrate that its memory can sustain worst-case concurrent events rather than relying on average occupancy estimates.

For fifteen minutes, a laboratory acceptance exercise can afford intensive whole-band spectral records, short raw buffers and repeated controlled reference injections while testing the most demanding queue and clock transitions. At sixty minutes, stable source operating conditions are more important: periodic gain calibration, rotating file segments, counter rollover, device temperature and GPU scheduler behaviour should be tested without disabling acquisition. A four-hour trial should deliberately include

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simultaneous event arrivals in several frequency slices, and should verify sustained disk flushing as well as the return of the buffers to their designated free-space watermark. In each case, test no-event intervals with a known weak injected event to determine whether the classifier may be silently missing the very waveform category for which a negative report is contemplated.

At eight and twelve hours, inspect oscillator holdover, synchronisation sources, sustained thermal load and the complete distribution of queue latencies rather than merely their average. A narrow ring-buffer margin that survives a quiet fifteen-minute test may fail during repeated bursts later in the observation. At twenty-four hours, assess day-night environmental drift, equipment-state changes and unintended daily patterns in the triggering threshold. The archive should retain a continuous coverage timeline so that a rise in reported event count can be separated from a gain adjustment or a changed spectral threshold. Daily summary records should be derived from retained raw events and validated spectral statistics, not from a user's manual notation of apparently quiet periods.

A thirty-hour run deliberately exceeds a conventional twenty-four-hour cycle and is useful for examining whether clock, thermal or signal-occupancy patterns repeat at different local times; the analyst must not infer stationarity from one repeated observation. A seventy-two-hour campaign raises problems of disk wear, transient backlog, reference-source changes, leap-second or time-scale representation, software revisions, and unattended failures. Design the experiment to include controlled loss-of-reference and dropped-packet tests that are marked explicitly rather than buried. Automated checkpointing should produce cryptographically

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verifiable manifests for completed recording epochs, and a restart should create a new provenance epoch linked to the preceding one, never a fictitious uninterrupted interval. Seven decades of forensic rhetoric cannot repair seven seconds of unrecorded source data.

The signal-extraction workflow operates on indexed candidates rather than blindly reprocessing the entire forty-gigahertz archive at full precision. Each candidate starts with an RF frequency interval, start and stop sample indices, receiver and clock identities, detector explanation, selection-threshold history and confidence or uncertainty statement. The extractor locates raw ring-buffer slices, retrieves the original packed representation, verifies sample continuity, converts to complex numerical coordinates with an explicitly documented scale, and selects a digital mixing and decimation path with appropriate anti-alias filtering. It then computes the permitted features: instantaneous frequency, amplitude and phase tracks, pulse-repetition pattern, modulation and code hypotheses, and spectral neighbourhood. Compare candidate features with independent reference recordings or held-out test conditions before declaring a waveform class. Do not treat a decoder's successful output as proof of source identity, physical location or legal authority to inspect carried content.

An event should retain its original complex samples plus a separate, reproducible chain of derived products. Record original sample number, original converter width, byte ordering, sign convention, physical centre frequency, acquisition rate, reference-clock condition, gain and analogue path, filter definitions, group-delay and decimation relationships, calibration dataset identifiers, processing-software digest, extracted signal classification and human examination. The metadata schema may follow the

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public Signal Metadata Format where appropriate, extended with clearly versioned private provenance fields. Such metadata describes a preserved record; it does not prove that the detector discovered every signal during unretained intervals. Encryption, retention periods and disclosure should be bounded by the lawful defensive purpose and the applicable jurisdiction.

The proper archival acceptance test is two-dimensional. First, establish whether the installation continuously observed the required forty gigahertz, including receiver overlap regions, clock lock, sample continuity, storage availability and successful coverage manifests, for each of the specified durations. Second, establish which event families, levels, widths, modulations and arrival times the detector preserves reliably, with known false-positive and false-negative characteristics under representative blockers and environmental changes. A system can satisfy coverage while missing a specified weak pulse because its trigger is insensitive; it can satisfy pulse detection in selected bands while failing forty-gigahertz continuity; and it can preserve raw events while mislabelling the waveform due to I/Q sign error. Publication-quality claims must report these possibilities separately, with quantitative results attributed to actual tests rather than projected storage arithmetic.

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Chapter Summary

Receiver coverage depends on time as well as sensitivity. Trigger behavior, pretrigger context, sample continuity, metadata, and reproducible processing determine whether an intermittent event can support a durable technical conclusion.

Model 15A begins with usable acquisition intervals and a positive contiguous-overlap criterion. It derives eligible event starts, merges their periodic union and introduces a phase distribution only when justified. Uniform timing, independent repeated trials and known detector capability are separate premises. A phase-locked event can miss indefinitely, and disconnected fragments do not become one uninterrupted capture.

The trigger and recording paths can observe different representations of the same event. Test their relationship with controlled stimuli, including closely spaced events and required pretrigger context. Preserve state changes and the timing reference of the trigger. A successful isolated pulse does not establish recovery behavior, full-event capture or availability throughout a nominal dwell.

Record the actual sample encoding and sustained storage behavior. Counters, validity flags and gap records establish acquisition continuity; hashes establish later byte consistency. Bind derived results to native samples, corrections and processing parameters. Reconcile planned, commanded, valid and preserved coverage before reporting a negative result, retaining the event classes and intervals that were never tested.

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Chapter 15 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C15-MCQ-001. What constitutes a qualifying capture in Model 15A?

A. One valid record supplies the specified positive contiguous overlap, with detector prerequisites satisfied

B. Several disconnected fragments have the same total duration

C. A tuning command was issued during the event

D. A trigger indicator illuminated regardless of sample validity

Answer: A. The criterion applies to one usable contiguous record and is conditional on detectability. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: One valid record supplies the specified positive contiguous overlap, with detector prerequisites satisfied.

Distinguishing consideration: compare this with option B, “Several disconnected fragments have the same total duration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-002. For window [a,a+D] and event duration b, which eligible-start interval applies when $0<r\leq min(b,D)$?

A. [a+r−b,a+D−r]

B. [a−b,a+D]

C. [a+r,a+D+b−r]

D. [a,a+D+b]

Answer: A. The two ends enforce at least r contiguous overlap with the event.

Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: [a+r−b,a+D−r].

Distinguishing consideration: compare this with option B, "[a−b,a+D]"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-003. Why merge eligible-start intervals before finding capture probability?

A. Their lengths are always equal

B. The same event phase can qualify in more than one window

C. Every window is statistically independent by definition

D. The union makes detector sensitivity irrelevant

Answer: B. Union length counts each eligible phase once. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: The same event phase can qualify in more than one window.

Distinguishing consideration: compare this with option A, “Their lengths are always equal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-004. In Application 15A.1, why not obtain a point-event rule by setting r=0 in the non-strict overlap test?

A. Even disjoint intervals satisfy overlap at least zero

B. A point event must be captured in every window

C. The schedule period would become zero

D. A point event necessarily has infinite bandwidth

Answer: A. The separate rule requires the instant to fall inside a usable window.

Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why the selected alternative fits: Even disjoint intervals satisfy overlap at least zero.

Distinguishing consideration: compare this with option B, “A point event must be captured in every window”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-MCQ-005. In Application 15A.7, what happens when a fixed-phase event repeatedly misses the same periodic window?

A. Its capture probability automatically approaches one with file count

B. It can miss indefinitely

C. Its phase becomes uniform after ten events

D. The receiver noise figure improves with repetition

Answer: B. A new independent phase experiment or changed schedule is needed.

Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

Why the selected alternative fits: It can miss indefinitely.

Distinguishing consideration: compare this with option A, “Its capture probability automatically approaches one with file count”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-C15-MCQ-006. In Application 15A.8, why keep a continuous window crossing the period origin intact on an unfolded axis?

A. Every adjacent file is necessarily continuous

B. A modulo operation eliminates actual acquisition gaps

C. The overlap criterion can then ignore event duration

D. The coordinate origin must not destroy genuine sample continuity

Answer: D. Coordinate boundaries and physical gaps are different. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why the selected alternative fits: The coordinate origin must not destroy genuine sample continuity.

Distinguishing consideration: compare this with option A, “Every adjacent file is necessarily continuous”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-MCQ-007. What must supplement a preserved-file hash to support acquisition continuity?

A. The receiver model's advertised sample rate alone

B. A screenshot of the file's spectrum alone

C. A second copy of the same hash alone

D. Sample counters, sequences, validity flags and gap records

Answer: D. Hash agreement establishes byte consistency, not original sample completeness. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Sample counters, sequences, validity flags and gap records.

Distinguishing consideration: compare this with option A, “The receiver model's advertised sample rate alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-008. Why use stored representation rather than ADC resolution in data-rate accounting?

A. Headers are already included in converter resolution

B. ADC resolution always equals file word width

C. Complex samples contain only one component

D. Container width, components and packing determine stored bytes

Answer: D. A 12-bit converter can be stored in a 16-bit container. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Container width, components and packing determine stored bytes.

Distinguishing consideration: compare this with option A, “Headers are already included in converter resolution”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-009. Why can a sensitive receiver miss an intermittent signal?

A. Its usable time, frequency or state coverage may not include the event

B. A missed event proves the source is absent

C. Adequate sensitivity guarantees every event is recorded

D. Sensitivity fixes the revisit phase automatically

Answer: A. Time and configuration coverage are independent requirements. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

Why the selected alternative fits: Its usable time, frequency or state coverage may not include the event.

Distinguishing consideration: compare this with option B, “A missed event proves the source is absent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Probability of Intercept and Observation Strategy.

Review: Chapter 15 — Probability of Intercept and Observation Strategy.

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V011-C15-MCQ-010. Which evidence requirement typically needs more than an identifiable fragment?

A. Computing the nominal schedule period

B. Establishing that some qualifying fragment occurred

C. Preserving complete startup and event boundaries

D. Recording one valid sample already inside a declared fragment

Answer: C. Different scientific questions require different contiguous durations and context. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: Preserving complete startup and event boundaries.

Distinguishing consideration: compare this with option A, “Computing the nominal schedule period”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-011. Which interval should define usable dwell?

A. The interval from tuning command to next command regardless of response

B. The display's acquisition-indicator interval alone

C. The interval remaining after demonstrated settling, recovery and validity exclusions

D. The saved file's nominal timestamp span without continuity checks

Answer: C. Commands, indicators and valid samples can have different boundaries.

Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: The interval remaining after demonstrated settling, recovery and validity exclusions.

Distinguishing consideration: compare this with option A, “The interval from tuning command to next command regardless of response”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-012. Does Model 15A establish a detector threshold or false-alarm rate?

A. No; therefore timing geometry is never useful

B. Yes; uniform event phase implies perfect detection

C. Yes; union length determines both

D. No; detector validity is a separate prerequisite

Answer: D. The model isolates conditional capture opportunity. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: No; detector validity is a separate prerequisite.

Distinguishing consideration: compare this with option A, “No; therefore timing geometry is never useful”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-013. What assumption permits capture probability to equal eligible-start union length divided by period?

A. Uniform event start phase over that period

B. Ignorance of the actual phase alone

C. A periodic event sharing the receiver clock

D. Equal numbers of saved files per hour

Answer: A. Uniformity is a stated event-phase law, not a default consequence of missing knowledge. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: Uniform event start phase over that period.

Distinguishing consideration: compare this with option B, “Ignorance of the actual phase alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-014. What changes for a known fixed event phase?

A. Multiply file count by dwell fraction

B. Assign probability one half regardless of geometry

C. Use the uniform length ratio as the actual deterministic outcome

D. Evaluate whether that phase belongs to the eligible set

Answer: D. A deterministic coverage statement replaces an unsupported uniform average. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: Evaluate whether that phase belongs to the eligible set.

Distinguishing consideration: compare this with option A, “Multiply file count by dwell fraction”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-015. In Application 15A.4, when is the eligible-start set empty?

A. Whenever a window crosses the period origin

B. Whenever the event begins before the window

C. Whenever the phase distribution is uniform

D. When required overlap exceeds the event or usable-window duration

Answer: D. No interval intersection can exceed either interval's length. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

Why the selected alternative fits: When required overlap exceeds the event or usable-window duration.

Distinguishing consideration: compare this with option A, “Whenever a window crosses the period origin”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

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V011-C15-MCQ-016. For one feasible window, what is the unfolded eligible-start length?

A. $D-b-2r$

B. $D+b-2r$

C. $D+b+r$

D. D alone in every case

Answer: B. Subtract the derived interval endpoints. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: $D+b-2r$.

Distinguishing consideration: compare this with option A, "$D-b-2r$"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-017. Why is the single-window periodic result capped at one?

A. Every event becomes independent after one period

B. Modulo reduction cannot cover more than one full period of start phases

C. The detector always responds exactly once

D. The event amplitude is capped

Answer: B. Probability is union length divided by period. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: Modulo reduction cannot cover more than one full period of start phases.

Distinguishing consideration: compare this with option A, “Every event becomes independent after one period”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-018. What is required before joining two adjacent recorded files as one continuous record?

A. Only matching center-frequency labels

B. Only adjacent displayed timestamps

C. Evidence that acquisition remained continuous across the boundary

D. Only equal file sizes

Answer: C. A file boundary need not be a gap, but continuity must be established.

Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: Evidence that acquisition remained continuous across the boundary.

Distinguishing consideration: compare this with option A, “Only matching center-frequency labels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-019. If two short overlaps lie on opposite sides of a real gap, do their durations satisfy one contiguous-overlap requirement?

A. Yes; modulo reduction removes the gap

B. Yes; only their sum matters

C. Only if the files have equal hashes

D. No; the gap interrupts the required record

Answer: D. Combining fragments would require a different justified evidence criterion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: No; the gap interrupts the required record.

Distinguishing consideration: compare this with option A, “Yes; modulo reduction removes the gap”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-020. In Application 15A.3, what does a change from fragment capture to whole-event capture alter?

A. Nothing if the detector recognizes the waveform

B. Only file naming

C. Only the event's physical amplitude

D. The eligible-start set even with the same event and schedule

Answer: D. The success criterion determines which starts qualify. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

Why the selected alternative fits: The eligible-start set even with the same event and schedule.

Distinguishing consideration: compare this with option A, “Nothing if the detector recognizes the waveform”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.3: Require the whole burst.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

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V011-C15-MCQ-021. In Application 15A.1, for T=100 ms and usable [10,30] ms, what is uniform ideal-point capture probability?

A. 0.50

B. 0.10

C. 0.30

D. 0.20

Answer: D. The usable length is 20 ms out of 100 ms. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why the selected alternative fits: 0.20.

Distinguishing consideration: compare this with option A, “0.50”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-MCQ-022. In Application 15A.1, for that window and a 0.1 ms event requiring complete capture, what start interval qualifies?

A. [10,30.1] ms

B. [9.9,30] ms

C. [10,29.9] ms

D. [10.1,30] ms

Answer: C. The entire event must end by 30 ms. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why the selected alternative fits: [10,29.9] ms.

Distinguishing consideration: compare this with option A, "[10,30.1] ms"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-MCQ-023. In Application 15A.1, what is the complete 0.1 ms event probability in that example?

A. 0.199

B. 0.201

C. 0.099

D. 0.200

Answer: A. The eligible interval length is 19.9 ms. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why the selected alternative fits: 0.199.

Distinguishing consideration: compare this with option B, “0.201”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-MCQ-024. In Application 15A.2, for [10,30] ms, b=5 ms and r=1 ms, which starts qualify?

A. [10,25] ms

B. [5,30] ms

C. [9,34] ms

D. [6,29] ms

Answer: D. Use a+r−b and a+D−r. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

Why the selected alternative fits: [6,29] ms.

Distinguishing consideration: compare this with option A, "[10,25] ms"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

Review: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

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V011-C15-MCQ-025. In Application 15A.2, what conditional probability follows from that 23 ms eligible interval with 100 ms period?

A. 0.15

B. 0.20

C. 0.23

D. 0.46

Answer: C. Eligible start phase can precede the usable window when an event tail suffices. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

Why the selected alternative fits: 0.23.

Distinguishing consideration: compare this with option A, “0.15”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

Review: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

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V011-C15-MCQ-026. In Application 15A.2, why can fragment-capture probability exceed the point dwell fraction?

A. The event phase is necessarily nonuniform

B. The receiver secretly observes longer than its dwell

C. The detector becomes noiseless for longer events

D. A finite event beginning outside the window may overlap it sufficiently

Answer: D. The geometry concerns event starts, not merely acquisition duration.

Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

Why the selected alternative fits: A finite event beginning outside the window may overlap it sufficiently.

Distinguishing consideration: compare this with option A, "The event phase is necessarily nonuniform"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

Review: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

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V011-C15-MCQ-027. In Application 15A.3, for [10,30] ms and a whole 5 ms event, which start interval qualifies?

A. [10,25] ms

B. [6,29] ms

C. [10,30] ms

D. [5,30] ms

Answer: A. Whole capture requires both boundaries inside the valid record. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

Why the selected alternative fits: [10,25] ms.

Distinguishing consideration: compare this with option B, "[6,29] ms"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.3: Require the whole burst.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

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V011-C15-MCQ-028. In Application 15A.3, what whole-event probability follows in the 100 ms schedule?

A. 0.23

B. 0.20

C. 0.25

D. 0.15

Answer: D. The complete-event start interval is 15 ms long. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

Why the selected alternative fits: 0.15.

Distinguishing consideration: compare this with option A, “0.23”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.3: Require the whole burst.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

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V011-C15-MCQ-029. In Application 15A.4, can a 2 ms event meet a 3 ms contiguous observation requirement with any longer dwell?

A. Yes, if its start is uniform

B. No

C. Yes, if the dwell exceeds 3 ms

D. Yes, if repeated 100 times

Answer: B. The event itself is too short for the specified criterion. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

Why the selected alternative fits: No.

Distinguishing consideration: compare this with option A, "Yes, if its start is uniform"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

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V011-C15-MCQ-030. In Application 15A.4, could combining several repeatable short events answer a different measurement question?

A. No, separated observations can never support any inference

B. Yes, and it automatically satisfies the original one-event criterion

C. Yes, without recording the combination rule

D. Yes, with a new justified repeatability and estimator model

Answer: D. A revised analysis must be explicit rather than relabeled as the original impossible capture. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

Why the selected alternative fits: Yes, with a new justified repeatability and estimator model.

Distinguishing consideration: compare this with option A, “No, separated observations can never support any inference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

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V011-C15-MCQ-031. In Application 15A.5, a nominal [0,30] ms dwell loses 4 ms settling and 3 ms closing guard. What is usable?

A. [7,30] ms

B. [4,30] ms

C. [4,27] ms

D. [0,23] ms

Answer: C. Both verified exclusions apply at their respective ends. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why the selected alternative fits: [4,27] ms.

Distinguishing consideration: compare this with option A, "[7,30] ms"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-MCQ-032. In Application 15A.5, for that usable interval, b=8 ms and r=2 ms, what unfolded start interval qualifies?

A. [4,19] ms

B. [−6,28] ms

C. [2,27] ms

D. [−2,25] ms

Answer: D. Compute 4+2−8 and 27−2. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why the selected alternative fits: [−2,25] ms.

Distinguishing consideration: compare this with option A, “[4,19] ms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-MCQ-033. In Application 15A.5, what is its union modulo 100 ms?

A. [98,100) together with [0,25] ms

B. [−2,25] ms without reduction

C. [0,27] ms only

D. [2,25] ms only

Answer: A. The negative start portion wraps to the end of the period. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why the selected alternative fits: [98,100) together with [0,25] ms.

Distinguishing consideration: compare this with option B, "[−2,25] ms without reduction"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-MCQ-034. In Application 15A.5, what probability results after the stated guards?

A. 0.23

B. 0.34

C. 0.27

D. 0.30

Answer: C. The union spans 2+25=27 ms. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why the selected alternative fits: 0.27.

Distinguishing consideration: compare this with option A, “0.23”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-MCQ-035. In Application 15A.5, why is the unguarded 0.34 estimate unsuitable for that verified receiver state?

A. It is always too low for every receiver

B. It double-counts both I and Q

C. It counts acquisition time known to be unusable

D. It assumes a smaller burst than specified

Answer: C. The valid interval, not nominal dwell, governs the geometry. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why the selected alternative fits: It counts acquisition time known to be unusable.

Distinguishing consideration: compare this with option A, “It is always too low for every receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-MCQ-036. In Application 15A.5, if settling depends on previous gain state, what should the record retain?

A. Only the tuning-command time

B. Only the final gain state

C. The applicable transition class and measured exclusion

D. One optimistic universal guard

Answer: C. Transition history can affect when data become usable. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why the selected alternative fits: The applicable transition class and measured exclusion.

Distinguishing consideration: compare this with option A, “Only the tuning-command time”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-MCQ-037. In Application 15A.6, for windows [10,25] and [28,43] ms, b = 20 ms and r = 5 ms, what are eligible intervals?

A. [−5,20] and [13,38] ms

B. [10,20] and [28,38] ms

C. [−10,25] and [8,43] ms

D. [5,30] and [23,48] ms

Answer: A. Apply the one-window bounds to each usable record separately. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why the selected alternative fits: [−5,20] and [13,38] ms.

Distinguishing consideration: compare this with option B, "[10,20] and [28,38] ms"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-MCQ-038. In Application 15A.6, what overlap of those eligible-start intervals would be double-counted by adding their lengths?

A. [20,28] ms

B. [25,28] ms

C. [10,13] ms

D. [13,20] ms

Answer: D. The 7 ms overlap represents starts qualifying in either record. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why the selected alternative fits: [13,20] ms.

Distinguishing consideration: compare this with option A, "[20,28] ms"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-MCQ-039. In Application 15A.6, what is the merged conditional probability for those windows in 100 ms?

A. 0.57

B. 0.50

C. 0.43

D. 0.30

Answer: C. The two 25 ms lengths share 7 ms, leaving 43 ms. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why the selected alternative fits: 0.43.

Distinguishing consideration: compare this with option A, “0.57”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-MCQ-040. In Application 15A.6, does merging eligible-start sets permit adding two individually insufficient waveform fragments?

A. Yes; any two partial overlaps become one record

B. Only when the windows have equal length

C. No; the union is over starts qualifying in at least one record

D. Yes; overlap of start sets creates sample continuity

Answer: C. Set union avoids double counting without altering the contiguous criterion. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why the selected alternative fits: No; the union is over starts qualifying in at least one record.

Distinguishing consideration: compare this with option A, "Yes; any two partial overlaps become one record"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-MCQ-041. In Application 15A.7, a 5 ms event always starts at phase 50 ms and the usable window is [10,30] ms. How many of 100 identical repetitions qualify?

A. 0

B. 23

C. 100

D. 20

Answer: A. The fixed event remains outside the usable interval every time. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

Why the selected alternative fits: 0.

Distinguishing consideration: compare this with option B, “23”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-C15-MCQ-042. In Application 15A.7, moving that usable window to [49,69] ms gives how many complete captures for the same 100 events?

A. 0

B. 100

C. 23

D. 20

Answer: B. Each fixed event [50,55] lies inside the new usable interval. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

Why the selected alternative fits: 100.

Distinguishing consideration: compare this with option A, “0”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-C15-MCQ-043. In Application 15A.7, why is neither count a random estimate in the constructed fixed-phase example?

A. The event/schedule relationship is deterministic

B. The number 100 is too small for probability

C. All receiver experiments are deterministic

D. A fixed phase implies zero noise in every instrument

Answer: A. The stipulated timing specifies the outcome directly. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

Why the selected alternative fits: The event/schedule relationship is deterministic.

Distinguishing consideration: compare this with option B, “The number 100 is too small for probability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-C15-MCQ-044. In Application 15A.8, for a continuous window [90,110] ms, b = 15 ms and r = 12 ms, what eligible starts occur before modulo reduction?

A. [90,95] ms

B. [87,98] ms

C. [78,113] ms

D. [0,10] ms

Answer: B. Keeping the 20 ms window intact gives 90+12−15 through 110−12.

Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why the selected alternative fits: [87,98] ms.

Distinguishing consideration: compare this with option A, “[90,95] ms”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-MCQ-045. In Application 15A.8, what conditional probability follows in a 100 ms period?

A. 0.11

B. 0

C. 0.22

D. 0.20

Answer: A. The eligible interval is 11 ms long. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why the selected alternative fits: 0.11.

Distinguishing consideration: compare this with option B, “0”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-MCQ-046. In Application 15A.8, an event starts at 95 ms and lasts 15 ms in that window. What overlap occurs?

A. 15 ms, so it qualifies

B. 12 ms exactly because r is 12

C. 10 ms, so it fails

D. 5 ms, so it fails

Answer: A. The event [95,110] lies wholly within [90,110]. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why the selected alternative fits: 15 ms, so it qualifies.

Distinguishing consideration: compare this with option B, “12 ms exactly because r is 12”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-MCQ-047. In Application 15A.8, the same periodic schedule sees a 15 ms event starting at phase 0. What relevant overlap occurs?

A. 20 ms, so it qualifies

B. 10 ms, so it fails the 12 ms criterion

C. 0 ms because period zero is forbidden

D. 15 ms, so it qualifies

Answer: B. The event [0,15] overlaps the previous window [−10,10] for 10 ms.

Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why the selected alternative fits: 10 ms, so it fails the 12 ms criterion.

Distinguishing consideration: compare this with option A, “20 ms, so it qualifies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-MCQ-048. In Application 15A.8, what error results from splitting the continuous [90,110] ms record at displayed zero?

A. The event duration doubles

B. A genuine rearm gap is preserved

C. Both apparent 10 ms pieces falsely seem too short for the 12 ms criterion

D. Capture probability becomes exactly correct by definition

Answer: C. The representational boundary is not a physical interruption. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why the selected alternative fits: Both apparent 10 ms pieces falsely seem too short for the 12 ms criterion.

Distinguishing consideration: compare this with option A, “The event duration doubles”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-MCQ-049. Under independent common-probability trials, what is the chance of at least one capture?

A. np for all n

B. $(1-p)^n$

C. p^n

D. $1-(1-p)^n$

Answer: D. Take the complement of all independent misses. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: $1-(1-p)^n$.

Distinguishing consideration: compare this with option A, “np for all n”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-050. In Application 15A.9, which observation alone fails to establish trial independence?

A. A controlled event-generation protocol that justifies independent phases

B. A randomized phase protocol with its assumptions checked

C. An explicitly stated validated joint timing model

D. Ten different timestamps in a field log

Answer: D. Distinct records can share periodic timing or triggers. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

Why the selected alternative fits: Ten different timestamps in a field log.

Distinguishing consideration: compare this with option A, “A controlled event-generation protocol that justifies independent phases”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

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V011-C15-MCQ-051. In Application 15A.9, for p = 0.23 and 10 independent trials, what is at-least-one probability?

A. 0.23

B. About 0.926733195

C. About 0.073266805

D. 2.30

Answer: B. The final alternative is the all-miss probability. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

Why the selected alternative fits: About 0.926733195.

Distinguishing consideration: compare this with option A, “0.23”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

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V011-C15-MCQ-052. In Application 15A.10, for the same p and target 0.99, what minimum integer trial count is required?

A. 10

B. 19

C. 18

D. 17

Answer: C. The ceiling of the logarithmic ratio is 18; 17 falls below target. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

Why the selected alternative fits: 18.

Distinguishing consideration: compare this with option A, “10”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

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V011-C15-MCQ-053. In Application 15A.10, why check the preceding integer when solving the trial-count formula?

A. To prove the phases are independent

B. To verify minimality and upward rounding at the boundary

C. To remove the need for the target probability

D. To estimate detector sensitivity from arithmetic alone

Answer: B. The model premises remain separate from the integer calculation.

Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

Why the selected alternative fits: To verify minimality and upward rounding at the boundary.

Distinguishing consideration: compare this with option A, “To prove the phases are independent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

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V011-C15-MCQ-054. If single-trial p=0, can any finite trial count reach a positive capture target?

A. Yes, if the target is below 0.5

B. Yes, because logarithms are finite at p = 0

C. No

D. Yes, if n exceeds 100

Answer: C. No trial supplies an opportunity under that model. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: No.

Distinguishing consideration: compare this with option A, "Yes, if the target is below 0.5"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-055. If single-trial p=1, how many valid trials suffice for a positive target no greater than one?

A. An unbounded number

B. One

C. Zero

D. Two

Answer: B. A valid trial succeeds with certainty within the stated conditional model.

Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: One.

Distinguishing consideration: compare this with option A, “An unbounded number”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-056. With 0<p<1, can a finite number of independent trials attain target exactly one?

A. Yes, if np exceeds one

B. No

C. Yes, if p is rational

D. Yes, whenever n is rounded upward

Answer: B. The all-miss probability remains positive for finite n. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: No.

Distinguishing consideration: compare this with option A, "Yes, if np exceeds one"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-057. For independent unequal probabilities $p_1 = 0.2$ and $p_2 = 0.5$, what is at-least-one capture probability?

A. 0.70

B. 0.60

C. 0.40

D. 0.10

Answer: B. One minus(.8×.5)=.60. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: 0.60.

Distinguishing consideration: compare this with option A, “0.70”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-058. If repeated trials are correlated, what replaces an unsupported product of miss probabilities?

A. A justified joint distribution or defensible bound

B. The same product with renamed trials

C. An assumption that all correlations are zero

D. A larger count to force independence

Answer: A. Dependence is part of the probability model. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why the selected alternative fits: A justified joint distribution or defensible bound.

Distinguishing consideration: compare this with option B, “The same product with renamed trials”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-MCQ-059. In Application 15A.9, if the schedule adapts after each miss, what must be preserved?

A. The adaptive rule and resulting experiment

B. An assertion that adaptation implies independence

C. Only the final count under the original fixed model

D. Only successful trials

Answer: A. The original fixed-trial expression may no longer describe the experiment. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

Why the selected alternative fits: The adaptive rule and resulting experiment.

Distinguishing consideration: compare this with option B, “An assertion that adaptation implies independence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

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V011-C15-MCQ-060. What limits a trigger placed after narrow filtering?

A. It necessarily sees every full-rate sample feature

B. It cannot respond to precursors outside that trigger passband

C. It proves the complete event was retained

D. Its bandwidth equals the saved waveform's bandwidth in all designs

Answer: B. Trigger location determines what signal representation it observes.

Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

Why the selected alternative fits: It cannot respond to precursors outside that trigger passband.

Distinguishing consideration: compare this with option A, “It necessarily sees every full-rate sample feature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Trigger Types and Pretrigger Context.

Review: Chapter 15 — Trigger Types and Pretrigger Context.

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V011-C15-MCQ-061. Why can a trigger after AGC be delayed or suppressed?

A. The input RF event must have changed

B. Control behavior changes the statistic reaching the trigger

C. AGC guarantees fixed trigger latency

D. A trigger threshold defines sample-clock phase

Answer: B. The actual trigger path must be characterized. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

Why the selected alternative fits: Control behavior changes the statistic reaching the trigger.

Distinguishing consideration: compare this with option A, “The input RF event must have changed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Trigger Types and Pretrigger Context.

Review: Chapter 15 — Trigger Types and Pretrigger Context.

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V011-C15-MCQ-062. Can a brief event pass through a recorder but fail its trigger?

A. Only if the file hash changes

B. Yes, if trigger bandwidth or timing is inadequate

C. No, saved and trigger paths are always identical

D. No, an acquisition light guarantees trigger response

Answer: B. The paths can use different rate, filtering and statistics. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why the selected alternative fits: Yes, if trigger bandwidth or timing is inadequate.

Distinguishing consideration: compare this with option A, “Only if the file hash changes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-MCQ-063. What should a known trigger-test stimulus represent?

A. Only a convenient strong isolated CW tone

B. Only average input power

C. Only the receiver's center-frequency label

D. Relevant edge, duration, level, modulation and prior quiet interval

Answer: D. The test must exercise the event and recovery conditions that matter.

Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why the selected alternative fits: Relevant edge, duration, level, modulation and prior quiet interval.

Distinguishing consideration: compare this with option A, “Only a convenient strong isolated CW tone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-MCQ-064. Why use controlled pairs of events in trigger validation?

A. To prove absolute time traceability without a reference

B. To test retrigger, holdoff and rearm behavior

C. To make all events independent automatically

D. To double the amplitude calibration range

Answer: B. An isolated pulse cannot expose all recovery misses. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why the selected alternative fits: To test retrigger, holdoff and rearm behavior.

Distinguishing consideration: compare this with option A, “To prove absolute time traceability without a reference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-MCQ-065. What can invalidate early pretrigger samples for a causal comparison?

A. The event being visible near the trigger

B. A tuning or gain-state change inside the buffer

C. A stable continuous state throughout

D. A sufficient nominal buffer length with validated samples

Answer: B. Depth is useful only when the retained samples are valid and comparable. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why the selected alternative fits: A tuning or gain-state change inside the buffer.

Distinguishing consideration: compare this with option A, “The event being visible near the trigger”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-MCQ-066. What must be known if the trigger timestamp refers to a software event rather than a sample aperture?

A. That the trigger name includes real time

B. Only the computer's wall-clock display

C. Only the record's file modification time

D. Its measured relationship to stored sample time

Answer: D. Trigger and acquisition clocks or processing can differ. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why the selected alternative fits: Its measured relationship to stored sample time.

Distinguishing consideration: compare this with option A, “That the trigger name includes real time”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-MCQ-067. What evidence establishes complete-event capture?

A. A recognizable fragment alone

B. A large file with unknown gaps

C. A trigger-centered display alone

D. Both event boundaries and required context within one verified continuous record

Answer: D. The claim requires retained boundaries and continuity. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why the selected alternative fits: Both event boundaries and required context within one verified continuous record.

Distinguishing consideration: compare this with option A, “A recognizable fragment alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-MCQ-068. What does a qualifying-fragment claim leave unknown?

A. The declared contiguous interval

B. The actual recorded trigger state when known

C. Unobserved beginning and end

D. The existence of all observed samples

Answer: C. The narrower claim must retain its boundary limitations. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why the selected alternative fits: Unobserved beginning and end.

Distinguishing consideration: compare this with option A, “The declared contiguous interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-MCQ-069. Why include post-event record time?

A. To eliminate storage overhead

B. To preserve relevant settling or recovery context

C. To make trigger latency exactly zero

D. To prove all earlier pretrigger samples were valid

Answer: B. Context extends on both sides according to the measurement question.

Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

Why the selected alternative fits: To preserve relevant settling or recovery context.

Distinguishing consideration: compare this with option A, “To eliminate storage overhead”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Trigger Types and Pretrigger Context.

Review: Chapter 15 — Trigger Types and Pretrigger Context.

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V011-C15-MCQ-070. Which acquisition defect can produce false transients if concealed by byte concatenation?

A. A correctly recorded continuous sequence

B. A known constant scale factor applied consistently

C. Dropped sample blocks

D. A documented stable sample rate

Answer: C. Removing the time gap changes the relation between sample index and elapsed time. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Dropped sample blocks.

Distinguishing consideration: compare this with option A, “A correctly recorded continuous sequence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-071. What does a repeated sample block threaten?

A. Only the file's human-readable title

B. Continuity and spectral/timing interpretation

C. Only absolute antenna gain

D. Nothing if the file length is correct

Answer: B. A file can have expected size yet contain duplicated rather than new samples. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

Why the selected alternative fits: Continuity and spectral/timing interpretation.

Distinguishing consideration: compare this with option A, “Only the file's human-readable title”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Wideband Recording and Data Integrity.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-MCQ-072. Why hash stable files after closure?

A. To determine analog receiver linearity

B. To replace all metadata

C. To bind the completed preserved bytes to the record

D. To prove no original samples were dropped

Answer: C. A hash made before the final bytes change would describe a different file. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

Why the selected alternative fits: To bind the completed preserved bytes to the record.

Distinguishing consideration: compare this with option A, “To determine analog receiver linearity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Wideband Recording and Data Integrity.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-MCQ-073. What is a risk of triggered segmented acquisition for occupancy estimates?

A. It preferentially retains triggered intervals and omits other time

B. It guarantees a uniform event sample

C. It automatically measures all quiet intervals

D. It eliminates trigger selection bias

Answer: A. The retained population depends on the trigger and schedule. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

Why the selected alternative fits: It preferentially retains triggered intervals and omits other time.

Distinguishing consideration: compare this with option B, “It guarantees a uniform event sample”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Wideband Recording and Data Integrity.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-MCQ-074. What can bind a separate metadata file to native samples?

A. A similar filename alone

B. A screenshot showing both icons

C. A controlled manifest with binding hashes

D. The same creation date alone

Answer: C. The association must be reconstructable and controlled. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

Why the selected alternative fits: A controlled manifest with binding hashes.

Distinguishing consideration: compare this with option A, “A similar filename alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Wideband Recording and Data Integrity.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-MCQ-075. Why test sustained writing for the planned duration?

A. Short bursts can be buffered despite inadequate long-run throughput

B. Storage capacity alone guarantees continuity

C. A file hash reveals all prior buffer overruns

D. Peak benchmark speed always equals sustained speed

Answer: A. The steady recording path and failure indicators must be exercised.

Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Short bursts can be buffered despite inadequate long-run throughput.

Distinguishing consideration: compare this with option B, “Storage capacity alone guarantees continuity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-076. Which representation information is required to interpret native sample words?

A. Byte order, signedness, scale, packing and channel/component arrangement

B. Only center frequency

C. Only the total file size

D. Only converter nominal bit depth

Answer: A. The same bytes can represent different values under different conventions. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Byte order, signedness, scale, packing and channel/component arrangement.

Distinguishing consideration: compare this with option B, “Only center frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-077. What does an explicit gap map preserve?

A. The waveform values that were never captured

B. A proof that every gap can be interpolated exactly

C. Missing intervals and the relation between sample index and elapsed time

D. A replacement for clock history

Answer: C. Analyses assuming uninterrupted uniform sampling should use valid segments. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Missing intervals and the relation between sample index and elapsed time.

Distinguishing consideration: compare this with option A, “The waveform values that were never captured”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-078. What should a derived spectrum identify beyond its picture?

A. Source, interval, channel, calibration, scale and processing parameters

B. Only the output image hash

C. Only its plotted peak frequency

D. Only the analyst's preferred window name

Answer: A. Reproduction requires the actual declared measurement chain. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Source, interval, channel, calibration, scale and processing parameters.

Distinguishing consideration: compare this with option B, “Only the output image hash”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-079. What is the purpose of a second analysis implementation?

A. Generate a visually similar plot regardless of scaling

B. Reproduce the declared quantity and expose convention or implementation differences

C. Replace the need for native samples

D. Guarantee both implementations are correct merely by agreement

Answer: B. Independent checks are stronger when inputs and conventions are explicit. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

Why the selected alternative fits: Reproduce the declared quantity and expose convention or implementation differences.

Distinguishing consideration: compare this with option A, “Generate a visually similar plot regardless of scaling”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Reproducible Analysis and Derived Products.

Review: Chapter 15 — Reproducible Analysis and Derived Products.

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V011-C15-MCQ-080. Why preserve manual exclusions and threshold decisions?

A. They affect the result and its reproducibility

B. Only automated processing can affect a result

C. Manual choices are always negligible

D. They can be reconstructed uniquely from the final image

Answer: A. The analysis chain includes human decisions. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

Why the selected alternative fits: They affect the result and its reproducibility.

Distinguishing consideration: compare this with option B, “Only automated processing can affect a result”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Reproducible Analysis and Derived Products.

Review: Chapter 15 — Reproducible Analysis and Derived Products.

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V011-C15-MCQ-081. What should be reported when a result depends strongly on one threshold or window?

A. An assertion that preprocessing never matters

B. A universal source conclusion

C. Only the most favorable version

D. That sensitivity and its tested conditions

Answer: D. Parameter dependence is a material limitation of the inference. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

Why the selected alternative fits: That sensitivity and its tested conditions.

Distinguishing consideration: compare this with option A, “An assertion that preprocessing never matters”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Reproducible Analysis and Derived Products.

Review: Chapter 15 — Reproducible Analysis and Derived Products.

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V011-C15-MCQ-082. What additional timing record is needed when correlating receiver data with another system's logs?

A. The receiver's carrier-frequency accuracy alone

B. A common time basis with known uncertainty and clock history

C. Matching timestamp text formats only

D. Equal file creation dates

Answer: B. Clock corrections, time zones and other timing conventions can affect alignment. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

Why the selected alternative fits: A common time basis with known uncertainty and clock history.

Distinguishing consideration: compare this with option A, “The receiver's carrier-frequency accuracy alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Metadata, Time, and Site Context.

Review: Chapter 15 — Metadata, Time, and Site Context.

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V011-C15-MCQ-083. Why retain human-readable notes alongside automated logs?

A. They record reasons for changes and unexpected conditions not captured by settings alone

B. They replace rapid machine state logging

C. They prove every recorded setting was valid

D. They eliminate all operator-dependent uncertainty

Answer: A. The records provide complementary context. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

Why the selected alternative fits: They record reasons for changes and unexpected conditions not captured by settings alone.

Distinguishing consideration: compare this with option B, “They replace rapid machine state logging”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Metadata, Time, and Site Context.

Review: Chapter 15 — Metadata, Time, and Site Context.

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V011-C15-MCQ-084. Before a negative coverage claim, what four stages should be reconciled?

A. Raw, plotted, colored and printed traces

B. Purchase, delivery, installation and invoicing dates

C. Nominal, advertised, estimated and preferred bandwidth

D. Planned, commanded, valid and successfully preserved coverage

Answer: D. A plan or command does not establish the data actually retained. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: Planned, commanded, valid and successfully preserved coverage.

Distinguishing consideration: compare this with option A, “Raw, plotted, colored and printed traces”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-085. Can a clean recording of one band establish absence outside its instantaneous passband?

A. Only if the file is large

B. Yes, after enough averaging

C. No

D. Yes, if its noise floor is low

Answer: C. The observation has a frequency-domain scope. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: No.

Distinguishing consideration: compare this with option A, “Only if the file is large”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-086. Does high conditional capture probability for one burst model establish absence of all emissions?

A. No; other durations, schedules or detector failures remain outside the model

B. Yes; probabilities above 0.99 are universal

C. Yes; uniform phase covers every waveform class

D. No; probabilities can never support any bounded statement

Answer: A. The event class and prerequisites limit the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: No; other durations, schedules or detector failures remain outside the model.

Distinguishing consideration: compare this with option B, “Yes; probabilities above 0.99 are universal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-087. What belongs in a storage plan beyond nominal payload capacity?

A. Only the number of output charts

B. Only total disk size

C. Reserve capacity, sustained speed, rollover and failure response

D. Only the ADC's analog resolution

Answer: C. Operational continuity requires margins and a plan for loss or device failure. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

Why the selected alternative fits: Reserve capacity, sustained speed, rollover and failure response.

Distinguishing consideration: compare this with option A, “Only the number of output charts”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Coverage Review and Storage Governance.

Review: Chapter 15 — Coverage Review and Storage Governance.

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V011-C15-MCQ-088. What is the role of controlled file rollover?

A. Make timestamps unnecessary

B. Keep files manageable while preserving chronology and continuity evidence

C. Erase earlier files automatically regardless of purpose

D. Guarantee each boundary is a true acquisition gap

Answer: B. File segmentation and sample continuity must be distinguished. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

Why the selected alternative fits: Keep files manageable while preserving chronology and continuity evidence.

Distinguishing consideration: compare this with option A, “Make timestamps unnecessary”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Coverage Review and Storage Governance.

Review: Chapter 15 — Coverage Review and Storage Governance.

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V011-C15-MCQ-089. What should happen to native captures when derived images are produced?

A. Assume images can restore discarded samples

B. Delete gap and state logs once a plot exists

C. Retain needed native evidence and document disposition under the authorized purpose

D. Silently replace all samples with images

Answer: C. Derived products do not contain all original information. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

Why the selected alternative fits: Retain needed native evidence and document disposition under the authorized purpose.

Distinguishing consideration: compare this with option A, “Assume images can restore discarded samples”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Coverage Review and Storage Governance.

Review: Chapter 15 — Coverage Review and Storage Governance.

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V011-C15-MCQ-090. For 40 MS/s,2 channels,2 components and 16 bits/component, what is uncompressed payload rate?

A. 160 MB/s

B. 640 MB/s

C. 320 MB/s

D. 80 MB/s

Answer: C. 40 million$\times 2 \times 2 \times \frac{16}{8}$=320 million bytes per second, using decimal units.

Source: §15.22 Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8712)

Why the selected alternative fits: 320 MB/s.

Distinguishing consideration: compare this with option A, “160 MB/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-091. At that rate, what payload is needed for 30 minutes?

A. 57.6 GB

B. 9.6 GB

C. 1.152TB

D. 576 GB

Answer: D. 320 MB/s×1800s=576000 MB before overhead. Source: §15.22 Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8712)

Why the selected alternative fits: 576 GB.

Distinguishing consideration: compare this with option A, “57.6 GB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-092. A 12-bit ADC's samples are stored in 16-bit containers. Which width enters byte-rate calculation?

A. 16 bits

B. 28 bits by adding both widths

C. 12 bits regardless of container

D. 4 bits because only overhead matters

Answer: A. The stored representation determines payload bytes. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: 16 bits.

Distinguishing consideration: compare this with option B, “28 bits by adding both widths”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-093. For a single real channel at 10 MS/s stored in 16-bit words, what payload rate results?

A. 10 MB/s

B. 160 MB/s

C. 40 MB/s

D. 20 MB/s

Answer: D. There is one component:10 million×16/8. Source: §15.21 Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8710)

Why the selected alternative fits: 20 MB/s.

Distinguishing consideration: compare this with option A, “10 MB/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-094. For one complex channel at 10 MS/s with 32-bit I and 32-bit Q, what payload rate results?

A. 320 MB/s

B. 80 MB/s

C. 40 MB/s

D. 20 MB/s

Answer: B. Two 32-bit components require 8 bytes per sample. Source: §15.21 Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8710)

Why the selected alternative fits: 80 MB/s.

Distinguishing consideration: compare this with option A, “320 MB/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-095. Are headers and file-system overhead included in the simple uncompressed payload equation?

A. Only when the sample rate is an integer

B. Yes; they equal converter resolution

C. No; account for them separately

D. Yes; the division by eight includes them

Answer: C. The equation counts declared component payload. Source: §15.21 Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8710)

Why the selected alternative fits: No; account for them separately.

Distinguishing consideration: compare this with option A, “Only when the sample rate is an integer”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-096. Does nominally lossless compression guarantee a fixed recording-rate reduction for every signal?

A. Yes; thermal noise always compresses to zero

B. Yes; every waveform compresses by the same factor

C. No; complex samples cannot be compressed

D. No; actual compression and storage behavior must be accounted for

Answer: D. The chapter requires accounting for actual stored format and performance. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why the selected alternative fits: No; actual compression and storage behavior must be accounted for.

Distinguishing consideration: compare this with option A, “Yes; thermal noise always compresses to zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-MCQ-097. Increasing pretrigger depth reveals a relay transition before every burst. What is established first?

A. A complete cause determination without controls

B. Temporal order and support for a switch-related hypothesis

C. Unique proof of the relay's internal mechanism

D. Unique proof that no external signal exists

Answer: B. The switch might generate a transient or admit a real signal or share another control. Source: §15.23 Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8713)

Why the selected alternative fits: Temporal order and support for a switch-related hypothesis.

Distinguishing consideration: compare this with option A, “A complete cause determination without controls”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-098. Which follow-up best discriminates the relay case?

A. A capability-matched reference comparison with the switch static or bypassed

B. Assuming temporal precedence proves causation

C. Removing all pretrigger samples again

D. Changing only the plot scale

Answer: A. A controlled intervention can separate the competing interpretations.

Source: §15.23 Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8713)

Why the selected alternative fits: A capability-matched reference comparison with the switch static or bypassed.

Distinguishing consideration: compare this with option B, “Assuming temporal precedence proves causation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-099. Why preserve both original and corrected-configuration observations in that case?

A. They retain the evidence and unresolved attribution across the intervention

B. The corrected record proves the original never existed

C. A source identity can be inferred from file order

D. Only the latest trace can be relevant

Answer: A. The evidence chain includes the initial observation and discriminating follow-up. Source: §15.23 Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8713)

Why the selected alternative fits: They retain the evidence and unresolved attribution across the intervention.

Distinguishing consideration: compare this with option B, “The corrected record proves the original never existed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-MCQ-100. In Application 15A.10, what makes a conditional trial-count prescription transferable to a new survey?

A. Only the same target probability

B. Only the same number of files

C. Matching event, usable-window, overlap, detectability and independence conditions

D. Only the same receiver brand

Answer: C. The count solves a particular model, not a universal search problem.

Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

Why the selected alternative fits: Matching event, usable-window, overlap, detectability and independence conditions.

Distinguishing consideration: compare this with option A, “Only the same target probability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

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Fill-in-the-Blank Questions

V011-C15-FIB-001. Model 15A begins with intervals in which data are actually _____.

Answer: usable. Nominal commands or indicators do not establish valid samples.

Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “usable” completes the stated technical proposition.

Question context: Model 15A begins with intervals in which data are actually _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-002. The required overlap r is a strictly _____ duration.

Answer: positive. A non-strict zero-overlap test would accept disjoint intervals.

Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “positive” completes the stated technical proposition.

Question context: The required overlap r is a strictly _____ duration

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-003. The event length b and each usable-window length D are strictly less than the schedule _____.

Answer: period. The declared periodic finite-window model has this domain. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “period” completes the stated technical proposition.

Question context: The event length b and each usable-window length D are strictly less than the schedule _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-004. A qualifying overlap must be contained in one _____ acquisition record.

Answer: contiguous. Disconnected pieces cannot be added under the original criterion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “contiguous” completes the stated technical proposition.

Question context: A qualifying overlap must be contained in one _____ acquisition record

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-005. The window [a,a+D] and event [s,s+b] overlap by max(0,min(s+b,a+D)−_____).

Answer: max(s,a). The smaller endpoint minus the larger start gives intersection length. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “max(s,a)” completes the stated technical proposition.

Question context: The window [a,a+D] and event [s,s+b] overlap by max(0,min(s+b,a+D)−_____)

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-006. The earliest eligible event start is

_____.

Answer: a+r−b. The event must extend at least r beyond the window start. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “a+r−b” completes the stated technical proposition.

Question context: The earliest eligible event start is _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-007. The latest eligible event start is

_____.

Answer: a+D−r. At least r of the event must occur before the window ends. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “a+D−r” completes the stated technical proposition.

Question context: The latest eligible event start is _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-008. Feasibility requires r no greater than

_____ .

Answer: min(b,D). The overlap cannot exceed either interval's length. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “min(b,D)” completes the stated technical proposition.

Question context: Feasibility requires r no greater than _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-009. In Application 15A.4, if r exceeds the event duration, the eligible-start set is _____.

Answer: empty. A longer dwell cannot create a longer individual event. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

Why this term is required: “empty” completes the stated technical proposition.

Question context: In Application 15A.4, if r exceeds the event duration, the eligible-start set is _____

Basis and qualification: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

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V011-C15-FIB-010. For a feasible single window, eligible-start length is _____.

Answer: D+b −2r. Subtract the derived interval endpoints. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “D+b −2r” completes the stated technical proposition.

Question context: For a feasible single window, eligible-start length is _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-011. Modulo reduction puts start phases into the interval _____ .

Answer: [0,T). The period endpoint is represented by zero. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: "[0,T)" completes the stated technical proposition.

Question context: Modulo reduction puts start phases into the interval _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-012. Multiple eligible-start sets must be merged by their set _____ before length is measured.

Answer: union. This prevents duplicate counting of starts qualifying in several windows. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “union” completes the stated technical proposition.

Question context: Multiple eligible-start sets must be merged by their set _____ before length is measured

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-013. Under a uniform start-phase law, capture probability is eligible-union length divided by _____.

Answer: T. The quotient is dimensionless. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “T” completes the stated technical proposition.

Question context: Under a uniform start-phase law, capture probability is eligible-union length divided by _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-014. Uniform phase is a stated probability model, not a consequence of mere _____.

Answer: ignorance. Unknown phase does not imply a uniform physical distribution.

Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “ignorance” completes the stated technical proposition.

Question context: Uniform phase is a stated probability model, not a consequence of mere _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-015. In Application 15A.1, an ideal instantaneous event is captured only if its instant lies inside a usable _____.

Answer: window. This is the separate point-observation rule. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why this term is required: “window” completes the stated technical proposition.

Question context: In Application 15A.1, an ideal instantaneous event is captured only if its instant lies inside a usable _____

Basis and qualification: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-FIB-016. In Application 15A.1, for a single window, ideal-point probability under uniform phase is _____.

Answer: $\frac{D}{T}$. The finite complete-event limit approaches this value. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why this term is required: "The finite complete-event limit approaches this value" completes the stated technical proposition.

Question context: In Application 15A.1, for a single window, ideal-point probability under uniform phase is _____

Basis and qualification: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-FIB-017. In Application 15A.1, for T = 100 ms and usable [10,30] ms, point probability is _____.

Answer: 0.20. The dwell occupies 20 percent of the period. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why this term is required: “0.20” completes the stated technical proposition.

Question context: In Application 15A.1, for T = 100 ms and usable [10,30] ms, point probability is _____

Basis and qualification: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-FIB-018. In Application 15A.1, a complete 0.1 ms event in that window must start by _____ ms.

Answer: 29.9. Its trailing edge must lie at or before 30 ms. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why this term is required: “29.9” completes the stated technical proposition.

Question context: In Application 15A.1, a complete 0.1 ms event in that window must start by _____ ms

Basis and qualification: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-FIB-019. In Application 15A.1, its eligible-start length is _____ ms.

Answer: 19.9. The interval runs from 10 to 29.9 ms. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why this term is required: “19.9” completes the stated technical proposition.

Question context: In Application 15A.1, its eligible-start length is _____ ms

Basis and qualification: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-FIB-020. In Application 15A.1, its conditional probability is _____.

Answer: 0.199. Divide 19.9 ms by 100 ms. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

Why this term is required: “0.199” completes the stated technical proposition.

Question context: In Application 15A.1, its conditional probability is _____

Basis and qualification: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

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V011-C15-FIB-021. In Application 15A.2, for b = 5 ms,r = 1 ms and usable [10,30] ms, earliest start is _____ ms.

Answer: 6. 10+1−5=6. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

Why this term is required: “6” completes the stated technical proposition.

Question context: In Application 15A.2, for b = 5 ms,r = 1 ms and usable [10,30] ms, earliest start is _____ ms

Basis and qualification: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

Review: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

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V011-C15-FIB-022. In Application 15A.2, the latest eligible start in that fragment case is _____ ms.

Answer: 29. 30−1=29. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

Why this term is required: “29” completes the stated technical proposition.

Question context: In Application 15A.2, the latest eligible start in that fragment case is _____ ms

Basis and qualification: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

Review: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

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V011-C15-FIB-023. In Application 15A.2, the eligible interval length is _____ ms.

Answer: 23. 29−6=23. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

Why this term is required: “23” completes the stated technical proposition.

Question context: In Application 15A.2, the eligible interval length is _____ ms

Basis and qualification: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

Review: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

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V011-C15-FIB-024. In Application 15A.2, the corresponding conditional probability is _____.

Answer: 0.23. The schedule period is 100 ms. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

Why this term is required: “0.23” completes the stated technical proposition.

Question context: In Application 15A.2, the corresponding conditional probability is _____

Basis and qualification: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

Review: Chapter 15 — Application 15A.2: Capture a burst when only part of it is required.

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V011-C15-FIB-025. In Application 15A.3, for whole 5 ms capture in the same window, earliest start is _____ ms.

Answer: 10. The complete event cannot begin before the valid record. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

Why this term is required: “10” completes the stated technical proposition.

Question context: In Application 15A.3, for whole 5 ms capture in the same window, earliest start is _____ ms

Basis and qualification: Chapter 15 — Application 15A.3: Require the whole burst.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

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V011-C15-FIB-026. In Application 15A.3, the latest complete-event start is _____ ms.

Answer: 25. The 5 ms event must end by 30 ms. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

Why this term is required: “25” completes the stated technical proposition.

Question context: In Application 15A.3, the latest complete-event start is _____ ms

Basis and qualification: Chapter 15 — Application 15A.3: Require the whole burst.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

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V011-C15-FIB-027. In Application 15A.3, whole-event probability is _____.

Answer: 0.15. There are 15 ms of eligible start phase. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

Why this term is required: “0.15” completes the stated technical proposition.

Question context: In Application 15A.3, whole-event probability is _____

Basis and qualification: Chapter 15 — Application 15A.3: Require the whole burst.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

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V011-C15-FIB-028. In Application 15A.3, the fragment and whole-event examples differ in their evidence _____, not their event or schedule.

Answer: requirement. The required contiguous duration changes eligibility. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

Why this term is required: “requirement” completes the stated technical proposition.

Question context: In Application 15A.3, the fragment and whole-event examples differ in their evidence _____, not their event or schedule

Basis and qualification: Chapter 15 — Application 15A.3: Require the whole burst.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

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V011-C15-FIB-029. In Application 15A.4, for b = 2 ms and r = 3 ms, capture probability is _____.

Answer: 0. The event is shorter than the requirement. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

Why this term is required: “0” completes the stated technical proposition.

Question context: In Application 15A.4, for b = 2 ms and r = 3 ms, capture probability is _____

Basis and qualification: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

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V011-C15-FIB-030. In Application 15A.4, combining separate short events would require a new repeatability and _____ model.

Answer: estimator. It would not satisfy the original one-event contiguous criterion.

Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

Why this term is required: “estimator” completes the stated technical proposition.

Question context: In Application 15A.4, combining separate short events would require a new repeatability and _____ model

Basis and qualification: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

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V011-C15-FIB-031. In Application 15A.5, a 0–30 ms nominal dwell with 4 ms leading and 3 ms closing exclusions has usable length _____ ms.

Answer: 23. The interval is 4–27 ms. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: “23” completes the stated technical proposition.

Question context: In Application 15A.5, a 0–30 ms nominal dwell with 4 ms leading and 3 ms closing exclusions has usable length _____ ms

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-032. In Application 15A.5, for that interval with b = 8 ms,r = 2 ms, earliest eligible start is _____ ms.

Answer: −2. 4+2−8=−2. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: "−2" completes the stated technical proposition.

Question context: In Application 15A.5, for that interval with b = 8 ms,r = 2 ms, earliest eligible start is _____ ms

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-033. In Application 15A.5, its latest eligible start is _____ ms.

Answer: 25. 27−2=25. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: “25” completes the stated technical proposition.

Question context: In Application 15A.5, its latest eligible start is _____ ms

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-034. In Application 15A.5, the wrapped negative portion occupies _____ through 100 ms.

Answer: 98. Modulo 100 maps −2 to 98. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: “98” completes the stated technical proposition.

Question context: In Application 15A.5, the wrapped negative portion occupies _____ through 100 ms

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-035. In Application 15A.5, the guarded probability is _____.

Answer: 0.27. The merged pieces total 27 ms. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: “0.27” completes the stated technical proposition.

Question context: In Application 15A.5, the guarded probability is _____

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-036. In Application 15A.5, ignoring the stated guards would incorrectly give probability _____.

Answer: 0.34. The nominal 30 ms window gives(30+8−4)/100. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: “0.34” completes the stated technical proposition.

Question context: In Application 15A.5, ignoring the stated guards would incorrectly give probability _____

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-037. In Application 15A.5, a tuning-command timestamp identifies a requested change, not the start of sample _____.

Answer: validity. Settling must be established from receiver behavior. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: “validity” completes the stated technical proposition.

Question context: In Application 15A.5, a tuning-command timestamp identifies a requested change, not the start of sample _____

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-038. In Application 15A.5, different preceding states can require different settling transition _____.

Answer: classes. One guard may not represent all gain or tuning transitions. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

Why this term is required: “classes” completes the stated technical proposition.

Question context: In Application 15A.5, different preceding states can require different settling transition _____

Basis and qualification: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

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V011-C15-FIB-039. In Application 15A.6, for usable [10,25] ms,b = 20 ms,r = 5 ms, eligible starts run from −5 to _____ ms.

Answer: 20. The latest start is 25−5. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why this term is required: “20” completes the stated technical proposition.

Question context: In Application 15A.6, for usable [10,25] ms,b = 20 ms,r = 5 ms, eligible starts run from −5 to _____ ms

Basis and qualification: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-FIB-040. In Application 15A.6, for usable [28,43] ms with the same event criterion, eligible starts begin at _____ ms.

Answer: 13. 28+5−20=13. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why this term is required: “13” completes the stated technical proposition.

Question context: In Application 15A.6, for usable [28,43] ms with the same event criterion, eligible starts begin at _____ ms

Basis and qualification: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-FIB-041. In Application 15A.6, for eligible-start intervals [−5,20] ms and [13,38] ms, their overlap lasts _____ ms.

Answer: 7. Their common part is 13–20 ms. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why this term is required: “7” completes the stated technical proposition.

Question context: In Application 15A.6, for eligible-start intervals [−5,20] ms and [13,38] ms, their overlap lasts _____ ms

Basis and qualification: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-FIB-042. In Application 15A.6, the merged eligible length in that example is _____ ms.

Answer: 43. 25+25−7=43. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why this term is required: “43” completes the stated technical proposition.

Question context: In Application 15A.6, the merged eligible length in that example is _____ ms

Basis and qualification: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-FIB-043. In Application 15A.6, its probability is

_____.

Answer: 0.43. The period is 100 ms. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why this term is required: “0.43” completes the stated technical proposition.

Question context: In Application 15A.6, its probability is _____

Basis and qualification: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-FIB-044. In Application 15A.6, adding the two separate probabilities would incorrectly produce _____.

Answer: 0.50. It counts the 7 ms common start region twice. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why this term is required: “0.50” completes the stated technical proposition.

Question context: In Application 15A.6, adding the two separate probabilities would incorrectly produce _____

Basis and qualification: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-FIB-045. In Application 15A.6, set union combines qualifying start phases, not disconnected waveform _____.

Answer: fragments. The record criterion remains contiguous. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

Why this term is required: “fragments” completes the stated technical proposition.

Question context: In Application 15A.6, set union combines qualifying start phases, not disconnected waveform _____

Basis and qualification: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-FIB-046. In Application 15A.7, a 5 ms event always at phase 50 ms is missed by a 10–30 ms window on _____ of 100 repetitions.

Answer: all 100. The relationship is deterministic and unchanged. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

Why this term is required: “all 100” completes the stated technical proposition.

Question context: In Application 15A.7, a 5 ms event always at phase 50 ms is missed by a 10–30 ms window on _____ of 100 repetitions

Basis and qualification: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-C15-FIB-047. In Application 15A.7, moving the window to 49–69 ms captures the same event on _____ of 100 repetitions.

Answer: all 100. Every event [50,55] lies inside the new record. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

Why this term is required: “all 100” completes the stated technical proposition.

Question context: In Application 15A.7, moving the window to 49–69 ms captures the same event on _____ of 100 repetitions

Basis and qualification: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-C15-FIB-048. In Application 15A.7, a fixed commensurate miss requires changed scheduling or justified phase _____ to create new opportunity.

Answer: variation. Merely repeating files does not establish independence. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

Why this term is required: “variation” completes the stated technical proposition.

Question context: In Application 15A.7, a fixed commensurate miss requires changed scheduling or justified phase _____ to create new opportunity

Basis and qualification: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-C15-FIB-049. In Application 15A.8, for a continuous 90–110 ms window,b = 15 ms,r = 12 ms, earliest eligible start is _____ ms.

Answer: 87. 90+12−15=87. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why this term is required: “87” completes the stated technical proposition.

Question context: In Application 15A.8, for a continuous 90–110 ms window,b = 15 ms,r = 12 ms, earliest eligible start is _____ ms

Basis and qualification: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-FIB-050. In Application 15A.8, the latest eligible start is _____ ms.

Answer: 98. 110−12=98. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why this term is required: “98” completes the stated technical proposition.

Question context: In Application 15A.8, the latest eligible start is _____ ms

Basis and qualification: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-FIB-051. In Application 15A.8, the probability in a 100 ms period is _____.

Answer: 0.11. The interval length is 11 ms. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why this term is required: “0.11” completes the stated technical proposition.

Question context: In Application 15A.8, the probability in a 100 ms period is _____

Basis and qualification: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-FIB-052. In Application 15A.8, an event beginning 95 ms has _____ ms overlap with 90–110 ms.

Answer: 15. Its full interval is 95–110 ms. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why this term is required: “15” completes the stated technical proposition.

Question context: In Application 15A.8, an event beginning 95 ms has _____ ms overlap with 90–110 ms

Basis and qualification: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-FIB-053. In Application 15A.8, an event beginning at phase 0 has only _____ ms overlap with the relevant crossing record.

Answer: 10. It intersects −10–10 ms over 0–10 ms. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why this term is required: “10” completes the stated technical proposition.

Question context: In Application 15A.8, an event beginning at phase 0 has only _____ ms overlap with the relevant crossing record

Basis and qualification: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-FIB-054. In Application 15A.8, splitting the crossing record at zero falsely creates two _____ ms pieces.

Answer: 10. Neither apparent piece can meet 12 ms, despite actual continuity.

Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why this term is required: “10” completes the stated technical proposition.

Question context: In Application 15A.8, splitting the crossing record at zero falsely creates two _____ ms pieces

Basis and qualification: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-FIB-055. In Application 15A.8, a period origin is a coordinate boundary, not necessarily an acquisition _____.

Answer: gap. Metadata must distinguish representational and physical boundaries.

Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

Why this term is required: “gap” completes the stated technical proposition.

Question context: In Application 15A.8, a period origin is a coordinate boundary, not necessarily an acquisition _____

Basis and qualification: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

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V011-C15-FIB-056. For n independent trials with common p, all-miss probability is _____.

Answer: $(1-p)^n$. Independence justifies multiplication of miss probabilities. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: "$(1-p)^n$" completes the stated technical proposition.

Question context: For n independent trials with common p, all-miss probability is _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-057. At-least-one probability is one _____ the all-miss probability.

Answer: minus. The two outcomes are complements. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “minus” completes the stated technical proposition.

Question context: At-least-one probability is one _____ the all-miss probability

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-058. In Application 15A.9, for p = 0.23 and n 10, all-miss probability is approximately _____.

Answer: 0.073266805. Compute 0.77 to the tenth power. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

Why this term is required: “0.073266805” completes the stated technical proposition.

Question context: In Application 15A.9, for p = 0.23 and n 10, all-miss probability is approximately _____

Basis and qualification: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

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V011-C15-FIB-059. In Application 15A.9, the corresponding at-least-one probability is approximately _____.

Answer: 0.926733195. Subtract the all-miss value from one. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

Why this term is required: “0.926733195” completes the stated technical proposition.

Question context: In Application 15A.9, the corresponding at-least-one probability is approximately _____

Basis and qualification: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

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V011-C15-FIB-060. For interior p and target q, minimum trials use the _____ of $\frac{\ln(1-q)}{\ln(1-p)}$.

Answer: ceiling. The count must be an integer meeting the target. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “ceiling” completes the stated technical proposition.

Question context: For interior p and target q, minimum trials use the _____ of

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-061. In Application 15A.10, for p = 0.23 and target 0.99, the minimum count is _____.

Answer: 18. Seventeen falls short; eighteen exceeds the target. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

Why this term is required: “18” completes the stated technical proposition.

Question context: In Application 15A.10, for p = 0.23 and target 0.99, the minimum count is _____

Basis and qualification: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

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V011-C15-FIB-062. In Application 15A.10, at 17 trials the probability is approximately _____.

Answer: 0.988241760. This verifies that 17 does not reach 0.99. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

Why this term is required: “0.988241760” completes the stated technical proposition.

Question context: In Application 15A.10, at 17 trials the probability is approximately _____

Basis and qualification: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

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V011-C15-FIB-063. In Application 15A.10, at 18 trials the probability is approximately _____.

Answer: 0.990946155. This verifies the first qualifying integer. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

Why this term is required: “0.990946155” completes the stated technical proposition.

Question context: In Application 15A.10, at 18 trials the probability is approximately _____

Basis and qualification: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

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V011-C15-FIB-064. If p = 0, no finite count reaches a _____ target.

Answer: positive. Every trial misses within the model. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “positive” completes the stated technical proposition.

Question context: If p = 0, no finite count reaches a _____ target

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-065. If p = 1, _____ valid trial suffices.

Answer: one. The conditional success is certain. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “one” completes the stated technical proposition.

Question context: If p = 1, _____ valid trial suffices

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-066. For 0<p<1, target exactly one requires no _____ solution.

Answer: finite. All-miss probability stays positive at every finite count. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “finite” completes the stated technical proposition.

Question context: For 0<p<1, target exactly one requires no _____ solution

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-067. For independent unequal probabilities, all-miss probability is the _____ of individual miss probabilities.

Answer: product. The complement then gives at-least-one capture. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “product” completes the stated technical proposition.

Question context: For independent unequal probabilities, all-miss probability is the _____ of individual miss probabilities

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-068. For two independent trials with $p_1 = 0.2$ and $p_2 = 0.5$, at-least-one probability is _____.

Answer: 0.60. 1−.8×.5=.60. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “0.60” completes the stated technical proposition.

Question context: For two independent trials with and at-least-one probability is _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-069. Correlated trials require their joint distribution or a defensible _____.

Answer: bound. The independent product cannot be assumed. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

Why this term is required: “bound” completes the stated technical proposition.

Question context: Correlated trials require their joint distribution or a defensible _____

Basis and qualification: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-FIB-070. In Application 15A.9, a schedule changed after each miss requires preserving the _____ rule.

Answer: adaptive. The resulting experiment may differ from a fixed-trial model.

Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

Why this term is required: “adaptive” completes the stated technical proposition.

Question context: In Application 15A.9, a schedule changed after each miss requires preserving the _____ rule

Basis and qualification: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

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V011-C15-FIB-071. A trigger after narrow filtering cannot respond to _____-of-band precursors.

Answer: out. Its input representation is restricted by that filter. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

Why this term is required: “out” completes the stated technical proposition.

Question context: A trigger after narrow filtering cannot respond to _____-of-band precursors

Basis and qualification: Chapter 15 — Trigger Types and Pretrigger Context.

Review: Chapter 15 — Trigger Types and Pretrigger Context.

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V011-C15-FIB-072. A trigger after AGC can inherit control-dependent latency or _____.

Answer: suppression. The trigger sees the altered statistic. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

Why this term is required: “suppression” completes the stated technical proposition.

Question context: A trigger after AGC can inherit control-dependent latency or _____

Basis and qualification: Chapter 15 — Trigger Types and Pretrigger Context.

Review: Chapter 15 — Trigger Types and Pretrigger Context.

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V011-C15-FIB-073. Trigger and saved-waveform bandwidths can be _____.

Answer: different. Their path locations and rates need separate characterization.

Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why this term is required: “different” completes the stated technical proposition.

Question context: Trigger and saved-waveform bandwidths can be _____

Basis and qualification: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-FIB-074. Paired test events at controlled separations reveal holdoff and _____ behavior.

Answer: rearm. An isolated pulse does not test recovery of a second event. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why this term is required: “rearm” completes the stated technical proposition.

Question context: Paired test events at controlled separations reveal holdoff and _____ behavior

Basis and qualification: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-FIB-075. Pretrigger memory is useful only if it contains valid samples from the same accepted _____.

Answer: configuration. A recent tuning or gain change can invalidate causal comparison. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
Why this term is required: “configuration” completes the stated technical proposition.
Question context: Pretrigger memory is useful only if it contains valid samples from the same accepted _____
Basis and qualification: Chapter 15 — Verify the trigger at its actual signal-path location.
Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-FIB-076. A comparator or software trigger time must be mapped to the stored sample _____.

Answer: apertures. The event timestamp may not directly identify a sample's acquisition instant. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why this term is required: “apertures” completes the stated technical proposition.

Question context: A comparator or software trigger time must be mapped to the stored sample _____

Basis and qualification: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-FIB-077. Complete-event capture requires both boundaries and required _____ in one continuous record.

Answer: context. A trigger-centered image alone does not establish that scope.

Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why this term is required: “context” completes the stated technical proposition.

Question context: Complete-event capture requires both boundaries and required _____ in one continuous record

Basis and qualification: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-FIB-078. For a fragment claim, the unobserved beginning and end remain _____.

Answer: unknown. The retained evidence must not be relabeled as a whole capture.

Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

Why this term is required: “unknown” completes the stated technical proposition.

Question context: For a fragment claim, the unobserved beginning and end remain _____

Basis and qualification: Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-FIB-079. Hashes should be calculated for stable files after _____.

Answer: closure. The hash must describe the completed preserved byte sequence.

Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

Why this term is required: “closure” completes the stated technical proposition.

Question context: Hashes should be calculated for stable files after _____

Basis and qualification: Chapter 15 — Wideband Recording and Data Integrity.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-FIB-080. Triggered segmented capture can bias _____ estimates.

Answer: occupancy. The saved set is selected by trigger conditions and omits other intervals. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

Why this term is required: “occupancy” completes the stated technical proposition.

Question context: Triggered segmented capture can bias _____ estimates

Basis and qualification: Chapter 15 — Wideband Recording and Data Integrity.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-FIB-081. Separate metadata can be bound to samples using hashes or a controlled _____.

Answer: manifest. The file association must remain verifiable. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

Why this term is required: “manifest” completes the stated technical proposition.

Question context: Separate metadata can be bound to samples using hashes or a controlled _____

Basis and qualification: Chapter 15 — Wideband Recording and Data Integrity.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-FIB-082. A 12-bit converter stored in 16-bit words uses _____ bits per component for byte accounting.

Answer: 16. Stored container width determines payload. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “16” completes the stated technical proposition.

Question context: A 12-bit converter stored in 16-bit words uses _____ bits per component for byte accounting

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-083. Complex I/Q data normally have _____ components per channel in Equation 29.

Answer: two. Both I and Q must be counted. Source: §15.21 Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8710)

Why this term is required: “two” completes the stated technical proposition.

Question context: Complex I/Q data normally have _____ components per channel in Equation 29

Basis and qualification: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-FIB-084. For 40 MS/s,two channels and 16-bit I/Q, payload rate is _____ MB/s.

Answer: 320. Use decimal bytes and all four components across the channels.

Source: §15.22 Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8712)

Why this term is required: “320” completes the stated technical proposition.

Question context: For 40 MS/s,two channels and 16-bit I/Q, payload rate is _____ MB/s

Basis and qualification: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-FIB-085. For 1800 seconds at 320 MB/s, payload is _____ GB.

Answer: 576. The calculation excludes headers and file-system overhead. Source: §15.22 Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8712)

Why this term is required: “576” completes the stated technical proposition.

Question context: For 1800 seconds at 320 MB/s, payload is _____ GB

Basis and qualification: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-FIB-086. A 10 MS/s single real channel in 16-bit words requires _____ MB/s payload.

Answer: 20. One component uses two bytes per sample. Source: §15.21 Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8710)

Why this term is required: “20” completes the stated technical proposition.

Question context: A 10 MS/s single real channel in 16-bit words requires _____ MB/s payload

Basis and qualification: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-FIB-087. A 10 MS/s single complex channel with 32-bit I andQ requires _____ MB/s.

Answer: 80. Two four-byte components give eight bytes per sample. Source: §15.21 Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8710)

Why this term is required: “80” completes the stated technical proposition.

Question context: A 10 MS/s single complex channel with 32-bit I andQ requires _____ MB/s

Basis and qualification: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-FIB-088. Headers, padding and timestamps require accounting beyond the _____ equation.

Answer: payload. Equation 29 does not include every file-system or framing contribution. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “payload” completes the stated technical proposition.

Question context: Headers, padding and timestamps require accounting beyond the _____ equation

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-089. Sustained-write tests must last long enough to expose storage performance hidden by _____.

Answer: buffers. Short peak bursts may not reveal the steady bottleneck. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “buffers” completes the stated technical proposition.

Question context: Sustained-write tests must last long enough to expose storage performance hidden by _____

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-090. Sample counters and block sequences help establish acquisition _____.

Answer: continuity. A hash alone cannot prove original completeness. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “continuity” completes the stated technical proposition.

Question context: Sample counters and block sequences help establish acquisition _____

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-091. A missing block changes the mapping from sample index to elapsed _____.

Answer: time. Concatenating remaining data conceals the gap. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “time” completes the stated technical proposition.

Question context: A missing block changes the mapping from sample index to elapsed _____

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-092. An explicit gap map permits analyses to be restricted to valid _____.

Answer: segments. Uniform-sampling estimators may not apply across unknown discontinuities. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “segments” completes the stated technical proposition.

Question context: An explicit gap map permits analyses to be restricted to valid _____

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-093. Native sample interpretation requires byte order, signedness, packing and _____.

Answer: scaling. The stored representation must map to the declared numerical quantity. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “scaling” completes the stated technical proposition.

Question context: Native sample interpretation requires byte order, signedness, packing and _____

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-094. Derived results should identify source file, interval, channel and processing _____.

Answer: parameters. A plot cannot encode the full transformation by itself. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “parameters” completes the stated technical proposition.

Question context: Derived results should identify source file, interval, channel and processing _____

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-095. Threshold sensitivity and manual exclusions belong in the preserved analysis _____.

Answer: record. They can materially affect reproducibility and interpretation. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

Why this term is required: “record” completes the stated technical proposition.

Question context: Threshold sensitivity and manual exclusions belong in the preserved analysis _____

Basis and qualification: Chapter 15 — Reproducible Analysis and Derived Products.

Review: Chapter 15 — Reproducible Analysis and Derived Products.

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V011-C15-FIB-096. Cross-system event correlation requires a common time basis and known _____.

Answer: uncertainty. Timestamp text alone is insufficient. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

Why this term is required: “uncertainty” completes the stated technical proposition.

Question context: Cross-system event correlation requires a common time basis and known _____

Basis and qualification: Chapter 15 — Metadata, Time, and Site Context.

Review: Chapter 15 — Metadata, Time, and Site Context.

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V011-C15-FIB-097. A timestamp without clock _____ is not a complete timing measurement.

Answer: history. Corrections, reference state and conventions can change its meaning. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

Why this term is required: “history” completes the stated technical proposition.

Question context: A timestamp without clock _____ is not a complete timing measurement

Basis and qualification: Chapter 15 — Metadata, Time, and Site Context.

Review: Chapter 15 — Metadata, Time, and Site Context.

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V011-C15-FIB-098. Negative coverage claims reconcile planned, commanded, valid and successfully _____ intervals.

Answer: preserved. Only the actual retained observation supports the claim. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

Why this term is required: “preserved” completes the stated technical proposition.

Question context: Negative coverage claims reconcile planned, commanded, valid and successfully _____ intervals

Basis and qualification: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-C15-FIB-099. In the relay case, extra pretrigger data establish temporal order but not unique _____.

Answer: causation. A switch transient, newly admitted signal or shared control remain alternatives. Source: §15.23 Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility (p. 8713)

Why this term is required: “causation” completes the stated technical proposition.

Question context: In the relay case, extra pretrigger data establish temporal order but not unique _____

Basis and qualification: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-FIB-100. Native evidence is preserved according to purpose; deletion or migration events are _____.

Answer: documented. Derived images do not silently replace the source record.

Source: §15.20 Coverage Review and Storage Governance (p. 8709)

Why this term is required: “documented” completes the stated technical proposition.

Question context: Native evidence is preserved according to purpose; deletion or migration events are _____

Basis and qualification: Chapter 15 — Coverage Review and Storage Governance.

Review: Chapter 15 — Coverage Review and Storage Governance.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C15-ESSAY-001. Derive the single-window eligible-start interval from the positive contiguous-overlap criterion.

- Opening: Present a thesis that answers this precise question: Derive the single-window eligible-start interval from the positive contiguous-overlap criterion. Identify which evidence would falsify the proposed conclusion Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Core terminology and scope: Define single-window, eligible-start, interval in the question's particular technical setting; explain how positive, contiguous-overlap, criterion differ if that distinction would change the analysis of "Derive the single-window eligible-start interval from the positive contiguous-overlap criterion" Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define a,D,b,r and the unfolded event interval Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the single-window eligible-start interval from the positive contiguous-overlap criterion to the claimed result, following "Application 15A.4: Reject an impossible overlap requirement"; name the intermediate states and measurable outputs Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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single-window eligible-start interval from the positive contiguous-overlap criterion. Derive both endpoint inequalities and feasibility then explain union reduction and the uniform-phase probability Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.7: Keep a deterministic repeated miss deterministic” that resolves the question about the single-window eligible-start interval from the positive contiguous-overlap criterion; derive the relevant result with units and stated validity conditions Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the single-window eligible-start interval from the positive contiguous-overlap criterion. Keep detector prerequisites separate Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Worked application or illustrative case: Build a worked example of “the single-window eligible-start interval from the positive contiguous-overlap criterion”, addressing this associated condition: Define a,D,b,r and the unfolded event interval. Define a,D,b,r and the unfolded event interval Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the single-window eligible-start interval from the positive contiguous-overlap criterion”. Using “Application 15A.7: Keep a deterministic repeated miss deterministic”, specify a

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discriminator and the result expected under each explanation Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the single-window eligible-start interval from the positive contiguous-overlap criterion, including the effect of missing measurements and inconsistent operating conditions Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Scholarly synthesis and implications: Explain what the result about the single-window eligible-start interval from the positive contiguous-overlap criterion authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Closing: Conclude by answering “Derive the single-window eligible-start interval from the positive contiguous-overlap criterion” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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V011-C15-ESSAY-002. Compare point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule.

- Opening: Present a thesis that answers this precise question: Compare point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule. Identify which evidence would falsify the proposed conclusion Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Core terminology and scope: Define point, fragment, complete-event in the question's particular technical setting; explain how capture, window, schedule differ if that distinction would change the analysis of "Compare point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule" Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Calculate 0.20 for a point,0.199 for a complete 0.1 ms event,0.23 for b = 5/r = 1 and 0.15 for whole 5 ms Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule to the claimed result, following "Application 15A.1: Distinguish a point observation from full capture of a short event"; name the intermediate states and measurable outputs Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule. Explain the different questions and why recognizable fragments do not establish startup or full-frame preservation Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.2: Capture a burst when only part of it is required” that resolves the question about point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule; derive the relevant result with units and stated validity conditions Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)
- Evidence and method: Specify the native observations, control records and calculations that would resolve point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule. Explain the different questions and why recognizable fragments do not establish startup or full-frame preservation Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Worked application or illustrative case: Build a worked example of “point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule”, addressing this associated condition: Calculate 0.20 for a point,0.199 for a complete 0.1 ms event,0.23 for b = 5/r = 1 and 0.15 for whole 5 ms. Calculate 0.20 for a point,0.199 for a complete 0.1 ms event,0.23 for b = 5/r = 1 and 0.15 for whole 5

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ms Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule”. Using “Application 15A.2: Capture a burst when only part of it is required”, specify a discriminator and the result expected under each explanation Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule, including the effect of missing measurements and inconsistent operating conditions Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Scholarly synthesis and implications: Explain what the result about point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Closing: Conclude by answering “Compare point, fragment and complete-event capture for the 10–30 ms window in a 100 ms schedule” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

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V011-C15-ESSAY-003. Explain why usable rather than nominal dwell controls coverage.

- Opening: Present a thesis that answers this precise question: Explain why usable rather than nominal dwell controls coverage. Identify which evidence would falsify the proposed conclusion Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Core terminology and scope: Define usable, nominal, dwell in the question's particular technical setting; explain how controls, coverage, measurement differ if that distinction would change the analysis of "Explain why usable rather than nominal dwell controls coverage" Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Account for settling, filter memory, AGC, rearming, transfer and validity flags Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why usable rather than nominal dwell controls coverage to the claimed result, following "Model 15A: calculate conditional event coverage from usable windows"; name the intermediate states and measurable outputs Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why

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usable rather than nominal dwell controls coverage. Reconstruct the guarded 4–27 ms example and 0.27 probability, explain transition-dependent guards, and distinguish commands from valid sample intervals Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.1: Distinguish a point observation from full capture of a short event” that resolves the question about why usable rather than nominal dwell controls coverage; derive the relevant result with units and stated validity conditions Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why usable rather than nominal dwell controls coverage. Reconstruct the guarded 4–27 ms example and 0.27 probability, explain transition-dependent guards, and distinguish commands from valid sample intervals Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Worked application or illustrative case: Build a worked example of “why usable rather than nominal dwell controls coverage”, addressing this associated condition: Account for settling, filter memory, AGC, rearming, transfer and validity flags. Account for settling, filter memory, AGC, rearming, transfer and validity flags Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “why usable rather than nominal dwell controls coverage”. Using “Application 15A.1: Distinguish a point observation from full capture of a short event”, specify a discriminator and the result expected under each explanation Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why usable rather than nominal dwell controls coverage, including the effect of missing measurements and inconsistent operating conditions Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)
- Scholarly synthesis and implications: Explain what the result about why usable rather than nominal dwell controls coverage authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Closing: Conclude by answering “Explain why usable rather than nominal dwell controls coverage” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

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V011-C15-ESSAY-004. Analyze overlapping eligible-start sets without violating the contiguous-record requirement.

- Opening: Present a thesis that answers this precise question: Analyze overlapping eligible-start sets without violating the contiguous-record requirement. Identify which evidence would falsify the proposed conclusion Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Core terminology and scope: Define overlapping, eligible-start, sets in the question's particular technical setting; explain how violating, contiguous-record, requirement differ if that distinction would change the analysis of "Analyze overlapping eligible-start sets without violating the contiguous-record requirement" Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use windows 10–25 and 28–43 ms with b = 20/r = 5, derive both intervals and 43 ms union Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting overlapping eligible-start sets without violating the contiguous-record requirement to the claimed result, following "Application 15A.3: Require the whole burst"; name the intermediate states and measurable outputs Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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overlapping eligible-start sets without violating the contiguous-record requirement. Explain the 7 ms double count and why union of qualifying starts does not add insufficient waveform fragments across the gap Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.8: Preserve one contiguous window across the period origin” that resolves the question about overlapping eligible-start sets without violating the contiguous-record requirement; derive the relevant result with units and stated validity conditions Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Evidence and method: Specify the native observations, control records and calculations that would resolve overlapping eligible-start sets without violating the contiguous-record requirement. Explain the 7 ms double count and why union of qualifying starts does not add insufficient waveform fragments across the gap Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Worked application or illustrative case: Build a worked example of “overlapping eligible-start sets without violating the contiguous-record requirement”, addressing this associated condition: Use windows 10–25 and 28–43 ms with b = 20/r = 5, derive both intervals and 43 ms union. Use windows 10–25 and 28–43 ms with b = 20/r = 5, derive both intervals and 43 ms union Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “overlapping eligible-start sets without

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violating the contiguous-record requirement". Using "Application 15A.8: Preserve one contiguous window across the period origin", specify a discriminator and the result expected under each explanation Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to overlapping eligible-start sets without violating the contiguous-record requirement, including the effect of missing measurements and inconsistent operating conditions Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Scholarly synthesis and implications: Explain what the result about overlapping eligible-start sets without violating the contiguous-record requirement authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Closing: Conclude by answering "Analyze overlapping eligible-start sets without violating the contiguous-record requirement" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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V011-C15-ESSAY-005. Explain deterministic repeated misses and how to change the observation strategy.

- Opening: Present a thesis that answers this precise question: Explain deterministic repeated misses and how to change the observation strategy. Identify which evidence would falsify the proposed conclusion Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Core terminology and scope: Define deterministic, repeated, misses in the question's particular technical setting; explain how observation, strategy, measurement differ if that distinction would change the analysis of "Explain deterministic repeated misses and how to change the observation strategy" Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the phase 50 ms event and 10–30 ms window, then the 49–69 ms alternative Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting deterministic repeated misses and how to change the observation strategy to the claimed result, following "Application 15A.3: Require the whole burst"; name the intermediate states and measurable outputs Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for deterministic repeated misses and how to change the observation

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strategy. Distinguish a fixed outcome from a uniform-phase average, and specify evidence needed for randomized or independent repeated trials Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.1: Distinguish a point observation from full capture of a short event” that resolves the question about deterministic repeated misses and how to change the observation strategy; derive the relevant result with units and stated validity conditions Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Evidence and method: Specify the native observations, control records and calculations that would resolve deterministic repeated misses and how to change the observation strategy. Distinguish a fixed outcome from a uniform-phase average, and specify evidence needed for randomized or independent repeated trials Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Worked application or illustrative case: Build a worked example of “deterministic repeated misses and how to change the observation strategy”, addressing this associated condition: Use the phase 50 ms event and 10–30 ms window, then the 49–69 ms alternative. Use the phase 50 ms event and 10–30 ms window, then the 49–69 ms alternative Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “deterministic repeated misses and how to change the observation strategy”. Using “Application 15A.1:

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Distinguish a point observation from full capture of a short event", specify a discriminator and the result expected under each explanation Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to deterministic repeated misses and how to change the observation strategy, including the effect of missing measurements and inconsistent operating conditions Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)
- Scholarly synthesis and implications: Explain what the result about deterministic repeated misses and how to change the observation strategy authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Closing: Conclude by answering "Explain deterministic repeated misses and how to change the observation strategy" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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V011-C15-ESSAY-006. Analyze continuity across a period origin and across a real acquisition gap.

- Opening: Present a thesis that answers this precise question: Analyze continuity across a period origin and across a real acquisition gap. Identify which evidence would falsify the proposed conclusion Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Core terminology and scope: Define continuity, period, origin in the question's particular technical setting; explain how real, acquisition, measurement differ if that distinction would change the analysis of "Analyze continuity across a period origin and across a real acquisition gap" Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use 90–110 ms,b = 15/r = 12 to derive 87–98 ms and 0.11 Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting continuity across a period origin and across a real acquisition gap to the claimed result, following "Metadata, Time, and Site Context"; name the intermediate states and measurable outputs Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for continuity across a period origin and across a real acquisition gap.

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Evaluate starts 95 and 0, explain coordinate versus file versus physical boundaries, and identify metadata needed before joining files Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- Analytical framework: Identify the equation, calibration or evidential decision test in “15. Evidence-grade metadata and reproducible processing” that resolves the question about continuity across a period origin and across a real acquisition gap; derive the relevant result with units and stated validity conditions Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)
- Evidence and method: Specify the native observations, control records and calculations that would resolve continuity across a period origin and across a real acquisition gap. Evaluate starts 95 and 0, explain coordinate versus file versus physical boundaries, and identify metadata needed before joining files Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Worked application or illustrative case: Build a worked example of “continuity across a period origin and across a real acquisition gap”, addressing this associated condition: Use 90–110 ms,b = 15/r = 12 to derive 87–98 ms and 0.11. Use 90–110 ms,b = 15/r = 12 to derive 87–98 ms and 0.11 Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “continuity across a period origin and across a real acquisition gap”. Using “15. Evidence-grade metadata and reproducible processing”, specify a discriminator and the result expected under each explanation Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to continuity across a period origin and across a real acquisition gap, including the effect of missing measurements and inconsistent operating conditions Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Scholarly synthesis and implications: Explain what the result about continuity across a period origin and across a real acquisition gap authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Closing: Conclude by answering “Analyze continuity across a period origin and across a real acquisition gap” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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V011-C15-ESSAY-007. Derive the independent repeated-trial probability and minimum-count expression with all endpoint cases.

- Opening: Present a thesis that answers this precise question: Derive the independent repeated-trial probability and minimum-count expression with all endpoint cases. Identify which evidence would falsify the proposed conclusion Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Core terminology and scope: Define independent, repeated-trial, probability in the question's particular technical setting; explain how expression, endpoint, cases differ if that distinction would change the analysis of "Derive the independent repeated-trial probability and minimum-count expression with all endpoint cases" Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use complement multiplication, derive the ceiling for interior p,q, and state p = 0,p = 1 and q 1 limits Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the independent repeated-trial probability and minimum-count expression with all endpoint cases to the claimed result, following "Application 15A.9: Calculate repeated capture only under independent start phases"; name the intermediate states and measurable outputs Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the independent repeated-trial probability and minimum-count expression with all endpoint cases. Verify 18 versus 17 for p.23/q.99 and explain why the count is conditional, not universal Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 15A.2: Capture a burst when only part of it is required" that resolves the question about the independent repeated-trial probability and minimum-count expression with all endpoint cases; derive the relevant result with units and stated validity conditions Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the independent repeated-trial probability and minimum-count expression with all endpoint cases. Verify 18 versus 17 for p.23/q.99 and explain why the count is conditional, not universal Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Worked application or illustrative case: Build a worked example of "the independent repeated-trial probability and minimum-count expression with all endpoint cases", addressing this associated condition: Use complement multiplication, derive the ceiling for interior p,q, and state p = 0,p = 1 and q 1 limits. Use complement multiplication, derive the ceiling for interior p,q, and state p = 0,p = 1

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and q 1 limits Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the independent repeated-trial probability and minimum-count expression with all endpoint cases”. Using “Application 15A.2: Capture a burst when only part of it is required”, specify a discriminator and the result expected under each explanation Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the independent repeated-trial probability and minimum-count expression with all endpoint cases, including the effect of missing measurements and inconsistent operating conditions Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Scholarly synthesis and implications: Explain what the result about the independent repeated-trial probability and minimum-count expression with all endpoint cases authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Closing: Conclude by answering “Derive the independent repeated-trial probability and minimum-count expression with all endpoint cases” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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V011-C15-ESSAY-008. Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials.

- Opening: Present a thesis that answers this precise question: Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials. Identify which evidence would falsify the proposed conclusion Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Core terminology and scope: Define Extend, trial, unequal in the question's particular technical setting; explain how probabilities, adaptive, trials differ if that distinction would change the analysis of "Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials" Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use the product of independent miss probabilities, identify required phase assumptions, and explain why field timestamps or new labels do not establish independence Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials to the claimed result, following "Application 15A.10: Solve for a conditional trial count and check the boundary"; name the intermediate states and measurable outputs Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials. Preserve the actual adaptation rule and require a joint model or defensible bound for dependence Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.3: Require the whole burst” that resolves the question about Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials; derive the relevant result with units and stated validity conditions Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials. Preserve the actual adaptation rule and require a joint model or defensible bound for dependence Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Worked application or illustrative case: Build a worked example of “Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials”, addressing this associated condition: Use the product of independent miss probabilities, identify required phase assumptions, and explain why field.... Use the product of independent miss probabilities, identify required phase assumptions, and explain why field timestamps or new labels... Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials”. Using “Application 15A.3: Require the whole burst”, specify a discriminator and the result expected under each explanation Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials, including the effect of missing measurements and inconsistent operating conditions Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)
- Scholarly synthesis and implications: Explain what the result about Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Closing: Conclude by answering “Extend the trial calculation to unequal probabilities and discuss correlated or adaptive trials” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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V011-C15-ESSAY-009. Design a trigger characterization protocol at its actual path location.

- Opening: Present a thesis that answers this precise question: Design a trigger characterization protocol at its actual path location. Identify which evidence would falsify the proposed conclusion Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Core terminology and scope: Define Design, trigger, characterization in the question's particular technical setting; explain how protocol, path, location differ if that distinction would change the analysis of "Design a trigger characterization protocol at its actual path location" Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify full-rate, decimated, filtered or software statistics, test relevant edge/duration/level/modulation Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a trigger characterization protocol at its actual path location to the claimed result, following "Trigger Types and Pretrigger Context"; name the intermediate states and measurable outputs Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a trigger characterization protocol at its actual path location. Identify full-rate, decimated, filtered or software statistics, test relevant

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edge/duration/level/modulation Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Metadata, Time, and Site Context” that resolves the question about a trigger characterization protocol at its actual path location; derive the relevant result with units and stated validity conditions Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a trigger characterization protocol at its actual path location. Identify full-rate, decimated, filtered or software statistics, test relevant edge/duration/level/modulation Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Worked application or illustrative case: Build a worked example of “a trigger characterization protocol at its actual path location”, addressing this associated condition: Identify full-rate, decimated, filtered or software statistics, test relevant edge/duration/level/modulation. Identify full-rate, decimated, filtered or software statistics, test relevant edge/duration/level/modulation Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a trigger characterization protocol at its actual path location”. Using “Metadata, Time, and Site Context”, specify a discriminator and the result expected under each explanation Source: §15.17 Metadata, Time, and Site Context (p. 8705)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a trigger characterization protocol at its actual path location, including the effect of missing measurements and inconsistent operating conditions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Scholarly synthesis and implications: Explain what the result about a trigger characterization protocol at its actual path location authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Closing: Conclude by answering “Design a trigger characterization protocol at its actual path location” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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V011-C15-ESSAY-010. Develop a pretrigger and posttrigger record plan for causal sequence analysis.

- Opening: Present a thesis that answers this precise question: Develop a pretrigger and posttrigger record plan for causal sequence analysis. Identify which evidence would falsify the proposed conclusion Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Core terminology and scope: Define pretrigger, posttrigger, record in the question's particular technical setting; explain how causal, sequence, analysis differ if that distinction would change the analysis of "Develop a pretrigger and posttrigger record plan for causal sequence analysis" Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Problem statement and purpose: Frame the actual measurement or decision in the question. the specific operating conditions identified in the accompanying guidance Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a pretrigger and posttrigger record plan for causal sequence analysis to the claimed result, following "Verify the trigger at its actual signal-path location"; name the intermediate states and measurable outputs Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a pretrigger and posttrigger record plan for causal sequence analysis.

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the specific operating conditions identified in the accompanying guidance Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Coverage Review and Storage Governance” that resolves the question about a pretrigger and posttrigger record plan for causal sequence analysis; derive the relevant result with units and stated validity conditions Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a pretrigger and posttrigger record plan for causal sequence analysis. the specific operating conditions identified in the accompanying guidance Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Worked application or illustrative case: Build a worked example of “a pretrigger and posttrigger record plan for causal sequence analysis”, addressing this associated condition: the specific operating conditions identified in the accompanying guidance. the specific operating conditions identified in the accompanying guidance Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a pretrigger and posttrigger record plan for causal sequence analysis”. Using “Coverage Review and Storage Governance”, specify a discriminator and the result expected under each explanation Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a pretrigger and posttrigger record plan for causal sequence analysis, including the effect of missing measurements and inconsistent operating conditions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Scholarly synthesis and implications: Explain what the result about a pretrigger and posttrigger record plan for causal sequence analysis authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Closing: Conclude by answering “Develop a pretrigger and posttrigger record plan for causal sequence analysis” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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V011-C15-ESSAY-011. Explain why a recorder and its trigger can disagree about a brief event.

- Opening: Present a thesis that answers this precise question: Explain why a recorder and its trigger can disagree about a brief event. Identify which evidence would falsify the proposed conclusion Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Core terminology and scope: Define recorder, trigger, disagree in the question's particular technical setting; explain how brief, event, measurement differ if that distinction would change the analysis of "Explain why a recorder and its trigger can disagree about a brief event" Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compare bandwidth, sample rate, filtering, estimator latency and state control in the two paths Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a recorder and its trigger can disagree about a brief event to the claimed result, following "Trigger Types and Pretrigger Context"; name the intermediate states and measurable outputs Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a recorder and its trigger can disagree about a brief event. Give bounded examples of recorder passage without triggering and

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trigger response without sufficient valid waveform, then propose a reference test Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Continuity proofs for sampled RF records, missing-data masks and sustained throughput” that resolves the question about why a recorder and its trigger can disagree about a brief event; derive the relevant result with units and stated validity conditions Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a recorder and its trigger can disagree about a brief event. Give bounded examples of recorder passage without triggering and trigger response without sufficient valid waveform, then propose a reference test Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Worked application or illustrative case: Build a worked example of “why a recorder and its trigger can disagree about a brief event”, addressing this associated condition: Compare bandwidth, sample rate, filtering, estimator latency and state control in the two paths. Compare bandwidth, sample rate, filtering, estimator latency and state control in the two paths Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a recorder and its trigger can disagree about a brief event”. Using “Continuity proofs for sampled RF records, missing-data masks and sustained throughput”, specify

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a discriminator and the result expected under each explanation Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a recorder and its trigger can disagree about a brief event, including the effect of missing measurements and inconsistent operating conditions Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Scholarly synthesis and implications: Explain what the result about why a recorder and its trigger can disagree about a brief event authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Closing: Conclude by answering “Explain why a recorder and its trigger can disagree about a brief event” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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V011-C15-ESSAY-012. Design a wideband storage plan using actual stored representation.

- Opening: Present a thesis that answers this precise question: Design a wideband storage plan using actual stored representation. Identify which evidence would falsify the proposed conclusion Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Core terminology and scope: Define Design, wideband, storage in the question's particular technical setting; explain how stored, representation, measurement differ if that distinction would change the analysis of "Design a wideband storage plan using actual stored representation" Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Calculate the 320 MB/s and 576 GB example, include container width, I/Q, channels, packing, overhead and reserve Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a wideband storage plan using actual stored representation to the claimed result, following "Coverage Review and Storage Governance"; name the intermediate states and measurable outputs Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a wideband storage plan using actual stored representation. Test

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sustained throughput for planned duration, monitor loss indicators and define controlled rollover/failure response Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Continuity proofs for sampled RF records, missing-data masks and sustained throughput” that resolves the question about a wideband storage plan using actual stored representation; derive the relevant result with units and stated validity conditions Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a wideband storage plan using actual stored representation. Test sustained throughput for planned duration, monitor loss indicators and define controlled rollover/failure response Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Worked application or illustrative case: Build a worked example of “a wideband storage plan using actual stored representation”, addressing this associated condition: Calculate the 320 MB/s and 576 GB example, include container width, I/Q, channels, packing, overhead and.... Calculate the 320 MB/s and 576 GB example, include container width, I/Q, channels, packing, overhead and reserve Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a wideband storage plan using actual stored representation”. Using “Continuity proofs for sampled RF records, missing-data masks and sustained throughput”, specify a

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discriminator and the result expected under each explanation Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a wideband storage plan using actual stored representation, including the effect of missing measurements and inconsistent operating conditions Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Scholarly synthesis and implications: Explain what the result about a wideband storage plan using actual stored representation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Closing: Conclude by answering “Design a wideband storage plan using actual stored representation” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-C15-ESSAY-013. Distinguish preserved-byte integrity from acquisition continuity.

- Opening: Present a thesis that answers this precise question: Distinguish preserved-byte integrity from acquisition continuity. Identify which evidence would falsify the proposed conclusion Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Core terminology and scope: Define preserved-byte, integrity, acquisition in the question's particular technical setting; explain how continuity, measurement, evidence differ if that distinction would change the analysis of "Distinguish preserved-byte integrity from acquisition continuity" Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain what a closed-file hash binds and what it cannot establish Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Distinguish preserved-byte integrity from acquisition continuity to the claimed result, following "Continuity proofs for sampled RF records, missing-data masks and sustained throughput"; name the intermediate states and measurable outputs Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Distinguish preserved-byte integrity from acquisition continuity. Use

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counters, sequence records, block lengths, flags and clock state to detect gaps or repeats; preserve a gap map and restrict estimators requiring uniform samples Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Wideband Recording and Data Integrity” that resolves the question about Distinguish preserved-byte integrity from acquisition continuity; derive the relevant result with units and stated validity conditions Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Distinguish preserved-byte integrity from acquisition continuity. Use counters, sequence records, block lengths, flags and clock state to detect gaps or repeats; preserve a gap map and restrict estimators requiring uniform samples Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Worked application or illustrative case: Build a worked example of “Distinguish preserved-byte integrity from acquisition continuity”, addressing this associated condition: Explain what a closed-file hash binds and what it cannot establish. Explain what a closed-file hash binds and what it cannot establish Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Distinguish preserved-byte integrity from acquisition continuity”. Using “Wideband Recording and Data

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Integrity", specify a discriminator and the result expected under each explanation Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Distinguish preserved-byte integrity from acquisition continuity, including the effect of missing measurements and inconsistent operating conditions Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Scholarly synthesis and implications: Explain what the result about Distinguish preserved-byte integrity from acquisition continuity authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Closing: Conclude by answering "Distinguish preserved-byte integrity from acquisition continuity" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-C15-ESSAY-014. Explain the risks of concatenating data around missing or repeated blocks.

- Opening: Present a thesis that answers this precise question: Explain the risks of concatenating data around missing or repeated blocks. Identify which evidence would falsify the proposed conclusion Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Core terminology and scope: Define risks, concatenating, data in the question's particular technical setting; explain how missing, repeated, blocks differ if that distinction would change the analysis of "Explain the risks of concatenating data around missing or repeated blocks" Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Track sample index against elapsed time and show how false transients or spectral behavior can arise Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the risks of concatenating data around missing or repeated blocks to the claimed result, following "Wideband Recording and Data Integrity"; name the intermediate states and measurable outputs Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the risks of concatenating data around missing or repeated blocks. Require

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explicit gap/repeat events, continuity-aware segmentation and retained metadata rather than silently restoring expected file length Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Acquisition provenance, loss masks and portable complex-sample metadata” that resolves the question about the risks of concatenating data around missing or repeated blocks; derive the relevant result with units and stated validity conditions Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the risks of concatenating data around missing or repeated blocks. Require explicit gap/repeat events, continuity-aware segmentation and retained metadata rather than silently restoring expected file length Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Worked application or illustrative case: Build a worked example of “the risks of concatenating data around missing or repeated blocks”, addressing this associated condition: Track sample index against elapsed time and show how false transients or spectral behavior can arise. Track sample index against elapsed time and show how false transients or spectral behavior can arise Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the risks of concatenating data around missing or repeated blocks”. Using “Acquisition provenance, loss masks and portable complex-sample metadata”, specify a

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discriminator and the result expected under each explanation Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the risks of concatenating data around missing or repeated blocks, including the effect of missing measurements and inconsistent operating conditions Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)
- Scholarly synthesis and implications: Explain what the result about the risks of concatenating data around missing or repeated blocks authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Closing: Conclude by answering “Explain the risks of concatenating data around missing or repeated blocks” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-C15-ESSAY-015. Develop a complete native-record metadata schema for reproducible receiver analysis.

- Opening: Present a thesis that answers this precise question: Develop a complete native-record metadata schema for reproducible receiver analysis. Identify which evidence would falsify the proposed conclusion Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Core terminology and scope: Define complete, metadata, schema in the question's particular technical setting; explain how reproducible, receiver, analysis differ if that distinction would change the analysis of "Develop a complete native-record metadata schema for reproducible receiver analysis" Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Include representation, rate, center frequency, state, path, calibration, device/software, trigger, time reference and uncertainty, geometry and relevant conditions Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a complete native-record metadata schema for reproducible receiver analysis to the claimed result, following "15. Evidence-grade metadata and reproducible processing"; name the intermediate states and measurable outputs Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a complete native-record metadata schema for reproducible receiver analysis. Bind separate metadata to hashes and include human reasons for changes alongside automated logs Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Acquisition provenance, loss masks and portable complex-sample metadata” that resolves the question about a complete native-record metadata schema for reproducible receiver analysis; derive the relevant result with units and stated validity conditions Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a complete native-record metadata schema for reproducible receiver analysis. Bind separate metadata to hashes and include human reasons for changes alongside automated logs Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Worked application or illustrative case: Build a worked example of “a complete native-record metadata schema for reproducible receiver analysis”, addressing this associated condition: Include representation, rate, center frequency, state, path, calibration, device/software, trigger, time.... Include representation, rate, center frequency, state, path, calibration, device/software, trigger, time

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reference and uncertainty, geometry and relevant... Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a complete native-record metadata schema for reproducible receiver analysis”. Using “Acquisition provenance, loss masks and portable complex-sample metadata”, specify a discriminator and the result expected under each explanation Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a complete native-record metadata schema for reproducible receiver analysis, including the effect of missing measurements and inconsistent operating conditions Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Scholarly synthesis and implications: Explain what the result about a complete native-record metadata schema for reproducible receiver analysis authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Closing: Conclude by answering “Develop a complete native-record metadata schema for reproducible receiver analysis” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.17 Metadata, Time, and Site Context (p. 8705)

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V011-C15-ESSAY-016. Create a reproducibility protocol for a derived spectrum or event result.

- Opening: Present a thesis that answers this precise question: Create a reproducibility protocol for a derived spectrum or event result. Identify which evidence would falsify the proposed conclusion Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Core terminology and scope: Define Create, reproducibility, protocol in the question's particular technical setting; explain how derived, spectrum, event differ if that distinction would change the analysis of "Create a reproducibility protocol for a derived spectrum or event result" Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain native source and selected interval, scaling, calibration, receiver state, window/normalization, mixing/decimation and exclusions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Create a reproducibility protocol for a derived spectrum or event result to the claimed result, following "Bind sample continuity, storage accounting and derived results"; name the intermediate states and measurable outputs Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Create a reproducibility protocol for a derived spectrum or event result.

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Rerun with a second implementation where practical, use reference and noise-only controls, and report parameter sensitivity Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Coverage Review and Storage Governance” that resolves the question about Create a reproducibility protocol for a derived spectrum or event result; derive the relevant result with units and stated validity conditions Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Create a reproducibility protocol for a derived spectrum or event result. Rerun with a second implementation where practical, use reference and noise-only controls, and report parameter sensitivity Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Worked application or illustrative case: Build a worked example of “Create a reproducibility protocol for a derived spectrum or event result”, addressing this associated condition: Retain native source and selected interval, scaling, calibration, receiver state, window/normalization,…. Retain native source and selected interval, scaling, calibration, receiver state, window/normalization, mixing/decimation and exclusions Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Create a reproducibility protocol for a derived spectrum or event result”. Using “Coverage Review and

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Storage Governance", specify a discriminator and the result expected under each explanation Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Create a reproducibility protocol for a derived spectrum or event result, including the effect of missing measurements and inconsistent operating conditions Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Scholarly synthesis and implications: Explain what the result about Create a reproducibility protocol for a derived spectrum or event result authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Closing: Conclude by answering "Create a reproducibility protocol for a derived spectrum or event result" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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V011-C15-ESSAY-017. Explain how triggered segmented acquisition can bias occupancy and context conclusions.

- Opening: Present a thesis that answers this precise question: Explain how triggered segmented acquisition can bias occupancy and context conclusions. Identify which evidence would falsify the proposed conclusion Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Core terminology and scope: Define triggered, segmented, bias in the question's particular technical setting; explain how occupancy, context, conclusions differ if that distinction would change the analysis of "Explain how triggered segmented acquisition can bias occupancy and context conclusions" Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Describe selection by threshold and schedule, omitted quiet or precursor intervals, and the role of circular buffers Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how triggered segmented acquisition can bias occupancy and context conclusions to the claimed result, following "Probability of Intercept and Observation Strategy"; name the intermediate states and measurable outputs Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how

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triggered segmented acquisition can bias occupancy and context conclusions. State what population the retained segments represent and what evidence would support a broader occupancy estimate Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

- Analytical framework: Identify the equation, calibration or evidential decision test in “15. Evidence-grade metadata and reproducible processing” that resolves the question about how triggered segmented acquisition can bias occupancy and context conclusions; derive the relevant result with units and stated validity conditions Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how triggered segmented acquisition can bias occupancy and context conclusions. State what population the retained segments represent and what evidence would support a broader occupancy estimate Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Worked application or illustrative case: Build a worked example of “how triggered segmented acquisition can bias occupancy and context conclusions”, addressing this associated condition: Describe selection by threshold and schedule, omitted quiet or precursor intervals, and the role of circular.... Describe selection by threshold and schedule, omitted quiet or precursor intervals, and the role of circular buffers Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how triggered segmented acquisition

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can bias occupancy and context conclusions". Using "15. Evidence-grade metadata and reproducible processing", specify a discriminator and the result expected under each explanation Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how triggered segmented acquisition can bias occupancy and context conclusions, including the effect of missing measurements and inconsistent operating conditions Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)
- Scholarly synthesis and implications: Explain what the result about how triggered segmented acquisition can bias occupancy and context conclusions authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Closing: Conclude by answering "Explain how triggered segmented acquisition can bias occupancy and context conclusions" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

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V011-C15-ESSAY-018. Develop a defensible negative coverage statement after a survey.

- Opening: Present a thesis that answers this precise question: Develop a defensible negative coverage statement after a survey. Identify which evidence would falsify the proposed conclusion Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Core terminology and scope: Define defensible, negative, coverage in the question's particular technical setting; explain how statement, survey, measurement differ if that distinction would change the analysis of "Develop a defensible negative coverage statement after a survey" Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Reconcile planned, commanded, valid and preserved intervals and passbands Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a defensible negative coverage statement after a survey to the claimed result, following "Model 15A: calculate conditional event coverage from usable windows"; name the intermediate states and measurable outputs Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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defensible negative coverage statement after a survey. Name event duration, overlap, phase law and detector prerequisites, retain excluded intervals and untested event classes, and avoid converting nonobservation into universal absence Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Coverage Review and Storage Governance” that resolves the question about a defensible negative coverage statement after a survey; derive the relevant result with units and stated validity conditions Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a defensible negative coverage statement after a survey. Name event duration, overlap, phase law and detector prerequisites, retain excluded intervals and untested event classes, and avoid converting nonobservation into universal absence Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Worked application or illustrative case: Build a worked example of “a defensible negative coverage statement after a survey”, addressing this associated condition: Reconcile planned, commanded, valid and preserved intervals and passbands. Reconcile planned, commanded, valid and preserved intervals and passbands Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a defensible negative coverage

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statement after a survey". Using "Coverage Review and Storage Governance", specify a discriminator and the result expected under each explanation Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a defensible negative coverage statement after a survey, including the effect of missing measurements and inconsistent operating conditions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Scholarly synthesis and implications: Explain what the result about a defensible negative coverage statement after a survey authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Closing: Conclude by answering "Develop a defensible negative coverage statement after a survey" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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V011-C15-ESSAY-019. Analyze the relay-transition pretrigger case without overclaiming causation.

- Opening: Present a thesis that answers this precise question: Analyze the relay-transition pretrigger case without overclaiming causation. Identify which evidence would falsify the proposed conclusion Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Core terminology and scope: Define relay-transition, pretrigger, case in the question's particular technical setting; explain how overclaiming, causation, measurement differ if that distinction would change the analysis of "Analyze the relay-transition pretrigger case without overclaiming causation" Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Explain temporal order and competing switch transient, newly admitted signal or shared-control hypotheses Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the relay-transition pretrigger case without overclaiming causation to the claimed result, following "Trigger Types and Pretrigger Context"; name the intermediate states and measurable outputs Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the

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relay-transition pretrigger case without overclaiming causation. Design a matched-reference static/bypass comparison with adequate sensitivity and preserve original and altered observations plus remaining attribution limits Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Bind sample continuity, storage accounting and derived results” that resolves the question about the relay-transition pretrigger case without overclaiming causation; derive the relevant result with units and stated validity conditions Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the relay-transition pretrigger case without overclaiming causation. Design a matched-reference static/bypass comparison with adequate sensitivity and preserve original and altered observations plus remaining attribution limits Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Worked application or illustrative case: Build a worked example of “the relay-transition pretrigger case without overclaiming causation”, addressing this associated condition: Explain temporal order and competing switch transient, newly admitted signal or shared-control hypotheses. Explain temporal order and competing switch transient, newly admitted signal or shared-control hypotheses Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “the relay-transition pretrigger case without overclaiming causation”. Using “Bind sample continuity, storage accounting and derived results”, specify a discriminator and the result expected under each explanation Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the relay-transition pretrigger case without overclaiming causation, including the effect of missing measurements and inconsistent operating conditions Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Scholarly synthesis and implications: Explain what the result about the relay-transition pretrigger case without overclaiming causation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Closing: Conclude by answering “Analyze the relay-transition pretrigger case without overclaiming causation” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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V011-C15-ESSAY-020. Explain how absolute and relative timing requirements change metadata needs.

- Opening: Present a thesis that answers this precise question: Explain how absolute and relative timing requirements change metadata needs. Identify which evidence would falsify the proposed conclusion Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Core terminology and scope: Define absolute, relative, timing in the question's particular technical setting; explain how requirements, metadata, needs differ if that distinction would change the analysis of "Explain how absolute and relative timing requirements change metadata needs" Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the intended cross-system comparison, clock source/history, time-zone and correction conventions, trigger-to-sample relation and uncertainty Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how absolute and relative timing requirements change metadata needs to the claimed result, following "15. Evidence-grade metadata and reproducible processing"; name the intermediate states and measurable outputs Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how absolute and relative timing requirements change metadata needs. Distinguish a timestamp string from a timing measurement and

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preserve state changes Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Acquisition provenance, loss masks and portable complex-sample metadata” that resolves the question about how absolute and relative timing requirements change metadata needs; derive the relevant result with units and stated validity conditions Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how absolute and relative timing requirements change metadata needs. Distinguish a timestamp string from a timing measurement and preserve state changes Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Worked application or illustrative case: Build a worked example of “how absolute and relative timing requirements change metadata needs”, addressing this associated condition: Define the intended cross-system comparison, clock source/history, time-zone and correction conventions,.... Define the intended cross-system comparison, clock source/history, time-zone and correction conventions, trigger-to-sample relation and uncertainty Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “how absolute and relative timing requirements change metadata needs”. Using “Acquisition provenance, loss masks and portable complex-sample metadata”, specify a discriminator and the result expected under each

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explanation Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how absolute and relative timing requirements change metadata needs, including the effect of missing measurements and inconsistent operating conditions Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Scholarly synthesis and implications: Explain what the result about how absolute and relative timing requirements change metadata needs authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Closing: Conclude by answering “Explain how absolute and relative timing requirements change metadata needs” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.17 Metadata, Time, and Site Context (p. 8705)

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V011-C15-ESSAY-021. Design a storage-governance plan that preserves evidence while respecting authorized purpose.

- Opening: Present a thesis that answers this precise question: Design a storage-governance plan that preserves evidence while respecting authorized purpose. Identify which evidence would falsify the proposed conclusion Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Core terminology and scope: Define Design, storage-governance, preserves in the question's particular technical setting; explain how respecting, authorized, purpose differ if that distinction would change the analysis of "Design a storage-governance plan that preserves evidence while respecting authorized purpose" Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify needed native records, reserve and rollover, access controls, retention and disposition, incidental-content minimization and documented migration/deletion Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a storage-governance plan that preserves evidence while respecting authorized purpose to the claimed result, following "Reproducible Analysis and Derived Products"; name the intermediate states and measurable outputs Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a storage-governance plan that preserves evidence while respecting authorized purpose. Explain why derived products cannot silently replace the source needed for verification Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Metadata, Time, and Site Context” that resolves the question about a storage-governance plan that preserves evidence while respecting authorized purpose; derive the relevant result with units and stated validity conditions Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a storage-governance plan that preserves evidence while respecting authorized purpose. Explain why derived products cannot silently replace the source needed for verification Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Worked application or illustrative case: Build a worked example of “a storage-governance plan that preserves evidence while respecting authorized purpose”, addressing this associated condition: Identify needed native records, reserve and rollover, access controls, retention and disposition,.... Identify needed native records, reserve and rollover, access controls, retention and disposition, incidental-content minimization and documented... Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a storage-governance plan that preserves evidence while respecting authorized purpose”. Using “Metadata, Time, and Site Context”, specify a discriminator and the result expected under each explanation Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a storage-governance plan that preserves evidence while respecting authorized purpose, including the effect of missing measurements and inconsistent operating conditions Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Scholarly synthesis and implications: Explain what the result about a storage-governance plan that preserves evidence while respecting authorized purpose authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Closing: Conclude by answering “Design a storage-governance plan that preserves evidence while respecting authorized purpose” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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V011-C15-ESSAY-022. Evaluate an impossible requested capture duration and propose a scientifically distinct alternative.

- Opening: Present a thesis that answers this precise question: Evaluate an impossible requested capture duration and propose a scientifically distinct alternative. Identify which evidence would falsify the proposed conclusion Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Core terminology and scope: Define impossible, requested, capture in the question's particular technical setting; explain how scientifically, distinct, alternative differ if that distinction would change the analysis of "Evaluate an impossible requested capture duration and propose a scientifically distinct alternative" Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use a 2 ms event with 3 ms requirement to show empty eligibility regardless of dwell or repetition Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an impossible requested capture duration and propose a scientifically distinct alternative to the claimed result, following "Application 15A.2: Capture a burst when only part of it is required"; name the intermediate states and measurable outputs Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an

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impossible requested capture duration and propose a scientifically distinct alternative. Propose either a changed question or a justified multi-event estimator, explicitly stating new repeatability/coherence premises rather than claiming original success Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.1: Distinguish a point observation from full capture of a short event” that resolves the question about an impossible requested capture duration and propose a scientifically distinct alternative; derive the relevant result with units and stated validity conditions Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an impossible requested capture duration and propose a scientifically distinct alternative. Propose either a changed question or a justified multi-event estimator, explicitly stating new repeatability/coherence premises rather than claiming original success Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Worked application or illustrative case: Build a worked example of “an impossible requested capture duration and propose a scientifically distinct alternative”, addressing this associated condition: Use a 2 ms event with 3 ms requirement to show empty eligibility regardless of dwell or repetition. Use a 2 ms event with 3 ms requirement to show empty eligibility regardless of dwell or

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repetition Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an impossible requested capture duration and propose a scientifically distinct alternative”. Using “Application 15A.1: Distinguish a point observation from full capture of a short event”, specify a discriminator and the result expected under each explanation Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an impossible requested capture duration and propose a scientifically distinct alternative, including the effect of missing measurements and inconsistent operating conditions Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Scholarly synthesis and implications: Explain what the result about an impossible requested capture duration and propose a scientifically distinct alternative authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)
- Closing: Conclude by answering “Evaluate an impossible requested capture duration and propose a scientifically distinct alternative” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

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V011-C15-ESSAY-023. Explain why a probability-of-capture calculation cannot by itself establish detection performance.

- Opening: Present a thesis that answers this precise question: Explain why a probability-of-capture calculation cannot by itself establish detection performance. Identify which evidence would falsify the proposed conclusion Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Core terminology and scope: Define probability-of-capture, calculation, cannot in the question's particular technical setting; explain how itself, detection, performance differ if that distinction would change the analysis of "Explain why a probability-of-capture calculation cannot by itself establish detection performance" Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate timing opportunity from threshold, SNR, false alarms, modulation recognition and minimum estimator duration Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a probability-of-capture calculation cannot by itself establish detection performance to the claimed result, following "Model 15A: calculate conditional event coverage from usable windows"; name the intermediate states and measurable outputs Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a probability-of-capture calculation cannot by itself establish detection performance. Describe controlled tests establishing prerequisites and show how failure of one changes the interpretation of a high geometric probability Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 15A.1: Distinguish a point observation from full capture of a short event" that resolves the question about why a probability-of-capture calculation cannot by itself establish detection performance; derive the relevant result with units and stated validity conditions Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a probability-of-capture calculation cannot by itself establish detection performance. Describe controlled tests establishing prerequisites and show how failure of one changes the interpretation of a high geometric probability Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Worked application or illustrative case: Build a worked example of "why a probability-of-capture calculation cannot by itself establish detection performance", addressing this associated condition: Separate timing opportunity from threshold, SNR, false alarms, modulation recognition and minimum estimator.... Separate timing

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opportunity from threshold, SNR, false alarms, modulation recognition and minimum estimator duration Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a probability-of-capture calculation cannot by itself establish detection performance”. Using “Application 15A.1: Distinguish a point observation from full capture of a short event”, specify a discriminator and the result expected under each explanation Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a probability-of-capture calculation cannot by itself establish detection performance, including the effect of missing measurements and inconsistent operating conditions Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Scholarly synthesis and implications: Explain what the result about why a probability-of-capture calculation cannot by itself establish detection performance authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Closing: Conclude by answering “Explain why a probability-of-capture calculation cannot by itself establish detection performance” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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V011-C15-ESSAY-024. Design a coverage plan for a mixture of continuous, periodic and hopping events.

- Opening: Present a thesis that answers this precise question: Design a coverage plan for a mixture of continuous, periodic and hopping events. Identify which evidence would falsify the proposed conclusion Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)
- Core terminology and scope: Define Design, coverage, continuous in the question's particular technical setting; explain how periodic, hopping, events differ if that distinction would change the analysis of "Design a coverage plan for a mixture of continuous, periodic and hopping events" Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Match instantaneous bandwidth, revisit, dwell, trigger and storage to each hypothesis; identify deterministic timing traps and needed state windows Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a coverage plan for a mixture of continuous, periodic and hopping events to the claimed result, following "Coverage Review and Storage Governance"; name the intermediate states and measurable outputs Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a coverage plan for a mixture of continuous, periodic and hopping

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events. Preserve the event-class-specific assumptions and avoid assigning one universal probability to the mixture without a model Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.10: Solve for a conditional trial count and check the boundary” that resolves the question about a coverage plan for a mixture of continuous, periodic and hopping events; derive the relevant result with units and stated validity conditions Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a coverage plan for a mixture of continuous, periodic and hopping events. Preserve the event-class-specific assumptions and avoid assigning one universal probability to the mixture without a model Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)
- Worked application or illustrative case: Build a worked example of “a coverage plan for a mixture of continuous, periodic and hopping events”, addressing this associated condition: Match instantaneous bandwidth, revisit, dwell, trigger and storage to each hypothesis; identify deterministic.... Match instantaneous bandwidth, revisit, dwell, trigger and storage to each hypothesis; identify deterministic timing traps and needed state windows Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a coverage plan for a mixture of

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continuous, periodic and hopping events". Using "Application 15A.10: Solve for a conditional trial count and check the boundary", specify a discriminator and the result expected under each explanation Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a coverage plan for a mixture of continuous, periodic and hopping events, including the effect of missing measurements and inconsistent operating conditions Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Scholarly synthesis and implications: Explain what the result about a coverage plan for a mixture of continuous, periodic and hopping events authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)
- Closing: Conclude by answering "Design a coverage plan for a mixture of continuous, periodic and hopping events" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

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V011-C15-ESSAY-025. Develop a release checklist that links claim strength to retained evidence rather than display appearance.

- Opening: Present a thesis that answers this precise question: Develop a release checklist that links claim strength to retained evidence rather than display appearance. Identify which evidence would falsify the proposed conclusion Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Core terminology and scope: Define release, checklist, links in the question's particular technical setting; explain how claim, strength, display differ if that distinction would change the analysis of "Develop a release checklist that links claim strength to retained evidence rather than display appearance" Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish qualifying fragment, complete event, stated schedule coverage and reproducible result Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a release checklist that links claim strength to retained evidence rather than display appearance to the claimed result, following "Coverage Review and Storage Governance"; name the intermediate states and measurable outputs Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a release checklist that links claim strength to retained evidence

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rather than display appearance. For each specify continuity, event boundaries, usable intervals, phase assumptions, native data and processing evidence, with the corresponding limitation preserved Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Reproducible Analysis and Derived Products” that resolves the question about a release checklist that links claim strength to retained evidence rather than display appearance; derive the relevant result with units and stated validity conditions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a release checklist that links claim strength to retained evidence rather than display appearance. For each specify continuity, event boundaries, usable intervals, phase assumptions, native data and processing evidence, with the corresponding limitation preserved Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Worked application or illustrative case: Build a worked example of “a release checklist that links claim strength to retained evidence rather than display appearance”, addressing this associated condition: Distinguish qualifying fragment, complete event, stated schedule coverage and reproducible result. Distinguish qualifying fragment, complete event, stated schedule coverage and reproducible result Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a release checklist that links claim strength to retained evidence rather than display appearance”. Using “Reproducible Analysis and Derived Products”, specify a discriminator and the result expected under each explanation Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a release checklist that links claim strength to retained evidence rather than display appearance, including the effect of missing measurements and inconsistent operating conditions Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Scholarly synthesis and implications: Explain what the result about a release checklist that links claim strength to retained evidence rather than display appearance authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Closing: Conclude by answering “Develop a release checklist that links claim strength to retained evidence rather than display appearance” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C15-DISCUSSION-001. A survey is sensitive enough in a bench test but misses a periodic burst. What should be checked?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A survey is sensitive enough in a bench test but misses a periodic burst. What should be checked?” Put this particular dispute to the panel: A survey is sensitive enough in a bench test but misses a periodic burst. What should be checked. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 02. Student A, terminology and scope: Agree the operational meanings of sensitive, bench, misses and periodic, burst, checked in “A survey is sensitive enough in a bench test but misses a periodic burst. What should be checked”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A survey is sensitive enough in a bench test but misses a periodic burst; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.5: Remove settling and closing guards from nominal dwell”. Separate sensitivity from opportunity and change schedule when a fixed miss is plausible Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A survey is sensitive enough in a bench test but misses a periodic burst; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.5: Remove settling and closing guards from nominal dwell”. Separate sensitivity from opportunity and change schedule when a fixed miss is plausible Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare event phase with usable dwell, settling and rearm intervals, and examine passband and trigger capability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A survey is sensitive enough in a bench test but misses a periodic burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A survey is sensitive enough in a bench test but misses a periodic burst; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A survey is sensitive enough in a bench test but misses a periodic burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A survey is sensitive enough in a bench test but misses a periodic burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A survey is sensitive enough in a bench test but misses a periodic burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A survey is sensitive enough in a bench test but misses a periodic burst. Separate sensitivity from opportunity and change schedule when a fixed miss is plausible Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A survey is sensitive enough in a bench test but misses a periodic burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A survey is sensitive enough in a bench test but misses a periodic burst. Separate sensitivity from opportunity and

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change schedule when a fixed miss is plausible Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A survey is sensitive enough in a bench test but misses a periodic burst and What should be checked; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A survey is sensitive enough in a bench test but misses a periodic burst”, addressing “What should be checked”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A survey is sensitive enough in a bench test but misses a periodic burst. What should be checked”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A survey is sensitive enough in a bench test but misses a periodic burst. What should be checked”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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V011-C15-DISCUSSION-002. A team calls every tuning-command interval usable. What evidence would you request?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team calls every tuning-command interval usable. What evidence would you request?” Put this particular dispute to the panel: A team calls every tuning-command interval usable. What evidence would you request. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 02. Student A, terminology and scope: Agree the operational meanings of calls, every, tuning-command and interval, usable, request in “A team calls every tuning-command interval usable. What evidence would you request”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team calls every tuning-command interval usable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.5: Remove settling and closing guards from nominal dwell”. Recompute coverage from demonstrated intervals Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team calls every tuning-command interval usable; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.5: Remove settling and closing guards from nominal dwell”. Recompute coverage from demonstrated intervals Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Measure response validity after each relevant transition, identify settling/AGC/filter/rearm exclusions and compare commands to actual sample flags Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A team calls every tuning-command interval usable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team calls every tuning-command interval usable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team calls every tuning-command interval usable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team calls every tuning-command interval usable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team calls every tuning-command interval usable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team calls every tuning-command interval usable. Recompute coverage from demonstrated intervals Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team calls every tuning-command interval usable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team calls every tuning-command interval usable. Recompute coverage from demonstrated intervals Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test

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or uncertainty term that limits confidence. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team calls every tuning-command interval usable and What evidence would you request; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team calls every tuning-command interval usable”, addressing “What evidence would you request”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team calls every tuning-command interval usable. What evidence would you request”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team calls every tuning-command interval usable. What evidence would you request”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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V011-C15-DISCUSSION-003. A recognizable fragment is presented as a complete capture. How would you review the claim?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A recognizable fragment is presented as a complete capture. How would you review the claim?” Put this particular dispute to the panel: A recognizable fragment is presented as a complete capture. How would you review the claim. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 02. Student A, terminology and scope: Agree the operational meanings of recognizable, fragment, presented and capture, review, claim in “A recognizable fragment is presented as a complete capture. How would you review the claim”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A recognizable fragment is presented as a complete capture; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.1: Distinguish a point observation from full capture of a short event”. Preserve the valid fragment observation while stating unknown leading/trailing portions and any missing startup information Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A recognizable fragment is

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presented as a complete capture; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.1: Distinguish a point observation from full capture of a short event”. Preserve the valid fragment observation while stating unknown leading/trailing portions and any missing startup information Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require both boundaries and necessary context in one continuous record Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A recognizable fragment is presented as a complete capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A recognizable fragment is presented as a complete capture; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A recognizable fragment is presented as a complete capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A recognizable fragment is presented as a complete capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A recognizable fragment is presented as a complete capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A recognizable fragment is presented as a complete capture. Preserve the valid fragment observation while stating unknown leading/trailing portions and any missing startup information Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A recognizable fragment is presented as a complete capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A recognizable fragment is presented as a complete capture. Preserve the valid fragment observation while

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stating unknown leading/trailing portions and any missing startup information Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A recognizable fragment is presented as a complete capture and How would you review the claim; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A recognizable fragment is presented as a complete capture”, addressing “How would you review the claim”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A recognizable fragment is presented as a complete capture. How would you review the claim”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A recognizable fragment is presented as a complete capture. How would you review the claim”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

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V011-C15-DISCUSSION-004. A planned observation requires 3 ms from a 2 ms event. What is the appropriate revision?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A planned observation requires 3 ms from a 2 ms event. What is the appropriate revision?” Put this particular dispute to the panel: A planned observation requires 3 ms from a 2 ms event. What is the appropriate revision. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 02. Student A, terminology and scope: Agree the operational meanings of planned, observation, requires and event, appropriate, revision in “A planned observation requires 3 ms from a 2 ms event. What is the appropriate revision”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A planned observation requires 3 ms from a 2 ms event; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.3: Require the whole burst”. Do not improve the nominal probability by invalid arithmetic Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A planned observation requires 3 ms from a 2 ms event; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.3: Require the whole burst”. Do not improve the nominal probability by invalid arithmetic Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Show that no timing schedule meets the stated one-event criterion, then reconsider the scientific question or define a new repeatable multi-event analysis Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A planned observation requires 3 ms from a 2

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ms event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A planned observation requires 3 ms from a 2 ms event; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A planned observation requires 3 ms from a 2 ms event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A planned observation requires 3 ms from a 2 ms event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A planned observation requires 3 ms from a 2 ms event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A planned observation requires 3 ms from a

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2 ms event. Do not improve the nominal probability by invalid arithmetic Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A planned observation requires 3 ms from a 2 ms event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A planned observation requires 3 ms from a 2 ms event. Do not improve the nominal probability by invalid arithmetic Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A planned observation requires 3 ms from a 2 ms event and What is the appropriate revision; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A planned observation requires 3 ms from a 2 ms event”, addressing “What is the appropriate revision”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A planned observation requires 3 ms from a 2

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ms event. What is the appropriate revision", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A planned observation requires 3 ms from a 2 ms event. What is the appropriate revision". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

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V011-C15-DISCUSSION-005. Two dwell probabilities sum to 0.50, but eligible-start sets overlap. How should coverage be calculated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two dwell probabilities sum to 0.50, but eligible-start sets overlap. How should coverage be calculated?” Put this particular dispute to the panel: Two dwell probabilities sum to 0.50, but eligible-start sets overlap. How should coverage be calculated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 02. Student A, terminology and scope: Agree the operational meanings of dwell, probabilities, sets and overlap, coverage, calculated in “Two dwell probabilities sum to 0.50, but eligible-start sets overlap. How should coverage be calculated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two dwell probabilities sum to 0.50, but eligible-start sets overlap; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.4: Reject an impossible overlap requirement”. Explain the difference between duplicate phases and physically combining fragmented data Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two dwell probabilities sum to 0.50, but eligible-start sets overlap; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.4: Reject an impossible overlap requirement”. Explain the difference between duplicate phases and physically combining fragmented data Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Derive each start set on the unfolded axis, reduce modulo period, merge overlaps and measure the union Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two dwell probabilities sum to 0.50, but eligible-start sets overlap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two dwell probabilities sum to 0.50, but eligible-start sets overlap; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two dwell probabilities sum to 0.50, but eligible-start sets overlap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two dwell probabilities sum to 0.50, but eligible-start sets overlap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two dwell probabilities sum to 0.50, but eligible-start sets overlap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two dwell probabilities sum to 0.50, but eligible-start sets overlap. Explain the difference between duplicate phases and physically combining fragmented data Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two dwell probabilities sum to 0.50, but eligible-start sets overlap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two dwell probabilities sum to 0.50, but eligible-start sets overlap. Explain the difference between duplicate phases

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and physically combining fragmented data Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two dwell probabilities sum to 0.50, but eligible-start sets overlap and How should coverage be calculated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two dwell probabilities sum to 0.50, but eligible-start sets overlap”, addressing “How should coverage be calculated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two dwell probabilities sum to 0.50, but eligible-start sets overlap. How should coverage be calculated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two dwell probabilities sum to 0.50, but eligible-start sets overlap. How should coverage be calculated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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V011-C15-DISCUSSION-006. One hundred repeated observations all miss a phase-locked event. Is the independent-trial formula applicable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One hundred repeated observations all miss a phase-locked event. Is the independent-trial formula applicable?” Put this particular dispute to the panel: One hundred repeated observations all miss a phase-locked event. Is the independent-trial formula applicable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 02. Student A, terminology and scope: Agree the operational meanings of repeated, observations, miss and event, formula, applicable in “One hundred repeated observations all miss a phase-locked event. Is the independent-trial formula applicable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One hundred repeated observations all miss a phase-locked event; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.9: Calculate repeated capture only under independent start phases”. More file count alone supplies no new phase opportunity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One hundred repeated observations all miss a phase-locked event; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.9: Calculate repeated capture only under independent start phases”. More file count alone supplies no new phase opportunity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No without a justified phase experiment; inspect fixed timing and change schedule or establish an appropriate joint model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving One hundred repeated observations all miss a phase-locked event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One hundred repeated observations all miss a phase-locked event; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One hundred repeated observations all miss a phase-locked event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One hundred repeated observations all miss a phase-locked event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One hundred repeated observations all miss a phase-locked event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One hundred repeated observations all miss a phase-locked event. More file count alone supplies no new phase opportunity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One hundred repeated observations all miss a phase-locked event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One hundred repeated observations all miss a phase-locked event. More file count alone supplies no new phase

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opportunity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One hundred repeated observations all miss a phase-locked event and Is the independent-trial formula applicable; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One hundred repeated observations all miss a phase-locked event”, addressing “Is the independent-trial formula applicable”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One hundred repeated observations all miss a phase-locked event. Is the independent-trial formula applicable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One hundred repeated observations all miss a phase-locked event. Is the independent-trial formula applicable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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V011-C15-DISCUSSION-007. Two files have adjacent timestamps around a period origin. May they be joined for a contiguous criterion?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two files have adjacent timestamps around a period origin. May they be joined for a contiguous criterion?” Put this particular dispute to the panel: Two files have adjacent timestamps around a period origin. May they be joined for a contiguous criterion. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 02. Student A, terminology and scope: Agree the operational meanings of adjacent, timestamps, period and origin, joined, contiguous in “Two files have adjacent timestamps around a period origin. May they be joined for a contiguous criterion”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two files have adjacent timestamps around a period origin; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “15. Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed…”. Require sample-counter and clock evidence that acquisition continued without a gap, distinguish file and coordinate boundaries, and preserve any genuine rearm interruption Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two files have adjacent timestamps around a period origin; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “15. Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed…”. Require sample-counter and clock evidence that acquisition continued without a gap, distinguish file and coordinate boundaries, and preserve any genuine rearm interruption Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require sample-counter and clock evidence that acquisition continued without a gap, distinguish file and coordinate boundaries, and preserve any

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genuine rearm interruption Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two files have adjacent timestamps around a period origin: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two files have adjacent timestamps around a period origin; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two files have adjacent timestamps around a period origin: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two files have adjacent timestamps around a period origin, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving Two files have adjacent timestamps around a period origin: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two files have adjacent timestamps around a period origin. Require sample-counter and clock evidence that acquisition continued without a gap, distinguish file and coordinate boundaries, and preserve any genuine rearm interruption Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two files have adjacent timestamps around a period origin, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what

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evidence would reverse the conclusion. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two files have adjacent timestamps around a period origin. Require sample-counter and clock evidence that acquisition continued without a gap, distinguish file and coordinate boundaries, and preserve any genuine rearm interruption Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two files have adjacent timestamps around a period origin and May they be joined for a contiguous criterion; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two files have adjacent timestamps around a period origin”, addressing “May they be joined for a contiguous criterion”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two files have adjacent timestamps around a period origin. May they be joined for a contiguous criterion”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two files have adjacent timestamps around a period origin. May they be joined for a contiguous criterion”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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V011-C15-DISCUSSION-008. A field log has ten different trigger times. Does that establish independent event phases?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A field log has ten different trigger times. Does that establish independent event phases?” Put this particular dispute to the panel: A field log has ten different trigger times. Does that establish independent event phases. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 02. Student A, terminology and scope: Agree the operational meanings of field, trigger, times and independent, event, phases in “A field log has ten different trigger times. Does that establish independent event phases”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A field log has ten different trigger times; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. State the actual phase model and do not infer independence from distinct timestamps Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A field log has ten different trigger times; explain what each record can establish State what the existing record establishes, what it does not establish, and which

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further measurement would change your opinion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. State the actual phase model and do not infer independence from distinct timestamps Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; examine periodic operation, shared clocks and trigger coupling or controlled randomization Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A field log has ten different trigger times:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A field log has ten different trigger times; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A field log has ten different trigger times: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A field log has ten different trigger times, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A field log has ten different trigger times: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A field log has ten different trigger times. State the actual phase model and do not infer independence from

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distinct timestamps Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A field log has ten different trigger times, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A field log has ten different trigger times. State the actual phase model and do not infer independence from distinct timestamps Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A field log has ten different trigger times and Does that establish independent event phases; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A field log has ten different trigger times”, addressing “Does that establish independent event phases”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A field log has ten different trigger times. Does that establish independent event phases”, specifying the next test,

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responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A field log has ten different trigger times. Does that establish independent event phases”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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V011-C15-DISCUSSION-009. A search plan adopts 18 trials because the chapter obtains 0.99. What applicability questions matter?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A search plan adopts 18 trials because the chapter obtains 0.99. What applicability questions matter?” Put this particular dispute to the panel: A search plan adopts 18 trials because the chapter obtains 0.99. What applicability questions matter. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 02. Student A, terminology and scope: Agree the operational meanings of search, trials, obtains and applicability, questions, matter in “A search plan adopts 18 trials because the chapter obtains 0.99. What applicability questions matter”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A search plan adopts 18 trials because the chapter obtains 0.99; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.2: Capture a burst when only part of it is required”. Recalculate for the actual conditions and retain boundary checks Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A search plan adopts 18 trials because the chapter obtains 0.99; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.2: Capture a burst when only part of it is required”. Recalculate for the actual conditions and retain boundary checks Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check event duration, usable window, required overlap, detector prerequisites and independent phase law Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A search plan adopts 18 trials because the chapter obtains 0.99: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A search plan adopts 18 trials because the chapter obtains 0.99; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A search plan adopts 18 trials because the chapter obtains 0.99: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A search plan adopts 18 trials because the chapter obtains 0.99, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A search plan adopts 18 trials because the chapter obtains 0.99: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A search plan adopts 18 trials because the chapter obtains 0.99. Recalculate for the actual conditions and retain boundary checks Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A search plan adopts 18 trials because the chapter obtains 0.99, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A search plan adopts 18 trials because the chapter obtains 0.99. Recalculate for the actual conditions and retain boundary checks Respond point by point to Student J. Distinguish a

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verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A search plan adopts 18 trials because the chapter obtains 0.99 and What applicability questions matter; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A search plan adopts 18 trials because the chapter obtains 0.99”, addressing “What applicability questions matter”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A search plan adopts 18 trials because the chapter obtains 0.99. What applicability questions matter”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A search plan adopts 18 trials because the chapter obtains 0.99. What applicability questions matter”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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V011-C15-DISCUSSION-010. The schedule is modified after each miss but the original fixed-trial probability is reported. How should this be repaired?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The schedule is modified after each miss but the original fixed-trial probability is reported. How should this be repaired?” Put this particular dispute to the panel: The schedule is modified after each miss but the original fixed-trial probability is reported. How should this be repaired. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 02. Student A, terminology and scope: Agree the operational meanings of schedule, modified, miss and probability, reported, repaired in “The schedule is modified after each miss but the original fixed-trial probability is reported. How should this be repaired”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The schedule is modified after each miss but the original fixed-trial probability is reported; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.10: Solve for a conditional trial count and check the boundary”. Preserve the adaptation rule and actual sequence, analyze the resulting conditional or joint experiment, and avoid assigning the old expression without matching assumptions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The schedule is modified after each miss but the original fixed-trial probability is reported; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.10: Solve for a conditional trial count and check the boundary”. Preserve the adaptation rule and actual sequence, analyze the resulting conditional or joint experiment, and avoid assigning the old expression without matching assumptions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Preserve the adaptation rule and actual sequence, analyze the resulting conditional or joint experiment, and avoid assigning the old expression without matching assumptions Put two specific

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questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The schedule is modified after each miss but the original fixed-trial probability is reported: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The schedule is modified after each miss but the original fixed-trial probability is reported; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The schedule is modified after each miss but the original fixed-trial probability is reported: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The schedule is modified after each miss but the original fixed-trial probability is reported, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving The schedule is modified after each miss but the original fixed-trial probability is reported: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The schedule is modified after each miss but the original fixed-trial probability is reported. Preserve the adaptation rule and actual sequence, analyze the resulting conditional or joint experiment, and avoid assigning the old expression without matching assumptions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The schedule is modified after each miss but the original fixed-trial probability is reported, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether

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the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The schedule is modified after each miss but the original fixed-trial probability is reported. Preserve the adaptation rule and actual sequence, analyze the resulting conditional or joint experiment, and avoid assigning the old expression without matching assumptions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The schedule is modified after each miss but the original fixed-trial probability is reported and How should this be repaired; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains

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within authorised laboratory and field boundaries. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The schedule is modified after each miss but the original fixed-trial probability is reported”, addressing “How should this be repaired”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The schedule is modified after each miss but the original fixed-trial probability is reported. How should this be repaired”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The schedule is modified after each miss but the original fixed-trial probability is reported. How should this be repaired”. Allocate the next measurement and documentary action to named student roles, and require each participant to

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distinguish accepted evidence from an unsupported assertion.

Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

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V011-C15-DISCUSSION-011. A full-rate recorder contains an event that its decimated trigger missed. What should change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A full-rate recorder contains an event that its decimated trigger missed. What should change?” Put this particular dispute to the panel: A full-rate recorder contains an event that its decimated trigger missed. What should change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 02. Student A, terminology and scope: Agree the operational meanings of recorder, contains, event and decimated, trigger, missed in “A full-rate recorder contains an event that its decimated trigger missed. What should change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A full-rate recorder contains an event that its decimated trigger missed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Do not assume recorder presence guarantees trigger detection Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A full-rate recorder contains an event that its decimated trigger missed; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Do not assume recorder presence guarantees trigger detection Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Characterize trigger bandwidth and latency relative to saved data, choose a suitable trigger path or criterion, and retain the demonstrated distinction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A full-rate recorder contains an event that its

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decimated trigger missed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A full-rate recorder contains an event that its decimated trigger missed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A full-rate recorder contains an event that its decimated trigger missed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A full-rate recorder contains an event that its decimated trigger missed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A full-rate recorder contains an event that its decimated trigger missed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A full-rate recorder contains an event that its decimated trigger missed. Do not assume recorder presence guarantees trigger detection Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A full-rate recorder contains an event that its decimated trigger missed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A full-rate recorder contains an event that its decimated trigger missed. Do not assume recorder presence guarantees trigger detection Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A full-rate recorder contains an event that its decimated trigger missed and What should change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A full-rate recorder contains an event that its decimated trigger missed”, addressing “What should change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A full-rate recorder contains an event that its decimated trigger missed. What should change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A full-rate recorder contains an event that its decimated trigger missed. What should change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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V011-C15-DISCUSSION-012. An isolated trigger test passes, but closely spaced event pairs fail. What is the likely test gap?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An isolated trigger test passes, but closely spaced event pairs fail. What is the likely test gap?” Put this particular dispute to the panel: An isolated trigger test passes, but closely spaced event pairs fail. What is the likely test gap. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 02. Student A, terminology and scope: Agree the operational meanings of isolated, trigger, passes and spaced, pairs, fail in “An isolated trigger test passes, but closely spaced event pairs fail. What is the likely test gap”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An isolated trigger test passes, but closely spaced event pairs fail; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Bound the usable schedule accordingly Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An isolated trigger test passes, but closely spaced event pairs fail; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Bound the usable schedule accordingly Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Holdoff, recovery or rearm behavior was not covered; vary controlled separation and inspect valid samples and trigger state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An isolated trigger test passes, but closely spaced event pairs fail: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An isolated trigger test passes, but closely spaced event pairs fail; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An isolated trigger test passes, but closely spaced event pairs fail: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An isolated trigger test passes, but closely spaced event pairs fail, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An isolated trigger test passes, but closely spaced event pairs fail: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An isolated trigger test passes, but closely spaced event pairs fail. Bound the usable schedule accordingly Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An isolated trigger test passes, but closely spaced event pairs fail, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An isolated trigger test passes, but closely spaced event pairs fail. Bound the usable schedule accordingly Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence.

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Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An isolated trigger test passes, but closely spaced event pairs fail and What is the likely test gap; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An isolated trigger test passes, but closely spaced event pairs fail”, addressing “What is the likely test gap”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An isolated trigger test passes, but closely spaced event pairs fail. What is the likely test gap”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An isolated trigger test passes, but closely spaced event pairs fail. What is the likely test gap”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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V011-C15-DISCUSSION-013. A larger pretrigger buffer includes a recent gain switch. Is the added context automatically comparable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A larger pretrigger buffer includes a recent gain switch. Is the added context automatically comparable?” Put this particular dispute to the panel: A larger pretrigger buffer includes a recent gain switch. Is the added context automatically comparable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 02. Student A, terminology and scope: Agree the operational meanings of larger, pretrigger, buffer and recent, context, comparable in “A larger pretrigger buffer includes a recent gain switch. Is the added context automatically comparable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A larger pretrigger buffer includes a recent gain switch; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Metadata, Time, and Site Context”. Nominal depth does not prove continuous same-state evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A larger pretrigger buffer includes a recent gain switch; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Metadata, Time, and Site Context”. Nominal depth does not prove continuous same-state evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; inspect state timestamps and validity flags, characterize settling and retain only applicable context Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A larger pretrigger buffer includes a recent gain switch: specify the altered receiver state or source condition,

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predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A larger pretrigger buffer includes a recent gain switch; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A larger pretrigger buffer includes a recent gain switch: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A larger pretrigger buffer includes a recent gain switch, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A larger pretrigger buffer includes a recent gain switch: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A larger pretrigger buffer includes a recent gain switch. Nominal depth does not prove continuous same-state evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be

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settled by visual appearance or a single unqualified reading. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A larger pretrigger buffer includes a recent gain switch, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A larger pretrigger buffer includes a recent gain switch. Nominal depth does not prove continuous same-state evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the

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particular claim about A larger pretrigger buffer includes a recent gain switch and Is the added context automatically comparable; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A larger pretrigger buffer includes a recent gain switch”, addressing “Is the added context automatically comparable”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A larger pretrigger buffer includes a recent gain switch. Is the added context automatically comparable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A larger pretrigger buffer includes a recent gain

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switch. Is the added context automatically comparable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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V011-C15-DISCUSSION-014. A trigger time comes from a software packet. How can it support sample-level timing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A trigger time comes from a software packet. How can it support sample-level timing?” Put this particular dispute to the panel: A trigger time comes from a software packet. How can it support sample-level timing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 02. Student A, terminology and scope: Agree the operational meanings of trigger, comes, software and packet, support, timing in “A trigger time comes from a software packet. How can it support sample-level timing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A trigger time comes from a software packet; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. Measure the relation between software event, acquisition clock and stored sample apertures, retain latency and uncertainty, and avoid treating the packet timestamp as a direct sample time Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A trigger time comes from a software packet; explain what each record can establish State what

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the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. Measure the relation between software event, acquisition clock and stored sample apertures, retain latency and uncertainty, and avoid treating the packet timestamp as a direct sample time Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Measure the relation between software event, acquisition clock and stored sample apertures, retain latency and uncertainty, and avoid treating the packet timestamp as a direct sample time Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A trigger time comes from a software packet: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A trigger time comes from a software packet; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A trigger time comes from a software packet: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion

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Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A trigger time comes from a software packet, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A trigger time comes from a software packet: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A trigger time comes from a software packet. Measure the relation between software event, acquisition clock and stored sample apertures, retain latency and uncertainty, and avoid treating the packet timestamp as a direct sample time Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A trigger time comes from a software packet, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A trigger time comes from a software packet. Measure the relation between software event, acquisition clock and

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stored sample apertures, retain latency and uncertainty, and avoid treating the packet timestamp as a direct sample time Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A trigger time comes from a software packet and How can it support sample-level timing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A trigger time comes from a software packet”, addressing “How can it support sample-level timing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A trigger time comes from a software packet. How can it support sample-level timing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A trigger time comes from a software packet. How can it support sample-level timing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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V011-C15-DISCUSSION-015. The storage benchmark is fast for five seconds but the survey lasts 30 minutes. What remains to test?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The storage benchmark is fast for five seconds but the survey lasts 30 minutes. What remains to test?” Put this particular dispute to the panel: The storage benchmark is fast for five seconds but the survey lasts 30 minutes. What remains to test. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of storage, benchmark, fast and seconds, lasts, minutes in “The storage benchmark is fast for five seconds but the survey lasts 30 minutes. What remains to test”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The storage benchmark is fast for five seconds but the survey lasts 30 minutes; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Wideband Recording and Data Integrity”. Capacity and burst speed alone do not establish continuity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The storage benchmark is fast for five seconds but the survey lasts 30 minutes; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §15.31 Archiving policies for fifteen minutes to seventy-two hours of instantaneous forty-gigahertz observation (p. 8740)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Wideband Recording and Data Integrity”. Capacity and burst speed alone do not establish continuity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Sustained writing in the planned configuration, buffer exhaustion, thermal and clock behavior, rollover and overrun indicators Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 08. Student D, answer to Student E: Design a discriminating experiment involving The storage benchmark is fast for five seconds

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but the survey lasts 30 minutes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The storage benchmark is fast for five seconds but the survey lasts 30 minutes; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.31 Archiving policies for fifteen minutes to seventy-two hours of instantaneous forty-gigahertz observation (p. 8740)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The storage benchmark is fast for five seconds but the survey lasts 30 minutes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The storage benchmark is fast for five seconds but the survey lasts 30 minutes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The storage benchmark is fast for five seconds but the survey lasts 30 minutes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The storage benchmark is fast for five seconds but the survey lasts 30 minutes. Capacity and burst speed alone do not establish continuity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.31 Archiving policies for fifteen minutes to seventy-two hours of instantaneous forty-gigahertz observation (p. 8740)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The storage benchmark is fast for five seconds but the survey lasts 30 minutes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The storage benchmark is fast for five seconds but the survey lasts 30 minutes. Capacity and burst speed alone do not establish continuity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.31 Archiving policies for fifteen minutes to seventy-two hours of instantaneous forty-gigahertz observation (p. 8740)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The storage benchmark is fast for five seconds but the survey lasts 30 minutes and What remains to test; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The storage benchmark is fast for five seconds but the survey lasts 30 minutes”, addressing “What remains to test”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The storage benchmark is fast for five seconds but the survey lasts 30 minutes. What remains to test”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The storage benchmark is fast for five seconds but the survey lasts 30 minutes. What remains to test”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-C15-DISCUSSION-016. A file has the expected length and a stable hash but contains a duplicated block. What has the hash proved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A file has the expected length and a stable hash but contains a duplicated block. What has the hash proved?” Put this particular dispute to the panel: A file has the expected length and a stable hash but contains a duplicated block. What has the hash proved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of expected, length, stable and hash, duplicated, block in “A file has the expected length and a stable hash but contains a duplicated block. What has the hash proved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A file has the expected length and a stable hash but contains a duplicated block; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Continuity proofs for sampled RF records, missing-data masks and sustained throughput”. Use sequence counters and block records, preserve the repeat event and limit affected analyses Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A file has the expected length

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and a stable hash but contains a duplicated block; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Continuity proofs for sampled RF records, missing-data masks and sustained throughput”. Use sequence counters and block records, preserve the repeat event and limit affected analyses Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Only unchanged preserved bytes relative to the hash, not original continuity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A file has the expected length and a stable hash but contains a duplicated block: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A file has the expected length and a stable hash but contains a duplicated block; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A file has the expected length and a stable hash but contains a duplicated block: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A file has the expected length and a stable hash but contains a duplicated block, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A file has the expected length and a stable hash but contains a duplicated block: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A file has the expected length and a stable hash but contains a duplicated block. Use sequence counters and block records, preserve the repeat event and limit affected analyses Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A file has the expected length and a stable hash but contains a duplicated block, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A file has the expected length and a stable hash but contains a duplicated block. Use sequence counters and block records, preserve the repeat event and limit affected analyses Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A file has the expected length and a stable hash but contains a duplicated block and What has the hash proved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A file has the expected length and a stable hash but contains a duplicated block”, addressing “What has the hash proved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A file has the expected length and a stable hash but contains a duplicated block. What has the hash proved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A file has the expected length and a stable hash but contains a duplicated block. What has the hash proved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-C15-DISCUSSION-017. An analyst deletes missing intervals and concatenates samples before the FFT. What is the concern?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An analyst deletes missing intervals and concatenates samples before the FFT. What is the concern?” Put this particular dispute to the panel: An analyst deletes missing intervals and concatenates samples before the FFT. What is the concern. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, deletes, missing and intervals, samples, concern in “An analyst deletes missing intervals and concatenates samples before the FFT. What is the concern”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An analyst deletes missing intervals and concatenates samples before the FFT; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.4: Reject an impossible overlap requirement”. Retain a gap map and use valid segments or a separately justified estimator Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst deletes missing intervals and concatenates samples before the FFT; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.4: Reject an impossible overlap requirement”. Retain a gap map and use valid segments or a separately justified estimator Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The index-to-time relation and boundary waveform are changed, potentially creating false spectral features Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An analyst deletes missing intervals and concatenates samples before the FFT: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst deletes missing intervals and concatenates samples before the FFT; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An analyst deletes missing intervals and concatenates samples before the FFT: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An analyst deletes missing intervals and concatenates samples before the FFT, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An analyst deletes missing intervals and concatenates samples before the FFT: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An analyst deletes missing intervals and concatenates samples before the FFT. Retain a gap map and use valid segments or a separately justified estimator Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An analyst deletes missing intervals and concatenates samples before the FFT, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An analyst deletes missing intervals and

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concatenates samples before the FFT. Retain a gap map and use valid segments or a separately justified estimator Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An analyst deletes missing intervals and concatenates samples before the FFT and What is the concern; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An analyst deletes missing intervals and concatenates samples before the FFT”, addressing “What is the concern”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An analyst deletes missing intervals and concatenates samples before the FFT. What is the concern”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An analyst deletes missing intervals and concatenates samples before the FFT. What is the concern”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-C15-DISCUSSION-018. A 12-bit converter is exported as 32-bit floating-point I/Q. Which representation governs storage planning?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A 12-bit converter is exported as 32-bit floating-point I/Q. Which representation governs storage planning?” Put this particular dispute to the panel: A 12-bit converter is exported as 32-bit floating-point I/Q. Which representation governs storage planning. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of converter, exported, representation and governs, storage, planning in “A 12-bit converter is exported as 32-bit floating-point I/Q. Which representation governs storage planning”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A 12-bit converter is exported as 32-bit floating-point I/Q; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Continuity proofs for sampled RF records, missing-data masks and sustained throughput”. Distinguish acquisition resolution from container size and test the resulting sustained rate Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A 12-bit converter is exported as 32-bit floating-point I/Q; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Continuity proofs for sampled RF records, missing-data masks and sustained throughput”. Distinguish acquisition resolution from container size and test the resulting sustained rate Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The actual 32-bit two-component export, including channel count and overhead Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A 12-bit converter is exported as 32-bit floating-point I/Q: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A 12-bit converter is exported as 32-bit floating-point I/Q; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A 12-bit converter is exported as 32-bit floating-point I/Q: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A 12-bit converter is exported as 32-bit floating-point I/Q, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A 12-bit converter is exported as 32-bit floating-point I/Q: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A 12-bit converter is exported as 32-bit floating-point I/Q. Distinguish acquisition resolution from container size and test the resulting sustained rate Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A 12-bit converter is exported as 32-bit floating-point I/Q, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A 12-bit converter is exported as 32-bit floating-point I/Q. Distinguish acquisition resolution from container size and test the resulting sustained rate Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.24 Acquisition provenance, loss masks and portable complex-sample metadata (p. 8714)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A 12-bit converter is exported as 32-bit floating-point I/Q and Which representation governs storage planning; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A 12-bit converter is exported as 32-bit floating-point I/Q”, addressing “Which representation governs storage planning”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A 12-bit converter is exported as 32-bit floating-point I/Q. Which representation governs storage planning”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A 12-bit converter is exported as 32-bit floating-point I/Q. Which representation governs storage planning”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-C15-DISCUSSION-019. Only triggered segments are used to estimate whole-day occupancy. What limitation should be stated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Only triggered segments are used to estimate whole-day occupancy. What limitation should be stated?” Put this particular dispute to the panel: Only triggered segments are used to estimate whole-day occupancy. What limitation should be stated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

- 02. Student A, terminology and scope: Agree the operational meanings of triggered, segments, used and estimate, occupancy, limitation in “Only triggered segments are used to estimate whole-day occupancy. What limitation should be stated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Only triggered segments are used to estimate whole-day occupancy; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Wideband Recording and Data Integrity”. Define the retained population and seek continuous or otherwise modeled exposure information for broader occupancy claims Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Only triggered segments are used to estimate whole-day occupancy; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Wideband Recording and Data Integrity”. Define the retained population and seek continuous or otherwise modeled exposure information for broader occupancy claims Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The sample is selected by trigger and schedule and omits untriggered periods Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Only triggered segments are used to estimate

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whole-day occupancy: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Only triggered segments are used to estimate whole-day occupancy; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Only triggered segments are used to estimate whole-day occupancy: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Only triggered segments are used to estimate whole-day occupancy, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Only triggered segments are used to estimate whole-day occupancy: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Only triggered segments are used to

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estimate whole-day occupancy. Define the retained population and seek continuous or otherwise modeled exposure information for broader occupancy claims Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Only triggered segments are used to estimate whole-day occupancy, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Only triggered segments are used to estimate whole-day occupancy. Define the retained population and seek continuous or otherwise modeled exposure information for broader occupancy claims Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the

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missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Only triggered segments are used to estimate whole-day occupancy and What limitation should be stated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Only triggered segments are used to estimate whole-day occupancy”, addressing “What limitation should be stated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Only triggered segments are used to estimate whole-day occupancy. What limitation should be stated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Only triggered segments are used to estimate whole-day occupancy. What limitation should be stated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.1 Probability of Intercept and Observation Strategy (p. 8676)

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V011-C15-DISCUSSION-020. A derived plot cannot be reproduced from the stated native file. What should be audited?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A derived plot cannot be reproduced from the stated native file. What should be audited?” Put this particular dispute to the panel: A derived plot cannot be reproduced from the stated native file. What should be audited. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 02. Student A, terminology and scope: Agree the operational meanings of derived, plot, reproduced and native, file, audited in “A derived plot cannot be reproduced from the stated native file. What should be audited”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A derived plot cannot be reproduced from the stated native file; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Bind sample continuity, storage accounting and derived results”. Compare a second implementation of the same declared quantity and preserve manual choices Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A derived plot cannot be reproduced from the stated native file; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Bind sample continuity, storage accounting and derived results”. Compare a second implementation of the same declared quantity and preserve manual choices Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Check selected interval/channel, scale, state, correction, window/normalization, decimation, exclusions and software version Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A derived plot cannot be reproduced from the stated native file: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A derived plot cannot be reproduced from the stated native file; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A derived plot cannot be reproduced from the stated native file: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A derived plot cannot be reproduced from the stated native file, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A derived plot cannot be reproduced from the stated native file: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A derived plot cannot be reproduced from the stated native file. Compare a second implementation of the same declared quantity and preserve manual choices Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A derived plot cannot be reproduced from the stated native file, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A derived plot cannot be reproduced from the stated native file. Compare a second implementation of the same declared quantity and preserve manual choices Respond point by

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point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A derived plot cannot be reproduced from the stated native file and What should be audited; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A derived plot cannot be reproduced from the stated native file”, addressing “What should be audited”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A derived plot cannot be reproduced from the stated native file. What should be audited”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A derived plot cannot be reproduced from the stated native file. What should be audited”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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V011-C15-DISCUSSION-021. Two event logs appear simultaneous but use different clock corrections. How should correlation be assessed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two event logs appear simultaneous but use different clock corrections. How should correlation be assessed?” Put this particular dispute to the panel: Two event logs appear simultaneous but use different clock corrections. How should correlation be assessed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 02. Student A, terminology and scope: Agree the operational meanings of logs, appear, simultaneous and corrections, correlation, assessed in “Two event logs appear simultaneous but use different clock corrections. How should correlation be assessed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two event logs appear simultaneous but use different clock corrections; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. Textual timestamp equality is insufficient Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two event logs appear simultaneous but use different clock corrections; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. Textual timestamp equality is insufficient Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reconstruct clock histories, common time basis, trigger-to-sample relation and uncertainties before asserting temporal order Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two event logs appear simultaneous but use different clock corrections: specify the altered receiver state or

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source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two event logs appear simultaneous but use different clock corrections; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two event logs appear simultaneous but use different clock corrections: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two event logs appear simultaneous but use different clock corrections, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two event logs appear simultaneous but use different clock corrections: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two event logs appear simultaneous but use different clock corrections. Textual timestamp equality is insufficient Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two event logs appear simultaneous but use different clock corrections, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two event logs appear simultaneous but use different clock corrections. Textual timestamp equality is insufficient Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two event logs appear simultaneous but use different clock corrections and How should correlation be assessed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two event logs appear simultaneous but use different clock corrections”, addressing “How should correlation be assessed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two event logs appear simultaneous but use different clock corrections. How should correlation be assessed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two event logs appear simultaneous but use different clock corrections. How should correlation be assessed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

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V011-C15-DISCUSSION-022. An analyst reports absence across a broad range from one narrowband continuous file. How should the statement change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An analyst reports absence across a broad range from one narrowband continuous file. How should the statement change?” Put this particular dispute to the panel: An analyst reports absence across a broad range from one narrowband continuous file. How should the statement change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, reports, absence and broad, narrowband, statement in “An analyst reports absence across a broad range from one narrowband continuous file. How should the statement change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An analyst reports absence across a broad range from one narrowband continuous file; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Reproducible Analysis and Derived Products”. Identify outside-band and excluded intervals explicitly Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst reports absence

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across a broad range from one narrowband continuous file; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Reproducible Analysis and Derived Products”. Identify outside-band and excluded intervals explicitly Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Restrict it to actually preserved passband and usable intervals with the tested event class and detector capability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An analyst reports absence across a broad range from one narrowband continuous file: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst reports absence across a broad range from one narrowband continuous file; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An analyst reports absence across a broad range from one narrowband continuous file: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An analyst reports absence across a broad range from one narrowband continuous file, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An analyst reports absence across a broad range from one narrowband continuous file: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An analyst reports absence across a broad range from one narrowband continuous file. Identify outside-band and excluded intervals explicitly Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An analyst reports absence across a broad range from one narrowband continuous file, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An analyst reports absence across a broad range from one narrowband continuous file. Identify outside-band and excluded intervals explicitly Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An analyst reports absence across a broad range from one narrowband continuous file and How should the statement change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An analyst reports absence across a broad range from one narrowband continuous file”, addressing “How should the statement change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An analyst reports absence across a broad range from one narrowband continuous file. How should the statement change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An analyst reports absence across a broad range from one narrowband continuous file. How should the statement change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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V011-C15-DISCUSSION-023. Pretrigger samples show a relay before every burst. What follow-up distinguishes plausible mechanisms?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Pretrigger samples show a relay before every burst. What follow-up distinguishes plausible mechanisms?” Put this particular dispute to the panel: Pretrigger samples show a relay before every burst. What follow-up distinguishes plausible mechanisms. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 02. Student A, terminology and scope: Agree the operational meanings of Pretrigger, samples, relay and burst, distinguishes, mechanisms in “Pretrigger samples show a relay before every burst. What follow-up distinguishes plausible mechanisms”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Pretrigger samples show a relay before every burst; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “15. Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed…”. Retain alternatives of generated transient, newly admitted signal or common control until discriminated Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Pretrigger samples show a

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relay before every burst; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “15. Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed…”. Retain alternatives of generated transient, newly admitted signal or common control until discriminated Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare static or bypassed switch operation with a matched desired reference and adequate detection capability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Pretrigger samples show a relay before every burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Pretrigger samples show a relay before every burst; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Pretrigger samples show a relay before every burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings,

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controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Pretrigger samples show a relay before every burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Pretrigger samples show a relay before every burst: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Pretrigger samples show a relay before every burst. Retain alternatives of generated transient, newly admitted signal or common control until discriminated Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Pretrigger samples show a relay before every burst, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.26 Additional study: sample continuity, acquisition clocks and the difference between stored bytes and observed RF time (p. 8721)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Pretrigger samples show a relay before every burst. Retain alternatives of generated transient, newly admitted signal or common control until discriminated Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Pretrigger samples show a relay before every burst and What follow-up distinguishes plausible mechanisms; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Pretrigger samples show a relay before every burst”, addressing “What follow-up distinguishes plausible mechanisms”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Pretrigger samples show a relay before every burst. What follow-up distinguishes plausible mechanisms”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Pretrigger samples show a relay before every burst. What follow-up distinguishes plausible mechanisms”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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V011-C15-DISCUSSION-024. A storage shortage prompts replacing native samples with screenshots. What evidence decision is needed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A storage shortage prompts replacing native samples with screenshots. What evidence decision is needed?” Put this particular dispute to the panel: A storage shortage prompts replacing native samples with screenshots. What evidence decision is needed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 02. Student A, terminology and scope: Agree the operational meanings of storage, replacing, native and samples, screenshots, decision in “A storage shortage prompts replacing native samples with screenshots. What evidence decision is needed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A storage shortage prompts replacing native samples with screenshots; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Reproducible Analysis and Derived Products”. Screenshots cannot restore discarded samples or processing context Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A storage shortage prompts replacing native samples with screenshots; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Reproducible Analysis and Derived Products”. Screenshots cannot restore discarded samples or processing context Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify native records required for the authorized purpose and later verification, preserve them with access controls, and document any disposition Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A storage shortage prompts replacing native

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samples with screenshots: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A storage shortage prompts replacing native samples with screenshots; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A storage shortage prompts replacing native samples with screenshots: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A storage shortage prompts replacing native samples with screenshots, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A storage shortage prompts replacing native samples with screenshots: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A storage shortage prompts replacing

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native samples with screenshots. Screenshots cannot restore discarded samples or processing context Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A storage shortage prompts replacing native samples with screenshots, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A storage shortage prompts replacing native samples with screenshots. Screenshots cannot restore discarded samples or processing context Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that

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limits confidence. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A storage shortage prompts replacing native samples with screenshots and What evidence decision is needed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A storage shortage prompts replacing native samples with screenshots”, addressing “What evidence decision is needed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A storage shortage prompts replacing native samples with screenshots. What evidence decision is needed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A storage shortage prompts replacing native samples with screenshots. What evidence decision is needed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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V011-C15-DISCUSSION-025. What would convince a reviewer that a capture claim is both technically valid and reproducible?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What would convince a reviewer that a capture claim is both technically valid and reproducible?” Put this particular dispute to the panel: What would convince a reviewer that a capture claim is both technically valid and reproducible. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 02. Student A, terminology and scope: Agree the operational meanings of convince, reviewer, capture and claim, technically, reproducible in “What would convince a reviewer that a capture claim is both technically valid and reproducible”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What would convince a reviewer that a capture claim is both technically valid and reproducible; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.1: Distinguish a point observation from full capture of a short event”. Match the conclusion to that evidence rather than to display appearance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What would convince a

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reviewer that a capture claim is both technically valid and reproducible; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.1: Distinguish a point observation from full capture of a short event”. Match the conclusion to that evidence rather than to display appearance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A declared event criterion and detector prerequisites, usable schedule and phase law, verified continuous samples, bound metadata/calibration, exact processing and retained limitations Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 08. Student D, answer to Student E: Design a discriminating experiment involving What would convince a reviewer that a capture claim is both technically valid and reproducible: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What would convince a reviewer that a capture claim is both technically valid and reproducible; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What would convince a reviewer that a capture claim is both technically valid and reproducible: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What would convince a reviewer that a capture claim is both technically valid and reproducible, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving

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What would convince a reviewer that a capture claim is both technically valid and reproducible: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What would convince a reviewer that a capture claim is both technically valid and reproducible. Match the conclusion to that evidence rather than to display appearance Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What would convince a reviewer that a capture claim is both technically valid and reproducible, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What would convince a reviewer that a capture claim is both technically valid and reproducible. Match the conclusion to that evidence rather than to display appearance Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What would convince a reviewer that a capture claim is both technically valid and reproducible and A declared event criterion and detector prerequisites, usable schedule and phase law, verified continuous…; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What would convince a reviewer that a capture claim is both technically valid and reproducible”, addressing “A declared event criterion and detector prerequisites, usable schedule and phase law, verified continuous…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What would convince a reviewer that a capture claim is both technically valid and reproducible”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What would convince a reviewer that a capture claim is both technically valid and reproducible”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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Chapter 15 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C15-ESSAY-001 — Define a,D,b,r and the unfolded event interval. Derive both endpoint inequalities and feasibility $r \leq min(b, D)$, then explain union reduction and the uniform-phase probability. Keep detector prerequisites separate.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-C15-ESSAY-002 — Calculate 0.20 for a point,0.199 for a complete 0.1 ms event,0.23 for b = 5/r = 1 and 0.15 for whole 5 ms. Explain the different questions and why recognizable fragments do not establish startup or full-frame preservation.

Review: Chapter 15 — Application 15A.1: Distinguish a point observation from full capture of a short event.

V011-C15-ESSAY-003 — Account for settling, filter memory, AGC, rearming, transfer and validity flags. Reconstruct the guarded 4–27 ms example and 0.27 probability, explain transition-dependent guards, and distinguish commands from valid sample intervals.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

V011-C15-ESSAY-004 — Use windows 10–25 and 28–43 ms with b = 20/r = 5, derive both intervals and 43 ms union. Explain the 7 ms double count and why union of qualifying starts does not add insufficient waveform fragments across the gap.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

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V011-C15-ESSAY-005 — Use the phase 50 ms event and 10–30 ms window, then the 49–69 ms alternative. Distinguish a fixed outcome from a uniform-phase average, and specify evidence needed for randomized or independent repeated trials.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

V011-C15-ESSAY-006 — Use 90–110 ms,b = 15/r = 12 to derive 87–98 ms and 0.11. Evaluate starts 95 and 0, explain coordinate versus file versus physical boundaries, and identify metadata needed before joining files.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

V011-C15-ESSAY-007 — Use complement multiplication, derive the ceiling for interior p,q, and state p = 0,p = 1 and q 1 limits. Verify 18 versus 17 for p.23/q.99 and explain why the count is conditional, not universal.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

V011-C15-ESSAY-008 — Use the product of independent miss probabilities, identify required phase assumptions, and explain why field timestamps or new labels do not establish independence. Preserve the actual adaptation rule and require a joint model or defensible bound for dependence.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-C15-ESSAY-009 — Identify full-rate, decimated, filtered or software statistics, test relevant edge/duration/level/modulation and prior quiet interval, compare saved sample time with trigger time, and use event pairs to measure holdoff and rearm.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

V011-C15-ESSAY-010 — Specify required leading and recovery context, ensure buffer samples are valid in the accepted state, retain transition flags and clock relationships, and distinguish whole-event evidence from a trigger-centered display.

Review: Chapter 15 — Trigger Types and Pretrigger Context.

V011-C15-ESSAY-011 — Compare bandwidth, sample rate, filtering, estimator latency and state control in the two paths. Give bounded examples of recorder passage without triggering and trigger response without sufficient valid waveform, then propose a reference test.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

V011-C15-ESSAY-012 — Calculate the 320 MB/s and 576 GB example, include container width, I/Q, channels, packing, overhead and reserve. Test sustained throughput for planned duration, monitor loss indicators and define controlled rollover/failure response.

Review: Chapter 15 — Hypothetical Applied Calculation: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-C15-ESSAY-013 — Explain what a closed-file hash binds and what it cannot establish. Use counters, sequence records, block lengths, flags and clock state to detect gaps or repeats; preserve a gap map and restrict estimators requiring uniform samples.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-C15-ESSAY-014 — Track sample index against elapsed time and show how false transients or spectral behavior can arise. Require explicit gap/repeat events, continuity-aware segmentation and retained metadata rather than silently restoring expected file length.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-C15-ESSAY-015 — Include representation, rate, center frequency, state, path, calibration, device/software, trigger, time reference and uncertainty, geometry and relevant conditions. Bind separate metadata to hashes and include human reasons for changes alongside automated logs.

Review: Chapter 15 — Metadata, Time, and Site Context.

V011-C15-ESSAY-016 — Retain native source and selected interval, scaling, calibration, receiver state, window/normalization, mixing/decimation and exclusions. Rerun with a second implementation where practical, use reference and noise-only controls, and report parameter sensitivity.

Review: Chapter 15 — Reproducible Analysis and Derived Products.

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V011-C15-ESSAY-017 — Describe selection by threshold and schedule, omitted quiet or precursor intervals, and the role of circular buffers. State what population the retained segments represent and what evidence would support a broader occupancy estimate.

Review: Chapter 15 — Wideband Recording and Data Integrity.

V011-C15-ESSAY-018 — Reconcile planned, commanded, valid and preserved intervals and passbands. Name event duration, overlap, phase law and detector prerequisites, retain excluded intervals and untested event classes, and avoid converting nonobservation into universal absence.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-C15-ESSAY-019 — Explain temporal order and competing switch transient, newly admitted signal or shared-control hypotheses. Design a matched-reference static/bypass comparison with adequate sensitivity and preserve original and altered observations plus remaining attribution limits.

Review: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

V011-C15-ESSAY-020 — Define the intended cross-system comparison, clock source/history, time-zone and correction conventions, trigger-to-sample relation and uncertainty. Distinguish a timestamp string from a timing measurement and preserve state changes.

Review: Chapter 15 — Metadata, Time, and Site Context.

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V011-C15-ESSAY-021 — Identify needed native records, reserve and rollover, access controls, retention and disposition, incidental-content minimization and documented migration/deletion. Explain why derived products cannot silently replace the source needed for verification.

Review: Chapter 15 — Coverage Review and Storage Governance.

V011-C15-ESSAY-022 — Use a 2 ms event with 3 ms requirement to show empty eligibility regardless of dwell or repetition. Propose either a changed question or a justified multi-event estimator, explicitly stating new repeatability/coherence premises rather than claiming original success.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

V011-C15-ESSAY-023 — Separate timing opportunity from threshold, SNR, false alarms, modulation recognition and minimum estimator duration. Describe controlled tests establishing prerequisites and show how failure of one changes the interpretation of a high geometric probability.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-C15-ESSAY-024 — Match instantaneous bandwidth, revisit, dwell, trigger and storage to each hypothesis; identify deterministic timing traps and needed state windows. Preserve the event-class-specific assumptions and avoid assigning one universal probability to the mixture without a model.

Review: Chapter 15 — Probability of Intercept and Observation Strategy.

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V011-C15-ESSAY-025 — Distinguish qualifying fragment, complete event, stated schedule coverage and reproducible result. For each specify continuity, event boundaries, usable intervals, phase assumptions, native data and processing evidence, with the corresponding limitation preserved.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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Discussion Guidance

V011-C15-DISCUSSION-001 — Compare event phase with usable dwell, settling and rearm intervals, and examine passband and trigger capability. Separate sensitivity from opportunity and change schedule when a fixed miss is plausible.

Review: Chapter 15 — Probability of Intercept and Observation Strategy.

V011-C15-DISCUSSION-002 — Measure response validity after each relevant transition, identify settling/AGC/filter/rearm exclusions and compare commands to actual sample flags. Recompute coverage from demonstrated intervals.

Review: Chapter 15 — Application 15A.5: Remove settling and closing guards from nominal dwell.

V011-C15-DISCUSSION-003 — Require both boundaries and necessary context in one continuous record. Preserve the valid fragment observation while stating unknown leading/trailing portions and any missing startup information.

Review: Chapter 15 — Application 15A.3: Require the whole burst.

V011-C15-DISCUSSION-004 — Show that no timing schedule meets the stated one-event criterion, then reconsider the scientific question or define a new repeatable multi-event analysis. Do not improve the nominal probability by invalid arithmetic.

Review: Chapter 15 — Application 15A.4: Reject an impossible overlap requirement.

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V011-C15-DISCUSSION-005 — Derive each start set on the unfolded axis, reduce modulo period, merge overlaps and measure the union. Explain the difference between duplicate phases and physically combining fragmented data.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets.

V011-C15-DISCUSSION-006 — No without a justified phase experiment; inspect fixed timing and change schedule or establish an appropriate joint model. More file count alone supplies no new phase opportunity.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

V011-C15-DISCUSSION-007 — Require sample-counter and clock evidence that acquisition continued without a gap, distinguish file and coordinate boundaries, and preserve any genuine rearm interruption.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin.

V011-C15-DISCUSSION-008 — No; examine periodic operation, shared clocks and trigger coupling or controlled randomization. State the actual phase model and do not infer independence from distinct timestamps.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

V011-C15-DISCUSSION-009 — Check event duration, usable window, required overlap, detector prerequisites and independent phase law. Recalculate for the actual conditions and retain boundary checks.

Review: Chapter 15 — Application 15A.10: Solve for a conditional trial count and check the boundary.

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V011-C15-DISCUSSION-010 — Preserve the adaptation rule and actual sequence, analyze the resulting conditional or joint experiment, and avoid assigning the old expression without matching assumptions.

Review: Chapter 15 — Application 15A.9: Calculate repeated capture only under independent start phases.

V011-C15-DISCUSSION-011 — Characterize trigger bandwidth and latency relative to saved data, choose a suitable trigger path or criterion, and retain the demonstrated distinction. Do not assume recorder presence guarantees trigger detection.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

V011-C15-DISCUSSION-012 — Holdoff, recovery or rearm behavior was not covered; vary controlled separation and inspect valid samples and trigger state. Bound the usable schedule accordingly.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

V011-C15-DISCUSSION-013 — No; inspect state timestamps and validity flags, characterize settling and retain only applicable context. Nominal depth does not prove continuous same-state evidence.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

V011-C15-DISCUSSION-014 — Measure the relation between software event, acquisition clock and stored sample apertures, retain latency and uncertainty, and avoid treating the packet timestamp as a direct sample time.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-C15-DISCUSSION-015 — Sustained writing in the planned configuration, buffer exhaustion, thermal and clock behavior, rollover and overrun indicators. Capacity and burst speed alone do not establish continuity.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-C15-DISCUSSION-016 — Only unchanged preserved bytes relative to the hash, not original continuity. Use sequence counters and block records, preserve the repeat event and limit affected analyses.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-C15-DISCUSSION-017 — The index-to-time relation and boundary waveform are changed, potentially creating false spectral features. Retain a gap map and use valid segments or a separately justified estimator.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-C15-DISCUSSION-018 — The actual 32-bit two-component export, including channel count and overhead. Distinguish acquisition resolution from container size and test the resulting sustained rate.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-C15-DISCUSSION-019 — The sample is selected by trigger and schedule and omits untriggered periods. Define the retained population and seek continuous or otherwise modeled exposure information for broader occupancy claims.

Review: Chapter 15 — Wideband Recording and Data Integrity.

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V011-C15-DISCUSSION-020 — Check selected interval/channel, scale, state, correction, window/normalization, decimation, exclusions and software version. Compare a second implementation of the same declared quantity and preserve manual choices.

Review: Chapter 15 — Reproducible Analysis and Derived Products.

V011-C15-DISCUSSION-021 — Reconstruct clock histories, common time basis, trigger-to-sample relation and uncertainties before asserting temporal order. Textual timestamp equality is insufficient.

Review: Chapter 15 — Metadata, Time, and Site Context.

V011-C15-DISCUSSION-022 — Restrict it to actually preserved passband and usable intervals with the tested event class and detector capability. Identify outside-band and excluded intervals explicitly.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results.

Cross-volume technical interface. S001-V020(Field Operations Evidence Handling Chain of Custody and Litigation Support) governs the broader transfer, sealing and custody record;S001-V021(Case Studies Deployment Lessons and Institutional Practice) provides comparative field practice; andS001-V025(Cross Volume Analytical Index Subject Taxonomy and Reference Apparatus) provides the topical retrieval route. A receiver artifact must still be distinguished here from an external emission by controlled changes in gain, reference input, antenna, localisation, time base and independent instrumentation, with alternative hypotheses, negative controls and uncertainty preserved in the finding.

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V011-C15-DISCUSSION-023 — Compare static or bypassed switch operation with a matched desired reference and adequate detection capability. Retain alternatives of generated transient, newly admitted signal or common control until discriminated.

Review: Chapter 15 — Hypothetical Case Adjudication: Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

V011-C15-DISCUSSION-024 — Identify native records required for the authorized purpose and later verification, preserve them with access controls, and document any disposition. Screenshots cannot restore discarded samples or processing context.

Review: Chapter 15 — Coverage Review and Storage Governance.

V011-C15-DISCUSSION-025 — A declared event criterion and detector prerequisites, usable schedule and phase law, verified continuous samples, bound metadata/calibration, exact processing and retained limitations. Match the conclusion to that evidence rather than to display appearance.

Review: Chapter 15 — Verify the trigger at its actual signal-path location.

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Chapter Glossary

CAPTURE FEASIBILITY: The existence of an event start that can satisfy the declared capture criterion under the model's domain. For one contiguous window, the positive required overlap cannot exceed the event or window duration. An impossible criterion produces zero probability before any averaging over start phases is considered.

CIRCULAR BUFFER: A recording arrangement that continually retains a rolling interval, replacing older data until selected content is preserved. Triggered extraction can provide pre-event context while controlling retained storage. That context remains usable only if its samples are valid and belong to the accepted configuration and continuous timing record.

CLOSING GUARD: An excluded interval at the end of a nominal acquisition during which the retained data no longer satisfy the declared validity conditions. It reduces the usable window independently of an initial settling guard. Coverage calculations must use the remaining contiguous interval and state the reasons for the exclusion.

CONDITIONAL CAPTURE PROBABILITY: The probability of meeting a defined acquisition geometry under a stated event-phase distribution and separately established signal and detector conditions.

CONTIGUOUS-OVERLAP CRITERION: A capture requirement met by one uninterrupted event-window intersection of at least a specified positive duration.

DEAD TIME: Interval during which an acquisition system cannot accept or record another event.

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DECIMATED TRIGGER: A trigger operating on a rate-reduced representation of the signal. The preceding filter and sample-rate change can alter the event information and timing available to it. Its behavior must be checked against the saved waveform and intended event criterion rather than assumed equivalent to a full-rate trigger.

DERIVED-PRODUCT LINEAGE: The documented relationship connecting a spectrum, decode, image, table or other processed result to its source record, selected interval, channel, calibration and exact processing decisions. It enables reproduction of the declared quantity. Visual similarity to a screenshot is insufficient when the underlying scaling, normalization or sample selection differs.

ELIGIBLE-START UNION: The union, over usable windows and schedule periods, of event start times that satisfy the declared capture criterion.

EVENT DURATION: The elapsed length assigned to an event in the stated capture model. It is distinct from the duration of signal that the intended measurement requires. Detecting a fragment, measuring a steady portion and preserving startup or the whole event can impose different criteria on the same event duration.

EVENT START PHASE: The event's start-time position relative to a repeating observation schedule, considered modulo the schedule period. A particular event can have a fixed phase, while a probabilistic model assigns a distribution to possible phases. These are different statements, and ignorance of the encountered phase does not itself justify uniformity.

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FILE ROLLOVER: The controlled transition from one recording file to the next during a longer acquisition. It keeps files manageable while requiring preserved chronology and explicit continuity evidence across the boundary. Successful closure and hashing of individual files do not by themselves show that no samples were lost or repeated between them.

FULL-RATE TRIGGER: A trigger operating on the undecreased sample stream at its stated processing location. Its relation to saved samples still depends on filtering, comparator behavior and latency. The contrast with a decimated trigger identifies a path distinction; it does not establish universal timing or sensitivity performance.

GAP MAP: An explicit record of missing or otherwise unusable sample intervals and their positions in the acquisition chronology. It prevents simple concatenation from erasing the true elapsed interval or creating a false signal discontinuity. Analyses requiring uninterrupted uniform sampling must respect the mapped boundaries.

INDEPENDENT CAPTURE TRIALS: Trials whose relevant event phases and capture outcomes satisfy the independence needed by the stated probability model. Counting separate files or repeated commands does not establish this property. Under the additional common-probability premise, the complement of all misses gives the probability of at least one capture.

MINIMUM TRIAL COUNT: The smallest positive integer number of qualifying trials that meets a specified conditional capture target under the stated probability assumptions. Model 15A rounds the interior logarithmic result upward and checks the preceding integer. Zero-probability, certain-capture and exactly-one target cases require their separate endpoint rules.

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PAYLOAD BYTE RATE: The byte rate occupied by the declared uncompressed sample components before additional headers, padding, timing records or file-system effects. It depends on actual stored component width, channel count and sample rate. Sustained recording capability must include the extra traffic and cannot be inferred solely from this ideal payload calculation.

PERIODIC REDUCTION: Representation of times by their positions within one declared schedule period. Model 15A first derives eligible event starts on an unfolded axis and then reduces their union modulo the period. This order preserves a genuinely contiguous window crossing the chosen origin and avoids mistaking the displayed split for an acquisition gap.

POINT-OBSERVATION LIMIT: The separate idealization in which an instantaneous event must lie inside a usable observation window. It is not obtained by treating zero overlap as a successful empty intersection. Model 15A relates it to the limit of fully capturing a shrinking event while preserving the intended detection criterion.

PRETRIGGER: Recorded interval preceding the condition that initiated an acquisition.

PROBABILITY OF INTERCEPT: Probability that an observation strategy overlaps and detects an event meeting the stated criterion.

REARM INTERVAL: The period required for the acquisition or trigger system to become ready for another qualifying event. A real rearm gap remains an exclusion in the usable-window model. Adjacent-looking timestamps or saved files do not establish continuous availability across that interval.

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RECORD CONTINUITY: Verified absence or documented location of gaps, repeats, lost packets, or clock discontinuities in sampled data.

REPEATED SAMPLE BLOCK: A portion of acquisition data preserved more than once where the intended sample sequence should advance. It can corrupt timing and spectral interpretation even if the final file is internally readable and unchanged. Sequence and sample-domain records are needed to distinguish it from a legitimately repeating waveform.

REPRODUCIBILITY: Ability to obtain a consistent result from preserved data and a documented method.

REQUIRED OVERLAP: The positive contiguous duration that an event and one usable acquisition window must share to meet the declared capture criterion. It must not exceed either duration for capture to be feasible. Combining disconnected fragments does not satisfy this one-window criterion unless the measurement question is explicitly changed.

REVISIT PERIOD: The elapsed period after which the declared observation schedule repeats. Model 15A places usable windows and event-start phases relative to that period. A nominal revisit specification must retain settling, rearm and transfer gaps; repeated schedules can continue to miss an event whose phase is locked to them.

SAMPLE COUNTER: A recorded index or count associated with the acquisition sequence. When its semantics, rollover and reset behavior are known, it helps test whether intended samples were retained in order. A plausible file duration or a stable byte hash does not replace this sample-domain continuity evidence.

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SCHEDULE PHASE LOCKING: A persistent relationship between event timing and the repeating observation schedule. It can place each event in the same usable interval or the same blind interval. Repeating the schedule then does not create independent opportunities, and a formula based on independent trial phases cannot be applied without changing or justifying the experiment.

SEGMENTED ACQUISITION: Recording selected intervals, often in response to triggers, instead of preserving every intervening sample. It can reduce storage but omit context and bias occupancy estimates. Each segment and the gaps between segments must retain their timing and validity information before an analysis assumes continuous observation.

SEQUENCE-NUMBER CHECK: A comparison of declared block or packet sequence identifiers to detect missing, repeated or reordered portions of a record. Its interpretation depends on the acquisition protocol and reset behavior. It supports continuity assessment alongside sample counters, block lengths, overrun flags and clock status.

SETTLING GUARD: An initial interval excluded from a nominal dwell because tuning, filtering, gain control or another state transition has not yet produced usable data. It reduces the window available to meet the event criterion. Its duration must follow the applicable observed or justified response rather than the mere completion of a control command.

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STORED SAMPLE REPRESENTATION: The actual encoding of recorded sample components, including real or complex form, container width, signedness, byte order, packing, interleaving and scaling. It determines payload accounting and interpretation. Converter resolution alone does not specify that representation, and an exported format can use a different byte rate for the same sample sequence.

TRIGGER HOLDOFF: A declared interval or condition during which further trigger acceptance is inhibited after a trigger event. It affects the ability to record a second closely spaced event. Characterization with controlled event pairs is therefore needed in addition to a successful isolated-event test.

TRIGGER HYSTERESIS: A dependence of trigger-state transitions on distinct entry and release conditions, used in the declared trigger logic. It affects whether and when nearby signal excursions generate new events. Its settings and behavior belong to the capture configuration rather than being inferred from the displayed trigger threshold alone.

TRIGGER LATENCY: The delay between the relevant event at a specified trigger-path boundary and the trigger indication or action. Its value and variability depend on the trigger location and processing. A known-stimulus test must relate it to the stored sample times; a trigger label alone does not identify that relationship.

TRIGGER PATH: The part of the receiver processing chain observed by the trigger decision. It may use full-rate samples, a decimated channel, filtering or a software statistic, giving it a different bandwidth or delay from the saved waveform. The event can therefore be present in one path without satisfying the other’s condition.

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UNEQUAL-TRIAL PROBABILITIES: Different declared single-trial capture probabilities used when the experiment varies across trials. Their miss probabilities can be multiplied only when the relevant independence assumptions remain justified. Assigning different numbers to correlated trials does not remove the need for a joint model or a defensible bound.

UNIFORM PHASE ASSUMPTION: The assumption that event starts are equally distributed over a schedule period. Under it, Model 15A converts the merged eligible-start duration into a conditional capture probability. A synchronized or concentrated event process requires its own distribution or a deterministic coverage statement rather than this convenient average.

USABLE ACQUISITION WINDOW: One contiguous interval in which the retained samples meet the stated configuration, settling, continuity and detector prerequisites.

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References and Works Cited

Tektronix. Fundamentals of Real-Time Spectrum Analysis. 37W-17249-4. August 2009. https://download.tek.com/document/37W_17249_4.pdf.

Annotation. Printed pages 17–18, “Discovering and Capturing Transient Events” and acquisition-gap discussion, and pages 32–34 on trigger timing, pretrigger buffering and full-rate versus decimated trigger locations. These architecture qualifications are retained without historical product-performance figures. Model 15A’s interval geometry and conditional probabilities are independently derived and presuppose separately established signal and detector validity; the recording and reproducibility procedures are the chapter’s application-specific synthesis. The publication explains analyser operation and measurement settings governing spectral detection, resolution and transient capture. Resolution bandwidth, video filtering, detector mode and acquisition duty cycle can alter a displayed spectrum without changing the external transmitter. A manufacturer’s application note supports stated instrument behaviour but does not certify that a particular survey captured every possible short-duration event. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

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Chapter 16. Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance

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16.1 Artifact Taxonomy and Competing Explanations

Receiver artifacts include residual responses, local-oscillator leakage, images, aliases, ADC clipping, quantization products, intermodulation, reciprocal mixing, filter ringing, detector transients, AGC effects, software false locks, dropped-sample splatter, clock spurs, power-converter noise, cable common mode, and enclosure leakage. Environmental alternatives include legitimate transmitters, reradiation, passive intermodulation, conducted coupling, reflections, and state-dependent emissions. The initial observation is classified as unexplained until these mechanisms are challenged.[1]

Artifact analysis starts with architecture. The practitioner asks where in the chain the component could have been created and which control lies before or after that location. Input attenuation tests products created after the attenuator differently from external signals. Preselection challenges out-of-band parents. Sample-rate and LO changes challenge aliases and spurs. Antenna termination, receiver substitution, clock substitution, channel swap, and physical relocation alter other mechanisms.

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1 United States Navy, Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles, NAVEDTRA 14189 (September 1998), 2-10–2-14, reproduced in SIGINTRADARTSCM.pdf, compilation pages 8388–8392; title and edition at page 8345. These passages establish receiver functions and superheterodyne IF and detection architecture. The complete configuration and evidence boundary in this paragraph is the author's synthesis, developed through Chapters 2–16; the historical training source does not certify a modern instrument or legal conclusion.

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16.2 Challenge-Test Design

A challenge test changes one causal factor while preserving enough of the measurement to compare results. Useful challenges include attenuation, preamplifier bypass, filter insertion, alternate antenna, polarization, location, power source, reference clock, sample rate, tuning plan, detector, bandwidth, and controlled operation of a suspected device. The predicted outcomes for at least two competing explanations are written before the test.

Tests should not be selected only after seeing a favorable result. Sequence, blinding, held-out captures, and negative controls reduce confirmation bias. A test that risks loss of evidence, interference with service, or unauthorized collection requires approval. The record includes unsuccessful challenges and instances where the system state could not be reproduced.

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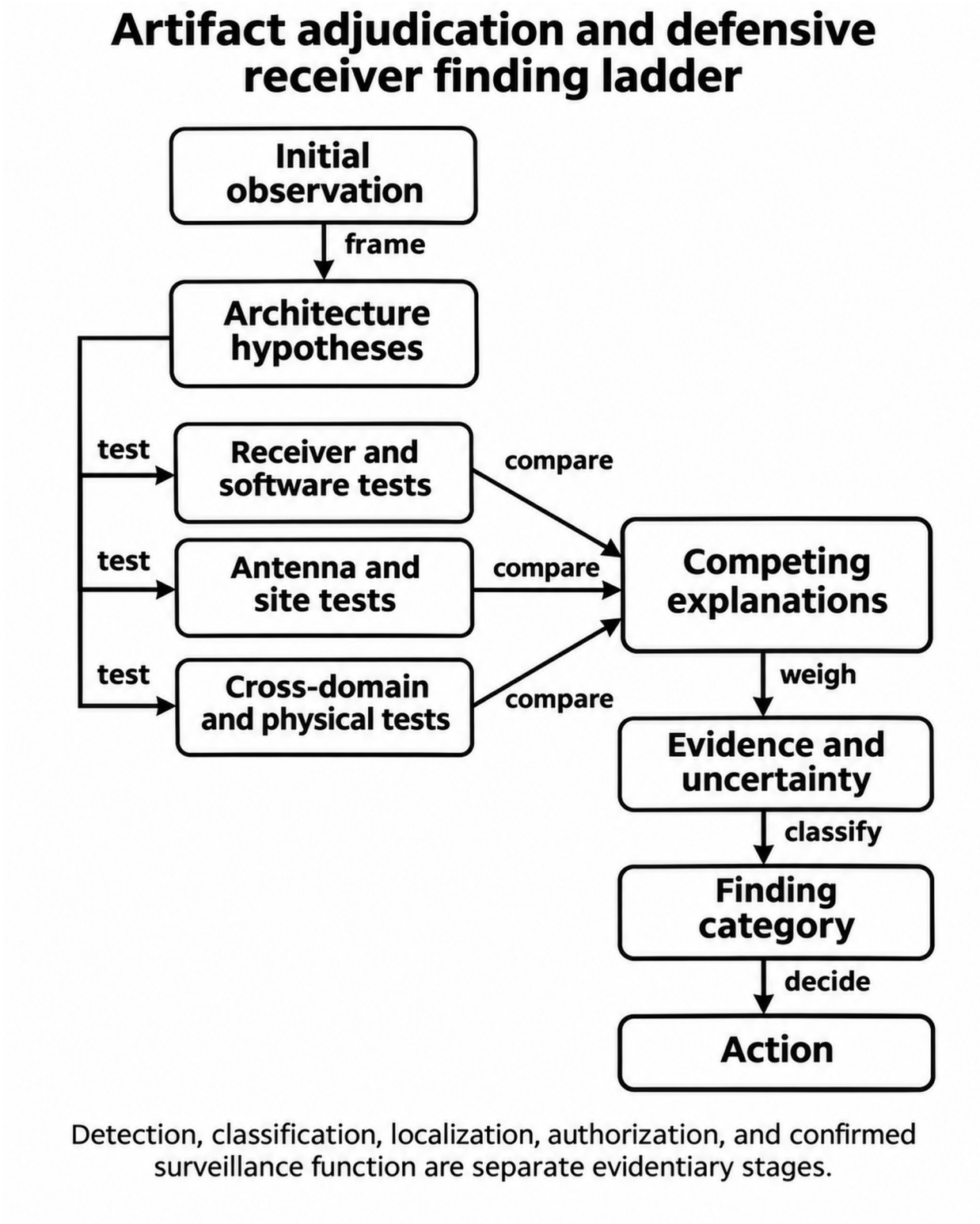

Figure 85. Receiver artefact adjudication and findings.

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16.3 Localize an artifact by changing the stage that could create it

Begin with an architecture map that places each plausible mechanism before or after accessible controls. A component generated in a broadband preamplifier should respond differently to bypassing that amplifier than one already present at the antenna connector. A sampled alias should move according to the actual sample-rate and frequency mapping. A conversion image should follow the signed translation and preselection described in Model 4A. A control transient should depend on the preceding state and timing. Write those predictions before changing the setup so the test has a discriminating purpose.

A useful challenge changes the error structure while preserving the desired comparison. Substituting a second receiver can be informative, but shared antennas, splitters, clocks, power supplies, software, or calibration files can preserve the original cause. Conversely, a substitution can change sensitivity enough to hide a real signal. Carry a known reference through both configurations so absence on the second path can be interpreted against its demonstrated capability. Agreement and disagreement both require this context.

Use the new model families as a connected diagnostic vocabulary. Model 4A predicts conversion sign and candidate spur movement, while Chapter 10 follows mixing and sampling in the digital path. Model 5A explains an identified control trajectory within its tested range. Models 6A and 6B separate amplitude, phase, and frequency behavior. Model 7A shows which alignment or normalization can conceal a demodulation defect. Models 12A

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and 12B distinguish deterministic timing errors from covariance-dependent phase effects. Model 15A separates a missed observation from a demonstrated absence.

A single successful challenge rarely establishes attribution. An unexplained line that scales like an external signal may still be an instrument emission coupled through the antenna path. A line that disappears with a terminated input may have depended on a mismatched termination or a removed external nonlinear element. A plausible decoded identifier may be repeated, stale, or generated by a false lock. Preserve the narrow consequence of each test and combine only those consequences whose assumptions are supported.

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16.4 Receiver challenges with interacting controls

A comparison made by changing one control is conditional on the settings that remain fixed. A result obtained with a particular clock, input route, and gain state therefore answers a narrower question than whether the changed component can ever create the observed response. Interaction matters when changing one factor has a different consequence at another setting of a second factor. The NIST experimental-design treatment explains why isolated one-factor searches can miss that dependence. In receiver work, the practical remedy is to examine the relevant combinations of states and retain their individual results. This does not require assigning statistical odds to a suspected artifact. It requires specifying what is changed, what is observed, and which alternative explanations each comparison can distinguish.[2]

Define factors by physical changes rather than by convenient front-panel labels. Selecting an external reference can alter frequency calibration, common-mode coupling, phase continuity, and cable connections. Bypassing an antenna switch can alter insertion loss, impedance, the signal route, and control transients. A nominal clock factor and a nominal switch factor are consequently bundles of physical consequences until those consequences are characterized. Record the actual reference source, connections, termination, switch route, control state, and acquisition

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2 Joint Committee for Guides in Metrology, International vocabulary of metrology: Basic and general concepts and associated terms, VIM3 online edition, entries 2.48, 2.49 and 2.53, https://jcgm.bipm.org/vim/en/2.48.html, https://jcgm.bipm.org/vim/en/2.49.html and https://jcgm.bipm.org/vim/en/2.53.html, read November 2, 2026. These entries support the measurement-model, measurement-function and correction distinctions. Model 1A and its synthetic cases are independently developed here.

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configuration for each combination. The existing conversion, timing, overload, and uncertainty models supply the interpretation of these changes. The experiment tests their applicability in the installed chain; a menu selection by itself does not isolate a mechanism.

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16.4.1 Arrange the comparisons before examining their outcomes

For two controls with two declared settings each, observe all four combinations when they are physically meaningful: original reference with the switch in circuit, original reference with the switch bypassed, alternate reference with the switch in circuit, and alternate reference with the switch bypassed. Compare the switch states within each reference state, then compare the reference states within each switch state. This arrangement exposes whether the apparent effect depends on the companion setting. It is the experimental-design principle of crossing the factor levels, applied here as a diagnostic record. If a combination is unavailable or changes the measurement beyond a defensible comparison, record that missing condition explicitly. The remaining observations cannot silently supply the absent comparison.[3]

Before acquisition, define the response at a physical reference plane. It might be corrected power within a declared frequency interval, a phase relation under the established timing convention, or the occurrence of a waveform meeting a prespecified criterion. Retain the underlying records as well as the summary. A binary label such as "visible" can conceal an ordinary sensitivity change: the same component may fall below a display threshold after additional loss, even though its physical source persists. Compare the

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3 Barry N. Taylor and Chris E. Kuyatt, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, NIST Technical Note 1297, 1994 edition (September 1994), Appendix A, A.1–A.5, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. The functional and covariance framework is used within its stated scope; the synthetic ranges, examples and recoverability conclusions are original.

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relevant continuous observations and the demonstrated observation limits before interpreting a conditional disappearance. Differences expressed as linear power, logarithmic level, and threshold crossings answer different questions. The response definition must remain fixed across the comparisons.

An interaction in the recorded response narrows the explanatory problem but does not locate the responsible circuit. A clock cable and a switch enclosure might jointly complete a coupling path. They might instead change receiver sensitivity in a way that becomes consequential only with a particular blocker. A third, uncontrolled condition could also track the selected combinations. Use the architecture map to propose discriminating follow-up observations, such as an independently observed reference-path emission or a calibrated desired signal in the presence of the admitted blocker. The combination record supports these next tests. It does not convert a dependence between settings into proof that either named component is defective.

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16.4.2 Preserve comparable observation capability

Carry an appropriate known reference through every configuration whose nondetection will support the conclusion. The reference should exercise the function being compared: a narrow continuous tone tests a different capability from a short burst, a wideband modulated waveform, or a weak signal beside a strong blocker. A check at one comfortable level does not establish performance near the observation limit. The NIST check-standard method emphasizes a representative, repeatable characteristic and an accumulated record of its behavior. Applied to this receiver comparison, the reference record should show the relevant frequency mapping, signal transfer, and acquisition capability in each state, with the accepted limits and their basis preserved.[4]

Keep the reference plane and the scope of each correction explicit. In the published vector-receiver calibration examined in Chapter 14, Kast and colleagues require the same reference plane, or correction for added paths, and bind calibration validity to the hardware and software configuration. The same discipline prevents a diagnostic comparison from treating a bypass cable, changed preselector, or new digital correction as transparent. Use the corrections already supported for each state and propagate their relevant shared uncertainties under Model 14B. If a state lacks the

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4 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers” (June 14, 2013), “Baseline Case: Cascade of Linear Circuit Blocks” and “Noise Temperature,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html; James P. Randa, Uncertainties in NIST Noise-Temperature Measurements, NIST Technical Note 1502 (March 1998), §§3.9–3.10, 16–17, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf. These sources distinguish receiver noise from source and path contributions; the scalar assumptions and synthetic cases are stated in Model 2B.

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necessary characterization, its record can still reveal an observation, but it cannot support the same quantitative comparison as a characterized state.[5]

Separate the settled state from the transition used to reach it. Changing a reference can require relocking; switching a route can create an impulse; returning to a gain setting can preserve a recovery history. Model 5A supplies the conditions under which its retained recovery law applies, while Chapters 12 and 15 define timing and usable acquisition intervals. Mark transition records and settled records separately. If the phenomenon occurs only during switching, that transient becomes the object of a dedicated comparison. Removing it from a settled-state analysis must not erase it from the evidence record or turn it into an unexplained exclusion.

5 H. T. Friis, “Noise Figures of Radio Receivers,” Proceedings of the IRE 32, no. 7 (July 1944): 419–22, https://doi.org/10.1109/JRPROC.1944.232049. The publisher’s abstract was read for the historical network, component, mismatch, and measurement framing. The full paper was not accessed; Model 2B supplies its own stated derivation and working conventions.

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16.4.3 Interpret hypothetical receiver records

Hypothetical clock-and-switch comparison. The unexplained component is reproducibly observed with the original reference and the switch in circuit. It is absent under the declared criterion in the other three combinations, while a suitable known reference remains observable in each configuration. This pattern makes the joint configuration a useful suspect and motivates a test of the connecting reference and return paths. It does not show that both components independently generate the line. Nor does it prove that the line is absent below the demonstrated observation limits in the other states. Preserve the actual level records, the interval over which the component could have been observed, and whether each return to the original combination reproduced the response.

Hypothetical preselection-and-gain comparison. A spur appears at high gain with broadband admission but not with a selective input filter. At lower gain it is absent in both input states. The pattern is compatible with an overload mechanism requiring both strong admitted parents and sufficient downstream gain. Its interpretation still depends on measured parent levels, desired-reference transfer, and source or combiner purity under Model 11A. The filter may also change mismatch or the gain-control trajectory. Test those alternatives before assigning the product to a particular stage. A four-state pattern provides more informative evidence than a single successful filter insertion, while retaining the physical qualifications already developed in Chapters 3 and 11.

Hypothetical detector-and-record comparison. A decoder reports valid-looking identifiers only when a permissive synchronization rule is applied to

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one recording. A stricter rule removes them, while known valid reference records survive both rules. Reprocess an independently obtained noise-only record under both rules and preserve its outputs. This crossed comparison can expose dependence on both the processing rule and the input record. It cannot retrospectively establish the origin of every event in the field recording. Training the stricter rule on those same events also changes the claim: an independently retained validation record is needed to assess performance beyond the examples used to choose the rule. Model 7A supplies the existing distinction between fitted and held-out data.

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16.4.4 Record repetition and the limits of the design

Revisit each configuration through fresh acquisitions. Replotting one capture, changing its display scale, or dividing it into overlapping windows does not repeat the intervention. The NIST factorial-design example uses replication to examine variability and randomizes run order to reduce systematic association with extraneous changes. A receiver sequence should likewise avoid assigning every occurrence of one setting to a different operating period from its comparison setting. Where relocking, access, or a stable source interval restricts the order, document the restriction and the corresponding limit. The temporal-control analysis belongs beside this design; it is not replaced by the four configuration labels.[6]

Blocking groups observations under a declared nuisance condition, such as the same source operating interval or the same installed fixture. It does not make that condition disappear. Keep the relevant comparisons within each group where practicable and preserve group membership in the analysis. If all original-reference observations come from one session and all alternate-reference observations from another, reference state and session are inseparable in those data. Repetition within either session cannot repair the missing cross-session comparison. Report the ambiguity and obtain the

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6 International Electrotechnical Commission, CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus, 5th ed. (May 22, 2019), official publication scope, https://webstore.iec.ch/en/publication/60774, checked November 1, 2026. The public scope identifies the 9 kHz–18 GHz apparatus range and EMI receivers and spectrum analyzers. No access to or clause-by-clause compliance review of the complete standard is claimed.

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missing combinations when the source and installation permit a meaningful repeat.[7]

Release the diagnostic record with the planned combinations, actual run order, physical states, source conditions, control-reference results, accepted records, excluded intervals, and unresolved alternatives. State whether the evidence shows a response associated with one setting, a response conditional on another setting, or insufficient comparability. Use the existing correction and uncertainty treatments for numerical differences and the existing capture model for observation opportunity. This procedural design introduces no numerical likelihood assignment or new universal receiver law. Its contribution is a more discriminating experiment: a later examiner can see precisely which combinations were observed and which causal distinctions the available records still cannot settle.

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7 Analog Devices, “System Noise-Figure Analysis for Modern Radio Receivers,” June 14, 2013, “Baseline Case: Cascade of Linear Circuit Blocks,” “A Heterodyne Receiver,” “Noise Temperature,” and “Y-Factor,” https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html. The scalar derivation and numerical cases here are original and explicitly exclude unmodeled image contributions.

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A. Instrument challenge table

Challenge	Possible external response	Possible artefact response
Attenuation	Approx. 1:1	Nonlinear slope
Preselector	Path-loss change	Product may vanish
LO retune	Stable RF location	Spur can move
Second receiver	May corroborate	Often differs
Dummy load	RF input removed	Spur may remain

B. Evidentiary decision flow

These are indicative challenge outcomes, not universal signatures. Report confounders and retained raw records.

Figure 86. Receiver artefact challenge matrix.

Table 16A. Select challenges that distinguish competing mechanisms

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Observation and proposed mechanism	Discriminating change	Confounder to control
An apparent signal may be a conversion image	Change the conversion plan or image-selective preselection and use Model 4A	Desired transfer and receiver state may also change
A discrete product may originate in a nonlinear stage	Change a parent or attenuation before the proposed stage and use Model 11A	Sources and combiners may generate the same product
An elevated floor may be reciprocal mixing	Vary admitted blocker power and retain fixed weighted output calibration under Model 11B	AGC, direct blocker leakage and baseline drift can mimic the change
A missing burst may reflect schedule coverage	Change usable windows and compare against Model 15A	The detector and event population must remain applicable
A phase discrepancy may be timing or common-reference behavior	Compare calibrated channels, reset histories and reference paths under Models 12A and 12B	Shared error and wrapped-phase ambiguity can conceal the cause

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16.5 Integration with Direction, Wireline, Optical, and Physical Evidence

Receiver evidence becomes stronger when it converges with independent domains. Direction finding or spatial gradients can localize a source, but indoor multipath and antenna phase centers must be considered. Wireline current, network logs, optical activity, acoustic state, power demand, thermal change, or physical inspection can establish a mechanism or authorization status. The time bases and configuration states of those observations must be reconciled.

Cross-domain agreement is not automatic independence. Sensors can share power, clocks, cables, software, or environmental causes. A receiver and current probe may both respond to the same instrument clock. Multiple software tools may use the same underlying decoder. The report identifies common dependencies and gives greater weight to evidence that changes the error structure.

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16.6 Findings, Reports, and Decision Ladders

A receiver report distinguishes normal occupancy, authorized device emissions, measurement artifact, installation defect, unexplained signal, unauthorized transmitter, and confirmed technical-surveillance function. A confirmed function requires more than frequency and modulation. It requires physical or operational linkage, information path, authorization status, reproducible behavior, and evidence continuity. Intermediate categories are useful because they support proportionate action without overstating certainty.

Reports include purpose, authority, equipment and configuration, coverage, baselines, calibration, uncertainty, significant observations, challenge tests, competing explanations, derived content handling, limitations, and recommendations. Figures and traces are linked to native data. Unresolved signals are described with enough detail for follow-up, including time, location, bandwidth, detector, antenna, state, and why the available evidence did not support attribution.

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16.7 Reconcile evidence without assigning unsupported probabilities

Equation 31 compares corrected levels at the same reference plane. Its value is meaningful only after gain, loss, bandwidth, detector, and relevant state changes have been reconciled. Chapter 14 supplies the correction and covariance-aware uncertainty framework. If the corrected difference lies within the justified uncertainty, the observations are compatible at that resolution. Compatibility does not prove one mechanism, and a difference beyond the interval identifies a discrepancy to investigate rather than naming its cause automatically.

Equation 32 states what a likelihood comparison would require: defined hypotheses and defensible probability models for the actual data and selection procedure. It is not used here to assign numerical odds to artifact or attribution categories. A visually persuasive coincidence, a count of favorable tests, or an expert confidence label does not supply those likelihoods. If calibrated statistical models are unavailable, report the observed discriminating consequences and remaining alternatives directly instead of manufacturing a numerical ratio.

Avoid multiplying evidence contributions as if each were independent merely because they have different labels. Two receivers may share a clock; a spectral plot and an EVM report may derive from the same samples; a trigger record and a software log may share one timestamp source. Their agreement can be technically useful while providing less independent confirmation than their count suggests. Document the common

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dependencies and seek an observation that changes the relevant coupling, timing, or processing path.

A negative control should test a specific alternative. A terminated input examines residual responses in that configuration. A known reference tests sensitivity and scale at its chosen frequency and level. A noise-only record tests a detector under that noise condition. None covers every field state. Use controls that bracket the actual observation, and retain failures as well as passes. If a closing check fails, identify which earlier conclusions depend on the affected function and narrow or repeat them accordingly.

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16.8 Write findings that preserve the strength and limit of each test

Organize a technical finding around the question, the accepted data, the calculation or comparison, the challenge results, and the resulting inference. State whether the data establish detection, waveform classification, temporal correlation, localization, device linkage, or a more limited observation. Link each figure or table to the native record and configuration. Keep derived quantities beside their units, bandwidths, normalization, reference planes, and uncertainty so they remain interpretable outside the original instrument session.

For an unresolved component, describe the work that would most effectively discriminate the remaining explanations. A repeat at the same settings may improve repeatability without testing a different cause. A changed clock, alternate conversion plan, controlled source state, independent timing observation, or physical path substitution may provide more decisive information. Prioritize the change according to the current evidence and operational authority. Record why a proposed test was not performed if that omission limits the conclusion.

When a receiver artifact is established, preserve enough detail to make the correction reusable. Identify the configurations that exhibit it, the known stimulus or state transition, the predicted and observed response, the successful challenge, and the accepted mitigation. Avoid converting a narrow incident into a universal rule about all instruments or environments. A controlled artifact record should help another examiner reproduce the

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effect and determine whether the same explanation applies to a later observation.

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16.9 Acceptance, Maintenance, and Lifecycle Control

Receiver systems used for defensive work require acceptance tests after purchase, repair, firmware change, calibration, accessory change, or major software update. Acceptance covers sensitivity, amplitude and frequency accuracy, dynamic range, preselection, images, spurs, phase noise, sample continuity, trigger behavior, metadata, and the complete field path. A simple self-test or calibrated center-frequency tone is insufficient.

Maintenance records include calibration, repairs, battery and power-supply condition, connector and switch wear, fan and thermal state, clock performance, software dependencies, correction files, and known limitations. Regression captures with stable references reveal drift. Retired data formats and software are preserved or migrated with checks. Lessons from field artifacts are added to controlled challenge procedures without turning one incident into a universal rule.

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16.10 Program Governance and Peer Review

Receiver findings with significant operational, legal, or reputational consequence receive independent technical review. The reviewer receives native data, configurations, calculations, calibration records, challenge results, and competing explanations rather than only the final narrative. Disagreements are resolved through additional tests or disclosed limitations, not suppressed through editorial consensus.

Program governance maintains approved receiver configurations, competency records, proficiency tests, field check standards, data-retention rules, known artifact libraries, and correction histories. New methods are validated before routine use. The organization records errors and reversals so that its procedures improve without converting a single case into unsupported doctrine.

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16.11 Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance

Equation 1. Normalized attenuation response error

$$e_A = P_{2,\mathrm{corr}} - P_{1,\mathrm{corr}}$$

After correcting two traces for the applied attenuation or gain change, normalized response error e_A is their level difference at the same reference plane. A value outside combined uncertainty suggests compression, a product generated after the changed element, or another state change.

Equation 2. Likelihood ratio for competing hypotheses

$$\Lambda = \frac{p(D \mid H_1)}{p(D \mid H_0)}$$

A likelihood ratio compares how probable data D are under competing hypotheses H_1 and H_0 when valid models exist. It is not a substitute for defining the hypotheses, accounting for selection effects, or establishing legal standards of proof.

Equation 31 reuses the signed calibration and uncertainty treatment of Chapter 14. Equation 32 is a definition for already specified probability or density models, with a positive denominator for a finite ratio. This chapter does not assign those models or numerical odds. Its challenge tests remain mechanism comparisons with disclosed dependencies and unresolved alternatives.

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Table 1. Chapter 16 receiver controls and interpretation limits

Control or quantity	Measurement or record	Interpretation value	Failure or limitation
Artifact challenge	Predicted mechanism, changed element, preserved controls, outcome, and uncertainty	Discriminates receiver-created and environmental components	Post hoc tests without predictions are vulnerable to bias
Cross-domain correlation	Time, location, state, calibration, shared dependencies, and independent controls	Can establish mechanism and attribution	Several sensors may share the same artifact source
Finding category	Normal, authorized, artifact, defect, unexplained, unauthorized, or confirmed function	Supports proportionate decisions	Frequency or decoding alone is not functional attribution
Lifecycle control	Acceptance, regression, calibration, repairs, software, corrections, and known limits	Maintains confidence across deployments	Self-test and a single reference tone do not test the full chain

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16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance

A component reads -83.0 dBm with zero input attenuation and -93.2 dBm after 10.0 dB attenuation. Correcting the second trace gives -83.2 dBm, a 0.2 dB difference within the 0.7 dB combined uncertainty. This scaling is consistent with an external signal but does not by itself establish its source or authorization.

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16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance

A weak burst correlates with keyboard activity and appears on two receiver channels. Investigation shows both channels share an external clock and antenna switch. An optical sensor independently records LED activity, but no field component remains when the receiver is powered from an isolated reference and the switch is bypassed. This joint intervention implicates the shared measurement path but changes two conditions at once. The report retains an instrumentation-artifact hypothesis pending separate reference and switch challenges, reversal checks, and verification that the modified chain still detects a suitable known reference. The optical observation remains evidence of LED activity and does not independently establish an RF source.

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16.14 Challenge-Test and Evidence Release Gate

Before a receiver observation becomes a reportable finding, the chain should be challenged through attenuation, preselection, antenna substitution, terminated-input tests, known-source injection, frequency-reference comparison, changed span and bandwidth, alternate receiver, time-domain correlation, and spatial movement. The test sequence must preserve the native data and the failed as well as successful hypotheses. A result that disappears under one challenge is not necessarily false, but the mechanism must be resolved before attribution.

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16.15 Close the receiver method through configuration-specific regression

A software, firmware, accessory, or repair change can alter several parts of the measurement chain at once. Select regression checks from the functions the deployed method actually uses: amplitude and noise calibration, frequency conversion, sample scaling, control recovery, modulation alignment, phase continuity, trigger geometry, and record integrity. Reuse the known references and accepted ranges that established those functions. A passing startup self-test is useful evidence about its covered functions, but it does not replace that configuration-specific comparison.

Preserve the prior accepted configuration and the changed configuration as distinct states until the relevant comparisons are complete. If a new correction or processing method changes reported results, rerun representative retained records and explain the difference. Keep both the original and revised derived products with their processing identities. This allows a later reviewer to distinguish a corrected interpretation from a change to the underlying observation.

The final release of a receiver finding should be bounded by the completed technical work. Unresolved calibration, discontinuous samples, unverified automatic state, or insufficient event coverage should remain visible in the conclusion. A method can still be useful within a narrower accepted domain. The purpose of lifecycle control is to preserve that known domain as equipment and software change, so future observations inherit tested capabilities and explicit limits rather than an undocumented history of apparently successful use.

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16.16 Falsification-led survey closure and the evidential status of negative observations

A receiver survey should end with a structured confrontation of alternative explanations rather than with the assertion that no suspicious transmitter was found. The relevant proposition is bounded by a named event class, frequency-time opportunity, instrument validity, declared threshold and the controls actually applied. A negative result can be very useful when it narrows a practical decision under demonstrated coverage. It does not prove the universal absence of every possible intermittent, shielded, frequency-agile or otherwise unobserved source. The investigator should identify the strongest plausible mechanism that could defeat the test, then determine whether the existing observations discriminate it. Where the mechanism remains untested, the final report should preserve that limitation without collapsing into an uninformative declaration that anything is possible.

Construct an explicit falsification register with one row per claim. For a narrowband candidate, list instrument-generated spur, external emission, environmental intermodulation, unstable reference, configuration-transition product and incidental source-generated artefact as competing explanations where applicable. For each row record a predicted response to an intervention, the original and comparator measurement capabilities, what was observed, and the residual uncertainty. Alternate attenuation may test downstream product location; alternate antenna geometry may test spatial coupling; reference-source substitution may test clock-related products; a controlled shielded-source challenge may test the detector's

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susceptibility and observation window. None of these controls is infallible, but a coherent pattern of observations can progressively eliminate explanations without creating a false sense of certainty from any single screenshot.

A quantitative illustration clarifies the limits of a negative survey. Suppose an idealised event model assigns each of ten independent, valid observation opportunities a probability $p = 0.25$ of detecting an event, conditional on the source being active and the model being appropriate. The probability of zero detections under that model is $(1 - p)^{10} = 0.75^{10}$, approximately 0.0563. This is not a posterior probability that the source was absent, nor is it valid when the ten dwells share blind intervals or detection probabilities. If the opportunities are strongly dependent, the simple multiplication is wrong. The result can assist experimental design only with a defensible event model, validated receiver sensitivity and actual coverage records, including unsuccessful acquisition intervals.

A closure record should include the original technical question, authority and minimisation controls; the installed receiving path; the current calibration and checks; retained native data or stated lawful substitutes; configuration and clock histories; detected events and rejected hypotheses; negative tests and failed captures; and the final bounded conclusion. Separate what was directly measured from what was inferred using propagation, waveform classification or statistical assumptions. Note any shared error mechanisms among apparent corroborating instruments, and mark periods when the receiver could not have detected the stipulated event. The final review should be repeatable by someone who did not attend the engagement, and strong claims about an individual source should never

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rest solely on an instrument's internal classification label. The formality of this procedure is valuable because it turns an otherwise fleeting RF observation into a transparent piece of engineering evidence.

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16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions

A survey report should distinguish an observation at an instrument output, a waveform classification, an inferred external source and a conclusion of legally relevant activity. Each step requires additional evidence. A narrow peak acquired with a declared detector and bandwidth can establish a bounded observation without establishing the identity or intent of an emitter. A modulation-family classification may be informative but still be confused by a receiver-generated product. A physical attribution may depend on geometry, coherent timing, antenna orientation, controlled equipment-state changes and exclusion of common error mechanisms. Legal characterisation adds further facts and jurisdiction-specific authority that cannot be supplied by RF measurements alone. A report that collapses these propositions is at risk even when its raw samples are technically excellent.

A structured alternative-hypothesis matrix gives every meaningful explanation a falsifiable prediction. For a component observed near one expected channel, list external emitter, local-oscillator leak, mixer product, ADC alias, unrecorded laboratory reference, cable common-mode current and algorithmic display artefact where physically plausible. For each hypothesis specify what should change under an independently authorised intervention: preselector state, input termination, antenna orientation, LO offset, sample rate, reference-clock substitution or controlled source power. Record the comparison's sensitivity, valid observation window and expected sign of the effect. A failed test does not automatically prove the favoured

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alternative; its power to discriminate depends on whether the purported mechanism would actually have been observed under the comparator conditions.

The meaning of independent corroboration deserves separate treatment. Two receiver enclosures connected through one splitter share the antenna path, external gain stage and potentially the same nonlinearity. Two analysis methods operating on the same clipped samples share the missing information. Two sensors with different antennas but one common noisy clock can show matching periodic features that originate in their reference distribution. The appropriate question is which error mechanisms differ, not how many displays agree. A direct source-on/source-off challenge can be powerful when authorised and controlled, but it may change the electromagnetic environment in several ways at once. A causal interpretation must account for that change and retain unsuccessful trials rather than treating agreement as a vote.

A reporting example shows the value of a bounded statement. Assume an independently calibrated receiver observed no events above threshold during 90 per cent of a stipulated 10-minute interval, while the remaining minute lacked valid capture because of an AGC state transition and subsequent buffer loss. The strongest direct negative conclusion is limited to the nine valid minutes, the tested band and defined event class. It does not establish absence during the other minute. If an event model assigns independent opportunities for detection, a probability-based inference may be possible, but that model and its independence assumption must be separately validated. A statement that the site was completely free of

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surveillance emissions is not supported by a record that did not observe the entire stipulated opportunity.

The closure matrix should contain the original task and lawful collection authority, configured receiving path, antenna and clock states, applicable calibration, source and combiner controls, sample validity, software processing lineage, uncertainty analysis, candidate observations, competing hypotheses, outcomes of challenges and final qualified statements. Required outputs should include native data where lawfully retainable, metadata and integrity digests, rejected tests, location and timing records and explicit scope exclusions. The final reviewer should be able to reconstruct not only the preferred interpretation but also why alternatives were weakened or retained. If source-to-claim verification is unfinished, mark it as a publication dependency rather than disguising it behind technical-sounding prose. Scientific authority arises from reproducible tests and bounded inference, not from the sheer length of a discussion.

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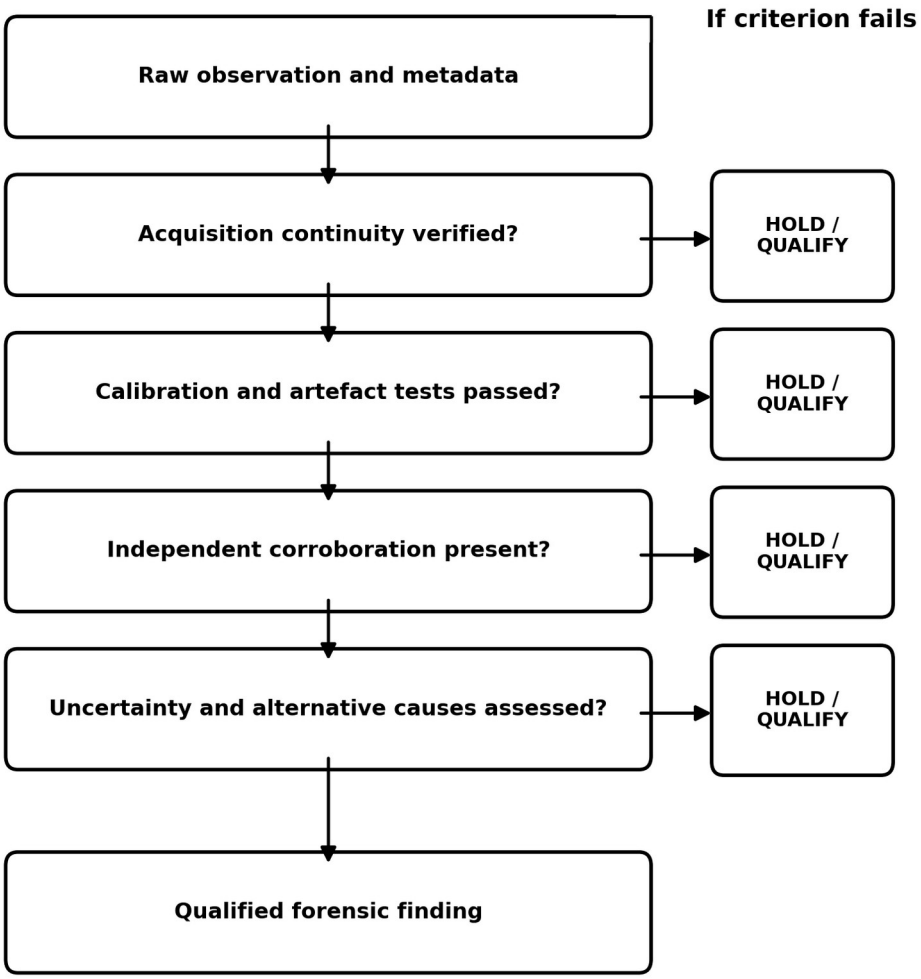

A release decision must specify evidence, limitations and unresolved hypotheses.

TECHNICAL INTERPRETATION

A defensible conclusion requires corroboration, traceable records and uncertainty accounting. Missing controls require an explicit qualification.

Figure 87. Evidence closure and qualified forensic findings.

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16.18 Advanced technical expansion. Hypothesis-led artifact adjudication and bounded assurance

The final receiver investigation is not a contest to produce the most visually striking spectrum. It is an exercise in discriminating alternative physical explanations while preserving the limits of each test. A detected feature can arise from an external emitter, passive intermodulation in an installed junction, nonlinear amplification, oscillator or clock leakage, sample-rate aliasing, digital processing, conducted coupling or an interaction of several mechanisms. A defensible report should begin with a hypothesis register that specifies what each mechanism predicts and which controlled change would be informative. A list of hypothetical causes without predicted observable differences is not yet an experimental plan. It may encourage arbitrary equipment adjustment until one favourite explanation appears to fit.

Consider an illustrative component observed at 437.5 MHz. Under an external-emitter hypothesis, moving the antenna can change amplitude and phase according to propagation and polarisation, though a disappearance is not conclusive without comparable sensitivity. Under a mixer-product hypothesis, changing the local oscillator by a known amount may move the IF or calculated spur according to a signed mixing relation. Under a clock-leakage hypothesis, substituting a reference can change the feature or its spectral shape. Under a software-generated hypothesis, the component may appear only after a particular processing step and not in an independently retained raw record. Each intervention requires an explicit counterfactual prediction. Two features can coexist; finding an internal

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product does not exclude a genuine external signal at the same apparent frequency.

The strength of evidence depends on error independence. A second receiver that shares the same antenna, cable, power source, frequency reference and analysis application may reproduce the first instrument's fault. Conversely, an independently configured receiver may fail to reproduce a genuine brief event because its dwell timing or sensitivity differs. The comparison should map shared and separate signal paths, clocks, firmware, processing and environmental exposures. A useful corroboration experiment changes suspected common error mechanisms while preserving the capability to observe the claimed emission. If the comparison cannot meet that condition, its negative result is qualified rather than treated as exclusion. Independence is an engineering relationship among causal mechanisms, not simply a count of boxes present in the room.

An evidential matrix should distinguish direct observations from model-based inferences. The observation column identifies raw data, time range, frequency, state and measurement uncertainties. The prediction column states what each candidate explanation would imply under a specified intervention. The result column records which predictions were confirmed, contradicted or left untested. The inference column then uses precise verbs: detected, consistent with, classified, localised under stated assumptions, attributed with corroboration or unresolved. A measured reduction in a spectral peak after introducing input attenuation can support an overload-related interpretation, but the strength of that inference depends on whether the desired reference remained observable and whether gain

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compensation changed automatically. The matrix should record such confounding variables instead of suppressing them in the narrative.

Negative findings need an equally disciplined formulation. Suppose an engagement includes 24 hours of clock time, of which four hours are demonstrably invalid because of instrument reconfiguration, eight hours observe only a subset of the required bands, and twelve hours have validated coverage for a specific event class. The report cannot claim 24 hours of complete negative monitoring. It may state that no events meeting a defined criterion were detected during the twelve hours of relevant validated coverage, with the other intervals classified accurately. The 12/24 = 0.5 fraction is a duration-based coverage statistic, not a universal capture probability. Converting that fraction into a confidence bound requires a model of source activity, event timing, threshold performance and missed detections. The model itself should be disclosed and challengeable.

Forensic reproducibility also depends on maintaining a distinction between authentic historical record and later analytical product. An instrument trace, original I/Q recording, time-and-state log, calibrated transfer measurement, model fit and expert narrative have different epistemic statuses. A source-to-claim concordance should identify which specific record supports each consequential assertion and where professional judgement enters. The report must also preserve the limits of collection authority, the handling of incidental information, relevant access restrictions and the process by which exhibits were selected. Credibility is strengthened when unsuccessful tests and contradictory observations remain available to independent reviewers rather than being hidden behind the final hypothesis.

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The chapter should close with an operational lifecycle model. Instruments enter service through documented acceptance, remain in controlled use through configuration and calibration checks, and are suspended or qualified after consequential overload, firmware change, damaged accessory or unexplained deviation. A return-to-service record demonstrates only the functions and conditions exercised during its tests; it does not retroactively repair historical invalid acquisitions. Periodic regression tests using known references can reveal drift, but must be interpreted together with environmental controls and statistical repeatability. A final conclusion is thus a bounded statement about a particular measurement system, at particular times and under particular states, not a permanent declaration that the entire installation or institution is free of all conceivable emitters.

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16.19 From a spectral observation to an experimentally identifiable cause

The central problem of receiver-artifact examination is one of identifiability, not merely one of recognizing familiar spur patterns. An observed complex sample stream can arise from an external electric field, intermodulation within an amplifier, local-oscillator leakage, a clock-derived spur, an image response, conducted ingress, or a composite of these causes. Distinct causes can yield numerically similar carrier frequencies, powers and apparent modulation; even a repeated observation does not make the mapping from output to physical source unique. The appropriate inverse problem begins by specifying a candidate causal mechanism and predicting how it must respond to an intervention. If two mechanisms predict the same behaviour for all interventions undertaken, the experiment has not discriminated between them. It is not legitimate to resolve that ambiguity by selecting the more dramatic narrative. State the surviving equivalence class of explanations and the next measurement that would distinguish its members.

A useful model represents the retained record as $r(t)=F[x(t),q(t),e(t)]+a(t)$, where $x(t)$ is the external electromagnetic input at a named plane, $q(t)$ is the instrument's time-varying hardware and firmware state, $e(t)$ comprises the environmental and coupling conditions, F is the configured transformation, and $a(t)$ represents contributions not included in that declared transformation. This is a structural description rather than a claim that disturbances simply add independently. Overload may alter F itself, and feedback may make $q(t)$ depend on $x(t)$. A challenge must consequently

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identify which variables it holds constant, which it deliberately changes, and which it merely observes. A subsequent amplitude correction cannot repair the information lost when the mapping was nonlinear or when a critical state was not recorded. The examiner should capture native data before, during and after the intervention, along with reference-source state and instrument control transitions.

The most informative interventions are designed to generate incompatible predictions. A component that originates upstream of a switched attenuator should, within a validated linear state, change by the applied attenuation in the raw receiver indication. A component generated downstream need not do so. Yet a gain-control loop can conceal the predicted change, and a nonlinear product arising upstream may fall much faster than the applied attenuation. Therefore the question is not whether a peak moved by precisely the same number of decibels shown in a menu, but whether the observed response lies within a predeclared uncertainty enclosure for each candidate mechanism. The attenuation element itself must be measured, and its placement relative to the suspected generation stage must be established. Repeating the test at a different blocker level helps distinguish a linear path from a cubic product or a limiting response.

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16.20 An intervention matrix that separates mechanism, state and common error

Before acquisition, construct a matrix whose rows are competing explanations and whose columns are interventions: input termination, preselector substitution, antenna relocation, attenuation change, independent clock, independent receiver, separate power source, controlled source injection, and repeated acquisition after thermal settling. For each cell enter an expected direction and range of change, and a list of ways the intervention could fail to isolate the intended cause. This avoids the retrospective practice of declaring whichever manipulation happened to remove a peak to be definitive. A preselector can remove a genuine external signal that lies outside its passband, while a terminated input can change oscillator loading or internal cable coupling. The exercise is strongest when these side effects are quantified before interpreting the result.

Factorial testing is preferable to uncontrolled serial experimentation when two receiver settings interact. Suppose factors A and B represent an input attenuator and an optional preamplifier, each at two settled states. Write the four response values y00, y10, y01 and y11 at the same reference plane and under equivalent source conditions. The interaction contrast I=y11-y10-y01+y00 measures whether the combined effect departs from the sum of the individual changes in the chosen response scale. Decibel responses may be suitable for level comparisons under specified conditions, but a logarithmic contrast is not automatically an additive physical-power interaction. For a power balance, first transform to compatible linear watts and formulate the corresponding hypothesis. A significant I may be

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produced by gain control, compression or changed filter loading rather than by the emission being sought; test the mechanism with further targeted controls.

Randomise the order of repeatable laboratory challenges when drift or warm-up could otherwise masquerade as a response. An AABB sequence may confound the intervention with time; an ABBA or randomised blocked sequence can expose temporal trend if settling is measured and source conditions remain comparable. Where changing a physical connection risks altering coupling, retain a reference branch so the operator can distinguish the expected difference from fixture movement. The experimental log needs actual transition timestamps rather than merely the order in which a script issued commands. A configuration change that has not settled is a third state, not an admissible sample of either adjacent steady state. Preserve transition intervals as excluded or separately analysed measurements.

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16.21 Nonlinear fingerprinting without circular source attribution

For a memoryless weak cubic response $y=a1\ x+a3\ x^3$ driven by two equal-frequency-separated sinusoids, the third-order product near one input frequency scales approximately with the cube of the input voltage while the corresponding small-signal fundamental scales linearly. Expressed in power decibels under fixed impedances and small-signal conditions, reducing both source tones by a common attenuation A dB reduces the third-order product approximately 3A dB and the fundamentals A dB. This familiar slope test is a hypothesis about a bounded transfer law. It is not valid through compression or automatic gain transitions, and it does not identify the physical circuit producing the nonlinearity unless source and combiner products have been independently bounded. A mixer, limiter, poor connector and test generator can all produce misleadingly similar slopes.

General nonlinear frequency formation is also not sufficient for source identification. An observed tone at $f_p=m\ f_1+n\ f_2$, with signed integer coefficients m and n, can be predicted from many input pairs, harmonics, images and frequency translations. Enumerate plausible combinations within the actual admitted input bands and establish whether the generators of the hypothesised terms were present. A local oscillator at f_{LO} can map an incoming signal to $f_{IF}=|f_{RF}-f_{LO}|$, but an image on the other side of the oscillator may yield the same magnitude. A clock harmonic may alias into the same digital bin. To separate these explanations, move the oscillator or sampling clock in a controlled way while keeping an independently identified external reference. The observed frequency shift

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must be compared with the signed prediction of each model and the applicable resolution uncertainty.

Receiver-origin attribution must survive a source-control test. Two RF signal generators that are insufficiently isolated can create intermodulation within their own output stages or combiner; a purported receiver spur is then already present at the input plane. Measure that plane with a suitably linear reference arrangement or separate the source paths with characterised isolation before accepting the nonlinear signature. Conversely, the absence of a product in a reference instrument proves little if its input filtering rejected the relevant frequency, if its sensitivity was inadequate, or if the particular transient occurred outside its valid observation interval. Every negative comparator must be qualified by matching frequency, time, noise, linearity and detector opportunity.

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16.22 Coupling paths that defeat the simple external-versus-internal dichotomy

Some observations arise from interaction between the building and the receiver rather than being either a freely radiated transmitter or a purely internal circuit error. Common-mode current on a coaxial cable can couple into an enclosure despite excellent differential shielding at the input connector. A powered USB lead, a network switch, an external reference cable, or a bias supply may convey structured interference into the digitiser or clock network. Moving the antenna can change the cable route, connector stress and common-mode impedance, so disappearance after relocation does not establish geometric localisation. A valid localisation trial measures or constrains those concomitant changes; ferrite and shield arrangements require their own frequency-dependent validation rather than being treated as magic suppression devices.

Mechanical coupling can produce microphonic phase or amplitude modulation in a resonator, cable, filter or oscillator. The visible trace may acquire spectral shoulders when a fan starts, a bench is touched, or vibration passes through a fixture. Instead of naming a specific component on the basis of correlation, perform a bounded mechanical or thermal challenge with a reference input whose physical RF characteristics are known. Record vibration or temperature synchronously with the raw RF stream. Distinguish a change in receiver transfer from a change in an actual radiating source, and avoid interventions that could damage hardware or move operation outside rated conditions. Thermal equilibration and

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connector torque belong to the measurement state if they materially affect the inference.

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16.23 Probabilistic evidence must preserve conditional assumptions

A likelihood ratio compares the probability of observed evidence E under two declared hypotheses, LR=P(E|H1)/P(E|H0). The computation is meaningful only when the probability models, nuisance variables and observation-selection process are specified. A report may use a likelihood-ratio framework to organise reasoning without assigning numerical probabilities when the necessary rates are unavailable. If a test is selected after an unusual peak appears, the conditioning on that selection is not optional. If two observations share the same sample data, clock, antenna path or analysis code, treating them as independent evidence multiplies support that has not been earned. An apparently precise ratio based on arbitrary priors or guessed false-alarm rates is inferior to an explicit statement that the mechanisms remain unresolved.

A negative survey finding is likewise a statement about a bounded event population and a demonstrated acquisition opportunity, not an unrestricted declaration of absence. Define C(f,t,s) as one for a time, frequency and receiver-state combination in which a stipulated event would have been observable with a validated criterion, and zero otherwise. This deterministic coverage indicator is not by itself a probability. A probability of missing an event requires a defensible model for when and where events occur and how the detector responds conditional on that opportunity. The report should separate unobserved frequency bands, settling intervals, missing samples, overload periods and threshold misses during valid acquisition.

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These gaps may affect different propositions and cannot be collapsed into a single unsupported percentage of confidence.

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16.24 Worked forensic adjudications with fully stipulated quantities

Case 16C.1. A controlled tone appears at -70.0 dBm before an input attenuation change and -80.2 dBm afterwards. The actual inserted loss, measured independently at the tone frequency, is 10.1 dB. The signed residual R=P_after-P_before+L is -0.1 dB. If the two level readings and loss calibration have independent standard uncertainties of 0.15, 0.15 and 0.10 dB, their combined standard uncertainty is sqrt(0.15^2+0.15^2+0.10^2)=0.2345 dB. The residual is compatible with zero under that model, but agreement does not establish that the component was external; a downstream gain correction or a correlated error could also produce agreement. Preserve raw readings, actual setting, covariance assumptions and source controls.

Case 16C.2. Two equal isolated input tones are each attenuated by 6 dB before a verified weak cubic receiver stage. A third-order component falls by 17.5 dB, with a combined measurement uncertainty of 0.7 dB. The ideal third-order prediction is an 18 dB decrease, whereas a linear external component predicts 6 dB under the same attenuation placement. The observation agrees with the cubic prediction within the stated uncertainty, but it does not distinguish receiver third-order response from upstream source or combiner nonlinearities unless those have been bounded independently. Repeating at two more levels and testing the product at the relevant input plane strengthens the mechanistic inference.

Case 16C.3. Four factorial observations of an explicitly defined detector-level statistic are y00=-90 dBm, y10=-100 dBm, y01=-75 dBm and y11=-93 dBm.

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The interaction contrast is -93-(-100)-(-75)+(-90)=-8 dB. A nonzero contrast indicates the effects of switching attenuation and gain are not additive in the chosen dBm response. It does not by itself specify compression, because the levels may reflect AGC response, changed bandwidth or source variation. The next experiment fixes the detector and bandwidth, monitors gain state and repeats an independently calibrated reference.

Case 16C.4. A putative external component persists in two receivers, but both share a reference oscillator that has a 20 MHz spur. A detector that derives its sample clock through the same multiplication chain can reproduce a related line in both systems. Treating the two observations as independent would overstate corroboration. A separate frequency reference and a controlled reference-switch test change the relevant error mechanism; the critical result is whether the candidate follows the clock-derived prediction while the external input and measurement opportunities remain equivalent.

Case 16C.5. A monitor records 30 hours, but 2 hours are invalid during calibration, 3 hours during retuning and 1 hour during known overload. If these exclusions are disjoint, valid recorded time is 24 hours, or 80 percent of elapsed time. The 80 percent is a verified time-coverage fraction, not an 80 percent probability of detecting an arbitrary transmitter. Such a probability would require the event-duration and start-time distribution, the observed frequencies and receiver sensitivity. If the excluded periods overlap, subtracting all six hours would itself be an error: compute the duration of their union.

Case 16C.6. Two independently measured bearings of 42 degrees and 47 degrees are obtained with estimated standard uncertainties of 3 and 4

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degrees, respectively. If errors are independent and small enough for local linear angular treatment, inverse-variance weighting yields (42/9+47/16)/(1/9+1/16)=43.8 degrees, with standard uncertainty sqrt(1/(1/9+1/16))=2.4 degrees. Shared antenna geometry, multipath or reference calibration invalidates the independence assumption and changes the result. This calculation does not show that a unique source exists, nor does a narrow angular interval establish ownership or intent.

Case 16C.7. A spectral candidate is present during a 10-second dwell while an independent monitor has a 1-second data gap overlapping that dwell. The monitor's negative exported trace cannot contradict the original observation unless the exact event window was actually acquired with adequate sensitivity. The correct comparison table records the candidate's earliest and latest physically supported occurrence, the comparator's valid sample-index intervals, and detector thresholds. File-creation timestamps are insufficient substitutes for acquisition epochs.

Case 16C.8. A hypothetical classifier labels 94 of 100 known calibration products correctly but has not been tested on novel external sources. The 94 percent accuracy pertains to the selected known-product population and says nothing about open-set false attribution. For a test of twenty independently selected new sources with no false labels, a one-sided binomial 95 percent upper false-label probability is 1-0.05^(1/20), approximately 13.9 percent, even under identical independent-trial assumptions. The result is too weak to support a universal identification assertion; explain population selection and independence before assigning quantitative confidence.

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Case 16C.9. A corrected input estimate is -88 dBm in a linear state. A second state gives -90 dBm, but its gain transition overlaps the event and the instantaneous response was not recorded. The difference is not a two-decibel environmental change measurement. Treat the first estimate as bounded by its calibration and the second as conditional or unusable for amplitude attribution until the transition response is recovered. Do not hide the uncertainty by averaging to -89 dBm.

Case 16C.10. A report has verified an RF component, an authorised device-state correlation and an independent directional constraint, but no unique evidence of a particular transmitter or individual. A defensible finding describes the signal, tested conditions and observed correlation, and states that source identification is unresolved. The case illustrates why a technically strong, bounded conclusion is more useful to a reviewing court or laboratory than an invented numerical probability of malicious purpose.

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16.25 An enforceable quality-release rule for the instrument and the report

Technical acceptance should be based on a matrix joining each permitted finding to its necessary evidence and validity checks. Detection requires a defined statistic and threshold over eligible acquisition intervals. Waveform classification adds calibrated signal-processing information and adversarial or out-of-class challenge tests. Physical localisation adds independently checked geometry, timing and propagation assumptions. Source attribution requires evidence that discriminates one candidate source from reasonable alternatives. A report should never promote a finding to a higher class simply because a more sophisticated receiver or algorithm was used. Each class has a failure state: nonreproducible observations, missing configuration, calibration inconsistency, clipping, unknown reference behaviour, or an untested alternative explanation.

Release of the receiver configuration is a separate proposition from release of a case conclusion. A receiver may pass a laboratory acceptance test and later operate in an invalid field state; conversely, a particular observation may be reproducible even if another function of the instrument is defective. Preserve asset identity, firmware and FPGA versions, preselector response, gain limits, clock distribution, software processing, calibration revisions and relevant environmental conditions as a controlled configuration. After repairs, firmware changes or suspected overload, rerun the tests that exercise affected functions. The continuous record should identify intervals for which the asserted validity is supported, the specific tests used and any

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untested mechanisms. A passed self-test is evidence about the self-test, not proof of every measurement performed in the preceding engagement.

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16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information

The evidential chain starts at the declared input plane. An observed transient must be associated with a receiver slice whose gain, phase, clock, bandwidth and overload state were valid at the sample times. The next inference is that a signal-like structure was present in the retained complex measurements; a further inference may classify modulation family or emission behaviour. Identifying the physical emitter requires additional independent evidence, such as antenna bearing, controlled equipment-state changes or corroboration under a differently configured receiver. Identifying the owner, authorised use, intended purpose or information content is a distinct legal and evidential problem. Treating a cyclostationary feature, an I/Q constellation or a protocol-shaped packet as proof of a particular device collapses those inference levels without justification.

A robust artifact test varies the measurement chain while retaining the observation capability. An image at a mirrored complex frequency which changes when I/Q gain imbalance is corrected may be a conversion artifact rather than a second source. A narrow line which moves when the ADC sample clock changes may be a sampling spur. A frequency component that appears only when a high-gain front end is connected may arise from receiver compression, but external signals can also respond to changed detection thresholds. A second receiver's nondetection is discriminating only if it had comparable relevant frequency coverage, timing opportunity, sensitivity and gain validity. Preserve predicted changes for each hypothesis

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before looking at the outcome; post hoc storytelling can make almost any trace appear consistent with a preferred mechanism.

For a large parallel system, common-mode artifacts can defeat apparent multiplicity. Four hundred simultaneous receive channels do not constitute four hundred independent confirmations when they share one defective reference, one network clock, common power supply, contaminated calibration injection, flawed sign convention or common GPU spectral transform. Review the graph of shared dependencies and seek a test that breaks the suspected common cause. A candidate line appearing simultaneously in many channels can be powerful evidence of a common error rather than proof of a wideband source. Correlation should be calculated with timestamps and appropriate channel noise covariance; a coloured spectrogram is an illustration, not an inferential model.

The retention rule is as important as the classifier. A four-hour archive of peak lists but no raw samples may preserve valuable spectral occupancy evidence, but it generally cannot support later re-estimation of pulse phase code or recovery of a transient suppressed by the original detector. An event-triggered archive may preserve just the right I/Q segments, yet an absent segment cannot exclude an event which the trigger was not designed to recognise. Therefore record a per-band, per-time coverage ledger, detector thresholds and revisions, sample gaps, ring-buffer deadlines, known tests and rejected candidates. A negative conclusion must specify the event class and tested capability rather than claiming the RF environment was empty.

Scientific reconstruction requires versioned transformations from raw I/Q through channel selection, demodulation, feature extraction, classification

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and any lawful content interpretation. The processing graph should retain original hashes, each output's source-sample interval, software version, coefficients, RF-to-baseband mapping and uncertainty. A new algorithm can legitimately identify a waveform previously missed within saved samples, but it cannot retroactively acquire waveforms that were never stored. Independent replication should include at least one receiver or recording whose significant hardware, clock or processing error paths differ from the original. When source identity remains unresolved, report the measurements and surviving hypotheses with precision rather than extending the result into unsupported attribution.

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Chapter Summary

Receiver conclusions are earned through architecture-based challenge tests, independent evidence, explicit finding categories, and lifecycle control. The strongest result is not the most dramatic trace but the one that survives changes to the measurement chain and competing explanations.

Begin with mechanisms located in the measurement architecture and write competing predictions before changing controls. Preserve desired observation capability through each comparison. A disappearance can reflect changed sensitivity, coupling or state, and agreement between two receivers can retain shared errors. The model families provide conditional predictions; no single signature establishes attribution.

Cross relevant control settings when their combinations are physically meaningful. Define the response consistently, retain fresh acquisitions and run order, and distinguish settled behavior from transitions. Replication, randomization and blocking address different design questions. An interaction narrows the explanatory problem while leaving component identity and mechanism to further discriminating evidence.

Report the category and limit actually supported: detection, classification, localization, linkage or an unresolved observation. Reconcile cross-domain timing and common dependencies instead of manufacturing independent evidence or numerical odds. Preserve failed tests and native records for review. After hardware, software or correction changes, regression checks maintain the specific accepted functions and explain any revised result without changing the underlying observation.

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Chapter 16 Assessments

This section contains 250 items: 100 multiple-choice, 100 fill-in-the-blank, 25 essay and 25 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

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Multiple-Choice Questions

V011-C16-MCQ-001. What makes a receiver challenge discriminating?

A. The intervention always removes the feature

B. The operator prefers one explanation before testing

C. The changed control has an intuitive label

D. Competing mechanisms predict different outcomes while relevant observation capability is preserved

Answer: D. Predictions and controlled capability turn a change into a meaningful mechanism comparison. Source: §16.2 Challenge-Test Design (p. 9258)

Why the selected alternative fits: Competing mechanisms predict different outcomes while relevant observation capability is preserved.

Distinguishing consideration: compare this with option A, “The intervention always removes the feature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Challenge-Test Design.

Review: Chapter 16 — Challenge-Test Design.

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V011-C16-MCQ-002. Does corrected attenuation scaling alone prove an external emitter?

A. Yes; all internal emissions ignore attenuation

B. No; attenuation tests never provide useful evidence

C. No; instrument emission coupled through the input path can scale similarly

D. Yes; agreement within uncertainty proves authorization

Answer: C. The result supports a bounded transfer compatibility, not unique source attribution. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: No; instrument emission coupled through the input path can scale similarly.

Distinguishing consideration: compare this with option A, “Yes; all internal emissions ignore attenuation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-003. Why not derive numerical likelihoods from a count of favorable challenge tests?

A. Every test result has equal likelihood by definition

B. An expert confidence label supplies the missing probabilities

C. Valid models for hypotheses, data, dependence and selection are required

D. Different test names guarantee statistical independence

Answer: C. Equation 32 defines a model-based ratio, not an arbitrary evidence score. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: Valid models for hypotheses, data, dependence and selection are required.

Distinguishing consideration: compare this with option A, “Every test result has equal likelihood by definition”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-004. What must a regression release preserve?

A. Only a passing startup self-test

B. Prior and changed configurations, reference checks, processing identity and unresolved limits

C. Only the revised conclusion without the original derivation

D. Only the latest corrected chart

Answer: B. Native observations and both processing states make revisions reviewable. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why the selected alternative fits: Prior and changed configurations, reference checks, processing identity and unresolved limits.

Distinguishing consideration: compare this with option A, “Only a passing startup self-test”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-MCQ-005. Why can a successful one-control challenge leave a mechanism unresolved?

A. Changing one menu option guarantees one physical cause changed

B. Its effect can depend on another fixed control setting

C. One-control tests are always mathematically invalid

D. Any disappearance proves that control is defective

Answer: B. Relevant combinations may reveal interaction outside the original comparison. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why the selected alternative fits: Its effect can depend on another fixed control setting.

Distinguishing consideration: compare this with option A, “Changing one menu option guarantees one physical cause changed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-MCQ-006. A line appears only with the original reference and switch in circuit, with comparable capability in all four states. What follows immediately?

A. The response is associated with that tested joint configuration

B. Both components independently generate the line

C. The switch alone is proved defective

D. The line is physically absent at every level in the other states

Answer: A. The pattern motivates shared-path tests but does not uniquely locate the source. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: The response is associated with that tested joint configuration.

Distinguishing consideration: compare this with option B, “Both components independently generate the line”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-007. Why is a passing continuous-tone check insufficient for every negative burst observation?

A. Burst detectability is independent of acquisition timing

B. It may leave trigger, settling, dead time and continuity untested

C. A continuous tone cannot test any amplitude transfer

D. Tone agreement proves every waveform class has equal sensitivity

Answer: B. The reference should exercise the capability supporting the negative claim. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: It may leave trigger, settling, dead time and continuity untested.

Distinguishing consideration: compare this with option A, “Burst detectability is independent of acquisition timing”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-MCQ-008. How should an unexplained initial line be classified before challenges?

A. As a receiver artifact solely because artifacts exist

B. As an unexplained observation with competing mechanisms

C. As an unauthorized transmitter by default

D. As a confirmed surveillance function if modulation is recognizable

Answer: B. Classification should follow evidence rather than the drama of the trace.

Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)

Why the selected alternative fits: As an unexplained observation with competing mechanisms.

Distinguishing consideration: compare this with option A, “As a receiver artifact solely because artifacts exist”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Artifact Taxonomy and Competing Explanations.

Review: Chapter 16 — Artifact Taxonomy and Competing Explanations.

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V011-C16-MCQ-009. Why begin artifact analysis with an architecture map?

A. Component labels alone identify all causal paths

B. Controls act differently on mechanisms before and after their location

C. Every artifact originates in the final detector

D. The map supplies numerical likelihoods automatically

Answer: B. Stage placement gives conditional predictions for interventions. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: Controls act differently on mechanisms before and after their location.

Distinguishing consideration: compare this with option A, “Component labels alone identify all causal paths”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-010. Which change directly challenges an alias hypothesis when interpreted with the actual mapping?

A. Only changing the plot color scale

B. A controlled sample-rate change

C. Only increasing post-detection averaging at unchanged rate

D. Only relabeling the center frequency

Answer: B. An alias should follow the sampling map, while other mechanisms may behave differently. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: A controlled sample-rate change.

Distinguishing consideration: compare this with option A, “Only changing the plot color scale”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-011. Which evidence helps distinguish a conversion image?

A. A large file with no frequency metadata

B. A stable displayed label under an unknown LO state

C. A single antenna certificate

D. Movement under a declared conversion plan or image-selective preselection

Answer: D. The signed conversion model predicts candidate movement and admission. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: Movement under a declared conversion plan or image-selective preselection.

Distinguishing consideration: compare this with option A, “A large file with no frequency metadata”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-012. Where should attenuation be changed to test generation in a proposed nonlinear stage?

A. Before that stage, with parent levels and desired transfer controlled

B. Anywhere, because attenuation location never matters

C. At an unrelated output that never reaches the stage

D. Only after the final display detector

Answer: A. Products generated after the changed input can scale differently from an already present signal. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: Before that stage, with parent levels and desired transfer controlled.

Distinguishing consideration: compare this with option B, “Anywhere, because attenuation location never matters”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-013. What can a preamplifier bypass test discriminate when capability is preserved?

A. Every possible cause uniquely from one disappearance

B. A response generated in or dependent on that active path versus one already at its input

C. The absolute time of an external event without clock information

D. The source's authorization status

Answer: B. Bypass changes the architecture, but its gain and sensitivity effects must be accounted for. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: A response generated in or dependent on that active path versus one already at its input.

Distinguishing consideration: compare this with option A, “Every possible cause uniquely from one disappearance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-014. Why write predictions for at least two explanations before the intervention?

A. To guarantee one prediction will be correct

B. To turn every observed difference into causation

C. To avoid recording unexpected outcomes

D. To define what the test could distinguish and reduce post hoc interpretation

Answer: D. Predeclared alternatives give the test a reviewable purpose. Source: §16.2 Challenge-Test Design (p. 9258)

Why the selected alternative fits: To define what the test could distinguish and reduce post hoc interpretation.

Distinguishing consideration: compare this with option A, "To guarantee one prediction will be correct"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 16 — Challenge-Test Design.

Review: Chapter 16 — Challenge-Test Design.

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V011-C16-MCQ-015. What should be retained when a challenge fails to reproduce the original state?

A. Only the successful trials from other states

B. The failed reproduction and its limitation

C. A revised hypothesis pretending the state was reproduced

D. An assumed copy of the missing original response

Answer: B. An unreproducible state limits comparison and belongs in the record.

Source: §16.2 Challenge-Test Design (p. 9258)

Why the selected alternative fits: The failed reproduction and its limitation.

Distinguishing consideration: compare this with option A, “Only the successful trials from other states”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Challenge-Test Design.

Review: Chapter 16 — Challenge-Test Design.

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V011-C16-MCQ-016. What is a limitation of receiver substitution using a shared antenna, clock and software?

A. Two receivers necessarily provide independent confirmation

B. Shared resources guarantee both instruments are correct

C. Substitution eliminates all coupling paths automatically

D. The original cause can persist through shared dependencies

Answer: D. An informative substitution should change relevant error structure.

Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: The original cause can persist through shared dependencies.

Distinguishing consideration: compare this with option A, “Two receivers necessarily provide independent confirmation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-017. Why carry a known reference through both substitute receivers?

A. To identify the external emitter directly

B. To interpret nondetection against demonstrated capability

C. To eliminate the need for state-specific corrections

D. To prove all internal errors are independent

Answer: B. A less sensitive path can hide a real feature. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: To interpret nondetection against demonstrated capability.

Distinguishing consideration: compare this with option A, “To identify the external emitter directly”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-018. What does a line disappearing under antenna termination establish by itself?

A. Unique proof of a real external transmitter

B. Unconditional absence of mismatch effects

C. Unique proof of receiver self-noise

D. Dependence on that changed input configuration within tested limits

Answer: D. Termination can alter impedance or remove an external nonlinear element. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: Dependence on that changed input configuration within tested limits.

Distinguishing consideration: compare this with option A, “Unique proof of a real external transmitter”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-019. Why is a plausible decoded identifier insufficient for attribution?

A. Modulation cannot carry identifiers

B. A decoder output automatically proves physical device linkage

C. It may be stale, repeated or a false lock

D. Every decoded identifier is necessarily false

Answer: C. Waveform interpretation needs validation and linkage evidence. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: It may be stale, repeated or a false lock.

Distinguishing consideration: compare this with option A, “Modulation cannot carry identifiers”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-020. What makes a negative control useful?

A. It guarantees every field hypothesis is excluded

B. It tests a specific alternative under relevant conditions

C. It supplies a universal detection threshold

D. It makes calibration scope irrelevant

Answer: B. Controls have bounded purposes and should bracket the observation.

Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: It tests a specific alternative under relevant conditions.

Distinguishing consideration: compare this with option A, “It guarantees every field hypothesis is excluded”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-021. What is an interaction between two receiver controls?

A. Both menu settings change at the same instant only

B. Any difference between two instruments

C. Both controls have effects that are necessarily independent

D. The effect of one control depends on the other's setting

Answer: D. Crossing relevant levels exposes conditional response. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why the selected alternative fits: The effect of one control depends on the other's setting.

Distinguishing consideration: compare this with option A, “Both menu settings change at the same instant only”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-MCQ-022. Why define factors by physical changes rather than menu labels?

A. A named clock factor changes only frequency and nothing else

B. Labels specify all underlying impedances

C. Physical changes are always perfectly isolated

D. A menu change can alter several coupling, timing or transfer properties

Answer: D. The actual bundle of consequences must be characterized. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why the selected alternative fits: A menu change can alter several coupling, timing or transfer properties.

Distinguishing consideration: compare this with option A, “A named clock factor changes only frequency and nothing else”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-MCQ-023. Selecting an external reference can change which combination?

A. Frequency behavior, common-mode coupling, phase continuity and connections

B. Only the data-file extension

C. Only absolute frequency with every other property fixed by definition

D. Only the display units

Answer: A. The intervention is not automatically a single-mechanism manipulation.

Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why the selected alternative fits: Frequency behavior, common-mode coupling, phase continuity and connections.

Distinguishing consideration: compare this with option B, “Only the data-file extension”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-MCQ-024. Bypassing a switch can alter which properties?

A. Only the mechanical enclosure identity

B. Loss, impedance, route and control transients

C. Nothing except the front-panel label

D. Only the final detector threshold

Answer: B. Those changes may confound an otherwise useful challenge. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why the selected alternative fits: Loss, impedance, route and control transients.

Distinguishing consideration: compare this with option A, “Only the mechanical enclosure identity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-MCQ-025. For two controls with two physically meaningful states each, how many combinations make the crossed comparison?

A. Three

B. Eight

C. Four

D. Two

Answer: C. Each level of one factor is observed with each level of the other. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: Four.

Distinguishing consideration: compare this with option A, “Three”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-026. How should switch effects be compared in the clock-and-switch design?

A. Within each reference state before generalizing across references

B. Only in the original reference state and assuming universality

C. By pooling all four levels without retaining labels

D. Only by comparing the two most different overall states

Answer: A. Conditional comparisons reveal whether the effect changes with the companion factor. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: Within each reference state before generalizing across references.

Distinguishing consideration: compare this with option B, “Only in the original reference state and assuming universality”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-027. One crossed combination is physically unavailable. What must be reported?

A. A complete four-state conclusion anyway

B. An imputed outcome from the other three without a model

C. The missing comparison and its limit on inference

D. A claim that the factor has no interaction

Answer: C. Observed states cannot silently supply an absent condition. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: The missing comparison and its limit on inference.

Distinguishing consideration: compare this with option A, “A complete four-state conclusion anyway”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-028. What should be defined before acquiring the crossed-state data?

A. The response at a physical reference plane and its fixed criterion

B. The most favorable display threshold after observing the results

C. A universal uncertainty score for every response

D. A source attribution category independent of data

Answer: A. A consistent response definition makes the comparisons interpretable.

Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: The response at a physical reference plane and its fixed criterion.

Distinguishing consideration: compare this with option B, “The most favorable display threshold after observing the results”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-029. Why can a binary visible/not-visible label be misleading?

A. A gain or noise change can cross the display threshold without removing the source

B. Visibility is always independent of sensitivity

C. Every continuous measure is less informative

D. Binary data prove physical absence

Answer: A. Retain continuous observations and demonstrated detection limits where relevant. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: A gain or noise change can cross the display threshold without removing the source.

Distinguishing consideration: compare this with option B, “Visibility is always independent of sensitivity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-030. Why distinguish linear-power differences, dB differences and threshold crossings?

A. Each automatically establishes a likelihood ratio

B. They are numerically identical under every calibration

C. They require no reference-plane agreement

D. They answer different quantitative questions

Answer: D. The response definition must remain consistent across states. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: They answer different quantitative questions.

Distinguishing consideration: compare this with option A, “Each automatically establishes a likelihood ratio”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-031. Does an observed interaction locate the responsible circuit?

A. Yes; the factor with the larger name is responsible

B. No; interactions provide no information at all

C. Yes; both components must independently emit

D. No; several joint coupling, sensitivity or third-condition mechanisms can remain

Answer: D. An interaction narrows the problem and guides further discrimination.

Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: No; several joint coupling, sensitivity or third-condition mechanisms can remain.

Distinguishing consideration: compare this with option A, “Yes; the factor with the larger name is responsible”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-032. What follow-up could distinguish a clock-and-switch coupling path from mere sensitivity change?

A. Only recounting the four labels

B. Only taking more screenshots of the same capture

C. An independent reference-path emission check plus a suitable calibrated desired signal

D. Only changing the plotted threshold until agreement appears

Answer: C. Different physical mechanisms need different reference observations.

Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why the selected alternative fits: An independent reference-path emission check plus a suitable calibrated desired signal.

Distinguishing consideration: compare this with option A, “Only recounting the four labels”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-MCQ-033. Why test a weak reference near the relevant observation limit?

A. Reference strength never affects comparison validity

B. Any saturated tone proves all sensitivity levels

C. A comfortable strong tone may not establish weak-feature capability

D. A weak reference replaces all noise calibration

Answer: C. The control must exercise the actual claim. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: A comfortable strong tone may not establish weak-feature capability.

Distinguishing consideration: compare this with option A, “Reference strength never affects comparison validity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-MCQ-034. Why might a wideband modulated reference be preferable to a narrow tone?

A. It removes all calibration uncertainty

B. It always has lower distortion than a tone

C. The comparison concerns wideband modulation performance

D. It automatically establishes every trigger condition

Answer: C. Reference choice follows the function being compared. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: The comparison concerns wideband modulation performance.

Distinguishing consideration: compare this with option A, “It removes all calibration uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-MCQ-035. When a bypass cable changes the reference plane, what is needed?

A. A relabeling with no measurement change

B. Applicable path correction and uncertainty or a narrower quantitative claim

C. An assumption that all bypasses are transparent

D. Only the same nominal connector type

Answer: B. Comparisons must refer to the same supported measurand. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: Applicable path correction and uncertainty or a narrower quantitative claim.

Distinguishing consideration: compare this with option A, “A relabeling with no measurement change”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-MCQ-036. A state lacks necessary characterization but yields a visible feature. What can be retained?

A. An automatic rejection of all data in every other state

B. A zero uncertainty because the feature is visible

C. The observation with limited quantitative comparability

D. A fully calibrated difference by association

Answer: C. Incomplete characterization limits the claim rather than erasing the observation. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: The observation with limited quantitative comparability.

Distinguishing consideration: compare this with option A, “An automatic rejection of all data in every other state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-MCQ-037. Why separate settled-state records from transition records?

A. Settled behavior proves all transitions harmless

B. Every observed burst is a steady-state signal

C. Relocking, impulses and recovery history can change the mechanism

D. Transitions are always invalid and should be deleted

Answer: C. A transition-only phenomenon may deserve its own dedicated comparison. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: Relocking, impulses and recovery history can change the mechanism.

Distinguishing consideration: compare this with option A, “Settled behavior proves all transitions harmless”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-MCQ-038. What should happen to transition data excluded from a settled analysis?

A. Assume they contain no useful mechanism information

B. Preserve them with the exclusion reason

C. Relabel them as settled if the final plot looks smooth

D. Erase them to simplify the record

Answer: B. Exclusion from one estimator should not destroy the evidence. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: Preserve them with the exclusion reason.

Distinguishing consideration: compare this with option A, “Assume they contain no useful mechanism information”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-MCQ-039. In the hypothetical clock/switch pattern, what should repeated returns to the original combination test?

A. Whether the response reproduces under that state

B. Whether every other configuration has zero physical power

C. Whether both factors are independent causes by definition

D. Whether the factor labels are unchanged

Answer: A. Fresh reversals strengthen the state-association record while retaining limits. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: Whether the response reproduces under that state.

Distinguishing consideration: compare this with option B, “Whether every other configuration has zero physical power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-040. What qualifies a conclusion that a line is absent in the other three states?

A. A proof that the source no longer exists

B. Universal absence at every possible level

C. The declared criterion and demonstrated observation limits

D. Absence in every untested frequency band

Answer: C. Nondetection is bounded by capability and exposure. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: The declared criterion and demonstrated observation limits.

Distinguishing consideration: compare this with option A, “A proof that the source no longer exists”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-041. A spur appears only with high gain and broadband admission. Which hypothesis is compatible?

A. Loading requiring admitted strong parents and sufficient downstream gain

B. A proved external transmitter unaffected by the receiver

C. A universal rule that high gain generates every spur

D. A proved defect in the input filter alone

Answer: A. Parent levels, source purity, mismatch and control behavior still require checks. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: Loading requiring admitted strong parents and sufficient downstream gain.

Distinguishing consideration: compare this with option B, “A proved external transmitter unaffected by the receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-042. Why not attribute that spur immediately to one nonlinear stage?

A. A four-state design cannot reveal any dependence

B. The receiver's gain setting has no physical effect

C. Sources, combiners, mismatch or gain-control changes can mimic the pattern

D. Nonlinear products never respond to preselection

Answer: C. The pattern is informative but not stage-unique. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: Sources, combiners, mismatch or gain-control changes can mimic the pattern.

Distinguishing consideration: compare this with option A, “A four-state design cannot reveal any dependence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-043. A stricter decoder rule removes field identifiers while valid reference records survive. What additional comparison is useful?

A. An independently acquired noise-only record processed under both rules

B. An assumption that stricter always means correct

C. Only the original field record re-plotted

D. A new identifier selected from the same training events

Answer: A. The crossed input/rule comparison tests false-lock behavior under that noise condition. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: An independently acquired noise-only record processed under both rules.

Distinguishing consideration: compare this with option B, “An assumption that stricter always means correct”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-044. If the stricter rule was chosen using the same suspicious events, what is needed for broader validation?

A. More overlapping windows from the same fitted events alone

B. A higher confidence label

C. A guarantee that all future events share the training distribution

D. An independently retained validation record

Answer: D. Fitted examples do not establish held-out performance. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: An independently retained validation record.

Distinguishing consideration: compare this with option A, “More overlapping windows from the same fitted events alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-045. What is genuine replication of a receiver intervention?

A. Fresh acquisitions revisiting the physical configuration

B. Replotting the same capture at another scale

C. Exporting the same spectrum twice

D. Dividing one record into overlapping windows only

Answer: A. Replication should revisit the experimental state and its variability.

Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: Fresh acquisitions revisiting the physical configuration.

Distinguishing consideration: compare this with option B, “Replotting the same capture at another scale”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-046. Why randomize run order when feasible?

A. To make every physical error disappear

B. To substitute for calibration

C. To establish Gaussian noise automatically

D. To reduce systematic association between setting and extraneous temporal changes

Answer: D. Order control addresses drift and confounding, not all validity conditions. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: To reduce systematic association between setting and extraneous temporal changes.

Distinguishing consideration: compare this with option A, “To make every physical error disappear”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-047. When relocking or access constrains run order, what should be done?

A. Discard all timing information

B. Assume the constraint creates independence

C. Document the restriction and corresponding limitation

D. Describe the order as randomized anyway

Answer: C. The actual design must remain visible. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: Document the restriction and corresponding limitation.

Distinguishing consideration: compare this with option A, “Discard all timing information”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-048. What is blocking in the chapter's design discussion?

A. A synonym for independent replication

B. Removing the nuisance condition from physical reality

C. Grouping comparisons under a declared nuisance condition

D. Preventing every unwanted RF signal

Answer: C. Within-group comparisons can control a condition while retaining group membership. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: Grouping comparisons under a declared nuisance condition.

Distinguishing consideration: compare this with option A, “A synonym for independent replication”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-049. All original-reference observations occur in session 1 and alternate-reference observations in session 2. What is confounded?

A. Reference state and session

B. Only the displayed frequency units

C. The two receivers' serial-number syntax

D. Every within-session measurement independently

Answer: A. More repetitions inside each session cannot supply missing crossed comparisons. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: Reference state and session.

Distinguishing consideration: compare this with option B, “Only the displayed frequency units”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-050. How can that session/reference ambiguity be resolved when feasible?

A. Acquire meaningful missing combinations across sessions or report the limit

B. Assign the full difference to reference state

C. Remove session labels from the dataset

D. Average each session more and assume the confound vanishes

Answer: A. The design needs the missing causal contrast. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: Acquire meaningful missing combinations across sessions or report the limit.

Distinguishing consideration: compare this with option B, “Assign the full difference to reference state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-051. What should a diagnostic release include besides state summaries?

A. Only the factor names

B. Planned combinations, actual order, physical states, references, exclusions and alternatives

C. Only the successful comparison chart

D. Only the final preferred mechanism

Answer: B. The record must show observed and missing comparisons. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: Planned combinations, actual order, physical states, references, exclusions and alternatives.

Distinguishing consideration: compare this with option A, “Only the factor names”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-052. Why can cross-domain agreement fail to be independent?

A. Different sensor types are always independent

B. Optical observations automatically validate RF source identity

C. Only RF sensors can share errors

D. Sensors may share power, clocks, cables, software or environmental causes

Answer: D. Common dependencies can preserve one cause across apparently different channels. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why the selected alternative fits: Sensors may share power, clocks, cables, software or environmental causes.

Distinguishing consideration: compare this with option A, “Different sensor types are always independent”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-MCQ-053. What makes a new modality particularly valuable?

A. It changes the relevant error structure while observing the needed question

B. It repeats the same decoder on identical samples

C. It shares every timing and coupling path

D. It has a different product label alone

Answer: A. Independent mechanisms of observation strengthen discrimination.

Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why the selected alternative fits: It changes the relevant error structure while observing the needed question.

Distinguishing consideration: compare this with option B, “It repeats the same decoder on identical samples”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-MCQ-054. Why reconcile time bases when combining receiver and physical-event records?

A. Equal displayed seconds guarantee simultaneity

B. A physical sensor has no timing uncertainty

C. Temporal agreement depends on clock relation and uncertainty

D. Any simultaneous-looking plot proves causation

Answer: C. State and time alignment are prerequisites for cross-domain inference.

Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why the selected alternative fits: Temporal agreement depends on clock relation and uncertainty.

Distinguishing consideration: compare this with option A, “Equal displayed seconds guarantee simultaneity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-MCQ-055. What limits indoor direction-finding or spatial-gradient interpretation?

A. A universal single-path assumption

B. Only the sample file's byte order

C. The impossibility of any spatial information

D. Multipath and antenna phase-center effects

Answer: D. Localization requires a model appropriate to the environment. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why the selected alternative fits: Multipath and antenna phase-center effects.

Distinguishing consideration: compare this with option A, “A universal single-path assumption”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-MCQ-056. What does an optical sensor observing LED activity establish directly?

A. The receiver's absence of clock artifacts

B. The authorization status of a transmitter

C. LED activity under its own timing and observation conditions

D. An independently confirmed RF emitter

Answer: C. It is distinct evidence whose relation to RF must be established. Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why the selected alternative fits: LED activity under its own timing and observation conditions.

Distinguishing consideration: compare this with option A, “The receiver's absence of clock artifacts”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-057. Which elements are needed beyond frequency and modulation for confirmed technical-surveillance function?

A. Physical or operational linkage, information path, authorization, reproducibility and continuity

B. Only two receivers seeing a line

C. Only a plausible decoded identifier

D. Only strong signal power

Answer: A. Functional attribution is a stronger claim than waveform classification.

Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

Why the selected alternative fits: Physical or operational linkage, information path, authorization, reproducibility and continuity.

Distinguishing consideration: compare this with option B, “Only two receivers seeing a line”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-MCQ-058. Why retain intermediate finding categories such as unexplained signal or installation defect?

A. They prove a surveillance function indirectly

B. They are interchangeable with unauthorized transmitter

C. They allow missing evidence to be ignored

D. They support proportionate conclusions without overstating attribution

Answer: D. The category should match the demonstrated claim. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

Why the selected alternative fits: They support proportionate conclusions without overstating attribution.

Distinguishing consideration: compare this with option A, “They prove a surveillance function indirectly”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-MCQ-059. What detail helps another examiner follow up an unresolved signal?

A. Only the peak level without reference plane

B. Only the preferred hypothesis name

C. Time, location, bandwidth, detector, antenna, state and remaining attribution limits

D. Only a dramatic screenshot

Answer: C. The observation must be reconstructable in its configuration. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

Why the selected alternative fits: Time, location, bandwidth, detector, antenna, state and remaining attribution limits.

Distinguishing consideration: compare this with option A, “Only the peak level without reference plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-MCQ-060. How should significant technical disagreement in review be handled?

A. Deletion of failed controls

B. A numerical confidence label chosen by seniority

C. Editorial consensus suppressing contrary evidence

D. Additional tests or disclosed limitations

Answer: D. Review should preserve the evidential issue. Source: §16.10 Program Governance and Peer Review (p. 9281)

Why the selected alternative fits: Additional tests or disclosed limitations.

Distinguishing consideration: compare this with option A, “Deletion of failed controls”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-MCQ-061. Which materials should independent reviewers receive?

A. Native data, configurations, calculations, calibration, challenges and alternatives

B. Only the final narrative

C. Only selected successful plots

D. Only the equipment purchase list

Answer: A. Substantive review requires the underlying argument and evidence.

Source: §16.10 Program Governance and Peer Review (p. 9281)

Why the selected alternative fits: Native data, configurations, calculations, calibration, challenges and alternatives.

Distinguishing consideration: compare this with option B, “Only the final narrative”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-MCQ-062. For normalized attenuation error, what planes should corrected levels share?

A. The same physical reference plane

B. Any planes with equal labels despite different paths

C. Planes chosen afterward to minimize discrepancy

D. One receiver output and one antenna input without correction

Answer: A. The difference must compare the same measurand. Source: §16.11 Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9282)

Why the selected alternative fits: The same physical reference plane.

Distinguishing consideration: compare this with option B, “Any planes with equal labels despite different paths”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-063. Which settings must be reconciled before a corrected-level comparison?

A. Gain, loss, bandwidth, detector and relevant state

B. Only file timestamp formatting

C. Only instrument manufacturer

D. Only displayed frequency

Answer: A. Differences in measurement definition can masquerade as physical change. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: Gain, loss, bandwidth, detector and relevant state.

Distinguishing consideration: compare this with option B, “Only file timestamp formatting”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-064. If a corrected difference lies within justified uncertainty, what follows?

A. Compatibility at that resolution

B. Proof of exact equality

C. Proof of a unique common mechanism

D. Proof of authorization

Answer: A. Compatibility is a bounded numerical finding. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: Compatibility at that resolution.

Distinguishing consideration: compare this with option B, “Proof of exact equality”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-065. If the corrected difference exceeds justified uncertainty, what follows first?

A. A discrepancy requiring investigation

B. A uniquely identified nonlinear stage

C. A guaranteed external transmitter

D. A proof that the uncertainty must be enlarged until agreement

Answer: A. Several state or mechanism changes can produce the discrepancy.

Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: A discrepancy requiring investigation.

Distinguishing consideration: compare this with option B, “A uniquely identified nonlinear stage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-066. What does a finite likelihood ratio require in addition to defined data models?

A. Independent labels rather than actual dependence

B. An expert adjective replacing a density

C. A zero null likelihood in every case

D. A positive denominator

Answer: D. Equation 32 is a ratio of specified probabilities or densities within its domain. Source: §16.11 Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9282)

Why the selected alternative fits: A positive denominator.

Distinguishing consideration: compare this with option A, “Independent labels rather than actual dependence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-067. Why must selection effects be included in a likelihood analysis?

A. The data-selection procedure affects the model for observed evidence

B. Selection never changes probability

C. Only the number of plots matters

D. A favorable test can always be treated as preplanned

Answer: A. Post-selection can alter the evidential interpretation. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: The data-selection procedure affects the model for observed evidence.

Distinguishing consideration: compare this with option B, “Selection never changes probability”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-068. A spectrum and EVM report derive from the same samples. What should be avoided?

A. Using both for complementary technical interpretation

B. Retaining their shared source identity

C. Counting them as independent evidence solely because outputs differ

D. Comparing their declared measurement conventions

Answer: C. Shared input can induce dependence even with different analyses.

Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: Counting them as independent evidence solely because outputs differ.

Distinguishing consideration: compare this with option A, “Using both for complementary technical interpretation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-069. Two software decoders use the same underlying implementation. What is the limitation of their agreement?

A. It establishes absolute source identity

B. It proves independent validation

C. It removes the need for reference records

D. It may repeat the same processing error

Answer: D. Independent labels do not imply independent mechanisms. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why the selected alternative fits: It may repeat the same processing error.

Distinguishing consideration: compare this with option A, “It establishes absolute source identity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-MCQ-070. What does a terminated-input negative control test directly?

A. Every field coupling state

B. Residual response in that terminated configuration

C. Every external source's absence

D. Every possible receiver gain state

Answer: B. Controls must be interpreted within their actual configuration. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: Residual response in that terminated configuration.

Distinguishing consideration: compare this with option A, “Every field coupling state”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-071. What does a noise-only decoder control test directly?

A. The origin of every field decode

B. The authorization of a signal

C. Detector behavior under that retained noise condition and processing rule

D. Universal false-alarm performance under all noise laws

Answer: C. Its scope is specific and should not be generalized without evidence.

Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: Detector behavior under that retained noise condition and processing rule.

Distinguishing consideration: compare this with option A, “The origin of every field decode”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-072. Why retain failed as well as passed controls?

A. Only passes affect validity

B. Failures can limit earlier conclusions and reveal state dependence

C. They can be replaced by an average confidence score

D. Failed controls become irrelevant after one successful repeat

Answer: B. The evidence record should preserve unfavorable outcomes. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why the selected alternative fits: Failures can limit earlier conclusions and reveal state dependence.

Distinguishing consideration: compare this with option A, “Only passes affect validity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-MCQ-073. What should a technical finding explicitly distinguish?

A. Detection, classification, correlation, localization and device linkage

B. Only old versus new instruments

C. All inference categories as equivalent

D. Only strong versus weak display levels

Answer: A. Each claim requires different evidence. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why the selected alternative fits: Detection, classification, correlation, localization and device linkage.

Distinguishing consideration: compare this with option B, “Only old versus new instruments”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-MCQ-074. Why put units, bandwidth, normalization, planes and uncertainty beside derived values?

A. To prove the chosen mechanism

B. To replace native samples

C. To preserve their meaning outside the original instrument session

D. To make all values directly comparable without further checks

Answer: C. A bare number loses its measurement definition. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why the selected alternative fits: To preserve their meaning outside the original instrument session.

Distinguishing consideration: compare this with option A, “To prove the chosen mechanism”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-MCQ-075. What makes a follow-up test more informative than repeating unchanged settings?

A. It necessarily raises the signal level

B. It produces more visually attractive data

C. It avoids recording calibration

D. It discriminates remaining mechanisms by changing a relevant path or state

Answer: D. Repeatability and causal discrimination are different objectives. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why the selected alternative fits: It discriminates remaining mechanisms by changing a relevant path or state.

Distinguishing consideration: compare this with option A, "It necessarily raises the signal level"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-MCQ-076. When a proposed discriminating test is not performed, what should be recorded?

A. An assumed favorable outcome

B. Why it was omitted and how that limits the conclusion

C. A declaration that the omission is irrelevant

D. Only tests that were convenient

Answer: B. Missing evidence should remain visible. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why the selected alternative fits: Why it was omitted and how that limits the conclusion.

Distinguishing consideration: compare this with option A, “An assumed favorable outcome”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-MCQ-077. What belongs in a reusable established-artifact record?

A. A universal condemnation of the instrument class

B. Exhibiting configurations, stimulus/state, predicted and observed response, challenge and mitigation

C. Only a source attribution label

D. Only the final corrected spectrum

Answer: B. The record should let another examiner reproduce and test applicability.

Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why the selected alternative fits: Exhibiting configurations, stimulus/state, predicted and observed response, challenge and mitigation.

Distinguishing consideration: compare this with option A, “A universal condemnation of the instrument class”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-MCQ-078. Why not turn one artifact incident into a universal receiver rule?

A. No receiver model can be useful

B. Every future instrument has identical coupling

C. The mechanism was established only within tested conditions

D. Artifacts never repeat

Answer: C. A narrow controlled result should retain its domain. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why the selected alternative fits: The mechanism was established only within tested conditions.

Distinguishing consideration: compare this with option A, “No receiver model can be useful”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-MCQ-079. Which change can warrant acceptance or regression testing?

A. Only purchasing a new receiver

B. Only changing the room's report name

C. Repair, firmware, accessory, calibration or major software change

D. Only replacing the antenna manufacturer logo

Answer: C. Changes can affect several measurement functions. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

Why the selected alternative fits: Repair, firmware, accessory, calibration or major software change.

Distinguishing consideration: compare this with option A, “Only purchasing a new receiver”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

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V011-C16-MCQ-080. Why is a center-frequency calibration tone insufficient for full-chain acceptance?

A. It proves all modulation performance automatically

B. It leaves many noise, dynamic-range, image, timing, trigger and continuity functions untested

C. It replaces the need for sample metadata

D. It cannot verify any frequency or amplitude behavior

Answer: B. Acceptance must cover the deployed method's actual functions. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

Why the selected alternative fits: It leaves many noise, dynamic-range, image, timing, trigger and continuity functions untested.

Distinguishing consideration: compare this with option A, “It proves all modulation performance automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

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V011-C16-MCQ-081. What is the purpose of stable-reference regression captures?

A. Identify all unauthorized devices automatically

B. Reveal drift or changed method behavior against known prior capability

C. Replace every independent calibration

D. Prove every environmental signal is stationary

Answer: B. They maintain configuration-specific evidence over time. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

Why the selected alternative fits: Reveal drift or changed method behavior against known prior capability.

Distinguishing consideration: compare this with option A, "Identify all unauthorized devices automatically"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

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V011-C16-MCQ-082. How should retired formats or software be handled when needed for evidence?

A. Assume all future exports are numerically identical

B. Preserve or migrate them with checks

C. Keep only screenshots of the user interface

D. Discard native data once software is old

Answer: B. Reproducibility can depend on retained processing and representation.

Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

Why the selected alternative fits: Preserve or migrate them with checks.

Distinguishing consideration: compare this with option A, “Assume all future exports are numerically identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

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V011-C16-MCQ-083. What should happen before a new method enters routine use?

A. Validation within its intended scope

B. Assuming any published example certifies the installed method

C. Skipping references when initial plots look plausible

D. Only renaming an existing script

Answer: A. Governance maintains tested capabilities and limits. Source: §16.10 Program Governance and Peer Review (p. 9281)

Why the selected alternative fits: Validation within its intended scope.

Distinguishing consideration: compare this with option B, “Assuming any published example certifies the installed method”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-MCQ-084. Why record errors and reversals in program history?

A. To erase earlier conclusions without trace

B. To make one incident universal doctrine

C. To avoid future independent review

D. To improve controlled procedures while preserving what changed

Answer: D. Learning requires a visible evidential history. Source: §16.10 Program Governance and Peer Review (p. 9281)

Why the selected alternative fits: To improve controlled procedures while preserving what changed.

Distinguishing consideration: compare this with option A, “To erase earlier conclusions without trace”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-MCQ-085. For raw levels −83.0 and −93.2 dBm with 10.0 dB added attenuation on the second, what is corrected second level?

A. −93.2 dBm

B. −73.2 dBm

C. −83.2 dBm

D. −103.2 dBm

Answer: C. Refer the second reading upstream by adding the attenuation. Source: §16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9284)

Why the selected alternative fits: −83.2 dBm.

Distinguishing consideration: compare this with option A, "−93.2 dBm"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-086. For corrected levels P1,corr=−83.0 dBm and P2,corr=−83.2 dBm, what is signed eA=P2,corr−P1,corr?

A. +10.0 dB

B. +0.2 dB

C. −10.2 dB

D. −0.2 dB

Answer: D. −83.2−(−83.0)=−0.2 dB. Source: §16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9284)

Why the selected alternative fits: −0.2 dB.

Distinguishing consideration: compare this with option A, “+10.0 dB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-087. For corrected levels −83.0 and −83.2 dBm with 0.7 dB combined comparison uncertainty, what interpretation is supported?

A. The 0.2 dB magnitude is compatible with corrected scaling at that resolution

B. Both corrected levels are exactly equal

C. The source is uniquely external and unauthorized

D. The receiver is proved artifact-free at every state

Answer: A. The test does not establish source or authorization. Source: §16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9284)

Why the selected alternative fits: The 0.2 dB magnitude is compatible with corrected scaling at that resolution.

Distinguishing consideration: compare this with option B, “Both corrected levels are exactly equal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-088. In the keyboard/clock/switch case, why is removing the line after a joint intervention incomplete attribution evidence?

A. The disappearance proves both components independently emit

B. Two conditions changed and capability plus separate effects remain to be checked

C. LED activity proves the removed RF line's source

D. A joint change is never informative at all

Answer: B. Separate reference/switch challenges, reversals and suitable-reference checks are needed. Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why the selected alternative fits: Two conditions changed and capability plus separate effects remain to be checked.

Distinguishing consideration: compare this with option A, “The disappearance proves both components independently emit”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-089. What does the release gate require when a result disappears under a challenge?

A. Delete the original trace

B. Assign a universal artifact category without capability checks

C. Resolve the mechanism sufficiently for the proposed attribution while preserving data and alternatives

D. Declare the original observation false automatically

Answer: C. Disappearance can reflect sensitivity or route changes. Source: §16.14 Challenge-Test and Evidence Release Gate (p. 9286)

Why the selected alternative fits: Resolve the mechanism sufficiently for the proposed attribution while preserving data and alternatives.

Distinguishing consideration: compare this with option A, “Delete the original trace”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Challenge-Test and Evidence Release Gate.

Review: Chapter 16 — Challenge-Test and Evidence Release Gate.

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V011-C16-MCQ-090. How should old and changed configurations be treated during regression?

A. As interchangeable once the new software launches

B. As identical if the hardware serial is unchanged

C. As one averaged state to reduce paperwork

D. As distinct states until relevant comparisons are complete

Answer: D. The accepted domain must be established for the new configuration.

Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why the selected alternative fits: As distinct states until relevant comparisons are complete.

Distinguishing consideration: compare this with option A, “As interchangeable once the new software launches”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-MCQ-091. A new processing correction changes reported results from retained samples. What should be preserved?

A. A modified native file made to match the new conclusion

B. Both derived versions with processing identities and an explanation of the difference

C. Only the correction's filename

D. Only the new output, with old labels reused

Answer: B. The underlying observation and revised derivation must remain distinguishable. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why the selected alternative fits: Both derived versions with processing identities and an explanation of the difference.

Distinguishing consideration: compare this with option A, “A modified native file made to match the new conclusion”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-MCQ-092. Which regression tests should be selected after a method change?

A. Only the easiest startup check

B. Those exercising functions actually used by the deployed method

C. Only tests that passed previously without recording conditions

D. Every possible unrelated instrument function regardless of use

Answer: B. Configuration-specific validation follows the relevant measurement chain. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why the selected alternative fits: Those exercising functions actually used by the deployed method.

Distinguishing consideration: compare this with option A, “Only the easiest startup check”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-MCQ-093. What should final release do with unresolved sample discontinuity or event-coverage limits?

A. Assume repeated use has established validity

B. Replace them with a generic confidence percentage

C. Keep them visible and narrow the accepted claim where needed

D. Hide them if the main plot is persuasive

Answer: C. A useful bounded method can remain valid in a narrower domain.

Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why the selected alternative fits: Keep them visible and narrow the accepted claim where needed.

Distinguishing consideration: compare this with option A, “Assume repeated use has established validity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-MCQ-094. Why is a common clock a possible dependency across two receiver channels?

A. It can contribute a shared spur or timing error

B. It makes every RF line externally generated

C. It guarantees all channel errors are independent

D. It eliminates reference-path coupling

Answer: A. Multiple channels can retain one instrumental cause. Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why the selected alternative fits: It can contribute a shared spur or timing error.

Distinguishing consideration: compare this with option B, “It makes every RF line externally generated”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-MCQ-095. Why retain parent-source and combiner purity during a nonlinear-product challenge?

A. They can generate the same product attributed to the receiver

B. They cannot create intermodulation

C. Only the receiver can produce products at combination frequencies

D. Their effects vanish after gain correction

Answer: A. A valid stage attribution must exclude or bound upstream contamination. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: They can generate the same product attributed to the receiver.

Distinguishing consideration: compare this with option B, “They cannot create intermodulation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-096. Why might a filter insertion change a spur without proving parent rejection as the cause?

A. A disappearing spur is always below zero physical power

B. Filters never affect transfer

C. A filter is transparent to every admitted waveform

D. It can also change mismatch or the gain-control trajectory

Answer: D. The intervention can bundle several physical changes. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why the selected alternative fits: It can also change mismatch or the gain-control trajectory.

Distinguishing consideration: compare this with option A, “A disappearing spur is always below zero physical power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-MCQ-097. What is the strongest general role of the chapter's model families in diagnosis?

A. Replace reference tests with formulas alone

B. Assign automatic numerical odds to every finding category

C. Guarantee one signature maps to one cause

D. Provide conditional predictions and validity limits for specific mechanisms

Answer: D. Models guide discriminating tests when their premises are supported.

Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why the selected alternative fits: Provide conditional predictions and validity limits for specific mechanisms.

Distinguishing consideration: compare this with option A, “Replace reference tests with formulas alone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-MCQ-098. What should be compared if a challenge changes only a display-threshold label but no underlying samples?

A. Count the two views as two independent controls

B. Treat the new display as an independent acquisition

C. Claim the feature physically vanished

D. The same raw response and processing criterion, recognizing no new physical replication

Answer: D. Display changes can reveal presentation dependence but do not repeat the intervention. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: The same raw response and processing criterion, recognizing no new physical replication.

Distinguishing consideration: compare this with option A, “Count the two views as two independent controls”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-099. Why preserve the actual run order in a diagnostic release?

A. It makes state-specific corrections unnecessary

B. It determines source authorization by itself

C. It proves randomization even when none occurred

D. It exposes associations with drift, source intervals and recovery history

Answer: D. Temporal confounding and transitions depend on sequence. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why the selected alternative fits: It exposes associations with drift, source intervals and recovery history.

Distinguishing consideration: compare this with option A, “It makes state-specific corrections unnecessary”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-MCQ-100. What should a conclusion say when configurations lack comparable sensitivity?

A. That all observed signals are artifacts

B. That the available comparison is insufficient for the proposed nondetection inference

C. That the less sensitive state's silence proves absence

D. That quantitative differences can be ignored

Answer: B. Capability limits constrain the meaning of agreement or disappearance.

Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why the selected alternative fits: That the available comparison is insufficient for the proposed nondetection inference.

Distinguishing consideration: compare this with option A, “That all observed signals are artifacts”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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Fill-in-the-Blank Questions

V011-C16-FIB-001. An initial component without resolved mechanism is classified as _____.

Answer: unexplained. Artifact and environmental alternatives remain to be challenged. Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)
Why this term is required: “unexplained” completes the stated technical proposition.
Question context: An initial component without resolved mechanism is classified as _____
Basis and qualification: Chapter 16 — Artifact Taxonomy and Competing Explanations.
Review: Chapter 16 — Artifact Taxonomy and Competing Explanations.

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V011-C16-FIB-002. Artifact analysis begins by locating mechanisms in the receiver _____.

Answer: architecture. Control placement determines possible differential responses. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “architecture” completes the stated technical proposition.

Question context: Artifact analysis begins by locating mechanisms in the receiver _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-003. A discriminating challenge writes competing _____ before changing the setup.

Answer: predictions. The test should be designed to distinguish mechanisms rather than interpreted only afterward. Source: §16.2 Challenge-Test Design (p. 9258)

Why this term is required: “predictions” completes the stated technical proposition.

Question context: A discriminating challenge writes competing _____ before changing the setup

Basis and qualification: Chapter 16 — Challenge-Test Design.

Review: Chapter 16 — Challenge-Test Design.

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V011-C16-FIB-004. The relevant desired transfer and observation _____ must remain established during comparison.

Answer: capability. A disappearance can otherwise reflect reduced sensitivity.

Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “capability” completes the stated technical proposition.

Question context: The relevant desired transfer and observation _____ must remain established during comparison

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-005. Input attenuation affects a product differently depending on whether generation occurs before or _____ it.

Answer: after. The physical stage relationship matters. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “after” completes the stated technical proposition.

Question context: Input attenuation affects a product differently depending on whether generation occurs before or _____ it

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-006. A sampled alias should follow the actual sample-rate and frequency _____.

Answer: mapping. A controlled rate change tests that conditional prediction. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “mapping” completes the stated technical proposition.

Question context: A sampled alias should follow the actual sample-rate and frequency _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-007. Conversion images should be compared with signed translation and image-selective _____.

Answer: preselection. These controls address the predicted conversion path. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “preselection” completes the stated technical proposition.

Question context: Conversion images should be compared with signed translation and image-selective _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-008. A control transient can depend on preceding state and transition _____.

Answer: timing. Steady-state tests do not cover every recovery trajectory. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “timing” completes the stated technical proposition.

Question context: A control transient can depend on preceding state and transition _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-009. Substituted receivers can retain a common cause through shared clocks, power, software or _____.

Answer: antennas. Different hardware labels do not guarantee independent error structure. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “antennas” completes the stated technical proposition.

Question context: Substituted receivers can retain a common cause through shared clocks, power, software or _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-010. A suitable known reference helps interpret a second receiver's _____.

Answer: nondetection. The path must be capable of revealing the feature under comparison. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “nondetection” completes the stated technical proposition.

Question context: A suitable known reference helps interpret a second receiver's _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-011. An input termination can change source impedance as well as remove the antenna _____.

Answer: path. Its effect is not uniquely an external-source test. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “path” completes the stated technical proposition.

Question context: An input termination can change source impedance as well as remove the antenna _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-012. A plausible decoded identifier can be stale, repeated or a false _____.

Answer: lock. Decoding alone does not establish physical attribution. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

Why this term is required: “lock” completes the stated technical proposition.

Question context: A plausible decoded identifier can be stale, repeated or a false _____

Basis and qualification: Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-C16-FIB-013. The effect of one control depending on another's setting is an _____.

Answer: interaction. Crossed combinations expose conditional effects. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why this term is required: “interaction” completes the stated technical proposition.

Question context: The effect of one control depending on another's setting is an _____

Basis and qualification: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-FIB-014. Factors should be defined by physical changes rather than front-panel _____.

Answer: labels. One menu operation can alter several relevant properties. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why this term is required: “labels” completes the stated technical proposition.

Question context: Factors should be defined by physical changes rather than front-panel _____

Basis and qualification: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-FIB-015. An external reference selection may change frequency calibration and common-mode _____.

Answer: coupling. Connections and timing behavior can change too. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why this term is required: “coupling” completes the stated technical proposition.

Question context: An external reference selection may change frequency calibration and common-mode _____

Basis and qualification: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-FIB-016. Switch bypass can change insertion loss, impedance, signal route and control _____.

Answer: transients. It is not automatically a transparent single-property intervention. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

Why this term is required: “transients” completes the stated technical proposition.

Question context: Switch bypass can change insertion loss, impedance, signal route and control _____

Basis and qualification: Chapter 16 — Receiver challenges with interacting controls.

Review: Chapter 16 — Receiver challenges with interacting controls.

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V011-C16-FIB-017. Two factors with two states each yield _____ combinations in a complete crossed design.

Answer: four. Every state of each factor is paired with both states of the other.

Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “four” completes the stated technical proposition.

Question context: Two factors with two states each yield _____ combinations in a complete crossed design

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-018. Switch states should be compared within each reference _____ to expose conditional effects.

Answer: state. Pooling without labels can conceal interaction. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “state” completes the stated technical proposition.

Question context: Switch states should be compared within each reference _____ to expose conditional effects

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-019. Unavailable state combinations must be recorded as _____ comparisons.

Answer: missing. The remaining observations cannot silently supply them. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “missing” completes the stated technical proposition.

Question context: Unavailable state combinations must be recorded as _____ comparisons

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-020. The response should be defined at a physical reference _____ before acquisition.

Answer: plane. Corrections and uncertainty then refer to a consistent quantity.

Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “plane” completes the stated technical proposition.

Question context: The response should be defined at a physical reference _____ before acquisition

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-021. Binary visibility can conceal an ordinary change in _____.

Answer: sensitivity. A feature may cross threshold while its physical source persists.

Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “sensitivity” completes the stated technical proposition.

Question context: Binary visibility can conceal an ordinary change in _____

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-022. Linear power, logarithmic level and threshold crossing are different response _____.

Answer: definitions. Their differences do not answer identical questions. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “definitions” completes the stated technical proposition.

Question context: Linear power, logarithmic level and threshold crossing are different response _____

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-023. An observed interaction narrows the problem but does not locate the responsible _____.

Answer: circuit. Several physical dependencies may explain the same pattern.

Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “circuit” completes the stated technical proposition.

Question context: An observed interaction narrows the problem but does not locate the responsible _____

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-024. A third uncontrolled condition that tracks factor settings can create _____.

Answer: confounding. State association alone need not isolate the proposed mechanism. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

Why this term is required: “confounding” completes the stated technical proposition.

Question context: A third uncontrolled condition that tracks factor settings can create _____

Basis and qualification: Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-FIB-025. A check reference should exercise the actual _____ being compared.

Answer: function. A CW tone does not test every burst or wideband capability.

Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why this term is required: “function” completes the stated technical proposition.

Question context: A check reference should exercise the actual _____ being compared

Basis and qualification: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-FIB-026. A comfortable strong reference does not establish behavior near the observation _____.

Answer: limit. Weak-signal capability needs an appropriate test. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why this term is required: “limit” completes the stated technical proposition.

Question context: A comfortable strong reference does not establish behavior near the observation _____

Basis and qualification: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-FIB-027. Comparisons must preserve the same reference plane or correct added _____.

Answer: paths. A bypass cable or new filter is not automatically transparent. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why this term is required: “paths” completes the stated technical proposition.

Question context: Comparisons must preserve the same reference plane or correct added _____

Basis and qualification: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-FIB-028. Shared correction uncertainties should be retained through their _____.

Answer: covariance. Separate states can share calibration influences. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why this term is required: “covariance” completes the stated technical proposition.

Question context: Shared correction uncertainties should be retained through their _____

Basis and qualification: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-FIB-029. A state lacking characterization may support an observation but not the same _____ comparison.

Answer: quantitative. The numerical correction and uncertainty scope are incomplete. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why this term is required: “quantitative” completes the stated technical proposition.

Question context: A state lacking characterization may support an observation but not the same _____ comparison

Basis and qualification: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-FIB-030. Transition records should be separated from _____-state records.

Answer: settled. Relocking, switching impulses and recovery can create different behavior. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why this term is required: “settled” completes the stated technical proposition.

Question context: Transition records should be separated from _____-state records

Basis and qualification: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-FIB-031. Removing a transition from one estimator must not erase it from the evidence _____.

Answer: record. The exclusion needs a reason and retained source. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

Why this term is required: “record” completes the stated technical proposition.

Question context: Removing a transition from one estimator must not erase it from the evidence _____

Basis and qualification: Chapter 16 — Preserve comparable observation capability.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-FIB-032. In the clock/switch example, the line appears only with the original reference and switch in _____.

Answer: circuit. That joint configuration is associated with the response. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “circuit” completes the stated technical proposition.

Question context: In the clock/switch example, the line appears only with the original reference and switch in _____

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-033. That pattern does not prove that both named components _____ generate the line.

Answer: independently. A shared path or other conditional mechanism can produce it. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “independently” completes the stated technical proposition.

Question context: That pattern does not prove that both named components _____ generate the line

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-034. Absence in other states remains bounded by demonstrated observation _____.

Answer: limits. Nondetection is not universal zero physical power. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “limits” completes the stated technical proposition.

Question context: Absence in other states remains bounded by demonstrated observation _____

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-035. Repeated returns to the original state test _____ of the response.

Answer: reproducibility. Fresh acquisitions can expose unstable state association.

Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “reproducibility” completes the stated technical proposition.

Question context: Repeated returns to the original state test _____ of the response

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-036. The high-gain broadband spur pattern is compatible with sufficient gain and strong admitted _____.

Answer: parents. Loading hypotheses require actual parent-level evidence. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “parents” completes the stated technical proposition.

Question context: The high-gain broadband spur pattern is compatible with sufficient gain and strong admitted _____

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-037. Sources and combiners can themselves generate the tested nonlinear _____.

Answer: product. Their purity matters to stage attribution. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “product” completes the stated technical proposition.

Question context: Sources and combiners can themselves generate the tested nonlinear _____

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-038. A preselection filter can change mismatch and gain-control _____ as well as parent admission.

Answer: trajectory. The intervention can have several physical effects. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “trajectory” completes the stated technical proposition.

Question context: A preselection filter can change mismatch and gain-control _____ as well as parent admission

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-039. The decoder-rule comparison should include an independently acquired _____-only record.

Answer: noise. It tests false-looking outputs under a defined noise condition.

Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “noise” completes the stated technical proposition.

Question context: The decoder-rule comparison should include an independently acquired _____-only record

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-040. A rule selected using the same suspicious events needs an independent _____ record for broader claims.

Answer: validation. Fitted data cannot establish held-out performance. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

Why this term is required: “validation” completes the stated technical proposition.

Question context: A rule selected using the same suspicious events needs an independent _____ record for broader claims

Basis and qualification: Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-FIB-041. Fresh acquisitions revisiting a configuration constitute experimental _____.

Answer: replication. Replotting the same record does not repeat the intervention.

Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why this term is required: “replication” completes the stated technical proposition.

Question context: Fresh acquisitions revisiting a configuration constitute experimental _____

Basis and qualification: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-FIB-042. Randomizing run order reduces association with extraneous temporal _____.

Answer: changes. It addresses order confounding, not every model error. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why this term is required: “changes” completes the stated technical proposition.

Question context: Randomizing run order reduces association with extraneous temporal _____

Basis and qualification: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-FIB-043. When physical constraints restrict run order, preserve the restriction and its _____.

Answer: limitation. The actual sequence cannot be represented as randomized.

Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why this term is required: “limitation” completes the stated technical proposition.

Question context: When physical constraints restrict run order, preserve the restriction and its _____

Basis and qualification: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-FIB-044. Grouping under a declared nuisance condition is called _____.

Answer: blocking. The condition remains present and group membership matters.

Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why this term is required: “blocking” completes the stated technical proposition.

Question context: Grouping under a declared nuisance condition is called _____

Basis and qualification: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-FIB-045. If reference state changes only between sessions, state and session are _____.

Answer: confounded. Within-session repetition does not supply the missing cross-comparison. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
Why this term is required: “confounded” completes the stated technical proposition.
Question context: If reference state changes only between sessions, state and session are _____
Basis and qualification: Chapter 16 — Record repetition and the limits of the design.
Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-FIB-046. More repetitions inside those sessions cannot repair the missing _____-session comparison.

Answer: cross. The needed state combinations were not observed. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why this term is required: “cross” completes the stated technical proposition.

Question context: More repetitions inside those sessions cannot repair the missing _____-session comparison

Basis and qualification: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-FIB-047. A diagnostic release retains planned combinations and actual run _____.

Answer: order. Temporal history affects interpretation. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why this term is required: “order” completes the stated technical proposition.

Question context: A diagnostic release retains planned combinations and actual run _____

Basis and qualification: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-FIB-048. Cross-domain agreement is not automatically statistical _____.

Answer: independence. Sensors can share clocks, power, cables or processing.

Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why this term is required: “independence” completes the stated technical proposition.

Question context: Cross-domain agreement is not automatically statistical _____

Basis and qualification: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-FIB-049. Evidence that changes the relevant error _____ can provide stronger confirmation.

Answer: structure. Different labels alone may repeat the same cause. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why this term is required: “structure” completes the stated technical proposition.

Question context: Evidence that changes the relevant error _____ can provide stronger confirmation

Basis and qualification: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-FIB-050. Spatial localization indoors must consider _____.

Answer: multipath. Reflections and phase centers can alter directional interpretation. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why this term is required: “multipath” completes the stated technical proposition.

Question context: Spatial localization indoors must consider _____

Basis and qualification: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-FIB-051. Cross-domain observations require reconciled time bases and configuration _____.

Answer: states. Apparent temporal agreement needs a valid comparison. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why this term is required: “states” completes the stated technical proposition.

Question context: Cross-domain observations require reconciled time bases and configuration _____

Basis and qualification: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-FIB-052. An optical record of an LED directly establishes LED _____, not RF source identity.

Answer: activity. The RF linkage requires additional evidence. Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why this term is required: “activity” completes the stated technical proposition.

Question context: An optical record of an LED directly establishes LED _____, not RF source identity

Basis and qualification: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-053. Confirmed function requires physical or operational linkage and an information _____.

Answer: path. Frequency and modulation alone do not establish function. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

Why this term is required: “path” completes the stated technical proposition.

Question context: Confirmed function requires physical or operational linkage and an information _____

Basis and qualification: Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-FIB-054. Authorization status is distinct from waveform _____.

Answer: classification. Recognizable modulation does not establish permitted use.

Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

Why this term is required: “classification” completes the stated technical proposition.

Question context: Authorization status is distinct from waveform _____

Basis and qualification: Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-FIB-055. Intermediate finding categories permit proportionate action without overstating _____.

Answer: certainty. The category should match evidence strength. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

Why this term is required: “certainty” completes the stated technical proposition.

Question context: Intermediate finding categories permit proportionate action without overstating _____

Basis and qualification: Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-FIB-056. An unresolved finding should retain the reason evidence did not support _____.

Answer: attribution. This guides useful follow-up. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

Why this term is required: “attribution” completes the stated technical proposition.

Question context: An unresolved finding should retain the reason evidence did not support _____

Basis and qualification: Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-FIB-057. Every significant figure should link to native data and its _____.

Answer: configuration. A display alone does not convey the full measurement state.

Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why this term is required: “configuration” completes the stated technical proposition.

Question context: Every significant figure should link to native data and its _____

Basis and qualification: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-FIB-058. Normalized attenuation error compares corrected levels at the same reference _____.

Answer: plane. The two readings must represent the same quantity. Source: §16.11 Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9282)

Why this term is required: “plane” completes the stated technical proposition.

Question context: Normalized attenuation error compares corrected levels at the same reference _____

Basis and qualification: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-059. Before comparing corrected levels, reconcile gain, loss, bandwidth and _____.

Answer: detector. State and processing changes can alter the measurement definition. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “detector” completes the stated technical proposition.

Question context: Before comparing corrected levels, reconcile gain, loss, bandwidth and _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-060. Compatibility within uncertainty does not prove a unique _____.

Answer: mechanism. Several causes may produce consistent scaling. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “mechanism” completes the stated technical proposition.

Question context: Compatibility within uncertainty does not prove a unique _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-061. A difference beyond justified uncertainty identifies a _____ to investigate.

Answer: discrepancy. It does not automatically name its cause. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “discrepancy” completes the stated technical proposition.

Question context: A difference beyond justified uncertainty identifies a _____ to investigate

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-062. The likelihood ratio is p(D given H1) divided by _____.

Answer: p(D given H0). Both hypotheses and their data models must be defined.

Source: §16.11 Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9282)

Why this term is required: "p(D given H0)" completes the stated technical proposition.

Question context: The likelihood ratio is p(D given H1) divided by _____

Basis and qualification: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-063. A finite ratio in Equation 32 requires a positive _____.

Answer: denominator. The stated mathematical domain excludes division by zero.

Source: §16.11 Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9282)

Why this term is required: “denominator” completes the stated technical proposition.

Question context: A finite ratio in Equation 32 requires a positive _____

Basis and qualification: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Quantitative Model for Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-064. Valid likelihood models must account for data _____ effects.

Answer: selection. Post-selection changes the observed evidence model. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “selection” completes the stated technical proposition.

Question context: Valid likelihood models must account for data _____ effects

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-065. A count of favorable tests does not supply numerical _____.

Answer: likelihoods. Dependence and model validity cannot be replaced by a tally.

Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “likelihoods” completes the stated technical proposition.

Question context: A count of favorable tests does not supply numerical _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-066. A spectrum and EVM report from the same samples have a shared data _____.

Answer: source. Different output labels do not establish independence. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “source” completes the stated technical proposition.

Question context: A spectrum and EVM report from the same samples have a shared data _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-067. Two tools using the same decoder share a processing _____.

Answer: dependency. Their agreement can repeat the same implementation error.

Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

Why this term is required: “dependency” completes the stated technical proposition.

Question context: Two tools using the same decoder share a processing _____

Basis and qualification: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-C16-FIB-068. A terminated-input control tests residual responses in that _____.

Answer: configuration. It does not cover every installed field state. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “configuration” completes the stated technical proposition.

Question context: A terminated-input control tests residual responses in that _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-069. A known reference tests sensitivity and scale at its chosen frequency and _____.

Answer: level. The control's scope must match the intended comparison. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “level” completes the stated technical proposition.

Question context: A known reference tests sensitivity and scale at its chosen frequency and _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-070. A noise-only record tests the detector under that noise _____.

Answer: condition. It does not automatically establish universal false-alarm behavior. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “condition” completes the stated technical proposition.

Question context: A noise-only record tests the detector under that noise _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-071. Control failures must be preserved alongside _____.

Answer: passes. A failed closing check can limit earlier conclusions. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

Why this term is required: “passes” completes the stated technical proposition.

Question context: Control failures must be preserved alongside _____

Basis and qualification: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-FIB-072. A report should distinguish detection from classification, localization and device _____.

Answer: linkage. These are progressively different evidential claims. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why this term is required: “linkage” completes the stated technical proposition.

Question context: A report should distinguish detection from classification, localization and device _____

Basis and qualification: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-FIB-073. Derived values retain units, bandwidth, normalization and _____.

Answer: uncertainty. They must remain interpretable outside the original session.

Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why this term is required: “uncertainty” completes the stated technical proposition.

Question context: Derived values retain units, bandwidth, normalization and _____

Basis and qualification: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-FIB-074. A follow-up should discriminate remaining explanations rather than merely improve _____.

Answer: repeatability. Repeating unchanged settings may not test a different cause.

Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why this term is required: “repeatability” completes the stated technical proposition.

Question context: A follow-up should discriminate remaining explanations rather than merely improve _____

Basis and qualification: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-FIB-075. If a proposed test is omitted, record why and its effect on the _____.

Answer: conclusion. Missing evidence limits the supported inference. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why this term is required: “conclusion” completes the stated technical proposition.

Question context: If a proposed test is omitted, record why and its effect on the _____

Basis and qualification: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-FIB-076. A reusable artifact record includes the accepted _____.

Answer: mitigation. It should also identify conditions, stimulus, predicted and observed response and challenge. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why this term is required: “mitigation” completes the stated technical proposition.

Question context: A reusable artifact record includes the accepted _____

Basis and qualification: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-FIB-077. A narrow established incident should not become an unsupported universal _____.

Answer: rule. Its tested domain must be preserved. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

Why this term is required: “rule” completes the stated technical proposition.

Question context: A narrow established incident should not become an unsupported universal _____

Basis and qualification: Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-FIB-078. Acceptance may need renewal after repair, firmware, accessory or software _____.

Answer: change. Several functions may be affected at once. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

Why this term is required: “change” completes the stated technical proposition.

Question context: Acceptance may need renewal after repair, firmware, accessory or software _____

Basis and qualification: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

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V011-C16-FIB-079. A startup self-test does not replace configuration-specific _____.

Answer: regression. The deployed method can use functions outside the self-test scope. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why this term is required: “regression” completes the stated technical proposition.

Question context: A startup self-test does not replace configuration-specific _____

Basis and qualification: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-FIB-080. Stable-reference regression captures can reveal _____.

Answer: drift. Comparison with accepted behavior maintains the method over time.

Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

Why this term is required: “drift” completes the stated technical proposition.

Question context: Stable-reference regression captures can reveal _____

Basis and qualification: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

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V011-C16-FIB-081. Retired formats needed for evidence should be preserved or migrated with _____.

Answer: checks. Representation and processing identity must remain recoverable.

Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

Why this term is required: “checks” completes the stated technical proposition.

Question context: Retired formats needed for evidence should be preserved or migrated with _____

Basis and qualification: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

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V011-C16-FIB-082. New methods require _____ before routine use.

Answer: validation. Their intended scope and limits must be established. Source: §16.10 Program Governance and Peer Review (p. 9281)

Why this term is required: “validation” completes the stated technical proposition.

Question context: New methods require _____ before routine use

Basis and qualification: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-FIB-083. Independent reviewers need native records and competing _____, not only the final narrative.

Answer: explanations. The underlying evidence and alternatives permit substantive review. Source: §16.10 Program Governance and Peer Review (p. 9281)

Why this term is required: “explanations” completes the stated technical proposition.

Question context: Independent reviewers need native records and competing _____, not only the final narrative

Basis and qualification: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-FIB-084. Technical disagreement should be resolved through tests or disclosed _____.

Answer: limitations. Editorial consensus should not erase unresolved evidence.

Source: §16.10 Program Governance and Peer Review (p. 9281)

Why this term is required: “limitations” completes the stated technical proposition.

Question context: Technical disagreement should be resolved through tests or disclosed _____

Basis and qualification: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-FIB-085. Governance records errors and

_____.

Answer: reversals. A transparent correction history supports improvement. Source:

§16.10 Program Governance and Peer Review (p. 9281)

Why this term is required: “reversals” completes the stated technical proposition.

Question context: Governance records errors and _____

Basis and qualification: Chapter 16 — Program Governance and Peer Review.

Review: Chapter 16 — Program Governance and Peer Review.

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V011-C16-FIB-086. Adding 10.0 dB attenuation to the −93.2 dBm second reading gives corrected level _____ dBm.

Answer: −83.2. The correction refers the reading upstream. Source: §16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9284)

Why this term is required: "−83.2" completes the stated technical proposition.

Question context: Adding 10.0 dB attenuation to the −93.2 dBm second reading gives corrected level _____ dBm

Basis and qualification: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-087. For corrected levels P1=−83.0 dBm and P2=−83.2 dBm, signed difference P2−P1 is _____ dB.

Answer: −0.2. P2,corr−P1,corr=−0.2 dB. Source: §16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9284)

Why this term is required: "−0.2" completes the stated technical proposition.

Question context: For corrected levels P1=−83.0 dBm and P2=−83.2 dBm, signed difference P2−P1 is _____ dB

Basis and qualification: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-088. The magnitude 0.2 dB lies within the stipulated _____ dB comparison uncertainty.

Answer: 0.7. This supports compatibility, not source identity. Source: §16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9284)

Why this term is required: “0.7” completes the stated technical proposition.

Question context: The magnitude 0.2 dB lies within the stipulated _____ dB comparison uncertainty

Basis and qualification: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-089. Corrected external-like scaling does not establish source or _____.

Answer: authorization. Transfer behavior and functional/legal status are different claims. Source: §16.12 Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9284)

Why this term is required: "authorization" completes the stated technical proposition.

Question context: Corrected external-like scaling does not establish source or _____

Basis and qualification: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-090. In the keyboard case, isolated reference plus switch bypass is a _____ intervention.

Answer: joint. Two conditions change at once, leaving separate effects unresolved.

Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why this term is required: “joint” completes the stated technical proposition.

Question context: In the keyboard case, isolated reference plus switch bypass is a _____ intervention

Basis and qualification: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-091. That case requires separate reference and switch challenges plus _____ checks.

Answer: reversal. Returning to prior states tests reproducibility of the effect. Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why this term is required: “reversal” completes the stated technical proposition.

Question context: That case requires separate reference and switch challenges plus _____ checks

Basis and qualification: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-092. The modified chain must still detect a suitable known _____.

Answer: reference. Capability preservation supports the interpretation of disappearance. Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why this term is required: “reference” completes the stated technical proposition.

Question context: The modified chain must still detect a suitable known _____

Basis and qualification: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-093. A result disappearing under one challenge is not necessarily _____.

Answer: false. Sensitivity, coupling or state can change the observation. Source: §16.14 Challenge-Test and Evidence Release Gate (p. 9286)

Why this term is required: “false” completes the stated technical proposition.

Question context: A result disappearing under one challenge is not necessarily _____

Basis and qualification: Chapter 16 — Challenge-Test and Evidence Release Gate.

Review: Chapter 16 — Challenge-Test and Evidence Release Gate.

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V011-C16-FIB-094. During regression, prior and changed configurations remain distinct _____.

Answer: states. Their equivalence must be demonstrated for relevant functions.

Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why this term is required: “states” completes the stated technical proposition.

Question context: During regression, prior and changed configurations remain distinct _____

Basis and qualification: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-FIB-095. Reprocessing retained records should preserve both original and revised derived _____.

Answer: products. Their processing identities explain changed interpretation without changing native evidence. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why this term is required: “products” completes the stated technical proposition.

Question context: Reprocessing retained records should preserve both original and revised derived _____

Basis and qualification: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-FIB-096. Regression checks should match functions actually used by the deployed _____.

Answer: method. A generic easy test does not cover every consequential change.

Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why this term is required: “method” completes the stated technical proposition.

Question context: Regression checks should match functions actually used by the deployed _____

Basis and qualification: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-FIB-097. Unverified automatic state and inadequate coverage should remain visible in the release _____.

Answer: conclusion. They may require a narrower accepted domain. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why this term is required: “conclusion” completes the stated technical proposition.

Question context: Unverified automatic state and inadequate coverage should remain visible in the release _____

Basis and qualification: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-FIB-098. An established narrower method can remain useful within its accepted _____.

Answer: domain. Limits need not invalidate every supported result. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

Why this term is required: “domain” completes the stated technical proposition.

Question context: An established narrower method can remain useful within its accepted _____

Basis and qualification: Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-FIB-099. A shared clock may supply a common spur or timing _____.

Answer: error. Multiple receiver channels can retain one instrumental cause. Source: §16.13 Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance (p. 9285)

Why this term is required: “error” completes the stated technical proposition.

Question context: A shared clock may supply a common spur or timing _____

Basis and qualification: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

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V011-C16-FIB-100. A physical challenge changes the error structure; merely replotting changes the _____.

Answer: presentation. It is not a fresh acquisition or intervention replication. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

Why this term is required: “presentation” completes the stated technical proposition.

Question context: A physical challenge changes the error structure; merely replotting changes the _____

Basis and qualification: Chapter 16 — Record repetition and the limits of the design.

Review: Chapter 16 — Record repetition and the limits of the design.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-C16-ESSAY-001. Design an architecture-based challenge sequence for an unexplained spectral component.

- Opening: Present a thesis that answers this precise question: Design an architecture-based challenge sequence for an unexplained spectral component. Identify which evidence would falsify the proposed conclusion Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Core terminology and scope: Define Design, challenge, sequence in the question's particular technical setting; explain how unexplained, spectral, component differ if that distinction would change the analysis of "Design an architecture-based challenge sequence for an unexplained spectral component" Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Map plausible sources before and after controls, specify at least two competing predictions, preserve desired references, and include unsuccessful tests Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an architecture-based challenge sequence for an unexplained spectral component to the claimed result, following "Localize an artifact by changing the stage that could create it"; name the intermediate states and measurable outputs Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an architecture-based challenge sequence for an unexplained spectral component. Distinguish conditional movement or scaling from unique source attribution Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Challenge-Test Design” that resolves the question about an architecture-based challenge sequence for an unexplained spectral component; derive the relevant result with units and stated validity conditions Source: §16.2 Challenge-Test Design (p. 9258)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an architecture-based challenge sequence for an unexplained spectral component. Distinguish conditional movement or scaling from unique source attribution Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Worked application or illustrative case: Build a worked example of “an architecture-based challenge sequence for an unexplained spectral component”, addressing this associated condition: Map plausible sources before and after controls, specify at least two competing predictions, preserve desired.... Map plausible sources before and after controls, specify at least two competing predictions, preserve desired references, and include unsuccessful tests Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “an architecture-based challenge sequence for an unexplained spectral component”. Using “Challenge-Test Design”, specify a discriminator and the result expected under each explanation Source: §16.2 Challenge-Test Design (p. 9258)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an architecture-based challenge sequence for an unexplained spectral component, including the effect of missing measurements and inconsistent operating conditions Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)
- Scholarly synthesis and implications: Explain what the result about an architecture-based challenge sequence for an unexplained spectral component authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Closing: Conclude by answering “Design an architecture-based challenge sequence for an unexplained spectral component” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

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V011-C16-ESSAY-002. Analyze corrected attenuation scaling as evidence and as a limitation.

- Opening: Present a thesis that answers this precise question: Analyze corrected attenuation scaling as evidence and as a limitation. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define corrected, attenuation, scaling in the question's particular technical setting; explain how limitation, measurement, evidence differ if that distinction would change the analysis of "Analyze corrected attenuation scaling as evidence and as a limitation" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Reconstruct −83.2 dBm and signed −0.2 dB from the chapter example, compare with 0.7 dB uncertainty, and explain compatible external-like pathways including receiver leakage entering through the... Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting corrected attenuation scaling as evidence and as a limitation to the claimed result, following "Findings, Reports, and Decision Ladders"; name the intermediate states and measurable outputs Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for corrected attenuation scaling as evidence and as a limitation. Require additional linkage for attribution Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Nonlinear fingerprinting without circular source attribution” that resolves the question about corrected attenuation scaling as evidence and as a limitation; derive the relevant result with units and stated validity conditions Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Evidence and method: Specify the native observations, control records and calculations that would resolve corrected attenuation scaling as evidence and as a limitation. Require additional linkage for attribution Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of “corrected attenuation scaling as evidence and as a limitation”, addressing this associated condition: Reconstruct −83.2 dBm and signed −0.2 dB from the chapter example, compare with 0.7 dB uncertainty, and.... Reconstruct −83.2 dBm and signed −0.2 dB from the chapter example, compare with 0.7 dB uncertainty, and explain compatible external-like pathways including receiver... Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “corrected attenuation scaling as evidence

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and as a limitation". Using "Nonlinear fingerprinting without circular source attribution", specify a discriminator and the result expected under each explanation Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to corrected attenuation scaling as evidence and as a limitation, including the effect of missing measurements and inconsistent operating conditions Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Scholarly synthesis and implications: Explain what the result about corrected attenuation scaling as evidence and as a limitation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering "Analyze corrected attenuation scaling as evidence and as a limitation" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-ESSAY-003. Explain why receiver substitution is informative only with shared dependencies and capability considered.

- Opening: Present a thesis that answers this precise question: Explain why receiver substitution is informative only with shared dependencies and capability considered. Identify which evidence would falsify the proposed conclusion Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Core terminology and scope: Define substitution, informative, shared in the question's particular technical setting; explain how dependencies, capability, considered differ if that distinction would change the analysis of "Explain why receiver substitution is informative only with shared dependencies and capability considered" Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Map shared antennas, clocks, power, software and corrections; carry a suitable reference through both paths; compare noise, bandwidth and timing Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why receiver substitution is informative only with shared dependencies and capability considered to the claimed result, following "Preserve comparable observation capability"; name the intermediate states and measurable outputs Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why receiver substitution is informative only with shared dependencies and capability considered. State what agreement or disappearance can support under the demonstrated scope Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Integration with Direction, Wireline, Optical, and Physical Evidence” that resolves the question about why receiver substitution is informative only with shared dependencies and capability considered; derive the relevant result with units and stated validity conditions Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why receiver substitution is informative only with shared dependencies and capability considered. State what agreement or disappearance can support under the demonstrated scope Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Worked application or illustrative case: Build a worked example of “why receiver substitution is informative only with shared dependencies and capability considered”, addressing this associated condition: Map shared antennas, clocks, power, software and corrections; carry a suitable reference through both paths;.... Map shared antennas, clocks, power, software and corrections; carry a

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suitable reference through both paths; compare noise, bandwidth… Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “why receiver substitution is informative only with shared dependencies and capability considered”. Using “Integration with Direction, Wireline, Optical, and Physical Evidence”, specify a discriminator and the result expected under each explanation Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why receiver substitution is informative only with shared dependencies and capability considered, including the effect of missing measurements and inconsistent operating conditions Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Scholarly synthesis and implications: Explain what the result about why receiver substitution is informative only with shared dependencies and capability considered authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Closing: Conclude by answering “Explain why receiver substitution is informative only with shared dependencies and capability considered” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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V011-C16-ESSAY-004. Develop a complete two-factor clock-and-switch diagnostic design.

- Opening: Present a thesis that answers this precise question: Develop a complete two-factor clock-and-switch diagnostic design. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define complete, two-factor, clock-and-switch in the question's particular technical setting; explain how diagnostic, design, measurement differ if that distinction would change the analysis of "Develop a complete two-factor clock-and-switch diagnostic design" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Describe physical changes in each factor, all four meaningful combinations, fixed response plane and criterion, known-reference checks, actual order and missing states Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a complete two-factor clock-and-switch diagnostic design to the claimed result, following "Record repetition and the limits of the design"; name the intermediate states and measurable outputs Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a complete two-factor clock-and-switch diagnostic design. Explain

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conditional effects without assigning unsupported component causation Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Receiver challenges with interacting controls” that resolves the question about a complete two-factor clock-and-switch diagnostic design; derive the relevant result with units and stated validity conditions Source: §16.4 Receiver challenges with interacting controls (p. 9262)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a complete two-factor clock-and-switch diagnostic design. Explain conditional effects without assigning unsupported component causation Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of “a complete two-factor clock-and-switch diagnostic design”, addressing this associated condition: Describe physical changes in each factor, all four meaningful combinations, fixed response plane and…. Describe physical changes in each factor, all four meaningful combinations, fixed response plane and criterion, known-reference checks, actual order and missing states Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a complete two-factor clock-and-switch diagnostic design”. Using “Receiver challenges with interacting controls”, specify a discriminator and the result expected under each explanation Source: §16.4 Receiver challenges with interacting controls (p. 9262)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a complete two-factor clock-and-switch diagnostic design, including the effect of missing measurements and inconsistent operating conditions Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Scholarly synthesis and implications: Explain what the result about a complete two-factor clock-and-switch diagnostic design authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering “Develop a complete two-factor clock-and-switch diagnostic design” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-ESSAY-005. Explain interaction in a receiver challenge without treating it as automatic mechanism identification.

- Opening: Present a thesis that answers this precise question: Explain interaction in a receiver challenge without treating it as automatic mechanism identification. Identify which evidence would falsify the proposed conclusion Source: §16.4 Receiver challenges with interacting controls (p. 9262)
- Core terminology and scope: Define interaction, challenge, treating in the question's particular technical setting; explain how automatic, mechanism, identification differ if that distinction would change the analysis of "Explain interaction in a receiver challenge without treating it as automatic mechanism identification" Source: §16.4 Receiver challenges with interacting controls (p. 9262)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Show how the effect of one factor can depend on another Source: §16.4 Receiver challenges with interacting controls (p. 9262)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting interaction in a receiver challenge without treating it as automatic mechanism identification to the claimed result, following "Close the receiver method through configuration-specific regression"; name the intermediate states and measurable outputs Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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interaction in a receiver challenge without treating it as automatic mechanism identification. Show how the effect of one factor can depend on another Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- Analytical framework: Identify the equation, calibration or evidential decision test in “An intervention matrix that separates mechanism, state and common error” that resolves the question about interaction in a receiver challenge without treating it as automatic mechanism identification; derive the relevant result with units and stated validity conditions Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Evidence and method: Specify the native observations, control records and calculations that would resolve interaction in a receiver challenge without treating it as automatic mechanism identification. Show how the effect of one factor can depend on another Source: §16.4 Receiver challenges with interacting controls (p. 9262)
- Worked application or illustrative case: Build a worked example of “interaction in a receiver challenge without treating it as automatic mechanism identification”, addressing this associated condition: Show how the effect of one factor can depend on another. Show how the effect of one factor can depend on another Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “interaction in a receiver challenge without treating it as automatic mechanism identification”. Using “An intervention matrix that separates mechanism, state and

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common error", specify a discriminator and the result expected under each explanation Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to interaction in a receiver challenge without treating it as automatic mechanism identification, including the effect of missing measurements and inconsistent operating conditions Source: §16.10 Program Governance and Peer Review (p. 9281)
- Scholarly synthesis and implications: Explain what the result about interaction in a receiver challenge without treating it as automatic mechanism identification authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4 Receiver challenges with interacting controls (p. 9262)
- Closing: Conclude by answering "Explain interaction in a receiver challenge without treating it as automatic mechanism identification" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4 Receiver challenges with interacting controls (p. 9262)

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V011-C16-ESSAY-006. Design capability controls for weak bursts, wideband modulation and steady tones.

- Opening: Present a thesis that answers this precise question: Design capability controls for weak bursts, wideband modulation and steady tones. Identify which evidence would falsify the proposed conclusion Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Core terminology and scope: Define Design, capability, controls in the question's particular technical setting; explain how bursts, wideband, steady differ if that distinction would change the analysis of "Design capability controls for weak bursts, wideband modulation and steady tones" Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Match references to frequency mapping, relevant level, bandwidth, timing, trigger and record continuity Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting capability controls for weak bursts, wideband modulation and steady tones to the claimed result, following "Close the receiver method through configuration-specific regression"; name the intermediate states and measurable outputs Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for capability controls for weak bursts, wideband modulation and

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steady tones. Explain why a strong CW check cannot support every negative observation and retain state-specific corrections and limits Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Record repetition and the limits of the design” that resolves the question about capability controls for weak bursts, wideband modulation and steady tones; derive the relevant result with units and stated validity conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Evidence and method: Specify the native observations, control records and calculations that would resolve capability controls for weak bursts, wideband modulation and steady tones. Explain why a strong CW check cannot support every negative observation and retain state-specific corrections and limits Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Worked application or illustrative case: Build a worked example of “capability controls for weak bursts, wideband modulation and steady tones”, addressing this associated condition: Match references to frequency mapping, relevant level, bandwidth, timing, trigger and record continuity. Match references to frequency mapping, relevant level, bandwidth, timing, trigger and record continuity Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “capability controls for weak bursts,

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wideband modulation and steady tones". Using "Record repetition and the limits of the design", specify a discriminator and the result expected under each explanation Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to capability controls for weak bursts, wideband modulation and steady tones, including the effect of missing measurements and inconsistent operating conditions Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)
- Scholarly synthesis and implications: Explain what the result about capability controls for weak bursts, wideband modulation and steady tones authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Closing: Conclude by answering "Design capability controls for weak bursts, wideband modulation and steady tones" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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V011-C16-ESSAY-007. Separate transition behavior from settled-state evidence in a diagnostic plan.

- Opening: Present a thesis that answers this precise question: Separate transition behavior from settled-state evidence in a diagnostic plan. Identify which evidence would falsify the proposed conclusion Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Core terminology and scope: Define Separate, transition, behavior in the question's particular technical setting; explain how settled-state, diagnostic, measurement differ if that distinction would change the analysis of "Separate transition behavior from settled-state evidence in a diagnostic plan" Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Record relocking, switch impulses and recovery history, use validated usable intervals, and retain excluded transition records Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Separate transition behavior from settled-state evidence in a diagnostic plan to the claimed result, following "Record repetition and the limits of the design"; name the intermediate states and measurable outputs Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Separate transition behavior from settled-state evidence in a diagnostic plan.

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If the feature occurs only during a transition, define a dedicated criterion rather than erase it Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Arrange the comparisons before examining their outcomes” that resolves the question about Separate transition behavior from settled-state evidence in a diagnostic plan; derive the relevant result with units and stated validity conditions Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Separate transition behavior from settled-state evidence in a diagnostic plan. If the feature occurs only during a transition, define a dedicated criterion rather than erase it Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Worked application or illustrative case: Build a worked example of “Separate transition behavior from settled-state evidence in a diagnostic plan”, addressing this associated condition: Record relocking, switch impulses and recovery history, use validated usable intervals, and retain excluded.... Record relocking, switch impulses and recovery history, use validated usable intervals, and retain excluded transition records Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Separate transition behavior from settled-state evidence in a diagnostic plan”. Using “Arrange the

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comparisons before examining their outcomes", specify a discriminator and the result expected under each explanation Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Separate transition behavior from settled-state evidence in a diagnostic plan, including the effect of missing measurements and inconsistent operating conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Scholarly synthesis and implications: Explain what the result about Separate transition behavior from settled-state evidence in a diagnostic plan authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Closing: Conclude by answering "Separate transition behavior from settled-state evidence in a diagnostic plan" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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V011-C16-ESSAY-008. Adjudicate the four-state original-reference/switch-in-circuit pattern.

- Opening: Present a thesis that answers this precise question: Adjudicate the four-state original-reference/switch-in-circuit pattern. Identify which evidence would falsify the proposed conclusion Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Core terminology and scope: Define Adjudicate, four-state, original-reference/switch-in-circuit in the question's particular technical setting; explain how pattern, measurement, evidence differ if that distinction would change the analysis of "Adjudicate the four-state original-reference/switch-in-circuit pattern" Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the joint association under preserved capability, retain measured levels and observation limits, revisit original states, and propose reference/return-path tests Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Adjudicate the four-state original-reference/switch-in-circuit pattern to the claimed result, following "Interpret hypothetical receiver records"; name the intermediate states and measurable outputs Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Adjudicate the four-state original-reference/switch-in-circuit pattern.

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Explain why neither independent causation by both components nor universal absence follows Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Record repetition and the limits of the design” that resolves the question about Adjudicate the four-state original-reference/switch-in-circuit pattern; derive the relevant result with units and stated validity conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Adjudicate the four-state original-reference/switch-in-circuit pattern. Explain why neither independent causation by both components nor universal absence follows Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Worked application or illustrative case: Build a worked example of “Adjudicate the four-state original-reference/switch-in-circuit pattern”, addressing this associated condition: . State the joint association under preserved capability, retain measured levels and observation limits, revisit original states, and propose reference/return-path tests Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Adjudicate the four-state original-reference/switch-in-circuit pattern”. Using “Record repetition and the limits of the design”, specify a discriminator and the result

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expected under each explanation Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Adjudicate the four-state original-reference/switch-in-circuit pattern, including the effect of missing measurements and inconsistent operating conditions Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Scholarly synthesis and implications: Explain what the result about Adjudicate the four-state original-reference/switch-in-circuit pattern authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Closing: Conclude by answering “Adjudicate the four-state original-reference/switch-in-circuit pattern” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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V011-C16-ESSAY-009. Analyze the preselection-and-gain hypothetical record.

- Opening: Present a thesis that answers this precise question: Analyze the preselection-and-gain hypothetical record. Identify which evidence would falsify the proposed conclusion Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Core terminology and scope: Define preselection-and-gain, hypothetical, record in the question's particular technical setting; explain how terminology, computational, relationships differ if that distinction would change the analysis of "Analyze the preselection-and-gain hypothetical record" Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Connect admitted parents and gain to a plausible loading mechanism, check actual parent levels and source/combiner purity, and control mismatch and gain trajectory Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the preselection-and-gain hypothetical record to the claimed result, following "Reconcile evidence without assigning unsupported probabilities"; name the intermediate states and measurable outputs Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the preselection-and-gain hypothetical record. Use four-state evidence

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to narrow hypotheses without uniquely assigning a stage Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Record repetition and the limits of the design” that resolves the question about the preselection-and-gain hypothetical record; derive the relevant result with units and stated validity conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the preselection-and-gain hypothetical record. Use four-state evidence to narrow hypotheses without uniquely assigning a stage Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Worked application or illustrative case: Build a worked example of “the preselection-and-gain hypothetical record”, addressing this associated condition: Connect admitted parents and gain to a plausible loading mechanism, check actual parent levels and.... Connect admitted parents and gain to a plausible loading mechanism, check actual parent levels and source/combiner purity, and control mismatch and gain trajectory Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the preselection-and-gain hypothetical record”. Using “Record repetition and the limits of the design”, specify a discriminator and the result expected under each explanation Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the preselection-and-gain hypothetical record, including the effect of missing measurements and inconsistent operating conditions Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)
- Scholarly synthesis and implications: Explain what the result about the preselection-and-gain hypothetical record authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Closing: Conclude by answering “Analyze the preselection-and-gain hypothetical record” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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V011-C16-ESSAY-010. Evaluate the detector-rule and input-record crossed comparison.

- Opening: Present a thesis that answers this precise question: Evaluate the detector-rule and input-record crossed comparison. Identify which evidence would falsify the proposed conclusion Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Core terminology and scope: Define detector-rule, input-record, crossed in the question's particular technical setting; explain how terminology, crossed, computational differ if that distinction would change the analysis of "Evaluate the detector-rule and input-record crossed comparison" Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain permissive/strict outputs on field, valid-reference and independent noise-only records Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the detector-rule and input-record crossed comparison to the claimed result, following "Coupling paths that defeat the simple external-versus-internal dichotomy"; name the intermediate states and measurable outputs Source: §16.22 Coupling paths that defeat the simple external-versus-internal dichotomy (p. 9305)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the detector-rule and input-record crossed comparison. Explain fitted

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versus held-out data and why rule changes cannot retrospectively establish the origin of every field event Source: §16.22 Coupling paths that defeat the simple external-versus-internal dichotomy (p. 9305)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Program Governance and Peer Review” that resolves the question about the detector-rule and input-record crossed comparison; derive the relevant result with units and stated validity conditions Source: §16.10 Program Governance and Peer Review (p. 9281)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the detector-rule and input-record crossed comparison. Explain fitted versus held-out data and why rule changes cannot retrospectively establish the origin of every field event Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Worked application or illustrative case: Build a worked example of “the detector-rule and input-record crossed comparison”, addressing this associated condition: Retain permissive/strict outputs on field, valid-reference and independent noise-only records. Retain permissive/strict outputs on field, valid-reference and independent noise-only records Source: §16.22 Coupling paths that defeat the simple external-versus-internal dichotomy (p. 9305)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the detector-rule and input-record crossed comparison”. Using “Program Governance and Peer Review”, specify a discriminator and the result expected under each explanation Source: §16.10 Program Governance and Peer Review (p. 9281)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the detector-rule and input-record crossed comparison, including the effect of missing measurements and inconsistent operating conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Scholarly synthesis and implications: Explain what the result about the detector-rule and input-record crossed comparison authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Closing: Conclude by answering “Evaluate the detector-rule and input-record crossed comparison” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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V011-C16-ESSAY-011. Distinguish replication, randomization and blocking in receiver diagnostics.

- Opening: Present a thesis that answers this precise question: Distinguish replication, randomization and blocking in receiver diagnostics. Identify which evidence would falsify the proposed conclusion Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Core terminology and scope: Define replication, randomization, blocking in the question's particular technical setting; explain how receiver, diagnostics, measurement differ if that distinction would change the analysis of "Distinguish replication, randomization and blocking in receiver diagnostics" Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define fresh intervention acquisitions, order control against drift, and grouping under nuisance conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Distinguish replication, randomization and blocking in receiver diagnostics to the claimed result, following "Close the receiver method through configuration-specific regression"; name the intermediate states and measurable outputs Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Distinguish replication, randomization and blocking in receiver

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diagnostics. Explain restricted order, retained group membership and why replotting or overlapping windows are not physical replication Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- Analytical framework: Identify the equation, calibration or evidential decision test in “An intervention matrix that separates mechanism, state and common error” that resolves the question about Distinguish replication, randomization and blocking in receiver diagnostics; derive the relevant result with units and stated validity conditions Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Distinguish replication, randomization and blocking in receiver diagnostics. Explain restricted order, retained group membership and why replotting or overlapping windows are not physical replication Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Worked application or illustrative case: Build a worked example of “Distinguish replication, randomization and blocking in receiver diagnostics”, addressing this associated condition: Define fresh intervention acquisitions, order control against drift, and grouping under nuisance conditions. Define fresh intervention acquisitions, order control against drift, and grouping under nuisance conditions Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Distinguish replication, randomization and blocking in receiver diagnostics”. Using “An intervention matrix that separates mechanism, state and common error”, specify a discriminator and the result expected under each explanation Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Distinguish replication, randomization and blocking in receiver diagnostics, including the effect of missing measurements and inconsistent operating conditions Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Scholarly synthesis and implications: Explain what the result about Distinguish replication, randomization and blocking in receiver diagnostics authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Closing: Conclude by answering “Distinguish replication, randomization and blocking in receiver diagnostics” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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V011-C16-ESSAY-012. Analyze a design where reference state is confounded with recording session.

- Opening: Present a thesis that answers this precise question: Analyze a design where reference state is confounded with recording session. Identify which evidence would falsify the proposed conclusion Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Core terminology and scope: Define design, reference, confounded in the question's particular technical setting; explain how recording, session, measurement differ if that distinction would change the analysis of "Analyze a design where reference state is confounded with recording session" Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Show why within-session repetition cannot separate the effects, identify meaningful missing combinations, and propose a feasible crossed/blocking plan Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a design where reference state is confounded with recording session to the claimed result, following "Write findings that preserve the strength and limit of each test"; name the intermediate states and measurable outputs Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a design

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where reference state is confounded with recording session. If unavailable, state the unresolved comparison without imputing results Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Interpret hypothetical receiver records” that resolves the question about a design where reference state is confounded with recording session; derive the relevant result with units and stated validity conditions Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a design where reference state is confounded with recording session. If unavailable, state the unresolved comparison without imputing results Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Worked application or illustrative case: Build a worked example of “a design where reference state is confounded with recording session”, addressing this associated condition: Show why within-session repetition cannot separate the effects, identify meaningful missing combinations, and…. Show why within-session repetition cannot separate the effects, identify meaningful missing combinations, and propose a feasible crossed/blocking plan Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a design where reference state is confounded with recording session”. Using “Interpret hypothetical

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receiver records", specify a discriminator and the result expected under each explanation Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a design where reference state is confounded with recording session, including the effect of missing measurements and inconsistent operating conditions Source: §16.2 Challenge-Test Design (p. 9258)
- Scholarly synthesis and implications: Explain what the result about a design where reference state is confounded with recording session authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Closing: Conclude by answering "Analyze a design where reference state is confounded with recording session" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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V011-C16-ESSAY-013. Develop a cross-domain evidence plan for RF, wireline and optical observations.

- Opening: Present a thesis that answers this precise question: Develop a cross-domain evidence plan for RF, wireline and optical observations. Identify which evidence would falsify the proposed conclusion Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Core terminology and scope: Define cross-domain, wireline, optical in the question's particular technical setting; explain how observations, measurement, evidence differ if that distinction would change the analysis of "Develop a cross-domain evidence plan for RF, wireline and optical observations" Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define each direct observable, reconcile time and state, identify common clocks/power/software and seek changes in error structure Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a cross-domain evidence plan for RF, wireline and optical observations to the claimed result, following "Reconcile evidence without assigning unsupported probabilities"; name the intermediate states and measurable outputs Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a cross-domain evidence plan for RF, wireline and optical observations. Discuss multipath and phase centers where localization is used and avoid treating sensor count as independence Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Write findings that preserve the strength and limit of each test” that resolves the question about a cross-domain evidence plan for RF, wireline and optical observations; derive the relevant result with units and stated validity conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a cross-domain evidence plan for RF, wireline and optical observations. Discuss multipath and phase centers where localization is used and avoid treating sensor count as independence Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Worked application or illustrative case: Build a worked example of “a cross-domain evidence plan for RF, wireline and optical observations”, addressing this associated condition: Define each direct observable, reconcile time and state, identify common clocks/power/software and seek.... Define each direct observable, reconcile time and state, identify common clocks/power/software and seek changes in error structure Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a cross-domain evidence plan for RF, wireline and optical observations”. Using “Write findings that preserve the strength and limit of each test”, specify a discriminator and the result expected under each explanation Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a cross-domain evidence plan for RF, wireline and optical observations, including the effect of missing measurements and inconsistent operating conditions Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Scholarly synthesis and implications: Explain what the result about a cross-domain evidence plan for RF, wireline and optical observations authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Closing: Conclude by answering “Develop a cross-domain evidence plan for RF, wireline and optical observations” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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V011-C16-ESSAY-014. Explain the finding ladder from detection to confirmed function.

- Opening: Present a thesis that answers this precise question: Explain the finding ladder from detection to confirmed function. Identify which evidence would falsify the proposed conclusion Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Core terminology and scope: Define finding, ladder, detection in the question's particular technical setting; explain how confirmed, function, measurement differ if that distinction would change the analysis of "Explain the finding ladder from detection to confirmed function" Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish classification, temporal correlation, localization, device linkage and authorization Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the finding ladder from detection to confirmed function to the claimed result, following "Write findings that preserve the strength and limit of each test"; name the intermediate states and measurable outputs Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the finding ladder from detection to confirmed function. Specify physical/operational linkage, information path, reproducibility and evidence continuity needed for the strongest claim and retain

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intermediate categories Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- Analytical framework: Identify the equation, calibration or evidential decision test in “An evidence-closure matrix that links physical tests to permissible forensic propositions” that resolves the question about the finding ladder from detection to confirmed function; derive the relevant result with units and stated validity conditions Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the finding ladder from detection to confirmed function. Specify physical/operational linkage, information path, reproducibility and evidence continuity needed for the strongest claim and retain intermediate categories Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Worked application or illustrative case: Build a worked example of “the finding ladder from detection to confirmed function”, addressing this associated condition: Distinguish classification, temporal correlation, localization, device linkage and authorization. Distinguish classification, temporal correlation, localization, device linkage and authorization Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the finding ladder from detection to confirmed function”. Using “An evidence-closure matrix that links physical tests to permissible forensic propositions”, specify a discriminator and the result expected under each explanation Source:

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§16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the finding ladder from detection to confirmed function, including the effect of missing measurements and inconsistent operating conditions Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Scholarly synthesis and implications: Explain what the result about the finding ladder from detection to confirmed function authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Closing: Conclude by answering “Explain the finding ladder from detection to confirmed function” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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V011-C16-ESSAY-015. Compare uncertainty-based compatibility with likelihood-based hypothesis comparison.

- Opening: Present a thesis that answers this precise question: Compare uncertainty-based compatibility with likelihood-based hypothesis comparison. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define uncertainty-based, compatibility, likelihood-based in the question's particular technical setting; explain how hypothesis, measurement, evidence differ if that distinction would change the analysis of "Compare uncertainty-based compatibility with likelihood-based hypothesis comparison" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define corrected same-plane differences and their covariance-aware uncertainty Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting uncertainty-based compatibility with likelihood-based hypothesis comparison to the claimed result, following "Nonlinear fingerprinting without circular source attribution"; name the intermediate states and measurable outputs Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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uncertainty-based compatibility with likelihood-based hypothesis comparison. Explain why a discrepancy or favorable-test count is not attribution odds Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Challenge-Test Design” that resolves the question about uncertainty-based compatibility with likelihood-based hypothesis comparison; derive the relevant result with units and stated validity conditions Source: §16.2 Challenge-Test Design (p. 9258)
- Evidence and method: Specify the native observations, control records and calculations that would resolve uncertainty-based compatibility with likelihood-based hypothesis comparison. Explain why a discrepancy or favorable-test count is not attribution odds Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of “uncertainty-based compatibility with likelihood-based hypothesis comparison”, addressing this associated condition: . Define corrected same-plane differences and their covariance-aware uncertainty Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “uncertainty-based compatibility with likelihood-based hypothesis comparison”. Using “Challenge-Test Design”, specify a discriminator and the result expected under each explanation Source: §16.2 Challenge-Test Design (p. 9258)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to uncertainty-based compatibility with likelihood-based hypothesis comparison, including the effect of missing measurements and inconsistent operating conditions Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Scholarly synthesis and implications: Explain what the result about uncertainty-based compatibility with likelihood-based hypothesis comparison authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering “Compare uncertainty-based compatibility with likelihood-based hypothesis comparison” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-ESSAY-016. Design negative controls that each test a specific alternative.

- Opening: Present a thesis that answers this precise question: Design negative controls that each test a specific alternative. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define Design, negative, controls in the question's particular technical setting; explain how test, specific, alternative differ if that distinction would change the analysis of "Design negative controls that each test a specific alternative" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use terminated input, known reference and noise-only processing with their distinct scopes Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting negative controls that each test a specific alternative to the claimed result, following "Close the receiver method through configuration-specific regression"; name the intermediate states and measurable outputs Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for negative controls that each test a specific alternative. Bracket the actual observation, retain failures and checks after changes, and explain

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what none of the controls establishes universally Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Challenge-Test Design” that resolves the question about negative controls that each test a specific alternative; derive the relevant result with units and stated validity conditions Source: §16.2 Challenge-Test Design (p. 9258)
- Evidence and method: Specify the native observations, control records and calculations that would resolve negative controls that each test a specific alternative. Bracket the actual observation, retain failures and checks after changes, and explain what none of the controls establishes universally Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of “negative controls that each test a specific alternative”, addressing this associated condition: Use terminated input, known reference and noise-only processing with their distinct scopes. Use terminated input, known reference and noise-only processing with their distinct scopes Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “negative controls that each test a specific alternative”. Using “Challenge-Test Design”, specify a discriminator and the result expected under each explanation Source: §16.2 Challenge-Test Design (p. 9258)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to negative controls that each test a specific alternative, including the effect of missing measurements and inconsistent operating conditions Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)
- Scholarly synthesis and implications: Explain what the result about negative controls that each test a specific alternative authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering “Design negative controls that each test a specific alternative” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-ESSAY-017. Write the structure of a technically reproducible unresolved finding.

- Opening: Present a thesis that answers this precise question: Write the structure of a technically reproducible unresolved finding. Identify which evidence would falsify the proposed conclusion Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Core terminology and scope: Define structure, technically, reproducible in the question's particular technical setting; explain how unresolved, finding, measurement differ if that distinction would change the analysis of "Write the structure of a technically reproducible unresolved finding" Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Organize question, accepted native records, configuration, calculation, challenges and inference Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the structure of a technically reproducible unresolved finding to the claimed result, following "Artifact Taxonomy and Competing Explanations"; name the intermediate states and measurable outputs Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the structure of a technically reproducible unresolved finding. Retain units, planes, normalization and uncertainty, name competing

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explanations, and prioritize the next discriminating test with omission limits Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Findings, Reports, and Decision Ladders” that resolves the question about the structure of a technically reproducible unresolved finding; derive the relevant result with units and stated validity conditions Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the structure of a technically reproducible unresolved finding. Retain units, planes, normalization and uncertainty, name competing explanations, and prioritize the next discriminating test with omission limits Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Worked application or illustrative case: Build a worked example of “the structure of a technically reproducible unresolved finding”, addressing this associated condition: Organize question, accepted native records, configuration, calculation, challenges and inference. Organize question, accepted native records, configuration, calculation, challenges and inference Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the structure of a technically reproducible unresolved finding”. Using “Findings, Reports, and Decision Ladders”, specify a discriminator and the result expected

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under each explanation Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the structure of a technically reproducible unresolved finding, including the effect of missing measurements and inconsistent operating conditions Source: §16.10 Program Governance and Peer Review (p. 9281)
- Scholarly synthesis and implications: Explain what the result about the structure of a technically reproducible unresolved finding authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Closing: Conclude by answering “Write the structure of a technically reproducible unresolved finding” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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V011-C16-ESSAY-018. Develop a reusable artifact record without overgeneralizing from one incident.

- Opening: Present a thesis that answers this precise question: Develop a reusable artifact record without overgeneralizing from one incident. Identify which evidence would falsify the proposed conclusion Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Core terminology and scope: Define reusable, artifact, record in the question's particular technical setting; explain how overgeneralizing, incident, measurement differ if that distinction would change the analysis of "Develop a reusable artifact record without overgeneralizing from one incident" Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify exhibiting states, known stimulus or transition, predicted and observed response, successful challenge and mitigation Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reusable artifact record without overgeneralizing from one incident to the claimed result, following "An intervention matrix that separates mechanism, state and common error"; name the intermediate states and measurable outputs Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a reusable artifact record without overgeneralizing from one incident. Include reproduction instructions and applicability limits so a later examiner can test whether the mechanism recurs Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Record repetition and the limits of the design” that resolves the question about a reusable artifact record without overgeneralizing from one incident; derive the relevant result with units and stated validity conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reusable artifact record without overgeneralizing from one incident. Include reproduction instructions and applicability limits so a later examiner can test whether the mechanism recurs Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Worked application or illustrative case: Build a worked example of “a reusable artifact record without overgeneralizing from one incident”, addressing this associated condition: Identify exhibiting states, known stimulus or transition, predicted and observed response, successful.... Identify exhibiting states, known stimulus or transition, predicted and observed response, successful challenge and mitigation Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a reusable artifact record without overgeneralizing from one incident”. Using “Record repetition and the limits of the design”, specify a discriminator and the result expected under each explanation Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reusable artifact record without overgeneralizing from one incident, including the effect of missing measurements and inconsistent operating conditions Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Scholarly synthesis and implications: Explain what the result about a reusable artifact record without overgeneralizing from one incident authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Closing: Conclude by answering “Develop a reusable artifact record without overgeneralizing from one incident” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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V011-C16-ESSAY-019. Create an acceptance and maintenance plan for the complete deployed receiver method.

- Opening: Present a thesis that answers this precise question: Create an acceptance and maintenance plan for the complete deployed receiver method. Identify which evidence would falsify the proposed conclusion Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)
- Core terminology and scope: Define Create, acceptance, maintenance in the question's particular technical setting; explain how complete, deployed, method differ if that distinction would change the analysis of "Create an acceptance and maintenance plan for the complete deployed receiver method" Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Cover relevant amplitude/noise, conversion, dynamic range, images/spurs, timing, sample continuity, trigger, metadata and external path Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Create an acceptance and maintenance plan for the complete deployed receiver method to the claimed result, following "Close the receiver method through configuration-specific regression"; name the intermediate states and measurable outputs Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Create

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an acceptance and maintenance plan for the complete deployed receiver method. Use stable references after consequential changes and retain calibration, repairs, software and correction history Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Artifact Taxonomy and Competing Explanations” that resolves the question about Create an acceptance and maintenance plan for the complete deployed receiver method; derive the relevant result with units and stated validity conditions Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Create an acceptance and maintenance plan for the complete deployed receiver method. Use stable references after consequential changes and retain calibration, repairs, software and correction history Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)
- Worked application or illustrative case: Build a worked example of “Create an acceptance and maintenance plan for the complete deployed receiver method”, addressing this associated condition: Cover relevant amplitude/noise, conversion, dynamic range, images/spurs, timing, sample continuity, trigger,.... Cover relevant amplitude/noise, conversion, dynamic range, images/spurs, timing, sample continuity, trigger, metadata and external path Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Create an acceptance and maintenance

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plan for the complete deployed receiver method". Using "Artifact Taxonomy and Competing Explanations", specify a discriminator and the result expected under each explanation Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Create an acceptance and maintenance plan for the complete deployed receiver method, including the effect of missing measurements and inconsistent operating conditions Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Scholarly synthesis and implications: Explain what the result about Create an acceptance and maintenance plan for the complete deployed receiver method authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)
- Closing: Conclude by answering "Create an acceptance and maintenance plan for the complete deployed receiver method" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

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V011-C16-ESSAY-020. Design independent technical review for a consequential receiver finding.

- Opening: Present a thesis that answers this precise question: Design independent technical review for a consequential receiver finding. Identify which evidence would falsify the proposed conclusion Source: §16.10 Program Governance and Peer Review (p. 9281)
- Core terminology and scope: Define Design, independent, technical in the question's particular technical setting; explain how review, consequential, finding differ if that distinction would change the analysis of "Design independent technical review for a consequential receiver finding" Source: §16.10 Program Governance and Peer Review (p. 9281)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Provide native data, configurations, calculations, calibration, challenges and alternatives; ask reviewers to reconstruct claims and limits Source: §16.10 Program Governance and Peer Review (p. 9281)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting independent technical review for a consequential receiver finding to the claimed result, following "Findings, Reports, and Decision Ladders"; name the intermediate states and measurable outputs Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for independent technical review for a consequential receiver finding. Resolve disagreement through further tests or explicit limitations,

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preserving errors and reversals rather than enforcing narrative consensus Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Challenge-Test Design” that resolves the question about independent technical review for a consequential receiver finding; derive the relevant result with units and stated validity conditions Source: §16.2 Challenge-Test Design (p. 9258)
- Evidence and method: Specify the native observations, control records and calculations that would resolve independent technical review for a consequential receiver finding. Resolve disagreement through further tests or explicit limitations, preserving errors and reversals rather than enforcing narrative consensus Source: §16.10 Program Governance and Peer Review (p. 9281)
- Worked application or illustrative case: Build a worked example of “independent technical review for a consequential receiver finding”, addressing this associated condition: Provide native data, configurations, calculations, calibration, challenges and alternatives; ask reviewers to.... Provide native data, configurations, calculations, calibration, challenges and alternatives; ask reviewers to reconstruct claims and limits Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “independent technical review for a consequential receiver finding”. Using “Challenge-Test Design”, specify a discriminator and the result expected under each explanation Source: §16.2 Challenge-Test Design (p. 9258)

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- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to independent technical review for a consequential receiver finding, including the effect of missing measurements and inconsistent operating conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Scholarly synthesis and implications: Explain what the result about independent technical review for a consequential receiver finding authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.10 Program Governance and Peer Review (p. 9281)
- Closing: Conclude by answering “Design independent technical review for a consequential receiver finding” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.10 Program Governance and Peer Review (p. 9281)

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V011-C16-ESSAY-021. Analyze the keyboard, shared clock, switch and LED hypothetical case.

- Opening: Present a thesis that answers this precise question: Analyze the keyboard, shared clock, switch and LED hypothetical case. Identify which evidence would falsify the proposed conclusion Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Core terminology and scope: Define keyboard, shared, clock in the question's particular technical setting; explain how switch, hypothetical, case differ if that distinction would change the analysis of "Analyze the keyboard, shared clock, switch and LED hypothetical case" Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate RF and optical direct observations, identify the joint intervention and shared dependencies, then propose separate crossed factors, reversals and a suitable known-reference test Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the keyboard, shared clock, switch and LED hypothetical case to the claimed result, following "Nonlinear fingerprinting without circular source attribution"; name the intermediate states and measurable outputs Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the keyboard, shared clock, switch and LED hypothetical case. State the

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provisional artifact hypothesis and remaining attribution limits Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Write findings that preserve the strength and limit of each test” that resolves the question about the keyboard, shared clock, switch and LED hypothetical case; derive the relevant result with units and stated validity conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the keyboard, shared clock, switch and LED hypothetical case. State the provisional artifact hypothesis and remaining attribution limits Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Worked application or illustrative case: Build a worked example of “the keyboard, shared clock, switch and LED hypothetical case”, addressing this associated condition: Separate RF and optical direct observations, identify the joint intervention and shared dependencies, then.... Separate RF and optical direct observations, identify the joint intervention and shared dependencies, then propose separate crossed factors, reversals and a suitable... Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “the keyboard, shared clock, switch and LED hypothetical case”. Using “Write findings that preserve the strength and limit of each test”, specify a discriminator and the

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result expected under each explanation Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the keyboard, shared clock, switch and LED hypothetical case, including the effect of missing measurements and inconsistent operating conditions Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Scholarly synthesis and implications: Explain what the result about the keyboard, shared clock, switch and LED hypothetical case authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Closing: Conclude by answering “Analyze the keyboard, shared clock, switch and LED hypothetical case” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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V011-C16-ESSAY-022. Develop configuration-specific regression after a firmware or processing change.

- Opening: Present a thesis that answers this precise question: Develop configuration-specific regression after a firmware or processing change. Identify which evidence would falsify the proposed conclusion Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Core terminology and scope: Define configuration-specific, regression, firmware in the question's particular technical setting; explain how processing, measurement, evidence differ if that distinction would change the analysis of "Develop configuration-specific regression after a firmware or processing change" Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain old and new states, select tests for actual deployed functions, rerun representative native records, preserve both derived versions and explain differences Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting configuration-specific regression after a firmware or processing change to the claimed result, following "Program Governance and Peer Review"; name the intermediate states and measurable outputs Source: §16.10 Program Governance and Peer Review (p. 9281)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for

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configuration-specific regression after a firmware or processing change. Distinguish corrected interpretation from alteration of the original observation Source: §16.10 Program Governance and Peer Review (p. 9281)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Interpret hypothetical receiver records” that resolves the question about configuration-specific regression after a firmware or processing change; derive the relevant result with units and stated validity conditions Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Evidence and method: Specify the native observations, control records and calculations that would resolve configuration-specific regression after a firmware or processing change. Distinguish corrected interpretation from alteration of the original observation Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Worked application or illustrative case: Build a worked example of “configuration-specific regression after a firmware or processing change”, addressing this associated condition: Retain old and new states, select tests for actual deployed functions, rerun representative native records,.... Retain old and new states, select tests for actual deployed functions, rerun representative native records, preserve both derived versions and explain... Source: §16.10 Program Governance and Peer Review (p. 9281)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “configuration-specific regression after a

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firmware or processing change". Using "Interpret hypothetical receiver records", specify a discriminator and the result expected under each explanation Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to configuration-specific regression after a firmware or processing change, including the effect of missing measurements and inconsistent operating conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Scholarly synthesis and implications: Explain what the result about configuration-specific regression after a firmware or processing change authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Closing: Conclude by answering "Develop configuration-specific regression after a firmware or processing change" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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V011-C16-ESSAY-023. Explain why a result that disappears under a challenge is not automatically false.

- Opening: Present a thesis that answers this precise question: Explain why a result that disappears under a challenge is not automatically false. Identify which evidence would falsify the proposed conclusion Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Core terminology and scope: Define disappears, challenge, automatically in the question's particular technical setting; explain how false, measurement, evidence differ if that distinction would change the analysis of "Explain why a result that disappears under a challenge is not automatically false" Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Consider changed sensitivity, passband, impedance, trigger opportunity and coupling Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why a result that disappears under a challenge is not automatically false to the claimed result, following "Preserve comparable observation capability"; name the intermediate states and measurable outputs Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why a result that disappears under a challenge is not automatically false.

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Require mechanism-specific predictions and relevant capability references, preserve the original observation and state the strongest bounded inference Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Write findings that preserve the strength and limit of each test” that resolves the question about why a result that disappears under a challenge is not automatically false; derive the relevant result with units and stated validity conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why a result that disappears under a challenge is not automatically false. Require mechanism-specific predictions and relevant capability references, preserve the original observation and state the strongest bounded inference Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Worked application or illustrative case: Build a worked example of “why a result that disappears under a challenge is not automatically false”, addressing this associated condition: Consider changed sensitivity, passband, impedance, trigger opportunity and coupling. Consider changed sensitivity, passband, impedance, trigger opportunity and coupling Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “why a result that disappears under a

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challenge is not automatically false". Using "Write findings that preserve the strength and limit of each test", specify a discriminator and the result expected under each explanation Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why a result that disappears under a challenge is not automatically false, including the effect of missing measurements and inconsistent operating conditions Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Scholarly synthesis and implications: Explain what the result about why a result that disappears under a challenge is not automatically false authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Closing: Conclude by answering "Explain why a result that disappears under a challenge is not automatically false" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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V011-C16-ESSAY-024. Evaluate common evidence-dependence traps in a multi-output report.

- Opening: Present a thesis that answers this precise question: Evaluate common evidence-dependence traps in a multi-output report. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define common, evidence-dependence, traps in the question's particular technical setting; explain how multi-output, report, measurement differ if that distinction would change the analysis of "Evaluate common evidence-dependence traps in a multi-output report" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use two receivers sharing a clock, spectrum/EVM from one record and two wrappers around one decoder Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting common evidence-dependence traps in a multi-output report to the claimed result, following "Record repetition and the limits of the design"; name the intermediate states and measurable outputs Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for common

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evidence-dependence traps in a multi-output report. Explain the useful but dependent information, avoid unsupported multiplication, and propose an observation that changes the relevant error path Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Write findings that preserve the strength and limit of each test” that resolves the question about common evidence-dependence traps in a multi-output report; derive the relevant result with units and stated validity conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Evidence and method: Specify the native observations, control records and calculations that would resolve common evidence-dependence traps in a multi-output report. Explain the useful but dependent information, avoid unsupported multiplication, and propose an observation that changes the relevant error path Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of “common evidence-dependence traps in a multi-output report”, addressing this associated condition: Use two receivers sharing a clock, spectrum/EVM from one record and two wrappers around one decoder. Use two receivers sharing a clock, spectrum/EVM from one record and two wrappers around one decoder Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “common evidence-dependence traps in a

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multi-output report". Using "Write findings that preserve the strength and limit of each test", specify a discriminator and the result expected under each explanation Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to common evidence-dependence traps in a multi-output report, including the effect of missing measurements and inconsistent operating conditions Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)
- Scholarly synthesis and implications: Explain what the result about common evidence-dependence traps in a multi-output report authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering "Evaluate common evidence-dependence traps in a multi-output report" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-ESSAY-025. Develop a final release decision for a method with some unresolved limits.

- Opening: Present a thesis that answers this precise question: Develop a final release decision for a method with some unresolved limits. Identify which evidence would falsify the proposed conclusion Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Core terminology and scope: Define final, release, decision in the question's particular technical setting; explain how method, unresolved, limits differ if that distinction would change the analysis of "Develop a final release decision for a method with some unresolved limits" Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify which functions remain accepted and which are limited by calibration, discontinuity, automatic state or coverage Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a final release decision for a method with some unresolved limits to the claimed result, following "Write findings that preserve the strength and limit of each test"; name the intermediate states and measurable outputs Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a final

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release decision for a method with some unresolved limits. Narrow the claim while retaining useful supported results, and define regression needed before extending the domain Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Record repetition and the limits of the design” that resolves the question about a final release decision for a method with some unresolved limits; derive the relevant result with units and stated validity conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a final release decision for a method with some unresolved limits. Narrow the claim while retaining useful supported results, and define regression needed before extending the domain Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Worked application or illustrative case: Build a worked example of “a final release decision for a method with some unresolved limits”, addressing this associated condition: Identify which functions remain accepted and which are limited by calibration, discontinuity, automatic state.... Identify which functions remain accepted and which are limited by calibration, discontinuity, automatic state or coverage Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a final release decision for a method with

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some unresolved limits". Using "Record repetition and the limits of the design", specify a discriminator and the result expected under each explanation Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a final release decision for a method with some unresolved limits, including the effect of missing measurements and inconsistent operating conditions Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Scholarly synthesis and implications: Explain what the result about a final release decision for a method with some unresolved limits authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Closing: Conclude by answering "Develop a final release decision for a method with some unresolved limits" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-C16-DISCUSSION-001. A line follows external-like attenuation scaling. What should be claimed and what tested next?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A line follows external-like attenuation scaling. What should be claimed and what tested next?” Put this particular dispute to the panel: A line follows external-like attenuation scaling. What should be claimed and what tested next. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 02. Student A, terminology and scope: Agree the operational meanings of line, follows, attenuation and scaling, claimed, tested in “A line follows external-like attenuation scaling. What should be claimed and what tested next”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A line follows external-like attenuation scaling; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Do not infer authorization or unique external origin Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A line follows external-like attenuation scaling; explain what each record can establish State

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what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Do not infer authorization or unique external origin Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Claim compatibility at the stated plane and uncertainty, retain possible receiver emission through the input path, and select a source/path-discriminating intervention Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A line follows external-like attenuation scaling: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A line follows external-like attenuation scaling; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A line follows external-like attenuation scaling: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings,

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controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A line follows external-like attenuation scaling, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A line follows external-like attenuation scaling: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A line follows external-like attenuation scaling. Do not infer authorization or unique external origin Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A line follows external-like attenuation scaling, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A line follows external-like attenuation scaling. Do not infer authorization or unique external origin Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test

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or uncertainty term that limits confidence. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A line follows external-like attenuation scaling and What should be claimed and what tested next; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A line follows external-like attenuation scaling”, addressing “What should be claimed and what tested next”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A line follows external-like attenuation scaling. What should be claimed and what tested next”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A line follows external-like attenuation scaling. What should be claimed and what tested next”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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V011-C16-DISCUSSION-002. Two receivers show the same line while sharing clock and antenna. Is that independent confirmation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two receivers show the same line while sharing clock and antenna. Is that independent confirmation?” Put this particular dispute to the panel: Two receivers show the same line while sharing clock and antenna. Is that independent confirmation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 02. Student A, terminology and scope: Agree the operational meanings of receivers, line, sharing and clock, antenna, confirmation in “Two receivers show the same line while sharing clock and antenna. Is that independent confirmation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two receivers show the same line while sharing clock and antenna; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Localize an artifact by changing the stage that could create it”. Agreement is useful but may repeat the same instrument or coupling cause Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two receivers show the same line while sharing clock and antenna; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Localize an artifact by changing the stage that could create it”. Agreement is useful but may repeat the same instrument or coupling cause Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Map shared causes and carry suitable references; change a relevant dependency where feasible Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two receivers show the same line while sharing clock and antenna: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two receivers show the same line while sharing clock and antenna; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two receivers show the same line while sharing clock and antenna: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two receivers show the same line while sharing clock and antenna, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two receivers show the same line while sharing clock and antenna: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two receivers show the same line while sharing clock and antenna. Agreement is useful but may repeat the same instrument or coupling cause Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two receivers show the same line while sharing clock and antenna, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two receivers show the same line while sharing clock and antenna. Agreement is useful but may repeat the same

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instrument or coupling cause Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two receivers show the same line while sharing clock and antenna and Is that independent confirmation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two receivers show the same line while sharing clock and antenna”, addressing “Is that independent confirmation”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two receivers show the same line while sharing clock and antenna. Is that independent confirmation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two receivers show the same line while sharing clock and antenna. Is that independent confirmation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-DISCUSSION-003. An antenna termination removes a component. What alternative explanations remain?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An antenna termination removes a component. What alternative explanations remain?” Put this particular dispute to the panel: An antenna termination removes a component. What alternative explanations remain. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 02. Student A, terminology and scope: Agree the operational meanings of antenna, termination, removes and alternative, explanations, remain in “An antenna termination removes a component. What alternative explanations remain”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An antenna termination removes a component; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Preserve the narrow dependence rather than declare unique source identity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An antenna termination removes a component; explain what each record can establish State

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what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Preserve the narrow dependence rather than declare unique source identity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider impedance change, removed external nonlinear elements and input-coupled instrument emissions, with capability checks Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An antenna termination removes a component: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An antenna termination removes a component; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An antenna termination removes a component: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An antenna termination removes a component, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An antenna termination removes a component: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An antenna termination removes a component. Preserve the narrow dependence rather than declare unique source identity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An antenna termination removes a component, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An antenna termination removes a component. Preserve the narrow dependence rather than declare unique source identity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An antenna termination removes a component and What alternative explanations remain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An antenna termination removes a component”, addressing “What alternative explanations remain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An antenna termination removes a component. What alternative explanations remain”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An antenna termination removes a component. What alternative explanations remain”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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V011-C16-DISCUSSION-004. A clock switch and route bypass together remove a line. How should the next experiment be organized?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A clock switch and route bypass together remove a line. How should the next experiment be organized?” Put this particular dispute to the panel: A clock switch and route bypass together remove a line. How should the next experiment be organized. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 02. Student A, terminology and scope: Agree the operational meanings of route, bypass, remove and line, experiment, organized in “A clock switch and route bypass together remove a line. How should the next experiment be organized”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A clock switch and route bypass together remove a line; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. The joint intervention alone cannot separate main and conditional effects Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A clock switch and route bypass together remove a line; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. The joint intervention alone cannot separate main and conditional effects Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Cross the two settings where meaningful, characterize bundled physical changes, retain comparable references and revisit original states Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A clock switch and route bypass together remove a line: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A clock switch and route bypass together remove a line; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A clock switch and route bypass together remove a line: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings,

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controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A clock switch and route bypass together remove a line, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A clock switch and route bypass together remove a line: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A clock switch and route bypass together remove a line. The joint intervention alone cannot separate main and conditional effects Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A clock switch and route bypass together remove a line, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A clock switch and route bypass together remove a line. The joint intervention alone cannot separate main and conditional effects Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A clock switch and route bypass together remove a line and How should the next experiment be organized; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A clock switch and route bypass together remove a line”, addressing “How should the next experiment be organized”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A clock switch and route bypass together remove a line. How should the next experiment be organized”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A clock switch and route bypass together remove a line. How should the next experiment be organized”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

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V011-C16-DISCUSSION-005. Only one of four clock/switch configurations shows the feature. What is the defensible conclusion?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Only one of four clock/switch configurations shows the feature. What is the defensible conclusion?” Put this particular dispute to the panel: Only one of four clock/switch configurations shows the feature. What is the defensible conclusion. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 02. Student A, terminology and scope: Agree the operational meanings of four, configurations, shows and feature, defensible, conclusion in “Only one of four clock/switch configurations shows the feature. What is the defensible conclusion”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Only one of four clock/switch configurations shows the feature; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpret hypothetical receiver records”. Do not claim both components independently emit Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Only one of four clock/switch configurations shows the feature; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpret hypothetical receiver records”. Do not claim both components independently emit Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Report association with that joint state under tested limits, retain levels and reference evidence, and investigate shared paths or state-dependent sensitivity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Only one of four clock/switch configurations

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shows the feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Only one of four clock/switch configurations shows the feature; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Only one of four clock/switch configurations shows the feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Only one of four clock/switch configurations shows the feature, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Only one of four clock/switch configurations shows the feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Only one of four clock/switch configurations shows the feature. Do not claim both components independently emit Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Only one of four clock/switch configurations shows the feature, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Only one of four clock/switch configurations shows the feature. Do not claim both components independently emit Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Only one of four clock/switch configurations shows the feature and What is the defensible conclusion; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Only one of four clock/switch configurations shows the feature”, addressing “What is the defensible conclusion”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Only one of four clock/switch configurations shows the feature. What is the defensible conclusion”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Only one of four clock/switch configurations shows the feature. What is the defensible conclusion”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-DISCUSSION-006. A configuration is unavailable because it cannot maintain reference lock. How should the design be reported?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A configuration is unavailable because it cannot maintain reference lock. How should the design be reported?” Put this particular dispute to the panel: A configuration is unavailable because it cannot maintain reference lock. How should the design be reported. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 02. Student A, terminology and scope: Agree the operational meanings of configuration, unavailable, maintain and lock, design, reported in “A configuration is unavailable because it cannot maintain reference lock. How should the design be reported”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A configuration is unavailable because it cannot maintain reference lock; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. Do not fill the cell by assumption Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A configuration is unavailable because it cannot maintain reference lock; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. Do not fill the cell by assumption Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Mark the missing condition and resulting comparison limit, preserve the other observations and seek a physically meaningful alternative Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A configuration is unavailable because it

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cannot maintain reference lock: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A configuration is unavailable because it cannot maintain reference lock; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A configuration is unavailable because it cannot maintain reference lock: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A configuration is unavailable because it cannot maintain reference lock, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A configuration is unavailable because it cannot maintain reference lock: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A configuration is unavailable because it cannot maintain reference lock. Do not fill the cell by assumption Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A configuration is unavailable because it cannot maintain reference lock, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A configuration is unavailable because it cannot maintain reference lock. Do not fill the cell by assumption Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test

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or uncertainty term that limits confidence. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A configuration is unavailable because it cannot maintain reference lock and How should the design be reported; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A configuration is unavailable because it cannot maintain reference lock”, addressing “How should the design be reported”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A configuration is unavailable because it cannot maintain reference lock. How should the design be reported”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A configuration is unavailable because it cannot maintain reference lock. How should the design be reported”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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V011-C16-DISCUSSION-007. A binary visibility chart suggests a dramatic factor interaction. What raw evidence should be inspected?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A binary visibility chart suggests a dramatic factor interaction. What raw evidence should be inspected?” Put this particular dispute to the panel: A binary visibility chart suggests a dramatic factor interaction. What raw evidence should be inspected. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 02. Student A, terminology and scope: Agree the operational meanings of binary, visibility, suggests and factor, interaction, inspected in “A binary visibility chart suggests a dramatic factor interaction. What raw evidence should be inspected”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A binary visibility chart suggests a dramatic factor interaction; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Reconcile evidence without assigning unsupported probabilities”. Determine whether a sensitivity boundary creates the visible/not-visible pattern Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A binary visibility chart suggests a dramatic factor interaction; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Reconcile evidence without assigning unsupported probabilities”. Determine whether a sensitivity boundary creates the visible/not-visible pattern Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare continuous corrected levels, noise and threshold behavior at a common plane, plus relevant weak references Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A binary visibility chart suggests a dramatic factor interaction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A binary visibility chart suggests a dramatic factor interaction; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A binary visibility chart suggests a dramatic factor interaction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A binary visibility chart suggests a dramatic factor interaction, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A binary visibility chart suggests a dramatic factor interaction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A binary visibility chart suggests a dramatic factor interaction. Determine whether a sensitivity boundary creates the visible/not-visible pattern Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A binary visibility chart suggests a dramatic factor interaction, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A binary visibility chart suggests a dramatic factor interaction. Determine whether a sensitivity boundary creates the visible/not-visible pattern Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A binary visibility chart suggests a dramatic factor interaction and What raw evidence should be inspected; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A binary visibility chart suggests a dramatic factor interaction”, addressing “What raw evidence should be inspected”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A binary visibility chart suggests a dramatic factor interaction. What raw evidence should be inspected”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A binary visibility chart suggests a dramatic factor interaction. What raw evidence should be inspected”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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V011-C16-DISCUSSION-008. A strong CW reference passes in every state but short bursts vanish in one. What is missing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A strong CW reference passes in every state but short bursts vanish in one. What is missing?” Put this particular dispute to the panel: A strong CW reference passes in every state but short bursts vanish in one. What is missing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 02. Student A, terminology and scope: Agree the operational meanings of strong, passes, short and bursts, vanish, missing in “A strong CW reference passes in every state but short bursts vanish in one. What is missing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A strong CW reference passes in every state but short bursts vanish in one; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpret hypothetical receiver records”. The CW check supports only its own steady transfer capability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A strong CW reference passes in every state but short bursts vanish in one; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change

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your opinion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpret hypothetical receiver records”. The CW check supports only its own steady transfer capability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Test burst duration, trigger path, dead time, settling and continuity with a suitable reference Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A strong CW reference passes in every state but short bursts vanish in one: specify the altered receiver state or

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source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A strong CW reference passes in every state but short bursts vanish in one; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A strong CW reference passes in every state but short bursts vanish in one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A strong CW reference passes in every state but short bursts vanish in one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A strong CW reference passes in every state but short bursts vanish in one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A strong CW reference passes in every state

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but short bursts vanish in one. The CW check supports only its own steady transfer capability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A strong CW reference passes in every state but short bursts vanish in one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A strong CW reference passes in every state but short bursts vanish in one. The CW check supports only its own steady transfer capability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that

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limits confidence. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A strong CW reference passes in every state but short bursts vanish in one and What is missing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A strong CW reference passes in every state but short bursts vanish in one”, addressing “What is missing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A strong CW reference passes in every state but short bursts vanish in one. What is missing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A strong CW reference passes in every state but short bursts vanish in one. What is missing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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V011-C16-DISCUSSION-009. A transition-only burst is excluded from all settled analyses. Should it be deleted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A transition-only burst is excluded from all settled analyses. Should it be deleted?” Put this particular dispute to the panel: A transition-only burst is excluded from all settled analyses. Should it be deleted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 02. Student A, terminology and scope: Agree the operational meanings of transition-only, burst, excluded and settled, analyses, deleted in “A transition-only burst is excluded from all settled analyses. Should it be deleted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A

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transition-only burst is excluded from all settled analyses; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Exclusion from one estimator is not evidence that the event is irrelevant Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A transition-only burst is excluded from all settled analyses; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Exclusion from one estimator is not evidence that the event is irrelevant Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; retain transition records, state timing and exclusion reasons, and define a dedicated transient comparison Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A transition-only burst is excluded from all

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settled analyses: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A transition-only burst is excluded from all settled analyses; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A transition-only burst is excluded from all settled analyses: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A transition-only burst is excluded from all settled analyses, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A transition-only burst is excluded from all settled analyses: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A transition-only burst is excluded from all settled analyses. Exclusion from one estimator is not evidence that the event is irrelevant Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A transition-only burst is excluded from all settled analyses, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A transition-only burst is excluded from all settled analyses. Exclusion from one estimator is not evidence that the event is irrelevant Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A transition-only burst is excluded from all settled analyses and Should it be deleted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A transition-only burst is excluded from all settled analyses”, addressing “Should it be deleted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A transition-only burst is excluded from all settled analyses. Should it be deleted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A transition-only burst is excluded from all settled analyses. Should it be deleted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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V011-C16-DISCUSSION-010. A filter removes a high-gain spur. How would you challenge the preferred overload explanation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A filter removes a high-gain spur. How would you challenge the preferred overload explanation?” Put this particular dispute to the panel: A filter removes a high-gain spur. How would you challenge the preferred overload explanation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 02. Student A, terminology and scope: Agree the operational meanings of removes, spur, challenge and preferred, overload, explanation in “A filter removes a high-gain spur. How would you challenge the preferred overload explanation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A filter removes a high-gain spur; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.2 Challenge-Test Design (p. 9258)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Challenge-Test Design”. The filter's multiple physical effects leave alternatives Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.2 Challenge-Test Design (p. 9258)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A filter removes a high-gain spur; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Challenge-Test Design”. The filter's multiple physical effects leave alternatives Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.2 Challenge-Test Design (p. 9258)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Measure admitted parent levels, desired reference and source purity; compare gain states and evaluate mismatch or AGC changes Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A filter removes a high-gain spur: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected

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result, and identify how you would document an unexpected observation. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A filter removes a high-gain spur; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A filter removes a high-gain spur: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A filter removes a high-gain spur, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.2 Challenge-Test Design (p. 9258)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A filter removes a high-gain spur: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A filter removes a high-gain spur. The filter's multiple physical effects leave alternatives Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

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- 14. Student J, Socratic challenge to Student I: For the precise observation involving A filter removes a high-gain spur, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.2 Challenge-Test Design (p. 9258)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A filter removes a high-gain spur. The filter's multiple physical effects leave alternatives Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A filter removes a high-gain spur and How would you challenge the preferred overload explanation; exclude protections irrelevant to the scenario Question Student F about the

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custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A filter removes a high-gain spur”, addressing “How would you challenge the preferred overload explanation”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A filter removes a high-gain spur. How would you challenge the preferred overload explanation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A filter removes a high-gain spur. How would you challenge the preferred overload explanation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an

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unsupported assertion. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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V011-C16-DISCUSSION-011. A stricter decoder was tuned until suspicious identifiers disappeared. How should validation proceed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A stricter decoder was tuned until suspicious identifiers disappeared. How should validation proceed?” Put this particular dispute to the panel: A stricter decoder was tuned until suspicious identifiers disappeared. How should validation proceed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 02. Student A, terminology and scope: Agree the operational meanings of stricter, decoder, tuned and suspicious, identifiers, validation in “A stricter decoder was tuned until suspicious identifiers disappeared. How should validation proceed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A stricter decoder was tuned until suspicious identifiers disappeared; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Do not infer field-event origin from training success Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A stricter decoder was tuned until suspicious identifiers disappeared; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Do not infer field-event origin from training success Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use independently retained valid and noise-only records under both rules, disclose fitted choices and preserve outputs Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A stricter decoder was tuned until suspicious identifiers disappeared: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A stricter decoder was tuned until suspicious identifiers disappeared; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A stricter decoder was tuned until suspicious identifiers disappeared: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a

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rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A stricter decoder was tuned until suspicious identifiers disappeared, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A stricter decoder was tuned until suspicious identifiers disappeared: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A stricter decoder was tuned until suspicious identifiers disappeared. Do not infer field-event origin from training success Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A stricter decoder was tuned until suspicious identifiers disappeared, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A stricter decoder was tuned until suspicious identifiers disappeared. Do not infer field-event origin from training success Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A stricter decoder was tuned until suspicious identifiers disappeared and How should validation proceed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A stricter decoder was tuned until suspicious identifiers disappeared”, addressing “How should validation proceed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A stricter decoder was tuned until suspicious identifiers disappeared. How should validation proceed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A stricter decoder was tuned until suspicious identifiers disappeared. How should validation proceed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

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V011-C16-DISCUSSION-012. An analyst counts ten re-plots as ten replications. What correction is needed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An analyst counts ten re-plots as ten replications. What correction is needed?” Put this particular dispute to the panel: An analyst counts ten re-plots as ten replications. What correction is needed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 02. Student A, terminology and scope: Agree the operational meanings of analyst, counts, re-plots and replications, correction, measurement in “An analyst counts ten re-plots as ten replications. What correction is needed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An analyst counts ten re-plots as ten replications; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Record repetition and the limits of the design”. Use actual independent or modeled repetitions to assess variability and retain the original source identity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst counts ten re-plots as ten replications; explain what each record can establish State what the existing record establishes, what it does not establish, and

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which further measurement would change your opinion. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Record repetition and the limits of the design”. Use actual independent or modeled repetitions to assess variability and retain the original source identity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Distinguish presentation/analysis repetitions from fresh acquisitions revisiting the physical state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An analyst counts ten re-plots as ten

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replications: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An analyst counts ten re-plots as ten replications; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An analyst counts ten re-plots as ten replications: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the

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proposed test. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An analyst counts ten re-plots as ten replications, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An analyst counts ten re-plots as ten replications: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An analyst counts ten re-plots as ten

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replications. Use actual independent or modeled repetitions to assess variability and retain the original source identity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An analyst counts ten re-plots as ten replications, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An analyst counts ten re-plots as ten replications. Use actual independent or modeled repetitions to assess variability and retain the original source identity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test

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or uncertainty term that limits confidence. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An analyst counts ten re-plots as ten replications and What correction is needed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An analyst counts ten re-plots as ten replications”, addressing “What correction is needed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An analyst counts ten re-plots as ten replications. What correction is needed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An analyst counts ten re-plots as ten replications. What correction is needed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.26 Interpreting extracted I/Q features without confusing waveform identity, source identity and transmitted information (p. 9315)

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V011-C16-DISCUSSION-013. All alternate-clock runs occur after the room temperature rises. What design issue arises?

- 01. Moderator, opening proposition: Introduce the exact dispute, “All alternate-clock runs occur after the room temperature rises. What design issue arises?” Put this particular dispute to the panel: All alternate-clock runs occur after the room temperature rises. What design issue arises. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 02. Student A, terminology and scope: Agree the operational meanings of runs, occur, room and rises, issue, arises in “All alternate-clock runs occur after the room temperature rises. What design issue arises”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of All alternate-clock runs occur after the room temperature rises; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. Use interleaved or blocked comparisons where possible, retain order and temperature, and state limits if the missing contrast cannot be obtained Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of All alternate-clock runs occur

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after the room temperature rises; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. Use interleaved or blocked comparisons where possible, retain order and temperature, and state limits if the missing contrast cannot be obtained Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Clock setting and temporal/environmental change are associated Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving All alternate-clock runs occur after the room temperature rises: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of All alternate-clock runs occur after the room temperature rises; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving All alternate-clock runs occur after the room temperature rises: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving All alternate-clock runs occur after the room temperature rises, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving All alternate-clock runs occur after the room temperature rises: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for All alternate-clock runs occur after the room temperature rises. Use interleaved or blocked comparisons where possible, retain order and temperature, and state limits if the missing contrast cannot be obtained Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving All alternate-clock runs occur after the room temperature rises, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for All alternate-clock runs occur after the room temperature rises. Use interleaved or blocked comparisons where possible, retain order and temperature, and state limits if the

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missing contrast cannot be obtained Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about All alternate-clock runs occur after the room temperature rises and What design issue arises; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “All alternate-clock runs occur after the room temperature rises”, addressing “What design issue arises”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “All alternate-clock runs occur after the room temperature rises. What design issue arises”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “All alternate-clock runs occur after the room temperature rises. What design issue arises”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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V011-C16-DISCUSSION-014. Access restrictions prevent random order. Does that make the work unusable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Access restrictions prevent random order. Does that make the work unusable?” Put this particular dispute to the panel: Access restrictions prevent random order. Does that make the work unusable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 02. Student A, terminology and scope: Agree the operational meanings of Access, restrictions, prevent and random, make, work in “Access restrictions prevent random order. Does that make the work unusable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Access

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restrictions prevent random order; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Do not claim randomization that did not occur Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Access restrictions prevent random order; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Do not claim randomization that did not occur Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Not necessarily; document the restriction, identify possible confounding, preserve within-block comparisons and narrow conclusions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Access restrictions prevent random order: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-

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examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Access restrictions prevent random order; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Access restrictions prevent random order: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Access restrictions prevent random order, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Access restrictions prevent random order: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Access restrictions prevent random order. Do not claim randomization that did not occur Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a

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single unqualified reading. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Access restrictions prevent random order, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Access restrictions prevent random order. Do not claim randomization that did not occur Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the

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particular claim about Access restrictions prevent random order and Does that make the work unusable; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Access restrictions prevent random order”, addressing “Does that make the work unusable”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Access restrictions prevent random order. Does that make the work unusable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Access restrictions prevent random order. Does that make the work

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unusable". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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V011-C16-DISCUSSION-015. Two sessions contain many replicates but only one clock state each. Can more averaging solve attribution?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two sessions contain many replicates but only one clock state each. Can more averaging solve attribution?” Put this particular dispute to the panel: Two sessions contain many replicates but only one clock state each. Can more averaging solve attribution. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 02. Student A, terminology and scope: Agree the operational meanings of sessions, contain, clock and averaging, solve, attribution in “Two sessions contain many replicates but only one clock state each. Can more averaging solve attribution”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two sessions contain many replicates but only one clock state each; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. Obtain meaningful additional combinations or report the confound rather than assigning the difference to the clock Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two sessions contain many

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replicates but only one clock state each; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Arrange the comparisons before examining their outcomes”. Obtain meaningful additional combinations or report the confound rather than assigning the difference to the clock Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; the missing crossed session/state comparison remains Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two sessions contain many replicates but only one clock state each: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two sessions contain many replicates but only one clock state each; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two sessions contain many replicates but only one clock state each: specify the altered receiver state or source condition, predicted change, test statistic and

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rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two sessions contain many replicates but only one clock state each, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two sessions contain many replicates but only one clock state each: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two sessions contain many replicates but only one clock state each. Obtain meaningful additional combinations or report the confound rather than assigning the difference to the clock Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two sessions contain many replicates but only one clock state each, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two sessions contain many replicates but only one clock state each. Obtain meaningful additional combinations or report the confound rather than assigning the difference to the clock Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two sessions contain many replicates but only one clock state each and Can more averaging solve attribution; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.25 An enforceable quality-release rule for the instrument and the report (p. 9313)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two sessions contain many replicates but only one clock state each”, addressing “Can more averaging solve attribution”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two sessions contain many replicates but only one clock state each. Can more averaging solve attribution”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two sessions contain many replicates but only one clock state each. Can more averaging solve attribution”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-DISCUSSION-016. An optical sensor and RF receiver respond during keyboard use. What must be reconciled?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An optical sensor and RF receiver respond during keyboard use. What must be reconciled?” Put this particular dispute to the panel: An optical sensor and RF receiver respond during keyboard use. What must be reconciled. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 02. Student A, terminology and scope: Agree the operational meanings of optical, sensor, receiver and respond, keyboard, reconciled in “An optical sensor and RF receiver respond during keyboard use. What must be reconciled”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An optical sensor and RF receiver respond during keyboard use; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “An evidence-closure matrix that links physical tests to permissible forensic propositions”. Optical activity alone does not establish an RF information path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An optical sensor and RF receiver respond during keyboard use; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “An evidence-closure matrix that links physical tests to permissible forensic propositions”. Optical activity alone does not establish an RF information path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Their direct observables, clock/state alignment, shared dependencies and possible common control Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An optical sensor and RF receiver respond during keyboard use: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An optical sensor and RF receiver respond during keyboard use; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An optical sensor and RF receiver respond during keyboard use: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An optical sensor and RF receiver respond during keyboard use, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An optical sensor and RF receiver respond during keyboard use: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An optical sensor and RF receiver respond during keyboard use. Optical activity alone does not establish an RF information path Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An optical sensor and RF receiver respond during keyboard use, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An optical sensor and RF receiver respond during keyboard use. Optical activity alone does not establish an RF

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information path Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An optical sensor and RF receiver respond during keyboard use and What must be reconciled; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An optical sensor and RF receiver respond during keyboard use”, addressing “What must be reconciled”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An optical sensor and RF receiver respond during keyboard use. What must be reconciled”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An optical sensor and RF receiver respond during keyboard use. What must be reconciled”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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V011-C16-DISCUSSION-017. A report calls a waveform a confirmed surveillance function based on frequency and modulation. What evidence is missing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A report calls a waveform a confirmed surveillance function based on frequency and modulation. What evidence is missing?” Put this particular dispute to the panel: A report calls a waveform a confirmed surveillance function based on frequency and modulation. What evidence is missing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 02. Student A, terminology and scope: Agree the operational meanings of calls, confirmed, surveillance and function, based, missing in “A report calls a waveform a confirmed surveillance function based on frequency and modulation. What evidence is missing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A report calls a waveform a confirmed surveillance function based on frequency and modulation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integration with Direction, Wireline, Optical, and Physical Evidence”. Use a narrower finding category until those links are demonstrated Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A report calls a waveform a

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confirmed surveillance function based on frequency and modulation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integration with Direction, Wireline, Optical, and Physical Evidence”. Use a narrower finding category until those links are demonstrated Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Physical or operational linkage, information path, authorization status, reproducibility and continuity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A report calls a waveform a confirmed surveillance function based on frequency and modulation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A report calls a waveform a confirmed surveillance function based on frequency and modulation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A report calls a waveform a confirmed surveillance function based on frequency and

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modulation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A report calls a waveform a confirmed surveillance function based on frequency and modulation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A report calls a waveform a confirmed surveillance function based on frequency and modulation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A report calls a waveform a confirmed surveillance function based on frequency and modulation. Use a narrower finding category until those links are demonstrated Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A report calls a waveform a confirmed surveillance function based on frequency and modulation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A report calls a waveform a confirmed surveillance function based on frequency and modulation. Use a narrower finding category until those links are demonstrated Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A report calls a waveform a confirmed surveillance function based on frequency and modulation and What evidence is missing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A report calls a waveform a confirmed surveillance function based on frequency and modulation”, addressing “What evidence is missing”; specify the exact

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measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A report calls a waveform a confirmed surveillance function based on frequency and modulation. What evidence is missing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A report calls a waveform a confirmed surveillance function based on frequency and modulation. What evidence is missing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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V011-C16-DISCUSSION-018. A corrected difference exceeds its uncertainty. May the report name compression as the cause?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A corrected difference exceeds its uncertainty. May the report name compression as the cause?” Put this particular dispute to the panel: A corrected difference exceeds its uncertainty. May the report name compression as the cause. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 02. Student A, terminology and scope: Agree the operational meanings of corrected, difference, exceeds and report, compression, cause in “A corrected difference exceeds its uncertainty. May the report name compression as the cause”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A corrected difference exceeds its uncertainty; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Preserve the discrepancy, examine gain control, products and calibration scope, and avoid cause identification from magnitude alone Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A corrected difference exceeds its uncertainty; explain what each record can establish State what

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the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Preserve the discrepancy, examine gain control, products and calibration scope, and avoid cause identification from magnitude alone Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Only as a hypothesis until stage/state controls discriminate alternatives Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A corrected difference exceeds its uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A corrected difference exceeds its uncertainty; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A corrected difference exceeds its uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H

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to identify an alternative that could survive the proposed test. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A corrected difference exceeds its uncertainty, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A corrected difference exceeds its uncertainty: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A corrected difference exceeds its

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uncertainty. Preserve the discrepancy, examine gain control, products and calibration scope, and avoid cause identification from magnitude alone Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A corrected difference exceeds its uncertainty, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A corrected difference exceeds its uncertainty. Preserve the discrepancy, examine gain control, products and calibration scope, and avoid cause identification from magnitude alone Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A corrected difference exceeds its uncertainty and May the report name compression as the cause; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A corrected difference exceeds its uncertainty”, addressing “May the report name compression as the cause”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A corrected difference exceeds its uncertainty. May the report name compression as the cause”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A corrected difference exceeds its uncertainty. May the report name compression as the cause”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

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V011-C16-DISCUSSION-019. A reviewer suggests multiplying five favorable-test scores into odds. What should be required?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reviewer suggests multiplying five favorable-test scores into odds. What should be required?” Put this particular dispute to the panel: A reviewer suggests multiplying five favorable-test scores into odds. What should be required. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 02. Student A, terminology and scope: Agree the operational meanings of reviewer, suggests, multiplying and five, scores, odds in “A reviewer suggests multiplying five favorable-test scores into odds. What should be required”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reviewer suggests multiplying five favorable-test scores into odds; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Record repetition and the limits of the design”. Without them, report discriminating consequences and unresolved alternatives directly Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer suggests multiplying five favorable-test scores into odds; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Record repetition and the limits of the design”. Without them, report discriminating consequences and unresolved alternatives directly Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Defined hypotheses and defensible likelihood models including dependence and selection Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A reviewer suggests multiplying five favorable-

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test scores into odds: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reviewer suggests multiplying five favorable-test scores into odds; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reviewer suggests multiplying five favorable-test scores into odds: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reviewer suggests multiplying five favorable-test scores into odds, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A reviewer suggests multiplying five favorable-test scores into odds: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reviewer suggests multiplying five favorable-test scores into odds. Without them, report discriminating consequences and unresolved alternatives directly Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reviewer suggests multiplying five favorable-test scores into odds, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reviewer suggests multiplying five favorable-test scores into odds. Without them, report discriminating consequences and unresolved alternatives directly Respond point by point to Student J. Distinguish a verified observation from a

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conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reviewer suggests multiplying five favorable-test scores into odds and What should be required; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reviewer suggests multiplying five favorable-test scores into odds”, addressing “What should be required”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reviewer suggests multiplying five favorable-test scores into odds. What should be required”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reviewer suggests multiplying five favorable-test scores into odds. What should be required”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-DISCUSSION-020. A spectrum and demodulation-quality plot support the same finding. How should their evidential relation be stated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A spectrum and demodulation-quality plot support the same finding. How should their evidential relation be stated?” Put this particular dispute to the panel: A spectrum and demodulation-quality plot support the same finding. How should their evidential relation be stated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 02. Student A, terminology and scope: Agree the operational meanings of spectrum, plot, support and finding, evidential, relation in “A spectrum and demodulation-quality plot support the same finding. How should their evidential relation be stated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A spectrum and demodulation-quality plot support the same finding; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Identify their shared native samples and processing dependencies, explain complementary measurements, and avoid counting them as independent observations solely from output labels Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A spectrum and demodulation-quality plot support the same finding; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Identify their shared native samples and processing dependencies, explain complementary measurements, and avoid counting them as independent observations solely from output labels Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify their shared native samples and processing dependencies, explain complementary measurements, and avoid counting them as independent observations solely from output labels Put two specific questions to Student D about the stated competing options and the

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instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A spectrum and demodulation-quality plot support the same finding: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A spectrum and demodulation-quality plot support the same finding; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A spectrum and demodulation-quality plot support the same finding: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A spectrum and demodulation-quality plot support the same finding, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A spectrum and demodulation-quality plot support the same

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finding: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A spectrum and demodulation-quality plot support the same finding. Identify their shared native samples and processing dependencies, explain complementary measurements, and avoid counting them as independent observations solely from output labels Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A spectrum and demodulation-quality plot support the same finding, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A spectrum and demodulation-quality plot support the same finding. Identify their shared native samples and processing dependencies, explain complementary measurements, and avoid counting them as independent observations solely from output labels Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A spectrum and demodulation-quality plot support the same finding and How should their evidential relation be stated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A spectrum and demodulation-quality plot support the same finding”, addressing “How should their evidential relation be stated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A spectrum and demodulation-quality plot support the same finding. How should their evidential relation be stated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A spectrum and demodulation-quality plot support the same finding. How should their evidential relation be stated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-C16-DISCUSSION-021. A closing reference fails after an important observation. How should the finding change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A closing reference fails after an important observation. How should the finding change?” Put this particular dispute to the panel: A closing reference fails after an important observation. How should the finding change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 02. Student A, terminology and scope: Agree the operational meanings of closing, reference, fails and important, observation, finding in “A closing reference fails after an important observation. How should the finding change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A closing reference fails after an important observation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.14 Challenge-Test and Evidence Release Gate (p. 9286)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Challenge-Test and Evidence Release Gate”. Do not discard the failure or apply unsupported blanket correction Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.14 Challenge-Test and Evidence Release Gate (p. 9286)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A closing reference fails after an important observation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Challenge-Test and Evidence Release Gate”. Do not discard the failure or apply unsupported blanket correction Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.14 Challenge-Test and Evidence Release Gate (p. 9286)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the affected function and last valid state, preserve data and checks, then narrow, repeat or qualify dependent conclusions according to evidence Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A closing reference fails after an important

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observation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A closing reference fails after an important observation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A closing reference fails after an important observation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A closing reference fails after an important observation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.14 Challenge-Test and Evidence Release Gate (p. 9286)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A closing reference fails after an important observation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A closing reference fails after an important

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observation. Do not discard the failure or apply unsupported blanket correction Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A closing reference fails after an important observation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.14 Challenge-Test and Evidence Release Gate (p. 9286)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A closing reference fails after an important observation. Do not discard the failure or apply unsupported blanket correction Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits

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confidence. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A closing reference fails after an important observation and How should the finding change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A closing reference fails after an important observation”, addressing “How should the finding change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A closing reference fails after an important observation. How should the finding change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A closing reference fails after an important observation. How should the finding change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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V011-C16-DISCUSSION-022. A technical reviewer disagrees with the preferred explanation. What is a constructive resolution?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A technical reviewer disagrees with the preferred explanation. What is a constructive resolution?” Put this particular dispute to the panel: A technical reviewer disagrees with the preferred explanation. What is a constructive resolution. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

- 02. Student A, terminology and scope: Agree the operational meanings of technical, reviewer, disagrees and preferred, explanation, resolution in “A technical reviewer disagrees with the preferred explanation. What is a constructive resolution”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A technical reviewer disagrees with the preferred explanation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Editorial agreement cannot substitute for evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A technical reviewer disagrees with the preferred explanation; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Editorial agreement cannot substitute for evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Provide native evidence and model assumptions, identify the discriminating disagreement, obtain further tests where authorized or disclose the limit Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A technical reviewer disagrees with the preferred explanation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A technical reviewer disagrees with the preferred explanation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A technical reviewer disagrees with the preferred explanation: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A technical reviewer disagrees with the preferred explanation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A technical reviewer disagrees with the preferred explanation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A technical reviewer disagrees with the preferred explanation. Editorial agreement cannot substitute for evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A technical reviewer disagrees with the preferred explanation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A technical reviewer disagrees with the preferred explanation. Editorial agreement cannot substitute for evidence Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A technical reviewer disagrees with the preferred explanation and What is a constructive resolution; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A technical reviewer disagrees with the preferred explanation”, addressing “What is a constructive resolution”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A technical reviewer disagrees with the preferred explanation. What is a constructive resolution”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A technical reviewer disagrees with the preferred explanation. What is a constructive resolution”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.23 Probabilistic evidence must preserve conditional assumptions (p. 9307)

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V011-C16-DISCUSSION-023. A firmware update preserves a startup self-test but changes reported EVM. What should regression retain?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A firmware update preserves a startup self-test but changes reported EVM. What should regression retain?” Put this particular dispute to the panel: A firmware update preserves a startup self-test but changes reported EVM. What should regression retain. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 02. Student A, terminology and scope: Agree the operational meanings of firmware, update, preserves and startup, reported, regression in “A firmware update preserves a startup self-test but changes reported EVM. What should regression retain”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A firmware update preserves a startup self-test but changes reported EVM; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Acceptance, Maintenance, and Lifecycle Control”. A startup test does not cover every measurement function Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A firmware update preserves a startup self-test but changes reported EVM; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change

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your opinion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Acceptance, Maintenance, and Lifecycle Control”. A startup test does not cover every measurement function Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Old/new configurations, accepted references, exact processing and representative native inputs; compare both derived outputs and explain changed alignment or correction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A firmware update preserves a startup self-

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test but changes reported EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A firmware update preserves a startup self-test but changes reported EVM; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A firmware update preserves a startup self-test but changes reported EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A firmware update preserves a startup self-test but changes reported EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A firmware update preserves a startup self-test but changes reported EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A firmware update preserves a startup self-test but changes reported EVM. A startup test does not cover every measurement function Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A firmware update preserves a startup self-test but changes reported EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A firmware update preserves a startup self-test but changes reported EVM. A startup test does not cover every measurement function Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A firmware update preserves a startup self-test but changes reported EVM and What should regression retain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A firmware update preserves a startup self-test but changes reported EVM”, addressing “What should regression retain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A firmware update preserves a startup self-test but changes reported EVM. What should regression retain”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A firmware update preserves a startup self-test but changes reported EVM. What should regression retain”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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V011-C16-DISCUSSION-024. One established artifact becomes a blanket exclusion rule for all future surveys. What should be reconsidered?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One established artifact becomes a blanket exclusion rule for all future surveys. What should be reconsidered?” Put this particular dispute to the panel: One established artifact becomes a blanket exclusion rule for all future surveys. What should be reconsidered. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 02. Student A, terminology and scope: Agree the operational meanings of established, artifact, blanket and exclusion, future, surveys in “One established artifact becomes a blanket exclusion rule for all future surveys. What should be reconsidered”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One established artifact becomes a blanket exclusion rule for all future surveys; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Program Governance and Peer Review”. A reusable artifact record should guide testing without turning one incident into universal doctrine Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One established artifact becomes a blanket exclusion rule for all future surveys; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Program Governance and Peer Review”. A reusable artifact record should guide testing without turning one incident into universal doctrine Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Recover the tested configurations, stimulus and mechanism, require applicability checks and preserve alternatives Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving One established artifact becomes a blanket exclusion rule for all future surveys: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One established artifact becomes a blanket exclusion rule for all future surveys; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One established artifact becomes a blanket exclusion rule for all future surveys: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One established artifact becomes a blanket exclusion rule for all future surveys, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One established artifact becomes a blanket exclusion rule for all future surveys: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One established artifact becomes a blanket exclusion rule for all future surveys. A reusable artifact record should guide testing without turning one incident into universal doctrine Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One established artifact becomes a blanket exclusion rule for all future surveys, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One established artifact becomes a blanket exclusion rule for all future surveys. A reusable artifact record should guide testing without turning one incident into universal

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doctrine Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One established artifact becomes a blanket exclusion rule for all future surveys and What should be reconsidered; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One established artifact becomes a blanket exclusion rule for all future surveys”, addressing “What should be reconsidered”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One established artifact becomes a blanket exclusion rule for all future surveys. What should be reconsidered”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One established artifact becomes a blanket exclusion rule for all future surveys. What should be reconsidered”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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V011-C16-DISCUSSION-025. The method is valid for conducted steady signals but not yet for short bursts after retune. How should release be bounded?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The method is valid for conducted steady signals but not yet for short bursts after retune. How should release be bounded?” Put this particular dispute to the panel: The method is valid for conducted steady signals but not yet for short bursts after retune. How should release be bounded. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 02. Student A, terminology and scope: Agree the operational meanings of method, conducted, steady and bursts, retune, release in “The method is valid for conducted steady signals but not yet for short bursts after retune. How should release be bounded”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The method is valid for conducted steady signals but not yet for short bursts after retune; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Useful narrower results need not be overstated as universal capability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of The method is valid for conducted steady signals but not yet for short bursts after retune; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Useful narrower results need not be overstated as universal capability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the accepted steady-signal domain and explicit timing/coverage limitation, retain needed references and define further validation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The method is valid for conducted steady signals but not yet for short bursts after retune: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The method is valid for conducted steady signals but not yet for short bursts after retune; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The method is valid for

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conducted steady signals but not yet for short bursts after retune: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The method is valid for conducted steady signals but not yet for short bursts after retune, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The method is valid for conducted steady signals but not yet for short bursts after retune: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The method is valid for conducted steady signals but not yet for short bursts after retune. Useful narrower results need not be overstated as universal capability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The method is valid for conducted steady signals but not yet for short bursts after retune, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The method is valid for conducted steady signals but not yet for short bursts after retune. Useful narrower results need not be overstated as universal capability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The method is valid for conducted steady signals but not yet for short bursts after retune and How should release be bounded; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.25 An enforceable quality-release rule for the instrument and the report (p. 9313)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The method is valid for conducted steady signals but not yet for short bursts after retune”, addressing “How should release be bounded”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The method is valid for conducted steady signals but not yet for short bursts after retune. How should release be bounded”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The method is valid for conducted steady signals but not yet for short bursts after retune. How should release be bounded”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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Chapter 16 Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-C16-ESSAY-001 — Map plausible sources before and after controls, specify at least two competing predictions, preserve desired references, and include unsuccessful tests. Distinguish conditional movement or scaling from unique source attribution.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-C16-ESSAY-002 — Reconstruct −83.2 dBm and signed −0.2 dB from the chapter example, compare with 0.7 dB uncertainty, and explain compatible external-like pathways including receiver leakage entering through the input. Require additional linkage for attribution.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

V011-C16-ESSAY-003 — Map shared antennas, clocks, power, software and corrections; carry a suitable reference through both paths; compare noise, bandwidth and timing. State what agreement or disappearance can support under the demonstrated scope.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-C16-ESSAY-004 — Describe physical changes in each factor, all four meaningful combinations, fixed response plane and criterion, known-reference checks, actual order and missing states. Explain conditional effects without assigning unsupported component causation.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-ESSAY-005 — Show how the effect of one factor can depend on another, discuss joint coupling, sensitivity/blocker behavior and third-condition confounding, and propose independent follow-ups that distinguish these alternatives.

Review: Chapter 16 — Receiver challenges with interacting controls.

V011-C16-ESSAY-006 — Match references to frequency mapping, relevant level, bandwidth, timing, trigger and record continuity. Explain why a strong CW check cannot support every negative observation and retain state-specific corrections and limits.

Review: Chapter 16 — Preserve comparable observation capability.

V011-C16-ESSAY-007 — Record relocking, switch impulses and recovery history, use validated usable intervals, and retain excluded transition records. If the feature occurs only during a transition, define a dedicated criterion rather than erase it.

Review: Chapter 16 — Preserve comparable observation capability.

V011-C16-ESSAY-008 — State the joint association under preserved capability, retain measured levels and observation limits, revisit original states, and propose reference/return-path tests. Explain why neither independent causation by both components nor universal absence follows.

Review: Chapter 16 — Interpret hypothetical receiver records.

V011-C16-ESSAY-009 — Connect admitted parents and gain to a plausible loading mechanism, check actual parent levels and source/combiner purity, and control mismatch and gain trajectory. Use four-state evidence to narrow hypotheses without uniquely assigning a stage.

Review: Chapter 16 — Interpret hypothetical receiver records.

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V011-C16-ESSAY-010 — Retain permissive/strict outputs on field, valid-reference and independent noise-only records. Explain fitted versus held-out data and why rule changes cannot retrospectively establish the origin of every field event.

Review: Chapter 16 — Interpret hypothetical receiver records.

V011-C16-ESSAY-011 — Define fresh intervention acquisitions, order control against drift, and grouping under nuisance conditions. Explain restricted order, retained group membership and why replotting or overlapping windows are not physical replication.

Review: Chapter 16 — Record repetition and the limits of the design.

V011-C16-ESSAY-012 — Show why within-session repetition cannot separate the effects, identify meaningful missing combinations, and propose a feasible crossed/blocking plan. If unavailable, state the unresolved comparison without imputing results.

Review: Chapter 16 — Record repetition and the limits of the design.

V011-C16-ESSAY-013 — Define each direct observable, reconcile time and state, identify common clocks/power/software and seek changes in error structure. Discuss multipath and phase centers where localization is used and avoid treating sensor count as independence.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

V011-C16-ESSAY-014 — Distinguish classification, temporal correlation, localization, device linkage and authorization. Specify physical/operational linkage, information path, reproducibility and evidence continuity needed for the strongest claim and retain intermediate categories.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-C16-ESSAY-015 — Define corrected same-plane differences and their covariance-aware uncertainty, then state the separate requirements for a likelihood ratio, including hypotheses, positive denominator, dependence and selection. Explain why a discrepancy or favorable-test count is not attribution odds.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-C16-ESSAY-016 — Use terminated input, known reference and noise-only processing with their distinct scopes. Bracket the actual observation, retain failures and checks after changes, and explain what none of the controls establishes universally.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-C16-ESSAY-017 — Organize question, accepted native records, configuration, calculation, challenges and inference. Retain units, planes, normalization and uncertainty, name competing explanations, and prioritize the next discriminating test with omission limits.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

V011-C16-ESSAY-018 — Identify exhibiting states, known stimulus or transition, predicted and observed response, successful challenge and mitigation. Include reproduction instructions and applicability limits so a later examiner can test whether the mechanism recurs.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-ESSAY-019 — Cover relevant amplitude/noise, conversion, dynamic range, images/spurs, timing, sample continuity, trigger, metadata and external path. Use stable references after consequential changes and retain calibration, repairs, software and correction history.

Review: Chapter 16 — Acceptance, Maintenance, and Lifecycle Control.

V011-C16-ESSAY-020 — Provide native data, configurations, calculations, calibration, challenges and alternatives; ask reviewers to reconstruct claims and limits. Resolve disagreement through further tests or explicit limitations, preserving errors and reversals rather than enforcing narrative consensus.

Review: Chapter 16 — Program Governance and Peer Review.

V011-C16-ESSAY-021 — Separate RF and optical direct observations, identify the joint intervention and shared dependencies, then propose separate crossed factors, reversals and a suitable known-reference test. State the provisional artifact hypothesis and remaining attribution limits.

Review: Chapter 16 — Hypothetical Case Adjudication: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

V011-C16-ESSAY-022 — Retain old and new states, select tests for actual deployed functions, rerun representative native records, preserve both derived versions and explain differences. Distinguish corrected interpretation from alteration of the original observation.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-C16-ESSAY-023 — Consider changed sensitivity, passband, impedance, trigger opportunity and coupling. Require mechanism-specific predictions and relevant capability references, preserve the original observation and state the strongest bounded inference.

Review: Chapter 16 — Challenge-Test and Evidence Release Gate.

V011-C16-ESSAY-024 — Use two receivers sharing a clock, spectrum/EVM from one record and two wrappers around one decoder. Explain the useful but dependent information, avoid unsupported multiplication, and propose an observation that changes the relevant error path.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-C16-ESSAY-025 — Identify which functions remain accepted and which are limited by calibration, discontinuity, automatic state or coverage. Narrow the claim while retaining useful supported results, and define regression needed before extending the domain.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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Discussion Guidance

V011-C16-DISCUSSION-001 — Claim compatibility at the stated plane and uncertainty, retain possible receiver emission through the input path, and select a source/path-discriminating intervention. Do not infer authorization or unique external origin.

Review: Chapter 16 — Hypothetical Applied Calculation: Receiver Artifacts, Challenge Tests, Survey Integration, Reporting, and Lifecycle Governance.

V011-C16-DISCUSSION-002 — Map shared causes and carry suitable references; change a relevant dependency where feasible. Agreement is useful but may repeat the same instrument or coupling cause.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-C16-DISCUSSION-003 — Consider impedance change, removed external nonlinear elements and input-coupled instrument emissions, with capability checks. Preserve the narrow dependence rather than declare unique source identity.

Review: Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-C16-DISCUSSION-004 — Cross the two settings where meaningful, characterize bundled physical changes, retain comparable references and revisit original states. The joint intervention alone cannot separate main and conditional effects.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-C16-DISCUSSION-005 — Report association with that joint state under tested limits, retain levels and reference evidence, and investigate shared paths or state-dependent sensitivity. Do not claim both components independently emit.

Review: Chapter 16 — Interpret hypothetical receiver records.

V011-C16-DISCUSSION-006 — Mark the missing condition and resulting comparison limit, preserve the other observations and seek a physically meaningful alternative. Do not fill the cell by assumption.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

V011-C16-DISCUSSION-007 — Compare continuous corrected levels, noise and threshold behavior at a common plane, plus relevant weak references. Determine whether a sensitivity boundary creates the visible/not-visible pattern.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes.

V011-C16-DISCUSSION-008 — Test burst duration, trigger path, dead time, settling and continuity with a suitable reference. The CW check supports only its own steady transfer capability.

Review: Chapter 16 — Preserve comparable observation capability.

V011-C16-DISCUSSION-009 — No; retain transition records, state timing and exclusion reasons, and define a dedicated transient comparison. Exclusion from one estimator is not evidence that the event is irrelevant.

Review: Chapter 16 — Preserve comparable observation capability.

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V011-C16-DISCUSSION-010 — Measure admitted parent levels, desired reference and source purity; compare gain states and evaluate mismatch or AGC changes. The filter's multiple physical effects leave alternatives.

Review: Chapter 16 — Interpret hypothetical receiver records.

V011-C16-DISCUSSION-011 — Use independently retained valid and noise-only records under both rules, disclose fitted choices and preserve outputs. Do not infer field-event origin from training success.

Review: Chapter 16 — Interpret hypothetical receiver records.

V011-C16-DISCUSSION-012 — Distinguish presentation/analysis repetitions from fresh acquisitions revisiting the physical state. Use actual independent or modeled repetitions to assess variability and retain the original source identity.

Review: Chapter 16 — Record repetition and the limits of the design.

V011-C16-DISCUSSION-013 — Clock setting and temporal/environmental change are associated. Use interleaved or blocked comparisons where possible, retain order and temperature, and state limits if the missing contrast cannot be obtained.

Review: Chapter 16 — Record repetition and the limits of the design.

V011-C16-DISCUSSION-014 — Not necessarily; document the restriction, identify possible confounding, preserve within-block comparisons and narrow conclusions. Do not claim randomization that did not occur.

Review: Chapter 16 — Record repetition and the limits of the design.

V011-C16-DISCUSSION-015 — No; the missing crossed session/state comparison remains. Obtain meaningful additional combinations or report the confound rather than assigning the difference to the clock.

Review: Chapter 16 — Record repetition and the limits of the design.

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V011-C16-DISCUSSION-016 — Their direct observables, clock/state alignment, shared dependencies and possible common control. Optical activity alone does not establish an RF information path.

Review: Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

V011-C16-DISCUSSION-017 — Physical or operational linkage, information path, authorization status, reproducibility and continuity. Use a narrower finding category until those links are demonstrated.

Review: Chapter 16 — Findings, Reports, and Decision Ladders.

V011-C16-DISCUSSION-018 — Only as a hypothesis until stage/state controls discriminate alternatives. Preserve the discrepancy, examine gain control, products and calibration scope, and avoid cause identification from magnitude alone.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-C16-DISCUSSION-019 — Defined hypotheses and defensible likelihood models including dependence and selection. Without them, report discriminating consequences and unresolved alternatives directly.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-C16-DISCUSSION-020 — Identify their shared native samples and processing dependencies, explain complementary measurements, and avoid counting them as independent observations solely from output labels.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-C16-DISCUSSION-021 — Identify the affected function and last valid state, preserve data and checks, then narrow, repeat or qualify dependent conclusions according to evidence. Do not discard the failure or apply unsupported blanket correction.

Review: Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-C16-DISCUSSION-022 — Provide native evidence and model assumptions, identify the discriminating disagreement, obtain further tests where authorized or disclose the limit. Editorial agreement cannot substitute for evidence.

Review: Chapter 16 — Program Governance and Peer Review.

V011-C16-DISCUSSION-023 — Old/new configurations, accepted references, exact processing and representative native inputs; compare both derived outputs and explain changed alignment or correction. A startup test does not cover every measurement function.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

V011-C16-DISCUSSION-024 — Recover the tested configurations, stimulus and mechanism, require applicability checks and preserve alternatives. A reusable artifact record should guide testing without turning one incident into universal doctrine.

Review: Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-C16-DISCUSSION-025 — State the accepted steady-signal domain and explicit timing/coverage limitation, retain needed references and define further validation. Useful narrower results need not be overstated as universal capability.

Review: Chapter 16 — Close the receiver method through configuration-specific regression.

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Chapter Glossary

ARCHITECTURE MAP: A representation placing plausible mechanisms and accessible controls at their locations in the measurement chain. It supports predictions about how a controlled change should affect a candidate cause. A front-panel setting is not a causal location by itself, especially when the setting changes several paths or states together.

ARTIFACT RECORD: A reusable account of a demonstrated measurement artifact, including its affected configurations, stimulus or transition, predicted and observed response, challenge evidence and accepted mitigation. Its scope remains the tested conditions. A single incident should not become a universal rule about other receivers or environments without additional evidence.

ARTIFACT TAXONOMY: An organized inventory of mechanisms that could produce an observed indication through the receiver, installed path or environment. Its purpose is to generate competing explanations and discriminating tests. Membership in a familiar category does not identify the cause of a particular observation without supporting architecture and challenge evidence.

BLINDING: A design measure that limits access to information capable of influencing a comparison or interpretation before the relevant observations or decisions are recorded. It can reduce confirmation bias when feasible. Its role and restrictions must be documented; merely calling a test blinded does not establish independent observations or comparable receiver states.

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CHALLENGE TEST: A controlled intervention selected because competing causal explanations predict different observable consequences. The comparison retains enough configuration, desired-signal transfer and observation capability to interpret the change; an unexplained disappearance alone does not identify a mechanism.

CONDITIONAL EFFECT: The observed consequence of changing one factor at a specified setting of the other relevant factors. It may differ at another setting, indicating an interaction in the response. The result narrows the tested relationship without automatically identifying a faulty component or the unique physical cause.

CONFIGURATION COMPARABILITY: Established compatibility of reference planes, corrections, observation limits, timing, and relevant instrument states sufficient to support a specified comparison.

CONFOUNDING: An inability of the available design to separate the consequences of factors that vary together. Reference state and session are confounded when each state is observed in only one distinct session. More observations within the same incomplete arrangement do not establish the missing distinction.

CONTROL INTERACTION: Dependence of the observed effect of changing one control on the setting of another, evaluated for a declared response and measurement context.

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CROSS-DOMAIN CORROBORATION: Agreement among observations from different physical or information domains after their timing, state and dependencies have been reconciled. It can support a mechanism or linkage, but the domains may still share a cause. An optical observation establishes optical activity within its scope and does not automatically establish an RF source.

CROSSED CONTROL STATES: An experimental arrangement in which every selected setting of one control is observed with every selected setting of another, subject to documented physical feasibility and comparability.

DEVICE LINKAGE: Evidence connecting an observation to a particular physical device or its operation. A frequency, modulation label or plausible decoded identifier alone may be insufficient. The report distinguishes such linkage from mere temporal association, localization, authorization status and confirmation of an information path or surveillance function.

EVIDENCE CONTINUITY: The documented connection from the acquired observations through their configurations, processing and supporting records to the reported inference. It allows later review of what was observed and what was derived. Preserving this connection is distinct from asserting that every sample was acquired continuously; both may be relevant to a particular claim.

EXPERIMENTAL BLOCKING: Grouping observations under a declared nuisance condition while retaining the relevant comparisons within groups where practicable. It makes the condition explicit rather than removing it. If each reference setting occurs only in a different session, repetition within those sessions cannot recover the missing crossed comparison.

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FACTOR LEVEL: A specified physical setting or condition of a factor used in an experimental comparison. Its implementation can change several electrical or processing properties at once. Document the actual connections, terminations, routes and states rather than treating a convenient menu label as a uniquely isolated mechanism.

FALSE POSITIVE: Result incorrectly satisfying a detection or classification rule in the absence of the claimed phenomenon.

FINDING CATEGORY: The explicitly stated evidential status assigned to a reportable observation, such as normal occupancy, artifact, installation defect or unexplained signal. Categories allow a conclusion to remain proportionate to the completed work. Moving to a stronger category requires its additional evidence rather than a more confident adjective.

FUNCTIONAL ATTRIBUTION: An inference establishing the relevant operation or information function of a linked system. In the chapter's finding ladder, confirmation requires physical or operational linkage, an information path, authorization context, reproducible behavior and evidence continuity. A dramatic trace or recognizable modulation does not independently establish that complete claim.

HELD-OUT VALIDATION: Evaluation on records not used to select the fitted model, processing rule or decision setting. It supports a claim about behavior beyond the examples used for that choice. Reprocessing the same selected field events under a stricter rule does not by itself provide this independent validation.

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INDEPENDENT EVIDENCE: Evidence whose relevant error mechanisms and dependencies have been examined and are sufficiently distinct for the intended inference. Different sensors or software names alone do not supply that distinction. A useful additional observation changes the particular coupling, timing or processing path that could explain the existing agreement.

KNOWN-REFERENCE CONTROL: An observation of an appropriately specified reference used to establish the comparison capability of a configuration. Its waveform, level, frequency and timing must exercise the relevant function. Detecting a comfortable continuous tone does not establish performance for a weak burst beside a blocker or prove general absence after substitution.

LIKELIHOOD RATIO: The ratio of the probability or probability density assigned to the same data by two specified hypotheses, with a positive denominator for a finite result. It requires defensible models of the data and selection procedure. This chapter uses the definition to state that requirement and assigns no numerical odds to its artifact or attribution categories.

LOCALIZATION: An inference about where a source or coupling region is situated from spatially informative observations. Receiver evidence may contribute through direction or gradients, subject to propagation, geometry and calibration. Localization is a different evidential step from classifying a waveform or linking it to a particular device and function.

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MECHANISM PREDICTION: A stated consequence expected from a proposed physical or processing explanation under a specified intervention. Writing competing predictions before changing the setup gives the challenge a discriminating purpose. An observed match supports only the consequences tested and does not exclude alternatives that predict the same behavior.

NEGATIVE CONTROL: A comparison selected to test a specific alternative explanation under defined conditions. Examples include a terminated input or a noise-only record, each with its own scope. A successful control does not cover every field state, and failures must remain in the record alongside passes.

NORMALIZED RESPONSE ERROR: The difference between observations after the stated gain, attenuation and other required corrections have referred them to a comparable quantity and plane. Its uncertainty and receiver states determine the meaning of agreement. A discrepancy can motivate investigation of compression, internal products or state changes without uniquely naming the cause.

OBSERVATION LIMIT: The demonstrated boundary of what a specified configuration and record could reveal under the declared criterion. Nondetection above a supported limit is different from proof of complete absence. A substitution that changes sensitivity must retain suitable reference evidence before its negative result can support the intended comparison.

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REGRESSION TEST: A repeatable comparison with previously accepted results after a repair or a change in equipment, firmware, software, calibration or accessories. Checks are selected for the functions used by the deployed measurement configuration and retain their known references, accepted ranges and relevant states; a startup self-test covers only its own exercised functions.

REPLICATION: Fresh execution of an intervention and acquisition under the declared conditions to examine variability and reproducibility. Replotting one capture or dividing it into overlapping windows does not replicate the physical intervention. The repeated records must retain state, order and source conditions so their relationship can be assessed.

RESIDUAL RESPONSE: Instrument-generated indication remaining with a terminated or otherwise controlled input.

RESPONSE DEFINITION: The quantity or criterion fixed before evaluating experimental configurations, including its reference plane, units, bandwidth and processing. Corrected power, logarithmic level and a visibility threshold answer different questions. Keeping the definition consistent prevents an apparent disappearance from being interpreted without accounting for changed sensitivity or scaling.

RETAINED-RECORD REPROCESSING: Applying a changed correction or processing method to a preserved acquisition record while retaining the original data, both derived products and their processing identities. This comparison can explain a changed interpretation without treating it as a new physical observation. Independent validation remains necessary when the retained record helped select the new method.

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REVERSAL CHECK: A planned return from a modified setup to an earlier configuration to test whether the earlier response returns under comparable observation capability. It checks reversibility and can expose drift or state-history dependence. Reproducing the response does not by itself isolate which changed path caused it.

RUN-ORDER RANDOMIZATION: Assignment of feasible experimental configurations to acquisition order by a declared random procedure. It can reduce systematic association between a setting and unrelated temporal changes. It does not remove physical restrictions, relocking requirements or changing source behavior; those constraints and the actual order remain part of the diagnostic record.

SELECTION EFFECT: A change in the interpretation of evidence caused by how observations, tests or processing rules were chosen. Favorable tests selected after viewing outcomes cannot be treated as though they were the only predeclared possibilities. Preserve failed challenges, held-out records and the actual selection procedure when assessing what the evidence supports.

SHARED DEPENDENCY: A common clock, power supply, path, software component, calibration input or other influence linking nominally separate observations. It can preserve the same error across instruments or derived products. Counting labels or devices therefore does not establish the amount of independent confirmation.

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STATE-TRANSITION RECORD: A preserved record of the operation and timing by which the receiver moved between configurations, including any relock, impulse or recovery interval. It distinguishes transition behavior from settled behavior. Excluding a transient from a settled-state analysis does not remove its evidential relevance or justify deleting it.

TECHNICAL PEER REVIEW: Independent examination of the native data, configurations, calculations, calibration, challenge results and competing explanations supporting a finding. It tests the reasoning and evidence rather than merely approving a narrative. Unresolved disagreements lead to further measurements or explicit limitations, preserving the actual strength of the conclusion.

TEMPORAL CORRELATION: A relationship in the timing of observed events under a stated time basis and uncertainty. It can guide a causal investigation without proving its direction or mechanism. Shared control activity, instrument timing or another common cause must remain possible until discriminating evidence resolves those alternatives.

UNEXPLAINED SIGNAL: Observed component that survives initial validity checks but lacks sufficient evidence for source or functional attribution.

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References and Works Cited

Kester, Walt. MT-080, Mixers and Modulators. Rev. 0. Analog Devices, October 2008. https://www.analog.com/media/en/training-seminars/tutorials/mt-080.pdf.

Annotation. Printed pages 1–2 and 5 support mixing terminology, dimensional scaling and image locations. The printed sine-product signs in equations (1)/(1a) on page 5 are not adopted; Model 4A independently derives its cosine-product law. No commercial performance inference is made. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver's actual topology. Ideal mixer identities do not establish that a real component is free of compression, leakage, spurs or path-dependent calibration errors. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions.

Kester, Walt. MT-002, What the Nyquist Criterion Means to Your Sampled Data System Design. Rev. A. Analog Devices, October 2008. Pages 4–7 and 9–11. https://www.analog.com/media/en/training-seminars/tutorials/MT-002.pdf.

Annotation. Printed pages 4–7 and 9–11 support sampling and analog-band selection. The actual sample-rate, mixing and data-continuity conventions are those developed in Chapter 10, not a generic inference

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from an observed line. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

Kester, Walt. MT-012, Intermodulation Distortion Considerations for ADCs. Rev. A. Analog Devices, October 2008. Pages 1–4. https://www.analog.com/media/en/training-seminars/tutorials/mt-012.pdf.

Annotation. Printed pages 1–4 distinguish converter distortion behavior and the limitations of ordinary intercept extrapolation. The mechanism inventory does not make a single observed scaling signature uniquely diagnostic. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. Its use here is bounded by the physical reference plane, implementation version and the evidentiary proposition being tested.

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Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Analog Devices. Specifications and Measurement of Local Oscillator Noise in Integrated Circuit Base Station Mixers. June 18, 2003. Mixer Noise Model and Effective Noise Floor of LO Driver. https://www.analog.com/en/resources/technical-articles/2022/07/16/08/18/specifications-and-measurement-of-local-oscillator-noise-in-integrated-circuit-base-station-mixers.html.

Annotation."Mixer Noise Model" supports the reciprocal-mixing mechanism inventory. Model 11B separately supplies its weighting, reference planes and premises; the chapter's challenge tests are applied synthesis rather than quoted universal receiver procedures. The technical treatment concerns the conversion of strong off-channel energy and local-oscillator phase noise into receiver degradation. An apparent rise in the noise floor can reflect oscillator-sideband mixing rather than increased external thermal noise or a new transmitter. Conclusions require blocker level, frequency offset, preselection, instrument state and phase-noise conditions at specified reference planes. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

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National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.2.1.2, "One Variable at a Time." Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/pri/section2/pri212.htm

Annotation. Section 5.2.1.2 identifies limitations of changing one factor at a time when effects depend on other settings. The receiver examples specify their own physical factors and do not infer numerical likelihoods from this design principle. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically guarantees representative physical operating conditions. Interpretation requires separating the publication's stated scope from the chapter's constructed experimental examples and their necessarily conditional conclusions.

National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.3.3.3.2, "Full Factorial Example." Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/pri/section3/pri3332.htm

Annotation. Section 5.3.3.3.2 supports crossing factor levels, replication and randomized run order. The receiver application retains physical restrictions, missing combinations and temporal confounding rather

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than treating a four-state record as automatic causal identification. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically guarantees representative physical operating conditions. In this chapter the citation should be read against the local receiver model and the expressly defined quantities, not as a general endorsement of every design choice.

National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 2.1.2, "What Is a Check Standard?" Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/mpc/section1/mpc12.htm

Annotation. Section 2.1.2 supports a representative, repeatable check characteristic and an accumulated record of its behavior. The chapter applies that principle to the actual waveform, level, timing and receiver function needed by a comparison. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically guarantees representative physical operating conditions. Its use here is bounded by the physical reference plane, implementation

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version and the evidentiary proposition being tested. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Kast, Joshua M., Paritosh Manurkar, Kate A. Remley, Dylan F. Williams, and Robert D. Horansky. “System-Level Calibration of a Millimeter-Wave Vector Signal Analyzer with Uncertainties.” IEEE Transactions on Microwave Theory and Techniques 73, no. 11 (November 2025): 9085–95. https://doi.org/10.1109/TMTT.2025.3597240. NIST-hosted manuscript, pages 1–9, especially sections II–III: https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=959731.

Annotation.NIST-hosted manuscript section II.C, printed page 6, supports consistent reference planes or correction for added paths and configuration-bound calibration validity. The published experiment does not certify the constructed challenge configurations. The research concerns complex-vector calibration or noise-temperature measurement where amplitude, phase and uncertainty propagate through the measurement chain. Reference-plane consistency, added cable paths and calibration-state changes are material to a repeatable comparison. Published experimental results cannot automatically be transferred to a different apparatus or treated as certification of the book’s constructed numerical examples. The cited work is a methodological reference; the worked examples and the conclusions drawn from them remain separate authorial derivations requiring their own checks.

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National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.7, "A Glossary of DOE Terminology," entries for blocking, confounding, crossed factors, interactions, and replication. Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/pri/section7/pri7.htm

Annotation. Entries for blocking, confounding, crossed factors, interactions and replication. These terms are applied to documented physical receiver comparisons, with response definition and design limitations preserved. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically guarantees representative physical operating conditions. Interpretation requires separating the publication’s stated scope from the chapter’s constructed experimental examples and their necessarily conditional conclusions. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Volume Summary

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Define the question and the complete measurement chain

A receiver finding begins with a defined question, an authorized objective and a measurement quantity. Detection establishes that a stated criterion was met under the observed conditions. Classification, localization, device linkage and recovery of information require additional evidence. State the intended reference plane, frequency and time intervals, estimator and decision criterion before selecting a mode. This makes the later correction, uncertainty and challenge record intelligible to another examiner who was not present at the instrument.

The measurement chain includes the installed antenna, cables, adapters, filters, protection, gain stages, converters, clocks, sampling, software and stored representation. Each element can alter the signal, add a contribution or discard information. A calibrated scalar transfer can support an inverse calculation within its stated domain, while clipping, unknown automatic state or discarded data can defeat that inverse. Keep the raw indication and the ordered corrections, with their units and physical boundaries. Keep the result reversible to those declared inputs and states.

Configuration is therefore part of the measurement law. A requested gain, sample rate or filter setting is a command; its settled and valid state needs evidence. Preserve transition times, excluded intervals and the versioned corrections applicable to each accepted segment. Closing references test the functions they traverse at the time of the check. They can reveal a failure and guide investigation of an affected interval, but cannot by themselves prove uninterrupted validity throughout an earlier acquisition.

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Preserve the signal through gain, filtering and conversion

Sensitivity depends on the source plane, bandwidth, noise environment and decision procedure. The matched fixed-state cascade carries desired gain and added noise together. Early gain can reduce the input-equivalent effect of later noise, while preceding dissipative loss both attenuates and contributes thermal noise according to its temperature. The reference noise factor and actual signal-to-noise degradation answer related but different questions when the source temperature changes. Hot-cold inversion requires compatible gain, bandwidth, source temperatures and linearity in both states; its admissible ratio and conditioning are part of the calculation. Validate event detection separately in the intended environment.

Follow every important blocker as well as the desired signal. The first vulnerable stage may lose validity before a narrow downstream filter or display acts. Preselection can improve rejection while adding desired-path loss, and gain must fit between the noise-derived minimum and the downstream-loading maximum. An empty feasible interval calls for a changed architecture or operating condition. Input protection adds further distinctions among small-signal loss, leakage, survival and recovery. Use a weak reference and an observable-specific recovery criterion to identify intervals of impaired measurement after hardware survives.

Retain signed frequency, the selected conversion branch, loading and phase until a real representation requires folding. Images and spur lattices identify admitted possibilities, with amplitudes and coherent collisions requiring their own transfer and phase treatment. Filter skirts, ripple, group delay and ringing affect different observables. Automatic control introduces a

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trajectory whose calibrated state and sign must be retained through target changes. Detector takeoff, averaging law and recovery limits then determine what a displayed level represents. A narrow, stable trace can still carry the consequences of a broader or time-varying upstream path.

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Keep representation and estimator conventions explicit

Analog and digital demodulation are configured inferences from the retained waveform. The complex envelope distinguishes amplitude from phase and connects mean power to the actual averaging convention. Magnitude detection can lose an envelope reversal, and a phase derivative or finite difference requires a valid branch, nonzero signal where needed and explicit handling of resets. Frequency modulation, phase modulation and pulse observations therefore require appropriate bandwidth and time evidence. Intelligibility and waveform classification remain processing-dependent observations requiring further evidence for source and purpose.

For a digital quality metric, define the symbol experiment, reference, synchronization, alignment and normalization. A fit can remove effects that another question intends to measure, so retain its degrees of freedom and evaluate appropriate records outside the fitting set. Error-vector results and error counts also have different denominators and conditions. Rate accounting starts from declared finite populations: symbol opportunities, coded labels, information bits, complete frames and unique payload positions. Overheads act on their specified populations, mode changes require duration weighting, and retransmission or overlap does not create new delivered information. A stated rate is meaningful only with its count, wall interval and exclusions.

Spectral displays likewise depend on operations that need not commute. Averaging powers and averaging logarithmic levels yield different statistics. Resolution bandwidth, equivalent noise bandwidth and observation time have distinct roles. A finite Fourier analysis retains its actual samples,

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window convention and normalization; zero padding adds frequency-grid points without supplying new measured time history. Coherent amplitude, power density and integrated power need compatible scaling. Cross-spectral analysis additionally preserves channel order, conjugation and joint averaging. Shared noise or coherent cancellation requires examining the complex relationships and estimator assumptions before interpreting a scalar curve.

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Treat timing and acquisition integrity as part of the quantity

A software-defined receiver adds explicit numerical and data-path conventions. Mixing, filtering, decimation, channelization and quantization depend on ordering, state and scaling. Keep absolute sample indices, oscillator phase, filter history and valid output ranges through processing boundaries. Correct transforms still require the correct segment, binary-point interpretation and channel order. Executable identity, configuration, calibration and native format must remain connected to the record so that a second implementation can reproduce the same declared quantity instead of merely creating a similar-looking plot.

Clock accuracy, phase noise and multichannel alignment describe different aspects of timing. Initial epoch error, fractional-frequency offset and drift determine a deterministic time-error law within a stated interval. Physical delay has its own transfer-phase sign and wrapped-phase ambiguity. Integrated phase noise gives a band-limited timing RMS after a carrier-dependent conversion, while coherent power also depends on covariance and, for the exact Gaussian calculation, an additional distributional premise. Shared frequency does not establish aligned apertures, triggers or stored samples. Calibrate the actual boundaries and preserve discontinuities rather than forcing separately acquired segments into one coherent interpretation.

Coverage is determined by usable intervals and a declared event criterion. The timing model forms eligible event starts and merges their periodic union before calculating a probability under a justified phase distribution. Independent repeated trials require a separate assumption; a phase-locked event can repeatedly miss the same window. Verify the trigger at its actual

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processing location and retain valid pretrigger context. Sustained storage tests, sequence evidence and gap maps establish what was preserved. File hashes support later byte consistency, while continuity and actual coverage need their own acquisition evidence. Negative findings remain bounded by the tested bands, states, event classes and intervals.

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Calibrate the assembled result and retain its uncertainty

The installed receiving path belongs to the measurement. Antenna-terminal power and field strength are different measurands, and field conversion adds direction, polarization, loading, geometry and environment. Remote gain, bias delivery, cable routing and unused branches can alter noise, stability, mismatch or common-mode coupling. A conducted correction characterizes the path and conditions it actually measures. An optical or battery comparison may remove one coupling opportunity while changing gain, noise or sensitivity. Preserve the desired reference, assembly, state and corrections so each intervention remains interpretable.

Linearity and noise validity must also be maintained at the relevant signal levels. A local cubic model distinguishes per-tone powers, unequal products and extrapolated intercepts under stated loading. Source-generated products can contaminate the same observation, and formal extrapolation is not an attainable operating point. Reciprocal mixing instead depends on admitted blocker power and the oscillator phase-noise distribution weighted by the observation channel. A flat spectral shortcut, a noise subtraction or a remainder bound is valid only under its own premises. These mechanisms motivate different challenges and cannot be compressed into one universal dynamic-range score.

Calibration connects the scoped result to references and uncertainties, distinct from adjustment and verification. Signed corrections follow the physical path, and an uncertainty budget retains their dependencies rather than hiding configuration or implementation mistakes. Affine covariance propagation is exact with fixed coefficients and finite second moments; a

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nonlinear calculation requires attention to local adequacy, curvature and domain. Standard uncertainty is not a maximum error bound, and a coverage factor alone does not establish a probability guarantee. Apply the predeclared decision rule, allowing an indeterminate outcome when the available interval cannot settle the requirement.

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Earn the finding and preserve the accepted method

Locate candidate mechanisms in the architecture and predict their response to controlled changes. Preserve observation capability so a disappearance remains interpretable. A successful challenge can narrow alternatives while leaving source identity unresolved. When controls interact, observe the relevant combinations with a fixed response definition. Fresh acquisitions, run-order control and blocking address distinct limitations. Repeated plots, favorable coincidences and configuration labels cannot replace a missing physical comparison.

Reconcile timing, configuration and shared dependencies before combining domains. Instruments may share a clock or input path, and derived reports may use the same samples. Their agreement does not become independent by being counted twice. Report the observed consequences and remaining alternatives at the supported finding category. Numerical likelihoods require specified hypotheses and defensible data and selection models. Otherwise describe the discriminating evidence directly and identify the next useful test.

Link native data, configuration, corrections, uncertainty, coverage and inference in the final record. Preserve failed challenges, unknown intervals and alternatives for independent review. Changes to hardware, firmware, software or accessories trigger checks of the deployed method’s measurement functions. Retain the prior accepted state and explain revised derived results without rewriting observations. This record gives later examiners a reproducible basis for confirming, narrowing or correcting the conclusion as installations and software evolve.

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EXPERT ROUNDTABLE

This expert roundtable comprises one hundred substantive discussions. Its preserved question numbering runs from 001 to 107, omitting identifiers 008–012, 015 and 032 by authorial direction. The reconstructed exchanges are fictional educational dialogue, not quotations from or authentic meetings of the deceased specialists. A populated question is not, by itself, proof that every technical calculation or cited source has passed independent publication review.

Moderator: Dr. James M. Atkinson

All historical contributor speech in recovered discussions is constructed pedagogical reconstruction. It must not be quoted as an authentic transcript of deceased participants. Technical case studies, calculations, and receiver examples are hypothetical unless the source explicitly establishes otherwise.

A recovered source establishes presence of substantial text. It does not independently establish that each numerical calculation, historical attribution, citation, or peer-exchange word minimum has passed a final whole-volume publication audit.

No.	Roundtable question	Source status
001	When may a receiver observation become an evidential claim?	Recovered manuscript
002	How should the intended measurement determine the receiver architecture and its reference planes?	Recovered manuscript
003	What must be preserved when a receiver changes state during an investigation?	Recovered manuscript
004	When does agreement among receivers constitute independent corroboration?	Recovered manuscript
005	What makes a receiver challenge test capable of revealing a material failure?	Recovered manuscript
006	How should uncertainty,	Recovered manuscript

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	competing explanations, and decision costs govern the wording of a receiver finding?	
007	When may observations, bearings, and timing evidence support localisation or attribution of an electromagnetic source?	Recovered manuscript
013	What can preselection establish about the external origin of a spectral feature?	
014	How should gain distribution be selected when strong signals coexist with weak emissions?	
016	How can local-oscillator leakage and reciprocal mixing imitate or obscure emissions?	
017	What does a receiver noise figure establish when the observed environment is not thermal noise?	
018	How should intermodulation products be challenged before calling a feature an emitter?	
019	Where do analogue filtering and group delay distort the interpretation of short bursts?	
020	How should an investigator validate a replacement receiver without losing comparability?	
021	How should aperture jitter be budgeted at high input frequencies?	
022	When does analogue front-end bandwidth invalidate an otherwise adequate sampling rate?	
023	How can saturation and recovery effects create false pulse histories?	
024	How should differential and integral nonlinearity enter a forensic uncertainty account?	
025	What is lost when a converter clips, and what remains inferable?	
026	When may dither improve a quantitative estimate without increasing intrinsic converter resolution?	Recovered manuscript
027	How do converter interleaving mismatches create periodic spectral artifacts?	Recovered manuscript
028	When is an effective-number-of-bits calculation relevant to an intermittent signal?	Recovered manuscript
029	How should quantisation noise be distinguished from thermal and clock-related noise?	
030	What does calibration reveal about ADC performance across temperature and time?	Recovered manuscript

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031	When is bandpass sampling safe, and what must the analogue filter guarantee?	
033	Which resampling operations preserve time, amplitude and phase claims?	Recovered manuscript
034	What calibration is required for coherent time-interleaved digitisation?	Recovered manuscript
035	How should polyphase channelisers be validated at channel boundaries?	Recovered manuscript
036	When does decimation remove information that a later forensic question requires?	Recovered manuscript
037	How may oversampling reduce in-band noise without increasing the independent information available?	Recovered manuscript
038	How does finite word length change digital oscillator and filter behaviour?	Recovered manuscript
039	Which apparent transient features can be created by sample-rate conversion?	Recovered manuscript
040	How can the investigator reconcile different sampling clocks in one evidential timeline?	Recovered manuscript
041	What do FFT resolution and bin spacing mean for a transient emission?	Recovered manuscript
042	How do window functions trade leakage, resolution and amplitude bias?	Recovered manuscript
043	When does spectral averaging conceal short-lived signals?	Recovered manuscript
044	How should overlapping windows affect counts of independent detection opportunities?	Recovered manuscript
045	Which limits govern time-frequency localisation of a short burst?	Recovered manuscript
046	What is the proper evidential use of multitaper and robust spectral estimates?	Recovered manuscript
047	How can cyclostationary	Recovered manuscript

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	analysis help without manufacturing a unique device identity?	
048	What does a matched filter actually test about an unknown waveform?	Recovered manuscript
049	How should spectral occupancy be reported when observation is intermittent?	Recovered manuscript
050	When are waterfall displays misleading representations of retained samples?	Recovered manuscript
051	When must RF arrival time be separated from a software timestamp at the host?	
052	How should traceability of frequency standards govern coherent captures separated in time?	
053	When can oscillator disciplining conceal rather than correct a phase discontinuity?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
054	How can common-reference distribution create correlated errors in supposedly independent receivers?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
055	Which observations discriminate clock drift, sample loss and delayed receiver buffering?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
056	What can network time synchronisation establish about an RF acquisition chronology?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
057	How do frequency-counter gate time and dead time bias observations of a drifting burst carrier?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
058	What do phase-noise sidebands reveal about defects in an RF reference distribution network?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
059	When is a spectrum analyser timebase adequate for multistation arrival-time localisation?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
060	How can oscillator ageing be separated from thermal cycling in long-duration RF	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and

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	surveillance?	verification pending
061	When do common-mode currents on coaxial screens imitate a spatially localised emitter?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
062	Which near-field observations distinguish electric coupling from magnetic coupling in an enclosure?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
063	What is missing when an antenna is calibrated exclusively under far-field conditions?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
064	How should polarisation mismatch and pattern nulls qualify a negative surveillance search?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
065	When do preselector switching transients corrupt a frequency-agile receiver?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
066	How do clock feedthrough and oscillator harmonics traverse an instrument enclosure?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
067	What connector and cable defects cause reproducible movement of receiver spectral peaks?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
068	How can antenna substitution distinguish incident RF energy from instrument-generated signals?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
069	When do resolution and video bandwidth settings cause a swept analyser to miss brief pulses?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
070	How should antenna, cable, preamplifier and receiver uncertainties be combined without double counting?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
071	What constitutes one event when threshold crossings form correlated clusters?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
072	How should rare-burst searches quantify blind time and the likelihood of a missed	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and

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	event?	verification pending
073	When do harmonic and sideband relationships support a common-oscillator hypothesis?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
074	How do adjacent-channel leakage and selectivity change site-to-site occupancy comparisons?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
075	When may phase-coherent integration continue across receiver retuning?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
076	What do pulse-to-pulse timing distributions establish about scheduled telemetry?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
077	When can inter-arrival statistics identify a class of intermittent control links?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
078	When do adaptive detection thresholds conceal a rising RF noise floor?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
079	How should false-alarm probability be controlled across millions of spectral comparisons?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
080	What experiment distinguishes stimulus-responsive RF activity from accidental coincidence?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
081	What may coding structure reveal about a waveform without decoding protected communication content?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
082	When does payload compression defeat entropy-based sender attribution?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
083	How should frequency-hopping bursts be surveyed when scanner dwell is incomplete?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
084	When does cyclic-prefix correlation indicate multicarrier structure rather	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and

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	than periodic interference?	verification pending
085	What distinguishes a spread-spectrum burst from impulsive broadband interference?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
086	How should beacon-like repetition be described without assuming a named protocol?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
087	Can power-on transients support transmitter-class inference without unique fingerprinting?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
088	How does antenna switching affect bearings of a moving or rapidly duty-cycled source?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
089	When does a public synchronisation field become unreliable evidence of a particular transmitter?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
090	How can a surveillance report avoid unnecessary communication-content collection?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
091	What integrity and provenance records are needed to verify unchanged RF sample files?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
092	Which configuration values are indispensable for reproducing a waterfall determination?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
093	Which RF phase and transient findings become untestable after lossy sample compression?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
094	How should conflicting clocks and sample dropouts be represented in a multi-receiver chain of custody?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
095	What makes a software-defined receiver processing pipeline independently reproducible?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
096	Why must exploratory threshold adjustment be separated from confirmatory	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and

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	RF tests?	verification pending
097	What selection bias follows when only alarm-triggered IQ data are preserved?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
098	How should calibration uncertainty and alternative explanations be communicated in technical testimony?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
099	What evidence separates waveform detection, device class and individual-emitter attribution?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
100	When does a finite negative technical-surveillance survey provide useful assurance?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
101	Can parallel converter channels increase effective resolution without synthesising nonexistent physical bits?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
102	How should ultrawideband SDR capture balance instantaneous bandwidth and usable dynamic range?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
103	When is compressive sampling of rare RF emissions defensible without a validated sparsity model?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
104	How should machine-assisted RF anomaly detection be assessed under distribution shift?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
105	What must an SDR recorder prove about firmware, FPGA bitstreams and runtime configuration?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
106	Which design decisions permit rigorous one-, five-, ten- and twenty-year receiver projections?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending
107	What combined evidential standard should close a complex TSCM receiver investigation?	Newly commissioned. Editorial topic and expert plan only; dialogue, applications and verification pending

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Roundtable question navigator

001. When may a receiver observation become an evidential claim?

002. How should the intended measurement determine the receiver architecture and its reference planes?

003. What must be preserved when a receiver changes state during an investigation?

004. When does agreement among receivers constitute independent corroboration?

005. What makes a receiver challenge test capable of revealing a material failure?

006. How should uncertainty, competing explanations, and decision costs govern the wording of a receiver finding?

007. When may observations, bearings, and timing evidence support localisation or attribution of an electromagnetic source?

013. What can preselection establish about the external origin of a spectral feature?

014. How should gain distribution be selected when strong signals coexist with weak emissions?

016. How can local-oscillator leakage and reciprocal mixing imitate or obscure emissions?

017. What does a receiver noise figure establish when the observed environment is not thermal noise?

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018. How should intermodulation products be challenged before calling a feature an emitter?

019. Where do analogue filtering and group delay distort the interpretation of short bursts?

020. How should an investigator validate a replacement receiver without losing comparability?

021. How should aperture jitter be budgeted at high input frequencies?

022. When does analogue front-end bandwidth invalidate an otherwise adequate sampling rate?

023. How can saturation and recovery effects create false pulse histories?

024. How should differential and integral nonlinearity enter a forensic uncertainty account?

025. What is lost when a converter clips, and what remains inferable?

026. When may dither improve a quantitative estimate without increasing intrinsic converter resolution?

027. How do converter interleaving mismatches create periodic spectral artifacts?

028. When is an effective-number-of-bits calculation relevant to an intermittent signal?

029. How should quantisation noise be distinguished from thermal and clock-related noise?

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030. What does calibration reveal about ADC performance across temperature and time?

031. When is bandpass sampling safe, and what must the analogue filter guarantee?

033. Which resampling operations preserve time, amplitude and phase claims?

034. What calibration is required for coherent time-interleaved digitisation?

035. How should polyphase channelisers be validated at channel boundaries?

036. When does decimation remove information that a later forensic question requires?

037. How may oversampling reduce in-band noise without increasing the independent information available?

038. How does finite word length change digital oscillator and filter behaviour?

039. Which apparent transient features can be created by sample-rate conversion?

040. How can the investigator reconcile different sampling clocks in one evidential timeline?

041. What do FFT resolution and bin spacing mean for a transient emission?

042. How do window functions trade leakage, resolution and amplitude bias?

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043. When does spectral averaging conceal short-lived signals?

044. How should overlapping windows affect counts of independent detection opportunities?

045. Which limits govern time-frequency localisation of a short burst?

046. What is the proper evidential use of multitaper and robust spectral estimates?

047. How can cyclostationary analysis help without manufacturing a unique device identity?

048. What does a matched filter actually test about an unknown waveform?

049. How should spectral occupancy be reported when observation is intermittent?

050. When are waterfall displays misleading representations of retained samples?

051. When must RF arrival time be separated from a software timestamp at the host?

052. How should traceability of frequency standards govern coherent captures separated in time?

053. When can oscillator disciplining conceal rather than correct a phase discontinuity?

054. How can common-reference distribution create correlated errors in supposedly independent receivers?

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055. Which observations discriminate clock drift, sample loss and delayed receiver buffering?

056. What can network time synchronisation establish about an RF acquisition chronology?

057. How do frequency-counter gate time and dead time bias observations of a drifting burst carrier?

058. What do phase-noise sidebands reveal about defects in an RF reference distribution network?

059. When is a spectrum analyser timebase adequate for multistation arrival-time localisation?

060. How can oscillator ageing be separated from thermal cycling in long-duration RF surveillance?

061. When do common-mode currents on coaxial screens imitate a spatially localised emitter?

062. Which near-field observations distinguish electric coupling from magnetic coupling in an enclosure?

063. What is missing when an antenna is calibrated exclusively under far-field conditions?

064. How should polarisation mismatch and pattern nulls qualify a negative surveillance search?

065. When do preselector switching transients corrupt a frequency-agile receiver?

066. How do clock feedthrough and oscillator harmonics traverse an instrument enclosure?

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067. What connector and cable defects cause reproducible movement of receiver spectral peaks?

068. How can antenna substitution distinguish incident RF energy from instrument-generated signals?

069. When do resolution and video bandwidth settings cause a swept analyser to miss brief pulses?

070. How should antenna, cable, preamplifier and receiver uncertainties be combined without double counting?

071. What constitutes one event when threshold crossings form correlated clusters?

072. How should rare-burst searches quantify blind time and the likelihood of a missed event?

073. When do harmonic and sideband relationships support a common-oscillator hypothesis?

074. How do adjacent-channel leakage and selectivity change site-to-site occupancy comparisons?

075. When may phase-coherent integration continue across receiver retuning?

076. What do pulse-to-pulse timing distributions establish about scheduled telemetry?

077. When can inter-arrival statistics identify a class of intermittent control links?

078. When do adaptive detection thresholds conceal a rising RF noise floor?

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079. How should false-alarm probability be controlled across millions of spectral comparisons?

080. What experiment distinguishes stimulus-responsive RF activity from accidental coincidence?

081. What may coding structure reveal about a waveform without decoding protected communication content?

082. When does payload compression defeat entropy-based sender attribution?

083. How should frequency-hopping bursts be surveyed when scanner dwell is incomplete?

084. When does cyclic-prefix correlation indicate multicarrier structure rather than periodic interference?

085. What distinguishes a spread-spectrum burst from impulsive broadband interference?

086. How should beacon-like repetition be described without assuming a named protocol?

087. Can power-on transients support transmitter-class inference without unique fingerprinting?

088. How does antenna switching affect bearings of a moving or rapidly duty-cycled source?

089. When does a public synchronisation field become unreliable evidence of a particular transmitter?

090. How can a surveillance report avoid unnecessary communication-content collection?

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091. What integrity and provenance records are needed to verify unchanged RF sample files?

092. Which configuration values are indispensable for reproducing a waterfall determination?

093. Which RF phase and transient findings become untestable after lossy sample compression?

094. How should conflicting clocks and sample dropouts be represented in a multi-receiver chain of custody?

095. What makes a software-defined receiver processing pipeline independently reproducible?

096. Why must exploratory threshold adjustment be separated from confirmatory RF tests?

097. What selection bias follows when only alarm-triggered IQ data are preserved?

098. How should calibration uncertainty and alternative explanations be communicated in technical testimony?

099. What evidence separates waveform detection, device class and individual-emitter attribution?

100. When does a finite negative technical-surveillance survey provide useful assurance?

101. Can parallel converter channels increase effective resolution without synthesising nonexistent physical bits?

102. How should ultrawideband SDR capture balance instantaneous bandwidth and usable dynamic range?

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103. When is compressive sampling of rare RF emissions defensible without a validated sparsity model?

104. How should machine-assisted RF anomaly detection be assessed under distribution shift?

105. What must an SDR recorder prove about firmware, FPGA bitstreams and runtime configuration?

106. Which design decisions permit rigorous one-, five-, ten- and twenty-year receiver projections?

107. What combined evidential standard should close a complex TSCM receiver investigation?

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BIOGRAPHICAL DIRECTORY OF ROUNDTABLE CONTRIBUTORS

Eighty deceased historical specialists appear in this consolidated register: fifty-seven retained active contributors plus twenty-three newly nominated specialists whose topic assignments are documented in the developmental programme. No biography of moderator Dr. James M. Atkinson is included.

The biographies describe documented historical achievement and explain the limited relevance of that achievement to receiver engineering, signal analysis, mathematics or evidential evaluation. Every roundtable exchange is newly constructed pedagogical dialogue, not an authentic quotation, interview or meeting of these historical persons. Later technological developments are not imputed to them.

Editorial provenance: the fifty-seven earlier participant biographies are retained without rewriting; twenty-three new biographical accounts are interfiled alphabetically. Removed biographies exclusive to deleted discussions have not been restored. The new speakers are nominated only; their full dialogue remains unwritten.

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Contributors. Alphabetical register

Abraham Lempel

The historical record identifies Abraham Lempel (1936–2023) with lossless versus lossy representation, data complexity and reproducibility of retained digital evidence. An accurate professional description is an Israeli computer scientist and electrical engineer; co-developed Lempel-Ziv lossless compression.

Lempel developed compression methods which are mathematically reversible when their assumptions and coding rules are retained. For digital evidence the distinction between a lossless representation and a lossy transformation is decisive, particularly when subtle phase, amplitude or transient details may become important in a later investigation. A discussion within his expertise should ask for an unambiguous bit-exact reconstruction test and the exact coding state or dictionary rules used. The existence of a compressed file says nothing about its forensic fidelity unless the transform and verification evidence are preserved. This is a data-representation issue, not a claim that Lempel designed SDR recorders.

Within the new programme, Question 093 provides a suitable test of this expertise: Which RF phase and transient findings become untestable after lossy sample compression? The test design calls for the investigator to apply controlled bit-depth reduction and predictive compression to the same calibrated burst set, then compare recovered features. The possible error is straightforward: a saved image or lossy trace may be insufficient to re-examine a previously unknown modulation feature.

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Limits of attribution: His demonstrated authority lies in data compression and complexity, not in certifying a particular receiver or chain of custody. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Abraham Wald

Abraham Wald (1902–1950) developed mathematical statistics and statistical decision theory during a career that took him from European mathematical circles to Columbia University. His work is associated with sequential analysis and the sequential probability ratio test, in which evidence is assessed as observations accumulate rather than after an arbitrarily fixed number of samples. Wartime statistical research furnished important practical contexts for his examination of competing errors and decision rules. His death in 1950 places a clear chronological boundary on his experience: he could not have assessed digital receivers or the subsequent development of software-defined instruments.

In this roundtable Wald provides a rigorous standpoint for setting thresholds and interpreting an apparent success or failure. A spectrum monitor does not merely collect numbers; its decision procedure balances a probability of false alarm against the probability of missing a stipulated event. His work is especially pertinent when a test can be stopped as soon as a sufficient body of evidence has accumulated, or when the investigator changes the observation policy after several promising indications. Each of those choices alters the sampling and stopping model. The relevant subject is not a vaguely expressed desire for confidence, but the operating characteristics of a specified procedure under specified hypotheses.

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The editorial reconstruction confines Wald's contribution to statistical inference, experimental design and decision consequences. It does not present him as the inventor of receiver hardware or as an authority on modern spectrum-surveillance law. His historical research supports a demand for explicit null and alternative propositions, a declared sequence of permissible observations, and an explanation of the costs attached to mistaken conclusions. A forensic examiner can apply that discipline to receiver evidence while independently establishing the physical and electronic validity of each recorded sample.

Historical reference consulted: https://doi.org/10.1080/00031305.2025.2604805

Alan Mathison Turing

Alan Mathison Turing (1912–1954) was a British mathematician, logician and pioneer of theoretical computation. Born in London on 23 June 1912, he attended Sherborne School before winning a mathematics scholarship to King’s College, Cambridge. His paper of 1936, commonly identified by its title On Computable Numbers, introduced a mathematical account of effective calculation that subsequently became central to computer science. That work concerns the logical capabilities and limitations of procedures, rather than the electrical specifications of any modern receiver or analogue-to-digital converter. His significance for a discussion of digital measurement lies in disciplined separation of a formal algorithm from the physical assumptions under which its input is acquired.

During the Second World War Turing worked at the Government Code and Cypher School at Bletchley Park, contributing importantly to the cryptanalysis of Enigma traffic. His wartime role involved mathematical reasoning, electromechanical methods and careful operational testing, but

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it should not be recast as personal familiarity with present-day software-defined radios. He subsequently worked on automatic computing machinery and became associated with the development of early stored-program computing in Britain. In 1950 his paper Computing Machinery and Intelligence offered a famous argument about what could meaningfully be asserted of machine behaviour under an explicitly stated test.

In this constructed expert exchange, Turing's historical standpoint is represented as an insistence on the limits of inference from a digital representation. Quantising an observed analogue amplitude into a discrete code is a mapping, not a guarantee that the original physical state can be uniquely reconstructed. The biography does not imply that Turing made the words attributed to him in the fictional roundtable, nor that he derived the particular converter equations used here. The supporting Cambridge archival chronology establishes the principal dates and areas of work; the present engineering application is an editorial extrapolation and must be judged on its own mathematics.

Albert Abraham Michelson

Albert Abraham Michelson (1852–1931) was a physicist distinguished by precision optical measurement and experimental investigations of light. He developed interferometric methods in which coherent beams followed different paths before being recombined to reveal small differences of phase and length. His work won the 1907 Nobel Prize in Physics, the first physics Nobel awarded to an American. The historical context was the nineteenth- and early twentieth-century laboratory, with optical standards and mechanical adjustments rather than sampled complex waveforms or computer-controlled instruments.

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Michelson's proper connection to this roundtable is the difficulty of establishing an accurate measurement reference. Interferometry makes the phase consequence of a small path change visible and measurable, but the interpretation depends on coherent illumination, stable geometry and calibrated apparatus. The corresponding receiver question is not whether an SDR is an interferometer in the ordinary optical sense. It is whether a claimed phase difference or time-difference observation preserves the reference and stability requirements needed to compare distinct paths. Differential cable delay, clock wander, oscillator coherence and measurement-plane definition deserve scrutiny when an electromagnetic source is localised or when observations from separate receivers are combined.

His constructed peer contribution is therefore metrological, not an anachronistic judgement on particular digital converters. It asks which quantities were compared, what common reference was retained, and what systematic errors could move the apparent fringe or phase. A sharply presented spectral line can conceal substantial uncertainty in its physical origin, just as a beautifully resolved interference pattern is meaningful only under the conditions that produced it. Modern forensic conclusions must add their own uncertainty budget and evidence-preservation record; Michelson supplies the historical experimental sensibility, not that modern certificate.

Historical reference consulted: https://www.nobelprize.org/laureate/11

Andrey Nikolaevich Kolmogorov

Andrey Nikolaevich Kolmogorov (1903–1987) was a Russian mathematician whose work placed probability on an axiomatic foundation.

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His 1933 monograph formulated probability in terms of measure-theoretic principles and provided a coherent mathematical vocabulary for random variables, conditional expectations and events. He also contributed to stochastic processes, turbulence and mathematical analysis. This breadth matters because probability models are not ornaments attached to measurements after an experiment; they define what is being treated as random, what remains conditioned upon the observing procedure, and what conclusions can legitimately be drawn.

For receiver engineering, Kolmogorov's relevant intellectual domain is the stochastic interpretation of observed interference, noise and event arrivals. Noise samples may be uncorrelated under one model yet dependent under another; a nominally stationary process can cease to be so when a transmitter changes state or an automatic-gain loop adapts. Distinguishing an event probability from an empirical fraction of threshold crossings therefore requires a probability space, an observation mechanism and assumptions about temporal dependence. His historical work also encourages the separation of a mathematical proposition about random processes from physical evidence that the specified process describes the instrument and its environment.

The imagined questions assigned to him do not purport to reconstruct a lecture he gave on digitisation. They test whether analysts have defined the distributions and dependence structures implicit in statements such as 'independent detections' or 'white noise'. In the present roundtable, the force of Kolmogorov's work is to compel the author to name the assumptions under which confidence, variance or a false-alarm probability is calculated. Receiver circuits, calibration, antenna coupling and forensic

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attribution must still be established by their respective engineering and evidential methods.

Historical reference consulted: https://mathshistory.st-andrews.ac.uk/Biographies/Kolmogorov/

Antony Hewish

Antony Hewish (1924–2021) enters the discussion on the strength of a recorded career as a British radio astronomer; scintillation arrays and the pulsar discovery programme. This context is materially connected to short transient detection, array methods, propagation effects and the interpretation of weak radio events.

Hewish's radio-astronomy research involved antennas and analysis designed to reveal rapidly varying, weak radio phenomena. His connection to a rare-emission survey is therefore stronger than a superficial analogy to stars. In the subject-specific case, the moderator may ask how an intermittent astronomical signal is distinguished from environmental interference, how array geometry affects sensitivity and whether the receiving schedule creates a spurious periodicity. The experiment ought to preserve individual observation times and detector settings. Such a contribution can illuminate the difficulty of transients without suggesting that astronomical pulsars are covert radio transmitters.

Question 064 is the most direct illustrative assignment, asking: How should polarisation mismatch and pattern nulls qualify a negative surveillance search? Its recommended measurement challenge is to rotate a calibrated test emitter through orthogonal polarisations and map missed detections across a surveyed room. The author must recognise the counterexample: a clear display in one antenna orientation cannot certify the absence of an emitter with a different polarisation.

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Any proposed attribution must survive the challenge that a clear display in one antenna orientation cannot certify the absence of an emitter with a different polarisation. The chosen scholarly intervention has value only insofar as short transient detection, array methods, propagation effects and the interpretation of weak radio events supplies a relevant explanation.

Limits of attribution: His historical research is particularly appropriate for transient-source discrimination, not the identification of contemporary commercial emitters. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Arthur Edwin Kennelly

Arthur Edwin Kennelly (1861–1939) was an electrical engineer whose professional life connected cable telegraphy, alternating-current theory and the teaching of electrical engineering. Born near Bombay in British India and educated principally in Europe, he worked in electrical communication before becoming associated with leading engineering research and instruction in the United States. He is particularly relevant to the development and practical use of complex impedance, alternating-current circuit concepts and the analysis of transmission systems. His era preceded electronic sampling, but not the fundamental problems of loading, loss, reflection and the difference between a circuit model and a real connection.

Kennelly's role in this book is sharply physical. A receiver does not observe an antenna signal in isolation from conductors, grounding arrangements and the impedance of the devices to which it is connected. A nominal fifty-ohm termination, for example, can be a useful reference

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convention while still leaving uncertainties in connectors, common-mode paths and frequency-dependent matching. The investigator who removes an antenna or substitutes a termination is performing a challenge to a particular coupling mechanism, not a universal proof that every remaining signal has an internal origin. Such questions are natural extensions of classical electrical-network reasoning.

In constructed dialogue Kennelly may appropriately challenge a claim about reference planes, line conditions or the diagnostic meaning of a terminated port. He is not represented as having known the architecture or firmware of twenty-first-century software-defined radios. His authority is confined to the documented electrical principles that survive changes in technology. The modern examiner remains responsible for measuring actual network properties, recording configuration changes and distinguishing a calculated transmission relationship from verified behaviour in the field.

Historical reference consulted: https://doi.org/10.1093/ref:odnb/45958

Bertrand Russell

Bertrand Russell (1872–1970), the British philosopher, mathematician and public intellectual, was educated at Trinity College, Cambridge. His collaboration with Alfred North Whitehead on Principia Mathematica belongs to a sustained programme in the logical foundations of mathematics. His wider philosophical writing examined knowledge, language, inference and the limits of apparently self-evident propositions. He was not a radio-receiver designer, and his substantial political and literary activities must not be mistaken for specialist training in electromagnetic measurement.

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Russell is present here because an expert witness can slide from a precisely defined observation into a far stronger assertion while using the same persuasive vocabulary. If a spectrum analyser reports a peak, the proposition 'the selected estimator exceeded its threshold' is not logically identical to 'a particular transmitting device was present'. Additional premises about front-end integrity, interference, timing, signal classification and source identity are required. Russell's concern with logical form offers a valuable editorial test: identify the premises, distinguish necessary from sufficient conditions, and determine whether the conclusion is stronger than the evidence permits.

His reconstructed exchanges thus examine the grammar of technical argument rather than pretending to deliver nineteenth- or twentieth-century radio laboratory testimony. A formally valid deduction can still rest on a false engineering premise; conversely, a useful engineering indication may remain too weak for the specific forensic conclusion desired. Russell's presence helps maintain that separation. He would not be quoted as authorising any specific modern test protocol, threshold, legal conclusion or software implementation. Those matters belong to contemporary standards, measurements and properly attributed expert analysis.

Historical reference consulted: https://russell.humanities.mcmaster.ca/about-russell/russells-life/

Charles Hard Townes

The historical record identifies Charles Hard Townes (1915–2015) with spectral purity, quantum resonance, high-frequency measurement and the relationship between oscillator physics and signals. An accurate professional description is an American physicist; maser and laser research, Nobel Prize in Physics 1964.

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The maser supplies a historically grounded example of highly selective electromagnetic oscillation. Its significance for this volume lies in the physics of coherence, spectral purity and measurements whose interpretation depends on the reference oscillator. A suitable question might ask how additive noise from a distribution amplifier differs from intrinsic oscillator fluctuations, and what phase-noise sideband measurements can actually establish about their origin. Such debate should state the instrument noise floor, carrier power, offset frequency and any simultaneous supply perturbation. Townes would contribute resonance physics rather than an invented analysis of later SDR software.

Within the new programme, Question 054 provides a suitable test of this expertise: How can common-reference distribution create correlated errors in supposedly independent receivers? The test design calls for the investigator to inject a known correlated perturbation and compare outcomes under one shared reference, separated references and cross-reference switching. The possible error is straightforward: agreement between receivers supplied by the same defective reference is not independent corroboration.

The intended teaching purpose is to illuminate partition shared clock-tree noise, correlated supply disturbances, cable dispersion and true antenna-channel phase variation. without blurring the quite different historical evidence concerning spectral purity, quantum resonance, high-frequency measurement and the relationship between oscillator physics and signals.

Limits of attribution: His direct historical contributions concern masers, spectroscopy and related instrumentation, rather than all present-day

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phase-noise test procedures. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Charles Proteus Steinmetz

Charles Proteus Steinmetz was born in Breslau in 1865 and died in 1923. An engineer and mathematical analyst whose career became closely associated with the development of alternating-current power systems in the United States, he contributed substantially to the practical theory of electrical circuits and magnetic phenomena. After emigrating to the United States, he joined General Electric in Schenectady and helped develop mathematical methods which made complex alternating-current relationships easier to calculate and engineer. The National Inventors Hall of Fame records his work on alternating-current technology, magnetic hysteresis and the wider advancement of electrical engineering. His career demonstrates the close partnership between analytical models and the physical impedances, losses and operating conditions of actual equipment.

In this hypothetical roundtable Steinmetz challenges the assumption that a static gain correction adequately describes a converter surrounded by frequency-dependent analogue circuitry. That concern is historically aligned with his expertise in network behaviour and alternating-current analysis. It does not imply familiarity with a modern switched-capacitor converter or digital signal-processing software. The intended educational value is to extend the questions of loading, phase, transient response and material-dependent losses into a contemporary measurement problem while keeping the modern technical details plainly identified as the present author's construction. His biography also illustrates why apparently small

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changes in electrical configuration may be material to a claimed calibration: a system is defined by its network of interacting components rather than by the most conveniently isolated device in its schematic. His constructed intervention also emphasises that a calibration is a measurement of relationships within a network, not a permanent property of a single isolated component.

Charles Sanders Peirce

Charles Sanders Peirce (1839–1914) combined work in logic and the philosophy of science with practical experience in geodesy, gravimetry, spectroscopy and scientific measurement. His long association with the United States Coast Survey furnished a setting in which instrumental observations, errors and physical standards had practical consequences. He became a major figure in the development of pragmatism and in the analysis of signs and inference, notably the movement between observation, explanatory hypothesis and experimental test. This breadth makes him a more specifically relevant experimental thinker than a generic commentator on truth.

The technical-surveillance investigator repeatedly faces an abductive problem: a spectral feature might arise from an external emitter, a receiver-generated image, mixing in an overloaded stage or some ordinary environmental system. Peirce's treatment of explanatory reasoning is useful for asking how one proposes a hypothesis that accounts for a striking observation without treating the proposal as proof. The hypothesis gains force when it yields discriminating predictions that rival mechanisms do not share, and when those predictions survive a suitably documented challenge. For example, a preselector change, receiver substitution or controlled

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injection can test a proposed signal path, although none is decisive without considering its own instrumental dependencies.

The imaginary roundtable does not imply that Peirce encountered an SDR, performed spectrum-forensic casework or endorsed contemporary legal practice. It makes limited use of his documented work in inference and measurement. His biography also reminds readers that logic and metrology have a common discipline: observations need provenance, hypotheses need explicit content, and the investigator must keep the difference visible in the written conclusion. Such a role respects his historical career while offering an appropriate philosophical challenge to engineering overstatement.

Historical reference consulted: https://plato.stanford.edu/entries/peirce/

Christiaan Huygens

Christiaan Huygens (1629–1695) was a Dutch mathematician, physicist, astronomer and inventor associated with foundational work on pendulum motion, improved timekeeping and the wave theory of light. He developed practical pendulum clocks and investigated the theoretical relation between an oscillator's geometry and its period. His astronomical work included observations of Saturn and the improvement of optical instruments. These accomplishments belong to the seventeenth century, long before electronic oscillators, quartz frequency standards or digital sample clocks, yet they illuminate enduring problems in timing and phase.

The immediate relevance of Huygens to receiver measurement is the distinction between a mathematical period and a clock's realised performance. An ideal periodic model contains no environmental drift; a physical oscillator responds to mechanical, thermal and other disturbances. Modern multisite time-difference measurements similarly require the

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investigator to distinguish a nominal sample rate from actual clock phase, an indicated timestamp from a radio-frequency arrival time, and common triggering from independent frequency stability. Huygens's work does not supply the mathematics of present-day disciplined oscillators. It illustrates why the behaviour of the timekeeper must be measured rather than taken for granted.

His participation is a deliberately constructed historical perspective, not a claim that he discussed radio surveillance or stochastic clock-noise spectra. The commentator may reasonably ask what period has been defined, how it has been compared, and what observational evidence supports a timing relationship. Contemporary contributors to the argument must then provide phase-noise models, calibration certificates and uncertainty propagation. In this narrow role the older history of clocks and waves enriches the engineering discussion without assigning impossible twentieth-century knowledge to its speaker.

Historical reference consulted: https://mathshistory.st-andrews.ac.uk/Biographies/Huygens/

Claude Elwood Shannon

Claude Elwood Shannon was born in Michigan in 1916 and died in 2001. He completed undergraduate studies in mathematics and electrical engineering at the University of Michigan and graduate work at the Massachusetts Institute of Technology, including a doctorate in 1940. His work on switching circuits and his 1948 mathematical treatment of communication became central contributions to their respective disciplines. MIT's institutional obituary documents his education, his academic career, and his long association with communications research. The form Dr Shannon is supported by that record. [B03]

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In this roundtable, Shannon's constructed role concerns the relation between a retained representation and the distinctions required by a later analytical question. It is not a biographical claim that he anticipated the particular storage systems, acquisition metadata, or forensic workflows used as modern examples. Those examples are introduced to test a general reasoning discipline: a record's size, numerical word length, and visual richness do not by themselves establish that it preserves the information needed for a proposed inference. The principal response follows the physical and sampling boundaries established by the preceding speakers.

The editorial purpose is also to prevent information-theoretic language from becoming an unqualified promise of recovery. Where a transformation has discarded distinctions, a documented calculation cannot simply recreate the missing observations. Conversely, a carefully selected representation can support a useful restricted claim without preserving every possible property of the input. The dialogue examines that choice through retention, processing provenance, and the difference between discovery and later reanalysis. Readers should distinguish this present application from Shannon's published historical work. His documented expertise justifies the perspective; the supported signal model and the actual acquisition determine whether any specific modern claim succeeds.

Historical expertise and source concordance: Information theory, communication limits and Boolean switching theory. Data loss and non-invertible observations fit his documented mathematical field, while attribution of specific modern receiver designs would exceed that evidence. Independent historical source: https://www.itsoc.org/about/shannon

David George Kendall

David George Kendall (1918–2007) was a British mathematician and a leading figure in applied probability. Born in Ripon, Yorkshire, he performed

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wartime scientific work before becoming associated with Oxford and, subsequently, the University of Cambridge, where he held a professorship in mathematical statistics. His research encompassed queueing systems, branching processes, stochastic modelling and geometrical probability. The best-known queueing notation bearing his name is a reminder that observable events can arise from systems with distinct arrival and service characteristics rather than from a single stationary Bernoulli mechanism.

Kendall is useful in a technical-surveillance discussion whenever emissions arrive irregularly or when acquisition opportunities are separated by receiver retuning, scanning or data-retention schedules. A monitor can see many threshold crossings during one prolonged transmission, then miss a sequence of short transmissions during an unobserved interval. These counts do not automatically give independent trials. Mathematical models of arrivals, event durations and service or dwell time can make the investigator's assumptions explicit. A well-posed probability problem distinguishes elapsed time, valid exposure time, the number of distinct events and the chosen sampling process.

The historical Kendall did not design modern SDR monitoring software. His fictional peer intervention should therefore challenge the probabilistic assumptions underlying occupancy estimates and missed-event claims, while leaving hardware claims to physical evidence. An effective answer would show why the proposed acquisition schedule represents the relevant population and how dependence affects uncertainty. The contribution provides a precise intellectual counterweight to the attractive but unsupported practice of dividing alarm counts by wall-clock duration and presenting the result as a transmitter's actual duty cycle.

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Historical reference consulted: https://mathshistory.st-andrews.ac.uk/Biographies/Kendall/

David Harold Blackwell

David Harold Blackwell (1919–2010) was an American mathematician and statistician whose contributions extended across probability, game theory, information theory and Bayesian inference. He taught at Howard University before joining the University of California, Berkeley, where he became an influential member of the statistics faculty. His career also illustrates the institutional obstacles encountered by Black scholars in twentieth-century American mathematics. His historical research included decision problems and the comparison of statistical experiments, providing a distinctive point of entry to arguments about whether a measurement procedure retains sufficient information for a proposed decision.

Blackwell's contribution to this roundtable concerns the informativeness of competing observations. A broadband recording and a narrowband, thresholded alarm may be derived from the same physical signal yet support different classes of later inference. A summary statistic can be adequate for a specified decision without retaining everything needed for a different question. Similarly, combining two detector outputs does not necessarily yield independent evidence, especially when they share an antenna, front end or decision logic. His tradition encourages the examiner to describe exactly what decisions can be justified from the retained observation and what information a processing stage has erased.

The imaginary dialogue does not attribute to Blackwell the invention of any particular receiver circuit or test instrument. It draws upon his demonstrable work on information and decision theory while acknowledging that contemporary RF engineering supplies the physical

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model. Forensic reports should therefore distinguish relative statistical informativeness from metrological validity. A mathematically more informative record can still be corrupted by overload or timing error, just as a perfectly calibrated receiver can retain too little information to answer the later forensic question.

Historical reference consulted: https://mathematics.howard.edu/articles/david-harold-blackwell-1919-2010

David Lennox Mills

David Lennox Mills (1938–2024) was an American computer engineer; creator of Network Time Protocol. The contribution relevant to this manuscript is network clock synchronisation, packet timing, host time, error budgets and protocol assumptions.

He developed the Network Time Protocol to address the difficulty of coordinating distributed computer clocks over networks with variable packet delays. That problem is close to, but not identical with, RF time-of-arrival measurement. A useful reconstructed exchange would force the moderator to separate a device clock, a network-disciplined operating-system clock and the timestamp associated with an analogue sampling aperture. Path asymmetry, queueing delay and host scheduling can produce timestamp changes without an RF event moving. Mills is well suited to challenge unjustified precision claims for software logs and to specify what a better trace would contain.

In the planned Question 051, the concrete issue is: When must RF arrival time be separated from a software timestamp at the host? An appropriate proposed experiment is to inject a calibrated simultaneous pulse into an RF input and an independently time-tagged reference path; measure the

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latency distribution and its drift under processing load. The corresponding interpretive caution is that a timestamp generated when a buffer is written can be repeatable yet systematically late relative to arrival at the antenna.

Limits of attribution: He is authoritative on network time and system chronology, but network timestamps are not automatically RF arrival time and must not be portrayed as such. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

David Slepian

David Slepian was an American mathematician whose research career at Bell Laboratories involved information theory, coding and finite-record spectral concentration. Biographical information maintained by the IEEE Information Theory Society identifies his training at Michigan and Harvard, military service during the Second World War, and research appointments that preceded his long Bell Laboratories career. His contributions were recognised through awards in information theory and related mathematical fields. The discrete prolate spheroidal sequences associated with his name provide a foundation for understanding how a finite data sequence can concentrate energy in an explicitly defined frequency region. The relationship between this mathematics and multitaper spectral estimation is documented in modern scientific computing references. [R1, R5]

His relevance to the present discussion is methodological rather than historical testimony. A modern investigator may obtain multiple concentrated spectral estimates from the same physical acquisition, but

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mathematical orthogonality does not itself establish independence of electromagnetic sources or of the receiver's errors. The scholarly persona used here reasons from Slepian's concentration framework to contemporary forensic questions concerning false negatives, shared instrument paths and the retention of raw complex samples. Those hypothetical cases were not experiments undertaken by Slepian, and no constructed speech should be attributed to him as a historical quotation. His work is represented as an intellectual precedent for disciplined spectral estimation, not as an endorsement of any modern surveillance apparatus or its claimed sensitivity.

The distinctive merit of this analytical tradition is that its boundary conditions can be stated and challenged. That quality is particularly important when a forensic laboratory moves from a mathematical claim about leakage to a physical claim about the presence or absence of a transmitter. The two inferences require different validation, even when they share the same retained data.

Historical expertise and source concordance: Bell Laboratories researcher in information theory, prolate spheroidal wave functions and signal concentration. Relevant to spectral-estimation conversations, with no assertion of knowledge of later field SDR systems. Independent historical source: https://www.itsoc.org/profile/8962

Dennis Gabor

Dennis Gabor was born in Hungary in 1900 and died in 1979. The American Institute of Physics archival catalogue identifies his papers and their coverage of electron optics, communication theory, information theory, holography, and work associated with Imperial College. Imperial's archival description likewise records his teaching and research papers and the documentation of his Nobel Prize. These institutional records support

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the description of a Hungarian-born physicist working in Britain and the academic form Professor Gabor. This account does not assign an unsupported citizenship date or extend his historical work into an endorsement of contemporary receiver software. [B10, B10a]

Gabor's constructed peer question concerns the representation of a transient. A chosen analysis interval, window, or display convention can emphasise one property while obscuring another. The modern example asks how an examiner can compare several valid views without selecting only the one that favours a preferred explanation. His documented interests in communication and the representation of signals supply the basis for that perspective. The present acquisition examples and proposed reporting rules are newly authored, not historical quotations.

The exchange is intended to preserve both analytical flexibility and evidential discipline. Reanalysis can be valuable when the source observations survive and the transformation is explicit. Its usefulness does not justify silently replacing a declared confirmatory procedure with an exploratory setting chosen after the event. Gabor's question therefore asks what the report should retain: not an indiscriminate gallery of displays, but the relation between each view, the property it estimates, and the reason for comparing it with another. The resulting distinction is important for burst timing, spectral discrimination, and the separation of physical duration from display persistence. His contribution remains bounded by those methodological and signal-representation concerns.

Historical expertise and source concordance: Communications representation, time-frequency analysis, electron physics and holography. His historical work supports interrogation of transient localisation and finite observation; modern FFT implementation details are editorially constructed.

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Independent historical source: https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA6123&src=CalmView.Persons

Donald Watts Davies

The historical record identifies Donald Watts Davies (1924–2000) with packet timing, networking state, reproducibility of message chains and digital infrastructure. An accurate professional description is a Welsh computer scientist; packet switching at the UK National Physical Laboratory.

Davies helped establish packet switching as an efficient method for sharing communications infrastructure. Packet ordering and variable delay matter to a multireceiver system when digital samples pass through host queues, interfaces or networks before their final archival timestamp. A proposed exchange would compare time of RF acquisition with time of packet transport, asking which header values belong to which events and which delays remain unobserved. He is appropriately linked to network architecture, queueing and documentation. The moderator must keep RF phase measurements in the remit of frequency and receiver specialists.

Within the new programme, Question 056 provides a suitable test of this expertise: What can network time synchronisation establish about an RF acquisition chronology? The test design calls for the investigator to capture the same calibration event with hardware timestamps while changing upstream network delay asymmetry and logging system clock steps. The possible error is straightforward: a narrow network-time offset estimate does not bound unmeasured analogue group delay.

The intended teaching purpose is to illuminate explain network offset estimation, asymmetrical delay, server hierarchy, host-clock corrections and why synchronised log time is not automatically rf sample time. without

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blurring the quite different historical evidence concerning packet timing, networking state, reproducibility of message chains and digital infrastructure.

Limits of attribution: His authority concerns communication systems and packet networks; conclusions about RF front-end physics require additional specialists. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Edsger Wybe Dijkstra

Edsger Wybe Dijkstra (1930–2002) enters the discussion on the strength of a recorded career as a Dutch computer scientist; algorithms, program correctness and systems reasoning. This context is materially connected to concurrency, deterministic processes, implementation assurance and reproducibility of digital acquisition.

Dijkstra's methods of programming and algorithmic correctness support a crucial distinction between logical ordering and physical measurement time. A receiver may process queued samples in a correct computational order while still assigning the wrong arrival-time semantics to its outputs. His contribution could examine invariants linking sample indexes, buffer boundaries, timestamps and explicit invalid intervals. A proof that software runs correctly under one implementation does not certify analogue capture latency, yet it can expose hidden assumptions about state and reproducibility. That boundary makes him a defensible participant in SDR software provenance discussions.

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Question 055 is the most direct illustrative assignment, asking: Which observations discriminate clock drift, sample loss and delayed receiver buffering? Its recommended measurement challenge is to introduce independent perturbations of clock frequency, simulated packet loss and host load, then measure distinct residual signatures. The author must recognise the counterexample: a gap in displayed time does not prove an RF emitter ceased transmitting.

Any proposed attribution must survive the challenge that a gap in displayed time does not prove an rf emitter ceased transmitting. The chosen scholarly intervention has value only insofar as concurrency, deterministic processes, implementation assurance and reproducibility of digital acquisition supplies a relevant explanation.

Limits of attribution: He is valuable for software invariants and the separation of logical from physical time, not for unverified analogue receiver performance claims. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Edward Weston

Edward Weston was born in Wolverhampton, England, and moved to the United States in 1870. His engineering work connected materials, electrical instrumentation, and practical measurement. The National Inventors Hall of Fame records his development of stable-resistance alloys and accurate portable electrical instruments, including the direct-reading portable voltmeter associated with his induction. His work belongs to the physical construction of measurement systems, not to the later digital receiver

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technologies discussed in this volume. The biographical dates and the English-to-American career description are supported by that institutional record; no unsupported doctorate or citizenship date is assigned here. He is addressed as Mr Weston. [B01]

Weston's selection as the first principal respondent is an editorial decision grounded in that measurement expertise. His constructed role concerns the relation between a reference, the instrument that carries a comparison, and the quantity reported at a declared boundary. That role permits useful questions about loading, connection changes, transfer corrections, and the distinction between a stable indication and a valid physical measurement. It does not imply that Weston historically devised the modern logging or validation procedures placed in his dialogue. Those applications are newly authored and are supported separately by the volume's receiver-system discussion.

The contribution is deliberately narrower than a general authority over every part of an SDR. Weston establishes the physical comparison that later speakers test from sampling, informational, statistical, and methodological perspectives. This separation prevents the historical name from becoming a substitute for the modern technical evidence. Readers should assess the proposed experiments and their assumptions on their merits, while using the biography to understand why this particular historical perspective has been included. His place in the discussion is that of a measurement engineer whose documented work makes the opening boundary intelligible.

Historical expertise and source concordance: Electrical instruments and precision measurement, including portable voltmeters and resistance alloys; not a historical radio-Forensics practitioner. Independent historical source: https://www.invent.org/inductees/edward-weston

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Edwin Howard Armstrong

Edwin Howard Armstrong (1890–1954) was an American radio engineer whose work was associated with Columbia University. His historically documented areas of work include regenerative reception, superheterodyne conversion, and wideband frequency-modulation practice. The relevance of that intellectual tradition to this textbook is interpretive rather than personal: no historical endorsement, eyewitness evidence, modern SDR testing, or authenticated quotation is attributed to him. The constructed discussions draw upon this methodological background while evaluating contemporary hypothetical instrumentation. In particular, the associated questions 013, 016, 018, 022, 023, 031 explore mechanisms and evidence in which conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. The panel uses his named contribution to ask a specific and falsifiable question: how should an investigator test actual mixer behaviour, oscillator products and interference rather than merely a final detector trace? To answer responsibly, one must examine S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, rather than treating the apparatus readout as a self-authenticating account of physical origin. One illustrative circumstance is that the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible. A competing interpretation is that an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. This contrast should be tested by introduce a level-verified signal ahead of the antenna connector, interchange the filter with a

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matched dummy section, and repeat with a terminated rf port, with adverse observations and calibration states preserved. The biographical facts establish professional chronology and domain of scholarship; the imagined question and answer are editorial devices used to teach the distinction between direct observation and model-dependent inference. No claim is made that the individual employed, approved, or could have anticipated the exact modern instrumentation named in this educational exercise. The reader must rely on the measured variables, explicit assumptions, and the validity of the controlled comparison rather than on the prestige of the historical contributor.

Historical expertise and source concordance: Regenerative and superheterodyne receiver engineering and wideband frequency modulation. Attribution is appropriate for RF-stage mixing, gain, receiver images and overload, but not for personal knowledge of later digital-forensics protocols. Independent historical source: https://www.ee.columbia.edu/content/edwin-howard-armstrong

Egon Sharpe Pearson

Egon Sharpe Pearson was born in Hampstead in 1895 and died in 1980. University College London's archival account records his education at the Dragon School, Winchester College, and Trinity College, Cambridge, followed by his appointment at UCL. He became Professor of Statistics in 1935. The same record describes his collaboration with Jerzy Neyman on hypothesis testing and with Walter Shewhart on statistical methods in industrial production. It also records his presidency of the Royal Statistical Society and election to the Royal Society. Professor Pearson is therefore a supported form of address. [B11]

His peer question examines a practical complication in the boundary between development and validation. A receiver may legitimately adapt its

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threshold as part of a fixed procedure. Testing only a constant threshold would then test a different system, while allowing unrestricted changes after observing results would compromise the interpretation of validation. Pearson asks the principal respondent to distinguish these situations and to confront the possibility that a precisely implemented adaptive rule operates outside the background model supporting its claimed performance.

This is a newly authored receiver application, not a statement that Pearson evaluated the contemporary systems described. The historical connection lies in his documented testing and industrial-statistics work. His role gives the discussion a concrete challenge: what exactly is frozen, what is allowed to change, and which observations show that the resulting procedure meets the intended claim? The exchange also addresses the preservation of reference membership, threshold history, and shared dependencies. Its purpose is not to reject adaptation, but to prevent the adjective adaptive from obscuring an undefined experiment. The biography and role together explain why a statistical collaborator is needed to question the principal answer rather than merely repeat its conclusions.

George Ashley Campbell

George Ashley Campbell (1870–1954) was an American electrical engineer who helped develop the mathematical theory and practice of long-distance telephone transmission. His work on loading coils and electric wave filters arose from the need to transmit many telephone conversations over long circuits while managing attenuation and interference. The National Inventors Hall of Fame identifies him with early wave-filter development and the engineering applications of mathematical transmission theory. His

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contribution is therefore relevant to the origins of frequency-selective networks, not merely to the later terminology of digital filtering.

Campbell's practical significance to an SDR roundtable lies before the analogue-to-digital converter. A preselector, transformer, cable or filter gives the receiver a frequency-dependent and load-dependent view of the external environment. That view changes when the signal path is substituted, terminated or retuned. Filter rejection of a strong adjacent signal may be essential to preventing a mixer or amplifier from producing a spurious in-band product. Conversely, an erroneously matched or insufficiently characterised filter may attenuate the very emission that an investigation seeks to detect. Such observations cannot be reduced to a nominal bandwidth value printed on the instrument front panel.

The reconstructed speaker may be asked to distinguish desirable passband behaviour from achieved performance and to analyse the consequences of cascading sections. He is not represented as a modern RF surveillance operator or the designer of contemporary software architectures. The limits of his historical competence are those of classical transmission and filter engineering, which remain necessary elements of the complete measurement chain. His inclusion encourages genuine circuit-level challenge tests, not an anachronistic claim that old network theory alone establishes the identity of a present-day source.

Historical reference consulted: https://www.invent.org/inductees/george-ashley-campbell

George Edward Pelham Box

George Edward Pelham Box (1919–2013) was a British-born statistician whose career spanned industrial experiment, quality engineering, time-series modelling and academic research in the United States. During the

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Second World War, practical measurement problems encouraged his development as a statistician. He subsequently became strongly associated with the design and analysis of experiments and with the investigation of processes that change over time. The University of Wisconsin was an important centre of his later research and teaching. His work is unusually well suited to a discussion of experiments that are designed to expose the causes of a receiver anomaly.

An RF investigator may propose changing an antenna, gain level or preselector to see whether a suspicious spectral feature moves or disappears. Box's experimental tradition asks whether that intervention is properly isolated and whether the resulting interpretation confuses a changed cause with a changed measurement system. Factorial designs, controlled replication and examination of interactions offer alternatives to an improvised sequence in which several receiver settings are altered together. His time-series work is likewise relevant to drifting backgrounds, periodic disturbances and the possibility that a process has changed regime during the investigation.

This editorial reconstruction is careful not to make Box a source of specific modern SDR instrument specifications. His role concerns experimental thinking, model criticism and the interpretation of repeated measurements. If a proposed factor is confounded with temperature, retuning or operator selection, the results need qualification even when the resulting graph looks impressive. The central lesson is practical: the best experiment is one in which competing mechanisms make distinguishable predictions, and the record preserves the actual design rather than a retrospective account tailored to the most striking result.

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Historical reference consulted:
https://www.informs.org/Explore/History-of-O.R.-Excellence/Biographical-Profiles/Box-George-E.-P

Grace Brewster Murray Hopper

The historical record identifies Grace Brewster Murray Hopper (1906–1992) with software reproducibility, machine representation, program versions and documentation necessary for independent examination. An accurate professional description is an American computer scientist and United States Navy officer; compiler and programming-language pioneer.

Hopper helped make computing programs reproducible, inspectable and maintainable across increasingly complex systems. A modern SDR receiver can retain identical raw samples while producing different classifications under changed source code, firmware, dependency versions or data-type handling. Her contributions to programming systems justify a rigorous discussion of build records, configuration manifests, deterministic transformations and the distinction between data integrity and algorithmic correctness. It would be inappropriate to present her as a witness to present-day FPGA products, but fitting to apply her systematic approach to the documentation and independent reconstruction of acquisition software.

Within the new programme, Question 090 provides a suitable test of this expertise: How can a surveillance report avoid unnecessary communication-content collection? The test design calls for the investigator to compare a privacy-minimising triggered metadata record with a full-IQ recording for the stated detection task. The possible error is straightforward: more retained information is not automatically necessary, proportionate or probative.

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The intended teaching purpose is to illuminate distinguish energy and timing metadata, spectrum occupancy, publicly specified physical-layer fields and the acquisition of private payloads. without blurring the quite different historical evidence concerning software reproducibility, machine representation, program versions and documentation necessary for independent examination.

Limits of attribution: She is not depicted as having worked on current SDR instruments; her contributions provide a computing and software-engineering foundation. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Grote Reber

Grote Reber (1911–2002) enters the discussion on the strength of a recorded career as an American electrical engineer and radio astronomer; early purpose-built radio telescope. This context is materially connected to low-noise reception, antenna sensitivity, sky-source mapping and repeatability after failed experiments.

Reber designed and repeatedly modified antennas and receivers in the demanding early practice of radio astronomy. His sensitivity experiments invite particular attention to the difference between a plausible source and a measurement chain actually capable of revealing it. A planned peer challenge might ask what happens to the apparent sky signal when antenna pattern, receiver gain, noise temperature or environmental interference changes. The engineering lesson is that negative results depend on the tested instrument and its geometry. An elegant plot by itself cannot prove

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that a faint phenomenon was absent when the instrument was not adequately sensitive.

Question 063 is the most direct illustrative assignment, asking: What is missing when an antenna is calibrated exclusively under far-field conditions? Its recommended measurement challenge is to compare antenna factor in a controlled far-field arrangement with the same antenna placed close to a conductive reference enclosure. The author must recognise the counterexample: a laboratory antenna factor may not describe the sensor's response inside an equipment rack.

Any proposed attribution must survive the challenge that a laboratory antenna factor may not describe the sensor's response inside an equipment rack. The chosen scholarly intervention has value only insofar as low-noise reception, antenna sensitivity, sky-source mapping and repeatability after failed experiments supplies a relevant explanation.

Limits of attribution: His relevance concerns receiver sensitivity and controlled weak-signal surveys; personal device identification is beyond his historical work. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Harold Hotelling

Harold Hotelling (1895–1973) was an American mathematical statistician and economist whose research helped establish multivariate statistical methods. He worked at Stanford and Columbia before founding a major statistical research programme at the University of North Carolina at Chapel Hill. His contributions included work connected with principal components

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and multivariate tests, as well as mathematical economics. These methods are relevant whenever an investigator attempts to interpret several correlated measurements as though each were a separate and independent reason for believing one hypothesis.

For example, a receiver may record amplitude, phase, bandwidth, spectral shape and repeated time-frequency features from the same candidate event. Those measurements are informative, but their joint variability matters. If they are correlated through a common source, clock, automatic-gain process or digital transformation, combining marginal confidence statements can badly overstate the strength of evidence. Hotelling's mathematical legacy provides a way to ask what the covariance structure is, whether dimensional reduction discards a discriminating feature, and whether an apparent outlier remains unusual after legitimate correlations have been accounted for. It also draws attention to the number of observations available for estimating the covariance itself.

In this constructed roundtable Hotelling acts as a statistical reviewer of correlated measurements, rather than a developer of present-day waveform classifiers. His historical work supports caution about multivariate inference; it does not verify a particular machine-learning model or signal catalogue. A responsible report should state the variables chosen, the sample from which their relationships were estimated, the stability of that sample, and the effect of alternative processing choices. His perspective is especially valuable when a visually distinctive spectral signature is presented as unique device identification without adequate population evidence.

Historical reference consulted: https://www.nationalacademies.org/read/11522/chapter/13

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Harold Stephen Black

Harold Stephen Black was an American engineer whose name is associated with the invention and practical development of negative-feedback amplification. Born in Leominster, Massachusetts, in April 1898, he completed engineering studies at Worcester Polytechnic Institute and joined the research environment which became Bell Telephone Laboratories. His work on controlling distortion in long-distance communication provided an important link between the behaviour of electronic circuits and more general principles of feedback and stability. The National Inventors Hall of Fame records his contributions, the negative-feedback amplifier patent and his subsequent professional work. The present dialogue is original educational reconstruction; it does not attribute practical familiarity with software-defined radio, modern ADC arrays or digital correlation software to Black. [B1]

Black's assigned role is to return abstract signal detection to the physical behaviour of the receiver. A mathematical algorithm may perfectly compute a matched-filter output while a local oscillator, gain-control transition or switching path generates the pulse to which it responds. Such receiver artefacts can be highly repeatable. Their existence must be tested through independent physical observations and a calibrated signal path, rather than inferred solely from a peak's position on a display. The constructed discussion invokes Black's documented engineering tradition of controlled feedback and measurement to examine these possibilities. It emphasises that a fixed template and an adaptive receiver can form a feedback-like selection mechanism, particularly when the template is learned from the same archived recording. This is a contemporary application of a historical

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intellectual method, not a claim that Black conducted any of the imaginary experiments described in the roundtable.

Harry Nyquist

Harry Nyquist was born in Nilsby, Sweden, and moved to the United States in 1907. He studied electrical engineering at the University of North Dakota and received a doctorate from Yale University in 1917. His subsequent communications research addressed transmission, thermal noise, and feedback. The engineering-history record identifies his work in the development and research organisation of the American Telephone and Telegraph Company and later at Bell Telephone Laboratories, from which he retired in 1954. It records his death in 1976. His doctorate supports the form Dr Nyquist used in this constructed discussion. [B02]

His assigned role is to examine what an acquisition preserves, rather than to treat every numerical output as a transparent view of an external signal. The connection to his documented research is substantive: transmission restrictions, sampling relationships, and feedback all require an explicit model of the system under examination. The modern discussion applies that discipline to admitted analogue bands, sample continuity, frequency mappings, and the history of digital transformations. Those particular applications are the author's present synthesis, not reconstructed statements from Nyquist's lifetime.

The biography also sets an important boundary. A foundational contribution to communications theory does not supply an experimental certificate for a present receiver. The dialogue therefore distinguishes a mathematical representation from a measured demonstration that its

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assumptions hold. Nyquist's exchanges ask how alternative inputs can become indistinguishable and how a controlled change might restore a useful distinction. They do not promise that a nominal sampling specification resolves every ambiguity. This makes his contribution complementary to Weston's physical comparison and Shannon's account of retained information. Historical standing supplies a reason for the perspective, while the receiver model and evidence must still support each modern conclusion.

Heinrich Rudolf Hertz

Heinrich Rudolf Hertz (1857–1894) enters the discussion on the strength of a recorded career as a German physicist; experimental demonstration of electromagnetic waves. This context is materially connected to propagation, resonance, electromagnetic coupling and controlled confirmation of rf phenomena.

Hertz’s experimental investigation of electromagnetic waves links theory to resonant circuits, detection methods and controlled radiation phenomena. The questions about coupling and instrument response benefit from this emphasis upon demonstrable physical change. A reconstructed intervention might insist that a suspected radiated component respond predictably to changes of geometry, polarisation or source excitation while alternative internal artefacts behave differently. The appropriate connection is resonance, propagation and the logic of laboratory tests. He must not be presented as having used modern spectrum analysers or assessed a software-defined receiver.

Question 062 is the most direct illustrative assignment, asking: Which near-field observations distinguish electric coupling from magnetic coupling

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in an enclosure? Its recommended measurement challenge is to map the same controlled component with calibrated miniature E-field and H-field probes, varying orientation and standoff. The author must recognise the counterexample: a near-field maximum cannot be interpreted as far-field radiated power without a field model.

Any proposed attribution must survive the challenge that a near-field maximum cannot be interpreted as far-field radiated power without a field model. The chosen scholarly intervention has value only insofar as propagation, resonance, electromagnetic coupling and controlled confirmation of rf phenomena supplies a relevant explanation.

Limits of attribution: He is an apt historical physical experimentalist, not an author of digital signal processing or software-defined receiver techniques. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Hendrik Antoon Lorentz

1853–1928. Dutch theoretical physicist; Nobel laureate in physics, 1902. Hendrik Antoon Lorentz was a major figure in theoretical physics whose work on electromagnetism, electrons and the relation between fields and matter influenced the development of modern physics. He pursued much of his career in the Netherlands and shared the 1902 Nobel Prize in Physics with Pieter Zeeman for research on the influence of magnetism upon radiation phenomena. His analytical contributions helped make electromagnetic descriptions more exact and provided a language for subtle distinctions between an observed field and its underlying physical causes. In

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the present fictional dialogue Lorentz challenges the sufficiency of internal phase calibration when an antenna array is used in a site with reflections, coupling and uncertain propagation. The example is modern and constructed. No claim is made that Lorentz participated in radio-forensic surveys or prescribed present-day calibration procedures. His attributed question instead extends the general virtue of precise physical modelling to an operational problem: an electronic reference may validate one part of a measuring chain without validating its antenna, installation or environment. He therefore stands for a distinction essential to trustworthy metrology, namely that a correction demonstrated at one boundary cannot simply be transported to another boundary unless the relationships between them have themselves been examined. In this educational setting the central question concerns transferability of a calibration claim. A mathematical relation may be well verified within an electronic loop and poorly tested in its external environment. The constructed exchange asks the examiner to mark the boundary where measured evidence ends and a physically plausible but still unverified model begins.

Hendrik Wade Bode

Hendrik Wade Bode was born in Madison, Wisconsin, in 1905 and died in 1982. The American Automatic Control Council reproduces an engineering-academy memorial account documenting his mathematical education, his doctorate in physics from Columbia University in 1935, and his work on electrical networks, filters, feedback, and systems engineering. After his industrial research career, he held a systems-engineering professorship at Harvard. His 1945 book on network analysis and feedback-amplifier design

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is identified in that account. The form Dr Bode is supported by the documented doctorate. [B08]

Bode's assigned peer role addresses memory and changing state in the analogue path. Correctly sampled data can faithfully describe the output of a system whose transfer during an event differs from its settled calibration response. The modern example involves a burst following a strong disturbance and an automatic gain transition. It is an original receiver case for this volume, not a claim that Bode examined the particular instrument or implementation. His established network and feedback expertise explains why this challenge follows Nyquist's account of the sampling boundary.

The question is intentionally diagnostic rather than merely cautionary. It asks whether an apparent discrepancy belongs to sampling, an inadequate analogue model, or the combined inference from them. It also asks what preceding history and state information must survive in the record. This framing prevents a well-documented digital stage from being used to certify an unobserved upstream condition. At the same time, it avoids treating every changing response as irrecoverable. A properly identified and tested model may support a restricted correction. Bode's contribution therefore helps the reader distinguish known dynamics, unsupported steady-state extrapolation, and genuine non-uniqueness in reconstructing the physical input.

Historical expertise and source concordance: Electrical network theory, feedback stability, magnitude/phase representation; not a witness to modern SDR investigations. His network arguments in Q013, Q014, Q017–020, Q022 and Q023 are historically consonant when restricted to transfer functions and control behaviour. Independent historical source: https://ethw.org/Hendrik_W._Bode

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Herbert Kroemer

Herbert Kroemer (1928–2024) was a German-born physicist; semiconductor heterostructures and high-speed electronic devices. The contribution relevant to this manuscript is analogue front-end limits, semiconductor nonlinearity, transistor behaviour and plausible trajectories of device technology.

Kroemer's theoretical and experimental work on semiconductor heterostructures provides a physical constraint on extravagant projections of electronic receiver capability. Bandwidth, nonlinearity, gain, noise and power dissipation are linked to device structures and their operating conditions, not merely to the number of bits declared by an output register. A useful debate would ask what changes when a high-speed front end becomes hotter, faces a strong blocker or moves outside its specified linear region. This work supports disciplined forecasting of devices; it does not license numerical predictions for an untested future architecture.

In the planned Question 066, the concrete issue is: How do clock feedthrough and oscillator harmonics traverse an instrument enclosure? An appropriate proposed experiment is to vary clock frequency with the RF input terminated and trace spur trajectories through shield, supply and reference changes. The corresponding interpretive caution is that a discrete line that moves with digital sampling clock settings is not necessarily an external transmission.

This contributor will be evaluated against the concrete distinction between study grounding, leakage paths, pcb return currents, shielding apertures and cross-coupling between adc clock and analogue front end. and a discrete line that moves with digital sampling clock settings is not

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necessarily an external transmission. rather than against an invented claim of personal experience with the specified apparatus.

Limits of attribution: His device-physics expertise supports physical constraints on future conversion systems, but not predictions of specific products. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Irving S. Reed

Irving S. Reed (1923–2012) was an American electrical engineer and information theorist; detection and error-correcting codes. The contribution relevant to this manuscript is coding structure, radar data detection, recoverable information and the limitations of code-family inference.

Reed contributed to coding theory and to automatic processing of radar data. In an unknown-waveform investigation, redundancy can disclose the existence of structured transmission without yielding a private payload or a unique device identity. He is an appropriate principal speaker for tests comparing syndrome consistency, synchronisation failure, channel errors and the possibility that a non-communication periodic process mimics a coded sequence. The moderator should distinguish recognising an error-control architecture from claiming successful decoding and should require controlled counterexamples. The presence of a recognised code family remains a class characteristic rather than individual identification.

In the planned Question 081, the concrete issue is: What may coding structure reveal about a waveform without decoding protected communication content? An appropriate proposed experiment is to transmit

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public test sequences using contrasting block and convolutional encoders and compare blind syndrome or correlation statistics. The corresponding interpretive caution is that a recognised code family is shared by many devices and cannot by itself identify the transmitter.

This contributor will be evaluated against the concrete distinction between consider redundancy, symbol timing, frame boundaries, error signatures and the gap between a coding-family hypothesis and a decoded message. and a recognised code family is shared by many devices and cannot by itself identify the transmitter. rather than against an invented claim of personal experience with the specified apparatus.

Limits of attribution: Coding expertise can support waveform-family analysis without implying that Reed examined any contemporary confidential traffic. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Isidor Isaac Rabi

Among the historical authorities newly considered for Volume 11 is Isidor Isaac Rabi (1898–1988). The documented career is that of a Physicist; molecular-beam magnetic resonance and the 1944 Nobel Prize in Physics. Its appropriate scope here is controlled resonance experiments, frequency selectivity, systematic perturbation and measurement calibration.

The decisive feature of his molecular-beam work was a controllable resonance experiment in which the response changed with an applied field of definite frequency. That approach is directly pertinent to experimental challenge: the investigator should manipulate one physical cause and

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observe a predicted change, rather than merely admire a stable spectral line. A reconstructed contribution may examine how resonance linewidth, field stability and measurement selectivity interact, or how a calibration source can expose instrumental responses. It must not convert Rabi into a posthumous commentator on digital protocols.

The contribution can be tested against Question 052: How should traceability of frequency standards govern coherent captures separated in time? There, the proposed discriminating experiment would compare two independently disciplined frequency chains by logging phase difference against averaging time, reference changes and loss-of-lock events. The stated failure mode is equally important: nominally identical ten-megahertz references do not imply coherent samples after an unobserved cycle slip.

For editorial quality, the speaker assignment must remain anchored in controlled resonance experiments, frequency selectivity, systematic perturbation and measurement calibration; the manuscript should plainly separate documented historical discovery from the modern test concerning separate accuracy of a frequency standard from its short-term phase stability and from the transfer path delivering that standard to adcs and mixers.

Limits of attribution: His experimental methods illuminate frequency references and the identification of instrumental artefacts, not modern time-tag metadata systems. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

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Jacob Ziv

Jacob Ziv (1931–2023) enters the discussion on the strength of a recorded career as an Israeli engineer and information theorist; universal data compression with Abraham Lempel. This context is materially connected to compression, entropy, source redundancy and limits of identifying payload semantics from statistics.

Universal compression shows that apparent randomness can arise from highly structured source material after efficient encoding. This is of immediate relevance when a spectrum-monitoring examiner encounters a high-entropy burst and is tempted to infer encryption or covert activity. A credible reconstruction would distinguish entropy estimation, sample size, compressor state and the effects of framing and modulation. The comparison should include known data compressed by different methods and genuinely random test data, exposing where common tests fail. Ziv's historic work justifies a methodological warning against conflating data compressibility with a particular transmitter or user.

Question 082 is the most direct illustrative assignment, asking: When does payload compression defeat entropy-based sender attribution? Its recommended measurement challenge is to compare identical source messages before and after lossless compression and randomisation while retaining controlled framing metadata. The author must recognise the counterexample: high apparent entropy does not prove a signal is encrypted or malicious.

Any proposed attribution must survive the challenge that high apparent entropy does not prove a signal is encrypted or malicious. The chosen scholarly intervention has value only insofar as compression, entropy,

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source redundancy and limits of identifying payload semantics from statistics supplies a relevant explanation.

Limits of attribution: He can analyse compression and information content, but not assert the identity or intention of an unknown transmitter. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

James Clerk Maxwell

Among the historical authorities newly considered for Volume 11 is James Clerk Maxwell (1831–1879). The documented career is that of a Scottish mathematical physicist; classical electromagnetic field theory. Its appropriate scope here is field boundaries, propagation, polarisation and the distinction between source currents and observed electromagnetic fields.

Maxwell established the mathematical relations between electric and magnetic fields and helped show that electromagnetic radiation follows from them. His theory sets limits on casual extrapolation from a local near-field probe reading to a far-field transmitter claim. A proper exchange would distinguish source currents, boundary conditions, polarisation and the relative contribution of reactive and propagating fields. The precise conditions matter because a local maximum beside a conductor is not necessarily a remote-emitter bearing. He is an appropriate foundational physicist for the interpretation, though not a participant in present-day antenna certification procedures.

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The contribution can be tested against Question 063: What is missing when an antenna is calibrated exclusively under far-field conditions? There, the proposed discriminating experiment would compare antenna factor in a controlled far-field arrangement with the same antenna placed close to a conductive reference enclosure. The stated failure mode is equally important: a laboratory antenna factor may not describe the sensor's response inside an equipment rack.

For editorial quality, the speaker assignment must remain anchored in field boundaries, propagation, polarisation and the distinction between source currents and observed electromagnetic fields; the manuscript should plainly separate documented historical discovery from the modern test concerning distinguish far-field gain and polarisation patterns from reactive loading, cable interaction and enclosure-coupled perturbations.

Limits of attribution: His mathematical field theory can guide RF interpretation without implying a historical contribution to contemporary antenna test standards. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Jean-Baptiste Joseph Fourier

Jean-Baptiste Joseph Fourier was a French mathematician and physicist whose work on heat conduction and the analysis of functions by trigonometric series profoundly influenced later mathematical physics. Fourier's treatise on the analytical theory of heat is a major landmark in the development of methods that are now indispensable to signal processing. His historical setting preceded radio broadcasting, electronic receivers and

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digital sampling; the present text therefore uses his mathematical ideas in an explicitly fictional contemporary dialogue. It would be historically false to treat these constructed remarks as personal observations about software-defined radios, FFT implementations or digital forensic records. [T3, T7]

Fourier's relevance to the discussion rests on the separation of a mathematical representation from the physical uniqueness of its cause. A transform may rearrange the information contained in a finite list of measured values without establishing that those values uniquely determined the original analogue input. The difference bears directly on the evidential meaning of transient spectra. Finite-window multiplication, loss of phase in power displays, digital decimation and record selection can affect which physical alternatives remain observable. Modern inverse problems also require calibrated transfer functions and independent physical tests, matters that should not be conflated with the historical derivation of Fourier methods. In this roundtable, his imaginary contribution provides a disciplined mathematical perspective on the distinction between computing a spectrum correctly and identifying an electromagnetic emitter from it.

Biographical scholarship records his work amid the tumult of revolutionary and Napoleonic France, his involvement in teaching and public administration, and his later position in the Académie des Sciences. Those circumstances place his achievements in their proper historical setting rather than allowing a modern author to transport his scientific career uncritically into the digital age. The historical record also documents his analyses of heat conduction and his interactions with the scientific institutions of Paris. These are the grounds for invoking his intellectual

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tradition, not evidence of opinions on present-day investigative instrumentation.

Jerzy Neyman

Jerzy Neyman was a Polish-born statistician whose career bridged European and American mathematical research. Born in 1894 and educated in eastern Europe, he worked in Poland and in the British statistical research environment before moving to the University of California, Berkeley, in 1938. At Berkeley he helped establish a major programme of mathematical statistics, and the university records his foundational role in creating its Department of Statistics. Neyman's work on hypothesis testing, confidence intervals and sampling design contributed profoundly to twentieth-century statistical methodology. The National Academies' biographical record describes his approach as deriving procedures for carefully stated mathematical questions. None of these historical sources records him discussing present-day software-defined surveillance receivers. [B3]

His relevance here is the distinction between a procedure's repeated-use performance and the interpretation of a selected observation. A receiver may announce thousands of candidate alarms from overlapping FFT windows, but the confidence assigned to a test depends upon the experiment, the statistical population and the dependence of the decisions. Neyman's framework offers a way to articulate those premises before making an evidential claim. It also exposes the problem of choosing thresholds or clustering gaps after seeing the examples upon which the method's success is judged. Such selection may be legitimate in exploratory analysis but changes the meaning of a nominal confidence or false-positive calculation.

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In this newly constructed dialogue, Neyman insists that known injected physical events, rather than repeated frames from the same event, form the correct denominator for a declared event-level sensitivity claim. He further distinguishes the family-wise chance of at least one false alarm from the conditional probability of a signal being present when a particular detector alarm occurs. Those are different mathematical questions with different evidence requirements. His role is to sharpen the logic of inference, not to offer a historical endorsement of any particular SDR platform. The result is a considered bridge between foundational statistical scholarship and the practical ethics of forensic reporting, where visible uncertainty is preferable to unsupported certainty dressed in decimal places.

Historical expertise and source concordance: Confidence procedures, hypothesis testing and sampling design, including his historical work at University College London and Berkeley. The fictional statistical objections are methodological extrapolations, not transcripts or real modern findings. Independent historical source: https://statistics.berkeley.edu/about/history

John Bardeen

John Bardeen (1908–1991) was an American physicist whose work joined fundamental solid-state theory to practical electronics. At Bell Telephone Laboratories he participated with Walter Brattain and William Shockley in the research leading to the transistor, for which they shared the 1956 Nobel Prize in Physics. Later, at the University of Illinois, Bardeen worked with Leon Cooper and John Robert Schrieffer on the microscopic theory of superconductivity, leading to a second Nobel Prize in 1972. These are distinct accomplishments, but both exemplify his attention to the physical behaviour of materials that electronic circuits rely upon.

In a receiver, a semiconductor device is not a perfect linear amplifier. Its behaviour depends upon bias, temperature, signal amplitude, frequency

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and loading, and it may generate distortion or recover slowly following overload. Bardeen's historical expertise therefore supplies a defensible reason to challenge simplistic models of the analogue signal path. If an unexpected line appears in sampled data, the examination cannot stop at a digital spectrum estimate. It must also consider whether active devices, protective junctions or stages driven beyond their intended region could have produced a mixing product. This application of semiconductor physics must be tested with the actual device and configuration; its mere plausibility does not prove the mechanism.

The fictional peer contribution uses Bardeen as a specialist in material and device physics, not as a forensic witness to contemporary SDR surveys. His life and work do not authorise claims about proprietary receiver designs or unseen environmental transmitters. Instead his inclusion illustrates how a sound digital calculation can coexist with an incorrect physical interpretation if the analogue source of the sample stream is not independently examined. The engineering conclusion remains bounded by observed device behaviour and documented instrumentation conditions.

Historical reference consulted: https://ece.illinois.edu/about/history/hall-of-fame/bardeen

John Daniel Kraus

1910–2004. American electrical engineer, antenna specialist and radio astronomer. John Daniel Kraus became internationally recognised for his contributions to antenna engineering and radio astronomy. Trained at the University of Michigan, he worked on electromagnetic and radar-related problems during the Second World War before joining Ohio State University, where he taught, researched and helped establish a major radio observatory. His engineering achievements included important antenna

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designs and widely used writing on antennas and radio astronomy. He directed the development of large radio receiving instruments and encouraged hands-on experimentation that made the dependence of performance upon physical geometry particularly evident. In the constructed dialogue Kraus questions a familiar procurement and forensic habit: quoting one nominal direction-finding accuracy across a wide span of frequency, signal strength, installation and dwell conditions. The electronic size of the array changes with wavelength; so do coupling, sensitivity and ambiguities. The modern validation requirements described in the answer are original editorial synthesis, not statements taken from Kraus's books. His contribution is chosen to remind the reader that even a refined algorithm remains coupled to an antenna's physical aperture, pattern, installation and interaction with the surrounding environment. The accuracy warranted by a field result must be demonstrated over the actual conditions rather than borrowed from a convenient summary figure. His research and teaching show that the antenna is not a detachable ornament on a receiving instrument. It establishes the interface between the measurable field and the connected electronics. The dialogue uses this principle to insist that installation, frequency and burst duration be reflected in the reported performance, rather than buried under a single instrument specification.

John Harrison

The historical record identifies John Harrison (1693–1776) with chronometer error, environmental disturbance, calibration and the principle of traceable time. An accurate professional description is an English clockmaker and inventor; marine chronometers and precision timekeeping.

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Harrison's chronometers transformed maritime navigation by confronting the difficulty of accurate timekeeping under changing physical conditions. His relevance to a modern frequency-standard debate is historical and metrological, rather than digital. A careful analogy would examine environmental influence, repeatability, mechanical disturbance and the need for a tested reference independent of the observer's wish for precision. Chronometer error at sea demonstrates why a clock's nominal design is not sufficient evidence of its behaviour in use. The moderator must refrain from attributing knowledge of atomic clocks, RF distribution amplifiers or network timing to Harrison.

Within the new programme, Question 052 provides a suitable test of this expertise: How should traceability of frequency standards govern coherent captures separated in time? The test design calls for the investigator to compare two independently disciplined frequency chains by logging phase difference against averaging time, reference changes and loss-of-lock events. The possible error is straightforward: nominally identical ten-megahertz references do not imply coherent samples after an unobserved cycle slip.

The intended teaching purpose is to illuminate separate accuracy of a frequency standard from its short-term phase stability and from the transfer path delivering that standard to adcs and mixers. without blurring the quite different historical evidence concerning chronometer error, environmental disturbance, calibration and the principle of traceable time.

Limits of attribution: Harrison contributes historical mechanical timing expertise only; no digital, RF or network clock procedures are attributed to him. This is a modern scholarly introduction, not a transcription of historical

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speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

John Robinson Pierce

John Robinson Pierce (1910–2002) was an American electrical engineer and communication scientist whose long career at Bell Telephone Laboratories included work on travelling-wave tubes and the early development of communications satellites. The California Institute of Technology preserves an oral-history record of his Bell Labs research, radar-related work and involvement in the Echo and Telstar satellite programmes. He later returned to academic research and also took an interest in psychoacoustics and computer-generated sound. His work exemplified the interaction of propagation physics, electronic apparatus and system-level communication design.

Pierce's appropriate contribution to the roundtable is to ask whether a receiver observation is being interpreted within a sufficiently complete communication system. A spectral line or transient pulse must be considered in relation to the source, path, antenna, receiver and detector, rather than assigned to a transmitter merely because it appears in a saved image. At microwave frequencies, components and transmission paths can impose strong frequency selectivity and phase variation. The result may be especially misleading when comparing observations from geographically separated sensors or when trying to infer a source's behaviour from one limited capture window.

An imagined Pierce intervention should not claim that he tested modern SDR forensic software. His documented background supports questions

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about communication channels, amplification, propagation and instrumentation integration. The modern survey must supply measurements of its own receiver noise, timing and front-end transfer function. The principal lesson is methodological as well as technological: communication engineering requires a complete system model, and forensic attribution requires evidence distinguishing that model from plausible alternatives. A theory of a possible path is useful only where the record can test whether that path was actually operating.

Historical reference consulted:
https://digital.archives.caltech.edu/collections/OralHistories/OH_Pierce_J/

John von Neumann

John von Neumann (1903–1957) was a Hungarian-born American mathematician whose research reached across mathematical foundations, quantum theory, game theory, numerical computation and the architecture of electronic computing systems. He participated in major wartime and post-war scientific programmes and made fundamental contributions to the understanding of computation as a physical and mathematical process. Although his name is attached to influential computer-architecture concepts, the historical attribution of specific stored-program developments is more complex than a single-inventor story. His lifetime ended before the modern software-defined radio emerged.

Within this roundtable, von Neumann's work is useful for distinguishing numerical operations from the information present in their inputs. A computer may implement a mathematically correct transform while the samples supplied to it are clipped, aliased or badly timed. Similarly, a reconstruction algorithm can produce a definite array of values even where

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multiple physical waveforms were compatible with the retained record. Numerical stability, finite precision and the form of the computational model must therefore be examined separately from the validity of the analogue acquisition. Where a complex signal is transformed or decimated, the researcher should state which degrees of freedom remain available for later analysis.

His fictional peer challenge appropriately addresses mathematical computation, modelling and the epistemic limits of algorithms. It must not imply firsthand knowledge of present receiver firmware, and it should not use his stature to resolve an engineering dispute for which no contemporary measurement has been supplied. The historical connection is strongest where mathematical formalisation clarifies the experiment: describe the input, the computational operation, the physical assumptions and the observable consequence of each alternative model. That is a properly bounded use of his research legacy.

Historical reference consulted: https://mathshistory.st-andrews.ac.uk/Biographies/Von_Neumann/

John Wilder Tukey

John Wilder Tukey was an American mathematician and statistician closely associated with Princeton University and Bell Telephone Laboratories. Historical accounts document his education at Brown and Princeton, influential contributions to exploratory data analysis, and his collaboration with James W. Cooley on the fast Fourier transform algorithm. His career extended across mathematical statistics, numerical computing and practical applications in science and engineering. He received significant professional honours, including the United States National Medal of Science. The breadth of his work makes him a particularly appropriate intellectual

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figure for an imagined debate about what analysts learn from data before they possess a settled model. [R6]

The present dialogue does not reproduce Tukey's historical utterances. It uses his documented methodological concerns as a basis for new discussion of robust spectral summaries and event selection. A robust measure of ordinary background can be statistically useful while suppressing an intermittent transmission whose unusual appearance is precisely why a defensive investigator wishes to preserve it. Exploratory detection may reveal patterns that motivate new hypotheses, but confirmatory performance must be evaluated with controlled trials and a disclosed selection rule. These modern forensic applications are newly authored educational constructions. They should not be mistaken for reports of Tukey personally examining software-defined surveillance receivers or prescribing the specific procedures presented in this volume.

His methodological example encourages scientists to examine the behaviour of individual observations before accepting a reassuring aggregate. Within a surveillance inquiry, that disposition is relevant to both the unexpectedly high measurement and the awkward missing interval. Neither should be erased merely to improve the apparent smoothness of a plotted background.

Historical expertise and source concordance: Exploratory data analysis, statistical practice, computing and co-development of the fast Fourier transform; source-compatible for critiques of display-selected evidence. Independent historical source: https://history.computer.org/pioneers/tukey.html

Jules Henri Poincaré

1854–1912. French mathematician, theoretical physicist and philosopher of science. Henri Poincaré pursued a remarkably wide mathematical and

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philosophical career, contributing to differential equations, celestial mechanics, mathematical physics and the foundations of later developments in topology. Born in Nancy, he studied and worked in France, where his investigations repeatedly exposed the relationship between a precise mathematical formalism and the limits of prediction in a complicated physical system. His writings also addressed the role of convention, hypothesis and scientific explanation. In the present constructed conversation, he presses Professor Bracewell to distinguish mathematical uniqueness from numerical stability and from the evidential separation of competing source hypotheses. An algorithm may return one solution despite severe ill-conditioning, an untested prior or a second physical arrangement compatible with the data. The speech does not assert that Poincaré formulated modern SDR forensic requirements. Rather, it places his methodological insistence on the careful interpretation of mathematics within a present-day inverse problem. The role is particularly relevant where a highly detailed computed coordinate seems to outrun the finite, noisy and incomplete measurements from which it was inferred. His question requires the examiner to test how the output changes when assumptions and nuisance parameters change, and to present non-unique alternatives when the observation cannot decide between them. The question is chiefly epistemological: a numerical solution can be formally correct and practically unstable, or stable within a model that excludes the true physical cause. The dialogue links this distinction to receiver localisation and to the duty to preserve alternate hypotheses. This is an application of mathematical caution, not a claimed historical quotation.

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Karl Guthe Jansky

Among the historical authorities newly considered for Volume 11 is Karl Guthe Jansky (1905–1950). The documented career is that of an American radio physicist; discovered radio emission from the Milky Way while investigating terrestrial interference. Its appropriate scope here is environmental radio noise, antenna directionality, propagation and disciplined differentiation of source origins.

Jansky was investigating sources of interference affecting transatlantic radiotelephony when he established that one persistent component of observed radio noise arrived from beyond the Earth. His observational discipline is essential for separating a genuine incident field from equipment artefacts and misleading local assumptions. An appropriate question asks how changing antenna direction, sidereal timing, weather, receiver state and reference loads alters the competing predictions. The relevance is the act of distinguishing possible origins using repeatable evidence. It does not turn a twentieth-century sky-noise investigation into an endorsement of contemporary software classification claims.

The contribution can be tested against Question 068: How can antenna substitution distinguish incident RF energy from instrument-generated signals? There, the proposed discriminating experiment would run antenna, matched-load, dummy-source and second-front-end substitutions under constant receiver state. The stated failure mode is equally important: a disappearing feature after antenna removal can also arise from changes in gain-control or impedance environment.

For editorial quality, the speaker assignment must remain anchored in environmental radio noise, antenna directionality, propagation and

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disciplined differentiation of source origins; the manuscript should plainly separate documented historical discovery from the modern test concerning use known source impedance, preselector bypass, shielded terminations and independent input paths to establish where energy entered the measurement chain.

Limits of attribution: He contributes directly to source discrimination and radio background studies, not digital modulation classifications invented decades later. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Karl Pearson

Karl Pearson (1857–1936) was a British mathematician and statistician associated particularly with University College London and the institutional development of mathematical statistics. He worked on the formal treatment of correlation, distributions and quantitative comparison, and helped establish the journal Biometrika. His intellectual and professional career also included eugenics research and advocacy. That history is an important qualification, not an achievement to be imported uncritically into modern forensic practice; his contributions to mathematical method can be studied without accepting the social claims to which he sometimes applied them.

Pearson's statistical methods enter receiver engineering when investigators compare measurement groups, estimate relationships among variables or assert that a spectral anomaly is exceptional. Correlation between successive samples or between frequency bins does not establish physical causation. An elevated correlation coefficient can be generated by a

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shared gain-control response, common oscillator drift or a signal-processing choice rather than by two independent sources. A statistical model must distinguish the quantity estimated from the mechanism inferred, particularly where a threshold or feature set has been selected after examining the same data. These concerns are directly relevant to laboratory challenge tests and the analysis of large spectral catalogues.

The constructed contribution attributed to Pearson is limited to statistical reasoning and its interpretive conditions. It does not give his views special authority in contemporary law, sociology or ethics, and does not suggest he could evaluate later software-defined instruments. A defensible use of his methods will name the sample, explain dependence, show the consequences of alternatives and avoid treating statistical association as unique source identification. His biography makes the distinction between mathematical accomplishment and broader historical judgement explicit.

Historical reference consulted: https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA8002&src=CalmView.Persons

Lord Rayleigh

1842–1919. British physicist and Nobel laureate in physics, 1904. John William Strutt, third Baron Rayleigh, made foundational contributions to acoustics, optics, waves and experimental physics. His work on wave phenomena and diffraction helped establish enduring methods for thinking about resolution and the limitations of finite apertures. He occupied important scientific positions in Britain, including service at Cambridge and leadership of the Royal Society, and received the 1904 Nobel Prize in Physics for work associated with the density of gases and the discovery of argon. The present contribution borrows the discipline of careful discrimination,

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not a quotation or purported historical research on modern arrays. A direction-finding processor can draw a sharply located maximum without demonstrating that two nearby emitters are resolvable or that environmental bias is absent. Resolution, precision and accuracy therefore have separate evidential meanings. Rayleigh's assigned question asks an investigator to demonstrate those differences rather than to count pixels or decimal places in a finished display. The historical authority of his investigations must not be used to suggest endorsement of a particular modern algorithm, receiver or forensic threshold. His function in this deliberately constructed conversation is to make the physical aperture and the population of competing wavefronts visible behind the apparently effortless output of an electronic processor. Rayleigh appears not as a modern compliance authority but as an exemplar of patient experimental distinction. His assigned question encourages separate study of resolution, bias and random variation. In scholarly terms, each quantity answers a different question, and none becomes a fact merely because software can display several decimal places.

Lotfi Asker Zadeh

Lotfi Asker Zadeh (1921–2017) was an electrical engineer and computer scientist whose work extended from system theory to artificial intelligence and fuzzy-set methods. After education including the University of Tehran, the Massachusetts Institute of Technology and Columbia University, he joined the faculty of the University of California, Berkeley. His research in time-varying systems, sampled-data analysis and state-space representations preceded his influential 1965 paper introducing fuzzy sets. Berkeley's institutional account provides a useful chronology connecting

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these stages of his work rather than reducing his career to the single adjective 'fuzzy'.

His relevance to receiver analysis arises when an investigator must distinguish uncertainty in a physical measurement from vagueness in the categories used to describe it. A poorly resolved burst may be partially compatible with several signal classes, and software may assign degrees of membership to those classes. Such a classification can be useful for triage but is not automatically a calibrated probability that a particular transmitter was present. Further, a system-state model must account for changing filter, gain and timing states if it is to support retrospective interpretation. These questions belong naturally to Zadeh's documented interests in systems, mathematical representations and approximate reasoning.

The hypothetical contribution should therefore challenge analysts who equate a confidence-like score with a forensic posterior probability without validating that interpretation. It should also ask whether a flexible classifier preserves a stable definition across hardware and software revisions. Zadeh did not personally test the contemporary SDR systems described in the volume; his historical work is an intellectual resource for handling incomplete classification and dynamic system models. Physical source attribution still requires independent RF observations, calibration and a properly specified inferential procedure.

Historical reference consulted: https://engineering.berkeley.edu/news/2017/09/remembering-lotfi-zadeh/

Louis Essen

Louis Essen (1908–1997) enters the discussion on the strength of a recorded career as a British physicist and metrologist; precision frequency

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measurement and the caesium atomic clock. This context is materially connected to frequency standards, clock comparisons, long-term drift and the practical problem of traceability.

His metrological career connected accurate oscillator behaviour to comparisons of standards under practical laboratory conditions. The planned clock questions require the distinction between frequency offset, short-term fluctuation, environmental drift and the uncertainty of transfer between devices. An appropriate discussion could compare a reference counter with two independently operated oscillators, testing whether an apparent improvement after averaging reflects genuine reference stability or merely cancellation of common errors. It should record temperature, control state, holdover and frequency history, so that the authority of a standard is not inferred from its label.

Question 053 is the most direct illustrative assignment, asking: When can oscillator disciplining conceal rather than correct a phase discontinuity? Its recommended measurement challenge is to apply controlled reference interruptions and record both raw phase residuals and closed-loop control voltages before and after reacquisition. The author must recognise the counterexample: a clean long-term Allan deviation curve can conceal a short, consequential phase step.

Any proposed attribution must survive the challenge that a clean long-term allan deviation curve can conceal a short, consequential phase step. The chosen scholarly intervention has value only insofar as frequency standards, clock comparisons, long-term drift and the practical problem of traceability supplies a relevant explanation.

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Limits of attribution: Essen may address reference accuracy and metrological discipline; detailed FPGA or software-clock behaviour is a modern editorial extension. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Marvin Lee Minsky

Among the historical authorities newly considered for Volume 11 is Marvin Lee Minsky (1927–2016). The documented career is that of an American mathematician and computer scientist; artificial intelligence research. Its appropriate scope here is algorithmic classification, machine perception, model dependence and the limits of intelligent inference.

Minsky's work helped build the intellectual foundations of artificial intelligence and machine perception. The present technical problem is not whether a classifier can produce a label, but whether the label is warranted when signals, receiver hardware and operating conditions differ from those represented in training. A reconstructed discussion might identify the difference between a pattern memorised from receiver artefacts and a feature causally associated with an external emission. It should demand held-out apparatus and environment tests. Contemporary machine-learning architectures remain an editorial context, not part of an invented historical laboratory record.

The contribution can be tested against Question 104: How should machine-assisted RF anomaly detection be assessed under distribution shift? There, the proposed discriminating experiment would reserve independent locations, receiver hardware and interference regimes as held-out challenges rather than random windows from the same recording. The

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stated failure mode is equally important: an accurate classifier on correlated test data can be unreliable when the receiver, room or emitters change.

For editorial quality, the speaker assignment must remain anchored in algorithmic classification, machine perception, model dependence and the limits of intelligent inference; the manuscript should plainly separate documented historical discovery from the modern test concerning examine training-set contamination, novelty scoring, changing gain states, open-set errors and the possibility of memorising instrument artefacts.

Limits of attribution: He provides foundational AI reasoning, not knowledge of trained RF classifiers or evaluation datasets introduced after his era. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Maurice Stevenson Bartlett

Maurice Stevenson Bartlett was a British statistician whose work connected probability theory with practical observations evolving in space and time. Born in London on 18 June 1910, he studied mathematics at Cambridge and contributed to the theory of statistical processes, multivariate analysis and spectral estimation. His election as a Fellow of the Royal Society in 1961 recognised the importance of that scientific work. The Royal Society's historical catalogue identifies his later academic position as Professor of Biomathematics at Oxford and preserves research records concerning the development of statistical models. The precise modern receiver applications in this discussion are new educational constructions rather than assertions about what Bartlett personally examined. [B1]

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Bartlett is especially pertinent to overlapping spectral analysis because averaging does not cease to be a statistical problem when a Fourier transform is involved. He was associated with periodogram and time-series methods which helped establish the distinction between individual noisy spectral estimates and procedures that combine information across a record. His intellectual legacy assists the present discussion at the level of correlation, covariance, model assumptions and the meaning of a statistical unit. A receiver can generate many periodograms, but their mean's uncertainty depends upon how they were produced and on any dependence among them. The temptation to divide an error estimate by the square root of the number of frames without examining sample reuse is precisely the kind of modelling error his methodological perspective helps expose.

In the constructed dialogue, Bartlett therefore represents the requirement to analyse correlations between overlapping outputs and to define which quantity a receiver is estimating. His role does not imply that he knew contemporary SDR software or judged the performance of any instrument marketed today. It illustrates how established statistical reasoning can interrogate an engineering method without confusing a hypothetical application with a historical quotation. His contribution also links British mathematical statistics with the practical demands of forensic evidence: an uncertainty interval has meaning only in relation to a measurement model and a repeatable experimental procedure. The educational portrayal should be read in that limited spirit.

Michael Faraday

Michael Faraday (1791–1867) was a British experimental physicist and chemist; electromagnetic induction and field reasoning. The contribution

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relevant to this manuscript is magnetic coupling, induction, conductor and shield interactions, and experiments testing the physical route of interference.

Faraday's experiments made electromagnetic induction a physical fact subject to repeatable observation. Within technical surveillance countermeasures, his work bears upon magnetic coupling between wiring, equipment enclosures and nearby sensors. A well-chosen experiment changes loop orientation, separation and current while preserving the measurement chain. Such a test may differentiate a genuine local magnetic field from a response introduced by a cable or receiving probe. Faraday's historical contribution is the experimental account of induction and fields. Modern calibrated near-field probe practices should be attributed to contemporary engineering rather than to his nineteenth-century laboratory.

In the planned Question 062, the concrete issue is: Which near-field observations distinguish electric coupling from magnetic coupling in an enclosure? An appropriate proposed experiment is to map the same controlled component with calibrated miniature E-field and H-field probes, varying orientation and standoff. The corresponding interpretive caution is that a near-field maximum cannot be interpreted as far-field radiated power without a field model.

This contributor will be evaluated against the concrete distinction between compare probe orientation, source impedance, field gradients, loop area and distance scaling below the reactive near-field boundary. and a near-field maximum cannot be interpreted as far-field radiated power without a field model. rather than against an invented claim of personal experience with the specified apparatus.

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Limits of attribution: His laboratory investigations inform near-field physics, whereas modern VNA calibration and digital RF instruments are later editorial applications. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Norbert Wiener

Norbert Wiener was an American mathematician born in 1894 and deceased in 1964. MIT Press records his long service in MIT's mathematics department, beginning in 1919, and identifies his books on cybernetics, prediction, and related mathematical subjects. The Science Museum Group's institutional biography records his doctorate and his work connecting feedback, control, and communication. These records support the form Dr Wiener. His inclusion in this volume concerns those demonstrated mathematical and systems interests, not a religious or theological role. [B12, B12a]

Wiener's constructed question examines the feedback between observer, instrument, and retained evidence. An adaptive receiver or an operator responding to preliminary results can change the conditions under which later observations are selected. Such adaptation may be legitimate and useful, yet the resulting archive cannot automatically be treated as an unselected record of the full observation period. The hypothetical triggered-retention example is newly authored for this volume. It is not represented as an experiment conducted by Wiener or as a historical prediction of a particular modern platform.

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The contribution asks how discovery can remain productive without allowing selection to disguise incomplete coverage. It therefore links control and communication concerns with the evidential distinctions developed by the other speakers. The relevant question is not whether the observer is perfectly detached, but whether the coupled procedure is defined and its consequences can be examined. A record of selected events can support some findings while leaving prevalence or non-detection claims unresolved. Wiener challenges Popper to identify an experiment capable of testing those omissions rather than merely praising openness to criticism. His role closes the peer sequence by bringing the operator and acquisition policy back inside the system boundary that the first principal respondent established.

Historical expertise and source concordance: Mathematics of stochastic processes, prediction, feedback and cybernetics. Conditional observer-and-control-loop reasoning is consistent with that body of work; modern firmware examples are editorial applications. Independent historical source: https://mitpress.mit.edu/author/norbert-wiener-18445/

Norman Foster Ramsey Jr.

Norman Foster Ramsey Jr. (1915–2011) was an American physicist; separated oscillatory fields and hydrogen maser. The contribution relevant to this manuscript is atomic and molecular resonance, clock precision, and distinction between reference frequency and phase stability.

In a receiver with several clock domains, the question of when an oscillator was stable differs from the question of whether every derived clock preserved phase. His separated-oscillatory-fields research gives a rigorous conceptual basis for asking how a frequency reference is tested against its own noise and against independent instruments. In a proposed comparison, the moderator should ask for the averaging interval, the duration of any reference interruption, the time of reacquisition and a

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measurement of the residual phase. Those details determine whether two recordings may legitimately be combined coherently.

In the planned Question 052, the concrete issue is: How should traceability of frequency standards govern coherent captures separated in time? An appropriate proposed experiment is to compare two independently disciplined frequency chains by logging phase difference against averaging time, reference changes and loss-of-lock events. The corresponding interpretive caution is that nominally identical ten-megahertz references do not imply coherent samples after an unobserved cycle slip.

This contributor will be evaluated against the concrete distinction between separate accuracy of a frequency standard from its short-term phase stability and from the transfer path delivering that standard to adcs and mixers. and nominally identical ten-megahertz references do not imply coherent samples after an unobserved cycle slip. rather than against an invented claim of personal experience with the specified apparatus.

Limits of attribution: Ramsey belongs in discussions of frequency standards, clock stability and coherent measurements. He must not be represented as a designer of contemporary SDR firmware. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Oliver Heaviside

1850–1925. British electrical engineer, mathematician and pioneer of electromagnetic theory. Oliver Heaviside was a largely self-taught mathematical physicist whose work transformed the practical and analytical

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treatment of electromagnetic theory. Born in London, he began professional life in telegraphy, where the behaviour of electrical signals along conductors motivated a lifetime of independent investigation. He recast Maxwellian electromagnetic theory into forms widely used in engineering, studied transmission lines, developed operator methods and examined effects that could limit or improve the passage of signals through real circuits. His theoretical work also contributed to the prediction of a conducting region of the upper atmosphere important to radio propagation. His career is notable because some of its most consequential ideas emerged outside the conventional institutional arrangements of British science. In the constructed roundtable he challenges the casual substitution of a bearing ray for a complicated field near conductive structures. Cable trays, enclosures and nearby metalwork can shape the observations of a survey instrument even when a remote source is unchanged. The specific SDR measurements, antenna movements and reporting duties described in the question belong to this volume, not to Heaviside's historical papers. His role is to keep the measurement anchored in boundary conditions and in the physical relationships that give a displayed direction meaning. The relevance is not simply historical admiration for equations. Conductors, insulation, impedance and the dimensions of apparatus remain actual contributors to electromagnetic measurement. By challenging the validity of a far-field bearing near metallic structures, his assigned role guards against a common error: confusing a convenient representation of a field with a demonstration of its source.

Historical expertise and source concordance: Transmission-line theory, electromagnetic field analysis and operator calculus. Relevant to cable reflections and filter transients; historically an independent researcher rather than a modern receiver-software engineer. Independent historical

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source: https://www.theiet.org/membership/library-and-archives/the-iet-archives/biographies/oliver-heaviside-1850-1925

Percy Williams Bridgman

Percy Williams Bridgman was an American physicist whose career was closely associated with Harvard University. His investigations of matter under high pressure required the development of specialised experimental apparatus, and he received the Nobel Prize in Physics in 1946 for work in that field. The Society of Rheology's institutional account records his Harvard education, including his doctorate, his long teaching career, and his interest in the foundations of physical thought. It supplies the life dates 1882–1961. Professor Bridgman is the form used here. [B06]

His peer question is directed to the identity of the measured quantity. Two calibrated procedures can produce different numbers because they estimate different properties, not because one instrument is defective. Conversely, different procedures intended to estimate the same quantity require evidence of the relevant correspondence. Bridgman's documented combination of experimental apparatus and philosophical interest provides an appropriate perspective for this distinction. The burst and filtering example in the dialogue is newly authored for the receiver context and is not presented as a historical problem he personally investigated.

The editorial aim is to prevent operational detail from becoming either an empty checklist or an arbitrary definition. A procedure must be specific enough to reproduce, while the intended comparison must be clear enough to judge whether a changed procedure still answers the same question. Bridgman's contribution therefore challenges Weston rather than merely endorsing him. It asks what remains invariant across a method change and

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how the examiner would establish equivalence. Readers should not infer from the historical name that every modern claim has been validated. The exchange supplies a disciplined question; its answer must still be supported by the chosen measurement model, reference conditions, and tests of the actual receiver chain.

Historical expertise and source concordance: Experimental high-pressure physics and operational analysis of measurement. The work provides a defensible lens for physical reference planes and operational definitions, not evidence that Bridgman developed modern spectrum-surveillance procedures. Independent historical source: https://fi.edu/en/awards/laureates/percy-williams-bridgman

Peter Elias

Among the historical authorities newly considered for Volume 11 is Peter Elias (1923–2001). The documented career is that of an American information theorist and MIT professor; source and channel coding. Its appropriate scope here is redundancy, convolutional encoding, decoding assumptions and quantifying transmitted information.

Elias developed important ideas in source and channel coding, including convolutional codes and the representation of digital information. His work is useful when the physical observation suggests redundancy or a structured stream. A rigorous analysis would consider how much information about a code can be extracted from a short, corrupted or truncated capture, how erasures should be represented, and when a statistical match may be attributable to common formatting alone. It should also explain why the absence of recognised redundancy does not prove a channel was unoccupied. His contribution would remain theoretical and specific to coding.

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The contribution can be tested against Question 086: How should beacon-like repetition be described without assuming a named protocol? There, the proposed discriminating experiment would compare laboratory beacon generators with periodic industrial control bursts under matched observation gaps. The stated failure mode is equally important: identical intervals occur in many unrelated systems, especially after receiver scheduling is considered.

For editorial quality, the speaker assignment must remain anchored in redundancy, convolutional encoding, decoding assumptions and quantifying transmitted information; the manuscript should plainly separate documented historical discovery from the modern test concerning analyse timer quantisation, drift, jitter and packet-length patterns without attaching device identity to an unverified standard.

Limits of attribution: His coding work supports analytical treatment of structure; claims about named modern wireless protocols are editorial applications, not historical testimony. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

Ralph Beebe Blackman

Ralph Beebe Blackman (1904–1990) was an American mathematician and engineer whose career at Bell Telephone Laboratories combined circuit research, statistical signal analysis and practical data processing. An IEEE biographical account records his early work on acoustics, electromechanical transducers and filtering, followed by studies of electrical networks,

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equalisation and feedback. He is particularly associated with spectral-analysis methods and with the work on power-spectrum measurement published with John Wilder Tukey. The familiar Blackman window reflects his place in the history of practical frequency-domain estimation, not an implication that one window is optimal for every detection problem.

Blackman's relevance is immediate in the study of finite records. A discrete spectral estimate depends on the selected data window, its equivalent noise bandwidth, sidelobe behaviour and the way adjacent frames are averaged. A short burst can disappear in an average or spread into neighbouring frequencies under a poorly understood window; a visually narrow peak can also arise from processing choices. When a monitoring report uses a frequency-bin value as physical evidence, the investigator should disclose the window length, weighting, overlap and relation between the recorded samples and the displayed estimate. These properties affect both resolution and the effective number of independent detection opportunities.

In the editorial discussion Blackman can legitimately challenge the mathematics and practice of spectral estimation, while another contributor addresses the receiver's analogue integrity. He is not represented as having used modern interactive waterfalls or device-fingerprinting systems. His documented research supports a sharper question: which characteristics of the measurement belong to the source, and which follow from the finite-window estimator selected by the analyst? Answering it requires both the retained original samples and a transparent account of every processing choice.

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Historical reference consulted:
https://ethw-images.s3.us-east-va.perf.cloud.ovh.us/ethw/9/9f/IEEE_1964-03_OCR.pdf

Ralph Vinton Lyon Hartley

Ralph Vinton Lyon Hartley was born in Nevada in 1888 and died in 1970. The engineering-history record describes his undergraduate education at the University of Utah and subsequent Oxford study as a Rhodes Scholar. His research included oscillator circuits, receiver development, and the relation between information transmission, bandwidth, and duration. The record also identifies his work on repeaters, carrier transmission, and later control problems. He is addressed as Mr Hartley here; professional distinction is not used to invent an academic title. [B09]

His peer question challenges the idea that a wide recorded band and a large numerical word automatically make one acquisition superior to another. The constructed example contrasts a broad but compromised observation with a narrower path that preserves the feature of interest under better-characterised conditions. Hartley's documented concern with transmission and its restrictions makes him an appropriate interlocutor. The particular converter and archive comparison is an original modern application rather than a historical statement attributed to him.

The editorial purpose is to force the comparison to retain its task. A record may provide broader context while supporting a weaker measurement of a particular component. Another may support a precise restricted observation while excluding much of the surrounding spectrum. Neither limitation should be concealed by a single advertised number. Hartley's contribution asks what alternatives the data distinguish and what assumptions permit the resulting comparison. It also leads naturally to the

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question of complementary acquisition paths, which require demonstrated timing and reference relationships before they are combined. His role is not to dismiss broad capture, but to insist that its benefit be described through the evidence it preserves for the specified inference rather than through the visual or numerical size of its output.

Richard Wesley Hamming

Richard Wesley Hamming was an American mathematician and computer scientist associated with the development of error-detecting and error-correcting codes, numerical computation and digital signal analysis. Born in Chicago in 1915, he studied mathematics at the University of Chicago, the University of Nebraska and the University of Illinois, where he completed his doctorate. His work during the Second World War included computational activity at Los Alamos; he subsequently spent a long period at Bell Telephone Laboratories, where the mathematical and engineering challenges of reliable communication and computation informed major contributions. He later taught at the Naval Postgraduate School in Monterey. His scientific name is associated with Hamming codes and a widely used spectral window. The National Academy of Engineering's memorial tribute, a mathematical biography and other historical institutional accounts record these features of his life and work. [S9]

Hamming's peer intervention here concerns the distinction between a mathematical weighting operation and a physical measurement improvement. A taper changes the response of the finite-record estimator. Coherent gain and equivalent noise bandwidth are useful descriptive quantities, but neither is a universal restoration of an arbitrary transient waveform. The question therefore draws from the genuine disciplinary

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terrain of numerical analysis, spectral windows and computational reliability, while treating the specific forensic hypothetical as newly authored educational application. Hamming did not participate in this discussion, did not evaluate the instruments described, and is not credited with the numerical examples created for the volume. His voice serves to challenge the careless conflation of visual frequency interpolation, sample acquisition, and improvements in the information actually recorded. That separation is central both to technical measurement and to the responsible presentation of expert evidence.

Ronald Newbold Bracewell

1921–2007. Australian-born radio astronomer and electrical engineer. Ronald Newbold Bracewell was born in Sydney and pursued mathematics, physics and engineering before developing an international career in radio astronomy and electrical engineering. During the Second World War he worked on microwave radar research; afterwards he undertook graduate work at Cambridge and contributed to the growing discipline of radio astronomy. He later joined the faculty of Stanford University, where his research embraced antennas, Fourier analysis, astronomical imaging, image construction and the reconstruction methods that would also influence medical imaging. His influential book on Fourier transforms became a familiar companion to advanced students of signals and systems. Bracewell's work is particularly apt for this dialogue because a reconstructed image may depend heavily on the available frequency information, sampling geometry and assumptions inserted into an inverse calculation. In this fictional educational exchange he is asked to test whether a highly detailed source map necessarily corresponds to one uniquely established physical

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cause. The technical examples involving RF sources, multipath and receiver-generated mixing products are constructed applications rather than historical quotations. They illustrate the general principle that successful inversion requires attention to what the measurement operator has retained and to what has been supplied by assumptions. His assigned role also helps distinguish honest model-based reconstruction from unsupported confidence in the visual detail of a processed result. For this volume, his biography also illustrates a connection between radio and medical imaging: both must interpret incomplete observations through physical models. Whether the output is an image or a map, apparent detail is not a substitute for identifiability. The dialogue uses that insight to demand competing explanations and empirical checks of reconstruction stability.

Rudolf Emil Kálmán

1930–2016. Hungarian-born American mathematician and systems theorist. Rudolf Emil Kálmán was born in Budapest and developed an extraordinary career at the intersection of mathematics, electrical engineering and automatic control. After study in the United States and important work in linear systems, he became closely associated with modern state-space methods, mathematical observability and the filtering technique bearing his name. The Kalman filter provided a systematic framework for updating an estimate of an unobserved state from measurements and an explicit model of dynamics and uncertainty. Its influence extends across navigation, aerospace engineering, robotics and communications. Kálmán held senior academic posts including appointments associated with the University of Florida and the Swiss Federal

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Institute of Technology in Zürich. The present dialogue uses his disciplinary contribution to illuminate a common forensic hazard: a tracking system can produce a persuasive trajectory even when sensor geometry, prior assumptions or measurement selection prevent the trajectory from being uniquely determined. The source's movement, the sensor's movement and the algorithm's adaptation must not be silently conflated. The particular SDR scenarios and speech supplied here are modern editorial constructions, not historical statements. His role is to compel the investigator to disclose the dynamical model, observation likelihood, conditions of observability and persistent influence of initial assumptions before turning a sequence of bearings into the story of a moving transmitter. A further editorial distinction is between the state that a model predicts and the variable that a sensor has actually measured. In a forensic setting the distinction carries consequences for disclosure, reproducibility and cross-examination. The assigned dialogue deliberately requires a tracking system to reveal predicted intervals, observation gaps, competing associations and assumptions about movement.

Sir David Cox

Sir David Roxbee Cox (1924–2022) was a British statistician whose work influenced experimental design, statistical inference, survival analysis and the interpretation of complex observational data. His academic career included positions at Birkbeck College, Imperial College London and the University of Oxford, where he served as Warden of Nuffield College. He also edited Biometrika for many years. His influence reaches beyond the proportional hazards model associated with his name; he was a major

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contributor to careful statistical modelling, the formulation of scientific questions and the relationship between design and inference.

For an SDR investigation Cox's most pertinent concern is the relation between an estimand and the way the observations were selected. A receiver that records only threshold-triggered windows creates a different sample from a receiver that preserves an uninterrupted band. The two may be compared only after the selection mechanism and target quantity are made explicit. In a negative survey, the absence of a reported alarm is conditioned on the signal family, sensitivity and valid exposure. No universal probability of absence follows from a single number. Conversely, carefully planned trials of known reference bursts can provide useful performance estimates without pretending that an entirely unknown emission population has been sampled.

The constructed peer intervention is therefore an exercise in statistical specification, not a retroactive judgement by Cox on modern instruments. His work supports attention to the analysis plan, conditioning, model checks and the difference between a retrospective explanation and a prospective test. A correct equation cannot rescue a poorly defined question. By including his historical perspective, the roundtable requires the examiner to describe what was measured, why the design is informative, and how the final claim responds to possible departures from its assumptions.

Historical reference consulted: https://www.maths.ox.ac.uk/node/41104

Sir Edward Victor Appleton

1892–1965. British physicist; Nobel laureate in physics, 1947. Sir Edward Victor Appleton's work on radio propagation changed the scientific understanding of the upper atmosphere and its importance to terrestrial

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communications. Born in Bradford, he studied at Cambridge and undertook experimental work associated with the Cavendish Laboratory. In the 1920s his measurements contributed decisively to the recognition of ionised atmospheric layers capable of returning radio waves to Earth, and subsequent investigations revealed the higher region associated with his name. His work provided practical foundations for radio-frequency planning and for understanding the variable paths that long-distance signals may follow. He held academic appointments in London and Cambridge, served in the British scientific administration and became Principal and Vice-Chancellor of the University of Edinburgh. He was elected to the Royal Society, knighted and awarded the 1947 Nobel Prize in Physics. The present discussion draws upon the significance of his field: the arrival of a radio wave at an antenna cannot invariably be read as the geographical direction to its transmitter. The modern SDR, forensic and source-attribution applications placed in his mouth are newly written teaching material. They should not be cited as Appleton's historical opinions or as descriptions of experiments he performed. His role is to insist that the Earth's propagation environment remains part of the measurement rather than a nuisance excluded by a tidy map. Editorial relevance also lies in the distinction between a reproducible laboratory transmission path and the variable propagation encountered outside the laboratory. Modern receiver software can refine numerical estimates, but a change of atmosphere can change the measured field before the numbers exist. The assigned question makes this physical limit central to the ethics of source attribution.

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Sir Harold Jeffreys

1891–1989. British mathematician, geophysicist and statistician. Sir Harold Jeffreys pursued a career spanning geophysics, astronomy, applied mathematics and statistical inference. Associated for much of his career with Cambridge and elected to the Royal Society, he became influential in the treatment of uncertainty and the use of probability to compare scientific explanations. His methods were particularly important in problems where indirect measurements had to be related to hidden physical quantities through mathematical models. The present fictional conversation draws on that intellectual setting to challenge careless movement between the likelihood of evidence under a hypothesis and the probability that a hypothesis is true after observing the evidence. A technically impressive correspondence between signals may provide some support for a particular physical-source proposition, but the strength and meaning of that support depend upon the competing proposition, the relevant population and the evidential model. Jeffreys is not being quoted as the author of modern forensic-reporting standards; the practical example is newly written. He serves instead as a reminder that conditional probabilities have direction, that unstudied alternatives cannot be silently eliminated and that experts ought not to insert the conclusion of a judicial or managerial decision where the scientific evidence supports only a narrower comparison. His contribution lends an appropriately rigorous close to the panel's discussion of attribution. The teaching objective is to separate the scientist's comparison of evidence under hypotheses from the decision-maker's eventual judgement about action or responsibility. Those judgements may use different premises, costs and standards. The distinction is especially

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important when a technically credible signal match is mistakenly presented as a numerical probability that a person committed an act. Sources and read scope. Question 007 The original dialogue, hypothetical case facts and numerical examples were written for this volume. The following are technical and biographical reference sources, not records of the speeches assigned to historical speakers. Consulted 9 November 2026. No actual receiver tests or independent certifications were undertaken for these illustrative calculations. [Q7-T1] International Telecommunication Union, Recommendation ITU-R SM.854-3 (2011), Direction Finding and Location Determination at Monitoring Stations. https://www.itu.int/rec/R-REC-SM.854-3-201109-I/en . Read scope: bearing and localisation principles, physical and operational qualifications. [Q7-T2] International Telecommunication Union, Report ITU-R SM.2356-2 (2018), Procedures for Planning and Optimization of Spectrum-Monitoring Networks in the VHF/UHF Frequency Range. https://www.itu.int/hub/publication/r-rep-sm-2356-2-2018/ . Read scope: AOA, TDOA and combined AOA/TDOA location geometries. [Q7-T3] International Telecommunication Union, Spectrum Monitoring Recommendation List, including SM.2060, SM.2061, SM.2080, SM.2097 and SM.2117. https://www.itu.int/en/ITU-R/terrestrial/monitoring/listVIII/pages/recommendations.aspx . Read scope: accuracy, multipath, timestamp precision, on-site testing and I/Q data interchange standards. [Q7-T4] National Institute of Standards and Technology, Guide to Integrating Forensic Techniques into Incident Response, NIST SP 800-86 (2006). https://csrc.nist.gov/pubs/sp/800/86/final . Read scope: preservation, examination, analysis, integrity and limits of digital forensic practice. [Q7-T5] National Institute of Standards and Technology, Common View GPS Time

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Transfer. https://tf.nist.gov/time/commonviewgps.htm . Read scope: comparison of remote clocks and related time-reference principles. [Q7-B1]
The Institution of Engineering and Technology, Sir Edward Appleton, biographical archive. https://www.theiet.org/membership/library-and-archives/the-iet-archives/biographies/sir-edward-appleton .

Sir Karl Raimund Popper

Karl Raimund Popper was born in Vienna in 1902 and died in 1994. The London School of Economics identifies Sir Karl Popper as the founder of its Department of Philosophy, Logic and Scientific Method in 1946 and describes his work on falsifiability, criticism, and the distinction between science and non-science. The institutional record supports the title Sir Karl used here. His inclusion rests on philosophy of scientific method, not on an asserted career in receiver engineering. No technical invention or later instrument specification is attributed to him in this biography. [B05]

The constructed role examines whether an evidential claim remains open to a relevant adverse observation. In this volume, that question arises when a receiver trace has several plausible explanations and the examiner changes settings to distinguish them. Popper's contribution asks whether the changes expose a genuine difference between predictions or merely produce another result that can be accommodated after the fact. The particular receiver examples belong to the author's present synthesis and to the technical models developed in the main chapters. They are not

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represented as Popper's own historical judgements about modern equipment.

This methodological role is deliberately limited. Philosophy does not supply the missing transfer function, calibration record, or probability model. It can, however, expose a claim that has become protected against every possible experimental result. The discussion therefore keeps engineering predictions, measurement conditions, and the interpretation of failed challenges distinct. Popper also addresses the legitimate use of an indeterminate category when a necessary premise remains unestablished. His task is to make that category criticisable rather than convenient. The result is a perspective on how the report can preserve disagreement and specify a useful next test without manufacturing unanimity or converting uncertainty into a universal refusal to draw conclusions.

Sir Martin Ryle

1918–1984. British radio astronomer; Nobel laureate in physics, 1974. Sir Martin Ryle was among the principal architects of modern radio interferometry and aperture synthesis. Born in Brighton, he studied at Oxford and worked on wartime radar before pursuing research at the University of Cambridge. His subsequent work with radio receiving systems and interferometric methods enabled increasingly detailed astronomical surveys, while establishing the importance of calibrated baselines and coherent measurements. As director of the Mullard Radio Astronomy Observatory, a Cambridge professor and later Astronomer Royal, Ryle helped turn radio astronomy into an exact experimental discipline with demanding instrumental foundations. He shared the 1974 Nobel Prize in Physics with Antony Hewish, the award specifically recognising Ryle's

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observations, inventions and aperture synthesis. For the present dialogue, his contribution provides an intellectual bridge between the geometry of an antenna array and the interpretation of a reconstructed direction. The case of an SDR direction finder near a building is a modern hypothetical scenario rather than any assertion about Ryle's historical work. The editorial emphasis on oscillator calibration, cable delays and model-dependent localisation is consistent with the measurement challenges encountered in radio interferometry, but the precise forensic doctrines in the question are original to this volume. His appearance therefore honours the methodological lineage without fabricating a transcript from the past. The editorial lesson is not that radio astronomy and building surveillance are identical practices. Their shared discipline is the need to understand phase, geometry, calibration and the information supported by sparse measurements. A precise reconstruction is valuable when its instrumental premises are available for challenge and re-examination, and misleading when the premises are assumed away.

Sir Robert Alexander Watson-Watt

Sir Robert Alexander Watson-Watt was a Scottish engineer and pioneer of radar whose work in the British scientific establishment combined experimental radio physics with the demands of operational detection. Born in Brechin, he studied at Dundee when the college was part of the University of St Andrews, and he developed interests in radio waves and meteorology. His work on atmospheric electrical disturbances and radio direction finding helped prepare the technical foundation for radar. During the 1930s he played a central role in the development of British aircraft-detection systems, and the resulting early-warning network became of exceptional

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importance in the Battle of Britain. He was elected a fellow of the Royal Society and was knighted for his wartime scientific contribution. The United Kingdom's public scientific and archival institutions maintain historical accounts of this work. [S8]

Within this newly constructed educational discussion, Watson-Watt asks whether nominally accurate hardware can support a negative-surveillance conclusion when the observation schedule may miss brief transmissions. His historical expertise supplies a pertinent conceptual standpoint: the operational value of a detector depends upon the event's arrival, the apparatus's opportunity to observe it, and the action that follows the indication. An electrical measurement which is extremely precise only at the moments when it is performed does not necessarily establish that no relevant event occurred between those moments. The dialogue deliberately avoids suggesting that he witnessed modern converter ENOB testing, contemporary digital sample retention, or current TSCM equipment. Instead, it uses a documented interest in rapid warning and radiolocation to interrogate a modern hypothetical concerning exposure probability, scanner duty cycle and the difference between a silent alarm system and an electromagnetically silent environment. His comments are original reconstruction, not an archival transcript.

Sir Ronald Aylmer Fisher

Sir Ronald Aylmer Fisher (1890–1962) was a British statistician and geneticist whose work was associated with Rothamsted Experimental Station and Cambridge. His historically documented areas of work include experimental design, likelihood reasoning and the statistical comparison of competing hypotheses. The relevance of that intellectual tradition to this

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textbook is interpretive rather than personal: no historical endorsement, eyewitness evidence, modern SDR testing, or authenticated quotation is attributed to him. The constructed discussions draw upon this methodological background while evaluating contemporary hypothetical instrumentation. In particular, the associated questions 017 explore mechanisms and evidence in which noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. The panel uses his named contribution to ask a specific and falsifiable question: how should an investigator declare the sampling scheme and distinguish exploratory discovery from preplanned confirmation? To answer responsibly, one must examine noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, rather than treating the apparatus readout as a self-authenticating account of physical origin. One illustrative circumstance is that an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions. A competing interpretation is that thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails. This contrast should be tested by compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals, with adverse observations and calibration states preserved. The biographical facts establish professional chronology and domain of scholarship; the imagined question and answer are editorial devices used to teach the distinction between direct observation and model-dependent inference. No claim is made that the individual employed,

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approved, or could have anticipated the exact modern instrumentation named in this educational exercise. The reader must rely on the measured variables, explicit assumptions, and the validity of the controlled comparison rather than on the prestige of the historical contributor.

Historical expertise and source concordance: Experimental design, statistical likelihood and biological statistics. Role in receiver noise and observation-schedule exchanges is a methodological reconstruction, not historical technical testimony. Independent historical source: https://mathshistory.st-andrews.ac.uk/Biographies/Fisher/

Solomon Kullback

Solomon Kullback (1907–1994) was an American mathematician, statistician and cryptanalyst. The contribution relevant to this manuscript is information divergence, statistical discrimination, uncertainty and the difference between class models.

Kullback's statistical work offers a disciplined language for distinguishing probability distributions, but the chosen model determines what its numerical divergence actually means. In a radio-source classification problem, one can compare a suspected waveform with alternatives by a divergence measure while still failing to identify its physical origin. He can interrogate reference distributions, independence assumptions, rare classes and the consequences of short records. An appropriate application would calculate or simulate the divergence between two specified observation models and test how calibration errors alter it. An attractive number cannot replace physical corroboration.

In the planned Question 079, the concrete issue is: How should false-alarm probability be controlled across millions of spectral comparisons? An appropriate proposed experiment is to run calibrated noise-only simulations preserving channel covariance, then compare maximum statistics with

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nominal single-bin thresholds. The corresponding interpretive caution is that a probability of one in a million per bin is not a one-in-a-million probability for the largest of many bins.

This contributor will be evaluated against the concrete distinction between separate per-test significance, family-wise error, false-discovery rate, effective trials under correlation and post-selection inference. and a probability of one in a million per bin is not a one-in-a-million probability for the largest of many bins. rather than against an invented claim of personal experience with the specified apparatus.

Limits of attribution: Statistical distance can rank hypotheses under assumptions, but it is not proof of a particular physical emitter or private message. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

W. Edwards Deming

W. Edwards Deming was born in 1900 and died in 1993. Trained in mathematical physics, he became an influential statistician, teacher and adviser whose work connected variation, measurement, organisational learning and the improvement of processes. He received a doctorate from Yale University and developed strong intellectual connections with Walter A. Shewhart's work in statistical process control. His professional influence extended across American and Japanese industry, most famously through post-war teaching and consulting activities that linked technical quality methods with management responsibility. Institutional biographies from

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the W. Edwards Deming Institute and the American Society for Quality provide the principal historical foundations for this account.

For the present educational dialogue, Deming's relevance lies in the institutional interpretation of a calibration record. A laboratory can possess excellent measurement equipment and still produce unreliable evidence if its incentives favour suppressing failed tests, discarding inconvenient data or reporting only the final result after repeated adjustment. Deming's documented emphasis on systems and improvement provides a framework for examining such failures without reducing them to the moral weakness of an individual technician. His constructed peer challenge asks whether the quality of a laboratory's evidence can be evaluated separately from the organisational arrangements that produce, preserve and disclose it. The point is not to attach Deming's name to a modern forensic standard he did not write. Rather it is to use his documented statistical and managerial contributions to test whether a measurement-assurance programme is designed to learn from instability or merely to manufacture an appearance of conformity. His thought is particularly pertinent where the instrument is reliable only when its operators can preserve adverse evidence without institutional penalty.

Walter Andrew Shewhart

Walter Andrew Shewhart was an American physicist, engineer and statistician, born in New Canton, Illinois, in 1891. His academic preparation included study at the University of Illinois and doctoral work at the University of California, Berkeley. He joined Western Electric in 1918 and became a foundational figure in statistical quality control. His development of control-chart thinking helped industrial investigators distinguish ordinary

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process variation from signals that a process had changed. That achievement is documented in standard historical accounts of statistical engineering. The present dialogue applies his intellectual principles to modern digital receiver records; it does not claim that he designed contemporary FFT detectors or investigated contemporary technical surveillance systems. [B2]

Shewhart's importance for this question lies in his attention to the process which produces measurements. An electronic receiver can have stable hardware at one moment and a different effective detection characteristic after changes in gain, threshold estimation or interference. A sequence of alarm records may then mix observations taken under different operating conditions. Shewhart's perspective directs attention to those state transitions and to whether apparently repeated alarms reflect distinct physical events or the continuing effect of a system with memory. The correspondence with industrial process control is methodological, not a declaration that every radio signal should be interpreted using an ordinary factory control chart.

In the fictional roundtable, Shewhart asks that event-clustering procedures be tested against deliberately varied challenge bursts, including cases near the threshold where a rule is likely to fail. He also stresses that an algorithm selected after viewing the field evidence must not be described as though its reported detection probability were validated independently. Such distinctions are central to defensible scientific reporting. His intellectual persona is suited to a discipline in which reproducibility, transparent operating conditions and honest records of unfavourable observations are as important as the apparent precision of a numerical

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output. The biography rests on documented professional history, while the exchanges remain newly authored educational prose.

Historical expertise and source concordance: Statistical quality control, control charts and distinguishing process changes from stable variation; not an authority on late digital receiver standards by personal historical experience. Independent historical source: https://asq.org/about-asq/honorary-members/shewhart

William Feller

William Feller (1906–1970) was a Croatian-born American mathematician whose contributions to probability theory influenced the analysis of random events, stochastic processes and limiting behaviour. His widely read works on probability theory joined mathematical precision with carefully developed examples. His career took him through European mathematical institutions and eventually to academic work in the United States. The historical Feller did not research digital spectrum monitors, but his methods are particularly valuable when a technical report relies on rare-event probabilities or the mathematical properties of long observation sequences.

A monitoring team might wish to estimate the probability of missing a short emission, the frequency of false alarms or the distribution of waiting times between detected events. Such quantities depend not only on the nominal detection probability but also on event duration, temporal dependence, sampling policy and censoring. Counting a hundred threshold crossings does not necessarily mean a hundred independent occurrences. Likewise, a long run of negative observations cannot be interpreted without defining what events would have been visible to the detector. Feller's probability tradition presses the investigator to identify the random process, the event being counted and the assumptions under which an approximation is valid.

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The imaginary peer challenge belongs to probability, not to microwave circuit design or instrument certification. His perspective supports the careful use of binomial, Poisson or renewal models only when their respective premises have been examined. A model can be illuminating while still failing as a description of a deliberately adaptive transmitter or a receiver that changes state in response to previous detections. The present-day engineering author must therefore combine Feller's mathematical principles with evidence about actual capture windows, thresholds and system behaviour before drawing a forensic conclusion.

Historical reference consulted: https://mathshistory.st-andrews.ac.uk/Biographies/Feller/

William Ralph Bennett

William R. Bennett (1904–1983) was an American communications researcher whose work was associated with Bell Telephone Laboratories. His historically documented areas of work include quantisation-noise and telecommunications signal analysis. The relevance of that intellectual tradition to this textbook is interpretive rather than personal: no historical endorsement, eyewitness evidence, modern SDR testing, or authenticated quotation is attributed to him. The constructed discussions draw upon this methodological background while evaluating contemporary hypothetical instrumentation. In particular, the associated questions 024, 025, 029 explore mechanisms and evidence in which dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. The panel uses his named contribution to ask a specific and falsifiable question: how should an investigator distinguish idealised stochastic error laws from input-dependent spurs and overload signatures? To answer responsibly, one must examine LSB size, DNL, endpoint INL, best-

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fit INL, missing-code count, temperature drift and calibration residuals, rather than treating the apparatus readout as a self-authenticating account of physical origin. One illustrative circumstance is that some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit. A competing interpretation is that differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. This contrast should be tested by acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, with adverse observations and calibration states preserved. The biographical facts establish professional chronology and domain of scholarship; the imagined question and answer are editorial devices used to teach the distinction between direct observation and model-dependent inference. No claim is made that the individual employed, approved, or could have anticipated the exact modern instrumentation named in this educational exercise. The reader must rely on the measured variables, explicit assumptions, and the validity of the controlled comparison rather than on the prestige of the historical contributor.

William Redington Hewlett

Among the historical authorities newly considered for Volume 11 is William Redington Hewlett (1913–2001). The documented career is that of an American electronics engineer; resistance-capacitance oscillator and electronic instrumentation. Its appropriate scope here is oscillator design, precision instrument development, frequency measurement and experimental engineering practice.

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Hewlett’s oscillator work was instrumental in the development of practical electronic test equipment. His contribution is best placed at the intersection of circuit design and the need to measure what instruments actually deliver. Consider a gate-time experiment in which an oscillator drifts during a very short carrier burst. A displayed frequency estimate will depend on the count strategy and the accepted measurement window. A historically sensitive intervention would insist upon calibrated standards, identified switching states and direct tests of the output waveform. He should not be used as an authority for modern legal evidence standards.

The contribution can be tested against Question 057: How do frequency-counter gate time and dead time bias observations of a drifting burst carrier? There, the proposed discriminating experiment would apply gates of several durations to a programmed chirp and compare recovered centre frequency against the original waveform chronology. The stated failure mode is equally important: an apparently precise counter display can average over the very drift the investigator must describe.

Limits of attribution: He is relevant to analogue measurement architecture and circuit behaviour, not to forensic legal opinions beyond instrument competence. This is a modern scholarly introduction, not a transcription of historical speech. Supporting institutional and professional references are recorded in the editorial contributor research register.

William Sealy Gosset

William Sealy Gosset (1876–1937), best known by the pseudonym 'Student', was a British chemist and statistician whose mathematical work grew directly from industrial experiments. Educated at Winchester College

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and New College, Oxford, he joined the Guinness brewery in Dublin and became concerned with drawing useful conclusions from small numbers of observations. His work helped establish the Student t-distribution and the practical treatment of small-sample uncertainty. His historical achievement is particularly pertinent to applied engineering, where carefully controlled experiments may be costly and a large independent sample is not always available.

In the roundtable, Gosset's proper concern is the amount of evidence actually contained in a finite sequence of receiver tests. A dozen successful detection trials can be valuable, but they do not establish the same performance bounds as thousands of independently prepared trials. When the variance is estimated from a small sample, uncertainty in that variance cannot simply be ignored. Moreover, repeated measurements of one uninterrupted burst may be highly dependent despite producing a large numerical sample count. His statistical approach encourages the examiner to describe the unit of replication and to avoid representing an overly narrow interval as proof of receiver reliability over untested conditions.

The reconstructed dialogue does not attribute to Gosset any knowledge of present-day ADC datasheets, spectrum-monitoring software or technical-surveillance investigations. It applies the legitimate small-sample logic of his work to modern engineering questions while leaving the electronics to experts in that discipline. His historical role is also a reminder that sound statistical methods arise from practical problems: measurements should be designed around the decision they are meant to support, and the resulting conclusions must state the conditions under which the chosen approximation has genuine evidential force.

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Historical reference consulted: https://mathshistory.st-andrews.ac.uk/Biographies/Gosset/

Historical expertise and source concordance: Chemist and statistician at Guinness, known for small-sample statistical inference under the pseudonym Student; methodological analogy should not be described as radio engineering expertise. Independent historical source: https://mathshistory.st-andrews.ac.uk/Biographies/Gosset/

William Thomson, Baron Kelvin

William Thomson, Baron Kelvin of Largs (1824–1907), was born in Belfast and became one of the nineteenth century's most influential British mathematical physicists and experimental engineers. He entered the University of Glasgow as a child and held its professorship of natural philosophy from 1846. His work extended across thermodynamics, electrical measurement, electromagnetic theory and practical telegraph engineering. He is particularly associated with an absolute scale of temperature and with scientific instruments whose construction and calibration permitted weak electrical effects to be distinguished from the limitations of earlier apparatus.

The transatlantic telegraph cable offered Kelvin a demanding field problem in which electrical theory, transmission-line behaviour, instrumentation and economic consequences met. He made important contributions to the understanding of cable signalling and to the development of sensitive receiving instruments, including the mirror galvanometer and siphon recorder. Their historical significance is the insistence that the physical system and the receiving instrument must be analysed together. A recorded waveform could be delayed or distorted by the transmission path, and improvements in measurement could alter the apparent behaviour of the same remote source.

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Kelvin was not familiar with present-day analogue-to-digital converters or software-controlled calibration. His role in this constructed dialogue is instead a historical point of comparison for modern metrology. A calibration established under one load, temperature, frequency or receiver configuration cannot simply be transported to a different state. Trends in gain and timing must be tied to traceable reference conditions and, where appropriate, a stated uncertainty. The modern numerical examples are separately authored pedagogical illustrations and not historical exercises carried out by Kelvin. This distinction is necessary both for scholarly accuracy and for the integrity of the fictional expert discussion.

Historical-source qualification: the directory identifies all speaking contributors, but the relevance notes are editorial interpretations of historical research, not evidence that any participant encountered present-day SDR equipment or took part in this fictional discussion. Full bibliographical verification remains a separate publication requirement.

End of contributor biographies. The formal moderated discussion begins with Question 001 on the following page.

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QUESTION 001

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When may a receiver observation become an evidential claim?

Source: V011_Roundtable_Q001-Q011_CP011_Integrated_Candidate(2).docx | Recovered substantive manuscript. Constructed educational dialogue.

Constructed educational dialogue. The speeches below are newly authored, not historical quotations or a transcript. Modern cases and inferences are the author's applications of the cited manuscript material.

Dr. James M. Atkinson

Opening question

Mr Weston, can you comment on the conditions under which a receiver observation becomes a measurement, and on the further conditions required before that measurement can support an evidential claim? Our question is deliberately prior to the choice of receiver. A narrow line on a spectrum display, a sequence of stored samples, and a conclusion concerning an external source are different objects of knowledge. The first can be persuasive without the second being complete; the second can be intact without the third being justified. We shall examine those distinctions through an expressly hypothetical acquisition, not through an invented account of a field engagement. The receiver admits an identified band, preserves a stream of samples, and reports intermittent activity. Its operator wishes both to describe the activity and to exclude other activity during intervals without detections. [V1, V16]

The case leaves several matters open. We do not yet know whether the displayed amplitude refers to the antenna terminals or to a later boundary. We do not know whether an automatic gain change occurred immediately before the candidate event. The data format is known, but the continuity of

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its sample sequence has not been demonstrated. A second display appears to corroborate the first, although the two observations may share an antenna network, reference clock, or processing history. These are not allegations that the result is wrong. They identify propositions that a confident report would otherwise have to assume. Our task is to convert those assumptions into observations, justified restrictions, or explicit qualifications.

I invite the five principal respondents to examine successive boundaries rather than repeat a general appeal for caution. Mr Weston will consider the physical measurement and its reference. Dr Nyquist will address what the acquisition preserves and what its transformations make ambiguous. Dr Shannon will distinguish a retained representation from the information needed for a particular question. Professor Neyman will examine the trial population and the meaning of validated detection performance. Sir Karl Popper will consider how competing explanations can be challenged without turning every adverse observation into a new excuse. Seven colleagues will question those positions, with each question answered before the discussion passes onward.

The inherited chapters provide our common technical vocabulary. The discussion does not impute knowledge of present instruments to historical participants, and none of its speech is offered as a historical quotation. Modern applications and experimental proposals are newly authored for this volume. We shall not ask an instrument certificate to settle source identity, nor ask statistical terminology to repair an unobserved physical boundary. Equally, we shall not make perfect knowledge a prerequisite for

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every useful finding. A limited conclusion can be rigorous when its premises and remaining alternatives are stated. [V1, V10, V16]

At the end, the panel must identify what the record would need to contain for another examiner to reproduce the stated analysis and to contest its interpretation. It must distinguish a measurement that requires a correction from one whose proposed inverse has lost uniqueness. It must also identify circumstances in which a negative result is indeterminate rather than reassuring. Mr Weston, may I first invite your account of the physical comparison and the discipline that should govern its passage into a report?

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Edward Weston

The physical comparison and its declared boundary

Dr. Atkinson, thank you. My observation is that a measurement begins with a comparison whose physical meaning survives the instruments used to perform it. The visible indication is the conclusion of that comparison, not its complete definition. In the present case, an amplitude value becomes interpretable only after we identify the point at which the quantity is claimed, the conditions of loading there, and the transformations between that point and the indication. A correction is an assertion about those transformations. Its presence in software does not establish that the asserted relationship held when the event was acquired. I would therefore begin by tracing the connection from the input boundary to the retained result, marking which relationships were measured and which were merely selected from nominal settings. [V1]

Consider a cable correction derived in a separate calibration. There is nothing objectionable about applying it where the relevant connection, frequency, loading, and environmental conditions remain within its supported use. The difficulty begins when a replacement adapter, changed routing, or different input state is treated as immaterial without examination. It may be immaterial for the proposed uncertainty; that is a conclusion to establish, not a privilege conferred by the component's small size. A physical drawing can help here, but only if it records the arrangement actually used. An elegant diagram of the intended system does not repair an undocumented change made while pursuing a transient.

I would next separate the identity of the reference from the applicability of the comparison. A reference can have a sound calibration history while

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the present transfer from it to the receiver remains defective. The operator must show how the reference reached the point being tested, which parts of the chain it traversed, and what it failed to traverse. A signal injected after a vulnerable stage can establish a downstream response without demonstrating the upstream stage's condition. That distinction is especially important when the reference appears normal during an interval in which the desired external signal could have been distorted earlier in the chain. The reference is not false; its evidential scope has simply been overstated. [V1, V16]

The same separation applies to repeatability. A stable indication gives evidence concerning stability under the conditions repeated. It does not independently establish the accuracy of a common correction, the absence of a common unwanted component, or the correctness of a frequency mapping. Repetition is powerful when it varies the circumstance that could create the error. Repetition without that variation can leave the most important explanation untouched. I would consequently record the physical reason why each proposed repeat is informative. Did it alter a loading condition, challenge an internal source, test a different gain state, or merely demonstrate that the same stored data produce the same display?

Dr. Atkinson, the hypothetical receiver should also be examined across its transitions, not solely in settled states. Suppose the stored event follows a large disturbance and the displayed trace has returned to an ordinary appearance. The relevant question is whether the weak-signal measurement has recovered, not whether an indicator looks familiar. We can propose a controlled probe at a declared boundary, observe its response before and after the disturbance, and compare that response with the acceptance

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condition for the intended measurement. A probe that tests amplitude recovery does not necessarily test phase recovery. The claim must follow the property actually examined, while the untested properties remain separate. [A1]

A useful field record would connect each reported interval to its configuration and validity state. This need not become an administrative burden detached from the physics. It is the minimum information required to distinguish a change in the external signal from a change in the instrument's response. Unknown transitions should remain visible. Joining two accepted records across an unresolved interval may create the appearance of continuous observation without providing it. A reader should be able to see both what was measured and where the experiment ceased to support the proposed interpretation.

There is also a boundary between correcting an indication and reconstructing an input. Where the measurement relationship is sufficiently characterised and reversible for the specified quantity, a correction can be justified. Where several materially different inputs produce the same retained output, an apparently precise inverse must depend on additional assumptions. Clipping provides an instructive example already developed in the volume: numerical rescaling can change the surviving values without uniquely recovering the amplitudes that exceeded the range. The operator should state what remains measurable, rather than treating every compromised record as either wholly useless or fully restored. [V10]

My proposed acceptance rule is therefore practical. State the quantity and boundary; identify the applicable comparison; demonstrate the relevant operating state; preserve the observations supporting the correction; and

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distinguish that corrected quantity from a causal account of the source. The report should be strong where these links are strong and restricted where they are not. Precision is not achieved by refusing every conclusion, but by preventing a conclusion from quietly extending beyond its comparison. Professor Bridgman, may I invite your question about whether this account defines the quantity through an operation or merely gathers conditions around an undefined name?

Percy Williams Bridgman

Peer question 1 to Edward Weston

Mr Weston, thank you. Your insistence on the physical comparison is persuasive, but I should like to test the identity of the quantity being compared. Suppose two examiners both report the amplitude of the same burst. One reports a peak taken after a narrow analysis filter; the other reports an average over a retained interval. Both possess calibrated references and reproducible procedures, yet their numbers differ. It would be misleading to begin by treating that difference as an instrumental disagreement. The operations may define different quantities. Conversely, two differently implemented procedures might be intended to estimate the same quantity but require a demonstrated relation before their results are combined. How would you require the examiner to distinguish these cases without reducing measurement to an arbitrary collection of operational definitions? In particular, what should remain invariant when a procedure is changed, and what evidence would establish that the revised procedure still addresses the original question?

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Edward Weston

Answer to Percy Williams Bridgman

Professor Bridgman, I would first require the intended comparison to be stated independently enough that the operations can be judged against it. The word amplitude is insufficient. The record should identify the waveform quantity, reference plane, bandwidth, time interval, and estimator. Your peak and average can then be recognised as different results rather than forced into spurious agreement. Their relation may be calculable for a specified waveform and filter, but that relation should not be assumed for an unknown burst. A common label cannot supply the missing model. [V1, V10]

The invariant is therefore not necessarily the numerical indication. It is the declared quantity or proposition that the procedures are intended to estimate. A changed filter may preserve a calibrated integrated-power result under identified conditions while altering the peak and timing of a transient. To establish equivalence, I would compare the procedures with signals that exercise those conditions and preserve the transformations needed to refer their results to the common quantity. A single comfortable calibration tone would not settle a claim about arbitrary bursts.

Dr. Atkinson has asked us to identify an evidential boundary rather than formulate a universal measurement philosophy. At that boundary, an examiner can state that the procedures agree for a tested signal class and uncertainty requirement, while leaving their equivalence elsewhere unestablished. This is neither arbitrary operationalism nor a promise of access to an unconditioned physical

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reality. It is a controlled correspondence between an intended quantity and an implemented procedure. The definitions permit the comparison to be criticised; the experiments determine how far the correspondence has been demonstrated.

I would retain both results where they answer different useful questions. The peak may inform an overload assessment, while the interval average may characterise another aspect of the event. Their separation strengthens the report by preventing one result from being borrowed to support the other's claim. Where a revised procedure genuinely supersedes an earlier one, the record should preserve the reason and the transformation, not merely replace the old number. Dr Shewhart, may I invite your challenge concerning the stability evidence required before we treat such a correspondence as continuing through a long acquisition?

Walter Andrew Shewhart

Peer question 2 to Edward Weston

Mr Weston, I appreciate that distinction. My concern is the passage from an acceptable comparison on one occasion to a claim that the same comparison governed a later interval. Suppose a reference check is made before a survey and another after it, and both fall inside the chosen acceptance limits. During the survey, however, the receiver warms, changes gain, and encounters unusually strong signals. The endpoint checks do not reveal every intervening state. A trace might also be stable because an automatic process has suppressed variation, not because the underlying response remained unchanged. What evidence would justify continuing to use the original calibration across the interval, and when

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should a change become a reason to divide the record? I am particularly interested in how you would avoid treating every fluctuation as a fault while also avoiding an unsupported inference of stability from two satisfactory endpoints, especially when the intervening acquisition contains unlogged automatic changes.

Edward Weston

Answer to Walter A. Shewhart

Dr Shewhart, the endpoint checks establish endpoint facts, and interpolation between them is a model that requires its own support. I would not present the absence of an endpoint discrepancy as proof that every intermediate state remained acceptable. The experiment should first identify which changes can materially affect the intended quantity. If gain selection, temperature, or a preceding overload can alter the applicable transfer, the acquisition should record those states with sufficient timing to associate them with the observations. Where an important state is unknown, that interval should be qualified rather than assigned the most convenient correction. [V1, A1]

It is equally important not to turn a list of possible influences into a declaration that the instrument is always unfit. A characterised state range may justify continued use without continuous recalibration. The question is whether the present observations fall within that demonstrated range, including its uncertainty and response history. A change within the range may require no special treatment; a change outside it may require a new correction, a waiting interval, or rejection

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of a particular measurement. These actions should follow previously stated criteria when practicable.

Dr. Atkinson, I would divide the record when the interpretation changes, not merely when a display line twitches. A known gain transition with a supported correction can be retained as a distinct state. An unresolved transition might remain usable for a coarse detection while failing a precise amplitude comparison. The validity label should therefore refer to the claimed measurement. It need not declare every recorded sample universally valid or universally worthless.

The proposed evidence is a combination of characterisation, state logging, and appropriately placed checks. Each supplies something the others lack. Characterisation supports a relationship, logging identifies where it was applied, and checks can reveal departure from expected behaviour. None should be allowed to stand silently for all three. I would preserve their disagreements because those disagreements can identify the boundary of the claimed result. Dr Nyquist, may I now pass the discussion to you and ask how the sampling and frequency mapping can impose further limits even when this physical comparison has been competently established?

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Harry Nyquist

Sampling preserves a conditional representation

Mr Weston, thank you for establishing that boundary. Dr. Atkinson, I would distinguish the existence of a digital record from the recoverability of the analogue quantity that the record is intended to represent. A sequence of numbers can be preserved exactly while the process producing it remains ambiguous. Sampling maps admitted input behaviour into a discrete representation. The useful question is not whether the converter generated many samples, but whether materially different admitted inputs can produce the same recorded evidence for the question under examination. The volume's treatment of aliasing makes this distinction explicit. The analogue band selection and the actual sampling arrangement are part of the meaning of the record. [V10]

A frequency label cannot remove an ambiguity created before the label was assigned. Suppose a component is retained at a stable digital frequency. That observation does not by itself identify a unique external frequency if more than one admitted input band could map there. The appropriate examination varies the conditions that distinguish those possibilities within the safe and authorised limits of the equipment, such as the admitted analogue band or the sampling configuration, and records the predicted mappings before inspecting the result. This is a test of competing explanations, not a ritual performed merely to obtain a second attractive trace. A persistent line may remain entirely reproducible while its original frequency is misidentified.

The word actual is essential in this account. A requested sample rate, a menu selection, and a verified timing relationship are different records. The

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operator may legitimately begin from the instrument's configured rate, but the evidential claim should identify whether that rate was measured, nominal, or subject to an uncertainty model. A local oscillator and a sampling clock can enter the frequency interpretation in different ways. Replacing their separate roles with one generic statement that the receiver was synchronised conceals the relationships on which a frequency or timing comparison depends.

Continuity presents a second boundary. A file with the expected number of bytes need not contain the expected succession of physical sampling instants. Missing, duplicated, reordered, or restarted blocks can affect interpretation even when each surviving value lies within the permitted numerical range. A continuity record should identify source indices or an equivalent verifiable relation, rather than infer uninterrupted observation from the smooth progress of a playback cursor. Where gaps are known, the analysis must preserve them. Interpolation may create a convenient display, but it must not be counted as an additional observation of an event that was not captured. [V10, A1]

The third boundary concerns transformations after sampling. Mixing, filtering, and decimation can be sound operations, yet their output is a particular representation with a particular history. Its frequency origin, retained phase, response delay, initial state, and numerical scale must be identified to support a later comparison. The source record may permit those choices to be repeated or changed. A derived stream may not. Therefore the analyst should distinguish what can be recomputed from retained data from what would require a new acquisition. A changed

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analysis window can answer a new question about preserved samples; it cannot recover an analogue band that the front end rejected.

Dr. Atkinson, this account also changes the interpretation of nominal resolution. A large digital word describes a representation. Whether small changes in that representation correspond to recoverable input differences depends on the complete acquisition and the error processes relevant to the measurement. Arithmetic can preserve fractional results from an average without proving an equal improvement in every aspect of analogue performance. Likewise, a high aggregate sample rate can support a denser sampling grid without establishing freedom from mismatch, aliasing, or common disturbances. These are separate claims, and the proposed validation should keep them separate. [V10]

I would test the receiver with deliberately varied but controlled inputs chosen to challenge the proposed mapping. Move a known signal across relevant band boundaries, change the input amplitude within the claimed operating range, examine short records after state changes, and compare the retained output with the declared transformation. The point is not to simulate every possible environment. It is to find cases that expose the assumptions essential to the intended use. A test selected only because it is easy to reproduce can demonstrate repeatability while leaving the decisive ambiguity untouched.

My conclusion is consequently narrower and more useful than the assertion that digitisation preserves the signal. It preserves a representation under specified admission, timing, range, and processing conditions. The examiner must identify which properties remain recoverable and which distinctions have been lost or require additional information. This gives the

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later statistical analysis an honest observational basis. Otherwise, even impeccable calculations may describe a variable different from the one named in the report. Dr Bode, may I invite your question concerning the relationship between this sampled description and the dynamic states of the analogue network that precedes it?

Hendrik Wade Bode

Peer question 3 to Harry Nyquist

Dr Nyquist, thank you. Your account makes the sampling boundary explicit, but a receiver also carries memory in its filters and control loops. Suppose a burst arrives after a strong input has altered an automatic gain state. The recorded samples are continuous, the clock is well characterised, and the digital transformation is correctly documented. Yet the physical transfer during the burst is not the same as the transfer measured with a steady calibration signal. A frequency-domain response established in a settled condition may not predict the transient. Would you regard this as an error in the sampling representation, an inadequacy in the analogue model, or an ambiguity that belongs to both? More practically, what should the record contain to distinguish a changed source waveform from the receiver's changing response without assuming that a convenient steady-state correction remains valid throughout the event and across the preceding recovery history?

A further constraint follows from the conversion of an observed receiver indication into a bounded evidential proposition. The emitter identity, analogue reference-plane voltage, and activity outside the observed aperture remain outside the direct observation. If the examiner reports only those cases in which the indicated feature agreed with the

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preferred model, what correction would you require to the exposure denominator, alternative-hypothesis analysis, and reproducibility account?

Harry Nyquist

Answer to Hendrik W. Bode

Thank you for that question. Dr Bode, I would locate the inadequacy in the claim being made about the chain rather than force every problem into one stage. The samples can faithfully preserve the output of a changing analogue system while failing to identify its input uniquely. A correct description of the sampling process does not supply the missing state of that analogue system. Equally, a valid analogue model cannot repair undocumented sample gaps. The stages are distinct, but the final inference depends on their combined description. That is why the volume begins with the configured measurement system rather than the converter in isolation. [V1, V10]

The record should preserve the state information and preceding history required by the model used for correction. If a transient model has been identified and tested over the relevant operating range, the analyst can examine whether the present event satisfies its conditions. If only a settled response is known, applying it during a transition is an extrapolation. Its status should be explicit. A better-looking corrected pulse does not establish that the extrapolation was valid, because several different input histories may explain the same changing output.

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Dr. Atkinson, one useful proposed experiment is to compare a known probe through both settled and deliberately disturbed states, retaining the chronology rather than merely collecting final amplitudes. That experiment should examine the quantity at issue. A recovery criterion for power does not establish the recovery of phase or a trigger's event timing. Nor does a downstream probe certify an untested upstream path. The experimental boundary remains as important here as the sampling boundary.

Where the necessary state is unavailable, I would preserve the narrower statement: the receiver output contained the reported feature under an unresolved transfer condition. That may justify further investigation without supporting a reconstructed source waveform. We should not erase the observation, but neither should we restore missing premises by assumption. Dr Shannon, may I invite you to consider what information must be retained for later, potentially unforeseen analytical questions, and why a larger recording or a wider numerical word does not automatically resolve the distinctions we have identified?

A further constraint follows from the conversion of an observed receiver indication into a bounded evidential proposition. I would add the following qualification to my answer. For quantitative interpretation, the distinction between signal power at the antenna reference plane and displayed power after digital processing must remain explicit. A numerical threshold has meaning only together with calibration uncertainty, analysis bandwidth, detector statistic and valid observation exposure. Overlapping Fourier windows do not

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create fully independent measurements merely by providing additional rows. The result should therefore be accompanied by a denominator tied to genuine measurement opportunities, an account of clipped or missing intervals and a description of the nuisance conditions under which the decision procedure was challenged. In this particular question, the controlled observation is a timestamped receiver output obtained with a declared configuration, whereas the material uncertainty concerns the emitter identity, analogue reference-plane voltage, and activity outside the observed aperture. Consequently the adversarial comparison ought to include a documented reference-source injection and independent measurement path and its failed as well as successful outcomes. I would not advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

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Claude Elwood Shannon

Retained representation and the questions it can answer

Dr Nyquist, thank you. Dr. Atkinson, my observation is that the value of a retained representation is relative to a question and a model of the alternatives that matter. A large file can be inadequate for a question whose distinguishing information has been discarded. A much smaller record can be adequate for a narrowly defined comparison if the retained statistic is sufficient under its supported model. These propositions do not license indiscriminate compression. They require the examiner to state what later distinctions must remain possible and what assumptions make the selected representation adequate. The original acquisition and its derived products should not be treated as interchangeable merely because both produce recognisable spectra. [V1, V10]

Consider a record containing only averaged spectral powers. It can support questions about those powers within the estimator's conditions. It does not ordinarily retain every phase relationship or the precise ordering of short events that contributed to the average. A later request for coherent combination or burst timing therefore asks for information that the stored product may not contain. The issue is not that the product was badly designed. It may have been designed for another purpose. The defect arises when its purpose is silently enlarged after acquisition. A proper retention decision should make both the supported uses and the abandoned possibilities visible.

The same reasoning applies to broad acquisition. Capturing a wide frequency interval can preserve context useful for identifying strong inputs, simultaneous activity, and possible receiver artefacts. It does not itself make

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every weak component detectable. The analysis still depends on admitted noise, distortion, the signal's distinguishing structure, and the interval over which that structure can be used. The wider record may make a better subsequent test possible, but it does not guarantee that the test's premises hold. A statement about captured bandwidth should therefore be kept separate from a statement about achieved detection performance for a specified signal class. [V10, V16]

I would ask what alternatives the proposed data reduction preserves. If the immediate purpose is to detect a known waveform, a specialised statistic may be informative. If the purpose is to investigate an unexplained event whose model may change, retaining only that statistic can make the investigation dependent on the first hypothesis. This is a design choice with evidential consequences. A cautious workflow may preserve a suitable source segment and its context when a detector identifies a candidate, while maintaining a broader account of coverage and acquisition validity. Its adequacy still depends on whether the trigger captured the necessary prehistory and whether the recording path remained sound.

Dr. Atkinson, there is an important difference between documenting a transformation and demonstrating that it is reversible for the intended use. A complete account of an average tells the reader how values were combined. It does not in general allow every original value to be recovered. A checksum can identify the retained bytes without establishing that the desired physical information was ever represented in them. A reconstruction can be mathematically consistent with a stored product while remaining non-unique. The report must therefore separate reproducibility of a

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calculation, integrity of a file, and identifiability of the physical quantity. Their evidence overlaps, but none automatically supplies the others. [V1, A1]

A further complication is the temptation to regard a confident classification as an independent source of information. Suppose a processing system assigns an event to a familiar waveform family. That result reflects the retained observations and the classification rule. If two different physical mechanisms produce the same relevant observations, the label does not distinguish them merely by sounding more specific. Additional context, an independently informative feature, or a controlled experiment is required. The classifier can be useful without becoming an oracle. Its task, training or fitting conditions where applicable, and limits of discrimination should remain part of the measurement account.

For an auditable archive, I propose a chain of representations rather than one supposedly definitive file. Identify the original retained sample intervals, their acquisition state, the transformations used to derive each product, and the propositions each product supports. Preserve the relation between an event marker and the source interval from which it was calculated. Where information was deliberately discarded, record the operation and the reason. The archive then permits a later examiner to distinguish a legitimate new analysis from a claim that would require observations no longer available. This is a practical architecture for criticism rather than a demand to preserve everything indefinitely.

The physical and legal boundaries of acquisition remain controlling. An engineering ability to retain more does not decide what may properly be collected or how long it should be kept. Within the authorised purpose, however, the retention scheme should be assessed against the uncertainty

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of future analytical questions. The most defensible scheme is one whose losses are understood and whose remaining claims are explicit. Mr Hartley, may I invite your question concerning the relation between a wide representation, a limited observation interval, and the distinctions a receiver can actually support?

Ralph Vinton Lyon Hartley

Peer question 4 to Claude E. Shannon

Dr Shannon, thank you. The distinction between a representation's size and its usefulness needs a practical test. Suppose an operator claims that a larger converter word and a wider retained band together make a recording more informative in every relevant respect. Yet the analogue front end admits a strong unwanted signal, and the stored values have been rescaled after a range excursion. Another acquisition uses a narrower, well-characterised path and retains less data, but preserves the weak feature of interest without that excursion. I do not suggest that narrower is invariably better. I ask how the examiner should compare these records without turning bandwidth, numerical precision, or file size into a single misleading league table. What must be specified about the task and the admitted alternatives before one can say that the first record contains more useful evidence than the second for a specified conclusion about the admitted physical signal?

Claude Elwood Shannon

Answer to Ralph V. L. Hartley

Thank you for that question. Mr Hartley, the comparison must begin with the proposition to be resolved and the conditions under

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which the records were formed. If the weak feature is irreversibly obscured by a range excursion in the broad acquisition, its nominal representation cannot repair that loss. The narrower acquisition may then support a stronger conclusion about that feature while supporting weaker conclusions about activity outside its admitted band. Neither record is universally superior. They preserve different distinctions under different physical conditions. A single score would conceal precisely the trade-off the examiner needs to understand. [V10]

Dr. Atkinson, I would compare at least the relevant frequency and time coverage, the operating validity of each path, the uncertainty of the retained quantity, and the alternative explanations that remain distinguishable. Those are not interchangeable units to be added casually. A record can gain coverage while losing useful amplitude discrimination, or gain sensitivity to one class while excluding another. The comparison should state that structure rather than borrowing the best attribute from each arrangement and presenting the combination as an achieved instrument.

Your example also shows why the evidence record should distinguish the original values from subsequent scaling. A change in representation may be entirely legitimate and precisely documented, but it must not conceal an earlier loss. Where the raw record is retained, an examiner may challenge the processing. Where only the rescaled product survives, the extent of that challenge can be limited. Documentation makes the limitation visible; it does not abolish it. A comparison record should therefore state which claimed distinctions

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survive each acquisition, rather than assume that a common file format establishes equivalence between their physical information.

The appropriate conclusion may therefore be that the records are complementary. The broad record provides context for possible interferers, while the narrower record supports the specified weak-signal measurement. Combining them requires demonstrated timing and reference relationships, not merely placing two traces on the same screen. Professor Gabor, may I invite your question about how transient behaviour and the choice of representation affect the temporal and spectral claims that such an archive can sustain?

Dennis Gabor

Peer question 5 to Claude E. Shannon

Dr Shannon, I welcome the insistence on complementary records. A transient presents a particular difficulty because a representation that makes its spectrum convenient may obscure the chronology that gives the event its significance. A long analysis interval can combine several physical episodes, while a short interval can change the discrimination between nearby components. Display persistence can further suggest a duration that belongs to presentation rather than acquisition. If the same source samples permit several legitimate analyses, how should an examiner choose among them without selecting only the representation that appears to support a preferred explanation? Should the report preserve one standard view, a family of views, or the procedure by which the views were compared? I ask especially how a disagreement between views should be described when it reveals different sensitivities to the

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event rather than an error in either calculation, and when both views remain reproducible from the same retained observations.

Claude Elwood Shannon

Answer to Dennis Gabor

Professor Gabor, I would preserve the distinction between the event and the operations used to examine it. The source samples, where valid and available, provide a common observational record. Each analysis then answers a specified question through a declared transformation. The report should identify the time interval, window, filtering, averaging, and display conventions that materially affect the result. It should not imply that a displayed extent is a direct measurement of transmitter duration when the transformation itself can broaden or retain the event. [V10, V16]

Dr. Atkinson, one useful safeguard is to state the primary analysis rule before reviewing the disputed event, while permitting clearly labelled exploratory analyses afterwards. An alternative view can reveal a weakness in the original interpretation or suggest a further test. It should not silently replace the original rule and inherit its validation claim. Exploratory settings can be preserved as exploratory settings, with their selection history intact, while a later confirmatory analysis applies a separately justified rule to an appropriate record. Where several views address different properties, report those properties separately. A view useful for estimating integrated energy need not be the preferred view for locating an onset.

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I would retain the procedure of comparison as well as the views necessary to explain the conclusion. A long catalogue of pictures is not a substitute for identifying what each comparison tests. If two views differ because they combine different intervals, their disagreement may be expected. If they purport to estimate the same quantity under equivalent conditions and disagree beyond the stated uncertainty, that discrepancy requires investigation. The report should show the distinction rather than resolve it by selecting the visually more persuasive panel.

The archive should also preserve observations that weakened the preferred account. Otherwise, later review encounters a curated conclusion rather than a reproducible analysis. This is an argument for disciplined selection, not for indefinite accumulation of redundant outputs. Professor Neyman, may I pass the discussion to you and invite your account of how the declared analysis rule, the trial population, and the uncertainty of its validation constrain the meaning of a claimed detection probability?

I thank the questioning colleague for that important distinction. The chronology of the point at which an antenna-terminal indication becomes an evidential proposition is indispensable. Assume for a moment that a signal seen at the receiver output could have originated in a mixer or through a common-mode path. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should inject a stable reference into the same physical port and then substitute a termination, and treat time spent switching, settling or clipping as

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measured invalidity rather than as an unoccupied channel. The state record needs absolute input power, receiver gain history, detector threshold and independent antenna-side confirmation. If a known reference remains measurable whereas the disputed feature changes after the antenna path is isolated, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

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Jerzy Neyman

Performance belongs to a defined experiment

Dr Shannon, thank you. Dr. Atkinson, I would begin by distinguishing a procedure's observed success in a set of trials from its performance in a specified population of possible trials. The former is a record; the latter is an inference. That inference requires a sampling or experimental model, including what changes between trials and what is held fixed. A long list of successful replays can demonstrate reproducibility of processing without establishing performance across changes in analogue noise, signal timing, receiver state, or propagation. The word trial therefore carries more responsibility than the presence of a numbered row in a table. [A1, N1]

Our hypothetical operator wishes to make both positive and negative claims. For a positive detection, the decision rule and its alternatives must be defined. An event crossing a threshold is not automatically a correctly identified external source. The validation should distinguish detection of a stipulated signal, classification of a waveform, and attribution to a physical mechanism. Their errors can differ, and success at one stage does not establish success at the next. A test programme that presents only familiar, favourable examples cannot validate unrestricted classification merely because the reported labels are consistently correct.

For a negative finding, the relevant experiment includes the opportunity to observe the signal. A sensitivity test performed while the receiver is settled and correctly tuned does not establish detection during a gap, a sweep elsewhere, or a recovery interval. The acquisition schedule and validity history must therefore enter the claim. One should not use the scheduled duration as though every instant supplied equivalent evidence.

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The proposed report should identify the signal class, the conditions represented in validation, and the actual intervals over which those conditions were supported. Unknown coverage is a missing premise, not a particularly quiet observation. [V1, A1]

Uncertainty in the performance estimate is equally important. Even when the trial model is suitable, a finite set of outcomes does not reveal an underlying probability without uncertainty. The appropriate interval or bound depends on the inferential method and its assumptions. A statement about the long-run behaviour of a confidence procedure is not identical to a posterior probability for a particular parameter. The report should use the interpretation belonging to the chosen method rather than move between them because both employ percentages. The supplied expansion already develops exact zero-failure and zero-event examples with their respective conditions; those calculations should remain attached to those conditions. [A1, N1]

Dr. Atkinson, I would also resist pooling convenient conditions into a single attractive average. Suppose most challenge signals are strong and continuous, while a smaller but important group consists of short, weak bursts near a channel boundary. An overall success fraction can conceal poor performance in that smaller group. The proper remedy is not invariably to insist on an enormous experiment. It is to identify the material conditioning variables and report the limits of what the design establishes. Where the data do not support a reliable estimate in a relevant region, that region remains a qualification rather than borrowing the average performance of easier cases.

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Dependence between observations must be examined for the same reason. Several overlapping spectral windows can share much of their input. Two detectors can share a noise estimate. Separate receivers can share a front end or disturbance. Treating their outcomes as independent may assign the evidence a strength that the experiment never supplied. Independence is a property of the adopted model supported by the arrangement, not a reward for counting different labels. Where dependence is material but incompletely characterised, the examiner should choose an analysis that recognises it or restrict the resulting claim.

The distinction between development and validation is particularly useful. During development, thresholds, filters, and exclusion rules may be adjusted in response to observations. That process can improve a detector, but the observations used to make the adjustments do not automatically supply independent confirmation of the selected procedure. A confirmatory test should assess the resulting rule under a defined design without quietly allowing further favourable revisions. Where revision is necessary, preserve the chronology and identify the resulting test as further development. The scientific value of the work does not disappear; only its proper description changes. [V16, A1]

My proposed conclusion is conditional rather than evasive. State the tested procedure, the trial population, the relevant acquisition state, the observed outcomes, the inferential method, and the uncertainty. Then state which field observations satisfy the conditions needed to use that result. This provides a rational basis for a strong claim where the evidence permits one and exposes the particular work needed elsewhere. It is more informative than an unqualified assertion of sensitivity and more useful than

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a general declaration that certainty is impossible. Professor Pearson, may I invite your question concerning how a predeclared rule can remain meaningful in a receiver that legitimately adapts during observation?

Egon Sharpe Pearson

Peer question 6 to Jerzy Neyman

Professor Neyman, thank you. The separation between development and validation is necessary, but the receiver in our case may employ an adaptive threshold as part of its intended operation. Its background estimate changes with recent observations, and an event can affect the estimate used for later decisions. Freezing a single numerical threshold would then test a different instrument from the one deployed. At the same time, allowing unrestricted adjustment after seeing each result would make a performance claim difficult to interpret. Where would you draw the boundary between legitimate adaptation inside a defined procedure and post hoc revision of that procedure? Please also consider a noise reference contaminated by a neighbouring signal. Can the adaptation be called validated merely because its code is fixed, or must the trial design separately exercise the circumstances in which its reference ceases to represent the tested cell and its nominal false-alarm interpretation consequently becomes questionable?

Jerzy Neyman

Answer to Egon S. Pearson

Professor Pearson, the object to freeze is the decision procedure, not necessarily a constant numerical threshold. A specified adaptive rule can be tested as a rule, including its state updates, reference

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selection, guard conditions, and response to previous observations. The validation then concerns that dynamic procedure under the conditions represented in the trials. It does not concern an imaginary stationary threshold. Conversely, altering the adaptation rule after inspecting favourable outcomes is a revision of the procedure and must be identified as such. This distinction allows adaptation without concealing the role of development data. [A1, V16]

A fixed implementation is necessary for some reproducibility claims but does not establish statistical validity. Your contaminated reference is a direct challenge to the background model. The trials should include the types of neighbouring activity, nonstationarity, and state change that matter to the intended application. A rule can be precisely implemented while its claimed false-alarm interpretation fails outside the reference conditions used to derive it. The appropriate outcome is a qualified operating domain or a revised rule followed by further validation, not the assertion that executable code makes its assumptions true.

Dr. Atkinson, the record should preserve enough of the adaptive state to reproduce the actual decision. Retaining only the tested cell's power while discarding the reference membership and threshold history can make a later review unable to reconstruct why a detection occurred. It also conceals dependencies when several decisions share a fluctuating reference. Those dependencies matter when one interprets a cluster of detections as repeated confirmation. The required record concerns the actual reference used, not merely the default reference-window setting listed in a software manual.

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I would therefore validate both ordinary operation and declared failure behaviour. The system should identify conditions in which its evidence is insufficient for the usual interpretation, rather than conceal every difficulty through a new threshold. A qualified or indeterminate interval can be a correct result. Sir Karl, may I invite you to examine how such restrictions can remain genuinely testable, and how an examiner should distinguish a legitimate refinement from a succession of qualifications that merely protects a preferred explanation?

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Sir Karl Raimund Popper

A conclusion must remain vulnerable to a relevant test

Professor Neyman, thank you. Dr. Atkinson, the central distinction is between restricting a claim because its evidence has a demonstrated limit and restricting it whenever an adverse observation appears. The first makes criticism more precise. The second can deprive criticism of any possible consequence. In this constructed receiver case, an examiner should state which observations would count against the proposed explanation and why the instrument could obtain them. A promised test is not severe merely because it is elaborate. It must expose a difference between the explanation and a relevant alternative under conditions that permit that difference to be observed. [V16]

Suppose the preferred explanation is that a displayed line originates from an external source. The alternative might involve a conversion product, a sampled alias, or an instrument emission coupled through an external path. A useful challenge would identify how the predicted observation changes when an appropriate part of the arrangement is changed. The result must be interpreted through the actual physical consequences of that change. Terminating an input, for example, can remove several pathways at once. Disappearance is therefore evidence about the changed arrangement, not automatically a complete attribution. The test becomes informative through its specified predictions and preserved conditions, not through a ceremonial act of disconnection. [V16]

Dr. Atkinson, I would also insist that a failed challenge remain part of the account. If an examiner tries several changes and reports only the one that appears to favour the preferred explanation, the reader receives a selected

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narrative. The omitted results may reveal a missing interaction, insufficient sensitivity in a comparison path, or an unstable system state. They might also weaken an alternative explanation. In either direction, their value depends on preserving the sequence and the reasoning. A report should not become more certain simply because its inconvenient observations have been removed from view.

This does not require treating every imaginable possibility as equally plausible. An investigation must choose alternatives that are relevant to the architecture, environment, and observation. Their selection can be justified by known mechanisms and by the consequences of being wrong. What matters is that the selected alternatives remain open to discriminating examination and that important untested possibilities are not silently excluded. A catalogue of exotic causes can be as unhelpful as premature certainty when it supplies no predictions and no means of decision. Criticism should direct the next experiment, not merely multiply expressions of doubt.

The methodological role of the historical name must itself remain bounded. My participation here supplies a perspective on testability, not a historical endorsement of present receiver specifications. The engineering predictions belong to the models and evidence identified in this volume. Where those predictions fail, one must examine both the proposed source explanation and the auxiliary assumptions concerning the instrument. A single adverse result can be consequential without uniquely identifying which assumption failed. The responsible response is to formulate further discriminating tests or narrow the claim, while recording why that change is warranted.

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Dr. Atkinson, the proposed three-way distinction between a qualifying detection, a valid negative observation, and an indeterminate interval is valuable precisely because it can be criticised. Each category should have conditions that a reviewer can inspect. Indeterminate must not become a refuge used only when the result is inconvenient. Nor should it be suppressed because a client expects a decisive answer. The same classification rule should govern an interval that appears favourable and an interval that appears adverse to the investigator's preferred account. Its proper use identifies a missing observation or unsupported condition and explains what would be needed to resolve it. That account can guide action while refusing to invent evidence. [A1]

There is also a difference between an explanation that fits the retained record and one that survived a test designed to discriminate it. Fitting can be useful for proposing a mechanism. It does not independently establish that mechanism when several candidates can fit the same observations or when the adjustment itself has absorbed the distinguishing discrepancy. The report should separate exploratory modelling from the subsequent challenge. A successful challenge supports the limited proposition it was designed to test; it does not confer a general immunity from further criticism.

My proposed reporting discipline would therefore name the conclusion, its supporting observations, the alternatives actually examined, the predictions used to distinguish them, and the unresolved conditions. Agreement among the participants should not be manufactured where the observations leave a material question open. A properly bounded disagreement can expose the most valuable next test. The achievement is

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not the appearance of unanimous assurance, but a record in which another competent examiner can locate the premise they dispute and identify an observation capable of changing the result. Dr Wiener, may I invite your question concerning the feedback between the observer, the adaptive instrument, and the evidence subsequently offered for its own reliability?

Norbert Wiener

Peer question 7 to Karl R. Popper

Sir Karl, thank you. Our observer is not always outside a fixed experiment. The receiver can change its gain, tuning, or threshold in response to the very activity being investigated, and the operator can alter the search after seeing its first results. Dr. Atkinson has asked for a record that preserves these changes, but recording them does not by itself remove their effect on the evidence selected for review. Suppose the instrument preferentially retains intervals that its own detector finds interesting and discards the remainder. A later examiner then sees a collection shaped by that detector's responses. How can your requirement for a genuinely discriminating test accommodate this feedback without pretending that adaptation is inherently improper? In particular, what evidence would distinguish successful discovery from a selected archive that exaggerates persistence, suppresses contrary observations, or leaves negative coverage unestablished because the unretained intervals were never independently examined under an adequate procedure?

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Sir Karl Raimund Popper

Answer to Norbert Wiener

Dr Wiener, the feedback must become part of the account of how the observations were selected. A discovery procedure can legitimately concentrate attention on promising intervals. What it cannot do is present the selected archive as though it were an unselected observation of the entire period. The claim should identify the selection rule and the information retained about intervals that were not stored. A collection of triggered events may support investigation of those events while leaving their prevalence, the completeness of the search, or the conditions of non-detection unresolved. [V1, V16, A1]

Dr. Atkinson, the proposed distinction is between discovery and the test of a subsequent claim. Discoveries may be opportunistic. A hypothesis suggested by them can then be examined through a separately specified acquisition or a genuinely held-out record appropriate to the proposition. If the instrument continues to adapt during that test, its adaptation must be part of the defined procedure and the validation must address the relevant operating conditions. Calling a sequence adaptive neither excuses selection bias nor makes the sequence scientifically useless.

Your archive should therefore preserve coverage information and material state transitions in addition to selected events. It should show what the detector could retain, what it actually retained, and where validity was unknown. Where the search was redirected by a preliminary result, the chronology should make that redirection

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visible. These records allow a reviewer to distinguish evidence about an observed event from evidence about the completeness of observation. They do not manufacture the missing intervals, but they prevent the absence of those intervals from masquerading as evidence of absence.

I would finally ask that the proposed discovery mechanism itself be challenged with cases capable of exposing its omissions, not only with examples it already favours. That is a practical response to feedback: study the coupled observer and instrument as the procedure actually used, including the choices that determine which observations can subsequently be inspected. Professor Atkinson, I return the floor to you for the closing synthesis, with the reservation that our agreed record architecture supports bounded conclusions rather than a universal certificate of source identity.

Jerzy Neyman, Cross-Peer Question to Edward Weston: Mr Weston, your insistence upon a declared reference plane is persuasive for a stable measurement, but I want to know whether the practitioner can test the claim when the specimen and receiver environment are capable of changing during the test. Suppose a weak spectral component is observed at the receiver connector with a calibrated reference source nearby. The operator repeats the experiment after exchanging a cable and finds agreement within a small numerical tolerance. That agreement might arise because both configurations share the same unrecognised source of error, because the component changed at the same time as the chain, or because the reported tolerance was selected after the results became known. How would you design the comparison so that agreement and disagreement

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have measurable significance? Please identify the objects requiring independent observation, the assumptions carried by the correction from one connector to another, and the means of reporting an apparently successful comparison whose uncertainty budget still excludes an important systematic mechanism.

Edward Weston, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, an observer who has only the final corrected values has no adequate basis for declaring that two physical experiments were comparable. The first act must be to define the measurand, including the receiving plane, frequency and time interval, bandwidth, detector, loading and operating state. For each arrangement we should retain both the indication at the actual measurement connector and the independently characterised transfer of the intervening path. The calibrated reference source should be characterised before it is trusted as a witness. Its level, spectral purity, connection geometry and own temporal stability may all become relevant. Agreement between two numbers corrected using the same erroneous gain table would not establish physical correctness, and that possibility should be incorporated into the experimental design. I would use a bounded sequence that separates changes in the environment from changes in the receiver path. First, observe a stable reference and the candidate simultaneously with the original path. Second, change the cable or attenuator under a plan fixed before seeing the outcome, retaining a controlled input and the actual switch time. Third, return to the original configuration and repeat the reference observation. Finally, where feasible, substitute a comparator system that changes the relevant error mechanism rather than merely carrying the same software correction into another

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enclosure. The procedure should include tests under conditions in which the expected candidate response is known to fail, for otherwise a failure-detection method may never have been challenged. Uncertainty is not a decoration added after the numbers agree. A correction for an identified passive loss has a sign, frequency dependence, loading condition and calibration uncertainty. An amplifier's gain depends upon level, state and possibly temperature. When the same calibration source or algorithm enters both estimates, covariance can be material. We should not simply divide its uncertainty by the square root of the number of repeated traces. Nor can an interval containing an unknown state transition be made valid by widening the final error bar. The state must be reconstructed or its corresponding result reported as conditional or unavailable. A successful comparison should therefore be reported narrowly: under the stated conditions, the two estimates were consistent to an identified criterion that accounted for the measured variability and specified systematic influences. If a consequential coupling path or state was not tested, name it plainly. The experiment can still be valuable because it narrows the set of plausible explanations and tells the next investigator what measurement would have the greatest power to discriminate them. I would not ask an engineering result to prove more than its chain of observation permits.

Edward Weston, Cross-Peer Question to Harry Nyquist: Professor Nyquist, your analysis of sampled representation is indispensable, yet instruments sometimes report an extraordinarily stable apparent phase in spite of short interruptions to their acquisition clocks or memory transfers. A recording may contain an exact number of samples and a plausible centre-frequency label while a hidden automatic gain change, a sample-index discontinuity or

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an interpolating firmware stage has altered the intended measurement. An expert might nevertheless calculate an FFT, compare nominal noise floors and report that no transient occurred. Which observations would you require before treating the samples as a continuous physical-time record? Can a band-limited reconstruction be invoked to fill an interval whose original samples were never acquired? Explain, also, how you would compare two channels disciplined by a common nominal oscillator when the physical distribution delays and reference switching may differ, and how the limits should appear in the technical evidence. I seek a practical acceptance test, not merely a mathematically attractive reconstruction of missing information.

Harry Nyquist, Cross-Peer Answer to Edward Weston: Mr Weston, the mathematical ability to reconstruct a band-limited waveform from a suitable sample sequence is not an assurance that an instrument supplied such a sequence. A sampling theorem requires hypotheses about the input, its admitted band, sampling times and the information retained. It cannot create missing samples merely because software knows the nominal conversion rate. The instrument record must therefore distinguish physical acquisition, buffering, processing and display. A contiguous file offset is not by itself a contiguous sample history. I would require an unambiguous hardware index, a known relationship between the index and the sample aperture under the actual clock state, and a record of missing, duplicated, reordered or deliberately discarded samples. When the instrument changes acquisition rate or reference source, the affected samples and settling intervals should be separately identified. For a complex SDR channel we must also specify its frequency convention. A negative baseband frequency,

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after frequency conversion and possible inversion, need not denote a different physical emitter. Likewise, a phase difference between channels is meaningful only after propagation and channel-transfer contributions have been declared. A shared reference can reduce some relative-frequency errors but can also introduce common phase steps which two channels repeat. Cable delay, distribution-amplifier noise, clock multiplication and the analogue frequency-conversion paths can still differ. An experiment comparing two channels should inject a controlled signal through independently characterised paths while capturing the phase relationship before and after deliberate switching, reference loss and reacquisition. Repeatability of a displayed phase under the same shared failure mechanism is not independent evidence of continuity. Interpolation across a gap may be an appropriate derivative product when the signal model and purpose justify it. It is not an acquired observation. An analyst might fit a sinusoid through two retained windows and obtain a continuous extension, but another waveform agreeing with both windows could have occupied the gap. Quantify the model dependence, retain the gap markers and label the reconstructed interval. A model that forces phase continuity may be extremely helpful for recovering an authorised communication from a clean channel, yet it cannot then be used as an independent test that phase continuity was physical. Finally, separate the spectral statistic from the event question. An FFT peak or reduced noise floor can be statistically well behaved while failing to observe a brief pulse or a reference transition. Observation opportunity depends upon when the receiver actually sampled the relevant frequencies and which samples survived filtering, gating and buffering. The evidential statement should identify actual acquired intervals,

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valid clock states and the signal classes tested. Without those conditions, numerical precision is not an answer to the question whether the relevant event could have been seen.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, an investigator often retains an attractive spectrogram, a list of detections and perhaps a demodulated audio excerpt but discards the original complex samples after processing. Those derived products may be compact and useful, especially in a survey with limited storage; nevertheless, the decision of what to keep may have been made by a threshold detector whose own errors are unknown. A later reviewer asks whether a weak transient, a phase-reversed signal, or a different waveform of the same power might have been present during a rejected interval. Which claims remain possible from the derived products, and which become formally unidentifiable? How would you distinguish a defensible compression or event-retention policy from a process that silently turns discarded data into an assertion of absence? Please address both reproducibility and lawful minimisation, because indiscriminate retention is not automatically authorised merely because complete samples would be analytically convenient. I particularly ask which original observations must remain distinguishable from software-generated hypotheses after extraction.

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Professor Nyquist, we should start from the map between the original observed waveform and the retained representation. A magnitude-only spectrum can be well suited to estimating energy under a specified window, bandwidth and calibration. It cannot in general recover the original complex phase, sample chronology or event timing. A detected-event list can be suitable for

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counting events that exceed a particular validated criterion. It cannot prove that no other event occurred unless the detector's operating characteristics, observation opportunity and retained evidence justify such a claim. A demodulated fragment may retain intelligible content but discard the carrier, phase-noise and modulation characteristics needed for a different forensic question. Each output is thus useful, but only in relation to the questions it can still answer. An event-driven recorder should preserve a coverage ledger as carefully as it preserves the selected events. The ledger identifies bands and valid time intervals actually examined, detector thresholds, effective bandwidths, gain and overload states, clock quality, and known losses of acquisition or processing. When the detector fires, the retained complex samples should include the preceding history needed to evaluate the trigger and the following interval needed to understand the event. Multiple simultaneously observed subbands may require an explicit association across channels, preserving hardware indices and phase-calibration states rather than silently stitching them into a synthetic waveform. If no event is retained from a valid interval, the resulting statement is that none met the particular criterion in the observed domain. It is not universal proof of electromagnetic silence. The decision to discard raw data also has a lawful boundary. One cannot justify retaining all incidental communications merely because a future hypothesis might benefit from them. The proper design follows the authorised technical question and uses the least intrusive retention that leaves the necessary evidence reviewable. In some cases calibrated statistical summaries with controlled validation will be sufficient. In others the question requires original I/Q samples and an event-dependent protected recording. A policy

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should define those cases in advance, distinguish metadata about measurement validity from communication content and disclose when privacy constraints limit later reconstruction. A cryptographic digest of a retained product establishes byte correspondence under its custody chain, not the truth of the conclusions selected by the processing algorithm. Nor does a later successful reproduction of the same software output prove that the upstream detector was sensitive to the unknown event of interest. A proper independent challenge uses held-out physical test emissions, including weak and nonconforming cases, and compares what the recording system retains against an independently instrumented reference. Report misses as misses, not as noise-only successes. By preserving what the system decided, how it decided, and what it never observed, an investigator can give a compressed record a defensible evidential meaning without pretending that lost information remains available.

Claude Elwood Shannon, Cross-Peer Question to Jerzy Neyman: Professor Neyman, your discussion of specified error probabilities is vital when a receiver searches many spectral cells. Yet a technical survey seldom tests only one fixed frequency and one noise hypothesis. It may search millions of overlapping FFT bins across changing gain states, then choose a handful of visually striking candidates and ask an examiner to explain them. A report sometimes quotes a low single-bin false-alarm probability as though that were the probability of an erroneous conclusion after the entire adaptive search. How should the practitioner formulate a valid test when the search region, threshold and follow-up measurements can change in response to earlier observations? What must be retained to distinguish discovery from independent confirmation? I also ask how an unresolved receiver artefact

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should affect the interpretation of a statistically significant peak, and whether a negative observation in unexamined frequency-time cells can ever be included in the stated error probability. Would an explicit held-out challenge set change that assessment?

Jerzy Neyman, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the first safeguard is to define the experiment whose error probability is being reported. The probability of a threshold crossing in one prespecified noise-only cell is not the probability that some cell exceeds the same threshold after an extensive search. Nor is a confidence interval calculated for a candidate selected because it looked extreme automatically valid as an unconditional interval for that selected candidate. Dependence among adjacent FFT bins, overlapping windows and repeated acquisitions must be addressed by the test design or a validated approximation. The entire search procedure is the relevant statistical object: it includes candidate generation, adaptive processing, rejection criteria, exclusions and any selection of favourable intervals. I would separate exploration from confirmation. Exploration may search broadly and adaptively to discover a component worth investigating. Its function is to generate hypotheses. Confirmation then uses a declared measurement protocol chosen independently of the confirming data, with a defined reference plane, detection statistic, permitted operating states and controlled challenge conditions. The confirming record must be capable of observing the proposed event class; otherwise a nondetection is not a valid refutation. If independent confirmation is impossible, report the exploratory finding as exploratory and qualify its error probability. Do not transfer a probability calculated for one narrow test into a conclusion about the entire

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investigation. Instrumental artefacts create a further distinction. A statistically extreme spectral line may genuinely depart from a model of random receiver noise while still originate in a local oscillator, clipping, intermodulation or clock distribution. Statistical significance rejects a specified statistical model, not every alternative physical explanation. A useful test therefore changes one or more causal conditions: input termination, known attenuation, preselection, clock source, equipment location or a separately controlled receiver architecture. Under each change, make the predicted response explicit for the competing hypotheses. A comparison that changes detector sensitivity at the same time as the proposed causal variable must account for that change rather than attribute every difference to source identity. Unobserved cells cannot be treated as negative observations unless an independent bound or probability model justifies their inclusion. A receiver's wide tuning range does not imply that all those frequencies were examined at the relevant times, and a clean average trace does not establish response to a short transient. Record actual frequency-time coverage, the selected confidence convention and the relation between the expected event and the observation schedule. If false alarms or missed events cannot be estimated with acceptable precision, state that limitation. Useful scientific evidence remains possible, but the claim must not be presented with an invented numerical certainty. The resulting report should state an observed component, a measurement procedure, a justified statistical comparison, and the physical alternatives that survived controlled challenges. It should identify which confirmation data were independent and which shared the discovery process or calibration. Such a report will be less dramatic than a declaration of

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universal certainty, but it will be much more resistant to a legitimate technical objection.

Dr. James M. Atkinson

Closing synthesis

Mr Weston, Dr Nyquist, Dr Shannon, Professor Neyman, Sir Karl, and our seven questioning colleagues, thank you. The discussion has identified several different conditions that must not be compressed into a single assertion that the receiver is trustworthy. Mr Weston distinguished the physical comparison from its displayed indication and the applicability of a reference from the prestige of its calibration history. Dr Nyquist then showed why a faithfully retained sequence can still leave the admitted input ambiguous. Dr Shannon distinguished the integrity and size of a representation from its ability to answer a particular later question. Professor Neyman located performance claims within a defined experiment and trial population. Sir Karl required the resulting account to remain open to observations that would materially change its interpretation.

The peer exchanges sharpened those positions rather than merely endorsing them. Professor Bridgman required the measured quantity to survive a change of method without relying on an ambiguous label. Dr Shewhart challenged the inference from satisfactory endpoint checks to uninterrupted validity. Dr Bode identified the unresolved analogue state that can precede correctly sampled data. Mr Hartley refused a single league table of bandwidth and word length, while Professor Gabor distinguished the event from the analysis interval and display that represent it. Professor Pearson separated a fixed adaptive procedure from a fixed numerical

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threshold. Dr Wiener exposed the selection introduced by a search that changes in response to its own discoveries.

Our resulting doctrine is specific. A significant receiver finding should retain a traceable relation among its claimed quantity, physical reference plane, acquisition state, source interval, processing transformation, and decision rule. A comparison should identify what changed and what remained sufficiently comparable. A performance claim should identify the tested population and its uncertainty. A negative observation should identify valid exposure rather than borrow assurance from scheduled time alone. These requirements reinforce the volume's existing distinction between detection, classification, attribution, and content recovery; they do not collapse those distinct achievements into one result. [V1, V10, V16, A1]

Several questions remain deliberately unresolved. No universal recovery interval has been prescribed. No single retention format has been declared sufficient for every future question. No generic statistical percentage has been made applicable to every signal or environment. These omissions are not gaps to be filled with confident numbers. They identify dependencies that the relevant later chapters and experiments must address. Where a practical decision must precede their resolution, the report should state the supported observation, the missing premise, and the consequence of that limitation for the proposed use.

The next primary question will examine how the intended measurement should determine the receiver architecture and the location of its reference planes. That discussion should begin from the distinctions established here, not repeat their introduction. For this question, our conclusion is that evidence formation is a controlled sequence of physical comparisons and

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stated inferences. Its quality lies in the reader's ability to test the connections between them. The visible trace remains important, but its persuasive appearance must never substitute for those connections.

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Ten worked engineering applications | Question 001

Application 01. Thermal reference noise in a declared measurement bandwidth

In the illustrative 001.01 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. Take the equivalent noise bandwidth B = 4,500 Hz and calibrated noise figure NF = 2.70 dB at an assumed 290 K. The thermal-reference estimate is N = $-174 + 10 \log_{10}(B/1\ \text{Hz}) + NF$ = -134.77 dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 02. Filter or cable rejection referred to a physical input

In the illustrative 001.02 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. For an admitted input P_i = -43 dBm and separately measured loss L = 25 dB, the linear prediction is $P_o = P_i - L$ = -68 dBm. In SI power this becomes 10^((-68 − 30)/10) = 1.58e-10 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 03. Difference between two instruments relative to stated uncertainty

In the illustrative 001.03 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. The paired instrument contrast is Δ = 1.110 dB. Set independent standard

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uncertainties u_1 = 0.340 dB and u_2 = 0.470 dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)}$ = 0.580 dB, giving the dimensionless ratio $\Delta/u\Delta$ = 1.914. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 04. Family-wise probability when many candidates are searched

In the illustrative 001.04 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. If each of M = 161 independent pre-specified search opportunities has false-alarm probability α = 0.0008, the probability of one or more false positives is 1 − (1 − α)^M = 0.12090, or 12.09%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 05. Preserved sample continuity across an acquisition interval

In the illustrative 001.05 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. A converter expected to retain f_s = 1.30 million samples/s for T = 1.15 s should supply f_sT = 1,495,000 complex sample instants. If 82 sequence positions are missing, the retained count is 1,494,918 and loss fraction is 0.00548%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block

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must therefore be preserved. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 06. Observed exposure fraction of a channel scanner

In the illustrative 001.06 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. Let the channel be observed on n = 171 valid visits, each lasting d = 6 ms, with revisit spacing R = 0.55 s. Valid exposure is nd/1000 = 1.026 s across the nominal interval nR = 94.05 s. The observed fraction of elapsed time is therefore 1.09%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 07. Combined and expanded measurement uncertainty

In the illustrative 001.07 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. For independent standard-uncertainty contributions 0.52, 0.48 and 0.46 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.52^2 + 0.48^2 + 0.46^2)} = 0.844$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 1.688$ units. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 08. Stored-sample volume and the limits of retrospective analysis

In the illustrative 001.08 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. With complex sample rate f_s = 3 MS/s, duration T = 36 s, and 16-bit in-phase plus 16-bit quadrature integers, the raw payload is $f_sT \times 4$ bytes =

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432,000,000 bytes, or 0.432 GB (decimal). The calculation excludes timestamps, metadata, framing and file-system overhead. Maintaining a wideband buffer of this capacity does not establish that upstream analogue clipping was absent. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 09. Accumulated sample-clock time error

In the illustrative 001.09 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. A free-running sample clock with fractional rate error $\varepsilon = 0.950$ ppm over $T = 438$ s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T = 0.4161$ ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. Restrict the finding to the directly observed response and its demonstrated uncertainty.

Application 10. Cascade gain and observed headroom

In the illustrative 001.10 test, a calibrated receiver indication is compared against a challenged antenna-side reference plane. A first amplifier contributes $G_1 = 10$ dB, an intentional attenuation contributes $G_2 = -8$ dB, and a later stage contributes $G_3 = 16$ dB. The small-signal sum is 10 + (-8) + 16 = 18 dB. For $P_i = -69$ dBm, the ideal output is $P_o = -51$ dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. Restrict the finding to the directly observed response and its demonstrated uncertainty.

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QUESTION 002

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How should the intended measurement determine the receiver architecture and its reference planes?

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Constructed educational dialogue. The speeches are newly authored, not historical quotations or a transcript. Numerical cases are hypothetical and do not certify an instrument.

Dr. James M. Atkinson

Opening question

Professor Bridgman, can you comment on how the intended measurement should determine the receiver architecture and the physical locations of its reference planes? Our previous discussion separated an observation from a warranted claim. This discussion must turn that distinction into an engineering choice. We are not selecting an instrument by its largest advertised bandwidth or its most imposing numerical display. We are deciding what relationship must survive between an external electrical quantity, the receiver's internal transformations, and the result retained for examination. A suitable architecture for discovering an intermittent component may differ from an architecture for measuring its phase, and neither purpose automatically establishes the ability to recover an earlier waveform.

Consider two hypothetical acquisition paths. The first offers broad instantaneous coverage and internal calibration. The second admits a narrower band but allows a reference stimulus to traverse more of the input chain. Both report calibrated amplitudes. Neither deserves preference until the quantity and required uncertainty are stated. We must determine which

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path demonstrates the comparison under the signals, states, and transitions encountered, without presuming that narrower coverage necessarily provides greater accuracy.

Our source framework treats a measurement model as a relationship involving the quantities required to obtain the intended result, and asks whether that model remains adequate within its declared range. The following receiver cases are the author's constructions, not examples reported by a standards committee. They will distinguish the meaning of the measured quantity, the physical transfer through a network, the information admitted by sampling, the stability of the operating regime, and the evidential support for accepting a correction. [M2-1]

Professor Bridgman will examine the choice of quantity. Dr Bode will consider transfer, memory, and inversion. Dr Nyquist will examine the boundary between an admitted analogue band and a recoverable sampled representation. Dr Shewhart will consider whether the calibrated regime persisted. Professor Neyman will distinguish an identified calibration relationship from an inadequately tested decision procedure. Seven colleagues will challenge particular propositions, not merely restate the need for caution. Each question will receive an immediate answer before the floor passes onward.

The reference-plane decision also fixes what a later disagreement means. Two laboratories may agree on their own connector measurements yet disagree after different external corrections. Before blaming either receiver, we must determine whether they measured the same quantity under comparable conditions and whether their correction chains have compatible uncertainty statements.

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I ask the panel to work ten illustrative cases through to their consequences. The numerical inputs are stipulated and must not be read as specifications of an actual receiver. Every calculation should identify what it proves within its model and what further observation would be needed before using it in an investigation. We must also keep architectural choice separate from institutional authority: an elegant equation does not establish that its inputs were measured, and a calibration certificate does not decide whether the intended conclusion is recoverable. Professor Bridgman, please begin with the decision that ought to precede the circuit diagram: what, precisely, are we asking the receiver to measure?

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Percy Williams Bridgman

The intended quantity governs the comparison

Dr. Atkinson, thank you. I would begin by refusing to let a familiar noun decide the experiment. Amplitude, strength, and sensitivity are useful words only after we have specified the operations and physical conditions that make them quantities in this case. A receiver can report a peak voltage, a root-mean-square voltage, or a time-averaged power without any arithmetic fault, yet those results answer different questions. The task is not to force every possible procedure into one vocabulary. It is to establish sufficient correspondence between the declared quantity and the chosen procedure that a second examiner can determine whether a changed method still addresses the same proposition.

In our first worked application, suppose a sinusoidal voltage is applied across an exactly stipulated resistance R of 50 ohms. Let V_{rms} denote root-mean-square voltage in volts and P the mean dissipated power in watts. The declared relation is P = V_{rms} squared divided by R. If the report's 10 millivolts is an RMS value, the mean power is 2 microwatts. If the same numerical voltage instead denotes the sinusoid's peak, its RMS value is smaller by the square root of two, and the mean power is 1 microwatt. The ambiguity has doubled the inferred power without changing a single digit in the reported voltage. We have stipulated a resistor and sinusoid; arbitrary impedances and waveforms require their corresponding models.

$$P = \frac{V_{rms}^2}{R}$$

$$P = \frac{(0.010)^2}{50} = 2 \times 10^{-6} W$$

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This first case supplies an architectural consequence. A detector intended to report the average power of a burst must preserve the interval and averaging convention required for that quantity. A peak-hold arrangement can still be valuable, but its held maximum is not the same result. If the aim changes from determining mean heating to protecting a stage against an instantaneous excursion, the appropriate retained statistic can change. That is a change in the question, not necessarily an inconsistency in the instrument. The examiner should make this distinction before comparing outputs that happen to carry the same unit or occupy neighbouring columns in a report.

The second worked application concerns the order of correction. Let x be the input voltage in millivolts, y the indicated output voltage in millivolts, g a dimensionless voltage gain, and b an output-referred additive offset in millivolts. Stipulate y = gx + b with g = 100, b = 20 millivolts, and y = 1,020 millivolts. Removing the output offset before division gives x = 10 millivolts. Dividing first and then subtracting the same numerical offset gives minus 9.8 millivolts, an entirely different result. The correct alternative after division would subtract b divided by g, namely 0.2 millivolts. Reference plane and order are therefore mathematical commitments, not decorative annotations.

$$x = \frac{y - b}{g} = \frac{1020 - 20}{100} = 10\,mV$$

A calibration input situated after the element producing b may not expose that offset. Similarly, a source injected after a cable does not characterise the cable merely because the resulting readout is expressed as input-referred voltage. The location at which the reference enters

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determines which transformations the comparison exercises. I would therefore draw the physical path and mark the reference entry, the claimed measurand plane, and each correction boundary. Where a quantity is referred backwards across an unmeasured element, the report should identify the assumption or independent evidence that permits that referral. A software label cannot move the physical injection point.

Dr. Atkinson, this does not imply that every result must be measured at the antenna terminals. A receiver-input result can be entirely defensible when that is the declared quantity. The defect occurs when the conclusion quietly migrates to a different boundary. A laboratory may need an internal check for maintenance and an external comparison for the assembled measurement chain. Their coexistence is sensible, provided the internal check is not described as though it traversed the external components. A practical architecture can provide both facilities and preserve their distinct purposes in the acquisition record.

I would also distinguish the intended quantity from a supposed account of all reality. A finite measurement may deliberately average over phase, omit content outside a specified band, or retain only an event count. Such choices are not errors when the intended inference requires no discarded information. They become errors when a later claim depends on a distinction the procedure was never designed to preserve. The governing question is whether the relevant alternatives remain distinguishable in the chosen representation. That question connects the physical comparison to the sampling and evidential arguments that our colleagues will develop.

My recommendation is consequently a declared comparison, not a universal preference for one receiver. State the waveform class, electrical

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boundary, temporal interval, estimator, and required uncertainty; then examine which architecture can sustain them in the actual environment. Where two architectures answer different questions, preserve both answers with their respective meanings. Mr Weston, may I invite your challenge concerning the relation between this specification and the practical calibration of a physical instrument? A further test of operational equivalence is to substitute two precision terminations with independently measured reflection coefficients at the same connector. The indication may change despite an unchanged source because the delivered power depends upon impedance. Record the calibration-plane mismatch, the cable loss and the receiver state separately. If the supposed quantity is field strength at an aerial rather than power available at the receiver input, the uncertainty must also include antenna-factor calibration, the local electromagnetic environment and the extent to which the receiving structure perturbs that environment. Such comparisons specify what another laboratory can reproduce without claiming that a meter reading alone determines the original physical field.

Edward Weston

Peer question 1 to Percy Williams Bridgman

Professor Bridgman, thank you. Suppose the customer asks for field strength at a particular location, but the receiver is directly calibrated only for power at its input connector. An antenna factor and cable correction are available from earlier measurements. Your account seems to permit a chain of comparisons, yet it could also be read as demanding that every element be measured anew in the final arrangement. How should the examiner distinguish a legitimate transfer from an

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unsupported extension? Dr. Atkinson has asked for an architecture that can be used, not merely one that can be criticised. In particular, what record would permit the retained antenna and cable information to support the new result, and what change would defeat that permission? Please distinguish the identity of an earlier calibration from evidence that its assumptions still apply to the present connection and surroundings. How would you state the uncertainty when no direct final-plane comparison is possible?

Percy Williams Bridgman

Answer to Edward Weston

Mr Weston, a chain of comparisons is legitimate when each link concerns the quantity and conditions actually needed for the result. I would not require fresh calibration as a ritual. I would require a reason why the earlier characterisation remains applicable. That reason may include a defined configuration, a supported frequency range, a condition history, and uncertainty that includes the transfer from the earlier arrangement to the present one. A certificate identifies a comparison performed; an applicability argument explains why its result may now be used. Those are related but separate evidential tasks.

For the proposed field-strength result, the antenna relationship must refer to the intended field quantity, orientation, loading, and environment within the model employed. A documented cable loss can support a receiver-input correction without establishing the antenna's response in an arbitrary surrounding structure. We should not collapse these links because their corrections can be added

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numerically. Where the environmental contribution cannot be bounded adequately, the receiver-input measurement may remain reportable even though the requested field-strength inference requires qualification. The narrower result is not a failed measurement; it is the result actually supported.

Dr. Atkinson, a useful transfer record would therefore connect each correction to its source, declared domain, relevant physical configuration, and present verification. If a connector is replaced, the issue is whether that change is significant for the required uncertainty, not whether replacements are forbidden. An intermediate check might demonstrate continuity of a relevant response, but its scope must match the possible change. An internal source that bypasses the replacement cannot alone settle its effect.

The proposed architecture should make these distinctions easy to test. Accessible reference planes, recorded component identities, and a means of comparing the assembled response can be more valuable than an additional nominal digit. The residual uncertainty may still be acceptable for the investigation, or it may require a narrower claim. Mr Hartley, may I invite your question about whether a common numerical format is sufficient to preserve the distinction between the quantities being reported?

A further constraint follows from the fitness of receiver architecture and its reference-plane definitions for the intended measurand. I would add the following qualification to my answer. An instrument specification does not by itself establish the result of a field experiment. A preselector may reject one interfering band while

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leaving a different ingress path; a sample clock may be stable in the mean while its phase fluctuates; and a file may be authentic while the analogue interpretation remains contested. The expert should distinguish a certificate describing a manufacturer test condition from a verified statement about the present configuration. Record the intervention and its physical reference, the raw output where available and the particular source hypothesis which the intervention could actually exclude. In this particular question, the controlled observation is measurements made at an explicit antenna, connector, preselector, or digital sample boundary, whereas the material uncertainty concerns the unattested voltage and phase before unknown transfer functions. Consequently the adversarial comparison ought to include a stepped reference-source comparison at each declared reference plane and its failed as well as successful outcomes. I would not advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

Ralph Vinton Lyon Hartley

Peer question 2 to Percy Williams Bridgman

Professor Bridgman, I should like to examine that last distinction through two records of the same event. One preserves calibrated complex samples; the other retains integrated power in a sequence of short intervals. Both may estimate the mean power requested today. Tomorrow an examiner asks whether a phase change preceded an amplitude change. The first representation may support that inquiry and the second may not. Must the architecture therefore retain the most

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detailed representation available whenever future questions are unknown? Such a requirement could make every limited recording appear defective. Alternatively, may we define a defensible sufficiency relative to an explicit family of questions, while acknowledging that it does not preserve every possible distinction? Please explain how this choice should be disclosed so that an efficient acquisition is not later mistaken for an unrestricted archive of the electromagnetic event. The distinction should remain visible even when the original examiner is unavailable to explain the choice.

Percy Williams Bridgman

Answer to Ralph V. L. Hartley

Mr Hartley, sufficiency must be stated relative to the questions, not promoted into a universal attribute of a file. A sequence of integrated powers can be appropriate for a specified occupancy or mean-power analysis while excluding a later phase inquiry. The record should say what operation produced each retained value, over which samples and interval, with what calibration. It should also identify the principal distinctions that the operation intentionally discards. That disclosure permits a later examiner to recognise a new question as new, rather than assume that its answer was latent in a representation designed for another purpose.

The decision to retain a richer representation can be sensible where the anticipated analysis genuinely requires it and collection is authorised. It should not be justified through an unlimited promise of future recoverability. Complex samples themselves remain conditioned by the admitted band, quantisation, timing, and

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instrument state. They are richer than a power average for some questions, but they are not an unfiltered history of the external field. An architecture should therefore preserve the most informative representation justified by the task and its constraints, with an explicit account of what has not been acquired.

Dr. Atkinson, this leads to a useful distinction between a retention choice and a measurement defect. Deliberately reducing valid data according to an authorised, declared operation is a choice whose consequences can be stated. Discovering that the original acquisition clipped is a different problem because the intended representation may already have failed. The first should not be excused by calling it perfect preservation, and the second should not be normalised by describing it as ordinary compression.

For the present case, I would retain a mapping from each reported statistic to its source interval and processing definition, even where the source samples are not retained indefinitely. That mapping cannot recreate discarded phase, but it prevents an unsupported phase claim. Dr Bode, the distinction now passes naturally to you: what must the network preserve if a correction is to recover more than an attractive numerical result?

I thank the questioning colleague for that important distinction. The chronology of selection of receiver architecture for the investigative measurand is indispensable. Assume for a moment that a superheterodyne conversion product can masquerade as a new radio emission. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We

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should compare direct-conversion and superheterodyne capture on the same calibrated stimulus, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs image response, LO plan, RF preselection and conversion loss. If a true external feature retains its RF coordinate while an internal image follows the oscillator plan, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

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Hendrik Wade Bode

Network memory, inverse sensitivity, and the choice of reference plane

Professor Bridgman, thank you. Dr. Atkinson, the circuit diagram must be interpreted as a set of transformations with operating conditions, not as a procession of nominal gains. Two paths can have the same settled gain and different transient responses. An internal reference can traverse the stages correctly while failing to reproduce their loading at the external boundary. An inverse can exist mathematically while magnifying measurement error beyond the tolerance of the intended result. These distinctions determine whether an architecture is merely capable of producing data or capable of supporting the correction that the analyst proposes to apply.

Let us first distinguish a known deterministic transformation from the information available to invert it. If y = Hx + e for a single real component, x and y are voltages, H is a known dimensionless transfer coefficient, and e is output-referred error in volts. Division by H gives an input estimate only when H is nonzero. The error in that estimate includes e divided by H. The third worked application sets H = 0.02, y = 0.20 millivolts, and an output error bounded in magnitude by 0.01 millivolts. The corrected estimate is 10 millivolts, but the corresponding contribution to its error bound is 0.5 millivolts. A small displayed disturbance has become important at the inferred input. In the display below, delta x denotes the error in the inferred input voltage.

$$\hat{x} = \frac{y}{H} = \frac{0.20}{0.02} = 10\,mV$$

$$|\delta x| \leq \frac{0.01}{0.02} = 0.50\,mV$$

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The example does not say that equalisation is illegitimate. It says that a channel with a deep response minimum can impose an unfavourable inverse problem. Improving output numerical precision does not reduce an independently imposed analogue error. At H = 0, the same scalar model supplies no observation of x at all. A constraint on x may permit a selected estimate, but that constraint must be distinguished from information furnished by this channel. A receiver architecture intended for quantitative reconstruction should therefore consider the transfer where the intended signal lies, not only the maximum gain elsewhere in its band.

Now consider the fourth worked application, a stipulated discrete-time system with memory. Let x[n] and y[n] be input and output voltages in millivolts, where n is an integer sample index. Define y[n] = 0.5y[n-1] + 0.5x[n], and let the preceding output be zero. A constant input of 10 millivolts gives successive outputs of 5, 7.5, and 8.75 millivolts. Its settled gain is unity, yet treating the first output as the instantaneous input would be wrong. The current sample is an observation of a state-dependent response, not a complete instantaneous description of its cause.

$$y_n = 1/2\, y_{n-1} + 1/2\, x_n;\; x_n = 2\, y_n - y_{n-1}$$

With the stipulated recurrence and preceding output known, the inverse recovers 10 millivolts from each of those steps. But if measurement errors in adjacent output values are independent with identical standard deviation s, the reconstructed error has standard deviation the square root of five times s. The coefficients two and minus one square to four and one. If those errors are correlated, their covariance changes this result. Thus retaining the preceding state makes inversion identifiable under the model, while the

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error calculation determines whether the identified inverse is useful. These are distinct tests and neither should be omitted.

Dr. Atkinson, an internal calibration that observes only a settled tone may identify the unity gain of this example without identifying its recurrence. That calibration is suitable for a settled-amplitude claim but not automatically for reconstructing the beginning of a burst. A test sequence must excite the behaviour that matters. The proposed receiver should permit reference signals at the relevant input boundary, with histories and transitions representative of the intended task. This is a measurement-design inference from our stipulated model, not a universal prescription for a particular commercial circuit.

Architectural redundancy can help when different paths retain complementary information. A protected low-gain path may remain linear during an excursion that saturates a high-gain path; the latter may provide better resolution for smaller inputs. Joining their records requires a calibrated overlap, compatible timing, and an explicit selection rule. Merely choosing whichever output appears preferable can conceal the switching boundary and create a reconstruction whose provenance is unclear. The same reasoning applies to frequency slices: a coverage diagram is not evidence of continuity of complex response across their interfaces.

A useful diagnostic is to calculate the forward prediction as well as the inverse estimate. The inferred input, passed through the declared model with its retained state, should reproduce the observation within the stated residual allowance. Agreement is necessary but not sufficient: a nonunique model can admit many inputs that all reproduce the same output. This

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check detects inconsistent implementation without claiming to establish unique physical origin.

I would therefore evaluate a candidate architecture through three questions. Which transformations does it apply? Which states and inputs does it observe sufficiently to support the intended inverse? How sensitive is that inverse to the remaining uncertainty? A larger retained word cannot answer the second question, and a lower residual on fitted calibration data cannot alone answer the third. Dr Shannon, may I invite your challenge concerning the information that a chosen inverse appears to recover when the forward transformation has discarded distinctions?

Claude Elwood Shannon

Peer question 3 to Hendrik W. Bode

Dr Bode, your distinction between existence and sensitivity of an inverse is useful, but the reconstruction algorithm may introduce additional assumptions without announcing them. Suppose the low-gain path is missing during a short interval, and the software fills the gap by selecting the smoothest waveform consistent with the remaining observations. The resulting curve can look physically reasonable and can join its neighbours without an obvious discontinuity. Does that curve constitute recovered measurement information, or a prediction conditional on a smoothness assumption? I would ask you to identify what must be preserved so that an examiner can tell the difference. In particular, how should the method treat two distinct input histories that generate the same retained outputs but imply different peak amplitudes? A single plotted answer cannot itself establish that the other admissible history has been excluded. The exported record should make

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the additional assumption discoverable without access to a proprietary display.

Hendrik Wade Bode

Answer to Claude E. Shannon

Thank you for identifying the principal uncertainty in this evidence. Thank you for that question. Dr Shannon, the smooth curve is a model-conditioned reconstruction, not an additional observation. It may be useful if the smoothness restriction is supported for the signal class and if the conclusion is stated accordingly. The defect is presenting the selected history as uniquely measured when the retained data and admitted model allow alternatives. I would preserve the measured intervals separately from the predicted interval, the rule that selected the prediction, and a description of the alternatives relevant to the intended claim. A peak-amplitude conclusion deserves particular care because smoothness preferences can suppress precisely the excursion whose magnitude matters.

For the recurrence just discussed, the missing preceding state provides a simple illustration. A present output can be produced by different combinations of current input and earlier output. The inverse equation does not cease to be algebraically valid; it contains an unobserved quantity. Assigning that quantity its settled value makes a conditional estimate. The assignment may be justified by an independently known quiet interval, but it cannot be justified solely because it produces a plausible reconstruction. The missing premise must be supplied by evidence or remain explicit in the conclusion.

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Dr. Atkinson, a practical implementation should mark predicted samples or intervals in a way that survives export and later analysis. It should not permit a rendered trace to become a replacement for the original record without a transformation history. Where several admissible histories imply materially different peaks, the report should retain a bound or alternative results rather than resolve the disagreement by aesthetics. Numerical optimisation chooses according to its objective; it does not independently demonstrate that the objective describes the source.

The same discipline applies when regularisation stabilises an inverse near a response minimum. Stability can be purchased by restricting the solution class, but the restriction becomes part of the evidential model. We should evaluate its consequences using cases that challenge the restriction, not only cases chosen to satisfy it. Professor Wiener, may I invite your question about the additional difficulty when the receiver's own controller changes the transformation while the event is occurring?

Norbert Wiener

Peer question 4 to Hendrik W. Bode

Dr Bode, thank you. Suppose an automatic gain controller responds to the same input whose amplitude we wish to infer. Its gain is therefore not merely an external setting; it is a state affected by preceding observations. Dr. Atkinson's question then seems to involve a coupled system rather than a fixed cascade. The recorded gain command may also differ from the actual analogue gain during settling. What is the minimum distinction required between controller intention, physical

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response, and the correction applied after acquisition? I should also like you to address a possible circular argument. If the analyst infers an unlogged gain state from the waveform that the correction is meant to recover, what independent evidence prevents the assumed waveform from dictating the gain history and then returning as an apparently measured result? Please distinguish a state that is measured independently from one that is inferred only by assuming the desired conclusion.

Hendrik Wade Bode

Answer to Norbert Wiener

Professor Wiener, the command is an input to the controlled system, not proof of its achieved state. A model of the controller and analogue path may connect the two, but its parameters, delays, and range must be established. I would therefore distinguish requested gain, confirmed configuration, and any measured or modelled settling interval. The correction should identify which of these supplied its state information. Treating the command timestamp as the instant of completed physical change can misassign samples even where the eventual gain is exactly what was requested.

Inference from the waveform is not necessarily invalid, but it makes the problem joint. If both input amplitude and gain are unknown, their product can fail to distinguish them. A known pilot, an independent state measurement, a constrained controller history, or a second calibrated path might supply the missing information. Which method is adequate depends on the unknowns and observations. A waveform assumption chosen after seeing the desired answer does

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not supply independent support. The calculation should reveal the ambiguity rather than hide it inside a gain-estimation routine.

Dr. Atkinson, the architecture should therefore expose the controller's relevant state where that state materially affects the intended result. It need not log every internal variable. It must retain those quantities, or validated bounds upon them, without which different permissible input histories remain indistinguishable. A fixed-gain mode can simplify some measurements, while a characterised adaptive mode can be appropriate for others. Neither is universally superior independently of the task and the surrounding signal conditions.

A state estimator can be tested against independently recorded conditions, with its failures retained. Agreement only with its own corrected output would not be an independent check.

Finally, the validation should include transitions with independently known inputs. Testing only the equilibrium points would leave the disputed interval unexamined. If the transition cannot be qualified for amplitude reconstruction, it may still support a narrower observation, provided its limitation is preserved. Dr Nyquist, may I now pass the floor to you for the related question of what the sampling and frequency-conversion architecture admits before any reconstruction begins?

I thank the questioning colleague for that important distinction. Before offering an opinion about selection of receiver architecture for the investigative measurand, I would define the measurand and its

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uncertainty. The proposed rival mechanism is that a superheterodyne conversion product can masquerade as a new radio emission. Consequently a calibration certificate for one nominal receiver setting does not settle the question. The more informative operation is to compare direct-conversion and superheterodyne capture on the same calibrated stimulus, with image response, LO plan, RF preselection and conversion loss reported in units and tied to an input reference plane. The adverse prediction is concrete: a true external feature retains its RF coordinate while an internal image follows the oscillator plan. I would challenge it across a range of input powers and hold one independently measured source constant throughout the switching sequence. A correction estimated after seeing the unknown feature may assist an exploratory analysis; it must not be presented as though it had been fixed before acquisition. Where systematic effects share a reference, their covariance belongs in the reported uncertainty rather than being silently assumed zero. This is the distinction between an instrument number that appears stable and a defensible physical measurement.

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Harry Nyquist

Admitted frequency, digital representation, and irreversible ambiguity

Dr Bode, thank you. Dr. Atkinson, I would locate the first sampling question before the converter. What set of analogue inputs is permitted to reach it, and which of those inputs must remain distinguishable for the intended measurement? A nominal sampling rate does not answer either part. It specifies a succession of sampling instants under a timing model. The restriction that makes those samples informative about an analogue waveform must come from the admitted signal class, the physical filtering, and the calibration of the actual path. A frequency label attached afterwards cannot distinguish alternatives that already produced the same sequence.

The fifth worked application makes the ambiguity exact. Let x[n] denote samples of a unit-amplitude real cosine, let n be an integer, and stipulate an exact sampling frequency f_s of 100 megasamples per second. A cosine at 10 megahertz and one at 110 megahertz produce the same sample values at every integer n under this ideal sampling model. Adding one complete cycle per sample leaves the cosine unchanged. We have not shown that a physical receiver admits both signals with equal gain; we have shown why its analogue admission and frequency response must be part of the explanation of the retained sequence.

$$\cos\left(2\pi\frac{110}{100}n\right)=\cos\left(2\pi\frac{10}{100}n\right)$$

If a characterised input network excludes the higher-frequency possibility to a justified level, the ambiguity can be constrained for the intended result. If the network is unknown, assigning the lower frequency is a convention or hypothesis rather than a conclusion established by the

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samples alone. This is particularly important in a survey seeking unexpected signals. The fact that the desired transmitter was expected in one band does not establish that all other energy was excluded. A test should challenge the relevant unwanted bands through the actual input path, not merely inject a convenient digital waveform after the ambiguous transformation.

The sixth worked application moves the same issue to a different boundary. Suppose a real stream at 100 megasamples per second contains a desired 5-megahertz component and an unwanted 30-megahertz component. Retaining every fourth sample without adequate prior filtering produces an output rate of 25 megasamples per second. At that output, the 30-megahertz cosine is indistinguishable in frequency from a 5-megahertz cosine because their frequencies differ by one output sampling rate. Both can therefore contribute to the same retained component. Increasing the precision of the output representation does not restore their separate amplitudes.

$$f_{out}=\frac{100}{4}=25\,MS/s;30-25=5\,MHz$$

The first ambiguity concerned what reached the original sampling operation. The second concerns a later sample-rate reduction. A receiver can satisfy the first requirement and fail the second. Conversely, a perfect digital decimation filter cannot remove an ambiguity already established by analogue sampling. The architecture must therefore identify each change in sampling rate, its associated filtering, and the signal interval actually retained. The assumptions belong at their respective boundaries rather than being collected under a general assertion that the receiver obeys a sampling theorem.

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Dr. Atkinson, a complex representation adds another boundary to preserve: the sign convention connecting its frequency coordinate to the physical input. The definition of the in-phase and quadrature channels, any conjugation, and the local-oscillator convention determine that connection. The familiar shape of a magnitude spectrum does not independently verify it. A controlled offset from a known reference can challenge the mapping, but the reference must enter before the operation being tested. Again, a successful software-only test validates software against supplied samples without proving that the hardware acquired the samples under the claimed convention.

I would not infer that broader acquisition is inherently less trustworthy. It can preserve simultaneous context that a tuned narrow channel misses. The burden is to demonstrate the combination actually used: admission, dynamic range, timing, sustained throughput, and processing history. A broad path that clips under a strong neighbouring signal does not preserve useful context simply because its file is large. A narrower path may miss that neighbour and therefore fail to explain an artefact. Complementary paths can help, but their joint interpretation must preserve timing and reference relationships rather than combine whichever displays look most persuasive.

The qualification must also survive a change in configuration. An analogue filter accepted for one sampling rate may not establish the same exclusions after a rate change. A digital filter whose coefficients are retained can still be misinterpreted if its rate, decimation phase, or frequency translation is omitted. Consequently, the architecture includes the means of retaining its actual configuration, not merely the hardware capable of implementing several possible configurations.

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For architectural selection, the practical test is whether the requested distinction survives each irreversible step. Once only a power average remains, phase history is not generally available. Once two admitted frequencies coincide in the sampled representation, an independent restriction is required to separate them. Once clipping maps different inputs to the same code, the code alone does not determine their peaks. Professor Gabor, may I invite your challenge concerning the temporal detail needed when the instrument must characterise a short event rather than merely establish that some spectral energy was present?

Dennis Gabor

Peer question 5 to Harry Nyquist

Dr Nyquist, your examples establish frequency ambiguity, but an examiner may instead lose the distinction through the observation interval. Suppose the architecture offers a narrow spectral estimate obtained from a long record and a rapidly updated estimate obtained from a shorter record. A brief event appears in both, although its displayed width and peak differ. What prevents the operator from selecting the more attractive representation and describing its apparent duration as a property of the source? I would ask for a concrete connection between the retained waveform, the window applied, and the temporal claim. It seems that frequency admission alone cannot determine whether the measurement preserves an onset, a burst maximum, or an average over several events. How should the architectural requirement specify the temporal distinction that the later analysis is expected to make? The measurement requirement should

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make that distinction before the analyst sees which representation produces the clearest event.

Harry Nyquist

Answer to Dennis Gabor

Thank you for that question. Professor Gabor, the requirement should identify the temporal quantity and the operation used to estimate it. The first sample exceeding a threshold after filtering is not automatically the physical onset at the input. A duration measured from a displayed intensity region is not automatically the duration of the source waveform. In each case, the filter response, window, overlap, threshold, and time assignment enter the interpretation. The architecture should retain sufficient samples and state information to reproduce that operation and test it against events whose timing properties are independently specified.

I would preserve an acquisition time coordinate separately from the presentation coordinate. A rapid screen update can reuse much of the preceding data; it need not represent a new independent observation interval. Conversely, a long record can contain a short event without giving every estimator applied to it the same temporal response. The analyst should be able to trace a displayed feature to the exact source interval and response that generated it. Changing the estimator then changes a documented analysis, not the past physical acquisition.

Dr. Atkinson, a defensible architectural specification could require recognition of an event class with stated durations and amplitudes,

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together with a maximum permitted timing error under declared conditions. Its validation would vary event alignment relative to acquisition boundaries rather than always place the event conveniently at the centre of a record. Such variation tests an omission that a single attractive demonstration can conceal. No universal temporal resolution follows merely from the number of displayed FFT bins.

The requirement should also identify whether timing refers to the input boundary, the filtered output, or the display. Those coordinates need not coincide even when every timestamp is stored correctly.

Where the retained representation is inadequate for the requested onset, the report can still describe a filtered detection interval or another supported quantity. That is preferable to silently reversing an unqualified temporal response. Dr Shewhart, may I now pass the floor to you to examine a different continuity question: how do we know that the calibrated response governing these operations remained applicable throughout the observation?

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Walter Andrew Shewhart

The calibrated regime and the record of change

Dr Nyquist, thank you. Dr. Atkinson, a calibration describes a relationship under conditions, while an operational record must establish where those conditions continued to apply. It is tempting to treat a receiver as one object with one enduring response. Yet the same enclosure can present different gains, temperatures, filter states, or control histories. The practical problem is to determine which variations belong to an adequately characterised regime and which indicate a change that alters the interpretation. Without that distinction, repeated measurements can be combined because they share a filename rather than because they share a measurement law.

For the seventh worked application, use a deliberately simple voltage model with zero offset. In state A the dimensionless gain is 100; in state B it is 110. An output of 22 millivolts therefore corresponds to an input of 0.22 millivolts in A and 0.20 millivolts in B. Suppose checks before and after the disputed interval identify A, but no state record exists during the interval. The endpoint observations do not logically exclude an excursion into B and back. Selecting A throughout may be a justified stability assumption after suitable characterisation, but it is not a consequence of the two endpoint values alone.

$$x_A = \frac{22}{100} = 0.22\,mV\,;\, x_B = \frac{22}{110} = 0.20\,mV$$

This does not require treating every fluctuation as a failure. The intended tolerance may accommodate both states, or a recorded state transition may permit separate valid corrections. What matters is whether the distinction affects the conclusion. A coarse discovery task and a fine amplitude

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comparison can therefore have different validity classifications for the same interval. The classification should follow the measurement objective rather than a general description of the receiver as operational or defective. A state can be serviceable for one purpose and insufficiently characterised for another.

The eighth worked application concerns an error shared by two readings. Let a and b be two voltage estimates, each with a standard uncertainty of 0.20 millivolts. For their difference d = a - b, suppose the correlation coefficient of their errors is rho = 0.90. Under the declared joint uncertainty model, the variance of the difference is the sum of the individual variances minus twice their covariance. The resulting standard uncertainty is approximately 0.0894 millivolts. If the errors were independent it would instead be approximately 0.2828 millivolts. The sign of the sensitivity to a shared input matters; root-sum-of-squares without the covariance would answer a different model. [M2-2]

$$u(d)=\sqrt{0.20^2+0.20^2-2(0.90)(0.20)(0.20)}$$

$$u(d)\approx 0.08944\,mV$$

The small difference uncertainty does not establish equally small uncertainty in either absolute reading. A common correction error can cancel in the difference while surviving in both values. Conversely, adding positively correlated quantities increases the contribution rather than cancelling it. Therefore, two agreeing receiver channels do not independently establish their common input calibration. The covariance is a description to justify, not a numerical setting chosen to make the budget attractive. Its relevant value depends on the conditions, interval, and error sources represented in the comparison.

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Dr. Atkinson, I would organise the operating record around changes capable of defeating an applicable correction. Temperature may be one variable, but it should not become a universal surrogate for state. A stable temperature trace does not prove that a relay, gain command, input loading, or software coefficient remained unchanged. Nor does a change in one of those variables necessarily invalidate every measurand. The proposed record should connect the variable to a specific dependence or qualification in the model, so that the reviewer can understand why an interval was retained, separated, or excluded.

A check source is especially useful when its path is selected to challenge the suspected change. A source that shares a drifting reference with the receiver can leave certain common errors hidden. A reference that bypasses the affected stage can remain stable while the desired path changes. These are reasons to design checks with known scope, not reasons to abandon them. Independent physical variation, recorded state, and a suitable uncertainty model can together provide a stronger argument than any one favourable indicator.

There is a further distinction between evidence that a process changed and evidence about why it changed. A check discrepancy can justify separating an interval before its cause is known. Calling the change thermal, however, requires additional support. Preserving this distinction permits timely protective action without promoting an early diagnosis into an established physical explanation. The eventual cause can then be investigated against the retained state and comparison records.

The resulting procedure should preserve the chronology of changes and the acceptance rule used to interpret them. It should not reconstruct that

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rule after seeing which intervals contain desired detections. Nor should statistical smoothing erase evidence of a state transition by treating it as an inconvenient outlier. Professor Pearson, may I invite your question about how a laboratory should distinguish an appropriate adaptation of its model from a retrospective adjustment that conceals a failure of the procedure under test?

Egon Sharpe Pearson

Peer question 6 to Walter A. Shewhart

Dr Shewhart, thank you. Suppose a laboratory notices that residual errors become larger after a particular gain transition. It adds a settling exclusion and obtains much better agreement. The revised procedure may be genuinely better, yet the same observations have suggested the exclusion and demonstrated its apparent success. What conclusion can be drawn from that development record? I would also ask whether a fixed adaptation rule should be treated differently from discretionary intervention. A receiver may be designed to alter its threshold whenever a documented reference statistic changes. If that rule is frozen and tested as part of the complete procedure, adaptation need not be a defect. Please distinguish those cases and explain what additional testing would support a performance claim without condemning every scientifically justified revision as improper manipulation. Please also distinguish evidence that the change improves accepted-interval accuracy from evidence that it preserves the required event coverage.

A final evidential safeguard is that a stepped reference-source comparison at each declared reference plane. The unattested voltage and phase before unknown transfer functions remain outside the direct

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observation. If the examiner reports only those cases in which the indicated feature agreed with the preferred model, what correction would you require to the exposure denominator, alternative-hypothesis analysis, and reproducibility account?

Walter Andrew Shewhart

Answer to Egon S. Pearson

Professor Pearson, the development observations support the reason for revising the procedure and permit examination of its behaviour on those observations. They do not independently establish its performance on fresh cases drawn from the intended operating conditions. I would preserve the original discrepancy, the proposed explanation, the revised exclusion rule, and the outcomes before and after revision. A further test should then challenge the fixed revised procedure with conditions selected to expose the explanation, not simply replay the case that inspired it. This separates learning from certification without treating learning as misconduct.

A predetermined adaptive rule is part of the procedure being tested. The validation should include its state evolution, the reference observations that drive it, and the conditions under which its threshold can change. Testing only a constant-threshold surrogate would not establish the adaptive procedure's performance. Conversely, allowing an operator to alter exclusions without recording those decisions leaves no single procedure whose trial outcomes can be interpreted consistently. The important boundary is specified operation versus unrecorded discretion, not adaptation versus immobility.

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Dr. Atkinson, residual analysis can reveal structure that challenges a calibration relationship, but a favourable overall fit statistic is not a complete validation. The official statistical guidance we consulted specifically treats residual patterns and assumptions as relevant to model assessment. Our proposed receiver test extends that principle to gain transitions by conditioning the comparisons on their histories. It is an authored application, not a claim that the source evaluated this particular instrument. [M2-3]

Where the revised exclusion is substantial, its coverage consequence should be a separate reported outcome rather than hidden inside an improved error statistic.

If a revised settling exclusion removes important portions of the observation interval, the report must retain the resulting loss of coverage. Improved accuracy on accepted intervals does not establish improved capture of every event. It may be the correct trade-off, but its consequence belongs in the performance claim. Professor Neyman, may I pass the floor to you for the final question of what the resulting calibration and validation evidence actually permits us to infer?

I thank the questioning colleague for that important distinction. There is a statistical difficulty in the assertion concerning selection of receiver architecture for the investigative measurand: we have not yet ruled out the possibility that a superheterodyne conversion product can masquerade as a new radio emission. The investigation should record its chosen detector threshold, visit schedule, selection of frequencies and expected failure modes before the prospective

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confirmatory test. To examine the difference we should compare direct-conversion and superheterodyne capture on the same calibrated stimulus, collecting image response, LO plan, RF preselection and conversion loss over a predeclared range rather than selecting the most attractive subset afterward. An observation in which a true external feature retains its RF coordinate while an internal image follows the oscillator plan would strengthen a restricted causal account, but it cannot certify every unvisited frequency-time interval. I would state which recordings are dependent, which have been excluded as invalid, and which inferences rely upon a model of rare events or stationary interference. A numerical interval can have impeccable arithmetic and still misdescribe the physical world if its sampling population was chosen because the signal already looked unusual. We should therefore preserve exploratory leads separately from independently designed validation evidence.

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Jerzy Neyman

Identifiability, tested decisions, and the remaining alternatives

Dr Shewhart, thank you. Dr. Atkinson, I would distinguish a parameter estimate, a model adequate for the observations, and a decision procedure with demonstrated performance. These are not interchangeable achievements. A calculation can return a unique set of coefficients because the software imposes a preference, while the observations permit several physically distinct explanations. A model can fit the calibration observations closely while giving inadequate predictions elsewhere. A corrected estimate can be precise enough for one decision and insufficient for another. The final report should identify which of these propositions its evidence supports.

The ninth worked application makes parameter ambiguity explicit. Let x and y be input and output voltages in millivolts and assume y = gx + b, with dimensionless gain g and offset b in millivolts. A single calibration observation x = 10, y = 11 is compatible with g = 1, b = 1 and with g = 0.9, b = 2. Repeating precisely that level without other information can reduce uncertainty about its response while leaving gain and offset inseparable. The ambiguity is structural. It is not removed simply by acquiring a larger number of copies of the same equation.

A second level x = 20, y = 21 distinguishes those two pairs in the stipulated exact model. Subtracting the two equations gives g = (21 - 11)/(20 - 10) = 1, and substitution gives b = 1 millivolt. With uncertain calibration inputs and outputs, the fitted coefficients would carry uncertainty and dependence. Moreover, two exact points identify the affine parameters only after the affine form has been assumed. They do not establish that the

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physical receiver is affine between those points or beyond them. An independent challenge to the functional form remains necessary. [M2-4]

$$g=\frac{21-11}{20-10}=1\,;b=11-g(10)=1\,mV$$

The tenth worked application concerns a bounded correction rather than a probability distribution. Suppose the observed output lies between 21 and 23 millivolts, the additive output offset between 1 and 3 millivolts, and the positive dimensionless gain between 90 and 110. Under x = (y - b)/g and these independent admissible ranges, monotonicity gives an input interval from 18/110 to 22/90 millivolts, approximately 0.1636 to 0.2444 millivolts. A claim that the input exceeded 0.20 millivolts is not established across that interval. Choosing the midpoint would create a point estimate without resolving the bounded alternatives.

$$x_{min}=\frac{21-3}{110}\approx 0.16364\,mV$$

$$x_{max}=\frac{23-1}{90}\approx 0.24444\,mV$$

If instead the output interval is 26 to 28 millivolts with the same bounds on gain and offset, the input interval becomes approximately 0.2091 to 0.3000 millivolts. It lies entirely above the stipulated decision value. The calculation now supports that bounded claim, provided the assumptions and ranges are valid. Neither interval is a confidence interval merely because it is written with two endpoints. We have supplied allowed ranges, not a sampling distribution or posterior distribution. A numerical interval must retain the interpretation justified by the method that produced it.

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$$x_{min} = \frac{26-3}{110} \approx 0.20909\, mV$$

$$x_{max} = \frac{28-1}{90} = 0.30000\, mV$$

Dr. Atkinson, the architectural implication is that additional information should be selected to resolve the uncertainty relevant to the decision. More repeated output samples may reduce random variation without constraining an unknown gain state. A second calibration level can identify parameters under a model without proving its applicability over frequency. A second receiver can share the same reference error. The purpose of an additional observation must therefore be stated: which alternative does it constrain, under what assumptions, and by how much? An experiment that cannot distinguish the important alternatives may be elaborate without being informative.

This also affects how validation trials are counted. A collection of successful tests is meaningful only relative to the population of conditions and the decision rule exercised. A receiver used for weak bursts near gain transitions should not be validated solely with strong steady carriers. If the procedure adapts, the adaptive mechanism belongs in the tested object. If the analyst chooses a new procedure after seeing a failure, the revision can be valuable, but its performance requires an appropriately separated assessment. The distinction is between a supported improvement and an inference whose test has been selected by its desired outcome.

Where a joint distribution is used instead of bounded ranges, the dependency assumptions require the same scrutiny as the marginal uncertainties. Gain and offset estimated from one calibration are not automatically independent. Their joint variation can matter when applying

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the inverse away from the centre of the calibration interval. The method should carry the estimated relationship into the final result rather than retain only the two most convenient standard errors.

I would accept a correction when the quantity is defined, the relevant parameters are identifiable to the required extent, the functional and operating assumptions have been challenged, and the remaining uncertainty permits the intended conclusion. Where these conditions are only partly met, a narrower result or an indeterminate decision can be the scientifically correct outcome. Sir Karl, may I invite your final challenge concerning how such a conditional acceptance remains open to criticism without becoming either an impossible demand for certainty or an excuse for every unfavourable result?

Sir Karl Raimund Popper

Peer question 7 to Jerzy Neyman

Professor Neyman, your account identifies several premises on which a correction depends. My concern is that the investigator might protect the preferred conclusion by changing those premises whenever a challenge fails. An unexpected response could be assigned to a different gain state, an unmodelled transient, or a newly restricted signal class. Each explanation might be physically possible. Taken together, they could make the original claim resistant to every practical objection. How should a laboratory distinguish an informative refinement from an adjustment that merely preserves the conclusion? Please identify what must be stated before the challenge and what must remain visible afterwards. I would also ask whether rejecting one correction model requires rejecting the entire observation, or whether a narrower,

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independently supported result may survive without allowing that survival to conceal the original model's failure. An explanation that can accommodate every outcome seems unable to discriminate among the competing causes we set out to examine.

Jerzy Neyman

Answer to Karl R. Popper

Sir Karl, the challenge should state the proposed claim, the conditions under which it is expected to hold, and outcomes that would require revision or rejection. A subsequent refinement is informative when it explains the discrepancy through an independently examinable relationship and is exposed to further tests capable of distinguishing it from alternatives. It is not enough that the refinement can be made to reproduce the original observation. The laboratory should preserve the failed prediction and its original scope, so that the history of the claim remains visible rather than being rewritten into an uninterrupted sequence of successes.

A rejected model need not erase every observation. If the file reliably records a receiver-output disturbance, that finding can survive failure of an attempted input-amplitude reconstruction. The narrower result must be stated at its actual boundary, with no implication that the failed inference has been restored. This is not an escape from criticism; it is a distinction between propositions. A model failure should limit the proposition that depended on it, while independent evidence remains available for other conclusions.

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Dr. Atkinson, we should likewise avoid making uncertainty a universal defence. An uncertainty statement must arise from a defined model and justified information, not expand opportunistically until every outcome is accommodated. If a new state is invoked, evidence about that state and its relevance should be sought. If the applicable signal class is narrowed, the validation and conclusion must adopt the narrower class openly. The cost of revision can include loss of previously claimed coverage or precision.

The acceptance decision is therefore revisable but not arbitrary. It rests on stated boundaries, identifiable quantities, observable checks, and an explicit account of unresolved alternatives. Further evidence can strengthen it or show that it was too broad. That is a discipline of accountable inference rather than a promise of certainty. Professor Atkinson, I return the floor to you for the closing synthesis and for the consequences this discussion should carry into the next examination of a changing receiver record.

I thank the questioning colleague for that important distinction. I should distinguish the physical occurrence under inquiry from the information actually retained when studying selection of receiver architecture for the investigative measurand. Because a superheterodyne conversion product can masquerade as a new radio emission, more than one historical account may produce the same saved trace. The controlled comparison should be to compare direct-conversion and superheterodyne capture on the same calibrated stimulus, preserving image response, LO plan, RF preselection and conversion loss at the measurement point and in the evidential

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metadata. If a true external feature retains its RF coordinate while an internal image follows the oscillator plan, that result would narrow the admissible explanations, not establish a uniquely identified emitter outside the tested conditions. A subsequent software reconstruction may recalculate a statistic from retained samples, yet it cannot recover components rejected by the front-end filter or intervals never recorded. I would make those distinctions explicit in the final report and invite an independent examiner to reproduce the challenge, including its failed steps. Scientific restraint is not a weakness of the investigation. It prevents a detector output, however striking on the screen, from becoming a claim about unobserved activity that the original measurement never established.

Percy Williams Bridgman, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, may I press the distinction between a reference plane selected for convenience and one selected because its measured quantity answers the actual inquiry? A cascade can be calibrated with admirable precision at its digitiser input while the antenna, attenuator, preselector and cable before that interface remain uncharacterised. If we move the nominal input boundary after an inconvenient component, the instrument's displayed accuracy may improve merely because we have excluded the principal cause of uncertainty. The question is not whether the later plane is legitimate; it is what physical proposition that plane entitles us to infer. How should a measurement model handle a lossy, mismatch-sensitive network when neither its reverse transfer nor its time-dependent operating state is fully known? Would you permit a calibrated inverse to reconstruct the earlier

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input at all, or insist on reporting only the directly supported downstream value?

Hendrik Wade Bode, Cross-Peer Answer to Percy Williams Bridgman: Professor Bridgman, I agree that the plane must follow the declared question, not the prettier residual error. We should distinguish three propositions. One is the value measured at the accessible receiver connector; another is an estimate of what reached the antenna terminals; the third is a purported property of the remote emitter. These have different dependencies, and the first cannot be silently promoted into the third. In a small-signal, linear and time-invariant regime one may represent the intervening network by a measured complex transfer function H(f). Reconstructing an upstream spectral component from the downstream component means dividing by H(f), and that operation becomes fragile wherever the magnitude of H approaches zero or the calibration uncertainty is large. If H is estimated with uncertainty, its phase and amplitude covariance enters the reconstruction, not just an average insertion-loss correction. If gain compression, switching, reflections or temperature drift make the network nonstationary, a single H is an inadequate model. I would record the connector result as directly measured, present any upstream reconstruction as conditional on the verified transfer state, and state frequencies at which inversion is not defensible. A second test could inject a calibrated source at the intended upstream plane while recording the full network response and an independent level measurement. Such a challenge establishes a bounded relationship for those settings, not a universal certificate for unknown waveforms. The uncertainty budget must follow the

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entire measurement path, including coupled quantities, before we claim that two receiver architectures agree.

Harry Nyquist, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, how should an investigator define a genuinely comparable statistical experiment when two receiver architectures admit different bands and accumulate different dwell times? A narrow receiver may provide more reliable estimates inside its passband than a broadband receiver, yet the two are not sampling identical sets of events. Their plots may share a frequency label while differing in preselector history, analysis window, detector response and exclusion intervals. A difference in recorded detections is then partly a difference in exposure, not necessarily a difference in sensitivity. I ask how the acceptance design should record the transfer function and observation opportunity before analysts compare means or construct alarm thresholds. Can a post hoc filter applied to one instrument make the two outcomes comparable when the original analogue path clipped or failed to observe a short burst?

Walter Andrew Shewhart, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the answer requires an experimental protocol that was fixed before the resulting traces were inspected. I would begin with a written comparison table: physical input reference, calibrated gain regime, admitted bandwidth, equivalent noise bandwidth, time windows, trigger dead time, detector statistic and the definition of a positive event. These are not merely settings to be copied between instruments. They define the population to which each recorded observation pertains. Common-input trials should include weak steady carriers, known transient pulses, strong adjacent blockers and deliberately empty intervals. We would measure the fraction of

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opportunities actually observed and report detection probability conditional upon each waveform class. In particular, a receiver that visits a narrow channel for one millisecond each second cannot be judged to have remained silent throughout the other 999 milliseconds. Nor can a digital filter repair an unrecorded pulse or reverse analogue saturation. If paired observations share the same source or reference oscillator, their errors may be correlated; the uncertainty of the difference must include that covariance rather than simply treating the two outputs as independent. I would retain both raw measurements and the inclusion/exclusion rules, and investigate a disagreement before replacing it with an averaged aggregate. Only when the observation sets are adequately matched should the resulting comparison be called a sensitivity or fidelity test. Otherwise the conclusion must be qualified as an architectural coverage comparison.

Jerzy Neyman, Cross-Peer Question to Percy Williams Bridgman: Professor Bridgman, I should like to place a decision problem upon your definition of the measurand. Suppose the operator is asked whether a suspected emitter was present during a four-hour investigation, but the apparatus was calibrated to measure power at a connector for several narrower intervals. A threshold on that connector power is not a direct decision rule for the historical existence of an emitter. Even with a well-calibrated reading, the alternative explanations include internally generated spurs, unrelated transmitters, multipath and unobserved intervals. How would you restate the question so that the reported measurement remains relevant to the investigator without claiming a conclusion for which the observation model supplies no identifiable parameter? I am particularly concerned that the

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word 'absence' sounds definitive even where the apparatus offers only a small set of negative measurements.

Percy Williams Bridgman, Cross-Peer Answer to Jerzy Neyman: Dr Neyman, I would insist on a precise operational statement before choosing a threshold. 'A component at the receiver input exceeded a specified calibrated level during an admitted observation interval' is one measurable claim. 'A particular external emitter operated anywhere throughout the four hours' is not the same claim; it requires an account of interception opportunity, source attribution and competing causes. The instrument can support the former through traceable calibration and a defined detection rule. It may contribute evidence towards the latter but cannot convert missing exposure into an observation of absence. I would formulate the report using nested statements: what the system physically admitted, what it recorded, what the software classified, what independent challenges were performed and which explanations survived. The classification stage should preserve false-alarm and missed-detection qualifications, and any inference to an external source should be conditional on tests of image products, leakage and overload. An investigator is entitled to an answer that is useful, but usefulness is not served by disguising uncertainty with unqualified language. A narrow, accurately formulated observation may be more valuable than an imposing but scientifically untestable assertion. This distinction also protects the ability of another examiner to repeat the analysis or dispute the proposed interpretation on the recorded evidence.

Claude Elwood Shannon, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, your transfer-function analysis is a persuasive way to relate analogue planes, but I ask how you would distinguish invertible distortion from

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information irretrievably discarded before the recording stage. A sampled complex stream may preserve amplitude and phase within its admitted passband, yet it has no unique inverse for an out-of-band signal removed by a preselector or for two different analogue inputs folded onto the same sampled coordinate. A strong signal can also cause clipping, producing new components that resemble external emissions. Suppose the archive includes metadata describing the nominal filter and digitiser rate but has no independent evidence of their actual state during the event. Under what conditions would you allow the recording to support a reconstruction of the external waveform, and where must the analyst stop at a limited equivalence class?

Hendrik Wade Bode, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, I would draw a boundary between numerical inversion and physical identifiability. Given a verified linear network with a nonzero transfer over the band of interest, a computational inverse may estimate the admitted input, subject to its noise amplification and calibration uncertainty. That mathematical possibility does not imply recovery of information rejected by analogue filtering or overwritten through clipping and quantisation. In the alias case, several distinct RF histories can lead to the same sampled sequence. Their equivalence cannot be broken by post-processing that sees only that sequence; additional constraints must come from the preselector, an independent receiver, a controlled retune or a known calibration stimulus. I would therefore require that the metadata identify actual, not merely commanded, filter state, gain, oscillator frequency and sample clock, ideally with reliable change boundaries. The record must preserve raw complex samples before irreversible detection

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and provide integrity evidence for those bytes. An inferred upstream reconstruction should specify which input classes are compatible with the observation and test whether plausible alternatives remain. If the analogue chain suffered hard clipping, an elegant inversion algorithm can still produce a plausible waveform, but that plausibility is not proof of the missing amplitude or phase. Forensically, the principled outcome is to preserve the measured stream, document the tested model and state explicitly what cannot be reconstructed.

Dr. James M. Atkinson

Closing synthesis

Professor Bridgman, Dr Bode, Dr Nyquist, Dr Shewhart, Professor Neyman, and our questioning colleagues, thank you. The panel has made architectural selection answer to the intended measurement rather than the other way round. It has not identified one universally superior receiver. It has shown how to ask which physical and numerical distinctions must survive for the proposed conclusion, and which reference observations can demonstrate that survival. This is a more demanding comparison than a catalogue of maximum specifications, but it is also more useful because it connects the chosen arrangement to a testable result.

The ten constructed applications exposed different failures. Ambiguous voltage conventions changed the inferred power. An offset applied at the wrong plane changed the correction itself. A small transfer coefficient amplified error; a system with memory required preceding state. Analogue sampling and later decimation introduced distinct ambiguities at different boundaries. An unobserved gain excursion survived endpoint checks. Shared uncertainty affected a difference differently from either absolute

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reading. A repeated single calibration level failed to identify two parameters. Finally, bounded correction intervals showed when a threshold claim remained indeterminate and when the supplied bounds supported it.

The peer challenges prevented those calculations from becoming isolated demonstrations. An earlier calibration required an applicability argument. A sufficient record remained sufficient only for specified questions. A smooth reconstruction could embody an assumption rather than recovered information. A controller command did not establish its achieved analogue state. A displayed duration required a temporal measurement model. Adaptation could be legitimate when tested as part of a declared procedure. A failed correction model did not erase every observation, but neither could a surviving narrower observation be used to conceal that failure.

The unresolved trade-offs remain real. Broader coverage may preserve context while imposing different demands on dynamic range and sustained recording. Narrower acquisition may support a particular comparison while excluding relevant events elsewhere. More detailed retention may enable later questions without restoring anything lost before recording. Additional calibration can constrain an important error or merely repeat a comparison that leaves it untouched. These choices should be evaluated against the actual task, with the resulting scope preserved in the report rather than hidden behind a single adjective such as accurate or sensitive.

The governing sources support a discipline of explicit modelling and assessment. The receiver arrangements and ten numerical cases remain our independently constructed applications. Their value is that they expose

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testable premises; their arithmetic does not establish that an unspecified instrument satisfies those premises in operation.

Our conclusion is a chain of accountable decisions. Define the quantity and boundary; choose an architecture that can preserve it; identify the state and transfer required by the correction; test the assumptions at the relevant interfaces; and report the uncertainty and alternatives that remain. The next question will examine how that chain is preserved when the receiver changes state during the observation itself. A correct diagram at the beginning is not yet a faithful history of the measurement. We shall therefore turn from selecting the architecture to retaining a record that permits its changing operation to be reconstructed and challenged.

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Ten worked engineering applications | Question 002

Application 01. Filter or cable rejection referred to a physical input

In the illustrative 002.01 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. For an admitted input P_i = -44 dBm and separately measured loss L = 26 dB, the linear prediction is $P_o = P_i - L$ = -70 dBm. In SI power this becomes 10^((-70 − 30)/10) = 1e-10 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. State which architecture-specific limits the physical evidence actually tested.

Application 02. Cascade gain and observed headroom

In the illustrative 002.02 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. A first amplifier contributes G_1 = 11 dB, an intentional attenuation contributes G_2 = -7 dB, and a later stage contributes G_3 = 16 dB. The small-signal sum is 11 + (-7) + 16 = 20 dB. For P_i = -71 dBm, the ideal output is P_o = -51 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. State which architecture-specific limits the physical evidence actually tested.

Application 03. Thermal reference noise in a declared measurement bandwidth

In the illustrative 002.03 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. Take the equivalent noise bandwidth B = 12,000 Hz and calibrated noise figure NF

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= 2.90 dB at an assumed 290 K. The thermal-reference estimate is N = $-174 + 10 \log_{10}(B/1\ \text{Hz}) + NF$ = -130.31 dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. State which architecture-specific limits the physical evidence actually tested.

Application 04. Alias-location prediction and its non-unique inverse

In the illustrative 002.04 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. For an actual sampling frequency f_s = 19 MHz and analogue input f_i = 60.040 MHz, the nearest-replica folding rule gives $f_a = |f_i - \text{round}(f_i/f_s)f_s|$ = 3.040 MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. State which architecture-specific limits the physical evidence actually tested.

Application 05. Combined and expanded measurement uncertainty

In the illustrative 002.05 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. For independent standard-uncertainty contributions 0.59, 0.36 and 0.43 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.59^2 + 0.36^2 + 0.43^2)}$ = 0.814 units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c$ = 1.628 units. State which architecture-specific limits the physical evidence actually tested.

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Application 06. Accumulated sample-clock time error

In the illustrative 002.06 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. A free-running sample clock with fractional rate error $\varepsilon = 0.860$ ppm over $T = 336$ s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T = 0.2890$ ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. State which architecture-specific limits the physical evidence actually tested.

Application 07. The frequency dependence of aperture-jitter-limited SNR

In the illustrative 002.07 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. At sinusoidal input frequency $f = 275$ MHz with uncorrelated rms aperture jitter $\sigma_t = 1.14$ ps, the idealised jitter-imposed ceiling is $SNR_j = -20 \log_{10}(2\pi f \sigma_t) = 54.11$ dB. A common clock source may correlate errors across parallel ADC channels, so treating their outputs as independent for noise cancellation would need an additional experiment. Converter nonlinearity and thermal noise can make actual performance worse. State which architecture-specific limits the physical evidence actually tested.

Application 08. Frequency-bin spacing versus independent information

In the illustrative 002.08 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. With

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sampled bandwidth f_s = 7 MS/s and N = 16,384 transform samples, the discrete-frequency grid is $\Delta f = f_s/N$ = 427.246 Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. State which architecture-specific limits the physical evidence actually tested.

Application 09. Gain allocation and blocker headroom

In the illustrative 002.09 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. Assume a calibrated digital full-scale equivalent of -9 dBm, a blocker applied at -35 dBm, and net analogue gain 32 dB. The projected converter input is -3 dBm and remaining margin is -9 − (-3) = -6 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. State which architecture-specific limits the physical evidence actually tested.

Application 10. Difference between two instruments relative to stated uncertainty

In the illustrative 002.10 test, two unlike receiver architectures are compared under a known common electromagnetic stimulus. The paired instrument contrast is Δ = 1.390 dB. Set independent standard uncertainties u_1 = 0.380 dB and u_2 = 0.520 dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)}$ = 0.644 dB, giving the dimensionless ratio $\Delta/u\Delta$ = 2.158. This ratio is not automatically a significance test: correlated calibration errors and non-

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normal uncertainty require separate treatment. State which architecture-specific limits the physical evidence actually tested.

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QUESTION 003

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What must be preserved when a receiver changes state during an investigation?

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Constructed educational dialogue. The speeches are newly authored, not historical quotations or a transcript. Numerical cases are hypothetical and do not certify an instrument.

Dr. James M. Atkinson

Opening question

Mr Hartley, can you comment on what must be preserved when a receiver changes state while an investigation is running? The preceding discussion established that an architecture must answer to the intended measurement. We must now examine the history of that architecture. A diagram can identify its possible paths without telling us which path operated during a particular event. A file can contain intact samples while omitting the gain change, clock interruption, retuning interval, or selection decision that gives those samples their physical meaning. The question is therefore not whether the record is large, but whether its relevant dependencies remain reconstructible.

Our case is again hypothetical. A wideband acquisition is running when an unexpected component prompts the operator to alter gain and retain a narrower channel. Some data are held in a circular buffer, some are already on disk, and some derived displays are updated from overlapping windows. A reference clock adjustment occurs during the same period. Later, a second examiner is given an exported recording with a plausible start time, a nominal sample rate, and a statement that it contains the event. We must

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identify which claims can be reconstructed from that package and which require information that its apparent continuity does not supply.

The consulted recording specification distinguishes stored sample positions from indices in an original stream, while the evidence-preservation guidance distinguishes the protected object and its history from a merely convenient copy. These are bounded source contributions. Our acquisition ledger, timing calculations, and proposed tests are original applications for this volume, not claims that either source certifies a receiver. We must also distinguish the preservation of bytes from the correctness of the physical declarations attached to them. [M3-1, M3-2]

Mr Hartley will address the record's identity and coordinates. Professor Wiener will examine control actions and achieved states. Professor Gabor will separate acquisition time from the time assigned by analysis and display. Professor Pearson will consider the population of decisions created by overlapping and selective observations. Dr Shannon will examine the transformations connecting original data to an export, including the point at which a useful derivative ceases to support the earlier question. Seven colleagues will test these arguments through immediate questions and answers.

The resulting record must permit later corrections without obscuring what was originally observed, declared, inferred, or changed. Those categories should remain distinct throughout the discussion.

I ask the panel to retain the chronology rather than treat every change as a new unrelated file. Conversely, no one should join incompatible intervals merely to produce a smooth trace. Ten worked applications will use

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stipulated counts, rates, and transformations, so that an examiner can check the arithmetic and identify the assumptions. We shall distinguish count discontinuity from elapsed-time uncertainty, a requested state from a settled state, and a reproducible calculation from a verified acquisition. The desired conclusion is a practical record capable of supporting criticism, not a demand to document every internal operation without regard to its significance. Mr Hartley, please begin by identifying what a sample position actually denotes after acquisition has been interrupted, cropped, or exported.

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Ralph Vinton Lyon Hartley

A recording needs both identity and coordinates

Dr. Atkinson, thank you. A position in a stored array identifies an element of that array. It does not, without a mapping, identify the element's place in the original physical acquisition. The distinction becomes important whenever samples are discarded, files are divided, or a selected interval is exported. Reassigning the first retained sample the convenient index zero is harmless if the relation to the original stream is retained. It becomes misleading when the new ordinal is treated as though no earlier acquisition or intervening loss existed. A recording needs coordinates as well as content.

For the first worked application, suppose one retained segment begins at source index 10,000 and contains 1,000 consecutive samples. Its final source index is therefore 10,999. The next retained segment begins at source index 11,250. The missing source indices are 11,000 through 11,249, a total of 250. At an exactly stipulated sampling frequency of one million samples per second, the omitted sample slots represent 250 microseconds. If the second segment is simply placed after the first in a file, its first stored ordinal may be 1,000. That ordinal must map to source index 11,250, not to 11,000.

$$N_{gap} = 11250 - (10000 + 1000) = 250$$

$$T_{gap} = \frac{250}{10^6} = 250\,\mu s$$

The calculation presumes a reliable source counter and unchanged sampling interval. A counter generated after the point of loss may not reveal the missing samples. An error flag can indicate a discontinuity without establishing its length. The source of the count is therefore part of the

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record. The signal-metadata specification offers a distinction between sample position in the retained dataset and a corresponding global stream index. That distinction permits documentation of this kind of gap; it does not itself prove that a recorder populated the fields correctly. [M3-1]

The second worked application considers a finite counter. Stipulate a counter modulus M of 65,536, and two successive retained samples with counter values 65,530 and 10. If there was at most one wrap and no reset, their advance is 16 sample intervals. Fifteen samples between them are therefore absent from this retained pair. If the elapsed time could permit additional complete wraps, or if the device could reset the counter, the same pair of values no longer establishes that unique advance. A numerical rollover calculation is useful only with the conditions that make it identifiable.

$$\Delta n = (10 - 65530) \bmod 65536 = 16 \,;\, N_{missing} = 16 - 1 = 15$$

These examples concern different questions. The first maps a known gap between segments. The second shows an ambiguity in the coordinate mechanism itself. The recording should not hide the latter by selecting the shortest plausible advance unless a timing bound or other evidence justifies that selection. A monotonically increasing derived index can be convenient for software, but it should not replace the observed counter values and reset information. The transformed coordinate is a conclusion, and its inputs should remain available where the conclusion matters to the measurement.

Dr. Atkinson, data identity requires similar care. A digest can help establish whether a particular byte sequence has changed relative to a protected reference digest. It does not establish that the bytes describe the claimed antenna, sample rate, or time. The reference digest itself needs

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trustworthy preservation if it is to support comparison. The consulted evidence-preservation guidance discusses retaining origin information, hashes, and controls over those hashes; our application is to preserve these records for the acquisition and its derivatives. The receiver's metrological validity remains a separate question. [M3-2]

I would accordingly bind a recording to its configuration and coordinate history through an explicit manifest. Each retained segment would identify its source, its place in the original stream, the applicable state record, and any known loss or qualification. The precise implementation can vary. The requirement is that a later examiner can determine which observations underlie a reported feature without relying on an operator's recollection or a misleadingly continuous display. A manifest is useful because it preserves relationships, not because the word itself confers authority.

Coordinates also require a declared representation. Signed and unsigned words, byte order, interleaved real and imaginary components, and padding can assign different values to identical bytes. A versioned schema should define those choices and their relation to physical units. The manifest should bind that interpretation to the correct segment, not merely to the folder in which several incompatible recordings happen to reside. A checksum of the sample file alone does not resolve a disagreement between competing descriptions of its encoding.

A derivative should retain both its own identity and the mapping back to its parent. Cropping, reordering, and conversion can produce a valid new object, but the relationship should identify what changed. If the original data are unavailable, the derivative may still support a limited analysis; it should not be described as proof that nothing relevant was omitted. This is

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a question of evidential scope rather than an automatic rejection of every reduced record. Professor Bridgman, may I invite your challenge concerning which parts of that history can be treated as information about the event rather than merely information about the file?

Percy Williams Bridgman

Peer question 1 to Ralph V. L. Hartley

Mr Hartley, your proposed manifest identifies the origin and ordering of samples, but origin information can itself be generated incorrectly. Suppose two exports carry identical data and different sample-rate declarations, and both declarations were signed by the same acquisition software. The files are internally well formed and each has a correct digest. What additional proposition would establish which declaration governs the physical event? Dr. Atkinson has asked that the record support criticism, so I should like you to distinguish a test of internal consistency from a test of the claimed relationship to the receiver. Must an external timing observation always be available, or can a validated clock and configuration history suffice? Please explain how the conclusion should change when only the internally consistent export survives and the physical acquisition history has been lost.

In particular, would agreement between two descriptions generated from the same untested configuration supply any independent support for either description?

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Ralph Vinton Lyon Hartley

Answer to Percy Williams Bridgman

Thank you for identifying the principal uncertainty in this evidence. Thank you for that question. Professor Bridgman, internal consistency can show that the files conform to their respective descriptions, but it cannot choose between contradictory physical declarations merely because both are signed. The missing proposition concerns the connection between the declared rate and the actual acquisition timing. A calibrated reference and validated configuration history may support that connection without an independent timing observation in every record. The claim should state the evidence and conditions on which the connection rests. A digital signature identifies an authenticated declaration under its verification assumptions; it does not convert a mistaken declaration into a physical fact.

An independent observation can be valuable when it challenges the disputed relationship. A timing marker acquired through a known path, a hardware counter with a characterised clock, or a suitable reference waveform may constrain the ambiguity. None should be treated as universally sufficient. The marker might share the same erroneous clock assumption; the reference waveform might be interpreted through an incorrect frequency mapping. The test needs to distinguish the alternatives actually at issue, not merely add another internally consistent label.

Dr. Atkinson, if only the contradictory exports survive, the honest result may be two possible time interpretations or a narrower statement in sample coordinates. Some analyses remain meaningful

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in index space even when absolute time is uncertain. Others, including an asserted event duration in seconds, may require qualification. The loss of timing support should attach to the claims that depend on it, rather than being hidden or used to dismiss every retained observation indiscriminately.

A consistency test can still be useful as a screening test. Contradictory declarations can reveal a defect even before the physical truth is established. Passing that screening removes one detected inconsistency; it does not positively establish every remaining declaration. Its value should be retained without enlarging its scope.

The proposed manifest is therefore part of the evidence, not an oracle. It should preserve the source of each material declaration and permit conflicts to remain visible. An examiner can then distinguish recorded fact, validated configuration, and later inference. Mr Weston, may I invite your question about how this preservation discipline should treat a hardware change made during the observation?

Edward Weston

Peer question 2 to Ralph V. L. Hartley

Mr Hartley, suppose the operator replaces an input attenuator between two retained segments while keeping the same receiver and software settings. The resulting files could appear to form one continuous acquisition, and the replacement might be remembered only when the analysis reveals an amplitude discrepancy. How should the

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record accommodate a later correction to its configuration history without making the correction indistinguishable from a contemporaneous observation? I would not wish a mistaken initial entry to become permanent merely because it has already been hashed. Yet replacing it silently would erase evidence of what was known at the time. Please distinguish a legitimate amendment from an alteration that obscures provenance, and explain whether the two segments can be combined before the replacement component's effect has been characterised for the intended measurement.

The distinction matters even when the revised component value seems small compared with the range shown on the receiver display.

Ralph Vinton Lyon Hartley

Answer to Edward Weston

Mr Weston, preserving an initial record does not require perpetuating its error as the current interpretation. A later amendment should identify the original entry, the revised assertion, the evidence supporting the change, the time of amendment, and the responsible author. The earlier entry remains part of the history. The current analysis can use the correction while disclosing that it was established retrospectively. This approach distinguishes an improved account from a rewritten account whose uncertainty and chronology have disappeared.

The hardware replacement creates a physical comparison to resolve. If its effect has not been characterised sufficiently for a common amplitude reference, the segments should not be combined

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as though they shared one calibrated path. They can still be retained as separate observations with their respective uncertainty or qualification. A later comparison may justify a transfer between them, but that transfer should remain an explicit operation in the analysis. It should not be encoded solely by changing a number in a global header and leaving the earlier interpretation unrecoverable.

Dr. Atkinson, a retrospective statement based only on memory should be distinguished from one supported by an equipment log, photograph, or retained component identification. The particular evidence may be adequate for a limited purpose without establishing every relevant characteristic. An attenuator's nominal value does not prove its complete response over the band. The amendment should therefore correct what it can support and preserve what remains unknown, rather than convert a recovered recollection into an unqualified calibration.

A revision identifier can connect the old and new accounts to their respective analyses. The later report can then show which result changes and which remains invariant. That comparison is more informative than either suppressing the correction or asserting that every earlier conclusion survives it unchanged.

The record can evolve responsibly when its versions and their relationships remain intelligible. Integrity protects the history needed to assess the correction; it does not forbid correction. Professor Wiener, may I pass the floor to you for the more continuous version of this problem, in which the receiver's controller changes the acquisition state without a physical component being replaced?

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A further constraint follows from preservation of receiver state and acquisition metadata through changes of configuration. I would add the following qualification to my answer. A second instrument adds evidential force only to the extent that its error mechanisms are independent or adequately modelled. Two receivers supplied by the same antenna network can share impedance anomalies, a local oscillator reference, or a strong interfering field. If they report the same feature, the comparison is valuable but must not be represented as two independent confirmations until those common pathways are examined. Where practical, vary a reference source, a cable route or a gain state under controlled conditions, and assess whether the observed changes conform to the proposed transfer relations. In this particular question, the controlled observation is a sequence of timestamped settings, control events, instrument outputs, and raw capture blocks, whereas the material uncertainty concerns the transient analogue response occurring between state commands and valid samples. Consequently the adversarial comparison ought to include a replayable transition log tied to a stable reference signal and its failed as well as successful outcomes. I would not advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

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Norbert Wiener

Control actions are part of the observation history

Mr Hartley, thank you. Dr. Atkinson, the receiver's control history belongs to the experiment whenever it affects what can be observed or retained. A gain command, retuning request, or trigger decision is not external commentary upon an otherwise fixed measurement. It can change the transformation through which the next signal is acquired. We should therefore retain both the action and the evidence of its effect. The central distinction is causal: what the system was instructed to do, what it physically did, and what a later correction assumes it did need not coincide at one instant.

The third worked application supplies exact indices to avoid that confusion. Suppose a gain command is issued at source index 50,000, its receipt is acknowledged at 50,040, and an independent acceptance criterion is first satisfied at 50,120. At one million samples per second, the interval from command to accepted state is 120 microseconds. Excluding the half-open range from index 50,000 through just before 50,120 removes 120 sample slots. Using acknowledgement as the settled-state boundary would instead retain 80 slots whose validity has not been established by the stipulated criterion. The numbers concern this constructed chronology, not a universal receiver settling time.

$$T_{settle} = \frac{50120 - 50000}{10^6} = 120\,\mu s$$

There is an additional assumption in that exclusion: it treats all earlier samples as valid under the prior state and all later samples as valid under the new state for the defined objective. If the command has uncertain

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timing, if the previous state was already overloaded, or if recovery occurs differently for phase and amplitude, the classification requires refinement. A validity boundary is not established by selecting a convenient integer. It is established by evidence about the measurement properties that the interval must support.

The fourth worked application shows why state-dependent correction must precede an inappropriate aggregate. Stipulate two equal-duration segments with dimensionless voltage gains 10 and 100. Their input amplitude estimates are 1 and 3 millivolts, producing outputs 10 and 300 millivolts. The mean of the two segment-level input amplitude estimates is 2 millivolts. Dividing the mean output, 155 millivolts, by the mean gain, 55, gives approximately 2.818 millivolts instead. Averaging the labels has not preserved the relationship between each observation and its state.

$$\frac{1}{2}\left(\frac{10}{10}+\frac{300}{100}\right)=2\,mV$$

$$\frac{155}{55}\approx 2.81818\,mV$$

That mean is specifically the mean of two segment-level amplitude estimates. If each segment contains a sinusoid with the stated RMS amplitude and the desired quantity is the RMS value over both equal-duration segments, the result is the square root of five multiplied by one millivolt, approximately 2.236 millivolts. These results are not contradictory. They refer to different aggregation rules. The example therefore joins control history to measurand definition: preserving the gains is necessary, but the final operation must still correspond to the quantity requested.

Dr. Atkinson, adaptation can be valuable. A controller may protect a path or concentrate analysis on a candidate event. The record should retain how

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the adaptation changes observation capability. When a broad discovery channel triggers a narrow recording, later statements must distinguish the broad interval actually acquired from the narrower interval retained for detail. The trigger is a selection operation. Its successful detection of one event does not establish that every other event would have caused the same retention, especially where controller state affects sensitivity or dead time.

A useful design would maintain a state ledger connected to source indices and would preserve the inputs relevant to major control decisions. The ledger need not contain every internal arithmetic operation. It should contain enough information to reconstruct the changes that materially alter the measurement law, calibration applicability, or capture opportunity. Where a state is inferred rather than directly observed, that distinction belongs in the ledger. Otherwise a model's estimate of the state can later be mistaken for an independent measurement of it.

The identity of a state must also be stable across subsystems. A hardware gain code, software scale factor, and exported label may all refer to a setting called high gain while denoting different combinations. The record should connect their meanings and identify the point at which a change takes effect. A shared state identifier is useful only if its interpretation is controlled. Reusing an old identifier after altering its coefficients can make a formally complete ledger describe the wrong transformation. This failure would not necessarily appear as a missing log entry.

I would test the record with deliberately timed changes near event boundaries, not only with comfortable intervals between signals. The test should determine whether state entries and sample coordinates remain

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aligned, whether requested and achieved values are distinguished, and whether processing delays are accounted for. A trace that appears continuous is not the acceptance criterion. The criterion is that a reviewer can assign each relevant observation the correct supported interpretation. Dr Bode, may I invite your challenge concerning the history required when filters and control loops carry memory across a recorded state boundary?

Hendrik Wade Bode

Peer question 3 to Norbert Wiener

Professor Wiener, the ledger may identify a new coefficient set at a precise sample index, yet the filter's internal state can still contain contributions from earlier samples. Suppose the software changes its coefficients and preserves its delay elements; another implementation resets those elements at the same declared boundary. Their subsequent outputs can differ even when their configuration logs list identical new coefficients. What must the record preserve to make the transition reproducible? I would also ask how the analyst should handle an export beginning immediately after the change, when the state inherited from the earlier interval is absent. Is it sufficient to discard a fixed number of samples, or must that number follow a model of the particular response and the error permitted by the intended measurement? Please distinguish reproducible processing from justified physical interpretation.

A correct coefficient list may otherwise conceal the precise memory contribution that dominates the first few outputs retained after a transition.

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Norbert Wiener

Answer to Hendrik W. Bode

Thank you for that question. Dr Bode, coefficients describe the rule of evolution but not necessarily its initial state. The record should identify whether the implementation preserved, reset, or transformed its state at the boundary, and retain the information required to reproduce that action. For a finite filter, the relevant preceding samples may be sufficient. For another implementation, a saved state vector and its defined meaning may be required. Merely recording that a filter changed does not establish which output sequence followed from the change.

A fixed exclusion can be justified where the response and permitted error support it for the intended input class. It should not be selected only because the trace appears settled after that many samples in one example. A finite-memory operation may permit an exact boundary; an operation with a longer tail requires a tolerance and model. The record should preserve the acceptance condition and the assumptions about preceding excitation. Otherwise an interval chosen for convenience can be mistaken for a demonstrated recovery period.

Dr. Atkinson, an export that lacks the preceding state may still support analysis after a qualified startup interval. The unsupported interval should remain visible, and the processing should not silently invent earlier samples as though they had been acquired. Zero padding is a numerical choice, not evidence that the physical input

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was zero. If the choice affects the reported event, the conclusion must carry that dependence or rely on additional retained information.

Where an implementation reports a saved state, its coordinate convention must be documented. A list of delay-register values is not automatically a list of preceding physical inputs. Restoring it under a different realisation can produce an incorrect transient even though both filters have the same settled frequency response.

Reproducing the same output from the same declared numerical inputs is an implementation test. Showing that those numerical inputs and state describe the physical acquisition is a further measurement test. Both are necessary for a strong reconstruction claim, but neither substitutes for the other. Dr Shewhart, may I invite your question concerning how these state qualifications should be used without retrospectively selecting only the intervals that favour the proposed finding?

Walter Andrew Shewhart

Peer question 4 to Norbert Wiener

Professor Wiener, suppose an operator marks several intervals invalid after noticing unusual amplitudes, then reports excellent stability over the retained record. The exclusions may have sound physical causes, but their selection has depended upon the same observations used to describe stability. Dr. Atkinson's question requires the record to support a later examination of this process. What should be retained about the decision to exclude, and how should discovery of a previously unknown failure mode affect earlier conclusions? I would distinguish an interval

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excluded by an already validated overload rule from one excluded after an investigator decides that its result is inconvenient. Yet there may be legitimate cases between those extremes. Please explain how the ledger can preserve that distinction without making a necessary scientific reassessment look equivalent to arbitrary deletion.

The retained result should make this distinction inspectable without requiring the reviewer to accept an unrecorded explanation supplied after the event.

Norbert Wiener

Answer to Walter A. Shewhart

Dr Shewhart, the ledger should record both the excluded interval and the basis of exclusion. A predeclared overload rule, a later diagnosis supported by an independent test, and an unresolved concern are different entries. They should not all become one unlabeled blank. The original observations remain available within the authorised retention scheme, together with the time at which the classification was made and any change in that classification. This permits a reviewer to distinguish a physically motivated revision from selection that merely favours a desired result.

Discovery of a new failure mode can legitimately require reassessment. The laboratory should identify which earlier results depended on the affected condition, examine them under the revised understanding, and preserve the original conclusions and their amendments. It should not imply that the later knowledge was present during the original examination. Nor should every earlier

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result be discarded automatically. The scope of reassessment follows the demonstrated failure mechanism and the claims that relied on it.

Dr. Atkinson, stability of the retained record is then a conditional statement about retained intervals. It does not establish stability during excluded intervals or complete-period capture capability. If those omissions are related to strong events, they may preferentially remove circumstances relevant to the investigation. That dependence should be examined rather than hidden by a reduced variance. A smaller reported spread can result from selecting the observations, not from improving the instrument.

It is useful to retain both the original classification and the current analytical mask. The first records the operational judgement; the second expresses the later, supported interpretation. Neither should be overwritten by the other. Their difference identifies exactly where reassessment has altered the evidential use of the acquisition.

The control ledger therefore records more than machine commands. It also records material analytical decisions and their chronology. That is not an invitation to replace physics with paperwork; it preserves the information required to test how the physics was interpreted. Professor Gabor, may I pass the floor to you to examine the different time coordinates introduced when those retained observations are filtered, windowed, and displayed?

I thank the questioning colleague for that important distinction. The chronology of the chain of custody for SDR operating state as well as samples is indispensable. Assume for a moment that an apparently

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simultaneous feature may reflect a gain change or retuning gap. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should reproduce the original gain and filter sequence while retaining independently clocked samples, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs gain register, sample indices, firmware settings, filter configuration and timestamp confidence. If a feature confined to receiver transition intervals suggests an instrumental cause rather than an external arrival, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

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Dennis Gabor

The time coordinate must follow the operation

Professor Wiener, thank you. Dr. Atkinson, a time attached to a displayed feature can refer to several different events: the sampling instant, the centre of an analysis window, the output of a causal filter, the arrival of a block at a host, or the moment at which a display was refreshed. These times need not coincide. The record should identify which one is asserted and how it relates to the original observation. Merely printing more decimal places cannot resolve an unstated convention. A timestamp is useful only when its meaning survives the transformations that produced the reported feature.

The fifth worked application uses a simple causal operation whose entire response is known. Let the input sequence be x[n], and let y[n] be the mean of its current value and four preceding values. The sampling interval is one microsecond. Suppose all input samples are zero except for a unit impulse at index 100. Nonzero output appears at indices 100 through 104, each with amplitude one fifth of the input impulse. The centre of that symmetric response lies at index 102. Its displacement from the original impulse is two microseconds, although the first nonzero output occurs at index 100.

$$y[n]=\frac{1}{5}\sum_{k=0}^{4} x[n-k]$$

$$n_{centre}=102;\tau_{centre}=2\mu s$$

A timestamp assigned to the centre of this response therefore differs from one assigned to the first nonzero output. Neither is necessarily a mistake. The mistake would be to call both the input-event time without retaining the applicable convention. The example does not establish a universal two-sample onset correction for arbitrary signals or thresholds. An

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extended input, a different filter, or a threshold crossing can require a different interpretation. A known linear phase delay supports a stated relationship; it does not abolish the distinction between a waveform feature and a physical event.

The sixth worked application concerns retained sampling phase. Let z[n] be an already filtered stream acquired at ten million samples per second. Define a decimated output by w[m]=z[3+10m], where n and m are integer sample indices. The output rate is one million samples per second, but its origin is displaced by three input samples. Output index 100 corresponds to input index 1,003, or 100.3 microseconds after the stipulated input origin. Assigning only the output interval and index would produce 100 microseconds and omit the retained phase.

$$w(m)=z(3+10m);t_{100}=\frac{1003}{10^7}=100.3\,\mu s$$

That mapping refers to samples of z, not automatically to an event at the antenna. Any preceding filter delay and input reference-plane delay remain separate quantities. They should not be corrected twice, once in a timestamp and again in an analyst's subtraction, nor omitted because the output rate looks familiar. A transformation ledger can carry the index map, its time origin, and the declared response convention explicitly. The same numerical sequence may then support several derived representations without forcing all their timestamps into one undocumented definition.

Dr. Atkinson, a spectrogram introduces another convention. Each displayed column represents an operation over an interval, not an instantaneous observation of every plotted frequency. Its assigned time may be the beginning, centre, or end of the contributing sample window.

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That choice can be harmless when stated and consequential when a short event is compared with a physical action. A visible line extending across neighbouring columns can reflect overlapping analysis windows as well as the source's duration. The examiner should recover the contributing sample intervals before reporting a temporal association.

Processing latency must also be distinguished from signal delay. A block can wait in a queue before its analysis begins without changing the sampling times of the data it contains. A display can update late while correctly labelling the earlier interval. Conversely, a prompt display can carry an incorrect time origin. Measuring host arrival or screen refresh can characterise system responsiveness, but it cannot alone establish the original sampling coordinate. A useful record preserves the distinction rather than subtracting an average latency and assuming every event followed it.

The time origin must be preserved when records from different channels are compared. An identical sample rate does not establish a shared epoch, and equal host arrival times do not establish simultaneous sampling. Each channel needs a supported mapping to the comparison coordinate. Where only relative timing is known, report relative timing. A later assignment of a civil-time label should not acquire greater accuracy than the observations connecting it to the source indices.

My proposed validation would inject events at known positions relative to block, filter, and decimation boundaries, then compare each reported coordinate with the operation that defines it. The examiner should test events near starts, stops, and state changes as well as those centred comfortably within a record. The aim is not to demand a single preferred

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timestamp for all analyses. It is to make each timestamp reconstructible and to carry its limitations into comparisons with other evidence. Dr Nyquist, may I invite your question concerning what remains recoverable when the retained stream has already discarded some of the original samples?

Harry Nyquist

Peer question 5 to Dennis Gabor

Professor Gabor, your decimation example preserves a precise mapping for retained output samples, but an investigator may ask about an event that occurred between those samples or outside the retained passband. Suppose the export contains only the decimated channel and its timing metadata, while the wideband parent has been overwritten. The output interval and filter coefficients are known. Does that knowledge permit reconstruction of the earlier waveform, or merely description of the transformation that would have produced the export? Please distinguish a valid reconstruction within an explicitly restricted signal class from an attempt to recover arbitrary discarded information. I would also ask whether a smooth interpolated trace should be retained as evidence of intermediate measured voltages. Our concern is not to deny the usefulness of interpolation, but to prevent its numerical completeness from concealing the physical assumptions on which its interpretation depends, particularly around a transient or an acquisition gap.

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Dennis Gabor

Answer to Harry Nyquist

Thank you for that question. Dr Nyquist, knowledge of an operation is not the same as possession of its inverse on every possible input. A properly restricted signal class may permit reconstruction from retained samples under a stated sampling model. That result depends on the admissible bandwidth, continuity, timing, and other conditions of the model. It does not imply that an arbitrary wideband parent can be recovered from a narrow channel merely because the channel's coefficients are known. Several different parent records can produce the same retained result.

An interpolated trace should therefore be identified as derived. Its intermediate values are consequences of retained samples and an interpolation rule, not additional voltages directly observed at those instants. This distinction need not diminish its legitimate use. Interpolation can support estimation within a justified model and can make a record intelligible. The problem arises when the representation is offered as evidence independent of the assumptions used to construct it. A dense plot does not increase the number of independently acquired samples.

Dr. Atkinson, the overwritten parent also limits later questions. The retained channel can support those measurements that survive its documented bandwidth and processing. It cannot certify absence of a contemporaneous signal outside that band. A transient crossing an acquisition gap may remain ambiguous even if the display joins the edges smoothly. The analyst should preserve the gap and identify

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which conclusions depend on a proposed completion. Alternative completions can be examined as hypotheses, but they are not recovered observations.

An interpolation rule should also identify its treatment of record edges. Extending an assumed periodic signal, padding zeros, or truncating an interpolation kernel can produce different estimates near a boundary. Those choices are not new data. Where they matter to the finding, retain and test them explicitly.

The strongest record links an export to its supported purpose and retains the parent where the authorised investigation requires future questions beyond that purpose. Where only the derivative remains, the conclusion should contract to its information content rather than expand to match the examiner's later curiosity. Professor Pearson, may I pass the floor to you to examine how overlapping analysis and selective retention change the number and character of the observations counted in a performance claim?

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Egon Sharpe Pearson

A frame count does not define an experiment's exposure

Professor Gabor, thank you. Dr. Atkinson, a count becomes evidence only after we identify what has been counted. Ten plotted spectra, ten threshold decisions, and ten independent acquisitions are not interchangeable units. A system can generate many decisions from largely shared samples, or retain only decisions that caused a trigger. Neither operation is inherently improper, but each changes the population to which the results refer. The experimental record should distinguish the available source observations from the analytical opportunities created by the procedure.

The seventh worked application makes the overlap explicit. Let each analysis frame contain N=4,096 samples, let the sampling frequency be 2.048 million samples per second, and let successive frames begin H=1,024 samples apart. Each frame spans two milliseconds in the sample-slot convention, while successive starts are separated by half a millisecond. Ten consecutive frames use a union of N+9H=13,312 sample slots, corresponding to 6.5 milliseconds. Adding the ten frame durations would instead report twenty milliseconds of exposure and count shared samples repeatedly.

$$T_{union} = \frac{N + (K-1)H}{f_s}$$

$$T_{union} = \frac{4096 + 9(1024)}{2.048 \times 10^6} = 6.5\,ms$$

Here K=10 is the frame count and f_s is the sampling frequency in samples per second. The duration convention assigns one sampling interval to each slot; the elapsed time between the first and last sample instants is one

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interval shorter. State the convention when that distinction matters. More importantly, the shared input creates possible statistical dependence between decisions. The union duration does not supply a universal effective number of independent tests. That number, or a more complete joint model, depends on the statistic, window, overlap, and underlying process.

The eighth worked application concerns invalid intervals. During a ten-second acquisition, suppose the ranges [1,1.003) seconds and [1.002,1.006) seconds are independently marked invalid for the same measurement. Their union is [1,1.006), lasting six milliseconds. Summing the individual durations would give seven milliseconds by counting their one-millisecond overlap twice. Under the stipulated classification, accepted duration is therefore 9.994 seconds. This is a duration for the identified channel and measurement, not proof of simultaneous observation across every frequency the receiver could tune.

$$T_{invalid} = 0.006\,s\,;\,T_{accepted} = 10 - 0.006 = 9.994\,s$$

An event whose required detection window crosses the invalid boundary introduces a further question. Counting its start time as accepted may not establish that the entire observation required by the detector was available. The acceptance function should correspond to the event class and detection procedure. An interval adequate for detecting a long carrier may be inadequate for measuring the onset of a short burst. Thus the record should retain the geometry of the intervals rather than only their total duration. A scalar total can discard information needed for a later exposure calculation.

Dr. Atkinson, triggering creates selection as well as convenience. If only positive decisions cause retention, the resulting archive is not a complete record of the opportunities that failed to trigger. It can document the

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retained events without directly estimating a missed-detection rate. A background channel, scheduled checks, or a validated trigger-performance record may supply additional information, but their contribution should be stated separately. An archive containing only successful captures cannot prove that capture was successful whenever the stipulated event occurred.

The same issue appears when an analyst revises a threshold after inspecting the record. The revision may be scientifically sensible, but the observations used to choose it are no longer a wholly independent assessment of its performance. Preserve the development history and identify which observations test the frozen procedure. Otherwise a succession of increasingly favourable results may merely reflect repeated accommodation to one dataset. The appropriate response is a transparent experimental distinction, not an assumption that every adjustment invalidates all previous work.

An event catalogue introduces its own counting rule. Several adjacent positive frames may belong to one physical burst, while a gap between positive frames may reflect a threshold crossing within a continuous transmission. The rule that joins or separates them should be retained with the original decisions. Otherwise a reported event rate can change when an undocumented clustering parameter changes, even though the acquisition itself is identical. The catalogue is a derived classification of observations, not an independent set of arrivals.

The same care applies across channels. If neighbouring filtered outputs respond to one emission, counting every channel decision as a separate source can inflate the catalogue. A merging rule may be justified, but it must preserve the evidence for association and the possibility that two distinct

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events overlap. Counting should follow the question being answered, not the convenience of the output table.

I would require the performance record to identify the trial unit, inclusion rule, applicable receiver state, and treatment of incomplete observations. Decisions sharing data should retain their common ancestry. Exclusions should preserve their reasons and chronology. Confidence statements should then follow the resulting experimental design rather than the visual abundance of plotted frames. Professor Neyman, may I invite your question about the uncertainty that remains when a carefully counted exposure is combined with a detection probability estimated from separate trials?

Jerzy Neyman

Peer question 6 to Egon S. Pearson

Professor Pearson, suppose the investigation preserves its accepted intervals exactly and then weights them by a detection probability estimated from a finite validation experiment. The product is reported as effective detection exposure. The analyst subsequently uses zero detections to calculate an upper bound on event occurrence. Where should the uncertainty of the validation probability enter that conclusion? A precise time counter does not make the weight exact, and the validation population may differ from the field population in signal amplitude or duration. Please distinguish uncertainty within an applicable model from uncertainty about the model's transfer to the investigation. I would also ask whether multiplying two separately stated confidence limits preserves their advertised confidence level. The purpose of my challenge is to keep a legitimate exposure calculation

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from acquiring more certainty than its least well established input, especially when the final report expresses a strong negative finding.

A further constraint follows from preservation of receiver state and acquisition metadata through changes of configuration. The transient analogue response occurring between state commands and valid samples remain outside the direct observation. If the examiner reports only those cases in which the indicated feature agreed with the preferred model, what correction would you require to the exposure denominator, alternative-hypothesis analysis, and reproducibility account?

Egon Sharpe Pearson

Answer to Jerzy Neyman

Thank you for that question. Professor Neyman, the validation estimate must remain an estimate in the exposure model. Treating it as a known constant can omit an uncertainty contribution that is material to the final bound. A joint analysis can address the validation outcomes and field count together, or a conservative construction can allocate error probabilities to separate bounds with its dependence assumptions stated. Two intervals each labelled ninety-five per cent do not automatically produce a ninety-five per cent statement about their product or a derived rate.

That statistical treatment presupposes applicability. If validation used long, strong signals while the field claim concerns short, weak bursts, the uncertainty is not repaired merely by calculating a narrower interval around the validation success fraction. The fraction estimates performance for the population actually tested under its

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design. Transfer to another population requires evidence or a model whose assumptions remain open to examination. The report should distinguish an uncertain parameter inside a supported model from an unsupported change in what the parameter describes.

Dr. Atkinson, accepted-time bookkeeping supplies one necessary part of this analysis, not the entire inference. An exact duration and a well-formed formula cannot compensate for a missing relationship between field events and validation conditions. Where that relationship is unresolved, a bounded qualitative conclusion may be more defensible than a numerical rate limit. The investigator can still state what was observed and which detection capability was demonstrated, without asserting that every possible event class shared it.

The final statement should also identify its conditioning variables. An amplitude-dependent detection curve may support a bound for a stipulated amplitude class without supporting a bound for arbitrarily weak signals. Preserving that qualification is not a weakness of the result. It states which experiment the numerical conclusion actually describes.

The record should preserve the inputs needed for later reassessment: validation trials, condition labels, interval masks, detector version, and the population definition. A future analyst can then revise the calculation when additional evidence becomes available without pretending the earlier model was certain. Dr Shannon, may I pass the floor to you to consider the information retained across the sequence of exports and transformations, and to

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distinguish a reproducible derivative from a recoverable original acquisition?

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Claude Elwood Shannon

The processing history defines which questions remain answerable

Professor Pearson, thank you. Dr. Atkinson, a derivative is useful when it preserves the distinctions needed for its intended purpose. It becomes misleading when its convenient representation is treated as though it preserved every distinction available in the parent record. Cropping, filtering, resampling, averaging, and conversion can each change the set of questions that remain answerable. A processing history should identify those changes without implying that a perfectly documented loss has thereby been reversed. Documentation can establish what was done; it cannot generally recreate what was discarded.

The ninth worked application concerns a clock declaration. Let a record contain a separation of N=10,000,000 sample intervals. Its nominal rate is f_0=1,000,000 samples per second, but the stipulated actual rate is two parts per million above that nominal rate. The true elapsed time for those intervals is approximately 9.99998000004 seconds, whereas the nominal calculation gives ten seconds. The difference is approximately 19.99996 microseconds. A correct file digest does not choose between those time mappings, because the discrepancy belongs to the physical rate declaration rather than the sample bytes.

$$t = \frac{10^7}{10^6\left(1+2\times 10^{-6}\right)} \approx 9.99998000004\, s$$

The example assumes a constant rate error. A varying error requires a model or observation of its evolution, not merely the same correction applied globally. The record should preserve whether the rate is requested, nominal, estimated, or calibrated, and the scope of the supporting evidence.

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A corrected time axis can be a legitimate improvement while remaining a derived result. Its relation to the originally declared axis should be retained so that another analyst can reproduce either interpretation and understand the reason for the change.

The tenth worked application shows that operation order matters even when every operation is individually specified. Define q[n] as the average of x[n] and its three preceding samples. Stipulate x[97]=x[98]=0, x[99]=4 millivolts, and x[100]=0. Filtering the original stream gives q[100]=1 millivolt. If the raw stream is first cropped to begin at index 100 and unavailable preceding values are replaced by zero, filtering that altered input gives zero at its first output. Identical coefficients have produced different results because the histories differ.

$$q[100]=\frac{x[100]+x[99]+x[98]+x[97]}{4}=1\,mV$$

This is not a numerical rounding dispute. Crop-then-filter with an assumed initial history and filter-then-crop are different transformations. Their provenance should identify the ordering, crop coordinates, state policy, and any padding. A processor that faithfully reproduces the wrong assumed history is reproducible in one sense and unsuitable for the physical claim in another. The example is especially consequential near an event boundary, where a seemingly harmless export can alter a transient's estimated onset or amplitude.

Dr. Atkinson, preservation should follow the chain of dependence. An export manifest can identify parent objects, operations, parameters, and resulting objects. Where software or coefficients influence the result, retain their identifiers and the particular settings used. Where a human selection

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determines which interval survives, preserve the selection rule or annotation. These proposals concern the evidence needed for this receiver problem. The consulted preservation guidance supports protecting origins and integrity records; it does not independently certify the physical truth of every metadata assertion. [M3-2]

There is also a distinction between an executable history and a meaningful history. A sequence of software calls may reproduce a file while leaving the physical units, complex-frequency convention, or input reference plane unspecified. Conversely, a clear mathematical description may fail to reproduce a particular implementation because its rounding, initialisation, or state reset differs. A strong record addresses both levels. It identifies the scientific transformation being claimed and the concrete procedure used to realise it, including qualifications where their correspondence has not been established.

Software identity alone may be insufficient for exact replay when numerical execution depends on additional settings. The record should retain precision choices, coefficient versions, initial conditions, and any stochastic seed where those features materially affect the output. This does not require claiming bit-for-bit equivalence between every computing platform. It requires distinguishing exact replay from agreement within a declared numerical tolerance, then selecting the criterion appropriate to the measurement.

Likewise, a visually identical export can omit distinctions retained in a numerical parent. Rounding a marker to a display label, saving an image instead of complex samples, or retaining peak hold without its contributing times can preserve appearance while reducing answerable questions. The

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derivative should therefore be described by its content and transformation, not merely called a copy of the acquisition.

I would not require indiscriminate retention of every possible intermediate. The retention decision should follow the investigation's authorised objectives and the consequences of irreversible reduction. Preserve sufficient parent information or validated alternatives to answer the questions the report actually raises. When a later question exceeds that scope, acknowledge the limit rather than treating a compact derivative as a universal surrogate. A file's small size is not its defect; an unsupported expansion of its evidential meaning is. Sir Karl Popper, may I invite your challenge concerning how to test a reconstruction without merely confirming the same assumptions that produced it?

Sir Karl Raimund Popper

Peer question 7 to Claude E. Shannon

Dr Shannon, a laboratory can reproduce an export exactly with the software and settings recorded in its manifest. Yet the software may consistently implement an incorrect sign convention, or both the original run and the reconstruction may use the same mistaken clock declaration. What experiment would expose such an error rather than merely confirm the repeatability of the procedure? I ask particularly about the temptation to declare a record complete when every internal consistency check passes. Completeness should be relative to a claim, but that claim must face a possible adverse result. Please identify a challenge that distinguishes correct physical correspondence from agreement between dependent implementations, and explain what the examiner should report when the parent acquisition has been lost so that the decisive

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challenge can no longer be performed. We should preserve useful evidence without making its interpretation immune to criticism through the disappearance of the test that could refute it.

Claude Elwood Shannon

Answer to Karl R. Popper

Sir Karl, the challenge should introduce information whose relevant relationship is established independently of the suspected convention. A known frequency displacement can test complex-frequency sign; a timed stimulus compared through a separately characterised path can test the mapping from sample indices to time. The particular design must identify its own uncertainty and shared dependencies. Merely running a second program that inherits the same definition does not guarantee independence. The experiment is discriminating when the competing interpretations predict observably different outcomes under the chosen conditions.

An exact replay remains valuable. It can establish that a retained procedure produces the same derivative from the same declared inputs. The report should state that limited achievement without promoting it into complete physical validation. A reference comparison or challenge test supplies a different proposition. The strongest result connects both: a reproducible transformation and evidence that its assumptions corresponded to the acquisition for the quantity under examination.

Dr. Atkinson, where the parent has been lost, the scope of possible challenge may narrow. Surviving references, logs, and independent

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observations can still constrain some interpretations. They should be examined rather than assuming that loss renders every conclusion worthless. But a missing distinction must remain missing when no evidence restores it. A later simulation can show what alternative inputs would have done; it cannot establish which unobserved input actually occurred. The retained derivative should be assessed for the questions it still supports, with the unresolved alternatives stated.

The challenge record should retain adverse as well as favourable outcomes. If a sign or timing discrepancy is discovered, the affected derivations can be corrected and their scope reviewed. Removing the failed test would preserve a more persuasive narrative while destroying information needed to assess the correction.

The scientific discipline is therefore to preserve the possibility of relevant criticism while evidence exists, and to describe honestly what remains when it does not. The record need not answer every imaginable future question. It must not imply answers to questions whose decisive information was never retained. Professor Atkinson, may I return the floor for the closing account of the state history, timing conventions, and evidential limits that this discussion has established?

Ralph Vinton Lyon Hartley, Cross-Peer Question to Norbert Wiener: Professor Wiener, I ask how a recorder should bind an operator's gain-change command to the physical instant when the changed state actually influences the stored samples. The software log may timestamp the requested value, while the control path passes through a queue and the analogue gain element settles over a finite interval. A sample counter

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identifies order, not necessarily the relevant analogue state. If the recorder has a ring buffer and transmits data in packets, a packet stamped after the transition may still contain earlier samples. What evidence would allow an analyst to divide the recording into valid regimes without converting a commanded state into an asserted achieved state? Please also address the case in which the control event and the digitiser share neither a reliable clock nor a common epoch.

Norbert Wiener, Cross-Peer Answer to Ralph Vinton Lyon Hartley: Mr Hartley, the history should be treated as a dynamical experiment rather than an administrative diary. I would separate at least four timestamps: command issuance, hardware acknowledgement, independently observable onset of the analogue response and the earliest sample demonstrated to have reached the stable new state. Their order may be established in a local monotonic clock, but translation to sample indices requires measured clock relationships, not an assumption that wall-clock strings coincide. Where the controller and ADC are asynchronous, a test signal or recorded digital marker can establish a mapping and its uncertainty. The output immediately following a gain change may reflect the prior state through filter memory, AGC hysteresis or queued samples, so the validation must define a guard interval. I would not simply remove a fixed number of samples without checking the worst relevant settling process. A repeatable controlled transition, measured across temperatures and signal levels, can provide a bounded interval after which the achieved state is credible. If that test is unavailable, mark the affected samples as transition data and retain them with a qualification, rather than assigning them retrospectively to one regime. Keep the source sequence counter, packet receive order, command

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log and state-change record independent in the archive so later reviewers can detect disagreements. These distinctions serve both reproducibility and the proper interpretation of any apparent burst occurring at the transition.

Dennis Gabor, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, your account of recording history raises a question about the apparent precision of later transformations. A long narrowband FFT applied to a stored I/Q segment can locate a persistent component finely in frequency, but a short pulse embedded in that segment may require a much shorter time aperture to locate its onset. Analysts sometimes present a smooth 30 Hz spectrum and assume that its narrow bins prove the absence of wideband bursts during the same interval. How should the original recording preserve both kinds of evidence, particularly where a trigger retains only selected time windows and deletes most samples labelled as dead air? Can the metadata alone supply information that was never stored?

Claude Elwood Shannon, Cross-Peer Answer to Dennis Gabor: Professor Gabor, the archive must distinguish information preserved in samples from summaries computed from them. If raw I/Q is present, a later examiner can choose different window lengths, demodulation algorithms and detection statistics, within the bandwidth and dynamic-range limits of the original hardware. If the original data were reduced to averaged FFT magnitudes, much of the instantaneous phase and waveform timing is lost; a metadata description of the averaging process cannot reconstruct those missing degrees of freedom. Nor does a 30 Hz bin width imply microsecond pulse sensitivity, because the associated observation aperture and averaging rule may dilute a brief event. The defensible design is a continuously operating fast candidate detector that controls a sample ring buffer, alongside a

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slower high-resolution spectral estimator. Each retained event should carry pretrigger and post-trigger I/Q, precise sample indices, actual configuration history, and the decision statistic that caused retention. Intervals excluded from storage should still have verifiable monitoring and loss records, including detector health, blind intervals and threshold changes. One cannot describe those intervals as signal-free merely because the algorithm found nothing worth preserving. A false-negative audit using injected, labelled waveforms across pulse widths and signal levels is indispensable to any claim about the coverage of selective recording. The stored spectrum is a useful index; it is not a substitute for absent complex samples.

Walter Andrew Shewhart, Cross-Peer Question to Egon Sharpe Pearson: Dr Pearson, when a receiver changes state the total observation period may include periods of settling, lost acquisition packets and intervals for which the trigger algorithm was disabled. Suppose a report counts detections per hour while excluding invalid samples from its denominator, but it does not explain that the excluded intervals were disproportionately associated with strong-signal overload. The selection is then coupled to precisely the phenomenon being investigated. What statistical summary should replace the naive hourly event rate, and how should an examiner express uncertainty about the unobserved periods without inventing the missing emissions?

Egon Sharpe Pearson, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, I would retain separate denominators for nominal elapsed time, instrument-operational time, valid observation exposure and exposure eligible under the specified detection criterion. A rate based on valid exposure can be meaningful for the stated regime, but it must not be

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represented as an unconditional rate over the whole investigation when exclusions are informative. The report should identify the reasons, locations and durations of invalid intervals. If overload causes a gap, the unseen event rate during that gap need not match the rate during quiet operation; imputing an equal rate is a model assumption that ought to be labelled and stress-tested. An appropriate display could show the observed count and valid-exposure rate, then a sensitivity analysis under explicitly bounded hypothetical event rates for excluded intervals. It is also wise to distinguish a threshold crossing from a physically independent emitter event, because one transmission can produce many detections across adjacent channels or overlapping FFT windows. The uncertainty should include selection, calibration, false-alarm and time-mapping effects, not just a Poisson interval around the counted positives. If the data cannot identify a meaningful full-period rate, the academically sound conclusion is a partial observation statement. Such an admission is not a failure of mathematics; it is a recognition that the experiment did not observe the required quantity.

Harry Nyquist, Cross-Peer Question to Percy Williams Bridgman: Professor Bridgman, let us examine what the word 'same' means when an archived dataset is transferred from one computing system to another. Two files can produce nearly identical amplitude spectra even if one reverses the sign of Q, swaps the I and Q channels, assumes the wrong sample rate or misinterprets signed data as unsigned. A digest certifies byte identity relative to a known reference but cannot establish that either file was decoded with the correct physical meaning. How should the manuscript define the evidential object so that source sample indices, sample

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representation, actual receiver settings and the intended electrical reference plane remain linked even after later extraction or channelisation?

Percy Williams Bridgman, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the evidential object must contain more than an unlabelled array of numbers. I would preserve the original unmodified bytes together with a protected manifest specifying datatype, signedness, endianness, I/Q ordering, sample rate, centre frequency, gain, analogue filtering and the physical reference plane. Each item should state whether it comes from a measured hardware register, a commanded setting, a validated configuration or a later inference. The sample coordinate of a retained file is not necessarily the coordinate of the original acquisition: a source counter or equivalent mapping is needed to distinguish genuine continuity from a file made by joining selected segments. The distinction is explicit in the SigMF vocabulary, which separates dataset-local sample positions from source-stream indices when the latter are available. A cryptographic digest is useful to demonstrate the continued identity of particular bytes but does not verify the correctness of the acquisition, the timing or the semantic annotations. I would therefore require a reproducible decoding test using a known complex calibration signal. A sign inversion in Q or an erroneous sample rate will then produce a predictable discrepancy, allowing the encoding to be challenged. Every later channelised product should preserve a documented derivation chain to the immutable source segment and its metadata, rather than silently replacing the original recording. Only this linked record allows the result to be interpreted at the declared physical input plane.

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Dr. James M. Atkinson

Closing synthesis

Thank you, Dr Shannon, and thank you to the panel. The discussion has distinguished six relationships that a continuous-looking record can conceal: stored position and source position; requested state and achieved state; sampling time and analysis time; frame count and independent observation; retained exposure and detection capability; and reproducible processing and verified physical correspondence. These distinctions are connected, but none can be settled merely by verifying another. A valid digest cannot determine the clock rate, and a precise clock cannot restore a discarded frequency interval.

Mr Hartley's examples established why coordinates must survive cropping and discontinuity. A retained ordinal is not automatically an original stream index, and a finite counter requires conditions that make its rollover interpretation unique. His exchange with Mr Weston also preserved the possibility of legitimate retrospective correction. An erroneous entry need not remain the accepted account, but its amendment should retain chronology, supporting evidence, and unresolved uncertainty rather than silently replacing the historical record.

Professor Wiener treated control actions as part of the measurement. Acknowledgement of a command did not establish a settled response, and averaging gains before correction did not reproduce correction of the observations in their actual states. Dr Bode's challenge extended that reasoning to filter memory. Dr Shewhart required exclusions to preserve their cause and time of classification, so that a stable retained subset cannot be mistaken for an equally stable complete acquisition.

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Professor Gabor separated the time coordinates introduced by filtering, decimation, and display. His cases supplied explicit mappings, not universal corrections for every waveform. Dr Nyquist's challenge identified the point at which a derivative's documented origin ceases to make its parent recoverable. Professor Pearson then distinguished shared analysis windows from independent trials and interval unions from duplicated duration. Professor Neyman showed why a known interval mask cannot make an estimated detection weight exact or establish its applicability to another signal population.

Dr Shannon's final cases joined these issues to processing provenance. A nominal clock and an actual clock can assign different times to unchanged bytes. Cropping before filtering can alter an event because initial history has been removed. Sir Karl's challenge required tests that distinguish physical correctness from repeated execution of a shared assumption. The panel has consequently proposed a record that preserves meaningful dependencies, not merely a long list of files or an unqualified certificate of integrity.

These requirements also leave room for proportionate recording. A declared limited purpose can justify reduction, provided the later report does not silently claim the broader capability that the reduction has removed.

The practical conclusion is bounded. Preserve the observations, coordinates, consequential state history, reference evidence, transformations, and reasons for exclusions that support the actual claims. Mark unknown relationships explicitly. A reduced record may still be useful, but its use must follow what it retains. The next question will examine how an investigator designs a controlled challenge that separates competing

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explanations without simultaneously changing the ability to observe the signal. That problem follows naturally: once the history is intelligible, the experiment must make the rival interpretations answer differently.

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Ten worked engineering applications | Question 003

Application 01. Accumulated sample-clock time error

In the illustrative 003.01 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. A free-running sample clock with fractional rate error ε = 0.980 ppm over T = 164 s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T$ = 0.1607 ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 02. Preserved sample continuity across an acquisition interval

In the illustrative 003.02 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. A converter expected to retain f_s = 1.70 million samples/s for T = 0.85 s should supply $f_s T$ = 1,445,000 complex sample instants. If 63 sequence positions are missing, the retained count is 1,444,937 and loss fraction is 0.00436%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block must therefore be preserved. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 03. Stored-sample volume and the limits of retrospective analysis

In the illustrative 003.03 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive.

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With complex sample rate f_s = 5 MS/s, duration T = 21 s, and 16-bit in-phase plus 16-bit quadrature integers, the raw payload is $f_sT \times 4$ bytes = 420,000,000 bytes, or 0.420 GB (decimal). The calculation excludes timestamps, metadata, framing and file-system overhead. Maintaining a wideband buffer of this capacity does not establish that upstream analogue clipping was absent. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 04. Difference between two instruments relative to stated uncertainty

In the illustrative 003.04 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. The paired instrument contrast is Δ = 1.580 dB. Set independent standard uncertainties u_1 = 0.420 dB and u_2 = 0.520 dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)}$ = 0.668 dB, giving the dimensionless ratio Δ/uΔ = 2.364. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 05. Combined and expanded measurement uncertainty

In the illustrative 003.05 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. For independent standard-uncertainty contributions 0.66, 0.36 and 0.46 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.66^2 + 0.36^2 + 0.46^2)}$ = 0.881 units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c$ = 1.763 units. Preserve the full

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instrument state history so a different examiner can reproduce the decision.

Application 06. Observed exposure fraction of a channel scanner

In the illustrative 003.06 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. Let the channel be observed on n = 189 valid visits, each lasting d = 8 ms, with revisit spacing R = 0.85 s. Valid exposure is nd/1000 = 1.512 s across the nominal interval nR = 160.65 s. The observed fraction of elapsed time is therefore 0.94%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 07. Cascade gain and observed headroom

In the illustrative 003.07 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. A first amplifier contributes G_1 = 12 dB, an intentional attenuation contributes G_2 = -7 dB, and a later stage contributes G_3 = 21 dB. The small-signal sum is 12 + (-7) + 21 = 26 dB. For P_i = -68 dBm, the ideal output is P_o = -42 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 08. Family-wise probability when many candidates are searched

In the illustrative 003.08 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. If

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each of M = 215 independent pre-specified search opportunities has false-alarm probability α = 0.0008, the probability of one or more false positives is 1 − (1 − α)^M = 0.15808, or 15.81%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 09. Frequency-bin spacing versus independent information

In the illustrative 003.09 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. With sampled bandwidth f_s = 8 MS/s and N = 20,480 transform samples, the discrete-frequency grid is $\Delta f = f_s/N$ = 390.625 Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. Preserve the full instrument state history so a different examiner can reproduce the decision.

Application 10. First-order recovery envelope after a state change

In the illustrative 003.10 test, a field sdr changes gain, preselector state and software detector while retaining a complex-sample archive. If an illustrative recovery follows $A(t) = A_0 \exp(-t/\tau)$, let A_0 = 1.30 V and τ = 12.00 ms. At t = 30.00 ms the residual is 1.30e^(−30.00/12.00) = 0.1067 V. Real automatic gain control often has nonlinear or multi-time-constant behaviour, so this exponential is a test model, not a universal

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reconstruction of the input during overload. Preserve the full instrument state history so a different examiner can reproduce the decision.

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QUESTION 004

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When does agreement among receivers constitute independent corroboration?

Source: V011_Roundtable_Q001-Q011_CP011_Integrated_Candidate(2).docx | Recovered substantive manuscript. Constructed educational dialogue.

Constructed educational dialogue. Numerical cases are hypothetical, not instrument certifications.

Dr. James M. Atkinson

Opening question

Professor Wiener, can you comment on the circumstances in which agreement between two receiver records constitutes independent corroboration, rather than two presentations of the same unexamined dependency? Our earlier discussions established the intended quantity and the need to preserve acquisition history. We now encounter a tempting inference: a feature appears on two displays, and the investigator therefore considers its external origin confirmed. The second display is useful evidence, but precisely what it adds depends upon the route by which its observations were obtained. Two independent computations of one recording, two digitizers supplied by one amplifier, and two separately calibrated acquisition chains are different experimental arrangements. None should inherit the evidential description of another merely because each produces two traces.

The hypothetical arrangement has two receivers connected through a common distribution network. Their clocks may share a reference; their calibration corrections may derive from the same source; and their event lists may use the same threshold estimate. A weak feature appears

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simultaneously in both records. We have not stipulated whether it entered through the intended antenna terminals, arose in the shared network, or followed a common disturbance elsewhere. These alternatives are neither equally probable by declaration nor exhaustively disproved by the visual agreement. We must decide which additional measurements could discriminate among them while preserving the ability to observe the weak feature.

Professor Wiener will distinguish shared signal from shared measurement error. Dr Bode will examine the network connecting the receivers and the limits of what a difference measurement can reveal. Professor Neyman will consider dependence between detection decisions and explain why multiplying individual false-alarm probabilities may be unjustified. Dr Shewhart will propose an experimental arrangement that separates configuration effects from time-dependent change. Sir Karl Popper will then examine the precise claim that survives when corroboration has eliminated some explanations but not others. Seven colleagues will challenge these accounts before we draw a conclusion.

The ten worked applications are constructed examples, not measurements of an actual apparatus. Their purpose is to make the assumptions visible: common and private error, cancellation in a cross-spectrum, mixtures of operating states, and comparisons whose apparent agreement is built into their design. Where physical literature supplies an example of correlated instrumentation noise, its relevance must remain confined to the mechanism actually demonstrated. It is not evidence that every matching receiver trace is an artefact. Equally, an unusual mechanism cannot be excluded merely because the operator did not expect it.

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Our final account should replace the unqualified adjective independent with a description of the dependency that was tested. It should identify which observation would challenge a shared-path explanation, which comparison remains sensitive only to receiver differences, and which remaining uncertainty prevents a stronger attribution. Professor Wiener, may I invite you to begin with the distinction between correlation in the desired phenomenon and correlation in the errors of its measurement?

A further constraint follows from the distinction between genuinely independent corroboration and common-mode instrument error. The written conclusion must separate a directly retained observation from an inferred physical explanation. A short anomaly may be real in the stored digital sequence yet originate in quantisation, analogue recovery or the acquisition policy. Conversely, the absence of an alarm cannot establish the absence of an event outside valid temporal and frequency coverage. Such limitations do not make the work futile. They guide a useful next test, specify the conditions in which the present record is persuasive and protect the evidential chain against later exaggeration. At the close of this discussion I would require the published conclusion to identify cross-correlation, residual dependence, independent sensor coverage, and false-alarm conditioning and explain which claims remain untested because shared calibration dependencies, antennas, oscillators, power supplies, and reporting software. Such candour is not weakness but the condition under which this roundtable can inform a rigorous TSCM investigation.

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Norbert Wiener

Shared observations and shared errors are not the same covariance

Dr. Atkinson, thank you. The first discipline is to name the random quantities before discussing their correlation. When two receivers observe the same fluctuating source, correlated outputs are expected and may be the object of the investigation. That fact tells us little, by itself, about the dependence of their errors after the common source contribution has been accounted for. Conversely, two output streams can be correlated because an unwanted disturbance reaches both measurement paths. An empirical covariance is therefore not self-interpreting. Its physical meaning follows from a model of the quantities whose variation has entered the calculation.

Consider a simple real-valued model for repeated measurements of the same constant voltage s. Receiver outputs are $x_1 = s + c + e_1$ and $x_2 = s + c + e_2$. The term c is a zero-mean common error in volts; e_1 and e_2 are zero-mean private errors, also in volts. For the first application only, suppose all three errors are mutually independent, c has variance four square microvolts, and each private error has variance one square microvolt. Each receiver then has error variance five. Their covariance is four, giving an error correlation of 0.8. Averaging their outputs leaves the common error unchanged and halves the combined private contribution. The mean consequently has error variance 4.5, not 2.5, and its standard uncertainty is about 2.121 microvolts. The apparent two-channel improvement is modest because most of the uncertainty belongs to a shared term.

$$var\left(\frac{x_1+x_2}{2}\right)=4+\frac{1+1}{4}=4.5\left(\mu V\right)^2$$

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In the second application retain these assumptions but subtract the receivers. The constant voltage and common error cancel, leaving x_1 minus x_2 equal to e_1 minus e_2. Its variance is two square microvolts and its standard deviation is about 1.414 microvolts. Now imagine making both private variances one hundred times smaller while leaving the common variance unchanged. The differential standard deviation becomes approximately 0.1414 microvolts, although the average still has variance 4.005. Exceptionally close channel agreement is therefore compatible with an essentially unchanged two-microvolt common uncertainty. These are exact consequences of the stipulated linear model, not claims that all error distributions are Gaussian. [M4-1]

$$var\left(x_1 - x_2\right) = 1 + 1 = 2\left(\mu V\right)^2$$

The point is not to discourage difference measurements. Their ability to reject common terms makes them valuable for examining differential behaviour. The error is to use a result about the difference as though it measured what the subtraction deliberately removed. A calibration programme could exploit both operations: use channel differences to investigate private instabilities, and a separately established reference to investigate common accuracy. The second experiment supplies information missing from the first. Merely collecting more difference records cannot reveal a term whose coefficient in every such record is zero.

Dr. Atkinson, the constant-source assumption also deserves attention. With a time-varying source, the covariance of the uncorrected outputs includes source variation. To infer error covariance, one needs a defensible way to separate the source contribution or a sufficiently specified repeated-input experiment. A laboratory source may itself fluctuate; a common

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splitter may contribute another term. Calling that source stable is a hypothesis to support over the relevant amplitude, bandwidth, and duration, not a numerical operation that removes its uncertainty. The modelling decision determines whether the resulting covariance can be carried into a later weak-signal calculation.

A finite covariance estimate introduces a further question. It describes the observed records under their conditions and does not guarantee the same dependence after the system changes state. If the shared disturbance appears only during a thermal transition, a quiet settled test may miss it. If a common gain correction changes both records together, the effect may be systematic over one run rather than a zero-mean fluctuation. A single random-error model must not be used to conceal these distinct mechanisms. The record should distinguish corrected bias, uncertainty about that correction, and fluctuations represented by the chosen covariance.

There is an additional distinction between dependence of observed fluctuations and uncertainty about a fixed correction. A correction can remain constant throughout a recording, producing no time-series covariance that exposes its error, while its uncertain value is common to both reported results. Estimating covariance from within-run fluctuations alone would omit that contribution. The uncertainty model must therefore include information from the calibration process and not merely what varies visibly during the event. A quiet record cannot measure every uncertainty shared by its interpretations.

A final evidential safeguard is that a deliberately independent reference path and documented perturbation of shared dependencies. A second

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instrument adds evidential force only to the extent that its error mechanisms are independent or adequately modelled. Two receivers supplied by the same antenna network can share impedance anomalies, a local oscillator reference, or a strong interfering field. If they report the same feature, the comparison is valuable but must not be represented as two independent confirmations until those common pathways are examined. Where practical, vary a reference source, a cable route or a gain state under controlled conditions, and assess whether the observed changes conform to the proposed transfer relations. Applied to the present engineering problem, one coupled source of error propagating through apparently independent records may create a spectrum or timestamp that looks persuasive while leaving shared calibration dependencies, antennas, oscillators, power supplies, and reporting software inaccessible. The experimental answer lies in a deliberately independent reference path and documented perturbation of shared dependencies, carried out with explicit controls and independent retention of all the relevant receiver states. The account should quantify cross-correlation, residual dependence, independent sensor coverage, and false-alarm conditioning, separating input-referred values from software-derived quantities. If the calculation assumes constant noise statistics or a linear front end, an overload or irregular interference challenge should test that premise. The examiner should preserve negative outcomes and show why the proposed mechanism is better supported than the surviving alternatives. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Finally, a second receiver adds evidence even when it is not independent in every respect. It can localize some errors to an individual branch, show

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that a feature survives a changed conversion path, or constrain the timing of an event. Its contribution should be expressed at that level. Independence is not an honour bestowed upon an instrument; it is a relation among specified observations under specified conditions. Dr Shannon, may I invite your challenge concerning whether a second representation of the same acquired samples adds any new information about their physical origin?

Claude Elwood Shannon

Peer question 1 to Norbert Wiener

Professor Wiener, thank you. Two processing chains may be designed independently yet receive exactly the same digital recording. Their agreement can expose some implementation errors, but neither has observed the analogue input independently. I would ask you to distinguish the information added by algorithmic diversity from the information added by another physical acquisition. Dr. Atkinson has placed both within the general question of corroboration, and it would be easy to let the useful independence of programmers become an unsupported independence of observations. Suppose the two chains agree on a candidate frequency after using different numerical methods. What has been strengthened, and what has not? Please also consider whether a second method that shares an undocumented convention about scaling or sample time could repeat the same interpretative error. How should the report describe the additional evidence without either dismissing the comparison or counting it as a second observation of the external field?

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Norbert Wiener

Answer to Claude E. Shannon

I welcome that careful objection and shall address it directly. Thank you for that question. Dr Shannon, the comparison can strengthen a claim about the calculation performed on the retained recording. If independently implemented methods converge upon the same frequency under explicitly matched conventions, some classes of numerical or implementation mistake become less plausible. The result remains conditional upon the recording and its coordinate definitions. It does not establish that the analogue input was unclipped, that a frequency translation was correctly documented, or that the feature was not generated before the digital branch point. Those questions require information that neither processing chain received.

Dr. Atkinson, the relevant boundary should therefore appear in the report: independently processed, not independently acquired. The qualification is not disparaging. It identifies exactly where diversity was introduced. An independent calculation can be exceptionally valuable when a disputed result depends on subtle normalization, windowing, or reconstruction. Its evidential force is increased by preserving the inputs and conventions and by testing the implementations on cases with known outcomes, not by broadening its description beyond the boundary it actually challenges.

Shared assumptions deserve their own examination. Two teams may use different software while adopting the same mistaken sample rate supplied in a configuration file. Agreement then supports

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consistency with that stated rate, not its physical accuracy. The appropriate additional test might compare the acquisition clock with an independent reference or inspect the receiver's verified frequency mapping. Changing only the numerical method does not vary the uncertain clock. The same logic applies to a common amplitude calibration or a shared rule for interpreting missing samples.

The records of this comparison should also identify which test cases were selected independently of the disputed event. Otherwise a method developed to reproduce that event may appear to validate it through agreement that its development process was designed to obtain.

I would preserve a dependency diagram rather than award one undifferentiated count of corroborating methods. Identify common data, common metadata, common calibration, and separately exercised operations. Then state which alternatives each comparison addresses. The phrase independent evidence is useful only after its relevant independence has been specified. Dr Nyquist, may I invite you to examine whether apparently matching spectral peaks can conceal different admitted frequencies or acquisition bands?

Harry Nyquist

Peer question 2 to Norbert Wiener

Professor Wiener, the dependency diagram should include frequency mappings, not merely shared boxes. Two receivers can display the same numerical frequency while admitting different analogue bands, or display different numerical frequencies for the same physical input after

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different conversions. Agreement of labels would then conceal rather than establish an agreement of observations. Suppose each receiver has a different sample rate and its own input filter, but the analysis converts both results to an absolute frequency scale using incomplete configuration records. What evidence would make that comparison meaningful? In particular, should we require a controlled signal to traverse each relevant path before describing the observations as corroborating, or can a sufficiently complete model supply the missing connection? Please distinguish a common alias that survives similar architectures from genuinely complementary frequency coverage, and explain how to preserve the information that could later expose a mistaken mapping.

A further constraint follows from the distinction between genuinely independent corroboration and common-mode instrument error. Shared calibration dependencies, antennas, oscillators, power supplies, and reporting software remain outside the direct observation. If the examiner reports only those cases in which the indicated feature agreed with the preferred model, what correction would you require to the exposure denominator, alternative-hypothesis analysis, and reproducibility account?

Norbert Wiener

Answer to Harry Nyquist

Dr Nyquist, matching labels are not enough. A meaningful comparison requires a supported mapping from each retained coordinate to the analogue reference plane being discussed. A model can supply that mapping when its architecture, settings, and

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operating state are sufficiently established, but the model's applicability must be tested where uncertainty could change the conclusion. A controlled signal is useful precisely because it can challenge the mapping through the physical path. Its value depends on traversing the ambiguous stages and covering the relevant branch, not simply producing an expected marker somewhere on the display.

Dr. Atkinson, a shared alias can be a common consequence of shared sampling and filtering assumptions. Using different sample rates or preselection may separate some candidate analogue frequencies, provided the resulting observations are compared through their actual admissible mappings. It is not enough to say that the hardware differs. One should state how the competing candidate frequencies predict different outcomes under the chosen change. If both candidates remain admissible after every configuration tested, the ambiguity has not been resolved by acquiring another trace.

The record should retain native sample coordinates, selected analogue bands, conversion frequencies and signs, sample rates, and the transformations used to produce the common frequency display. Retaining only the final labels prevents a later examiner from reconsidering the mapping. A reconstructed absolute-frequency axis should remain a derived product with identifiable inputs. That is especially important where software combines several tuned intervals into a display that appears simultaneous although the acquisitions were sequential.

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Where the original configuration cannot be recovered, retain alternative admissible mappings instead of choosing the mapping that makes the two traces agree. Their agreement is then conditional, and an unresolved branch remains a real limitation on the proposed corroboration.

I would not impose one universal calibration ritual on every comparison. The evidence required follows the uncertainty that could defeat the claim. A well-supported fixed mapping may need only appropriate verification; a changed or incompletely logged path may require new measurements or a restricted conclusion. Dr Bode, may I now invite your examination of how the shared network itself can generate agreement, disagreement, or cancellation that neither receiver's individual specification predicts?

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Hendrik Wade Bode

The shared network is part of the corroboration experiment

Professor Wiener, thank you. Dr. Atkinson, the common network cannot be treated as an invisible connection between otherwise independent instruments. It has a transfer relation, loading conditions, internal sources, and possible paths by which one branch influences another. A comparison intended to identify the origin of a weak feature should therefore include the network's boundaries. Removing it may answer one question while also changing the source loading or the noise presented to each receiver. A test that alters several relevant quantities at once can remain informative, but its outcome requires a model broad enough to include those changes.

For application three, let two real, zero-mean random voltages be s and c, mutually independent with variances S and C. Define branch observations x_1 = s + c and x_2 = s minus c. Their covariance is S minus C, while each individual variance is S plus C. Choose S = C = one square microvolt. Each branch has variance two, yet their cross-covariance is zero. The wanted contribution has not vanished from either input; its contribution to the cross statistic is cancelled by the oppositely coupled contribution. If the same algebra is applied at a frequency to uncorrelated stationary processes, S and C denote compatible spectral densities rather than integrated variances. The units and bandwidth convention must change accordingly.

$$cov(x_1, x_2) = S - C = 1 - 1 = 0 (\mu V)^2$$

This constructed example has a relevant physical counterpart. NIST researchers report that thermal noise from a common power splitter can enter cross-spectrum measurement channels with anticorrelated contributions and cause underestimation or collapse of the measured noise

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spectrum. That published result concerns the tested measurement configuration. It supplies a mechanism worth checking, not a universal explanation for every unexpectedly low cross-spectrum. [M4-2]

Application four introduces directional leakage instead of an oppositely coupled common term. Let independent real noise variables n1 and n2 each have variance one square microvolt. Define x_1 = n1 and x_2 = n2 + k n1, where the dimensionless leakage coefficient k is 0.1. The covariance is 0.1 square microvolt; the variances are one and 1.01. Their correlation is about 0.09950, and its square is approximately 0.009901. There is no separate external common signal in this construction. The nonzero correlation is created by leakage. This is an elementary scalar analogue of a frequency-dependent channel-coupling problem, not a replacement for a complete spectral model.

$$r = \frac{0.1}{\sqrt{1 \times 1.01}} \approx 0.09950 \, , r^2 \approx 0.009901$$

Dr. Atkinson, these two examples warn against opposite mistakes. A strong correlation need not identify an external common source, and a small cross statistic need not establish absence of a wanted contribution. The distinction requires knowledge of how the relevant components enter both branches. Merely comparing their individual noise floors does not supply those signs, phases, or transfer paths. Nor does a lower result automatically deserve preference because it resembles improved sensitivity. A measurement should be accepted through a supported model and challenge tests, not through the attractiveness of its numerical outcome.

A practical experiment can vary the location of a reference injection, the branch termination, or a verified isolating element while documenting the

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transfer changes. If a feature appears in a terminated branch when the other branch is driven, that observation can constrain coupling. If replacing a splitter changes the cross statistic, one must still examine altered insertion loss, impedance, and reference conditions before attributing the entire change to one mechanism. This proposal is a test of competing transfer models. It does not assume that replacing a component produces a perfectly selective intervention.

The test should retain the complex cross quantity where the measurement supports it. Reducing it immediately to a magnitude can conceal signs or phase changes important to a cancellation argument. Finite-record fluctuations should also be distinguished from an expected cross term. A single small estimate does not establish a zero expectation, while a stable nonzero estimate does not identify its source. The relevant experimental question is which controlled change would make the candidate components respond differently and whether the observed response matches that prediction within the stated uncertainty.

Another hazard appears when software corrects the two branches by dividing by estimated transfer functions. A transfer minimum can make a small calibration error dominate a corrected cross quantity. Agreement after that correction is not necessarily stronger than agreement before it. The laboratory should retain both representations and the uncertainty of the correction, especially near response minima. A calibration derived by forcing the branches to agree cannot then use that same agreement as independent evidence that the correction is right.

I would conclude that corroboration is a property of the whole arrangement, including common components, rather than of receiver serial

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numbers. The network can provide a useful common input for comparing branches, yet that very commonality may conceal a shared error. Its benefits and limitations should be stated together. Dr Gabor, may I invite your question concerning the time and phase information that must be retained before a cross-spectrum can be treated as a physically meaningful comparison?

Dennis Gabor

Peer question 3 to Hendrik W. Bode

Dr Bode, thank you. The cross-spectrum requires a relationship between records, but that relationship may be estimated after acquisition rather than physically preserved. An analyst can shift one record in time or rotate its phase to maximize agreement. Such alignment may compensate a genuine known delay, yet it can also make a weak common feature appear more persuasive by selecting the transformation that favours it. What distinguishes a calibrated alignment from a fitted alignment whose uncertainty and selection are part of the result? Please consider a short transient rather than a stationary carrier. The two records have different filtering and uncertain trigger origins. Under those conditions, which properties must be established before their apparent common structure is evidence of the same event? How should the analyst record failed alignments and alternative delays, rather than preserving only the most attractive overlay?

May I press the principal contributor on independence of electromagnetic corroboration between two receiving systems? The chronology of independence of electromagnetic corroboration between two receiving systems is indispensable. Assume for a moment that

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common-oscillator phase noise or an antenna splitter might reproduce one false feature in both streams. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should repeat a common-stimulus test after separating power, frequency references and physical antenna paths, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs shared dependency graph, calibration offsets, correlated noise and near-threshold decisions. If purported independent agreement fails when the common error path is removed, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Hendrik Wade Bode

Answer to Dennis Gabor

Thank you for that question. Dr Gabor, an alignment derived from an independently characterised delay and applied within its supported state is a correction with a defined evidential basis. An alignment estimated from the event being examined is part of the

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inference. It may be useful, but the search range, criterion, degrees of freedom, and residual ambiguity must be retained. A favourable match obtained after trying many transformations cannot be described as though the correct transformation had been specified beforehand. The calibration and the event must not exchange roles without disclosure.

Dr. Atkinson, for a transient I would first identify the acquisition time origins and the filter responses that determine what each record preserves. A delay defined for a narrowband phase comparison may not align a broadband pulse whose components experience different group delays. If the response is not adequately known, the comparison may support only a limited correspondence of timing or structure. It should not be forced into sample-by-sample agreement by an unconstrained transformation that can absorb the very differences under investigation.

Preserve the original records, the alignment objective, candidate delays, admissible transformations, and the criterion used to select a result. Retain sufficient intermediate information to examine whether several alignments fit comparably well. A held-out portion or independent reference event can test whether the fitted relationship generalizes, provided its relevance is justified. Such validation does not make the original fit independent, but it supplies a new opportunity for the proposed mapping to fail.

The time tolerance should likewise be chosen for the stated claim. A broad coincidence window may establish that activity occurred in

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the same general interval while providing little evidence that the receivers captured the same short physical event.

Failed alignments matter when the method allowed them to influence the selected result. Reporting only the successful overlay can exaggerate uniqueness. The final statement should distinguish an observed correspondence from an inferred common event and state the transformations upon which that inference depends. Mr Weston, may I invite you to question how changing branch loading affects the interpretation of the reference measurements proposed for this shared network?

A further constraint follows from the distinction between genuinely independent corroboration and common-mode instrument error. I would add the following qualification to my answer. The written conclusion must separate a directly retained observation from an inferred physical explanation. A short anomaly may be real in the stored digital sequence yet originate in quantisation, analogue recovery or the acquisition policy. Conversely, the absence of an alarm cannot establish the absence of an event outside valid temporal and frequency coverage. Such limitations do not make the work futile. They guide a useful next test, specify the conditions in which the present record is persuasive and protect the evidential chain against later exaggeration. In this particular question, the controlled observation is two or more nominally separate receiver indications, whereas the material uncertainty concerns shared calibration dependencies, antennas, oscillators, power supplies, and reporting software. Consequently the adversarial comparison ought to include a

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deliberately independent reference path and documented perturbation of shared dependencies and its failed as well as successful outcomes. I would not advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

Edward Weston

Peer question 4 to Hendrik W. Bode

Dr Bode, the investigator may disconnect one receiver, fit a terminator, and interpret the remaining trace as a clean test of branch independence. Yet the substituted load may not resemble the operating receiver, particularly across the frequency range under examination. Dr. Atkinson's question therefore requires a distinction between a convenient control state and a physically comparable one. How would you demonstrate that a change attributed to leakage or splitter noise is not simply the consequence of altered loading? Please address a case in which the common source itself responds to the changed impedance. Would measurements at additional reference planes be necessary, and how would their own connections be prevented from changing the experiment? I am asking for a practicable hierarchy of checks, not a demand that every parasitic quantity be known exactly before any useful conclusion is allowed.

May I press the principal contributor on independence of electromagnetic corroboration between two receiving systems? Before offering an opinion about independence of electromagnetic corroboration between two receiving systems, I would define the measurand and its uncertainty. The proposed rival mechanism is that

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common-oscillator phase noise or an antenna splitter might reproduce one false feature in both streams. Consequently a calibration certificate for one nominal receiver setting does not settle the question. The more informative operation is to repeat a common-stimulus test after separating power, frequency references and physical antenna paths, with shared dependency graph, calibration offsets, correlated noise and near-threshold decisions reported in units and tied to an input reference plane. The adverse prediction is concrete: purported independent agreement fails when the common error path is removed. I would challenge it across a range of input powers and hold one independently measured source constant throughout the switching sequence. A correction estimated after seeing the unknown feature may assist an exploratory analysis; it must not be presented as though it had been fixed before acquisition. Where systematic effects share a reference, their covariance belongs in the reported uncertainty rather than being silently assumed zero. This is the distinction between an instrument number that appears stable and a defensible physical measurement. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Hendrik Wade Bode

Answer to Edward Weston

Mr Weston, the first check is to identify the loading property that matters to the proposed comparison and the uncertainty within which it must remain comparable. A nominal resistance printed on a terminator does not establish its complete complex impedance at

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every relevant frequency. The operating receiver may also present a state-dependent input response. One should therefore measure or otherwise support the admissible loading range and ask whether variation within that range could account for the observed change. The answer determines whether further characterization is necessary.

Dr. Atkinson, an additional reference-plane measurement is useful when it separates hypotheses that would otherwise remain confounded. It is not automatically benign. A coupler, probe, or adapter becomes part of the arrangement and requires its own transfer and loading assessment. The measurement plan should explain why its disturbance is acceptably small or how the disturbance enters the correction. When that explanation cannot be supported, the extra reading may create another uncertain boundary rather than resolve the first.

A practicable hierarchy begins with the existing circuit description and component characterisation, follows with a bounded sensitivity calculation, and introduces new measurements where the predicted uncertainty could alter the conclusion. Controlled substitutions should span plausible operating loads rather than merely contrast the original apparatus with an idealized termination. Repetition can then determine whether the response is stable within each declared state. These are proposed engineering controls, not a guarantee that every source can be interrogated without changing it.

The hierarchy should end when the remaining loading uncertainty is demonstrably immaterial to the particular conclusion, not when every possible parameter has been measured. The acceptance

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criterion supplies that stopping point and keeps a practical investigation from becoming an unbounded component survey.

The report should preserve what the substitution establishes. It may show that the feature depends on a branch condition without proving which internal mechanism causes that dependence. That narrower result can guide the next test. Professor Neyman, may I now return the statistical question to you: when two detection decisions share a fluctuating background or calibration state, how should their joint false-alarm probability be evaluated?

A final evidential safeguard is that a deliberately independent reference path and documented perturbation of shared dependencies. I would add the following qualification to my answer. A second instrument adds evidential force only to the extent that its error mechanisms are independent or adequately modelled. Two receivers supplied by the same antenna network can share impedance anomalies, a local oscillator reference, or a strong interfering field. If they report the same feature, the comparison is valuable but must not be represented as two independent confirmations until those common pathways are examined. Where practical, vary a reference source, a cable route or a gain state under controlled conditions, and assess whether the observed changes conform to the proposed transfer relations. In this particular question, the controlled observation is two or more nominally separate receiver indications, whereas the material uncertainty concerns shared calibration dependencies, antennas, oscillators, power supplies, and reporting software. Consequently the adversarial

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comparison ought to include a deliberately independent reference path and documented perturbation of shared dependencies and its failed as well as successful outcomes. I would not advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

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Jerzy Neyman

Agreement must be evaluated under the relevant joint model

Dr Bode, thank you. Dr. Atkinson, the probability of two false alarms is not determined by the two marginal probabilities alone. Multiplication is justified only under the relevant independence condition. Separate receiver enclosures, different programs, and separate operators do not establish that condition. A common environmental state can affect both decisions even if their private fluctuations are independent once the state is specified. The distinction between conditional independence and unconditional independence is particularly important when a validation campaign combines quiet and disturbed operating periods.

Application five supplies an explicit construction. Let Z identify a common state: quiet with probability 0.99, disturbed with probability 0.01. Conditional on Z, suppose the two detectors make independent false-alarm decisions, each with probability 0.001 in the quiet state and 0.5 in the disturbed state. The unconditional false-alarm probability of either detector is 0.99 times 0.001 plus 0.01 times 0.5, or 0.00599. Their joint probability is instead 0.99 times 0.001 squared plus 0.01 times 0.5 squared, which equals 0.00250099. Squaring the marginal probability gives only 0.0000358801. The true joint probability in this construction is about 69.7 times that product.

$$p = 0.99(0.001) + 0.01(0.5) = 0.00599$$

$$P(A \cap B) = 0.99(0.001)^2 + 0.01(0.5)^2 = 0.00250099$$

Here A and B denote the respective false-alarm events. The probabilities, including the common-state mixture, are stipulated for instruction; they are not estimates from field data. The example demonstrates how agreement can be dominated by rare shared conditions that a marginal performance

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summary conceals. Requiring both detectors to respond has reduced false alarms relative to either detector alone, but not by the factor predicted through an invalid multiplication. The fusion rule is not useless; its claimed operating characteristic was wrong.

Application six considers the case in which only the two marginal probabilities are known, both equal to 0.01. Basic probability bounds give a joint probability between zero and 0.01. The lower bound follows because probabilities cannot be negative and the sum of the marginals is less than one. The upper bound follows because the intersection is contained within each event. An independence value of 0.0001 lies inside that interval, but is only one admissible choice. Perfectly coincident false alarms achieve the upper bound; disjoint false alarms achieve the lower bound. Marginal validation alone does not select among them.

$$max\left(0, p_A + p_B - 1\right) \leq P\left(A \cap B\right) \leq min\left(p_A, p_B\right)$$

Dr. Atkinson, the natural experiment is to validate the actual fusion procedure under relevant common states, retaining paired decisions rather than only individual totals. A joint record can be analysed for coincidences, timing offsets, and the conditions surrounding them. If the operational rule allows detections within a time tolerance to count as coincident, that tolerance belongs to the tested procedure. Enlarging it after observing the events changes the experiment. So does searching many frequency tolerances and retaining the one that yields the strongest apparent agreement.

The trial population remains central. A joint false-alarm rate measured on a terminated bench input need not describe a site containing common interferers. A useful validation specifies the signal-absent condition and the

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disturbances admitted under it. Signal absent does not necessarily mean all electromagnetic input absent. The hypothesis should exclude the signal class of interest while retaining plausible nuisance processes. Otherwise the test may demonstrate rejection of private receiver noise while leaving common environmental false alarms almost unexamined.

One should also avoid treating the joint false-alarm probability as the probability that a particular event is false. Those are different conditional statements. The latter requires an inference about competing hypotheses and their prior or sampling context; it does not follow from a detector operating characteristic alone. The report can state the tested rate and the conditions supporting it without assigning an unsupported probability to source attribution. That restraint is especially necessary when the observed event prompted changes in the procedure that were not represented in validation.

Paired validation should retain detections in which only one branch responded, not merely the coincident subset. Those discordant outcomes help identify coverage, sensitivity, and timing differences. Removing them before estimating performance changes the population to one selected for agreement. Similarly, a detector disabled during a shared disturbance cannot contribute a negative decision as though it had remained valid. Joint outcomes should include the acquisition state needed to determine which decision combinations were possible, and uncertainty about that state should remain visible rather than being filled with convenient zeros.

Dr. Atkinson, I would frame the problem as follows. There is a statistical difficulty in the assertion concerning independence of electromagnetic corroboration between two receiving systems: we have not yet ruled out the

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possibility that common-oscillator phase noise or an antenna splitter might reproduce one false feature in both streams. The investigation should record its chosen detector threshold, visit schedule, selection of frequencies and expected failure modes before the prospective confirmatory test. To examine the difference we should repeat a common-stimulus test after separating power, frequency references and physical antenna paths, collecting shared dependency graph, calibration offsets, correlated noise and near-threshold decisions over a predeclared range rather than selecting the most attractive subset afterward. An observation in which purported independent agreement fails when the common error path is removed would strengthen a restricted causal account, but it cannot certify every unvisited frequency-time interval. I would state which recordings are dependent, which have been excluded as invalid, and which inferences rely upon a model of rare events or stationary interference. A numerical interval can have impeccable arithmetic and still misdescribe the physical world if its sampling population was chosen because the signal already looked unusual. We should therefore preserve exploratory leads separately from independently designed validation evidence.

Finally, finite paired trials create uncertainty about the joint rate. An absence of observed coincidences is evidence under the trial model, not proof that coincidences are impossible. Dependence across repeated trials can reduce the information in their count, just as dependence between receivers changes the information in their agreement. Mr Pearson, may I invite you to challenge how the proposed joint validation should handle a common-state mechanism that is suspected but not directly recorded?

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Egon Sharpe Pearson

Peer question 5 to Jerzy Neyman

Professor Neyman, the common-state example is persuasive because its state labels and probabilities are supplied. In an actual record the investigator may see clustered coincidences without a logged disturbance that explains them. Fitting an unobserved mixture afterward could describe the data, but many mixtures might do so. How should the laboratory use such a model without mistaking explanatory flexibility for identified mechanism? Please distinguish an empirical estimate of the joint false-alarm rate from a causal account of why the false alarms coincide. Also consider a threshold selected after inspecting these clusters. Can the same observations then establish the revised procedure's operating characteristic, or should they be treated as development data? I would welcome a concrete account of what remains reportable when no unique hidden-state interpretation is justified, yet the original independence assumption has clearly ceased to be credible.

May I press the principal contributor on independence of electromagnetic corroboration between two receiving systems? I should distinguish the physical occurrence under inquiry from the information actually retained when studying independence of electromagnetic corroboration between two receiving systems. Because common-oscillator phase noise or an antenna splitter might reproduce one false feature in both streams, more than one historical account may produce the same saved trace. The controlled comparison should be to repeat a common-stimulus test after separating power, frequency references and physical antenna paths, preserving shared dependency graph,

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calibration offsets, correlated noise and near-threshold decisions at the measurement point and in the evidential metadata. If purported independent agreement fails when the common error path is removed, that result would narrow the admissible explanations, not establish a uniquely identified emitter outside the tested conditions. A subsequent software reconstruction may recalculate a statistic from retained samples, yet it cannot recover components rejected by the front-end filter or intervals never recorded. I would make those distinctions explicit in the final report and invite an independent examiner to reproduce the challenge, including its failed steps. Scientific restraint is not a weakness of the investigation. It prevents a detector output, however striking on the screen, from becoming a claim about unobserved activity that the original measurement never established. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Jerzy Neyman

Answer to Egon S. Pearson

Mr Pearson, the paired observations can support an empirical description of joint decisions even when their causal mechanism is unresolved. That description should retain the uncertainty appropriate to the actual sampling plan and dependence across trials. A fitted latent-state model may help formulate further tests or interpolate within a justified regime, but a satisfactory fit does not identify the physical state uniquely. The report must separate

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observed clustering, the statistical representation adopted, and the causal explanation proposed for it.

Dr. Atkinson, the inability to name the common cause does not restore an independence assumption contradicted by the paired record. One can replace the product calculation with directly estimated joint performance for the specified population, or report bounds where the data do not support a precise estimate. What cannot be justified is selecting a convenient latent model solely because it supplies a reassuring tail probability, while concealing other models that fit the observations comparably well and imply different risks.

Changing the threshold after studying the clusters belongs to development. The same records remain informative about what motivated the change, but an independent assessment should test the resulting frozen rule. Its operating characteristic may differ from the apparent performance on the data used to choose it. A sound record preserves the earlier rule, the selection procedure, and the new rule, making clear which observations evaluated which version. The requirement concerns the inference, not an administrative preference for separate file names.

The validation set should include complete paired outcomes, including discordance and invalid acquisition, under its declared sampling plan. A catalogue containing only retained coincidences cannot estimate how frequently the fusion rule failed or how often it had a valid opportunity to decide.

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Further experiments should seek measurements capable of separating candidate causes: common reference behaviour, branch coupling, environmental activity, or a shared reference estimate. They need not resolve every mechanism before the laboratory reports the observed joint behaviour. An honest unresolved cause is preferable to a falsely precise explanation. Dr Shewhart, may I invite your account of arranging those experiments so that receiver changes are not systematically entangled with time, temperature, or operator sequence?

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Walter Andrew Shewhart

Corroboration requires a comparison design, not merely repeated agreement

Professor Neyman, thank you. Dr. Atkinson, the experimental plan should make the comparison of interest possible before the observations arrive. If one receiver is tested only in the morning and another only in the afternoon, a difference between their results cannot be assigned uniquely to the receiver. If a suspect shared component is present in every warm run and absent in every cool run, component and temperature effects are similarly entangled. Repeating each arrangement many times can estimate the corresponding combined effect precisely while leaving the desired separation unavailable.

A useful design identifies the primary change and the nuisance conditions that can plausibly alter its result. Conditions that can be held sufficiently comparable may define blocks within which the primary alternatives are exercised. Randomisation can help prevent remaining variations from being systematically assigned to one alternative. These principles are described in the NIST treatment of randomized block designs. Their application here is a proposed receiver experiment, not a claim that a statistical design can eliminate unmeasured physical interactions. [M4-3]

Application seven demonstrates the problem with invented measurements in arbitrary but consistent indication units. Receiver A produces 8 and 9 in one period; receiver B produces 12 and 13 in a later period. The difference of means is four units. Under an additive model in which the later period adds five units independently of receiver, the receiver effect B minus A would instead be minus one unit. The original design does

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not determine which decomposition is correct. Four is an observed contrast between receiver-and-period combinations, not an identified receiver effect. Neither sample mean is arithmetically wrong; the attribution is unsupported.

Now consider application eight. Exercise both receivers in each of three blocks and stipulate negligible within-block change and an additive block effect. The paired readings are A = 10, 20, 30 and B = 12, 22, 32. Each within-block difference is two units, so their average is two. The block levels vary substantially, yet the contrast is invariant in this constructed model. Compare this with taking A only from the first block and B only from the third: the apparent difference would be 22 units. Pairing has supplied the comparison that the latter selection cannot provide. It has not proved that real receiver effects are additive or that a block can be made arbitrarily long.

$$\bar{d}=\frac{(12-10)+(22-20)+(32-30)}{3}=2\,units$$

Dr. Atkinson, a switching experiment introduces its own dynamics. Changing a path can alter impedance, control state, or settling, so the accepted observation interval should be specified for each transition. Alternating rapidly is not automatically superior to slower blocked operation. The choice must preserve the quantity under comparison. If the source itself changes faster than the switching experiment can resolve, simultaneous observation may be needed, with the common network's limitations explicitly assessed. The design has to respect the physical time scales rather than treating run order as a purely statistical abstraction.

Interactions deserve attention because they can make the desired attribution state-dependent. Removing a shared amplifier may improve one

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receiver's result but degrade another's because their downstream noise contributions differ. A test that averages over both receivers without retaining the interaction can conceal this behaviour. A complete factorial experiment may be impracticable, but a reduced design should state which effects are confounded and which negligible-interaction assumptions permit the proposed interpretation. The NIST discussion of fractional designs makes that trade-off explicit; our receiver plan must identify its own relevant factors rather than borrow the language without the design. [M4-4]

The record should preserve failures and unusable states as outcomes, not simply remove them from the comparison. If one arrangement cannot sustain valid acquisition during a disturbance, that loss is part of its operating performance. Restricting the analysis to intervals where both arrangements behaved well may answer a useful conditional question, but it does not answer which arrangement provides better overall coverage. The analysis population should be declared, and any exclusions should retain their physical reasons and their effect on the question being asked.

A useful record distinguishes the planned allocation from the allocation actually executed. Failed transitions, reordered runs, and interrupted blocks can destroy the balance assumed in the analysis. Their occurrence need not invalidate every observation, but the final model must follow the executed experiment. Reproducing the planned schedule in a report while silently analysing a different sequence would confer design properties that the data do not possess.

There is also a practical limit to precision. Additional repeats cannot compensate for a contrast that the design never isolates. Conversely, a carefully selected small set of interventions can establish a limited but

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valuable fact without characterizing every possible source of variation. The objective is to create observations whose competing explanations differ, then measure those differences with suitable controls. Dr Bridgman, may I invite your challenge concerning whether swapping components preserves the same measurand, or inadvertently changes the physical question we intended to investigate?

Percy Williams Bridgman

Peer question 6 to Walter A. Shewhart

Dr Shewhart, thank you. Your design assumes that the measurements being compared continue to represent the same intended quantity. Yet changing an antenna network, an input impedance, or a filter may change which physical field components reach the receiver and how the specified quantity is realized. A well-balanced experiment could then estimate the effect of changing the measurement definition, rather than isolate an error in a common definition. How would you distinguish these possibilities? Please consider a proposed independence test that replaces a shared antenna distribution system with two different antennas. The new arrangement has less shared electronics but different spatial and polarization responses. What can its agreement establish, and what would its disagreement leave unresolved? I ask how the experimental plan should carry the measurand across this change without pretending that the two physical arrangements are identical.

May I press the principal contributor on independence of electromagnetic corroboration between two receiving systems? I am concerned with independence of electromagnetic corroboration between two receiving systems. The unresolved alternative is that common-

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oscillator phase noise or an antenna splitter might reproduce one false feature in both streams. I should therefore separate the physical input from its representation on the receiver display. Let us repeat a common-stimulus test after separating power, frequency references and physical antenna paths, ensuring that the operator records shared dependency graph, calibration offsets, correlated noise and near-threshold decisions. The anticipated discriminating observation is that purported independent agreement fails when the common error path is removed. A failure of this test would not compel us to accept a more dramatic transmitter hypothesis; it would instead mean that our proposed transfer-path model is incomplete. I would retain the measured contrary result and identify the exact connector, stimulus, receiver settings and elapsed intervals in the report. Such a procedure has a modest but valuable result: it converts an initially persuasive visual indication into an experimentally bounded account of what could have produced the retained data. Our duty is not to force agreement but to specify which physical explanations are still consistent with the recorded state. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Walter Andrew Shewhart

Answer to Percy Williams Bridgman

Dr Bridgman, the distinction must be written into the experiment before its results are compared. A substitution may preserve the intended measurand while changing the measurement method, or it may create a different measurand. If the target is terminal power at a

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specified connector, replacing the antenna system can change the input itself. If the target is evidence of an emission within a defined region and interval, differently situated antennas may supply complementary observations, but their amplitudes need not agree. The inference must follow the question actually common to the arrangements.

Dr. Atkinson, in the proposed example, agreement could support the presence of a feature through two distinct reception paths after their frequency and time mappings have been established. It does not automatically establish equal field strength, common polarization, or a unique source position. Disagreement may arise from the antenna responses or propagation as well as from the shared electronics being tested. These alternatives should be specified rather than allowing whichever explanation favours the investigator's initial expectation to be chosen afterward.

One approach is to separate the experiment into narrower comparisons. Characterise the receiving paths with appropriate references, preserve the observations at their own declared boundaries, and test a proposition for which the expected relationship is supported. That relationship might concern timing or frequency rather than amplitude. A separate conducted test can examine the electronics without pretending to reproduce the full radiated path. The different tests then constrain different parts of the causal account.

A disagreement can therefore be productive when it identifies the boundary at which the two measurement definitions diverge. The

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appropriate next step is to test that divergence, not to average the incompatible readings into a fictitious common quantity.

No balance of run order cures a mismatched measurement definition. Design and metrology must agree about the quantity being compared. Their collaboration is what gives a statistical contrast physical meaning. Sir Karl Popper, may I invite your examination of the remaining inferential question: after a comparison excludes one shared-path explanation, how should its result be stated without implying that all alternatives have been eliminated?

I thank the questioning colleague for that important distinction. The chronology of independence of electromagnetic corroboration between two receiving systems is indispensable. Assume for a moment that common-oscillator phase noise or an antenna splitter might reproduce one false feature in both streams. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should repeat a common-stimulus test after separating power, frequency references and physical antenna paths, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs shared dependency graph, calibration offsets, correlated noise and near-threshold decisions. If purported independent agreement fails when the common error path is removed, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the

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opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

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Sir Karl Raimund Popper

A corroborated proposition must remain narrower than the explanations not tested

Dr Shewhart, thank you. Dr. Atkinson, the most useful conclusion may be a carefully bounded proposition rather than an impressive attribution. If a feature persists after replacing one suspected component, that observation challenges an explanation requiring that component under the tested conditions. It does not establish that the feature originated from an independent transmitter, still less identify an owner or intention. The experiment has altered one part of the explanatory landscape. Its success should be expressed through that alteration, not through a leap to an explanation whose alternatives were never exposed to the test.

For application nine, consider three explicitly constructed hypotheses about a spectral feature. Hypothesis E assigns it to an input common to both receivers; hypothesis S assigns it solely to a particular shared distribution element; hypothesis R assigns it solely to receiver one's private chain. Suppose all three predict the original detection at receiver one, but only E and S predict a detection at receiver two. Observing the second detection excludes R within this stipulated deterministic prediction model. Two hypotheses remain. Repeating the same two-receiver configuration a hundred times, with the same predictions and no added model of stochastic error, does not distinguish E from S. The number of matching records is not the number of independent explanations eliminated.

A second intervention now removes the specified distribution element while preserving an independently verified path for the input feature. Stipulate that E predicts continued detection and S predicts its absence.

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Continued detection rejects S within this model, leaving E among these three hypotheses. The qualification among these three is indispensable. An omitted common disturbance or an incorrect transfer assumption might still require examination. This example works through a finite prediction table in words; it does not assign invented probabilities to hypotheses. Its force is logical and conditional upon the stated predictions, including the validity of the replacement path.

Application ten shows why apparently corroborating numerical results need not possess overlapping uncertainty intervals. Let two stipulated bounds for the same scalar quantity be the closed intervals [9, 11] and [10, 12] in microvolts. Their intersection is [10, 11]. If both bounds are valid deterministic constraints on the same quantity, the intersection is the admissible set satisfying both, and it is narrower than either. Replace the second interval with [12, 14]; the intersection becomes empty. One cannot repair the contradiction by averaging the centres and silently reporting 11.5. At least one bound, the shared-quantity assumption, or another premise needs reconsideration.

These are bounds, not confidence intervals. Intersecting two confidence intervals does not automatically preserve either interval's stated coverage probability. That would require a joint statistical argument. The example concerns the logic of simultaneously asserted constraints and the discipline required when they conflict. It also clarifies that agreement can mean several things: similar estimates, overlapping uncertainty regions, compatible hypothesis predictions, or reproducibility of a processing result. A report should identify which sense is intended instead of sliding between them.

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Dr. Atkinson, a test can be severe for one explanation and weak for another. The proposed intervention is informative only if the explanation challenged would ordinarily predict a distinguishable outcome under it. A nominal component replacement that preserves an unrecognised common coupling may not challenge the mechanism the investigator imagines. This is why the technical accounts offered by my colleagues are not optional decorations to the argument. They determine whether the intended counterexample was physically possible and whether a failure to observe it has any discriminatory force.

The report should also preserve unresolved disagreement. One investigator may consider a common-path alternative insufficiently tested while another judges the remaining uncertainty immaterial to a limited detection claim. Those positions can coexist if the propositions differ. The useful response is to state the claim each accepts, the premise each disputes, and an observation that could narrow the disagreement. Compelling everyone to endorse a broad phrase such as independent confirmation conceals rather than resolves the issue.

There is no contradiction between demanding a severe test and acknowledging uncertainty in its predicted outcome. A physical prediction usually occupies an admissible range rather than one exact number. The challenge is to state that range before the result is interpreted and explain how it follows from supported assumptions. Expanding it afterward solely to accommodate every result deprives the test of discrimination. Conversely, rejecting an explanation because of a discrepancy smaller than its admitted uncertainty gives numerical difference more significance than the experiment supports.

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I would therefore ask for a conclusion that names the tested alternatives, the observation that challenged each, and the alternatives still compatible with the record. It should distinguish empirical support from the adoption of an operating decision. A laboratory may act cautiously on an unresolved candidate without claiming to have proved its source. That distinction protects both scientific candour and practical judgement. Mr Hartley, may I invite your final challenge concerning whether a compressed corroboration summary preserves enough information for another examiner to reconsider those alternatives?

Ralph Vinton Lyon Hartley

Peer question 7 to Karl R. Popper

Sir Karl, a final report cannot reproduce every sample and every unsuccessful trial. It must compress the record into a statement that a reader can understand. Yet compression can erase precisely the distinctions you require: the branches that share a reference, the intervals excluded from comparison, or the hypotheses that predicted identical results. What should a concise corroboration claim retain in its visible text, and what can properly remain in linked supporting material? Please distinguish omission for readability from omission that changes the meaning of the conclusion. An expert reviewer may consult detailed files, whereas another decision-maker may read only the summary. How can the same report serve both without offering the latter an apparently categorical attribution that the former would discover to be heavily qualified? I ask for an evidential structure, not simply a recommendation to attach more pages.

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Professor, the proposal to treat two receiver readings as independent corroboration needs a more demanding physical test. Suppose both receivers share one rooftop antenna through a common distribution amplifier, and the amplifier itself oscillates briefly when a nearby high-power transmission begins. The two downstream displays may show remarkably similar narrowband events, yet their agreement would have arisen before the signal paths separated. How would your proposed corroboration test distinguish this common-mode artefact from a field emitter? I would ask you to compare simultaneous measurements through electrically separate antennas, independent power supplies and independently characterised front ends, while preserving a shared timing standard only where its own uncertainty is documented. Would you regard agreement in absolute frequency and onset time as sufficient, or require an intervention that changes one receiver chain without changing the electromagnetic environment? Finally, how should a forensic report describe dependence when some of those shared components cannot be removed without altering the original observation conditions?

Sir Karl Raimund Popper

Answer to Ralph V. L. Hartley

Thank you for that question. Mr Hartley, the visible conclusion should retain every qualification necessary to prevent a materially different proposition from being inferred. The measured feature, the interval and reference boundary, the tested basis for corroboration, and the principal unresolved alternative belong in that account when they limit its meaning. Detailed settings, calculations, and complete

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records may reside in identified supporting material. Their location should permit a reviewer to reconstruct the argument without searching an undifferentiated archive. Brevity is compatible with precision when it preserves the logical structure rather than merely the favourable outcome.

Dr. Atkinson, a useful summary might state that the feature was observed through two separately characterised receiver branches, survived a specified shared-component substitution, and remains unassigned to a physical source. That is stronger than saying only that an unexplained line appeared, but narrower than saying that an external covert transmitter was confirmed. The specific wording must follow the actual tests; this is an illustrative structure, not a prescribed conclusion for an unperformed investigation. Its limitations are visible rather than relegated to a footnote that reverses the headline.

Supporting material should distinguish observations, transformations, and judgements. Provide stable references to the relevant records and state the version of the analysis. Preserve adverse results and excluded intervals when they affect the scope. A reviewer should be able to determine which premises are documented, which are model assumptions, and which remain disputed. The report need not display every intermediate number to accomplish that task, but it must not make the argument impossible to inspect.

An evidence map can serve both audiences: one short statement of each tested proposition, its supporting record, and its principal

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qualification. Its purpose is to preserve the route of reasoning, not to replace the measurements with another unexplained score.

The decision-maker who reads only the summary should receive the same proposition as the specialist, though not every derivation supporting it. If the shortened version asserts more, it is not a summary but a different claim. Professor Atkinson, I return the floor to you for the closing account of what this discussion establishes about independent corroboration and what it deliberately leaves unresolved.

Hendrik Wade Bode, Cross-Peer Question to Jerzy Neyman: Professor Neyman, I should like to test the statistical meaning of a cross-spectrum that becomes unexpectedly small. In a constructed pair of channels, a desired common process contributes positive cross-power, while a splitter's thermal contribution is anti-correlated between the outputs. Their signed contributions can oppose one another. An average near zero may therefore arise even though neither process is negligible. If we select only the most reassuring frequency bins or average away the phase, we risk mistaking cancellation for independent confirmation that nothing was present. What inferential model would you require before calling the two instruments independent corroborators, and how would you compare results before and after changing the splitter without treating that change as if it had no other physical consequences?

Jerzy Neyman, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, an estimated cross-spectrum is a statistic with a joint sampling distribution and a physical measurement model, not a self-evident count of corroborating witnesses. One must retain its complex value, averaging convention and

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estimator uncertainty, and explain what positive and negative contributions are permitted by the circuit. Failure of a test against zero does not prove that every constituent signal vanishes, particularly when an opposing contribution can cancel it. I should require a declared model under the null and relevant alternatives, then an intervention which changes the suspected common-path contribution in a known or bounded way. A revised splitter, isolator or termination may change insertion loss and impedance match as well as its noise behaviour, so the before-and-after comparison requires its own transfer measurements. Repeated records taken through the unchanged splitter are useful observations, but their number cannot convert the same unresolved model error into independent evidence. The educational illustration is consistent with published NIST work on splitter-induced cross-spectral collapse; it is not a historical statement by either of us.

Walter Andrew Shewhart, Cross-Peer Question to Percy Williams Bridgman: Professor Bridgman, a validation committee has two spectra from separate receivers but only one calibration laboratory, one ambient-temperature record and one reference oscillator. It wishes to call the records independently measured, while its traceability file cannot separate receiver-specific correction errors from the common calibration source. How would you define the operation which the adjective independent is meant to describe? More importantly, what additional experiment would disclose whether apparent agreement survives a genuinely different calibration path, without changing so many experimental conditions that one cannot tell which difference caused the result?

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Percy Williams Bridgman, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, I would begin with an operational distinction. Separate digitiser boards do not constitute independent metrological evidence for every proposition if they inherit the same uncertain reference. Specify whether the inquiry concerns a frequency coordinate, an amplitude at a named terminal, a detection decision or the alleged origin of the emission. For each, draw the chain of instruments and corrections actually used. Then vary one suspected dependency at a time, or use a planned comparison whose combinations of reference, receiver and date can separate the effects. A second traceability route, a different physical transfer path, and an unchanged check artefact can reveal a bias concealed by the shared reference; however, none provides magical independence if it merely repeats the same calibration assumption. The result should state precisely which uncertainty terms were independently constrained and which covariance terms remain. That is a stronger report than a categorical assurance issued because two displays look alike.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, suppose the laboratory keeps two separately named recordings, derived from different receiver cards. A common timing daemon writes the sample-rate label to both containers; the cards are not phase locked, and the daemon has recorded a nominal rate rather than the actual realised rate of either card. A downstream program nevertheless aligns their spectral peaks on an apparently identical hertz scale. The two files are independent in storage, yet their displayed coordinates may share a software assumption. What information has genuinely been corroborated, and what acquisition

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record must survive before the match can be promoted from a numerical coincidence into a physical frequency comparison?

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, storage duplication and instrument diversity support different claims. The two raw sample sequences may represent distinct conversions of an external field, provided their analogue input paths and actual acquisition states warrant that description. The numbers assigned to their spectral axes are nevertheless conditional on the clock model and metadata. If the common daemon supplies one unsupported sampling frequency, agreement of displayed hertz values does not validate the physical rate. Preserve each card's native sample index, measured or independently bounded clock rate, timestamp origin, analogue preselection and any digital resampling history. Where absolute timing is uncertain, compare invariant or directly measured quantities and disclose the uncertainty instead of forcing coordinates to agree. A deliberately different clock or independently checked frequency reference may distinguish a common labelling error from a physical signal, but the comparison must retain its changed response and uncertainty. Two separately hashed files prove file identity at most. The dependency graph, not the number of file names, establishes the scope of corroboration.

Sir Karl Raimund Popper, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, let us confront a receiver pair which agrees perfectly until the investigator changes the splitter termination, after which the disputed narrow feature disappears. One interpretation is that the first observation was a splitter artefact; another is that the termination altered the impedance environment, so a genuine input became too weak to detect. A

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third is that the changed arrangement drove a different mixer or amplifier state. Which adverse comparison is capable of putting these alternatives at risk rather than simply exchanging one unverified explanation for another, and what evidence should remain in the record when the proposed falsification yields an ambiguous outcome?

Hendrik Wade Bode, Cross-Peer Answer to Sir Karl Raimund Popper: Sir Karl, the experiment should be designed as a system identification problem before it is used as a verdict. Measure the forward gain, return loss, isolation, noise contribution and operating state under both terminations, so far as practicable over the relevant frequency and power conditions. Apply a known independent challenge through a declared injection plane and demonstrate that a comparable small signal remains observable after the change; check that the reference stimulus is not coupled through the suspect path. If the feature vanishes while the known challenge survives and the altered dependency is measured, a shared-path explanation gains support. If both vanish, the experiment has not discriminated between artefact and sensitivity loss. If clipping or intermodulation changes, that alternative must be modelled rather than ignored. Retain the pre-change samples, control measurements, negative controls, configuration and exact timing. The appropriate conclusion may be that the present evidence cannot distinguish the causes. A disconfirming test is valuable only when its own physical opportunity to reveal a failure is supported.

Dr. James M. Atkinson

Closing synthesis

Professor Wiener, Dr Bode, Professor Neyman, Dr Shewhart, and Sir Karl Popper, thank you. Our discussion establishes that a second trace is an

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additional observation only in a specified sense. It may supply independent computation, another branch of a shared acquisition network, or a substantially different physical measurement. Those contributions have different evidential reach. The correct description identifies the boundary at which diversity entered and the alternatives that the comparison could distinguish. It does not count screens, receiver enclosures, or software packages as interchangeable units of independent evidence.

The ten constructed applications make the limitations concrete. A common error survives averaging while disappearing from a difference. Oppositely coupled contributions can cancel in a cross statistic, and leakage can create correlation without the separate external source imagined by the observer. Conditional independence within a known operating state does not imply independence after states are mixed. Marginal false-alarm probabilities do not specify their joint probability. A receiver comparison entangled with time or another nuisance condition may estimate a combined effect rather than the intended one. Finally, repeated observations that leave two hypotheses making identical predictions cannot resolve their disagreement merely through repetition.

These conclusions do not diminish the value of multiple receivers. They identify how that value should be developed. Characterise the shared and private paths; preserve frequency and time mappings; compare the actual fusion rule under relevant conditions; and design interventions whose competing predictions differ. A common input can be useful for testing branch differences, provided it is not then treated as independent evidence of the common input's accuracy. A changed antenna can supply

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complementary reception, provided the different spatial response is not mistaken for an electronic calibration error.

The panel has also preserved several unresolved matters. No universal criterion for independence was proposed, because the required independence depends upon the claim and the model. No probability of source identity was inferred from the joint false-alarm rate. No specific receiver was certified by the hypothetical calculations. The physical cross-spectrum literature supplies a demonstrated mechanism, not an accusation against every apparatus. These boundaries are part of the result, not reasons to abandon useful measurement.

A useful acceptance record would also preserve discordant outcomes, invalid intervals, and the uncertainty of corrections common to both branches. These are not embarrassing exceptions to be removed from a corroboration story. They identify where the story is conditional and where another test could add information. The resulting account can be decisive about a limited proposition without pretending to be final about every possible source.

For practice, the report should carry a compact dependency account: what was shared, what was changed, what was measured independently, and what remained observationally equivalent. Its headline and technical appendix must support the same proposition. A bounded statement that a feature survives specified challenges is more informative than an unqualified assertion of independent confirmation. Our next question turns from agreement to deliberate challenge: how should a validation campaign be designed so that its successes, failures, and exclusions genuinely test the claim the investigator intends to make?

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Ten worked engineering applications | Question 004

Application 01. Difference between two instruments relative to stated uncertainty

In the illustrative 004.01 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. The paired instrument contrast is $\Delta = 1.500$ dB. Set independent standard uncertainties $u_1 = 0.460$ dB and $u_2 = 0.370$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.590$ dB, giving the dimensionless ratio $\Delta/u\Delta = 2.541$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The contrast supports a calibrated difference estimate, but its evidential interpretation requires a model for shared uncertainty.

Application 02. Combined and expanded measurement uncertainty

In the illustrative 004.02 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. For independent standard-uncertainty contributions 0.73, 0.48 and 0.40 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.73^2 + 0.48^2 + 0.40^2)} = 0.961$ units. Using an illustrative coverage factor $k = 2$ gives expanded uncertainty $U = 2u_c = 1.922$ units. The quoted coverage factor remains illustrative until the distributional assumptions and desired coverage probability are established.

Application 03. Family-wise probability when many candidates are searched

In the illustrative 004.03 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. If each of $M = 193$ independent pre-specified search

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opportunities has false-alarm probability $\alpha = 0.0011$, the probability of one or more false positives is $1 - (1 - \alpha)^M = 0.19137$, or 19.14%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. The family-wise figure concerns pre-specified independent opportunities, not an uncorrected sweep of dependent spectral bins.

Application 04. Observed exposure fraction of a channel scanner

In the illustrative 004.04 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. Let the channel be observed on $n = 194$ valid visits, each lasting $d = 13$ ms, with revisit spacing $R = 1.00$ s. Valid exposure is $nd/1000 = 2.522$ s across the nominal interval $nR = 194.00$ s. The observed fraction of elapsed time is therefore 1.30%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. Such sparse temporal access cannot independently corroborate a claim of continuous reception.

Application 05. Stored-sample volume and the limits of retrospective analysis

In the illustrative 004.05 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. With complex sample rate $f_s = 6$ MS/s, duration $T = 27$ s, and 16-bit in-phase plus 16-bit quadrature integers, the raw payload is $f_sT \times 4$ bytes = 648,000,000 bytes, or 0.648 GB (decimal). The calculation excludes timestamps, metadata, framing and file-system overhead.

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Maintaining a wideband buffer of this capacity does not establish that upstream analogue clipping was absent. An archive size establishes storage burden, not independent analogue acquisition or freedom from clipping.

Application 06. Accumulated sample-clock time error

In the illustrative 004.06 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. A free-running sample clock with fractional rate error ε = 1.100 ppm over T = 342 s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T$ = 0.3762 ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. Agreement of timestamps cannot establish independent clock accuracy when both receivers share a reference error.

Application 07. Preserved sample continuity across an acquisition interval

In the illustrative 004.07 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. A converter expected to retain f_s = 1.90 million samples/s for T = 1.35 s should supply $f_s T$ = 2,565,000 complex sample instants. If 125 sequence positions are missing, the retained count is 2,564,875 and loss fraction is 0.00487%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block must therefore be preserved. Sample-continuity evidence must be linked to the exact disputed event interval in each receiver.

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Application 08. Cascade gain and observed headroom

In the illustrative 004.08 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. A first amplifier contributes G_1 = 13 dB, an intentional attenuation contributes G_2 = -3 dB, and a later stage contributes G_3 = 14 dB. The small-signal sum is 13 + (-3) + 14 = 24 dB. For P_i = -70 dBm, the ideal output is P_o = -46 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The summed small-signal gain must be supplemented by stage-by-stage compression and common-path checks.

Application 09. Opportunity-limited detection under independent visits

In the illustrative 004.09 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. For n = 45 genuinely independent valid observation opportunities, each with stipulated event detection chance p = 0.06, the probability of no detections is $(1 - p)^n$ = 0.06177; its complement is 93.82%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The calculated capture probability cannot be transferred to phase-locked revisit schedules without a different event model.

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Application 10. Thermal reference noise in a declared measurement bandwidth

In the illustrative 004.10 test, two receivers apparently corroborate one spectrum feature although their power supplies and input splitter are shared. Take the equivalent noise bandwidth B = 13,500 Hz and calibrated noise figure NF = 3.75 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -128.95$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The noise estimate constrains a declared reference condition, not the presence or absence of an environmental emitter.

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QUESTION 005

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What makes a receiver challenge test capable of revealing a material failure?

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Constructed educational dialogue. Numerical cases are hypothetical, not instrument certifications.

Dr. James M. Atkinson

Opening question

Mr Weston, can you comment on what makes a receiver challenge test capable of revealing a material failure, rather than simply reproducing a favourable demonstration? We have discussed measurement boundaries, acquisition history, and the qualified meaning of corroboration. The next task is to design an experiment whose success would justify a specified claim. That task begins before a reference generator is connected. The investigator must identify the signal class, input boundary, operating conditions, decision rule, and failure criterion. Without those definitions, a collection of impressive detections can remain detached from the proposition it is offered to establish.

Consider a hypothetical receiver intended to discover weak, intermittent emissions while stronger legitimate activity occupies other portions of its admitted band. A laboratory demonstrates repeated detection of a continuous carrier in a quiet condition. The demonstration is genuine, but it does not reproduce every element of the intended task. A second test introduces bursts whose starting times are synchronized with the receiver's observation windows. A third changes the threshold until all selected

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examples are recognized. We must distinguish what each test actually establishes from the broader capability that an enthusiastic reader might infer.

Mr Weston will begin with the physical challenge and the location at which the reference enters the chain. Dr Shewhart will examine the composition of the trial population and the distinction between a stable laboratory procedure and representative operating conditions. Professor Neyman will explain what finite trials can establish about a detection probability, including simultaneous requirements across several conditions. Mr Pearson will then compare alternative procedures and distinguish an operating characteristic from the probability that a particular alarm represents a signal. Sir Karl Popper will examine whether changing or restarting the experiment after an unfavourable outcome has removed its capacity to test the original claim.

Our numerical applications use deliberately constructed observations and probability models. They are not evidence that a particular instrument achieves the calculated performance. The purpose is to expose choices that often remain invisible: the phase of a burst relative to a scan, the weights assigned to easy and difficult trials, the number of conditions claimed simultaneously, and the selection of successful experiments from a larger history. A test can be arithmetically correct and nevertheless answer a different question from the one printed in its conclusion.

The panel should also identify a practicable stopping rule. Validation must not require exhaustive knowledge of every conceivable electromagnetic circumstance, but neither may it certify an unlimited claim from a narrow demonstration. We need a declared operating envelope,

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explicit exclusions, and evidence sufficient for the conclusions actually required. Failures should produce diagnostic information and justified restrictions rather than disappear during revision of the summary. Mr Weston, may I invite your account of a physical challenge that preserves the intended measurand and provides a real opportunity for the receiver to fail?

A further constraint follows from designing receiver challenge tests that can reveal material failures. A useful adverse control changes a physical component while leaving the hypothesised emitter unchanged. It should predict an observation which is different under the leading alternative explanation. The investigator must record the condition preceding and following this intervention, since receiver recovery and retuning can mimic a source transition. A failure to obtain the anticipated difference should remain visible, rather than being removed as a supposedly unsuccessful measurement. This is the point at which a plausible narrative is converted into a proposition capable of being tested, revised or rejected by another laboratory. At the close of this discussion I would require the published conclusion to identify test coverage, detection probability, observed failures, and conditional error bounds and explain which claims remain untested because operating regions never exposed to the chosen challenge. Such candour is not weakness but the condition under which this roundtable can inform a rigorous TSCM investigation.

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Edward Weston

The challenge must traverse the part of the instrument being claimed

Dr. Atkinson, thank you. A reference stimulus is informative only about the path it actually exercises. If it enters after the vulnerable input amplifier, its successful detection cannot establish that amplifier's ability to preserve a weak signal during a strong disturbance. If it is introduced through a different filter state from the field acquisition, its amplitude calibration does not automatically apply to that acquisition. The first requirement is therefore a physical account of the connection, loading, admitted bandwidth, and receiver state. The experiment should make the uncertain mechanism observable rather than arrange for the reference to bypass it.

Application one concerns time coverage, a property easily concealed by a synchronized demonstration. Suppose a receiver observes a particular band for a window of length L = 10 milliseconds in each cycle of duration T = 100 milliseconds. A burst has duration d = 5 milliseconds, and its start is uniformly distributed over one cycle. Assume d and L are positive, d is no greater than L, and their sum is less than T. For any positive temporal overlap, the admissible start interval has length L plus d, so the overlap probability is 0.15. To retain the whole burst, its start must lie within a window of length L minus d, giving probability 0.05. These are geometric opportunities, not detection probabilities that include noise, settling, or triggering error.

$$P_{overlap}=\frac{10+5}{100}=0.15\,,P_{full}=\frac{10-5}{100}=0.05$$

Now synchronize every test burst to begin two milliseconds after the observation window opens. The entire five-millisecond burst lies inside the

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window on every trial. Repeated success is consistent with a perfect result for that phase condition, yet it does not establish either a fifteen-per-cent overlap opportunity or a five-per-cent full-capture opportunity for independently timed starts; those follow from the different uniform-start experiment. A report must preserve the distinction. A test source that always supplies the favourable timing can conceal an acquisition limitation without producing a single false numerical result.

Application two concerns a calibration model. Let u denote a dimensionless input coordinate running from zero to one, and let v denote a dimensionless output. Two proposed transfers are $v_1 = 2u$ and $v_2 = 2u + 4u(1 \text{ minus } u)$. Both give zero at u = 0 and two at u = 1. At u = 0.5 the first gives one while the second gives two. Thus two endpoint observations cannot distinguish the transfers. The second expression is a constructed counterexample, not a model asserted for an actual receiver. It proves that agreement at the selected calibration points does not by itself establish the assumed relationship between them.

$$v_1(0.5)=1, v_2(0.5)=1+4(0.5)(0.5)=2$$

Dr. Atkinson, these examples share a practical lesson. The selected reference conditions can leave the relevant failure mode untested. An engineer should therefore ask what variation would expose that mode. For timing, vary the event's relation to the observation schedule and record the achieved phase distribution. For transfer linearity, choose independent intermediate levels and relevant frequencies, including conditions near operating boundaries where the claim matters. The test plan need not use every possible input, but it should explain why its chosen inputs constrain the proposed model and where extrapolation remains unsupported.

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A strong blocker should also be characterized at the reference plane actually reaching the vulnerable stage. Nominal generator settings may differ from admitted levels because the path includes losses, mismatch, filters, or coupling. The desired probe and blocker can interact in the combining network before they reach the receiver. A product observed during the challenge may therefore originate in the test fixture. The laboratory should preserve fixture checks and alternative configurations capable of separating that possibility. This is a proposed validation precaution, not an assertion that every fixture is nonlinear.

The challenge should include recovery as well as the disturbance itself. A receiver may regain a familiar display before it regains the weak-signal performance required by the claim. Define the property whose restoration counts, and supply a probe capable of testing it. Preserve intervals in which that property remains unestablished. A successful detection after a long wait does not establish immediate recovery. Equally, a missed probe during a known invalid interval should be analysed as a coverage limitation rather than silently removed from the experiment's history.

The available stimulus should not dictate an unstated simplification of the claim. A convenient generator may reproduce amplitude and centre frequency while failing to reproduce crest factor or transition history. When that difference matters, qualify the test rather than treating the convenient waveform as interchangeable with the intended one.

Finally, calibrate the reference pathway independently of the result it is meant to test. Adjusting the injected amplitude until the receiver reports the expected value makes the receiver part of the reference definition. That may be suitable for a particular comparison, but it is not an independent

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verification of its absolute response. Dr Bridgman, may I invite your challenge concerning the precise claim that a challenge test should be required to realize?

Percy Williams Bridgman

Peer question 1 to Edward Weston

Mr Weston, thank you. A phrase such as weak-signal detection can conceal several different operations: noticing excess energy, retaining a complete burst, recognizing a waveform class, or measuring its amplitude. Your timing example distinguishes two of these, but a laboratory might still select whichever outcome looks most favourable after the trial. Dr. Atkinson's question requires a definition that survives that temptation. How should the intended claim be written so that a clear success cannot later be reclassified merely because another metric failed? Please also consider whether a test can legitimately have several acceptance criteria, such as detection probability and amplitude error, without conflating them. What should the record state when the receiver detects the signal reliably but does not preserve enough information for the promised quantitative characterization? I ask for a hierarchy of claims rather than one broad pass label.

A further constraint follows from designing receiver challenge tests that can reveal material failures. Operating regions never exposed to the chosen challenge remain outside the direct observation. If the examiner reports only those cases in which the indicated feature agreed with the preferred model, what correction would you require to the exposure denominator, alternative-hypothesis analysis, and reproducibility account?

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Edward Weston

Answer to Percy Williams Bridgman

Dr Bridgman, the claim should identify the observation that counts as success and the conditions under which it is required. Energy detection, complete capture, classification, and quantitative measurement should have separate criteria where they answer separate questions. A test may assess all of them, but its record must preserve their individual outcomes. Reliable detection can justify a detection statement even when amplitude accuracy fails; it cannot justify the amplitude claim merely because the instrument noticed something at the right time.

Dr. Atkinson, a hierarchy can state that a qualifying event was detected, that an adequate record was retained, and that the record supported specified further measurements. Each level requires its own evidence. The order need not imply that every investigation seeks the most demanding outcome. A discovery receiver may properly provide limited characterization. The error is to let the reader infer a higher level from a lower one, especially where the same word capture is used for both a trigger declaration and a complete waveform record.

Several acceptance criteria should be fixed before confirmatory testing. Their logical combination must also be stated: must all pass, or are different operating modes accepted for different uses? A test report should not select the favourable criterion after examining outcomes while leaving the original broader claim unchanged. Failed criteria should remain visible and may support a restricted release for

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a narrower task. Such a restriction is an engineering decision that should follow the evidence rather than appear as a retrospective redefinition of success.

A partial success should retain its practical value without borrowing a broader label. Separating outcomes makes that possible: it permits a justified detection finding while identifying the additional acquisition or calibration work required before quantitative characterization can be claimed.

The record should include the exact version of the rule applied to each trial. That makes a later revision legitimate and reviewable without rewriting the earlier result. A revised criterion can be tested anew; it does not alter what the prior experiment established. Dr Bode, may I invite your question about the combining network and the possibility that the challenge fixture, rather than the receiver, limits the apparent performance?

Hendrik Wade Bode

Peer question 2 to Edward Weston

Mr Weston, a weak probe and strong blocker must often share a path before they reach the receiver. The combining network may alter either signal through mismatch, isolation limitations, or nonlinear response. A clean generator output measured separately does not establish the combined condition at the receiver input. How should the laboratory determine whether a newly observed product belongs to the receiver, the reference source, or the fixture? Please distinguish a calibrated transfer correction from an unsupported assumption that the fixture

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remains linear for the applied waveform. I would also ask how the experiment can preserve adequate dynamic range in its monitoring instruments. A monitor that itself overloads may offer an apparently authoritative but corrupted account of the stimulus. What minimum evidence would let another examiner reconstruct the actual challenge without trusting every nominal setting as a physical measurement?

May I press the principal contributor on whether the adverse receiver challenge is capable of exposing the hypothesised error? The chronology of whether the adverse receiver challenge is capable of exposing the hypothesised error is indispensable. Assume for a moment that a test performed only on a convenient amplitude might miss overload or weak-signal suppression. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should apply calibrated stressors near threshold and near compression while preserving failed observations, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs input third-order intercept, overload settling, noise figure and detection probability. If the challenged receiver produces a false event or misses a reference event under the predicted stress, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a

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chronological comparison under named operating states. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Edward Weston

Answer to Hendrik W. Bode

Dr Bode, the reference pathway requires characterization under the combined conditions relevant to the claim. Separate low-level checks cannot establish that its response remains unchanged when the blocker is admitted. The laboratory should identify plausible generating stages and choose substitutions or monitoring points whose predictions differ among those stages. For example, varying the combination method or introducing a verified attenuation change at a particular boundary can help localize a product, provided the resulting gain and loading changes are also accounted for. No single manipulation is conclusive without its applicable model.

Dr. Atkinson, a monitoring receiver must be qualified for the measurement assigned to it. Its nominal amplitude range does not establish its own large-signal validity. A monitor may need independently verified attenuation, preselection, or a separate method suited to the relevant component. The record should state the monitor's limitations and avoid using its silence as proof that the fixture generates no smaller products than it could detect. Monitoring uncertainty is part of the stimulus description, not an exemption granted because the instrument is labelled a reference.

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At minimum, preserve the physical connections, calibrated levels at the declared plane, source identities and settings, combining-path characteristics, relevant operating states, and evidence of stimulus continuity. Distinguish measured quantities from values inferred through a correction. The correction should identify its supporting calibration and conditions of use. Preserve observations made with the probe absent and with the blocker absent when those comparisons help separate products. Such controls answer limited questions and should be interpreted accordingly.

The fixture check should include a statement of its own detection limit for unwanted products. A product not observed by the monitor is bounded only within the monitor experiment; it has not been shown physically absent at every amplitude and frequency.

Another examiner should be able to reconstruct not merely the nominal waveform but the uncertainty about what reached the receiver. Where that uncertainty could explain the result, the receiver claim remains qualified. Dr Shewhart, may I now invite your analysis of how the collection of individual trials should represent the operating task rather than merely the conditions most convenient for the laboratory?

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Walter Andrew Shewhart

The composition of the trial population determines the claim

Mr Weston, thank you. Dr. Atkinson, a collection of accurately executed trials can still provide a misleading summary if it overrepresents the easy conditions. The arithmetic fraction of successes is then correct for that collection but does not describe the mixture of conditions intended by the operational claim. The laboratory must specify whether it is estimating performance for a known population, characterizing performance across separate conditions, or screening for particular failure mechanisms. Those objectives require different allocations and should not share an unexplained overall percentage.

Application three uses two stipulated signal classes. In an illustrative test collection, 900 easy trials all succeed, while only ten of 100 difficult trials succeed. The pooled result is 910 successes in 1,000 trials, or 91 per cent. The difficult-class result is ten per cent. Neither fraction requires a complex statistical model, yet they support very different descriptions. A statement that the receiver detects 91 per cent of weak intermittent signals would be unsupported if the easy class consists of strong continuous carriers. The labels and the allocation belong beside the count.

$$\hat{p}_{pool}=\frac{900+10}{900+100}=0.91\,,\,\hat{p}_{difficult}=\frac{10}{100}=0.10$$

Application four distinguishes sample proportions from a population model. Stipulate, solely for this example, true detection probabilities of one for the easy class and 0.1 for the difficult class. A population containing 90 per cent easy events has detection probability 0.91. A population containing only 20 per cent easy events has detection probability 0.28. The receiver's

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conditional performance has not changed; the population weights have. In an actual analysis those probabilities and weights may be uncertain and require estimation. The construction demonstrates why transporting a pooled percentage between populations needs evidence, not merely the same receiver model number.

$$p_{field} = 0.20(1) + 0.80(0.10) = 0.28$$

Dr. Atkinson, a useful validation design therefore retains condition-specific outcomes even when an overall figure is required. Relevant conditions may include amplitude, duration, frequency location, spectral occupancy, gain state, and the timing relation between signal and acquisition. Their importance follows the intended task and plausible failure mechanisms. They should not be selected only after the aggregate result looks disappointing. Deliberately challenging a difficult boundary can be more informative for engineering diagnosis than adding many easy repeats that scarcely change the uncertainty about that boundary.

This does not require an equally weighted grid across every parameter. Such a grid may be wasteful or physically inappropriate. A proposed allocation should state its purpose: representative weighting for a specified event population, stratification to estimate several conditional probabilities, or targeted stress testing. A stress test can expose a mechanism without estimating its field prevalence. A representative sample can estimate average performance while missing a rare but consequential condition. The report should retain these distinctions and avoid converting diagnostic cases into an unsupported frequency estimate of operational failures.

The observation unit also matters. Reprocessing one captured burst a thousand times can test deterministic software reproducibility but does not

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supply a thousand independent physical acquisitions. Repeating an analogue acquisition without changing a shared source state may likewise provide less diversity than the nominal count suggests. Independence and exchangeability should be considered in relation to the estimated quantity. A procedure can be entirely suitable for regression testing while being insufficient for the broader probability statement attached to its results.

Changes made during development must be separated from the confirmatory experiment. When a detector's settings are tuned after inspecting failures, the revised detector is a new procedure for purposes of validation. The failures are valuable development information and should remain in its history. A later frozen version can be assessed on new or properly reserved observations. The mere existence of a file called test data does not make it independent if its content influenced the selection. A procedural record should state which observations were available to the designer at each decision point.

Operational prevalence is sometimes unknown, especially for unusual signal classes. In that case the laboratory can publish conditional performance and analyse several explicit mixtures rather than invent a single authoritative population. The differences between those mixtures are informative: they show which operational assumptions drive the overall result. A worst-case claim requires adequate control of the relevant worst case, not simply equal weighting of several chosen cases. The report should preserve the distinction between a measured condition, an interpolated condition, and an untested region.

I would also preserve the executed trial schedule, not only the intended one. Lost reference bursts, skipped difficult conditions, and periods of

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invalid receiver operation can alter the effective population. Their treatment should be determined by the claim and the reason for failure. Excluding them silently can improve a reported fraction by removing the occasions when the system was least capable. The experiment may report conditional performance among valid trials, but must also report the validity conditions needed for that interpretation. Professor Wiener, may I invite your question concerning dependence between repeated trials and the meaning of an apparently large validation sample?

Norbert Wiener

Peer question 3 to Walter A. Shewhart

Dr Shewhart, suppose a laboratory acquires many trials in rapid succession while a slow common disturbance remains nearly constant across them. The private receiver noise changes, but the reference amplitude, temperature, or common threshold estimate moves much more slowly. A large trial count may then explore one narrow state repeatedly. How would you separate the evidence concerning conditional repeatability from the evidence concerning performance across states? Please also consider a failure mechanism that appears only after prolonged operation. A short, dense sequence might contain more trials than a long-duration test while being less relevant to that mechanism. Can the design combine both objectives without inventing a single effective sample size that conceals the physical distinction? I would welcome an account of which variables should be retained so that later analysis can assess the dependence actually relevant to the performance claim.

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May I press the principal contributor on whether the adverse receiver challenge is capable of exposing the hypothesised error? Before offering an opinion about whether the adverse receiver challenge is capable of exposing the hypothesised error, I would define the measurand and its uncertainty. The proposed rival mechanism is that a test performed only on a convenient amplitude might miss overload or weak-signal suppression. Consequently a calibration certificate for one nominal receiver setting does not settle the question. The more informative operation is to apply calibrated stressors near threshold and near compression while preserving failed observations, with input third-order intercept, overload settling, noise figure and detection probability reported in units and tied to an input reference plane. The adverse prediction is concrete: the challenged receiver produces a false event or misses a reference event under the predicted stress. I would challenge it across a range of input powers and hold one independently measured source constant throughout the switching sequence. A correction estimated after seeing the unknown feature may assist an exploratory analysis; it must not be presented as though it had been fixed before acquisition. Where systematic effects share a reference, their covariance belongs in the reported uncertainty rather than being silently assumed zero. This is the distinction between an instrument number that appears stable and a defensible physical measurement. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

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Walter Andrew Shewhart

Answer to Norbert Wiener

I welcome that careful objection and shall address it directly. Thank you for that question. Professor Wiener, the design should distinguish repetitions within a state from replications across states. Within-state trials can characterize private variability and conditional performance. Between-state observations address variation associated with the changed conditions. Pooling them into one count is not necessarily wrong, but its uncertainty calculation must represent the hierarchy and the intended population. A scalar effective sample size may approximate a particular statistic under a specified dependence model; it cannot replace the physical description of what was repeated and what was changed.

Dr. Atkinson, a long-duration failure mechanism calls for exposure to the duration and operating history that can produce it. Increasing the number of short bursts within a brief quiet interval does not reproduce hours of thermal evolution or storage pressure. The test programme can include dense conditional trials and sustained-operation trials, with separate outcomes and claims. Their results are complementary. An overall release decision may require both, but should not disguise one as a substitute for the other.

Retain trial times, source-state observations, receiver settings, relevant environmental measurements, configuration transitions, and the identities of shared references. Preserve block and run membership so that a reviewer can identify which trials share a state. Document the operating duration preceding each trial when history

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could matter. The purpose is not indiscriminate logging; it is to retain variables needed to examine the proposed dependence and the mechanisms that might invalidate its simplifications.

Duration should therefore appear as an experimental factor or declared exposure requirement when the suspected mechanism depends on it. Recording only the number of bursts discards that information and can make a short dense test look equivalent to sustained operation when it is not.

The resulting analysis may conclude that a conditional probability is well estimated while performance in rare or unobserved states remains uncertain. That is a useful result and a guide to further testing. It should not be converted into universal performance through a large nominal count. Dr Nyquist, may I invite you to examine a different aspect of representation: how the generation and recording of challenge waveforms can introduce the same sampling assumptions that the test was supposed to challenge?

Harry Nyquist

Peer question 4 to Walter A. Shewhart

Dr Shewhart, a digital reference waveform is often synthesized from a finite record and then replayed through a converter. Its repetition, filtering, and sample clock can create a stimulus rather different from the arbitrary event implied by its description. Dr. Atkinson has requested tests of intermittent activity, and a repeated test sequence may inadvertently provide stable timing or spectral cues that the deployed detector will not have. How should the laboratory characterize the

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generated stimulus as an actual analogue signal, rather than trusting the numerical design alone? Please distinguish validation of the receiver algorithm using synthetic samples from validation of the complete acquisition chain using a physical signal. What safeguards prevent a shared sample clock or a repeated record from making the challenge easier in a way that remains hidden in the reported detection probability?

May I press the principal contributor on whether the adverse receiver challenge is capable of exposing the hypothesised error? There is a statistical difficulty in the assertion concerning whether the adverse receiver challenge is capable of exposing the hypothesised error: we have not yet ruled out the possibility that a test performed only on a convenient amplitude might miss overload or weak-signal suppression. The investigation should record its chosen detector threshold, visit schedule, selection of frequencies and expected failure modes before the prospective confirmatory test. To examine the difference we should apply calibrated stressors near threshold and near compression while preserving failed observations, collecting input third-order intercept, overload settling, noise figure and detection probability over a predeclared range rather than selecting the most attractive subset afterward. An observation in which the challenged receiver produces a false event or misses a reference event under the predicted stress would strengthen a restricted causal account, but it cannot certify every unvisited frequency-time interval. I would state which recordings are dependent, which have been excluded as invalid, and which inferences rely upon a model of rare events or stationary interference. A numerical

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interval can have impeccable arithmetic and still misdescribe the physical world if its sampling population was chosen because the signal already looked unusual. We should therefore preserve exploratory leads separately from independently designed validation evidence. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Walter Andrew Shewhart

Answer to Harry Nyquist

Dr Nyquist, the numerical reference and the delivered analogue stimulus should be treated as separate records connected by a characterized generation path. The source file specifies intended samples; it does not alone establish the analogue waveform at the receiver input. Reconstruction filtering, repetition, clock behaviour, and output-level limitations can alter that waveform. Relevant properties should be measured or supported at the declared reference plane, with uncertainty sufficient to determine whether the challenge satisfies its intended conditions.

Dr. Atkinson, synthetic-sample testing is valuable for the digital algorithm because it permits controlled inputs and exact comparisons. It bypasses analogue acquisition, however, and should be labelled accordingly. A physical test includes more of the chain but introduces uncertainty in the stimulus. Neither is intrinsically superior for every purpose. A complete validation argument can combine them while stating which boundary each tests and where their coverage overlaps or leaves gaps.

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Shared clocks and repeated sequences require particular disclosure when they affect the claim. A test of asynchronous event discovery should vary or independently control the event's phase relative to acquisition. A detector that can learn a repeating reference pattern should also face appropriately held-out patterns when the intended task includes unseen events. The actual variation achieved should be recorded, not inferred from a randomisation setting alone. A pseudorandom source with a short repeated sequence may supply fewer distinct conditions than its description suggests.

A source-quality check should be repeated when a changed generation setting could alter the delivered waveform. The earlier check remains evidence for its original state; it does not automatically certify a new repetition interval, clock relationship, or output level.

The safeguard is to make the facilitating relationship visible and either preserve it as part of a deliberately narrow claim or change the experiment to remove it. Repeated success under synchronised conditions remains a legitimate observation, but not a universal one. Professor Neyman, may I now invite your account of the statistical bounds that finite, properly defined trials can support once these physical and population conditions have been established?

A further constraint follows from designing receiver challenge tests that can reveal material failures. I would add the following qualification to my answer. A useful adverse control changes a physical component while leaving the hypothesised emitter unchanged. It should predict an observation which is different under the leading alternative explanation. The investigator must record the

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condition preceding and following this intervention, since receiver recovery and retuning can mimic a source transition. A failure to obtain the anticipated difference should remain visible, rather than being removed as a supposedly unsuccessful measurement. This is the point at which a plausible narrative is converted into a proposition capable of being tested, revised or rejected by another laboratory. In this particular question, the controlled observation is the receiver response to a known applied physical stimulus and documented controls, whereas the material uncertainty concerns operating regions never exposed to the chosen challenge. Consequently the adversarial comparison ought to include blinded or preregistered adverse cases covering sensitivity, blocking, retune, and recovery and its failed as well as successful outcomes. I would not advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

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Jerzy Neyman

Finite success counts support bounds, not perfect performance

Dr Shewhart, thank you. Dr. Atkinson, a result of complete success in the observed trials is not a demonstration that the underlying success probability equals one. The result is a sample outcome under a specified trial process. A statistical bound expresses what that outcome supports within the process model. NIST's instrument-performance guidance distinguishes estimates of detection or false-alarm performance from the confidence statements attached to them. The construction used here is an exact binomial example, with assumptions stated explicitly rather than inferred from a large count. [M5-1, M5-2]

For application five, assume n independent trials with the same detection probability p, a procedure fixed before the trials, and a fixed trial count. Suppose every trial succeeds. For a one-sided lower confidence bound at confidence level one minus alpha, the endpoint p_L solves p_L raised to n equals alpha. Therefore p_L = alpha raised to one over n. With alpha = 0.05 and n = 59, the lower endpoint is about 0.95049. Complete success in these 59 trials supports this one-sided bound under the stated model. It does not prove perfect detection, and it does not provide a posterior probability that p exceeds the endpoint.

$$p_L = \alpha^{1/n} = 0.05^{1/59} \approx 0.950492$$

The familiar observed fraction of one remains useful as a description of the record, but its uncertainty cannot be evaluated by substituting that fraction into an approximation that incorrectly yields zero width. Exact binomial constructions handle such endpoints without making zero observed failure equivalent to zero possible failure. The bound also

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concerns the stipulated population. If all trials use one signal amplitude, its interpretation does not automatically extend to weaker amplitudes, different durations, or an acquisition regime absent from the experiment.

Application six considers twenty separately specified conditions for which lower bounds are to hold simultaneously. To obtain at least 95 per cent joint coverage through a conservative union-bound allocation, assign alpha_i = 0.05 divided by 20 = 0.0025 to each condition. For a desired lower endpoint of at least 0.95 after complete success in a condition, the trial count must satisfy n no less than ln(0.0025) divided by ln(0.95). Rounding upwards gives 117 trials in each condition. The union-bound argument does not require independence between the twenty confidence statements, but each individual bound still requires its own valid sampling model.

$$n \geq \frac{\ln(0.0025)}{\ln(0.95)} \approx 116.808, n_{min} = 117$$

Dr. Atkinson, the difference between individual and simultaneous claims is easily lost in a summary. Twenty conditions each accompanied by a nominal 95 per cent bound do not automatically provide a 95 per cent statement that every condition satisfies its requirement. The allocation above is one transparent way to control the family of statements; it is not universally the most efficient design. More specialized joint methods may be appropriate when their assumptions and implementation are supported. The important point is that the claim's scope determines the statistical construction.

The all-success calculation is also a planning condition, not a prediction that the experiment will succeed. If failures occur, calculate the bound appropriate to the observed count and the declared procedure. Do not

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discard the failed condition, substitute a new signal, or restart the count while preserving the original confidence language. Such changes alter the experiment. A development programme may legitimately revise the receiver after a failure, but the new version and its validation record should be distinguished from the earlier one.

The binomial model requires scrutiny beyond the word independent. Equal success probability may be unsuitable when a condition drifts during the test, and a frozen count does not ensure a frozen procedure. If the laboratory inspects outcomes and changes settings, the actual decision process should enter the analysis. It is preferable to report a narrower descriptive result than attach an exact formula to an experiment that does not satisfy its conditions. Precision in the arithmetic cannot repair a mismatch in the sampling model.

An acceptance requirement should also distinguish a performance threshold from the confidence level used to assess it. Requiring detection probability at least 0.95 is not the same as using a 95 per cent confidence construction. Both numbers happen to appear in this example, but they play different roles. The first defines the engineering requirement; the second specifies a property of the inferential procedure. Keeping them separate prevents an otherwise common confusion in which confidence is reported as though it were another estimate of the detector success probability.

A final evidential safeguard is that blinded or preregistered adverse cases covering sensitivity, blocking, retune, and recovery. The written conclusion must separate a directly retained observation from an inferred physical explanation. A short anomaly may be real in the stored digital sequence yet originate in quantisation, analogue recovery or the acquisition

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policy. Conversely, the absence of an alarm cannot establish the absence of an event outside valid temporal and frequency coverage. Such limitations do not make the work futile. They guide a useful next test, specify the conditions in which the present record is persuasive and protect the evidential chain against later exaggeration. Applied to the present engineering problem, favourable demonstration bias, threshold selection, selective retention, and nonlinear failure under overload may create a spectrum or timestamp that looks persuasive while leaving operating regions never exposed to the chosen challenge inaccessible. The experimental answer lies in blinded or preregistered adverse cases covering sensitivity, blocking, retune, and recovery, carried out with explicit controls and independent retention of all the relevant receiver states. The account should quantify test coverage, detection probability, observed failures, and conditional error bounds, separating input-referred values from software-derived quantities. If the calculation assumes constant noise statistics or a linear front end, an overload or irregular interference challenge should test that premise. The examiner should preserve negative outcomes and show why the proposed mechanism is better supported than the surviving alternatives. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Finally, confidence is attached to a method of constructing statements over repeated admissible experiments. It is not a degree of personal certainty produced by observing an attractive fraction. The practical benefit is discipline: the reader can inspect what was assumed, what was observed, and which statement the method supports. Dr Shannon, may I invite your question concerning whether a trial that produces the right detection flag

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but loses the underlying data should count as success for a receiver whose stated purpose includes later analysis?

Claude Elwood Shannon

Peer question 5 to Jerzy Neyman

Professor Neyman, a receiver may issue a correct detection flag while retaining only part of the event or storing it with an unresolved sample discontinuity. For a discovery task the flag may be useful; for subsequent analysis the record may be inadequate. How should the trial outcome represent this distinction without turning a multidimensional result into an ambiguous binary success? Please consider a system whose trigger identifies nearly every challenge but whose recording path occasionally overruns. If the validation counts only the trigger, it may certify a capability narrower than the user believes. If it counts everything as one composite failure, useful diagnostic information is lost. What should be fixed in advance, and how should the confidence statement distinguish detection, successful recording, and valid downstream measurement while preserving their dependence on the same physical trial?

May I press the principal contributor on whether the adverse receiver challenge is capable of exposing the hypothesised error? I should distinguish the physical occurrence under inquiry from the information actually retained when studying whether the adverse receiver challenge is capable of exposing the hypothesised error. Because a test performed only on a convenient amplitude might miss overload or weak-signal suppression, more than one historical account may produce the same saved trace. The controlled comparison should be to apply calibrated stressors near threshold and near compression while preserving failed

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observations, preserving input third-order intercept, overload settling, noise figure and detection probability at the measurement point and in the evidential metadata. If the challenged receiver produces a false event or misses a reference event under the predicted stress, that result would narrow the admissible explanations, not establish a uniquely identified emitter outside the tested conditions. A subsequent software reconstruction may recalculate a statistic from retained samples, yet it cannot recover components rejected by the front-end filter or intervals never recorded. I would make those distinctions explicit in the final report and invite an independent examiner to reproduce the challenge, including its failed steps. Scientific restraint is not a weakness of the investigation. It prevents a detector output, however striking on the screen, from becoming a claim about unobserved activity that the original measurement never established. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Jerzy Neyman

Answer to Claude E. Shannon

Dr Shannon, the outcome can be a vector even when particular acceptance criteria are binary. Record detection, adequate retention, and validity of the required analysis separately, with operational definitions established before confirmatory testing. A composite success can then be defined as the conjunction required by the intended task. The statistical statement for that composite uses the actual joint outcome, not the product of marginal success fractions

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unless an appropriate independence condition has been justified. Since the stages share a physical trial, dependence is generally a matter to examine rather than assume away.

Dr. Atkinson, the diagnostic record should remain richer than the acceptance flag. A trial may fail because no trigger occurred, because an event was detected but lost, or because retained data did not support the promised measurement. These failures have different engineering implications. Preserving them separately permits correction without changing the meaning of the original composite criterion. A narrower release can be justified for detection alone, provided the report clearly excludes capabilities that failed or remained untested.

Conditional rates are useful but need their denominators stated. The recording-success fraction among triggered events is not the probability of recording an arbitrary qualifying event. Events missed by the trigger have disappeared from that conditional population. To support an end-to-end claim, retain all planned qualifying trials and determine their outcomes through the complete chain. Reference-source failures require a declared treatment distinct from receiver failures, with evidence sufficient to justify exclusions.

Preserve an outcome category for indeterminate reference or acquisition conditions when the evidence cannot justify a binary assignment. Its treatment in the acceptance analysis must be specified, and its frequency should remain visible rather than disappearing from the denominator without explanation.

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Confidence statements should identify which outcome they describe and whether several claims are asserted simultaneously. A single percentage cannot communicate these distinctions by itself. The analysis should preserve both the whole-chain result and the stage-specific evidence needed to understand it. Mr Pearson, may I now invite your comparison of two candidate receiver procedures when their outcomes are paired on the same challenges and their errors need not be independent?

A final evidential safeguard is that blinded or preregistered adverse cases covering sensitivity, blocking, retune, and recovery. I would add the following qualification to my answer. The written conclusion must separate a directly retained observation from an inferred physical explanation. A short anomaly may be real in the stored digital sequence yet originate in quantisation, analogue recovery or the acquisition policy. Conversely, the absence of an alarm cannot establish the absence of an event outside valid temporal and frequency coverage. Such limitations do not make the work futile. They guide a useful next test, specify the conditions in which the present record is persuasive and protect the evidential chain against later exaggeration. In this particular question, the controlled observation is the receiver response to a known applied physical stimulus and documented controls, whereas the material uncertainty concerns operating regions never exposed to the chosen challenge. Consequently the adversarial comparison ought to include blinded or preregistered adverse cases covering sensitivity, blocking, retune, and recovery and its failed as well as successful outcomes. I would not

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advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

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Egon Sharpe Pearson

Comparing procedures and interpreting alarms require different probabilities

Professor Neyman, thank you. Dr. Atkinson, comparing two procedures on the same physical challenges creates paired observations. Their common successes and common failures carry information about the challenge population, while their discordances are particularly relevant to a comparison of marginal success probabilities. Treating the two success counts as unrelated samples discards that pairing. The appropriate analysis follows the design and the claim, rather than selecting whichever familiar formula produces the smaller uncertainty.

Application seven uses one hundred stipulated paired trials. Both procedures succeed on eighty; both fail on ten; procedure A alone succeeds on eight; procedure B alone succeeds on two. A therefore succeeds on eighty-eight trials and B on eighty-two. To examine a simple null model of equal direction probability among independent discordances, condition on the ten discordant trials. Under that model, the number favouring A has a binomial distribution with ten trials and probability one half. The two-sided tail probability for eight versus two is twice the probability of at most two successes, namely twice the sum of the binomial coefficients for zero, one, and two divided by 1,024. The result is 0.109375.

$$p_{tail} = 2\frac{\binom{10}{0}+\binom{10}{1}+\binom{10}{2}}{2^{10}} = 0.109375$$

This calculation is an exact conditional comparison under the stated null and independence assumptions. It is not a probability that the procedures

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are equally good, nor proof that their difference is practically unimportant. The observed six-percentage-point difference remains the sample contrast. The experiment may lack sufficient information to distinguish the specified alternatives at a chosen decision threshold. A practical equivalence claim would require its own margin, design, and analysis; failure to reject equality does not establish equivalence.

Application eight addresses a different confusion. Stipulate a population in which the signal of interest occurs in one test opportunity out of one thousand. Let the detector's conditional detection probability be 0.9 and its false-alarm probability in signal-absent opportunities be 0.01. Among a hypothetical million opportunities, expected true positives are 900 and expected false positives are 9,990. The proportion of positive decisions attributable to signal-present opportunities under this model is 900 divided by 10,890, approximately 0.082645. The detector is reasonably sensitive under the stipulation, yet most positive decisions arise from the much larger absent population.

$$q=\frac{0.001(0.9)}{0.001(0.9)+0.999(0.01)}\approx 0.082645$$

Here q denotes the conditional probability of signal presence given a positive detector decision. The population proportion is an explicit assumption, not a prior probability assigned to an actual surveillance incident. The expected counts merely make Bayes' rule visible. A laboratory false-alarm rate cannot by itself provide the probability that one observed field alarm is false; the latter depends on the relevant population or prior model and on whether the tested conditions apply. When those quantities

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are unknown, reporting an invented posterior percentage would be less defensible than retaining the conditional operating characteristics.

Dr. Atkinson, these two applications show why the same word probability can conceal different questions. A tail probability evaluates a statistic under a specified hypothesis. A detection probability describes a decision when the signal is present. A positive predictive probability concerns signal presence after a decision. None can be substituted for another by verbal convenience. A technically competent report should define the conditioning event explicitly, particularly when the numerical result may influence a consequential interpretation.

The comparative experiment should also preserve costs and relevant failure classes. One procedure may detect more weak events while producing many more false alarms or retaining poorer records. A decision about which is preferable requires a stated objective and acceptable trade-offs. There is no universal ranking supplied by one success fraction. The laboratory can estimate a family of operating characteristics and identify dominated alternatives without pretending that engineering priorities emerge automatically from the statistics.

If the comparative objective includes a cost of false alarms, the paired detection table is only part of the required evidence. Signal-absent opportunities should be evaluated under an appropriate design, with the same matching and retention rules. A procedure can increase detections simply by declaring activity more often. The useful comparison therefore includes the price of that increase and the domain in which it occurs. A claimed improvement should not be established by comparing sensitivity at different, unreported false-alarm operating points.

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A further constraint follows from designing receiver challenge tests that can reveal material failures. A useful adverse control changes a physical component while leaving the hypothesised emitter unchanged. It should predict an observation which is different under the leading alternative explanation. The investigator must record the condition preceding and following this intervention, since receiver recovery and retuning can mimic a source transition. A failure to obtain the anticipated difference should remain visible, rather than being removed as a supposedly unsuccessful measurement. This is the point at which a plausible narrative is converted into a proposition capable of being tested, revised or rejected by another laboratory. Applied to the present engineering problem, favourable demonstration bias, threshold selection, selective retention, and nonlinear failure under overload may create a spectrum or timestamp that looks persuasive while leaving operating regions never exposed to the chosen challenge inaccessible. The experimental answer lies in blinded or preregistered adverse cases covering sensitivity, blocking, retune, and recovery, carried out with explicit controls and independent retention of all the relevant receiver states. The account should quantify test coverage, detection probability, observed failures, and conditional error bounds, separating input-referred values from software-derived quantities. If the calculation assumes constant noise statistics or a linear front end, an overload or irregular interference challenge should test that premise. The examiner should preserve negative outcomes and show why the proposed mechanism is better supported than the surviving alternatives. With respect, I now return the floor to Dr. Atkinson for the next contribution.

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Where settings are chosen to favour each procedure, the selection protocol should be matched to the intended deployment and documented. A fixed-setting comparison differs from a comparison after expert tuning for each trial. Both can be legitimate, but they assess different systems, including different amounts of operator information. The report should not compare one procedure with hindsight against another operating without it. Dr Gabor, may I invite your challenge concerning tolerances in time and frequency, and the danger that a permissive matching rule improves a detection score while weakening its physical meaning?

Dennis Gabor

Peer question 6 to Egon S. Pearson

Mr Pearson, a detector response is often counted as correct when it falls within a tolerance of the reference event's frequency and time. Widening that tolerance can increase the apparent detection rate even though the receiver's physical localization or timing has not improved. How should the validation distinguish successful discovery from precise characterization? Please consider two procedures, one producing a sharply timed event and another producing a long persistent indication. A broad matching window may count both as equally successful while concealing materially different information. Conversely, an excessively narrow tolerance may reject a useful detection because of a known reference uncertainty. What determines a defensible tolerance, and how should uncertainty in the reference event be incorporated without allowing the tolerance to expand after the outcomes are seen? I would also ask how multiple nearby events should be matched without counting one response several times.

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May I press the principal contributor on whether the adverse receiver challenge is capable of exposing the hypothesised error? I am concerned with whether the adverse receiver challenge is capable of exposing the hypothesised error. The unresolved alternative is that a test performed only on a convenient amplitude might miss overload or weak-signal suppression. I should therefore separate the physical input from its representation on the receiver display. Let us apply calibrated stressors near threshold and near compression while preserving failed observations, ensuring that the operator records input third-order intercept, overload settling, noise figure and detection probability. The anticipated discriminating observation is that the challenged receiver produces a false event or misses a reference event under the predicted stress. A failure of this test would not compel us to accept a more dramatic transmitter hypothesis; it would instead mean that our proposed transfer-path model is incomplete. I would retain the measured contrary result and identify the exact connector, stimulus, receiver settings and elapsed intervals in the report. Such a procedure has a modest but valuable result: it converts an initially persuasive visual indication into an experimentally bounded account of what could have produced the retained data. Our duty is not to force agreement but to specify which physical explanations are still consistent with the recorded state. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

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Egon Sharpe Pearson

Answer to Dennis Gabor

Thank you for that question. Dr Gabor, the tolerance should follow the intended outcome and the uncertainty of the reference comparison. A discovery claim may permit a broader interval than a quantitative timing claim, but the distinction must be explicit. The reference's uncertainty should be characterized independently and incorporated into the predefined matching procedure. It should not become an adjustable explanation applied only to failures. A broad interval can be justified for a limited proposition without supporting a more precise one.

Dr. Atkinson, the matching algorithm is part of the tested detector system. It should specify whether one reported event may match several reference events, how conflicts are resolved, and how unmatched detections count. For a one-to-one capture claim, allowing one persistent indication to satisfy numerous distinct bursts would inflate performance. If the intended measurand is occupied time rather than event count, a different comparison may be appropriate. The scoring rule must be aligned with that measurand, not merely convenient to implement.

For comparing procedures, preserve timing and frequency errors as distributions or appropriately qualified summaries in addition to binary matches. The binary detection criterion can then be interpreted alongside the information retained by each procedure. A system that detects within a broad window but cannot characterize onset precisely should not inherit the tighter capability of another

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merely because both pass the same discovery threshold. Reference uncertainty places limits on how sharply those error distributions can be resolved and should remain visible.

The matching code itself merits test cases with deliberately ambiguous event arrangements. Those cases can expose duplicate credit, order-dependent association, and boundary errors without claiming to validate the analogue receiver. They strengthen a specific computational boundary within the larger experiment.

The tolerances, association rules, and software version should be frozen for confirmatory testing. A revised rule can be assessed separately, preserving the earlier results as development evidence. Sir Karl Popper, may I now invite your examination of the broader issue raised by these adjustments: when does legitimate improvement of a method become a retrospective rescue of a claim that the original test did not support?

I thank the questioning colleague for that important distinction. The chronology of whether the adverse receiver challenge is capable of exposing the hypothesised error is indispensable. Assume for a moment that a test performed only on a convenient amplitude might miss overload or weak-signal suppression. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should apply calibrated stressors near threshold and near compression while preserving failed observations, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs input third-order intercept, overload settling, noise figure and

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detection probability. If the challenged receiver produces a false event or misses a reference event under the predicted stress, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

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Sir Karl Raimund Popper

A failed test must not disappear inside the revised procedure

Mr Pearson, thank you. Dr. Atkinson, there is nothing objectionable about improving a receiver after discovering a failure. Indeed, a well-designed challenge should make such improvement possible. The difficulty is an account that changes the method, restarts the evidence, and then presents the eventual success as though the original claim had faced one unchanged test. Scientific criticism requires a history in which an adverse result remains identifiable. Improvement should produce a new claim and a new test, not erase the observation that motivated it.

Application nine makes the statistical consequence explicit. Suppose a procedure has true independent trial success probability p = 0.95. The probability of a clean run of 59 trials is p raised to 59, approximately 0.0484945. Now perform twenty independent runs of that length and select any run with complete success. The probability of obtaining at least one such run is one minus the twentieth power of one minus 0.0484945, approximately 0.629979. A clean run that would be unusual in one specified experiment is quite likely to appear somewhere in this larger search. Reporting only that run hides the procedure used to find it.

$$P(cleanrun)=0.95^{59}\approx 0.0484945$$

$$P(atleastone)=1-\left(1-0.95^{59}\right)^{20}\approx 0.629979$$

The example does not prohibit repeated testing or require that the same analysis be used forever. It shows that a selection mechanism changes the evidential meaning of the selected observation. If the instrument was altered between runs, the simple identical-probability calculation is no longer the model; the version history becomes even more important. A final

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frozen version may deserve a fresh assessment. What it cannot inherit is the assertion that the favourable run arose under a single prespecified test when a different search was actually conducted.

Application ten considers ten alternative analysis branches applied to the same record. Suppose each branch has a false-alarm probability at most 0.001 under its own valid null model. Without assuming independence, the probability that at least one branch signals falsely is bounded above by their sum, 0.01. If their false alarms were independent and each probability exactly 0.001, the exact union probability would be one minus 0.999 raised to ten, approximately 0.00995512. Perfectly coincident false alarms would instead yield 0.001. The search across branches is a procedure of its own, and should be evaluated as such.

$$P\left(\bigcup_{i=1}^{10} A_i\right) \le \sum_{i=1}^{10} P\left(A_i\right) \le 0.01$$

Here A_i denotes the false-alarm event of branch i. The union bound is elementary probability, not a statement that every analysis branch is well calibrated. If a branch's stated probability is unsupported, the resulting bound is unsupported too. Nor does the calculation supply the probability that a particular selected alarm is false. It demonstrates how an apparently stringent per-branch criterion can lose its advertised meaning when the observer searches several branches and reports the best result without identifying that search.

Dr. Atkinson, the corrective discipline is to preserve development and confirmation as different activities. During development, examine failures, change settings, compare representations, and form new hypotheses. Record what was learned. During confirmation, test a defined version using

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a plan that can expose the errors relevant to its stated claim. Where adaptation is essential to the deployed system, validate the adaptive rule itself rather than pretending that its selected setting was fixed beforehand. The object of assessment is the actual procedure, including its opportunities to search and revise.

A difficult failure can also expose a defect in the reference or in the test's definition rather than in the receiver. Such a finding should be investigated and documented, not automatically counted against the instrument. But the correction requires evidence independent of the desire to rescue the result. If every adverse outcome can be dismissed through an unmeasured auxiliary explanation, the test no longer discriminates. The report should state which reference defects were demonstrated, which trials were invalidated for that reason, and how the replacement trials were chosen.

A test can also lose discriminatory force through an unspecified stopping rule. Continuing observations is not inherently improper, but a result interpreted through a fixed-sample calculation must actually follow the sampling plan assumed by that calculation. A sequential procedure may supply a different valid analysis when its conditions are met. The issue is not whether the examiner was patient or persistent; it is whether the probability statement describes the rule by which observations were collected, selected, and finally reported.

Dr. Atkinson, I would frame the problem as follows. Before offering an opinion about whether the adverse receiver challenge is capable of exposing the hypothesised error, I would define the measurand and its uncertainty. The proposed rival mechanism is that a test performed only on a convenient amplitude might miss overload or weak-signal suppression.

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Consequently a calibration certificate for one nominal receiver setting does not settle the question. The more informative operation is to apply calibrated stressors near threshold and near compression while preserving failed observations, with input third-order intercept, overload settling, noise figure and detection probability reported in units and tied to an input reference plane. The adverse prediction is concrete: the challenged receiver produces a false event or misses a reference event under the predicted stress. I would challenge it across a range of input powers and hold one independently measured source constant throughout the switching sequence. A correction estimated after seeing the unknown feature may assist an exploratory analysis; it must not be presented as though it had been fixed before acquisition. Where systematic effects share a reference, their covariance belongs in the reported uncertainty rather than being silently assumed zero. This is the distinction between an instrument number that appears stable and a defensible physical measurement.

The strongest outcome is not an unblemished narrative. It is a reproducible account in which the intended claim survives relevant challenges, failures lead to supported restrictions or revisions, and remaining uncertainty is not concealed. A system can be accepted for one use while rejected for another. That is a more informative judgement than an unrestricted declaration of success. Mr Hartley, may I invite your final question about the information that must survive from this validation history when the resulting instrument is transferred to another laboratory or operating environment?

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Ralph Vinton Lyon Hartley

Peer question 7 to Karl R. Popper

Sir Karl, a receiving laboratory may obtain the instrument, an accepted software version, and a concise validation certificate, but not the full development history. It may then reproduce the nominal configuration while changing a clock, a data interface, or an operating condition that the original validation quietly depended upon. What information must accompany the transfer so that acceptance does not become detached from its conditions? Please distinguish historical detail that is merely interesting from information necessary to determine whether the validated procedure is still being used. I would also ask how the record should treat a configuration update that appears numerically identical at the display but changes the acquisition or processing path. A checklist of version numbers alone may be insufficient, yet an unlimited demand for every historical file is impracticable. What is the appropriate evidential boundary for transfer and subsequent revalidation?

May I press you upon the evidential value of an adverse challenge which deliberately stresses a receiver outside its comfortable operating region? A system may fail to recognise a calibrated weak signal while a strong blocker is present, although its nominal sensitivity measurement was perfectly sound with the blocker absent. That failure tests the combined linearity, preselection and detection policy rather than one isolated manufacturer specification. What minimum experimental controls would let an independent observer determine whether the missed event resulted from analogue compression, a threshold adaptation, or a dropped acquisition block? I suggest retaining both the

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injected witness's independently monitored waveform and the receiver's raw gain-state history, and repeating the test with a preselector or input attenuator changed one at a time. Does successful recovery under one modified state permit any general assurance about the original operating state? In your answer, please distinguish a challenge which usefully falsifies an assumption from one whose own disturbances make its outcome impossible to interpret.

Sir Karl Raimund Popper

Answer to Ralph V. L. Hartley

Mr Hartley, the transferred record should identify the accepted claims, their operating envelope, the configuration that produced the supporting evidence, and the changes that would require renewed assessment. Preserve the validation procedure, outcome definitions, source and reference qualifications, and material failures or exclusions that limit the acceptance. Those records explain what was demonstrated and why it applies. A complete development archive may be retained separately, but the receiving laboratory must not need to discover a hidden limitation in it before using the stated acceptance correctly.

Dr. Atkinson, a version number is an identifier, not a demonstration of measurement equivalence. A change that alters timing, numerical scaling, reference selection, or the admitted signal path may affect a claim even when the display looks unchanged. The update should therefore be evaluated against the dependencies of the validated procedure. Targeted regression can be appropriate where the changed boundary and its consequences are well understood. Where

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the dependency is unresolved, broader revalidation or a restricted claim is preferable to an unsupported assertion of equivalence.

The receiving laboratory should verify the configuration actually loaded and the reference conditions actually achieved. Nominal replication does not establish physical correspondence if cables, fixtures, loading, or environmental conditions differ materially. A transfer check can test selected anchor conditions, but its scope should be explicit. Passing it should not certify regions it never exercises. The governing question is whether the premises supporting the accepted claim remain true in the transferred arrangement.

Material changes should be assessed through a documented impact argument. That argument may justify a narrow regression rather than complete repetition, but it should identify which accepted claims remain unaffected and the evidence supporting that conclusion. Administrative similarity is not sufficient.

The record should consequently connect claims to tests and tests to their relevant conditions, rather than merely collect documents by date. That structure allows change to be assessed without requiring every component to be retested indiscriminately. It preserves criticism as a practical engineering process. Professor Atkinson, I return the floor for your closing synthesis of how a challenge programme can support a bounded, transferable receiver claim without concealing the failures that define its limits.

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Edward Weston, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, a test engineer verifies nominal sensitivity after a strong blocker has been removed, yet the event of interest can begin only six milliseconds after removal. A later steady-state measurement may find the converter within range while an automatic gain-control loop is still recovering during that six-millisecond interval. In a constructed receiver challenge, how would you define the actual transfer path and time reference, and which observation would discriminate transient suppression from a genuine absence of the weak event? Would a conventional input-power sweep, performed only after the chain has settled, be a sufficient adverse test?

Hendrik Wade Bode, Cross-Peer Answer to Edward Weston: Mr Weston, it would not. A steady-state sweep constrains settled gain and perhaps compression under its particular conditions; it does not certify recovery after a large-signal history. Define the blocker amplitude, occupied bandwidth, removal transition, impedance and the weak challenge waveform at the chosen physical input plane. Record the gain-control state where available, but also retain a continuous, calibrated observation of the response through the critical interval. Vary the delay between blocker removal and weak-event onset, using a separate reference channel or independently measured stimulus timing to distinguish source absence from receiver blindness. A simple exponential decay may guide an illustrative design, but real loops can have multiple time constants, switching and saturation hysteresis. A challenge is persuasive when the weak event is known to be applied at a specified instant and the measured output is evaluated against a predeclared criterion. Record blanking, dropped samples and clipping flags

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separately. The absence of a visible trace after overload is otherwise ambiguous, however neatly the later display returns to normal.

Jerzy Neyman, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, the laboratory conducts a thousand detection trials, but all occur within a few bursts of a common reference source and under one receiver thermal state. It then reports a small confidence interval as though the thousand outcomes were independent Bernoulli observations. If burst timing, common reference errors and gain state make neighbouring results dependent, how should a challenge programme be redesigned so that its claimed assurance reflects independent experimental opportunities, rather than the impressive but misleading size of a counter?

Walter Andrew Shewhart, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, I would first identify the unit that the performance claim is meant to generalise over. A thousand threshold decisions within one burst may describe that particular burst rather precisely while providing only a handful of independent opportunities to examine sensitivity to changing conditions. Organise trials into documented blocks covering source setting, receiver state, power level, temperature and relevant timing relationships. Randomise or counterbalance the order of admissible challenges so that drift cannot masquerade as a treatment effect. Record block identity, failure mechanisms and omissions, rather than presenting only a pooled numerator and denominator. The analysis must either model within-block dependence or use inference whose experimental units correspond to the independently varied blocks. A simple binomial interval is conditional on its independence and identical-probability premises; those premises are not supplied by the raw trial count. Repeating a challenge after a deliberate

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reset can strengthen a distinct claim, but a reset which leaves the same reference error untouched does not remove that covariance. The final statement should identify both the experimental population tested and the states not examined.

Egon Sharpe Pearson, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, imagine a receiver that announces every injected short signal in its live event list, while its archival pipeline fails to write the complex samples for several of those events. An evaluator records one hundred per cent detection because the alarm records are intact, and later speaks as though each event could be independently re-examined for spectral identity and timing. Which distinct propositions should the test separate? How might a validation scheme establish that an asserted detection has actually yielded an intact, retrievable evidential record rather than an attractive summary entry?

Claude Elwood Shannon, Cross-Peer Answer to Egon Sharpe Pearson: Mr Pearson, the operations must be measured separately. An event decision, an archived baseband representation, a complete timestamp lineage and a later identification are not interchangeable outputs. Define a known challenge with source-controlled event identity and timing. For each trial, record whether the receiver alarmed, whether raw complex samples covering the full required pre-trigger and post-trigger interval were retained, whether sample sequence continuity passed, and whether a separate analysis could reproduce the claimed features from the saved bytes. Compare file metadata with sample counters and content hashes; a metadata label alone does not show that the corresponding samples exist. The resulting outcome vector may be alarmed but not retained, retained but

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incomplete, or retained and independently analysable. The overall chain succeeds only for the evidential function specified at the outset. A high alarm-detection fraction may be excellent operational information, yet cannot support the stronger assertion that the material survives for forensic review. The test report ought to give separate denominators and failure counts for those different claims.

Sir Karl Raimund Popper, Cross-Peer Question to Percy Williams Bridgman: Professor Bridgman, a development team subjects a receiver to a difficult blocker test, obtains a failed result, changes the fixture and declares the original trial invalid. The team may be correct: an improperly terminated reference path can create a false failure. Yet a convenient explanation devised after seeing an adverse result could equally remove every obstacle to an unblemished validation record. What operational conditions would let us distinguish a justified invalidation from an after-the-fact rescue of the hypothesis, and what should the final evidence contain when the first experiment cannot be interpreted confidently?

Percy Williams Bridgman, Cross-Peer Answer to Sir Karl Raimund Popper: Sir Karl, an invalid trial must have an identifiable physical defect, not merely an inconvenient result. State the reference plane, admitted input waveform, loading, instrument state, timing and required observations before testing. Define the disqualifying conditions that would make the trial uninterpretable, then preserve the measurements which show whether such a condition occurred. A discovered mismatch, for example, should be measured or independently bounded at the relevant frequency; an asserted mismatch is not evidence. If the fixture is corrected, retain the original trial as a documented exception with its reason and collect a fresh result under a

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frozen revised procedure. Do not silently relabel an adverse outcome as an absence of data. When the first trial remains ambiguous, describe the unresolved alternatives and restrict the assurance claim to tests whose reference conditions were actually demonstrated. That discipline preserves the possibility of technical improvement while denying the illusion that an examiner can manufacture a perfect receiver through retrospective choice of what shall count as a trial.

Dr. James M. Atkinson

Closing synthesis

Mr Weston, Dr Shewhart, Professor Neyman, Mr Pearson, and Sir Karl Popper, thank you. A receiver challenge test must have a genuine opportunity to contradict the claim it is meant to support. That requirement is physical, statistical, and inferential. The stimulus must traverse the relevant path; the trial population must represent the specified task or deliberately test its boundaries; and the procedure evaluated must include the settings, searches, exclusions, and adaptations actually used. A favourable display is not a substitute for these conditions.

The worked applications expose distinct ways in which an honest observation can be assigned an excessive meaning. Synchronized bursts can conceal limited temporal coverage. Endpoint calibration can leave alternative transfers indistinguishable. A pooled success fraction can be dominated by easy trials and can change when the population mixture changes. Complete success in finite trials supports a conditional bound rather than perfect performance. Simultaneous claims across many conditions require a corresponding joint construction. Paired comparisons

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must preserve their pairing, and detection probabilities must not be confused with probabilities of signal presence after an alarm.

The final two applications address selection. Repeating or searching until a favourable result appears creates a larger procedure whose outcome must be interpreted accordingly. The panel has not prohibited development, adaptive algorithms, or repeated experimentation. It has required their history and rules to remain visible. A revised receiver can be tested and accepted on its own evidence. What cannot be justified is allowing the revision to erase the failure or to borrow an acceptance statement designed for an experiment that was never actually conducted.

The proposed validation record should therefore retain several connected layers. Define each claim and its operating envelope. Preserve the reference and acquisition conditions, the executed trial schedule, the outcome rules, and the version tested. Record detection, retention, and subsequent measurement validity separately where they support different uses. State the uncertainty appropriate to the actual trial model and identify conclusions that remain conditional or indeterminate. Finally, connect accepted claims to the changes that would require renewed verification.

The record must also preserve the reference experiment as an object capable of error. A demonstrated fixture defect may invalidate a trial, but an imagined defect cannot excuse every inconvenient result. By keeping reference limitations, receiver failures, and analysis changes distinct, the laboratory makes improvement possible without rewriting its evidential history. That is the discipline required for a transferable acceptance decision.

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These requirements allow practical limits. No finite campaign establishes performance under every conceivable condition. A laboratory can nevertheless support a useful and precise operating claim, provided its exclusions are meaningful and its tests address the consequential mechanisms. A restriction following a difficult test is progress when it replaces unsupported confidence with a reliable boundary. The quality of the final account lies in that boundary and in the evidence permitting another examiner to challenge it. The next discussion can build upon this foundation by examining how uncertainty and unresolved alternatives should govern the wording of the receiver's final findings.

Dr. Atkinson, I would frame the problem as follows. I should distinguish the physical occurrence under inquiry from the information actually retained when studying whether the adverse receiver challenge is capable of exposing the hypothesised error. Because a test performed only on a convenient amplitude might miss overload or weak-signal suppression, more than one historical account may produce the same saved trace. The controlled comparison should be to apply calibrated stressors near threshold and near compression while preserving failed observations, preserving input third-order intercept, overload settling, noise figure and detection probability at the measurement point and in the evidential metadata. If the challenged receiver produces a false event or misses a reference event under the predicted stress, that result would narrow the admissible explanations, not establish a uniquely identified emitter outside the tested conditions. A subsequent software reconstruction may recalculate a statistic from retained samples, yet it cannot recover components rejected by the front-end filter or intervals never recorded. I

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would make those distinctions explicit in the final report and invite an independent examiner to reproduce the challenge, including its failed steps. Scientific restraint is not a weakness of the investigation. It prevents a detector output, however striking on the screen, from becoming a claim about unobserved activity that the original measurement never established.

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Ten worked engineering applications | Question 005

Application 01. Opportunity-limited detection under independent visits

In the illustrative 005.01 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. For $n = 39$ genuinely independent valid observation opportunities, each with stipulated event detection chance $p = 0.10$, the probability of no detections is $(1 - p)^n = 0.01642$; its complement is 98.36%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The result tests a stipulated visit model only; synchronised misses remain an untested failure mechanism.

Application 02. Observed exposure fraction of a channel scanner

In the illustrative 005.02 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. Let the channel be observed on $n = 199$ valid visits, each lasting $d = 10$ ms, with revisit spacing $R = 1.15$ s. Valid exposure is $nd/1000 = 1.990$ s across the nominal interval $nR = 228.85$ s. The observed fraction of elapsed time is therefore 0.87%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. The measured duty fraction gives the challenge programme a coverage boundary rather than a claim of continuous observation.

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Application 03. Family-wise probability when many candidates are searched

In the illustrative 005.03 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. If each of M = 206 independent pre-specified search opportunities has false-alarm probability α = 0.0011, the probability of one or more false positives is 1 − (1 − α)^M = 0.20286, or 20.29%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. The reported probability is conditional on the declared test family and cannot retrospectively legitimise a wider search.

Application 04. Combined and expanded measurement uncertainty

In the illustrative 005.04 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. For independent standard-uncertainty contributions 0.80, 0.60 and 0.22 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.80^2 + 0.60^2 + 0.22^2)} = 1.024$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 2.048$ units. The combined uncertainty is useful only for the stated independent contributions and remains conditional on the chosen coverage factor.

Application 05. Gain allocation and blocker headroom

In the illustrative 005.05 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. Assume a calibrated digital full-scale equivalent of -6 dBm, a blocker applied at -36 dBm, and net analogue gain 31 dB. The projected

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converter input is -5 dBm and remaining margin is -6 − (-5) = -1 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. The negative headroom identifies a configuration that must be rejected or independently qualified before weak-signal performance is claimed.

Application 06. Alias-location prediction and its non-unique inverse

In the illustrative 005.06 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. For an actual sampling frequency f_s = 31 MHz and analogue input f_i = 65.100 MHz, the nearest-replica folding rule gives $f_a = |f_i - \mathrm{round}(f_i/f_s)f_s|$ = 3.100 MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. The folded coordinate alone does not identify the analogue source without measured preselection and alias-rejection evidence.

Application 07. Thermal reference noise in a declared measurement bandwidth

In the illustrative 005.07 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. Take the equivalent noise bandwidth B = 21,000 Hz and calibrated noise figure NF = 2.35 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \mathrm{Hz}) + NF$ = -128.43 dBm. The result is available-noise power in that specific bandwidth; impulsive

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interference at the antenna is not represented by the 290 K assumption. The calculation establishes a thermal reference, which must not be substituted for a measured blocker environment.

Application 08. Accumulated sample-clock time error

In the illustrative 005.08 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. A free-running sample clock with fractional rate error ε = 1.360 ppm over T = 415 s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T$ = 0.5644 ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. The clock-offset estimate identifies one timing failure mode, not a bound on every burst-detection or acquisition interruption.

Application 09. Difference between two instruments relative to stated uncertainty

In the illustrative 005.09 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. The paired instrument contrast is Δ = 1.870 dB. Set independent standard uncertainties u_1 = 0.500 dB and u_2 = 0.470 dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)}$ = 0.686 dB, giving the dimensionless ratio $\Delta/u\Delta$ = 2.725. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The receiver comparison requires an uncertainty and dependence model before it becomes an acceptance decision.

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Application 10. First-order recovery envelope after a state change

In the illustrative 005.10 test, an investigative receiver undergoes a deliberately adverse challenge intended to reveal a known failure mechanism. If an illustrative recovery follows $A(t) = A_0 \exp(-t/\tau)$, let $A_0 = 1.50$ V and $\tau = 7.00$ ms. At $t = 17.50$ ms the residual is $1.50e^{(-17.50/7.00)} = 0.1231$ V. Real automatic gain control often has nonlinear or multi-time-constant behaviour, so this exponential is a test model, not a universal reconstruction of the input during overload. The recovery envelope supplies a testable hypothesis for this constructed loop, not a certified transient response for an actual receiver.

The register covers the twelve contributors used in Questions 001-005. It does not complete the 250-person register for the programme. Historical facts and the editorial discussion-role analyses prepared for their first appearance in Question 001 remain distinguished. The moderator has no biographical entry.

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Sources and read scope

The dialogue is original educational synthesis. Bracketed keys identify manuscript passages and research records informing it; they do not attribute the constructed speech to a historical author. External records were consulted on 9 November 2026.

[V1] James M. Atkinson. Protected Volume 11 master, Chapter 1, pages 11–15 in its indexed 3,080-page rendering.

V011_PhaseI_Approved_Integrated_Core_Working(1).docx

Read scope: receiver boundaries, observation versus attribution, reference planes, and configuration identity. Parsed text was reviewed. Original DOCX bytes were not available to this editing runtime.

[V10] James M. Atkinson. Protected Volume 11 master, Chapter 10, pages 1390–1394 in the same indexed rendering.

V011_PhaseI_Approved_Integrated_Core_Working(1).docx

Read scope: sampling, aliasing, clipping, and digital-downconversion boundaries. Equations omitted by text extraction were not reconstructed or treated as independently verified.

[V16] James M. Atkinson. Protected Volume 11 master, Chapter 16, pages 2187–2191 in the same indexed rendering.

V011_PhaseI_Approved_Integrated_Core_Working(1).docx

Read scope: competing artifact explanations, controlled challenges, receiver substitution, interacting factors, and bounded conclusions.

[A1] James M. Atkinson. Receiver Validity, Noise Uncertainty, and the Limits of Negative Evidence. R01, 9 November 2026.

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Author-approved insertion document. Original local DOCX was available. This question draws on its validity and detection-exposure reasoning; inclusion in the protected master has not been verified.

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Official publication abstract consulted in this pass. It supports the scope of performance estimates and confidence bounds; no full-report or clause-level review is claimed.

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Institution-authored archival description read: Hungarian origin, education, professor appointment, research subjects and life years. The archive itself was not inspected.

[B11] University College London Special Collections. Egon Sharpe Pearson Papers.

https://archives.ucl.ac.uk/CalmView/Record.aspx?id=E+S+PEARSON&src=CalmView.Catalog

Institutional archival biography: education, professorship, Neyman and Shewhart collaborations, life dates. Archival papers themselves were not inspected.

[B12] MIT Press. Norbert Wiener.

https://mitpress.mit.edu/author/norbert-wiener-18445/

Institutional author biography: life years, MIT career and published subjects.

[B12a] Science Museum Group. Wiener, Norbert.

https://collection.sciencemuseumgroup.org.uk/people/ap28721/wiener-norbert

Institutional biographical record used to support identity, nationality and doctorate. No unsupported modern expertise is inferred.

[M2-1] Joint Committee for Guides in Metrology. JCGM GUM-6:2020. Guide to the expression of uncertainty in measurement. Part 6: Developing and using measurement models.

https://www.bipm.org/en/doi/10.59161/jcgmgum-6-2020

Read scope: Official PDF consulted: printed page 5 on the measurand and model domain; pages 57-59 on adequacy, comparisons and checks; page 61 on extrapolation. Relevant page images inspected. Only these passages are claimed

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as reviewed. The receiver cases and proposed tests in Question 002 are original hypothetical constructions, not examples attributed to JCGM.

[M2-2] National Institute of Standards and Technology. NIST Technical Note 1297, Appendix A: Law of Propagation of Uncertainty.

https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty

Read scope: Official web appendix consulted for first-order sensitivity coefficients, covariance terms, and the inclusion of relevant quantities in the measurement model. Question 002 application 8 uses independently stipulated uncertainties and an independently checked calculation.

[M2-3] NIST/SEMATECH e-Handbook of Statistical Methods. Section 4.4.4: How can I tell if a model fits my data?

https://www.itl.nist.gov/div898/handbook/pmd/section4/pmd44.htm

Read scope: Official web section consulted for model validation and residual examination; a large coefficient of determination alone is not a sufficient validation. No claim of full-handbook review or instrument certification.

[M2-4] NIST/SEMATECH e-Handbook of Statistical Methods. Section 2.3.6.5: Data analysis and model validation.

https://www.itl.nist.gov/div898/handbook/mpc/section3/mpc365.htm

Read scope: Official calibration subsection consulted for calibration-model fitting and validation context. The affine and bounded-interval examples are original calculations, not NIST experimental results.

[M3-1] Signal Metadata Format Project. SigMF Specification, version 1.2.6.

https://sigmf.org/

Read scope: Official HTML specification consulted: global sample-rate and data-hash fields; captures, sample_start and global_index; capture ordering and relationship to retained data. The specification defines metadata semantics, not proof that an implementation or acquisition populated them correctly. No whole-specification compliance test is claimed.

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[M3-2] Barbara Guttman, Douglas R. White and Tracy Walraven. Digital Evidence Preservation: Considerations for Evidence Handlers. NISTIR 8387, September 2022.

https://nvlpubs.nist.gov/nistpubs/ir/2022/NIST.IR.8387.pdf

Read scope: Official PDF consulted, particularly printed pages 7 and 11 on origin, preservation and protected integrity information; page images inspected. The author list follows the PDF title/citation information. Receiver timing and processing examples are original applications, not a statement of legal compliance or complete instrument validation.

[M4-1] National Institute of Standards and Technology. NIST Technical Note 1297, Appendix A: Law of Propagation of Uncertainty.

https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty

Read scope: Official web appendix consulted for the measurement-process model and covariance contributions. The shared-error examples, variances, and deductions in Q004 are original hypothetical constructions, independently calculated. No source is represented as reporting the example instrument values.

[M4-2] Craig W. Nelson, Archita Hati and David A. Howe. Cross-spectral Collapse from Anti-correlated Thermal Noise in Power Splitters. Proceedings of the 2016 European Frequency and Time Forum.

https://tf.nist.gov/general/pdf/2844.pdf

Read scope: Pages 1-2 of the official NIST-hosted paper read and their page images inspected, covering the cross-spectral-collapse mechanism and tested measurement setup. The scalar cancellation and leakage examples in Q004 are authorial constructions, not transferred experimental measurements or universal receiver specifications.

[M4-3] NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.3.3.2: Randomized block designs.

https://www.itl.nist.gov/div898/handbook/pri/section3/pri332.htm

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Read scope: Official web section consulted for nuisance factors, within-block comparisons, and the additive block model. The receiver trial allocations and numerical pairs in Q004 are original examples, not data from the source.

[M4-4] NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.3.3.4.3: Confounding (also called aliasing).

https://www.itl.nist.gov/div898/handbook/pri/section3/pri3343.htm

Read scope: Official web section consulted for the loss of separately estimable effects in reduced designs and assumptions about interactions. No specific factorial receiver experiment has been performed or certified.

[M5-1] Zhan-Qian John Lu. Estimating Instrument Performance: with Confidence Intervals and Confidence Bounds. NIST Technical Note 2119, September 2020. DOI: 10.6028/NIST.TN.2119.

https://www.nist.gov/publications/estimating-instrument-performance-confidence-intervals-and-confidence-bounds

Read scope: Official publication record and abstract read for the scope of instrument-performance estimates and confidence bounds. The full PDF retrieval timed out in this pass; no new full-text reading is claimed. Q005 numerical examples are independently derived from their stated probability models.

[M5-2] NIST Dataplot Reference Manual. Exact Binomial Confidence Limits.

https://www.itl.nist.gov/div898/software/dataplot/refman2/auxillar/exacbici.htm

Read scope: Official web documentation consulted for exact binomial limits and the distinction between one-sided and two-sided constructions. The all-success formula, 59-trial illustration, simultaneous union-bound allocation and 117-trial result are independently derived and checked, with trial assumptions stated in the dialogue.

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QUESTION 006

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How should uncertainty, competing explanations, and decision costs govern the wording of a receiver finding?

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Constructed educational dialogue. Every speech is newly authored; no passage purports to reproduce the words of a historical participant. All receiver cases, numerical observations, assumptions, and decisions below are hypothetical, not experimental certifications.

Dr. James M. Atkinson

Opening question

Professor Tukey, can you comment upon the distance between discovering an unusual spectral feature and issuing a defensible finding about what produced it? We arrive here after five examinations of the physical reference, the receiver architecture, its changing acquisition state, the dependence of corroborating channels, and the design of tests capable of exposing failure. We have established that a challenge must be capable of contradicting its proposed claim. We have not yet determined how the residual uncertainty should pass into the final sentence read by an investigator, a court, a laboratory director, or the client who commissioned a technical surveillance countermeasures examination. A beautifully resolved waterfall image, moving across a display in precise colours, may have been created by an uncertain sequence of analogue states, mathematical thresholds, retention policies, and deliberate exclusions. The published conclusion must preserve the important qualifications without being so evasive that no reader can determine what the examination established.

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Consider a wideband software-defined receiver screening a large, occupied spectrum. It returns an intermittent narrowband event appearing in several windows, sometimes accompanied by a changing harmonic structure. A second receiver appears to corroborate the observation. The operators find a probable physical location. A preliminary report describes a covert transmitter, but further examination reveals that both receivers shared an antenna distribution path, the candidate frequency was selected after an extensive search, and the alleged localisation was derived from measurements whose uncertainties have not been traced to common references. These discoveries do not by themselves prove that the event was fictitious. They disclose different gaps between event observation, classification, spatial inference, and source attribution. Each gap requires its own evidence and an expression of uncertainty appropriate to the claim made.

I ask the panel to separate the following propositions in its reasoning: an instrument recorded a numerical feature; a physical emission existed at a declared reference boundary; the emission had specified measurable properties; it probably arose from a class of devices; and a particular person or apparatus produced it. These propositions are not equivalent, and one may be well supported while the next remains unresolved. The term *confidence* cannot be used as an ornamental seal on the entire chain. Statistical coverage, engineering uncertainty, likelihood under competing hypotheses, and the practical consequences of acting upon evidence have different mathematical meanings. A single impressive percentage must not pretend to answer all of them.

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Professor Tukey will begin by examining the effect of searching many time-frequency cells and choosing an attractive feature after looking at the data. Mr Gosset will test the trial count and its assumptions, particularly when bursts, scans, and environmental states are correlated. Dr Wald will distinguish evidence from a decision whose costs and urgency may be asymmetric. Sir Harold Jeffreys will examine what a likelihood comparison can and cannot establish about a source. Mr Peirce will consider the logic of inference to an explanation and the obligation to preserve credible rivals. Seven colleagues will put directed questions to these five principal contributors; each question will be answered before its respondent hands the discussion onwards. The modern SDR applications are editorial constructions, not claims that historical panellists possessed knowledge of contemporary receivers.

We shall require a concrete reporting doctrine: what must be said about the acquisition interval, what should be done with an apparently impressive result arising after an enormous search, when a negative search warrants reassurance, when an immediate protective decision is proper despite uncertainty, and when a report must stop at an observation rather than identify an emitter. Our numerical worked applications are intended to expose the assumptions hidden inside attractive calculations. They are not substitute acceptance data. Professor Tukey, may I invite your principal analysis of what an exploratory search does to the meaning of the feature it discovers?

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John Wilder Tukey

Principal response. Exploration, multiplicity, and the burden of independent confirmation

Dr. Atkinson, thank you. My observation is that a successful search does not automatically provide a successful test of the hypothesis subsequently written around its discovery. An exploratory algorithm asks where a feature may be found; a confirmatory procedure asks whether specified evidence behaves as predicted by a proposition whose challenge has been fixed with adequate independence from the evidence being used to judge it. Both are necessary to an intelligent investigation. The first discovers patterns that no prior engineer thought to enumerate; the second protects an inference against the tremendous freedom exercised during discovery. When the same selected trace is made to perform both roles without allowance for its selection, even a rigorous local significance calculation can possess a wholly misleading global meaning. [M6-1]

This issue is acute in a wideband receiver. Search dimensions include centre frequency, FFT size, window, overlap, dwell, triggering rule, background estimator, demodulation choice, burst length, and perhaps a retrospective interval chosen after the feature is seen. Counting only the number of frequency bins ignores the search performed across time and analysis configurations. Yet multiplying all displayed bins is not automatically correct either: neighbouring frequency cells overlap under many window functions, adjacent time records can share samples, and a detection algorithm may cluster connected indications into one physical candidate. The proper family of tests must be defined by what the search procedure could have selected, not by the most convenient count available

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after it did select something. I yield the floor courteously for the next scientific examination.

The two calculations are not an argument for declaring that a detected spectral component is probably false. A familywise false-alarm probability concerns a repeated procedure under a particular null model. It is not the probability that this particular alarm was caused by noise after the alarm has been observed. That latter inference also requires information about the prevalence or prior plausibility of relevant signals and about the probabilities of the observed data under alternatives. Confusing these probabilities is especially dangerous when the report is intended to attribute conduct to a particular source. A statistical test can have a beautifully stated false-alarm rate while the probability of a source attribution remains unexamined.

I would distinguish three records. The discovery record preserves the search space actually examined, the settings tried, and the lineage of the candidate. The test record states the procedure fixed to challenge that candidate, including any hold-out data, independent receiving path, or deliberately changed antenna geometry. The interpretation record identifies the proposition supported by that second record. If no genuinely new evidence is available, a competent report can still describe the observation, its processing, and its exploratory status. It simply should not assign a confirmatory probability calculated for a single comparison to an event selected from an unspecified multiplicity of comparisons.

A complication deserves emphasis. Retrospective analysis is not intrinsically dishonest. Reprocessing retained I/Q data can reveal a weak signal previously obscured by an unfortunate display choice; it may recover

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valuable temporal and spectral structure without changing the underlying samples. The analyst should preserve the original data, each meaningful processing choice, and the point at which the candidate was selected. Later confirmation must then address the mechanism proposed, preferably through a different measurement or a prospectively specified challenge. An additional view of the same bytes can be evidence about their contents, but it does not become a new physical observation merely because its waterfall looks different. The distinction is mathematical, operational, and forensic. [M6-4, M6-6]

A further constraint follows from reporting receiver findings under uncertainty and competing physical explanations. For quantitative interpretation, the distinction between signal power at the antenna reference plane and displayed power after digital processing must remain explicit. A numerical threshold has meaning only together with calibration uncertainty, analysis bandwidth, detector statistic and valid observation exposure. Overlapping Fourier windows do not create fully independent measurements merely by providing additional rows. The result should therefore be accompanied by a denominator tied to genuine measurement opportunities, an account of clipped or missing intervals and a description of the nuisance conditions under which the decision procedure was challenged. Applied to the present engineering problem, selection bias, undercovered nuisance regimes, decision-cost asymmetry, and uncertain priors may create a spectrum or timestamp that looks persuasive while leaving counterfactual outcomes and poorly modelled interference states inaccessible. The experimental answer lies in independent validation and explicit sensitivity analysis across plausible models, carried out with explicit

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controls and independent retention of all the relevant receiver states. The account should quantify uncertainty components, likelihood ratios, false-positive burden, and adverse decision consequences, separating input-referred values from software-derived quantities. If the calculation assumes constant noise statistics or a linear front end, an overload or irregular interference challenge should test that premise. The examiner should preserve negative outcomes and show why the proposed mechanism is better supported than the surviving alternatives. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Sir Ronald Fisher, I invite your question about the relationship between nominal significance and the many candidate explanations an examiner can construct after seeing one attractive pattern.

Sir Ronald Aylmer Fisher

Peer question 1 to John Wilder Tukey

Professor Tukey, thank you for distinguishing the exploratory and confirmatory functions. I should like to sharpen your treatment of the test statistic itself. Suppose the investigator first tries a dozen filters and several thresholds, retains only the most impressive trace, and then quotes the probability that a prespecified single filter would have produced a statistic as extreme under a particular null model. That probability does not have the advertised meaning for the selection actually conducted. Yet it would be equally inappropriate to announce that every exploratory result is devoid of evidential value or that a single universal correction can repair every flexible analysis. How should the final report identify its selection history in language sufficiently clear for a reader to distinguish an observed discrepancy from a claimed

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statistical rarity? In particular, what must be done when the family of candidate tests cannot be reconstructed fully, and what would count as genuinely new evidence rather than a differently coloured re-expression of the same retained samples?

John Wilder Tukey

Answer to Ronald Aylmer Fisher

Sir Ronald, I agree that the number printed beside the trace must refer to the actual inferential procedure or be explicitly restricted to a conditional calculation. An analyst who has tried many filters may truthfully say that one selected output exceeded a stated threshold under a stated model. The analyst should not call its single-filter tail probability the experiment-wide probability of seeing such an extreme result anywhere in the search. Where the search history is incomplete, the report should say that the nominal probability is unadjusted and that its multiplicity cannot be quantified from the available record. This is a material limitation, not merely a missing software setting. [M6-1]

I would require the record to name at least the classes of frequency intervals, time periods, transformations, and candidate criteria examined, together with the point at which each choice became fixed. A candidate that appeared only after the threshold was adjusted to reveal it may be scientifically interesting. Its subsequent statistical evaluation must not be represented as if the threshold had been fixed independently. A new antenna position, a physically independent reference, an independently acquired interval with declared exposure, or an induced change predicted by the source hypothesis can

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contribute more discriminating evidence than another rendering of the same archived cells. Independence has to be shown for the claim under consideration; an apparent second channel sharing a front-end fault may provide very little additional information.

A useful sentence would therefore read: “The spectral feature was identified during exploratory processing of the retained interval. The nominal single-cell test statistic and threshold are reported for reproducibility; the probability of finding a feature this extreme somewhere in the full exploratory search has not been established.” That statement retains the observed fact and makes clear what the statistic does not establish. If a subsequent fixed test succeeds, the report can add its distinct result with the conditions of that test and the alternative mechanisms it was capable of discriminating. If it fails, the earlier discovery remains part of the record rather than disappearing from the file.

I would not put a broad “false signal” label on a candidate merely because discovery was flexible. The correct restriction is on the claimed significance and the movement from candidate to cause. Professor Tukey's distinction is most valuable when it permits investigation to continue without granting an exploratory calculation an authority it never possessed. Sir David Cox, may I invite your question concerning whether our proposal for a hold-out experiment retains its independence when the same laboratory has already learnt the candidate's distinctive features?

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Sir David Cox

Peer question 2 to John Wilder Tukey

Professor Tukey, a further difficulty concerns what the word *independent* might mean in a receiver validation report. An examiner may freeze the selected frequency and ask a second analyst, who is shown the candidate waveform and its predicted modulation, to search an additional hour of data from the same front end. The second analyst does not alter the algorithm after looking at that additional hour, but a common clock defect, periodic interference source, or mischaracterised analogue response may persist. Alternatively, a new receiver may be employed while the candidate source and the environment have themselves changed. Neither experiment is unconditionally superior. What should be declared in advance so that the subsequent result evaluates the intended source hypothesis, rather than a different question about whether a recognisable pattern can be recovered? Should a held-out test define temporal exposure and invalid intervals before its outcomes are seen, and how should its report distinguish procedural independence from physical independence?

John Wilder Tukey

Answer to Sir David Cox and transfer of the floor

Sir David, the phrase “independent confirmation” should never substitute for specifying *independent with respect to which potential failure*. Separate acquisition time may guard against some transient errors without guarding against a stable spurious signal in a shared reference oscillator. Separate hardware may guard against one receiver's internal artefact while a common antenna, distribution

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amplifier, power supply, or nearby emitter preserves another. An examiner should write down the rival explanations and describe the changed conditions that each would predict. A fixed test against the wrong rival is not rescued by impeccable randomisation, because its result answers a different proposition.

The held-out protocol should identify the signal class; the required observation opportunity; the valid and invalid operating states; the allowed adjustments; the decision statistic; the candidate rule; and the reporting treatment of inconclusive records. If the intended claim concerns localisation, the test must vary or measure geometry under a model that can discriminate source positions. If it concerns persistence, it must establish valid temporal exposure and cannot treat unrecorded intervals as quiet ones. Where calibration or background conditions have changed, the test should show why the result remains comparable. A report might properly state that the pattern repeated in a prespecified second interval, but that both intervals used the same analogue input path and therefore do not constitute physically independent validation of that path.

One should also resist the idea that a confirmatory experiment's sole virtue lies in producing a binary answer. When a challenge exposes a shared oscillator artefact, the experiment may be more informative than a favourable replication. When a receiver is valid for only part of the intended operating envelope, a restricted conclusion is a genuine result. The common obligation is to distinguish a successful test of a defined proposition from a pleasing display that has not tested the required alternatives. Dr. Atkinson, with your

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permission, I pass the floor to Mr Gosset, whose question concerns the meaning of the trial count when a receiver's many observations are far from independent.

A further constraint follows from reporting receiver findings under uncertainty and competing physical explanations. I would add the following qualification to my answer. For quantitative interpretation, the distinction between signal power at the antenna reference plane and displayed power after digital processing must remain explicit. A numerical threshold has meaning only together with calibration uncertainty, analysis bandwidth, detector statistic and valid observation exposure. Overlapping Fourier windows do not create fully independent measurements merely by providing additional rows. The result should therefore be accompanied by a denominator tied to genuine measurement opportunities, an account of clipped or missing intervals and a description of the nuisance conditions under which the decision procedure was challenged. In this particular question, the controlled observation is finite measurements with known thresholds and instrument histories, whereas the material uncertainty concerns counterfactual outcomes and poorly modelled interference states. Consequently the adversarial comparison ought to include independent validation and explicit sensitivity analysis across plausible models and its failed as well as successful outcomes. I would not advise treating a change in the displayed indication as an authenticated physical attribution until its causal mechanism has been experimentally distinguished.

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William Sealy Gosset

Principal response. Small samples, repeated exposures, and the illusion of a large trial population

Dr. Atkinson, thank you. My observation is that the numeral written beside the word *trials* cannot be interpreted without the experimental unit and the circumstances of its repetition. A laboratory may display ten thousand FFT records, yet those records can arise from a handful of bursts emitted by one generator in one physical state, observed through one receiver configuration. The extraordinary apparent precision of a count is not itself evidence of a large or representative experiment. Before a rate is estimated, the investigator must say what constituted an opportunity for success or failure and which opportunities were observed independently under the assumed probability model. My own historical work arose from the practical demands of small-sample industrial experimentation. The SDR applications here are newly constructed from that statistical concern, not alleged statements about instruments unknown in my lifetime. [B14]

The problem is particularly evident in a negative search. The client may ask whether an undiscovered emitter was absent, while the receiver has operated under variable sensitivity, intermittent tuning, shared interference, and triggered retention. There may be no defensible denominator for a universal probability of missing such an emitter. Where a narrowly specified trial model can be established, a useful bound may nevertheless be derived. One must then make its assumptions and units visible, rather than transfer the resulting percentage to every untested signal, location, or source behaviour. I pass the floor to the next participant with thanks for this considered exchange.

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My recommendation is to stratify and preserve the circumstances that plausibly govern failure. A receiver should be tested across declared signal strengths, dwell ratios, duty cycles, stronger adjacent emissions, reference conditions, gain states, and environmental changes. If a single number is required, the mixture of these conditions must be part of the claim. A weighted average over predominantly easy trials cannot demonstrate reliable detection in a rare but consequential difficult state. An uncertainty bound conditional on controlled laboratory exposures is valuable, but it should not be dressed as a universal field guarantee. The omitted strata must appear as limitations in the final findings.

I would also separate three different counts: the number of emitted challenges, the number of valid opportunities for the receiver to observe those challenges, and the number of retained records on which later algorithms operated. These counts can disagree without anyone having falsified a log. A challenge outside the receiver's active tuning interval is not an ordinary missed detection if the performance claim did not require that interval to be covered; it is, however, a failure of the broader surveillance coverage if that broader promise was made. A challenge during documented receiver invalidity cannot simply disappear from a denominator chosen to make performance attractive. It must be classified according to a declared rule that was not invented after seeing the outcome.

A further constraint follows from reporting receiver findings under uncertainty and competing physical explanations. For quantitative interpretation, the distinction between signal power at the antenna reference plane and displayed power after digital processing must remain explicit. A numerical threshold has meaning only together with calibration

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uncertainty, analysis bandwidth, detector statistic and valid observation exposure. Overlapping Fourier windows do not create fully independent measurements merely by providing additional rows. The result should therefore be accompanied by a denominator tied to genuine measurement opportunities, an account of clipped or missing intervals and a description of the nuisance conditions under which the decision procedure was challenged. Applied to the present engineering problem, selection bias, undercovered nuisance regimes, decision-cost asymmetry, and uncertain priors may create a spectrum or timestamp that looks persuasive while leaving counterfactual outcomes and poorly modelled interference states inaccessible. The experimental answer lies in independent validation and explicit sensitivity analysis across plausible models, carried out with explicit controls and independent retention of all the relevant receiver states. The account should quantify uncertainty components, likelihood ratios, false-positive burden, and adverse decision consequences, separating input-referred values from software-derived quantities. If the calculation assumes constant noise statistics or a linear front end, an overload or irregular interference challenge should test that premise. The examiner should preserve negative outcomes and show why the proposed mechanism is better supported than the surviving alternatives.

The relevant operational qualification is that finite measurements with known thresholds and instrument histories. An instrument specification does not by itself establish the result of a field experiment. A preselector may reject one interfering band while leaving a different ingress path; a sample clock may be stable in the mean while its phase fluctuates; and a file may be authentic while the analogue interpretation remains contested. The

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expert should distinguish a certificate describing a manufacturer test condition from a verified statement about the present configuration. Record the intervention and its physical reference, the raw output where available and the particular source hypothesis which the intervention could actually exclude. Applied to the present engineering problem, selection bias, undercovered nuisance regimes, decision-cost asymmetry, and uncertain priors may create a spectrum or timestamp that looks persuasive while leaving counterfactual outcomes and poorly modelled interference states inaccessible. The experimental answer lies in independent validation and explicit sensitivity analysis across plausible models, carried out with explicit controls and independent retention of all the relevant receiver states. The account should quantify uncertainty components, likelihood ratios, false-positive burden, and adverse decision consequences, separating input-referred values from software-derived quantities. If the calculation assumes constant noise statistics or a linear front end, an overload or irregular interference challenge should test that premise. The examiner should preserve negative outcomes and show why the proposed mechanism is better supported than the surviving alternatives. With respect, I now return the floor to Dr. Atkinson for the next contribution.

The resulting reporting doctrine may be less dramatic than a universal percentage, but it is considerably more useful. Say, for example, that under a particular challenge protocol and specified signal state the instrument detected the defined events at a stated observed rate, with uncertainty conditional upon the trial design. Say separately that temporal coverage was incomplete, that some bursts fell outside the effective observation intervals, and that no inference about those intervals has been established. The units

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of observation, like the physical units of a measurement, determine whether a numerical statement means anything at all. Professor Feller, may I invite your question about repeating measurements whose outcomes inherit the same environmental cause?

William Feller

Peer question 3 to William Sealy Gosset

Mr Gosset, the receiver's statistical output may be especially deceptive because hundreds of FFT frames appear to constitute hundreds of observations, while each belongs to an event cluster sharing the same source, frequency drift, background state, and gain setting. It is possible to obtain a highly stable within-cluster estimate and a much less stable estimate over future environments. How should an engineer distinguish these quantities without discarding useful repeated observations? I also ask how the trial count should be interpreted for intermittent bursts whose timing may be synchronised with a periodic scan. A laboratory may generate fifty nominal bursts and congratulate itself on a low probability of missing all fifty, but if the bursts always arrive during the receiver's inactive part of the scan the nominal probability calculation is plainly irrelevant. Can a concise worked example explain both the information repeated samples provide and the information they do not provide?

William Sealy Gosset

Answer to William Feller and transfer of the floor

Thank you for that question. Professor Feller, the first step is to recognise the cluster as part of the experimental design rather than

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as an embarrassment discovered during analysis. Repeated records within a burst can be excellent evidence of that burst's detailed waveform or modulation, provided the samples and processing are preserved. They are not, without a model, independent evidence about how frequently the instrument will succeed across other transmitters and other environmental conditions. The analysis must distinguish uncertainty within a cluster from uncertainty across the population of clusters to which the claim is meant to generalise.

These examples lead to distinct claims. An accurate record of many related frames can strengthen the description of a single retained event; it cannot create independent field exposures. An accepted test based on random burst phase need not support performance against an adversary who times activity to the scan. I would have the laboratory preserve the event-cluster identifiers, the scan schedule, the realised phase relation where known, and the excluded intervals. It should evaluate uncertainty at the level appropriate to the decision being reported. If the planned use requires defence against phase-synchronised signals, the validation must challenge that circumstance directly. My work in brewing was concerned with practical variation rather than decorative quantities, and I would apply the same scepticism here. Dr. Atkinson, with respect, I pass the floor to Dr Wald to address the consequences of acting upon such bounded evidence.

I thank the questioning colleague for that important distinction. The chronology of how uncertainty and decision costs constrain a forensic receiver opinion is indispensable. Assume for a moment that a clean plot may conceal low exposure, false alarms and a costly false

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assurance. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should evaluate the detector against several predeclared signal levels and background regimes, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses. If the preferred classification changes when its threshold or sampling assumption is challenged, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

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Abraham Wald

Principal response. Sequential evidence, asymmetric losses, and the error of making a decision look like a measurement

Dr. Atkinson, I thank Mr Gosset and Professor Feller. My observation is that the decision to act and the statement that a physical proposition has been established belong to different parts of an investigation. An organisation may properly institute an immediate protective measure upon evidence that remains insufficient to identify a source. Conversely, an impressive statistical anomaly might warrant further measurement rather than a costly, irreversible accusation. A decision rule combines evidence with the consequences of possible errors, the available actions, and the opportunity to obtain more information. A measurement report should not disguise those normative choices as though they were inherent properties of a receiver. My historical work on sequential analysis and statistical decision functions provides the methodological perspective; the contemporary TSCM situations are constructions for this volume. [B15]

Let the hypotheses be stated without suggestive labels. H0 might mean that the observations arise from a specified combination of legitimate emissions and receiver artefacts, while H1 means that an additional emission of a defined kind is present. These are models, not descriptions of every possible world. Both can be wrong. A sequential procedure examines new evidence as it arrives and may stop when a declared rule is satisfied, or continue when the evidence is insufficient. Its claimed error rates depend upon the assumptions and the complete stopping procedure. Repeatedly checking a fixed-sample significance test and stopping whenever the result

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looks favourable is not the same procedure merely because each individual calculation was performed correctly.

The value of a sequential experiment is obvious in long-duration monitoring. A narrowband burst may emerge only after a period of valid listening; a successful controlled challenge may settle a bounded engineering question before a large scheduled campaign ends; a newly observed receiver fault may require the campaign to halt and its earlier intervals to be reclassified. None of these possibilities justifies changing the rule retrospectively to exclude difficult trials or recasting a discovery threshold as a validated test. A sequential design should identify the statistic, the incoming evidence unit, its dependence structure, the allowed stopping boundaries, and the treatment of interrupted or invalid data. Where these cannot be supported, the report should avoid promising nominal sequential error probabilities. I yield the floor courteously for the next scientific examination.

The example shows why an investigator may act protectively at a relatively low posterior probability while maintaining an appropriately cautious evidential statement. Moving equipment, preserving a recording, or extending a survey can be comparatively reversible. Publicly naming a culprit, interfering with another person's communications, or declaring that evidence proves criminal conduct may impose very different consequences and legal constraints. Those decisions cannot be made legitimate by presenting a loss table as a substitute for authority. The table merely makes the trade-off visible. It must not be mistaken for a legal permission or an ethical licence.

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A further distinction concerns the time value of evidence. If the alleged emitter is intermittent, delaying a new observation may lose an opportunity to test its existence; rushing attribution may lose the ability to distinguish a local oscillator from an external emission. The investigator can choose a low-impact action that preserves evidence while postponing a more consequential conclusion. The report should distinguish an operational recommendation from an evidentiary finding and describe what additional observation would change either. This is precisely where disciplined uncertainty becomes useful rather than paralysing.

Dr. Atkinson, I would frame the problem as follows. Before offering an opinion about how uncertainty and decision costs constrain a forensic receiver opinion, I would define the measurand and its uncertainty. The proposed rival mechanism is that a clean plot may conceal low exposure, false alarms and a costly false assurance. Consequently a calibration certificate for one nominal receiver setting does not settle the question. The more informative operation is to evaluate the detector against several predeclared signal levels and background regimes, with detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses reported in units and tied to an input reference plane. The adverse prediction is concrete: the preferred classification changes when its threshold or sampling assumption is challenged. I would challenge it across a range of input powers and hold one independently measured source constant throughout the switching sequence. A correction estimated after seeing the unknown feature may assist an exploratory analysis; it must not be presented as though it had been fixed before acquisition. Where systematic effects share a reference, their covariance belongs in the

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reported uncertainty rather than being silently assumed zero. This is the distinction between an instrument number that appears stable and a defensible physical measurement.

The laboratory should report its stopping rule and any material changes to that rule. A series of campaigns, each abandoned because it was inconclusive, cannot be represented by the one successful campaign alone if the claimed significance assumes a single prespecified experiment. Similarly, a test suspended because of invalid receiver conditions should record those conditions and explain whether the resulting absence of detections provides any information. The absence of a source may be one hypothesis; the absence of adequate observation may be an entirely different fact. Professor von Neumann, may I invite your question concerning the relationship between the mathematical decision rule, the available actions, and the limitations of its hypothetical probability model?

John von Neumann

Peer question 4 to Abraham Wald

Dr Wald, your loss comparison clarifies why a protective decision may be justified before an attribution is proved. Yet the rule depends upon posterior probabilities, costs, and available actions whose values are not directly supplied by a receiver. An engineer may construct a compact two-hypothesis model and compute a decisive number while omitting an unimagined receiver defect or an ordinary but unusual source. Furthermore, a prolonged search supplies evidence sequentially, sometimes with strongly correlated increments. How should the analyst prevent an elegant stopping boundary from acquiring the false status of a physical law? Please distinguish a sequential likelihood calculation with

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defined error properties from the ordinary habit of taking repeated looks at an evolving waterfall until one look crosses a threshold, and explain what the final report should say when the mathematical prerequisites were not satisfied.

A further constraint follows from reporting receiver findings under uncertainty and competing physical explanations. Counterfactual outcomes and poorly modelled interference states remain outside the direct observation. If the examiner reports only those cases in which the indicated feature agreed with the preferred model, what correction would you require to the exposure denominator, alternative-hypothesis analysis, and reproducibility account?

Abraham Wald

Answer to John von Neumann and transfer of the floor

Thank you for that question. Professor von Neumann, I would first require the decision analysis to be labelled as conditional upon its action set and loss assumptions. Its output is a recommendation under that model, not an estimated physical quantity. Every unmodelled alternative or material defect reduces the warrant for transferring its numerical conclusion to practice. If an omitted state could change the preferred decision, that sensitivity should be described. A decision table can help reveal where an urgent and inexpensive protective action is reasonable, but the operational authority to take that action belongs to the relevant law, policies, and circumstances rather than to the arithmetic itself.

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If the receiver's consecutive FFT frames overlap and its background model is wrong, multiplying per-frame likelihood ratios as though the observations were conditionally independent can produce grossly overstated evidence. Proper sequential analysis may model the dependence explicitly, define appropriate increments, or use empirical validation of the whole stopping procedure. One cannot simply cite a famous sequential formula and bypass the actual acquisition mechanism. It is also possible to formulate valid methods with continuously monitored evidence under different mathematical assumptions, but those assumptions must be established for the method actually used. The record must preserve not only the endpoint but the sequence of threshold comparisons and any changes made after earlier results.

I would recommend two linked report fields: “evidential status under the named measurement and inference model” and “operational decision and its declared assumptions”. This avoids confusing a decision to investigate with a statement that a device was found, and avoids disguising an unresolved event behind a phrase such as “no action required” when valid observation was incomplete. Reversibility, urgency, collateral consequences, and the possibility of further measurement should be explicit. Sir Harold Jeffreys, may I now invite your analysis of what it means to compare competing explanations when a receiver measurement can be generated by more than one cause?

I thank the questioning colleague for that important distinction. There is a statistical difficulty in the assertion concerning how

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uncertainty and decision costs constrain a forensic receiver opinion: we have not yet ruled out the possibility that a clean plot may conceal low exposure, false alarms and a costly false assurance. The investigation should record its chosen detector threshold, visit schedule, selection of frequencies and expected failure modes before the prospective confirmatory test. To examine the difference we should evaluate the detector against several predeclared signal levels and background regimes, collecting detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses over a predeclared range rather than selecting the most attractive subset afterward. An observation in which the preferred classification changes when its threshold or sampling assumption is challenged would strengthen a restricted causal account, but it cannot certify every unvisited frequency-time interval. I would state which recordings are dependent, which have been excluded as invalid, and which inferences rely upon a model of rare events or stationary interference. A numerical interval can have impeccable arithmetic and still misdescribe the physical world if its sampling population was chosen because the signal already looked unusual. We should therefore preserve exploratory leads separately from independently designed validation evidence.

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Sir Harold Jeffreys

Principal response. Likelihood, prior assumptions, and source attribution beyond the instrument reading

Dr. Atkinson, I thank Dr Wald. My observation is that a source hypothesis must be evaluated through the probability of the actual observations under that hypothesis, rather than by attaching a confidence adjective to the instrument's classification label. It is possible for a waveform to be highly unusual under one model and still be insufficient to identify the source responsible. A receiver may faithfully preserve a burst, and a validated classifier may recognise a modulation family, while several physically different devices remain capable of producing the same family. The inverse problem is not resolved by the fidelity of the forward recording. My historical engagement with inverse probability and scientific inference supplies the intellectual perspective; the modern receiver and forensic examples are newly authored. [B16, M6-7]

Consider H1, “the event was emitted by the proposed device”, and H2, “the event was emitted by an alternative device or instrumental mechanism”. Let E denote the retained evidence, and I the conditioning information that both explanations are permitted to use. The likelihood ratio is LR = P(E | H1, I)/P(E | H2, I), provided these conditional probabilities are coherently specified. A ratio materially greater than one indicates greater support from E for H1 than H2 under that pair of models. It does not mean that H1 is true with the numerical probability represented by the ratio, nor that every other possible explanation has been excluded. The chosen alternatives, data supporting the likelihood assignments, and assumptions of independence matter to its interpretation. The modern forensic literature

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emphasises the distinction between the probability of evidence given a proposition and the probability of the proposition given the evidence. [M6-7]

There is a further problem in TSCM practice. A broad claim that a signal is “unauthorised” often mixes technical observations with permission, ownership, purpose, and human conduct. Those concepts are not established by waveform morphology. A carrier can be narrow, strong, periodic, or encrypted without announcing the legal or organisational authority of the emitter. A finding that a discrete, externally coupled electromagnetic component was present within a validated input band can be well supported. A finding that the component came from a covert listening device may require additional evidence of hardware, spatial geometry, wiring, emission structure, controlled response, or content, and a claim about intentional surveillance requires still further facts. Attribution should proceed through explicit evidential transitions, not through an imaginative leap from unusual to nefarious. I respectfully return the discussion to Dr. Atkinson.

This is why the terms *false positive* and *false alarm* demand denominators. The false-alarm probability asks how a detector behaves when the defined source is absent; the post-alarm probability asks how the population of candidate explanations was distributed before observing the alarm. Neither is interchangeable with engineering amplitude uncertainty, which concerns the range and conditions of a particular measurand. The report should never turn a frequency-level p-value, a confidence bound for a trial population, or a generic classification score into a claim about an identifiable source without the necessary inference model.

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Even where Bayesian updating is sensible, an unquantified prior cannot be concealed within a precise-looking posterior. Analysts often have genuine contextual information: the physical scene, known authorised apparatus, prior survey findings, and the observed behaviour of likely interferers. Such information can help choose meaningful alternatives. It can also introduce circularity if the same observation influences both the prior and the likelihood while the resulting double use goes unrecognised. I would therefore ask that the report show the hypotheses, conditioning information, and likelihood evidence in separate statements where practicable. If the data cannot justify numerical probabilities, a qualitative and carefully bounded comparison may be more faithful than a spurious decimal.

Dr. Atkinson, I would frame the problem as follows. I should distinguish the physical occurrence under inquiry from the information actually retained when studying how uncertainty and decision costs constrain a forensic receiver opinion. Because a clean plot may conceal low exposure, false alarms and a costly false assurance, more than one historical account may produce the same saved trace. The controlled comparison should be to evaluate the detector against several predeclared signal levels and background regimes, preserving detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses at the measurement point and in the evidential metadata. If the preferred classification changes when its threshold or sampling assumption is challenged, that result would narrow the admissible explanations, not establish a uniquely identified emitter outside the tested conditions. A subsequent software reconstruction may recalculate a statistic from

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retained samples, yet it cannot recover components rejected by the front-end filter or intervals never recorded. I would make those distinctions explicit in the final report and invite an independent examiner to reproduce the challenge, including its failed steps. Scientific restraint is not a weakness of the investigation. It prevents a detector output, however striking on the screen, from becoming a claim about unobserved activity that the original measurement never established.

The comparison should remain open to a third, unmodelled possibility. H1 and H2 need not be exhaustive, and evidence favouring H1 relative to a poorly specified H2 does not establish that H1 is the only possible explanation. Receiver substitution, a different antenna geometry, direct inspection of suspect circuitry, or controlled removal of an environmental emitter may discriminate alternatives more effectively than extensive calculation applied to the same unresolved trace. Professor Box, may I invite your question about what happens when an elegant probability model fails to describe the mechanism that actually generated the spectrum?

George Edward Pelham Box

Peer question 5 to Sir Harold Jeffreys

Sir Harold, you require a likelihood ratio tied to declared explanations, but the laboratory's noise model may itself be the principal weakness. A stationary Gaussian background is convenient for deriving a threshold; real environments can exhibit impulsive interference, mixtures of operating states, intermittent electronics, and common front-end artefacts. The model might fit its central observations while failing in precisely the tails that determine alarms. An analyst can refine a likelihood model after seeing the event until the feature appears more

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persuasive, then report the final ratio without revealing the model's development. How would you prevent the apparent exactness of the calculation from becoming more persuasive than the empirical evidence for its premises? Is there a practical hierarchy of sensitivity checks and physical challenges before a numerical source likelihood ought to be reported?

May I press the principal contributor on how uncertainty and decision costs constrain a forensic receiver opinion? I am concerned with how uncertainty and decision costs constrain a forensic receiver opinion. The unresolved alternative is that a clean plot may conceal low exposure, false alarms and a costly false assurance. I should therefore separate the physical input from its representation on the receiver display. Let us evaluate the detector against several predeclared signal levels and background regimes, ensuring that the operator records detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses. The anticipated discriminating observation is that the preferred classification changes when its threshold or sampling assumption is challenged. A failure of this test would not compel us to accept a more dramatic transmitter hypothesis; it would instead mean that our proposed transfer-path model is incomplete. I would retain the measured contrary result and identify the exact connector, stimulus, receiver settings and elapsed intervals in the report. Such a procedure has a modest but valuable result: it converts an initially persuasive visual indication into an experimentally bounded account of what could have produced the retained data. Our duty is not to force agreement but to specify which physical explanations are still consistent with the recorded

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state. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Sir Harold Jeffreys

Answer to George Edward Pelham Box and transfer of the floor

Professor Box, the first question is whether the model's probability assignments are based upon evidence appropriate to the claimed population. A Gaussian null can be a useful approximation in a carefully restricted environment; it is not a property conferred upon a receiver by calling its baseline noise. When real backgrounds contain bursts, gain transitions, clipping, harmonics, and other structures, the tail probability used in an alarm calculation may differ greatly from its nominal value. The laboratory should test the relevant tails, timing dependence, and state mixtures under conditions in which the candidate is known not to be present, so far as those conditions can be established. It should also test how the source comparison changes when credible alternative models are used. [M6-1, M6-3]

A practical hierarchy begins with the physical question, not the numerical model. Establish the reference boundary and whether the alleged event survives challenges capable of distinguishing input emission from receiver response. Preserve raw data and the processing transformations needed to reproduce the feature. Examine null data that resemble the operating circumstances, including awkward cases rather than solely the quiet periods for which the model was constructed. Evaluate whether changes in threshold, background estimation, candidate selection, and

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dependence materially alter the inference. Only then consider whether probability assignments are sufficiently supported to justify a likelihood ratio. Where they are not, describe the observation and the unresolved alternatives without decorating them with an invented posterior percentage.

Model revision is lawful scientific practice when its history is preserved and its resulting performance is tested on evidence that was not simply used to choose the revision. It may produce a better explanation, but it does not retroactively convert development data into an untouched confirmation. I would also caution against treating a posterior odds calculation as a verdict about permission or culpability. An external emission might be genuine and its modulation might be characterised, while the identity and purpose of the transmitter remain uncertain. The report should travel only as far as the evidence can take it. Mr Peirce, I invite your final principal analysis of how an investigator should compare explanatory causes without treating a plausible story as an observed fact.

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Charles Sanders Peirce

Principal response. Abduction, discriminating predictions, and the difference between no evidence and evidence of absence

Dr. Atkinson, thank you. My observation concerns a fundamental habit of inquiry. When an unexpected appearance occurs, one proposes a cause capable of making it intelligible. That generative step is not itself an observation of the cause. To observe a rhythmic spectral ridge and conjecture a concealed device may be a useful beginning; to write that the device was discovered without undertaking the work of distinguishing the conjecture from rivals confuses explanation with demonstration. The scientific merit of a hypothesis appears when it yields consequences that differ from those of credible alternatives, and when those consequences can be examined by a procedure whose limitations are recognised. My historical work on logic, scientific inquiry, and abduction supplies the role assigned here; the modern receiver vocabulary is an editorial application. [B17]

The temptation is especially strong when an investigator encounters an unfamiliar pattern in a high-resolution spectrum. The human visual system seeks regularity in faint structure, and a time-frequency display may reward that search with an apparently purposeful shape. The result can be an excellent stimulus to further work. It cannot itself establish purpose. A periodic burst might arise from a communication system, a switching converter, a local oscillator, a scanning service, intermodulation, or a processing artefact, depending upon the actual frequency, temporal structure, environment, and signal path. The relevant possibilities cannot be reduced to a universal catalogue; they must be developed from the present physical system and the particulars of the observations.

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Consider, for example, a candidate classified as an external signal because it appears in two receivers. If those receivers share an active antenna distributor, both could inherit the same external emission or the same distributor-generated mixing product. A controlled change in input termination, preselector state, attenuation, or physical placement may have different consequences under those hypotheses. Yet each intervention has its own limitations. Disconnecting an antenna can alter a receiver's loading and cause an oscillator or protection circuit to change state. A disappearing trace after disconnection is therefore evidence about a changed configuration, not an automatic proof that the former trace travelled through space from the suspected room. The experiment must specify the mechanism by which the change is expected to discriminate the causes. [M6-3]

There is an equal danger in a negative finding. The statement “no signal was observed” can have at least three materially different meanings. One is that a valid, adequately sensitive receiver observed the declared band and time interval and the defined signal class did not cross the prespecified decision rule. Another is that a receiver was powered on but did not possess adequate exposure or sensitivity for the target class. A third is that raw observations were not retained, and the report is limited to the absence of a saved trigger. Only the first can be considered a valid negative under its bounded test conditions, and even that does not demonstrate that every possible transmitter was absent at every moment and frequency. The absence of a retained file does not repair a gap in the physical observation.

A proper forensic conclusion would separate four levels. First, the observations: what was retained, measured, and verified. Second, the

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analytical model: what processing and calibration make those observations intelligible. Third, the explanatory comparison: which proposed causes were genuinely challenged, and what material alternatives survived. Fourth, the decision or recommendation: what should now be done, given the evidence, uncertainty, permissible actions, and consequences. The distinctions are important because one level can be reliable while another remains unsettled. A well-recorded burst may support an excellent technical description without warranting the allegation that a particular operator intentionally installed a surveillance device.

One might object that complete certainty is impossible and therefore demands for alternative explanations have no stopping point. That objection misstates the problem. The investigator need not refute every imaginable story. The investigator should identify plausible causes that materially affect the conclusion, devise tests capable of separating them when feasible, and state where the remaining indistinguishability lies. When the next experiment is impossible, prohibitively destructive, or disproportionate to the decision, a bounded finding is still possible. It can be precise about the measured event and honest about the absent attribution. The greatest practical failing is not uncertainty. It is allowing uncertainty to vanish silently as the narrative progresses from instrument screen to authoritative prose.

Dr. Atkinson, I would frame the problem as follows. The chronology of how uncertainty and decision costs constrain a forensic receiver opinion is indispensable. Assume for a moment that a clean plot may conceal low exposure, false alarms and a costly false assurance. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should evaluate the detector against several

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predeclared signal levels and background regimes, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses. If the preferred classification changes when its threshold or sampling assumption is challenged, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

Lord Russell, may I invite your question about the grammar of claims, especially the distinction between rejecting a proposed cause and affirmatively establishing an entirely different one?

Bertrand Russell

Peer question 6 to Charles Sanders Peirce

Mr Peirce, the language of an expert report can move from a weak observational statement to a strong existential assertion without any new evidence. If the investigator has not identified a covert transmitter, that failure of identification does not demonstrate that no such device exists. Yet the converse error is equally serious: observing a signal inconsistent with a favoured authorised source does not establish that it originated from a covert device. How should the examiner formulate logically disciplined alternatives when the hypotheses are neither

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exhaustive nor mutually exclusive, and how can a conclusion remain intelligible to a non-technical reader? I am particularly concerned with words such as *proved*, *excluded*, *identified*, *consistent with*, and *could not be ruled out*, whose apparent clarity often conceals profoundly different logical commitments.

May I press the principal contributor on how uncertainty and decision costs constrain a forensic receiver opinion? Before offering an opinion about how uncertainty and decision costs constrain a forensic receiver opinion, I would define the measurand and its uncertainty. The proposed rival mechanism is that a clean plot may conceal low exposure, false alarms and a costly false assurance. Consequently a calibration certificate for one nominal receiver setting does not settle the question. The more informative operation is to evaluate the detector against several predeclared signal levels and background regimes, with detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses reported in units and tied to an input reference plane. The adverse prediction is concrete: the preferred classification changes when its threshold or sampling assumption is challenged. I would challenge it across a range of input powers and hold one independently measured source constant throughout the switching sequence. A correction estimated after seeing the unknown feature may assist an exploratory analysis; it must not be presented as though it had been fixed before acquisition. Where systematic effects share a reference, their covariance belongs in the reported uncertainty rather than being silently assumed zero. This is the distinction between an instrument number that appears stable and a defensible physical measurement.

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With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Charles Sanders Peirce

Answer to Bertrand Russell

Lord Russell, I appreciate your caution about the proper scope of a negative finding. The decisive distinction is between what a procedure would have found under specified circumstances and what exists beyond those circumstances. A negative observation can contradict a particular predicted emission if the prediction required the event to be present during valid exposure and the instrument was demonstrably capable of recognising it. That may weaken a defined hypothesis. It does not automatically prove a universal negative. Equally, eliminating one proposed innocent cause does not prove the most dramatic remaining cause when the alternatives were not exhaustive. The structure of the propositions, not the vigour of the prose, determines the inference.

I would therefore replace the unqualified sentence “No transmitters were present” with a statement that identifies the band, interval, observation opportunity, target class, validity conditions, and decision criterion, followed by an express indication of the limitations. Where the record warrants no stronger result, a suitable form is: “During the specified valid observation intervals, no event meeting the stated detection criterion was recorded within the examined bands. This result does not establish the absence of signals outside those intervals, below the validated detection capability, or of types

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not encompassed by the criterion." This is not ceremonial caution. It tells a later examiner exactly what contrary observation would challenge the report.

The phrase "consistent with" should be used with great restraint. Almost any observation is consistent with many flexible explanations. A meaningful report should identify whether the result was expected under a stated explanation, whether its rivals also predict it, and whether the observation discriminates those rivals at all. The phrase "identified as" is stronger and should be reserved for a classification whose criteria, validation, and competing causes warrant that degree of specificity. A report may describe the observed signal as *compatible with* a modulation family while explicitly withholding source attribution. That distinction preserves the scientific discovery and avoids an unjustified allegation.

The general rule is to make each inferential step contestable. The raw observation should survive independent inspection where possible; the calibration should be traceable; the proposed explanation should yield testable consequences; and the final wording should stop where the evidence stops. Dr Shannon, I invite your question on what happens when a retained representation has irretrievably discarded information required for such a contest.

Claude Elwood Shannon

Peer question 7 to Charles Sanders Peirce

Mr Peirce, the physical event may have left only a reduced representation. Imagine an SDR system that keeps a sparse collection of

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FFT magnitudes, threshold crossings, and waterfall images while discarding phase, precise source timestamps, rejected intervals, and raw complex samples. Several different waveforms and acquisition states might yield an identical saved trace. Later examination may establish that the retained trace is internally consistent, but it cannot infer a unique predecessor when the recording operation was many-to-one. How should an examiner state this limitation without declaring all such evidence useless? Is it possible to describe a legitimate, narrower question that the reduced record can answer, while refusing a source-identification claim that would require information never retained?

May I press the principal contributor on how uncertainty and decision costs constrain a forensic receiver opinion? There is a statistical difficulty in the assertion concerning how uncertainty and decision costs constrain a forensic receiver opinion: we have not yet ruled out the possibility that a clean plot may conceal low exposure, false alarms and a costly false assurance. The investigation should record its chosen detector threshold, visit schedule, selection of frequencies and expected failure modes before the prospective confirmatory test. To examine the difference we should evaluate the detector against several predeclared signal levels and background regimes, collecting detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses over a predeclared range rather than selecting the most attractive subset afterward. An observation in which the preferred classification changes when its threshold or sampling assumption is challenged would strengthen a restricted causal account, but it cannot certify every unvisited frequency-time interval. I would state which recordings are

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dependent, which have been excluded as invalid, and which inferences rely upon a model of rare events or stationary interference. A numerical interval can have impeccable arithmetic and still misdescribe the physical world if its sampling population was chosen because the signal already looked unusual. We should therefore preserve exploratory leads separately from independently designed validation evidence. With regard to the evidence available here, which observation would cause you to withdraw the proposed interpretation, and which calibration record would let another examiner check that result?

Charles Sanders Peirce

Answer to Claude Elwood Shannon and return to the moderator

Dr Shannon, a reduced record can be highly useful if its retained information is matched to the question it is asked to answer. A time-stamped threshold log can document that a specified detector registered an event under a known configuration. A sequence of spectral magnitudes can describe energy distribution over the represented frequencies and times, subject to its analysis window, calibration, and retention rules. It need not be discarded merely because phase or raw samples are absent. The logical error begins when the analyst claims to reconstruct what the representation did not preserve, or treats a uniquely stored file as evidence that the underlying physical cause was uniquely determined.

Where the mapping from possible physical inputs to saved outputs is many-to-one, the observation establishes an equivalence class under that mapping unless additional evidence distinguishes its members. A reconstruction may select a plausible member by

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imposing a model, but that choice should be stated as model-dependent. A method that assigns a waveform to the spectral magnitude alone without the lost phase cannot promise that it has recovered the uniquely original waveform. Equally, a threshold log that contains only registered alarms does not establish what occurred during intervals in which the logging conditions were unknown. The needed limitation is not philosophical ornament; it is an engineering fact about information loss.

I would make the reporting record say what objects survive, which fields and metadata are authenticatable, which transformations were reversible for the declared question, and which conclusions rest upon assumptions not recoverable from the saved data. A subsequent controlled experiment may add source-discriminating evidence even when the earlier raw waveform is lost. It cannot retroactively place missing phase and unrecorded time intervals into the original archive. The inference should acknowledge that boundary and exploit new observations rather than imagine its way around it. Dr. Atkinson, I return the floor for a synthesis that separates the quality of a physical observation, the uncertainty of its interpretation, and the propriety of an operational decision.

I thank the questioning colleague for that important distinction. I should distinguish the physical occurrence under inquiry from the information actually retained when studying how uncertainty and decision costs constrain a forensic receiver opinion. Because a clean plot may conceal low exposure, false alarms and a costly false assurance, more than one historical account may produce the same

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saved trace. The controlled comparison should be to evaluate the detector against several predeclared signal levels and background regimes, preserving detection probability, false-alarm rate, coverage, nuisance conditions and stated decision losses at the measurement point and in the evidential metadata. If the preferred classification changes when its threshold or sampling assumption is challenged, that result would narrow the admissible explanations, not establish a uniquely identified emitter outside the tested conditions. A subsequent software reconstruction may recalculate a statistic from retained samples, yet it cannot recover components rejected by the front-end filter or intervals never recorded. I would make those distinctions explicit in the final report and invite an independent examiner to reproduce the challenge, including its failed steps. Scientific restraint is not a weakness of the investigation. It prevents a detector output, however striking on the screen, from becoming a claim about unobserved activity that the original measurement never established.

John Wilder Tukey, Cross-Peer Question to Sir Ronald Aylmer Fisher: Sir Ronald, permit me to challenge the way a discovery threshold becomes the reported significance of a finding. Suppose an analyst searches one million time-frequency opportunities, tries several FFT lengths, adjusts the waterfall contrast after seeing a candidate, and finally quotes the smallest single-cell tail area as though the frequency and analysis procedure had been chosen before the observation. A strict familywise calculation for a fixed one-million-cell search is available, but the number of independent tests is not necessarily the number of pixels, and the analyst's post-selection choices

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create additional degrees of freedom. What would constitute a defensible null experiment here? In particular, should we distinguish the chance of seeing a signal-like feature anywhere, the chance of producing a specified detection statistic in a preselected cell, and the chance that a real transmitter rather than an instrumental response produced a selected feature?

Sir Ronald Aylmer Fisher, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, I would insist upon distinct propositions and an explicit sampling procedure before attaching any frequency to an event. A significance calculation describes the behaviour of a defined statistic under a stipulated model when the procedure is repeated. It does not, merely through impressive decimal places, state the probability that the observed feature is an artefact or that a suspected transmitter exists. The one-million-cell example belongs to a known family only if the examined frequency ranges, observation intervals, selection rules and any subsequent analytical searches are accounted for. Correlated cells cannot be treated as a million independent repetitions, yet dependence does not make multiplicity disappear. A predeclared test applied to genuinely withheld recordings can assess the selected proposition more cleanly than the data that first suggested it. If a separate receiver is used, its acquisition chain and common calibration dependencies must be included. Where those conditions cannot be reconstructed, report the feature as exploratory, preserve all settings and unselected candidates, and qualify rather than disguise the inferential calculation. An investigator may still pursue an exploratory discovery, but a report must not confer retrospective experimental control upon it.

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William Sealy Gosset, Cross-Peer Question to Sir David Cox: Sir David, consider the laboratory that reports no false alarms in one hundred tests and therefore declares its receiver effectively infallible in quiet offices. Its hundred files were obtained from ten sessions, each contributing ten nearly identical traces, with the same automatic-gain-control configuration and one particularly favourable interference background. Our worked example gives an exact upper bound of about 2.95 per cent only under one hundred independent Bernoulli opportunities with common event probability. Under what conditions should the examiner regard the session, rather than the file, as the replicating unit? How should the laboratory represent the untested temperatures, source strengths and acquisition states without pretending that a simple effective-sample-size correction establishes an exact binomial confidence limit?

Sir David Cox, Cross-Peer Answer to William Sealy Gosset: Mr Gosset, the question begins by identifying the object whose probability is sought. If it is the probability of a false alarm on a specified independent search opportunity under a defined operational distribution, the laboratory must demonstrate that its trials genuinely sample that population. Ten runs of the same stored waveform do not become ten independent environmental trials merely because the software emits ten records. An exchangeable cluster model may estimate variance inflation for a mean under particular correlation assumptions; its resulting effective count should not be inserted without justification into the exact zero-event binomial expression. I would arrange fresh independent sessions, change relevant interference and equipment states according to a registered test matrix, and preserve session-level results. Hierarchical or cluster-resampling analysis may be

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appropriate when its assumptions can be assessed, although an observation of zero events places severe limits on estimating all nuisance components. The written conclusion should state the observed zero, the experimental opportunity definition, which factors varied and which did not, and the precise scope of any interval. The untested situations remain limitations, not successes hidden in the denominator.

Abraham Wald, Cross-Peer Question to Sir Harold Jeffreys: Sir Harold, our illustration makes investigation rational at a modelled posterior source probability just above nine per cent because the stipulated costs of missed detection are much greater than the costs of a precautionary inquiry. I fear that an editor might convert this operational threshold into a claim that the evidence itself is nine per cent conclusive, or that any alarm above the threshold merits naming an identified person. What separation do you require between the analyst's likelihood account, the decision-maker's prior assumptions and consequences, and a legally consequential attribution? How should a report treat an attractive likelihood ratio that omits plausible alternate emitters or whose uncertainty changes across operating environments?

Sir Harold Jeffreys, Cross-Peer Answer to Abraham Wald: Dr Wald, the calculation is legitimate as a conditional decision example and illegitimate as an evidential certificate. A loss function compares proposed actions under stated consequences; it does not create a frequency of truth for a transmitter identification. A likelihood ratio, when a defensible model exists, compares probabilities of evidence under the alternatives actually specified. Updating odds introduces prior assumptions, and omitting an important competing source can make the numerical conclusion misleading even

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when the multiplication is arithmetically correct. An expert ought to communicate observations, measured uncertainty, model comparisons, test conditions and known limitations. The official deciding whether to investigate may separately apply safety, cost, proportionality and legal standards. The expert should not smuggle those policy choices into the instrument's findings, still less elevate suspicion concerning an individual into an assertion of identity. For an unvalidated distribution of alternative emitters I would report qualified compatibility and the scope of exclusion testing rather than a spurious numerical weight. One must also disclose uncertainty in any likelihood ratio itself, not merely print a single number.

Charles Sanders Peirce, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, allow me to ask about the familiar report that a protected room was silent. The monitoring receiver inspected a channel for ten milliseconds in every hundred, while the alleged device, if it existed, might transmit bursts two milliseconds long or adjust its schedule after detecting activity. The illustration gives a twelve per cent temporal overlap probability for one uniformly phased burst and a small miss probability after fifty independent bursts. Neither assumption may describe an adaptive or periodically synchronised transmitter. What can a negative record actually eliminate, and how should a detective preserve its informational limits before an assurance of absence is conveyed to the building's occupants?

Claude Elwood Shannon, Cross-Peer Answer to Charles Sanders Peirce: Professor Peirce, the absence of a threshold crossing is information about a particular observation process. It is not a physical measurement of every emission that might have occurred outside the receiver's dwell, passband, sensitivity, linear operating range or chosen decision rule. For the stated

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uniform-phase model, overlap probability is twelve per cent, but overlap is not synonymous with recognition; the waveform must also survive filtering, gain state and processing. Fifty opportunities share the independent-trial exponent only if their relevant phases and operating states genuinely provide independent opportunities. An adversarial transmitter could defeat that assumption, and ordinary periodic machinery could make the same mistake apparent without adversarial intent. Retain a machine-readable acquisition timetable, local oscillator and clock records, selected antenna and preselector, raw data where actually retained, event thresholds and a description of coverage gaps. A useful negative finding would say that no qualifying event was detected within the monitored bands, intervals and verified performance limits. Additional methods may reduce the unexplored region of possibilities, but the report cannot turn finite observation into an absolute absence claim.

Dr. James M. Atkinson

Closing synthesis

Professor Tukey, Mr Gosset, Dr Wald, Sir Harold Jeffreys, Mr Peirce, and the seven questioning colleagues, thank you. The central result of this discussion is that uncertainty is not a singular number to be appended at the end of an otherwise unqualified conclusion. A receiver finding passes through different inferential stages, each with distinct assumptions and possible failure modes. Statistical multiplicity governs the interpretation of an anomaly selected from many opportunities. Trial design and dependence govern how measured performance may be generalised. Sequential stopping and decision costs govern certain operational choices. Likelihood comparisons govern the relative support supplied by specified evidence for

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specified competing explanations. Physical measurement uncertainty governs the relationship between the measurand and the reported value. None of these constructs, however impressive its notation, independently identifies an unauthorised person or device.

The first two principals have shown how substantial false-alarm and detection uncertainty can remain concealed by large numbers. In a million nominally independent opportunities, a one-in-a-million per-cell false-alarm probability produces at least one crossing more often than not. A zero-failure validation over one hundred ideal trials gives a nonzero upper bound, and 200 records from a few correlated clusters do not necessarily confer the precision of 200 independent exposures. A burst occurring outside a scan's active dwell is not rescued by an elaborate spectral estimator applied to data that were never acquired. These results do not discredit wideband SDR surveillance. They direct attention toward appropriate detection families, valid acquisition exposure, defensible trial units, and explicitly challenged operating conditions.

Dr Wald then distinguished the amount of support for a proposition from the decision to take an action. An organisation may properly preserve evidence, move to a safer operating state, or commission a further survey when the consequences of ignoring a plausible concern are material, provided the chosen action is lawful and proportionate. Such a decision does not license the report to promote a candidate signal to a positively identified covert transmitter. Sequential analyses must describe their stopping rules, units of evidence, and dependence assumptions. A powerful mathematical criterion applied to the wrong observation model remains a poor basis for a confident finding.

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Sir Harold Jeffreys distinguished a conditional likelihood under a source hypothesis from the posterior probability of that hypothesis. He showed why even a detector with apparently excellent operating characteristics may generate a substantial proportion of alarms from sources other than the rare target under a particular assumed population. A likelihood ratio of twenty does not mean a hypothesis has a twenty-to-one posterior probability without the prior odds and the hypotheses' scope. A third credible explanation cannot be removed by giving only two alternatives names. Professor Box's challenge sharpened the point: a perfectly executed computation does not certify that its background model describes the tails, dependencies, or changing operating states responsible for the observed event. [M6-7]

Mr Peirce, challenged by Lord Russell and Dr Shannon, brought the matter back to the logic of investigative statements. An event may have been faithfully recorded without its source having been identified. An input path may have failed without the absence of a transmitter having been established. A reduced archive may answer a question about the detector's recorded output while leaving the original phase history or the unobserved intervals unknowable. The error is not to make a limited finding. It is to hide the limitation while passing from the display to a causal narrative. An investigative hypothesis earns authority through discriminating observations, not through the elegance of the story that explains them.

Accordingly, the programme adopts a five-part reporting discipline for subsequent roundtable questions and for eventual editorial review of the volume. The report must state the physical observation and the valid exposure to which it pertains. It must identify the measurement model, the

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relevant calibration and state uncertainty, and the original evidence needed to reproduce its numerical results. It must distinguish exploratory selection from confirmatory testing and give any statistical rate its correct population, denominator, dependence assumptions, and error interpretation. It must compare material alternative explanations to the extent the evidence permits, identifying where information was never acquired or has irretrievably been lost. Finally, it must separate the supported technical finding from the operational action proposed upon it, including the lawful authority and consequence assumptions relevant to that action.

A defensible positive conclusion might read: “During the stated valid measurement intervals, an externally coupled spectral component was recorded at the declared reference plane. Its estimated frequency and temporal characteristics are reported with the identified measurement limitations. The event persisted through the specified controlled challenges; source identity and purpose remain undetermined.” That wording presupposes that the claimed external coupling was actually established by the challenges, rather than inferred only from appearance. A defensible negative conclusion might instead read: “No event meeting the validated detection criterion was observed within the stated bands and valid intervals. The result is limited by the documented sensitivity, dwell schedule, excluded conditions, and signal classes.” These are examples of the logical form a finding might take, not prewritten conclusions for any actual survey.

It remains possible to issue a precise and consequential report without pretending to exhaustive knowledge. The duty of the expert is to preserve the chain between data and proposition so that another qualified reader can examine, reproduce, and, where appropriate, challenge it. Every figure of

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merit, confidence bound, posterior comparison, or decision threshold must be attached to the model under which it has meaning. The next question should investigate a different but related boundary: how does a wideband receiver preserve reliable frequency and time relationships when multiple analogue-to-digital converters, oscillators, and processing paths must act as one measurement system? The present discussion has set the epistemic limits. The next should confront the architecture that makes such evidence possible.

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Ten worked engineering applications | Question 006

Worked application 1. The cost of a million opportunities. Suppose a fixed search produces M = 1,000,000 independent candidate cells under a specified null model, and the probability of a false threshold crossing in any one cell is p = 0.000001. The probability of at least one false crossing is F = 1 - (1 - p)^M = 1 - (0.999999)^1,000,000 = approximately 0.632121. Thus an apparently severe one-in-a-million per-cell threshold would yield at least one false alarm in approximately 63.2 per cent of such null searches. Independence and a correctly calibrated constant p are declared assumptions of this illustration. Neither holds automatically for an actual SDR waterfall.

Worked application 2. A bounded familywise target. If the same idealised search must keep the probability of at least one false crossing at or below A = 0.01, solve 1 - (1 - p_star)^M = A. It follows that p_star = 1 - (1 - A)^(1/M) = approximately 1.00503 × 10^-8. A conservative Bonferroni allocation uses A/M = 10^-8 without requiring the cells to be independent, provided the relevant per-test error probabilities are controlled and the family has been specified. This is a choice of statistical design, not an automatic threshold in ADC counts or decibels. Transferring it to instrument settings demands a validated relationship between the test statistic and its distribution under realistic backgrounds. [M6-1]

Worked application 3. No false alarms in one hundred trials. Assume n = 100 valid, independent Bernoulli trials with the same unknown false-alarm probability q per trial, and suppose the laboratory

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observes zero false alarms. A one-sided 95 per cent exact upper confidence bound is $q_U = 1 - (0.05)^{(1/n)} = 1 - (0.05)^{(1/100)}$ = approximately 0.029513. Zero observed failures therefore does not justify a statement that the probability is zero, nor does it establish q below one per cent with 95 per cent one-sided confidence. The bound describes the trial model and the procedure that selected those hundred units, not all conceivable receiver conditions. [M6-2]

Worked application 4. The number of clean trials needed for a stringent bound. To obtain a one-sided 95 per cent upper bound below $q_0 = 0.001$ after observing zero false alarms, require $1 - (0.05)^{(1/n)} < q_0$. Solving gives $n > \ln(0.05)/\ln(0.999)$ = approximately 2994.23, so at least n = 2995 clean, independent trials are needed for a strict “below” conclusion. The arithmetic is straightforward; the physical acquisition of 2,995 genuinely qualifying and adequately diversified opportunities may be anything but straightforward. Replaying one clean waveform 2,995 times does not demonstrate performance under unknown interference environments merely because the counter reaches the required integer.

Worked application 5. Correlated repeated trials. Suppose a simplified exchangeable-cluster model contains k = 10 clusters, each with m = 20 observations, so n = km = 200, and a common intracluster correlation coefficient rho = 0.3 for a mean of identically variable observations. The familiar design effect is $D = 1 + (m - 1)\text{rho} = 1 + 19(0.3) = 6.7$. Its variance-equivalent independent count is $n_{eff} = n/D = 200/6.7$ = approximately 29.85. This does not mean that the experiment secretly contained exactly thirty independent Bernoulli observations; it describes the loss of precision for the specified mean under the stipulated

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exchangeable correlation model. It must not be inserted mechanically into an exact binomial formula or treated as valid for arbitrary correlated event processes.

Worked application 6. Periodic dwell and a randomly phased burst. Assume a receiver observes a channel for d = 10 milliseconds every T = 100 milliseconds and that a burst has fixed duration b = 2 milliseconds. If the burst's start phase is uniformly random relative to the scan and it is recognised whenever any portion overlaps the active dwell, the probability of overlap in this idealised circular-period model is $p_{overlap} = (d + b)/T = 12/100 = 0.12$. If fifty burst phases were genuinely independent under this model, the probability of missing all fifty would be $(1 - 0.12)^{50}$ = approximately 0.001675. If, however, all fifty bursts are synchronised to the same unfavourable phase, the misses can be completely dependent, and this calculation is inapplicable. Practical detection additionally requires adequate dwell integration, signal-to-noise ratio, front-end validity, and a defined decision rule, none of which is included in the simple overlap expression.

Worked application 7. A decision threshold built from losses rather than confidence rhetoric. Suppose the decision is either to investigate an apparent source at an incremental cost $C_{FP} = 100$ arbitrary monetary units if no relevant source exists, or to dismiss the event at a consequence $C_{FN} = 1{,}000$ units if a relevant source exists. For illustration, suppose correct decisions have zero incremental loss and an available, properly calibrated posterior probability of a relevant source is r. Expected loss of investigation is $100(1 - r)$; expected loss of dismissal is $1{,}000r$. Investigation has lower expected loss when $100(1 - r) < 1{,}000r$,

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giving r > 100/1,100 = approximately 0.09091. This threshold is a feature of the stipulated losses and actions, not a universal evidential standard and not a finding that the source exists with 90.9 per cent certainty. In real investigations, additional actions, information costs, legal restrictions, and non-monetary harms alter the analysis.

Worked application 8. Illustrative sequential likelihood boundaries. In the simple two-hypothesis sequential probability ratio framework, let alpha = 0.05 denote a target upper probability of accepting H1 when H0 is true, and beta = 0.10 denote a target upper probability of accepting H0 when H1 is true. Common approximate likelihood-ratio boundaries are A = (1 - beta)/alpha = 0.90/0.05 = 18 and B = beta/(1 - alpha) = 0.10/0.95 = approximately 0.105263. A cumulative likelihood ratio L at or above A favours stopping for H1 under the specified procedure; at or below B favours stopping for H0; values between call for additional observations. These are customary approximations to a sequential design, not guarantees for any receiver. Exact operating errors depend upon the specified statistical model, discretisation, overshoot, evidence dependence, and stopping implementation. [M6-8]

Worked application 9. Why a rare target changes the meaning of an alarm. Suppose a hypothetical detector has sensitivity s = P(alarm | relevant source) = 0.90 and specificity c = P(no alarm | no relevant source) = 0.999. Suppose, solely for calculation, that the prior probability of the relevant source in the defined screening population is pi = 0.001. Then the probability of a relevant source given an alarm is P(source | alarm) = s pi/[s pi + (1 - c)(1 - pi)] = 0.0009/[0.0009 + 0.000999] =

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approximately 0.473934. The detector's one-per-thousand false-alarm probability conditional on absence of source is not a 99.9 per cent probability that any particular alarm identifies a real source. The hypothetical base rate is not a claim about the prevalence of covert surveillance in any population. The formula also assumes that the specified sensitivity, specificity, and prior apply to the case under consideration.

Worked application 10. A likelihood ratio does not erase the prior odds. Suppose a qualified model yields a likelihood ratio LR = 20 in favour of H1 over H2. If the prior odds of H1 to H2 are 1:99, posterior odds become 20:99 under Bayes' rule, and the corresponding posterior probability of H1 within this two-hypothesis model is 20/(20 + 99) = approximately 0.168067, or 16.8 per cent. If another plausible prior or an unmodelled third source changes the calculation, the original 16.8 per cent is not a portable property of the waveform. The likelihood ratio concerns the comparison of two stated models; its conversion into odds introduces assumptions not contained in the signal alone.

Sources and read scope. Question 006

The dialogue, numerical examples, reporting formulations, and hypothetical receiver cases are original educational material. Bracketed keys identify sources supporting selected historical or methodological premises, not the imagined words of the contributors. Source pages described below were consulted on 9 November 2026. The original protected master manuscript could not be opened as editable DOCX bytes in this runtime; only the prior Q001–Q005 checkpoint and its indexed excerpts were checked. No insertion into the protected master is claimed.

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[M6-1] NIST/SEMATECH e-Handbook of Statistical Methods. Section 7.4.7, “How can we make multiple comparisons?” and Section 7.4.7.3, “Bonferroni's method”. https://itl.nist.gov/div898/handbook/prc/section4/prc47.htm and https://itl.nist.gov/div898/handbook/prc/section4/prc473.htm . Read scope: HTML discussion of simultaneous versus repeated individual comparisons and the familywise confidence principle. The million-cell Bernoulli illustration and corresponding algebra are original hypothetical calculations, not an NIST receiver experiment. The NIST pages address comparisons in statistical experiments, not a certified universal SDR threshold.

[M6-2] National Institute of Standards and Technology. Dataplot Reference Manual, “Exact Binomial Confidence Limits”. https://www.itl.nist.gov/div898/software/dataplot/refman2/auxillar/exacbici.htm . Read scope: HTML description of exact binomial confidence limits. Worked applications 3 and 4 specialise the all-zero-failure one-sided bound to original hypothetical trial counts. The independence and constant-probability assumptions are required for those numerical interpretations.

[M6-3] Joint Committee for Guides in Metrology, *JCGM 100:2008, Guide to the Expression of Uncertainty in Measurement*. Official publication page: https://www.bipm.org/en/doi/10.59161/jcgm100-2008e . Also JCGM VIM 2.47, “metrological compatibility of measurement results”: https://jcgm.bipm.org/vim/en/2.47.html . Read scope: official HTML publication description and vocabulary entry identifying effects of correlation. The text's inference about common receiver paths and the need to avoid treating measurements as independent is an original application. No claim of complete PDF audit is made.

[M6-4] James Lyle and colleagues. *Digital Investigation Techniques: A NIST Scientific Foundation Review*. NISTIR 8354, 2022. https://www.nist.gov/publications/digital-investigation-techniques-nist-scientific-foundation-review . Read scope: NIST HTML abstract on the scientific basis and limitations of digital investigation, including incomplete evidence discovery and changed meanings of artefacts. The text applies those principles to SDR acquisition and retention but does not assert that the report certified any receiver system.

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[M6-5] Signal Metadata Format Project. *SigMF Specification*. https://sigmf.org/ . Existing Volume 11 Q001–Q005 source register [M3-1] records read scope for sample rate, capture timing, sample offsets, and data hashes. Question 006 references acquisition provenance conceptually; it makes no new claim that a particular capture has been verified under the specification.

[M6-6] *I have a question about evaluative reporting: a comprehensive collection of FAQs*. *Forensic Sciences Research*, 2024, doi: 10.1093/fsr/owae062. https://pmc.ncbi.nlm.nih.gov/articles/PMC11757676/ . Read scope: HTML article framing the evaluative-reporting and likelihood-ratio approach and its methodological distinctions. This source is used for the role of stated competing propositions, not as a directly transferable source-attribution rule for RF receivers.

[M6-7] University of Cambridge, Statistical Laboratory. “History of the Statistical Laboratory”. https://www.statslab.cam.ac.uk/history-statistical-laboratory . And *Forensic Sciences Research* evaluative-reporting article [M6-6]. Read scope: Cambridge's description of Harold Jeffreys' interest in inverse probability and the modern article's distinction between evidential support and hypotheses. The Bayesian arithmetic and hypothetical detector base rates in applications 9 and 10 are independently derived from expressly stipulated assumptions; no true TSCM prevalence rate is claimed.

[M6-8] Joel B. Greenhouse and Christopher J. Phillips. “Abraham Wald and the Origins of the Sequential Probability Ratio Test”. *The American Statistician*, online 17 February 2026. https://www.tandfonline.com/doi/full/10.1080/00031305.2025.2604805 . Read scope: HTML historical abstract on Wald's sequential method, not a full technical review of all sequential test conditions. Application 8 gives a conventional approximate two-boundary formula, with explicit caveats about the actual achieved error rates and dependence.

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[B14] Dictionary of Irish Biography. “Gosset, William Sealy (‘Student’)”. https://www.dib.ie/biography/gosset-william-sealy-student-a3543 . University of St Andrews, MacTutor, “William Sealy Gosset”. https://mathshistory.st-andrews.ac.uk/Biographies/Gosset/ . Read scope: birthplace, life dates, education, statistical work, and pseudonym.

[B15] University of St Andrews, MacTutor. “Abraham Wald”. https://mathshistory.st-andrews.ac.uk/Biographies/Wald/ . Read scope: life dates, career transition, emigration, Columbia work, decision theory and sequential analysis.

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[B17] Stanford Encyclopedia of Philosophy. “Charles Sanders Peirce”, revised 2021. https://plato.stanford.edu/entries/peirce/ . Read scope: life dates, philosophy of inquiry, logic, scientific work, and fields of activity. The modern TSCM dialogue is not attributed to this source.

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[B19] Royal Society. “Sir David Cox FBA FRS”. https://royalsociety.org/people/david-cox-11275/ . Royal Statistical Society. “Sir David Cox, 1924–2022”. https://rss.org.uk/news-publication/news-publications/2022/general-news/sir-david-cox-1924-2022/ . Read scope: life dates, career, methodology and knighthood.

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[B21] Institute for Advanced Study. “John von Neumann: Life, Work, and Legacy”. https://www.ias.edu/von-neumann . Read scope: origins, life dates, Princeton career, computing, and decision-related scholarship.

[B22] Institute of Mathematical Statistics. “Obituary: George E. P. Box, 1919–2013”. https://imstat.org/2013/07/16/obituary-george-e-p-box-1919-2013/ . University of Wisconsin–Madison. “Renowned statistician George Box dies at 93”. https://news.wisc.edu/renowned-statistician-george-box-dies-at-93/ . Read scope: life dates, British origins, career, industrial statistics and research interests.

[B23] Stanford Encyclopedia of Philosophy. “Bertrand Russell”, revised 2024. https://plato.stanford.edu/entries/russell/ . Read scope: life dates, philosophical and logical work, and use of the historical title Lord Russell.

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QUESTION 007

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When may observations, bearings, and timing evidence support localisation or attribution of an electromagnetic source?

Source: V011_Roundtable_Q001-Q011_CP011_Integrated_Candidate(2).docx | Recovered substantive manuscript. Constructed educational dialogue.

Original educational reconstruction. The historical participants did not take part in this conversation, and none of the speeches is offered as a quotation. All places, observations, numerical readings, alleged devices and investigative decisions are hypothetical. Source notes identify technical background, not documentary proof of the constructed exchanges.

Dr. James M. Atkinson

Opening question

Sir Edward Appleton, may I invite you to examine the distance between an observed spectral event and an identifiable emitter? Our preceding question distinguished the probability of a feature under a specified noise model from the probability that a proposed cause is true. We now approach a harder inverse problem: the examiner has an electromagnetic trace, perhaps several bearings and a timestamp, and is tempted to give that trace a street address, an instrument serial number or even an owner. The display can be brilliant and the uncertainty unobtrusive. Neither the beauty of a waterfall nor the apparent sharpness of two converging bearing lines determines what the waves have crossed before reaching the receiving apparatus.

Consider a protected building in which an intermittent, frequency-agile emission has been observed near a sensitive office. A stationary receiver

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first discovers the feature with one antenna. A second station later records something similar, and the investigator draws two bearing rays on a plan. Yet the first receiver shared its time reference with several channels; both antennas have patterns altered by adjacent metalwork; and part of the supposed source's activity occurred while neither receiver was actually dwelling at the relevant frequency. The event might originate within the building, beyond it, or from an otherwise unremarkable device whose signal has been redirected through glass, steel and masonry. The first evidential obligation is therefore to say exactly what was observed at each physical and computational boundary.

Our question is not whether direction finding is useful. It is indispensable when its physical, geometrical and statistical requirements are met. Our question is how the examiner distinguishes an angle measured at an antenna from the direction of a direct ray to a transmitter, the intersection of nominal rays from a justified position estimate, the recurrence of a waveform from proof of common source identity, and a source location from an accusation against a particular person. An uncertainty ellipse may be more persuasive than a confident pin, but even its boundaries can be wrong when the assumed error distribution omits a systematic reflection.

I propose that the panel travel through five distinct problems. Sir Edward Appleton will examine propagation and the physical meaning of arrival direction. Sir Martin Ryle will examine arrays, baseline calibration and ambiguities in phase and angle. Professor Ronald Bracewell will address inverse-source inference and the loss of uniqueness when incomplete field measurements are made to carry an elaborate narrative. Professor Rudolf Kalman will examine tracking, dynamical models and observability.

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Professor Dennis Gabor will return us to coherence, retained information and the temptation to extract identity from patterns that have several plausible causes. Seven colleagues will question the principals. Each question will receive its answer before a courteous transfer of the floor, so that a point of disagreement is neither evaded by the next speech nor hidden under unanimity.

We shall also work ten numerical examples, with every variable, assumption and unit declared. Such calculations illustrate the constraints of a method; they do not certify a particular monitoring installation. At the conclusion I shall request an evidence ladder, beginning with a recorded numerical feature and ending, where the evidence allows, with an expressly bounded account of source class, probable location and attribution. Sir Edward, as one whose study of radio propagation helped make the invisible atmosphere experimentally intelligible, would you distinguish the measured direction of arrival from the geographical assertion which an investigator may wish to draw from it?

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Sir Edward Victor Appleton

Principal response. Propagation, reflective geometry and the unearned certainty of a bearing

Dr. Atkinson, I am grateful for that exact separation. A receiving antenna does not observe an address. It receives a field, or more precisely responds to the component of an electric or magnetic field to which its effective aperture, polarisation, installation and connected receiver make it sensitive. The arrival of a wave at the aperture may be a direct component, a diffracted component, a reflection from a façade or a mixture of paths whose relative amplitudes and phases vary with time. One must therefore distinguish the measured direction of a dominant field component from the direction in which a physical transmitter lies. In many circumstances those directions are approximately equal, and direction finding is productive. The approximation must nevertheless be earned by the conditions, not granted by the title of the instrument.

The caution becomes particularly urgent in the high-frequency bands. A wave returning from the ionosphere may reach a receiver at an elevation and azimuth shaped by electron density, geomagnetic conditions and the geometry of the path, not by simple terrestrial line of sight. If an investigator treats a skywave bearing as though it were a ground-wave bearing, the arithmetic of an intersection may be impeccable while the geographical premise is wrong. A change of ionospheric state can move an apparent arrival direction without any motion of the transmitter. A second station, seeing a different mixture of propagation paths, may report a bearing that seems incompatible. Such disagreement need not incriminate either instrument. It may reveal different observations of a nontrivial field.

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The lower-level record must therefore contain frequency, antenna location and orientation, mounting conditions, polarisation response where known, receiving bandwidth, integration interval, signal-to-noise circumstances, interfering signals and calibration state. Where the method depends upon a direct-ray assumption, the analyst should record how that assumption was challenged. An antenna relocation, a change of height, a different polarisation or measurements on multiple independent paths can be informative precisely because the reflected component may change differently from the direct component. Yet a changed result is diagnostic only when the change of procedure is documented; moving equipment without preserving coordinates and cable states replaces one unknown with another. I yield the floor courteously for the next scientific examination.

The temptation to suppress unfavourable bearings is dangerous. If the investigator retains two agreeable rays out of twelve, the displayed crossing conceals an earlier choice made after seeing the evidence. A disciplined analysis preserves all valid bearings, records exclusions with reasons fixed independently of the desired source position, and tests sensitivity to plausible systematic errors. One may use robust estimation or a mixture model when reflections produce outlying paths, but those methods must be specified and validated for the observation class. Statistical ingenuity cannot turn unobserved direct paths into observations.

I also distinguish localisation from identification. A sustained emission detected from a confined area can materially narrow a search. Still, shared modulation, oscillator phase noise or a recurring schedule can arise from several transmitters or a common external reference. Conversely a single transmitter can emit differently after warming, changing gain or selecting

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another operating mode. A similarity measure must therefore be described as a similarity measure, with its conditions, rather than presented as a permanent fingerprint of an individual object. This is especially important in forensic reporting, where the words 'from this room' and 'produced by this person' occupy different evidential categories.

It is proper that our report end with a bounded proposition. We might say that two specified receivers observed a feature whose tested directional estimates are consistent with a defined region under a calibrated direct-path model, while stating the remaining multipath alternatives. We should not say that those rays prove where the transmitter stood unless the physical model and its adversarial challenges support that narrower possibility. I should welcome the scrutiny of Mr Heaviside, who may ask whether the very language of a ray is too simple a description of a field near conductive structures.

A further constraint follows from the defensible scope of localisation and electromagnetic-source attribution. An instrument specification does not by itself establish the result of a field experiment. A preselector may reject one interfering band while leaving a different ingress path; a sample clock may be stable in the mean while its phase fluctuates; and a file may be authentic while the analogue interpretation remains contested. The expert should distinguish a certificate describing a manufacturer test condition from a verified statement about the present configuration. Record the intervention and its physical reference, the raw output where available and the particular source hypothesis which the intervention could actually exclude. Applied to the present engineering problem, reflections, clock offsets, antenna-pattern errors, and non-identifiable inverse solutions may create a spectrum or

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timestamp that looks persuasive while leaving line-of-sight paths and true source positions concealed by multipath inaccessible. The experimental answer lies in independent sites, calibrated clocks, geometry variation, and residual analysis, carried out with explicit controls and independent retention of all the relevant receiver states. The account should quantify angular error, propagation delay, baseline length, clock uncertainty, and confidence region, separating input-referred values from software-derived quantities. If the calculation assumes constant noise statistics or a linear front end, an overload or irregular interference challenge should test that premise. The examiner should preserve negative outcomes and show why the proposed mechanism is better supported than the surviving alternatives. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Oliver Heaviside

Peer question 1 to Sir Edward Appleton

Sir Edward, thank you for restoring the field to an argument which too readily becomes a map. I should like to distinguish the distant, propagating component of a field from the induction and scattering phenomena in the vicinity of conductors. Imagine a survey antenna only a short distance from a cable tray, an equipment enclosure and a bundle of energised wiring. The recorded response might combine an external plane-wave component with a local current-induced field and a re-radiated signal from the metalwork. Yet the operator may aim the antenna until an apparent null appears and then publish a bearing towards the alleged transmitter. In what circumstances would you treat that null as a geometrical observation, rather than as a property of the

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antenna's local coupling environment? And how should the investigator test the hypothesis that the structure itself, rather than a hidden transmitter at the apparent intersection of rays, generated the directional contrast?

Sir Edward Victor Appleton

Answer to Oliver Heaviside

Mr Heaviside, your distinction is essential. The plane-wave approximation does useful work in an appropriate far-field region, but a receiver positioned beside a conductive assembly may be measuring a vector sum created by boundary conditions, local coupling, standing waves and re-radiation. An apparent null can therefore move when the operator moves the antenna by a small fraction of a wavelength, even though the remote emitter has not moved. The null is a repeatable feature of the measurement arrangement only if its state and geometry are preserved. The word bearing is too generous where the experiment has not established that the relevant observable is monotonically or uniquely related to azimuth.

A practicable challenge would record the antenna's trajectory, height, polarisation, cable route and instrument settings, then compare predictions of at least two hypotheses. Under a direct far-field model the direction should remain consistent after translating the antenna within a declared region, allowing for predictable parallax when applicable. Under a local-coupling model the null may be highly sensitive to cable position, nearby conductor geometry or the orientation of a shielding enclosure. A separately calibrated

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antenna, a field probe of another type or a test with the suspect structure safely disconnected may provide additional evidence. Disconnection is an intervention, not a conclusion: any signal change must be reconciled with the broader electrical network that the intervention also altered.

The test must also protect against an interpretative error in which a legitimate change of signal intensity is translated into a change of source position. If a conductor carries current induced by an external field, varying its connection or terminating impedance can change the local field without establishing that a transmitter was attached to it. The report should say that a coupling path was modified, describe the observed response and retain the external-emitter hypothesis until an experiment discriminates between them. Where switching a circuit is unsafe or operationally prohibited, the limitation must be stated instead of replaced by imagined intervention results.

The physically valuable output is an account of conditions under which the contrast persisted and conditions under which it disappeared. If an investigator finds that the alleged bearing follows a cable route rather than a position in space, the localisation claim must be withdrawn or reformulated as a coupling-path observation. None of this forbids subsequent localisation; it supplies better constraints for it. I thank you for pressing the matter, and pass the discussion to Lord Rayleigh for the array's limits of angular discrimination.

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Lord Rayleigh

Peer question 2 to Sir Edward Appleton

Sir Edward, may I ask whether the desire for a sharp directional peak can outrun the actual resolving power of the receiving aperture? The experimenter may possess several widely separated antenna elements and a processor that paints a remarkably narrow lobe on a screen. Yet the observed field includes finite observation time, uncertain phase, variable source strength and two nearby rays whose separation is smaller than the information supported by the apparatus. Would you oblige the examiner to distinguish the angular width of the display's interpolated peak from demonstrated resolution between two sources? In addition, could a single dominant peak, arising from unresolved direct and reflected components, justify a one-source assumption when the hypothesis at issue is whether a second and weaker device is present? I would also ask how you would challenge a processor that reports a single elegant angle when the true field contains two unresolved arrivals. Would you require controlled dual-source tests, and should the uncertainty statement include the rate at which the instrument silently merges those alternatives rather than merely reporting random variation when one source is present?

Sir Edward Victor Appleton

Answer to Lord Rayleigh and transfer of the floor

Lord Rayleigh, I would not accept display smoothness as a substitute for tested resolving power. An estimator can interpolate a maximum to a fraction of a plotted angular bin while remaining biased or unable to separate two nearby components. Resolution,

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uncertainty and bias must be distinguished. Resolution concerns the discrimination of alternatives, precision concerns variation under a repeatable model and accuracy concerns closeness to the intended physical quantity after systematic effects are considered. A narrow peak can coincide with a wrong direction. A broad peak can still provide useful exclusion of certain directions when its calibration supports the assertion.

The burden is an empirical one. The laboratory should challenge the array with known angular separations, frequencies, relative amplitudes, polarisations and coherent or incoherent signal conditions relevant to the surveillance task. It should report the cases in which two sources were merged, one was missed, or a reflected component drew the estimate away from the true line of sight. The number of plotted degrees is not the number of degrees warranted by the evidence. Equally, the mere theoretical possibility of another source need not defeat a narrowly supported one-source approximation when the intended claim is explicitly conditional and the alternatives have been bounded by experiment.

I would additionally require the laboratory to record the rule by which a result is called one source or two. If that rule is chosen after viewing the test population, a claimed resolution threshold may be optimistically biased. Controlled cases should include unequal source levels and changing phase relationships as well as equal-level signals, because a strong component can conceal a weaker one. The probability of merging sources and the probability of inventing a spurious second source are distinct performance measures. An

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examination report should state which of those risks matters to the proposition being advanced, and whether the apparatus was actually validated against it.

Your point connects the atmospheric and local-field ambiguities to the architecture of the receiving array. I therefore respectfully pass the floor to Sir Martin Ryle, whose work with radio interferometry makes the relationship between baseline, phase and reconstructed structure especially instructive. Sir Martin, would you examine what a phase comparison can and cannot identify when the clocks, cables and geometry are imperfect?

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Sir Martin Ryle

Principal response. Baselines, coherence and the ambiguity of phase

Dr. Atkinson, thank you. An interferometric observation is a comparison across paths and receivers. Its value lies in a carefully governed relationship between phase, delay, frequency, array geometry and the field whose arrival is being assessed. This relationship can provide finer angular discrimination than a single small aperture. It does not annul the requirement to know the instrumental phase, reference position and frequency-dependent transfer of each branch. When an investigator offers a high-resolution bearing, I would first ask for the phase-calibration history and the validity range of the model used to convert the measured complex correlation into that bearing.

For two antennas separated by a baseline vector b and observing a plane wave from a unit arrival vector u, the ideal geometrical delay may be written $\tau g = (b \cdot u)/c$, with the sign determined by the declared convention; c is the speed of light in vacuum. In a real installation the measured delay or phase difference may also contain differential cable delay, local oscillator offsets, clock errors and contributions from reflected wavefronts. If the analyst treats their sum as wholly geometrical, an electronic problem becomes a supposed source displacement. Moreover, a single baseline constrains only one projection of arrival direction. A geometrically complete location requires further independent constraints, and that independence can be undermined by common systematic errors. With gratitude for the challenge, I invite Dr. Atkinson to continue the discussion.

The sampling interval also warrants precision. A receiver can sample its own oscillator faithfully and still provide a poor inter-receiver timing comparison. When stations have independent clocks, their relative offset

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and drift must be established over the event interval. When they share a reference, their common error may cancel for some relative observables but remain in an absolute timestamp or source-frequency estimate. The covariance structure changes with the architecture. A claim that two channels 'agree' should identify whether that agreement is evidence of the external field or a product of their shared reference.

A particularly subtle problem arises when the carrier cycles many times over the possible delay. The phase is measured modulo a complete turn. Multiple directions may yield the same measured phase unless the baseline, bandwidth, ambiguity resolution and other information are sufficient. Phase unwrapping is a model-based inference; its success is not verified by producing a smooth bearing trace. To validate an unwrapped trajectory, one should ask whether alternate integer-cycle assignments remain compatible with the measured data under realistic noise and drift.

A validation report should also distinguish a geometric baseline, which is the surveyed separation of antenna reference positions, from an effective phase baseline, which may vary with frequency and with the response of individual elements. If a cable becomes warmer, its propagation delay may change without the surveyor moving an antenna by a millimetre. If a receive chain retunes its oscillator, a phase discontinuity may render earlier phase-calibration constants inapplicable. The admissible inference therefore depends not merely on the diagram of the installation but on a recorded sequence of configurations and phase-reference checks. A field calibration taken yesterday is not equivalent to one demonstrably applicable during the disputed event, and the distinction should be apparent in the uncertainty budget.

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Finally, a reciprocal test can isolate system behaviour from source behaviour. Inject a controlled reference through specified ports, interchange receivers where practicable, or rotate the calibrated array relative to the scene. Each intervention changes a known subset of the physical relationship. A valid design predicts what should remain invariant and what should transform. The strongest evidence is not the experiment in which every plot agrees, but the one in which a materially different hypothesis would have yielded a distinguishable result. Professor Lorentz may challenge whether the propagation medium and phase reference have been separated as cleanly as my equation implies.

Dr. Atkinson, I would frame the problem as follows. The chronology of whether bearings and timing could localise a radiating source is indispensable. Assume for a moment that correlated multipath can give a deceptively narrow intersection between imperfect bearings. In that case, rearranging snapshots to create a smooth chart will conceal the sequence of instrumental changes. We should move antenna baselines and repeat calibrated phase-centre measurements at independently logged times, and treat time spent switching, settling or clipping as measured invalidity rather than as an unoccupied channel. The state record needs antenna phase centre, geometry, covariance, clock offset and propagation environment. If a spurious intersection moves with the reflective surroundings instead of following a fixed emitter position, the first obligation is to determine whether the apparent motion in the display arose from the receiver or from the observed field. I would repeat the initial configuration after the challenge to expose drift, and I would preserve the records that fail to match the opening measurement. An operator may fairly publish a difference

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between the two visits, but may not infer a unique intervening event when the acquisition supplied no valid samples at the relevant instant. The result must be reported as a chronological comparison under named operating states.

A more precise objection comes from Sir Martin Ryle and the finite observation aperture in when may observations, bearings, and timing evidence support localisation or attribution of an electromagnetic source?. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when alternative receiver operation or selection bias. For that reason, record time reference, calibrated gain, detector threshold, and valid exposure for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After repeat with independently calibrated reference equipment under controlled conditions, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. Professor Lorentz, I invite your examination of the difference between cable-calibrated array delays and the paths taken by a wave reflected from a metal roof; those are not interchangeable geometries.

Hendrik Antoon Lorentz

Peer question 3 to Sir Martin Ryle

Sir Martin, your geometric delay equation is admirably compact, but I should like to press upon its implicit medium and reference. Imagine an

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array whose channels are phase-calibrated with a cable-fed reference, then used to observe a field reflected from a metal-roofed building. The cable calibration demonstrates a relationship among the electronic branches, while the field trial introduces the antennas, their mutual coupling and a frequency-dependent propagation path. If the system reports a constant offset from the desired bearing, does that offset represent a calibration correction, a scene-dependent scattering effect or an alternative source direction? Can the record establish this distinction without a field reference of known position and a deliberate variation of the scattering environment? I am especially concerned about a supposed calibration correction obtained by subtracting one offset found in a single trial. What evidence would distinguish a generally transferable correction from a number that merely compensates the particular reflector geometry on that occasion, and what residual experiments would expose the difference?

Sir Martin Ryle

Answer to Hendrik Antoon Lorentz

Thank you for identifying the principal uncertainty in this evidence. Thank you for that question. Professor Lorentz, I agree. An internal reference can be indispensable while remaining insufficient for the external measurand. The cable-fed comparison tests much of the receiver chain, but may bypass the antenna phase centre, mutual coupling, radome or housing, and propagation from a known point in space. Consequently, its success cannot certify the whole array for a particular scene. Nor should an offset observed on one trial be added indiscriminately as a universal correction. The correction is justified

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only over the conditions for which its dependence has been characterised, including frequency, array orientation and surroundings.

A deliberate set of contrasts is needed. A field source of known position and controlled frequency can quantify the array's response under a specified site configuration. Repeating the trial at differing heights and azimuths helps separate stable instrumental bias from site-dependent scattering, although the separation remains conditional on the adequacy of the field model. Swapping electronic channels while retaining antenna positions challenges receiver-path bias; swapping antenna connections can challenge a different subset of hypotheses. Moving the entire array or changing the environment is useful when the shift is recorded accurately, but it also changes the observed propagation and thus cannot be interpreted by simple subtraction without a physical model.

A particularly useful record is a partition of the calibration path. The frequency reference may reach a synthesiser, the synthesiser a mixer, the mixer an intermediate-frequency converter, and the converter a sampler; a successful loopback test may still omit the antenna and propagation. Marking those boundaries allows the expert to say exactly which errors an intervention could expose. It also prevents the comforting phrase 'fully calibrated' from concealing several distinct physical relationships. If later measurements show a stable bias under one environment, the resulting correction belongs to that environment until transfer has been demonstrated. It is not a free-standing property of the receiver's model number.

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The investigator should preserve a layered uncertainty account. Electronic calibration uncertainty, antenna-placement uncertainty, phase-centre uncertainty, and model discrepancy from the environment need not be independent or Gaussian. When the latter dominates, reporting a narrow confidence interval derived solely from instrumental noise would be unsound. A properly qualified statement might say that the observed phase difference is compatible with an arrival sector under a specified calibrated propagation model, while alternative scattering configurations remain unexcluded. I thank you for demanding that the external wave be admitted into the calibration argument.

John Daniel Kraus

Peer question 4 to Sir Martin Ryle

Sir Martin, let me ask about a more practical failure. A wideband monitoring array is advertised with a single angular accuracy figure, even though its electrical aperture, matching, mutual coupling, feed phase and pattern vary across the band. The direction-finding processor returns the same nominal number of decimal places whether a signal is strong and persistent or a brief burst arrives near the threshold. Should a forensic team publish one uncertainty figure across the band, or should it define separate acceptance regions by frequency, dwell, signal class and installation? And what evidence would be required before measurements from a narrow-aperture sector could be pooled with those from a frequency at which the array has substantially greater electrical size? I would further ask whether a published specification may be carried unchanged from one vehicle roof or equipment rack to

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another. If installation changes the ground plane and coupling, surely the competent examiner needs evidence that the original performance envelope survives those changes, rather than assuming it survives by name.

Sir Martin Ryle

Answer to John Daniel Kraus and transfer of the floor

Professor Kraus, one figure may summarise an instrument for procurement, but it rarely suffices as an uncertainty statement for a particular contested event. Accuracy is an attribute of a defined measuring process under specified conditions. Frequency alters the electrical size of the aperture, the effect of cable delay, the phase of mutual coupling and the array's susceptibility to ambiguous lobes. The burst duration controls how many independent or nearly independent measurements the processor can accumulate. The relevant confidence statement must therefore be conditional on a documented operating envelope and on evidence that the event actually fell within it.

If tests justify an uncertainty function or a set of validated strata, those can be reported without pretending that every condition deserves a wholly bespoke investigation. A sensible programme might classify frequency ranges, source modulation classes, signal strengths, dwell durations and site configurations. Within each class it would record systematic bias, random variation, invalid-result rates and the possibility of multiple resolved directions. The pooled estimator should then account for differences among classes rather than simply average their values. Averaging biased bearings from

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different frequencies may create a pleasingly stable number while masking a changing physical relationship.

When data from different validated strata are pooled, the calculation should explicitly model their relative weights and common influences. An error shared by all frequency settings, such as a mistaken antenna position, will not diminish because many independently noisy estimates have been averaged. Conversely two installations that produce disagreeing bearings may be revealing a systematic effect that no one-setting calibration can detect. I would preserve such discrepancies in the report rather than delete them to make the combined result look tidier. The point is not to multiply uncertainty figures without purpose, but to connect each figure to a physically defined measurement condition.

The governing doctrine is to report what the validation actually covers and to preserve when an event falls outside it. A transient detected for only a few milliseconds may support event discovery but not the same directional certainty as a sustained reference. A differently installed antenna may retain the signal but invalidate the earlier site-specific calibration. I therefore pass the floor to Professor Ronald Bracewell, whose account of reconstruction can place this geometrical evidence within the larger problem of deciding what, if anything, uniquely caused it.

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Ronald Newbold Bracewell

Principal response. Inverse sources, observational equivalence and the limits of a reconstructed image

Dr. Atkinson, I should begin by distinguishing a reconstruction that displays the consequences of a model from a discovery that proves the model uniquely true. A receiver samples a field through an antenna, an analogue front end, an acquisition process and a computational representation. A map or bearing estimate is then calculated by applying an inverse operator, an optimisation rule, or a model-conditioned likelihood. The resulting picture can possess striking detail. Yet detail in a reconstructed output may reflect the constraints imposed by the algorithm, including its assumed number of sources, permitted positions, smoothness penalties and treatment of missing samples. It is not a photograph taken by an omniscient electromagnetic eye.

One should ask whether materially different arrangements could have produced the observed input. A direct emission from one location and a reflection from a different emitter may have similar time-frequency characteristics at a particular receiver. Two narrowband emitters can be unresolved within a chosen dwell. A harmonic from an external transmitter may imitate a fundamental from a local device when front-end nonlinearity or mixer images have not been excluded. In each case the observation constrains possibilities, but its inverse is non-unique unless additional data or assumptions discriminate among them. When the assumptions are plausible but untested, they belong in the report as assumptions rather than disappearing into a numerical estimate.

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The concept of an equivalence class is valuable. Let Y denote the retained receiver observations, let H_i represent a candidate physical source and propagation account, and let $F(H_i)$ represent the observations predicted by that account under an explicit instrument model. Distinct hypotheses H_1 and H_2 may satisfy $F(H_1) \approx F(H_2)$ within measurement uncertainty. Their apparent equivalence is not necessarily perfect, and additional intervention may break it. But one cannot use a result from the inverse operator F^{-1} to claim a unique H when F maps many admissible causes into effectively the same Y. The correct practical question is which additional measurement will separate the candidates at acceptable cost and without destroying evidence.

A useful workflow therefore constructs rival predictions before the next measurement. If a supposed local transmitter drives a cable or near-field path, changing an antenna's position relative to that cable may change signal intensity in a distinctive manner. If the feature is a second-order mixer product, altering preselection or front-end gain may change its behaviour in ways a real external carrier does not. If the signal is a reflection of an external emitter, a shielded reference antenna positioned outside the structure might retain the original transmission while the indoor observation changes. These are tests only if the expected outcomes under each alternative are sufficiently distinct, and if the intervention does not introduce a competing artifact. I pass the floor to the next participant with thanks for this considered exchange.

The panel should resist a related confusion between detection and attribution. The observation of a recurring digital sequence may justify a claim that a common waveform pattern is present. It may not establish that the same hardware emitted the pattern, for an authorised repeater, a

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playback, a networked system or another transmitter using the same protocol may reproduce it. Even a carefully measured analogue imperfection is a feature subject to stability testing and population overlap. Without an appropriate population and validation model, the uniqueness of a 'fingerprint' is rhetoric, not an observed statistic.

Reports can make the inverse nature of the argument visible. First present the observed data and their acquisition conditions. Then describe the forward model and the assumptions on which the inversion depends. Then give the resulting estimate with its statistical and systematic uncertainty. Finally list plausible alternatives not excluded, together with specific experiments that would distinguish them. A document ordered in this fashion permits a second examiner to disagree about the model while still understanding the measurements. That is a stronger form of reproducibility than asking the second examiner merely to obtain the same position icon from the same software.

Professor Poincaré, I should be grateful for your challenge concerning what counts as a genuine solution when several physical configurations explain the data equally well.

Dr. Atkinson, I would frame the problem as follows. Before offering an opinion about whether bearings and timing could localise a radiating source, I would define the measurand and its uncertainty. The proposed rival mechanism is that correlated multipath can give a deceptively narrow intersection between imperfect bearings. Consequently a calibration certificate for one nominal receiver setting does not settle the question. The more informative operation is to move antenna baselines and repeat calibrated phase-centre measurements at independently logged times, with

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antenna phase centre, geometry, covariance, clock offset and propagation environment reported in units and tied to an input reference plane. The adverse prediction is concrete: a spurious intersection moves with the reflective surroundings instead of following a fixed emitter position. I would challenge it across a range of input powers and hold one independently measured source constant throughout the switching sequence. A correction estimated after seeing the unknown feature may assist an exploratory analysis; it must not be presented as though it had been fixed before acquisition. Where systematic effects share a reference, their covariance belongs in the reported uncertainty rather than being silently assumed zero. This is the distinction between an instrument number that appears stable and a defensible physical measurement. I pass the floor to Professor Poincaré, whose scrutiny of an ill-conditioned inverse should reveal when a seemingly precise bearing becomes an unstable source location.

Jules Henri Poincaré

Peer question 5 to Ronald Newbold Bracewell

Professor Bracewell, I welcome your distinction between the forward relation and its inverse. Let me extend it to the stability of the inverse. Even when a mathematical model yields a unique answer in an idealised noiseless setting, a minute error in arrival angle, phase or time may produce an enormous displacement of the inferred source when the geometry is ill-conditioned. An optimiser can nonetheless return one attractive coordinate because it must return something. How would you require an expert to demonstrate not merely the uniqueness of a nominal solution but its stability under realistic perturbations, including uncertain station position, clock error, propagation bias and algorithm

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selection? And when two different source explanations are both stable within their restricted models, on what basis may one be preferred without smuggling the investigator's suspicion into the prior assumptions? Would you include a method for detecting a second, distant optimum that a routine local uncertainty calculation might miss? I am concerned that one reported confidence ellipse may describe only the neighbourhood of an arbitrarily selected solution while a rival physical interpretation remains equally consistent with every received sample.

Ronald Newbold Bracewell

Answer to Henri Poincaré and transfer of the floor

Professor Poincaré, I would separate mathematical identifiability, numerical stability and evidential discrimination. A solution is identifiable when distinct admissible model parameters lead to distinguishable probability distributions or observables, under the model actually asserted. It is stable when reasonable perturbations of data and nuisance parameters do not drive the reported quantity beyond a declared tolerance. It is evidentially discriminating when plausible competing physical accounts fail against some observation they should have explained. These are related but not interchangeable requirements. A unique maximum of an optimisation routine may satisfy none of them.

The examination should therefore include perturbation analysis. Recompute the estimate under the measured uncertainty of station coordinates, antenna orientations, cable delays and clock offsets. Vary the model of multipath within justified bounds. Use alternative

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initialisations and, where legitimate, different estimation families. Report multimodal solutions rather than concealing secondary peaks. A confidence set constructed only from local curvature around one optimum may be disastrously narrow if the objective has a remote second optimum or if model error dominates random noise. The investigator should preserve the likelihood surface, residual maps or appropriate equivalent, not merely the maximum's coordinates.

Selection among two adequate explanations may rest on a prior or on practical consequences, but the basis must be exposed. A model comparison may be legitimate when the prior, nuisance treatment and sampling frame are defensible, and the result should be sensitive-tested against reasonable alternatives. A physical intervention that causes the two hypotheses to predict different outcomes is usually more valuable than sharpening an untested preference. If the rival accounts remain observationally equivalent, the report must say so. Such restraint is not a confession of incompetence; it is the scientifically precise description of the evidence's reach.

One should also test the effect of the search bounds themselves. An algorithm restricted to the surveyed building will necessarily produce a point within that building even if the true source lies outside it. A result that moves towards a boundary when the permitted region is enlarged signals dependence on the constraint, not proof of occupancy. Stating the model domain and comparing wider alternatives are therefore elementary safeguards against an

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inverse solution manufactured by the investigator's original area of suspicion.

The next difficulty concerns whether a succession of bearings can identify a moving source. That question introduces dynamics and temporal dependence, so I pass the floor with respect to Professor Rudolf Kalman. Professor Kalman, how should an investigator prevent a tracking algorithm's smooth trajectory from becoming a false story of motion?

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Rudolf Emil Kálmán

Principal response. Tracking, observability and the distinction between a state estimate and a witnessed path

Dr. Atkinson, I thank Professor Bracewell for stating the static inverse problem so plainly. A tracking algorithm is an additional model placed upon observations over time. It can exploit repeated measurements and predictable dynamics to produce estimates that a single bearing cannot supply. Yet a smooth path may owe much of its smoothness to the assumed transition law and covariance weights. The output is an inference about an unobserved state. It should not be described as though a camera had witnessed the transmitter traversing each point of the line.

Let x_k denote the state of a hypothesised source at time index k, such as two-dimensional position and velocity. A simplified linear dynamic model writes $x_{(k+1)} = A x_k + w_k$, where A describes the assumed motion and w_k is process disturbance. Observations may be written $z_k = H x_k + v_k$, with H linking the state to measurable quantities and v_k representing observation error. In a real direction-finding problem the relationship may be nonlinear, so H may be a local Jacobian or the model may require a nonlinear estimator. Every symbol is a proposition about the system. In particular, the covariance used for v_k must not quietly omit persistent multipath bias, and the model for w_k must not be tuned only after seeing the path one wishes to obtain.

Observability addresses whether the state can in principle be distinguished through the available measurements over time under an adopted model. If a single station measures only bearing to an uncooperative source, changes in source range can remain poorly

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constrained without additional geometry or motion assumptions. A filter can still produce a range value by propagating its initial estimate. Its existence in the display does not demonstrate that the measurements determined it. One must therefore review observability, geometric dilution and the prior's continuing influence before assigning physical confidence to the output. I respectfully return the discussion to Dr. Atkinson.

The process becomes more treacherous when an adaptive receiver changes its own observation policy. If the system dwells longer after an initial alarm, a sequence of repeated detections may look like increasing signal persistence. In reality the opportunity to observe has changed. Similarly, a scanning network can create artificial timing gaps and apparent movement by visiting different sectors in sequence. The observation likelihood should be conditioned on the actual sensor schedule, and missed detections should be represented only where a valid exposure opportunity existed. A missing record during a period when the receiver was tuned elsewhere is not a negative bearing and cannot be introduced as such.

A reasoned validation campaign would inject or radiate known trajectories, including stationary emitters, rapidly changing paths, multiple simultaneous sources and controlled reflections. It would measure not merely root-mean-square position error but false-track rate, loss-of-track rate, track fragmentation, association errors and performance when the assumed motion model is deliberately violated. It would preserve all rejected observations and the gating decisions that led to exclusion. A track shown only after removing 'outliers' selected by visual proximity to that track risks becoming self-confirming.

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Forensic language must recognise three levels: observed measurements, model-conditioned state estimates and causal interpretations of the estimated behaviour. An expert can say that the data support a trajectory within a stated model and tested uncertainty envelope. An expert must not automatically say that the same identified hardware moved along that trajectory, and still less that a person carried it. If an identification rests on additional evidence such as physical possession, device logs or independent video, its provenance and independence from the radio evidence should be made explicit.

A further problem is the treatment of invalid or absent measurements during a track. Many estimators advance a state prediction through intervals in which no usable measurement has arrived. The resulting curve may remain continuous on screen and may carry a covariance that widens according to the chosen process model. The operator must not mistake this prediction for a set of fresh radio observations. Every rendered trajectory should therefore distinguish measured updates, predicted segments and rejected associations, with the confidence attached to each made conditional on the assumptions actually used. In an investigation involving two potentially indistinguishable emitters, a model may prefer continuity even when a physically different source has taken over. Preserving the competing association hypotheses and the underlying measurements is often more informative than publishing one uninterrupted line.

Dr. Atkinson, I would frame the problem as follows. There is a statistical difficulty in the assertion concerning whether bearings and timing could localise a radiating source: we have not yet ruled out the possibility that correlated multipath can give a deceptively narrow intersection between

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imperfect bearings. The investigation should record its chosen detector threshold, visit schedule, selection of frequencies and expected failure modes before the prospective confirmatory test. To examine the difference we should move antenna baselines and repeat calibrated phase-centre measurements at independently logged times, collecting antenna phase centre, geometry, covariance, clock offset and propagation environment over a predeclared range rather than selecting the most attractive subset afterward. An observation in which a spurious intersection moves with the reflective surroundings instead of following a fixed emitter position would strengthen a restricted causal account, but it cannot certify every unvisited frequency-time interval. I would state which recordings are dependent, which have been excluded as invalid, and which inferences rely upon a model of rare events or stationary interference. A numerical interval can have impeccable arithmetic and still misdescribe the physical world if its sampling population was chosen because the signal already looked unusual. We should therefore preserve exploratory leads separately from independently designed validation evidence.

I invite Professor Wiener to challenge whether the filter's adaptation and the operator's reaction are properly included in the dynamical system whose history the record must preserve.

Norbert Wiener

Peer question 6 to Rudolf Emil Kálmán

Professor Kalman, your account of observability is persuasive, yet I fear that the investigator may keep the observer outside the model while the observer is actively changing it. Imagine a monitoring team whose operator moves a directional antenna towards the strongest apparent

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bearing, while software changes gain, dwell and detection threshold in response to successive tentative localisations. The later record is therefore conditional upon earlier alarms and decisions, including decisions which may have been wrong. Would a conventional process-and-measurement noise model sufficiently describe this coupled observer, or must the policy of observation be treated as part of the state history? In particular, how could one test whether the apparent approach of a source was actually caused by the team approaching a reflective surface? I also ask about the archive itself. If the control loop saves only measurements that reinforced its current track, does the resulting file permit a valid comparison between the true-source and reflection hypotheses, or has the adaptive retention policy removed precisely the observations needed to decide?

Rudolf Emil Kálmán

Answer to Norbert Wiener and transfer of the floor

Professor Wiener, I agree that the observation policy belongs within the mathematical and evidential boundary. When an operator or controller changes the sampling pattern in response to a preliminary estimate, the distribution of later measurements is conditional on those earlier decisions. This does not make adaptation illegitimate, but it changes what the observation sequence can support. A state estimator that models the source while leaving the moving sensor's position, pointing direction and gain-control state unrecorded is incomplete for an investigation in which those variables materially affect the readings.

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One may enlarge the state or treat the sensor policy as a recorded controlled input. The required choice depends on whether those controls are known accurately, estimated with uncertainty or themselves influenced by feedback. Sensor pose, time synchronisation, antenna orientation, threshold history, calibration version and discarded observations should accompany the retained detections. When the controller makes an active selection, its decision rule and the information available at that moment should be recoverable. Otherwise a later analyst cannot reconstruct the likelihood of obtaining the observed sequence under competing source and reflection hypotheses.

An auditable controller should retain the policy that generated each decision and, where feasible, the score or measurement that caused it. Recording the final antenna orientation alone is inadequate when the route to that orientation depended upon discarded candidate peaks. Such provenance permits simulation of the observation process under different hypotheses and makes clear where retrospective conditioning has entered. It also distinguishes a deliberate operator choice from an automatic receiver-state transition that the operator may never have noticed. The physics of a presumed emitter cannot be reconstructed responsibly while the sampling mechanism that selected its apparent evidence remains hidden.

A strong challenge would hold the supposed source stationary, move the sensor through a documented route and compare the predicted direct-path and reflection-dependent patterns. Another would retain the sensor position while changing the suspected

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reflector or introducing a controlled reference field, where lawful and physically appropriate. If one explanation predicts a stable spatial source bearing and the other predicts a changing pattern tied to the observer's movement, the intervention may discriminate between them. The test must also preserve what happened when the signal disappeared or failed to cross threshold, subject to known observation opportunity. I thank you for putting the human operator back into the system, and pass the final principal turn to Professor Gabor for an account of information, coherence and identity.

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Dennis Gabor

Principal response. Coherence, finite information and the difference between a matching waveform and an identified emitter

Dr. Atkinson, I should first remind the panel that all localisation methods operate on a finite record of the electromagnetic field. The instrument retains projections of a wave over limited time, frequency, polarisation, dynamic range and space. A computational method can represent those projections with great sophistication, but no method can extract evidence of a distinction absent from every accessible part of the record without introducing assumptions or external information. The claim becomes most hazardous when the examiner moves from the similarity of signals to the identity of a physical device.

Coherence can supply powerful evidence that observations share a structured component. Two time-aligned records may exhibit high complex correlation over a declared interval and bandwidth. Yet shared content can arise from a common transmitted waveform, an intercepted relay, an environmental interferer, leakage from common instrumentation or two receivers processing the same reference contamination. Correlation is a relation between records, not a signed certificate of provenance. If the equipment shares a reference oscillator, digital transport or trigger policy, the source of common structure must be investigated before the records are called independent witnesses.

One must also respect the instrument's phase and bandwidth ambiguity. A narrowband measurement may establish phase consistency without resolving a unique delay, because numerous delays differ by integer carrier periods. A finite filter produces a smeared observation of a sufficiently short

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pulse; apparent pulse width depends in part on the measurement response. Recovering a subresolution waveform by deconvolution can be possible under a valid model and adequate signal-to-noise ratio, but the result may be dominated by regularisation where information was lost. An inferred sharp pulse should not be reported as directly measured merely because a mathematical inverse has drawn it. I return the token to the moderator for the succeeding contribution.

A stronger identification claim needs population evidence and a stability model. If a hardware imperfection produces a distinctive spur or modulation characteristic, the expert must investigate how that feature varies with temperature, supply voltage, operating mode and elapsed time. The analyst must also examine the prevalence of similar imperfections among candidate devices. Searching a large library of emitters and finding the closest match is not equivalent to demonstrating that a specified device emitted the signal. The search itself creates opportunities for apparently remarkable similarities, and the underlying device population may be far larger than the candidates conveniently available to the examiner.

I would permit strong language where the record warrants it. If a particular emitter is recovered, tested under appropriate conditions and shown to reproduce multiple distinctive signal properties while plausible rival mechanisms are challenged, the evidence may become persuasive. But even then the report should separate the device-to-waveform relationship from the device-to-person relationship. Ownership, operation and intent demand evidence of a different kind. A physical signal is not a witness to the legal status of its user.

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One more qualification concerns the numerical scale of similarity. A correlation coefficient close to one can be obtained from a common narrowband carrier even when the modulated content differs, especially after aggressive filtering or alignment selected to maximise the match. The relevant discriminator may reside in sidebands or timing details discarded by that processing. Conversely a genuine common source can yield a lower raw correlation after separate multipath channels or clock drift have altered the observed waveforms. The expert must therefore identify the preprocessing applied, the search over offsets, the bandwidth retained and the population of alternatives against which the claimed similarity was assessed. A single decimal coefficient is no substitute for a validated comparison protocol.

The proper closing question concerns the logical and probabilistic vocabulary of the forensic report. Sir Harold Jeffreys, I should be pleased if you would examine how an expert may express support for a source hypothesis without turning conditional probabilities or likelihood ratios into declarations of certainty.

Dr. Atkinson, I would frame the problem as follows. I should distinguish the physical occurrence under inquiry from the information actually retained when studying whether bearings and timing could localise a radiating source. Because correlated multipath can give a deceptively narrow intersection between imperfect bearings, more than one historical account may produce the same saved trace. The controlled comparison should be to move antenna baselines and repeat calibrated phase-centre measurements at independently logged times, preserving antenna phase centre, geometry, covariance, clock offset and propagation environment at the measurement

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point and in the evidential metadata. If a spurious intersection moves with the reflective surroundings instead of following a fixed emitter position, that result would narrow the admissible explanations, not establish a uniquely identified emitter outside the tested conditions. A subsequent software reconstruction may recalculate a statistic from retained samples, yet it cannot recover components rejected by the front-end filter or intervals never recorded. I would make those distinctions explicit in the final report and invite an independent examiner to reproduce the challenge, including its failed steps. Scientific restraint is not a weakness of the investigation. It prevents a detector output, however striking on the screen, from becoming a claim about unobserved activity that the original measurement never established.

A more precise objection comes from Dennis Gabor and the finite observation aperture in when may observations, bearings, and timing evidence support localisation or attribution of an electromagnetic source?. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when alternative receiver operation or selection bias. For that reason, record time reference, calibrated gain, detector threshold, and valid exposure for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After repeat with independently calibrated reference equipment under controlled conditions, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical

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source cannot be distinguished, the conclusion must remain conditional. Sir Harold Jeffreys, I would value a challenge to the evidential weight assigned to a location when alternative emitters and uncertain prior assumptions remain in play. Please take the floor.

Sir Harold Jeffreys

Peer question 7 to Dennis Gabor

Professor Gabor, thank you. Your example is salutary because it requires a prior probability as well as an evidential ratio. In practice, the examiner may be asked a more modest question: whether the observed radio evidence supports the proposition that a recovered device produced the emission over the alternative that some other relevant device did so. The hypotheses are not necessarily exhaustive, and an unknown source population can make the alternative difficult to quantify. What language would you permit when the analyst can compare evidence under two explicit propositions but cannot defensibly assign their prior odds? Should the numerical likelihood ratio be omitted, reported with strong qualifications or replaced by a broader expression that reflects validation limits? How can a tribunal be helped without being presented with an unjustified probability of guilt? Would you require an explicit declaration when the relevant population is not known, and would you prohibit a verbal strength label that implies a precision unavailable from the empirical comparisons? The language of confidence must surely be no more exact than the evidence from which it derives.

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Dennis Gabor

Answer to Sir Harold Jeffreys and transfer to the moderator

Thank you for that question. Sir Harold, the essential safeguard is to keep the conditional direction of inference visible. A likelihood ratio, where defensibly estimated, compares how probable the evidence would be under specified alternative propositions. It does not, by itself, state the probability that either proposition is true. The ratio may be informative without a prior, provided the expert declares the propositions, relevant population, measurement model, uncertainty and the scope of validation. The decision-maker must not be invited to read that conditional comparison as a posterior probability or as a probability of innocence or guilt.

Where the alternative source population is poorly characterised, a precise likelihood ratio may not be supportable. One may then report the observed correspondence, its repeatability, the features examined, the range of tested alternative devices and the conditions not studied. Qualified verbal statements can be preferable to an unearned number, although verbal scales also need consistent definitions and must not imply validation they lack. The expert should avoid labels such as unique, impossible or conclusively matched unless the relevant scientific premise has truly been established. A match obtained after flexible searching also requires disclosure of the search and selection process.

Even a non-numeric formulation should identify a boundary at which stronger language would become justified. If the relevant alternative population can be sampled, if the similarity statistic is fixed

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in advance, and if repeated tests show satisfactory discrimination across changing environments, a more explicit comparison may be warranted. Until then, a detailed account of observed correspondence and unexcluded alternatives is superior to an adjective which sounds quantitative while lacking a defined calibration. The final decision may be urgent, but the expert's words ought to remain proportional to what the laboratory has actually established.

I would particularly avoid fusing distinct propositions. That the observed signal resembles one emitted by a recovered device is a technical proposition. That the device was present at a location during the relevant interval adds temporal and spatial premises. That a named individual caused its operation adds still another layer of independent evidence. These layers can support a final account, but their uncertainties should not be replaced by the confidence of the strongest individual step. I thank you for the challenge and return the floor to Dr. Atkinson for the conclusions and the next question.

Sir Edward Victor Appleton, Cross-Peer Question to Sir Martin Ryle: Sir Martin, two stations supply extraordinarily neat intersecting bearings, apparently fixing a radiating source to a particular building. Yet one station stands beside a steel-framed structure and the other receives a strong reflected path over a nearby roof; the apparent crossing may therefore be the intersection of two propagation artefacts. How would you test whether the two measured directions actually belong to the same direct arriving wave rather than to correlated reflections? Would the crossing deserve less confidence if changing an antenna height or a receiver position shifts the

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estimated location, even where the instrument continues to report a narrow angular error?

Sir Martin Ryle, Cross-Peer Answer to Sir Edward Victor Appleton: Sir Edward, an angular estimator can be precise with respect to the signal arriving at its antenna and still be biased as an estimate of the emitter's geometrical direction. An impressively narrow peak is not a guarantee of direct-path propagation. I should repeat the observation across spatial baselines, heights and, where the signal permits, frequencies or polarisation conditions, and compare the resulting angular stability with a propagation model. Calibrated reference emitters in the relevant environment can disclose site-specific bearing bias, although one reference location cannot characterise an entire city. Measurements that vary with a roofline or a building edge warrant investigation of reflection, not an immediate declaration that a source is moving. The angular uncertainty quoted by an algorithm often represents the estimator's internal variation under an assumed model; it may omit dominant propagation bias. Preserve the raw antenna channels where available, exact station geometry, phase calibration, frequency, receiving interval and obstacles. If a source region remains broad or multimodal, present the credible regions and alternative paths instead of plotting a false pinpoint on a map.

Sir Martin Ryle, Cross-Peer Question to Rudolf Emil Kálmán: Professor Kálmán, our example illustrates that a one-nanosecond delay at one hundred megahertz produces thirty-six degrees of phase, whereas ten nanoseconds makes one full turn and may be observationally indistinguishable at one frequency. A tracking program that unwraps phase has nevertheless selected one integer cycle for every measurement and

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then draws a smooth trajectory with vanishingly small error bars. Could a numerically stable filter be observing the wrong state because clock offset, cable delay or cycle count is treated as known? What test of observability and innovation residuals would justify treating this trajectory as a measurement rather than an artefact of the estimator?

Rudolf Emil Kálmán, Cross-Peer Answer to Sir Martin Ryle: Sir Martin, a recursive estimator can be internally consistent while its measurement function is insufficiently informative about the state one hopes to infer. The question is not merely whether a covariance update converges but whether the geometry and time history distinguish position, velocity, timing bias and the possible integer-cycle ambiguities. I would write an augmented measurement model containing those nuisance variables when they matter, inspect the local Jacobian and the information gained from successive independent geometries, and challenge competing cycle hypotheses rather than fixing a convenient one. A small innovation computed against an overconfident model is not independent validation; the process and observation noise covariance, common clock terms and model mismatch must be tested with external controls. Additional carrier frequencies, baseline changes and calibrated synchronisation may make an ambiguity observable, but only within their demonstrated accuracy. Where multiple tracks fit, retain those hypotheses and show how the result changes under plausible clock offsets and reflected paths. A publishable report should name the observation period, geometry, bias assumptions and the coverage of its uncertainty region, not merely the coordinates issued by a filter.

Ronald Newbold Bracewell, Cross-Peer Question to Dennis Gabor: Professor Gabor, consider a stored waveform whose cyclostationary pattern appears

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to match an emissions catalogue entry. The receiver observed only a finite band and a short interval, and a digital resampler altered the apparent phase history. The investigators then leap from resemblance to a claim that the catalogued device, specifically, was present. In an inverse-source problem with incomplete aperture, how do we determine which physical attributes have been recovered from the data and which remain members of an observationally indistinguishable set? What experiments would discriminate a shared modulation family from the particular analogue and clock imperfections of one identified emitter?

Dennis Gabor, Cross-Peer Answer to Ronald Newbold Bracewell: Professor Bracewell, a finite time-frequency aperture limits the distinctions the observations can support. A recovered modulation family, symbol timing, spectral occupancy or periodic structure may survive reasonable receiver transformations; an alleged device-specific fingerprint may be far more sensitive to clock reference error, gain nonlinearity, temperature and the estimator's processing choices. One should begin with an explicit forward model from emitter through propagation and analogue receiver to sampled data, including any resampling. Then compare the candidate device with a realistic alternative population using an analysis procedure settled before the confirmatory tests. Where feasible, collect repeat observations under changed temperatures, supply voltages, channels and geometries to see which features are stable and which belong to the environment or receiver. A catalogue match is weak if the catalogue itself contains few similar devices or shares the reference receiver's bias. The defensible result may be that recordings are consistent with a class of emission processes, while the evidence cannot distinguish an individual apparatus. No clever

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reconstruction can create the unmeasured degrees of freedom from a finite record without additional assumptions.

Rudolf Emil Kálmán, Cross-Peer Question to Jules Henri Poincaré: Professor Poincaré, the tracking software connects two radio localisations separated by twenty seconds and assigns a constant-speed motion of three metres per second, thus implying a sixty-metre displacement. A second interpretation is that two fixed emitters operated in succession; a third is that a reflected path changed as a vehicle passed; a fourth is that the clock correction changed between observations. The plotted trajectory is smooth and gives a reassuring covariance ellipse. What would you demand before converting the mathematical continuity of a fitted path into evidence that one physical transmitter moved through the proposed locations, much less that a named person controlled it?

Jules Henri Poincaré, Cross-Peer Answer to Rudolf Emil Kálmán: Professor Kálmán, mathematical regularity is a property of the adopted model and its fitting procedure. It does not resolve an inverse problem whose observable consequences are substantially alike under different physical histories. The alleged continuous track depends upon data association: the two positions must first be shown to concern the same emitter, not merely chosen because a smooth connection was possible. I would require further simultaneous measurements capable of separating the alternatives, such as independently calibrated radio features, additional receiver geometry, a direct-path check, and sufficiently continuous timing to test whether an intervening emission actually existed. The model should be run against an explicit two-source alternative and a reflection-change alternative, not only against perturbations of its own favoured trajectory. Where the evidence

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fails to discriminate, preserve multiple hypotheses and describe the uncertainty as potentially multimodal rather than forcing all doubt into one small ellipse. Finally, the identity of a person is not a coordinate transformation. It requires separate evidential steps beyond the technical inference that an emission may have originated in a region.

Dr. James M. Atkinson

Moderator's synthesis. A five-stage evidential ladder for radio localisation and attribution

The panel has reached a conclusion more useful than either suspicion masquerading as science or scepticism so absolute that no observation can be reported. A radio receiver produces a record of a defined response under defined conditions. A direction finder may convert a properly calibrated field measurement into an arrival-direction estimate. Several such estimates, or suitably synchronised arrival-time differences, may under adequately tested propagation assumptions yield a bounded location inference. Cross-record correspondences may then support a source-class or common-source proposition. Attribution to identified hardware or a person requires further independently justified evidence. These stages are distinct; none is made automatic by a dramatic display or by a chain of technically correct calculations applied to an inadequate premise.

First, the observation stage should identify every sensor, antenna, reference plane, receiver setting, valid observation interval, sample history and preserved raw record. The analyst should be able to show what the instrument actually retained, not merely the final graphical localisation. Second, the signal stage should account for receiver-generated artifacts, aliases, images, preselection, clipping and coherent contamination, with the

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results of any controlled challenges. Third, the geometrical stage should preserve the array, station coordinates, clock and cable delay budgets, bearing measurements, unselected candidates and the geometry-sensitive uncertainty calculation. Fourth, the inverse stage should state the propagation model, alternative scattering paths, environmental assumptions, source multiplicity and the stability of the inferred solutions. Fifth, the attribution stage should separate waveform correspondence, device identity, custody, operation and personal responsibility.

These requirements have practical consequences. A report may reliably state that a candidate signal was present at specified receivers over a particular period without naming its transmitter. It may give a search region rather than a street address. It may state that data are consistent with one device among a set of tested candidates, without declaring the set to exhaust the world. It may explain that a negative result was indeterminate because dwell, sensitivity or propagation left meaningful gaps. Such qualifications are not decorative disclaimers. They define precisely what the evidence establishes, what it does not establish and which further experiment would most efficiently reduce the remaining uncertainty.

The calculations have exposed several separate dimensions of risk. A mathematically exact bearing crossing can still rely on reflected paths. A one-degree angular uncertainty can lead to a much larger geographical uncertainty when rays cross poorly. A microsecond of timing difference imposes a path-length difference but not a unique coordinate. A hundred nanoseconds of unrecognised clock bias corresponds to roughly thirty metres of path-length difference. The electrical aperture of a fixed array changes radically across a decade of frequency. Relative carrier offsets can

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arise from either the source or the receiver. A half-microsecond reflection may imitate a second event. An apparently smooth track can be a dynamical prior rather than a witnessed movement. A single-frequency phase match can conceal an integer-cycle timing ambiguity. Finally, even a sizeable likelihood ratio can leave a low posterior attribution probability when the proposition was initially improbable under an explicit, justified prior.

For future cases I adopt the following reporting convention. Every asserted position shall be paired with the measurement interval, the physical geometry, the stated propagation model and an uncertainty account that includes material systematic effects or an explanation why they cannot be bounded. Every asserted common-source relation shall identify the measured similarities and their demonstrated discriminating power. Every claim about a particular person shall identify the non-radio evidence on which it depends. If the record cannot support one of those steps, it shall not be supplied by the investigator's confidence, the client's anxiety or the software's polished display.

I thank all five principals and seven peers for a properly disciplined exchange. The next question moves from localisation to the digitised record itself. We shall consider how ADC resolution, parallel receivers, oversampling, resampling, time shifting and pulse broadening affect the information that can honestly be recovered from finite-bandwidth observations. It will require a firm distinction between creating a better estimator of a surviving quantity and pretending to recreate information which the analogue chain or sampling process never preserved.

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Ten worked engineering applications | Question 007

Worked application 1. A geometrically exact crossing of two ideal bearings. Place station A at coordinates (-500 m, 0 m) and station B at (500 m, 0 m), where x increases east and y increases north. In this hypothetical plane the source is at (0 m, 500 m). Station A's ideal ray has slope +1, expressed as y = x + 500 m; station B's ideal ray has slope -1, expressed as y = -x + 500 m. Equating the two yields x = 0 m and hence y = 500 m. The intersection is correct only for the assumed rays, coordinate reference and absence of material propagation bias. It is not, by itself, a confidence region, and it identifies no device or person.

Worked application 2. The effect of crossing geometry. Suppose an angular standard uncertainty σθ = 1 degree = 0.0174533 radians is observed at a characteristic slant range R = 1,000 m. The first-order transverse scale Rσθ is about 17.45 m. For a simple illustrative two-ray geometry, a poor crossing angle φ = 10 degrees introduces a factor approximately 1/sin(φ) = 5.76, raising the corresponding characteristic positional scale to roughly 100.5 m. The expression is a sensitivity illustration, not a general formula for a two-dimensional covariance ellipse: the latter depends on both ranges, orientations, covariance and bias. An apparently precise pair of azimuth readings can therefore yield a much less precise position when its rays nearly coincide.

Worked application 3. Delay as a difference of path lengths. Let c = 299,792,458 m/s and let the measured time difference between two receiving sites be Δt = 1.0 microsecond = 10^-6 s. The corresponding path-length difference is ΔL = cΔt = 299.792458 m. In two dimensions,

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one such difference constrains the emitter to a branch of a hyperbola having the two receivers as foci. It does not supply a unique geographical coordinate. A third suitably placed station, or a justified directional constraint, is needed to resolve the missing degree of freedom, and an unknown clock offset moves the hyperbola itself.

Worked application 4. Differential clock error. Suppose the receivers' relative timestamps contain an unrecognised bias $\delta t = 100$ ns = 100×10^{-9} s. The equivalent path-difference bias is $c\delta t = 29.9792458$ m. A smaller bias of 20 ns still corresponds to approximately 6.0 m of path difference. Neither number is automatically the error of an estimated position, which also depends on site geometry. Both demonstrate why the synchronisation budget, antenna cable delays and clock-state transitions must be part of the location record rather than merely instrument housekeeping.

Worked application 5. Aperture in wavelengths. With an antenna aperture $D = 0.50$ m and a carrier frequency $f = 1.0$ GHz, the free-space wavelength is $\lambda = c/f \approx 0.300$ m, so $D/\lambda \approx 1.67$. At $f = 100$ MHz, $\lambda \approx 3.00$ m and the same aperture has $D/\lambda \approx 0.167$. The electrical size has fallen by a factor of ten. This is not a promise of any particular bearing accuracy; array topology, calibration, signal-to-noise ratio, multipath and the estimation rule remain decisive. It explains why a fixed compact antenna arrangement cannot be assumed to retain the same discrimination across a decade of frequency.

Worked application 6. Frequency-offset ambiguity. Suppose a nominal 900 MHz carrier appears 900 Hz higher than a selected reference. The fractional offset is $\varepsilon = \Delta f/f = 900/900{,}000{,}000 = 1 \times 10^{-6}$,

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or 1 part per million. A 0.1 ppm difference at that frequency corresponds to 90 Hz. These calculations describe relative frequency, not the responsibility of a particular oscillator. A frequency error can arise in the transmitting device, receiver reference, intermediate conversion, clock disciplining or mathematical resampling; assigning it to the emitter requires independent evidence about the other contributors.

Worked application 7. A multipath delay. Let an indirect propagation path exceed the direct path by $\Delta L = 150$ m. Using $c \approx 3.00 \times 10^8$ m/s, the extra delay is $\Delta\tau = \Delta L/c \approx 0.50$ microsecond. A sufficiently resolved channel impulse response might reveal that delayed component, but an observed half-microsecond structure is not proof of a specific wall or reflector. Different geometries can share a similar excess path length, and limited signal bandwidth may prevent the two components from being separated cleanly. A single delay constrains possible geometry; it does not name a room.

Worked application 8. Nominal displacement versus source identity. Suppose two position estimates are separated by $\Delta t = 20$ s and a model assigns a constant speed $v = 3$ m/s. The predicted displacement is $d = v\Delta t = 60$ m. This calculation describes the trajectory permitted by the model; it does not demonstrate that one transmitter was present at both endpoints. Two stationary emitters separated by approximately 60 m, an alternating reflection or a corrupted association process might produce a similar sequence of observations. A valid tracker must therefore test the data-association hypothesis and report the possibility of track switching.

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Worked application 9. The scale of a phase-delay ambiguity. For a sinusoidal carrier f = 100 MHz and an uncorrected differential delay δt = 1 ns, the phase shift is Δφ = 2π fδt = 0.2π radians = 36 degrees. At δt = 10 ns the shift is 2π radians, or 360 degrees, indistinguishable from zero phase modulo a whole cycle in a single-frequency observation. This example shows why nominal phase agreement cannot by itself prove exact time coincidence or a unique source direction. Additional bandwidth, calibrated baselines or other constraints may be required to resolve the cycle ambiguity.

Worked application 10. Posterior odds under stated assumptions. Let H denote the hypothesis that a specified source produced the observation, and suppose the prior odds are 1:999, corresponding to prior probability P(H) = 0.001. If independently validated evidence E has a likelihood ratio LR = P(E|H)/P(E|not H) = 20 under the adopted hypothesis definitions, posterior odds are 20:999. The corresponding posterior probability is 20/(20 + 999) ≈ 0.0196, or about 1.96 per cent. This hypothetical calculation does not provide a universal prior or a forensic error rate. It shows that a visually impressive match need not make a rare attribution probable, and that the result is sensitive to the prior and the LR's validation.

Editorial contextual continuation. Read scope: life dates, aperture synthesis and prize attribution. [Q7-B3] Stanford University, Memorial Resolution: Ronald N. Bracewell. https://news.stanford.edu/stories/2007/11/memorial-resolution-ronald-n-bracewell . Read scope: education, wartime radar, Cambridge and Stanford research. [Q7-B4] University of Florida, Remembering Rudolf E. Kalman (1930–2016). https://www.eng.ufl.edu/news/ece/remembering-rudolf-e-kalman-1930-2016/ . Read scope: life dates, research and professional

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appointments. [Q7-B5] Nobel Foundation, Dennis Gabor, Nobel Prize in Physics 1971. https://www.nobelprize.org/prizes/physics/1971/summary/ . Read scope: holography prize and historical context. [Q7-B6] Institution of Engineering and Technology, Oliver Heaviside, archive biography. https://www.theiet.org/membership/library-and-archives/the-iet-archives/biographies/oliver-heaviside-1850-1925 . Read scope: life and electromagnetic contributions. [Q7-B7] Nobel Foundation, Lord Rayleigh, Nobel Prize in Physics 1904. https://www.nobelprize.org/prizes/physics/1904/summary/ . Read scope: identity, prize and historical work. [Q7-B8] Nobel Foundation, Hendrik A. Lorentz, Nobel Prize in Physics 1902. https://www.nobelprize.org/prizes/physics/1902/summary/ . Read scope: electromagnetism, historical prize. [Q7-B9] Ohio State University, John D. Kraus. https://research.osu.edu/john-d-kraus . Read scope: antennas, radio astronomy, academic contribution. [Q7-B10] University of St Andrews, MacTutor, Henri Poincaré. https://mathshistory.st-andrews.ac.uk/Biographies/Poincare/ . Read scope: life and mathematical contributions. [Q7-B11] Massachusetts Institute of Technology Press, Norbert Wiener. https://mitpress.mit.edu/author/norbert-wiener-18445/ . Read scope: MIT career, books and mathematical contribution. [Q7-B12] Royal Society archive, Sir Harold Jeffreys. https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA6946&src=CalmView.Persons . Read scope: dates, fellowship and Cambridge career.

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QUESTION 013

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What can preselection establish about the external origin of a spectral feature?

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Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 013 asks: What can preselection establish about the external origin of a spectral feature? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is preselection as a physical discrimination experiment rather than proof of transmitter identity. Our primary observation is the amplitude and spectral behaviour of a feature before and after a characterised RF preselector; by contrast, what remains unseen is whether the feature originated in an external radiator, cable, mixer image, or nonlinear internal product. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Filter selectivity and hidden coupling. Suppose a preselector is measured to provide 62 dB rejection at an unwanted signal frequency. An unwanted input of minus 20 dBm should then contribute approximately minus 82 dBm

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through that characterised port, before subsequent gain, provided the filter remains linear. If the observed spur is minus 45 dBm, the nominal two-port rejection cannot, by itself, explain the observation. The examiner should inspect shielding, cable common-mode paths, local-oscillator coupling and state-dependent impedance rather than declare a newly discovered transmitter. A matched reference injection through the antenna port, followed by an independently shielded termination, separates some paths but not every bypass mechanism. Record both the passband insertion loss and the stopband rejection under the gain, temperature and termination used for the questioned observation. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns the amplitude and spectral behaviour of a feature before and after a characterised RF preselector; it is not interchangeable with whether the feature originated in an external radiator, cable, mixer image, or nonlinear internal product. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is a swept, calibrated preselector comparison with reference-plane controls and a terminated-input check. A claim drawn from that comparison has to carry its actual uncertainties: insertion loss, stop-band rejection, return loss, gain compression, and response repeatability. The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. A filter state change can move an internally created intermodulation product even with an unchanged external environment.

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Cable leakage and common-mode pickup can bypass the nominal two-port network and invalidate a simple attenuation model. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Hendrik Wade Bode | Principal contribution 1: The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen.

Dr. Atkinson, the first diagram I would request is not the spectrum display but a network drawing showing where the preselector sits relative to the antenna, feeder, protection device, amplifier and first mixer. Consider a band-pass network specified to attenuate a blocker by forty decibels at its own calibrated ports. Once installed between an unmatched antenna and a converter with a frequency-dependent input impedance, its actual transducer attenuation may differ substantially. A signal seen after this network has not thereby proved that it entered through the intended antenna path: it might have passed through a leaky switch contact, a common return conductor or the receiver enclosure. We should measure insertion response with terminations representing the operational impedances, and then repeat the investigation with a second filter topology whose shielding and grounding are genuinely independent. The most persuasive experiment would predict not merely a lower line on a display but a specific change in the disputed component relative to a fixed reference signal. If that prediction fails, the filter's attractive laboratory curve must yield to the assembled network's behaviour.

In this physical path examination of Question 013, the decisive claim is that the preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. The preselector has two evidential roles which must be separated. Its measured insertion loss can predict how an admitted wanted tone ought to change, while its rejection response can test whether an out-of-band interferer is capable of driving a

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mixer product. Neither property proves where the energy originated. A conductive path along an imperfectly screened feeder, or a spur generated after the filter, may respond differently from an externally radiated field. Measurements must therefore be repeated with a known source injected at the antenna terminal, then at the receiver input, and finally with the RF connector terminated. The order of the interventions matters: it makes the competing entry paths distinguishable without asking the spectrum display to identify an emitter. A useful falsification proceeds from the actual controversy: filter selectivity and hidden coupling. Suppose a preselector is measured to provide 62 dB rejection at an unwanted signal frequency. An unwanted input of minus 20 dBm should then contribute approximately minus 82 dBm through that characterised port, before subsequent gain, provided the filter remains linear. If the observed spur is minus 45 dBm, the nominal two-port rejection cannot, by itself, explain the observation. The examiner should inspect shielding, cable common-mode paths, local-oscillator coupling and state-dependent impedance rather than declare a newly discovered transmitter. A matched reference injection through the antenna port, followed by an independently shielded termination, separates some paths but not every bypass mechanism. Record both the passband insertion loss and the stopband rejection under the gain, temperature and termination used for the questioned observation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

A meaningful preselector experiment requires an input-level-verified source, a trace of the complete cabling arrangement and observations at

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several reference planes. First establish the two-port S-parameters of the filter at the relevant temperature and drive. Next compare the questioned spectral feature with a matched through section while the receiver gain and analyser bandwidth remain fixed. Finally connect a shielded termination and measure common-mode feeder current. Only a change predicted uniquely by a stated coupling mechanism can exclude that mechanism; an isolated amplitude reduction is insufficient. I would take S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is to introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. A response consistent with a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event,

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and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. A survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response, and measure their behaviour separately before reconnecting the assembled system. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. It is therefore material to establish S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level rather than infer them from a single scalar output. The limiting test is concrete: Introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port. If the intervention produces a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the

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shield of the feeder remain possible as a new transmitter before challenging the most economical instrumental explanation. For a fair comparison the antenna-side stimulus and reference path must be preserved, not merely the filter setting. Professor Tukey, I invite your challenge to the inference drawn from the attenuated display.

John Wilder Tukey | Peer question 1 to Hendrik Wade Bode

Hendrik Wade Bode, may I test the exact physical inference in your account of a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel? The proposed mechanism appears plausible only if changes after introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port are compared with a stable reference condition. The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level which would settle that narrower claim, rather than a visual impression of improvement.

Hendrik Wade Bode | Immediate answer to John Wilder Tukey

Dr Tukey, the decisive comparison is between a tone which passes through the characterised filter and a feature produced after it. When

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I substitute a calibrated through connection, I must also preserve the source and load impedances, because their mismatch can change the apparent attenuation. A subsequent terminated-input acquisition will test whether the trace depends upon radiated input. If it remains, I shall examine internal mixing and shield ingress rather than use the filter response as proof of an exterior transmitter. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 013, the specific physical candidate is rejection of out-of-band energy by a finite filter with non-zero leakage and state-dependent impedance. The unresolved physical pathway is material: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The retained record permits a conditional claim about S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, but cannot alone resolve conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a survey antenna leads through a switchable 145 MHz preselector to a receiver

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displaying a narrow, unexplained feature near the tuned channel. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port, and only a response matching a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated rf port. If the response instead remained fixed when the nominal through path was strongly

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attenuated, the bypass explanation would deserve priority. This concerns S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Hendrik Wade Bode

I appreciate your explanation, Hendrik Wade Bode. How would your conclusion survive a deliberately independent test of the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible? A second receiver might share more of the supposed evidence than its separate enclosure suggests. A filter state change can move an internally created intermodulation product even with an unchanged external environment. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level and document which differences remain unexplained? Would you also state what observed change in S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level would invalidate the preferred account, and which aspect of introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated rf port would make that negative result independently repeatable?

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Hendrik Wade Bode | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 013, the specific physical candidate is rejection of out-of-band energy by a finite filter with non-zero leakage and state-dependent impedance. The unresolved physical pathway is material: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The retained record permits a conditional claim about S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, but cannot alone resolve conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. I would draw the actual distribution network before collecting new corroborating evidence,

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marking where two receivers share signal, power or time references. A filter state change can move an internally created intermodulation product even with an unchanged external environment. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response; I would challenge it with introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port. Two responses consistent with a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. A discordant measurement would then be interpreted by tracing that difference through S21, S11, input compression, insertion

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loss, coaxial common-mode current, and displayed spur level; an agreement lacking such a dependency analysis is weak corroboration.

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Edwin Howard Armstrong | Principal contribution 2: A filter state change can move an internally created intermodulation product even with an unchanged external environment.

The receiver's apparent selectivity often belongs to the frequency converter rather than to the aerial, Dr. Atkinson. I would expose the instrument to a controlled image-frequency tone, then lower its amplitude until the unwanted response disappears in the noise. Suppose an operator sees a spur near a desired channel and adds a narrow preselector; its disappearance could show that an image-frequency interferer formerly reached the mixer, but it would not identify who transmitted it. A second possibility is that the preselector altered front-end loading sufficiently to change oscillator leakage or gain compression inside the box. The two accounts produce different predictions when the same filter is inserted after, rather than before, the suspect gain stage. A bench examination should therefore employ a shielded termination, a calibrated coupling point, and a deliberate variation of local-oscillator frequency. No allegation concerning a hidden emitter should precede the demonstration that the received spectral coordinate survives these transformations without an internally generated explanation.

In this control and stability examination of Question 013, the decisive claim is that a filter state change can move an internally created intermodulation product even with an unchanged external environment. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy:

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filter selectivity and hidden coupling. Suppose a preselector is measured to provide 62 dB rejection at an unwanted signal frequency. An unwanted input of minus 20 dBm should then contribute approximately minus 82 dBm through that characterised port, before subsequent gain, provided the filter remains linear. If the observed spur is minus 45 dBm, the nominal two-port rejection cannot, by itself, explain the observation. The examiner should inspect shielding, cable common-mode paths, local-oscillator coupling and state-dependent impedance rather than declare a newly discovered transmitter. A matched reference injection through the antenna port, followed by an independently shielded termination, separates some paths but not every bypass mechanism. Record both the passband insertion loss and the stopband rejection under the gain, temperature and termination used for the questioned observation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note a filter state

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change can move an internally created intermodulation product even with an unchanged external environment. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Armstrong’s receiver engineering points to actual conversion products and oscillation conditions rather than abstract spectral indications; the crucial question is where the energy first appears. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. This predicts a response which should be tested against a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss. An operator may be tempted to

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interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements discarded during retuning. Where conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room, the correct claim must name the operational states and the evidence available in each. A proper image-rejection test would retain the LO state and the independent witness measurement at every change. Dr Pearson, please take the floor to examine the statistical weight of those paired observations.

Egon Sharpe Pearson | Peer question 3 to Edwin Howard Armstrong

Edwin Howard Armstrong, your calibration argument invites a question about reference planes, especially because conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. The reference stimulus and the unknown emission need not occupy the same physical regime. Cable leakage and common-mode pickup can bypass the nominal two-port network and invalidate a simple attenuation model. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port without relying upon the

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original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Edwin Howard Armstrong | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 013, the specific physical candidate is rejection of out-of-band energy by a finite filter with non-zero leakage and state-dependent impedance. The unresolved physical pathway is material: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The retained record permits a conditional claim about S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, but cannot alone resolve conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level. Cable leakage and common-mode pickup can bypass the nominal two-port network and invalidate a simple attenuation model. I would not carry a correction obtained at one

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frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port, with before-and-after values of S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level. If the instrument behaves as predicted, then a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. The feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

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Ralph Vinton Lyon Hartley | Peer question 4 to Edwin Howard Armstrong

There is an inferential difficulty, Edwin Howard Armstrong: an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The population of admissible observations needs to be fixed before any confidence argument. In this situation, conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. The response of a weak candidate must be compared against a deliberately injected, traceable reference signal. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level would invalidate the preferred account, and which aspect of introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated rf port would make that negative result independently repeatable?

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Edwin Howard Armstrong | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 013, the specific physical candidate is rejection of out-of-band energy by a finite filter with non-zero leakage and state-dependent impedance. The unresolved physical pathway is material: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The retained record permits a conditional claim about S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, but cannot alone resolve conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible. I would distinguish trials selected in advance from those added after an unexpected peak

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appeared. The response of a weak candidate must be compared against a deliberately injected, traceable reference signal. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response; its prediction should be recorded alongside a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a 40 db specified stop-band attenuation need not yield a 40 db display reduction when the uncharacterised bypass dominates the residue. A second examiner can then determine

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whether the competing explanations give genuinely different measurements.

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Percy Williams Bridgman | Principal contribution 3: Cable leakage and common-mode pickup can bypass the nominal two-port network and invalidate a simple attenuation model.

There is a useful distinction between the word external and the words external to a particular circuit board. A component observed at the ADC pins might have arrived by an unintended conductor from another part of the same receiver; a component observed at the receiver antenna socket could still have been generated in its test cable or connector. I should require the investigator to state the physical boundary at which the assertion is made. In a defensible comparison, first connect the receiver to a screened reference source, then to a characterised passive load at the same reference plane, and lastly to the survey aerial. The sequence must not be allowed to change the receiver's gain, clock or mixer configuration without logging the alteration. If the feature appears only with the aerial fitted, that is useful evidence about the path, but a poorly screened feeder and a local electrical load are still alternatives to a distant radiator. Such distinctions are operational, not philosophical decoration.

In this operational measurand examination of Question 013, the decisive claim is that cable leakage and common-mode pickup can bypass the nominal two-port network and invalidate a simple attenuation model. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: filter selectivity and hidden coupling. Suppose a preselector is measured to provide 62 dB rejection at an unwanted signal frequency. An unwanted input of minus 20 dBm should then contribute approximately minus 82 dBm through that

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characterised port, before subsequent gain, provided the filter remains linear. If the observed spur is minus 45 dBm, the nominal two-port rejection cannot, by itself, explain the observation. The examiner should inspect shielding, cable common-mode paths, local-oscillator coupling and state-dependent impedance rather than declare a newly discovered transmitter. A matched reference injection through the antenna port, followed by an independently shielded termination, separates some paths but not every bypass mechanism. Record both the passband insertion loss and the stopband rejection under the gain, temperature and termination used for the questioned observation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The experiment should distinguish conducted rejection at the front-panel connector from rejection of an external radiating source. A preselector may suppress an image response inside a receiver without establishing whether the rejected energy originated in a nearby device, the receiver's own oscillator, a poorly terminated test lead, or a second harmonic generated upstream. The informative trial uses a calibrated source at the antenna reference plane and a separate terminated-input control. Measure insertion loss, passband ripple and out-of-band rejection under the same gain setting, then compare the suspect feature with the predicted input-to-output transfer ratio. If the indication survives input termination, conducted preselection alone cannot support external attribution; a local spurious mechanism remains viable. If the indication tracks deliberate source frequency changes according to the measured filter response, the evidence supports frequency-path compatibility, not unique emitter identity. The

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report must retain the filter switch state and acknowledge that an out-of-band product generated before the filter is not eliminated merely by the nominal stopband figure. Accordingly, the laboratory record for Question 013 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. Bridgman's operational approach requires a measurement procedure that defines each quantity physically. A stated number unsupported by the operation that produced it is methodologically incomplete. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a survey antenna leads through a switchable 145 mhz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an

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instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A 40 dB specified stop-band attenuation need not yield a 40 dB display reduction when the uncharacterised bypass dominates the residue. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. The measurement definition must include unintended cable and common-mode routes. Dr Turing, I invite you to ask what the retained IQ record can establish when those paths were not separately observed.

Alan Mathison Turing | Peer question 5 to Percy Williams Bridgman

Percy Williams Bridgman, I should like to examine what the recorded data actually preserve when a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. The physical input and the retained numerical array are not interchangeable things. A successful exclusion of an out-of-band image restricts a mechanism; it does not establish a unique emitter. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in S21, S11, input compression, insertion loss,

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coaxial common-mode current, and displayed spur level would invalidate the preferred account, and which aspect of introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated rf port would make that negative result independently repeatable?

Percy Williams Bridgman | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 013, the specific physical candidate is rejection of out-of-band energy by a finite filter with non-zero leakage and state-dependent impedance. The unresolved physical pathway is material: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The retained record permits a conditional claim about S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, but cannot alone resolve conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. I propose separating acquired information from model-dependent reconstruction. A successful exclusion of an out-of-band image restricts a mechanism; it does not establish a unique emitter. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level and a fresh trial in which the operator introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port. If that trial demonstrates a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include introduce a level-verified signal ahead of the

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antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated rf port. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Claude Elwood Shannon | Principal contribution 4: The response of a weak candidate must be compared against a deliberately injected, traceable reference signal.

A preselector's effect can be stated as information about a test configuration without assigning a transmitter identity. Suppose that two physically distinct inputs, one at the wanted frequency and one at an image frequency, become the same post-mixer complex sample stream. No later software analysis of that stream can distinguish the origins unless an earlier operation has preserved a difference. Changing a well-characterised analogue filter can create such a difference by altering the two candidate inputs unequally. Yet a single before-and-after amplitude ratio becomes ambiguous if automatic gain control reacts to the altered blocker power. I would retain the raw complex samples, actual gain-state records and the measured transfer functions for every intervention. A properly designed paired test gives a comparison between hypotheses about paths into the receiver. It does not generate the missing information about the source's location, purpose or ownership. Those are further questions requiring independently discriminating evidence.

In this information retention examination of Question 013, the decisive claim is that the response of a weak candidate must be compared against a deliberately injected, traceable reference signal. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: filter selectivity and hidden coupling. Suppose a preselector is measured to provide 62 dB rejection at an unwanted signal frequency. An unwanted input of minus 20 dBm should then contribute

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approximately minus 82 dBm through that characterised port, before subsequent gain, provided the filter remains linear. If the observed spur is minus 45 dBm, the nominal two-port rejection cannot, by itself, explain the observation. The examiner should inspect shielding, cable common-mode paths, local-oscillator coupling and state-dependent impedance rather than declare a newly discovered transmitter. A matched reference injection through the antenna port, followed by an independently shielded termination, separates some paths but not every bypass mechanism. Record both the passband insertion loss and the stopband rejection under the gain, temperature and termination used for the questioned observation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port. The scientific point of the response of a weak candidate must be compared against a deliberately injected, traceable reference signal. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If

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independent sessions repeatedly show a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. The feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible. Shannon's information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. The issue becomes especially sharp because an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated rf port. That comparison should keep the unprocessed complex

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values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the proposed case, a 40 db specified stop-band attenuation need not yield a 40 db display reduction when the uncharacterised bypass dominates the residue. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. An injected reference gives a comparison, not an inverse of information that the instrument discarded. Dr Deming, I now pass the floor for a test capable of overturning the preferred source explanation.

W. Edwards Deming | Peer question 6 to Claude Elwood Shannon

I thank you, Claude Elwood Shannon, for distinguishing measurement from attribution, but the observation is that the feature weakens after the filter is substituted, although an external radiator, a mixer image, and ingress through the shield of the feeder remain possible. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a 40 dB specified stop-band attenuation need not yield a 40 dB display reduction when the uncharacterised bypass dominates the residue. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss on one day but fails after the instrument has been reconfigured? The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. Would you disclose the

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disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

Claude Elwood Shannon | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 013, the specific physical candidate is rejection of out-of-band energy by a finite filter with non-zero leakage and state-dependent impedance. The unresolved physical pathway is material: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The retained record permits a conditional claim about S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, but cannot alone resolve conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a 40 dB specified stop-band attenuation need not yield a 40 dB display

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reduction when the uncharacterised bypass dominates the residue. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. Its bearing on the dispute can be evaluated through the predicted response, namely a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss. Because an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response, the procedure introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match report the eliminated signal-path mechanism rather than an unproved transmitter identity, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. A genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss. I would retain the

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unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: A successful exclusion of an out-of-band image restricts a mechanism; it does not establish a unique emitter.

Dr. Atkinson, I would formulate two rival propositions before permitting the operator to touch the filter switch. One says that the suspect line is produced by external in-band power; the other says that out-of-band power drives a nonlinear or image response. Each proposition requires a predicted distribution of observations under controlled filter changes, including imperfect responses and measurement noise. If repeated filter swaps are selected for analysis only when the line looks most dramatic, a nominal confidence interval is not the one promised by the intended procedure. Randomise the order of the filter and bypass states where practicable, log every eligible observation, and estimate the paired contrast with its dependence and instrument uncertainty. A sharp reduction of the line can favour the nonlinear-path account while remaining compatible with several physical sources of the original blocker. A negative result, conversely, may be powerless when the substituted filter has inadequate rejection at the relevant frequencies. The report must disclose that limitation rather than conceal it inside a favourable percentage.

In this statistical inference examination of Question 013, the decisive claim is that a successful exclusion of an out-of-band image restricts a mechanism; it does not establish a unique emitter. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: filter selectivity and

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hidden coupling. Suppose a preselector is measured to provide 62 dB rejection at an unwanted signal frequency. An unwanted input of minus 20 dBm should then contribute approximately minus 82 dBm through that characterised port, before subsequent gain, provided the filter remains linear. If the observed spur is minus 45 dBm, the nominal two-port rejection cannot, by itself, explain the observation. The examiner should inspect shielding, cable common-mode paths, local-oscillator coupling and state-dependent impedance rather than declare a newly discovered transmitter. A matched reference injection through the antenna port, followed by an independently shielded termination, separates some paths but not every bypass mechanism. Record both the passband insertion loss and the stopband rejection under the gain, temperature and termination used for the questioned observation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. A successful exclusion of an out-of-band image restricts a mechanism; it does not establish a unique emitter. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to introduce a level-verified signal ahead of the antenna connector, interchange the filter with a

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matched dummy section, and repeat with a terminated RF port, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say report the eliminated signal-path mechanism rather than an unproved transmitter identity, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman’s statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. One could stratify the experiment by

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nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a 40 db specified stop-band attenuation need not yield a 40 db display reduction when the uncharacterised bypass dominates the residue, is not an estimate of any actual investigation. Exclusion of one mixer image narrows the candidate mechanisms but cannot certify a particular transmitter. Sir Karl, I invite your scrutiny of the propositions that remain open to refutation.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise report the eliminated signal-path mechanism rather than an unproved transmitter identity? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. A filter state change can move an internally created intermodulation product even with an unchanged external environment. Please connect S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level with a declared detection threshold and the

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measurement exposure. If the experiment introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 013, the specific physical candidate is rejection of out-of-band energy by a finite filter with non-zero leakage and state-dependent impedance. The unresolved physical pathway is material: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. The retained record permits a conditional claim about S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level, but cannot alone resolve conducted attenuation measured between two coaxial ports is not automatically radiated-source isolation in a populated equipment room. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. A filter state change can move an internally created intermodulation product even with an unchanged external environment. I would use the observations of S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port, not an assertion based on the operator's impression of a quiet display. If it yields a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding

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offers a path which bypasses the nominal filter response, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to report the eliminated signal-path mechanism rather than an unproved transmitter identity, with the untested physical possibilities made visible.

Hendrik Wade Bode, Cross-Peer Question to Percy Williams Bridgman: Professor Bridgman, the committee sees a feature diminish when a nominally sixty-decibel stop-band filter is inserted, and the resulting trace is being offered as proof that the energy arrived through the survey antenna. The filter's attenuation was measured at specified coaxial ports, whereas the installed receiver has a lossy switch, an imperfect shield, a feeder with common-mode current and a temperature-sensitive input match. A direct-port injection obeys the predicted attenuation, but a nearby radiated field does not fall by the same amount. Which physical operation would tell us whether the measurement describes the intended two-port path rather than an unmeasured bypass? How should one distinguish a legitimate suppression experiment from the logically stronger and generally unjustified conclusion that a particular remote emitter has thereby been located?

Percy Williams Bridgman, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, the first obligation is to name the reference surface on which the quantity is defined. A scattering-parameter measurement between matched laboratory ports is not a measurement of the complete receiving installation. I should document the filter's installed input and output impedance, the switch state and the screened and common-mode routes that might couple energy around it. A shielded termination at the receiver

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port, a controlled reference injection at the antenna-side plane, and a deliberately altered feeder geometry make different predictions for conductive, radiative and internally generated responses. These tests must be performed in a sequence that preserves the receiver operating point and records any unavoidable changes. A fall in amplitude after the filter is inserted supports the proposition that the altered network affects the feature; it does not uniquely demonstrate where that feature originated. If input-mismatch changes or independent leakage paths remain unmeasured, the inferred rejection has an unquantified uncertainty. The report should state precisely which candidate coupling routes were tested and which remain plausible, even when the spectrum display presents a beautifully clean line.

Edwin Howard Armstrong, Cross-Peer Question to Jerzy Neyman: Professor Neyman, two strong input tones predict an input-referred third-order product at three times the tone level minus twice the quoted intercept point. We obtain an attractive straight-line extrapolation, but the measured receiver spur does not always rise three decibels for every one-decibel change in the blockers. The apparent signal survives on the display when the antenna is changed, and a colleague concludes that the remaining line must be an external carrier because the textbook cubic relation fits poorly. What experiment would discriminate an imperfect intermodulation model from a true externally radiated component without assuming the very slope whose validity is in dispute?

Jerzy Neyman, Cross-Peer Answer to Edwin Howard Armstrong: Dr Armstrong, a discrepancy from a simplified model is not affirmative evidence for the preferred alternative. The cubic approximation assumes a

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specified small-signal regime and well-behaved input-referred characteristics; compression, memory effects, filtering and mixed mechanisms may change the measured slopes. I would vary both blocker amplitudes in a registered grid, retain the output product frequency and power at each setting, and compare alternative response models rather than forcing the observations onto an ideal slope. A calibrated attenuation step before the first active stage should affect internally generated products differently from attenuation introduced after the nonlinear site, provided those interventions do not alter other gains or impedances. A matched termination and a known injected weak carrier offer additional, imperfect controls. Because the product frequency can coincide with a real emission, the observed feature may contain both components. The final conclusion should disclose the demonstrated power dependence, the instrument state and the unexcluded external contribution. The statistical distinction is between models that predict discriminating changes under intervention, not between a perfect cubic law and an unexplained remainder presumed to be a transmitter.

Claude Elwood Shannon, Cross-Peer Question to John Wilder Tukey: Professor Tukey, a single spectral line at the digitiser output can correspond to analogue tones in more than one Nyquist zone. The case example folds a 99.2-megahertz input sampled at thirty-one megahertz to 6.2 megahertz, but an analogue spur or a different out-of-band tone could occupy the same sampled coordinate. A technician searched several sample rates and preselector states until one combination made the line disappear, then presented the decisive trace alone. What confirmatory experiment would preserve the information lost in that post-selection, and what is the

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strongest claim the analyst may properly make when the original raw samples and state changes remain available?

John Wilder Tukey, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the investigator must record the entire sequence of interventions rather than selecting the most persuasive frame. Aliasing gives a many-to-one mapping from analogue frequency to a sampled coordinate, and the change of sampling rate may itself alter clock coupling, analogue response or image rejection. I would specify a set of candidate analogue frequencies, predict their signed folds under at least two independently calibrated sampling configurations, and then challenge those predictions with known injected sources at relevant frequencies and amplitudes. The filter passband, out-of-band transfer, oscillator reference and all digital resampling must be documented. The hypothesis should be written before a new independent run, not after one has found a favourable setting. If two physical mechanisms retain the same predicted observations within calibration uncertainty, they remain observationally equivalent. The most that the data support is exclusion of the mechanisms actually challenged under the stated instrument conditions, plus any positive result that survives genuinely independent confirmation. A frequency on the digital screen is a measurement coordinate. It is not by itself a certificate of RF origin.

Jerzy Neyman, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, the preselector trial reports a contrast of 1.970 decibels and a quadrature standard uncertainty of about 0.540 decibels, producing a ratio near 3.65. It is tempting to stamp the feature as external because the result is numerically several standard uncertainties from zero. Yet both readings

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share the same reference source, the same ambient field, perhaps a common frequency-dependent mismatch, and the same decision to inspect that particular spectral cell. Which quantities would you put into the measurement function before calling the contrast discriminating, and how would you prevent the apparent statistical precision from concealing a shared physical bias?

Hendrik Wade Bode, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, the two-port transfer change and the measured spectral difference are separate measurands, and their relationship is conditional on the installed circuit. A valid uncertainty budget begins with the actual readings and the corrections applied to them; shared calibration errors and common drift may produce covariance terms that cannot be handled by indiscriminate root-sum-of-squares arithmetic. I would measure the repeatability of the preselector state transition, port match, source amplitude, cable radiation and receiver gain state, and document which correlations are cancelled by differencing and which survive it. A ratio of difference to combined standard uncertainty is not automatically a formal significance test, still less a proof of transmission origin. The null distribution, selection procedure and systematic model have not yet been specified. An independent injection or shielded-port test can challenge the physical account without assigning more certainty than the test supports. The report may establish that the feature changed by a measured amount under a named filter operation. It should not silently equate that change with an identified emitter.

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Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of preselection as a physical discrimination experiment rather than proof of transmitter identity has established a point which the specialist must not overlook. The receiver records the amplitude and spectral behaviour of a feature before and after a characterised RF preselector; it does not, merely by drawing a clear trace, give direct access to whether the feature originated in an external radiator, cable, mixer image, or nonlinear internal product. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, The preselector transfer function must be measured at the antenna-side reference plane, not inferred from the screen. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

Dr Atkinson thanks Professor Bode for insisting upon the measured two-port behaviour of a preselector, and Dr Bridgman for requiring the reference plane to be made physically accessible. The crucial result is not that a filter caused a trace to weaken, but whether the observed weakening is predicted by independently measured insertion loss at the actual source and load impedances. A signal that persists with a shielded termination attached may have entered beyond the filter or been generated inside the receiver; a change with filter substitution alone cannot settle that distinction. The next survey should therefore record forward transmission and return loss, repeat the injection on both sides of the suspected entry

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point, and make the order of component substitutions recoverable from the evidence log. We must close without naming a transmitter. What can presently be defended is an experimentally constrained statement about which RF paths remain plausible, together with the untested paths that warrant a second investigation.

Replacing the filter weakened the observed feature, but a measured diminution by itself does not identify an external radiator. A mixer image, common-mode feeder ingress, or frequency-dependent loading could account for a similar change. The report should give the insertion loss and return loss at the relevant frequencies, identify each injection plane and retain every challenged recording. A finding about a particular signal path may be defensible even where the source identity remains unresolved. The more useful outcome is a discriminating protocol: Introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port. In applying it, the examiner must retain all readings supporting S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level and identify the physical plane to which the measurements refer. At the outset of the investigation, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel; that circumstance makes the alternative mechanism material, specifically an out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. A result approaching a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss

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may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore report the eliminated signal-path mechanism rather than an unproved transmitter identity. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

The defensible conclusion is confined to the signal pathways excluded or supported by controlled preselection tests. Properly measured transfer and rejection curves can contradict a proposed path; they cannot independently name a transmitter. The remainder of the report must state the paths which were not challenged and the limits arising from the measured input match. The decisive experiment is concrete: Introduce a level-verified signal ahead of the antenna connector, interchange the filter with a matched dummy section, and repeat with a terminated RF port. In conducting it, the examiner must explicitly retain S21, S11, input compression, insertion loss, coaxial common-mode current, and displayed spur level. If the outcome matches the stated prediction, a genuine through-path input follows the measured filter transmission, whereas leakage downstream of the switch is insensitive to its stated stop-band loss, the supported conclusion concerns that test domain. An alternative remains: An out-of-band blocker drives a nonlinear stage, while imperfect connector shielding offers a path which bypasses the nominal filter response. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the

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methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 013

Application 01. Filter or cable rejection referred to a physical input

In the illustrative 013.01 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. For an admitted input P_i = -48 dBm and separately measured loss L = 30 dB, the linear prediction is $P_o = P_i - L$ = -78 dBm. In SI power this becomes 10^((-78 − 30)/10) = 1.58e-11 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. If the feature remains after the predicted 30 dB attenuation, test common-mode and enclosure-coupled ingress before assigning energy to the antenna port.

Application 02. Cascade gain and observed headroom

In the illustrative 013.02 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. A first amplifier contributes G_1 = 14 dB, an intentional attenuation contributes G_2 = -6 dB, and a later stage contributes G_3 = 16 dB. The small-signal sum is 14 + (-6) + 16 = 24 dB. For P_i = -73 dBm, the ideal output is P_o = -49 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The 24 dB net gain does not establish intermediate headroom; record blocker and probe powers at each potentially nonlinear stage.

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Application 03. Thermal reference noise in a declared measurement bandwidth

In the illustrative 013.03 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. Take the equivalent noise bandwidth B = 24,000 Hz and calibrated noise figure NF = 3.25 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -126.95$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The -126.95 dBm thermal-reference result is conditional on the 24 kHz equivalent bandwidth and specified 290 K noise model, not a field-noise measurement.

Application 04. Alias-location prediction and its non-unique inverse

In the illustrative 013.04 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. For an actual sampling frequency f_s = 31 MHz and analogue input f_i = 99.200 MHz, the nearest-replica folding rule gives $f_a = |f_i - \text{round}(f_i/f_s)f_s| = 6.200$ MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. A 6.2 MHz sampled line admits multiple analogue origins; repeat the investigation with known injected tones and independently verified preselector states.

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Application 05. Two-tone third-order products and input intercept

In the illustrative 013.05 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. With two equal input tones each at P = -31 dBm and a hypothetical input third-order intercept IIP_3 = +9 dBm, the extrapolated input-referred third-order product is $P_3 = 3P - 2IIP_3$ = -111 dBm, or -80 dBc relative to either input tone. The cubic approximation ceases to be reliable in compression. A two-tone slope check and input attenuation test must establish whether the predicted spur arises inside the receiver rather than externally. The -111 dBm cubic intercept prediction is only a small-signal extrapolation; measured IMD slopes and blocker attenuation tests must check the assumed model.

Application 06. Gain allocation and blocker headroom

In the illustrative 013.06 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. Assume a calibrated digital full-scale equivalent of -5 dBm, a blocker applied at -40 dBm, and net analogue gain 27 dB. The projected converter input is -13 dBm and remaining margin is -5 − (-13) = 8 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. Eight decibels of nominal converter margin is not proof that every upstream amplifier is linear during stronger or simultaneous blockers.

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Application 07. Combined and expanded measurement uncertainty

In the illustrative 013.07 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. For independent standard-uncertainty contributions 0.87, 0.48 and 0.28 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.87^2 + 0.48^2 + 0.28^2)} = 1.032$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 2.065$ units. The 2.065-unit expanded uncertainty is illustrative; shared calibration and drift terms must be examined before interpreting a physical attenuation difference.

Application 08. Difference between two instruments relative to stated uncertainty

In the illustrative 013.08 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. The paired instrument contrast is $\Delta = 1.970$ dB. Set independent standard uncertainties $u_1 = 0.340$ dB and $u_2 = 0.420$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.540$ dB, giving the dimensionless ratio $\Delta/u\Delta = 3.646$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The 3.646 contrast-to-uncertainty ratio cannot identify an emitter without a declared physical measurement model, covariance account and selection rule.

Application 09. Preserved sample continuity across an acquisition interval

In the illustrative 013.09 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow,

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unexplained feature near the tuned channel. A converter expected to retain f_s = 1.30 million samples/s for T = 0.75 s should supply f_sT = 975,000 complex sample instants. If 210 sequence positions are missing, the retained count is 974,790 and loss fraction is 0.02154%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block must therefore be preserved. The loss of 210 samples may conceal an entire short event; retain the exact missing sequence positions rather than reporting only a 0.02154 per cent aggregate loss.

Application 10. Family-wise probability when many candidates are searched

In the illustrative 013.10 test, a survey antenna leads through a switchable 145 MHz preselector to a receiver displaying a narrow, unexplained feature near the tuned channel. If each of M = 359 independent pre-specified search opportunities has false-alarm probability α = 0.0010, the probability of one or more false positives is 1 − (1 − α)^M = 0.30175, or 30.18%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. A 30.18 per cent familywise false-alarm probability belongs to the specified independent search model, not to the probability that a selected feature has an external cause.

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Contributor identification and editorial scope

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

National Institute of Standards and Technology, TN 1297, sections 5–7: combined uncertainty and reporting, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-7-reporting-uncertainty (consulted 11 November 2026).

“Swept IMD and IM Spectrum Concepts”, measurement-application documentation, https://helpfiles.keysight.com/csg/e5080b/Applications/Swept_IMD_and_IM_Spectrum_Concepts.htm (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 014

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How should gain distribution be selected when strong signals coexist with weak emissions?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 014 asks: How should gain distribution be selected when strong signals coexist with weak emissions? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is dynamic-range allocation through a cascade of analogue gain, attenuation, and conversion stages. Our primary observation is input-referred and digital power levels under simultaneously present strong and weak signals; by contrast, what remains unseen is unlogged compression, overload recovery, or quantiser masking that distorts the apparent weak feature. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Cascade noise and overload are competing constraints. Consider a receiver whose first amplifier has 20 dB available gain and a linear noise

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factor of 1.5. A following stage with a noise factor of 6 contributes only (6 minus 1)/100 = 0.05 to the overall linear noise factor under the ordinary Friis cascade assumptions, producing 1.55 or about 1.90 dB total noise figure. But a strong blocker raised by the same 20 dB can exceed the next stage's compression threshold. Adding attenuation in advance of the amplifier may preserve linearity while increasing the effective input-referred noise, and the correct setting therefore depends upon the actual blocker population. Distinguish a thermal-noise-limited experiment from a large-signal-limited experiment. A single pleasing noise-figure number cannot establish that weak emissions remain observable during simultaneous high-level traffic. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns input-referred and digital power levels under simultaneously present strong and weak signals; it is not interchangeable with unlogged compression, overload recovery, or quantiser masking that distorts the apparent weak feature. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is a two-tone plus weak-signal swept-level challenge with gain-state and intercept-point logging. A claim drawn from that comparison has to carry its actual uncertainties: noise figure, cascade gain, input third-order intercept, headroom, and converter occupancy. A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. A strong blocker may drive a later stage into compression even when the desired weak signal is far

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beneath its noise floor. Programmable attenuation should be treated as a documented state transition, not invisible software hygiene. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Hendrik Wade Bode | Principal contribution 1: A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom.

Gain distribution is not a contest to obtain the largest voltage at the analogue-to-digital converter. I would first mark the available headroom at the antenna-facing limiter, the first amplifier, the mixer and the final converter, all referred to consistent power and impedance conventions. A preamplifier that makes a weak signal comfortably visible can also place an adjacent authorised transmitter above the compression point of a later stage. Conversely, a protective attenuator placed too early sacrifices input-referred sensitivity in a way that a later digital gain adjustment cannot reverse. For each proposed gain plan, the investigator needs the largest credible blocker at each stage and the smallest signal the evidence task requires. The operating regime may favour switchable attenuation under a documented state machine rather than a fixed maximum-gain setting. I would insist that gain-step transitions be challenged with bursts of varied duration, because a receiver that is linear once settled can give an entirely different account during its recovery.

In this physical path examination of Question 014, the decisive claim is that a first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. Gain distribution is a constrained optimisation, not a contest to obtain the largest displayed peak. A low-noise first stage may improve small-signal sensitivity while reducing the maximum admissible blocker level at every following stage. The engineer must plot signal and interferer powers along the cascade, not merely calculate its final gain. A controlled gain step made ahead of the nonlinear device has a

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different evidential meaning from attenuation inserted after overload has already occurred. Where a converter clips, digital rescaling only changes the representation of corrupted samples. The proposed gain plan must therefore be tested against the actual mixture of weak targets, adjacent-channel carriers and transient high-power transmissions. A useful falsification proceeds from the actual controversy: cascade noise and overload are competing constraints. Consider a receiver whose first amplifier has 20 dB available gain and a linear noise factor of 1.5. A following stage with a noise factor of 6 contributes only (6 minus 1)/100 = 0.05 to the overall linear noise factor under the ordinary Friis cascade assumptions, producing 1.55 or about 1.90 dB total noise figure. But a strong blocker raised by the same 20 dB can exceed the next stage's compression threshold. Adding attenuation in advance of the amplifier may preserve linearity while increasing the effective input-referred noise, and the correct setting therefore depends upon the actual blocker population. Distinguish a thermal-noise-limited experiment from a large-signal-limited experiment. A single pleasing noise-figure number cannot establish that weak emissions remain observable during simultaneous high-level traffic. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Use a calibrated two-tone source and a separately monitored faint probe. At fixed input frequencies, increase the strong carrier in steps through the onset of front-end compression while alternately inserting attenuation before the first active component and later in the chain. Measure the probe SINAD, third-order products and recovery time, retaining the raw converter

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flags. Then repeat with the antenna connected under a declared safety limit. The winning gain allocation is the one that preserves a validated detection envelope, not a visually clean but overdriven waterfall. I would take input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. A response consistent with where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. A weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised

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transmitter, with front-end amplification presently set high. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range, and measure their behaviour separately before reconnecting the assembled system. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. It is therefore material to establish input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction rather than infer them from a single scalar output. The limiting test is concrete: Sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. If the intervention produces where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret the candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier as a new transmitter before challenging the most economical instrumental explanation. The gain schedule therefore needs the actual blocker powers and the receiver state, not a single laboratory noise figure. Professor Tukey, I invite you to examine how the selection of favourable traces could distort that judgement.

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John Wilder Tukey | Peer question 1 to Hendrik Wade Bode

Hendrik Wade Bode, may I test the exact physical inference in your account of a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high? The proposed mechanism appears plausible only if changes after sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state are compared with a stable reference condition. A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction which would settle that narrower claim, rather than a visual impression of improvement.

Hendrik Wade Bode | Immediate answer to John Wilder Tukey

Dr Tukey, your objection is answered only by varying the position of the attenuation, not by repeating the same test at several overall gains. A pad before the LNA may protect its input while increasing the input-referred noise contribution; a pad after it may protect the ADC without correcting any distortion already created upstream. I propose measuring both circumstances, then reporting separate detection and overload limits instead of one nominal sensitivity figure. The

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correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 014, the specific physical candidate is gain redistribution between low-noise amplification, filtering, mixing, IF gain, and converter full scale. The unresolved physical pathway is material: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The retained record permits a conditional claim about input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, but cannot alone resolve cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction;

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they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state, and only a response matching where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, not a conjecture about the operator's intentions.

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Richard Wesley Hamming | Peer question 2 to Hendrik Wade Bode

I appreciate your explanation, Hendrik Wade Bode. How would your conclusion survive a deliberately independent test of the candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier? A second receiver might share more of the supposed evidence than its separate enclosure suggests. A strong blocker may drive a later stage into compression even when the desired weak signal is far beneath its noise floor. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction and document which differences remain unexplained? Would you also state what observed change in input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction would invalidate the preferred account, and which aspect of sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state would make that negative result independently repeatable?

Hendrik Wade Bode | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the

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level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 014, the specific physical candidate is gain redistribution between low-noise amplification, filtering, mixing, IF gain, and converter full scale. The unresolved physical pathway is material: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The retained record permits a conditional claim about input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, but cannot alone resolve cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. A strong blocker may drive a later stage into compression even when the desired weak signal is far beneath its noise floor. An independent test must alter a physical dependency,

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not merely open another software window. The relevant controlled alternative remains the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range; I would challenge it with sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. Two responses consistent with where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. A discordant measurement would then be interpreted by tracing that difference through input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction; an agreement lacking such a dependency analysis is weak corroboration.

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Harry Nyquist | Principal contribution 2: A strong blocker may drive a later stage into compression even when the desired weak signal is far beneath its noise floor.

Dr. Atkinson, an indicated dynamic range is meaningful only with its observation bandwidth and quantisation regime specified. If a narrow channelised view follows a large-gain front end, the displayed noise floor may look comfortably low while a powerful signal outside that narrow view has already exhausted the ADC input range. Doubling the numerical precision of the software cannot reconstruct amplitudes flattened by a preceding limiter. Nor can a decimator restore a pulse lost during an automatic gain-control transition. I would use a test comprising a weak wanted tone and a much stronger nearby interferer, then sweep the interferer's amplitude with gain states recorded. The weak tone's detection probability, false detections and converter clipping rate should all be reported, instead of inferring receiver quality from a single noise figure. Sampling theory tells us which information a properly band-limited converter can represent; it does not excuse an analogue chain driven outside its valid range.

In this control and stability examination of Question 014, the decisive claim is that a strong blocker may drive a later stage into compression even when the desired weak signal is far beneath its noise floor. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: cascade noise and overload are competing constraints. Consider a receiver whose first

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amplifier has 20 dB available gain and a linear noise factor of 1.5. A following stage with a noise factor of 6 contributes only (6 minus 1)/100 = 0.05 to the overall linear noise factor under the ordinary Friis cascade assumptions, producing 1.55 or about 1.90 dB total noise figure. But a strong blocker raised by the same 20 dB can exceed the next stage's compression threshold. Adding attenuation in advance of the amplifier may preserve linearity while increasing the effective input-referred noise, and the correct setting therefore depends upon the actual blocker population. Distinguish a thermal-noise-limited experiment from a large-signal-limited experiment. A single pleasing noise-figure number cannot establish that weak emissions remain observable during simultaneous high-level traffic. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by the candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note a strong blocker may drive a later stage into compression even when the desired weak signal is far beneath its noise

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floor. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, the candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. This predicts a response which should be tested against where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements discarded during

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retuning. Where cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints, the correct claim must name the operational states and the evidence available in each. A stepped-blocker test should document both the compression onset and the effective sensitivity of the desired channel. Dr Pearson, the floor is yours to challenge whether the comparisons support a reliable conclusion.

Egon Sharpe Pearson | Peer question 3 to Harry Nyquist

Harry Nyquist, your calibration argument invites a question about reference planes, especially because cascade noise figure, third-order intercept, maximum linear power and ADC headroom measure different performance constraints. The reference stimulus and the unknown emission need not occupy the same physical regime. Programmable attenuation should be treated as a documented state transition, not invisible software hygiene. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When the candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

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Harry Nyquist | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 014, the specific physical candidate is gain redistribution between low-noise amplification, filtering, mixing, IF gain, and converter full scale. The unresolved physical pathway is material: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The retained record permits a conditional claim about input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, but cannot alone resolve cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction. Programmable attenuation should be treated as a documented state transition, not invisible software hygiene. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be sweep the strong blocker through calibrated power steps while measuring the weak test tone under

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fixed and changed attenuation, preserving each gain state, with before-and-after values of input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction. If the instrument behaves as predicted, then where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. The candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Harry Nyquist

There is an inferential difficulty, Harry Nyquist: the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The population of admissible observations needs to be fixed before any confidence argument. In this situation, cascade noise figure, third-order

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intercept, maximum linear power and ADC headroom measure different performance constraints. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. The optimum gain plan depends upon the external interference population rather than a solitary nominal sensitivity specification. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction would invalidate the preferred account, and which aspect of sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state would make that negative result independently repeatable?

Harry Nyquist | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 014, the specific physical candidate is gain redistribution between low-noise amplification, filtering, mixing, IF gain, and

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converter full scale. The unresolved physical pathway is material: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The retained record permits a conditional claim about input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, but cannot alone resolve cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because the candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier. I would distinguish trials selected in advance from those added after an unexpected peak appeared. The optimum gain plan depends upon the external interference population rather than a solitary nominal sensitivity specification. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range; its

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prediction should be recorded alongside where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Cascade noise figure, third-order intercept, maximum linear power and ADC headroom measure different performance constraints. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a 20 db preamplifier followed by an unlogged 15 db pad is not equivalent to putting that pad before the low-noise amplifier. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Walter Andrew Shewhart | Principal contribution 3: Programmable attenuation should be treated as a documented state transition, not invisible software hygiene.

A receiver may meet its manufacturer's noise and gain specifications on Monday and still cease to behave comparably after a temperature excursion on Tuesday. This is a process-monitoring problem, not merely a circuit-design exercise. I would choose a small set of reference challenges: a terminated-input noise measurement, a weak two-tone discrimination test, and a strong blocker test that exercises gain reduction and recovery. Their results should be plotted by actual gain state and operating temperature rather than pooled into a reassuring average. If the system changes state automatically, the state changes themselves form part of the measurement record. A discontinuity after changing the RF attenuator could be expected and benign, while the same discontinuity with no logged cause would deserve investigation. Control limits must be established from a validated baseline, not fitted retrospectively around the very excursion being assessed. Reproducibility includes the receiver's decision history as well as its final spectrum.

In this operational measurand examination of Question 014, the decisive claim is that programmable attenuation should be treated as a documented state transition, not invisible software hygiene. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: cascade noise and overload are competing constraints. Consider a receiver whose first amplifier has 20 dB available gain and a linear noise factor of 1.5. A following stage with a noise factor of

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6 contributes only (6 minus 1)/100 = 0.05 to the overall linear noise factor under the ordinary Friis cascade assumptions, producing 1.55 or about 1.90 dB total noise figure. But a strong blocker raised by the same 20 dB can exceed the next stage's compression threshold. Adding attenuation in advance of the amplifier may preserve linearity while increasing the effective input-referred noise, and the correct setting therefore depends upon the actual blocker population. Distinguish a thermal-noise-limited experiment from a large-signal-limited experiment. A single pleasing noise-figure number cannot establish that weak emissions remain observable during simultaneous high-level traffic. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Gain budgeting in a crowded receiver is a constrained optimisation, not a contest to maximise the indicated level of the weakest emission. The relevant quantities are the greatest credible blocker power at the antenna connector, the compression and intercept limits of each preceding device, the noise contribution of each stage and the resolution available after analogue-to-digital conversion. A low-noise amplifier placed before adequate selectivity may improve nominal thermal sensitivity while making the subsequent mixer unusable in the presence of a local transmitter. An attenuator has the opposite trade-off: it improves large-signal margin but raises the input-referred noise floor. Establish at least two calibrated operating states, one sensitivity-oriented and one blocker-tolerant, and inject a weak witness tone while varying a strong adjacent tone. A disappearing witness under high blocker power is a test of overload

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susceptibility; it is not evidence that the external witness ceased transmitting. Every spectrum capture must carry its complete gain and attenuation history. Accordingly, the laboratory record for Question 014 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Cascade noise figure, third-order intercept, maximum linear power and ADC headroom measure different performance constraints. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous

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output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A 20 dB preamplifier followed by an unlogged 15 dB pad is not equivalent to putting that pad before the low-noise amplifier. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. I would therefore attach the uncertainty analysis to the *operational definition* itself instead of printing an unexplained confidence interval beside the most appealing trace.

A further, separately testable aspect of a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high concerns input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction. The proposed challenge would be sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. The decision is conditional upon the observed result, with particular attention to cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints. The competing account remains the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. Changing attenuation changes the experiment even when the displayed frequency remains unchanged. Dr Turing, please take the floor and examine what a retrospective state log must contain to recover the meaning of each observation.

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Alan Mathison Turing | Peer question 5 to Walter Andrew Shewhart

Walter Andrew Shewhart, I should like to examine what the recorded data actually preserve when a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. The physical input and the retained numerical array are not interchangeable things. Headroom, overload recovery, and weak-signal detection must be tested together across the range of gain states. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction would invalidate the preferred account, and which aspect of sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state would make that negative result independently repeatable?

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Walter Andrew Shewhart | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 014, the specific physical candidate is gain redistribution between low-noise amplification, filtering, mixing, IF gain, and converter full scale. The unresolved physical pathway is material: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The retained record permits a conditional claim about input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, but cannot alone resolve cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Cascade noise figure, third-order intercept, maximum linear power and ADC headroom measure different performance constraints. I propose separating acquired information

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from model-dependent reconstruction. Headroom, overload recovery, and weak-signal detection must be tested together across the range of gain states. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction and a fresh trial in which the operator sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. If that trial demonstrates where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Norbert Wiener | Principal contribution 4: The optimum gain plan depends upon the external interference population rather than a solitary nominal sensitivity specification.

The gain-control mechanism is a dynamical system driven by the traffic it observes. Consider a receiver in which a strong pulse lowers the RF gain for a tenth of a second. A brief candidate transmission appearing immediately afterwards can be suppressed even though its amplitude would have been detectable in isolation. One measurement of sensitivity therefore cannot describe the receiver without specifying the input history. I would probe the impulse and step responses of the gain controller, including its attack, hold and release intervals; then examine whether a second weak pulse is detected at different delays after the blocker. A fixed-gain reference channel would help distinguish an emitter's silence from the instrument's temporary blindness. If operators change thresholds in response to alarms, their decisions become additional feedback paths. The archive should retain sufficient state and timing data to model these paths, rather than representing an uninterrupted spectral ribbon where the underlying system was continuously changing its transfer behaviour.

In this information retention examination of Question 014, the decisive claim is that the optimum gain plan depends upon the external interference population rather than a solitary nominal sensitivity specification. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: cascade noise and overload are competing constraints. Consider a receiver whose first amplifier has 20 dB available gain and a linear noise factor of 1.5. A following stage with a noise factor of

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6 contributes only (6 minus 1)/100 = 0.05 to the overall linear noise factor under the ordinary Friis cascade assumptions, producing 1.55 or about 1.90 dB total noise figure. But a strong blocker raised by the same 20 dB can exceed the next stage's compression threshold. Adding attenuation in advance of the amplifier may preserve linearity while increasing the effective input-referred noise, and the correct setting therefore depends upon the actual blocker population. Distinguish a thermal-noise-limited experiment from a large-signal-limited experiment. A single pleasing noise-figure number cannot establish that weak emissions remain observable during simultaneous high-level traffic. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. The scientific point of the optimum gain plan depends upon the external interference population rather than a solitary nominal sensitivity specification. is not that the result should be made more impressive but that a contrary result should be allowed to alter

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the proposed explanation. If independent sessions repeatedly show where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. The candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier. Wiener's feedback perspective questions how an adaptive controller changes the distribution of the observations it subsequently presents as independent evidence. The issue becomes especially sharp because the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. That comparison should keep the unprocessed complex values or, where only detector outputs exist,

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disclose precisely the interval and frequency domain actually examined. For the proposed case, a 20 db preamplifier followed by an unlogged 15 db pad is not equivalent to putting that pad before the low-noise amplifier. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The appropriate gain setting follows the measured interference population, not an abstract desire for maximum amplification. Dr Deming, I invite an adverse test based on the candidate disappearing as the authorised carrier keys.

W. Edwards Deming | Peer question 6 to Norbert Wiener

I thank you, Norbert Wiener, for distinguishing measurement from attribution, but the observation is that the candidate is more visible in quiet conditions but disappears whenever the authorised transmitter keys its carrier. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a 20 dB preamplifier followed by an unlogged 15 dB pad is not equivalent to putting that pad before the low-noise amplifier. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages on one day but fails after the instrument has been reconfigured? A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment? Would you also state what observed change in input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3,

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attenuation, and ADC peak code fraction would invalidate the preferred account, and which aspect of sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state would make that negative result independently repeatable?

Norbert Wiener | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 014, the specific physical candidate is gain redistribution between low-noise amplification, filtering, mixing, IF gain, and converter full scale. The unresolved physical pathway is material: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The retained record permits a conditional claim about input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, but cannot alone resolve cascade noise figure, third-order intercept, maximum linear power and adc headroom measure different performance constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a 20 dB preamplifier followed by an unlogged 15 dB pad is not equivalent to putting that pad before the low-noise amplifier. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. Its bearing on the dispute can be evaluated through the predicted response, namely where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages. Because the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range, the procedure sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match choose the gain plan that maximises validated detectability for the actual blocker distribution, not the highest numerical gain, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

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The original run and the revised run would be reported separately. Where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Percy Williams Bridgman | Principal contribution 5: Headroom, overload recovery, and weak-signal detection must be tested together across the range of gain states.

The expression optimum gain plan needs an explicit operational definition. For a low-duty-cycle candidate, missed short emissions might dominate the consequence of an error; for a crowded regulatory environment, spurious alarms caused by overload may be more damaging to the investigation. I would ask the engineer to specify a decision loss for both mistakes and to validate the operating regimes likely to be encountered. Measurements must be stratified by blocker strength, frequency separation, gain state and event duration. A plan performing best for an isolated weak tone can be inferior when the receiver must endure occasional high-power transmissions. The most useful output is not one celebrated noise-floor number but a performance surface showing sensitivity and false-alarm rate under named conditions. If the eventual survey contains conditions outside the characterised surface, that constitutes an uncertainty to disclose, not a reason to interpolate performance optimistically. Choosing a defensible gain allocation is itself an empirical decision under constraints.

In this statistical inference examination of Question 014, the decisive claim is that headroom, overload recovery, and weak-signal detection must be tested together across the range of gain states. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: cascade noise and

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overload are competing constraints. Consider a receiver whose first amplifier has 20 dB available gain and a linear noise factor of 1.5. A following stage with a noise factor of 6 contributes only (6 minus 1)/100 = 0.05 to the overall linear noise factor under the ordinary Friis cascade assumptions, producing 1.55 or about 1.90 dB total noise figure. But a strong blocker raised by the same 20 dB can exceed the next stage's compression threshold. Adding attenuation in advance of the amplifier may preserve linearity while increasing the effective input-referred noise, and the correct setting therefore depends upon the actual blocker population. Distinguish a thermal-noise-limited experiment from a large-signal-limited experiment. A single pleasing noise-figure number cannot establish that weak emissions remain observable during simultaneous high-level traffic. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. Headroom, overload recovery, and weak-signal detection must be tested together across the range of gain states. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to sweep the strong blocker through calibrated power steps while measuring the weak

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test tone under fixed and changed attenuation, preserving each gain state, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say choose the gain plan that maximises validated detectability for the actual blocker distribution, not the highest numerical gain, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Bridgman’s operational approach requires a measurement procedure that defines each quantity physically. A stated number unsupported by the operation that produced it is methodologically incomplete. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range.

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One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a 20 db preamplifier followed by an unlogged 15 db pad is not equivalent to putting that pad before the low-noise amplifier, is not an estimate of any actual investigation. A gain plan should fail openly when recovery time or converter headroom exceeds its declared operating limits. Sir Karl, I pass the floor to you for the question that might falsify our claimed compromise.

Sir Karl Raimund Popper | Peer question 7 to Percy Williams Bridgman

Percy Williams Bridgman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise choose the gain plan that maximises validated detectability for the actual blocker distribution, not the highest numerical gain? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. A strong blocker may drive a later stage into compression even when the desired weak signal is far beneath its noise floor. Please connect input-referred noise in dBm/Hz, cascade

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noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction with a declared detection threshold and the measurement exposure. If the experiment sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Percy Williams Bridgman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 014, the specific physical candidate is gain redistribution between low-noise amplification, filtering, mixing, IF gain, and converter full scale. The unresolved physical pathway is material: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. The retained record permits a conditional claim about input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction, but cannot alone resolve cascade noise figure, third-order intercept,

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maximum linear power and adc headroom measure different performance constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. A strong blocker may drive a later stage into compression even when the desired weak signal is far beneath its noise floor. I would use the observations of input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state, not an assertion based on the operator's impression of a quiet display. If it yields where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

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To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to choose the gain plan that maximises validated detectability for the actual blocker distribution, not the highest numerical gain, with the untested physical possibilities made visible.

Hendrik Wade Bode, Cross-Peer Question to Harry Nyquist: Dr Nyquist, a low-noise amplifier ahead of an SDR can make the predicted receiver sensitivity look magnificent when the antenna sees a thermal-like background, yet the same amplifier may consume the headroom needed to survive a powerful adjacent authorised carrier. A gain sheet combines fifteen, minus six, and fifteen decibels into a twenty-four-decibel net increase, but that sum conceals the levels at the first amplifier and mixer. Which performance envelope must be mapped before an engineer chooses the highest available front-end gain? In particular, what observation would demonstrate that the weak candidate was truly preserved while a strong blocker was present, rather than hidden by compression or resuscitated as a spurious intermodulation ridge?

Harry Nyquist, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, the meaningful design variable is not total gain in isolation but the ordering of noise, filtering, attenuation and nonlinear stages under the expected signal population. For each stage I would tabulate the wanted and blocking powers, the available gain, noise factor, compression onset and relevant

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intermodulation behaviour, all at identified reference planes. Early attenuation can protect a subsequent amplifier at the price of worsening input-referred sensitivity, whereas attenuation inserted after an overloaded component cannot undo damage already created. The decision should therefore be empirical over a calibrated matrix of blocker levels and frequencies, including concurrent weak test tones and transient signals. A low-level display feature is not proved recoverable merely because its trace remains visible; one should examine distortion products, demodulation error, false alarms, missed detections and the raw ADC clipping or state flags. Where two gain configurations yield comparable detection performance, preference may turn on stability under worst-case realistic blocking and recovery rather than on the smallest theoretical noise figure. The accepted gain plan must be accompanied by its verified operating envelope.

Harry Nyquist, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, an automatic gain controller changes attenuation whenever a carrier reaches a threshold. The manufacturer's software records the steady gain setting but omits the transition's start time and several settling frames. A brief burst appears in the waterfall precisely as the controller returns from strong-signal protection, creating a spectral streak whose amplitude is subsequently treated as an external emission. How would you distinguish normal state-dependent transient behaviour from a meaningful radio event, and what process-control evidence would show that a gain schedule remained stable across a forensic recording?

Walter Andrew Shewhart, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the gain transition must be treated as an experimental event with a

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beginning, duration and verified settling criterion, not as invisible housekeeping. I should record control-command time, measured gain state, amplifier bias where relevant, ADC overload or clipping flags, blanking interval and the timestamps of the samples that receive each correction. A test signal can be injected before the active device to measure the recovery response under several blocker amplitudes and histories, whilst a second independent low-gain receiver can supply a comparison if its independence is actually established. Charts of trigger rate, duration and post-transition residual can reveal drift and recurrent operating states; they do not by themselves establish a universal distribution. An apparent ridge arising only within a documented recovery window should be reported as unresolved until a state-matched control separates instrument transient from external emission. It is essential to preserve the original uncorrected samples where they were actually recorded. A digital amplitude correction applied after saturation cannot restore missing peaks, and a smooth reconstructed trace cannot certify that lost information was present.

Norbert Wiener, Cross-Peer Question to Percy Williams Bridgman: Professor Bridgman, a designer argues for one fixed gain setting because a specification sheet quotes an impressive noise figure and a nominal ADC bit depth. Actual site measurements include a changing population of high-level transmitters, and an apparently quiet receiver sometimes raises its gain until a strong intermittent carrier forces a recovery cycle. How should the engineer define an operating population and a test procedure that covers useful weak-signal detectability across changing blocker patterns? Would you rely on a single worst-case tone, a random statistical model, or a deliberately structured suite of physically distinct adverse states?

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Percy Williams Bridgman, Cross-Peer Answer to Norbert Wiener: Professor Wiener, each of those tests answers a different question. A single strong tone establishes a repeatable compression or blocking boundary for a specified frequency and level; a two-tone challenge examines intermodulation under its own input conditions. A statistical survey of actual blockers describes the observed site's distribution during the measured interval, not every future environment. A structured adverse-state suite is therefore needed to investigate tails and unusual combinations which a short survey may miss. I would vary input power, spectral separation, burst duty cycle, gain state and recovery history whilst retaining one independently measured weak reference signal. Results should be expressed as detection probability, measurement bias or recovered dynamic range under declared conditions, accompanied by uncertainty and sample count. A gain plan should not be selected by simply maximising full-scale use or nominal sensitivity. The recorded configuration must also preserve the actual receiver state, the input reference plane and the distinct paths through which out-of-band interference may reach the converter. Where an adverse case defeats every setting, the operating limitation belongs explicitly in the technical and forensic conclusions.

Percy Williams Bridgman, Cross-Peer Question to Richard Wesley Hamming: Dr Hamming, the instrument combines two nominally twelve-bit ADC channels, assumes their quantisation noise is independent and claims to have created a twenty-four-bit observation simply by adding the codes. In reality the converters share a reference, analogue front end and sampling clock, and one channel may clip on a powerful blocker while the other does not. The worked examples also use an ideal full-scale sine formula and a

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jitter-only SNR ceiling at hundreds of megahertz. Which numerical tests would separate a potentially useful averaging or oversampling improvement from a misleading assertion that bit counts and physical instantaneous dynamic range have doubled?

Richard Wesley Hamming, Cross-Peer Answer to Percy Williams Bridgman: Professor Bridgman, the addition of two twelve-bit integer words can produce a wider computational representation, but it cannot turn those inputs into a physical twenty-four-bit conversion with the signal-to-noise and linearity of an ideal twenty-four-bit converter. Effective resolution is determined by measured noise, distortion, input range and calibration, and the averaging benefit depends on a model of the errors and their covariance. If errors are perfectly correlated, their contribution does not diminish through averaging. An experiment should measure the actual small-signal and large-signal transfer functions, coherent spurious content, clipping boundary and signal-to-noise ratio over the relevant bandwidth. Oversampling and suitable filtering may redistribute quantisation noise or provide genuine processing gain under specified conditions; it does not recover peaks already clipped before sampling. At high input frequency, sampling-clock aperture jitter places another ceiling which must be combined with rather than substituted for other imperfections. Publish effective-number-of-bits and spurious-free dynamic-range results with the test frequency, sample rate, acquisition bandwidth and reference conditions. Calling the resulting file twenty-four bits wide is a storage description; calling it twenty-four-bit accurate requires evidence that the physical converter can support that claim.

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Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of dynamic-range allocation through a cascade of analogue gain, attenuation, and conversion stages has established a point which the specialist must not overlook. The receiver records input-referred and digital power levels under simultaneously present strong and weak signals; it does not, merely by drawing a clear trace, give direct access to unlogged compression, overload recovery, or quantiser masking that distorts the apparent weak feature. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, A first low-noise amplifier can improve the cascade noise figure while consuming dynamic-range headroom. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

I thank Dr Nyquist for the insistence upon closed-loop stability and Professor Bode for the discipline of carrying power levels through an entire cascade. An attractive weak-signal gain figure cannot certify a receiver whose following mixer or digitiser is periodically overdriven. The decisive engineering record is a stage-by-stage map of maximum admissible blocker power, input-referred noise and gain-state chronology, supplemented by a probe signal which demonstrates whether a faint target remained detectable while the blocker was present. The investigator should distinguish attenuation placed before the first nonlinear element from attenuation introduced downstream, because the latter cannot reverse

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distortion already generated. A gain schedule that wins a laboratory sensitivity comparison but loses a field overload challenge must be rejected for that environment. Let the closing recommendation therefore take the form of two tested envelopes, one for detection and one for overload, each tied to frequency, bandwidth, temperature and input impedance. Any confident identification of an intermittent source must remain conditional upon those envelopes.

The weak candidate vanished whenever the legitimate blocker was present. That temporal coincidence cannot establish that the candidate stopped transmitting: it could have become unobservable through reciprocal mixing, compression or converter saturation. The capture should contain the blocker level, each gain-state transition and an independently injected probe demonstrating whether the receiver remained sensitive at that instant. The more useful outcome is a discriminating protocol: Sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. In applying it, the examiner must retain all readings supporting input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction and identify the physical plane to which the measurements refer. At the outset of the investigation, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high; that circumstance makes the alternative mechanism material, specifically the high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-scale range. A result approaching where clipping governs, reducing gain can restore the

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weak candidate despite raising the small-signal noise contribution of later stages may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore choose the gain plan that maximises validated detectability for the actual blocker distribution, not the highest numerical gain. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

The appropriate gain plan is the configuration which demonstrably retains usable dynamic range in the measured blocker environment while providing adequate weak-signal sensitivity. Its acceptance criteria must include intermediate-stage headroom, not just converter full scale, and must be repeated when the RF environment changes. The decisive experiment is concrete: Sweep the strong blocker through calibrated power steps while measuring the weak test tone under fixed and changed attenuation, preserving each gain state. In conducting it, the examiner must explicitly retain input-referred noise in dBm/Hz, cascade noise factor, P1dB, IIP3, attenuation, and ADC peak code fraction. If the outcome matches the stated prediction, where clipping governs, reducing gain can restore the weak candidate despite raising the small-signal noise contribution of later stages, the supported conclusion concerns that test domain. An alternative remains: The high-gain front end may improve input-referred thermal sensitivity yet compress an intermediate stage or exhaust the converter full-

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scale range. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 014

Application 01. Cascade gain and observed headroom

In the illustrative 014.01 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. A first amplifier contributes G_1 = 15 dB, an intentional attenuation contributes G_2 = -6 dB, and a later stage contributes G_3 = 15 dB. The small-signal sum is 15 + (-6) + 15 = 24 dB. For P_i = -73 dBm, the ideal output is P_o = -49 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. Use stage-by-stage blocker levels and compression checks before accepting the 24 dB net gain as a usable weak-signal configuration.

Application 02. Thermal reference noise in a declared measurement bandwidth

In the illustrative 014.02 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. Take the equivalent noise bandwidth B = 4,500 Hz and calibrated noise figure NF = 3.90 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF$ = -133.57 dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The -133.57 dBm thermal estimate defines the selected noise bandwidth and noise figure, not the ambient interference floor beside a strong transmitter.

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Application 03. Gain allocation and blocker headroom

In the illustrative 014.03 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. Assume a calibrated digital full-scale equivalent of -11 dBm, a blocker applied at -42 dBm, and net analogue gain 25 dB. The projected converter input is -17 dBm and remaining margin is -11 − (-17) = 6 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. Six decibels of nominal full-scale margin is insufficient assurance if an earlier stage compresses or a transient carrier exceeds the assumed blocker level.

Application 04. Two-tone third-order products and input intercept

In the illustrative 014.04 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. With two equal input tones each at P = -31 dBm and a hypothetical input third-order intercept IIP_3 = +10 dBm, the extrapolated input-referred third-order product is $P_3 = 3P - 2IIP_3$ = -113 dBm, or -82 dBc relative to either input tone. The cubic approximation ceases to be reliable in compression. A two-tone slope check and input attenuation test must establish whether the predicted spur arises inside the receiver rather than externally. The -113 dBm third-order product is extrapolated from an ideal slope; verify actual intermodulation growth before trusting a weak line near that level.

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Application 05. Filter or cable rejection referred to a physical input

In the illustrative 014.05 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. For an admitted input P_i = -54 dBm and separately measured loss L = 41 dB, the linear prediction is P_o = P_i − L = -95 dBm. In SI power this becomes 10^((-95 − 30)/10) = 3.16e-13 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. An attenuation result referred to a matched port cannot prove installed-system rejection without tests for feeder bypass and common-mode coupling.

Application 06. Ideal code step, variance, and full-scale sine SNR

In the illustrative 014.06 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. Taking an ideal N = 12-bit uniform converter across 3.00 V peak-to-peak, one nominal code interval is $\Delta = Vpp/2^N$ = 0.7324 mV. Under the independent uniform-error approximation its rms quantisation error is $\sigma = \Delta/\sqrt{12}$ = 0.2114 mV. The ideal full-scale sinusoidal SNR approximation is 6.02N + 1.76 = 74.00 dB. A coherent low-level waveform may violate the uniform-error assumption; clipping and integral nonlinearity are separate limitations. The 74.00 dB ideal converter SNR is not measured ENOB; verify SINAD, distortion and clipping at the required signal amplitude and bandwidth.

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Application 07. The frequency dependence of aperture-jitter-limited SNR

In the illustrative 014.07 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. At sinusoidal input frequency f = 309 MHz with uncorrelated rms aperture jitter σ_t = 1.74 ps, the idealised jitter-imposed ceiling is $SNR_j = -20 \log_{10}(2\pi f \sigma_t)$ = 49.43 dB. A common clock source may correlate errors across parallel ADC channels, so treating their outputs as independent for noise cancellation would need an additional experiment. Converter nonlinearity and thermal noise can make actual performance worse. The 49.43 dB jitter ceiling is conditional on the rms clock model; correlated sampling errors cannot be counted as independent noise for parallel averaging.

Application 08. Combined and expanded measurement uncertainty

In the illustrative 014.08 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. For independent standard-uncertainty contributions 0.45, 0.54 and 0.34 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.45^2 + 0.54^2 + 0.34^2)}$ = 0.781 units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c$ = 1.562 units. The 1.562-unit expanded uncertainty presumes the three contributions are independent; common gain-state errors demand covariance terms where applicable.

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Application 09. Difference between two instruments relative to stated uncertainty

In the illustrative 014.09 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. The paired instrument contrast is $\Delta = 0.920$ dB. Set independent standard uncertainties $u_1 = 0.380$ dB and $u_2 = 0.470$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.604$ dB, giving the dimensionless ratio $\Delta/u\Delta = 1.522$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. A contrast ratio of 1.522 is insufficient for any categorical improvement claim without predeclared acceptance criteria and a proper calibration covariance analysis.

Application 10. Opportunity-limited detection under independent visits

In the illustrative 014.10 test, a weak telemetry candidate occupies a frequency channel adjacent to a powerful authorised transmitter, with front-end amplification presently set high. For $n = 42$ genuinely independent valid observation opportunities, each with stipulated event detection chance $p = 0.06$, the probability of no detections is $(1 - p)^n = 0.07437$; its complement is 92.56%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The 7.44 per cent hypothetical miss probability assumes 42 independent opportunities; scheduled bursts and correlated gain states can invalidate that exponent.

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

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“Swept IMD and IM Spectrum Concepts”, measurement-application documentation, https://helpfiles.keysight.com/csg/e5080b/Applications/Swept_IMD_and_IM_Spectrum_Concepts.htm (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 016

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How can local-oscillator leakage and reciprocal mixing imitate or obscure emissions?

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Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 016 asks: How can local-oscillator leakage and reciprocal mixing imitate or obscure emissions? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is the ambiguity between genuine radiated emissions and local-oscillator leakage or reciprocal mixing. Our primary observation is a feature whose power or offset tracks receiver tuning, oscillator state, or a nearby strong blocker; by contrast, what remains unseen is the true electromagnetic field at the antenna reference plane. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Reciprocal mixing and oscillator contamination. A strong neighbouring carrier can become apparent noise around a weak desired signal through oscillator sidebands. The relevant variable is not merely the oscillator’s

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frequency error but its phase-noise density at the blocker's offset. If the blocker is minus 25 dBm, a single-sideband phase-noise level of minus 105 dBc per hertz at the relevant offset gives a first-order reciprocal-mixing density around minus 130 dBm per hertz, before the measurement-chain qualification. An integrated one-kilohertz analysis window then corresponds approximately to minus 100 dBm when the density is flat over that interval. This is not evidence that the antenna received broadband noise of that power. Repeating with a cleaner reference oscillator, moving the blocker or using an independent conversion chain helps separate receiver-borne phase-noise effects from external wideband radiation. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns a feature whose power or offset tracks receiver tuning, oscillator state, or a nearby strong blocker; it is not interchangeable with the true electromagnetic field at the antenna reference plane. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is independent LO-frequency perturbation, terminated-input check, and high-selectivity preselection trial. A claim drawn from that comparison has to carry its actual uncertainties: LO leakage level, offset phase noise, blocker power, and instrument dependence. Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. Phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in noise. Moving the LO

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changes the internal mixing relationship while a genuine external carrier remains at its physical frequency. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Edwin Howard Armstrong | Principal contribution 1: Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors.

The local oscillator is an active source within the receiving instrument, and that simple fact changes the evidential interpretation of a spectral line. Its leakage may pass through the mixer, its shielding or even the antenna port. A test signal entering at a different frequency can combine with oscillator components to yield a false feature at the intermediate frequency or baseband. I would vary the oscillator frequency in controlled increments while retaining a known RF reference. If the suspect feature follows a mixing relationship rather than an external fixed carrier, the receiver is implicated. Yet oscillator motion can also change the tuning presented to a real emitter, so the experiment needs an invariant external reference plane and careful accounting for image inversion. A shielded enclosure and a passive termination offer further tests, although neither is infallible where the mains and control cables provide ingress. The circuit hypothesis is established through predicted frequency movement and amplitude scaling, not by calling every unexplained line a spurious emission.

In this physical path examination of Question 016, the decisive claim is that mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. Reciprocal mixing and oscillator leakage are different physical phenomena and require different challenges. Oscillator leakage is an emission from the receiver or its cabling; reciprocal mixing elevates close-in noise when a strong input interacts with the phase noise of the receiver oscillator. A retune may shift one artefact with the local-oscillator control word while leaving an externally fixed carrier

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unchanged, but the tracking relationship is not by itself unique. To discriminate, the investigator must vary oscillator offset, blocker level and input termination independently. A second receiver with a demonstrably separate oscillator and acquisition path provides a stronger comparison than two demodulators sharing one synthesiser. A useful falsification proceeds from the actual controversy: reciprocal mixing and oscillator contamination. A strong neighbouring carrier can become apparent noise around a weak desired signal through oscillator sidebands. The relevant variable is not merely the oscillator's frequency error but its phase-noise density at the blocker's offset. If the blocker is minus 25 dBm, a single-sideband phase-noise level of minus 105 dBc per hertz at the relevant offset gives a first-order reciprocal-mixing density around minus 130 dBm per hertz, before the measurement-chain qualification. An integrated one-kilohertz analysis window then corresponds approximately to minus 100 dBm when the density is flat over that interval. This is not evidence that the antenna received broadband noise of that power. Repeating with a cleaner reference oscillator, moving the blocker or using an independent conversion chain helps separate receiver-borne phase-noise effects from external wideband radiation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Set the LO to three documented frequencies while holding a calibrated external source fixed. Record the spectral line at the antenna port with an independent receiver, then repeat with the suspicious receiver terminated and enclosed in a controlled screening arrangement. For reciprocal mixing, introduce a blocker at a known frequency separation and record the output

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noise density as its input power is varied. The noise contribution should follow the phase-noise mask and detector bandwidth, subject to compression and correlated errors. A leaking oscillator should instead show an emission in a physical radiation or conducted-coupling measurement. I would take LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. A response consistent with an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

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The circuit cannot be judged from its final trace alone. A frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by lo radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls, and measure their behaviour separately before reconnecting the assembled system. Armstrong's receiver engineering points to actual conversion products and oscillation conditions rather than abstract spectral indications; the crucial question is where the energy first appears. It is therefore material to establish LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope rather than infer them from a single scalar output. The limiting test is concrete: Perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. If the intervention produces an internal leakage product can move with the programmed lo offset while a genuine station remains at a fixed external rf frequency, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret the trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor as a new transmitter before challenging the most economical instrumental explanation. A trace tied to the oscillator command may be receiver leakage rather than another emitter. Professor Tukey,

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please take the floor and test which retuning comparisons could distinguish those accounts.

John Wilder Tukey | Peer question 1 to Edwin Howard Armstrong

Edwin Howard Armstrong, may I test the exact physical inference in your account of a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna? The proposed mechanism appears plausible only if changes after perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path are compared with a stable reference condition. Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope which would settle that narrower claim, rather than a visual impression of improvement.

Edwin Howard Armstrong | Immediate answer to John Wilder Tukey

Dr Tukey, a retune observation is useful only after we ask whether the same physical reference moved. The oscillator setting is a control variable, not a declaration that the antenna received a corresponding emitter. I would therefore measure the suspected leakage at a

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separate receiving antenna, and test reciprocal noise elevation with a level-verified blocker. If the two experiments disagree, that is evidence for different mechanisms rather than a reason to average their outputs. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 016, the specific physical candidate is LO leakage, reverse radiation from mixers, and phase-noise skirts multiplying adjacent strong signals. The unresolved physical pathway is material: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The retained record permits a conditional claim about LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope, but cannot alone resolve a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. I would first inject the known stimulus and verify its amplitude at the entrance to the

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claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path, and only a response matching an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Perturb the lo independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns LO frequency, mixer isolation, blocker offset, close-in phase-

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noise density, and spur-versus-retune slope, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Edwin Howard Armstrong

I appreciate your explanation, Edwin Howard Armstrong. How would your conclusion survive a deliberately independent test of the trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor? A second receiver might share more of the supposed evidence than its separate enclosure suggests. Phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in noise. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope and document which differences remain unexplained? Would you also state what observed change in LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope would invalidate the preferred account, and which aspect of perturb the lo independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path would make that negative result independently repeatable?

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Edwin Howard Armstrong | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 016, the specific physical candidate is LO leakage, reverse radiation from mixers, and phase-noise skirts multiplying adjacent strong signals. The unresolved physical pathway is material: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The retained record permits a conditional claim about LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope, but cannot alone resolve a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. I would draw the actual distribution network before collecting new corroborating evidence,

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marking where two receivers share signal, power or time references. Phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in noise. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls; I would challenge it with perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. Two responses consistent with an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, lo radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. A discordant measurement would then be interpreted by tracing that difference through LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope; an agreement lacking such a dependency analysis is weak corroboration.

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Hendrik Wade Bode | Principal contribution 2: Phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in noise.

Reciprocal mixing presents a subtler problem than an isolated oscillator spur. A large neighbouring carrier may combine with the oscillator's phase-noise sidebands, converting broad skirts into the frequency region where a weak target is sought. This depends on phase-noise spectral density at the appropriate offset, blocker amplitude and the receiver's filter chain. I would measure the oscillator sidebands with a suitable phase-noise or cross-correlation method, then introduce a characterised blocker at several offsets and powers. The resulting rise in in-channel noise should be compared against an independent receiver chain whose oscillator noise is materially different. A single oscillator phase-noise figure quoted at one offset cannot predict the entire disturbance when strong carriers lie across a band. Likewise, replacing a synthesiser may alter both phase-noise levels and discrete spur patterns. The record should distinguish a broad reciprocal-mixing pedestal from a stable local-oscillator birdie. They demand different causes, different experiments and different limits on any source attribution.

In this control and stability examination of Question 016, the decisive claim is that phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in noise. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: reciprocal mixing and oscillator contamination. A strong neighbouring carrier can become apparent noise

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around a weak desired signal through oscillator sidebands. The relevant variable is not merely the oscillator’s frequency error but its phase-noise density at the blocker’s offset. If the blocker is minus 25 dBm, a single-sideband phase-noise level of minus 105 dBc per hertz at the relevant offset gives a first-order reciprocal-mixing density around minus 130 dBm per hertz, before the measurement-chain qualification. An integrated one-kilohertz analysis window then corresponds approximately to minus 100 dBm when the density is flat over that interval. This is not evidence that the antenna received broadband noise of that power. Repeating with a cleaner reference oscillator, moving the blocker or using an independent conversion chain helps separate receiver-borne phase-noise effects from external wideband radiation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by the trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in

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noise. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, the trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. This predicts a response which should be tested against an internal leakage product can move with the programmed lo offset while a genuine station remains at a fixed external rf frequency. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore

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measurements discarded during retuning. Where a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain, the correct claim must name the operational states and the evidence available in each. Phase-noise skirts must be challenged with a blocker of known level and separation, while the local-oscillator state is recorded. Dr Pearson, I invite you to examine the evidential force of that calibration.

Egon Sharpe Pearson | Peer question 3 to Hendrik Wade Bode

Hendrik Wade Bode, your calibration argument invites a question about reference planes, especially because a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. The reference stimulus and the unknown emission need not occupy the same physical regime. Moving the LO changes the internal mixing relationship while a genuine external carrier remains at its physical frequency. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When the trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

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Hendrik Wade Bode | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 016, the specific physical candidate is LO leakage, reverse radiation from mixers, and phase-noise skirts multiplying adjacent strong signals. The unresolved physical pathway is material: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The retained record permits a conditional claim about LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope, but cannot alone resolve a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope. Moving the LO changes the internal mixing relationship while a genuine external carrier remains at its physical frequency. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be perturb the LO independently of the antenna frequency, substitute a matched

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termination, and compare with a separately clocked direct-sampling path, with before-and-after values of LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope. If the instrument behaves as predicted, then an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. The trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Hendrik Wade Bode

There is an inferential difficulty, Hendrik Wade Bode: lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The population of admissible observations needs to be fixed before any confidence argument. In this situation, a frequency-correlated display does not

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establish whether energy traversed the antenna or was generated within the conversion chain. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Terminated-port tests can exclude some radiated mechanisms but cannot rule out every cable-mediated path. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope would invalidate the preferred account, and which aspect of perturb the lo independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path would make that negative result independently repeatable?

Hendrik Wade Bode | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 016, the specific physical candidate is LO leakage, reverse

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radiation from mixers, and phase-noise skirts multiplying adjacent strong signals. The unresolved physical pathway is material: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The retained record permits a conditional claim about LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope, but cannot alone resolve a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because the trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Terminated-port tests can exclude some radiated mechanisms but cannot rule out every cable-mediated path. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real

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external carrier can create superficially similar waterfalls; its prediction should be recorded alongside an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. A frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, if an indicated carrier shifts by 250 khz following a 250 khz lo change, that covariation is a diagnostic clue, not a transmitter fingerprint. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Dennis Gabor | Principal contribution 3: Moving the LO changes the internal mixing relationship while a genuine external carrier remains at its physical frequency.

What troubles me is the apparent certainty that can arise from a narrow time-frequency plot of an oscillator-related transient. A synthesiser may have a settling trajectory during retuning; a waterfall renders a sequence of FFT magnitudes, not an instantaneous account of the oscillator's phase history. A short slanted mark after a frequency change can thus be created by the interaction of chirped local oscillator, finite analysis window and display update. I would retain raw I/Q through a controlled retune and compute several window lengths, looking for the time-frequency geometry predicted by the synthesiser model. If the line is reinterpreted as an external frequency sweep, then the same waveform should survive an independently disciplined receiver with a stable LO and an independently captured RF reference. We must not turn a convenient graphical trajectory into a history of a transmitter that may never have existed.

In this operational measurand examination of Question 016, the decisive claim is that moving the LO changes the internal mixing relationship while a genuine external carrier remains at its physical frequency. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: reciprocal mixing and oscillator contamination. A strong neighbouring carrier can become apparent noise around a weak desired signal through oscillator sidebands. The relevant variable is not merely the oscillator’s frequency error but its phase-noise density at the blocker’s offset. If the blocker is minus 25 dBm, a single-

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sideband phase-noise level of minus 105 dBc per hertz at the relevant offset gives a first-order reciprocal-mixing density around minus 130 dBm per hertz, before the measurement-chain qualification. An integrated one-kilohertz analysis window then corresponds approximately to minus 100 dBm when the density is flat over that interval. This is not evidence that the antenna received broadband noise of that power. Repeating with a cleaner reference oscillator, moving the blocker or using an independent conversion chain helps separate receiver-borne phase-noise effects from external wideband radiation. The speaker must not confuse the result of this bounded comparison with a general finding concerning every possible external transmission. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

A local oscillator is an active electromagnetic source within the measurement chain, and its leakage may escape through the antenna port, couple into adjacent receivers or mix with an unrelated external carrier. An apparent emission at the image or intermediate-frequency offset must therefore be tested with frequency-plan perturbations. Move the tuned centre frequency by a prescribed increment while retaining the same antenna and gain configuration. A genuine fixed-frequency external carrier remains at the same absolute RF frequency, whereas a receiver-generated product may move according to an oscillator harmonic or mixing equation. Reciprocal mixing demands a second, different trial: a powerful off-channel signal combined with oscillator phase noise can raise the apparent close-in noise floor and conceal a weak target without forming one sharp spurious line. The appropriate evidence includes oscillator offsets, filter

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characteristics, measured phase-noise skirts and strong-signal loading. A silent waterfall during the blocker condition does not certify an empty external channel. Accordingly, the laboratory record for Question 016 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. A frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. Gabor’s time-frequency work makes the time support and spectral concentration of an observation inseparable; a display cannot recover temporal detail that the window suppressed. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous output, an average over

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admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: If an indicated carrier shifts by 250 kHz following a 250 kHz LO change, that covariation is a diagnostic clue, not a transmitter fingerprint. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. Retuning can change an internal product while leaving an external carrier physically stationary. Dr Turing, I pass the floor to you to interrogate what the logged tuning sequence actually makes recoverable.

Alan Mathison Turing | Peer question 5 to Dennis Gabor

Dennis Gabor, I should like to examine what the recorded data actually preserve when a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. The physical input and the retained numerical array are not interchangeable things. An independent receiver using a materially different conversion plan can reduce common-circuit ambiguity. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope would invalidate the preferred account,

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and which aspect of perturb the lo independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path would make that negative result independently repeatable?

Dennis Gabor | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 016, the specific physical candidate is LO leakage, reverse radiation from mixers, and phase-noise skirts multiplying adjacent strong signals. The unresolved physical pathway is material: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The retained record permits a conditional claim about LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope, but cannot alone resolve a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire

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analogue environment. A frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. I propose separating acquired information from model-dependent reconstruction. An independent receiver using a materially different conversion plan can reduce common-circuit ambiguity. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope and a fresh trial in which the operator perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. If that trial demonstrates an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include perturb the lo independently of the antenna frequency, substitute a matched termination, and compare with a

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separately clocked direct-sampling path. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Claude Elwood Shannon | Principal contribution 4: Terminated-port tests can exclude some radiated mechanisms but cannot rule out every cable-mediated path.

It is helpful to separate two inverse questions. One asks whether a digital line could have arisen from a known oscillator-and-mixer mechanism; the other asks which physical source, among many possibilities, produced the analogue inputs. A matched digital signature may strongly favour one mechanism, but the digital record alone rarely identifies a unique external radiator. For the first question, preserve oscillator settings, PLL lock indicators, synthesiser programming history and gain-state changes synchronised with the samples. For the second, measure how the signal behaves when the antenna is disconnected or the preselector is altered, remembering that those actions can themselves affect mixer loading and oscillator leakage. An apparent absence after disconnecting the aerial is not proof of an emitter outside the building unless an alternative ingress path has been tested. Information lost at mixing cannot be recreated by a confident interpretation of a single waterfall pixel.

In this information retention examination of Question 016, the decisive claim is that terminated-port tests can exclude some radiated mechanisms but cannot rule out every cable-mediated path. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: reciprocal mixing and oscillator contamination. A strong neighbouring carrier can become apparent noise around a weak desired signal through oscillator sidebands. The relevant variable is not merely the oscillator’s frequency error but its phase-noise density at the blocker’s offset.

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If the blocker is minus 25 dBm, a single-sideband phase-noise level of minus 105 dBc per hertz at the relevant offset gives a first-order reciprocal-mixing density around minus 130 dBm per hertz, before the measurement-chain qualification. An integrated one-kilohertz analysis window then corresponds approximately to minus 100 dBm when the density is flat over that interval. This is not evidence that the antenna received broadband noise of that power. Repeating with a cleaner reference oscillator, moving the blocker or using an independent conversion chain helps separate receiver-borne phase-noise effects from external wideband radiation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. The scientific point of terminated-port tests can exclude some radiated mechanisms but cannot rule out every cable-mediated path. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions repeatedly show an internal leakage product can move with the

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programmed LO offset while a genuine station remains at a fixed external RF frequency, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. The trace follows an offset from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor. Shannon's information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. The issue becomes especially sharp because lo radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Perturb the lo independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the proposed case, if an

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indicated carrier shifts by 250 khz following a 250 khz lo change, that covariation is a diagnostic clue, not a transmitter fingerprint. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A further, separately testable aspect of a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna concerns LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope. The proposed challenge would be perturb the lo independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. The decision is conditional upon the observed result, with particular attention to a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. The competing account remains lo radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. A terminated antenna port can remove one coupling path without excluding leakage through conductors or receiver controls. Dr Deming, I invite you to design the challenge that might reveal that residual route.

W. Edwards Deming | Peer question 6 to Claude Elwood Shannon

I thank you, Claude Elwood Shannon, for distinguishing measurement from attribution, but the observation is that the trace follows an offset

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from a local-oscillator control word rather than a fixed frequency measured by a second independent sensor. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: if an indicated carrier shifts by 250 kHz following a 250 kHz LO change, that covariation is a diagnostic clue, not a transmitter fingerprint. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency on one day but fails after the instrument has been reconfigured? Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

Claude Elwood Shannon | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 016, the specific physical candidate is LO leakage, reverse radiation from mixers, and phase-noise skirts multiplying adjacent strong signals. The unresolved physical pathway

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is material: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The retained record permits a conditional claim about LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope, but cannot alone resolve a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, if an indicated carrier shifts by 250 kHz following a 250 kHz LO change, that covariation is a diagnostic clue, not a transmitter fingerprint. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. Its bearing on the dispute can be evaluated through the predicted response, namely an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency. Because lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls, the procedure perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path should be repeated with the same calibration and an independent witness path. If

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agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match distinguish receiver self-emission and reciprocal-mixing artefacts before declaring a separate clandestine source, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. An internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Walter Andrew Shewhart | Principal contribution 5: An independent receiver using a materially different conversion plan can reduce common-circuit ambiguity.

I would treat the oscillator-artifact diagnosis as an experimental process with reference controls. Establish a stable source, move the local oscillator according to a predeclared sequence, and record the expected movement of real carriers, image responses, internal spurs and reciprocal-mixing skirts. Then test whether each expected class follows its assigned rule over temperature and repeated power cycles. A spectral spur that disappears in one of ten trials should not be excluded from the failure model simply because the remaining nine trials looked consistent. Control runs must also include transitions, since a PLL's acquisition period can create brief, highly persuasive artefacts. The engineer should report false identification rates under the tested conditions and preserve outliers for explanation. The distinction between a nuisance line and a genuine emitter emerges from the reproducibility of competing physical predictions, not the visual neatness of a laboratory display.

In this statistical inference examination of Question 016, the decisive claim is that an independent receiver using a materially different conversion plan can reduce common-circuit ambiguity. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: reciprocal mixing and oscillator contamination. A strong neighbouring carrier can become apparent noise around a weak desired signal through oscillator sidebands. The relevant

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variable is not merely the oscillator's frequency error but its phase-noise density at the blocker's offset. If the blocker is minus 25 dBm, a single-sideband phase-noise level of minus 105 dBc per hertz at the relevant offset gives a first-order reciprocal-mixing density around minus 130 dBm per hertz, before the measurement-chain qualification. An integrated one-kilohertz analysis window then corresponds approximately to minus 100 dBm when the density is flat over that interval. This is not evidence that the antenna received broadband noise of that power. Repeating with a cleaner reference oscillator, moving the blocker or using an independent conversion chain helps separate receiver-borne phase-noise effects from external wideband radiation. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. An independent receiver using a materially different conversion plan can reduce common-circuit ambiguity. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two

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displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say distinguish receiver self-emission and reciprocal-mixing artefacts before declaring a separate clandestine source, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that lo radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are

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LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from an internal leakage product can move with the programmed lo offset while a genuine station remains at a fixed external rf frequency, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, if an indicated carrier shifts by 250 khz following a 250 khz lo change, that covariation is a diagnostic clue, not a transmitter fingerprint, is not an estimate of any actual investigation. Two receivers agreeing is useful only when their conversion dependencies are genuinely different. Sir Karl, please take the floor and consider what contrary observation would defeat our asserted independence.

Sir Karl Raimund Popper | Peer question 7 to Walter Andrew Shewhart

Walter Andrew Shewhart, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise distinguish receiver self-emission and reciprocal-mixing artefacts before declaring a separate clandestine source? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in noise. Please connect LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope with a declared detection threshold and the measurement exposure. If the experiment perturb the LO

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independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Walter Andrew Shewhart | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 016, the specific physical candidate is LO leakage, reverse radiation from mixers, and phase-noise skirts multiplying adjacent strong signals. The unresolved physical pathway is material: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. The retained record permits a conditional claim about LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope, but cannot alone resolve a frequency-correlated display does not establish whether energy traversed the antenna or was generated within the conversion chain.

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That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Phase noise around a large local oscillator or blocker converts frequency offset into apparent close-in noise. I would use the observations of LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path, not an assertion based on the operator's impression of a quiet display. If it yields an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since lo radiation, mixer

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feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to distinguish receiver self-emission and reciprocal-mixing artefacts before declaring a separate clandestine source, with the untested physical possibilities made visible.

Edwin Howard Armstrong, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, a receiver shows a raised floor around a strong adjacent carrier at the same time that an independent probe detects weak radiation near its local-oscillator frequency. An operator has labelled both observations 'oscillator leakage' and claims that removing the nearby blocker will remove the internal emission. The receiver is retuned, and both the image and the noise skirt move on the waterfall, although they need not share a causal mechanism. How would you separate an oscillator signal escaping through a physical coupling path from reciprocal mixing caused by sideband phase noise, and which measurements must remain at a fixed radio-frequency reference plane?

Hendrik Wade Bode, Cross-Peer Answer to Edwin Howard Armstrong: Dr Armstrong, radiation of an oscillator component and reciprocal mixing are not the same measurand. For leakage I would use a calibrated, separately powered probe or receiver, record the absolute frequency and level at a declared external reference plane, and perturb the suspect oscillator while documenting screening, cables and terminations. For reciprocal mixing I would independently characterise the strong blocker's spectrum and the receiver oscillator's single-sideband phase-noise density at the offset that

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places sideband energy in the measurement filter. Then I would vary blocker power and offset with gain, filter bandwidth and tuning state recorded. Reciprocal-mixing noise may scale with blocker power even if the oscillator's escaped field at the probe is unchanged. A moving IF trace alone proves neither mechanism. If both occur, the report must retain two causal hypotheses and two uncertainty budgets rather than borrowing evidence from one to establish the other. With your leave, I pass the floor to Dr Shannon.

Claude Elwood Shannon, Cross-Peer Question to Dennis Gabor: Professor Gabor, the operator changes the LO by a specified increment and sees a feature translate by that increment in displayed intermediate frequency. The same software re-labels the horizontal axis as an inferred RF frequency, while a separately digitised antenna monitor shows a stationary feature. The result is described alternately as proof of internal spurious response and proof of external reception. What coordinate system and observation window should the experiment specify, and how can a retuning test distinguish a synthesiser spur from an actual emitter without treating a transformed display as a second sensor?

Dennis Gabor, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, write down the actual conversion and sampling map before interpreting the motion. The laboratory record should give LO frequency, injection side, intermediate-frequency sign convention, digital complex mixing frequency, sample rate, filter bandwidth and whether the software displays signed baseband or reconstructed RF. Simultaneously retain raw I/Q, the independent monitor's frequency standard and the absolute frequency of any oscillator leakage measured outside the receiver. Retuning can

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distinguish models only if we predict how each candidate moves in the chosen coordinates, including images, synthesiser-related spurs and external carriers. A feature that is stationary in reconstructed RF but moves in IF is compatible with external reception, yet it is not decisive if software or clocking shares a fault. Window length, time stamps and gain transitions must be preserved so that apparent line motion is not merely a change in time-frequency resolution or a skipped measurement interval. With your leave, I pass the floor to Dr Hamming.

Richard Wesley Hamming, Cross-Peer Question to Edwin Howard Armstrong: Dr Armstrong, our blocker trial reports an increase in in-band noise when the blocker rises by ten decibels. Another operator sees a similar rise when the ADC approaches full scale and calls the phenomenon reciprocal mixing. What intervention would distinguish sideband noise transferred through the mixer from compression, quantisation artefacts and third-order intermodulation? Please specify the observations that would count against the reciprocal-mixing explanation, not merely those that would make the plotted spectrum resemble the textbook picture.

Edwin Howard Armstrong, Cross-Peer Answer to Richard Wesley Hamming: Dr Hamming, a ten-decibel association by itself is inadequate. I should establish a known small-signal operating regime with a measured low-gain path and monitor the blocker level before every susceptible amplifier, mixer and converter. With the receiver gain and equivalent-noise bandwidth fixed, change blocker offset while recording the oscillator phase-noise spectrum at the corresponding offsets; the reciprocal-mixing hypothesis predicts a relationship between blocker power, sideband phase noise and noise integrated into the wanted filter. Repeat with the blocker removed, with a

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calibrated alternate oscillator if possible, and with a receiver architecture that avoids the suspect conversion stage. Compression instead predicts gain reduction and potential broadband distortion, while discrete intermodulation predicts frequency relations and often a different power slope in its applicable regime. Where the intervention changes multiple parameters, the mechanisms remain confounded. The evidence should identify which response contradicted which hypothesis, including any unresolved mixture of mechanisms. With your leave, I pass the floor to Dr Tukey.

John Wilder Tukey, Cross-Peer Question to Walter Andrew Shewhart: Mr Shewhart, a terminated-port survey records no obvious spur after a firmware update, and a later antenna-connected observation contains a small peak that the analyst therefore calls a remote transmitter. The technician searched many tuning states and inspected only the quiet termination trace, while the LO settled for a variable interval after every state change. What repeatability and decision-control procedure would prevent a merely negative internal test from becoming positive proof of external origin, especially when drift and post-selection are plausible?

Walter Andrew Shewhart, Cross-Peer Answer to John Wilder Tukey: Dr Tukey, I would make the decision rule and search family explicit before collecting confirmation data. The record must include every tuning state examined, dwell time, settling interval, gain or attenuation state, analogue preselector position, detector threshold, firmware version and missing acquisition intervals. Interleave terminated and antenna-connected observations, add a calibrated injection and an independent measurement channel, and use randomised or counterbalanced order where practical to expose systematic

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drift. A control chart may reveal temporal instability but does not confer causality on a spectral line. The power to exclude a receiver-generated spur must be demonstrated for the relevant amplitude and state, not assumed from a visually empty display. A non-detection bounds what that particular test could see; it cannot by itself identify an external radiator. The final finding should state the tested mechanism, the detection limit, the number of opportunities searched and the residual alternatives. With your leave, I pass the floor to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of the ambiguity between genuine radiated emissions and local-oscillator leakage or reciprocal mixing has established a point which the specialist must not overlook. The receiver records a feature whose power or offset tracks receiver tuning, oscillator state, or a nearby strong blocker; it does not, merely by drawing a clear trace, give direct access to the true electromagnetic field at the antenna reference plane. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, Mixer local oscillators are not perfectly isolated from the RF port and can couple into connected conductors. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

The exchanges have established a separation which is easily lost when several spectral features appear on the same waterfall. Radiation of a receiver's local oscillator is measurable as conducted or radiated emission;

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reciprocal mixing is a noise contribution caused by a powerful external signal interacting with oscillator phase noise. A spur which follows the tuning word need not be a newly discovered transmitter, and an elevated noise pedestal need not represent wideband external energy. Dr Armstrong's receiver perspective is most valuable here when coupled with an independent antenna, a separately clocked reference receiver and a source whose blocker power is stepped through a declared range. The report should show which feature moves with oscillator offset, which grows with blocker power, and which survives termination of the investigated input. I thank the panel for distinguishing these tests rather than merging them into an ambiguous label of oscillator interference. The final inference must identify a measured mechanism, not merely an unusually bright trace.

The questioned trace follows the internal oscillator setting, not a stable frequency established by a separately clocked sensor. That observation favours an instrumental explanation, although an emission coupled from the receiver housing cannot be distinguished from an internal spectral spur by the shared display alone. The report must distinguish a conducted leakage measurement from an inferred mixing product. The more useful outcome is a discriminating protocol: Perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. In applying it, the examiner must retain all readings supporting LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope and identify the physical plane to which the measurements refer. At the outset of the investigation, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna; that

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circumstance makes the alternative mechanism material, specifically lO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. A result approaching an internal leakage product can move with the programmed LO offset while a genuine station remains at a fixed external RF frequency may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore distinguish receiver self-emission and reciprocal-mixing artefacts before declaring a separate clandestine source. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

An oscillator-related artefact is supported only where its measured tuning or blocker-power dependence matches the relevant mechanism. A receiver-generated spectral line and a reciprocal-mixing noise pedestal should not be collapsed into one category, and neither establishes a second clandestine emitter. The decisive experiment is concrete: Perturb the LO independently of the antenna frequency, substitute a matched termination, and compare with a separately clocked direct-sampling path. In conducting it, the examiner must explicitly retain LO frequency, mixer isolation, blocker offset, close-in phase-noise density, and spur-versus-retune slope. If the outcome matches the stated prediction, an internal leakage product can move with the programmed lo offset while a genuine station remains at a fixed external rf frequency, the supported conclusion concerns that test

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domain. An alternative remains: LO radiation, mixer feedthrough, reciprocal mixing about a strong blocker and a real external carrier can create superficially similar waterfalls. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 016

Application 01. Two-tone third-order products and input intercept

In the illustrative 016.01 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. With two equal input tones each at P = -32 dBm and a hypothetical input third-order intercept IIP_3 = +12 dBm, the extrapolated input-referred third-order product is $P_3 = 3P - 2IIP_3$ = -120 dBm, or -88 dBc relative to either input tone. The cubic approximation ceases to be reliable in compression. A two-tone slope check and input attenuation test must establish whether the predicted spur arises inside the receiver rather than externally. The predicted intermodulation level describes a small-signal receiver model, not the strength or existence of a radiating source; verify the measured slope and the first nonlinear stage.

Application 02. Filter or cable rejection referred to a physical input

In the illustrative 016.02 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. For an admitted input P_i = -55 dBm and separately measured loss L = 41 dB, the linear prediction is $P_o = P_i - L$ = -96 dBm. In SI power this becomes 10^((-96 − 30)/10) = 2.51e-13 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. A measured forty-one-decibel network attenuation applies only at the characterised reference planes, and cannot independently exclude shield, feeder or common-mode bypass paths.

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Application 03. Thermal reference noise in a declared measurement bandwidth

In the illustrative 016.03 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. Take the equivalent noise bandwidth B = 12,000 Hz and calibrated noise figure NF = 2.55 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -130.66$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The thermal-reference estimate is neither a phase-noise spectrum nor a model of strong-blocker reciprocal mixing; the latter requires offset-specific oscillator and blocker data.

Application 04. Cascade gain and observed headroom

In the illustrative 016.04 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. A first amplifier contributes G_1 = 9 dB, an intentional attenuation contributes G_2 = -5 dB, and a later stage contributes G_3 = 18 dB. The small-signal sum is 9 + (-5) + 18 = 22 dB. For P_i = -69 dBm, the ideal output is P_o = -47 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. Even a correct twenty-two-decibel total gain conceals intermediate-stage overload; identify where the oscillator and blocking components enter the physical chain.

Application 05. Gain allocation and blocker headroom

In the illustrative 016.05 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the

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antenna. Assume a calibrated digital full-scale equivalent of -9 dBm, a blocker applied at -38 dBm, and net analogue gain 29 dB. The projected converter input is -9 dBm and remaining margin is -9 − (-9) = 0 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. Zero-decibel projected headroom is not a safe operating reserve: crest factor, uncertainty and transient gain may already cause clipping, so challenge the chain at reduced gain.

Application 06. Alias-location prediction and its non-unique inverse

In the illustrative 016.06 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. For an actual sampling frequency f_s = 11 MHz and analogue input f_i = 23.540 MHz, the nearest-replica folding rule gives $f_a = |f_i - \mathrm{round}(f_i/f_s)f_s|$ = 1.540 MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. Aliased frequency is not unique evidence of radio-frequency origin; vary the analogue preselector and sampling plan with independently measured clock and input conditions.

Application 07. Accumulated sample-clock time error

In the illustrative 016.07 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. A free-running sample clock with fractional rate error ε = 0.690 ppm over T = 413 s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T$ = 0.2850 ms.

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This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. An accumulated mean-rate offset is not the same as close-in oscillator phase noise; preserve separate measurements of sample timing, LO spectrum and actual dropped samples.

Application 08. Combined and expanded measurement uncertainty

In the illustrative 016.08 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. For independent standard-uncertainty contributions 0.59, 0.54 and 0.40 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.59^2 + 0.54^2 + 0.40^2)} = 0.894$ units. Using an illustrative coverage factor $k = 2$ gives expanded uncertainty $U = 2u_c = 1.789$ units. The expanded uncertainty assumes the stated independent components and illustrative factor of two; include covariance or coverage qualifications if those assumptions do not hold.

Application 09. Difference between two instruments relative to stated uncertainty

In the illustrative 016.09 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. The paired instrument contrast is $\Delta = 1.300$ dB. Set independent standard uncertainties $u_1 = 0.460$ dB and $u_2 = 0.470$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.658$ dB, giving the dimensionless ratio $\Delta/u\Delta = 1.977$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The ratio near two is

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an uncertainty-scaled contrast, not a probability of external transmission; specify the comparison model and correlated reference errors.

Application 10. Preserved sample continuity across an acquisition interval

In the illustrative 016.10 test, a frequency-agile receiver produces a narrow trace which shifts on retuning despite no obvious change at the antenna. A converter expected to retain f_s = 1.90 million samples/s for T = 0.85 s should supply f_sT = 1,615,000 complex sample instants. If 242 sequence positions are missing, the retained count is 1,614,758 and loss fraction is 0.01498%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block must therefore be preserved. Lost sample positions must be time-localised: a tiny average loss fraction could conceal the very burst a surveillance survey is intended to capture.

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Selected technical references and use limitations

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“Swept IMD and IM Spectrum Concepts”, measurement-application documentation, https://helpfiles.keysight.com/csg/e5080b/Applications/Swept_IMD_and_IM_Spectrum_Concepts.htm (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 017

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What does a receiver noise figure establish when the observed environment is not thermal noise?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 017 asks: What does a receiver noise figure establish when the observed environment is not thermal noise? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is the limited interpretation of a receiver noise figure when environmental noise is non-thermal. Our primary observation is input-referred noise density, receiver sensitivity, and measured spectral background; by contrast, what remains unseen is the proportions due to thermal noise, impulsive interference, atmospheric activity, and local equipment. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

External interference and the definition of noise figure. At approximately 290 kelvin the familiar available thermal-noise density is near minus 174

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dBm per hertz. Across a ten-kilohertz equivalent-noise bandwidth this becomes about minus 134 dBm, and adding a 5 dB receiver noise figure yields roughly minus 129 dBm of receiver-limited input-referred noise under matched-source assumptions. When the antenna collects a variable man-made interference environment at minus 107 dBm in the same bandwidth, reducing the receiver noise figure by one decibel will scarcely change the observed floor. The survey must measure the environmental contribution rather than infer it from the data sheet. In a recorded forensic finding, separate instrument noise, natural atmospheric noise, man-made interference and unmodelled short-duration occupancy. Treat the noise floor as a distribution conditioned on frequency, antenna and time, not an immutable line. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns input-referred noise density, receiver sensitivity, and measured spectral background; it is not interchangeable with the proportions due to thermal noise, impulsive interference, atmospheric activity, and local equipment. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is calibrated terminated-source noise comparison plus outdoor, antenna, and time-stratified surveys. A claim drawn from that comparison has to carry its actual uncertainties: noise factor, noise temperature, equivalent input bandwidth, and non-Gaussian tails. Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. A receiver with an excellent

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nominal noise figure can be overwhelmed by impulsive local interference. The choice of detector and integration time changes the statistics of a heavy-tailed interference environment. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Harry Nyquist | Principal contribution 1: Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform.

Noise figure is an input-referred comparison against a thermal reference, not a universal description of what an antenna will hear. The usual relationship N = kTBF assumes a specified reference temperature, bandwidth and small-signal operating state. It can be a valuable way to compare receiver front ends under controlled matched conditions, yet an aerial overlooking industrial machinery may receive impulsive interference and structured communications whose statistics are nothing like those of a thermal termination. I would therefore present two distinct measurements: a calibrated terminated-input noise figure and an occupied-site distribution of actual noise and interference power in the task's bandwidth. Mixing the two without explaining the operating conditions makes the site look quieter or louder for the wrong reason. An unusually low noise figure can be immaterial when external interference dominates; conversely, front-end nonlinearity can make a supposedly strong receiver unable to detect a small pulse near a blocker. Sensitivity must be evaluated for the actual detection task.

In this physical path examination of Question 017, the decisive claim is that noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. A specified noise figure describes a receiver under a reference-source noise model; it is not a percentile of the environmental disturbance encountered during a survey. The 290-kelvin thermal source used in an ordinary noise-figure characterisation is not a surrogate for impulsive interference from motors,

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switchgear, power converters or other transmitters. A low intrinsic noise figure may coexist with an intolerable false-alarm rate when the field environment is non-Gaussian. Consequently the panel should distinguish input-referred receiver-added noise, the measured environmental noise distribution and the detector's probability of responding to a specified signal class. A useful falsification proceeds from the actual controversy: external interference and the definition of noise figure. At approximately 290 kelvin the familiar available thermal-noise density is near minus 174 dBm per hertz. Across a ten-kilohertz equivalent-noise bandwidth this becomes about minus 134 dBm, and adding a 5 dB receiver noise figure yields roughly minus 129 dBm of receiver-limited input-referred noise under matched-source assumptions. When the antenna collects a variable man-made interference environment at minus 107 dBm in the same bandwidth, reducing the receiver noise figure by one decibel will scarcely change the observed floor. The survey must measure the environmental contribution rather than infer it from the data sheet. In a recorded forensic finding, separate instrument noise, natural atmospheric noise, man-made interference and unmodelled short-duration occupancy. Treat the noise floor as a distribution conditioned on frequency, antenna and time, not an immutable line. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Measure calibrated receiver noise figure using a suitable source and independently confirm gain and effective noise bandwidth. Then acquire time-tagged samples at the same receiver settings first with a termination, next with a calibrated aerial reference, and finally under the relevant

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operating states of local machinery. Report tail probabilities and pulse-duration distributions as well as mean power. Vary the detector threshold only through a documented rule, because thresholds optimised after observing bursts do not provide independent validation. I would take noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. A response consistent with the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. The laboratory reports a favourable receiver noise figure while the field site contains

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periodic switching transients and impulsive industrial interference. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails, and measure their behaviour separately before reconnecting the assembled system. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. It is therefore material to establish noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure rather than infer them from a single scalar output. The limiting test is concrete: Compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. If the intervention produces the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions as a new transmitter before challenging the most economical instrumental explanation. The calibrated noise figure is a property of a defined source condition, not a description of industrial interference. Professor Tukey, I invite you to assess what happens when transient-rich visits are discarded from the summary.

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John Wilder Tukey | Peer question 1 to Harry Nyquist

Harry Nyquist, may I test the exact physical inference in your account of the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference? The proposed mechanism appears plausible only if changes after compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals are compared with a stable reference condition. Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure which would settle that narrower claim, rather than a visual impression of improvement.

Harry Nyquist | Immediate answer to John Wilder Tukey

Dr Tukey, what appears to be an exceptionally quiet channel may merely be a low average with very heavy tails. I would compare the false-alarm distribution from a terminated input with that seen during machinery operation, retaining burst timestamps rather than just averaged PSD traces. A lower receiver noise figure is desirable, but it does not excuse the investigator from measuring the actual field-

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detection problem. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 017, the specific physical candidate is a specified receiver noise factor added to a source whose statistics need not be Gaussian or stationary. The unresolved physical pathway is material: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. The retained record permits a conditional claim about noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, but cannot alone resolve noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are noise factor, equivalent noise temperature,

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effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals, and only a response matching the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, not a conjecture about the operator's intentions.

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Richard Wesley Hamming | Peer question 2 to Harry Nyquist

I appreciate your explanation, Harry Nyquist. How would your conclusion survive a deliberately independent test of an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions? A second receiver might share more of the supposed evidence than its separate enclosure suggests. A receiver with an excellent nominal noise figure can be overwhelmed by impulsive local interference. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure and document which differences remain unexplained? Would you also state what observed change in noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure would invalidate the preferred account, and which aspect of compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals would make that negative result independently repeatable?

Harry Nyquist | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front

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panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 017, the specific physical candidate is a specified receiver noise factor added to a source whose statistics need not be Gaussian or stationary. The unresolved physical pathway is material: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. The retained record permits a conditional claim about noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, but cannot alone resolve noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. A receiver with an excellent nominal noise figure can be overwhelmed by impulsive local interference. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains thermal amplifier noise and

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non-Gaussian environmental interference may share average power while differing sharply in their detection tails; I would challenge it with compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. Two responses consistent with the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails. A discordant measurement would then be interpreted by tracing that difference through noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure; an agreement lacking such a dependency analysis is weak corroboration.

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Claude Elwood Shannon | Principal contribution 2: A receiver with an excellent nominal noise figure can be overwhelmed by impulsive local interference.

A noise-floor figure derived from averaged power can discard the feature the investigator most needs. A receiver could have an excellent mean PSD while rare, very large impulses repeatedly defeat a narrowband detector. I would retain a complementary account of the amplitude distribution, temporal occupancy and phase coherence of the noise record. If a nominally thermal background contains cyclostationary power or discrete spurs, it should not be passed off as memoryless Gaussian noise merely because the spectrum looks smooth after averaging. The data-processing inequality reminds us that replacing a full time series with one scalar noise figure is a lossy representation. That does not make the scalar useless; it makes the claims drawn from it conditional on the question posed. In a defensible survey, a quoted noise floor should be accompanied by the record length, effective bandwidth, averaging method and evidence of detector validity during strong bursts. Otherwise the information most relevant to missed detections is hidden by the statistical summary.

In this control and stability examination of Question 017, the decisive claim is that a receiver with an excellent nominal noise figure can be overwhelmed by impulsive local interference. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: external interference and the definition of noise figure. At approximately 290 kelvin the familiar available

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thermal-noise density is near minus 174 dBm per hertz. Across a ten-kilohertz equivalent-noise bandwidth this becomes about minus 134 dBm, and adding a 5 dB receiver noise figure yields roughly minus 129 dBm of receiver-limited input-referred noise under matched-source assumptions. When the antenna collects a variable man-made interference environment at minus 107 dBm in the same bandwidth, reducing the receiver noise figure by one decibel will scarcely change the observed floor. The survey must measure the environmental contribution rather than infer it from the data sheet. In a recorded forensic finding, separate instrument noise, natural atmospheric noise, man-made interference and unmodelled short-duration occupancy. Treat the noise floor as a distribution conditioned on frequency, antenna and time, not an immutable line. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note a receiver with an excellent nominal noise

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figure can be overwhelmed by impulsive local interference. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Shannon’s information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. This predicts a response which should be tested against the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational

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step does not restore measurements discarded during retuning. Where noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field, the correct claim must name the operational states and the evidence available in each. My proposed acceptance test would archive the entire control sequence and the independent witness measurement before any data-dependent threshold adjustment.

A further, separately testable aspect of the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference concerns noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure. The proposed challenge would be compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. The decision is conditional upon the observed result, with particular attention to noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. The competing account remains thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. Equal average powers may conceal very different impulsive tails and hence different miss probabilities. Dr Pearson, please take the floor and examine the decision model needed for a defensible comparison.

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Egon Sharpe Pearson | Peer question 3 to Claude Elwood Shannon

Claude Elwood Shannon, your calibration argument invites a question about reference planes, especially because noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. The reference stimulus and the unknown emission need not occupy the same physical regime. The choice of detector and integration time changes the statistics of a heavy-tailed interference environment. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Claude Elwood Shannon | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 017, the specific physical candidate is a specified receiver noise factor

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added to a source whose statistics need not be Gaussian or stationary. The unresolved physical pathway is material: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. The retained record permits a conditional claim about noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, but cannot alone resolve noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure. The choice of detector and integration time changes the statistics of a heavy-tailed interference environment. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals, with before-and-after values of noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure. If the instrument behaves as predicted, then the same average floor can coexist with markedly different alarm

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rates if one environment has heavy-tailed impulses; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. An input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Claude Elwood Shannon

There is an inferential difficulty, Claude Elwood Shannon: thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. The population of admissible observations needs to be fixed before any confidence argument. In this situation, noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Measurements with a matched

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terminator isolate receiver-added noise more effectively than sky-facing observations. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure would invalidate the preferred account, and which aspect of compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals would make that negative result independently repeatable?

Claude Elwood Shannon | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 017, the specific physical candidate is a specified receiver noise factor added to a source whose statistics need not be Gaussian or stationary. The unresolved physical pathway is material: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails.

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The retained record permits a conditional claim about noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, but cannot alone resolve noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Measurements with a matched terminator isolate receiver-added noise more effectively than sky-facing observations. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails; its prediction should be recorded alongside the same average floor can coexist with markedly different alarm rates if one environment has

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heavy-tailed impulses. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, two spectra with identical integrated watts need not yield the same threshold-exceedance statistics for a brief-event detector. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Hendrik Wade Bode | Principal contribution 3: The choice of detector and integration time changes the statistics of a heavy-tailed interference environment.

A cascade calculation is often more trustworthy than an unexplained number on a front-panel screen, but only within its own assumptions. Friis's formula combines stage noise factors and gains for a linear chain with appropriate impedances and a thermal reference. It does not predict the effect of a nearby transmitter driving a mixer into compression or a clock spur coupling into baseband. I would ask for stage-by-stage noise characterisation under both a well-defined termination and a realistic blocker profile. A change of preselector may reduce interference while increasing passive insertion loss; those two effects must be kept distinct. If the operator reports a six-decibel improvement in the displayed floor, the first question is whether the RBW, averaging and gain-state definitions stayed fixed. Noise figure is a network property under test conditions, not a magical conversion factor between every observed waveform and its physical cause.

In this operational measurand examination of Question 017, the decisive claim is that the choice of detector and integration time changes the statistics of a heavy-tailed interference environment. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: external interference and the definition of noise figure. At approximately 290 kelvin the familiar available thermal-noise density is near minus 174 dBm per hertz. Across a ten-kilohertz equivalent-noise bandwidth this becomes about minus 134 dBm,

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and adding a 5 dB receiver noise figure yields roughly minus 129 dBm of receiver-limited input-referred noise under matched-source assumptions. When the antenna collects a variable man-made interference environment at minus 107 dBm in the same bandwidth, reducing the receiver noise figure by one decibel will scarcely change the observed floor. The survey must measure the environmental contribution rather than infer it from the data sheet. In a recorded forensic finding, separate instrument noise, natural atmospheric noise, man-made interference and unmodelled short-duration occupancy. Treat the noise floor as a distribution conditioned on frequency, antenna and time, not an immutable line. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Noise figure describes degradation of signal-to-noise ratio under a reference noise model and specified source conditions; it is not a universal sensitivity certificate for a working building. A receiver may have a commendable laboratory noise figure while its input is dominated by industrial impulsive interference, broadband switching emissions or a strong adjacent-channel waveform. The field investigator should separately record system-added noise, environment-dependent background and detection-threshold behaviour. A hot-and-cold reference measurement or a characterised noise source can establish a bounded receiver noise parameter, but it cannot determine whether a weak field signal will be detectable during a burst of external interference. The relevant field experiment compares a terminated input, a calibrated injected witness and the live antenna path under matched bandwidth and detector settings. If

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the witness succeeds on termination yet fails on the antenna, the result points toward environmental masking or front-end overload rather than a sudden change in the intrinsic receiver noise figure. Accordingly, the laboratory record for Question 017 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should

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specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: Two spectra with identical integrated watts need not yield the same threshold-exceedance statistics for a brief-event detector. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. Detector integration time governs how a burst enters the statistic, even when the amplifier noise figure is unchanged. Dr Turing, I invite your examination of what a stored sequence does and does not preserve.

Alan Mathison Turing | Peer question 5 to Hendrik Wade Bode

Hendrik Wade Bode, I should like to examine what the recorded data actually preserve when the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. The physical input and the retained numerical array are not interchangeable things. The evidential report should distinguish receiver sensitivity from environmental detectability. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in noise factor, equivalent noise temperature, effective bandwidth, kurtosis,

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false-alarm rate and occupied-time exposure would invalidate the preferred account, and which aspect of compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals would make that negative result independently repeatable?

Hendrik Wade Bode | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 017, the specific physical candidate is a specified receiver noise factor added to a source whose statistics need not be Gaussian or stationary. The unresolved physical pathway is material: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. The retained record permits a conditional claim about noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, but cannot alone resolve noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. I propose separating acquired information from model-dependent reconstruction. The evidential report should distinguish receiver sensitivity from environmental detectability. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure and a fresh trial in which the operator compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. If that trial demonstrates the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include compare terminated-input noise

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measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Sir Ronald Aylmer Fisher | Principal contribution 4: Measurements with a matched terminator isolate receiver-added noise more effectively than sky-facing observations.

Dr. Atkinson, the word confidence is particularly vulnerable to misuse in a low-noise measurement. An uncertainty interval derived from repeated thermal noise readings can be very narrow while failing to encompass systematic calibration errors, temperature drift and a non-Gaussian interference population. Before estimating detection performance, the investigator should state whether the sample is drawn from receiver self-noise, environmental background or a mixture that changes with time. For impulsive events a robust or stratified description may be more meaningful than a Gaussian standard deviation, although the chosen estimator must also be tested against the event class of interest. If a threshold is set using the same record later offered to prove an exceptional detection, the claimed false-alarm probability needs a selection correction or independent validation. Strong claims about absence require an empirical detection-probability model, not only a manufacturer's sensitivity figure.

In this information retention examination of Question 017, the decisive claim is that measurements with a matched terminator isolate receiver-added noise more effectively than sky-facing observations. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: external interference and the definition of noise figure. At approximately 290 kelvin the familiar available thermal-noise density is near minus 174 dBm per hertz. Across a ten-kilohertz equivalent-noise bandwidth this becomes about minus 134 dBm, and adding a 5 dB receiver

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noise figure yields roughly minus 129 dBm of receiver-limited input-referred noise under matched-source assumptions. When the antenna collects a variable man-made interference environment at minus 107 dBm in the same bandwidth, reducing the receiver noise figure by one decibel will scarcely change the observed floor. The survey must measure the environmental contribution rather than infer it from the data sheet. In a recorded forensic finding, separate instrument noise, natural atmospheric noise, man-made interference and unmodelled short-duration occupancy. Treat the noise floor as a distribution conditioned on frequency, antenna and time, not an immutable line. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. The scientific point of measurements with a matched terminator isolate receiver-added noise more effectively than sky-facing observations. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions repeatedly show the same average floor can coexist

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with markedly different alarm rates if one environment has heavy-tailed impulses, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. An input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions. Fisher's inferential approach requires a clearly defined population, an implemented sampling design and a distinction between the chosen estimator and the process under observation. The issue becomes especially sharp because thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the proposed case, two spectra

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with identical integrated watts need not yield the same threshold-exceedance statistics for a brief-event detector. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A more precise objection comes from Sir Ronald Aylmer Fisher and the finite observation aperture in the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails. For that reason, record noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. Matched-termination measurements isolate an instrumental noise component but do not reproduce the antenna

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environment. Dr Deming, I pass the floor for a validation challenge spanning both conditions.

W. Edwards Deming | Peer question 6 to Sir Ronald Aylmer Fisher

I thank you, Sir Ronald Aylmer Fisher, for distinguishing measurement from attribution, but the observation is that an input-terminated receiver shows a quiet floor, although antenna-connected captures display rare, very large positive excursions. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: two spectra with identical integrated watts need not yield the same threshold-exceedance statistics for a brief-event detector. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses on one day but fails after the instrument has been reconfigured? Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment? Would you also state what observed change in noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure would invalidate the preferred account, and which aspect of compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals would make that negative result independently repeatable?

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Sir Ronald Aylmer Fisher | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 017, the specific physical candidate is a specified receiver noise factor added to a source whose statistics need not be Gaussian or stationary. The unresolved physical pathway is material: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. The retained record permits a conditional claim about noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, but cannot alone resolve noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, two spectra with identical integrated watts need not yield the same threshold-exceedance statistics for a brief-event detector. I would

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retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. Its bearing on the dispute can be evaluated through the predicted response, namely the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses. Because thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails, the procedure compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match state receiver-added noise separately from environmental detectability and report the tested temporal conditions, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. The same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Walter Andrew Shewhart | Principal contribution 5: The evidential report should distinguish receiver sensitivity from environmental detectability.

Noise measurement should be monitored as a process with multiple possible regimes. A receiver left overnight beside a switching supply may show a quiet median and a pronounced disturbance every few minutes. Averaging the week into one noise figure would conceal the regime changes. I would divide the record using known operational changes, then examine whether shifts in variance, pulse count or spectral shape coincide with lighting, machinery, temperature or receiver state. An anomaly that repeats on power cycling is evidence worth retaining, but it can arise from a start-up transient rather than from an outside radio transmitter. Calibration traces and environmental observations should remain chronological. If a process chart is tuned only after a conspicuous event is seen, that event has helped choose the chart and its statistical significance cannot be asserted as though the rule had been fixed beforehand. We should report what varied, not merely a pleasing central estimate.

In this statistical inference examination of Question 017, the decisive claim is that the evidential report should distinguish receiver sensitivity from environmental detectability. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: external interference and the definition of noise figure. At approximately 290 kelvin the familiar available thermal-noise density is near minus 174 dBm per hertz. Across a ten-kilohertz

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equivalent-noise bandwidth this becomes about minus 134 dBm, and adding a 5 dB receiver noise figure yields roughly minus 129 dBm of receiver-limited input-referred noise under matched-source assumptions. When the antenna collects a variable man-made interference environment at minus 107 dBm in the same bandwidth, reducing the receiver noise figure by one decibel will scarcely change the observed floor. The survey must measure the environmental contribution rather than infer it from the data sheet. In a recorded forensic finding, separate instrument noise, natural atmospheric noise, man-made interference and unmodelled short-duration occupancy. Treat the noise floor as a distribution conditioned on frequency, antenna and time, not an immutable line. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. The evidential report should distinguish receiver sensitivity from environmental detectability. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals, should be

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accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say state receiver-added noise separately from environmental detectability and report the tested temporal conditions, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. The laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals,

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and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, two spectra with identical integrated watts need not yield the same threshold-exceedance statistics for a brief-event detector, is not an estimate of any actual investigation. I would publish the test plan, sample exclusions, denominator and alternative accounts alongside the numerical result, so that a critical reader can identify which inference is conditional and which physical fact was directly observed.

A more precise objection comes from Walter Andrew Shewhart and the finite observation aperture in the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails. For that reason, record noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After compare terminated-input noise measurements with calibrated antenna

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states, time-tagged pulse statistics and detector thresholds over stratified intervals, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. An empty indication under one threshold must not become a claim of electromagnetic silence. Sir Karl, I invite you to identify the field observation that would oblige us to abandon that conclusion.

Sir Karl Raimund Popper | Peer question 7 to Walter Andrew Shewhart

Walter Andrew Shewhart, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise state receiver-added noise separately from environmental detectability and report the tested temporal conditions? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. A receiver with an excellent nominal noise figure can be overwhelmed by impulsive local interference. Please connect noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure with a declared detection threshold and the measurement exposure. If the experiment compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals cannot discriminate a masked weak signal from a genuinely

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absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later. Would you also state what observed change in noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure would invalidate the preferred account, and which aspect of compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals would make that negative result independently repeatable?

Walter Andrew Shewhart | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 017, the specific physical candidate is a specified receiver noise factor added to a source whose statistics need not be Gaussian or stationary. The unresolved physical pathway is material: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. The retained record permits a conditional claim about noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure, but cannot

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alone resolve noise figure characterises a stipulated reference temperature and linear noise transfer, not the probability of detecting an arbitrary burst in a changing field. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. A receiver with an excellent nominal noise figure can be overwhelmed by impulsive local interference. I would use the observations of noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified intervals, not an assertion based on the operator's impression of a quiet display. If it yields the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test

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boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since thermal amplifier noise and non-gaussian environmental interference may share average power while differing sharply in their detection tails, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to state receiver-added noise separately from environmental detectability and report the tested temporal conditions, with the untested physical possibilities made visible.

Harry Nyquist, Cross-Peer Question to Sir Ronald Aylmer Fisher: Professor Fisher, a manufacturer reports a low receiver noise figure measured at a specified reference temperature. During a field survey the external aerial, although properly matched, sees intermittent bursts with a long-tailed amplitude distribution. A colleague subtracts a single thermal-noise prediction from the observed spectral average and treats the residual as a numerical probability that a transmitter will be detected. Can the receiver-noise measurement establish that probability? What experiment would measure actual detection power without disguising the non-stationary environment behind an average noise density?

Sir Ronald Aylmer Fisher, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, a calibrated noise figure is an instrument characteristic under a reference-source and operating-state model. It is not itself a probability model for field interference or a statement of detection power. I would specify a target signal model, amplitude, waveform, duration, occupancy and decision

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threshold, then inject traceable examples at randomised or otherwise justified times during a representative set of field conditions. Estimate conditional probabilities of detection and false alarm separately, with uncertainty intervals and explicit denominators for valid observation opportunities. The analysis must preserve bursts and periods of saturation, not merely average spectral density. If the interference distribution changes with machinery schedules, weather or human activity, report stratified results rather than one pooled number that conceals the heterogeneity. No detection claim is valid without its observation schedule and the manner in which unobserved time was excluded or modelled. With your leave, I pass the floor to Dr Shannon.

Claude Elwood Shannon, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, two sites show the same mean spectral power in a nominal ten-kilohertz equivalent-noise bandwidth. At the first, the samples are approximately thermal and stationary; at the second, rare, high-amplitude bursts dominate errors and briefly force analogue gain reduction. A conventional average-power spectrum makes the sites look identical. Which measurements reveal the difference, and how should front-end linearity and detector settings be handled before the investigator converts either site into a proposed lower bound for a weak intermittent emission?

Hendrik Wade Bode, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, mean power is an incomplete statistic for this problem. Retain time-stamped unaveraged samples or justified event captures, record short-time power and amplitude quantiles, burst duration, duty cycle, complementary cumulative amplitude distributions and the frequency dependence of the events. Separately test the analogue front end for

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overload, recovery time and state-dependent gain, because a large burst may modify the measurements made immediately afterwards. Equivalent-noise bandwidth must be determined for the actual detector filter; a spectrum display's nominal frequency-bin spacing is not an adequate substitute. Establish thresholds against the relevant noise and interference population, allowing for repeated searching and temporal dependence. An isolated ten-kilohertz mean does not predict the probability of missing a millisecond event, and an improved amplifier noise figure can be useless if local switching interference and gain compression determine the detection limit. The conclusion must give a conditional performance envelope rather than a universal threshold. With your leave, I pass the floor to Dr Tukey.

John Wilder Tukey, Cross-Peer Question to W. Edwards Deming: Mr Deming, a matched termination is substituted for an antenna and the receiver's measured noise level falls substantially. The operator interprets the entire difference as the power of hostile radiators, disregarding mismatch, the antenna's effective noise temperature and a shared switching supply that changes noise coupling between the two configurations. What calibration sequence and uncertainty model would discriminate receiver-added noise, antenna-delivered noise and configuration-dependent instrumental bias? In particular, when would the familiar root-sum-of-squares uncertainty combination be invalid?

W. Edwards Deming, Cross-Peer Answer to John Wilder Tukey: Dr Tukey, the experiment should name the input reference plane and measure the installed termination, antenna match, insertion losses and gain state in both configurations. An independent hot-cold or calibrated noise-source determination of receiver noise figure gives a controlled instrument

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baseline, but it does not attribute the antenna-connected excess to a particular emitter. I would test the switching supply, cable common-mode current and local radiated coupling by planned interventions while monitoring the receiver's temperature and gain. Construct a measurement equation including any mismatch correction and environmental variability; share calibration terms only where their covariance is supported. If both observations depend on the same reference source or drift, an independent-error root-sum-of-squares rule can misstate the uncertainty of their difference. NIST's uncertainty framework requires covariance terms where correlations are material. Report remaining unidentified environmental components as such, without assigning them to malign transmissions on the strength of the noise difference alone. With your leave, I pass the floor to Professor Fisher.

Sir Ronald Aylmer Fisher, Cross-Peer Question to Walter Andrew Shewhart: Mr Shewhart, the investigator completes thirty-three listening intervals and obtains no detection. A manuscript application calculates a probability of no detections under an assumed independent-visit model, then a report moves too quickly from that illustrative calculation to a confident assurance that no intermittent emission exists. How would you design a surveillance acceptance test that treats clustered events, synchronisation with revisit timing and equipment downtime as limitations on the negative result, while avoiding a fictitious universal detection probability?

Walter Andrew Shewhart, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Professor Fisher, I would separate the calculation of a conditional probability from the evidential conclusion. Define the event class, minimum amplitude at the antenna reference plane, burst duration, temporal pattern, receiver

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sensitivity, dwell and revisit schedule before collecting data. Mark every valid observation interval, excluded downtime and state transition; test the acquisition path with injected pulses at different phases of the revisit cycle. If emissions are correlated or periodic, effective opportunities are not the simple count of displayed FFT frames, and the independent-visit formula is not a verified field probability. A stratified detection trial, with independent replay or injection challenges, can bound detection performance for the specified event population and duty cycle. Even after those controls, absence of an observed event can only limit the emission classes detectable under the tested schedule. It cannot demonstrate that no transmitter, of any waveform and time pattern, existed. With your leave, I pass the floor to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of the limited interpretation of a receiver noise figure when environmental noise is non-thermal has established a point which the specialist must not overlook. The receiver records input-referred noise density, receiver sensitivity, and measured spectral background; it does not, merely by drawing a clear trace, give direct access to the proportions due to thermal noise, impulsive interference, atmospheric activity, and local equipment. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, Noise figure is defined against a specified source noise condition and does not quantify every ambient waveform. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled

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challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

A noise figure measured against a standard thermal source supplies one characterisation of receiver-added noise, not an assurance about the intermittent electrical disturbances of an occupied building. That distinction matters when switch-mode converters, lifts, machinery and adjacent transmitters produce heavy-tailed samples whose probabilities cannot be inferred from a Gaussian reference measurement. I thank Professor Fisher for requiring an explicit distributional model and Professor Neyman for insisting that the confidence statement refer to the actual decision procedure. The next laboratory challenge should collect reference noise with a terminated input, a known noise source and a realistic antenna load, while preserving pulse arrival times rather than replacing the record with a single average floor. A very low intrinsic noise figure may coexist with poor short-burst detection if the detection threshold is continually raised by legitimate impulsive interference. Our conclusion concerns receiver sensitivity under nominated conditions and the distinct, empirically measured false-alarm and missed-event behaviour in the surveyed environment.

A quiet terminated-input spectrum and occasional very large antenna-connected transients are compatible observations. They refer to different measurands. Neither can be substituted for a validated probability of detecting a weak target under the same interference conditions in which the survey is conducted. The more useful outcome is a discriminating protocol: Compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics and detector thresholds over stratified

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intervals. In applying it, the examiner must retain all readings supporting noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure and identify the physical plane to which the measurements refer. At the outset of the investigation, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference; that circumstance makes the alternative mechanism material, specifically thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. A result approaching the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore state receiver-added noise separately from environmental detectability and report the tested temporal conditions. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

Report the receiver’s reference noise figure alongside, but separately from, the environmental noise and detector-performance data. Negative search claims must be limited to the combinations of signal strength, time exposure and interference state for which detection was demonstrated. The decisive experiment is concrete: Compare terminated-input noise measurements with calibrated antenna states, time-tagged pulse statistics

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and detector thresholds over stratified intervals. In conducting it, the examiner must explicitly retain noise factor, equivalent noise temperature, effective bandwidth, kurtosis, false-alarm rate and occupied-time exposure. If the outcome matches the stated prediction, the same average floor can coexist with markedly different alarm rates if one environment has heavy-tailed impulses, the supported conclusion concerns that test domain. An alternative remains: Thermal amplifier noise and non-Gaussian environmental interference may share average power while differing sharply in their detection tails. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 017

Application 01. Thermal reference noise in a declared measurement bandwidth

In the illustrative 017.01 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. Take the equivalent noise bandwidth B = 7,500 Hz and calibrated noise figure NF = 3.05 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -132.20$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The calculation applies to reference-source receiver noise, not the heavy-tailed ambient field; retain time-resolved amplitude statistics and detector false-alarm behaviour.

Application 02. Ideal code step, variance, and full-scale sine SNR

In the illustrative 017.02 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. Taking an ideal N = 11-bit uniform converter across 2.50 V peak-to-peak, one nominal code interval is $\Delta = Vpp/2^N = 1.2207$ mV. Under the independent uniform-error approximation its rms quantisation error is $\sigma = \Delta/\sqrt{12} = 0.3524$ mV. The ideal full-scale sinusoidal SNR approximation is $6.02N + 1.76 = 67.98$ dB. A coherent low-level waveform may violate the uniform-error assumption; clipping and integral nonlinearity are separate limitations. The ideal code width and sine-wave SNR do not guarantee detectability of short bursts; verify overload recovery, quantisation distribution and actual effective resolution.

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Application 03. The frequency dependence of aperture-jitter-limited SNR

In the illustrative 017.03 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. At sinusoidal input frequency f = 183 MHz with uncorrelated rms aperture jitter σ_t = 1.17 ps, the idealised jitter-imposed ceiling is $SNR_j = -20 \log_{10}(2\pi f \sigma_t)$ = 57.42 dB. A common clock source may correlate errors across parallel ADC channels, so treating their outputs as independent for noise cancellation would need an additional experiment. Converter nonlinearity and thermal noise can make actual performance worse. The jitter ceiling concerns the specified high-frequency sinusoid and uncorrelated timing error, not all field waveforms or a promise of independent parallel channels.

Application 04. Combined and expanded measurement uncertainty

In the illustrative 017.04 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. For independent standard-uncertainty contributions 0.66, 0.60 and 0.31 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.66^2 + 0.60^2 + 0.31^2)}$ = 0.944 units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c$ = 1.889 units. The illustrative factor-of-two interval assumes the stated uncertainty model; common calibration, field drift and heavy tails require separate covariance and coverage review.

Application 05. Cascade gain and observed headroom

In the illustrative 017.05 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching

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transients and impulsive industrial interference. A first amplifier contributes G_1 = 10 dB, an intentional attenuation contributes G_2 = -7 dB, and a later stage contributes G_3 = 19 dB. The small-signal sum is 10 + (-7) + 19 = 22 dB. For P_i = -71 dBm, the ideal output is P_o = -49 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. A twenty-two-decibel gain total does not show whether an impulsive blocker compressed an early stage; measure transient headroom and recovery throughout the chain.

Application 06. Filter or cable rejection referred to a physical input

In the illustrative 017.06 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. For an admitted input P_i = -61 dBm and separately measured loss L = 23 dB, the linear prediction is $P_o = P_i - L$ = -84 dBm. In SI power this becomes 10^((-84 − 30)/10) = 3.98e-12 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. The cable-loss prediction is not an antenna-to-receiver detection guarantee: input mismatch, variable noise temperature and alternate ingress can alter the observed level.

Application 07. Opportunity-limited detection under independent visits

In the illustrative 017.07 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. For n = 33 genuinely independent valid observation opportunities, each with stipulated event

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detection chance p = 0.06, the probability of no detections is $(1 - p)^n$ = 0.12978; its complement is 87.02%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The independent-visit formula is not an assurance that a periodic or clustered emitter was absent; document the dwell schedule, valid visits and tested event class.

Application 08. Family-wise probability when many candidates are searched

In the illustrative 017.08 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. If each of M = 397 independent pre-specified search opportunities has false-alarm probability α = 0.0008, the probability of one or more false positives is 1 − (1 − α)^M = 0.27220, or 27.22%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. The family-wise probability depends on the specified independent search opportunities; correlated FFT bins and retrospective selection change the false-alarm model.

Application 09. Observed exposure fraction of a channel scanner

In the illustrative 017.09 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. Let the channel be observed on n = 321 valid visits, each lasting d = 12 ms, with revisit

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spacing R = 0.85 s. Valid exposure is nd/1000 = 3.852 s across the nominal interval nR = 272.85 s. The observed fraction of elapsed time is therefore 1.41%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. An exposure fraction of roughly one per cent characterises receiver coverage, not transmitter occupancy or the absence of events between visits.

Application 10. Difference between two instruments relative to stated uncertainty

In the illustrative 017.10 test, the laboratory reports a favourable receiver noise figure while the field site contains periodic switching transients and impulsive industrial interference. The paired instrument contrast is $\Delta = 1.580$ dB. Set independent standard uncertainties $u_1 = 0.500$ dB and $u_2 = 0.520$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.721$ dB, giving the dimensionless ratio $\Delta/u\Delta = 2.190$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The uncertainty-scaled difference does not identify a radiating source; a systematic temperature, gain or antenna-state change could produce the same contrast.

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Contributor identification and editorial scope

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

National Institute of Standards and Technology, TN 1297, sections 5–7: combined uncertainty and reporting, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-7-reporting-uncertainty (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 018

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How should intermodulation products be challenged before calling a feature an emitter?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 018 asks: How should intermodulation products be challenged before calling a feature an emitter? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is causal discrimination of external emitters from internally generated intermodulation. Our primary observation is spectral features at combination frequencies of simultaneous strong input tones; by contrast, what remains unseen is where in the physical chain the nonlinear mixing occurred. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Third-order products and a two-tone falsification test. Let two strong external tones occur at 900 and 901 megahertz. A third-order mixing product can fall at 2 times 900 minus 901 = 899 megahertz, even without a

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transmitter operating at 899 megahertz. For a weakly nonlinear stage in its small-signal cubic regime, a 1 dB rise in each equal-level driving tone can produce about a 3 dB rise in the third-order product, whereas a genuine independent narrowband emitter need not follow that slope. This differential test is conditional: gain control, compression, filtering and antenna coupling can spoil the simple relation. Vary the two drive powers separately, trace the stimulus path and preserve the measured slopes. A spur that changes under this challenge is evidence about the chain's nonlinearity, not necessarily the whereabouts or intentions of any outside device. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns spectral features at combination frequencies of simultaneous strong input tones; it is not interchangeable with where in the physical chain the nonlinear mixing occurred. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is stepped input attenuation, two-tone prediction, filtering substitution, and independent reference-plane observation. A claim drawn from that comparison has to carry its actual uncertainties: third-order slope, input intercept point, tone spacing, compression, and product symmetry. Two strong tones can produce third-order components at twice one frequency minus the other. An internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime. A contact junction external to the receiver

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may itself generate intermodulation and must not be confused with mixer distortion. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Edwin Howard Armstrong | Principal contribution 1: Two strong tones can produce third-order components at twice one frequency minus the other.

An apparent third-order product can mimic a real transmission remarkably well, particularly when two legal high-power signals illuminate the first mixer. The critical test is not to search for a suggestive frequency relationship after observing the line, but to apply two controlled tones whose frequencies and powers are known before the measurement. For equal tone levels in the small-signal cubic regime, an unwanted component at $2f_1 - f_2$ or $2f_2 - f_1$ grows at approximately three decibels per one-decibel increase in each input tone, whereas an ordinary linear response grows by one. This rule ceases to be dependable near compression, under unequal powers, or if an external nonlinear junction has already created the intermodulation component. I would therefore repeat the amplitude sweep using an external filter and attenuator at different stages. A real emitter and an internally generated product are distinguishable only if the interventions separate their physical pathways.

In this physical path examination of Question 018, the decisive claim is that two strong tones can produce third-order components at twice one frequency minus the other. Third-order intermodulation is a hypothesis about a nonlinear transfer, not a label supplied by the shape of a spectral line. For two sufficiently strong inputs at f1 and f2, cubic behaviour predicts products at 2f1 minus f2 and 2f2 minus f1. Their observed power should initially vary approximately three decibels for each decibel change of the provoking tones in the small-signal region. The experiment must establish whether the nonlinearity is in the receiver, a corroded external contact, an

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active amplifier or a different junction. Changes in input attenuation only discriminate paths when the attenuation is inserted before the suspect nonlinear element. A useful falsification proceeds from the actual controversy: third-order products and a two-tone falsification test. Let two strong external tones occur at 900 and 901 megahertz. A third-order mixing product can fall at 2 times 900 minus 901 = 899 megahertz, even without a transmitter operating at 899 megahertz. For a weakly nonlinear stage in its small-signal cubic regime, a 1 dB rise in each equal-level driving tone can produce about a 3 dB rise in the third-order product, whereas a genuine independent narrowband emitter need not follow that slope. This differential test is conditional: gain control, compression, filtering and antenna coupling can spoil the simple relation. Vary the two drive powers separately, trace the stimulus path and preserve the measured slopes. A spur that changes under this challenge is evidence about the chain's nonlinearity, not necessarily the whereabouts or intentions of any outside device. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Generate two equal, independently verified RF tones, with enough isolation to avoid generator intermodulation. Sweep each input level over a range below compression while monitoring the third-order product slope. Fit the slope with uncertainty and repeat after moving a passive attenuator from before to after the first active stage. A junction outside the receiver may be challenged by antenna substitution or a physically different coupling path. Evidence for a cubic product is stronger than a visual resemblance, but still does not attribute the product to a unique junction. I would take 2f1−f2,

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2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: Two strong tones can produce third-order components at twice one frequency minus the other. A response consistent with within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. Two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by the product may originate in the receiver mixer, an

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overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane, and measure their behaviour separately before reconnecting the assembled system. Armstrong's receiver engineering points to actual conversion products and oscillation conditions rather than abstract spectral indications; the crucial question is where the energy first appears. It is therefore material to establish 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios rather than infer them from a single scalar output. The limiting test is concrete: Change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. If the intervention produces within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 db per 1 db increase of each equal blocker tone, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret a smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased as a new transmitter before challenging the most economical instrumental explanation. The frequencies predicted by twice one tone minus the other supply a hypothesis, not a diagnosis. Professor Tukey, I pass the floor for your assessment of which paired measurements make the spur explanation credible.

John Wilder Tukey | Peer question 1 to Edwin Howard Armstrong

Edwin Howard Armstrong, may I test the exact physical inference in your account of two strong broadcasting carriers surround the frequency

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of a suspected weak transmission within a wideband SDR capture? The proposed mechanism appears plausible only if changes after change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator are compared with a stable reference condition. Two strong tones can produce third-order components at twice one frequency minus the other. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios which would settle that narrower claim, rather than a visual impression of improvement.

Edwin Howard Armstrong | Immediate answer to John Wilder Tukey

Dr Tukey, if the product frequency is exactly predicted I should still be sceptical, because two external emitters or two nonlinear stages can produce a matching line. I shall look for the input-power slope, change the attenuation at a specified physical point, and check the signal generator’s own distortion. Only after those controls can the amplitude trajectory support a receiver-origin inference. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical

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variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 018, the specific physical candidate is quadratic, cubic, and higher-order responses in amplifiers, mixers, contacts, and overloaded sampling stages. The unresolved physical pathway is material: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The retained record permits a conditional claim about 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, but cannot alone resolve frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. Two strong tones can produce

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third-order components at twice one frequency minus the other. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator, and only a response matching within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Edwin Howard Armstrong

I appreciate your explanation, Edwin Howard Armstrong. How would your conclusion survive a deliberately independent test of a smaller trace appears near the predicted third-order frequency and grows rapidly

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when the strong signals are increased? A second receiver might share more of the supposed evidence than its separate enclosure suggests. An internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios and document which differences remain unexplained? Would you also state what observed change in 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios would invalidate the preferred account, and which aspect of change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator would make that negative result independently repeatable?

Edwin Howard Armstrong | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An

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independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 018, the specific physical candidate is quadratic, cubic, and higher-order responses in amplifiers, mixers, contacts, and overloaded sampling stages. The unresolved physical pathway is material: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The retained record permits a conditional claim about 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, but cannot alone resolve frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. An internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains the product may originate in the receiver mixer, an overloaded low-

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noise amplifier, or a corroded external junction before the nominal input reference plane; I would challenge it with change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. Two responses consistent with within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. A discordant measurement would then be interpreted by tracing that difference through 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios; an agreement lacking such a dependency analysis is weak corroboration.

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Hendrik Wade Bode | Principal contribution 2: An internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime.

The intercept-point model is a useful extrapolation, not a guarantee that every strong-signal experiment remains linear. With two equal inputs P at the reference plane and an ideal input-referred third-order intercept IIP3, the small-signal approximation $P_{IM3} \approx 3P - 2IIP3$ predicts an internally produced level. Yet a filter's group delay, a limiter's transfer curve or an amplifier's bias current may create a different amplitude law during a short burst. I would measure the amplitude trajectory of the alleged product across input levels and compare it with the onset of compression. Moving the intermodulation test to another RF frequency pair is valuable, because a genuine external line does not usually follow the combination-frequency grid selected by the engineer. Measurements must report which stage is presumed nonlinear and what happens when a notch filter removes one parent tone before that stage. Reversibility under a controlled stimulus is stronger evidence than formula matching alone.

In this control and stability examination of Question 018, the decisive claim is that an internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: third-order products and a two-tone falsification test. Let two strong external tones occur at 900 and 901 megahertz. A third-order

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mixing product can fall at 2 times 900 minus 901 = 899 megahertz, even without a transmitter operating at 899 megahertz. For a weakly nonlinear stage in its small-signal cubic regime, a 1 dB rise in each equal-level driving tone can produce about a 3 dB rise in the third-order product, whereas a genuine independent narrowband emitter need not follow that slope. This differential test is conditional: gain control, compression, filtering and antenna coupling can spoil the simple relation. Vary the two drive powers separately, trace the stimulus path and preserve the measured slopes. A spur that changes under this challenge is evidence about the chain's nonlinearity, not necessarily the whereabouts or intentions of any outside device. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by a smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note an internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime. has a

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consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, a smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. This predicts a response which should be tested against within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 db per 1 db increase of each equal blocker tone. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that

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presentational step does not restore measurements discarded during retuning. Where frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose, the correct claim must name the operational states and the evidence available in each. The approximate three-decibel slope of a third-order product is diagnostic only while the stages remain in the relevant regime. Dr Pearson, I invite your scrutiny of the measurement series and its uncertainty.

Egon Sharpe Pearson | Peer question 3 to Hendrik Wade Bode

Hendrik Wade Bode, your calibration argument invites a question about reference planes, especially because frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. The reference stimulus and the unknown emission need not occupy the same physical regime. A contact junction external to the receiver may itself generate intermodulation and must not be confused with mixer distortion. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When a smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator without relying upon the original screenshot or

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undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Hendrik Wade Bode | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 018, the specific physical candidate is quadratic, cubic, and higher-order responses in amplifiers, mixers, contacts, and overloaded sampling stages. The unresolved physical pathway is material: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The retained record permits a conditional claim about 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, but cannot alone resolve frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios. A contact junction external to the receiver may itself generate intermodulation and must not be confused with mixer distortion. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test.

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An appropriate reference check would be change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator, with before-and-after values of 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios. If the instrument behaves as predicted, then within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. A smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Hendrik Wade Bode

There is an inferential difficulty, Hendrik Wade Bode: the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The

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population of admissible observations needs to be fixed before any confidence argument. In this situation, frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Changing preselection can alter the interfering tone population and thereby change the spur without removing a transmitter. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios would invalidate the preferred account, and which aspect of change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator would make that negative result independently repeatable?

Hendrik Wade Bode | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps

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separate otherwise coincident aliases and mixer products. For Question 018, the specific physical candidate is quadratic, cubic, and higher-order responses in amplifiers, mixers, contacts, and overloaded sampling stages. The unresolved physical pathway is material: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The retained record permits a conditional claim about 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, but cannot alone resolve frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because a smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Changing preselection can alter the interfering tone population and thereby change the spur without removing a transmitter. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator, but it must be

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labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane; its prediction should be recorded alongside within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a predicted response at 2×151 mhz − 154 mhz equals 148 mhz, even if no transmitter is operating at 148 mhz. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Harry Nyquist | Principal contribution 3: A contact junction external to the receiver may itself generate intermodulation and must not be confused with mixer distortion.

If two excitation frequencies f_1 and f_2 are sampled near or beyond the analogue band edge, their images can deceive the engineer about where a nonlinear product was formed. A digital FFT showing a peak at a predicted combination does not distinguish a component produced before the ADC from a component created by converter nonlinearity or subsequent numerical overflow. I would demand a verified analogue frequency plan and an independent RF spectrum measurement ahead of the converter, with enough dynamic range to resolve the parent signals. The anti-alias network must be included, for products outside the admitted band can fold into the same digital frequency. The signal's motion under a deliberate shift of sample rate is informative only when the input analogues and clock relation are known. An image that moves in accordance with sampling need not imply any movement of the external transmitter. Correct frequency arithmetic is necessary but not sufficient for correct source attribution.

In this operational measurand examination of Question 018, the decisive claim is that a contact junction external to the receiver may itself generate intermodulation and must not be confused with mixer distortion. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: third-order products and a two-tone falsification test. Let two strong external tones occur at 900 and 901 megahertz. A third-order mixing product can fall at 2 times 900 minus 901 = 899 megahertz, even without a transmitter operating at 899

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megahertz. For a weakly nonlinear stage in its small-signal cubic regime, a 1 dB rise in each equal-level driving tone can produce about a 3 dB rise in the third-order product, whereas a genuine independent narrowband emitter need not follow that slope. This differential test is conditional: gain control, compression, filtering and antenna coupling can spoil the simple relation. Vary the two drive powers separately, trace the stimulus path and preserve the measured slopes. A spur that changes under this challenge is evidence about the chain's nonlinearity, not necessarily the whereabouts or intentions of any outside device. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

A third-order intermodulation product has a testable frequency arithmetic: two blockers at f_1 and f_2 can yield products near $2f_1 - f_2$ and $2f_2 - f_1$, even when no transmitter operates at those product frequencies. The strongest evidential test is not visual resemblance but controlled perturbation. Change one blocker frequency by Δf and determine whether the alleged emitter shifts by the predicted factor, while preserving the unaltered blocker as a control. Under a suitable unsaturated cubic approximation, the third-order product may increase roughly three decibels for each one-decibel rise in equal input tones; real receivers depart from this rule as compression and other nonlinearities become important. Vary input attenuation and gain, inspect the front-end filter state, and repeat using an independent receiver with a materially different analogue architecture. Do not infer an external source merely because two instruments show a peak: common illumination by the same powerful blockers can make their nonlinear products agree. Accordingly, the laboratory record for Question

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018 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband sdr capture; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare $2f1-f2$, $2f2-f1$, product slope, input intercept, compression onset and before/after attenuation ratios under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A predicted response at 2×151 MHz − 154 MHz equals 148 MHz, even if no transmitter is operating at 148 MHz. It demonstrates the danger of transferring a result across domains in

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which the defining measurement has changed. A corroded connector outside the receiver can produce the same mixing frequencies as an internal nonlinear stage. Dr Turing, please take the floor and ask which switching or isolation records locate the source of nonlinearity.

Alan Mathison Turing | Peer question 5 to Harry Nyquist

Harry Nyquist, I should like to examine what the recorded data actually preserve when two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. The physical input and the retained numerical array are not interchangeable things. Frequency prediction is useful screening evidence, but physical isolation tests establish stronger causal distinctions. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios would invalidate the preferred account, and which aspect of change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator would make that negative result independently repeatable?

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Harry Nyquist | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 018, the specific physical candidate is quadratic, cubic, and higher-order responses in amplifiers, mixers, contacts, and overloaded sampling stages. The unresolved physical pathway is material: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The retained record permits a conditional claim about 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, but cannot alone resolve frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. I propose separating acquired information from

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model-dependent reconstruction. Frequency prediction is useful screening evidence, but physical isolation tests establish stronger causal distinctions. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios and a fresh trial in which the operator change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. If that trial demonstrates within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Walter Andrew Shewhart | Principal contribution 4: Changing preselection can alter the interfering tone population and thereby change the spur without removing a transmitter.

An investigation containing multiple strong carriers will naturally offer many combinations of sums and differences. Having found an unexplained line, one can almost always discover a plausible pair among a large channel list. This is an exploratory hypothesis, not a formal confirmation. I would preselect a limited set of candidate parent tones based on the receiver's actual front-end passband, then perform controlled attenuation and input filtering with all trials logged. A control chart of suspect-power against parent-power can reveal whether a stable cubic regime exists, but an observation chosen from hundreds of spectral bins requires an allowance for that search. If the detector reuses overlapping windows, its nominal sample count exaggerates the independent evidence. The best report describes the response pattern under the declared intervention, including negative cases, and distinguishes internal mixing from possible external passive intermodulation at a connector or corroded junction.

In this information retention examination of Question 018, the decisive claim is that changing preselection can alter the interfering tone population and thereby change the spur without removing a transmitter. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: third-order products and a two-tone falsification test. Let two strong external tones occur at 900 and 901 megahertz. A third-order mixing product can fall at 2 times 900 minus 901 = 899 megahertz, even without a transmitter operating at 899 megahertz. For a weakly nonlinear

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stage in its small-signal cubic regime, a 1 dB rise in each equal-level driving tone can produce about a 3 dB rise in the third-order product, whereas a genuine independent narrowband emitter need not follow that slope. This differential test is conditional: gain control, compression, filtering and antenna coupling can spoil the simple relation. Vary the two drive powers separately, trace the stimulus path and preserve the measured slopes. A spur that changes under this challenge is evidence about the chain's nonlinearity, not necessarily the whereabouts or intentions of any outside device. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. The scientific point of changing preselection can alter the interfering tone population and thereby change the spur without removing a transmitter. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions repeatedly show within an unsaturated cubic regime, an internally generated third-order product

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grows approximately 3 dB per 1 dB increase of each equal blocker tone, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. A smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. The issue becomes especially sharp because the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the proposed case, a predicted

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response at 2×151 mhz − 154 mhz equals 148 mhz, even if no transmitter is operating at 148 mhz. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. Changing preselection changes the interfering inputs themselves, not simply the display. Dr Deming, I invite an experimental challenge that separates altered tone population from an actual change in the emitter.

W. Edwards Deming | Peer question 6 to Walter Andrew Shewhart

I thank you, Walter Andrew Shewhart, for distinguishing measurement from attribution, but the observation is that a smaller trace appears near the predicted third-order frequency and grows rapidly when the strong signals are increased. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a predicted response at 2×151 MHz − 154 MHz equals 148 MHz, even if no transmitter is operating at 148 MHz. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone on one day but fails after the instrument has been reconfigured? Two strong tones can produce third-order components at twice one frequency minus the other. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

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Walter Andrew Shewhart | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 018, the specific physical candidate is quadratic, cubic, and higher-order responses in amplifiers, mixers, contacts, and overloaded sampling stages. The unresolved physical pathway is material: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The retained record permits a conditional claim about 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, but cannot alone resolve frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a predicted response at 2×151 MHz − 154 MHz equals 148 MHz, even if no transmitter is operating at 148 MHz. I would retain the

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counterexample as part of the primary result, not as a footnote to an attractive conclusion. Two strong tones can produce third-order components at twice one frequency minus the other. Its bearing on the dispute can be evaluated through the predicted response, namely within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone. Because the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane, the procedure change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match report a bounded nonlinear-origin inference and retain alternate junction locations until physical isolation differentiates them, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. Within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: Frequency prediction is useful screening evidence, but physical isolation tests establish stronger causal distinctions.

To decide whether an alleged emitter is in fact a receiver product, one must specify the evidence that would refute the intermodulation explanation. I should favour a planned sequence in which one parent tone is suppressed before the suspected nonlinearity, while an independently monitored external antenna path remains unchanged. Under a cubic model the product should fall in a predictable relationship, but the expected slope and variance must be characterised for the actual circuit. If the suspect persists despite verified removal of a necessary parent tone, that outcome challenges the chosen model; it does not by itself prove an illicit transmitter. Competing accounts include another pair of parent signals, a spur from a different gain stage and a radiated product generated outside the test box. An interval estimate for the intervention effect should use the paired measurement errors and their correlations. Attribution depends on eliminating alternatives with empirical power, not on attaching a famous formula to a convenient spectral coincidence.

In this statistical inference examination of Question 018, the decisive claim is that frequency prediction is useful screening evidence, but physical isolation tests establish stronger causal distinctions. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: third-order products and a two-tone falsification test. Let two strong external tones occur at 900 and

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901 megahertz. A third-order mixing product can fall at 2 times 900 minus 901 = 899 megahertz, even without a transmitter operating at 899 megahertz. For a weakly nonlinear stage in its small-signal cubic regime, a 1 dB rise in each equal-level driving tone can produce about a 3 dB rise in the third-order product, whereas a genuine independent narrowband emitter need not follow that slope. This differential test is conditional: gain control, compression, filtering and antenna coupling can spoil the simple relation. Vary the two drive powers separately, trace the stimulus path and preserve the measured slopes. A spur that changes under this challenge is evidence about the chain's nonlinearity, not necessarily the whereabouts or intentions of any outside device. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. Frequency prediction is useful screening evidence, but physical isolation tests establish stronger causal distinctions. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator, should be accompanied by a second acquisition path whose dependencies are

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explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say report a bounded nonlinear-origin inference and retain alternate junction locations until physical isolation differentiates them, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. Two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman’s statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime.

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The relevant quantities are 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 db per 1 db increase of each equal blocker tone, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a predicted response at 2×151 mhz − 154 mhz equals 148 mhz, even if no transmitter is operating at 148 mhz, is not an estimate of any actual investigation. Numerical coincidence with a mixing equation cannot identify the physical junction responsible. Sir Karl, the floor is yours to ask which contrary test should overturn the intermodulation account.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise report a bounded nonlinear-origin inference and retain alternate junction locations until physical isolation differentiates them? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. An internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime. Please connect 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios with a declared detection threshold and the measurement exposure. If the experiment change input attenuation

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before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 018, the specific physical candidate is quadratic, cubic, and higher-order responses in amplifiers, mixers, contacts, and overloaded sampling stages. The unresolved physical pathway is material: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. The retained record permits a conditional claim about 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios, but cannot alone resolve frequency arithmetic and a cubic-power trend identify a nonlinear mechanism class, not necessarily the component in which it arose. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. An internally generated third-order response commonly changes approximately three decibels for a one-decibel input change within the small-signal cubic regime. I would use the observations of 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator, not an assertion based on the operator's impression of a quiet display. If it yields within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since the product may originate in the receiver mixer, an overloaded low-noise amplifier, or

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a corroded external junction before the nominal input reference plane, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to report a bounded nonlinear-origin inference and retain alternate junction locations until physical isolation differentiates them, with the untested physical possibilities made visible.

Edwin Howard Armstrong, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, the predicted products 2f1 minus f2 and 2f2 minus f1 coincide with narrow lines visible during a strong-signal survey. The operator varies a built-in input attenuator by six decibels and observes a smaller spur, whereupon the instrument labels that line as internally generated. Yet the receiver has an antenna preamplifier before this attenuator, and the two signal generators supplying the bench test share a coupling network. How should the power-law hypothesis be tested without assuming that the attenuator is situated before every possible nonlinear element or that the synthetic source is free of products?

Hendrik Wade Bode, Cross-Peer Answer to Edwin Howard Armstrong: Dr Armstrong, the test must be indexed to an actual reference plane. First characterise each generator alone and the combined generator output with an independent, demonstrably linear measurement path; isolators, filtering and a power monitor are needed to establish whether the product already exists at the input connector. Then record the powers of both fundamentals and the product while stepping attenuation at documented positions before and after the first susceptible stage. A product created inside a stage will follow its local drive, whereas a previously generated signal entering that stage can have a different transfer, yet either behaviour may be obscured by

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gain normalisation or compression. Equal-power third-order products in the small-signal cubic region have an approximate three-to-one absolute-power slope when both tones rise together; an unequal-tone experiment should be analysed using the appropriate second-power and first-power dependence. Fit the slope with measurement uncertainty rather than presuming a perfect integer. We cannot identify an emitter from frequency arithmetic or from attenuation alone. Physical source isolation and an independent receiving chain are required before attributing a line to an external radiator. I respectfully pass the floor to Dr Nyquist.

Harry Nyquist, Cross-Peer Question to Edwin Howard Armstrong: Dr Armstrong, suppose the two-tone test proves a cubic response at the receiving installation, but the product persists after the suspect mixer is replaced. The antenna coaxial connector is weathered, and the same combination frequency appears only when a remote broadcast service and a local repeater are operating. The survey team proposes that the product has therefore been transmitted by a third source. What discriminating intervention would separate a passive, imperfect-contact junction outside the receiver from a radiating transmitter operating at the product frequency, while keeping the laboratory intervention itself from manufacturing the effect?

Edwin Howard Armstrong, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the persistence of the product after mixer substitution transfers attention to the entire coupling network, not immediately to a third transmitter. I should document and preserve the suspect connector before disturbing it, including photographs, mechanical state, moisture and measured return loss. Establish a baseline with the antenna connected, then compare a well-

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screened termination at the receiver, a replacement coaxial path, and a separately positioned reference antenna or probe. Where safe and lawful, change the incident field at the suspect junction by altering one source or its propagation path and predict the resulting frequency and power response. Contact nonlinearity can mix two applied fields at the junction; a genuine product-frequency radiator can instead be received directly. Neither disappears by decree when one connector is changed, for the replacement also alters mismatch and antenna current. The test record must state what remained constant, what changed, and what alternate paths survived. Physical localisation, traceable isolation and repeatability distinguish the hypotheses more convincingly than a single waterfall line. I respectfully pass the floor to Dr Tukey.

John Wilder Tukey, Cross-Peer Question to Jerzy Neyman: Professor Neyman, our archive shows a feature on one of hundreds of frequency-time cells inspected after acquisition. In an illustrative family of 424 independent tests, each nominally run at false-alarm probability 0.001, the chance of at least one spurious positive is about 34.6 per cent. An investigator proposes to discard uninteresting cells, retain the most conspicuous peak and quote its original single-cell probability as proof of an illicit signal. Which inferential procedure would properly separate exploratory detection, a prescribed confirmation test and the distinct physical question of where the signal originated?

Jerzy Neyman, Cross-Peer Answer to John Wilder Tukey: Dr Tukey, the cell selected by the largest observed departure cannot be treated as though it had been selected in advance. We should preserve the full search family, temporal and frequency dependence, window overlaps, threshold settings

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and the criteria used to stop searching. The illustrative expression 1 minus (1 minus alpha) to the power M is justified only for the stated independent Bernoulli test model; correlated cells require the joint null distribution or a defensible resampling or simulation strategy. Treat the discovery trace as exploratory. Reserve an independent acquisition period and a prespecified feature and threshold for confirmation, or explicitly control the family-wise or false-discovery error appropriate to the scientific decision. Detection significance does not identify the nonlinearity location. An emitter-origin claim needs separate experiments on two-tone dependence, input attenuation, preselection, junctions and independent receiving hardware. The conclusion should report evidential strength by hypothesis and acknowledge failures to distinguish internal and external products. I respectfully pass the floor to Dr Shannon.

Claude Elwood Shannon, Cross-Peer Question to Walter Andrew Shewhart: Mr Shewhart, the SDR operator observes a line in the digitised baseband, raises the analogue gain and sees the line strengthen before it breaks into a broad skirt. At the same time the converter has only four decibels of calculated headroom in the ideal gain model, and the preselector passband moves when the channel changes. A colleague says that the irregularity demonstrates a third-order transmitter rather than clipping or an alias. What process-control and instrumentation records are needed to distinguish the mechanisms and to rule out a systematic software-coordinate error?

Walter Andrew Shewhart, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, first distinguish the analogue-input frequency, mixer coordinate, sampled baseband frequency and software-labelled RF frequency; log the

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actual sampling clock and preselector tuning state rather than trusting the display annotation. A gain-change experiment must retain raw complex samples together with overload flags, automatic-gain-control state, peak rather than merely mean power, sample clipping counts and calibrated tone levels at each stage. Repeat at sufficiently low drive that every susceptible stage has measured margin, not just theoretical converter headroom. Verify that analogue filtering rejects other Nyquist-zone inputs which could fold onto the apparent product, and use an independent channel with a different sample plan as a negative control. A change point in a control chart is evidence that the process changed, not an assignment of physical cause. If a product depends on preselection, the incident tone population may have changed as well. Only a preplanned comparison, with uncertainty and failed interventions retained, can narrow the causal alternatives. I respectfully pass the floor to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of causal discrimination of external emitters from internally generated intermodulation has established a point which the specialist must not overlook. The receiver records spectral features at combination frequencies of simultaneous strong input tones; it does not, merely by drawing a clear trace, give direct access to where in the physical chain the nonlinear mixing occurred. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, Two strong tones can produce third-order components at twice one frequency minus the other. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal

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operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

Dr Atkinson closes by returning to the physics of an intermodulation product. If a line occurs at twice one excitation frequency minus another, its position is compatible with a third-order mixing mechanism, but its position alone does not identify the physical device in which the nonlinearity occurred. A properly conducted two-tone challenge measures the candidate product while varying the independent input powers and retaining the gain state. In the small-signal cubic region, the product may exhibit the expected third-order power slope, but compression, filtering and multiple interacting nonlinear stages can alter that signature. The examining engineer must also guard against generating the product inside the signal generator, combiner or test leads. I thank the contributors for demanding a separate source-purity check and a second measurement path before attribution. The resulting evidence should specify whether the artefact is receiver-generated, test-set-generated or still unresolved; it should not be advertised as a uniquely identified external transmission.

The spur appeared near a predicted third-order frequency and strengthened as the large tones increased. This is compatible with nonlinearity but does not locate its source. A defensible report specifies the two fundamentals, their input powers, the inferred product order and the operating interval before gain compression. The more useful outcome is a discriminating protocol: Change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a properly characterised two-tone generator. In applying it, the examiner must retain

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all readings supporting 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios and identify the physical plane to which the measurements refer. At the outset of the investigation, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture; that circumstance makes the alternative mechanism material, specifically the product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. A result approaching within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 dB per 1 dB increase of each equal blocker tone may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore report a bounded nonlinear-origin inference and retain alternate junction locations until physical isolation differentiates them. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

The panel supports a bounded intermodulation finding where the observed frequencies and level slopes survive controlled tests. Source attribution requires a separately documented isolation of the nonlinear component; a calculated third-order frequency alone cannot provide it. The decisive experiment is concrete: Change input attenuation before the suspected nonlinear element, isolate the aerial, and compare slopes with a

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properly characterised two-tone generator. In conducting it, the examiner must explicitly retain 2f1−f2, 2f2−f1, product slope, input intercept, compression onset and before/after attenuation ratios. If the outcome matches the stated prediction, within an unsaturated cubic regime, an internally generated third-order product grows approximately 3 db per 1 db increase of each equal blocker tone, the supported conclusion concerns that test domain. An alternative remains: The product may originate in the receiver mixer, an overloaded low-noise amplifier, or a corroded external junction before the nominal input reference plane. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 018

Application 01. Two-tone third-order products and input intercept

In the illustrative 018.01 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. With two equal input tones each at P = -30 dBm and a hypothetical input third-order intercept IIP_3 = +14 dBm, the extrapolated input-referred third-order product is $P_3 = 3P - 2IIP_3$ = -118 dBm, or -88 dBc relative to either input tone. The cubic approximation ceases to be reliable in compression. A two-tone slope check and input attenuation test must establish whether the predicted spur arises inside the receiver rather than externally. The predicted minus 118 dBm product is an extrapolated input-referred component, not an instrument measurement; verify the actual cubic regime, the two-tone stimulus purity and the suspected nonlinear reference plane.

Application 02. Gain allocation and blocker headroom

In the illustrative 018.02 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. Assume a calibrated digital full-scale equivalent of -7 dBm, a blocker applied at -39 dBm, and net analogue gain 28 dB. The projected converter input is -11 dBm and remaining margin is -7 − (-11) = 4 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. Four decibels of calculated margin is not a verified peak-overload margin for two carriers or pulsed blockers; inspect converter overload indications and upstream-stage compression before drawing an origin inference.

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Application 03. Cascade gain and observed headroom

In the illustrative 018.03 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. A first amplifier contributes G_1 = 11 dB, an intentional attenuation contributes G_2 = -6 dB, and a later stage contributes G_3 = 17 dB. The small-signal sum is 11 + (-6) + 17 = 22 dB. For P_i = -70 dBm, the ideal output is P_o = -48 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The twenty-two-decibel total can hide different intermediate signal levels; document each stage's input, interstage attenuator location and compression point to determine where an intermodulation product could be born.

Application 04. Filter or cable rejection referred to a physical input

In the illustrative 018.04 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. For an admitted input P_i = -43 dBm and separately measured loss L = 22 dB, the linear prediction is $P_o = P_i - L$ = -65 dBm. In SI power this becomes 10^((-65 − 30)/10) = 3.16e-10 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. The watt conversion establishes power units at one declared plane, not source location; a connector or screening bypass must be challenged independently if the measured transfer differs.

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Application 05. Thermal reference noise in a declared measurement bandwidth

In the illustrative 018.05 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. Take the equivalent noise bandwidth B = 9,000 Hz and calibrated noise figure NF = 3.55 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -130.91$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. This thermal-reference noise estimate bounds only the stated bandwidth and receiver model; an observed peak near an intermodulation frequency cannot be classified by substituting the noise floor for a two-tone test.

Application 06. Alias-location prediction and its non-unique inverse

In the illustrative 018.06 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. For an actual sampling frequency f_s = 19 MHz and analogue input f_i = 42.180 MHz, the nearest-replica folding rule gives $f_a = |f_i - \text{round}(f_i/f_s)f_s| = 4.180$ MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. The four-point-one-eight-megahertz sampled coordinate has non-unique analogue preimages; test preselector changes and alternate sampling frequencies before assigning a frequency to an emitter.

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Application 07. Combined and expanded measurement uncertainty

In the illustrative 018.07 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. For independent standard-uncertainty contributions 0.73, 0.48 and 0.43 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.73^2 + 0.48^2 + 0.43^2)} = 0.974$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 1.948$ units. The expanded uncertainty assumes independent input contributions and a stated coverage factor; correlated reference errors and nonlinear sensitivity coefficients require re-evaluation.

Application 08. Difference between two instruments relative to stated uncertainty

In the illustrative 018.08 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. The paired instrument contrast is $\Delta = 1.590$ dB. Set independent standard uncertainties $u_1 = 0.300$ dB and $u_2 = 0.420$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.516$ dB, giving the dimensionless ratio $\Delta/u\Delta = 3.081$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The contrast-to-uncertainty ratio indicates scale of difference only; it neither localises the nonlinear junction nor supplies a false-positive probability without a specified decision model.

Application 09. Opportunity-limited detection under independent visits

In the illustrative 018.09 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a

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wideband SDR capture. For n = 48 genuinely independent valid observation opportunities, each with stipulated event detection chance p = 0.09, the probability of no detections is $(1 - p)^n = 0.01081$; its complement is 98.92%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The ninety-eight-point-nine-two-per-cent complement is conditional on independent valid visits each having the stipulated detection chance; field revisit synchronisation and censoring can invalidate it.

Application 10. Family-wise probability when many candidates are searched

In the illustrative 018.10 test, two strong broadcasting carriers surround the frequency of a suspected weak transmission within a wideband SDR capture. If each of M = 424 independent pre-specified search opportunities has false-alarm probability α = 0.0010, the probability of one or more false positives is 1 − (1 − α)^M = 0.34571, or 34.57%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. The approximately thirty-four-point-six-per-cent family-wise probability refers to a prespecified independent search family; inspect correlated bins and post-selection before treating any single peak as evidence of a transmitter.

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Contributor identification and editorial scope

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

National Institute of Standards and Technology, TN 1297, sections 5–7: combined uncertainty and reporting, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-7-reporting-uncertainty (consulted 11 November 2026).

“Swept IMD and IM Spectrum Concepts”, measurement-application documentation, https://helpfiles.keysight.com/csg/e5080b/Applications/Swept_IMD_and_IM_Spectrum_Concepts.htm (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 019

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Where do analogue filtering and group delay distort the interpretation of short bursts?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 019 asks: Where do analogue filtering and group delay distort the interpretation of short bursts? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is temporal interpretation of short bursts passing through real analogue filters. Our primary observation is the captured envelope, frequency-domain window, and estimated arrival time of a transient; by contrast, what remains unseen is the input pulse shape before filter memory, ringing, and conversion latency. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Group delay and burst chronology. A filter with nonuniform group delay can alter a short pulse’s apparent onset, shape and duration even while its passband magnitude looks satisfactory. Group delay is the negative

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derivative of unwrapped phase with respect to angular frequency, so a ripple of tens of nanoseconds across the occupied signal band may matter more to a brief transient than the advertised insertion loss. A 100-nanosecond pulse subjected to a 70-nanosecond variation across its spectral content need not retain a recognisable temporal envelope. Report the excitation waveform, filter state and delay reference plane. Compare measured impulse responses rather than attributing every multiple peak to multiple transmissions. In a localisation experiment, calibrate channel-to-channel delay separately, because a visually sharp filtered edge can still carry a systematic timing bias. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns the captured envelope, frequency-domain window, and estimated arrival time of a transient; it is not interchangeable with the input pulse shape before filter memory, ringing, and conversion latency. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is band-limited pulse injection, through-path group-delay measurement, and alternate-filter comparisons. A claim drawn from that comparison has to carry its actual uncertainties: impulse response, group-delay variation, bandwidth, rise time, and timing uncertainty. The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. Group delay is the negative derivative of filter phase with respect to angular frequency and may vary across a burst spectrum. A narrow filter can lengthen an apparently short

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event through its impulse response even if no emitted energy persists. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Hendrik Wade Bode | Principal contribution 1: The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response.

Dr. Atkinson, we should distinguish the group delay of an analogue network from the event time of a received emission. If the filter transfer function is $H(f)=|H(f)|\exp[j\varphi(f)]$, the local group delay is $-(1/2\pi)d\varphi/df$. A nearly flat magnitude response can conceal substantial variation of that derivative near the band edges. A short modulated pulse spans frequencies that are delayed differently, so its envelope may broaden, ring or develop a secondary maximum. The engineer who timestamps the largest peak after filtering may therefore report a time belonging to the instrument rather than to the aerial input. I recommend measuring the complex transfer response of the entire acquisition chain, not relying solely on nominal filter order. The calibration source must present a known time marker and a representative waveform family. Where the receiver retunes or changes bandwidth, treat each filter state as a different time-transfer instrument. No amount of downstream interpolation erases an analogue delay that was never characterised.

In this physical path examination of Question 019, the decisive claim is that the Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. A narrow amplitude passband may impose strongly nonuniform group delay, altering a received burst even when average power calibration appears satisfactory. The arrival time of a peak in the filtered output is not necessarily the arrival time of the earliest electromagnetic disturbance at the antenna. A frequency-dependent phase response can redistribute a

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short pulse into delayed lobes, and a real receiver may add sampling, buffering and threshold-trigger latency. These effects should be measured with a waveform spanning the admitted band, not inferred from the filter's magnitude response alone. A useful falsification proceeds from the actual controversy: group delay and burst chronology. A filter with nonuniform group delay can alter a short pulse's apparent onset, shape and duration even while its passband magnitude looks satisfactory. Group delay is the negative derivative of unwrapped phase with respect to angular frequency, so a ripple of tens of nanoseconds across the occupied signal band may matter more to a brief transient than the advertised insertion loss. A 100-nanosecond pulse subjected to a 70-nanosecond variation across its spectral content need not retain a recognisable temporal envelope. Report the excitation waveform, filter state and delay reference plane. Compare measured impulse responses rather than attributing every multiple peak to multiple transmissions. In a localisation experiment, calibrate channel-to-channel delay separately, because a visually sharp filtered edge can still carry a systematic timing bias. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Inject a calibrated short pulse and a swept, phase-coherent reference through the actual analogue filter. Measure unwrapped phase across frequency, compute its derivative with uncertainty and compare the resulting impulse response with a parallel broadband path that shares the same timing reference. Repeat after substituting a second filter of known bandwidth. If the displayed burst peak changes but the reference time does not, the excess delay should be assigned to the measurement chain rather

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than the unknown transmitter. I would take group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. A response consistent with a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. A receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by the

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emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input, and measure their behaviour separately before reconnecting the assembled system. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. It is therefore material to establish group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction rather than infer them from a single scalar output. The limiting test is concrete: Inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. If the intervention produces a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret the displayed pulse appears wider and delayed relative to a simultaneous broadband reference path as a new transmitter before challenging the most economical instrumental explanation. A short pulse broadens spectrally before any filter acts upon it, and the chosen passband reshapes what survives. Professor Tukey, I invite you to test how the analyst distinguishes processing distortion from transmitter duration.

John Wilder Tukey | Peer question 1 to Hendrik Wade Bode

Hendrik Wade Bode, may I test the exact physical inference in your account of a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature? The

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proposed mechanism appears plausible only if changes after inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths are compared with a stable reference condition. The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction which would settle that narrower claim, rather than a visual impression of improvement.

Hendrik Wade Bode | Immediate answer to John Wilder Tukey

Dr Tukey, the relevant control is not merely whether a pulse appears later on one screen. We must locate time zero at an identified connector or reference antenna and characterise the filter's group-delay function over the occupied spectrum. A differential measurement against a broadband reference will reveal whether the apparent latency is an instrumental convolution rather than a property of the emitting device. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must

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preserve inconvenient outcomes. For Question 019, the specific physical candidate is passband amplitude ripple and frequency-dependent group delay producing dispersion and post-cursor ringing. The unresolved physical pathway is material: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The retained record permits a conditional claim about group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, but cannot alone resolve digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. A stable residual after the reference

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path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths, and only a response matching a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Hendrik Wade Bode

I appreciate your explanation, Hendrik Wade Bode. How would your conclusion survive a deliberately independent test of the displayed pulse appears wider and delayed relative to a simultaneous broadband reference path? A second receiver might share more of the supposed evidence than its separate enclosure suggests. Group delay is the negative derivative of filter phase with respect to angular frequency and

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may vary across a burst spectrum. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction and document which differences remain unexplained? Would you also state what observed change in group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction would invalidate the preferred account, and which aspect of inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths would make that negative result independently repeatable?

Hendrik Wade Bode | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 019, the specific physical candidate is passband amplitude ripple and frequency-dependent group delay producing dispersion and post-cursor ringing. The unresolved physical pathway is material: The

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emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The retained record permits a conditional claim about group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, but cannot alone resolve digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. Group delay is the negative derivative of filter phase with respect to angular frequency and may vary across a burst spectrum. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input; I would challenge it with inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. Two responses consistent with a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains

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invariant would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. A discordant measurement would then be interpreted by tracing that difference through group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction; an agreement lacking such a dependency analysis is weak corroboration.

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Oliver Heaviside | Principal contribution 2: Group delay is the negative derivative of filter phase with respect to angular frequency and may vary across a burst spectrum.

A line connected to a receiver is not always electrically transparent, particularly when a fast transient encounters a poorly terminated cable or filter interface. Transmission-line reflections can add delayed replicas before the signal reaches the mixer; those replicas may be indistinguishable from multipath in a waterfall unless the cable geometry is examined. The propagation time is set by cable length and velocity factor, while the reflection coefficient depends on the impedances presented at the discontinuity. I would deliberately vary a known cable section and see whether the apparent secondary pulse moves by the expected round-trip delay. Such a result would implicate the measurement chain rather than a second external transmission. Where the cable is long relative to the transient's spatial extent, lumped-element intuition becomes inadequate. The distinction between a reflection in the feeder and a second emitter is experimentally accessible, but only if the test changes one causal path without simultaneously retuning the receiver or changing its gain control.

In this control and stability examination of Question 019, the decisive claim is that group delay is the negative derivative of filter phase with respect to angular frequency and may vary across a burst spectrum. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: group delay and burst chronology. A filter with nonuniform group delay can

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alter a short pulse’s apparent onset, shape and duration even while its passband magnitude looks satisfactory. Group delay is the negative derivative of unwrapped phase with respect to angular frequency, so a ripple of tens of nanoseconds across the occupied signal band may matter more to a brief transient than the advertised insertion loss. A 100-nanosecond pulse subjected to a 70-nanosecond variation across its spectral content need not retain a recognisable temporal envelope. Report the excitation waveform, filter state and delay reference plane. Compare measured impulse responses rather than attributing every multiple peak to multiple transmissions. In a localisation experiment, calibrate channel-to-channel delay separately, because a visually sharp filtered edge can still carry a systematic timing bias. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by the displayed pulse appears wider and delayed relative to a simultaneous broadband reference path. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note group delay is the negative derivative of filter phase with respect to angular frequency and may vary across a burst spectrum. has a consequence for the

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observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, the displayed pulse appears wider and delayed relative to a simultaneous broadband reference path. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Heaviside's line and field analysis calls for an explicit account of propagation, cable coupling and the electrical boundary conditions of the circuit. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. This predicts a response which should be tested against a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements discarded during retuning. Where digital timestamp precision cannot

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remove a poorly characterised group delay between the antenna and converter, the correct claim must name the operational states and the evidence available in each. My proposed acceptance test would archive the entire control sequence and the independent witness measurement before any data-dependent threshold adjustment.

A further, separately testable aspect of a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature concerns group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction. The proposed challenge would be inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. The decision is conditional upon the observed result, with particular attention to digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. The competing account remains the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. An uncalibrated slope of filter phase can displace apparent event time without moving the original emission. Dr Pearson, I pass the floor for a challenge to the claimed timing uncertainty.

Egon Sharpe Pearson | Peer question 3 to Oliver Heaviside

Oliver Heaviside, your calibration argument invites a question about reference planes, especially because digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. The reference stimulus and the unknown emission need not

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occupy the same physical regime. A narrow filter can lengthen an apparently short event through its impulse response even if no emitted energy persists. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When the displayed pulse appears wider and delayed relative to a simultaneous broadband reference path, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Oliver Heaviside | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 019, the specific physical candidate is passband amplitude ripple and frequency-dependent group delay producing dispersion and post-cursor ringing. The unresolved physical pathway is material: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The retained record permits a conditional claim about group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, but cannot alone resolve digital timestamp

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precision cannot remove a poorly characterised group delay between the antenna and converter. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction. A narrow filter can lengthen an apparently short event through its impulse response even if no emitted energy persists. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths, with before-and-after values of group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction. If the instrument behaves as predicted, then a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. The displayed pulse

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appears wider and delayed relative to a simultaneous broadband reference path. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Oliver Heaviside

There is an inferential difficulty, Oliver Heaviside: the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The population of admissible observations needs to be fixed before any confidence argument. In this situation, digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Changing filtering after recording cannot restore analogue frequencies that never reached the converter. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction would invalidate the preferred account, and which aspect of inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths would make that negative result independently repeatable?

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Oliver Heaviside | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 019, the specific physical candidate is passband amplitude ripple and frequency-dependent group delay producing dispersion and post-cursor ringing. The unresolved physical pathway is material: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The retained record permits a conditional claim about group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, but cannot alone resolve digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because the displayed pulse appears wider and delayed relative to a simultaneous broadband reference path. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Changing filtering after recording cannot

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restore analogue frequencies that never reached the converter. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input; its prediction should be recorded alongside a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a 30 ns path-delay correction is meaningful only with its filter state and uncertainty, particularly in multisite localisation. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Dennis Gabor | Principal contribution 3: A narrow filter can lengthen an apparently short event through its impulse response even if no emitted energy persists.

A pulse occupying a finite time-frequency region cannot simultaneously possess the infinite temporal precision and narrow spectral definition suggested by a very thin display line. If the physical waveform is convolved with a dispersive impulse response, different parts of its spectrum emerge at different times. I would analyse a chirped calibration pulse and an unmodulated reference pulse separately, because the apparent arrival-time bias will depend on the waveform's spectral weighting. A plot of filter group delay alone is insufficient if it omits the pulse's actual occupied band. Further, the spectral estimator contributes its own window-centre convention and temporal smoothing. The examiner should preserve raw complex samples before any optional equalisation so that alternative compensators can be compared. If one equaliser produces a remarkably sharp peak, that is evidence of a mathematical transformation; confidence in the earlier arrival time needs independent calibration of the entire transfer function and clock, not admiration for the image.

In this operational measurand examination of Question 019, the decisive claim is that a narrow filter can lengthen an apparently short event through its impulse response even if no emitted energy persists. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: group delay and burst chronology. A filter with nonuniform group delay can alter a short pulse’s apparent onset, shape and duration even while its passband magnitude looks satisfactory.

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Group delay is the negative derivative of unwrapped phase with respect to angular frequency, so a ripple of tens of nanoseconds across the occupied signal band may matter more to a brief transient than the advertised insertion loss. A 100-nanosecond pulse subjected to a 70-nanosecond variation across its spectral content need not retain a recognisable temporal envelope. Report the excitation waveform, filter state and delay reference plane. Compare measured impulse responses rather than attributing every multiple peak to multiple transmissions. In a localisation experiment, calibrate channel-to-channel delay separately, because a visually sharp filtered edge can still carry a systematic timing bias. The speaker must not confuse the result of this bounded comparison with a general finding concerning every possible external transmission. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Short-burst interpretation must account for the impulse response and group-delay variation of the complete analogue path. A filter with a steep amplitude transition may introduce ringing that makes one short external pulse resemble a series of weaker events, while unequal phase delay across the admitted spectrum may distort the inferred leading edge. To separate the emitter from the instrument, inject a characterised pulse before the front-end filter and record both the input reference and the digitised output. Compare the recovered time-domain envelope, threshold crossings and energy outside the nominal event interval. Repeat with a broader or differently shaped filter whose delay response has been independently characterised. If the trailing oscillation changes with the filter but not with

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the reference pulse, it belongs in the instrument-response explanation. The investigator must state the timing fiducial and whether recorded event duration means physical emission time, filter-output envelope width or duration above the software threshold. Accordingly, the laboratory record for Question 019 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. Gabor's time-frequency work makes the time support and spectral concentration of an observation inseparable; a display cannot recover temporal detail that the window suppressed. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should

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specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A 30 ns path-delay correction is meaningful only with its filter state and uncertainty, particularly in multisite localisation. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. Impulse-response ringing can resemble a longer transmitted event even where the source pulse was brief. Dr Turing, please take the floor and ask what the retained record permits us to reconstruct.

Alan Mathison Turing | Peer question 5 to Dennis Gabor

Dennis Gabor, I should like to examine what the recorded data actually preserve when a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. The physical input and the retained numerical array are not interchangeable things. Cross-receiver time comparisons require subtracting calibrated path delays and documenting residual variation. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in group delay in seconds, phase derivative, 10–90 per cent rise time, pulse

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width and arrival-time correction would invalidate the preferred account, and which aspect of inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths would make that negative result independently repeatable?

Dennis Gabor | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 019, the specific physical candidate is passband amplitude ripple and frequency-dependent group delay producing dispersion and post-cursor ringing. The unresolved physical pathway is material: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The retained record permits a conditional claim about group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, but cannot alone resolve digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. I propose separating acquired information from model-dependent reconstruction. Cross-receiver time comparisons require subtracting calibrated path delays and documenting residual variation. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction and a fresh trial in which the operator inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. If that trial demonstrates a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses

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across two known filter bandwidths. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Norbert Wiener | Principal contribution 4: Changing filtering after recording cannot restore analogue frequencies that never reached the converter.

The receiver's filter may possess memory through its poles, adaptive coefficients or automatic state changes. After a strong pulse, a resonant analogue stage can ring even in the absence of any new external excitation. A digital display that marks each threshold crossing as a separate event may then turn one physical burst into a sequence of apparent transmissions. I propose a controlled impulse challenge, followed by a silent interval of known duration, to measure how long the chain can produce output after the input is extinguished. Repeat with several pulse amplitudes because overload may make the response nonlinear and invalidate an impulse response measured only in the small-signal regime. An adaptive noise canceller may add a second kind of memory, since its coefficient trajectory depends on past observations. The time history of that adaptation belongs in the evidential record. Distinguishing an event's causal support from a receiver's recovery is a problem in dynamics, not merely spectral resolution.

In this information retention examination of Question 019, the decisive claim is that changing filtering after recording cannot restore analogue frequencies that never reached the converter. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: group delay and burst chronology. A filter with nonuniform group delay can alter a short pulse’s apparent onset, shape and duration even while its passband magnitude looks satisfactory. Group delay is the negative derivative of unwrapped phase with respect to angular

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frequency, so a ripple of tens of nanoseconds across the occupied signal band may matter more to a brief transient than the advertised insertion loss. A 100-nanosecond pulse subjected to a 70-nanosecond variation across its spectral content need not retain a recognisable temporal envelope. Report the excitation waveform, filter state and delay reference plane. Compare measured impulse responses rather than attributing every multiple peak to multiple transmissions. In a localisation experiment, calibrate channel-to-channel delay separately, because a visually sharp filtered edge can still carry a systematic timing bias. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. The scientific point of changing filtering after recording cannot restore analogue frequencies that never reached the converter. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions repeatedly show a filter-dependent tail should vary with the measured

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impulse response even when the injected pulse train remains invariant, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. The displayed pulse appears wider and delayed relative to a simultaneous broadband reference path. Wiener's feedback perspective questions how an adaptive controller changes the distribution of the observations it subsequently presents as independent evidence. The issue becomes especially sharp because the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the proposed case, a 30 ns path-delay correction is meaningful only with its filter state and uncertainty,

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particularly in multisite localisation. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A more precise objection comes from Norbert Wiener and the finite observation aperture in a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. For that reason, record group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. Once an analogue filter has rejected frequencies, later numerical equalisation cannot recover the exact missing field history. Dr Deming, I invite a test that exposes this boundary in an otherwise attractive waveform.

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W. Edwards Deming | Peer question 6 to Norbert Wiener

I thank you, Norbert Wiener, for distinguishing measurement from attribution, but the observation is that the displayed pulse appears wider and delayed relative to a simultaneous broadband reference path. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a 30 ns path-delay correction is meaningful only with its filter state and uncertainty, particularly in multisite localisation. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant on one day but fails after the instrument has been reconfigured? The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment? Would you also state what observed change in group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction would invalidate the preferred account, and which aspect of inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths would make that negative result independently repeatable?

Norbert Wiener | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples,

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complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 019, the specific physical candidate is passband amplitude ripple and frequency-dependent group delay producing dispersion and post-cursor ringing. The unresolved physical pathway is material: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The retained record permits a conditional claim about group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, but cannot alone resolve digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a 30 ns path-delay correction is meaningful only with its filter state and uncertainty, particularly in multisite localisation. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. Its bearing on the dispute can be evaluated through the predicted response, namely a filter-dependent

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tail should vary with the measured impulse response even when the injected pulse train remains invariant. Because the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input, the procedure inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match report timing at an explicit receiver reference plane with an uncertainty interval rather than treating the screen peak as RF arrival time, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. A filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Percy Williams Bridgman | Principal contribution 5: Cross-receiver time comparisons require subtracting calibrated path delays and documenting residual variation.

Operational measurement requires deciding which time is being asserted. Is it the first discernible departure from a reference noise distribution, the maximum of a matched-filter correlation, the time stamped by a firmware trigger, or the arrival at an antenna reference plane? These are different quantities even when presented on one timeline. I should request a table mapping each reported time coordinate through filter delay, buffer indexing, clock calibration and software processing latency, with uncertainty at each step. A signal of unknown spectral content does not permit the engineer to subtract one universal group-delay constant without a model. If the alleged event is especially short, the choice of detection threshold and noise environment also shifts its measured onset. The proper report should give the operational definition of arrival time and the calibration evidence supporting it. A statement that a pulse existed is less ambitious than one asserting its exact emission time or geographical origin.

In this statistical inference examination of Question 019, the decisive claim is that cross-receiver time comparisons require subtracting calibrated path delays and documenting residual variation. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: group delay and burst chronology. A filter with nonuniform group delay can alter a short pulse’s apparent onset, shape and duration even while its passband magnitude looks satisfactory.

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Group delay is the negative derivative of unwrapped phase with respect to angular frequency, so a ripple of tens of nanoseconds across the occupied signal band may matter more to a brief transient than the advertised insertion loss. A 100-nanosecond pulse subjected to a 70-nanosecond variation across its spectral content need not retain a recognisable temporal envelope. Report the excitation waveform, filter state and delay reference plane. Compare measured impulse responses rather than attributing every multiple peak to multiple transmissions. In a localisation experiment, calibrate channel-to-channel delay separately, because a visually sharp filtered edge can still carry a systematic timing bias. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. Cross-receiver time comparisons require subtracting calibrated path delays and documenting residual variation. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed;

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two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say report timing at an explicit receiver reference plane with an uncertainty interval rather than treating the screen peak as RF arrival time, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Bridgman's operational approach requires a measurement procedure that defines each quantity physically. A stated number unsupported by the operation that produced it is methodologically incomplete. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that the emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically

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meaningful regime. The relevant quantities are group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a 30 ns path-delay correction is meaningful only with its filter state and uncertainty, particularly in multisite localisation, is not an estimate of any actual investigation. Path delay must be calibrated before comparing receiver arrival times as evidence of source location. Sir Karl, I pass the floor for the observation that would make such a comparison untenable.

Sir Karl Raimund Popper | Peer question 7 to Percy Williams Bridgman

Percy Williams Bridgman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise report timing at an explicit receiver reference plane with an uncertainty interval rather than treating the screen peak as RF arrival time? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Group delay is the negative derivative of filter phase with respect to angular frequency and may vary across a burst spectrum. Please connect group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction with a declared detection threshold and the measurement

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exposure. If the experiment inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Percy Williams Bridgman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 019, the specific physical candidate is passband amplitude ripple and frequency-dependent group delay producing dispersion and post-cursor ringing. The unresolved physical pathway is material: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. The retained record permits a conditional claim about group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction, but cannot alone resolve digital timestamp precision cannot remove a poorly characterised group delay between the antenna and converter.

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That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Group delay is the negative derivative of filter phase with respect to angular frequency and may vary across a burst spectrum. I would use the observations of group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths, not an assertion based on the operator's impression of a quiet display. If it yields a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since the emitter may have transmitted a longer burst, or the receiver impulse response

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may have imposed a dispersive tail on a shorter input, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to report timing at an explicit receiver reference plane with an uncertainty interval rather than treating the screen peak as rf arrival time, with the untested physical possibilities made visible.

Hendrik Wade Bode, Cross-Peer Question to Oliver Heaviside: Mr Heaviside, the technician measures an unwrapped phase change of minus 0.480 radians across 0.60 megahertz, infers approximately 127 nanoseconds of group delay and subtracts that constant from every burst timestamp. But the passband is sharply selective, its phase curvature changes at the edges, and the injected field pulse occupies much of the useful band. Is that single finite-difference quotient a defensible arrival-time correction? Which distinction between the derivative at a frequency and the time-domain arrival of a broadband envelope must the teaching example make explicit?

Oliver Heaviside, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, the finite-difference quotient is a local estimate of minus d phi by d omega, not a certificate that every Fourier component of a broad burst incurs the same delay. The stated 127-nanosecond value presumes a valid phase unwrap, a measured transfer function and a reference plane that excludes unintended cables or conversion latency. To estimate the waveform effect, measure the complex transfer function over the occupied spectrum at sufficient frequency resolution, retain its magnitude as well as its phase, and form or measure the actual impulse response. Compare the output of a calibrated broadband pulse with a synchronised reference path before and after filter substitution. Where group delay varies appreciably, the output can broaden,

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ring and move its peak in a waveform-dependent fashion. There may be no single correction that transforms the peak of every input into the physical emission time. The report must define whether it is estimating a selected threshold crossing, energy centroid, correlation maximum or another arrival-time statistic and include calibration and noise uncertainty for that estimator. I respectfully pass the floor to Dr Gabor.

Dennis Gabor, Cross-Peer Question to Norbert Wiener: Professor Wiener, a short burst becomes a long ringing tail after a very narrow analogue filter. The software team proposes to deconvolve the stored I/Q against a nominal impulse response and announce a sharply localised original emission, even though much of the original burst spectrum lay beyond the analogue passband. When does inversion recover information legitimately, and when does it merely amplify noise or manufacture a pulse from unobserved spectral components?

Norbert Wiener, Cross-Peer Answer to Dennis Gabor: Dr Gabor, write the observation as the unknown input convolved with the measured system response, plus receiver noise, clock errors and any nonlinear gain transients. Where the transfer function is reliably measured and bounded away from zero across the retained frequencies, an appropriately regularised inversion can estimate the portion of the waveform admitted by the system. The prior assumptions and their effect on timing should be exposed by sensitivity tests with several plausible input pulse shapes. Where analogue attenuation removed frequencies below the usable noise floor, the inverse is ill-conditioned or non-identifiable; digitally amplifying a stopband does not recreate lost observations. A calculated narrow pulse under a strong prior is then a model-dependent reconstruction, not direct forensic

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evidence of an emitted impulse with that duration. A parallel wideband recorder at a common physical reference plane, followed by blind injections, can test whether the claimed improvement is genuine. Archive raw samples, filter calibration, regularisation settings, and uncertainty intervals so another examiner can reproduce or challenge the inference. I respectfully pass the floor to Professor Bridgman.

Percy Williams Bridgman, Cross-Peer Question to Harry Nyquist: Dr Nyquist, two receivers record the same injected calibration burst with timestamps separated by hundreds of microseconds. The timebase of one recorder has a known parts-per-million mean rate error over several minutes, while the other shares a disciplined frequency reference but not the same analogue filter or trigger comparator. Can the observed offset be treated as a propagation time difference or used for a location calculation? How ought the timing reference plane, filter delay and sample-clock behaviour be separated?

Harry Nyquist, Cross-Peer Answer to Percy Williams Bridgman: Professor Bridgman, a propagation comparison must refer each event to a common external time and a declared input plane, not merely to the digits stamped on two packets. The rate error integrated across an interval predicts accumulated clock drift only under its specified constancy assumption; it does not determine analogue front-end group delay, sample-to-host buffering or the trigger algorithm latency. Inject the same traceable pulse into each receiver at a known connector while recording the distribution of time differences over frequency, amplitude, temperature and processing state. Identify which clock supplies the sample time, which supplies the wall clock and whether their errors are correlated. For localisation, subtract

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measured per-channel delay and its uncertainty and test the residual for stability using an independent geometric or cabled reference. If delay changes with pulse spectrum or AGC state, report a condition-dependent calibration instead of a single offset. Without that chain of measurements, a timestamp difference cannot be attributed to transmitter position. I respectfully pass the floor to Dr Tukey.

John Wilder Tukey, Cross-Peer Question to W. Edwards Deming: Dr Deming, a channel is visited for sixteen milliseconds every 1.15 seconds and a capture log loses 252 complex samples in a nominal 0.75-second recording. A later analyst reports that the system continuously monitored the short-burst source, cites the low average sample-loss fraction and treats the absence of a pulse as evidence that no emission occurred. What quality-control record would reveal the distinction between receiver coverage and event occupancy, and how should unknown intervals affect a negative finding?

W. Edwards Deming, Cross-Peer Answer to John Wilder Tukey: Dr Tukey, retain a time-indexed acquisition ledger, not just a reassuring percentage. For every observation state record start and stop time, filter configuration, gain, overload recovery, clock validity, frame-sequence continuity, dead intervals, and whether a detection algorithm was actually running on samples preserved for review. The sixteen-millisecond dwell divided by the 1.15-second revisit yields only about 1.39 per cent planned receiver exposure for that channel under the stated schedule. This is not the source’s duty cycle, and a periodic emission may systematically avoid the observed windows. Likewise, 252 lost samples represent a small fraction of a longer capture yet may wholly conceal an event if they cluster in its critical interval.

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Test the system with injected bursts distributed over phase relative to the revisit schedule and with deliberately introduced loss patterns. A negative result should describe the detectable event class, validated exposure time and remaining unobservable periods. Unvisited and invalid periods are unknown, not documented silence. I respectfully pass the floor to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of temporal interpretation of short bursts passing through real analogue filters has established a point which the specialist must not overlook. The receiver records the captured envelope, frequency-domain window, and estimated arrival time of a transient; it does not, merely by drawing a clear trace, give direct access to the input pulse shape before filter memory, ringing, and conversion latency. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, The Fourier transform of a short pulse extends across a broad frequency interval and interacts with the complete passband response. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

An amplitude response can appear admirably flat while group delay varies sufficiently across the admitted burst spectrum to alter pulse shape and apparent time of arrival. We have therefore to consider more than the loss of a filter or cable measured at one frequency. The proposed proof

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should combine a network-analyser phase sweep, a reference impulse or calibrated modulation, and the receiver's own time-stamp record. A differential phase measurement must be unwrapped consistently, and the estimated slope must be accompanied by its frequency interval and uncertainty. When the observing apparatus changes filters, the same external burst may appear wider, shifted or split without the transmitter having changed its behaviour. I thank Dr Gabor for the concern over time-frequency resolution and Lord Kelvin for the older experimental lesson that the receiving path has a measurable history of its own. Our decision is to report delay introduced by the characterised system, retaining residual uncertainty rather than treating a screen cursor as an absolute arrival-time certificate.

The stored pulse appears wider and later in the selective path than in the contemporaneous broadband path. That difference supports an instrumental dispersion hypothesis if the two paths share a documented clock and their alignment uncertainties are small enough to resolve the effect. The more useful outcome is a discriminating protocol: Inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. In applying it, the examiner must retain all readings supporting group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction and identify the physical plane to which the measurements refer. At the outset of the investigation, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature; that circumstance makes the alternative mechanism material, specifically the emitter may have transmitted a longer burst, or the receiver impulse

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response may have imposed a dispersive tail on a shorter input. A result approaching a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore report timing at an explicit receiver reference plane with an uncertainty interval rather than treating the screen peak as RF arrival time. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

Timing evidence should be stated at a declared electrical reference plane with the filter delay and trigger latency included in its uncertainty budget. An uncorrected screen maximum is not an independently authenticated radio-frequency arrival time. The decisive experiment is concrete: Inject a calibrated pulse spanning the admitted channel and compare through-path impulse responses across two known filter bandwidths. In conducting it, the examiner must explicitly retain group delay in seconds, phase derivative, 10–90 per cent rise time, pulse width and arrival-time correction. If the outcome matches the stated prediction, a filter-dependent tail should vary with the measured impulse response even when the injected pulse train remains invariant, the supported conclusion concerns that test domain. An alternative remains: The emitter may have transmitted a longer burst, or the receiver impulse response may have imposed a dispersive tail on a shorter input. I thank the contributors for their careful and courteous

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disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 019

Application 01. Group delay from a local phase-versus-frequency slope

In the illustrative 019.01 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. Across a local frequency step $\Delta f = 0.60$ MHz, suppose unwrapped transmission phase changes by $\Delta\varphi = -0.480$ rad. The finite-difference group-delay estimate is $\tau g \approx -\Delta\varphi/(2\pi\Delta f) = 127.324$ ns. This is an average local slope. Dispersive responses require a finer phase sweep, a consistent unwrapping method and uncertainty treatment before extrapolating transient arrival times. The 127-nanosecond quotient characterises local phase slope only; broad-pulse arrival correction requires the measured impulse response across the occupied spectrum and a declared timestamp estimator.

Application 02. First-order recovery envelope after a state change

In the illustrative 019.02 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. If an illustrative recovery follows $A(t) = A_0 \exp(-t/\tau)$, let $A_0 = 1.30$ V and $\tau = 10.00$ ms. At $t = 25.00$ ms the residual is $1.30e^{(-25.00/10.00)} = 0.1067$ V. Real automatic gain control often has nonlinear or multi-time-constant behaviour, so this exponential is a test model, not a universal reconstruction of the input during overload. The 0.1067-volt value is a hypothetical exponential recovery sample, not a reconstructed input burst; calibrate gain-control state and repeat after controlled overload to establish any timing bias.

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Application 03. Accumulated sample-clock time error

In the illustrative 019.03 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. A free-running sample clock with fractional rate error $\varepsilon = 1.120$ ppm over $T = 282$ s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T = 0.3158$ ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. The 0.3158-millisecond drift estimate assumes a constant average clock-rate error; calibrate trigger latency and phase-coherent timing independently before using an inter-receiver time difference.

Application 04. Alias-location prediction and its non-unique inverse

In the illustrative 019.04 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. For an actual sampling frequency $f_s = 23$ MHz and analogue input $f_i = 74.520$ MHz, the nearest-replica folding rule gives $f_a = |f_i - \mathrm{round}(f_i/f_s) f_s| = 5.520$ MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. The 5.52-megahertz alias coordinate does not identify an RF arrival frequency; only a controlled analogue passband and sampling plan can exclude alternative frequency zones.

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Application 05. Frequency-bin spacing versus independent information

In the illustrative 019.05 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. With sampled bandwidth f_s = 6 MS/s and N = 4,096 transform samples, the discrete-frequency grid is $\Delta f = f_s/N$ = 1464.844 Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. Transform-bin spacing is not event-time precision. Report the taper, equivalent noise bandwidth, actual coherent duration and analogue impulse response when assessing transient detectability.

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Application 06. Thermal reference noise in a declared measurement bandwidth

In the illustrative 019.06 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. Take the equivalent noise bandwidth B = 15,750 Hz and calibrated noise figure NF = 3.60 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -128.43$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The negative 128.43 dBm thermal reference is an average power model under the stated bandwidth; it does not describe impulsive site interference or the delay of a detected threshold crossing.

Application 07. Difference between two instruments relative to stated uncertainty

In the illustrative 019.07 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. The paired instrument contrast is $\Delta = 1.690$ dB. Set independent standard uncertainties $u_1 = 0.340$ dB and $u_2 = 0.370$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.502$ dB, giving the dimensionless ratio $\Delta/u\Delta = 3.363$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The 3.363 ratio is not a timing significance statement absent a paired measurement model and covariance; gain and filter state may explain the contrast without any change in propagation time.

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Application 08. Combined and expanded measurement uncertainty

In the illustrative 019.08 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. For independent standard-uncertainty contributions 0.80, 0.54 and 0.22 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.80^2 + 0.54^2 + 0.22^2)} = 0.990$ units. Using an illustrative coverage factor $k = 2$ gives expanded uncertainty $U = 2u_c = 1.980$ units. The illustrative expanded uncertainty applies only to its common-unit components and independence assumptions; a time-of-arrival budget must also address frequency-dependent delay and clock correlation.

Application 09. Preserved sample continuity across an acquisition interval

In the illustrative 019.09 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase curvature. A converter expected to retain $f_s = 1.30$ million samples/s for $T = 0.75$ s should supply $f_sT = 975{,}000$ complex sample instants. If 252 sequence positions are missing, the retained count is 974,748 and loss fraction is 0.02585%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block must therefore be preserved. The 0.02585-per-cent loss fraction obscures the timestamps and clustering of the 252 missing samples; a pulse may be wholly absent from the stored I/Q despite a high retained count.

Application 10. Observed exposure fraction of a channel scanner

In the illustrative 019.10 test, a receiver stores a very short burst after it has traversed a high-selectivity analogue filter with substantial phase

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curvature. Let the channel be observed on n = 341 valid visits, each lasting d = 16 ms, with revisit spacing R = 1.15 s. Valid exposure is nd/1000 = 5.456 s across the nominal interval nR = 392.15 s. The observed fraction of elapsed time is therefore 1.39%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. The 1.39-per-cent planned exposure describes the recorder, not a transmitter's occupancy. Preserve unobserved revisit intervals when reporting evidence for or against a short-burst emission.

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

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“Basics of Band-Limited Sampling and Aliasing” (2005), https://www.analog.com/en/resources/technical-articles/basics-of-bandlimited-sampling-and-aliasing.html (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 020

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How should an investigator validate a replacement receiver without losing comparability?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 020 asks: How should an investigator validate a replacement receiver without losing comparability? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is comparability and validation when a field investigation replaces one receiver with another. Our primary observation is measurements from two independently configured acquisition systems over a common test population; by contrast, what remains unseen is whether differences result from the external source or instrument transfer functions and operational regimes. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Replacement receiver equivalence is a controlled measurement. Two receivers do not become interchangeable merely because they display the

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same frequency label and nominal decibel unit. Inject a calibrated reference sequence at several amplitudes and across the actual passband, record the receiver-specific transfer curves, and test clock and gain-state transitions. If receiver A reports minus 72.0 dBm and receiver B minus 70.4 dBm for one traceable input, the 1.6 dB difference must be corrected or carried as a documented inter-instrument discrepancy before historical trends are compared. Compare input reference planes, spectral window equivalent-noise bandwidths and average-detector settings, not just screen resolution. A defensible bridge study should include blind repeats and both positive and negative cases. Keep the outgoing apparatus's configuration records, because the replacement may expose a previously invisible artefact without proving that the field environment has changed. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns measurements from two independently configured acquisition systems over a common test population; it is not interchangeable with whether differences result from the external source or instrument transfer functions and operational regimes. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is parallel observation of calibrated weak, strong, pulsed, and interferer-rich reference scenarios. A claim drawn from that comparison has to carry its actual uncertainties: bias, repeatability, reproducibility, decision concordance, and uncertainty on differences. Comparability must be

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assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. Parallel recordings should preserve both instruments' complete state histories and physical input references. A reference source at several amplitudes reveals nonlinear differences that a single level misses. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Walter Andrew Shewhart | Principal contribution 1: Comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage.

The replacement receiver should be admitted into service by a deliberately challenging acceptance programme, not by the reassurance that its data sheet resembles the previous instrument's. I would preserve a set of reference observations from the old receiver, including gain, noise, spur response, time alignment, overload behaviour and transitions between states. Then subject both instruments to common blinded stimuli under the same environmental conditions. A simple constant offset may reconcile two amplitude scales in one linear regime, but it cannot correct a change in clipping threshold or a different automatic gain-control history. Process-monitoring evidence is strongest when repeated reference challenges show whether a difference is stable, drifting or dependent on the signal presented. If the new instrument's filter bandwidth differs, a changed count of short detections may reflect the measurement procedure rather than the surveillance environment. The acceptance record must describe the resulting change in what can be concluded, not merely record a successful power-on test.

In this physical path examination of Question 020, the decisive claim is that comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. A replacement receiver is not demonstrated equivalent merely because it produces a quieter trace on the same aerial. Different analogue filters, windows, dynamic ranges and detector logic can create different event populations from the same physical signal. The comparison must begin with

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a defined measurand and test envelope, including weak bursts, strong blockers, frequency drift and sample discontinuity. Where the original apparatus was used for earlier forensic captures, any proposed transfer of conclusions demands a bridge experiment with both instruments operating on demonstrably comparable inputs. A useful falsification proceeds from the actual controversy: replacement receiver equivalence is a controlled measurement. Two receivers do not become interchangeable merely because they display the same frequency label and nominal decibel unit. Inject a calibrated reference sequence at several amplitudes and across the actual passband, record the receiver-specific transfer curves, and test clock and gain-state transitions. If receiver A reports minus 72.0 dBm and receiver B minus 70.4 dBm for one traceable input, the 1.6 dB difference must be corrected or carried as a documented inter-instrument discrepancy before historical trends are compared. Compare input reference planes, spectral window equivalent-noise bandwidths and average-detector settings, not just screen resolution. A defensible bridge study should include blind repeats and both positive and negative cases. Keep the outgoing apparatus's configuration records, because the replacement may expose a previously invisible artefact without proving that the field environment has changed. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Split a reference source through a characterised distribution network and record both receivers concurrently, preserving the splitter loss and input mismatch. Challenge amplitude, timing, instantaneous bandwidth, false-alarm decision and overload recovery over multiple stimulus classes.

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Compare instrument differences against a predetermined equivalence margin, not only against the statistical significance of a mean difference. If a new waterfall uses a different FFT taper, retain raw sample sets from both systems so that equivalent processing can be attempted retrospectively. I would take mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: Comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. A response consistent with disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

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The circuit cannot be judged from its final trace alone. An investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections, and measure their behaviour separately before reconnecting the assembled system. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. It is therefore material to establish mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs rather than infer them from a single scalar output. The limiting test is concrete: Operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. If the intervention produces disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret the new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold as a new transmitter before challenging the most economical instrumental explanation. Matching two receiver readouts is not the same as holding their measurands and

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thresholds constant. Professor Tukey, I invite your examination of how selection after replacement can manufacture apparent agreement.

John Wilder Tukey | Peer question 1 to Walter Andrew Shewhart

Walter Andrew Shewhart, may I test the exact physical inference in your account of an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability? The proposed mechanism appears plausible only if changes after operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes are compared with a stable reference condition. Comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs which would settle that narrower claim, rather than a visual impression of improvement.

Walter Andrew Shewhart | Immediate answer to John Wilder Tukey

Dr Tukey, the cleaner image may reflect a more aggressive average or a higher alarm threshold rather than superior reception. I would ask both instruments to process the same injected event while recording their internal state, then compare the actual detection

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decisions. The equivalence statement should disclose precisely which classes of event survived the transfer and which remain untested. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 020, the specific physical candidate is unequal passbands, reference-plane loss, threshold settings, clock offsets, detector statistics, and gain history. The unresolved physical pathway is material: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The retained record permits a conditional claim about mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, but cannot alone resolve two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route

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enabled and isolated. The required observations are mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. Comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes, and only a response matching disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, not a conjecture about the operator's intentions.

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Richard Wesley Hamming | Peer question 2 to Walter Andrew Shewhart

I appreciate your explanation, Walter Andrew Shewhart. How would your conclusion survive a deliberately independent test of the new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold? A second receiver might share more of the supposed evidence than its separate enclosure suggests. Parallel recordings should preserve both instruments' complete state histories and physical input references. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs and document which differences remain unexplained? Would you also state what observed change in mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs would invalidate the preferred account, and which aspect of operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes would make that negative result independently repeatable?

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Walter Andrew Shewhart | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 020, the specific physical candidate is unequal passbands, reference-plane loss, threshold settings, clock offsets, detector statistics, and gain history. The unresolved physical pathway is material: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The retained record permits a conditional claim about mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, but cannot alone resolve two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. I would draw the actual distribution network before collecting new corroborating

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evidence, marking where two receivers share signal, power or time references. Parallel recordings should preserve both instruments' complete state histories and physical input references. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections; I would challenge it with operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. Two responses consistent with disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. A discordant measurement would then be interpreted by tracing that difference through mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and

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state-change logs; an agreement lacking such a dependency analysis is weak corroboration.

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Percy Williams Bridgman | Principal contribution 2: Parallel recordings should preserve both instruments' complete state histories and physical input references.

Two receivers can agree on a displayed number while measuring different physical quantities. I would therefore define a common reference plane at the antenna connector and a common waveform family before making a comparability claim. A calibrated injection at an IF test port might evaluate useful stages but bypass the antenna-facing preselector, limiter and first mixer. It cannot establish equivalence of the entire receiving chain. Similarly, matching RMS levels for a continuous sine wave does not imply equal response to a millisecond burst. I would document the old and new measurement operations separately and ask which proposition the investigation needs to transport between them. Where the proposition concerns the existence of a weak pulse, the acceptance test should include controlled pulses with varied amplitudes, durations and interference backgrounds. Where it concerns calibrated power, uncertainty in connectors, mismatch, gain and detector averaging must be included. Comparability is specific to an operation and a class of physical stimuli.

In this control and stability examination of Question 020, the decisive claim is that parallel recordings should preserve both instruments' complete state histories and physical input references. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: replacement receiver equivalence is a controlled measurement. Two receivers do not become interchangeable

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merely because they display the same frequency label and nominal decibel unit. Inject a calibrated reference sequence at several amplitudes and across the actual passband, record the receiver-specific transfer curves, and test clock and gain-state transitions. If receiver A reports minus 72.0 dBm and receiver B minus 70.4 dBm for one traceable input, the 1.6 dB difference must be corrected or carried as a documented inter-instrument discrepancy before historical trends are compared. Compare input reference planes, spectral window equivalent-noise bandwidths and average-detector settings, not just screen resolution. A defensible bridge study should include blind repeats and both positive and negative cases. Keep the outgoing apparatus's configuration records, because the replacement may expose a previously invisible artefact without proving that the field environment has changed. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by the new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note parallel recordings should preserve both

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instruments' complete state histories and physical input references. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, the new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Bridgman's operational approach requires a measurement procedure that defines each quantity physically. A stated number unsupported by the operation that produced it is methodologically incomplete. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. This predicts a response which should be tested against disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration. An operator may be tempted to interpolate a line between two clean sweeps and call the

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resulting curve continuous; that presentational step does not restore measurements discarded during retuning. Where two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic, the correct claim must name the operational states and the evidence available in each. My proposed acceptance test would archive the entire control sequence and the independent witness measurement before any data-dependent threshold adjustment.

A further, separately testable aspect of an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability concerns mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs. The proposed challenge would be operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. The decision is conditional upon the observed result, with particular attention to two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. The competing account remains the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. A parallel receiver is most useful when both input paths and changing states are recorded independently. Dr Pearson, please take the floor and test the uncertainty assigned to this comparison.

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Egon Sharpe Pearson | Peer question 3 to Percy Williams Bridgman

Percy Williams Bridgman, your calibration argument invites a question about reference planes, especially because two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. The reference stimulus and the unknown emission need not occupy the same physical regime. A reference source at several amplitudes reveals nonlinear differences that a single level misses. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When the new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith. Would you also state what observed change in mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs would invalidate the preferred account, and which aspect of operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes would make that negative result independently repeatable?

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Percy Williams Bridgman | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 020, the specific physical candidate is unequal passbands, reference-plane loss, threshold settings, clock offsets, detector statistics, and gain history. The unresolved physical pathway is material: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The retained record permits a conditional claim about mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, but cannot alone resolve two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs. A reference source at several amplitudes reveals nonlinear differences that a single level misses. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be operate both receivers in

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parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes, with before-and-after values of mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs. If the instrument behaves as predicted, then disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. The new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Percy Williams Bridgman

There is an inferential difficulty, Percy Williams Bridgman: the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The population of admissible observations needs to be fixed

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before any confidence argument. In this situation, two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Agreement near a decision threshold deserves separate analysis because a tiny bias can change the reported class. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs would invalidate the preferred account, and which aspect of operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes would make that negative result independently repeatable?

Percy Williams Bridgman | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For

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Question 020, the specific physical candidate is unequal passbands, reference-plane loss, threshold settings, clock offsets, detector statistics, and gain history. The unresolved physical pathway is material: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The retained record permits a conditional claim about mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, but cannot alone resolve two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because the new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Agreement near a decision threshold deserves separate analysis because a tiny bias can change the reported class. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is

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the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections; its prediction should be recorded alongside disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a 1.2 db detection bias can reverse a near-threshold classification even when both instruments pass an ordinary gain check. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Hendrik Wade Bode | Principal contribution 3: A reference source at several amplitudes reveals nonlinear differences that a single level misses.

Suppose a replacement receiver offers superior typical noise figure but a less linear front end. The apparent improvement could be illusory in a site dominated by nearby high-power services. I would assemble both signal paths with independently measured gain, noise, compression and image response, then show how each stage contributes to the detectable input range. A response correction based on low-level laboratory tones should not be carried into the high-level regime without a compression test. Frequency response must also be compared at the edges of the survey band, where one preselector may attenuate a candidate that the other admits. A meaningful replacement protocol documents which differences are allowed and which trigger a new calibration or a restricted finding. The recovered raw files remain valuable, but the historical and new receiver observations must retain their separate acquisition metadata. One cannot make the two instruments physically interchangeable by placing their waterfall pictures side by side.

In this operational measurand examination of Question 020, the decisive claim is that a reference source at several amplitudes reveals nonlinear differences that a single level misses. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: replacement receiver equivalence is a controlled measurement. Two receivers do not become interchangeable merely because they display the same frequency label and nominal decibel unit. Inject a calibrated

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reference sequence at several amplitudes and across the actual passband, record the receiver-specific transfer curves, and test clock and gain-state transitions. If receiver A reports minus 72.0 dBm and receiver B minus 70.4 dBm for one traceable input, the 1.6 dB difference must be corrected or carried as a documented inter-instrument discrepancy before historical trends are compared. Compare input reference planes, spectral window equivalent-noise bandwidths and average-detector settings, not just screen resolution. A defensible bridge study should include blind repeats and both positive and negative cases. Keep the outgoing apparatus's configuration records, because the replacement may expose a previously invisible artefact without proving that the field environment has changed. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

A replacement receiver cannot be deemed equivalent merely because both units share a nominal frequency range and display similar spectral peaks. Equivalence depends on a declared measurand, reference plane and allowable uncertainty across operating conditions. Before replacement, acquire reference measurements of frequency error, amplitude transfer, occupied bandwidth, gain-state transitions, overload response, timing latency and response to at least one short pulse. After substitution, repeat those exact stimuli while retaining the original antenna, cable, clock reference and analysis settings wherever physically possible. Where components must change, document them as controlled experimental factors rather than hiding them within a single before-and-after comparison. A difference smaller than the display resolution may still matter

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to a localisation claim built upon microsecond timing; conversely, a visible colour difference in a waterfall may be immaterial to a frequency-presence proposition. The evidential report should state which claims remain comparable and which require a new uncertainty budget. Accordingly, the laboratory record for Question 020 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should

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specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A 1.2 dB detection bias can reverse a near-threshold classification even when both instruments pass an ordinary gain check. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. I would therefore attach the uncertainty analysis to the *operational definition* itself instead of printing an unexplained confidence interval beside the most appealing trace.

A more precise objection comes from Hendrik Wade Bode and the finite observation aperture in an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. For that reason, record mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. A multi-level reference can expose nonlinear divergence

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that a single calibration point hides. Dr Turing, I invite you to question whether the archived control sequence can reproduce the observed differences.

Alan Mathison Turing | Peer question 5 to Hendrik Wade Bode

Hendrik Wade Bode, I should like to examine what the recorded data actually preserve when an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. The physical input and the retained numerical array are not interchangeable things. Documenting the replacement event guards against mistaking an instrument discontinuity for a source discontinuity. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs would invalidate the preferred account, and which aspect of operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes would make that negative result independently repeatable?

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Hendrik Wade Bode | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 020, the specific physical candidate is unequal passbands, reference-plane loss, threshold settings, clock offsets, detector statistics, and gain history. The unresolved physical pathway is material: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The retained record permits a conditional claim about mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, but cannot alone resolve two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. I propose separating acquired information from

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model-dependent reconstruction. Documenting the replacement event guards against mistaking an instrument discontinuity for a source discontinuity. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs and a fresh trial in which the operator operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. If that trial demonstrates disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Jerzy Neyman | Principal contribution 4: Agreement near a decision threshold deserves separate analysis because a tiny bias can change the reported class.

The decision to accept a replacement receiver is a question about error probabilities and their consequences. Define a test population comprising quiet channels, strong adjacent carriers, weak intermittent signals, and controlled receiver-state transitions; then estimate detection and false-alarm performance in each. An average across all test opportunities can conceal a serious failure in the rare, difficult subset. I would predefine equivalence margins for the outcomes that matter, rather than assume that a failure to detect a difference proves equivalence. A sufficiently wide confidence interval is not evidence that two receivers are the same. If the project has an earlier measurement series, use calibration transfer and paired trials to quantify any discontinuity. Retain failures and outliers, because selecting only successful examples would create an optimistically biased acceptance record. A replacement can be acceptable for one forensic task and unqualified for another; the conditions must be identified in the final decision.

In this information retention examination of Question 020, the decisive claim is that agreement near a decision threshold deserves separate analysis because a tiny bias can change the reported class. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: replacement receiver equivalence is a controlled measurement. Two receivers do not become interchangeable merely because they display the same frequency label and nominal decibel unit.

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Inject a calibrated reference sequence at several amplitudes and across the actual passband, record the receiver-specific transfer curves, and test clock and gain-state transitions. If receiver A reports minus 72.0 dBm and receiver B minus 70.4 dBm for one traceable input, the 1.6 dB difference must be corrected or carried as a documented inter-instrument discrepancy before historical trends are compared. Compare input reference planes, spectral window equivalent-noise bandwidths and average-detector settings, not just screen resolution. A defensible bridge study should include blind repeats and both positive and negative cases. Keep the outgoing apparatus's configuration records, because the replacement may expose a previously invisible artefact without proving that the field environment has changed. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. The scientific point of agreement near a decision threshold deserves separate analysis because a tiny bias can change the reported class. is not that the result should be made more impressive but that a contrary result

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should be allowed to alter the proposed explanation. If independent sessions repeatedly show disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. The new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold. Neyman's statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. The issue becomes especially sharp because the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose

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precisely the interval and frequency domain actually examined. For the proposed case, a 1.2 db detection bias can reverse a near-threshold classification even when both instruments pass an ordinary gain check. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A more precise objection comes from Jerzy Neyman and the finite observation aperture in an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. For that reason, record mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. Close to a threshold, a tiny systematic bias can reverse a

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binary classification. Dr Deming, I pass the floor for a challenge procedure that makes those borderline cases visible.

W. Edwards Deming | Peer question 6 to Jerzy Neyman

I thank you, Jerzy Neyman, for distinguishing measurement from attribution, but the observation is that the new receiver produces a cleaner trace, but its software uses a different spectral window and detection threshold. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a 1.2 dB detection bias can reverse a near-threshold classification even when both instruments pass an ordinary gain check. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration on one day but fails after the instrument has been reconfigured? Comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment? Would you also state what observed change in mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs would invalidate the preferred account, and which aspect of operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes would make that negative result independently repeatable?

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Jerzy Neyman | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 020, the specific physical candidate is unequal passbands, reference-plane loss, threshold settings, clock offsets, detector statistics, and gain history. The unresolved physical pathway is material: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The retained record permits a conditional claim about mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, but cannot alone resolve two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-normalised statistic. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a 1.2 dB detection bias can reverse a near-threshold classification even when both instruments pass an ordinary gain check. I would retain the counterexample as part of the primary result, not as a

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footnote to an attractive conclusion. Comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. Its bearing on the dispute can be evaluated through the predicted response, namely disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration. Because the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections, the procedure operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match define an instrument-equivalence envelope rather than retrospectively declaring all recordings interchangeable, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. Disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Claude Elwood Shannon | Principal contribution 5: Documenting the replacement event guards against mistaking an instrument discontinuity for a source discontinuity.

An acquisition change alters the information supplied to later analysts. If the old receiver stored full-band I/Q with precise sample counters while its replacement stores only FFT magnitudes, the replacement cannot support every later hypothesis test even if the two instruments produce matching screenshots. I would compare not only input sensitivity but also the information retained: clock epoch, gain-state logs, filter coefficients, clipping flags and the capacity for reprocessing. For a specific allegation, determine whether each file preserves the distinction between competing physical inputs. A transfer function could allow amplitude correction when its input assumptions are met, but no transformation can retrieve a missing pulse from an interval the new instrument failed to sample. The acceptance study should therefore include deliberately crafted counterexamples that agree under the new summary format but differ in their original physical meaning. Failure to preserve such distinctions may be a material loss of evidential capability, regardless of improvements elsewhere.

In this statistical inference examination of Question 020, the decisive claim is that documenting the replacement event guards against mistaking an instrument discontinuity for a source discontinuity. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: replacement receiver equivalence is a controlled measurement. Two receivers do not become

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interchangeable merely because they display the same frequency label and nominal decibel unit. Inject a calibrated reference sequence at several amplitudes and across the actual passband, record the receiver-specific transfer curves, and test clock and gain-state transitions. If receiver A reports minus 72.0 dBm and receiver B minus 70.4 dBm for one traceable input, the 1.6 dB difference must be corrected or carried as a documented inter-instrument discrepancy before historical trends are compared. Compare input reference planes, spectral window equivalent-noise bandwidths and average-detector settings, not just screen resolution. A defensible bridge study should include blind repeats and both positive and negative cases. Keep the outgoing apparatus's configuration records, because the replacement may expose a previously invisible artefact without proving that the field environment has changed. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. Documenting the replacement event guards against mistaking an instrument discontinuity for a source discontinuity. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to operate both receivers in parallel on a

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verified common stimulus spanning weak, near-threshold, overload and intermittent modes, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say define an instrument-equivalence envelope rather than retrospectively declaring all recordings interchangeable, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. An investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Shannon's information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. One could stratify the experiment by nuisance condition, retain a random sample

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of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a 1.2 db detection bias can reverse a near-threshold classification even when both instruments pass an ordinary gain check, is not an estimate of any actual investigation. I would publish the test plan, sample exclusions, denominator and alternative accounts alongside the numerical result, so that a critical reader can identify which inference is conditional and which physical fact was directly observed.

A more precise objection comes from Claude Elwood Shannon and the finite observation aperture in an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. For that reason, record mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent

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modes, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. The record must mark the instrument-replacement instant so that a discontinuity is not mislabelled a new signal. Sir Karl, please take the floor and press the logical limits of that finding.

Sir Karl Raimund Popper | Peer question 7 to Claude Elwood Shannon

Claude Elwood Shannon, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise define an instrument-equivalence envelope rather than retrospectively declaring all recordings interchangeable? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Parallel recordings should preserve both instruments' complete state histories and physical input references. Please connect mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs with a declared detection threshold and the measurement exposure. If the experiment operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

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Would you also state what observed change in mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs would invalidate the preferred account, and which aspect of operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes would make that negative result independently repeatable?

Claude Elwood Shannon | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 020, the specific physical candidate is unequal passbands, reference-plane loss, threshold settings, clock offsets, detector statistics, and gain history. The unresolved physical pathway is material: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. The retained record permits a conditional claim about mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs, but cannot alone resolve two receivers sharing nominal frequency coverage do not necessarily measure the same bandwidth-

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normalised statistic. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Parallel recordings should preserve both instruments' complete state histories and physical input references. I would use the observations of mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes, not an assertion based on the operator's impression of a quiet display. If it yields disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since the apparent

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improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to define an instrument-equivalence envelope rather than retrospectively declaring all recordings interchangeable, with the untested physical possibilities made visible.

Walter Andrew Shewhart, Cross-Peer Question to Jerzy Neyman: Professor Neyman, a laboratory replaces Receiver A with Receiver B and runs thirty paired challenges. The mean reading differs by 1.6 dB, but an ordinary two-sided test does not reject equality at its chosen level. A manager interprets that non-rejection as evidence that the older archive and the new stream can be pooled without adjustment. What hypothesis must instead be framed if the question is operational interchangeability, especially where a 1.2 dB bias can change a marginal detection into a reported absence?

Jerzy Neyman, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, failure to reject exact equality is not a finding of equivalence. Establish in advance the permitted difference for each relevant measurand, operating state and evidential decision, and justify the margin against the consequences of a missed or false detection. The paired differences must retain their temporal order and challenge classes. For a quantitative measurement, examine a confidence interval for the inter-instrument difference against the predeclared equivalence boundaries. In a two-one-sided-test design, both sides must support containment within that interval. For a binary detector, compare the paired discordances and estimate false-positive and false-negative performance separately in weak-signal and

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blocker-rich conditions. If different units share a calibrator, the common reference uncertainty may cancel in a difference but remain in absolute-power claims; recording covariance is therefore indispensable. The 1.6 dB example is a difference at one particular calibration point, not a universal transfer constant. An observed confidence interval straddling the tolerance boundary means equivalence has not been demonstrated, regardless of the conventional difference-test p-value. I respectfully pass the floor to Dr Bridgman to challenge the physical meaning of a common stimulus.

Percy Williams Bridgman, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, the operator divides one calibrated RF source into two receivers and calls their inputs identical because the distribution is nominally symmetric. However, the splitter ports have unequal loss, the receivers present different impedances, and the second instrument has a preamplifier preceding its user-accessible attenuator. How should the laboratory construct an actual transfer comparison which will not mistake the shared test set-up for an intrinsic equality of receiver response?

Hendrik Wade Bode, Cross-Peer Answer to Percy Williams Bridgman: Dr Bridgman, define the measurement reference plane at each input connector, then measure the source, splitter, interconnecting cables and receiver-port reflection characteristics over frequency. A simultaneous split is convenient for suppressing source drift, but it does not eliminate mismatch or supply a traceable power value by nomenclature alone. Characterise insertion loss, isolation and return loss at the relevant power and frequency; where practicable, reverse the two distribution legs and compare the sign and magnitude of the observed difference. Follow with controlled tests at multiple levels and under strong adjacent interference,

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because a single small-signal correction cannot bridge unequal compression or automatic-gain-control behaviour. Record the actual gain-state trajectory, windowing, equivalent noise bandwidth and time-stamp origin. A common calibrator creates correlated uncertainties which should appear in the covariance matrix; treating both readings as independent can exaggerate the uncertainty of their difference, while ignoring independent mismatch terms can diminish it improperly. We should state which measurable property has been compared and which hardware states remain outside the validated envelope. I respectfully pass the floor to Dr Shannon to examine whether the archived records preserve that experiment.

Claude Elwood Shannon, Cross-Peer Question to Alan Mathison Turing: Dr Turing, the historical Receiver A recorded threshold events with a proprietary decimator, whereas Receiver B can preserve complex samples and metadata. The archivist proposes to replay A’s event lists through B’s newer digital algorithm and to describe the resulting agreement as a calibrated reconstruction of the original electromagnetic scene. What information-theoretic objection should be made, and what minimum acquisition evidence would permit a legitimate comparison?

Alan Mathison Turing, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, a list of threshold crossings is a many-to-one mapping of possible input waveforms. Where the older system discarded unsatisfied windows, raw sample phase, overload intervals or analogue preselector state, a later algorithm cannot recreate those missing variables by applying a more elaborate decision rule. We can compare the old and new decisions on a common set of controlled stimuli only to the extent that their recorded outputs expose the same operational estimand. Retain the original event

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lists, unaltered time stamps, configuration files, decimation coefficients where accessible, clipping indicators, firmware versions, instrument serial identification and sample-loss markers. For new parallel trials, preserve the pre-decision complex samples where lawful and technically feasible, and separately publish the transformations that yield both detector outputs. Reprocessing B's raw data to emulate A's decision can test a candidate transfer model, but it cannot certify what A would have recorded during an earlier unobserved interval. The correct status for the historical comparison is conditional, with unobservable states marked as unresolved. I respectfully pass the floor to Mr Deming to consider process drift across the replacement date.

W. Edwards Deming, Cross-Peer Question to John Wilder Tukey: Dr Tukey, an operational dashboard seems to improve sharply on the very day Receiver B is installed, with half as many alarm marks and fewer missed acquisitions. The laboratory cannot place the old unit back in continuous service, yet management wants a single before-and-after percentage attributed to a cleaner surveillance environment. Which bridge design and graphical analysis would separate a real environment change from altered sensitivity, a changed opportunity denominator and maintenance-related selection?

John Wilder Tukey, Cross-Peer Answer to W. Edwards Deming: Mr Deming, first show the time-ordered record with the replacement moment, known failures, gain and detector settings, source exposures and invalid windows identified, rather than drawing a continuous curve through a change in measurement method. Conduct a bounded bridge with a stable calibrated source, blind positive and negative challenges and, where possible, a third independent witness receiver that spans the transition. Analyse paired

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differences and conditional detection probabilities within each defined stimulus stratum, particularly near the decision boundary and during overload recovery. The denominator must count valid opportunities and separately disclose lost or excluded opportunities; a smaller alarm count alone may arise from lost coverage. Randomise stimulus order or alternate the comparison path to expose instrument drift and order effects. Control charts may reveal instability or a change point, but a chart is not a causal experiment. If the retired unit cannot be operated safely, preserve the lack of direct simultaneity as a limitation and widen the uncertainty or restrict retrospective comparison accordingly. Report both instrument performance and environmental evidence without allowing either to stand in for the other. I respectfully pass the floor to Dr Atkinson for the concluding synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of comparability and validation when a field investigation replaces one receiver with another has established a point which the specialist must not overlook. The receiver records measurements from two independently configured acquisition systems over a common test population; it does not, merely by drawing a clear trace, give direct access to whether differences result from the external source or instrument transfer functions and operational regimes. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, Comparability must be assessed for the measurand and decision threshold, not simply by sharing nominal frequency coverage. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board

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unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

The panel's useful disagreement concerns what it means to replace a receiver without changing an experiment. Equal-looking spectra are not sufficient evidence of interchangeability, because filtering, clock discipline, overload limits, trigger latency and retained metadata can differ while the displayed line remains in the same place. A fair substitution must use a common reference input, document every adaptor and cable, synchronise clocks to a stated uncertainty and compare the entire measurement chain under challenging as well as benign signals. I thank Dr Bridgman for directing attention to operational definitions: one receiver may be equivalent for estimating a continuous carrier's frequency yet wholly unsuitable for recovering a microsecond burst's timing. This is not a contradiction but a restriction on the measurand. In the final record the laboratory should declare precisely which outputs have demonstrated agreement, which have not, and whether that disagreement bears upon the forensic proposition being advanced. An unqualified claim of instrument equivalence is not justified by similar waterfall images.

The replacement receiver gives a quieter spectral display but uses different windows and thresholds. It follows that a direct visual comparison is insufficient to preserve the meaning of previously recorded absence or presence findings. Equivalent processing and calibrated parallel observation are needed. The more useful outcome is a discriminating protocol: Operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. In applying it, the

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examiner must retain all readings supporting mean bias, paired difference, standard uncertainty, threshold concordance, sample continuity and state-change logs and identify the physical plane to which the measurements refer. At the outset of the investigation, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability; that circumstance makes the alternative mechanism material, specifically the apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. A result approaching disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore define an instrument-equivalence envelope rather than retrospectively declaring all recordings interchangeable. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

The correct outcome is an equivalence envelope for specified measurements and conditions. Historical receiver data should not be silently reinterpreted under the new instrument’s sensitivity, calibration or event logic. The decisive experiment is concrete: Operate both receivers in parallel on a verified common stimulus spanning weak, near-threshold, overload and intermittent modes. In conducting it, the examiner must explicitly retain mean bias, paired difference, standard uncertainty, threshold concordance,

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sample continuity and state-change logs. If the outcome matches the stated prediction, disagreements clustered near the decision threshold reveal sensitivity to calibration bias and differing detector integration, the supported conclusion concerns that test domain. An alternative remains: The apparent improvement could arise from reduced environmental emissions or from unlike decision functions and reference-plane corrections. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 020

Application 01. Difference between two instruments relative to stated uncertainty

In the illustrative 020.01 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. The paired instrument contrast is $\Delta = 1.880$ dB. Set independent standard uncertainties $u_1 = 0.380$ dB and $u_2 = 0.370$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.530$ dB, giving the dimensionless ratio $\Delta/u\Delta = 3.545$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The 3.545 ratio compares a reading difference with a modelled standard uncertainty, not an equivalence test. Apply a prespecified dB margin with covariance and paired measurement repeatability before pooling the series.

Application 02. Combined and expanded measurement uncertainty

In the illustrative 020.02 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. For independent standard-uncertainty contributions 0.87, 0.48 and 0.34 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.87^2 + 0.48^2 + 0.34^2)} = 1.050$ units. Using an illustrative coverage factor $k = 2$ gives expanded uncertainty $U = 2u_c = 2.100$ units. The 2.100-unit expanded uncertainty presumes independent contributions and coverage factor two; a common calibration reference or drift requires a covariance term and renewed interval interpretation.

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Application 03. Thermal reference noise in a declared measurement bandwidth

In the illustrative 020.03 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. Take the equivalent noise bandwidth B = 24,000 Hz and calibrated noise figure NF = 2.20 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -128.00$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The minus-128.00 dBm figure applies to a 24 kHz equivalent-noise bandwidth at the stated thermal reference. Receiver equivalence also requires matching window, detector and interference conditions.

Application 04. Cascade gain and observed headroom

In the illustrative 020.04 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. A first amplifier contributes G_1 = 13 dB, an intentional attenuation contributes G_2 = -3 dB, and a later stage contributes G_3 = 18 dB. The small-signal sum is 13 + (-3) + 18 = 28 dB. For P_i = -73 dBm, the ideal output is P_o = -45 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The twenty-eight-decibel net gain does not reveal interstage compression or gain-state differences. Compare power at each receiver reference plane throughout weak and overloaded tests.

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Application 05. Gain allocation and blocker headroom

In the illustrative 020.05 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. Assume a calibrated digital full-scale equivalent of -5 dBm, a blocker applied at -34 dBm, and net analogue gain 33 dB. The projected converter input is -1 dBm and remaining margin is -5 − (-1) = -4 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. The negative four-decibel projected margin predicts overload in this simple model; an apparent improvement in the replacement receiver cannot be classified without low-gain and peak-input controls.

Application 06. Opportunity-limited detection under independent visits

In the illustrative 020.06 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. For n = 36 genuinely independent valid observation opportunities, each with stipulated event detection chance p = 0.08, the probability of no detections is $(1 - p)^n = 0.04970$; its complement is 95.03%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The 95.03 per cent complement presumes thirty-six independent, valid visits with constant conditional detection probability. Different dwell policies between receivers invalidate direct percentage comparison.

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Application 07. Family-wise probability when many candidates are searched

In the illustrative 020.07 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. If each of $M = 429$ independent pre-specified search opportunities has false-alarm probability $\alpha = 0.0011$, the probability of one or more false positives is $1 - (1 - \alpha)^M = 0.37635$, or 37.63%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. The 37.63 per cent family-wise false-positive estimate presumes independent, predeclared opportunities; correlated FFT cells and changed thresholding can alter the apparent replacement benefit.

Application 08. Accumulated sample-clock time error

In the illustrative 020.08 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. A free-running sample clock with fractional rate error $\varepsilon = 1.240$ ppm over $T = 460$ s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T = 0.5704$ ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. The 0.5704-ms accumulated clock-rate offset is not aperture jitter or an absolute timestamp bias. Measure the common clock discipline and actual event-tagging planes in both receivers.

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Application 09. Filter or cable rejection referred to a physical input

In the illustrative 020.09 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. For an admitted input P_i = -52 dBm and separately measured loss L = 38 dB, the linear prediction is $P_o = P_i - L$ = -90 dBm. In SI power this becomes 10^((-90 − 30)/10) = 1e-12 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. The watt conversion establishes a power at the declared plane under its assumed loss. A new receiver's input mismatch or bypass leakage must be tested rather than absorbed into a blanket calibration offset.

Application 10. Observed exposure fraction of a channel scanner

In the illustrative 020.10 test, an investigation substitutes a second calibrated receiver after the first unit develops intermittent instability. Let the channel be observed on n = 350 valid visits, each lasting d = 13 ms, with revisit spacing R = 1.30 s. Valid exposure is nd/1000 = 4.550 s across the nominal interval nR = 455.00 s. The observed fraction of elapsed time is therefore 1.00%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. The one-per-cent valid coverage is a recorder duty factor, not absence of external emissions; differences in revisit timing must be controlled before comparing receiver event counts.

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

National Institute of Standards and Technology, TN 1297, sections 5–7: combined uncertainty and reporting, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-7-reporting-uncertainty (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 021

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How should aperture jitter be budgeted at high input frequencies?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 021 asks: How should aperture jitter be budgeted at high input frequencies? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is the frequency-dependent signal-to-noise penalty of random aperture-time error. Our primary observation is noise or phase uncertainty correlated with the slope of the analogue input waveform; by contrast, what remains unseen is the several independent or correlated clock and sampling-aperture contributors to total jitter. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Jitter constrains sampling precision at the input frequency. For a sinusoidal input of frequency f and rms aperture-time uncertainty sigma_t, the familiar small-jitter bound on signal-to-noise ratio is approximately

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minus 20 log10(2 pi f sigma_t), provided timing error is independent and appropriately modelled. At f = 1 gigahertz and sigma_t = 200 femtoseconds, the product 2 pi f sigma_t is about 0.001257 and the jitter-limited ratio is roughly 58.0 dB. Increasing nominal converter resolution beyond that limit does not by itself recover timing-lost information. Account separately for converter aperture jitter, sampling-clock phase noise and external source jitter, and do not assume those processes are independent unless the architecture supports the assumption. Characterise the full analogue path because an apparently pristine digital code can still be inaccurate in phase. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns noise or phase uncertainty correlated with the slope of the analogue input waveform; it is not interchangeable with the several independent or correlated clock and sampling-aperture contributors to total jitter. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is a clean swept-frequency sine input with independent clock-phase-noise measurement and amplitude control. A claim drawn from that comparison has to carry its actual uncertainties: rms aperture jitter, input frequency, phase-noise integration bandwidth, and jitter-limited SNR. For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. Doubling the input frequency worsens this idealised limit by approximately

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6.02 dB if jitter remains unchanged. A phase-noise measurement cannot be translated into one rms time value without stating the integration range and transfer function. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Harry Nyquist | Principal contribution 1: For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter.

Aperture jitter belongs to the instant at which an analogue input is sampled, not merely to a number printed on a converter specification. For a sinusoid of frequency f and root-mean-square sampling-time uncertainty σ_t, the familiar small-error bound is $SNR_j \approx -20 \log_{10}(2\pi f \sigma_t)$, provided the jitter is sufficiently small and the relevant assumptions hold. Notice that f is the analogue input frequency; a high-frequency tone translated by intentional bandpass sampling can produce a low digital alias while retaining sensitivity to timing uncertainty at the original RF frequency. I would ask for a measurement of the clock distribution path at the actual converter aperture, including reference oscillator, synthesiser, buffers and coupling. A quoted clock stability in parts per million describes average frequency accuracy rather than short-term aperture jitter. Those are different error mechanisms. The examiner should state the integration bandwidth over which timing noise was characterised and explain how correlation among clocks changes the observed result.

In this physical path examination of Question 021, the decisive claim is that for a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. Sampling-clock phase noise is a time-domain aperture error whose effect increases with the derivative of the input waveform. For a sine input, uncorrelated rms timing jitter produces a familiar noise-limited SNR bound proportional to the negative logarithm of input frequency and rms jitter. That relationship cannot by itself characterise

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a clock with strong deterministic spurs or phase errors correlated between parallel converters. Nor does it establish the clock uncertainty of a timestamp assigned by later firmware. Separate the aperture, sample-time mapping and timestamp stages before designing a coherent multi-receiver comparison. A useful falsification proceeds from the actual controversy: jitter constrains sampling precision at the input frequency. For a sinusoidal input of frequency f and rms aperture-time uncertainty sigma_t, the familiar small-jitter bound on signal-to-noise ratio is approximately minus 20 log10(2 pi f sigma_t), provided timing error is independent and appropriately modelled. At f = 1 gigahertz and sigma_t = 200 femtoseconds, the product 2 pi f sigma_t is about 0.001257 and the jitter-limited ratio is roughly 58.0 dB. Increasing nominal converter resolution beyond that limit does not by itself recover timing-lost information. Account separately for converter aperture jitter, sampling-clock phase noise and external source jitter, and do not assume those processes are independent unless the architecture supports the assumption. Characterise the full analogue path because an apparently pristine digital code can still be inaccurate in phase. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Measure a low-distortion sine at several known RF frequencies while using the same converter and analogue gain. Change the sample-clock source independently and measure SNR and spectral sidebands, retaining unaveraged samples and phase-noise data. Repeat with two channels sharing the clock and with independently disciplined clocks; differences in correlation determine whether sample combining can reduce the error. The

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experiment must distinguish random aperture jitter from deterministic clock spurs and from analogue input frequency drift. I would take input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. A response consistent with for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. A high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. A meaningful bench experiment begins with a source

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whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts, and measure their behaviour separately before reconnecting the assembled system. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. It is therefore material to establish input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR rather than infer them from a single scalar output. The limiting test is concrete: Sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. If the intervention produces for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited snr bound by approximately 6.02 db, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest as a new transmitter before challenging the most economical instrumental explanation. The familiar jitter-limited signal-to-noise expression assumes a specified sinusoid and an appropriate random timing-error model. Professor Tukey, I invite you to challenge the practice of reporting its bound as observed converter performance.

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John Wilder Tukey | Peer question 1 to Harry Nyquist

Harry Nyquist, may I test the exact physical inference in your account of a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network? The proposed mechanism appears plausible only if changes after sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures are compared with a stable reference condition. For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR which would settle that narrower claim, rather than a visual impression of improvement.

Harry Nyquist | Immediate answer to John Wilder Tukey

Dr Tukey, I would not call two ADC output errors independent merely because they appear in separate data arrays. If both converters sample from a common reference their timing fluctuations may cohere. I propose measuring phase-error covariance with a common test tone and then repeating with independent references. Only the measured covariance justifies the predicted improvement

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from combination. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 021, the specific physical candidate is small time perturbations translated into amplitude errors proportional to instantaneous input slew rate. The unresolved physical pathway is material: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The retained record permits a conditional claim about input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, but cannot alone resolve aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are input frequency, rms aperture-time uncertainty, phase-noise integration limits,

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correlation coefficient and jitter-limited SNR; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures, and only a response matching for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, not a conjecture about the operator's intentions.

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Richard Wesley Hamming | Peer question 2 to Harry Nyquist

I appreciate your explanation, Harry Nyquist. How would your conclusion survive a deliberately independent test of parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest? A second receiver might share more of the supposed evidence than its separate enclosure suggests. Doubling the input frequency worsens this idealised limit by approximately 6.02 dB if jitter remains unchanged. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR and document which differences remain unexplained? Would you also state what observed change in input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR would invalidate the preferred account, and which aspect of sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures would make that negative result independently repeatable?

Harry Nyquist | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the

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level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 021, the specific physical candidate is small time perturbations translated into amplitude errors proportional to instantaneous input slew rate. The unresolved physical pathway is material: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The retained record permits a conditional claim about input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, but cannot alone resolve aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. Doubling the input frequency worsens this idealised limit by approximately 6.02 dB if jitter remains unchanged. An independent test must alter a physical dependency, not merely open another

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software window. The relevant controlled alternative remains clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts; I would challenge it with sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. Two responses consistent with for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. A discordant measurement would then be interpreted by tracing that difference through input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR; an agreement lacking such a dependency analysis is weak corroboration.

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Dennis Gabor | Principal contribution 2: Doubling the input frequency worsens this idealised limit by approximately 6.02 dB if jitter remains unchanged.

The time-frequency representation of a jittered carrier need not be a uniform blur. Correlated timing perturbations can produce discrete phase-modulation sidebands, while approximately uncorrelated timing errors contribute a noise-like pedestal whose interpretation depends on spectrum estimation. I would separate the two cases using a coherent sine stimulus, measurements across input frequencies and a phase-noise record of the sampling clock. A slowly wandering sampling epoch can make one acquisition window appear phase-coherent and the next drift, even though the average number of samples is correct. It would be misleading to infer an external narrowband emitter from sidebands that track the internal clock's control cycle. Where the experimental aim is time-of-arrival, the relevant clock-error contribution differs from that in a spectral-SNR estimate. The instrument may meet an amplitude performance specification and still possess unacceptable timestamp uncertainty. Therefore the engineer should specify which observable the jitter budget is intended to protect.

In this control and stability examination of Question 021, the decisive claim is that doubling the input frequency worsens this idealised limit by approximately 6.02 dB if jitter remains unchanged. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: jitter constrains sampling precision at the input frequency. For a sinusoidal input of

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frequency f and rms aperture-time uncertainty sigma_t, the familiar small-jitter bound on signal-to-noise ratio is approximately minus 20 log10(2 pi f sigma_t), provided timing error is independent and appropriately modelled. At f = 1 gigahertz and sigma_t = 200 femtoseconds, the product 2 pi f sigma_t is about 0.001257 and the jitter-limited ratio is roughly 58.0 dB. Increasing nominal converter resolution beyond that limit does not by itself recover timing-lost information. Account separately for converter aperture jitter, sampling-clock phase noise and external source jitter, and do not assume those processes are independent unless the architecture supports the assumption. Characterise the full analogue path because an apparently pristine digital code can still be inaccurate in phase. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note doubling the input frequency worsens this idealised limit by approximately 6.02 db if jitter remains unchanged. has a

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consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Gabor's time-frequency work makes the time support and spectral concentration of an observation inseparable; a display cannot recover temporal detail that the window suppressed. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. This predicts a response which should be tested against for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited snr bound by approximately 6.02 db. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements

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discarded during retuning. Where aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it, the correct claim must name the operational states and the evidence available in each. My proposed acceptance test would archive the entire control sequence and the independent witness measurement before any data-dependent threshold adjustment.

A further, separately testable aspect of a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network concerns input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR. The proposed challenge would be sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. The decision is conditional upon the observed result, with particular attention to aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. The competing account remains clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. Doubling input frequency changes the ideal timing-error penalty even when the quoted clock jitter does not. Dr Pearson, I pass the floor to examine whether the uncertainty calculation follows the frequency actually captured.

Egon Sharpe Pearson | Peer question 3 to Dennis Gabor

Dennis Gabor, your calibration argument invites a question about reference planes, especially because aperture jitter is a time error whose

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voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. The reference stimulus and the unknown emission need not occupy the same physical regime. A phase-noise measurement cannot be translated into one rms time value without stating the integration range and transfer function. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Dennis Gabor | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 021, the specific physical candidate is small time perturbations translated into amplitude errors proportional to instantaneous input slew rate. The unresolved physical pathway is material: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The retained

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record permits a conditional claim about input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, but cannot alone resolve aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR. A phase-noise measurement cannot be translated into one rms time value without stating the integration range and transfer function. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures, with before-and-after values of input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR. If the instrument behaves as predicted, then for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the

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measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. Parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Dennis Gabor

There is an inferential difficulty, Dennis Gabor: clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The population of admissible observations needs to be fixed before any confidence argument. In this situation, aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Correlated jitter between multiple converters invalidates naive independent-noise improvement calculations. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in input frequency, rms aperture-time

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uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR would invalidate the preferred account, and which aspect of sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures would make that negative result independently repeatable?

Dennis Gabor | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 021, the specific physical candidate is small time perturbations translated into amplitude errors proportional to instantaneous input slew rate. The unresolved physical pathway is material: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The retained record permits a conditional claim about input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, but cannot alone resolve aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. That limitation belongs in

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the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Correlated jitter between multiple converters invalidates naive independent-noise improvement calculations. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts; its prediction should be recorded alongside for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Aperture jitter is a time error whose voltage consequence

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depends on the input slew rate; converter resolution alone cannot reveal it. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a 100 mhz signal subject to one picosecond rms sampling jitter has an idealised jitter-only snr of roughly 64 db. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Claude Elwood Shannon | Principal contribution 3: A phase-noise measurement cannot be translated into one rms time value without stating the integration range and transfer function.

I would distinguish the nominal sample count from the information contained in the values. A sequence may have the expected N samples at the advertised sample rate while timing uncertainty has altered their relationship to the continuous analogue waveform. If the jitter is independent and sufficiently small, a linearised error model attributes voltage error to signal slope times sampling-time error. That expression is especially revealing for a high-frequency tone: a steep derivative converts even tiny timing deviations into measurable voltage disturbance. It does not follow that storing the result in a 32-bit numerical type restores the accuracy lost at the sampling aperture. Nor does it follow that a down-converted carrier of modest digital frequency was insensitive to the original analogue slope. Retaining the acquisition clock diagnostics is therefore part of preserving what was measured. The eventual analyst may estimate a jitter contribution under a model, but cannot reconstruct the unique unperturbed waveform from samples alone.

In this operational measurand examination of Question 021, the decisive claim is that a phase-noise measurement cannot be translated into one rms time value without stating the integration range and transfer function. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: jitter constrains sampling precision at the input frequency. For a sinusoidal input of frequency f and rms aperture-time uncertainty sigma_t, the familiar small-jitter bound on

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signal-to-noise ratio is approximately minus 20 log10(2 pi f sigma_t), provided timing error is independent and appropriately modelled. At f = 1 gigahertz and sigma_t = 200 femtoseconds, the product 2 pi f sigma_t is about 0.001257 and the jitter-limited ratio is roughly 58.0 dB. Increasing nominal converter resolution beyond that limit does not by itself recover timing-lost information. Account separately for converter aperture jitter, sampling-clock phase noise and external source jitter, and do not assume those processes are independent unless the architecture supports the assumption. Characterise the full analogue path because an apparently pristine digital code can still be inaccurate in phase. The speaker must not confuse the result of this bounded comparison with a general finding concerning every possible external transmission. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Sampling aperture jitter converts timing uncertainty into amplitude error that grows with the analogue input frequency. For a sinusoidal signal the familiar small-jitter approximation gives a jitter-limited signal-to-noise ratio of $-20 \log_{10}(2\pi f \sigma_t)$, where f is the input frequency in hertz and σ_t is rms sampling-time error in seconds. This makes a nominally high-resolution converter vulnerable at very high RF or IF frequencies even when its sample rate is ample. The quantity to measure is not solely the advertised converter clock period but the effective uncertainty at the sampling aperture, including distribution and board-level contributions. Compare a low-frequency calibration sinusoid with a much higher-frequency one under otherwise matched full-scale conditions; increasing broadband error in the

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latter may indicate jitter limitation, although front-end distortion and source purity must first be excluded. Where separate clock sources contribute, the assumed independence of jitter terms must be demonstrated before combining their rms values in quadrature. Accordingly, the laboratory record for Question 021 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. Shannon’s information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether

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it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A 100 MHz signal subject to one picosecond rms sampling jitter has an idealised jitter-only SNR of roughly 64 dB. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. An integrated phase-noise figure cannot be converted to timing uncertainty without declaring its offset-frequency limits. Dr Turing, please take the floor and investigate the information omitted by a lone rms value.

Alan Mathison Turing | Peer question 5 to Claude Elwood Shannon

Claude Elwood Shannon, I should like to examine what the recorded data actually preserve when a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. The physical input and the retained numerical array are not interchangeable things. The calculation is an upper bound under stated conditions rather than a complete converter performance guarantee. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR would invalidate the

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preferred account, and which aspect of sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures would make that negative result independently repeatable?

Claude Elwood Shannon | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 021, the specific physical candidate is small time perturbations translated into amplitude errors proportional to instantaneous input slew rate. The unresolved physical pathway is material: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The retained record permits a conditional claim about input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, but cannot alone resolve aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. I propose separating acquired information from model-dependent reconstruction. The calculation is an upper bound under stated conditions rather than a complete converter performance guarantee. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR and a fresh trial in which the operator sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. If that trial demonstrates for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete

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challenge should include sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Hendrik Wade Bode | Principal contribution 4: Correlated jitter between multiple converters invalidates naive independent-noise improvement calculations.

A receiver's timing budget should be constructed along an actual clock distribution network. Phase noise injected by the reference, a phase-locked loop, fan-out buffers or a local supply need not be mutually independent. Simply squaring every published jitter figure and taking their square root could therefore give the wrong answer. I would obtain the relevant cross-spectral or correlation information where available, then test the assembled system across clock modes, temperatures and converter channels. A common timing error can cancel in some differential measurements while remaining decisive for a comparison against an independent external clock. The loop bandwidth of a synthesiser can move noise between offsets, so one integrated RMS number cannot characterise every pulse or spectral estimator. The network model must identify where timing is defined and where the ADC actually samples. If a clock distribution board is replaced, the timing validation should be repeated even when the converter's nominal resolution and rate are unchanged.

In this information retention examination of Question 021, the decisive claim is that correlated jitter between multiple converters invalidates naive independent-noise improvement calculations. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: jitter constrains sampling precision at the input frequency. For a sinusoidal input of frequency f and rms aperture-time uncertainty sigma_t, the familiar small-jitter bound on signal-to-noise ratio is

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approximately minus 20 log10(2 pi f sigma_t), provided timing error is independent and appropriately modelled. At f = 1 gigahertz and sigma_t = 200 femtoseconds, the product 2 pi f sigma_t is about 0.001257 and the jitter-limited ratio is roughly 58.0 dB. Increasing nominal converter resolution beyond that limit does not by itself recover timing-lost information. Account separately for converter aperture jitter, sampling-clock phase noise and external source jitter, and do not assume those processes are independent unless the architecture supports the assumption. Characterise the full analogue path because an apparently pristine digital code can still be inaccurate in phase. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. The scientific point of correlated jitter between multiple converters invalidates naive independent-noise improvement calculations. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions repeatedly show for fixed

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rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. Parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. The issue becomes especially sharp because clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval

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and frequency domain actually examined. For the proposed case, a 100 mhz signal subject to one picosecond rms sampling jitter has an idealised jitter-only snr of roughly 64 db. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A more precise objection comes from Hendrik Wade Bode and the finite observation aperture in a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. For that reason, record input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. Shared timing errors across converter channels defeat an independence

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assumption, however impressive the combined digital word appears. Dr Deming, I invite a comparison that exposes this correlation.

W. Edwards Deming | Peer question 6 to Hendrik Wade Bode

I thank you, Hendrik Wade Bode, for distinguishing measurement from attribution, but the observation is that parallel averaging does not improve the observed error as the simple square-root-of-channel-count heuristic would suggest. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a 100 MHz signal subject to one picosecond rms sampling jitter has an idealised jitter-only SNR of roughly 64 dB. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB on one day but fails after the instrument has been reconfigured? For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

Hendrik Wade Bode | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the

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physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 021, the specific physical candidate is small time perturbations translated into amplitude errors proportional to instantaneous input slew rate. The unresolved physical pathway is material: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The retained record permits a conditional claim about input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, but cannot alone resolve aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a 100 MHz signal subject to one picosecond rms sampling jitter has an idealised jitter-only SNR of roughly 64 dB. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. Its bearing on the dispute can be evaluated through the predicted response, namely for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB. Because clock-edge uncertainty may be

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correlated between channels, making their apparent noise reductions smaller than independent averaging predicts, the procedure sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match disclose the clock topology and tested frequency before interpreting converter-bit aggregation as improved dynamic range, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. For fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: The calculation is an upper bound under stated conditions rather than a complete converter performance guarantee.

An attractive jitter specification is meaningful only in relation to a stipulated population of signals and a measured uncertainty. Suppose an SDR must detect intermittent waveforms whose RF carrier frequency varies over a broad range. A performance estimate derived from a low-frequency sinusoid cannot be extrapolated to the highest input frequency without accounting for the frequency-dependent jitter error. I would test several frequencies and amplitudes, distinguishing oscillator-related spurs, thermal noise and nonlinear distortion from the jitter contribution. A regression of noise power against the square of input frequency may help under controlled conditions, but only if competing terms are sufficiently stable and the model has been challenged. Report uncertainty in σ_t, clock-path correlation and the detector's tolerance for additional phase disturbance. The correct decision is not whether an abstract jitter number is small, but whether the receiver remains fit for the specific evidence task throughout its intended operating envelope.

In this statistical inference examination of Question 021, the decisive claim is that the calculation is an upper bound under stated conditions rather than a complete converter performance guarantee. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: jitter constrains sampling precision at the input frequency. For a sinusoidal input of frequency f and

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rms aperture-time uncertainty sigma_t, the familiar small-jitter bound on signal-to-noise ratio is approximately minus 20 log10(2 pi f sigma_t), provided timing error is independent and appropriately modelled. At f = 1 gigahertz and sigma_t = 200 femtoseconds, the product 2 pi f sigma_t is about 0.001257 and the jitter-limited ratio is roughly 58.0 dB. Increasing nominal converter resolution beyond that limit does not by itself recover timing-lost information. Account separately for converter aperture jitter, sampling-clock phase noise and external source jitter, and do not assume those processes are independent unless the architecture supports the assumption. Characterise the full analogue path because an apparently pristine digital code can still be inaccurate in phase. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. The calculation is an upper bound under stated conditions rather than a complete converter performance guarantee. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures, should be accompanied by a

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second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say disclose the clock topology and tested frequency before interpreting converter-bit aggregation as improved dynamic range, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman’s statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each

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physically meaningful regime. The relevant quantities are input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited snr bound by approximately 6.02 db, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a 100 mhz signal subject to one picosecond rms sampling jitter has an idealised jitter-only snr of roughly 64 db, is not an estimate of any actual investigation. A computed jitter ceiling is a conditional upper limit, not an instrument certificate under every waveform and temperature. Sir Karl, I pass the floor for a test of that boundary.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise disclose the clock topology and tested frequency before interpreting converter-bit aggregation as improved dynamic range? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Doubling the input frequency worsens this idealised limit by approximately 6.02 dB if jitter remains unchanged. Please connect input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR with a declared detection threshold and the measurement exposure. If the experiment sweep input frequency at controlled amplitude while

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independently measuring clock phase noise and comparing correlated versus separately clocked captures cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 021, the specific physical candidate is small time perturbations translated into amplitude errors proportional to instantaneous input slew rate. The unresolved physical pathway is material: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. The retained record permits a conditional claim about input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR, but cannot alone resolve aperture jitter is a time error whose voltage consequence depends on the input slew rate; converter resolution alone cannot reveal it. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Doubling the input frequency worsens this idealised limit by approximately 6.02 dB if jitter remains unchanged. I would use the observations of input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures, not an assertion based on the operator's impression of a quiet display. If it yields for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging

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predicts, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to disclose the clock topology and tested frequency before interpreting converter-bit aggregation as improved dynamic range, with the untested physical possibilities made visible.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, our example calculates an ideal jitter ceiling of approximately 58.42 dB for a 120 MHz sinusoid sampled with 1.59 ps rms aperture uncertainty. A design team installs a second nominally fifteen-bit converter on the same clock and assumes the two outputs can be averaged into a twenty-four-bit equivalent receiver. Which distinction among nominal code width, quantisation-noise reduction and timing-noise correlation prevents that conclusion, even if their sampled waveforms appear highly coherent?

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the sample value is perturbed by the input waveform slope multiplied by the instantaneous timing error. In the idealised small-jitter sinusoidal model, the resulting ratio is determined by 2π times the analogue input frequency times rms timing uncertainty; merely enlarging the digital word does not remove this analogue sampling error. At 120 MHz and 1.59 ps the ideal 58.42 dB ceiling corresponds to roughly 9.4 bits only if it were translated into the conventional full-scale-sinusoid effective-number-of-bits expression. That comparison is an illustrative SNR equivalence, not a measurement of the converter’s actual ENOB. Two channels sharing a common clock can share a substantial timing-error component, which simple averaging leaves in place. Their uncorrelated quantisation and thermal noise may diminish under specific assumptions, but no general law converts two fifteen-bit

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words into a valid twenty-four-bit measurement. Measure the channel cross-spectrum, clock topology, analogue source noise and actual harmonic-free SNR under the stipulated input conditions. I respectfully pass the floor to Dr Gabor to test how the timing uncertainty was derived.

Dennis Gabor, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, the manufacturer quotes a small phase-noise value at a single offset from the oscillator carrier and a separate rms-jitter number taken over an unspecified band. The team inserts that number into the aperture SNR formula without investigating the sampling-clock distribution, an analogue-input generator or narrow phase spurs. What frequency-domain information must be supplied before those figures may be combined into a meaningful timing-noise budget?

Hendrik Wade Bode, Cross-Peer Answer to Dennis Gabor: Dr Gabor, a phase-noise value at one Fourier offset does not determine total rms time uncertainty. Obtain the phase-noise spectrum over the stated integration-offset range, account for the convention used to convert single-sideband noise to phase variance, and include appropriate transfer functions through synthesis, multiplication, distribution and converter aperture. Identify discrete spurs separately from random phase fluctuations rather than burying deterministic modulation in a single statistical number. The converter experiences relative timing uncertainty between its sampling instant and the analogue signal; a common oscillator may yield cancellation or reinforcement depending upon the signal paths and their delays. When phase variance is integrated, conversion to time variance requires the specified clock carrier frequency, and the practical integration limits must reflect relevant aliasing and measurement bandwidth. The resulting

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covariance between channels deserves its own estimate. Finally compare the inferred limit against measured SNR as input frequency varies, retaining thermal noise, distortion and source-purity controls. It is only under these declared conditions that a phase-noise measurement supports the jitter number used in an engineering model. I respectfully pass the floor to Professor Neyman for the cross-channel statistical consequence.

Jerzy Neyman, Cross-Peer Question to W. Edwards Deming: Mr Deming, suppose two parallel ADC channels have equal timing-error variance σ^2 and correlation coefficient ρ. Their designer averages the samples and advertises the familiar square-root-of-two improvement, but the clock tree is shared and ρ has never been estimated. What reproducible acceptance experiment would establish whether the claimed improvement is present over the useful operating range rather than merely on a favourable calibration tone?

W. Edwards Deming, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, if equal-variance error contributions are averaged, the variance of their mean is $\sigma^2(1 + \rho)/2$. Thus $\rho = 0$ gives the familiar halving of variance, whereas $\rho = 1$ gives no reduction at all. This expression is a model consequence, not a measured property of either converter. Repeat with controlled sinusoidal inputs across the intended frequency range and power levels, including near the converter's overload boundary; estimate the channel error covariance from synchronised records after accounting for signal and reference-source noise. Use a common clock and then a qualified independent clock, where the apparatus permits, while preserving all changed operating conditions. Separate random jitter from systematic skew and aperture delay, and test for frequency dependence. Examine spurious

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responses, interchannel leakage, dither, clipping and gain mismatch instead of relying solely upon total power on a waterfall. Any claimed ENOB gain must be inferred from measured SINAD using the stated measurement convention, not obtained by adding digital word lengths. Retain outliers and unexpected failures in the acceptance report. I respectfully pass the floor to Dr Hamming to challenge the continuity of the recorded data.

Richard Wesley Hamming, Cross-Peer Question to Ralph Vinton Lyon Hartley: Mr Hartley, an ADC acquisition contains 1,105,000 expected sample positions and 255 missing positions, a loss of only about 0.02308 per cent. Elsewhere the clock drifts by several tenths of a millisecond, and an anti-alias filter introduces approximately 67.641 ns of local group delay. The system designer calls all these quantities sampling jitter and proposes one numerical correction. Which distinctions among sampling-time noise, long-term rate error, propagation delay and absent observations are indispensable to an honest evidence ledger?

Ralph Vinton Lyon Hartley, Cross-Peer Answer to Richard Wesley Hamming: Dr Hamming, those are four different impairments. Random aperture-time variation is a stochastic displacement around nominal instants and can produce slope-proportional amplitude noise; fractional clock-rate error accumulates a systematic or slowly varying time-axis discrepancy; group delay belongs to an analogue or digital transfer path and may vary across the signal band; missing sample positions are absences which no interpolation can turn into observed evidence. The roughly 0.462-millisecond accumulated clock drift cannot be subtracted from the jitter budget without defining a time origin and calibration stability. The 67.641-ns group-delay quotient is a local phase-slope estimate and cannot

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automatically correct a broadband burst edge. Record sequence counters, disciplined-clock status, clock topology, missing-block positions, gain state, input-filter settings and the exact timestamp reference plane. Where short bursts might coincide with missing intervals, the proper conclusion is that the interval was not observed, however impressive the overall retained percentage. Numerical correction should be performed only for calibrated, separately identified mechanisms; uncertainty and unresolved evidence gaps remain on the record. I respectfully pass the floor to Dr Atkinson for the concluding synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of the frequency-dependent signal-to-noise penalty of random aperture-time error has established a point which the specialist must not overlook. The receiver records noise or phase uncertainty correlated with the slope of the analogue input waveform; it does not, merely by drawing a clear trace, give direct access to the several independent or correlated clock and sampling-aperture contributors to total jitter. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, For a sinusoid and sufficiently small independent random timing error, the jitter-limited SNR is minus twenty times the base-ten logarithm of 2π times input frequency times rms jitter. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

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Sampling-clock uncertainty is particularly dangerous when it is confused with a general statement of converter resolution. The timing error of an aperture manifests differently at low and high input frequencies; it is also necessary to distinguish uncorrelated jitter from a deterministic clock offset, a long-term drift and shared phase noise. I thank Dr Shannon for pointing out that later digital processing cannot reconstruct an analogue detail already corrupted at sampling. The appropriate validation applies known tones at several RF frequencies, compares measured signal-to-noise-and-distortion against the predicted jitter-limited envelope and separately examines spurious components caused by periodic clock modulation. A second channel fed from the same reference does not provide independent confirmation of that reference's failure. The concluding result must report the measured spectral consequences of clock instability together with the model assumptions, rather than multiply nominal ADC bit depth into an imaginary gain in physical resolution. The remaining uncertainty belongs in the acquisition record and any later timing-based localisation.

A frequency-dependent degradation in SNR is consistent with aperture jitter, yet converter distortion and input noise can display similar frequency dependence. A controlled clock substitution and the observed noise spectrum are needed before assigning a quantitative jitter value. The more useful outcome is a discriminating protocol: Sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. In applying it, the examiner must retain all readings supporting input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR and identify the physical plane to which the

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measurements refer. At the outset of the investigation, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network; that circumstance makes the alternative mechanism material, specifically clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. A result approaching for fixed rms timing jitter, doubling sinusoidal input frequency reduces the jitter-limited SNR bound by approximately 6.02 dB may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore disclose the clock topology and tested frequency before interpreting converter-bit aggregation as improved dynamic range. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

Report jitter-limited performance as a conditional bound with the tested input frequency, clock source and error correlation. Do not convert a nominal jitter figure into a universal claim of effective converter resolution. The decisive experiment is concrete: Sweep input frequency at controlled amplitude while independently measuring clock phase noise and comparing correlated versus separately clocked captures. In conducting it, the examiner must explicitly retain input frequency, rms aperture-time uncertainty, phase-noise integration limits, correlation coefficient and jitter-limited SNR. If the outcome matches the stated prediction, for fixed rms

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timing jitter, doubling sinusoidal input frequency reduces the jitter-limited snr bound by approximately 6.02 db, the supported conclusion concerns that test domain. An alternative remains: Clock-edge uncertainty may be correlated between channels, making their apparent noise reductions smaller than independent averaging predicts. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 021

Application 01. The frequency dependence of aperture-jitter-limited SNR

In the illustrative 021.01 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. At sinusoidal input frequency f = 120 MHz with uncorrelated rms aperture jitter σ_t = 1.59 ps, the idealised jitter-imposed ceiling is $SNR_j = -20 \log_{10}(2\pi f \sigma_t)$ = 58.42 dB. A common clock source may correlate errors across parallel ADC channels, so treating their outputs as independent for noise cancellation would need an additional experiment. Converter nonlinearity and thermal noise can make actual performance worse. The 58.42 dB idealised jitter ceiling applies to the specified sinusoid and rms relative timing error. Shared-clock timing noise is correlated and cannot be removed by increasing digital word length.

Application 02. Ideal code step, variance, and full-scale sine SNR

In the illustrative 021.02 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. Taking an ideal N = 15-bit uniform converter across 2.50 V peak-to-peak, one nominal code interval is $\Delta = Vpp/2^N$ = 0.0763 mV. Under the independent uniform-error approximation its rms quantisation error is $\sigma = \Delta/\sqrt{12}$ = 0.0220 mV. The ideal full-scale sinusoidal SNR approximation is 6.02N + 1.76 = 92.06 dB. A coherent low-level waveform may violate the uniform-error assumption; clipping and integral nonlinearity are separate limitations. The 0.0220-mV quantisation estimate assumes ideal, independent uniform errors and a full-scale code convention. It

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must not be summed as extra effective bits without measuring dither and converter nonlinearity.

Application 03. Frequency-bin spacing versus independent information

In the illustrative 021.03 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. With sampled bandwidth f_s = 8 MS/s and N = 16,384 transform samples, the discrete-frequency grid is $\Delta f = f_s/N$ = 488.281 Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. The 488.281-Hz DFT grid measures frequency-bin spacing, not aperture-jitter bandwidth. State the clock phase-noise integration band, equivalent noise bandwidth and overlapping-window correlations separately.

Application 04. Accumulated sample-clock time error

In the illustrative 021.04 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. A free-running sample clock with fractional rate error ε = 1.430 ppm over T = 323 s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T$ = 0.4619 ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. The 0.4619-ms accumulated offset reflects mean clock-rate error over 323 s, not random aperture

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jitter. Preserve the synchronisation and time-stamp reference planes before comparing channels.

Application 05. Group delay from a local phase-versus-frequency slope

In the illustrative 021.05 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. Across a local frequency step $\Delta f = 0.80$ MHz, suppose unwrapped transmission phase changes by $\Delta\varphi = -0.340$ rad. The finite-difference group-delay estimate is $\tau g \approx -\Delta\varphi/(2\pi\Delta f) = 67.641$ ns. This is an average local slope. Dispersive responses require a finer phase sweep, a consistent unwrapping method and uncertainty treatment before extrapolating transient arrival times. The 67.641-ns phase-slope quotient measures local group delay for the given filter, not ADC aperture-time noise or a universal broadband-burst correction.

Application 06. Thermal reference noise in a declared measurement bandwidth

In the illustrative 021.06 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. Take the equivalent noise bandwidth B = 4,500 Hz and calibrated noise figure NF = 2.55 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -134.92$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The minus-134.92 dBm thermal-reference estimate describes integrated receiver noise in 4.5 kHz; it does not fix timing-error SNR at 120 MHz or an oscillator phase-noise budget.

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Application 07. Combined and expanded measurement uncertainty

In the illustrative 021.07 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. For independent standard-uncertainty contributions 0.45, 0.48 and 0.25 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.45^2 + 0.48^2 + 0.25^2)} = 0.704$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 1.408$ units. The 1.408-unit expanded uncertainty assumes independent common-unit inputs and k = 2; a multi-channel jitter claim must instead identify correlated clock and signal-source contributions.

Application 08. Preserved sample continuity across an acquisition interval

In the illustrative 021.08 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. A converter expected to retain f_s = 1.70 million samples/s for T = 0.65 s should supply f_sT = 1,105,000 complex sample instants. If 255 sequence positions are missing, the retained count is 1,104,745 and loss fraction is 0.02308%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block must therefore be preserved. The 0.02308-per-cent missing-sample fraction is an acquisition-integrity measure, not clock jitter. Missing sequence positions may conceal an entire short event despite the low proportion.

Application 09. Alias-location prediction and its non-unique inverse

In the illustrative 021.09 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network.

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For an actual sampling frequency f_s = 31 MHz and analogue input f_i = 66.030 MHz, the nearest-replica folding rule gives $f_a = |f_i - \mathrm{round}(f_i/f_s)f_s|$ = 4.030 MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. The 4.030-MHz aliased coordinate is not the analogue input frequency controlling the jitter-sensitivity calculation; use the true 66.030-MHz input before drawing a clock-noise inference.

Application 10. Gain allocation and blocker headroom

In the illustrative 021.10 test, a high-frequency sinusoid is digitised by two converter channels sharing a common clock distribution network. Assume a calibrated digital full-scale equivalent of -11 dBm, a blocker applied at -41 dBm, and net analogue gain 26 dB. The projected converter input is -15 dBm and remaining margin is -11 − (-15) = 4 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. The four-decibel predicted converter margin assumes a linear input chain and known peak level. Verify overload and crest factor before interpreting any measured SNR shortfall as aperture jitter.

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Selected technical references and use limitations

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Walt Kester, “Aperture Time, Aperture Jitter, Aperture Delay Time”, tutorial MT-007 (2008), https://www.analog.com/media/en/training-seminars/tutorials/mt-007.pdf (equation and Figure 4 reviewed 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 022

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When does analogue front-end bandwidth invalidate an otherwise adequate sampling rate?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 022 asks: When does analogue front-end bandwidth invalidate an otherwise adequate sampling rate? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is limits imposed by the analogue front-end when sampling rate is superficially sufficient. Our primary observation is digitised spectral or transient data from a physically band-limited converter input; by contrast, what remains unseen is the rejected, attenuated, phase-distorted, or overloaded components before sampling. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Sampling rate cannot undo a narrow analogue passband. A converter may satisfy a Nyquist sampling criterion for the desired digital bandwidth while the preceding amplifier or track-and-hold has already attenuated or

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distorted that same signal. Suppose a 200-megasample-per-second converter is preceded by an analogue response that is 3 dB down at 60 megahertz. A 70-megahertz component lies below the 100-megahertz real-sampling Nyquist frequency, but it cannot be assumed to have unity amplitude merely because the sampling rate admits it. The analogue transfer magnitude, phase and slew performance require calibration. Harmonics of a short pulse may be attenuated unevenly, producing a longer apparent envelope. A reconstruction algorithm cannot distinguish this deterministic bandwidth shaping from a source envelope without independent knowledge of the front end. Test representative transients at the input reference plane, including strong neighbouring signals. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns digitised spectral or transient data from a physically band-limited converter input; it is not interchangeable with the rejected, attenuated, phase-distorted, or overloaded components before sampling. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is swept-frequency transfer and phase characterisation with a second known anti-alias filtering path. A claim drawn from that comparison has to carry its actual uncertainties: analogue input bandwidth, passband flatness, attenuation, sample rate, and aperture roll-off. A nominal sample rate characterises a discrete-time operation and does not certify a preceding analogue transfer function. The converter input may have frequency-

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dependent gain and phase even where digitiser throughput is adequate. Insufficient anti-alias rejection allows distant out-of-band signals to be folded into the displayed baseband. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Harry Nyquist | Principal contribution 1: A nominal sample rate characterises a discrete-time operation and does not certify a preceding analogue transfer function.

The sampling-rate condition is a statement about the analogue spectrum admitted to the sampling device, not a permission to ignore the receiver's preselector. A converter operating at a rate adequate for a deliberately low-pass-limited baseband may still fold a powerful out-of-band signal into the observed digital band if the analogue front end fails to suppress it. I would begin by drawing the spectral occupancy at the ADC input, including known image regions and the filter's actual transition bands. A manufacturer may quote bandwidth at a three-decibel point, but an alias-rejection claim requires stopband attenuation where competing signals can occur. In a forensic receiver, a weak candidate that appears near the displayed baseband centre can be the alias of a much stronger external service at a remote frequency. The experiment should vary the analogue preselector and the sample clock independently, keeping a calibrated source fixed. The observed frequency mapping can then be checked against the actual sampling law rather than an assumed one.

In this physical path examination of Question 022, the decisive claim is that a nominal sample rate characterises a discrete-time operation and does not certify a preceding analogue transfer function. The analogue anti-alias filter determines which portions of the external spectrum can enter the sampled representation. A mathematically correct alias frequency is not evidence that the corresponding RF source actually reached the converter with adequate amplitude. The filter’s stopband shape, temperature drift, input matching and large-signal performance must all be measured. In a

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wideband survey this is particularly important because a powerful out-of-band service can survive inadequate rejection even if the digital display faithfully reports the folded component. A useful falsification proceeds from the actual controversy: sampling rate cannot undo a narrow analogue passband. A converter may satisfy a Nyquist sampling criterion for the desired digital bandwidth while the preceding amplifier or track-and-hold has already attenuated or distorted that same signal. Suppose a 200-megasample-per-second converter is preceded by an analogue response that is 3 dB down at 60 megahertz. A 70-megahertz component lies below the 100-megahertz real-sampling Nyquist frequency, but it cannot be assumed to have unity amplitude merely because the sampling rate admits it. The analogue transfer magnitude, phase and slew performance require calibration. Harmonics of a short pulse may be attenuated unevenly, producing a longer apparent envelope. A reconstruction algorithm cannot distinguish this deterministic bandwidth shaping from a source envelope without independent knowledge of the front end. Test representative transients at the input reference plane, including strong neighbouring signals. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Inject calibrated tones just inside, at and well beyond the anti-alias transition band. Record their measured attenuation at the converter-side input and the resulting folded bins while varying sample rate in controlled steps. A second out-of-band tone should test compression and intermodulation, because small-signal S-parameters may not predict blocker behaviour. Retain amplitude and phase calibration, converter clock identity

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and the finite stopband rejection actually obtained rather than the advertised filter family. I would take front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: A nominal sample rate characterises a discrete-time operation and does not certify a preceding analogue transfer function. A response consistent with an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. An SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. A meaningful bench experiment begins with a source whose power,

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impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by an actual in-band emitter and a higher nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins, and measure their behaviour separately before reconnecting the assembled system. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. It is therefore material to establish front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth rather than infer them from a single scalar output. The limiting test is concrete: Map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. If the intervention produces an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated rf station, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret a distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent as a new transmitter before challenging the most economical instrumental explanation. The advertised sample rate cannot by itself certify the spectral contents of the analogue aperture. Professor Tukey, I invite you to challenge the evidential interpretation of a clean-looking digital band.

John Wilder Tukey | Peer question 1 to Harry Nyquist

Harry Nyquist, may I test the exact physical inference in your account of an SDR samples rapidly enough for the intended instantaneous

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passband but uses an analogue input network with poorly measured out-of-band attenuation? The proposed mechanism appears plausible only if changes after map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates are compared with a stable reference condition. A nominal sample rate characterises a discrete-time operation and does not certify a preceding analogue transfer function. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth which would settle that narrower claim, rather than a visual impression of improvement.

Harry Nyquist | Immediate answer to John Wilder Tukey

Dr Tukey, two different analogue frequencies can produce an identical sampled line, so the digital transform is underdetermined without the preconverter path. I should measure the filter at the frequencies of both candidate inputs and challenge the suspect alias by a modest, known sample-rate change. If the trace follows one predicted folding trajectory but not another, the result strengthens a path hypothesis while remaining conditional on the measured analogue passband. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then

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change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 022, the specific physical candidate is analogue amplitude roll-off, aperture response, filter group delay, and uncontrolled alias-band admission. The unresolved physical pathway is material: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. The retained record permits a conditional claim about front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, but cannot alone resolve nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. A nominal sample rate characterises a discrete-time operation

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and does not certify a preceding analogue transfer function. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates, and only a response matching an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Harry Nyquist

I appreciate your explanation, Harry Nyquist. How would your conclusion survive a deliberately independent test of a distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent? A second receiver might share more of the supposed evidence than its separate enclosure

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suggests. The converter input may have frequency-dependent gain and phase even where digitiser throughput is adequate. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth and document which differences remain unexplained? Would you also state what observed change in front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth would invalidate the preferred account, and which aspect of map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates would make that negative result independently repeatable?

Harry Nyquist | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 022, the specific physical candidate is analogue amplitude roll-off, aperture response, filter group delay, and uncontrolled alias-band admission.

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The unresolved physical pathway is material: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. The retained record permits a conditional claim about front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, but cannot alone resolve nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. The converter input may have frequency-dependent gain and phase even where digitiser throughput is adequate. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins; I would challenge it with map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. Two responses consistent with an aliased interference feature moves according to a sampling-fold relation when the sample rate

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changes, unlike a true calibrated RF station would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, an actual in-band emitter and a higher nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. A discordant measurement would then be interpreted by tracing that difference through front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth; an agreement lacking such a dependency analysis is weak corroboration.

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Edwin Howard Armstrong | Principal contribution 2: The converter input may have frequency-dependent gain and phase even where digitiser throughput is adequate.

A receiver front end can fail the sampling model while its numerical downstream processing is flawless. Consider a high-level input just beyond an analogue filter's stopband knee. The ADC captures it and generates an alias inside the wanted observation band; subsequent digital filtering may be unable to distinguish that alias from a genuine in-band emitter. I would require a measured stopband profile under realistic source and load impedances, not simply a nominal drawing in the instrument manual. Strong-signal intermodulation may also create energy inside the admitted band before sampling, making it impossible for any anti-alias filter placed after the offending nonlinear stage to repair the record. The design should put appropriate protection and preselection ahead of the most vulnerable component. A controlled substitution of a higher-rejection input filter, paired with a reference injection, can test a specific aliasing explanation without claiming to have located the physical source.

In this control and stability examination of Question 022, the decisive claim is that the converter input may have frequency-dependent gain and phase even where digitiser throughput is adequate. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: sampling rate cannot undo a narrow analogue passband. A converter may satisfy a Nyquist sampling criterion for the desired digital bandwidth while the

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preceding amplifier or track-and-hold has already attenuated or distorted that same signal. Suppose a 200-megasample-per-second converter is preceded by an analogue response that is 3 dB down at 60 megahertz. A 70-megahertz component lies below the 100-megahertz real-sampling Nyquist frequency, but it cannot be assumed to have unity amplitude merely because the sampling rate admits it. The analogue transfer magnitude, phase and slew performance require calibration. Harmonics of a short pulse may be attenuated unevenly, producing a longer apparent envelope. A reconstruction algorithm cannot distinguish this deterministic bandwidth shaping from a source envelope without independent knowledge of the front end. Test representative transients at the input reference plane, including strong neighbouring signals. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by a distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note the converter input may have frequency-

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dependent gain and phase even where digitiser throughput is adequate. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, a distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Armstrong’s receiver engineering points to actual conversion products and oscillation conditions rather than abstract spectral indications; the crucial question is where the energy first appears. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. The order would be time-stamped and should include invalid intervals, receiver recovery, and any gain or filter settling rather than treating silence during transition as evidence of a silent source. Our central rival is specific: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. This predicts a response which should be tested against an aliased interference feature

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moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated rf station. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements discarded during retuning. Where nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting, the correct claim must name the operational states and the evidence available in each. Amplitude and phase response upstream of the converter determine what was admitted before sampling. Dr Pearson, please take the floor and examine whether our calibration actually covers the relevant RF range.

Egon Sharpe Pearson | Peer question 3 to Edwin Howard Armstrong

Edwin Howard Armstrong, your calibration argument invites a question about reference planes, especially because nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. The reference stimulus and the unknown emission need not occupy the same physical regime. Insufficient anti-alias rejection allows distant out-of-band signals to be folded into the displayed baseband. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When a distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate

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preselection and sample rates without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Edwin Howard Armstrong | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 022, the specific physical candidate is analogue amplitude roll-off, aperture response, filter group delay, and uncontrolled alias-band admission. The unresolved physical pathway is material: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. The retained record permits a conditional claim about front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, but cannot alone resolve nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth. Insufficient anti-alias rejection allows distant out-of-band signals to be folded into the displayed baseband. I

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would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates, with before-and-after values of front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth. If the instrument behaves as predicted, then an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. A distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

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Ralph Vinton Lyon Hartley | Peer question 4 to Edwin Howard Armstrong

There is an inferential difficulty, Edwin Howard Armstrong: an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. The population of admissible observations needs to be fixed before any confidence argument. In this situation, nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. An anti-alias filter must be assessed over all folds relevant to the investigated band rather than only at its nominal corner. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth would invalidate the preferred account, and which aspect of map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates would make that negative result independently repeatable?

Edwin Howard Armstrong | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by

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reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 022, the specific physical candidate is analogue amplitude roll-off, aperture response, filter group delay, and uncontrolled alias-band admission. The unresolved physical pathway is material: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. The retained record permits a conditional claim about front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, but cannot alone resolve nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because a distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent. I would distinguish trials selected in advance from those added after an unexpected peak appeared. An anti-alias filter must be assessed over all folds relevant to the investigated band rather than only at its nominal corner. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can

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legitimately examine map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins; its prediction should be recorded alongside an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a sampler cannot distinguish two analogue tones whose frequencies differ by an integer multiple of its sampling rate from samples alone. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Claude Elwood Shannon | Principal contribution 3: Insufficient anti-alias rejection allows distant out-of-band signals to be folded into the displayed baseband.

Aliasing is an example of two distinct analogue inputs yielding the same sampled sequence. Once they coincide at the converter output, no clever choice of FFT bins can reveal which input was historically present without independent information. This is why the bandwidth statement must accompany the analogue filter and its actual attenuation, not just the digital sample rate. A wide acquisition system may deliberately exploit under-sampling of a restricted band; that technique is sound only if the admissible analogue zones are adequately separated. If two RF bands are permitted through an imperfect preselector, their sampled representations can overlap exactly. The retained I/Q file can reveal the digital ambiguity, but it cannot unmix unknown external sources without additional assumptions. I would preserve the filter state, sample-clock measurement and calibrated amplitude response together with every purported in-band detection, so the later investigator can examine which analogue origin hypotheses remain open.

In this operational measurand examination of Question 022, the decisive claim is that insufficient anti-alias rejection allows distant out-of-band signals to be folded into the displayed baseband. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: sampling rate cannot undo a narrow analogue passband. A converter may satisfy a Nyquist sampling criterion for the desired digital bandwidth while the preceding amplifier or track-and-

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hold has already attenuated or distorted that same signal. Suppose a 200-megasample-per-second converter is preceded by an analogue response that is 3 dB down at 60 megahertz. A 70-megahertz component lies below the 100-megahertz real-sampling Nyquist frequency, but it cannot be assumed to have unity amplitude merely because the sampling rate admits it. The analogue transfer magnitude, phase and slew performance require calibration. Harmonics of a short pulse may be attenuated unevenly, producing a longer apparent envelope. A reconstruction algorithm cannot distinguish this deterministic bandwidth shaping from a source envelope without independent knowledge of the front end. Test representative transients at the input reference plane, including strong neighbouring signals. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The Nyquist condition constrains the spectral content admitted to sampling, not merely the highest frequency printed on a receiver's tuning display. An ADC operating at a suitable nominal sample rate may still produce a misleading baseband signal if its analogue front end passes energy outside the band for which the anti-alias response was designed. For a real sampler, frequencies separated by integer multiples of the sampling frequency can fold to the same discrete-time frequency. A particularly important trial injects a strong out-of-band tone that ought to be suppressed, then changes the sampling rate by a controlled amount. A folded artefact moves predictably with that change; a genuine in-band emission does not obey the same alias trajectory. The examiner should retain the anti-alias filter's measured transition band, stopband attenuation

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and behaviour under large blockers. Numerical reconstruction cannot identify which analogue frequency produced a digital alias when the necessary pre-sampling discrimination was absent. Accordingly, the laboratory record for Question 022 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. Shannon's information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, an sdr samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous output, an average over

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admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A sampler cannot distinguish two analogue tones whose frequencies differ by an integer multiple of its sampling rate from samples alone. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. I would therefore attach the uncertainty analysis to the *operational definition* itself instead of printing an unexplained confidence interval beside the most appealing trace.

A further, separately testable aspect of an sdr samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation concerns front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth. The proposed challenge would be map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. The decision is conditional upon the observed result, with particular attention to nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. The competing account remains an actual in-band emitter and a higher nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. An out-of-band carrier that folds into the sampled band may appear numerically identical to an in-band emission. Dr Turing, I pass the floor for the question of what auxiliary measurements would distinguish them.

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Alan Mathison Turing | Peer question 5 to Claude Elwood Shannon

Claude Elwood Shannon, I should like to examine what the recorded data actually preserve when an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. The physical input and the retained numerical array are not interchangeable things. A successful sample-retention audit cannot distinguish a rejected analogue event from true radio silence. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth would invalidate the preferred account, and which aspect of map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates would make that negative result independently repeatable?

Claude Elwood Shannon | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the

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actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 022, the specific physical candidate is analogue amplitude roll-off, aperture response, filter group delay, and uncontrolled alias-band admission. The unresolved physical pathway is material: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. The retained record permits a conditional claim about front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, but cannot alone resolve nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. I propose separating acquired information from model-dependent reconstruction. A successful sample-retention audit cannot distinguish a rejected analogue event from true radio silence. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input

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or omitted by the acquisition policy. The discriminating record would include front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth and a fresh trial in which the operator map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. If that trial demonstrates an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Hendrik Wade Bode | Principal contribution 4: An anti-alias filter must be assessed over all folds relevant to the investigated band rather than only at its nominal corner.

The combined anti-alias filter and converter form a frequency-dependent system, not a catalogue of independent parts. A sharp nominal filter can introduce phase distortion and ringing into short bursts; an apparently generous analogue bandwidth can admit interfering power that exhausts converter headroom. I would model the whole chain, including source impedance, gain compression, filter skirts and the sample-and-hold aperture response. With a swept calibrated tone, the investigator can measure the alias map and identify frequencies whose outputs coincide inside the analysis band. That map should be repeated at several input powers to reveal nonlinear effects that a small-signal transfer function misses. If a firmware update changes the digital channeliser, it will not alter the ambiguity created at the ADC, but it may change how the ambiguity is displayed. The source record must separate analogue admissibility from downstream numerical selectivity.

In this information retention examination of Question 022, the decisive claim is that an anti-alias filter must be assessed over all folds relevant to the investigated band rather than only at its nominal corner. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: sampling rate cannot undo a narrow analogue passband. A converter may satisfy a Nyquist sampling criterion for the desired digital bandwidth while the preceding amplifier or track-and-hold has already attenuated or distorted that same signal. Suppose a 200-

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megasample-per-second converter is preceded by an analogue response that is 3 dB down at 60 megahertz. A 70-megahertz component lies below the 100-megahertz real-sampling Nyquist frequency, but it cannot be assumed to have unity amplitude merely because the sampling rate admits it. The analogue transfer magnitude, phase and slew performance require calibration. Harmonics of a short pulse may be attenuated unevenly, producing a longer apparent envelope. A reconstruction algorithm cannot distinguish this deterministic bandwidth shaping from a source envelope without independent knowledge of the front end. Test representative transients at the input reference plane, including strong neighbouring signals. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. The scientific point of an anti-alias filter must be assessed over all folds relevant to the investigated band rather than only at its nominal corner. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions

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repeatedly show an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. A distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. The issue becomes especially sharp because an actual in-band emitter and a higher nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the

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proposed case, a sampler cannot distinguish two analogue tones whose frequencies differ by an integer multiple of its sampling rate from samples alone. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. Rejection has to be assessed at each relevant alias fold, including filter transitions and strong blockers. Dr Deming, I invite your challenge to a qualification procedure based on one convenient test tone.

W. Edwards Deming | Peer question 6 to Hendrik Wade Bode

I thank you, Hendrik Wade Bode, for distinguishing measurement from attribution, but the observation is that a distant strong carrier appears folded inside the monitored baseband although the visible spectrum looks internally consistent. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a sampler cannot distinguish two analogue tones whose frequencies differ by an integer multiple of its sampling rate from samples alone. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station on one day but fails after the instrument has been reconfigured? A nominal sample rate characterises a discrete-time operation and does not certify a preceding analogue transfer function. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

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Hendrik Wade Bode | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 022, the specific physical candidate is analogue amplitude roll-off, aperture response, filter group delay, and uncontrolled alias-band admission. The unresolved physical pathway is material: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. The retained record permits a conditional claim about front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, but cannot alone resolve nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a sampler cannot distinguish two analogue tones whose frequencies differ by an integer multiple of its sampling rate from samples alone. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. A nominal sample rate

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characterises a discrete-time operation and does not certify a preceding analogue transfer function. Its bearing on the dispute can be evaluated through the predicted response, namely an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station. Because an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins, the procedure map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match state which analogue zones were excluded experimentally before claiming an in-band emission, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. An aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Walter Andrew Shewhart | Principal contribution 5: A successful sample-retention audit cannot distinguish a rejected analogue event from true radio silence.

A declaration that the sampling rate is sufficient must specify the intended error event. The failure may be an undetected short burst, a false in-band tone created by aliasing, or an amplitude bias near the filter transition. Each requires a different validation statistic. I would stratify trials by the interfering signal's frequency, amplitude and temporal occupancy, then estimate how often the chosen detector misclassifies the analogue origin. Testing only nominally in-band tones would be incapable of establishing rejection of a strong out-of-band service. If the investigator chooses the most impressive frequency from a broad exploratory sweep, the resulting apparent rejection margin needs independent replication. Confidence intervals must also accommodate correlated observations from overlapping analysis windows. An effective front end is not certified by counting large numbers of apparently quiet FFT bins; it is certified against defined adversarial and ordinary operating conditions, with their tested limitations clearly disclosed.

In this statistical inference examination of Question 022, the decisive claim is that a successful sample-retention audit cannot distinguish a rejected analogue event from true radio silence. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: sampling rate cannot undo a narrow analogue passband. A converter may satisfy a Nyquist sampling criterion for

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the desired digital bandwidth while the preceding amplifier or track-and-hold has already attenuated or distorted that same signal. Suppose a 200-megasample-per-second converter is preceded by an analogue response that is 3 dB down at 60 megahertz. A 70-megahertz component lies below the 100-megahertz real-sampling Nyquist frequency, but it cannot be assumed to have unity amplitude merely because the sampling rate admits it. The analogue transfer magnitude, phase and slew performance require calibration. Harmonics of a short pulse may be attenuated unevenly, producing a longer apparent envelope. A reconstruction algorithm cannot distinguish this deterministic bandwidth shaping from a source envelope without independent knowledge of the front end. Test representative transients at the input reference plane, including strong neighbouring signals. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. A successful sample-retention audit cannot distinguish a rejected analogue event from true radio silence. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to map the analogue transfer function with a synthesised out-of-band sweep while

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repeating under alternate preselection and sample rates, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say state which analogue zones were excluded experimentally before claiming an in-band emission, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. An SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that an actual in-band emitter and a higher nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. One could stratify the experiment by

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nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated rf station, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a sampler cannot distinguish two analogue tones whose frequencies differ by an integer multiple of its sampling rate from samples alone, is not an estimate of any actual investigation. Preserving every digital sample cannot tell us whether the analogue prefilter suppressed a brief event. Sir Karl, the floor is yours to test what such a negative finding can establish.

Sir Karl Raimund Popper | Peer question 7 to Walter Andrew Shewhart

Walter Andrew Shewhart, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise state which analogue zones were excluded experimentally before claiming an in-band emission? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. The converter input may have frequency-dependent gain and phase even where digitiser throughput is adequate. Please connect front-end amplitude and phase response, alias frequency, stop-band attenuation

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and analogue input bandwidth with a declared detection threshold and the measurement exposure. If the experiment map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later. Would you also state what observed change in front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth would invalidate the preferred account, and which aspect of map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates would make that negative result independently repeatable?

Walter Andrew Shewhart | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 022, the specific physical candidate is analogue amplitude roll-off, aperture response, filter group delay, and uncontrolled alias-band admission. The unresolved physical pathway is material: An actual in-band emitter and a higher Nyquist-

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zone alias can occupy the same discrete-time frequency without identical analogue origins. The retained record permits a conditional claim about front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth, but cannot alone resolve nyquist sampling conditions depend on the admitted analogue spectrum, not merely on the digital clock setting. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. The converter input may have frequency-dependent gain and phase even where digitiser throughput is adequate. I would use the observations of front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates, not an assertion based on the operator's impression of a quiet display. If it yields an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station, we may describe a conditional exclusion of the challenged

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mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since an actual in-band emitter and a higher nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to state which analogue zones were excluded experimentally before claiming an in-band emission, with the untested physical possibilities made visible.

Harry Nyquist, Cross-Peer Question to Edwin Howard Armstrong: Dr Armstrong, suppose the acquisition clock supplies thirty-five million samples per second, yet a transmitter at 110.950 MHz appears at the 5.950 MHz sampled coordinate. An investigator sees a strong single spectral line and declares a local 5.950 MHz emitter. What experiment distinguishes a genuinely admitted analogue signal from a remote out-of-band source that survives imperfect preselection? How would you prevent the filtering experiment itself from changing gain and therefore confusing the attribution?

Edwin Howard Armstrong, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the folding calculation identifies an equivalence class of possible analogue frequencies, not an emitter. First document the exact sample rate, tuner configuration, analogue band edges, mixer states and filter switching chronology. Inject traceable signals at the disputed coordinate and at every

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plausible folding zone, recording attenuation, return loss and receiver linearity at the input reference plane. A switchable, physically independent preselector can be useful, but its insertion loss must be measured and normalised, and the injection system must not bypass an unintended coupling path. Attenuating the actual 110.950 MHz stimulus while maintaining the desired-band reference provides a stronger falsification test than watching the screen trace alone. Cross-check using a receiver whose analogue conversion plan maps the competing candidates to different output coordinates. A vanished line after installing a filter does not, by itself, prove the identity or location of the emitter; it establishes behaviour under a controlled change. I respectfully pass the floor to Dr Bode for a question about stopband characterisation.

Claude Elwood Shannon, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, a laboratory cites its sampling theorem but supplies only a single anti-alias-filter corner frequency. The front end has nonlinear active stages and poor rejection in an untested Nyquist zone; a 1,098.633 Hz Fourier grid gives a persuasive-looking narrow line. Which transfer characteristics must be shown before the digital frequency coordinate can be used to exclude an out-of-band cause, and how should an uncertainty budget treat the ambiguity?

Hendrik Wade Bode, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, a passband corner is not a stopband specification. Obtain the complex analogue transfer function, including rejection versus frequency, component tolerance, temperature, gain state, impedance mismatch, and high-level behaviour. Injection tests should traverse analogue frequency intervals that fold into the alleged line, and should cover realistic blocker

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powers, harmonics, and intermodulation products. The 1,098.633 Hz quantity is a bin spacing computed from a sample rate and transform length; it does not certify the analogue frequency response or prove statistical independence between overlapping records. A narrow displayed peak can therefore be precise in the coordinate system of the sampler yet ambiguous as to its analogue parent frequency. Treat any unmeasured fold as an unresolved alternative hypothesis, not as a small symmetric error bar that could be added in quadrature. Explicitly separate calibrated amplitude uncertainty from structural ambiguity about source identity. I respectfully pass the floor to Dr Shewhart for a challenge concerning an apparently silent observation.

John Wilder Tukey, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, the operator reports hundreds of spectral visits without a detection, but the analogue path has an unverified frequency-response notch and the records cover only 2.36 percent of the nominal elapsed interval. May this negative result be described as evidence that the searched transmitter was absent, or must the experiment be redesigned so that non-observation remains interpretable?

Walter Andrew Shewhart, Cross-Peer Answer to John Wilder Tukey: Dr Tukey, this is a problem of measurement opportunity before it is a problem of statistical significance. A valid negative test requires a demonstrated detection probability for the specified signal, at the specified input frequency, duty cycle, amplitude and blocker condition. The receiver must be challenged in precisely the gain and preselector state used during collection, with time-stamped reference injections and independent checks of sample continuity. Four point seven five eight seconds of admitted

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observations across a 201.30-second nominal span do not license claims about the unsampled intervals. A notch can make a perfectly stored FFT sequence blind to an active source. Assign separate status to intervals where the instrument is demonstrably sensitive, intervals where sensitivity is untested, and intervals where it has actually failed. Report the provenance of any model for event arrival time and correlation between visits; do not infer independent Bernoulli trials merely from the number of displayed frames. I respectfully pass the floor to Dr Hartley to address a converter limitation that may coexist with aliasing.

Richard Wesley Hamming, Cross-Peer Question to Ralph Vinton Lyon Hartley: Dr Hartley, consider the illustrative 275 MHz input observed with 1.74 picoseconds of rms aperture jitter. A calculated ideal jitter limit of about 50.44 dB seems to imply only a handful of reliable amplitude bits, yet the selected 9 MS/s processing rate advertises a much narrower discrete spectrum. How would you distinguish analogue bandwidth, sampling-clock sensitivity, nominal converter bits and genuinely measured effective resolution?

Ralph Vinton Lyon Hartley, Cross-Peer Answer to Richard Wesley Hamming: Dr Hamming, the relevant frequency in the idealised jitter relation is the analogue sinusoid presented to the sampling aperture, not the apparent alias coordinate after sampling. At 275 MHz, a 1.74-ps time error changes sampled amplitude more than the same error at a low-frequency input; the approximately 50.44-dB result is a modelled noise limit for a particular jitter assumption, not an ENOB certificate. Converter harmonic distortion, input-network phase error, front-end noise, blocking and clock correlation may all reduce achieved performance. Conversely, narrowband coherent processing

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may improve detection of a tone without increasing the instantaneous information content or nominal bit depth of each sample. Characterise the complete analogue passband and clock phase-noise integration, measure actual SINAD over the relevant frequency and signal-level grid, and retain unprocessed acquisition records. I respectfully return the discussion token to Dr Atkinson for the moderator's synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of limits imposed by the analogue front-end when sampling rate is superficially sufficient has established a point which the specialist must not overlook. The receiver records digitised spectral or transient data from a physically band-limited converter input; it does not, merely by drawing a clear trace, give direct access to the rejected, attenuated, phase-distorted, or overloaded components before sampling. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, A nominal sample rate characterises a discrete-time operation and does not certify a preceding analogue transfer function. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

The anti-alias filter is a physical boundary, not a mathematical annotation placed on an FFT plot after sampling. A tone originating outside the admitted frequency range can fold to a perfectly plausible in-band coordinate when attenuation is insufficient, and an internal spur can occupy

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the same coordinate. The elementary alias formula supplies candidate locations but says nothing about which corresponding analogue frequencies were present. To test the asserted origin, the examiner must characterise rejection over the relevant stopband, vary the sampling frequency where practicable and check whether the observed feature moves according to the predicted fold. I thank the contributors for insisting that a sampled spectrum cannot be interpreted without the preceding analogue transfer. The result should identify the aliases excluded by measured attenuation, not assume that every bright spectral bin represents an in-band source. Any remaining alternative should be recorded with its possible analogue frequency range and the physical conditions under which it could evade the filter.

The sampled feature is compatible with an alias of an out-of-band signal, but several RF predecessors may map into the same digital bin. The measured anti-alias rejection mask and challenge results must be preserved with the spectrum. The more useful outcome is a discriminating protocol: Map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. In applying it, the examiner must retain all readings supporting front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth and identify the physical plane to which the measurements refer. At the outset of the investigation, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation; that circumstance makes the alternative mechanism material, specifically an actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency

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without identical analogue origins. A result approaching an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated RF station may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore state which analogue zones were excluded experimentally before claiming an in-band emission. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

An anti-alias assurance statement concerns the physically excluded input bands under demonstrated operating conditions. It should not imply that an apparent baseband feature uniquely identifies its unobserved radio-frequency predecessor. The decisive experiment is concrete: Map the analogue transfer function with a synthesised out-of-band sweep while repeating under alternate preselection and sample rates. In conducting it, the examiner must explicitly retain front-end amplitude and phase response, alias frequency, stop-band attenuation and analogue input bandwidth. If the outcome matches the stated prediction, an aliased interference feature moves according to a sampling-fold relation when the sample rate changes, unlike a true calibrated rf station, the supported conclusion concerns that test domain. An alternative remains: An actual in-band emitter and a higher Nyquist-zone alias can occupy the same discrete-time frequency without identical analogue origins. I thank the contributors

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for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 022

Application 01. Alias-location prediction and its non-unique inverse

In the illustrative 022.01 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. For an actual sampling frequency f_s = 35 MHz and analogue input f_i = 110.950 MHz, the nearest-replica folding rule gives $f_a = |f_i - \text{round}(f_i/f_s)f_s|$ = 5.950 MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. The 5.950-MHz alias is a sampled coordinate only. Confirm which analogue Nyquist zone actually contributed by swept, calibrated input injection and independent preselection before attributing an emitter.

Application 02. Filter or cable rejection referred to a physical input

In the illustrative 022.02 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. For an admitted input P_i = -49 dBm and separately measured loss L = 30 dB, the linear prediction is $P_o = P_i - L$ = -79 dBm. In SI power this becomes 10^((-79 − 30)/10) = 1.26e-11 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. The 1.26×10^{-11} W conversion assumes -79 dBm at the stated matched reference plane. An attenuation value does not establish stopband protection at every possible folding frequency.

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Application 03. Cascade gain and observed headroom

In the illustrative 022.03 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. A first amplifier contributes G_1 = 15 dB, an intentional attenuation contributes G_2 = -4 dB, and a later stage contributes G_3 = 17 dB. The small-signal sum is 15 + (-4) + 17 = 28 dB. For P_i = -74 dBm, the ideal output is P_o = -46 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The -46 dBm estimate applies only to a linear cascade. Record each intermediate stage level and check blocker-induced compression before using the overall gain as a sensitivity certificate.

Application 04. Thermal reference noise in a declared measurement bandwidth

In the illustrative 022.04 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. Take the equivalent noise bandwidth B = 2,250 Hz and calibrated noise figure NF = 3.05 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF$ = -137.43 dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The -137.43 dBm value is the integrated thermal-reference estimate for 2,250 Hz ENBW at 290 K; it neither includes out-of-band alias noise nor establishes the actual environmental noise floor.

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Application 05. Group delay from a local phase-versus-frequency slope

In the illustrative 022.05 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. Across a local frequency step $\Delta f = 0.90$ MHz, suppose unwrapped transmission phase changes by $\Delta\varphi = -0.410$ rad. The finite-difference group-delay estimate is $\tau g \approx -\Delta\varphi/(2\pi\Delta f) = 72.504$ ns. This is an average local slope. Dispersive responses require a finer phase sweep, a consistent unwrapping method and uncertainty treatment before extrapolating transient arrival times. The 72.504 ns figure is a local finite-difference group-delay estimate. Its uncertainty and possible phase-wrapping error must be assessed before any transient arrival-time reconstruction.

Application 06. Frequency-bin spacing versus independent information

In the illustrative 022.06 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. With sampled bandwidth $f_s = 9$ MS/s and $N = 8{,}192$ transform samples, the discrete-frequency grid is $\Delta f = f_s/N = 1098.633$ Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. The 1,098.633 Hz quantity is a discrete Fourier-bin spacing, not a guarantee of independent

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resolution, temporal event capture or adequate analogue anti-alias suppression.

Application 07. The frequency dependence of aperture-jitter-limited SNR

In the illustrative 022.07 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. At sinusoidal input frequency f = 275 MHz with uncorrelated rms aperture jitter σ_t = 1.74 ps, the idealised jitter-imposed ceiling is $SNR_j = -20 \log_{10}(2\pi f \sigma_t)$ = 50.44 dB. A common clock source may correlate errors across parallel ADC channels, so treating their outputs as independent for noise cancellation would need an additional experiment. Converter nonlinearity and thermal noise can make actual performance worse. The 50.44 dB result is an idealised jitter-related SNR ceiling at the true 275 MHz analogue input. It cannot be inferred from a lower-frequency alias bin or used as a converter ENOB certificate.

Application 08. Combined and expanded measurement uncertainty

In the illustrative 022.08 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. For independent standard-uncertainty contributions 0.52, 0.54 and 0.31 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.52^2 + 0.54^2 + 0.31^2)}$ = 0.811 units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c$ = 1.622 units. The 0.811-unit standard and 1.622-unit expanded uncertainties require independent, same-unit inputs and the

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declared k = 2. Correlated errors or untested analogue zones remain separate qualifications.

Application 09. Observed exposure fraction of a channel scanner

In the illustrative 022.09 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. Let the channel be observed on n = 366 valid visits, each lasting d = 13 ms, with revisit spacing R = 0.55 s. Valid exposure is nd/1000 = 4.758 s across the nominal interval nR = 201.30 s. The observed fraction of elapsed time is therefore 2.36%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. The 4.758 seconds of valid exposure represent about 2.36 percent of the 201.30-second nominal span. This duty fraction limits a negative finding and supplies no emitter-occupancy estimate.

Application 10. Gain allocation and blocker headroom

In the illustrative 022.10 test, an SDR samples rapidly enough for the intended instantaneous passband but uses an analogue input network with poorly measured out-of-band attenuation. Assume a calibrated digital full-scale equivalent of -10 dBm, a blocker applied at -40 dBm, and net analogue gain 27 dB. The projected converter input is -13 dBm and remaining margin is -10 − (-13) = 3 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. The three-decibel projected converter headroom is a small-signal estimate. Strong out-of-band blockers, instantaneous crest factor

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and upstream saturation may invalidate it even where the screen stays below full scale.

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

National Institute of Standards and Technology, TN 1297, sections 5–7: combined uncertainty and reporting, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-7-reporting-uncertainty (consulted 11 November 2026).

“Basics of Band-Limited Sampling and Aliasing” (2005), https://www.analog.com/en/resources/technical-articles/basics-of-bandlimited-sampling-and-aliasing.html (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 023

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How can saturation and recovery effects create false pulse histories?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 023 asks: How can saturation and recovery effects create false pulse histories? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is the false chronology that can result from analogue overload and recovery memory. Our primary observation is clipped, delayed, or spurious bursts after a high-power input event; by contrast, what remains unseen is the input waveform during overload and the settling state of upstream capacitors and control loops. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Overload memory can counterfeit multiple events. An amplifier or limiter can remain disturbed after a strong pulse has departed. The resulting baseline shift, automatic-gain recovery or filter ringing can cross an event

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detector’s threshold more than once. If a recovery constant is 2 milliseconds, the envelope of a simple first-order relaxation falls to about 37 per cent of its initial deviation after 2 milliseconds and about 5 per cent after 6 milliseconds; actual receiver recovery may involve several nonlinear states. Apparent secondary pulses at those delays should therefore be challenged with controlled strong-signal injections while monitoring gain-control registers and the analogue output. A detector’s count of threshold crossings is not automatically a count of separate radiation events. Report dead time, clipping intervals, pre-trigger data and the precise criterion by which separate pulse episodes were declared. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns clipped, delayed, or spurious bursts after a high-power input event; it is not interchangeable with the input waveform during overload and the settling state of upstream capacitors and control loops. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is stepped overdrive with calibrated recovery-time logging and a second independent low-gain path. A claim drawn from that comparison has to carry its actual uncertainties: compression onset, overload duration, recovery constant, minimum resolvable inter-event gap. An amplifier can retain memory of a previous strong signal through bias networks and stored charge. Automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission. Transient clipping can resemble a sequence of pulses after filtering and windowing

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even if the input contained only one event. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Edwin Howard Armstrong | Principal contribution 1: An amplifier can retain memory of a previous strong signal through bias networks and stored charge.

A receiver can continue making a signal after its input has stopped because energy remains stored in tuned circuits and control networks. A large blocker might drive a limiter into compression, charge coupling capacitors or force automatic gain reduction. When that blocker disappears, a ringing IF filter or recovering bias network can create several transient maxima even though no new RF burst entered the aerial. I would challenge the receiver with one precisely gated high-power pulse and measure the output through a controlled, source-confirmed silent interval. The sequence should be repeated with a shielded termination, then with the antenna and cable attached, to distinguish internal recovery from external multipath. An amplitude-dependent tail would be particularly important, because an impulse response measured at a tiny signal level cannot characterise a saturated stage. We should not interpret a cluster of digital pulse detections as multiple emitters before testing the instrument's physical memory.

In this physical path examination of Question 023, the decisive claim is that an amplifier can retain memory of a previous strong signal through bias networks and stored charge. Overload introduces memory into a receiver that is absent from a simple steady-state gain figure. A high-power transient may drive an amplifier, detector or automatic-gain controller into a state which remains abnormal after the inducing carrier has departed. A quiet display during that interval cannot be interpreted as a quiet RF environment, because the instrument may be temporarily insensitive. Recovery must therefore be characterised as a function of the preceding

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blocker amplitude, duration and signal history, not by a single nominal settling-time specification. A useful falsification proceeds from the actual controversy: overload memory can counterfeit multiple events. An amplifier or limiter can remain disturbed after a strong pulse has departed. The resulting baseline shift, automatic-gain recovery or filter ringing can cross an event detector's threshold more than once. If a recovery constant is 2 milliseconds, the envelope of a simple first-order relaxation falls to about 37 per cent of its initial deviation after 2 milliseconds and about 5 per cent after 6 milliseconds; actual receiver recovery may involve several nonlinear states. Apparent secondary pulses at those delays should therefore be challenged with controlled strong-signal injections while monitoring gain-control registers and the analogue output. A detector's count of threshold crossings is not automatically a count of separate radiation events. Report dead time, clipping intervals, pre-trigger data and the precise criterion by which separate pulse episodes were declared. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Inject a stepped, time-limited blocker while a calibrated weak test tone remains present. Record the onset of compression, the last saturated sample and the return of the weak tone to a specified detection probability. Repeat over several blocker lengths and with automatic gain control enabled and disabled. Fit a simple exponential only if the measured recovery supports it; multi-rate or hysteretic behaviour should be reported as such. The capture should include state-change telemetry and the location of every acquisition gap. I would take P1dB, overload pulse duration, gain-control

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time constant, settling curve and minimum separable event gap as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: An amplifier can retain memory of a previous strong signal through bias networks and stored charge. A response consistent with a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. A nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by bias-network settling and

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automatic gain-control memory can imitate delayed rf events or conceal genuinely present weak energy, and measure their behaviour separately before reconnecting the assembled system. Armstrong's receiver engineering points to actual conversion products and oscillation conditions rather than abstract spectral indications; the crucial question is where the energy first appears. It is therefore material to establish P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap rather than infer them from a single scalar output. The limiting test is concrete: Apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. If the intervention produces a recovery artefact follows the overload event and changes with receiver bias or agc settings, even with the weak test signal held constant, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret the waterfall contains delayed echoes and an apparently silent interval following the blocker as a new transmitter before challenging the most economical instrumental explanation. Amplifier bias networks can retain the history of a strong input after the visible carrier has disappeared. Professor Tukey, please take the floor and scrutinise whether our event selection wrongly labels recovery artefacts as transmissions.

John Wilder Tukey | Peer question 1 to Edwin Howard Armstrong

Edwin Howard Armstrong, may I test the exact physical inference in your account of a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the

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subsequent recovery interval? The proposed mechanism appears plausible only if changes after apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control are compared with a stable reference condition. An amplifier can retain memory of a previous strong signal through bias networks and stored charge. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap which would settle that narrower claim, rather than a visual impression of improvement.

Edwin Howard Armstrong | Immediate answer to John Wilder Tukey

Dr Tukey, the apparent disappearance of the weak signal cannot be attributed to the transmitter unless the receiver has demonstrated sensitivity throughout the period. I would keep an independent low-gain reference path active while inducing overload on the main channel. The reference would show whether the candidate emission continues while the principal receiver recovers, and its own limitations must also be disclosed. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder.

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The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 023, the specific physical candidate is saturation of gain stages, automatic gain-control hang time, amplifier slew limiting, and converter clipping. The unresolved physical pathway is material: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. The retained record permits a conditional claim about P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, but cannot alone resolve an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. An amplifier can retain memory of a previous strong signal through bias

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networks and stored charge. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control, and only a response matching a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Edwin Howard Armstrong

I appreciate your explanation, Edwin Howard Armstrong. How would your conclusion survive a deliberately independent test of the waterfall contains delayed echoes and an apparently silent interval following the blocker? A second receiver might share more of the supposed evidence

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than its separate enclosure suggests. Automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap and document which differences remain unexplained? Would you also state what observed change in P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap would invalidate the preferred account, and which aspect of apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control would make that negative result independently repeatable?

Edwin Howard Armstrong | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 023, the specific physical candidate is saturation of gain stages, automatic

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gain-control hang time, amplifier slew limiting, and converter clipping. The unresolved physical pathway is material: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. The retained record permits a conditional claim about P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, but cannot alone resolve an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. Automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy; I would challenge it with apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. Two responses consistent with a recovery

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artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, bias-network settling and automatic gain-control memory can imitate delayed rf events or conceal genuinely present weak energy. A discordant measurement would then be interpreted by tracing that difference through P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap; an agreement lacking such a dependency analysis is weak corroboration.

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Walter Andrew Shewhart | Principal contribution 2: Automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission.

The investigator should preserve the order and duration of the events that appear to change the receiver's state. A chart may show an intense pulse followed by two weaker indications and a temporarily depressed floor. Such a pattern could be produced by a legitimate transmission followed by gain-control recovery. I would define a reference stimulus sequence and obtain many runs with different blocker widths and gaps, recording gain state, clipping flags, and any reset or hold-off commands. Then construct a control chart for recovery time and residual transient amplitude, allowing for systematic variation with temperature. If a new anomaly appears only during one mode transition, it should not be averaged together with settled-state operation. Equally, a perfectly repeatable recovery defect is still a defect rather than proof of an external second transmission. The report should retain raw traces for all runs, including the ones whose inconvenient behaviour contradicts the operator's initial interpretation.

In this control and stability examination of Question 023, the decisive claim is that automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: overload memory can counterfeit multiple events. An amplifier or limiter can remain disturbed after a strong pulse has departed. The resulting baseline shift, automatic-

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gain recovery or filter ringing can cross an event detector's threshold more than once. If a recovery constant is 2 milliseconds, the envelope of a simple first-order relaxation falls to about 37 per cent of its initial deviation after 2 milliseconds and about 5 per cent after 6 milliseconds; actual receiver recovery may involve several nonlinear states. Apparent secondary pulses at those delays should therefore be challenged with controlled strong-signal injections while monitoring gain-control registers and the analogue output. A detector's count of threshold crossings is not automatically a count of separate radiation events. Report dead time, clipping intervals, pre-trigger data and the precise criterion by which separate pulse episodes were declared. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by the waterfall contains delayed echoes and an apparently silent interval following the blocker. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For

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each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, the waterfall contains delayed echoes and an apparently silent interval following the blocker. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. The order would be time-stamped and should include invalid intervals, receiver recovery, and any gain or filter settling rather than treating silence during transition as evidence of a silent source. Our central rival is specific: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. This predicts a response which should be tested against a recovery artefact follows the overload event and changes with receiver bias or agc settings, even with the weak test signal held constant. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements

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discarded during retuning. Where an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample, the correct claim must name the operational states and the evidence available in each. The interval during which automatic gain control recovers is a separate exposure condition, not an invisible pause. Dr Pearson, I invite you to question any detection-rate estimate that neglects it.

Egon Sharpe Pearson | Peer question 3 to Walter Andrew Shewhart

Walter Andrew Shewhart, your calibration argument invites a question about reference planes, especially because an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. The reference stimulus and the unknown emission need not occupy the same physical regime. Transient clipping can resemble a sequence of pulses after filtering and windowing even if the input contained only one event. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When the waterfall contains delayed echoes and an apparently silent interval following the blocker, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

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Walter Andrew Shewhart | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 023, the specific physical candidate is saturation of gain stages, automatic gain-control hang time, amplifier slew limiting, and converter clipping. The unresolved physical pathway is material: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. The retained record permits a conditional claim about P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, but cannot alone resolve an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap. Transient clipping can resemble a sequence of pulses after filtering and windowing even if the input contained only one event. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be apply reproducible blocker

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pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control, with before-and-after values of P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap. If the instrument behaves as predicted, then a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. The waterfall contains delayed echoes and an apparently silent interval following the blocker. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Walter Andrew Shewhart

There is an inferential difficulty, Walter Andrew Shewhart: bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. The population of admissible observations needs to be fixed before any confidence argument. In this situation, an overload record is a nonlinear history-

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dependent measurement, not a stable linear gain correction applied to the current sample. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Testing only steady-state compression omits the timing and history dependence that controls forensic interpretation. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap would invalidate the preferred account, and which aspect of apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control would make that negative result independently repeatable?

Walter Andrew Shewhart | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 023, the specific physical candidate is saturation of gain stages, automatic gain-control hang time, amplifier slew limiting, and

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converter clipping. The unresolved physical pathway is material: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. The retained record permits a conditional claim about P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, but cannot alone resolve an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because the waterfall contains delayed echoes and an apparently silent interval following the blocker. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Testing only steady-state compression omits the timing and history dependence that controls forensic interpretation. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy; its prediction should be recorded alongside a recovery artefact follows

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the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. An overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, five nominal time constants reduce a first-order residue to about 0.67 per cent, without proving that an actual multistage receiver follows one exponential. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Norbert Wiener | Principal contribution 3: Transient clipping can resemble a sequence of pulses after filtering and windowing even if the input contained only one event.

The underlying system includes control loops that react to the measured amplitude. When a strong input triggers attenuation, the resulting digital record partly describes the control law rather than simply the incident radio field. A weak transmission during the hold interval may vanish, and the spectrum's later return may look like the commencement of an independent emission. I would model the gain controller as a state-dependent filter, identifying trigger threshold, attack time, release time and any history-dependent hysteresis. The experiment should deliver the same weak test pulse at systematically varied delays after a strong blocker, with a second independent receiver monitoring the test source. If detections fail only during known recovery states, one has evidence of measurement blindness. The distinct physical claim that the emitter fell silent would require external corroboration. Event counters without controller-state history can turn a continuous physical signal into a fragmented narrative of apparently separate bursts.

In this operational measurand examination of Question 023, the decisive claim is that transient clipping can resemble a sequence of pulses after filtering and windowing even if the input contained only one event. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: overload memory can counterfeit multiple events. An amplifier or limiter can remain disturbed after a strong pulse has departed. The resulting baseline shift, automatic-

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gain recovery or filter ringing can cross an event detector’s threshold more than once. If a recovery constant is 2 milliseconds, the envelope of a simple first-order relaxation falls to about 37 per cent of its initial deviation after 2 milliseconds and about 5 per cent after 6 milliseconds; actual receiver recovery may involve several nonlinear states. Apparent secondary pulses at those delays should therefore be challenged with controlled strong-signal injections while monitoring gain-control registers and the analogue output. A detector’s count of threshold crossings is not automatically a count of separate radiation events. Report dead time, clipping intervals, pre-trigger data and the precise criterion by which separate pulse episodes were declared. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Saturation creates an asymmetric history because recovery after an overload can outlast the waveform that caused it. Limiting amplifiers, bias networks, automatic-gain-control loops and converters can each produce a different settling signature. A strong pulsed blocker may therefore be followed by apparent weak pulses or a temporary absence of normally detectable signals, even though neither phenomenon existed at the antenna port. Establish a reference pulse train with independently known amplitude and spacing, then increase a separate blocker until the suspect receiver enters compression. Observe the timing of baseline recovery, gain-control telemetry and the reappearance of the weak witness. Repeat with manual gain and, where available, a preselector that attenuates the blocker before the nonlinear stage. A detector's reported pulse timestamps are trustworthy only over the time interval in which analogue and digital states were valid.

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Data acquired during overload and recovery should be flagged, not quietly counted as ordinary negative observations. Accordingly, the laboratory record for Question 023 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. An overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. Wiener's feedback perspective questions how an adaptive controller changes the distribution of the observations it subsequently presents as independent evidence. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a

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latent physical parameter. The illustrative case is instructive: Five nominal time constants reduce a first-order residue to about 0.67 per cent, without proving that an actual multistage receiver follows one exponential. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. Clipped peaks can reappear as a procession of apparent pulses after filtering and windowing. Dr Turing, I pass the floor to examine what evidence distinguishes a generated pattern from the received waveform.

Alan Mathison Turing | Peer question 5 to Norbert Wiener

Norbert Wiener, I should like to examine what the recorded data actually preserve when a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. The physical input and the retained numerical array are not interchangeable things. A separate path operated below overload can disclose whether the apparent later pulse existed externally. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap would

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invalidate the preferred account, and which aspect of apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control would make that negative result independently repeatable?

Norbert Wiener | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 023, the specific physical candidate is saturation of gain stages, automatic gain-control hang time, amplifier slew limiting, and converter clipping. The unresolved physical pathway is material: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. The retained record permits a conditional claim about P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, but cannot alone resolve an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire

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analogue environment. An overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. I propose separating acquired information from model-dependent reconstruction. A separate path operated below overload can disclose whether the apparent later pulse existed externally. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap and a fresh trial in which the operator apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. If that trial demonstrates a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-

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gain channel as a control. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Hendrik Wade Bode | Principal contribution 4: Testing only steady-state compression omits the timing and history dependence that controls forensic interpretation.

There are at least two relevant time constants in the apparent pulse history: those of the RF and IF signal path and those of the receiver's control or supply networks. A phase response measured on a network analyser may characterise small-signal filter delay but say little about recovery from overload. I would investigate the latter with controlled power steps and a recorded waveform at several accessible internal nodes. If the preselector remains linear but a subsequent amplifier exhibits baseline wander after saturation, the source of delayed maxima can be localised. A separate bias-network recovery may imitate an emitter's change in duty cycle, while residual stored energy in a filter can produce decaying oscillations. The physical sequence of component states matters; a single global 'dead time' number can conceal multiple mechanisms with distinct dependencies on blocker frequency, amplitude and duration. Traceability of those measurements should determine which historical input claims the system can support.

In this information retention examination of Question 023, the decisive claim is that testing only steady-state compression omits the timing and history dependence that controls forensic interpretation. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: overload memory can counterfeit multiple events. An amplifier or limiter can remain disturbed after a strong pulse has departed. The resulting baseline shift, automatic-gain recovery or filter ringing can

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cross an event detector's threshold more than once. If a recovery constant is 2 milliseconds, the envelope of a simple first-order relaxation falls to about 37 per cent of its initial deviation after 2 milliseconds and about 5 per cent after 6 milliseconds; actual receiver recovery may involve several nonlinear states. Apparent secondary pulses at those delays should therefore be challenged with controlled strong-signal injections while monitoring gain-control registers and the analogue output. A detector's count of threshold crossings is not automatically a count of separate radiation events. Report dead time, clipping intervals, pre-trigger data and the precise criterion by which separate pulse episodes were declared. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. The scientific point of testing only steady-state compression omits the timing and history dependence that controls forensic interpretation. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions

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repeatedly show a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. The waterfall contains delayed echoes and an apparently silent interval following the blocker. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. The issue becomes especially sharp because bias-network settling and automatic gain-control memory can imitate delayed rf events or conceal genuinely present weak energy. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the proposed case, five nominal time constants

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reduce a first-order residue to about 0.67 per cent, without proving that an actual multistage receiver follows one exponential. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A further, separately testable aspect of a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval concerns P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap. The proposed challenge would be apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. The decision is conditional upon the observed result, with particular attention to an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. The competing account remains bias-network settling and automatic gain-control memory can imitate delayed rf events or conceal genuinely present weak energy. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. A steady-state compression measurement misses the recovery trajectory of a stage with stored charge. Dr Deming, please take the floor and demand the transient test that would expose it.

W. Edwards Deming | Peer question 6 to Hendrik Wade Bode

I thank you, Hendrik Wade Bode, for distinguishing measurement from attribution, but the observation is that the waterfall contains delayed echoes and an apparently silent interval following the blocker. A

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forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: five nominal time constants reduce a first-order residue to about 0.67 per cent, without proving that an actual multistage receiver follows one exponential. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant on one day but fails after the instrument has been reconfigured? An amplifier can retain memory of a previous strong signal through bias networks and stored charge. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

Hendrik Wade Bode | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 023, the specific physical candidate is saturation of gain stages, automatic gain-control hang time, amplifier slew limiting, and converter clipping. The unresolved physical pathway is material: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present

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weak energy. The retained record permits a conditional claim about P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, but cannot alone resolve an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, five nominal time constants reduce a first-order residue to about 0.67 per cent, without proving that an actual multistage receiver follows one exponential. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. An amplifier can retain memory of a previous strong signal through bias networks and stored charge. Its bearing on the dispute can be evaluated through the predicted response, namely a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant. Because bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy, the procedure apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match

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limit any negative finding to the periods when the instrument was demonstrably recovered and sensitive, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. A recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: A separate path operated below overload can disclose whether the apparent later pulse existed externally.

A negative search conducted during recovery is not equivalent to a negative search with the receiver fully responsive. The operational population must therefore distinguish valid exposure windows from intervals in which the front end is known to be saturated or recovering. Suppose the test pulse is present on an independent channel but missed by the survey receiver for the first twenty milliseconds after a blocker. The finding should estimate detection performance conditional on time since overload, not dilute the deficiency by averaging across many undisturbed seconds. Confidence calculations must acknowledge correlations among repeated tests that share the same temperature, supply and bias conditions. I would also test alternative explanations: an external pulsed source with similar timing, a cable reflection and an overloaded detector algorithm. A clear report states which explanation was challenged and at what power. It does not equate a visually orderly timeline with a fully observed electromagnetic history.

In this statistical inference examination of Question 023, the decisive claim is that a separate path operated below overload can disclose whether the apparent later pulse existed externally. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: overload memory can counterfeit multiple events. An amplifier or limiter can remain disturbed after a strong

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pulse has departed. The resulting baseline shift, automatic-gain recovery or filter ringing can cross an event detector's threshold more than once. If a recovery constant is 2 milliseconds, the envelope of a simple first-order relaxation falls to about 37 per cent of its initial deviation after 2 milliseconds and about 5 per cent after 6 milliseconds; actual receiver recovery may involve several nonlinear states. Apparent secondary pulses at those delays should therefore be challenged with controlled strong-signal injections while monitoring gain-control registers and the analogue output. A detector's count of threshold crossings is not automatically a count of separate radiation events. Report dead time, clipping intervals, pre-trigger data and the precise criterion by which separate pulse episodes were declared. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. A separate path operated below overload can disclose whether the apparent later pulse existed externally. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control, should be accompanied by a

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second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say limit any negative finding to the periods when the instrument was demonstrably recovered and sensitive, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman’s statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that bias-network settling and automatic gain-control memory can imitate delayed rf events or conceal genuinely present weak energy. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate

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sensitivity for each physically meaningful regime. The relevant quantities are P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from a recovery artefact follows the overload event and changes with receiver bias or agc settings, even with the weak test signal held constant, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, five nominal time constants reduce a first-order residue to about 0.67 per cent, without proving that an actual multistage receiver follows one exponential, is not an estimate of any actual investigation. An unsaturated parallel path may reveal whether a later burst existed outside the overloaded receiver. Sir Karl, I invite you to probe the limits of that independent corroboration.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise limit any negative finding to the periods when the instrument was demonstrably recovered and sensitive? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission. Please connect P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap with a declared detection threshold and the measurement exposure. If the experiment apply reproducible

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blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 023, the specific physical candidate is saturation of gain stages, automatic gain-control hang time, amplifier slew limiting, and converter clipping. The unresolved physical pathway is material: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. The retained record permits a conditional claim about P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap, but cannot alone resolve an overload record is a nonlinear history-dependent measurement, not a stable linear gain correction applied to the current sample. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Automatic gain control may suppress weak emissions while recovering from a legitimate strong transmission. I would use the observations of P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control, not an assertion based on the operator's impression of a quiet display. If it yields a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since bias-network settling and automatic gain-control memory can imitate delayed rf events or conceal genuinely present weak energy, an intervention

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that leaves both alternatives consistent does not settle their difference. The result should be limited to limit any negative finding to the periods when the instrument was demonstrably recovered and sensitive, with the untested physical possibilities made visible.

Edwin Howard Armstrong, Cross-Peer Question to Norbert Wiener: Dr Wiener, one strong emission strikes the front-end amplifier and produces a flat-topped converter waveform followed by a decaying shoulder. An automated classifier marks the plateau and the shoulder as separate transmissions from distinct devices. What test would distinguish a real second event from the receiver's internal recovery trajectory, and why is a reconstructed waveform not equivalent to a preserved measurement?

Norbert Wiener, Cross-Peer Answer to Edwin Howard Armstrong: Dr Armstrong, a saturated mapping is many-to-one: diverse analogue peaks yield the same maximum converter code. The lost input cannot be uniquely recovered by a smooth interpolation, even when its surrounding samples form an attractive curve. Make controlled blocker-on, blocker-off and stepped-level measurements with a known termination or RF source, preserving raw sample codes, gain commands, protection events, timestamps and the state of any automatic control loop. Compare the response with an independent low-gain receiver path that demonstrably remains linear and shares a calibrated time reference. If the trailing shoulder follows the instrument's recovery trajectory when the second alleged emitter is absent, it is evidence of an instrumental alternative, not a confirmed second transmission. An exponential fit may summarise an observed decay but cannot identify the overrange amplitude or prove that

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an independent burst never occurred. I respectfully pass the floor to Dr Bode for a challenge concerning recovery intervals.

Hendrik Wade Bode, Cross-Peer Question to Jerzy Neyman: Dr Neyman, suppose an isolated laboratory pulse appears to recover with a nominal 9 ms time constant. A field operator discards exactly 9 ms after every strong-signal alarm, resumes normal recording and calls all later non-detections conclusive. What statistical and physical conditions must be established before the instrument can again be described as sensitive to a weak signal?

Jerzy Neyman, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, a time constant is not a validated recovery time to a specified error limit. Under a single exponential, the residual at one time constant remains about 36.8 percent of its initial value; a threshold of one percent requires roughly 4.605 time constants, if that model applies. Real front ends can have amplifier saturation, protection-diode charge storage, AGC memory, digital filtering and pipeline latency with different trajectories. Establish a measurable recovery criterion, for example bounded gain error, phase error, spurious response and a known detection probability for the weak challenge signal. Measure its distribution across blocker levels, frequencies, temperatures, gains and repeated trials. A fixed nine-millisecond blanking rule without this challenge offers neither a coverage guarantee nor a justified absence inference. Record censored and recovery intervals explicitly; the statistical analysis must condition on actual receiver sensitivity and not silently count blind samples as valid trials. I respectfully pass the floor to Dr Pearson for a challenge about apparent detection confidence.

Claude Elwood Shannon, Cross-Peer Question to Egon Sharpe Pearson: Dr Pearson, the manuscript’s illustrative fifty-one independent trials each give a

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stipulated twelve-percent chance of detecting a burst, so it reports approximately 0.00147 probability of missing every trial. But what if the trials all fall within a common overload-recovery interval or a periodic emitter is aligned with the receiver's blind windows? What remains of the impressive numerical probability?

Egon Sharpe Pearson, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the arithmetic may be correct while the inferential model is false. The expression (1 − p) to the power n applies only if there are n valid opportunities and their relevant detection outcomes satisfy the stated independence and probability conditions. Repeating a blind receiver state does not produce fifty-one fresh chances; common overload and periodic scheduling can correlate failures so strongly that the effective number of independent opportunities is much smaller. Distinguish the number of scheduled visits, the number of fully valid sensitive visits, and the number of independent opportunities supported by the acquisition design. Include confidence intervals for any estimated detection probability and predefine the acceptable false-negative risk. Where sensitivity has not been demonstrated, state that the likelihood of a missed event is unquantified rather than presenting the Bernoulli calculation as empirical proof. I respectfully pass the floor to Dr Deming to examine evidential records of the receiver state.

Walter Andrew Shewhart, Cross-Peer Question to W. Edwards Deming: Dr Deming, a field log holds a spectrum waterfall, a 1.125 percent fraction of full-scale codes and a reassuring margin calculated at the converter input. It omits gain-transition times, input-path attenuation and the raw converter stream. How can a later expert separate actual intermittent emissions from

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hardware recovery artefacts without inventing events or claiming knowledge of signals erased by saturation?

W. Edwards Deming, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, the log does not contain enough information for a unique retrospective reconstruction. Treat the full-scale fraction as evidence that some samples reached an extreme code, not as a measure of lost energy or the number of transmissions. Preserve the original I/Q sequence, sample counters, overload flags, gain settings, calibration identifiers, input attenuator state, filter selection, trigger history and an independently synchronised reference trace. Construct a controlled laboratory reproduction with known strong pulses and weak probes, changing one relevant variable at a time; label the resulting artefact signatures and the range in which the method has actually been validated. A margin computed from nominal gain can coexist with local saturation in an upstream stage or with an unexpected peak crest factor. In the evidential conclusion distinguish confirmed external events, internally reproducible receiver artefacts and unresolved intervals. A missing raw stream must be reported as a limitation, not repaired by retrospective certainty. I respectfully return the discussion token to Dr Atkinson for the moderator's synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of the false chronology that can result from analogue overload and recovery memory has established a point which the specialist must not overlook. The receiver records clipped, delayed, or spurious bursts after a high-power input event; it does not, merely by drawing a clear trace, give direct access to the input waveform during overload and the settling state of upstream capacitors and control loops. A convincing engineering

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explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, An amplifier can retain memory of a previous strong signal through bias networks and stored charge. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

We must make room for the history of overload. An amplifier driven into compression, an automatic-gain-control loop whose control voltage has not settled, or a detector whose recovery is slow can continue to corrupt observations after a large legitimate transmission has ended. The significant datum is therefore not merely the peak input level but the response trajectory, including settling time and detection recovery for a known weak probe. I thank Professor Wiener for treating the receiver as a dynamic system with state, rather than an instantaneous multiplication of input power by nominal gain. The next experiment must inject a calibrated high-power pulse under controlled conditions, withdraw it, and measure the duration for which the test signal remains distorted or invisible. Repetition at different temperatures and gain settings would identify whether the effect is stable or conditional. Our report must distinguish a genuine absence of external signals from a period during which the instrument was recovering and could not have observed them reliably.

The main receiver was driven into overload by an authorised transmission and did not immediately recover. Measurements made during this unvalidated recovery interval cannot support a negative finding for

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weak or short events. The more useful outcome is a discriminating protocol: Apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. In applying it, the examiner must retain all readings supporting P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap and identify the physical plane to which the measurements refer. At the outset of the investigation, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval; that circumstance makes the alternative mechanism material, specifically bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. A result approaching a recovery artefact follows the overload event and changes with receiver bias or AGC settings, even with the weak test signal held constant may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore limit any negative finding to the periods when the instrument was demonstrably recovered and sensitive. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

Survey conclusions must exclude intervals in which calibrated sensitivity was lost or unknown. Recovery time is an experimentally determined property of the receiver state and preceding stimulus, not a correction that

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can be applied retrospectively to absent samples. The decisive experiment is concrete: Apply reproducible blocker pulses, observe recovery under multiple gain settings, and retain a simultaneous low-gain channel as a control. In conducting it, the examiner must explicitly retain P1dB, overload pulse duration, gain-control time constant, settling curve and minimum separable event gap. If the outcome matches the stated prediction, a recovery artefact follows the overload event and changes with receiver bias or agc settings, even with the weak test signal held constant, the supported conclusion concerns that test domain. An alternative remains: Bias-network settling and automatic gain-control memory can imitate delayed RF events or conceal genuinely present weak energy. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 023

Application 01. Clipping extent and an information-preserving statement

In the illustrative 023.01 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. Out of N = 1,778 acquired converter sample instants, K = 20 carry an extreme-code plateau. The directly observed fraction is K/N = 1.125%. It is not the fraction of analogue signal energy lost, because the unknown overrange amplitudes have many possible values. An independent lower-gain recording can bound those amplitudes if its transfer path and time alignment are demonstrated; no interpolation can establish an otherwise unobserved peak uniquely. The 1.125-percent extreme-code fraction quantifies recorded clipping indicators, not energy lost or the number of RF pulses. Report the unobserved overrange amplitudes as indeterminate.

Application 02. First-order recovery envelope after a state change

In the illustrative 023.02 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. If an illustrative recovery follows $A(t) = A_0 \exp(-t/\tau)$, let $A_0 = 1.70$ V and $\tau = 9.00$ ms. At t = 22.50 ms the residual is 1.70e^(−22.50/9.00) = 0.1395 V. Real automatic gain control often has nonlinear or multi-time-constant behaviour, so this exponential is a test model, not a universal reconstruction of the input during overload. The 0.1395 V exponential residual at 22.5 ms is a model prediction, not a validated gain-recovery threshold. Challenge the receiver with a weak probe until specified sensitivity is restored.

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Application 03. Gain allocation and blocker headroom

In the illustrative 023.03 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. Assume a calibrated digital full-scale equivalent of -9 dBm, a blocker applied at -46 dBm, and net analogue gain 21 dB. The projected converter input is -25 dBm and remaining margin is -9 − (-25) = 16 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. The nominal sixteen-decibel margin is calculated at one reference point under linear gain assumptions. A different upstream stage can saturate, so local peak levels and gain transients require testing.

Application 04. Cascade gain and observed headroom

In the illustrative 023.04 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. A first amplifier contributes G_1 = 16 dB, an intentional attenuation contributes G_2 = -6 dB, and a later stage contributes G_3 = 18 dB. The small-signal sum is 16 + (-6) + 18 = 28 dB. For P_i = -67 dBm, the ideal output is P_o = -39 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The minus-39-dBm cascade result assumes all three stages remain linear. Inspect each interstage node during a high-power pulse before treating the calculated output as a reliable capture limit.

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Application 05. Group delay from a local phase-versus-frequency slope

In the illustrative 023.05 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. Across a local frequency step Δf = 1.00 MHz, suppose unwrapped transmission phase changes by $\Delta\varphi$ = -0.480 rad. The finite-difference group-delay estimate is $\tau g \approx -\Delta\varphi/(2\pi\Delta f)$ = 76.394 ns. This is an average local slope. Dispersive responses require a finer phase sweep, a consistent unwrapping method and uncertainty treatment before extrapolating transient arrival times. The 76.394 ns phase-slope estimate describes filter group delay, not a direct estimate of overload recovery. Ringing and recovery are separate time-domain effects requiring independent tests.

Application 06. Ideal code step, variance, and full-scale sine SNR

In the illustrative 023.06 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. Taking an ideal N = 15-bit uniform converter across 3.50 V peak-to-peak, one nominal code interval is $\Delta = Vpp/2^N$ = 0.1068 mV. Under the independent uniform-error approximation its rms quantisation error is $\sigma = \Delta/\sqrt{12}$ = 0.0308 mV. The ideal full-scale sinusoidal SNR approximation is 6.02N + 1.76 = 92.06 dB. A coherent low-level waveform may violate the uniform-error assumption; clipping and integral nonlinearity are separate limitations. The 0.1068 mV code step, 0.0308 mV rms ideal quantisation error and 92.06 dB full-scale sinusoidal SNR do not apply to an overrange converter sequence or recovered transient amplitude.

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Application 07. Opportunity-limited detection under independent visits

In the illustrative 023.07 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. For n = 51 genuinely independent valid observation opportunities, each with stipulated event detection chance p = 0.12, the probability of no detections is $(1 - p)^n$ = 0.00147; its complement is 99.85%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The 0.00147 probability of no detection assumes fifty-one independent, sensitive opportunities, each with p = 0.12. Recovery-blind or synchronised intervals violate those assumptions.

Application 08. Observed exposure fraction of a channel scanner

In the illustrative 023.08 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. Let the channel be observed on n = 373 valid visits, each lasting d = 12 ms, with revisit spacing R = 0.70 s. Valid exposure is nd/1000 = 4.476 s across the nominal interval nR = 261.10 s. The observed fraction of elapsed time is therefore 1.71%, which is receiver coverage, not occupancy of the unvisited intervals. An occupancy percentage based only upon positive visits requires a separate sampling design. The 4.476 seconds of exposure across 261.10 seconds represent about 1.71-percent coverage, not continuous

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reception. Intervals hidden by overload require an additional sensitivity exclusion.

Application 09. Thermal reference noise in a declared measurement bandwidth

In the illustrative 023.09 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. Take the equivalent noise bandwidth B = 6,000 Hz and calibrated noise figure NF = 3.25 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -132.97$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The -132.97 dBm estimate is thermal-reference noise in 6,000 Hz at 290 K. It cannot describe a clipped signal, strong adjacent blockers or the recovery period after an overload.

Application 10. Combined and expanded measurement uncertainty

In the illustrative 023.10 test, a nearby high-power transmission drives the receiver into overload while a weak intermittent device may transmit during the subsequent recovery interval. For independent standard-uncertainty contributions 0.59, 0.36 and 0.40 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.59^2 + 0.36^2 + 0.40^2)} = 0.799$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 1.597$ units. The 0.799-unit combined and 1.597-unit expanded uncertainties presume independent inputs and the stated coverage factor. Unmodelled recovery bias and correlated components must be assessed separately.

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Contributor identification and editorial scope

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Selected technical references and use limitations

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These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 024

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How should differential and integral nonlinearity enter a forensic uncertainty account?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 024 asks: How should differential and integral nonlinearity enter a forensic uncertainty account? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is quantitative uncertainty associated with differential and integral converter nonlinearity. Our primary observation is code-width variation, cumulative transfer error, and distortion of amplitude estimates; by contrast, what remains unseen is the true analogue input amplitude in intervals mapped to biased or missing codes. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Code-transition imperfections deserve a measurement model. Differential nonlinearity measures a code-bin width relative to the ideal least-significant-bit width; integral nonlinearity measures accumulated

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departure from an ideal reference transfer characteristic under a stated convention. A code that occupies 1.3 ideal least-significant-bit widths has DNL of plus 0.3 LSB, but that number alone does not predict every harmonic artefact or transient distortion. Missing codes, temperature-sensitive transitions and input-dependent conversion errors can defeat an assumed additive-white-quantisation-noise model. Test a coherent sinusoid and a suitably slow precision ramp, respecting drive amplitude, distortion and clock coherence, and retain the observed code histogram. In forensic reconstruction, the digital word is evidence of a converter decision region, not an exact analogue voltage. Uncertainty must identify whether systematic code-boundary structure has been characterised. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns code-width variation, cumulative transfer error, and distortion of amplitude estimates; it is not interchangeable with the true analogue input amplitude in intervals mapped to biased or missing codes. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is slow calibrated ramp or histogram and sine-wave tests across operating temperature and frequency. A claim drawn from that comparison has to carry its actual uncertainties: DNL in LSB, INL in LSB, missing codes, residual calibration error, and amplitude uncertainty. Differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step. Integral nonlinearity describes a transfer

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deviation relative to a specified reference straight line, whose fitting convention matters. Under the usual non-negative code-width definition, a DNL of minus one LSB denotes a zero-width missing code; values below minus one LSB are not physically meaningful within that model. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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William Ralph Bennett | Principal contribution 1: Differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step.

A code-density plot and a high-frequency spectral measurement interrogate different aspects of an analogue-to-digital converter. Differential nonlinearity describes deviations of individual code widths from the ideal least-significant-bit interval; integral nonlinearity describes the accumulated departure of a transfer characteristic from a specified reference straight line. Neither quantity alone determines a receiver's dynamic distortion during an intermittent RF burst. A missing code, for example, can corrupt small-amplitude estimates even when a full-scale sinusoidal test produces a relatively respectable summary specification. I would demand the adopted endpoint or best-fit INL convention, test-source distribution and code histogram, together with a dynamic sine-wave characterisation. When the suspected signal dwells near a threshold, code-width irregularity can bias the probability of crossing that threshold. The detective task is to distinguish a physical change in input amplitude from a converter decision boundary that is not uniformly spaced. This requires calibrated input levels and raw code access, not merely an FFT screenshot.

In this physical path examination of Question 024, the decisive claim is that differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step. Differential nonlinearity and integral nonlinearity describe different departures from an ideal converter transfer. DNL concerns the width of an individual code interval relative to one ideal LSB; INL describes transition deviations from a declared reference line. Both depend upon the measurement convention and operating conditions. A

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visually regular sine-wave spectrum cannot establish that the ADC has no missing codes, and a single worst-case DNL figure cannot establish broadband spurious-free performance. The panel must distinguish static code-density evidence from dynamic spectral tests that excite different error mechanisms. A useful falsification proceeds from the actual controversy: code-transition imperfections deserve a measurement model. Differential nonlinearity measures a code-bin width relative to the ideal least-significant-bit width; integral nonlinearity measures accumulated departure from an ideal reference transfer characteristic under a stated convention. A code that occupies 1.3 ideal least-significant-bit widths has DNL of plus 0.3 LSB, but that number alone does not predict every harmonic artefact or transient distortion. Missing codes, temperature-sensitive transitions and input-dependent conversion errors can defeat an assumed additive-white-quantisation-noise model. Test a coherent sinusoid and a suitably slow precision ramp, respecting drive amplitude, distortion and clock coherence, and retain the observed code histogram. In forensic reconstruction, the digital word is evidence of a converter decision region, not an exact analogue voltage. Uncertainty must identify whether systematic code-boundary structure has been characterised. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Use a well-characterised slow ramp or dithered sine for a code-transition histogram, checking the excitation uniformity and population of rarely visited codes. Compute DNL under the selected transition convention, then calculate INL relative to both endpoint and best-fit lines, stating which will

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enter the uncertainty budget. Repeat with a high-frequency sine and controlled temperature changes. Observe whether spurs or missing-code signatures persist when input amplitude and sampling phase change. I would take LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: Differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step. A response consistent with large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. An ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. A meaningful

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bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level, and measure their behaviour separately before reconnecting the assembled system. Bennett's communications engineering perspective distinguishes stochastic noise models from deterministic signal-dependent converter errors and distortion products. It is therefore material to establish LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals rather than infer them from a single scalar output. The limiting test is concrete: Acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. If the intervention produces large dnl alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit as a new transmitter before challenging the most economical instrumental explanation. Differential nonlinearity concerns individual code-bin widths; it cannot be inferred from a tidy aggregate signal-to-noise ratio. Professor Tukey, I invite you to examine whether the reported histogram is representative of converter operation.

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John Wilder Tukey | Peer question 1 to William Ralph Bennett

William R. Bennett, may I test the exact physical inference in your account of an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits? The proposed mechanism appears plausible only if changes after acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions are compared with a stable reference condition. Differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals which would settle that narrower claim, rather than a visual impression of improvement.

William Ralph Bennett | Immediate answer to John Wilder Tukey

Dr Tukey, unequal code widths may occur without a single missing code, and a missing code can be hidden by a poorly populated histogram. I would first qualify the stimulus and count statistics, then specify the reference line before quoting INL. Dynamic SFDR must be assessed separately; it cannot be inferred simply by multiplying an isolated code-width error by the converter nominal resolution. The correct counterfactual begins with two models capable of producing

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the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 024, the specific physical candidate is DNL variations from ideal step width and INL departures from the fitted or endpoint transfer line. The unresolved physical pathway is material: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The retained record permits a conditional claim about LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals, but cannot alone resolve dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals; they should be retained as instrument readings with calibration information,

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rather than displayed only as a difference image. Differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, and only a response matching large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to William Ralph Bennett

I appreciate your explanation, William R. Bennett. How would your conclusion survive a deliberately independent test of some codes are noticeably wider than others, and a best-fit transfer curve differs from an

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endpoint fit? A second receiver might share more of the supposed evidence than its separate enclosure suggests. Integral nonlinearity describes a transfer deviation relative to a specified reference straight line, whose fitting convention matters. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals and document which differences remain unexplained? Would you also state what observed change in LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals would invalidate the preferred account, and which aspect of acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions would make that negative result independently repeatable?

William Ralph Bennett | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its

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pathway breaks a material common cause. For Question 024, the specific physical candidate is DNL variations from ideal step width and INL departures from the fitted or endpoint transfer line. The unresolved physical pathway is material: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The retained record permits a conditional claim about LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals, but cannot alone resolve dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. Integral nonlinearity describes a transfer deviation relative to a specified reference straight line, whose fitting convention matters. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level; I would challenge it with acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus

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amplitude with documented reference-line conventions. Two responses consistent with large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. A discordant measurement would then be interpreted by tracing that difference through LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals; an agreement lacking such a dependency analysis is weak corroboration.

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Walter Andrew Shewhart | Principal contribution 2: Integral nonlinearity describes a transfer deviation relative to a specified reference straight line, whose fitting convention matters.

The process used to measure linearity is itself vulnerable to uncontrolled variation. A code-density experiment driven by a sine wave assumes a known amplitude distribution; an imperfect stimulus with harmonic distortion can influence the estimated widths of ADC codes. I would inspect the source purity and synchronisation first, then repeat the histogram under amplitude and offset changes so that suspicious code regions are challenged in more than one way. Temperature, reference-voltage drift and sampling-clock state should be logged because the transfer curve may change across the survey. A control chart for measured INL extrema can disclose gradual degradation, but it should not disguise a single missing-code defect by averaging away the affected codes. The proper record identifies test conditions and whether a repair changed the converter or merely the test procedure. Statistical repeatability is evidence about the test process; it does not make an incorrectly modelled stimulus a faithful calibration standard.

In this control and stability examination of Question 024, the decisive claim is that integral nonlinearity describes a transfer deviation relative to a specified reference straight line, whose fitting convention matters. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: code-transition imperfections deserve a measurement model. Differential

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nonlinearity measures a code-bin width relative to the ideal least-significant-bit width; integral nonlinearity measures accumulated departure from an ideal reference transfer characteristic under a stated convention. A code that occupies 1.3 ideal least-significant-bit widths has DNL of plus 0.3 LSB, but that number alone does not predict every harmonic artefact or transient distortion. Missing codes, temperature-sensitive transitions and input-dependent conversion errors can defeat an assumed additive-white-quantisation-noise model. Test a coherent sinusoid and a suitably slow precision ramp, respecting drive amplitude, distortion and clock coherence, and retain the observed code histogram. In forensic reconstruction, the digital word is evidence of a converter decision region, not an exact analogue voltage. Uncertainty must identify whether systematic code-boundary structure has been characterised. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note integral

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nonlinearity describes a transfer deviation relative to a specified reference straight line, whose fitting convention matters. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Shewhart’s process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. This predicts a response which should be tested against large dnl alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp. An operator may be tempted to interpolate a line

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between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements discarded during retuning. Where dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments, the correct claim must name the operational states and the evidence available in each. My proposed acceptance test would archive the entire control sequence and the independent witness measurement before any data-dependent threshold adjustment.

A further, separately testable aspect of an adc undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits concerns LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals. The proposed challenge would be acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. The decision is conditional upon the observed result, with particular attention to dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. The competing account remains differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. Integral nonlinearity depends upon the defined reference straight line and measurement regime. Dr Pearson, the floor is yours to challenge a comparison that changes the reference between tests.

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Egon Sharpe Pearson | Peer question 3 to Walter Andrew Shewhart

Walter Andrew Shewhart, your calibration argument invites a question about reference planes, especially because dNL and INL are code-domain static specifications whose dynamic spectral consequences require separate experiments. The reference stimulus and the unknown emission need not occupy the same physical regime. Under the usual non-negative code-width definition, a DNL of minus one LSB denotes a zero-width missing code; values below minus one LSB are not physically meaningful within that model. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Walter Andrew Shewhart | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 024, the specific physical candidate is DNL variations from ideal step width

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and INL departures from the fitted or endpoint transfer line. The unresolved physical pathway is material: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The retained record permits a conditional claim about LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals, but cannot alone resolve dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals. Under the usual non-negative code-width definition, a DNL of minus one LSB denotes a zero-width missing code; values below minus one LSB are not physically meaningful within that model. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, with before-and-after values of LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals. If the instrument behaves as predicted, then large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp; if it does

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not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. Some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Walter Andrew Shewhart

There is an inferential difficulty, Walter Andrew Shewhart: differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The population of admissible observations needs to be fixed before any confidence argument. In this situation, dNL and INL are code-domain static specifications whose dynamic spectral consequences require separate experiments. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. Calibration against one tone does not necessarily reveal code-dependent distortion at another amplitude or phase. What is your unit of independent observation, and how will you treat censored records or

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correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals would invalidate the preferred account, and which aspect of acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions would make that negative result independently repeatable?

Walter Andrew Shewhart | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 024, the specific physical candidate is DNL variations from ideal step width and INL departures from the fitted or endpoint transfer line. The unresolved physical pathway is material: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The retained record permits a conditional claim about LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and

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calibration residuals, but cannot alone resolve dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit. I would distinguish trials selected in advance from those added after an unexpected peak appeared. Calibration against one tone does not necessarily reveal code-dependent distortion at another amplitude or phase. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level; its prediction should be recorded alongside large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

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The quantity has to remain attached to the physical operation defining it. DNL and INL are code-domain static specifications whose dynamic spectral consequences require separate experiments. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, at 12 bits over a 2 v span the ideal step is about 488.3 microvolts; a code-width error must be expressed against that particular step. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Harry Nyquist | Principal contribution 3: Under the usual non-negative code-width definition, a DNL of minus one LSB denotes a zero-width missing code; values below minus one LSB are not physically meaningful within that model.

A numerical sampling rate says how frequently the converter reports codes; it does not guarantee that adjacent codes represent equal analogue increments. If the conversion function is y=Q(x), then the digital sequence is simultaneously shaped by the analogue waveform and Q's thresholds. Reconstructing a continuous signal from the output requires knowledge of those thresholds and a signal model; oversampling alone cannot make an absent code reappear. I would compare a static ramp with a carefully scaled sine challenge, because dynamic converter errors can also arise from input bandwidth and aperture effects. For an RF receiver the gain state ahead of Q matters as much as the nominal converter bit count. A weak pulse falling within a troublesome region of the transfer may be distorted while a larger pulse remains acceptable. Measurements should therefore be tied to the relevant portion of the code range and the event amplitudes encountered in the field.

In this operational measurand examination of Question 024, the decisive claim is that a DNL at or below minus one LSB means a code may be absent in an ideal monotonic histogram interpretation. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: code-transition imperfections deserve a measurement model. Differential nonlinearity measures a code-bin width relative to the ideal least-significant-bit width; integral nonlinearity measures accumulated departure from an ideal reference transfer

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characteristic under a stated convention. A code that occupies 1.3 ideal least-significant-bit widths has DNL of plus 0.3 LSB, but that number alone does not predict every harmonic artefact or transient distortion. Missing codes, temperature-sensitive transitions and input-dependent conversion errors can defeat an assumed additive-white-quantisation-noise model. Test a coherent sinusoid and a suitably slow precision ramp, respecting drive amplitude, distortion and clock coherence, and retain the observed code histogram. In forensic reconstruction, the digital word is evidence of a converter decision region, not an exact analogue voltage. Uncertainty must identify whether systematic code-boundary structure has been characterised. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Differential nonlinearity describes the departure of an individual converter code width from the ideal quantisation step, while integral nonlinearity concerns the accumulated transfer deviation from the chosen reference line. Neither specification alone describes dynamic performance under a modulated RF input. A stuck or missing code may produce non-Gaussian amplitude errors that survive averaging, especially when a weak signal occupies a limited voltage range and the analogue noise does not sufficiently dither its transitions. An honest uncertainty account must therefore distinguish static code-domain calibration from spectral spurious-free dynamic range, effective number of bits and operating temperature. Sweep a precisely characterised low-distortion source through the relevant input range, retaining the raw codes rather than only averaged FFT magnitudes. The observation that a spectral feature changes as input level

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crosses a particular code boundary can implicate converter behaviour without establishing that the feature was absent from the external field. Accordingly, the laboratory record for Question 024 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. DNL and INL are code-domain static specifications whose dynamic spectral consequences require separate experiments. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, an adc undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: At

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12 bits over a 2 V span the ideal step is about 488.3 microvolts; a code-width error must be expressed against that particular step. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. I would therefore attach the uncertainty analysis to the *operational definition* itself instead of printing an unexplained confidence interval beside the most appealing trace.

A more precise objection comes from Harry Nyquist and the finite observation aperture in an adc undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. For that reason, record LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. A missing code demands a carefully specified DNL measurement, not a guess

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from a clipped spectrum. Dr Turing, please take the floor and ask what the sample archive reveals about unvisited code regions.

Alan Mathison Turing | Peer question 5 to Harry Nyquist

Harry Nyquist, I should like to examine what the recorded data actually preserve when an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. The physical input and the retained numerical array are not interchangeable things. Uncertainty must include both deterministic correction residuals and variable operating-condition effects. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals would invalidate the preferred account, and which aspect of acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions would make that negative result independently repeatable?

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Harry Nyquist | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 024, the specific physical candidate is DNL variations from ideal step width and INL departures from the fitted or endpoint transfer line. The unresolved physical pathway is material: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The retained record permits a conditional claim about LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals, but cannot alone resolve dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. DNL and INL are code-domain static specifications whose dynamic spectral consequences require separate experiments. I propose separating acquired information from model-dependent reconstruction. Uncertainty must include both

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deterministic correction residuals and variable operating-condition effects. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals and a fresh trial in which the operator acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. If that trial demonstrates large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Claude Elwood Shannon | Principal contribution 4: Calibration against one tone does not necessarily reveal code-dependent distortion at another amplitude or phase.

The information discarded by nonuniform quantisation is not always represented by one average error number. A converter with distorted code boundaries may bias some waveforms systematically, and two different analogue trajectories can map to identical recorded code strings. A static correction table can compensate the mean transfer relationship if it is known and stable, but cannot recover distinctions already collapsed into a single code. I would examine whether the proposed correction alters only the amplitude estimate or also the downstream detection threshold and alarm history. If the table is derived from the same suspicious record, its apparent success risks circularity. Retain the raw uncorrected codes and the independently measured transfer characterisation, so an examiner can reproduce the correction or contest its applicability. A beautiful straight line after digital linearisation should not be mistaken for proof that the physical input has been restored uniquely.

In this information retention examination of Question 024, the decisive claim is that calibration against one tone does not necessarily reveal code-dependent distortion at another amplitude or phase. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: code-transition imperfections deserve a measurement model. Differential nonlinearity measures a code-bin width relative to the ideal least-significant-bit width; integral nonlinearity measures accumulated departure from an ideal reference transfer characteristic under a stated

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convention. A code that occupies 1.3 ideal least-significant-bit widths has DNL of plus 0.3 LSB, but that number alone does not predict every harmonic artefact or transient distortion. Missing codes, temperature-sensitive transitions and input-dependent conversion errors can defeat an assumed additive-white-quantisation-noise model. Test a coherent sinusoid and a suitably slow precision ramp, respecting drive amplitude, distortion and clock coherence, and retain the observed code histogram. In forensic reconstruction, the digital word is evidence of a converter decision region, not an exact analogue voltage. Uncertainty must identify whether systematic code-boundary structure has been characterised. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. The scientific point of calibration against one tone does not necessarily reveal code-dependent distortion at another amplitude or phase. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed

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explanation. If independent sessions repeatedly show large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. Some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit. Shannon's information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. The issue becomes especially sharp because differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and

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frequency domain actually examined. For the proposed case, at 12 bits over a 2 v span the ideal step is about 488.3 microvolts; a code-width error must be expressed against that particular step. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A more precise objection comes from Claude Elwood Shannon and the finite observation aperture in an adc undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. It is possible to obtain a repeatable numerical output while leaving the operative cause unresolved, particularly when differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. For that reason, record LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals for each accepted exposure and preserve the actual time ordering rather than rearranging snapshots into an apparently continuous account. After acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, the investigator should document the units, decision threshold and predicted response for each competing explanation. An adverse observation would require revising the measurement model; it should not be silently omitted from the record merely because it contradicts an earlier suspicion. If a unique physical source cannot be distinguished, the conclusion must remain conditional. A single calibration tone may miss nonlinear behaviour under

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other amplitudes and frequencies. Dr Deming, I invite you to devise a challenge across the relevant code range.

W. Edwards Deming | Peer question 6 to Claude Elwood Shannon

I thank you, Claude Elwood Shannon, for distinguishing measurement from attribution, but the observation is that some codes are noticeably wider than others, and a best-fit transfer curve differs from an endpoint fit. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: at 12 bits over a 2 V span the ideal step is about 488.3 microvolts; a code-width error must be expressed against that particular step. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp on one day but fails after the instrument has been reconfigured? Differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

Claude Elwood Shannon | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest

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establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 024, the specific physical candidate is DNL variations from ideal step width and INL departures from the fitted or endpoint transfer line. The unresolved physical pathway is material: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The retained record permits a conditional claim about LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals, but cannot alone resolve dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, at 12 bits over a 2 V span the ideal step is about 488.3 microvolts; a code-width error must be expressed against that particular step. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. Differential nonlinearity describes the width error of each code bin relative to the nominal one-LSB step. Its bearing on the dispute can be evaluated through the predicted response, namely large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp. Because differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all

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perturb a reported weak-signal level, the procedure acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match publish both the converter convention and the residual error budget rather than translate one DNL number into a universal spectral claim, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. Large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: Uncertainty must include both deterministic correction residuals and variable operating-condition effects.

A confidence statement about DNL or INL must be attached to the chosen definition and measurement population. A single maximum-INL figure hides the shape of the transfer error; two converters with identical maxima can produce very different biases near the decision threshold used for rare-signal detection. I would identify the codes actually visited by representative signals, estimate the uncertainty in their boundaries, and propagate that uncertainty into the reported amplitude or event count. Dependence matters: adjacent code widths share calibration parameters, so treating every bin estimate as an independent draw can exaggerate precision. A comparison between two converter boards should be based on paired stimuli and predeclared tolerances, including temperature and gain-state effects. Where a reference curve was fitted after seeing the test results, disclose the fitting convention. The defensible conclusion concerns verified transfer performance in the tested regime, not an unrestricted declaration that an instrument is accurate.

In this statistical inference examination of Question 024, the decisive claim is that uncertainty must include both deterministic correction residuals and variable operating-condition effects. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: code-transition imperfections deserve a measurement model. Differential nonlinearity

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measures a code-bin width relative to the ideal least-significant-bit width; integral nonlinearity measures accumulated departure from an ideal reference transfer characteristic under a stated convention. A code that occupies 1.3 ideal least-significant-bit widths has DNL of plus 0.3 LSB, but that number alone does not predict every harmonic artefact or transient distortion. Missing codes, temperature-sensitive transitions and input-dependent conversion errors can defeat an assumed additive-white-quantisation-noise model. Test a coherent sinusoid and a suitably slow precision ramp, respecting drive amplitude, distortion and clock coherence, and retain the observed code histogram. In forensic reconstruction, the digital word is evidence of a converter decision region, not an exact analogue voltage. Uncertainty must identify whether systematic code-boundary structure has been characterised. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. Uncertainty must include both deterministic correction residuals and variable operating-condition effects. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to acquire a controlled

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histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say publish both the converter convention and the residual error budget rather than translate one DNL number into a universal spectral claim, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. An ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman’s statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a

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reported weak-signal level. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from large dnl alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, at 12 bits over a 2 v span the ideal step is about 488.3 microvolts; a code-width error must be expressed against that particular step, is not an estimate of any actual investigation. Correction residuals and environmental drift both belong in the uncertainty budget for a code-dependent measurement. Sir Karl, I pass the floor to test the claim that compensation has removed the error.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise publish both the converter convention and the residual error budget rather than translate one DNL number into a universal spectral claim? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Integral nonlinearity describes a transfer deviation relative to a specified reference straight line, whose fitting convention matters. Please connect LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration

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residuals with a declared detection threshold and the measurement exposure. If the experiment acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 024, the specific physical candidate is DNL variations from ideal step width and INL departures from the fitted or endpoint transfer line. The unresolved physical pathway is material: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. The retained record permits a conditional claim about LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals, but cannot alone resolve dnl and inl are code-domain static specifications whose dynamic spectral consequences require separate experiments. That limitation

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belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Integral nonlinearity describes a transfer deviation relative to a specified reference straight line, whose fitting convention matters. I would use the observations of LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions, not an assertion based on the operator's impression of a quiet display. If it yields large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since differential code-bin

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error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to publish both the converter convention and the residual error budget rather than translate one dnl number into a universal spectral claim, with the untested physical possibilities made visible.

William Ralph Bennett, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, a laboratory reports one code at minus 0.27 LSB DNL and then treats a calibrated RMS sine-wave spectrum as if every code had the same transfer uncertainty. The histogram was collected at a single temperature, and the report does not distinguish an endpoint reference from a least-squares transfer line. Which elements of its proposed uncertainty budget are measurable and which require fresh observations? Would a low sample count in one histogram bin alone establish a missing code?

Walter Andrew Shewhart, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, the measured bin width of 0.73 ideal LSB has a defined local meaning only when the stimulus probability density, input noise, bin population, reference step and operating state are documented. Its finite histogram count has sampling uncertainty. The best-fit and endpoint definitions of INL answer different geometrical questions, so their numerical results cannot be silently mixed. Repeat the code-density test across amplitude, temperature and relevant clock conditions; then validate transfer corrections with independently known analogue voltages and a dynamic sine-wave test. An empty bin might reflect inadequate occupancy or stimulus coverage. A missing code demands a sufficiently sensitive

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demonstration of zero or effectively unobservable width under the stated model. Quantify residual correction uncertainty and correlation instead of adding an unspecified DNL figure as broadband noise. I respectfully pass the floor to Dr Nyquist to examine the code-width boundary.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, the existing heading says that DNL may be at or below minus one LSB. Under the code-width definition DNL equals actual width divided by ideal width, less one. Can a physical code width be negative? If not, what must the treatise say about a zero-width code, nonmonotonic conversion, and apparent extreme estimates caused by test noise?

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, a non-negative code width constrains that form of DNL to values no smaller than minus one LSB. At exactly minus one the width is zero, so a code is absent under the conventional monotonic transfer model. A reported figure below minus one is not an additional degree of missingness; it signals a changed convention, an invalid estimator, uncertain transition ordering, or a model that no longer describes the observed transfer. A nonmonotonic mapping should be characterised by its actual transition history and hysteresis, rather than forced into a negative-width bin. Report the exact transition definition and histogram confidence limits. A static code-density test cannot by itself predict all dynamic harmonic effects at another frequency. I respectfully pass the floor to Dr Neyman to consider dependence between corrections.

John Wilder Tukey, Cross-Peer Question to Jerzy Neyman: Dr Neyman, several code-transition corrections were derived from one voltage reference and one temperature sensor, then combined as independent standard

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uncertainties. The result is a conveniently small root-sum-square interval. What evidence is needed before the independence assumption is defensible, and what does an unexpectedly large paired-instrument discrepancy actually prove?

Jerzy Neyman, Cross-Peer Answer to John Wilder Tukey: Dr Tukey, shared reference drift and common environmental dependence create covariance terms that do not vanish merely because the spreadsheet uses separate columns. Define the measurement function, sensitivity coefficients, covariance matrix and operating-state distributions. A calibration applied to the transfer curve corrects a recognised bias; its residual standard uncertainty is not the uncorrected bias itself. Use replicated standards, multiple independently routed references where practical, and paired tests to estimate the common components. In the illustrative 1.400 dB contrast, a 0.516 dB standard uncertainty and a ratio near 2.712 are arithmetic, not a universal evidential verdict. A significance or equivalence claim requires the sampling model, decision rule and independently defined criterion. Any untested code region remains a systematic coverage limitation, not a random quantity that can be wished away. I respectfully pass the floor to Dr Bridgman to examine reproducibility.

W. Edwards Deming, Cross-Peer Question to Percy Williams Bridgman: Dr Bridgman, an investigator retains a polished spectrum and a one-number INL specification, but discards the ramp profile, code counts, acquisition firmware and physical reference-plane description. The original waveform is no longer available. Which documentary requirements would allow a second laboratory to test the calibration claim without attributing an unexplained peak to an external source?

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Percy Williams Bridgman, Cross-Peer Answer to W. Edwards Deming: Dr Deming, the evidential object must include the code-density histogram, original code stream where retained, analogue stimulus probability model, calibration certificates and their uncertainties, full-scale definition, code transition convention, sample-clock settings, temperature, source impedance, preamplifier states and analysis software version. Retain both nominal settings and the observed instrument state. A later laboratory should reproduce the code-width and INL estimates with separate stimulus apparatus, while deliberately varying frequency and level to expose distortion that a static ramp misses. If such foundational records are absent, a single converter-linearity number supports only a limited manufacturer-style description, not retrospective attribution of a disputed spectral component. Keep experimentally established effects separate from model projections and state what observations would contradict the preferred account. I respectfully return the token to Dr Atkinson for the moderator's synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of quantitative uncertainty associated with differential and integral converter nonlinearity has established a point which the specialist must not overlook. The receiver records code-width variation, cumulative transfer error, and distortion of amplitude estimates; it does not, merely by drawing a clear trace, give direct access to the true analogue input amplitude in intervals mapped to biased or missing codes. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, Differential nonlinearity describes the width error of each code bin relative

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to the nominal one-LSB step. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

The distinction between differential and integral nonlinearity must remain numerically explicit. A code-width anomaly can alter the probability with which a slowly varying input visits individual output codes, whereas accumulated endpoint displacement changes the converter's overall transfer relation. Either can be confused with a physical spectral feature if the raw transfer has not been characterised. I thank the mathematical contributors for requiring a declared full-scale range and bit depth before presenting errors in least-significant-bit units. Code-density measurements require an input stimulus whose amplitude distribution is known well enough to support the proposed inference; the usual idealised sine-wave assumption is not a substitute for test-set validation. A missed code cannot be repaired by increasing the number of samples of the same damaged mapping. The appropriate conclusion is a bounded converter-characterisation result with environmental conditions and uncertainty, not a claim that a visually neat spectrum establishes faithful analogue amplitude recovery.

Measured code widths are unequal and the fitted transfer curve depends upon the chosen reference. These observations establish limited transfer-function properties, not an emitter identity or a universal amplitude error valid at every sampling frequency. The more useful outcome is a discriminating protocol: Acquire a controlled histogram and sine-wave series

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across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. In applying it, the examiner must retain all readings supporting LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals and identify the physical plane to which the measurements refer. At the outset of the investigation, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits; that circumstance makes the alternative mechanism material, specifically differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. A result approaching large DNL alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore publish both the converter convention and the residual error budget rather than translate one DNL number into a universal spectral claim. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

The converter report should publish the DNL and INL conventions, tested code regions and environmental conditions separately from dynamic distortion metrics. No single code-width number can substitute for an end-to-end spectral performance study. The decisive experiment is concrete:

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Acquire a controlled histogram and sine-wave series across temperature, input frequency, and stimulus amplitude with documented reference-line conventions. In conducting it, the examiner must explicitly retain LSB size, DNL, endpoint INL, best-fit INL, missing-code count, temperature drift and calibration residuals. If the outcome matches the stated prediction, large dnl alters local code frequency; a missing code may produce no observations under a sufficiently uniform calibration ramp, the supported conclusion concerns that test domain. An alternative remains: Differential code-bin error, integral transfer curvature and genuine analogue amplitude variation can all perturb a reported weak-signal level. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 024

Application 01. Code-bin width under differential nonlinearity

In the illustrative 024.01 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. For an N = 11-bit transfer over 2.20 V, one ideal least-significant-bit interval is Δ = 1.07422 mV. If one measured code has DNL = -0.270 LSB, its effective width is Δ(1 + DNL) = 0.78418 mV. A code-width result needs adequate stimulus uniformity, histogram population and a declared endpoint convention; it does not independently establish whole-transfer integral linearity. The 0.78418 mV width follows from the declared 2.20 V, 11-bit uniform scale and a −0.270 LSB DNL; finite ramp-histogram occupancy and excitation statistics limit its metrological meaning.

Application 02. Voltage-equivalent integral nonlinearity

In the illustrative 024.02 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. Under a specified transfer-line convention, an N = 12-bit ADC spanning 2.50 V has ideal step Δ = 0.61035 mV. A local integral nonlinearity of 0.760 LSB corresponds to 0.46387 mV of analogue-equivalent deviation. The endpoint or best-fit reference line must be declared, as must temperature, code region and input slew rate; otherwise two instruments may report incompatible INL values for the same transfer curve. The 0.46387 mV INL equivalent uses the declared 12-bit, 2.50 V scale; endpoint and best-fit reference conventions cannot be interchanged in an evidential comparison.

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Application 03. Ideal code step, variance, and full-scale sine SNR

In the illustrative 024.03 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. Taking an ideal N = 13-bit uniform converter across 2.00 V peak-to-peak, one nominal code interval is $\Delta = Vpp/2^N = 0.2441$ mV. Under the independent uniform-error approximation its rms quantisation error is $\sigma = \Delta/\sqrt{12} = 0.0705$ mV. The ideal full-scale sinusoidal SNR approximation is 6.02N + 1.76 = 80.02 dB. A coherent low-level waveform may violate the uniform-error assumption; clipping and integral nonlinearity are separate limitations. The 0.0705 mV RMS error and 80.02 dB ideal full-scale SNR require the usual uniform, uncorrelated quantisation-error model, not guaranteed by a code-dependent transfer defect.

Application 04. Thermal reference noise in a declared measurement bandwidth

In the illustrative 024.04 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. Take the equivalent noise bandwidth B = 3,750 Hz and calibrated noise figure NF = 3.75 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\text{ Hz}) + NF = -134.51$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The −134.51 dBm is the integrated 290 K thermal-reference calculation for 3,750 Hz ENBW with a 3.75 dB noise figure, not the unknown RF emission floor in an interference-rich environment.

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Application 05. Combined and expanded measurement uncertainty

In the illustrative 024.05 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. For independent standard-uncertainty contributions 0.66, 0.36 and 0.28 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.66^2 + 0.36^2 + 0.28^2)} = 0.802$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 1.604$ units. The 0.802-unit root-sum-square standard uncertainty and 1.604-unit k = 2 interval require uncorrelated inputs expressed in compatible units; shared calibration drift adds covariance.

Application 06. Clipping extent and an information-preserving statement

In the illustrative 024.06 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. Out of N = 1,862 acquired converter sample instants, K = 66 carry an extreme-code plateau. The directly observed fraction is K/N = 3.545%. It is not the fraction of analogue signal energy lost, because the unknown overrange amplitudes have many possible values. An independent lower-gain recording can bound those amplitudes if its transfer path and time alignment are demonstrated; no interpolation can establish an otherwise unobserved peak uniquely. The 3.545-percent extreme-code fraction identifies sample instants at the converter limit, not an energy-loss fraction or a measured amplitude beyond the rail.

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Application 07. Cascade gain and observed headroom

In the illustrative 024.07 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. A first amplifier contributes G_1 = 9 dB, an intentional attenuation contributes G_2 = -4 dB, and a later stage contributes G_3 = 21 dB. The small-signal sum is 9 + (-4) + 21 = 26 dB. For P_i = -71 dBm, the ideal output is P_o = -45 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The calculated 26 dB cascade gain and −45 dBm output presume linear operation at each stage; code-domain DNL cannot rule out overload in an analogue amplifier.

Application 08. Difference between two instruments relative to stated uncertainty

In the illustrative 024.08 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. The paired instrument contrast is Δ = 1.400 dB. Set independent standard uncertainties u_1 = 0.300 dB and u_2 = 0.420 dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)}$ = 0.516 dB, giving the dimensionless ratio Δ/uΔ = 2.712. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The 2.712 dimensionless contrast is not itself an equivalence decision. Declare correlation, coverage, comparison threshold and the intended decision procedure before drawing an instrument-comparability conclusion.

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Application 09. Family-wise probability when many candidates are searched

In the illustrative 024.09 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. If each of M = 495 independent pre-specified search opportunities has false-alarm probability α = 0.0009, the probability of one or more false positives is 1 − (1 − α)^M = 0.35962, or 35.96%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. The 35.96-percent family-wise false-positive probability applies only to 495 prespecified, independent opportunities; overlapping FFT frames and after-the-fact selection alter the model.

Application 10. Frequency-bin spacing versus independent information

In the illustrative 024.10 test, an ADC undergoes a slow ramp and code-density test while the investigative receiver is assessed for amplitude accuracy near its full-scale limits. With sampled bandwidth f_s = 11 MS/s and N = 4,096 transform samples, the discrete-frequency grid is $\Delta f = f_s/N$ = 2685.547 Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. The 2,685.547 Hz FFT grid spacing follows from 11 MS/s divided by 4,096, but cannot verify code-transition integrity or establish independent spectral resolution.

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Contributor identification and editorial scope

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Selected technical references and use limitations

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These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 025

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What is lost when a converter clips, and what remains inferable?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 025 asks: What is lost when a converter clips, and what remains inferable? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is the boundary between still-inferable facts and permanently lost amplitude information after clipping. Our primary observation is digital samples held at a converter limit during a high-amplitude event; by contrast, what remains unseen is the original peaks, detailed envelope, and possibly the original spectral content of saturated intervals. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Clipping destroys amplitude ordering beyond the rail. If a converter’s positive full-scale input is 1.0 volt and two analogue peaks reach 1.2 and 2.5 volts, both may be represented by the same maximum digital code. Their

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different amplitudes are not recoverable from that saturated code alone. Timing of threshold entry, unsaturated leading edges or measurements from an independent attenuated path may still convey useful information, provided the front-end and recovery behaviour are modelled. Some clipping can also introduce spectral regrowth that resembles wideband emissions, so reprocessing the clipped samples cannot prove that the reconstructed out-of-band content existed at the antenna. Preserve raw words and overload flags, record the fraction of saturated samples, and repeat with attenuation where possible. A forensic statement should distinguish demonstrated overload from conjectures about the missing peak waveform. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns digital samples held at a converter limit during a high-amplitude event; it is not interchangeable with the original peaks, detailed envelope, and possibly the original spectral content of saturated intervals. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is a simultaneous attenuated acquisition and deliberate overload-recovery calibration sequence. A claim drawn from that comparison has to carry its actual uncertainties: full-scale range, fraction of clipped samples, contiguous clipping duration, and bounded post-event conclusions. Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. Digital values at full scale can establish that a threshold was reached but not how far it was

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exceeded. Clipping creates harmonic and intermodulation-like spectral components that were not present in the linear input. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Claude Elwood Shannon | Principal contribution 1: Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints.

Clipping is a many-to-one transformation, which means that a plateau at the converter's highest code does not disclose the unknown analogue crest that produced it. The same stored sequence could come from a waveform only slightly above full scale or from a much larger transient whose peak was flattened. An algorithm that draws a smooth continuation through the plateau supplies assumptions about waveform shape, not recovered historical measurements. I would preserve the raw codes, clipping flags, gain settings and any independently recorded lower-gain channel. If a parallel receiver did not clip, its calibrated response could constrain the amplitude that the primary path lost, provided both channels shared a known time reference and adequately characterised analogue transfer. The peak itself is not identifiable from clipped samples alone. Even the pulse duration may be biased when saturation and recovery alter the time for which the signal remains above threshold. The evidential limit belongs in the finding, not in a footnote that the reader may miss.

In this physical path examination of Question 025, the decisive claim is that clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. Clipping is an irreversible many-to-one mapping of analogue amplitudes to one extreme converter code. When an input exceeds full scale, many physically different peaks are recorded identically. The duration of the extreme-code plateau may still bound the time spent at the converter limit if the timebase and transfer are valid, but it cannot reveal the unmeasured crest. A smooth extrapolated

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reconstruction is a model output, not an original sample. The proper analysis separates quantities still directly measured, quantities inferable under explicit waveform assumptions and amplitudes for which the record supplies only lower or upper bounds. A useful falsification proceeds from the actual controversy: clipping destroys amplitude ordering beyond the rail. If a converter's positive full-scale input is 1.0 volt and two analogue peaks reach 1.2 and 2.5 volts, both may be represented by the same maximum digital code. Their different amplitudes are not recoverable from that saturated code alone. Timing of threshold entry, unsaturated leading edges or measurements from an independent attenuated path may still convey useful information, provided the front-end and recovery behaviour are modelled. Some clipping can also introduce spectral regrowth that resembles wideband emissions, so reprocessing the clipped samples cannot prove that the reconstructed out-of-band content existed at the antenna. Preserve raw words and overload flags, record the fraction of saturated samples, and repeat with attenuation where possible. A forensic statement should distinguish demonstrated overload from conjectures about the missing peak waveform. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Record an intense short pulse simultaneously through two independently calibrated gain paths, one set to avoid overrange. Compare event onset, clip-code duration and subsequent settling while preserving the preamplifier and ADC states. Replay a calibrated pulse family through the saturated channel to test whether onset and timing remain reliable despite amplitude loss. If the lower-gain path is itself bandwidth-limited, its

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estimate of the original peak also requires a stated transfer-function correction and uncertainty. I would take full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. A response consistent with the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. A high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input

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connector. I would first inventory the physical elements implicated by the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence, and measure their behaviour separately before reconnecting the assembled system. Shannon's information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. It is therefore material to establish full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude rather than infer them from a single scalar output. The limiting test is concrete: Compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. If the intervention produces the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret a reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there as a new transmitter before challenging the most economical instrumental explanation. Hard clipping discards amplitude distinctions and is ordinarily not invertible from the clipped samples alone. Professor Tukey, I invite you to question the analyst who reconstructs a smooth crest from the saturation plateau.

John Wilder Tukey | Peer question 1 to Claude Elwood Shannon

Claude Elwood Shannon, may I test the exact physical inference in your account of a high-gain SDR captures a short intense burst with a

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plateau of samples pinned to the maximum converter code? The proposed mechanism appears plausible only if changes after compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test are compared with a stable reference condition. Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude which would settle that narrower claim, rather than a visual impression of improvement.

Claude Elwood Shannon | Immediate answer to John Wilder Tukey

Dr Tukey, interpolation through a flat-topped plateau provides no additional measurement of the missing peak. I would ask instead which event features survive the clipping operation: first threshold crossing, approximate duration, polarity and perhaps a bound on peak amplitude. An independent unsaturated channel can improve those bounds, but only with a demonstrated shared time reference and quantified gain mismatch. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder.

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The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 025, the specific physical candidate is many distinct analogue voltages mapped into the same maximum or minimum digital code. The unresolved physical pathway is material: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. The retained record permits a conditional claim about full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, but cannot alone resolve saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. A stable residual after the reference path is

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disabled calls for examining bypass or internal generation. The proposed discriminating operation is compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test, and only a response matching the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Claude Elwood Shannon

I appreciate your explanation, Claude Elwood Shannon. How would your conclusion survive a deliberately independent test of a reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there? A second receiver might share more of the supposed evidence than its separate enclosure suggests. Digital values at full scale can establish that a

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threshold was reached but not how far it was exceeded. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude and document which differences remain unexplained? Would you also state what observed change in full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude would invalidate the preferred account, and which aspect of compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test would make that negative result independently repeatable?

Claude Elwood Shannon | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 025, the specific physical candidate is many distinct analogue voltages mapped into the same maximum or minimum digital code. The

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unresolved physical pathway is material: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. The retained record permits a conditional claim about full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, but cannot alone resolve saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. Digital values at full scale can establish that a threshold was reached but not how far it was exceeded. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence; I would challenge it with compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. Two responses consistent with the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded

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amplitude information would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. A discordant measurement would then be interpreted by tracing that difference through full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude; an agreement lacking such a dependency analysis is weak corroboration.

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Harry Nyquist | Principal contribution 2: Digital values at full scale can establish that a threshold was reached but not how far it was exceeded.

It is sometimes suggested that collecting more sample points will reconstruct the missing top of a clipped sinusoid. This is true only under additional assumptions strong enough to identify the underlying waveform, such as a stipulated single-frequency model, correct timing and access to unsaturated phases. A broadband unknown burst admits many waveforms agreeing with every retained clipped sample while differing radically at the crest. I would test any reconstruction algorithm on a blinded collection containing modulated signals, multipath and pulses of different shapes. The algorithm's bias and coverage should be evaluated against a calibrated unclipped reference rather than against the aesthetically plausible output of another reconstruction. For a field report, the conservative result is a lower bound on the peak under a known clipping threshold, with an explicit statement of lost information. Sampling more often does not remove the ambiguity created by an earlier non-invertible analogue-to-digital mapping.

In this control and stability examination of Question 025, the decisive claim is that digital values at full scale can establish that a threshold was reached but not how far it was exceeded. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: clipping destroys amplitude ordering beyond the rail. If a converter’s positive full-scale input is 1.0 volt and two analogue peaks reach 1.2 and 2.5 volts, both may be represented by the same maximum digital code. Their different amplitudes are not recoverable

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from that saturated code alone. Timing of threshold entry, unsaturated leading edges or measurements from an independent attenuated path may still convey useful information, provided the front-end and recovery behaviour are modelled. Some clipping can also introduce spectral regrowth that resembles wideband emissions, so reprocessing the clipped samples cannot prove that the reconstructed out-of-band content existed at the antenna. Preserve raw words and overload flags, record the fraction of saturated samples, and repeat with attenuation where possible. A forensic statement should distinguish demonstrated overload from conjectures about the missing peak waveform. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by a reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note digital values at full scale can establish that a threshold was reached but not how far it was exceeded. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator

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should preserve time stamps, acquisition validity, applied gain, test-source state and full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, a reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. The order would be time-stamped and should include invalid intervals, receiver recovery, and any gain or filter settling rather than treating silence during transition as evidence of a silent source. Our central rival is specific: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. This predicts a response which should be tested against the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore

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measurements discarded during retuning. Where saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints, the correct claim must name the operational states and the evidence available in each. Full-scale codes establish a boundary crossing, not how far the unknown analogue peak exceeded that boundary. Dr Pearson, please take the floor and examine the resulting one-sided inference.

Egon Sharpe Pearson | Peer question 3 to Harry Nyquist

Harry Nyquist, your calibration argument invites a question about reference planes, especially because saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. The reference stimulus and the unknown emission need not occupy the same physical regime. Clipping creates harmonic and intermodulation-like spectral components that were not present in the linear input. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When a reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

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Harry Nyquist | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 025, the specific physical candidate is many distinct analogue voltages mapped into the same maximum or minimum digital code. The unresolved physical pathway is material: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. The retained record permits a conditional claim about full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, but cannot alone resolve saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude. Clipping creates harmonic and intermodulation-like spectral components that were not present in the linear input. I would not carry a correction obtained at one frequency or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be compare the clipped channel with a simultaneously acquired lower-gain reference

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and a calibrated overrange replay test, with before-and-after values of full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude. If the instrument behaves as predicted, then the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. A reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Harry Nyquist

There is an inferential difficulty, Harry Nyquist: the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. The population of admissible observations needs to be fixed before any confidence argument. In this situation, saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal

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constraints. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. A model-assisted interpolation may be useful for illustration but should never be relabelled as an authentic historical measurement. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude would invalidate the preferred account, and which aspect of compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test would make that negative result independently repeatable?

Harry Nyquist | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 025, the specific physical candidate is many distinct analogue voltages mapped into the same maximum or minimum digital code. The unresolved physical pathway is material: The crest may be modestly over range or many times over range; both

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possibilities collapse to the same stored saturated code sequence. The retained record permits a conditional claim about full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, but cannot alone resolve saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because a reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there. I would distinguish trials selected in advance from those added after an unexpected peak appeared. A model-assisted interpolation may be useful for illustration but should never be relabelled as an authentic historical measurement. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence; its prediction should be recorded alongside the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude

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information. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. Saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, sixteen consecutive maximum codes prove a saturation episode of at least sixteen sample instants, not its unmeasured analogue peak. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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William Ralph Bennett | Principal contribution 3: Clipping creates harmonic and intermodulation-like spectral components that were not present in the linear input.

Converter saturation also changes the spectral appearance of an event. A flattened waveform introduces harmonics and sidebands, and subsequent filtering may spread that distortion across the frequencies where a weak independent emission is sought. I would separate the physical phenomenon of overload from digital numerical clipping: an RF amplifier can compress before the ADC reaches its extreme code, while software display scaling can clip a picture without clipping stored samples. These failure modes must not be conflated. A diagnostic sequence should step a calibrated stimulus through the chain and compare analogue power at accessible nodes with the converter's raw-code distribution. If third-order products begin to grow before the ADC clips, reducing converter gain alone may not repair the RF distortion. The record should identify the first nonlinear boundary. That is where a claimed spectral measurement begins to lose fidelity, even if the later numerical word length remains large.

In this operational measurand examination of Question 025, the decisive claim is that clipping creates harmonic and intermodulation-like spectral components that were not present in the linear input. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: clipping destroys amplitude ordering beyond the rail. If a converter’s positive full-scale input is 1.0 volt and two analogue peaks reach 1.2 and 2.5 volts, both may be represented by the same maximum digital code. Their different amplitudes are not recoverable

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from that saturated code alone. Timing of threshold entry, unsaturated leading edges or measurements from an independent attenuated path may still convey useful information, provided the front-end and recovery behaviour are modelled. Some clipping can also introduce spectral regrowth that resembles wideband emissions, so reprocessing the clipped samples cannot prove that the reconstructed out-of-band content existed at the antenna. Preserve raw words and overload flags, record the fraction of saturated samples, and repeat with attenuation where possible. A forensic statement should distinguish demonstrated overload from conjectures about the missing peak waveform. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Clipping is an irreversible many-to-one transformation over the saturated part of the input waveform. Once distinct analogue peaks have produced the same maximum digital code, a subsequent programme cannot recover their true amplitudes or exact instantaneous waveform solely from those clipped samples. Some information remains: the onset and duration of saturation, the polarity of limiting, and unsaturated portions of the record can constrain possible source behaviour. The forensic report should make that distinction explicit. A test with a stepped calibrated source can identify the analogue input level at which clipping begins and whether an automatic-gain-control loop changes the threshold over time. If the same event is simultaneously observed through an independent lower-gain path, the second path may recover otherwise lost amplitude information. Merely interpolating across flat-topped samples, however attractive on a display, is a model-based reconstruction rather than a measurement of the original

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peak. Accordingly, the laboratory record for Question 025 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. Saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. Bennett's communications engineering perspective distinguishes stochastic noise models from deterministic signal-dependent converter errors and distortion products. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a high-gain sdr captures a short intense burst with a plateau of samples pinned to the maximum converter code; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: Sixteen consecutive maximum codes prove a saturation episode of at least sixteen sample instants, not its unmeasured analogue peak. It demonstrates the

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danger of transferring a result across domains in which the defining measurement has changed. I would therefore attach the uncertainty analysis to the *operational definition* itself instead of printing an unexplained confidence interval beside the most appealing trace.

A further, separately testable aspect of a high-gain sdr captures a short intense burst with a plateau of samples pinned to the maximum converter code concerns full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude. The proposed challenge would be compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. The decision is conditional upon the observed result, with particular attention to saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. The competing account remains the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. Nonlinear saturation generates spectral components that can masquerade as separate emissions. Dr Turing, I pass the floor for a test of whether those harmonics can be distinguished in the saved data.

Alan Mathison Turing | Peer question 5 to William Ralph Bennett

William R. Bennett, I should like to examine what the recorded data actually preserve when a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. The physical input and the retained numerical array are not interchangeable things. A calibrated lower-gain parallel channel can preserve information

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that the high-gain channel irretrievably discarded. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude would invalidate the preferred account, and which aspect of compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test would make that negative result independently repeatable?

William Ralph Bennett | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 025, the specific physical candidate is many distinct analogue voltages mapped into the same maximum or

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minimum digital code. The unresolved physical pathway is material: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. The retained record permits a conditional claim about full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, but cannot alone resolve saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. Saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. I propose separating acquired information from model-dependent reconstruction. A calibrated lower-gain parallel channel can preserve information that the high-gain channel irretrievably discarded. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude and a fresh trial in which the operator compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. If that trial demonstrates the low-gain record can retain peak ordering and duration where the

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original high-gain acquisition has discarded amplitude information, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Percy Williams Bridgman | Principal contribution 4: A model-assisted interpolation may be useful for illustration but should never be relabelled as an authentic historical measurement.

The operational definition of peak amplitude requires a physically specified reference and a measurement method capable of returning that value. When all samples above an unknown crest are reported as one maximum code, an exact peak amplitude cannot be measured by that instrument in that gain state. One may sometimes establish a minimum amplitude, the occurrence of overrange, or the existence of an input that exceeded a threshold. Those propositions should not be inflated into a calibrated waveform reconstruction. I would ask the engineer to repeat the controlled event at a lower gain while logging the change of gain, front-end loading and timing; if the source is repeatable, the comparison supplies new evidence. If it is a single unrepeatable forensic event, one must accept the limits of the surviving record. Experimental honesty is more valuable than a reconstructed crest whose smooth outline hides the assumptions on which it rests.

In this information retention examination of Question 025, the decisive claim is that a model-assisted interpolation may be useful for illustration but should never be relabelled as an authentic historical measurement. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: clipping destroys amplitude ordering beyond the rail. If a converter’s positive full-scale input is 1.0 volt and two analogue peaks reach 1.2 and 2.5 volts, both may be represented by the same maximum digital code. Their different amplitudes are not recoverable from

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that saturated code alone. Timing of threshold entry, unsaturated leading edges or measurements from an independent attenuated path may still convey useful information, provided the front-end and recovery behaviour are modelled. Some clipping can also introduce spectral regrowth that resembles wideband emissions, so reprocessing the clipped samples cannot prove that the reconstructed out-of-band content existed at the antenna. Preserve raw words and overload flags, record the fraction of saturated samples, and repeat with attenuation where possible. A forensic statement should distinguish demonstrated overload from conjectures about the missing peak waveform. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. The scientific point of a model-assisted interpolation may be useful for illustration but should never be relabelled as an authentic historical measurement. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions repeatedly show the low-gain record can retain peak ordering and

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duration where the original high-gain acquisition has discarded amplitude information, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. A reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there. The investigator should ask which rival input histories can produce the same retained sequence. Bridgman's operational approach requires a measurement procedure that defines each quantity physically. A stated number unsupported by the operation that produced it is methodologically incomplete. The issue becomes especially sharp because the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the

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interval and frequency domain actually examined. For the proposed case, sixteen consecutive maximum codes prove a saturation episode of at least sixteen sample instants, not its unmeasured analogue peak. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. A model-based interpolation can aid explanation without becoming an historical measurement of the erased peak. Dr Deming, I invite your challenge to any report that confuses the two.

W. Edwards Deming | Peer question 6 to Percy Williams Bridgman

I thank you, Percy Williams Bridgman, for distinguishing measurement from attribution, but the observation is that a reconstruction algorithm draws a smooth waveform crest above full scale despite the absence of unsaturated measurements there. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: sixteen consecutive maximum codes prove a saturation episode of at least sixteen sample instants, not its unmeasured analogue peak. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information on one day but fails after the instrument has been reconfigured? Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment? Would you also state what observed change in full-scale threshold,

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clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude would invalidate the preferred account, and which aspect of compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test would make that negative result independently repeatable?

Percy Williams Bridgman | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 025, the specific physical candidate is many distinct analogue voltages mapped into the same maximum or minimum digital code. The unresolved physical pathway is material: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. The retained record permits a conditional claim about full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, but cannot alone resolve saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, sixteen consecutive maximum codes prove a saturation episode of at least sixteen sample instants, not its unmeasured analogue peak. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. Its bearing on the dispute can be evaluated through the predicted response, namely the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information. Because the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence, the procedure compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match separate measured saturation bounds from illustrative restoration and never relabel an inferred crest as original evidence, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. The low-gain record can retain peak ordering and duration where the

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original high-gain acquisition has discarded amplitude information. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: A calibrated lower-gain parallel channel can preserve information that the high-gain channel irretrievably discarded.

The cost of a false peak claim and the cost of admitting uncertainty are not symmetrical in a forensic investigation. A spectacular reconstructed amplitude may influence equipment attribution, safety assessments and allegations about intentional conduct. I would require the algorithm to report its identified assumptions and to offer interval statements that retain the possibility of much larger peaks when the data cannot bound them. Simulated tests may show that a parametric fit performs well for a known single-tone waveform, yet that result should not be transferred to unknown pulse shapes without validation. If different plausible models yield incompatible maxima from the same clipped record, their disagreement is itself a result. The report may state with confidence that clipping occurred, with a calibrated lower limit on amplitude, while declining to assign the missing crest a unique value. The scientific question is what the retained evidence excludes, not how precise a plausible reconstruction can be made to look.

In this statistical inference examination of Question 025, the decisive claim is that a calibrated lower-gain parallel channel can preserve information that the high-gain channel irretrievably discarded. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: clipping destroys amplitude ordering beyond the rail. If a converter’s positive full-

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scale input is 1.0 volt and two analogue peaks reach 1.2 and 2.5 volts, both may be represented by the same maximum digital code. Their different amplitudes are not recoverable from that saturated code alone. Timing of threshold entry, unsaturated leading edges or measurements from an independent attenuated path may still convey useful information, provided the front-end and recovery behaviour are modelled. Some clipping can also introduce spectral regrowth that resembles wideband emissions, so reprocessing the clipped samples cannot prove that the reconstructed out-of-band content existed at the antenna. Preserve raw words and overload flags, record the fraction of saturated samples, and repeat with attenuation where possible. A forensic statement should distinguish demonstrated overload from conjectures about the missing peak waveform. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. A calibrated lower-gain parallel channel can preserve information that the high-gain channel irretrievably discarded. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange

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replay test, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say separate measured saturation bounds from illustrative restoration and never relabel an inferred crest as original evidence, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman's statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. One could stratify the experiment by nuisance condition, retain a random sample of nominally

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negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, sixteen consecutive maximum codes prove a saturation episode of at least sixteen sample instants, not its unmeasured analogue peak, is not an estimate of any actual investigation. A calibrated lower-gain parallel channel may preserve precisely the amplitude information the saturated channel lost. Sir Karl, I pass the floor to ask what independent evidence would make that restoration defensible.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise separate measured saturation bounds from illustrative restoration and never relabel an inferred crest as original evidence? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Digital values at full scale can establish that a threshold was reached but not how far it was exceeded. Please connect full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude with a declared detection

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threshold and the measurement exposure. If the experiment compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 025, the specific physical candidate is many distinct analogue voltages mapped into the same maximum or minimum digital code. The unresolved physical pathway is material: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. The retained record permits a conditional claim about full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude, but cannot alone resolve saturation is many-to-one, so the true peak is not identifiable from clipped codes without separately justified signal constraints. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Digital values at full scale can establish that a threshold was reached but not how far it was exceeded. I would use the observations of full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test, not an assertion based on the operator's impression of a quiet display. If it yields the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence, an intervention that leaves both alternatives consistent does not settle their

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difference. The result should be limited to separate measured saturation bounds from illustrative restoration and never relabel an inferred crest as original evidence, with the untested physical possibilities made visible.

Claude Elwood Shannon, Cross-Peer Question to Alan Mathison Turing: Dr Turing, a clipped SDR burst has thirty consecutive maximum-code samples, and software interpolates them to a smooth crest. The display looks plausible and reproduces a chosen band-limited waveform model. What distinguishes a permissible inverse-model estimate from the original measurement, and how would one demonstrate the nonuniqueness of the omitted analogue amplitudes?

Alan Mathison Turing, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, clipping maps a family of admissible amplitudes onto one extreme code. Construct two analogue input histories that agree at all unclipped sample instants yet exceed the converter limit by different amounts during the saturated interval. Both can yield the same stored codes under the assumed acquisition path. A band-limit, sparsity penalty or phase-continuity model may select one reconstruction, but its result is conditional on those constraints, their adequacy and calibration. Preserve the original sample stream unchanged, document the method and prior assumptions, and label the reconstructed crest as derived data. Check estimates against a separately acquired, demonstrably linear attenuated channel. An attractive curve is neither a recovered eyewitness record nor unique evidence of the emitted peak. I respectfully pass the floor to Dr Bennett to question spectral artefacts.

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William Ralph Bennett, Cross-Peer Question to Edwin Howard Armstrong: Dr Armstrong, after a severe burst reaches full scale, the FFT shows harmonics and wideband skirts. An examiner calls them new transmissions because they were absent in the quiet baseline. How may one distinguish nonlinear products of clipping from independently radiated energy, particularly when an upstream amplifier can overload before the ADC records an extreme code?

Edwin Howard Armstrong, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, the receiver must first be challenged with known, single-source stimuli at multiple input powers and with attenuation applied ahead of the suspected nonlinear element. If the extra spectral components change with level and disappear as the chain returns to its linear regime, an instrumental explanation becomes credible. A parallel low-gain, separately characterised path and controlled termination tests are useful checks, but either path can share an antenna-side nonlinearity. Compare observed harmonic and intermodulation frequencies with the nonlinear model, inspect gain-control and protection histories, and separate analogue preconverter distortion from digital clipping. The absence of maximum codes does not prove every earlier stage linear. A spectral shoulder on a clipped capture cannot by itself establish an external transmitter, its frequency occupancy or intention. I respectfully pass the floor to Dr Shewhart to address corroboration.

Harry Nyquist, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, a redundant low-gain converter records a candidate burst during the same interval that a sensitive channel clips. Both channels use the same clock and input splitter, and a worker calls them independent confirmations.

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What must be established before the lower-gain record can place reliable bounds on the lost envelope, and which uncertainties remain correlated?

Walter Andrew Shewhart, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, demonstrate that the lower-gain path remained linear across the event, including its amplifier, filter, protection network and ADC, not merely that the displayed codes stayed below full scale. Calibrate the splitter, attenuation, bandwidth, complex transfer function, group delay and timing offset against a common physical reference plane. Clock jitter, antenna-side nonlinearities and source coupling can be shared even when the amplifier gains differ; a common failure cannot be treated as two independent successes. If the attenuated record is valid, its measured peak can be transferred through a documented uncertainty model to bound the high-gain input, but a frequency-dependent or overloaded splitter may invalidate that transfer. Preserve both unprocessed streams and flags. I respectfully pass the floor to Dr Neyman for the evidential meaning of clipping percentages.

Percy Williams Bridgman, Cross-Peer Question to Jerzy Neyman: Dr Neyman, forty-two of 1,836 samples sit on the upper converter rail, approximately 2.288 percent of the record. A prosecution expert proposes that 2.288 percent of the signal energy was lost, while a second examiner treats a zero-detection sequence in thirty visits as proof that no intermittent transmitter was active. How would you limit these claims?

Jerzy Neyman, Cross-Peer Answer to Percy Williams Bridgman: Dr Bridgman, the numerator is a count of extreme-code sample instants, not an integral of unknown squared analogue voltage. The clipped samples tell us that the input reached a threshold under a specified gain and coding model, but they

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do not disclose the amount by which it exceeded that threshold. Signal energy could vary widely among analogue histories compatible with the record. Likewise, the illustrative probability 0.95 raised to the thirtieth power assumes thirty genuinely independent observation opportunities and a verified five-percent chance of detection per opportunity. It cannot license a statement about recovery-blind intervals or synchronised transmissions. Report the sample positions, missing blocks, observed gain states, calibrated sensitivity, alternatives and any model-assisted estimate as a separate layer. I respectfully return the discussion to Dr Atkinson for the concluding synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of the boundary between still-inferable facts and permanently lost amplitude information after clipping has established a point which the specialist must not overlook. The receiver records digital samples held at a converter limit during a high-amplitude event; it does not, merely by drawing a clear trace, give direct access to the original peaks, detailed envelope, and possibly the original spectral content of saturated intervals. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, Clipping is a many-to-one transformation and cannot generally be inverted without additional justified constraints. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

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A clipped acquisition can look remarkably persuasive after scaling and windowing, particularly if the largest samples are later hidden by plotting limits. Yet clipping collapses many possible input voltages into the same terminal code, and neither interpolation nor an elegant spectral estimator can restore the lost peak. The relevant inquiry must preserve the raw sample distribution, saturation flags, acquisition gain and channel-overload history. We should test an independently known input over and beyond full scale, then compare the clipped spectrum with the reference before attempting to interpret apparent harmonics. I thank Dr Nyquist for the sampling discipline, but his mathematical relation cannot supply the analogue excursions discarded by a converter's finite range. Our finding should therefore state the interval of invalid amplitude reconstruction and the limited propositions still supportable from uncorrupted portions of the record. The examiner must not promote post-processed appearance into proof that the original signal was neither stronger nor differently shaped.

The sampled waveform contains a plateau at the converter’s extreme code. That fact establishes at least an overrange or extreme-code event under the actual transfer convention; it does not establish the unique original waveform that produced it. The more useful outcome is a discriminating protocol: Compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. In applying it, the examiner must retain all readings supporting full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude and identify the physical plane to which the measurements refer. At the outset of the investigation, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the

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maximum converter code; that circumstance makes the alternative mechanism material, specifically the crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. A result approaching the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore separate measured saturation bounds from illustrative restoration and never relabel an inferred crest as original evidence. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

The manuscript should identify the saturation interval and report only the inferable bounds. Any reconstructed crest must be labelled as model-dependent, and no forensic claim may treat its plotted shape as recorded analogue evidence. The decisive experiment is concrete: Compare the clipped channel with a simultaneously acquired lower-gain reference and a calibrated overrange replay test. In conducting it, the examiner must explicitly retain full-scale threshold, clipped-sample proportion, contiguous overrange interval and lower-bound peak amplitude. If the outcome matches the stated prediction, the low-gain record can retain peak ordering and duration where the original high-gain acquisition has discarded amplitude information, the supported conclusion concerns that test domain.

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An alternative remains: The crest may be modestly over range or many times over range; both possibilities collapse to the same stored saturated code sequence. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 025

Application 01. Clipping extent and an information-preserving statement

In the illustrative 025.01 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. Out of N = 1,836 acquired converter sample instants, K = 42 carry an extreme-code plateau. The directly observed fraction is K/N = 2.288%. It is not the fraction of analogue signal energy lost, because the unknown overrange amplitudes have many possible values. An independent lower-gain recording can bound those amplitudes if its transfer path and time alignment are demonstrated; no interpolation can establish an otherwise unobserved peak uniquely. The observed 2.288-percent extreme-code fraction says nothing quantitative about energy above the rail or the unique true crest. Keep sample indices and raw codes unaltered.

Application 02. Ideal code step, variance, and full-scale sine SNR

In the illustrative 025.02 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. Taking an ideal N = 13-bit uniform converter across 2.50 V peak-to-peak, one nominal code interval is $\Delta = Vpp/2^N = 0.3052$ mV. Under the independent uniform-error approximation its rms quantisation error is $\sigma = \Delta/\sqrt{12} = 0.0881$ mV. The ideal full-scale sinusoidal SNR approximation is 6.02N + 1.76 = 80.02 dB. A coherent low-level waveform may violate the uniform-error assumption; clipping and integral nonlinearity are separate limitations. The 0.3052 mV nominal step, 0.0881 mV quantisation RMS and 80.02 dB ideal SNR describe an unclipped uniform converter; none reconstructs the overrange segment.

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Application 03. Gain allocation and blocker headroom

In the illustrative 025.03 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. Assume a calibrated digital full-scale equivalent of -7 dBm, a blocker applied at -44 dBm, and net analogue gain 23 dB. The projected converter input is -21 dBm and remaining margin is -7 − (-21) = 14 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain channel is needed before discussing the weak candidate. The projected 14 dB converter-input headroom is conditional on a calibrated linear gain path. Interstage compression may occur despite a positive final-stage margin.

Application 04. Cascade gain and observed headroom

In the illustrative 025.04 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. A first amplifier contributes G_1 = 10 dB, an intentional attenuation contributes G_2 = -8 dB, and a later stage contributes G_3 = 18 dB. The small-signal sum is 10 + (-8) + 18 = 20 dB. For P_i = -69 dBm, the ideal output is P_o = -49 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. The calculated −49 dBm output assumes 20 dB small-signal net gain; test each analogue stage and its peak response before treating that figure as a clipping boundary.

Application 05. Two-tone third-order products and input intercept

In the illustrative 025.05 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. With two equal input tones each at P = -27 dBm and a hypothetical input

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third-order intercept IIP_3 = +10 dBm, the extrapolated input-referred third-order product is $P_3 = 3P - 2IIP_3$ = -101 dBm, or -74 dBc relative to either input tone. The cubic approximation ceases to be reliable in compression. A two-tone slope check and input attenuation test must establish whether the predicted spur arises inside the receiver rather than externally. The −101 dBm third-order product and −74 dBc separation are extrapolations from a cubic small-signal intercept, unreliable once a stage compresses or saturates.

Application 06. Preserved sample continuity across an acquisition interval

In the illustrative 025.06 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. A converter expected to retain f_s = 1.30 million samples/s for T = 1.25 s should supply f_sT = 1,625,000 complex sample instants. If 261 sequence positions are missing, the retained count is 1,624,739 and loss fraction is 0.01606%. A low fractional loss cannot exclude a highly relevant short burst coinciding with the gap. Position and timing of each missing block must therefore be preserved. The 261 missing complex sample instants amount to 0.01606 percent of 1,625,000 expected instants, but even a tiny gap can remove an entire short emission.

Application 07. Thermal reference noise in a declared measurement bandwidth

In the illustrative 025.07 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. Take the equivalent noise bandwidth B = 18,000 Hz and calibrated noise figure NF = 2.35 dB at an assumed 290 K. The thermal-reference estimate

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is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF = -129.10$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. The −129.10 dBm thermal estimate in 18,000 Hz at 290 K does not describe an overloaded receiver, impulse statistics or the input energy above its coding range.

Application 08. Combined and expanded measurement uncertainty

In the illustrative 025.08 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. For independent standard-uncertainty contributions 0.73, 0.54 and 0.40 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.73^2 + 0.54^2 + 0.40^2)} = 0.992$ units. Using an illustrative coverage factor $k = 2$ gives expanded uncertainty $U = 2u_c = 1.984$ units. The 0.992-unit combined and 1.984-unit expanded uncertainties assume independent components and $k = 2$; censoring by clipping introduces a separate one-sided or model-based limitation.

Application 09. Opportunity-limited detection under independent visits

In the illustrative 025.09 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. For $n = 30$ genuinely independent valid observation opportunities, each with stipulated event detection chance $p = 0.05$, the probability of no detections is $(1 - p)^n = 0.21464$; its complement is 78.54%. The result is conditional upon the per-visit detection model and independence, neither of which follows from the number of FFT frames displayed. A periodic emitter synchronised with revisit timing can defeat this independent-visit estimate. The 0.21464 probability of zero detections

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presumes thirty valid independent opportunities with a known five-percent detection chance; clipped or missed intervals invalidate that inference.

Application 10. Difference between two instruments relative to stated uncertainty

In the illustrative 025.10 test, a high-gain SDR captures a short intense burst with a plateau of samples pinned to the maximum converter code. The paired instrument contrast is $\Delta = 1.770$ dB. Set independent standard uncertainties $u_1 = 0.340$ dB and $u_2 = 0.520$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.621$ dB, giving the dimensionless ratio $\Delta/u\Delta = 2.849$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. The 2.849 discrepancy ratio depends on independent standard uncertainties. The compared records must be aligned and checked for shared reference errors and clipped observations.

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Selected technical references and use limitations

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These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 026

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When may dither improve a quantitative estimate without increasing intrinsic converter resolution?

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Constructed educational dialogue. All remarks attributed to deceased historical contributors are newly written methodological reconstructions, not historical quotations or claims that these individuals handled present-day software-defined-radio instruments. Engineering cases are hypothetical, with stated assumptions and bounded conclusions.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, our preceding discussion of clipping established that the analogue-to-digital converter cannot disclose an amplitude it never represented. A subsequent discussion of dither must not contradict that boundary by suggesting that a random perturbation somehow manufactures information from nothing. Yet there is an apparent paradox, made visible in the repeated flicker of a least-significant-bit indication: a carefully characterised random disturbance sometimes makes the mean of an otherwise fixed low-level input more accurately estimable. The purpose of this question is to distinguish the statistical information recovered from repeated observations from the physical resolution and transfer characteristic of the converter itself. The distinction has considerable consequences for defensive technical surveillance countermeasures, where an investigator may be comparing a faint stationary spectral component against receiver-generated artefacts, rather than admiring an attractive number of decimal places on a display.

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I invite the panel to begin with three different objects which must not be confused. First is the native conversion mapping, by which the electronic instrument assigns discrete codes to a continuous input at specified instants. Second is the measurement protocol, which may include the injection or natural presence of an independent random signal, repeated samples, digital filtering, estimator selection, and calibration. Third is the evidential proposition to be reported. The code width belongs to the first object; the uncertainty of an estimator belongs to the second; the defensibility of a claim about an external emission belongs to the third. It is entirely possible to reduce an estimator's variance whilst making no improvement in integral nonlinearity, analogue bandwidth, aperture uncertainty, overload recovery, or source attribution. It is equally possible to injure a measurement by adding more noise after the required randomness is already present. [R1-R5]

We shall examine a finite-range uniform quantiser and its ideally simple counterpart before considering imperfect converters. Suppose a nearly constant analogue value lies between adjacent thresholds. Without adequate movement or independent perturbation, a succession of identical output codes offers a repeatable indication but may not distinguish different inputs inside the same code interval. With properly chosen dither, the probability of observing either code can depend upon the fractional position of the input. An average across independent observations may then estimate that fractional position. That statement is conditional upon the randomisation law, threshold stability, knowledge of the time interval, absence of overload, and the legitimacy of treating repeated samples as

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measurements of the same quantity. We must not use a favourable ideal model as a substitute for checking any of those conditions.

The central contrast will be between subtractive and nonsubtractive dither. In the former, the same known perturbation is introduced before conversion and removed digitally after conversion, requiring a faithful record of the perturbation. In the latter, the disturbance remains part of the total output error, although appropriate distributional design can suppress some signal-dependent error properties. Both approaches must be distinguished from merely adding numerical random values to codes after acquisition, which cannot alter what the converter originally captured. Nor should improved spurious-free dynamic range be casually translated into improved signal-to-noise ratio; a spur may diminish while the broadband noise floor rises. [R1-R3]

Dr Shannon will test the meaning of information and recoverability; Mr Bennett will analyse the quantisation-error conditions and their spectral consequences; Dr Nyquist will distinguish independent observations and bandwidth-limited acquisition; Professor Tukey will examine estimation and experimental validation; and Dr Shewhart will determine what operational controls make a nominally successful demonstration reproducible. Seven colleagues will then pose technical challenges that must be answered immediately before the discussion passes onwards. Ten numerical applications will define their variables and evaluate the limiting cases, including a deliberate near-overload failure. Our aim is not to celebrate a noise source as an instrument of magic. It is to specify the circumstances in which randomness makes a previously concealed relationship statistically visible, and to explain exactly what remains concealed.

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Dr Shannon, may I invite you to lead by distinguishing the information in one code from the information in a properly designed ensemble of codes? The floor is yours.

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Claude Elwood Shannon | Principal response 1: Information in the observation protocol

Dr. Atkinson, I thank you. The distinction between a quantised indication and information about an unknown parameter becomes sharper when we state what an observer is permitted to know. A single code from a uniform quantiser identifies a region of possible input values, not necessarily one input value. If a number of samples all receive the same code, we may be tempted to regard their unanimity as overwhelming evidence of a particular analogue amplitude. That temptation confuses repeatability with discrimination. Under a deterministic mapping, every input in a code interval can generate the same record indefinitely. No increase in arithmetic precision can undo that indistinguishability. The bits stored after the fact are simply a longer description of an unchanged ambiguity. [R1, R4]

An appropriately randomised observation protocol is different because the conditional distribution of the code can change with the unknown input. Consider a mid-tread quantiser with a code interval of width Δ and a positive constant input between zero and one code. Add independent dither drawn uniformly between minus one-half and plus one-half of Δ, and round the sum to the nearest integer multiple of Δ. If the input equals one-quarter of Δ, code one is observed with probability one-quarter, and code zero with probability three-quarters, ignoring measure-zero ties. Over many independent trials the fraction of ones estimates the input's fractional position. The converter has not acquired additional physical thresholds. The experiment has used known stochastic motion across an existing threshold to turn an otherwise flat response into a frequency-of-occurrence

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observation. An observer can recover a parameter from a probability law, but only by accepting that law as a tested premise. [R1, R2]

There are at least four constraints upon what the resulting estimate means. The input must remain sufficiently stable over the averaging interval, or the estimate becomes an average of changing inputs rather than the level at a stated instant. The dither must have the specified distribution and independence, for an unknown bias or correlation can reproduce the same changes in code occupancy. The converter must not overload, because saturation destroys the proposed threshold relationship. Finally, the estimator must be described with an uncertainty that reflects the actual data, not simply the ideal binomial approximation recited after the event. Where temporal noise is coloured, where digital decimation blends pulses, or where the data stream has missing blocks, the nominal sample count exaggerates the independent evidence. [R3, R5]

This discussion is sometimes expressed through the phrase 'resolution beyond a bit'. I would prefer language identifying the quantity that became better estimated. One may report the mean of a stationary voltage with a standard uncertainty below one least-significant-bit under an accepted calibration model. That does not say that a converter with twelve native bits now resolves twenty-four bits of instantaneous waveform amplitude. In particular, two analogue trajectories with markedly different sub-sample transients can produce the same sample sequence and even the same dithered histogram. The relevant equivalence class has been narrowed for one parameter without being abolished for every waveform. Forensic doctrine requires this limitation to appear in the conclusion, not disappear behind a visually precise decimal display.

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A second distinction concerns where noise may be helpful. A coherent interference tone can force quantisation error into periodic patterns whose discrete Fourier transform resembles a real spectral feature. Altering the threshold crossings through dither may distribute those error components more broadly, allowing a weak external tone to be distinguished in a controlled laboratory comparison. But the same added noise may obscure a genuinely weak transient. Whether information has increased depends upon the decision problem, the permitted false-alarm rate, and the time-frequency region of interest. A lower spurious peak is not the same outcome as a lower integrated noise density, and neither alone proves the presence or absence of an emitter. [R2, R6]

Suppose two archived datasets have identical sample codes but different unrecorded analogue histories, one of which contains a short pulse. No retrospective distribution of numbers can tell us which analogue history occurred unless the acquisition retained additional evidence constraining the alternatives. Digital noise added after quantisation may be useful to assess algorithm sensitivity or to suppress numerical limit cycles during subsequent requantisation; it cannot retroactively cause an old threshold to be crossed. If a numerical procedure claims otherwise, the examiner should demand the experiment which identifies new information in the original record rather than merely generating variation in a calculation. The data-processing inequality is a helpful conceptual discipline here, although it must not be invoked to deny the information contributed by a genuinely randomised *new* analogue observation.

Finally, there is an institutional distinction. A receiver manufacturer's statement that dither improves a converter characteristic is evidence about

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a specified measurement setup, waveform, band and analysis method. It is not a global metrological guarantee. The programme must preserve the parameters of the dither source, the analogue point of injection, the timing relationship, the filtering applied before and after sampling, and the raw unaltered codes. The investigator should compare a predeclared quantity across dither-on and dither-off trials while holding nuisance variables under control. Only then may the additional information claimed by the statistical model be attributed to the intervention with a defensible uncertainty. I offer that distinction to the panel and respectfully pass the floor to Professor Wiener for his examination of adaptive observation.

Norbert Wiener | Peer question 1 to Claude Elwood Shannon

Dr Shannon, I appreciate your separation of information from display precision, but the proposed experiment still contains a dynamic observer. In a practical receiver the noise injection may be adjusted automatically when the running code histogram appears too narrow, and the averaging interval may be prolonged when a faint target looks likely. Such feedback creates a selection process. The sample count is no longer independent of the apparent evidence, and the dither distribution may no longer have the same law across the entire record. A device can thereby accumulate beautiful-looking fractional-code averages while concealing a policy which chose favourable instants, rejected unfavourable blocks, or changed its sensitivity in response to provisional detections. How would your information analysis distinguish the useful feedback of a controlled experiment from the post hoc manufacture of confidence? More precisely, can a claimed gain in amplitude discrimination survive when the record does not preserve the controller's

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states, stopping rule, and unselected observations? I am concerned that the additional digits might describe the observer's adaptive policy more faithfully than they describe the external electromagnetic field.

Claude Elwood Shannon | Immediate answer to Norbert Wiener

Professor Wiener, the concern is decisive because the protocol determines the likelihood of the data. If a sequence is generated under a state-dependent injection rule, the probability of each subsequent code must be conditioned upon the controller state and the history that produced it. The elementary binomial illustration assumes an unchanging Bernoulli probability for independent trials. It is not licensed by the mere appearance of zeroes and ones in an adaptive archive. When a controller changes the injected amplitude, the number of trials, or the retention policy after examining interim results, the likelihood must include that decision process. Otherwise the analyst employs one model to gather data and another, more flattering model to report it.

A defensible design could be adaptive, but it would have to preserve every state transition and predefine the permitted adaptation. For example, the instrument might run an initial calibration tranche to choose among a fixed list of dither levels, freeze the selected level, and then acquire an independent validation tranche. The latter can support a claim about that chosen configuration if all its samples, failures and exclusions are retained. An alternative is a fully specified sequential estimator with a valid stopping rule and confidence procedure designed for optional stopping. Merely repeating the calculation for a fixed sample size at

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the moment the result appears impressive is not equivalent. The history-dependent sampling law has become part of the measurement instrument.

There is also a practical negative case. Suppose a weak emission is intermittent and the controller injects extra noise only during presumed quiet intervals. A lower average apparent error on the retained data may be true, yet irrelevant to bursts that occurred under other receiver states. The examiner must establish an observation envelope: what intervals were eligible, which were retained, what injection was applied, and what forms of target could have been hidden or displaced. The assertion that dither improved a *stationary mean* may remain supportable. The assertion that no intermittent transmission escaped detection does not follow from the same data. I would report the former with its conditions and withhold the latter.

Your question also helps us place the randomness correctly. Known stochastic input can create an informative experiment; unrecorded discretionary processing can create an opaque one. Randomness is not inherently virtuous, and feedback is not inherently disqualifying. What matters is whether the joint model of source, perturbation, converter, controller and archive is identifiable for the proposition being advanced. In scientific writing the word 'resolution' should not conceal those distinctions. I thank you for the challenge, and Dr. Atkinson, I return the token for the next principal contribution.

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Ralph Vinton Lyon Hartley | Peer question 2 to Claude Elwood Shannon

Dr Shannon, I should like to distinguish a communications measure from a measurement claim. A converter produces a fixed number of digital symbols, and a report which advertises more effective digits may tempt its reader to treat those symbols as if the channel capacity had somehow increased. Yet the extra statistical discrimination arises from repeated trials under a stochastic stimulus whose distribution the observer already knows. There is no evident contradiction, but the terminology can produce one if the roles of prior knowledge, measurement duration and independent observations are concealed. How would you describe the information gained when a constant voltage is measured many times with dither, without inviting the conclusion that each sample contains additional bits of instantaneous waveform information? Would you also distinguish a confidence interval around a mean from a code's ability to represent a rapid transient whose duration is shorter than the effective averaging interval? The distinction ought to survive even where the numerical results happen to agree with the calibration reference in a particular trial.

Claude Elwood Shannon | Immediate answer to Ralph Vinton Lyon Hartley

Mr Hartley, the clean expression is a statement about estimation under a specified experiment. One twelve-bit code is a member of an alphabet of at most 4,096 values. If the instrument produces repeated codes, the complete record has more possible sequences than a single code. The additional sequence variation can carry information

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about a stable parameter when its conditional probability law depends upon that parameter. Nothing in this account increases the alphabet of the instantaneous converter output. What has changed is the number and design of observations, and with it the statistical precision attainable for a restricted measurand. We should not label that result as a universal increase in native converter resolution.

The distinction becomes particularly important when the quantity is a function of time. If an amplitude changes during the averaging interval, the histogram of crossed thresholds reflects both analogue variation and injected dither. Without further structure those two causes may not be separable. The average can be well determined whilst the order, timing, peak and duration of constituent events remain unknown. To claim transient fidelity one would need a model for the waveform, sufficient sample timing information, the analogue transfer function, and evidence that the estimator preserves the feature of interest. Merely narrowing the standard error of a mean does not provide those requirements.

Consider also that a reported number can have many written digits and few defensible significant figures. A mean of 0.2500 least-significant-bit with a calculated statistical uncertainty of 0.0137 least-significant-bit may be meaningful in the ideal experiment we later construct. If the analogue reference scale itself is uncertain by 0.1 least-significant-bit, or threshold drift is unmeasured at that level, the numerical precision of the average does not establish that many accurate digits. The measurement report must propagate the calibration and drift components, including their correlations with

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other measurements. Precision obtained from repeatability is not immunity to bias.

For an intermittent electromagnetic search I would therefore keep two claims on separate lines of the report. One line might state that a calibration tone's stationary amplitude was estimated with a particular standard uncertainty under dithered acquisition. The other line would state what the detector established about time-limited external activity under separately validated operating conditions. The second does not inherit the first merely through a shared ADC. That formulation makes it possible to value improved estimation without pretending that a word of larger numerical width can repair the missing dimensions of the observation. I return the token to Dr. Atkinson.

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William Ralph Bennett | Principal response 2: The quantisation-error conditions

Dr. Atkinson, I am grateful for the opportunity to address the mathematical model which has become too familiar for its own good. A uniform quantiser is often accompanied by the statement that quantisation error behaves as independent, uniformly distributed noise with variance equal to Δ squared divided by twelve. That is an extremely serviceable engineering approximation under appropriate conditions, but it is not an axiom which holds for an arbitrary input. When the input is a small stable value, deterministic error may be constant. When a sinusoid is harmonically related to the sampling frequency, the error can be periodic and its energy can occupy spectral lines. When the input is nearly full scale, code transitions may reveal nonlinearity and overload rather than a neat independent process. Therefore the model must be earned by the experiment, not bestowed upon the ADC by the number printed on its package. [R2, R3, R7]

Dither attempts to change the distribution of quantisation error by altering the positions of the samples relative to the thresholds. Subtractive and nonsubtractive systems must be treated separately. In a subtractive arrangement an independent random quantity d is added to the analogue input x, the sum is converted, and the same d is subtracted from the digitised result, producing $z = Q(x + d) - d$. If the ideal unbounded quantiser and dither satisfy suitable distributional conditions, the total error $z - x$ can be uniform and independent of x, with variance Δ squared divided by twelve. That attractive theoretical property depends upon the subtracting apparatus knowing the actual perturbation, not a nominal specification for a noise

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generator. Timing, reconstruction and calibration errors in subtraction become additional components of measurement uncertainty. [R1, R2]

Nonsubtractive dither is more accessible in some practical instruments, because the added disturbance is not subtracted exactly afterwards. The total error is Q(x + d) - x, which includes the random perturbation as well as the quantisation error. A properly chosen triangular distribution, often constructed by adding two independent uniform variables each spanning one quantisation interval, has valuable first- and second-order error properties for an ideal quantiser without overload. Yet the total error variance may be greater than the quantisation error variance of an ideal independent-noise model. There is no contradiction: randomisation can exchange concentrated, signal-correlated distortions for broader stochastic uncertainty. If the operational goal is a weak-tone survey, reducing an apparent spurious line can be valuable even where the integrated noise power does not fall. If the goal is estimating a static voltage with minimal standard uncertainty, the added variance and averaging cost must be accounted for. [R1, R3]

The spectral question deserves careful language. A deterministic sequence, even when weak in amplitude, can produce a prominent narrow Fourier component after a long record, because coherent energy is concentrated in a few bins. Noise with comparable total energy is distributed across many bins according to its spectrum and the windowing process. Dither can alter the relative prominence of these structures. But one cannot infer that a newly flattened spectrum reveals only external emissions. The analog front end, interleaved sampling branches, clock phase noise and downstream digital arithmetic can introduce their own

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lines. Nor can one treat a spur that disappears with dither as absolute proof that it was a quantisation artefact. An injected noise signal may also mask a true weak tone or change the operating point of a nonlinear analogue stage. The proposed causal inference requires controlled interventions and their competing predictions.

An investigator could use three complementary acquisitions: a quiet reference with the same gain and clock, an externally injected calibrated tone that is known to traverse the relevant receiver boundary, and the unknown environment. Dither would be toggled according to a precommitted sequence, with its amplitude, spectral density and analog injection point recorded. The test would estimate the change in known converter-correlated lines, the change in broadband noise within the detection band, and any shift in a known external reference line. If the narrow suspect feature tracks a local digital or converter condition more closely than it tracks the antenna or calibrated RF input, an instrumental hypothesis gains support. Yet one should not transform correlation into an unqualified source identification without further physical tests.

I should emphasise a metrological subtlety about the words 'improve resolution'. Under repeated independent dithered observations, some estimates can possess standard errors smaller than Δ. The uncertainty of their mean can decline with the square root of the sample count when assumptions hold. The underlying code thresholds remain unchanged; differential and integral nonlinearity may remain unchanged; and any common offset or gain error persists across the entire average. The analyst should therefore report effective estimation precision for a specified signal class and observation duration. A claimed conversion to more intrinsic ADC

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bits would be physically mistaken. The ADC itself has not acquired additional independent comparators, a wider linear input span, a faster aperture, or an improved full-scale reference. [R3, R8]

Lastly, any test of dither should evaluate adverse conditions. Place a strong blocker near the upper input range and ask whether the added random signal causes overload at a measurable rate. Make the input phase coherent with the sampler in one trial and deliberately noncoherent in another. Repeat across temperature, reference voltage, and relevant analogue bandwidths. A narrow spectral improvement seen under one coherent stimulus may not transfer to the operational mixture of signals. A defensible report will specify the span of conditions studied and identify where the statistical randomisation model fails. Professor Bridgman, I respectfully offer you the token to test whether my term 'quantisation error' survives a change of measurement operation.

Percy Williams Bridgman | Peer question 3 to William Ralph Bennett

Mr Bennett, I wish to press the distinction between an abstract quantiser and the actual instrument. In your first expression the same dither is subtracted after conversion, but a physical noise source has finite bandwidth, delay, amplitude calibration and imperfect synchronisation. The mathematical subtraction of d is an operation upon a known function. The engineering subtraction may employ a separately digitised estimate or a pseudorandom sequence with a timing slip. These operations do not define identical results. If the recorded perturbation were misaligned by even a fraction of a sample, its removal could create a deterministic pattern that appears more persuasive than the original error. What operations should be required before the investigator can

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say the subtraction genuinely occurred at the asserted analogue reference plane? Moreover, if a common reference error affects both dither generation and the converter output, would repeated averaging conceal rather than reduce the error? I invite a criterion that can be tested at the bench rather than guaranteed by notation.

William Ralph Bennett | Immediate answer to Percy Williams Bridgman

Professor Bridgman, your objection supplies the boundary between a theorem and an instrument certificate. The formula is a map of desired operations. Its use in a finding requires an experimental account of those operations under relevant physical conditions. In particular, the apparatus must specify the injection reference plane, the transfer from its dither source to the quantiser's sampling input, the timing at which a dither value affects a particular conversion, and the transformation by which the digital subtraction reconstructs the value that was actually applied. A stored pseudorandom seed is not a sufficient record if the analogue reconstruction, filter, or clock relationship is unverified. Conversely, a genuinely digital subtractive scheme may be reproducible when its perturbation and timing are defined, although the independent converter calibration remains necessary.

A practical test would route a stable calibrated analogue input through the same front end while collecting the complete injected waveform and an independent record of the converter clock. The investigator could compare the residual after subtraction against the predicted distribution, test for correlation with the injected sequence,

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and repeat with deliberately shifted alignment. The shifted trials act as negative controls. If a change of one sample produces conspicuous periodic residuals, the system is sensitive to that error and should record its timing tolerance. An apparently white residual is not sufficient proof of proper subtraction; some wrong transformations can yield attractive marginal histograms. Joint correlation, spectral structure, and reference-plane gain should be examined.

For common errors, averaging is particularly powerless. Let a common offset b affect every measurement. Write $y_i = x + b + e_i$, with the random errors e_i having zero mean. The sample mean becomes $x + b + \mathrm{mean}(e_i)$. Its random error may shrink while the common bias remains exactly b. If the dither source and ADC share a drifting scale, the resulting error components may also correlate rather than average away. That is why the uncertainty budget must distinguish Type A components obtained by repeated observations from Type B contributions associated with calibration and the physical measurement model. Statistical precision is not an independent verification of traceability. [R5]

Your final question asks for a bench criterion. I would require documented agreement between the intended and measured dither sequence at the actual conversion boundary, sufficiently low subtraction residuals over the declared bandwidth, a characterised timing tolerance, and reproducibility under a changed input amplitude and operating temperature. Every acceptance threshold must be defined before the pass-or-fail observations are selected. If those conditions cannot be demonstrated, the result may be called a

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stochastic averaging procedure, but not a verified realisation of ideal subtractive-dither theory. The distinction is not verbal pedantry. It determines which variance formula may responsibly be propagated into a legal or forensic statement. I thank you and return the token to the moderator.

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Harry Nyquist | Principal response 3: Sampling, bandwidth and effective independent observations

Dr. Atkinson, I accept the account of quantisation but wish to draw attention to the clock and the bandwidth. The possibility of estimating a static or slowly changing quantity from many dithered samples rests upon the relation between the observation duration and the physical bandwidth of everything entering the converter. If a disturbance contains frequencies outside the admitted analogue band, it may be filtered before it can cross the threshold. If it reaches the sampler above the applicable Nyquist region without adequate anti-alias protection, it may fold into the frequency interval of interest. If the digital filter has a long impulse response, adjacent output values may be strongly correlated. These are different limitations, yet all three can be hidden behind a single expression such as 'average 1,024 samples'. The count of stored numbers is not always the count of independent observations. [R3, R8]

For a sequence of independent, zero-mean errors with variance σ^2, the variance of the arithmetic mean is σ^2 divided by N, where N is the number of observations. This is a mathematical statement about the error process, not a guarantee about any receiver. If the errors share a constant correlation coefficient ρ, an illustrative equicorrelation model gives variance of the mean equal to σ^2 times [1 + (N-1)ρ] divided by N. For sixty-four measurements with correlation one-tenth, the multiplier is 7.3 divided by 64 rather than 1 divided by 64. The effective independent sample count for the mean is therefore approximately 8.77. A receiver storing sixty-four codes would obtain a precision gain much closer to that of nine independent

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observations than sixty-four. The model is simplified but exposes the effect of an assumption that operators often leave invisible.

The oversampling ratio also needs an explicit bandwidth definition. An idealised converter whose noise is white over the Nyquist interval may acquire samples at a rate far above twice the final signal bandwidth. Filtering and decimation can remove much of the out-of-band noise. Under the usual ideal assumptions, increasing the oversampling ratio by a factor of four produces approximately six decibels of in-band noise-power reduction, equivalent to about one effective bit of *in-band noise-limited performance*. That rule is not a device-physics identity and should not be used for flickering threshold values without checking the error spectrum. If noise is signal-dependent, coloured, or dominated by a fixed analogue offset, the rule may fail. If the target is a short pulse whose duration is comparable to the digital filter's memory, the decimated record may be less faithful to that pulse than the original high-rate samples. [R8, R9]

The dither spectrum itself deserves the same attention as a signal spectrum. A broadband perturbation may improve statistical coverage of thresholds but raise noise in the detection band. An out-of-band perturbation may move some converter artefacts without directly contaminating the final detection band, provided the analogue and digital filter boundaries truly confine it. But an out-of-band tone or noise component can also intermodulate in the front end, alias during conversion, or overload a shared stage. Thus a design which is beneficial on an isolated converter board may perform badly in an installed receiver whose antenna, preselector, low-noise amplifier and mixer introduce different constraints. The engineering decision cannot be divorced from the full path.

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For TSCM work this is especially consequential because the observation object is not always stationary. Suppose an emitter activates for two milliseconds while the receiver averages an amplitude indicator over one second. The averaged reading may be statistically stable and precisely reported yet conceal nearly all timing information about the emission. Conversely, a detection pipeline retaining the unfiltered high-rate record may be capable of recognising the event while a secondary averaged channel estimates the background or calibrates slow drift. Both outputs may be useful if their intended estimands are stated. They cannot be interchanged merely because both ultimately derive from the same ADC codes. One channel is a transient-evidence path; the other is a low-bandwidth estimation path.

I would therefore insist upon a timing register that identifies actual sample clocks, their uncertainties, block losses, decimator group delay, digital filter coefficients, dither generation timing and the relationship of any trigger to the raw samples. The sample count in a data sheet does not disclose these matters. Under a chosen weak-signal model, the investigator should calculate detection probability and uncertainty using an effective number of independent observations or an explicit covariance model. This is preferable to asserting a universal 'six decibels per fourfold oversampling' rule while ignoring whether the relevant information was moved outside the retained band. Nor may one infer that a lower noise floor corresponds to lower false-alarm probability unless the decision rule is adjusted and validated.

There is a final distinction between rate and span. A faster conversion rate may admit a larger analogue bandwidth if the front end and sampling

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geometry are designed for it; it does not by itself create the dynamic range required to recognise a faint source beside a strong blocker. Averaging across time can reduce uncertainty for stable quantities, but cannot automatically preserve every event in a larger spectral span. One should characterise the permissible trade-off among bandwidth, temporal resolution, spectral resolution, dynamic range and independent measurement time. I pass the floor respectfully to Dr von Neumann, whose concern about assumed randomness may test the very foundation of this independent-sample argument.

John von Neumann | Peer question 4 to Harry Nyquist

Dr Nyquist, your caution about correlated samples is persuasive, but a practical implementation may derive its dither from a deterministic pseudorandom generator rather than an analogue noise source. Its sequence is computable and therefore not genuinely unpredictable to an informed examiner. Nevertheless, an appropriately long deterministic sequence may seem statistically well distributed over the short interval used to estimate a voltage. Does the absence of intrinsic randomness invalidate the proposed gain, or can a reproducible deterministic sequence provide the necessary threshold coverage for a specified estimator? If the latter, what is the relevant distinction between an average taken over an exact, repeated excitation pattern and a probabilistic interval derived as though every observation were independently random? I should like you also to address the danger that a dither sequence which repeats at an unfortunate rate produces periodic spectral structures precisely where the TSCM receiver is attempting to find unknown low-level emissions.

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Harry Nyquist | Immediate answer to John von Neumann

Thank you for that question. Professor von Neumann, it is not necessary to pretend that every useful excitation is ontologically random. A predetermined sequence can sweep thresholds and permit parameter estimation under a deterministic calibration model, provided its values, timing and relation to the input are sufficiently known. The investigator may then derive an estimator using the actual sequence and the converter's transfer function, or calibrate the response empirically. But it would be incorrect to attach a confidence interval based on independent identically distributed noise merely because the sequence's histogram resembles the chosen random distribution. Statistical properties of a sequence under one collection of tests do not automatically furnish independence from an unknown input or unrelated clock. The mathematical justification must correspond to the physical construction.

Suppose a pseudorandom pattern repeats every P samples. Its periodicity produces discrete spectral lines at multiples of the repetition frequency, potentially with sidebands after nonlinear conversion. If the target happens to be coherent with that pattern, threshold crossing probabilities may depend on phase in ways that a marginal histogram conceals. Randomising the starting phase, choosing a sequence whose period greatly exceeds the acquisition interval, or changing the dither clock relationship can reduce such effects, but each is an engineering hypothesis to be tested. It cannot be certified by the word 'random' in the software documentation. The

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validation should include spectral examination of the known dither itself and of the residual under a range of coherent reference signals.

For an uncertainty report, I would distinguish two kinds of inference. One concerns the response to a calibrated deterministic excitation whose complete sequence has been retained. Its error bound might come from measured transfer-function tolerances and repeatability across controlled trials. The other concerns an ensemble of hypothetical random excitations and makes a probability statement about estimator variability. The former can be strong without being the latter. When both are used, the report should identify which uncertainties arise from the actual observed sequence and which from an assumed distribution of future or repeated experiments. That distinction prevents an engineer from treating a convenient design sequence as a licence for unsupported tail probabilities.

Finally, the presence of a deterministic dither may be exceptionally useful for diagnosing an apparatus precisely because its sequence is reproducible. One can repeat a run, examine phase relationships, shift the injection timing intentionally, and test whether a suspect spectral line follows the internal sequence. In a forensic setting that controlled challenge may be more informative than a vague assertion that natural noise should be harmless. Yet the very power to repeat the excitation increases the responsibility to preserve the exact configuration and to avoid reporting the resultant spurs as external emissions. I thank you, and return the floor to Dr. Atkinson.

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John Wilder Tukey | Principal response 4: Estimation, experimental design and the adverse case

Dr. Atkinson, I should like to examine the purpose of the calculation rather than begin with a preferred signal-processing operation. The first question is what the engineer hopes to know: a mean voltage, an RMS amplitude, a spectral line's frequency, a low-level event's existence, or the probability that a particular alarm corresponds to an external source. An estimator which is efficient for a stationary mean can be unsatisfactory for an intermittent event. A detector which suppresses a fixed quantisation spur can lose power for a transient signal when additional noise enters its measurement band. The word improvement is incomplete until the loss function, operating conditions and comparison procedure are specified. We must therefore design the experimental challenge before selecting the dither amplitude which yields the most pleasing result. [R3, R6, R10]

I propose to divide the experiment into discovery and validation. In discovery, one may explore several amplitudes, probability distributions, spectral placements and processing parameters. Such exploratory work is scientifically valuable; it is how unforeseen failure modes are found. The danger arises when a particularly favourable choice is selected using the same observations that are later presented as an unbiased validation of that choice. A receiver may be tested with ten noise levels, five filters, three detector thresholds and several observation durations. An impressive apparent detection rate chosen from the best combination does not enjoy the nominal error probability of a single predeclared test. A separate validation population, or an analysis that properly accounts for adaptive selection, is required before the headline claim may be made.

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The simplest numerical illustration involves a fixed value one-quarter of a least-significant-bit above a rounding threshold. Add properly characterised uniform dither, perform one thousand independent trials and count the higher code. Under the ideal threshold model, the expected higher-code proportion is one quarter, and its binomial standard error is the square root of 0.25 times 0.75 divided by one thousand, or approximately 0.0137. The result supports a conditional estimate of the stationary fractional threshold position. But the calculation's elegance is not its proof. Before adopting the interval, I want a record of threshold drift, analogue noise correlations, code-selection logic, independent calibration, rejected samples and possible input variation. The experiment should also repeat at several unknown offsets, because a calibration procedure that works at one especially convenient fraction of a code may fail near the adjacent transition. [R1, R5]

Now consider the opposite outcome: false alarms. Suppose the analysis searches five hundred effectively independent spectral bins, each assessed at a nominal false-alarm probability of one in a thousand. Under the simplifying independence model, the chance of at least one false alarm somewhere in the search is one minus 0.999 raised to the five-hundredth power, approximately 39.4 percent. Dither may reduce a coherent instrumental line and still require recalibration of the detector because it changes the noise distribution. If the report quotes only the per-bin significance, the reader may infer a level of assurance not provided by the full search. The same problem recurs across observation times, antenna positions and receiver configurations. The family of opportunities to obtain an apparently significant result must be defined before evidential confidence is assigned. [R5]

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A sound experiment would contain a factorial structure with at least these dimensions: dither on or off; an independent known external test signal present or absent; a large blocker present or absent; and coherent or noncoherent relationships between input frequency and sampling clock. Additional blocks could vary temperature, analogue gain and filter settings, provided the design remains tractable. Randomising the order of trial conditions would help control gradual thermal drift. The raw data and the predeclared analysis code would be preserved. We would compare true-detection rates at a fixed *global* false-alarm specification, not award victory to whichever display looks quieter. We would inspect uncertainty intervals rather than merely compare means, and identify intervals where the receiver saturated or the dither failed to reach the conversion threshold.

One must beware of an attractive paradox in reporting. A randomised quantiser can reduce bias in estimating a mean whilst increasing variance of individual outputs. A weak tone may become more readily distinguishable from deterministic quantisation spurs while a single-shot pulse becomes harder to detect. These are not inconsistent outcomes. They are properties of different estimands, time scales and decision rules. The experiment should not place every capability under the single label 'sensitivity'. For a TSCM investigation, it is entirely plausible that a dithered high-rate background-estimation channel and a nondithered transient-preservation channel will have complementary roles. Such an arrangement is defensible when acquisition paths, cross-calibration and alert logic are carefully characterised, but not merely because two windows appear on the same console.

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An investigator should report an honest hierarchy of conclusions. A narrow claim might establish that a calibrated stationary signal can be estimated with reduced random uncertainty over a specified interval. A stronger claim might establish improved suppression of known converter-correlated spurs in a specified analysis band at unchanged global false-alarm probability. A still stronger claim about improved detection of unknown intermittent surveillance transmissions would require a representative challenge population including bursts, blockers and changing frequency. None follows automatically from the preceding claim. A clear methods appendix should enable another analyst to test the same hypotheses and obtain a comparable inference, including the conditions under which the intervention worsened performance.

In the end I would not demand that every study be perfect. I would demand that the study be clear about the problem it actually answers. Exploratory plots can suggest mechanisms; controlled challenges can test them; and a bounded acceptance criterion can support a practical decision. What must not occur is promotion of a convenient numerical result into an unlimited property of an instrument. Sir Ronald Fisher, may I courteously pass you the token to consider the price of repeated testing and the interpretation of apparent improvements?

Sir Ronald Aylmer Fisher | Peer question 5 to John Wilder Tukey

Professor Tukey, I agree that an intervention must be tested against the claim, but the design you describe is sufficiently elaborate to tempt an investigator into post hoc selection. Suppose a development team evaluates twenty dither amplitudes, inspects many spectra, and retains the setting with the smallest observed spurious line. It then calculates a

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confidence interval for that setting as though no alternatives had been examined. The apparent gain might be partly a selection effect. Conversely, a rigid rejection of every adaptive procedure would discourage useful engineering discovery. How should the investigator divide inference from exploration when the number of attempted configurations itself changes as technical anomalies are discovered? Would you require a reserved validation collection, a sequential testing rule, or some other restriction, and what exactly should a court or independent technical reviewer be told about the unselected configurations and trials? I should also like to know whether adverse data must remain available even when an engineering team believes those observations were anomalous.

John Wilder Tukey | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, the principal remedy is transparent separation of learning and testing. An exploratory sweep of twenty levels can identify patterns worth pursuing, including unforeseen regions in which added noise induces overload or analogue intermodulation. There is no need to conceal such learning or apologise for it. But the trial that determines the declared acceptance condition should either use independent validation data or apply a method whose error control accounts for the selection. A confidence interval computed as though the selected configuration had been chosen beforehand is not the same inferential object. The problem is not that selection occurred. It is that its consequences were omitted from the probability statement.

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I would record the complete candidate set, the chosen loss function and all data-dependent decisions. If the engineering team changes the candidate set after observing a fault, the history should distinguish the original and revised phases. A practical protocol might allocate one group of reference waveforms to discovery, then freeze the dither generation, filter coefficients and detector threshold, and use a separately generated set of coherent and noncoherent signals for validation. The trial order should be randomised where possible, while independent measurement standards check source amplitude and frequency. The validation report should state every failed and excluded trial, along with the predeclared reason for exclusion and any sensitivity analysis including those trials.

There are occasions where independent data are expensive, for example when a rare electromagnetic environment is difficult to reproduce. In that case one can use an appropriate sequential or resampling procedure if its assumptions are met, but the procedure and stopping rule must be specified sufficiently to control the relevant uncertainty. Repeatedly examining ordinary confidence intervals until one excludes zero does not achieve that objective. Nor does a large recorded sample count compensate for the dependence introduced by filtering or overlapping windows. An honest report may conclude that an intervention is promising but not yet independently validated. Such a finding is useful for further engineering work and less hazardous than an unsupported certification.

The forensic audience needs the operational rather than merely mathematical version of this account. State how many configurations

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were evaluated, whether the final setting was selected from those observations, which trials were reserved for validation, what detection and false-alarm definitions applied, and what environment was represented by the challenge signals. If a dither-on setting improved a certain spur by ten decibels but worsened burst sensitivity, both outcomes belong in the report. If the improvement was measured only under coherent laboratory tones, say so. The reader should be able to reconstruct the inferential pathway, not simply admire the chosen plot. Dr. Atkinson, I return the token.

Alan Mathison Turing | Peer question 6 to John Wilder Tukey

Professor Tukey, I wish to ask what a purported post-processing improvement can compute from an immutable evidence file. An analyst may take a twelve-bit recording, add carefully generated pseudorandom numbers to its samples, and then calculate averages or resample it onto a finer numerical grid. The output may contain many new values and display a smoother trajectory. In some settings numerical randomisation is a legitimate algorithmic convenience, but there may be pressure to describe the operation as recovery of an analogue signal that was never adequately sampled. Could you specify a test capable of distinguishing an estimator that merely changes its numerical behaviour from a procedure that has genuinely acquired new physical information? I am particularly concerned by reports of reconstructed pulse heights or durations obtained only after the acquisition has ended, where no independent contemporaneous measurement constrains the missing analogue waveform. An algorithmically stable answer may be reassuring

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to the eye while still depending entirely upon an untested prior assumption.

John Wilder Tukey | Immediate answer to Alan Mathison Turing

Dr Turing, your distinction is essential. A post-processing algorithm can reorganise the information already present, apply valid prior models and produce a useful conditional estimate. It cannot create a new observation of the physical event. If two different analogue inputs would have generated exactly the same retained code sequence under the known acquisition procedure, no processing of that sequence alone can decide which input was present without additional assumptions or external evidence. Adding random values to the stored numbers changes the computation, not the historic threshold crossings. The resulting variability is an attribute of the algorithm, not independent physical information from the instrument.

A direct test begins with a calibrated analogue signal whose fine structure is measured independently at the relevant reference plane. Record the raw converter data and run the proposed processing under a range of known inputs which lie within the same quantisation intervals. If the algorithm assigns different correct estimates to those inputs solely because its random seed differs, it is not identifying the analogue truth. It is producing a distribution of reconstructions conditional upon its assumptions. Such a distribution may be defensible as an uncertainty representation if the prior model and its validation are disclosed. It is not a measurement of an unrecorded pulse peak. Conversely, if repeated *new* analogue acquisitions are made under appropriately randomised excitation, their differing

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codes can provide additional information about a stable parameter, and the validation can demonstrate this experimentally.

The resulting report should separate observed data, introduced randomness, modelling choices and inferred properties. A reconstructed stationary mean may be consistent across several seeds without proving that each instantaneous amplitude was correct. A pulse may be reconstructed under an assumed waveform template whose limitations ought to be stated and tested. If the output is intended to support a legal finding, the method should preserve the original immutable file, the algorithm version, seed, parameter choices, calibration history and any independent test cases. Reproducibility of the computation is necessary but does not establish correctness of the source model. This is a familiar distinction between solving a calculation and validating its premises.

Your question also suggests a rule for professional vocabulary. Reserve 'acquired' for observations made by the physical measurement chain; use 'estimated', 'interpolated', 'modelled' or 'simulated' for results of subsequent computation as appropriate. If a digital resampling routine produces twenty-four-bit floating-point values from twelve-bit stored codes, it is entirely possible for the output to be numerically precise. It is not thereby a twenty-four-bit record of the original continuous waveform. An expert who makes that distinction plainly can still explain the merits of denoising or estimation without misleading the reader about instrumental resolution. I thank you and relinquish the floor to the moderator.

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Walter Andrew Shewhart | Principal response 5: Metrology, procedure and evidential trust

Dr. Atkinson, the preceding contributions have described a statistical benefit whose legitimacy depends upon stability. I should like to make stability the principal subject rather than an incidental qualification. A measurement process includes the reference standard, the physical input coupling, environmental conditions, the dither generator, converter transfer function, sample clock, digital processing and the people who configure or review the system. It is possible for each isolated component to possess a respectable specification while the assembled process operates differently after a cable replacement, a temperature excursion or a software update. The presence of randomly toggling low-order codes tells us little about the reliability of this combined process until its relevant state variables have been monitored and challenged. [R5, R10]

Control should begin with an explicit calibration hierarchy. A stable reference source tests amplitude and frequency at a defined plane. A noise or dither source should have a measured spectral distribution and amplitude at the point where it actually reaches the quantiser. The record should identify the sampling clock, its uncertainty and whether the dither generation shares that clock. A source whose amplitude changes with temperature may alter threshold occupancy in a way that resembles a drift of the unknown input. The analyst should therefore measure the dither itself in representative conditions and use independent checks to distinguish its changes from the converter's changes. This is not bureaucratic paperwork. It is what permits the observed code histogram to have the physical meaning assumed in the estimation model.

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Control charts can be useful, provided they monitor relevant quantities rather than decorate the report. One chart may track the mean of a calibrated stationary input; another may follow the variance or distributional shape of the dither; a third may record the level of a known converter-correlated spur. The purpose is to identify changes which require explanation, not to use a statistical limit as a substitute for physics. The process should define which conditions are expected to remain stable and how suspected changes prompt investigation. An excursion might arise from a converter threshold shift, injected-noise amplitude change, reference-scale error, clock disturbance or unrecorded operator intervention. The chart signals that the original model may no longer apply. It does not establish which mechanism occurred.

I would demand particular care in the use of repeated observations. A group of measurements can be highly repeatable because it shares one offset. A dither generator may be precisely repeatable because its output is controlled by a common reference whose error has not been checked. A hundred nominally independent receivers may share one antenna distribution stage and consequently one interference pathway. Additional counts do not automatically reduce such common errors. Every uncertainty budget should distinguish random components which can decline with averaging from common systematic components and covariances which do not. When the resulting calculated standard uncertainty is smaller than the smallest meaningful calibration error, the proper response is to report the combined uncertainty, not to suppress the calibration term for the sake of an impressive result.

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The legal and investigative consequences are direct. If the technique is employed while searching for unauthorised emitters, the primary evidence is the preserved record of what the receiver admitted and represented. The controlled dither should be treated as part of the instrument's operating state and the chain of acquisition, not as a later cosmetic adjustment. The examiner should retain raw codes, injection settings and monitoring records, software versions, calibrated references, source-selection history and all exclusions. A hash can demonstrate that a file was not altered after a specified point, but cannot prove that the original ADC was accurate or that the analogue channel was free of intermodulation. The difference between integrity and validity should be apparent to any later reviewer.

A practical procedure can be expressed as a sequence of questions. Was a dithered acquisition scientifically justified for this measurand? Was the unmodified acquisition retained alongside the dithered one where feasible? Did the intervention reduce the particular systematic artefact it was intended to reduce? Did it raise the relevant noise floor, overload rate or false-alarm count? Were both the successes and the failures preserved? Was the same result obtained under an independent reference or altered receiver configuration? If the answer to any critical question is unknown, the result may still be useful as an exploratory observation, but its scope should be described accordingly. A great many errors arise not from bad mathematics but from applying good mathematics to a changed process.

An acceptance test should include stable tones at several positions within a code interval, low-level noise-like signals, coherent tones, short bursts, a strong blocker and an apparently quiet reference. The test should be repeated under dither-on and dither-off conditions in a balanced order, and

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at the relevant environmental extremes. The evaluator must decide in advance what constitutes an unacceptable degradation of transient detection, a significant reduction of instrumental spurs, and a valid improvement in stationary amplitude estimation. These may be competing objectives. A process intended for general surveillance cannot be certified on the strength of only the easiest one. When a claim is made about the probability of detecting an intermittent emission, the relevant trials should contain intermittent emissions whose timing is not favourably synchronised with the receiver.

Finally, I would separate the language of quality control from that of attribution. A well-controlled ADC with dither may reduce uncertainty associated with a measurement of an admitted signal. It does not identify the transmitter, its owner, its purpose or the location from which the energy originated. Those propositions require further physical observations, competing-hypothesis tests and evidence beyond the digitiser. The best quality-control programme protects the credibility of a bounded claim by preventing it from expanding unnoticed into a claim the apparatus cannot establish. Mr Weston, may I respectfully pass you the token to ask whether our reference-plane assurance is itself independently tested?

Edward Weston | Peer question 7 to Walter Andrew Shewhart

Dr Shewhart, your controls are persuasive, but I remain concerned about the physical quantity being compared. A laboratory may calibrate an ADC at its accessible input pins and then advertise reduced error after dither, while the field receiver includes a preselector, amplifier, mixer, attenuator and cables. Their losses, temperature dependence and nonlinearities affect the electromagnetic quantity that the investigator

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intends to infer at the antenna port. A careful code histogram could therefore be quite accurate as a statement about converter voltage yet misleading as a statement about incident field strength. What evidence is required to carry a dither-assisted estimate through the full receiver chain without turning calibration of one boundary into certification of every preceding stage? And when an external test tone is injected through a convenient internal connector, which conclusions must remain restricted because the antenna and its surrounding environment have been bypassed? In particular, I would not want the convenient reference plane to conceal a material uncertainty in the installed system.

Walter Andrew Shewhart | Immediate answer to Edward Weston

Mr Weston, the transfer between reference planes must be demonstrated for the measurand and condition actually claimed. A converter-pin calibration establishes a relationship between voltage at those pins and observed codes within its stated operating range. It does not establish the amplitude of an electric field in a room, nor the power at an antenna terminal, nor a source location. Each additional inference requires the transfer of the intervening components to be characterised. The relevant measurements may include gain, loss, mismatch, bandwidth, intermodulation response, temperature dependence and their covariances. A nominal gain figure cannot repair a chain whose state changed during the acquisition. Where those relationships remain untested, the report should retain the narrower converter-plane quantity.

A reference tone introduced at an internal connector can be very useful for checking the downstream stages. The point of injection is

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the boundary of that particular test. If the antenna or preselector is bypassed, the result cannot certify their performance or the reception conditions outside that connector. To test the full chain, one may use an independently calibrated stimulus at the antenna port, or a radiated reference under carefully controlled conditions. The latter introduces its own environmental uncertainty, which must be evaluated rather than ignored. The strongest validation plan employs complementary reference planes so that a discrepancy can be localised. It does not treat one route as universally superior simply because it yields a cleaner graph.

Dither-assisted estimation can then be placed within a traceable model. Let the converter estimate a voltage v with standard uncertainty u_v, and let the analogue chain convert an input quantity s to voltage through a characterised gain g. Estimating $s = v/g$ requires uncertainty contributions from both v and g, including covariance if common references or environmental effects couple them. Repeated quantised samples may reduce a random part of u_v. They do not eliminate the calibration uncertainty of g. If the uncertainty in g is dominant, a hundredfold improvement in the variance of the converter's mean may produce almost no improvement in the uncertainty of s. A rigorous report displays this fact instead of withholding it.

A field record should accordingly preserve the exact connector arrangement, antenna identity and orientation, cable and attenuator configuration, preselector state, gain and clock settings, dither injection location, and independent references used before and after

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the observation. Any replacement receiver or changed analogue component should trigger a comparability check. The goal is not a limitless catalogue of hardware, but the minimum sufficient record needed for a competent colleague to reproduce or challenge the asserted transfer. I thank you for returning our abstract calculation to the measurement bench, and pass the floor to Dr. Atkinson for the worked applications and closing synthesis.

Ten worked technical applications | Moderator-led numerical examination

The following applications are original hypothetical examples, not tests of any named commercial receiver. Unless specifically stated, Δ denotes one ideal uniform-quantiser step in volts, N the number of native converter bits, n the number of repeated observations, and all stochastic conclusions presume the distributions and independence explicitly named. These computations are designed to test the panel's claims. Real instrument noise, nonlinearities, calibration and correlation must be measured before the results are applied to a field receiver.

Claude Elwood Shannon, Cross-Peer Question to William Ralph Bennett: Dr Bennett, when dithering makes threshold crossings more informative about a stationary voltage, how do we avoid confusing the new estimator precision with a physical improvement in converter code width? Please contrast subtractive and nonsubtractive practice, and identify the observation that would falsify the ideal result.

William Ralph Bennett, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, a 12-bit converter with a 0.48828125 mV nominal code interval

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remains a 12-bit converter even when repeated threshold observations estimate a fixed offset within that interval. In subtractive dithering, a recorded analogue perturbation is applied before quantisation and the corresponding numerical perturbation is removed after conversion. The ideal uniform-error theorem requires its distribution, independence, exact subtraction and an unsaturated quantiser. A nonsubtractive experiment instead retains added noise and requires a different estimator model. Test known sub-code voltage steps over several input positions and temperatures, then inspect residual bias, correlation and transition stability. If the measured occupancy does not follow the predicted input-dependent probabilities, the claimed uncertainty reduction is unsupported. A smoother displayed trace does not extend analogue bandwidth, recover a missed pulse or certify a new ADC bit. I respectfully pass the token to Dr Nyquist to address repeated observations.

Harry Nyquist, Cross-Peer Question to John Wilder Tukey: Professor Tukey, a survey obtains sixty-four observations and reports a standard error calculated as though every code were independent. The samples share a drifting reference and low-pass memory. How should the analyst establish an effective sample count before claiming sensitivity improvement, particularly when the event is shorter than the averaging window?

John Wilder Tukey, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the relevant quantity is variance of the specified estimator under its actual covariance structure, not merely the number of codes collected. Record sample cadence, filter impulse response, clock configuration, reference-voltage trend and stimulus stationarity. The example with n=64 and common pairwise correlation 0.10 yields an effective count of about 8.767,

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not 64, under the stated equicorrelation assumption. Estimate autocovariance from repeated independent runs, examine block means and challenge the model with hold-out acquisitions. A confidence interval that narrows solely through a presumed independence factor is inadequate. For transient signals, explicitly compare event duration with the processing window; averaging that removes the event cannot be called improved detection of the event. Account for experimental selection of the most favourable window. I respectfully pass the token to Dr Bennett to examine noise placement.

William Ralph Bennett, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, a laboratory claims that injecting a triangular dither improved a receiver because a narrow spur fell by fifteen decibels, but its integrated passband noise rose and its clipping counter occasionally advanced. Which control measurements would distinguish spectral whitening from a genuine detection benefit?

Walter Andrew Shewhart, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, require a before-and-after acquisition at matched analogue gain, temperature, input loading, sample rate, filter bandwidth, FFT window, averaging rule and false-alarm calibration. Measure the applied perturbation at the analogue reference plane, including its band-limited power, rather than infer it from the software setting. Compare spurious-free dynamic range, integrated SNR, noise density, detector operating curves and saturation statistics separately. The nominal 6.0206 dB noise-power penalty in the stated additive simplified model is not a general dither theorem; it cannot be silently transferred to the triangular nonsubtractive result with different moment conditions. Document the input distribution

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and the number of opportunities searched. A spur displaced into apparently random energy may improve one plot whilst worsening sensitivity to a weak burst. I respectfully pass the token to Professor Tukey for the final adverse trial.

John Wilder Tukey, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, near full scale the manuscript example assigns a 25 percent overload probability to one particular sample under uniform dither. How should an expert prevent that result from being misrepresented as a 25 percent overall clip rate, or as an argument for adding digital noise to an already stored I/Q stream?

Claude Elwood Shannon, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, specify that the 25 percent probability is conditional on the instantaneous input being +0.950 V, the upper permitted value being +1.000 V and the independent dither uniformly covering −0.100 to +0.100 V. The clip probability across a variable waveform requires integration over its amplitude distribution and the actual dither law. Noise added after ADC acquisition changes only downstream analysis; it cannot alter the threshold crossings or unsampled analogue history. Preserve original I/Q codes, dither-generation records, headroom state, random seed when reproducibility depends upon it, and derivative processing separately. Demonstrate any claimed performance gain against previously defined loss and false-alarm criteria using independent test stimuli, not merely a favourable displayed spectrum. A clipping-related loss of identifiability remains even when a reconstruction looks persuasive. I respectfully return the token to Dr Atkinson for synthesis.

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Dr. James M. Atkinson | Moderator concluding synthesis

Colleagues, the difference between quantitative estimation and intrinsic converter resolution is now explicit. Dither can be an instrument of measurement when it is applied before conversion, when its actual properties are sufficiently known, when the input has the stability appropriate to the measurand, and when the resulting probability law is experimentally defensible. Under such conditions a set of code occupancies may discriminate a stationary analogue parameter more finely than one native code interval. But the individual conversion thresholds remain where physics and calibration have placed them. The instrument has not acquired a larger instantaneous alphabet, extra analogue headroom, or an improved ability to preserve pulse shapes merely because an average has been reported to additional decimal places.

The first group of exchanges identified the epistemic boundary. Dr Shannon distinguished information in one conversion from information in a repeated experiment; Professor Wiener exposed how adaptive observation can invalidate a naive likelihood; and Mr Hartley insisted that a more accurate mean not be confused with more bits in each sample. Mr Bennett then showed why the classical uniform quantisation-noise model is conditional and why subtractive and nonsubtractive dither have different error structures. Professor Bridgman correctly demanded that a subtraction expressed in algebra be demonstrated in a physical chain. Dr Nyquist established that independent observations, not merely stored samples, govern statistical gain; Professor von Neumann showed that deterministic excitation can be useful without automatically satisfying a stochastic independence model. Professor Tukey located every claimed improvement

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in an explicit decision problem, and Sir Ronald Fisher and Dr Turing challenged experimental selection and the retrospective creation of apparently informative numbers. Dr Shewhart and Mr Weston returned those conclusions to metrological stability, actual reference planes and a reproducible evidential record.

Several findings are ready for operational use, provided they remain properly bounded. For a stable signal, a known dither may make threshold occupancy informative about fractional input position. For a coherent spectral-analysis problem, a suitable perturbation may reduce signal-correlated quantisation artefacts and improve a relevant spurious-free measure. For a bandwidth-limited estimator, sufficiently independent samples can reduce the random component of uncertainty through averaging. In none of these cases may an investigator automatically assert a comparable improvement in transient detection, immunity to external blockers, analogue linearity, or attribution of an observed spectral line to a clandestine transmitter. Each proposition has a different challenge population, measurement model and likely failure mechanism.

The numerical exercises illustrate the range of permissible conclusions. A twelve-bit converter across two volts has a native step of approximately 0.488 mV; independent repeated dithering can estimate a stationary fractional step with a statistical uncertainty well below that value under an ideal threshold model. Yet a modest common correlation can erase much of the predicted averaging gain. An apparently sensible 0.5-step broadband perturbation can increase in-band noise while reducing a deterministic spur. Near overload, a random intervention intended to improve measurement may produce clipped samples in one quarter of the deliberately constructed

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trials. A multiple-frequency search may face a much greater familywise false-alarm probability than the probability printed beside each tested spectral bin. These are not peripheral curiosities. They are the conditions under which the word improvement can become technically misleading.

For publication and forensic practice, the acceptance record should therefore carry the native bit width and analogue range; the intended measurand; the injection point, dither distribution, amplitude and spectrum; whether subtraction actually occurred; the raw conversion codes; the sampling and decimation history; the effective independent observation count; calibration and covariance contributions; and validation outcomes including failures. The report should distinguish raw observations from subsequent estimates and from interpretations of external source identity. It should explicitly disclose where original data have been filtered or averaged, especially when intermittent signals may have been suppressed. A reproducible software pipeline is valuable, but it is not an independent measurement of an analogue event that the converter did not capture.

I conclude that dither can improve a *specified, model-supported quantitative estimate* without improving the converter's intrinsic resolution. This statement is positive, not dismissive. It recognises a genuine and often useful measurement technique while prohibiting its extravagant interpretation. It is also provisional wherever the actual installed receiver departs from the ideal model or the source record remains incomplete. Our next question will move from the deliberate perturbation of one converter to the alignment of several converters. When interleaved ADC branches disagree in gain, offset, aperture timing or bandwidth, their periodic errors can resemble spectral emissions. The panel will examine how those

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artefacts are predicted, tested and distinguished from an external RF source. I thank every colleague for the discipline of the exchange and pass the token to the opening respondent of Question 027.

Biographical verification: https://turingarchive.kings.cam.ac.uk/about-alan-turing. Historical facts are separated from the modern, fictional engineering dialogue.

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Ten worked engineering applications | Question 026

Application 01. Native code width and idealised quantisation uncertainty

Let the input span V_{FS} be 2.000 V peak to peak and the uniform converter have B = 12 binary bits, corresponding to $2^B = 4096$ nominal codes. Define $\Delta = V_{FS}/2^B$, so $\Delta = 2.000/4096$ V = 0.00048828125 V = 0.48828125 mV. Under the classical, justified independent uniform quantisation-error model, the error standard deviation is $\sigma_q = \Delta/\sqrt{12}$ = 0.1409547 mV. This is a statistical scale, not proof that the converter actually has uniform errors for every input. If a constant voltage remains inside one code interval, the undithered error can instead be a fixed offset. The example establishes the starting code geometry and why a fractional millivolt printed after averaging does not imply a narrower physical ADC threshold.

Application 02. Threshold-crossing estimation of a quarter-code stationary signal

Let an ideal mid-tread quantiser round to the nearest multiple of Δ. Set the constant input $x = 0.25\Delta$ and introduce independent uniform dither $d \sim U(-0.5\Delta, +0.5\Delta)$. The digitiser selects code Δ when $x+d \geq 0.5\Delta$, requiring $d \geq 0.25\Delta$. The admissible dither interval has total width Δ, while the qualifying upper interval has width 0.25Δ; therefore $P(Q=\Delta)=0.25$ and $P(Q=0)=0.75$. Define the estimator $\hat{x} = \Delta$ times the observed fraction of higher-code events. For n=100 independent trials, the standard uncertainty from the binomial model is $\Delta\sqrt{(0.25\times0.75/100)}=0.0433013\Delta$. This is better than a whole step for a stable parameter, not a method for

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preserving unobserved pulse peaks. The frequency-based estimator is conditional on precisely known threshold and dither distribution.

Application 03. Independent repetitions and the conditional statistical interval

Continue Application 02 with n=1000 genuinely independent observations of the same fixed input and suppose the observed proportion is close to its model expectation, p=0.25. The binomial standard error of the observed proportion is $\sqrt{[p(1-p)/n]} = \sqrt{(0.1875/1000)} = 0.0136931$. Consequently the standard uncertainty of x_hat is 0.0136931Δ. A simple normal approximation gives a 95% half-width of 1.96×0.0136931Δ = 0.0268384Δ. The normal approximation is illustrative, not an exact finite-sample guarantee and not a complete combined uncertainty interval. A common analogue offset, calibrated-scale error, time-varying input or serial dependence requires separate treatment. Here the improvement arises from a thousand physical observations under a known probability law, not a change in the twelve native ADC bits.

Application 04. Proper subtractive-dither error for the ideal unbounded quantiser

Let Q be ideal uniform rounding with step Δ and no overload, and let an independent subtractive dither have suitable characteristic-function properties, for example an appropriate independent uniform perturbation over one step. Define z=Q(x+d)-d, so the total error is e=z-x. Under the stated subtractive-dither theorem, e is uniform on (-Δ/2,+Δ/2) independently of x, with E[e]=0 and $Var(e)=\Delta^2/12$. The standard deviation is $\sigma_e=\Delta/\sqrt{12}$. For 400 independent repetitions of an unchanged input,

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the mean's conditional standard deviation becomes $\Delta/\sqrt{(12\times400)} = 0.0144338\Delta$. If the implementation subtracts a delayed or mis-scaled replica d_hat rather than the perturbation actually present at the converter, the residual includes (d-d_hat); the ideal theorem cannot be cited without including that error. These results concern an estimator and the specified ideal model, not universal converter linearity.

Application 05. Triangular nonsubtractive dither and total-error variance

Define independent U1 and U2, each uniform on $(-\Delta/2,+\Delta/2)$, and let the triangular dither be d=U1+U2. Its mean is zero and its variance is $Var(d)=2(\Delta^2/12)=\Delta^2/6$. For the ideal nonsubtractive-dither model under appropriate theorem conditions, write the total error as e_total = Q(x+d)-x. The triangular dither gives useful input-independent first and second error moments; in the standard ideal result the total-error variance is $\Delta^2/4$, giving $\sigma_{total}=0.5\Delta$. This is greater than the ideal undithered uniform-model standard deviation $\Delta/\sqrt{12}\approx0.288675\Delta$. The benefit is not universally lower individual-sample noise, but reduced input-related bias and error modulation. Filtering or averaging may improve a specified resulting estimate if its covariance and bandwidth are known. Claims about other dither distributions need their own derivations.

Application 06. Oversampling gain and the number of independent measurements

Suppose a stationary quantity is observed through independent, approximately white errors and an ideal low-pass/decimation operation retains the required signal bandwidth. If the oversampling ratio OSR is 16 relative to the selected final Nyquist bandwidth, the ideal in-band

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noise-power reduction is 10log10(OSR) = 10log10(16) = 12.0412 dB. Using the ideal six-decibel-per-bit relationship, this corresponds to approximately 2.00 extra effective bits of noise-limited precision for that *bandwidth-limited estimator*. The converter still emits its original native code width per sample. To obtain an ideal four-bit gain by the same law requires OSR=4^4=256; a six-bit gain requires OSR=4^6=4096. These figures are not promises for signals with drift, harmonic quantisation error, correlated noise, converter nonlinearity or short transients that the filter removes. [R8, R9]

Application 07. Noise-floor penalty of a broadband dither setting

Assume for illustration that quantisation error initially satisfies the independent uniform model with variance $\Delta^2/12$. Introduce independent zero-mean broadband dither whose RMS amplitude equals 0.5Δ, and assume the total error contributions add in variance. Then $\sigma_total = \sqrt{(\Delta^2/12 + (0.5\Delta)^2)} = \sqrt{(\Delta^2/3)} = 0.577350\Delta$. Compared with $\sigma_q=0.288675\Delta$, the amplitude-noise ratio is 2, giving 20log10(2)=6.0206 dB more RMS noise amplitude relative to the baseline error. This simplified calculation is a deliberately conservative illustration of added in-band noise; real dithered-error correlations require the appropriate quantiser theorem and spectral placement. The added noise may still suppress coherent instrumental spurs, improving SFDR even when integrated SNR worsens. The report must not describe these distinct metrics as interchangeable. [R3]

Application 08. Correlation defeats naive averaging

Let n=64 observations each have error variance σ^2, with a constant pairwise correlation coefficient ρ=0.10, an illustrative covariance matrix

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that is positive semidefinite. The mean-error variance equals $\sigma^2[1+(n-1)\rho]/n = \sigma^2[1+63(0.10)]/64 = 7.3\sigma^2/64$. Define the effective independent sample count $n_{eff}=n/[1+(n-1)\rho]$, yielding $n_{eff}=64/7.3=8.7671$. The nominal independent-sample improvement would be $10\log10(64)=18.0618$ dB in noise power, whereas the correlated-case improvement is only $10\log10(8.7671)=9.4286$ dB. A filtered ADC sequence, a shared clock perturbation or low-frequency common drift may generate such dependence. The equicorrelation law is a transparent hypothesis, not a claimed universal model of receiver noise. Estimate the actual autocovariance before relying on the statistical gain.

Application 09. Dither may induce clipping near full scale

Let an ideal converter accept values only up to +1.000 V, and suppose the signal already reaches +0.950 V at a particular sample. Add uniform dither between -0.100 V and +0.100 V. Overload occurs if $d>+0.050$ V. The total dither support has width 0.200 V, and the overload-producing interval from +0.050 V to +0.100 V has width 0.050 V; the overload probability is therefore $0.050/0.200=0.25$, or 25% for this deliberately constructed input condition. Any resulting saturated codes lose the nominal invertible threshold relation. The calculation concerns this specific sample amplitude, not an overall clip rate for a varying waveform. A field system must examine blocker amplitude distributions and headroom before injecting dither for a theoretically attractive spur reduction.

Application 10. Multiple spectral trials and false-positive burden

Assume a detection test assigns each of $M=500$ effectively independent spectral bins a false-alarm probability $\alpha=0.001$ under the

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null hypothesis. The probability of at least one false alarm in the complete search is $P_{any}=1-(1-\alpha)^M = 1-(0.999)^{500} \approx 0.393621$, or 39.36%. An engineer might observe fewer quantisation-correlated spur bins after applying dither, yet if the broadband noise distribution changes the per-bin detector calibration must be revisited. If bins are correlated, the exact expression is not valid; use the joint noise model or a measured null distribution. The result demonstrates why claiming an instrument has become 'more sensitive' from a smaller highest spur does not establish a global detection advantage. The analysis must preserve the number of searched frequencies, durations and configurations, as well as the chosen false-alarm criterion.

Scholarly source register and read scope

[R1] Stanley P. Lipshitz, Robert A. Wannamaker and John Vanderkooy, 'Quantization and Dither: A Theoretical Survey,' Journal of the Audio Engineering Society, vol. 40, no. 5 (May 1992), pp. 355–375. https://aes.org/publications/elibrary/elibrary-page/?id=7047. Scope actually consulted: AES bibliographic record and abstract identifying distinct undithered, subtractively dithered and nonsubtractively dithered theories; no claim is made to have read the paywalled full text through the AES interface.

[R2] Robert M. Gray and Thomas G. Stockham Jr., 'Dithered Quantizers,' IEEE Transactions on Information Theory, vol. 39, no. 3 (1993), pp. 805–812, doi:10.1109/18.256489. https://ieeexplore.ieee.org/document/256489/. Scope actually consulted: IEEE bibliographic entry and abstract describing Fourier-based proofs for subtractive and nonsubtractive dither; detailed formulae in this manuscript are identified as ideal illustrative derivations rather than quotation of inaccessible pages.

[R3] Analog Devices, 'ADC Input Noise: The Good, the Bad, and the Ugly. Is No Noise Good Noise?', Analog Dialogue. https://www.analog.com/en/resources/analog-dialogue/articles/adc-input-

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noise.html. Scope actually consulted: HTML discussion of dither, ADC encoder nonlinearity, SFDR, approximately half-LSB noise and practical limits, including the possibility that inherent input noise makes additional injection unnecessary.

[R4] William R. Bennett, 'Spectra of Quantized Signals,' Bell System Technical Journal, vol. 27, no. 3 (July 1948), pp. 446–472. https://onlinelibrary.wiley.com/doi/10.1002/j.1538-7305.1948.tb01340.x. Scope actually consulted: bibliographic metadata confirming the foundational article; the article is not presented as a modern instrument test or a source of invented dialogue.

[R5] National Institute of Standards and Technology, 'NIST TN 1297: 2. Classification of Components of Uncertainty.' https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-2-classification-components-uncertainty. Scope actually consulted: official HTML text on Type A and Type B uncertainty components, standard deviations and correlation treatment.

[R6] Analog Devices, 'AN-835: Understanding High Speed ADC Testing and Evaluation.' https://www.analog.com/en/resources/app-notes/an-835.html. Scope actually consulted: HTML Dither Testing section distinguishing wideband and out-of-band dither and measurement of dynamic converter characteristics.

[R7] Analog Devices, 'Practical Analog Design Techniques: Use of Dither Signals to Increase ADC Dynamic Range.' https://www.analog.com/media/en/training-seminars/design-handbooks/Practical-Analog-Design-Techniques/Section5.pdf. Scope actually consulted: indexed web summary concerning coherent quantisation-error harmonics and dither; the full PDF was not independently analysed in this checkpoint.

[R8] Analog Devices, 'AC and DC Data Acquisition Signal Chains Made Easy.' https://www.analog.com/en/resources/analog-dialogue/articles/ac-and-dc-data-acquisition-signal-chains-made-easy.html. Scope actually consulted: HTML explanation of oversampling ratio and the conditional in-band processing-gain relationship.

[R9] Analog Devices, 'Defining and Testing Dynamic Parameters in High-Speed ADCs, Part 1.' https://www.analog.com/en/resources/technical-articles/defining-and-testing-dynamic-parameters-in-highspeed-adcs-part-1.html. Scope actually

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consulted: HTML presentation of ideal quantisation SNR, actual noise limitations and bandwidth-dependent processing gain.

[R10] National Institute of Standards and Technology, 'Measurement Uncertainty,' metrology information. https://www.nist.gov/itl/sed/topic-areas/measurement-uncertainty. Scope actually consulted: official HTML introduction distinguishing measurand, physical standard and instrumental indications. Together with [R5], supports the principle that smaller random uncertainty does not cancel common calibration uncertainty.

[B1] King's College, Cambridge, Turing Digital Archive, 'About Alan Turing.' https://turingarchive.kings.cam.ac.uk/about-alan-turing. Scope: institutional HTML biographical account.

[B2] Science Museum Group, 'Alan Turing.' https://collection.sciencemuseumgroup.org.uk/people/cp37701/alan-turing. Scope: institutional historical biography, dates and mathematical contributions.

[B3] Institution of Engineering and Technology, 'Archives Biographies: Alan Turing.' https://www.theiet.org/membership/library-and-archives/the-iet-archives/biographies/alan-turing. Scope: institutional biographical account of computing, education and professional work.

[B4] University of St Andrews MacTutor History of Mathematics, 'Walter Shewhart (1891–1967).' https://mathshistory.st-andrews.ac.uk/Biographies/Shewhart/. Scope: online biographical record identifying physics education, quality-control work, dates and institutions.

[B5] IEEE Information Theory Society, 'Claude E. Shannon.' https://www.itsoc.org/about/shannon. Scope: historical institutional biography, Bell Labs research and professional honours.

[B6] MIT News, 'Professor Emeritus Claude Shannon, founder of digital communications, dies at 84' (2001). https://news.mit.edu/2001/shannon. Scope: institutional obituary, dates and principal scholarly contribution.

End of Question 026. All speaker dialogue is fictional educational synthesis; claims of historical conversation, instrument testing and direct quotations are expressly excluded.

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QUESTION 027

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How do converter interleaving mismatches create periodic spectral artifacts?

Source: V011_Roundtable_Question_027_CP027_Standalone(1).docx | Recovered substantive manuscript. Constructed educational dialogue.

Constructed educational dialogue. The historical participants' speeches are original academic reconstructions rather than genuine quotations. Modern receiver cases and numerical examples are hypothetical. References distinguish consulted technical publications from historical source material.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, the preceding examination of dither concerned a perturbation deliberately introduced to change the statistical behaviour of an analogue-to-digital conversion experiment. We now turn to a different intervention: the combination of several converters so that their successive samples appear to have been obtained from one apparatus operating at a greater aggregate rate. In a clean block diagram, four branches complete four measurements in staggered succession, the resulting sample stream resembles that of one faster converter, and a wide spectrum glows across the display. The physical instrument is less innocent. Every branch possesses its own offset, gain, finite analogue bandwidth, aperture delay, recovery history and often its own sensitivity to temperature or the distribution of its clock. A periodic sequence of small discrepancies can modulate the very waveform which the equipment purports to observe. When translated into the frequency domain, that modulation can generate an orderly family of spectral components which were never independent emissions at the input connector.

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The forensic challenge is therefore not simply to recognise a particular spur shape. It is to identify the transformations which could have produced that shape, determine what the retained measurements actually establish, and design tests which distinguish an interleaving artefact from an external source. A line at a reproducible frequency is not automatically external, and a line which follows a real input signal is not automatically a second transmitter. The periodic branch-selection pattern may produce precisely such frequency tracking. Worse, an artefactual image of a strong legitimate emitter may reside inside the small, apparently quiet region in which a defensive survey searches for a weak clandestine transmission. Apparent spectral coherence may then invite confident misclassification, particularly where a waterfall display or automatic event logger records only a detection threshold and neglects the acquisition settings which created the plotted representation.

We must establish the nominal timing lattice first. Let the combined sampling rate be f_s samples per second and the number of branches be M, with each branch converting one sample every M/f_s seconds and nominal aggregate spacing $T_s=1/f_s$. Each branch is allocated a residue class of sample indices modulo M. If the branch gain or timing error is constant for that branch, the effective error repeats every M output samples. Periodicity in the sample index produces a discrete set of modulation frequencies spaced by f_s/M. A sine wave at input frequency f_{in} can consequently acquire images at frequencies congruent to $\pm f_{in}+k\, f_s/M$ after aliasing. Branch offsets produce a different family, typically at the residue-class harmonics $k\, f_s/M$ regardless of input tone frequency. These are predictions of a stated model and need experimental challenge; their mere

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mathematical elegance does not prove that any particular spectral event is such an artefact. [R1, R2]

The question is made more difficult by the legitimate complexity of real converter systems. Offset and gain mismatches coexist with time skew and unequal analogue frequency responses. Calibration may reduce them, but the operating point moves with frequency, temperature, analogue drive, converter overload, and internal adaptation. Background calibration can also learn from the prevailing signal environment, creating a new dependence between the observer and the observed. The same scalar spur frequency may therefore result from different physical imperfections, while the very act of injecting a test signal may alter the relevant state. A well-designed investigation must preserve configurations, raw and corrected streams where available, calibration versions and uncertainty estimates. It must ask whether the phenomenon is stable when input frequency, branch order, input attenuation, clock conditions or the interleaving pattern is deliberately changed.

I invite Dr Nyquist to establish why a nominally uniform output sequence is not sufficient proof of uniform physical sampling. Baron Fourier will then examine the consequence of periodic errors in the time domain, using harmonic decomposition to explain where images should appear. Dr Shannon will separate the information recorded in the output from the hypotheses required to reconstruct an external input. Professor Tukey will examine how receiver tests distinguish candidate mechanisms without selecting only favourable spectral plots, and Dr Shewhart will place the calibration procedure under statistical control. Seven peers will question the principals, each reply immediately following its challenge, before ten worked

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applications put the competing predictions into arithmetic. Our objective is to produce a technically defensible measurement and reporting doctrine, not a catalogue of spectacular-looking instrumental defects. Dr Nyquist, may I invite your account of the composite sampling lattice and the physical meaning of its errors?

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Harry Nyquist | Principal response 1: Nominal samples and physical apertures

Dr. Atkinson, thank you. I would begin by distinguishing a sequence of numerical indices from a sequence of physical measurements. The software may label the reconstructed samples x[0], x[1], x[2] and so forth and declare that sample n corresponds to the time nT_s, but the numerical label is not a metrological measurement of the instant when the analogue aperture actually closed. A time-interleaved converter instead forms its output by assigning different indices to separate acquisition branches. For M channels, branch m nominally samples at $t_{m,j}=(jM+m)T_s$. The realised aperture is more accurately expressed as $t_{m,j}=(jM+m)T_s+\delta t_{m,j}$, where $\delta t_{m,j}$ includes a branch-specific systematic component and a random or drifting component. That distinction should appear in the measurement model before the engineer begins speaking of a higher effective sample rate.

It is tempting to regard the individual branch rates as the sole limitation, but their clocks may form an entirely adequate composite lattice when they are phase aligned, their bandwidths are sufficient and their respective analogue transfer functions are characterised. The gain in aggregate throughput can be genuine. What cannot be inferred from throughput is equality of measurement response. An instrument that samples in the prescribed temporal order but alternates between two slightly different gains has not produced samples of one linear time-invariant system. Nor does a perfectly matched gain remove an alternating timing error. The output can be periodic in the branch index even where the original input is a pure tone. A frequency-domain observer may see a family of images whose

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spacing reflects the branch cycle rather than the frequencies generated by the external source.

Consider two converters alternating samples. If their gains are $1+\varepsilon$ and $1-\varepsilon$, the reconstructed signal can be written approximately $y[n]=(1+\varepsilon(-1)^n)x[n]$ when all other errors are excluded. The factor $(-1)^n$ represents digital modulation at the Nyquist edge of the aggregate sample lattice, not an independent analogue oscillator. For a band-limited sinusoid, multiplication shifts a copy of the original discrete spectrum by one-half the aggregate sample frequency; after aliasing, the first-band image lies at $f_s/2-f_{in}$. It moves when the stimulus frequency changes and scales with the amplitude of the stimulus. An investigator who finds the image close to an expected surveillance channel must not regard its apparent frequency stability in a stationary test as evidence that a separate device transmitted there. The evidence may instead be a property of the way the receiver assembled its samples. [R1]

The timing version is less forgiving at high frequencies. A small aperture error changes the value of a continuous waveform by an amount approximately proportional to the waveform derivative. For a sinusoid, the derivative has magnitude proportional to $2\pi f_{in}$ times the signal amplitude. Therefore an identical timing discrepancy which is negligible at a modest input frequency can be conspicuous near the upper end of the converter's admitted bandwidth. It is not enough to calibrate with an audio-frequency source and assume that the resulting confidence applies unchanged to a wideband RF survey. The test should traverse the operating frequency range, and the reported uncertainty should preserve a separate term for branch skew and for random aperture jitter. The two mechanisms produce

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different spectral and statistical signatures, though both may be referred to loosely as timing noise.

One ought also to inquire whether the branches have truly independent analogue paths. A shared sample-and-hold or input buffer may impose common distortion before the branch split, and that distortion will not be cured merely by aligning the branch clocks. Conversely, independent analogue front ends may have different frequency-dependent phase responses. A nominal time offset measured with one frequency is then not necessarily a complete description of the phase mismatch elsewhere. A scalar correction can give a comforting improvement at one test tone while leaving an unmeasured image at another. The proper claim is bounded: a stated calibration reduced a stated error under the conditions of the challenge, not that the receiver's physical response became universally equivalent to one ideal converter.

A useful validation campaign should retain both the signal stimulus and the branch-state record. Where raw branch samples are accessible, examine their separate means, scale factors, phase responses, noise distributions and temporal alignment. If an internally corrected output alone is stored, the instrument may still be usable, but the investigator should acknowledge that independent review of the correction is limited. A robust black-box test can sweep a calibrated input through frequencies and amplitudes; it can change the interleaving mode, preserve a declared stop rule and compare the predicted movement of image lines. An artefact hypothesis must make testable predictions that an external-transmitter hypothesis does not share. Testing only the presence of a strong reference tone fails to examine the weaker false features that matter in counter-surveillance work.

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Finally, I would insist upon preserving non-detections and failed calibrations, not merely successful figures of merit. If the receiver suppresses a spur only after ten undocumented tuning attempts, the final clean plot may demonstrate an achievable configuration without establishing stable field performance. If one branch clips during a strong blocker, the mathematical small-error model fails even though an FFT may still show familiar interleaving locations. The analyst should identify when the approximation is valid and when saturation or recovery introduces new histories. Measurement begins by identifying the quantity and its physical boundary; a regular index sequence is a convenience of recording, not proof that every electrical event occurred at its intended instant. Professor von Neumann, may I pass you the token to examine whether my lattice account conceals dependence on the test stimulus itself?

John von Neumann | Peer question 1 to Harry Nyquist

Dr Nyquist, your account separates the ideal index from the actual aperture, but the statistical machinery used to estimate the latter seems rather dependent upon the signal chosen for calibration. Suppose a laboratory uses a highly coherent sinusoid and estimates a timing correction by requiring all branch outputs to lie upon one fitted waveform. The fitted phase can improve spectacularly, yet the assumed model may hide a second harmonic, a clock-synchronous interference term or frequency-dependent analogue delay. An algorithm which minimises a residual under one model need not establish that the fitted parameter is physically unique. In particular, if an instrument observes only the interleaved output and not the branch-specific clocks, how would you distinguish an estimator that has discovered the actual

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aperture offsets from one which has merely found an equivalent mathematical explanation for the selected data? What alternate challenge would make the competing models predict different results, and how would you record the remaining ambiguity without abandoning the utility of the calibration?

Harry Nyquist | Immediate answer to John von Neumann

Professor von Neumann, I agree that a small residual is not the same as an identified physical cause. The fitted delay is an effective parameter under the chosen signal and transfer model. If gain, frequency-dependent phase and timing can all affect the relevant Fourier coefficient, several combinations may produce the same observed outcome. It would be improper to call one numerical optimum the aperture measurement without an independent reference or a set of challenges that renders those combinations distinguishable. The acceptance record should state the model, its degrees of freedom and the actual observations that constrain them. A calibration parameter may be useful for correction even when it is not a unique physical diagnosis, but its interpretation must remain at the level that the test justifies.

One complementary challenge changes input frequency while maintaining a traceable stimulus amplitude. A true constant time skew contributes a phase error approximately proportional to frequency, whereas a simple constant gain mismatch does not; a frequency-dependent analogue transfer mismatch may imitate the slope over a narrow band, requiring a broader or independently characterised sweep. A second challenge alters input amplitude to

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expose saturation and other nonlinear effects that a small-signal timing model excludes. A third compares branch-specific clock measurements or a separate sampled reference where such access exists. The point is not to demand every conceivable instrument, but to make the models yield measurably different predictions before reporting physical attribution.

The analyst should also preserve a test partition. Values used to fit the correction are not, by themselves, independent validation observations. A second set of frequencies, amplitudes, temperatures or input waveforms provides a more meaningful challenge to generalisation. If the system can estimate calibration parameters only while tracking the current signal, the record must include when those parameters changed and whether raw data remain available. An adaptive setting that follows the input may be excellent for receiver operation but does not automatically preserve an unselected evidential record. The investigator must distinguish a corrected representation from the original sample stream and from the scientific explanation proposed for either.

Where models remain observationally equivalent, the report can still say that a particular correction reduced the measured image energy under the specified operating envelope. It should not say that the actual aperture of each converter has been measured with a stated uncertainty if that conclusion depends on an untested decomposition. A physically limited proposition is not a weak proposition. It is the only sort that can survive a competent colleague's attempt to reproduce the experiment with another

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reference. The appropriate handover is therefore to examine the independent physical comparisons upon which such a claim depends.

Edward Weston | Peer question 2 to Harry Nyquist

Dr Nyquist, may I ask about the reference plane hidden inside your elegant timing lattice? The analogue input delivered to a branch may pass through a buffer, an attenuator, a switch and an imperfectly matched connection before it reaches the sampling aperture. If two branches possess different transfer characteristics, a measured phase disagreement may be as much a property of the route as a property of the clock. A reference injected after the shared preselector will not establish how the preselector behaves, while one introduced at the antenna port adds uncertainty from the entire intervening chain. How would you specify the actual quantity being compared, avoid assigning the same discrepancy to both aperture delay and analogue phase response, and make a correction record intelligible to an independent examiner who cannot open the converter package? Would the report properly certify the physical aperture or only the frequency-dependent effective response of the installed receiver?

Harry Nyquist | Immediate answer to Edward Weston

Mr Weston, your question requires the receiver to be treated as an assembled measurement chain rather than an immaculate diagram. I should define the reference plane at which the incident waveform is specified, the measurable output quantity and the transfer relationship which connects them. If the stimulus is injected at the antenna port, the resulting estimate concerns the complete path from that port to the reconstructed digital samples under its specified

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loading. If it is injected after the buffer, the estimate concerns a narrower chain. Neither is wrong, but the same number must not be advertised as having established both propositions. A calibrated reference is useful only when its physical location and its uncertainty are part of the record.

Frequency-dependent analogue phase and aperture delay may both contribute to an effective relative phase shift. A single-tone experiment generally cannot separate them. In a narrowband task, an effective phase correction may suffice for recovering a specified measured quantity. In a wideband task, especially one concerned with a short pulse or a multicarrier signal, the distinction may be essential because a constant time correction cannot remove arbitrary group-delay variation. A sweep or broadband reference can test the response over the frequency interval of interest, while independent clock measurements can help isolate actual aperture timing. Where those additional observations are unavailable, the result should be named an effective channel-alignment correction, not a direct physical measurement of aperture delay.

An examiner unable to inspect the converter package should nevertheless be able to challenge the bounded claim. The calibration record should preserve the reference source, its traceable accuracy where applicable, connecting impedances, analogue path configuration, raw and processed outputs, fit algorithm and rejected or invalid trials. A black-box challenge should test how the image responds to a changed stimulus frequency or amplitude, because the competing mechanisms predict different dependencies. If two

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hypotheses still produce indistinguishable outcomes, their equivalence is a stated limitation. The record can support a practical calibration without certifying a unique physical explanation.

The broader lesson is that labels must not outrun the comparison that gives them meaning. A receiver may exhibit excellent composite performance while its internal branches remain physically unlike one another; conversely, accurately measured branch parameters may be insufficient if the external path changes during an investigation. The purpose of a forensic report is not to confer a ceremonial title of perfection upon an instrument, but to explain what was measured, where it was measured and which alternatives remain. I return the token to Dr. Atkinson for the next principal examination of the periodic error structure.

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Jean-Baptiste Joseph Fourier | Principal response 2: Periodic branch errors and spectral images

Dr. Atkinson, I am grateful for the invitation to examine the harmonics. The distinctive mathematical feature of an interleaved converter is not merely that it contains several pieces of apparatus, but that the output selects those pieces in a repeating order. A periodic difference between successive measurement channels imposes a periodic coefficient upon the sampled waveform. That periodic coefficient can be decomposed into harmonics on the discrete sample lattice. Multiplication in the time domain corresponds to convolution in the frequency domain, so a single incident spectral component is copied or shifted by each harmonic of the branch-pattern error. If the investigator does not recognise the periodic mechanism, the resulting images may be mistaken for independent emissions. This is a problem of physical origin concealed behind the perfectly respectable mathematics of a Fourier transform.

Suppose the reconstructed output takes the form $y[n]=g[n]x[n]+o[n]$, initially neglecting skew and nonlinear conversion. Here $g[n]$ is a repeating gain sequence and $o[n]$ is a repeating branch-offset sequence, each with period M samples. Express $g[n]$ as a finite Fourier series $g[n]=\Sigma_k G_k \exp(j2\pi kn/M)$, and similarly express $o[n]=\Sigma_k O_k \exp(j2\pi kn/M)$. A single complex input tone $x[n]=A \exp(j\omega n)$ then produces components at $\omega+2\pi k/M$ weighted by $A G_k$, together with offset components at $2\pi k/M$ weighted by O_k. A real-valued sinusoid introduces the corresponding positive and negative frequency partners. The terms which appear in a displayed Nyquist band depend upon aliasing and the spectrum's real or complex representation. The model is simple, but it yields a disciplined test: the

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image family must transform under a changed incident frequency in a way predicted by the branch cycle. [R1, R2]

A two-branch case is particularly revealing. If g[even]=1+ε and g[odd]=1−ε, then g[n]=1+ε(−1)^n. One factor preserves the original tone; the other shifts it by π radians per sample, which corresponds to half the aggregate sampling rate. The image-to-signal amplitude ratio is ε in this idealised small-error case, not twice ε merely because the physical gains differ by 2ε. The difference between the branch gains must therefore be defined before an instrument specification quotes mismatch in per cent. An incorrectly defined denominator can introduce a six-decibel error in an otherwise impeccable-looking budget. Similarly, if offsets are +b and −b, the alternating offset creates a term at the Nyquist edge whose amplitude is b; comparing it with a sine-wave reference requires the investigator to specify whether peak, RMS or power conventions are being used.

With four branches, the possible spectral pattern is richer. The repeating gain sequence has four Fourier coefficients, and its nonconstant coefficients translate an input component by multiples of one quarter of the aggregate sample frequency. For a real input tone in the first Nyquist band, image candidates can appear at frequencies related to f_s/4−f_in, f_s/4+f_in and f_s/2−f_in, after appropriate folding. Offset errors create different components at fixed branch harmonics, including f_s/4 and f_s/2. Therefore a single apparent mystery line is weak evidence of a specific defect, while a coordinated family of lines moving under a controlled frequency change is stronger evidence of periodic channel selection. The key is not pattern recognition alone. The test must be run under a condition where an external signal and an internal image would predict different outcomes, and the

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results must be compared before the operator chooses which lines to display. [R1]

Timing errors can be added by replacing $x[n]$ with $x(nT_s+\delta t[n])$. Under small-error conditions, a first-order approximation gives $x(nT_s+\delta t[n])\approx x(nT_s)+\delta t[n]x'(nT_s)$. If $\delta t[n]$ repeats with period M, its Fourier coefficients modulate the derivative of the waveform. The resulting image magnitude therefore depends upon the frequency content and on the derivative of the input. For a sinusoid the derivative contributes a factor $2\pi f_{in}$, which explains why timing-spur energy increases with input frequency while simple constant gain mismatch does not necessarily do so. At a sufficiently broad bandwidth the branch analogue responses can no longer be represented solely by one gain and one delay; each branch contributes its own transfer function and the error family acquires a frequency-dependent shape. Such complexity calls for a richer measurement model rather than a declaration that Fourier analysis has failed.

The spectral signatures also caution against overconfident causal inference. An offset spur which remains fixed during a sweep is compatible with branch-offset mismatch but may also coincide with oscillator-related interference or a real carrier that happens to remain at the same frequency. A gain image which tracks the reference may arise from a branch gain error, a sampling pattern, or a different form of signal-correlated processing. The apparent alignment of an image with a reference is evidence about a relationship, not an immediate declaration of its physical origin. Demonstrating the hypothesis requires intervention, including changes to sample-rate configuration, branch interleaving, input frequency, gain and

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possibly analogue attenuation. Where an internal calibration suppresses the image, the analyst should preserve both before and after states and avoid calling the corrected trace a second independent observation.

It is equally important to preserve the entire tested band. An attractive comparison of two selected spectral bins may conceal a larger image family displaced elsewhere by the intervention. Conversely, a spur that falls outside a selected displayed range may have been moved, not eliminated. The investigator should identify the alias convention, window, FFT length and frequency mapping used before and after a configuration change. The negative evidence of an apparently quiet screen has meaning only relative to that screen's actual observation and processing envelope. The mathematical apparatus reveals how a coherent external input can produce a coherent internal imitation. It does not demand that every coherent line be disbelieved; it requires a controlled challenge before the line is attributed to a second emitter. Professor Bridgman, may I pass the token to your question about whether the mathematical expression defines a measurand or merely an elegant reconstruction?

Percy Williams Bridgman | Peer question 3 to Jean-Baptiste Joseph Fourier

Baron Fourier, your harmonic decomposition is compelling, but I should like to examine the experimental operations behind its coefficients. Suppose an engineer observes a family of images corresponding to period-four gain modulation and estimates coefficients G_k from a spectral transform of the combined output. The resulting numbers are precise within the fitted model. Yet the physical gain of each branch was never independently measured, the stimulus passed through

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a frequency-selective input network, and the converter's background calibration changed while the test was performed. In what sense do those coefficients establish the actual branch gains rather than the effective periodic response of the entire installed apparatus? If a colleague alters the input reference plane or the bandwidth of the stimulus and obtains different coefficients, is that a contradiction, or evidence that the original mathematical model was defined over a narrower operation? How would you prevent the authority of your series from being misused as a claim of physical uniqueness?

Jean-Baptiste Joseph Fourier | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, I welcome the distinction. My harmonic coefficients describe the periodic relationship present in the recorded sequence under the declared conditions; they are not themselves measurements of an inaccessible physical component. The same periodic output can arise from several combinations of gain, analogue frequency response, timing skew and digital correction. A fitted coefficient may be sufficient to predict and reduce an image in a specified frequency interval even though it cannot uniquely identify the electrical cause. The engineer should define the relevant operation precisely: which reference input was supplied, at what connector and impedance, through which acquisition configuration, and with which calibration state. Without that definition, the coefficients are parameters of an incompletely specified model.

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Changing the stimulus or reference plane is a legitimate way to test the asserted generality. If the model was calibrated for one sinusoidal frequency and one stable receiver state, obtaining a different result at another frequency may simply reveal that the branch response is frequency dependent. That is not necessarily a logical contradiction, provided the initial report did not claim universal applicability. If the initial claim asserted frequency-independent branch gains across the whole reception band, the changed response is material evidence against that stronger model. One ought to state in advance which forms of variation would count as rejection, rather than always recasting a failure as an allowable calibration correction after viewing the result.

The method may therefore be useful in three distinct forms. First, it can describe a recorded spectral pattern without making a physical-cause assertion. Second, it can predict how the pattern should move or scale under declared interventions, allowing a falsifiable image hypothesis. Third, after independent measurement of the relevant analogue paths and clocks, it may contribute to a more specific physical attribution. These forms are progressively demanding; the existence of the first does not imply the third. A precise spectrum is not a certificate that every physical component has been uniquely estimated.

In a defensive survey, the greatest danger is to let an internal correction silently rewrite the causal narrative. If an image disappears after calibration, the operator has established a useful sensitivity of the recorded representation to that operation. The event might have

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been an interleaving artefact, but suppression alone does not prove which branch mismatch produced it, nor does it show that no external signal existed at the same frequency. Preserve the raw record, the fitted coefficients, the corrected record and the complete test history. A properly restricted conclusion will remain scientifically valuable even if several internal mechanisms are left unresolved. I should now invite Mr Bennett to examine whether apparently clean residual noise permits a stronger declaration.

William Ralph Bennett | Peer question 4 to Jean-Baptiste Joseph Fourier

Baron Fourier, the periodic decomposition describes deterministic mismatch very clearly, but practical converters combine those periodic terms with quantisation error, analogue noise, switching transients and nonlinear transfer characteristics. Suppose a receiver's spectrum contains a faint line exactly where a gain-image formula predicts it, and the line becomes less visible after a calibration operation. The operator may declare success. Yet a weaker line could persist below the chosen window's sidelobe structure, while some mismatch energy could be spread into other frequencies by time variation or deliberately randomised channel assignments. Would a transform of one finite record justify treating the remaining noise as independent and stationary? How should the investigator distinguish genuinely reduced integrated error from a reduction of one conspicuous spur, and what must be preserved to make that comparison fair when the detection threshold is close to the level of the original image? Would you require a repeat at a second input amplitude before accepting the result as a calibrated improvement?

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Jean-Baptiste Joseph Fourier | Immediate answer to William Ralph Bennett

Mr Bennett, a Fourier transform identifies components of the sampled record under the transform's stated assumptions. It does not independently establish the stochastic law of the residual noise. A finite window produces leakage and resolution effects; a stationary input observed through time-varying mismatches may exhibit a broadened or nonstationary spectral signature. One should therefore compare calibrated and uncalibrated records with the same explicit window conventions, equivalent effective observation durations and an honest account of any changes in the analogue operating state. A reduction in the largest spur is a particular improvement, not proof of lower total error power, reduced false-alarm probability or better transient sensitivity.

I would ask the investigator to specify several measures separately. One measure is the amplitude of the predicted coherent image relative to a characterised input. Another is integrated error power over a named bandwidth, after accounting for relevant window normalisation. A third is the residual feature's behaviour under frequency and amplitude challenges. A fourth is the detection performance of the actual rule used to distinguish a signal from a background, tested against a population of legitimate emissions and instrumental artefacts. These quantities need not improve together. If a calibration method scrambles the image energy across a broader band, the highest peak may diminish while the energy relevant to a particular weak-signal search remains objectionable.

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A good test should save the pre-correction samples or an appropriate equivalent raw representation where possible. It should preserve the calibration coefficients and their timing, the window and transform definitions, and the receiver's nominal sample-rate and branch configuration. It should also retain failed or invalid experiments and avoid selecting only the pleasing before-and-after illustration. For a nonstationary problem, segment-wise diagnostics may reveal that a correction which succeeds in one interval is unsuitable in another. The absence of a line in one averaged spectrum is especially weak evidence about short-lived intermittent emissions, whose temporal contribution may have been diluted by the very averaging that made the background look smooth.

The mathematical conclusion is modest but productive. Periodic mismatch predicts a structured set of spectral relationships; an identified member of that family can be tested by controlled changes; and a candidate calibration can be judged against explicit measures of performance. The same mathematics does not convert any finite spectrum into proof that all residual error behaves as independent uniform noise. Your challenge correctly returns us to statistical modelling and the distinction between an elegant plotted representation and a validated observational claim. I pass the discussion back to Dr. Atkinson for the remaining principal examinations.

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Claude Elwood Shannon | Principal response 3: Information retained after reconstruction

Dr. Atkinson, our problem is one of representation and the conditions under which an inverse inference is warranted. The converter output is a sequence of retained numerical values produced by an acquisition procedure. The claim that those values originated from one external waveform is a model involving branch selection, calibration, analogue transfer, noise and sampling time. Several different combinations of external input and internal channel error may produce essentially indistinguishable output sequences over a finite observation interval. The recording can therefore be entirely genuine while the investigator's favourite explanation for a spectral line is wrong. A hash of the stored samples would establish that the same file was later examined; it could not by itself establish that the file is a transparent representation of an uncorrupted analogue event.

In a time-interleaved system one should distinguish three levels of proposition. The first is the integrity of the retained sequence: whether the samples and accompanying metadata have been preserved without undocumented alteration. The second is the validity of the instrument model: whether the conversion and reassembly procedure, including its errors and corrections, was sufficiently characterised under relevant conditions. The third is the source hypothesis: whether a feature present in the instrument record is more plausibly assigned to an emission at the antenna input or to an internal mechanism. The higher-level conclusion does not follow automatically from the lower-level one. The evidential structure resembles a communication problem in which the received

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symbols are known but both the channel and the transmitted message are partly unknown. Robust inference requires explicit channel assumptions and observations that can challenge them.

An interleaving image may appear indistinguishable from an external tone in a single stationary spectral snapshot. Its position can be rationally tested by changing a known stimulus frequency. For example, a two-branch gain image is predicted near $f_s/2-f_{in}$ in the first Nyquist band. If the calibrated reference moves upward by 20 MHz and the suspicious line moves downward by approximately the same amount while its strength scales with the reference amplitude, the image hypothesis gains support. Yet this dependence is not an absolute proof of its unique cause, because some other coherent processing error could move with the input. A stronger experiment changes the aggregate sampling frequency or interleaving mode and tests whether the line follows the branch-pattern relation. An independent receiver on a different architecture may provide complementary evidence, provided its reference and reception conditions are understood.

It is especially important to preserve the distinction between an image and an independent signal when the external electromagnetic environment contains multiple transmitters. A strong legitimate carrier may produce an internal translated copy precisely where the investigator expects a weak surveillance emitter. The presence of that translated copy is itself useful information about the receiving system; it is not a second source. But a genuine weak emitter could also coexist at the same frequency, hidden under the image. Suppressing a calibrated image may reveal the external component, or it may remove only internal energy, depending upon the

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system. The resulting correction must not be represented as a perfect separation unless a tested model permits that assertion. In difficult cases the evidence may support detection of energy in the corrected record while leaving source identity unresolved.

Information can also be lost when the acquisition process combines the branches in ways that do not preserve their identities. If raw branch codes and branch-selection metadata are unavailable, one may still investigate spectral patterns through external challenge tests, but direct diagnosis of individual offsets, gains and sample times is limited. If the system applies proprietary adaptive calibration and stores only corrected samples, some competing histories may be observationally equivalent even to a skilled examiner. It is a mistake to treat numerical precision in the saved output as a substitute for the missing acquisition state. The file may be reproducible as a digital object while the physical history that gave rise to it remains partly inaccessible. This qualification is material where a report purports to exclude a class of hidden transmitters from a long, sparsely observed search interval.

One should further distinguish the ability to reproduce a detector's result from the ability to validate its false-alarm rate. Suppose a programmed detector is trained using many spectral records taken with one interleaving configuration. Its threshold may incorporate a characteristic population of image frequencies. Changing the converter mode could make those learned frequencies move, altering the detector's null distribution. The same software and nominal numeric threshold would not thereby have the same operating characteristics. A validation report should preserve its acquisition population and explain how the detector was challenged with both genuine

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weak test signals and representative receiver artefacts. If test cases are selected after inspecting the output, the advertised detection probability may describe the selected demonstrations rather than future field observations.

A defensible report could therefore state that a spectral component is consistent with a branch-pattern image because it moved according to a specified relation under declared interventions, and because the image diminished when a prescribed calibration was applied. It should also record competing explanations not eliminated by the evidence, any unresolved overlap with a genuine external signal, and the scope of independent instrumentation. This does not reduce every measurement to scepticism. It gives the investigator a clear route from retained symbols to testable physical hypotheses. Professor Wiener, may I pass the token to your question concerning the effects of a calibration algorithm which learns from the same environment that it is asked to measure?

Norbert Wiener | Peer question 5 to Claude Elwood Shannon

Dr Shannon, your hierarchy appears to assume that the receiving channel can be characterised separately from the information it conveys. In modern equipment the correction algorithm may be coupled to the arriving signal and may update branch timing or gain according to statistics of the input itself. A strong legitimate transmitter could drive the adaptive estimator into one state, while a faint intermittent source might occur only during the transition to another. The stored output could then reflect a feedback process rather than one fixed linear channel. If the operator possesses only the corrected record and a list of final coefficients, can a later examiner reconstruct how a brief emission

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was treated at the moment it appeared? What does a meaningful validation test look like when observer and observed form a coupled system, and where should the uncertainty of that coupling appear in a forensic conclusion? I ask because a hidden controller state can mimic a new source even where the apparatus is operating as designed.

Claude Elwood Shannon | Immediate answer to Norbert Wiener

Thank you for that question. Professor Wiener, the coupling you identify makes the time history of the receiver an essential part of the measurement. A fixed transfer function may be an adequate local model over an interval in which adaptation was inactive or demonstrably stable. It is not automatically applicable to periods during which parameters were changing in response to the signal. If a correction system relies upon recent sample statistics, the apparent value of a brief pulse may depend upon activity preceding that pulse, not merely upon the pulse's own waveform. A later examiner given only the final coefficient set cannot reconstruct every intermediate output unless the algorithm, initial state and input history are sufficiently preserved. Where those materials are absent, the report must state that limitation.

A useful validation plan would deliberately expose the system to changes of state. Introduce a known low-level stimulus before, during and after a strong legitimate blocker; vary the blocker's amplitude and arrival time; repeat the experiment with adaptation enabled and disabled where the design permits. Record both successful detections and intervals during which a genuine reference event is attenuated, displaced or suppressed. The analysis must treat these as

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observations from a coupled procedure, not as exceptions discarded because they complicate a calibration plot. A final clean spectrum can be achieved after an unsatisfactory transition without demonstrating that the transition preserved a fleeting event.

The mathematical record should distinguish fixed parameters from state variables. In a simple adaptive model one might write $\theta[n+1]=F(\theta[n],y[n])$, with $\theta[n]$ the calibration state and $y[n]$ the output available to the algorithm. The corrected observation at time n depends upon $\theta[n]$, which in turn depends upon preceding samples. This is a model description, not a claim that every commercial converter uses that exact update law. Its significance is that conditional dependence across time undermines the convenient assumption of independent observations. Calibration tests should examine state trajectories, settling, lock-loss and recovery, rather than rely solely on steady-state frequency-domain figures of merit.

Where raw branch codes and state histories are retained, a later examiner may test whether a particular transient would survive replay and alternate correction settings. Where they are unavailable, one can still perform prospective black-box challenges, but retrospective statements about the missing event must be bounded. The absence of a detector alarm during a period of adaptive settling is not automatically evidence that no emitter was present. Conversely, detecting a feature during such a period requires caution because the algorithm itself may have created or displaced spectral energy. A trustworthy technical report would attach the adaptation state or a

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justified proxy to each finding, and would identify invalid or unassessed periods explicitly.

Thus the channel model is not discarded; it is enlarged to include the control loop and its memory. A calibration which improves ordinary operation can still demand special validation when deployed as an evidential instrument. The proper aim is not to abolish adaptive techniques, but to ensure that their successes and failures can be examined under the same declared rules. Dr. Atkinson, I return the token for a statistical assessment of the challenge campaign.

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John Wilder Tukey | Principal response 4: Diagnostic experiments and the discipline of exploratory displays

Dr. Atkinson, the danger in a well-designed spectral display is that it supplies persuasive pictures before it supplies sound inference. A recurring line can be highlighted, labelled and preserved in an event log while dozens of conflicting observations fade from the operator's attention. Time-interleaved converters make such visual persuasion particularly hazardous because a receiver image can behave like a physical signal in several respects. It can be narrow, stable, coherent with a genuine emitter and repeatable under an unchanged configuration. The crucial scientific question is not whether the picture looks convincing, but whether a test population and a decision rule were specified which could have exposed the instrument's explanation as false.

I would begin with exploratory analysis, but I would not allow that analysis to masquerade as confirmatory validation. Exploration should examine the locations of unexpected spectral lines, their amplitude relationships, time dependence, correlations with strong inputs and changes under altered clock or branch conditions. These observations suggest candidate mechanisms, including gain mismatch, offset error, skew, bandwidth asymmetry, clock leakage and aliasing. The investigator may plot difference spectra, branch-resolved traces where possible, and measured calibration coefficients. The exploratory process is valuable because a single theoretical model seldom anticipates every defect in an installed system. But the same evidence used to discover a hypothesis cannot, without allowance for selection, be presented as though it were an independent experiment designed to test it.

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For a confirmatory test, I would predefine at least two distinct predicted responses. Under a two-channel gain-image hypothesis, moving a known input tone from f_1 to f_2 should shift an image from $f_s/2-f_1$ to $f_s/2-f_2$, and a change of input amplitude should change the image amplitude in a predictable proportional manner within the linear regime. Under a fixed external-emitter hypothesis, the observed carrier should not automatically move in the opposite direction simply because the investigator swept a separate reference, although an actual nonlinear interaction or coupled transmitter would require separate consideration. Under an offset-mismatch hypothesis, the spur remains at the branch harmonic even without the stimulus. These predictions should be specified before the final challenge data are observed. The comparison is informative only when the receiver remains inside a documented operating envelope.

The experiment should also examine thresholds and search multiplicity. A survey may search hundreds or thousands of spectral bins and preserve only those crossing an alarm threshold. As the number of candidate events increases, apparent coincidences with expected image locations become more likely. A visually exact match found after examining every possible alias and every available sample-rate configuration has a different evidential weight from a match predicted and tested in advance. The statistical plan should record the number of configurations, frequencies and windows inspected, and should avoid retroactively reducing the trial count to the one successful illustration. A change in calibration may modify the null distribution and demand a new threshold rather than simply a new colour palette.

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The selection of a spectral estimator matters. A finite-window Fourier transform spreads energy according to the window's response; coherent sampling can minimise leakage for chosen tones but may conceal performance under untidy field conditions. Averaging spectra can improve the visibility of stationary features while diminishing the contribution of short events. Resolution bandwidth, window equivalent noise bandwidth, detector integration interval and sample-clock accuracy should be held constant or explicitly recalibrated when comparing before and after results. Otherwise an image may appear reduced merely because the measurement procedure smoothed or moved energy. A good report includes enough information to reconstruct the plotted numbers from retained samples and settings, and enough raw evidence to challenge alternate post-processing choices.

One should include negative controls. Remove or greatly attenuate the calibrated input and determine whether the suspected image persists. Change the aggregate sample rate while holding the external frequency constant. If possible, use a receiver with a materially different architecture rather than another channel of the same shared conversion chain. Deliberately perturb temperature or clock phase inside safe operating limits to examine whether the feature follows the expected sensitivities. The tests should be designed to discriminate among mechanisms; a collection of gestures that all reduce every signal in the apparatus is not persuasive. If a strong input attenuator suppresses both genuine emissions and instrumental images, attenuation alone has not identified the suspect feature.

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I would recommend recording the failures of the model in a residual register. A predicted image which is absent can be as instructive as an image which appears, provided the expected level was above the test's sensitivity. An observed line with the wrong scaling law should not be dismissed without investigation. The model may omit bandwidth mismatch, alias folding, nonlinearity or adaptive feedback; alternatively the line may be external. Every such case is an opportunity to improve the experiment's discriminating power. There is no scholarly merit in forcing all anomalies into one diagnosis merely because the demonstration was designed around it. An investigator who reports an unresolved cause with precise observations is often more useful than one who produces a confident but fragile label.

The appropriate endpoint is a bounded operational conclusion. One might show that under a declared configuration an image due to branch gain mismatch accounts for a specified family of features and that a tested correction reduces their amplitudes within an uncertainty interval. One might then demonstrate that a separate feature survives those challenges, justifying further external-source investigation without proving transmitter identity. It is essential to state whether the claim concerns a detector threshold, integrated noise, spurious-free dynamic range or source attribution. Those are different performance metrics. Mr Turing, may I invite a question about whether an algorithm which reproduces a spectral figure has thereby reproduced the experiment that figure represents?

Alan Mathison Turing | Peer question 6 to John Wilder Tukey

Professor Tukey, I should like to separate computational reproducibility from the physical information upon which a computation

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operates. Suppose two independent analysts receive an identical sequence of interleaved converter codes, the same software instructions, and the same saved calibration coefficients. They obtain precisely the same spectral image and the same corrected result. One then concludes that a suspect line must have originated within the receiver, while the other maintains that a real external emission may have been superimposed upon the image. Are both analysts correct in saying that their analysis is reproducible, even though their causal accounts differ? More importantly, can any deterministic transformation of the same recorded sequence create the missing information needed to settle that disagreement? What independent observation, intervention or metadata would you require before treating the internal-artifact explanation as exclusive rather than merely plausible? The disagreement seems especially serious when an investigator reports a categorical source identity from numerical data alone, although the necessary physical intervention was never performed.

John Wilder Tukey | Immediate answer to Alan Mathison Turing

Mr Turing, identical outputs from identical computational inputs establish a valuable property of the analytical procedure: another examiner can repeat the calculation. They do not establish that the original physical acquisition was complete, that the correction model was unique or that an external source cannot coexist with an artefactual image. The two analysts may be entirely agreed upon every computed quantity and still disagree about source attribution because that attribution depends on hypotheses not determined by the retained data alone. We should not try to resolve an

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underdetermined physical question by performing the same deterministic arithmetic with greater precision.

The suitable additional evidence would be chosen according to what the competing explanations predict differently. A controlled change of reference frequency or interleaving mode may alter an instrumental image while leaving an independent external carrier fixed. An independently calibrated receiver with a different conversion architecture may reveal a persistent emission, though common antennas or shared interference can limit independence. Raw branch data and time-stamped calibration states may expose which branch generated the periodic component. A separate physical clock measurement may constrain timing-skew hypotheses. No one test is universal; the investigator should explain which proposition it challenges and which alternatives remain possible.

An especially important distinction is between correcting a measurable quantity and reconstructing a unique original waveform. If a well-characterised linear transfer can be inverted for the signal and bandwidth of interest, numerical correction may be justified within uncertainty. But if saturation, discarded samples, adaptive filtering or unrecorded branch state have made several distinct inputs observationally equivalent, a computed inverse must import extra assumptions. The output may look plausible yet be insufficient for a stronger causal conclusion. A report should mark where those assumptions enter, and it should not treat a simulated reconstruction as an additional independent observation of the past.

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For publication, I should preserve the original file and cryptographic digest, the software version and reproducible configuration, but also the physical acquisition record: converter mode, aggregate and branch sample rates, reference clock, gain and offset states, calibration timing, analogue path and any invalid intervals. The two forms of reproducibility are complementary. Digital repeatability is a protection against undocumented post-processing; physical repeatability and controlled intervention address the validity of the causal inference. The strongest conclusion may be that a feature is consistent with a tested internal image mechanism while a coincident external signal has not been excluded. That is not a defect in the computation. It is an accurate description of the information the experiment actually supplied.

My answer, therefore, is that formal computation cannot conjure a missing physical discriminant into existence. It can reveal where the model permits one, guide the design of another test and prevent our language from overstating the record. Dr. Atkinson, I return the token to the question of calibration stability and its evidence.

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Walter Andrew Shewhart | Principal response 5: Calibration controls and field acceptance

Dr. Atkinson, our preceding colleagues have shown how an apparently precise spectrum can be generated by the recurrent imperfections of several measuring channels. I should like to translate that reasoning into a system of operational control. A receiver which exhibits low interleaving spur levels during a favourable laboratory demonstration may nevertheless produce unacceptable false features after thermal change, clock substitution, gain adjustment or an extended observation. Such variation is not adequately described by a solitary figure of merit. The measurement process should be characterised over the conditions in which it will actually be used, with procedures able to detect when it has departed from the validated state. This is the purpose of statistical quality control in the present constructed application: not to declare every output statistically random, but to distinguish ordinary process variation from changes that invalidate an earlier calibration.

I would begin by defining the relevant quality characteristics. Branch offset difference, relative gain mismatch, effective timing skew, image-to-carrier amplitude ratio, coherent spur level, in-band noise, calibration residual, clock-lock state and loss-of-sample indicators are distinct quantities. One chart showing a falling largest spectral peak cannot substitute for all of them. The laboratory should define a baseline operating envelope and the independent references available to assess each characteristic. Measurements should be taken at declared input amplitudes, frequencies, temperatures, receiver gains and interleaving modes. Acceptance limits must follow the intended task. A receiver intended to find

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very weak intermittent emissions near strong legitimate transmitters may require more stringent image testing than one intended merely to characterise a large continuous carrier.

The first concern is measurement system validity. A calibration standard must reach the portion of the chain that a claim addresses; an internal reference injected after the analogue preselector is not sufficient to certify the antenna and front-end path. Where a source reaches multiple branches through shared equipment, common reference error may move the apparent gains together without revealing their relationship to an independently defined external quantity. Conversely, comparing branch differences may be relatively insensitive to common gain error but still vulnerable to systematic phase and timing defects. The report should distinguish absolute accuracy, relative branch matching and performance of the corrected composite output. Each has its own reference conditions and uncertainty structure.

The second concern is process stability. If an image spur is measured repeatedly at one frequency, a stable mean with a narrow spread may justify a limited claim about that configuration, but it does not guarantee performance after the analogue input changes. Background calibration may track slow thermal drift; the monitoring record should show whether its coefficients vary under legitimate operations and whether those variations affect the weak-signal detector. An alarm or invalidation criterion can be established for departures from baseline. The purpose of such a criterion is to trigger investigation or revalidation, not to replace the original data with an automatically polished figure. A useful control record includes both the observed deviations and the operator's response, because repeated

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undocumented retuning can turn a genuine failure into a series of selectively retained successes.

The third concern is the interaction of several factors. Temperature, clock phase, gain setting and input frequency may not affect the measurement independently. A small gain mismatch at one temperature may be harmless until it combines with timing skew at a higher frequency. A change in attenuation can move the operating point into a more linear regime while also reducing the amplitude of any actual weak emission. A calibration that operates well with a sinusoidal reference may respond differently to a burst or a wideband waveform. A carefully designed matrix of conditions can reveal material interactions, but a limited matrix supports only the combinations actually represented or justified by a validated interpolation model. It does not certify every possible environment merely because its plotted points form a pleasing line.

The fourth concern is the relationship between detection and reporting. A field operator may see a line at a frequency predicted by the gain-image model and exclude it from investigation. That exclusion is a decision rule and should be validated with genuine weak injected events, including events near expected image frequencies. A genuine emission could coincide with an artefact; blindly suppressing the predicted region might increase the false-negative rate. Conversely, declining to recognise a known instrument image may lead to false accusations and wasted investigative effort. Validation should therefore measure the effect of the full procedure, not merely the size of one corrected spur. It should preserve false positives, false negatives, invalid trials and the uncertainty of estimated performance under the relevant test population.

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The fifth concern is traceability across revisions. Software calibration algorithms are often improved, detector thresholds changed and firmware updated. Each change can alter what an earlier event means. An examiner should be able to identify the version of the acquired data, the branch configuration, the correction parameters, the software used to render the plot and any subsequent reprocessing. A corrected record should be retained alongside the original where practicable. If the original branch data have been lost, the limitation should appear in the formal report rather than being disguised by reproducibility of a downstream calculation. A physical instrument cannot be retroactively calibrated into having acquired information which it never preserved.

A final acceptance programme would use several kinds of evidence. Test tones and broadband references establish aspects of the transfer; controlled input-frequency changes challenge predicted image motion; alternate sample-rate and branch configurations challenge the periodic cause; temperature and operating-state tests expose drift; and independent receiver observations help separate instrument-specific features from common external activity. None of these tests should be presented as exhaustive in isolation. Together they may support a bounded statement that the receiver is fit for a specified defensive-search task within a declared envelope, subject to explicit invalidation rules. A quality-control chart is not a forensic verdict. It is an aid to preserving the credibility of the comparisons upon which a verdict must rest. Sir Ronald Fisher, may I invite your challenge to the design of the acceptance experiment and the consequences of selecting favourable trials?

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Sir Ronald Aylmer Fisher | Peer question 7 to Walter Andrew Shewhart

Dr Shewhart, your monitoring scheme seeks stability, but I am concerned with what a finite experimental sample can establish when several operating conditions are examined. Suppose a laboratory tests an interleaved receiver at ten frequencies, four temperatures and three gain settings, performs repeated calibrations until each display looks satisfactory, and then quotes the best spur value as a property of the instrument. That number may be genuine but its inferential status is obscure. How would you distinguish a prespecified acceptance trial from a exploratory tuning exercise, account for the selection of conditions and repeated attempts, and prevent a high nominal pass rate from disguising poor performance in the difficult corner where a strong legitimate input overlaps a weak test signal? What probability statement, if any, would the completed experiment allow the examiner to make about performance beyond the exact conditions tested? I should also like to know which unsuccessful calibration attempts form part of the denominator of any purported reliability estimate.

Walter Andrew Shewhart | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, I accept the challenge without qualification. A tuning exercise is useful for development, but its successful endpoint is not an independent estimate of the probability of success under future operating conditions. If the engineer repeatedly alters calibration parameters and then retains only the passing trial, the apparent yield belongs to a selected sequence whose denominator has been

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concealed. The procedure can demonstrate that a satisfactory state was reached; it does not establish how frequently such a state would be reached without intervention or whether it remains stable in service. The acceptance population and stopping rule should therefore be specified before the confirmatory trials, and every trial, including invalid or failed ones, should be retained in the review record.

I would separate the operating envelope into meaningful strata rather than average everything into one impressive percentage. Strong-blocker conditions, high input frequencies, thermal extremes and weak-signal overlap may dominate the investigative risk even if they occupy a small fraction of simple laboratory tests. A pooled success rate can conceal a material deficiency in such a stratum. For each important condition, report the number and outcome of independent trials, including how correlation across repeated measures was handled. Confidence bounds may be calculated under an explicit sampling model, but they cannot automatically be extrapolated to untested conditions, a changed firmware version or a different installation. The statistical statement must be tied to the actual experimental population.

A practical campaign may use one set of observations to identify a candidate calibration, then an independent, locked-configuration set to test its performance. When the objective is to verify that a weak signal remains detectable despite an image, the trials should vary the relative timing and amplitude of the legitimate blocker and the test emission. The evaluation should consider both the receiver's

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spurious-free measure and the forensic detector's true-positive and false-positive behaviour. A calibration which produces a prettier spectrum but suppresses legitimate test events is not fit for that purpose merely because its largest instrument spur diminished. The performance criterion should be connected to the material decision required by the investigation.

Where the experiment lacks sufficient independent data for a reliable probability claim, there is no obligation to manufacture one. Report the observed outcomes, their limits, the exact tested envelope and the changes that would require revalidation. Control charts can reveal drift and trigger intervention; they do not make a finite set of favourable observations into an unlimited guarantee. A responsible acceptance record should be useful precisely because its limitations are stated. Dr. Atkinson, I pass the token to your worked numerical examination and concluding synthesis, with the hope that the arithmetic will sharpen rather than obscure those boundaries.

Ten worked engineering applications | Moderator-led numerical analysis

The following calculations use hypothetical examples and deliberately stated simplifications. Let M denote the number of interleaved ADC branches; f_s the aggregate sample rate in samples per second; f_{in} the frequency of an input sinusoid in hertz; A the peak amplitude of the sinusoidal input in volts; ε a dimensionless symmetric branch gain mismatch; b an alternating offset amplitude in volts; τ a branch-to-branch systematic time-skew difference in seconds; and σ_t the RMS random aperture jitter in seconds. Unless stated otherwise the input and

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receiver remain linear and unsaturated, sampling is coherent for the frequency-estimation example, and uncorrelated errors are assumed only where explicitly named. The image frequencies below are expressions of periodic branch selection, not proofs of a transmitter at those frequencies.

Harry Nyquist, Cross-Peer Question to Jean-Baptiste Joseph Fourier: Dr Fourier, a four-way interleaved converter presents a persistent line at 400 MHz and signal-following lines at 300, 500 and 700 MHz when driven by a 100 MHz reference at 1.600 GS/s. What distinctions between branch-offset harmonics and periodic gain or aperture effects are defensible from frequency positions alone?

Jean-Baptiste Joseph Fourier, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the periodic four-branch selection sequence has a fundamental repetition frequency of f_s/M, here 400 MHz, while harmonics and translated input copies can occupy several positions after folding into the Nyquist interval. Branch offsets may give fixed components independent of test-tone frequency; gain, timing and analogue response mismatch can translate the applied input. Frequencies predict a class of possible artefacts, not unique causes or amplitudes. Measure complex branch-specific gains and timing with independent reference stimuli, then repeat with input frequency shifted by a known amount. If the translated lines move with the stimulus but the offset harmonic does not, that differential behaviour supports, without proving exclusively, the interleaving account. Do not classify the lines as separate transmitters merely because a spectrum display renders each as a sharp peak. I respectfully pass the token to Dr Shannon to examine what survives in the recorded sequence.

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Jean-Baptiste Joseph Fourier, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, a field operator retains only a background-calibrated combined output stream and an FFT image. Branch identifiers and raw pre-calibration records were discarded. How can the investigator separate a corrected spectral picture from evidence of the original analogue wave and identify information that is no longer recoverable?

Claude Elwood Shannon, Cross-Peer Answer to Jean-Baptiste Joseph Fourier: Dr Fourier, the retained stream represents the output of a known or partly known transformation, not a transparent record of the original per-branch apertures. If branch identity, timing and correction coefficients are absent, multiple physical mismatch histories may be consistent with the same displayed spectrum. Preserve the calibration firmware, coefficient version, temperature log, branch order and raw or least-processed samples whenever technically available. Recompute spectra using declared windows, normalisation and record lengths; identify what was corrected rather than claiming that a spur was never there. A held-out calibration source and a separately routed receiver may discriminate hypotheses, provided their shared clocks, front ends and antenna path are accounted for. An image that tracks a reference could also be a mixing product, so the inverse explanation requires controlled challenges. I respectfully pass the token to Professor Tukey.

Claude Elwood Shannon, Cross-Peer Question to John Wilder Tukey: Professor Tukey, in the two-branch example a plus 30 MHz shift of the injected tone moves the predicted image minus 30 MHz. What adverse experiments could show that this tracking is attributable to interleaving,

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rather than an unexamined analogue mixer or coherent interference elsewhere in the receiver?

John Wilder Tukey, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, vary one experimental factor at a time and keep a contemporaneous audit trail. Repeat the frequency shift across multiple injection levels and branch configurations, including a single-branch operating mode where available. Measure whether the line follows f_s/2−f_in, whether a fixed offset spur remains at f_s/2, and whether calibrated preselector or path changes suppress the suspected mechanism. Sweep input frequency across representative analogue bandwidth conditions while controlling source harmonics, phase noise and gain compression. A response that disappears in single-branch operation is useful evidence, but it does not establish where every other source of nonlinearity resides. Pre-register the comparison metrics and inspect negative trials, not just the striking waterfall. Report frequencies and confidence bounds, with any conclusions restricted to the tested chain. I respectfully pass the token to Dr Shewhart to consider drift.

Walter Andrew Shewhart, Cross-Peer Question to Harry Nyquist: Dr Nyquist, a converter bank was skew-calibrated in the morning, then warmed by fifteen degrees. Its stated relative skew coefficient is 0.50 ps per degree, yet a report applies the morning image-rejection figure to a later 300 MHz capture. What can the calculated 7.5 ps change and approximately −43.01 dBc illustrative image actually establish?

Harry Nyquist, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, the 7.5 ps value follows only from the assumed linear coefficient over the specified fifteen-degree change. The image estimate uses the two-way

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small-skew approximation r approximately π f_in Δτ, which gives about 0.0070686 at 300 MHz and about −43.01 dBc. It represents a hypothetical incremental mismatch under that convention, not necessarily the total residual image after adding pre-existing skew, gain mismatch or phase-corrector error. Those contributions combine as complex phasors and can reinforce or partly cancel. Measure actual converter temperatures, branch-to-branch timing, reference-clock stability and correction coefficients both before and after the event. Revalidate across operating temperatures and signal frequencies; do not infer the temperature coefficient from a single changed peak. The example proves arithmetic consistency under assumptions, not real-world causation. I respectfully return the token to Dr Atkinson for synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Colleagues, our investigation has distinguished a numerically regular output sequence from a physically uniform acquisition. An interleaved receiver can genuinely increase aggregate sampling throughput, yet its branch-dependent gain, offset, aperture and analogue response can impose periodic errors which the Fourier transform faithfully displays as organised spectral features. The screen may shine with a line at a frequency never emitted by an independent external device. The crucial step is to recognise that periodic channel selection is an operation upon the incident waveform, and that the transformation can generate images whose apparent coherence and reproducibility mimic some properties of genuine reception. These features are not measurement frauds or necessarily evidence of defective engineering; they are predictable consequences of an architecture

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whose actual performance must be characterised within its operating envelope.

Dr Nyquist established the physical boundary of the nominal timing lattice. An index assigned by the software is not a measurement of the actual aperture time, and equal aggregate intervals do not imply equal branch gain, analogue phase response or recovery. Professor von Neumann demanded experimental identification rather than numerical curve-fitting alone, while Mr Weston required that every claimed correction be linked to its true reference plane. Baron Fourier then examined the periodic error coefficients and showed why harmonics of the branch-selection cycle shift a genuine input into correlated images. Professor Bridgman insisted that harmonic coefficients fitted from output data not be misrepresented as uniquely measured internal component parameters. Mr Bennett questioned the unjustified elevation of a smaller coherent spur into a universal improvement in random noise, sensitivity and detector performance.

Dr Shannon clarified the difference between a genuine stored record, the physical conversion model and the source-attribution hypothesis. The correct digital file can preserve an incorrect causal inference with perfect fidelity. Professor Wiener demonstrated why an adaptive correction algorithm can turn the receiving apparatus into a system with memory, so that a final calibration setting does not disclose every state through which a fleeting pulse passed. Professor Tukey then transformed the theoretical distinctions into a demanding experimental programme: controlled frequency moves, changes in interleaving mode, independent validation conditions, negative controls and transparent accounting for multiple comparisons. Mr Turing drew the boundary between reproducing a

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computation and reconstructing physical information absent from the record. Dr Shewhart finally required process-control evidence across the actual operating envelope, and Sir Ronald Fisher exposed the danger of reporting selected successful calibration trials as a statistical guarantee.

The worked examples give the reader concrete diagnostics. Four branches, each operating at 400 million conversions per second, may create a nominal 1.6-gigasample stream, yet their periodic errors can generate image locations related to 400-MHz branch harmonics. Two branches separated by a symmetric one-per-cent gain deviation can create a copy of a strong 120-MHz input at 380 MHz, approximately forty decibels below its parent, without a second transmitter. A two-picosecond branch skew at 200 MHz may generate a timing image near −58 dBc in the stipulated model; an uncorrected temperature drift of several picoseconds can materially worsen that result. Offset mismatch, coherent skew and random aperture jitter must not be combined casually under one label. Their spectral signatures and uncertainty relations differ.

For a defensive counter-surveillance investigation, the appropriate inference should follow controlled comparisons rather than the aesthetic appeal of a waterfall trace. A line which moves according to $f_s/2-f_{in}$ when a known reference moves is consistent with an internal interleaving image, especially if a separately declared branch-mode change produces the predicted accompanying result. Yet a coincident external emission may remain possible, and a different form of coherent processing might mimic the same simple movement. A correction which reduces an image can improve a specified spurious-free measure without proving improved probability of detecting every weak intermittent signal. Validation must

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therefore address the actual detector, the intended class of emissions, the relevant strong-blocker environment and any intervals of adaptive transition or failed calibration.

The publication record should preserve raw output and branch-resolved codes where available, exact aggregate and branch sample rates, the timing and analogue reference, calibration state history, firmware versions, gain and attenuator settings, stimulus characteristics, actual detector thresholds, transform parameters, invalid periods and all observed challenge outcomes. When a record is corrected, the uncorrected source should remain preserved, or its absence should be disclosed as a qualification. Where the relevant data were never saved, the analyst should avoid inventing them through retrospective arithmetic. Scientific restraint does not require an indefinite postponement of every finding; it requires a clear statement of the observation and the remaining physical alternatives.

I therefore conclude that periodic interleaving mismatches can generate coherent spectral artefacts whose positions are calculable and whose magnitudes can be bounded under declared models, but their exact physical origin in a particular receiver must be established through evidence. This is a positive doctrine of measurement: use the mathematics to predict, the experiment to discriminate, the source record to verify and the report to limit what can honestly be inferred. Our next question will examine how effective number of bits relates to intermittent signals, where a beautifully averaged spectral figure may conceal that the receiver possessed too little instantaneous information to preserve a brief event. I thank the contributors and pass the token onward.

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Biographical verification: https://mathshistory.st-andrews.ac.uk/Biographies/Fourier/. Historical facts are separated from the modern, fictional engineering dialogue.

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Ten worked engineering applications | Question 027

Application 01. Aggregate rate and branch timing for four converters

Let $M=4$ and let the aggregate rate be $f_s=1.600\times10^9$ samples/s. The nominal output interval is $T_s=1/f_s=0.625$ ns, while each individual branch converts at $f_s/M=0.400\times10^9$ samples/s, or 400 MS/s. Its interval between successive conversions is $M\,T_s=2.500$ ns. The branches occupy nominal phases separated by 0.625 ns in the sequence, with each branch repeating every 2.500 ns. This arithmetic establishes aggregate throughput, not independent proof that the analogue apertures follow those times accurately. A common-clock architecture, board delays and branch-specific aperture uncertainty must be measured before treating the nominal lattice as a traceable timing measurement.

Application 02. Two-way gain mismatch and a translated spectral image

Consider $M=2$, $f_s=1.000$ GS/s and a real input sinusoid at $f_{in}=120$ MHz with peak amplitude $A=0.500$ V. Let branch gains be $1+\varepsilon$ and $1-\varepsilon$ where $\varepsilon=0.010$, meaning a 2% full branch-to-branch difference relative to the nominal gain. The reconstructed output is approximately $y[n]=(1+\varepsilon(-1)^n)x[n]$. The gain-image frequency in the first Nyquist zone is $f_{image}=f_s/2-f_{in}=500-120=380$ MHz. The image peak amplitude is $\varepsilon A=0.010\times0.500=0.005$ V. Its ratio to the main signal is $\varepsilon=0.010$, giving $20\log10(0.010)=-40.000$ dBc under the stated amplitude convention. A line at 380 MHz is thus predicted without any second external transmitter. The 2% branch difference must not be substituted directly for ε or the estimate changes by approximately six decibels.

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Application 03. Two-way offset mismatch and a fixed branch harmonic

Retain f_s=1.000 GS/s and let branch offsets be +b and −b, with b=0.001 V. The periodic output error is $o[n]=b(-1)^n$, producing a discrete component at $f_s/2$=500 MHz, irrespective of the incident signal frequency in this ideal model. Compared with a stated reference sinusoid of A=0.500 V peak, the amplitude ratio is b/A=0.001/0.500=0.002. Its level is 20log10(0.002)=−53.9794 dBc relative to that chosen peak reference. The relative level depends on the reference amplitude, while the absolute offset-spur amplitude remains b. An investigation should not label the feature a universal −54 dBc defect without documenting that reference and the actual spectral normalisation.

Application 04. Symmetric two-way aperture skew at high RF input frequency

Let M=2, f_s=1.000 GS/s, f_{in}=200 MHz, and suppose the two branches deviate from their intended sample times by +τ/2 and −τ/2, with τ=2.0 ps as the full branch-to-branch difference. Linearising x(t+δt) for a sinusoid yields a first-order alternating timing error whose image-to-signal amplitude ratio is approximately $r_{skew}\approx\pi f_{in}\tau$. Substituting gives $r_{skew}\approx\pi\times(200\times10^6\text{ Hz})\times(2.0\times10^{-12}\text{ s})=0.00125664$. Therefore the image is approximately $20\log10(r_{skew})=-58.015$ dBc under this two-way convention. The same skew at 50 MHz would produce an image roughly twelve decibels lower because the small-error ratio scales with f_{in}. The approximation fails when the phase deviation is not small or when frequency-dependent analogue response dominates the effective phase difference.

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Application 05. Random aperture jitter is not the same as deterministic skew

Assume an input sinusoid at $f_{in}=200$ MHz and independent RMS aperture jitter $\sigma_t=0.500$ ps referred to the sample aperture. Under the usual small-noise ideal sinusoid model, the jitter-limited signal-to-noise ratio is $SNR_j=-20\log10(2\pi f_{in} \sigma_t)$. The dimensionless product is $2\pi\times(200\times10^6)\times(0.500\times10^{-12})=0.000628319$, giving $SNR_j\approx64.04$ dB. This broadband-noise limiting calculation is not a prediction of the coherent spur caused by the 2-ps branch timing mismatch in Application 04. A receiver can suffer both defects, and no honest uncertainty budget should combine them as though they were necessarily independent manifestations of one scalar timing error.

Application 06. Four-way image family and alias positions

Let $M=4$, $f_s=1.600$ GS/s and $f_{in}=100$ MHz, within the 0–800 MHz first Nyquist zone. Gain or timing mismatch periodicity can translate copies of the input to the relevant first-zone positions $|f_s/4-f_{in}|=|400-100|=300$ MHz, $f_s/4+f_{in}=400+100=500$ MHz, and $f_s/2-f_{in}=800-100=700$ MHz, when the corresponding branch-pattern coefficients are nonzero. The fourth-harmonic offset structure may generate fixed components at 400 and 800 MHz. A calibrated test which moves f_{in} upward by 10 MHz would predict moving gain images at 290, 510 and 690 MHz, not three new independent transmitting devices. Actual image amplitudes depend upon the complex branch-error coefficients and the input waveform, which are not stipulated by frequency-position arithmetic alone.

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Application 07. Temperature drift can invalidate a narrow timing calibration

Suppose a converter assembly has a relative timing-skew temperature coefficient $c_\tau=0.50$ ps/°C and the relevant temperature changes by $\Delta T=15$°C. If the relationship is linear over this limited range, the skew change is $\Delta\tau=c_\tau\Delta T=7.5$ ps. At $f_{in}=300$ MHz, the associated first-order two-way image-to-signal ratio is $r\approx\pi f_{in}\Delta\tau=\pi\times300\times10^6\times7.5\times10^{-12}\approx0.00706858$, or $20\log10(r)\approx-43.01$ dBc. This is the estimated contribution from the hypothetical change, not an independent claim about the converter's initial spur or a universal temperature coefficient. Calibration performed at one ambient condition cannot be assumed valid at another without an appropriate thermal record or validation exercise.

Application 08. Combining orthogonal image components under an explicit model

Suppose a two-way receiver has a relative gain-image coefficient $r_g=0.005$ and a timing-image coefficient $r_t=0.008$, and their spectral phasors are orthogonal under a stated single-tone model. The resultant image amplitude ratio is $r_{total}=\sqrt{(r_g^2+r_t^2)}=\sqrt{(0.000025+0.000064)}=0.00943398$. Its level is $20\log10(r_{total})=-40.506$ dBc. Simply adding the two scalar levels in decibels would be meaningless, while adding amplitude magnitudes to obtain 0.013 would be a conservative bound rather than the orthogonal prediction. The orthogonality premise requires verification in the relevant architecture; analogue bandwidth mismatch and other phases can alter the vector relationship.

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Application 09. A frequency challenge separates moving images from fixed carriers

In a two-way system let f_s=1.000 GS/s and initially inject a calibrated reference at f_{in}=130 MHz. The gain-image hypothesis predicts a first-zone image at $f_s/2-f_{in}=500-130=370$ MHz. Move the same reference to 160 MHz while retaining the sample rate and operating state; the predicted image moves to $500-160=340$ MHz. The displacement is −30 MHz for a +30 MHz reference change. A fixed external carrier at 370 MHz, all else equal, does not satisfy this prediction merely because the reference moves. The test provides discriminating evidence, not universal exclusivity, because a mixing product or other coherent input-related artefact may also track stimulus frequency. A second intervention, such as changing branch mode, should be used where possible.

Application 10. False-alarm interpretation across a family of test frequencies

Suppose a laboratory searches K=800 effective independent spectral decision cells, each having a calibrated null false-alarm probability $\alpha=0.0005$ after a declared image-suppression procedure. The probability of at least one false alarm under independence is $P_{any}=1-(1-\alpha)^K=1-(0.9995)^{800}\approx0.3298$, or about 33%. Thus a seemingly impressive per-cell threshold can produce a substantial familywise burden when applied to many frequencies. The formula is exact only under the stipulated independence; real overlapped FFT windows, neighbouring bins, adaptive thresholds and shared calibration errors can create dependence. Suppressing a known interleaving image

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does not automatically revalidate a detector's null distribution, and a familywise result is not a probability that a particular observed spectral line is an external transmitter.

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Scholarly reference register | Material actually reviewed and scope

[R1] Analog Devices, 'Interleaving ADCs: Unraveling the Mysteries,' Analog Dialogue. https://www.analog.com/en/resources/analog-dialogue/articles/interleaving-adcs.html. Scope reviewed: official HTML explanation of M-branch aggregate sample rate, branch-offset harmonics, gain/timing images at ±f_in + k f_s/M, two-way f_s/2−f_in image, four-way images, and dependence of timing artefacts upon input frequency. This modern article is evidence for engineering mechanisms, not historical speech.

[R2] Analog Devices, 'Advanced Digital Post-Processing Techniques Enhance Performance in Time-Interleaved ADC Systems.' https://www.analog.com/en/resources/analog-dialogue/articles/advanced-digital-post-processing-techniques.html. Scope reviewed: official HTML discussion of gain, phase, offset mismatches, error budgets, orthogonal gain/phase contributions and calibration demands. Equipment-specific performance examples were not transferred to any hypothetical survey instrument.

[R3] Analog Devices, 'The ABCs of Interleaved ADCs.' https://www.analog.com/en/resources/technical-articles/the-abcs-of-interleaved-adcs.html. Scope reviewed: indexed HTML explanation of the four principal interleaving mismatch classes and fixed two-way offset-spur position. No assertion is made that every architecture obeys the ideal small-error formula in the same way.

[R4] IEEE, 'Design Considerations for Interleaved ADCs,' IEEE Journal of Solid-State Circuits, vol. 48, no. 8 (2013), pages 1806–1817, doi:10.1109/JSSC.2013.2258814. https://doi.org/10.1109/JSSC.2013.2258814. Scope reviewed: publisher bibliographic record and abstract identifying interchannel mismatch, frequency-domain corruption, sampling benefits and background timing calibration. The full article's inaccessible experimental details are not reproduced.

[R5] IEEE, 'A 900-MS/s SAR-Based Time-Interleaved ADC With a Fully Programmable Interleaving Factor and On-Chip Scalable Background

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Calibrations,' IEEE Transactions on Circuits and Systems II (2022). https://ieeexplore.ieee.org/abstract/document/9793854. Scope reviewed: IEEE bibliographic entry and abstract reporting configurable interleaving and on-chip gain, offset and timing correction; instrument figures refer to the published chip, not the constructed forensic examples in this question.

[B1] University of St Andrews MacTutor History of Mathematics, 'Joseph Fourier (1768–1830).' https://mathshistory.st-andrews.ac.uk/Biographies/Fourier/. Scope reviewed: institutional historical account of Fourier's education, political service, heat research, mathematical series and chronology.

[B2] Académie française, 'Joseph FOURIER.' https://www.academie-francaise.fr/les-immortels/joseph-fourier. Scope reviewed: institutional biography, birth and death dates, membership, principal book, and public service.

[B3] IEEE History Center, 'Harry Nyquist, 1889–1976.' https://citeseerx.ist.psu.edu/document?doi=24901a03946cf301d52a11673fd6aa4d5feb27d7&repid=rep1&type=pdf. Scope reviewed: indexed historical summary for birth, university education, employment and death dates, not an independently inspected PDF page in this checkpoint.

[B4] IEEE Computer Society, 'Computer Pioneers: John Wilder Tukey.' https://history.computer.org/pioneers/tukey.html. Scope reviewed: institutional historical biography including educational degrees, Princeton and Bell Labs appointments, FFT work and death in 2000.

End of Question 027. All dialogue is original fictional educational reconstruction; it is not a transcript, quotation or claim of posthumous participation in any modern instrument experiment.

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QUESTION 028

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When is an effective-number-of-bits calculation relevant to an intermittent signal?

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Constructed educational dialogue. Every exchange is newly authored; no passage is an authentic historical quotation or a claim that a deceased contributor examined modern equipment. Numerical illustrations are hypothetical, and none certifies an actual receiver. Technical references are identified by bracketed source keys.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, our preceding discussion established that several nominally interleaved converters may produce an aggregate stream whose periodic blemishes resemble independent emissions. The question before us concerns a different and rather seductive shorthand. An engineer may announce that a receiver possesses a certain effective number of bits, or ENOB, and the figure appears to carry the authority of a calibrated ruler. Yet an intermittent signal is not a continuous sinusoid, and the ability to characterise a converter with a deliberately maintained test tone is not identical to the ability to detect, date, classify, and preserve a burst that crosses the input unexpectedly. I ask the panel to determine when the ENOB figure contributes real explanatory value and when it merely decorates a conclusion whose governing conditions have not been demonstrated.

The conventional relationship ENOB = (SINAD - 1.76 dB)/(6.02 dB per bit) is useful precisely because it is conditional. In its familiar form, the

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measured signal-to-noise-and-distortion ratio, SINAD, concerns a specified sinusoidal input, bandwidth, amplitude, acquisition state, and method of spectral analysis. The ideal full-scale sine-wave quantisation model supplies the constants; it does not establish the shape, arrival time, or amplitude of an unknown transient. At the bench, a pure laboratory tone may keep a converter operating near its favourable range while a field emission arrives far below full scale, beneath another carrier, or during a gain transition. The number printed on the converter's evaluation sheet cannot by itself reconstruct the missing observation. [S1, S2, S3]

Consider a defensive technical surveillance countermeasures examination with broad monitoring coverage and a second, deliberately narrower acquisition intended to adjudicate an unusual event. A weak emission may last only microseconds; the broadband monitor may retain a short block, then overwrite earlier samples while an operator hears a notification. If the effective resolution was measured using a long coherent sine-wave record at a different centre frequency, we must ask what information travels legitimately from that test to the retained event. Was the same analogue input boundary used? Was the front end linear? Was the converter's input actually populated sufficiently to make its numerical resolution meaningful? Were sample-clock disturbances, triggering latency, dropped blocks, digital scaling, and post-detection selection recorded? None of these particulars is settled by changing a ten-bit effective figure into an attractive twelve-bit label.

There is a second danger, less dramatic but scientifically consequential. An intermittent waveform has a finite observation interval, and frequency analysis of a finite record necessarily involves a spectral window, leakage

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and effective noise bandwidth. A longer Fourier transform can lower the displayed noise per bin while excluding part or all of the event; a shorter transform can preserve timing while spreading energy across more bins. These representations need not contradict one another. They answer different questions. We must not confuse the sound of a narrow spectral line on a demonstration with the evidence that a pulse survived a specified sampling and retention policy. Nor can coherent averaging be promised where the event lacks phase continuity or repeatability. The experimental challenge is to state which measure is invariant under an admissible change in analysis and which is an artefact of that change. [S3, S4, S5]

Our five principal respondents will therefore address successive boundaries. Professor Bridgman will define the proposed measurand and challenge the apparent independence of test procedure and reported result. Dr Nyquist will examine sampling, timing uncertainty and the bandwidth occupied by a transient. Professor Tukey will address spectral estimation, window choice, selection and diagnostic trials. Dr Shannon will distinguish converter information from the information retained by the entire acquisition system. Professor Neyman will treat claims of detection probability, false alarms and confidence as propositions requiring a specified trial population. Seven colleagues will interrogate those explanations, with each question answered immediately and courteously before the floor passes onward.

The ten worked applications are deliberately bounded. They expose the numerical meaning of ENOB, signal-amplitude back-off, jitter, record length, equivalent noise bandwidth, exposure coverage, multiple testing, and the uncertainty attached to a finite validation study. They are not substitute

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specifications for a particular converter. We shall keep the quantities, units and hypotheses visible, preserving a distinction familiar to rigorous British metrology: an indication may be measured with confidence while an attempted inference about the unseen source remains uncertain. When the discussion concludes, the panel must offer usable reporting language. It should tell the examiner what the ENOB result actually supports, what complementary experiments are required, and where a negative search or precise-looking bit count cannot justify reassurance.

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Percy Williams Bridgman | Principal response 1: The operational meaning of a conditional bit count

Dr. Atkinson, I thank you for placing the word 'relevant' rather than merely 'accurate' at the centre of the inquiry. A number can be accurately computed from the wrong experiment. If the arithmetic and instrumentation agree while the method fails to address the desired quantity, the result is not fraudulent; it is misplaced. The first requirement is an explicit account of the operation through which effective bits are obtained. In the familiar sine-wave method an input of controlled amplitude and frequency exercises the conversion chain, a specified algorithm separates fundamental energy from its noise-and-distortion residual, and the quotient is compared with an ideal quantiser. That is a perfectly intelligible comparison. It is not, however, a general statement that every future burst will be received with the same number of useful binary decisions. [S1, S2]

I would separate four proposed measurands before accepting the result. The first is the dynamic sine-wave performance of the bare converter at a specified input, sample rate, reference and temperature. The second is performance of the installed analogue-to-digital path, including preamplifier, filters, gain switching, sample clock and coupling impedances. The third is the detection probability of an intermittent signal class in a defined observation procedure. The fourth is the evidential reliability of attributing an observed feature to an external emitter rather than internal noise or distortion. These quantities can be connected by a physical and statistical model, but they are not synonyms. A report that substitutes the first for the third silently changes its subject. A report that substitutes the

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third for the fourth confuses a correctly registered event with a correctly identified source.

A further condition concerns signal amplitude. An ideal quantiser has discrete output codes, but an ENOB figure measured near full scale need not apply to a pulse which uses a hundredth of the available excursion. Analogue input noise, quantisation effects, nonlinearity and spectral interference need not maintain a common ratio as input amplitude changes. A strong continuous test tone may dominate a short acquisition while the intermittent signal is almost invisible; an operator may then interpret low noise in the displayed spectral bins as proof of greater sensitivity. That is an unwarranted transfer between a controlled comparison and a field event. It is necessary to record the amplitude range actually exercised, preferably with tests extending into the region containing the event of interest.

The reference plane itself deserves explicit treatment. The useful comparison might be at an antenna terminal, a bandpass-filter output, a converter input or a digital baseband stream. A gain correction that moves a result from converter codes back to an input voltage presupposes a transfer function, and the transfer function may change under strong adjacent-channel signals. An amplitude in arbitrary display units cannot be promoted into a calibrated input-referred quantity merely by dividing by a displayed scale factor. Similarly, if a peak was clipped before conversion, the effective bit count of the surviving samples cannot recreate the exceeding value. If the event occurred during a switch, the state of that switch is part of the conditions of the operation, not an optional narrative detail.

I would ask that each test produce two separate records. The first is a performance statement for the chosen reference condition, including

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numerical result and uncertainty. The second is an applicability account linking the reference condition to the intended intermittent signal: spectral occupancy, pulse duration, amplitude distribution, duty cycle, crest factor, gain state, time alignment and retention policy. If this linkage is absent, the number may still be valuable for comparing converter implementations in the laboratory, but its evidential reach must stop at that comparison. The word 'representative' should never be used without explaining representative of which population and which conditions.

It is possible for a lower ENOB receiver to perform better at a particular defensive detection task. A receiver with modest sine-wave SINAD but continuous observation, reliable time stamping, sound preselection and a correctly tuned detector may capture an event missed by a higher-ENOB converter hidden behind a slow scanning policy. This is not a paradox in the physics. It shows that one dimension of converter performance cannot stand for the performance of an entire instrument and acquisition procedure. We can reverse the example: a beautifully continuous receiver may produce reams of faithfully timestamped evidence but fail to discriminate a small signal against its own noise. We must test each part rather than declare one part a proxy for all.

One final matter is the language of certification. I should report, 'Under a specified continuous sinusoidal stimulus, the installed converter path exhibited an ENOB of approximately X, subject to the identified measurement conditions.' If an intermittent challenge was actually applied, I should state a second and distinct result, such as the observed fraction of accepted bursts, with confidence limits and exclusion criteria. Where the record does not contain such a challenge, a general assertion of transient

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detection capability must remain open. Measurement gains rigour not when every number is doubted, but when no number is allowed to answer a question it was never designed to address. Dr Gabor, may I respectfully invite your challenge concerning the measurement operation that combines a finite instant with a finite band?

Dennis Gabor | Peer question 1 to Percy Williams Bridgman

Professor Bridgman, I am obliged for your distinction between a converter's conditional performance and the practical receiver's evidential promise. Yet the intermittent event seems to introduce a more elementary difficulty. A pulse cannot be reduced to an infinitely long harmonic oscillation without losing the very starting and finishing times that make it a pulse. If an analyst chooses a long observation interval, the Fourier representation may place substantial energy into fine frequency bins and reveal a faint carrier, while the onset time is blurred by selection and averaging. If the interval is shortened to preserve onset, the spectral lines broaden and the same event can appear less impressive relative to a narrow-bin threshold. Which operation should define the relevant quantity? Can an ENOB measured under an indefinitely repeated sine wave be transferred by an explicit transformation, or must an entirely new operational performance statement be made for the particular time-frequency occupancy? I would also ask whether the reference experiment should vary pulse shape and duty cycle, since a rectangular envelope, a smoothly tapered burst and a chirped burst can place quite different demands upon the identical set of converter codes.

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Percy Williams Bridgman | Immediate answer to Dennis Gabor

Dr Gabor, your challenge exposes a limitation that becomes clearer when an investigator states what decision the measurement is intended to support. For a burst whose presence is the primary question, the relevant comparison may be a time-localised matched-filter statistic or an energy statistic over a defined signal class. For a burst whose carrier frequency is the primary question, the time-frequency resolution and any prior model of the envelope become essential. The two tasks can use the same recorded samples without being evaluated by an identical scalar. I would therefore retain the standard ENOB figure as a descriptive property of a defined sine-wave benchmark and introduce a second operational metric for the transient task, rather than forcing a universal reinterpretation of ENOB.

A transformation is legitimate only when its assumptions can be stated and challenged. If we know an input waveform family, the system's linear impulse response, the stationary noise statistics and a stable acquisition state, we can use the benchmark noise-and-distortion model to predict a conditional detection outcome. We must then test those predictions with held-out pulses. A mere algebraic rearrangement of the ENOB equation cannot supply a missing temporal model. A long Fourier analysis gives a small nominal bin width, but a short event does not suddenly acquire more independent cycles because we append zeros or retain quiet samples before and after it. Zero padding interpolates a sampled spectrum; it does not create observations not present at acquisition.

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I should also record the physical difference between peak amplitude, pulse energy, carrier power during the burst, and power averaged over the entire observation interval. A pulse occupying one percent of a long record can have an apparently poor average signal-to-noise result even when its in-burst amplitude is sufficient for reliable detection, or the reverse can happen if a rare strong disturbance dominates the selected statistic. Neither outcome licences a claim about the converter's universal resolution. The declared metric must identify which portion of the observation contributes signal and which contributes background, and it must state who selected those portions and on what evidence.

I would propose a paired evaluation. Test the installed receiver with a continuous reference tone to establish the conventional ENOB under stable conditions. Then inject a controlled population of bursts with specified envelopes, amplitudes, frequencies and random arrival phases relative to sampling and scan cycles. Preserve complete acquisition records, including failures and idle periods. Use a predetermined detector and compare observed performance with the model's prediction. Where the correspondence is satisfactory, the converter benchmark becomes explanatory evidence, but it remains one premise among several. Where the results diverge, the disagreement is itself a finding about temporal coverage, front-end dynamics, estimator design, or noise assumptions. Your insistence on relating time and frequency is therefore an invitation to define the task correctly, not an argument for discarding disciplined sine-wave tests. Mr Weston, may I invite the next question concerning whether

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the reference point chosen for the comparison remains physically stable when the event is weak?

Edward Weston | Peer question 2 to Percy Williams Bridgman

Professor Bridgman, suppose the laboratory performance measurement is impeccable at the converter pins, while the instrument used in the investigation contains a preamplifier, a variable attenuator, a bandpass filter, and an analogue switch before those pins. The operator later quotes the converter's ENOB as though it were a property of the antenna-terminal observation. In the laboratory the test source may be low impedance and a continuously maintained sine wave, whereas the field event arrives from an antenna and may coincide with a relay or automatic gain transition. I should like to know what observations permit transfer of the ENOB-derived noise and distortion description through this front end. In particular, how would you separate a genuine change in input-referred sensitivity from a computational rescaling that changes only the displayed units? And if the reference plane can move through calibration corrections, which data must be retained so that another examiner may verify the claimed correction independently?

Percy Williams Bridgman | Immediate answer to Edward Weston

Thank you for that question. Mr Weston, the converter terminal and the antenna terminal are distinct physical locations; a mapping between them is a measured relationship, not an editorial convention. I should require a schematic and a measured transfer description of each relevant gain state, including frequency-dependent insertion loss, noise contribution, linearity and impedance loading. A measured sine-wave ENOB at the converter might help explain its own residual

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noise and distortion, but an antenna-referred performance claim must include the entire cascaded path. A noiseless numerical division by the nominal amplifier gain cannot remove the amplifier's noise or undo distortion produced before conversion. It can alter the numerical scale of the trace while leaving its information unchanged.

If the front end changes state, the description must change with it. A gain control that adjusts in response to the pulse can reduce the pulse's peak, distort its envelope, or mask its opening samples; a filter can ring, delaying apparent onset or stretching the measured duration. These are physical transformations. The correction should therefore be linked to a retained state history and to a calibration obtained at relevant amplitudes and temporal conditions. A static gain table evaluated on a continuous tone may be insufficient when a transient arrives near a switching boundary. One ought to measure the changeover interval and test whether a known event survives it, rather than assume the change is instantaneous.

The useful record would preserve the uncorrected digital samples or the earliest accessible equivalent, the calibration version and date, gain-state and attenuation histories, clock and trigger information, the software transformation, and the reference-plane statement. It should also preserve uncertainty arising from those steps. This permits an independent examiner to reproduce the displayed amplitude and, more importantly, to challenge whether the display measures the intended quantity. If the record contains only a corrected number, the transformation becomes inaccessible to scrutiny. The problem is especially acute when high-precision decimal

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places suggest a certainty that the physical apparatus could never have justified.

The broader conclusion follows naturally. ENOB is relevant as a controlled account of one constituent's dynamic error. It is relevant to antenna-terminal inference only through a justified uncertainty and transfer model that includes the other constituents and their state. No amount of mathematical neatness can repair an unobserved gain transition or a lost reference-plane definition. I gladly pass the floor to Dr Nyquist, whose examination of the sampling lattice should illuminate the next boundary between a numerical rate and an actual temporal observation.

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Harry Nyquist | Principal response 2: Sampling cadence, aperture uncertainty and the temporal meaning of a burst

Dr. Atkinson, I would begin with the sampling operation itself. An analogue waveform is not encountered by a converter as an abstract, perfectly indexed sequence. Each code follows an aperture event with finite timing properties, a finite input bandwidth, and a conversion process which may have memory and nonlinear behaviour. We may write the desired sample as $x(nT_s)$, where x is the input waveform, n the sample index, and T_s the nominal interval. The practical sample is closer to a response to $x(nT_s + \delta t_n)$ after the analogue aperture and transfer network, where δt_n denotes timing error. The first statement describes an ideal lattice; the second identifies a physical mechanism which can corrupt a transient and may not be measured by a low-frequency sine-wave ENOB test. The uncertainty grows with waveform slope. [S1, S2]

For a sufficiently smooth waveform, a small timing perturbation produces approximately $\delta x_n = x'(nT_s)\delta t_n$. This relation is instructive because it does not put the same error at every instant. Near the peak of a sine wave the instantaneous slope is small; near a zero crossing it is large. For a sharply rising pulse the slope may be exceptionally large within a short interval, while the flat portion is much less sensitive. An RMS result averaged over many cycles can conceal the position-dependent severity of the same clock error when the observation of interest is a singular edge. An experiment which claims to date that edge must quantify timing uncertainty directly, not merely translate a measured sine-wave SINAD into an impressive number of bits.

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The familiar jitter-limited sine-wave relation, $SNR_j \approx -20 \log10(2\pi f_{in} \sigma_t)$, where f_{in} is the sinusoidal input frequency and σ_t is RMS aperture-time uncertainty, applies under a particular small-jitter, sine-wave model. At high input frequency even a very small timing deviation may dominate the noise budget. But a narrowband tone at one frequency is not a substitute for an unknown transient whose envelope, modulation and rise time vary. The relevant error involves the derivative and spectrum of the actual input. A receiver whose ENOB is adequate at a modest test frequency may exhibit poorer performance on fast edges or high-frequency components, especially when the analogue front end contributes additional delay and dispersion. A responsible engineering statement must say which frequency and amplitude were used, how the clock was characterised, and whether the inference is about waveform reconstruction or simply event detection.

A second boundary concerns finite exposure. Suppose the converter runs continuously at forty million samples per second, but the acquisition system retains a block only when an upstream detector triggers. The nominal 25 ns sample interval does not establish uninterrupted forensic observation. A microsecond burst could occur while memory is unavailable, while a transport buffer overflows, or while a display is being updated. In such a circumstance the converter might possess outstanding ENOB whenever actively sampling, but no sample of the burst may survive. An archive cannot be made more complete by assigning additional effective bits to a block collected at a different time. We need sample-continuity evidence, loss counters, memory overwrite policies, and a timebase whose relationship to the recorded triggers is known.

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A third limitation is aliasing. Nyquist sampling theory requires that relevant signal components be constrained relative to the admitted sampling bandwidth. For a transient, sharp edges can carry spectral content outside the passband assumed for an ordinary sinusoidal test. The analogue antialias filter may suppress those components, altering the observed rise time and ringing behaviour. That alteration may be appropriate and even essential for a correctly sampled system, but it must not be described as recovery of an arbitrary input waveform. An investigator who wishes to infer that an emission truly had a two-microsecond duration must separate the pulse as delivered to the converter from the earlier waveform at the antenna, and must confront the response of the intervening filters. A measured duration can be accurate for the retained filtered waveform while remaining a biased estimate of the external event's duration.

There are useful circumstances in which ENOB is strongly relevant. If the signal class consists of finite bursts of a well-characterised sinusoid, the front end remains linear and in a constant gain state, the acquisition has adequate temporal coverage, and clock and noise conditions are measured at the relevant centre frequency, a sine-wave dynamic benchmark can support an error-budget prediction for samples collected during the burst. It may help choose a converter, identify a quantisation-limited regime, or evaluate whether a proposed amplitude estimator is plausible. These are real uses. Yet the prediction must be made for the actual burst length and estimator; an average over thousands of quiet samples cannot be smuggled into the performance of a twenty-sample pulse. If coherent processing is proposed, the necessary phase relation must be independently shown rather than assumed from nominal carrier frequency.

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I would therefore prescribe three temporal challenges in addition to the usual continuous-tone examination. The first randomly varies the burst's starting phase relative to sample times. The second varies pulse width through the interval in which only a few samples fall inside the event. The third introduces bursts around actual instrument state changes and known possible data-loss intervals. Each challenge must retain both successes and failures, with the timing record needed to establish that an alleged miss was actually exposed to the receiver. The combination explains whether converter error, sampling geometry, trigger policy or retention dominated. It also prevents an analyst from attributing every negative observation to weak signal amplitude. Sir Robert Watson-Watt, whose historical work placed immediate operational value upon detecting rapidly arriving radio phenomena, may perhaps test the practical sufficiency of this account. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Sir Robert Alexander Watson-Watt | Peer question 3 to Harry Nyquist

Dr Nyquist, I thank you for the rigorous statement of the sampling lattice, but the field instrument must answer a question under conditions no laboratory can make entirely placid. A radar warning or a defensive monitoring receiver may confront a pulse amid interference and receive only a fleeting opportunity to record it. If an instrument is technically able to make many accurate samples per second, yet its observation pattern, trigger logic or display update suppresses some arrivals, the published dynamic performance does little to settle whether the operator should regard a blank interval as reassuring. I should like you to distinguish a receiver's ability to capture a representative sample of a

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known pulse from its ability to provide continuous surveillance of an unknown pulse population. What trials would show that the tested burst phases and durations were representative? Would you insist upon a deliberately randomised challenge during actual gain changes, or could periodic laboratory pulses suffice? Finally, how should the investigator communicate a negative result when the apparatus was accurate when exposed, but exposure itself has not been adequately established?

Harry Nyquist | Immediate answer to Sir Robert Alexander Watson-Watt

Thank you for that question. Sir Robert, the distinction is decisive. Accuracy conditional upon acquisition and probability of acquisition are independent elements of the apparatus's overall effectiveness. In a simple model their combination may be expressed as P(detect) = P(exposure) × P(detect | exposure), provided the chosen conditional formulation faithfully represents the events and neither probability is silently conditioned on a more favourable subset. The multiplication does not certify an instrument; it displays the logical dependence of a detection claim upon temporal coverage. A laboratory which reports excellent conditional recognition but never measures exposure has not established the unconditional probability required by a continuous monitoring assertion.

The temporal schedule matters as much as its nominal proportion. A periodic scan that watches one frequency for sixteen microseconds in a millisecond may expose a burst arriving at a uniformly random phase with probability approximately 0.016 under a narrowly defined model. But a burst source synchronised with the scan may be always

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visible or always absent. Similarly, successive pulses from one emitter may share the same phase relationship to a scanner; multiplying their apparent independent chances would exaggerate detection. The test population must include random arrival phase, realistic burst lengths and configurations, and deliberate challenges to likely correlations. The rate at which a converter produces codes is not the rate at which the investigation obtains informative evidence.

I would combine controlled periodic pulses with an independent randomised set. Periodic pulses are excellent for calibrating gain, delay, sampling aperture and steady-state behaviour. They are not sufficient alone to discover blind timing phases. A pseudorandomised arrival schedule with its seed, event list and reference timing retained would expose the receiver to periods the experimenter had not chosen for convenience. One must further include independent pulse amplitudes and shapes rather than allowing a single favourable waveform to dominate success statistics. The reception state must be recorded before, during and after each arrival, because an apparent failure at low amplitude may instead be due to a transient gain adjustment or an overwritten buffer.

For the report, I would not permit a negative observation to be translated directly into absence of a source. The properly bounded statement is that no qualifying event was retained in specified channels during specified exposures, with the measured or otherwise defensibly estimated coverage and the known detection limits described. If coverage is not known, report that deficiency without ornament. The operator can still say that no alarm appeared, which is

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an observation about the apparatus. The operator cannot claim from that fact alone that the electromagnetic environment was silent. We should now pass the token to Professor Tukey, whose methods can help us separate the statistical behaviour of the record from the habits of the person selecting its intervals.

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John Wilder Tukey | Principal response 3: Windows, estimators and the illusion of a single receiver figure

Dr. Atkinson, I should resist the temptation to give one beautiful number the job of making several untidy decisions. Effective bits are convenient because a decimal number orders a collection of converter test results. An intermittent signal, however, confronts the analyst with exploratory choices that can profoundly alter what is displayed: the event interval, transform length, taper, frequency-bin aggregation, baseline estimator, detector threshold and rule for selecting an alarm. These decisions can all be computationally legitimate while yielding different descriptive results. The methodological failing lies not in their variety but in pretending that an exploratory selection was preordained or that its chosen numerical outcome generalises to all events. [S3, S4]

Suppose an unknown burst lasts three microseconds and the sampled rate is forty megasamples per second. Approximately 120 samples lie inside that interval if the whole burst is acquired. The inverse duration is about 333 kHz. This is not a universal frequency accuracy limit, because model-based estimators can under suitable assumptions achieve different precision; it is the natural frequency spacing associated with a transform over three microseconds. If an operator appends many thousands of zeros and plots a smooth spectrum with visually fine frequency increments, the inserted zeros do not add samples of the event. A long FFT of a record containing the same burst and much quiet time may also give narrow mathematical bins, but the transient's spectral energy remains spread by its short envelope. The display's apparent granularity is not evidence that the original emission was observed with an equally long coherent duration.

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Window choice introduces another trade-off. A rectangular observation window preserves all included samples with equal weight but can generate conspicuous sidelobes when a periodic tone fails to fit an integer number of cycles. A tapered window suppresses some sidelobes but changes coherent gain, broadens the response and increases equivalent noise bandwidth. The Hann window, for example, has approximately 1.5-bin equivalent noise bandwidth under conventional normalisation, a penalty of about 1.76 dB in noise power per bin relative to a rectangular window of the same record length under white-noise assumptions. That fact is not an indictment of tapering. A taper may improve detection near strong spectral neighbours by reducing leakage. The point is that the estimator's behaviour must be characterised for the actual signal class rather than hidden behind a converter ENOB obtained by another procedure. [S4]

The order of analysis should be made auditable. I would begin by saving the earliest accessible samples and their acquisition state. Next, construct time-domain plots before selecting frequency windows; inspect for clipping, missing blocks, abrupt gain shifts and threshold selection. Then establish a predeclared reference method for the known signal family. Exploratory displays may be added to discover unanticipated structures, but they should be distinguished from confirmatory tests that fixed their decision rules in advance. If an analyst tries ten tapers and twenty thresholds, eventually choosing the pair that produces the most attractive burst, ordinary nominal significance calculations no longer describe that search without adjustment. A post hoc frequency label may be convenient for further investigation but is not a verified source property.

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This becomes especially important when the event itself chooses the window. A trigger that fires upon a large noise excursion selects a non-representative population of samples, so the average residual measured in triggered blocks may differ from the residual over continuous observation. Estimating a noise floor only from records that contain a strong selected pulse can be equally misleading, because the candidate signal may contaminate the background estimate. One must preserve the trigger logic and the population of excluded or overwritten intervals. A credible receiver validation set should include deliberately chosen negative controls as well as known positive challenges and a sufficient account of all trials attempted.

I would also distinguish analytic bandwidth from physical sensitivity. It is possible to lower a spectrum plot's average noise floor per bin by choosing a narrower bandwidth, longer coherent integration or more averages. Yet that change cannot necessarily improve detection of a one-off burst, because the burst may be diluted or misaligned by the integration. Similarly, adjacent-bin leakage from a strong carrier can remain the dominant impediment to a weak transient even when the converter's sine-wave ENOB is high. The right performance metric might be probability of detection at fixed false-alarm probability, measured across a defined burst population, rather than a raw number of equivalent ideal bits. The ENOB remains an input to interpreting the result, not an alternate name for it.

I would ask for comparisons which are deliberately inconvenient to the preferred model. Challenge the receiver with a pulse beginning near the edge of the transform window, then near its centre; with frequency drifting through a bin boundary; with an adjacent powerful carrier; and with a gain transition occurring during the burst. Evaluate both the predeclared

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processing chain and a small, justified set of alternatives. A discrepancy among those results may reveal a windowing problem, temporal sensitivity, or nonstationary background. It should not automatically be 'corrected' by selecting the most favourable method. The field examiner needs a diagnosis and a bounded capability statement, not a contest to produce the most decimal places.

A conscientious conclusion may be modest yet operationally valuable. We might say that ENOB from a specified sine-wave test predicts a particular noise-and-distortion contribution under stationary calibration conditions, while the observed burst detector meets a separately established recognition rate at a stated threshold and false-alarm level. We might also identify regimes where the model fails, such as short bursts beside strong carriers. Those failure boundaries are scientific knowledge. Dr Hamming, may I invite you to examine how numerical windowing can mislead even an analyst who knows that the window has been applied?

Richard Wesley Hamming | Peer question 4 to John Wilder Tukey

Professor Tukey, I agree that many lawful computational operations can answer different questions, but I fear that the phrase 'window correction' sometimes suggests that a window's effect can be entirely reversed by dividing by a convenient constant. The coherent gain corrects the amplitude of a tone in a particular alignment, while equivalent noise bandwidth describes noise-power behaviour, and neither guarantees that a pulse at the window boundary has the same response as a pulse at its centre. If an examiner sees a burst with a sharply defined onset and applies a taper designed for periodic spectral analysis, what proof should be demanded before its peak or energy is

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compared with a continuous-tone ENOB result? I would also ask whether zero padding, frequency interpolation and averaging of adjacent spectra can ever be justified as improvements in the evidential estimate, or whether their value must always be treated as merely visual. Finally, how should the uncertainty introduced by selecting one window over several alternatives be included in the reported conclusion?

John Wilder Tukey | Immediate answer to Richard Wesley Hamming

Thank you for that question. Dr Hamming, a scalar window correction answers only the problem for which it was derived. If a sinusoid occupies a complete analysis interval and its phase relation is appropriately controlled, a coherent-gain correction can restore an amplitude interpretation under the assumed model. For a transient which begins at one end of the window, the taper weights that particular event differently from the same event arriving centrally. A single constant cannot erase this time-location dependence. The correct procedure is to calculate the windowed detector's response to the intended family of transient envelopes and arrival times, then validate those calculations with injected signals. The result may be an uncertainty band or detection-efficiency curve rather than one universal correction.

Zero padding is not entirely decorative. It can improve the practical interpolation of a discrete Fourier representation and help locate a spectral maximum more accurately under an appropriate signal model; it is useful computationally. What it cannot do is create independent time samples, narrow the fundamental envelope caused

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by a short event, or retrieve missing information. Likewise, averaging can reduce the variance of a legitimate estimator when the data and independence conditions support the averaging. It cannot be expected to improve a singular burst by averaging it with records in which the burst was absent. One must state whether the operation averages complex amplitudes coherently, power spectra incoherently, or conditional candidate segments selected by a detector. Those methods have different statistical properties.

The uncertainty from window selection is partly a model-selection problem. Where the rule was selected before the challenge data were examined, the experiment can evaluate that rule's error characteristics directly. Where it was selected because it gave a favourable result on the same data, an ordinary confidence statement may be optimistic. The analyst can restore some discipline by applying the chosen method to independent held-out challenges, retaining the entire original search history, and comparing the result with an explicitly declared family of alternative processing chains. The held-out sample must not quietly become another exploration set after an inconvenient outcome.

I would also remind the examiner that time registration can carry meaning independent of amplitude. A window that suppresses the onset may yield a commendable spectral peak while impairing the estimate of when the source began transmitting. The task should say whether it requires frequency discovery, pulse timing, classification or presence detection. A numerical recipe optimised for one may be ill-suited for another. Dr Bennett, may I invite the complementary

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concern that the residual called 'noise' may be neither independent nor stationary over the interval chosen for the estimator?

William Ralph Bennett | Peer question 5 to John Wilder Tukey

Professor Tukey, much of the conventional sine-wave analysis assumes that the residual left after removal of the fundamental can be treated as a stable measure of noise plus distortion. An instrument used in a practical survey may instead experience nonstationary interference, bursts from unrelated sources, short power-supply transients and periodic converter artefacts whose phases vary with acquisition state. If the analyst computes ENOB from one record containing the candidate event and then quotes it as though it were an intrinsic property of the converter, the signal and residual may both have been selected for unusual behaviour. How should an examiner distinguish additive thermal-like fluctuations, deterministic spurious responses and rare impulsive disturbances before relying upon a single combined SINAD? Is there a useful role for median estimates or robust procedures, or might those procedures conceal precisely the rare interference which a technical surveillance countermeasures investigation is meant to detect? Finally, should the result be expressed as a scalar, a range conditioned on state, or a collection of separately measured noise and distortion mechanisms?

John Wilder Tukey | Immediate answer to William Ralph Bennett

Mr Bennett, I would not ask a robust estimator to make inconvenient phenomena disappear. Robust methods are tools for investigating how a result changes when a small subset of observations differs strongly from the remainder. They can show that

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the usual average is dominated by rare events, or that a typical background estimate differs from a worst-case impairment. Both observations may be valuable. The error would be to replace the raw evidence with only the robust summary and then deny that the discarded observations occurred. For a search intended to discover rare emissions, the exceptional observations may be the central evidential objects, not contamination to be tidied away.

I would insist upon retaining separate diagnostic displays of the time series, the power spectrum, the gain-state history and the ensemble of comparable trials. Estimate the background in regions not selected solely because they generated the alarm, but retain a record of the selection rule. Then examine whether the noise appears stationary within the intended interval and whether apparent distortion follows the stimulus when its amplitude or frequency is changed. A spur moving with a known internal branch pattern may require a different explanation from an independent external carrier; an impulsive disturbance might demand a heavy-tailed model instead of a Gaussian approximation. This classification must arise from challenge tests rather than labels imposed after the fact.

A state-conditioned performance map may be more informative than a universal scalar. Report ENOB for defined sinusoidal stimuli at relevant frequencies and amplitudes, and show its variation with converter gain, temperature, clock configuration and interfering-signal conditions. Alongside it report detection probabilities for the actual burst class at defined thresholds and exposure states. The investigator can then decide whether a particular benchmark

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materially constrains the event interpretation. A single ENOB number is acceptable for a narrow, declared test; a collection of numbers is appropriate when the instrument operates in materially different regimes.

One further caution concerns averaging statistics from selected records. If only strong detected bursts enter the analysis, the resulting signal-to-noise ratio will predictably look better than the ratio for the full population, including missed weak arrivals. The proper validation analysis must treat missed trials as outcomes, not exclude them from the denominator. Similarly, the strongest of many searched bins is not an ordinary randomly chosen bin. An extreme-value or multiple-comparison analysis may be required if the detector tests a large field of candidates. These are not subtleties to be reserved for a university seminar. They determine whether a forensic report speaks with measured confidence or merely repeats the instrument's self-congratulatory display. I pass the token to Dr Shannon, who can examine the information boundary between sampled digits and the later evidence archive.

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Claude Elwood Shannon | Principal response 4: The converter's digits and the information preserved by the observation system

Dr. Atkinson, the proper question about a recorded transient is not merely how many numerical labels were available to represent it. We must ask what distinctions among physically possible inputs remain distinguishable after the channel and acquisition transformations. A converter of fourteen nominal bits may assign many thousands of code values, yet a high-resolution code stream conveys little about an event which fell into a discarded interval. Conversely, a lower-resolution converter may preserve the decisive fact that a pulse occurred at a particular time, although its precise amplitude remains uncertain. The information required for detection, timing, classification and physical attribution differs. To infer that a larger ENOB necessarily implies more useful evidence for all four tasks would be to mistake a scalar benchmark for the channel's entire conditional behaviour.

For a known signal model in additive stationary Gaussian noise, a matched filter can accumulate evidence from many samples according to their expected waveform and noise covariance. Its performance depends upon the signal's energy relative to the applicable noise process and upon the correctness of the presumed waveform. It does not depend solely upon the resolution of any one code. Where errors are independent and the signal is coherent, appropriate integration may improve the statistic. Where the event occurs once, the samples outside it are not repeated independent observations of that event. A claim that 'averaging synthesises more bits' must identify what has been averaged and why the necessary independence

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and signal-coherence assumptions hold. A numerical increase in displayed precision is not an increase in the converter's intrinsic hardware resolution.

The distinction is illuminated by two possible recording policies. In the first, the receiver continuously preserves calibrated complex baseband samples across the observation interval, with acquisition metadata sufficient for later reanalysis. In the second, the receiver records only a list of threshold crossings and a compact spectral image. Both may employ the same converter and therefore display the same benchmark ENOB. Yet the first record can support later tests of waveform shape, timing, spectrum, alternative threshold policies and some competing hypotheses. The second may not preserve enough information to revisit the detector's decision. It can support a narrower proposition, namely that the configured detector produced certain alarms. The loss is caused by retention and representation, not necessarily by the quantiser.

There is also a difference between signal energy and mean power. A finite burst with peak amplitude A and duration τ can contain energy proportional to A squared times τ under a specified impedance and envelope. If the analyst divides that energy over a much longer observation duration T, the apparent average power decreases by the duty factor τ/T. That is not a converter suddenly becoming less capable. It is the result of changing the denominator and therefore the question. A detector designed for a known short pulse may integrate principally over τ, while a monitoring dashboard may average over T and dilute the event. These statistics can be reconciled only when the time interval and signal model are declared. A single ENOB figure cannot replace either.

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One must be careful with compression. A lossy time-frequency representation may be adequate for locating a broad interference source but inadequate for determining precise burst onset or excluding a short, weak emission. If the raw waveform was not retained, a later analyst cannot reconstruct all the alternatives that would have fitted it. The missing information is not restored by stating that the original converter had a favourable ENOB. Even nominally lossless storage requires calibration and configuration records if the numerical codes are to be interpreted physically. An archive is useful evidence only to the extent that its provenance, completeness and measurement meaning can be reconstructed.

I would therefore construct a layered validity argument. At the hardware layer, document the ENOB test under its stated stimulus and state. At the acquisition layer, document sampling continuity, front-end behaviour, timestamp meaning and trigger operation. At the analytical layer, specify the estimator and its detection threshold, including the relevant window and noise statistics. At the evidential layer, identify the claim: the event was retained, the event had an estimated property, the event was generated outside the receiver, or the event originated from a specified source. Every upward inference needs premises beyond the lower layer, and failure at one level may limit only particular conclusions. It is not necessary to discard the entire record merely because one component lacks full calibration, but it is necessary to restrict claims accordingly.

I should add a qualification concerning weak signals beneath ordinary quantisation steps. With suitable analogue noise or deliberately applied dither, some information about a small repeated signal can be recoverable statistically over multiple samples; this does not prove that every isolated

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sub-code transient is recoverable. The inference depends on the distribution of noise, sample independence and the known waveform. Dither may prevent systematic quantisation error under prescribed conditions but cannot rescue an event which never entered the retained samples. In a hostile electromagnetic environment, correlated interference may invalidate the simple model, and an alarm caused by nonlinear mixing may be distinguishable only through controlled perturbations. Information theory disciplines the question; it does not confer omniscience upon a receiver.

For the practical report I would keep the conditional converter benchmark, but would place beside it a statement about which information survived acquisition. A truthful result might read that the converter satisfied an eleven-bit effective benchmark for a stated sine-wave condition, the recorded event spans a specified number of valid samples, and a separately validated detector recognises a defined burst population under the tested environment. It should not say that eleven effective bits guarantee capture of all eleven-bit-equivalent signals. Professor Wiener, may I invite you to examine the further complication that a receiver may change the very observation policy in response to its earlier data?

Norbert Wiener | Peer question 6 to Claude Elwood Shannon

Dr Shannon, the layered account has much to commend it, but an adaptive receiver can couple what it observes to what it will observe next. Automatic gain control may lower sensitivity after a strong event; a detector may widen its search window after an apparent anomaly; a recording process may allocate more memory to channels generating alarms while discarding quiet channels. Such changes are neither necessarily faults nor necessarily improvements. They mean, however,

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that the sampling and retention policy is conditioned upon a preceding history. If the same ENOB is measured in a fixed laboratory state, how may its relevance be established for the time-varying states of this coupled system? In particular, does an unchanged converter mean that its numerical performance remains relevant even when the adaptive controller has selected a biased population of retained bursts? And what kind of experiment could distinguish a failure of analogue sensitivity from a failure caused by the controller's own decisions without requiring the entire installation to be dismantled?

Claude Elwood Shannon | Immediate answer to Norbert Wiener

Professor Wiener, an unchanged converter can retain the same narrowly defined intrinsic behaviour while the system's overall information transfer changes substantially. The conditional structure should be enlarged to include a state variable s(t) representing gain, tuning, thresholds, memory allocation or other controls relevant to the actual observation. The measurement channel is no longer described by one fixed transformation from input waveform to recorded result. Its output depends upon the preceding inputs and controller decisions through s(t). A sine-wave ENOB benchmark obtained at a particular fixed state remains information about that state; it cannot be treated as an unconditional description of all states reached during field operation.

A practical experiment could inject identical calibrated test bursts into a known input boundary while deliberately varying the preceding history. One sequence might contain a strong legitimate signal immediately before the weak challenge; another might contain quiet

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time. A third could trigger a gain change at an independently logged instant, and a fourth could force a memory-allocation transition. Compare the probability of retaining the known burst, its measured amplitude, its timestamp error and the state recorded at its arrival. The differences separate, at least partially, the converter's intrinsic errors from the adaptive system's behaviour. The experiment need not dismantle an installation, but it must have a traceable challenge path and a reference whose limitations are recorded.

The retained record should include not only the selected events but the information that explains why they were selected. A control log, sample-count sequence, buffer-loss indicators, applied thresholds and versioned configuration are valuable because they enable a different analyst to reconstruct the selection policy. If only the detected events are saved, the historical state of quiet periods may be irrecoverable. That means a claim about how often the environment emitted cannot automatically be inferred from how often the detector alarmed. The missing observations are not numerically small errors to be absorbed into a standard deviation; they represent a limitation on the population that the archive describes.

One should also test the controller at boundary conditions, not merely at a nominal steady state. A threshold chosen adaptively from a noise estimate may lag after a sudden interference step; a gain control may overshoot; a channel allocator may favour repeated false alarms. These mechanisms can create temporal blind spots or false apparent periodicity. ENOB measured with a continuous sinusoid remains one diagnostic of a converter, but system qualification must

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include the adaptive trajectory. The analyst should report which parts of that trajectory were exercised and where the controls were not observed. I now pass the floor to Professor Neyman, who can give precise meaning to the statistical claims that follow from a finite collection of successful challenge trials.

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Jerzy Neyman | Principal response 5: Detection performance, finite trials and the bounds of inference

Dr. Atkinson, a measurement of effective bits and an empirical claim of reliable intermittent detection belong to different statistical experiments. The first commonly results from a constructed sinusoidal excitation and an estimator of residual noise and distortion. The second requires a specified population of intermittent events, an exposure policy, a decision rule and a sampling design by which observed successes and failures represent that population. A high ENOB does not supply the denominator of a detection-rate calculation. Nor does a small collection of successfully captured pulses establish a universal detection probability. In statistics the meaning of a procedure is inseparable from the repetitions and conditions it purports to cover. [S1, S6]

For a defensible detection study, I should specify the trial as precisely as the measurand. Is each independently injected burst a trial, or each scan cycle, or each retained data block? If a burst arrives during a known blind interval, is it a miss or a trial excluded by design? The answer depends on whether the claim concerns unconditional surveillance or conditional detection once the receiver is exposed. Both can be studied, but they should not share a denominator without explanation. In a technical surveillance countermeasures report, I should prefer unconditional capability for claims about continuous search and conditional capability only when its limitation is prominent. The state and environment used for the challenges must resemble the circumstances in which the conclusion is intended to apply.

Suppose two hundred known bursts are injected at independently randomised arrival phases within a declared amplitude and frequency

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range. The receiver recognises one hundred and ninety according to a decision rule fixed beforehand. The observed proportion is 0.95, but the experiment does not demonstrate that the true recognition probability is exactly 0.95. Under an independent Bernoulli model, a conventional approximate 95 per cent Wilson interval spans roughly 0.910 to 0.973. This uncertainty must not be concealed behind the precision of a converter's reported ENOB. Moreover, the interval pertains to the stipulated trial population and detection rule. If several trials were correlated or the range of bursts was selected after viewing the successes, that statistical model requires re-examination.

A second issue is false alarms. The instrument may search thousands of spectral bins and many time slices, all while displaying a low per-test false-alarm probability. If ten thousand independent tests each have probability 0.001 of a false positive under a null condition, the expected number of false flags is ten. The probability of at least one is almost unity. These figures do not prove that all observed alarms are false, but they show why a threshold suitable for a single preselected channel may perform badly across a broad survey. Correlation among bins, overlapping windows and persistent interferers changes the effective multiplicity. The practitioner must estimate the relevant false-alarm process under representative conditions, not declare independence by convenience.

The ENOB figure can legitimately contribute to designing a trial. It may help estimate an instrumental noise contribution, choose amplitude ranges for challenges, and identify configurations in which converter distortion is likely to matter. But the final inference must arise from the trials relevant to the signal class. If a candidate emission lasts two microseconds, challenge

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the receiver with two-microsecond events, including the unfavourable phases and frequencies. If the purpose is to find extremely weak transmitters among strong legitimate emissions, include the strong emissions in the validation design. If temperature or gain state changes, stratify or otherwise model those states. An average recognition rate across easy and difficult conditions may hide unacceptable performance in the condition that matters most.

One can make the validation more informative by choosing an operating-characteristic curve rather than a single threshold. Measure how detection probability varies as the threshold changes, while tracking the accompanying false-alarm rate. Preserve the detector code, input references, randomisation seed and complete trial log. Distinguish development trials used to choose the rule from confirmation trials used to evaluate it. An instrument cannot be validated by repeatedly adjusting its threshold until it recognises all the test signals, then counting those same signals as independent confirmation. Such a procedure measures the success of a selected fit to a selected sample, not the declared out-of-sample capability.

Negative evidence requires special care. A failure to detect an unknown source may mean that no qualifying source was present; it may also mean that a source was too weak, too brief, outside the passband, masked by interference, clipped by overload, missed by the scan policy, or omitted by a retention rule. Under a validated model these alternatives may be bounded, but the mere presence of a high ENOB figure does not assign their probabilities. It would be improper to infer source absence from no alarm without a detection model that applies to the proposed source class.

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Equally, it would be improper to declare every negative finding meaningless; it can support a restricted assurance claim when exposure, sensitivity, configuration and relevant uncertainties have been satisfactorily established.

My concluding proposal is to report three classes of result in separate sentences. First, the converter's conditional sine-wave dynamic performance, citing the stimulus and measurement method. Second, the installed receiver's measured intermittent-event performance, including trial population, detection rule, false-alarm criterion, recognition fraction and uncertainty. Third, the interpretation of any field observation, distinguishing verified detection from localisation and attribution. These can form a persuasive cumulative chain when their assumptions agree, but no one result should masquerade as the other two. Sir Ronald Fisher, may I invite the final peer challenge about whether even a carefully calculated interval can conceal experimental choices made after the data were seen?

Sir Ronald Aylmer Fisher | Peer question 7 to Jerzy Neyman

Professor Neyman, your confidence interval for a fixed population of known pulses is admirably clear, but I should like to press the meaning of its design. The investigator may have developed the detector threshold using earlier trials, varied the event amplitudes while observing performance, and retained only configurations that achieved a pleasing recognition fraction. The final two hundred trials may appear random, but they could have been conducted only after a succession of unreported failures or modifications. There is also the difficulty of heterogeneous signal classes: perhaps one class of strong bursts is nearly always recognised while a small class of weak bursts is missed, yet

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the pooled success fraction looks excellent because the easy class dominates. How would you require the examiner to specify the prospective design, the scope of permissible adaptation and the reporting of rejected settings? Would you favour separate confidence statements for material strata, and how should those statements be reconciled when simultaneous claims are made about several conditions rather than one aggregate population?

Jerzy Neyman | Immediate answer to Sir Ronald Aylmer Fisher

Thank you for that question. Sir Ronald, the answer begins with the rule that a confidence procedure is calibrated for a specified experiment, not for an undefined history of human choices. The examiner should retain the full development history and identify a confirmatory set that was not used to tune the detector, thresholds, amplitude ranges or exclusion criteria. If the final evaluation is repeatedly reopened after each unfavourable result, the nominal coverage of an ordinary fixed-sample interval can be compromised. An adaptive experiment can be rigorous, but its sequential or selection-adjusted analysis must be designed as such. We should not relabel an exploratory success as confirmatory evidence merely because it was eventually expressed through the correct formula.

Heterogeneity can be addressed by deliberate design. If a weak-burst stratum is materially important, allocate enough known challenges to it for a useful estimate; do not allow an abundance of easy trials to drown its failures. Report stratum-specific recognition fractions and intervals. A pooled rate may still be informative for a declared mixture of events, but the mixture weights must be justified

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by the intended operational population. Where those weights are unknown, several scenario-weighted rates may be more honest than one false universal probability. The same principle applies to temperature, gain state, interference condition and pulse duration. A family of conditional results permits a later examiner to identify the regime matching the field observation.

Simultaneous claims require control of multiplicity or a joint confidence procedure appropriate to the design. If the report states that performance exceeds a threshold in five distinct regimes, separate nominal 95 per cent intervals do not automatically grant a 95 per cent simultaneous guarantee over all five. Simple conservative methods may allocate smaller individual error probabilities, though dependence among results and more efficient procedures can justify different choices. The method should be identified and checked rather than chosen for rhetorical force. The analyst should distinguish one prespecified primary conclusion from exploratory subsidiary observations, and preserve negative as well as positive results.

Ultimately the number of successful detections is evidence, not an incantation. It is meaningful because the input challenges are known, the rule was fixed, the trials were recorded and the proposed inference has a stated population. The ENOB figure may help explain the mechanism behind some of the successes and failures, but it does not replace the experimental population. A well-written forensic conclusion should allow another examiner to ask not merely 'What number did you obtain?' but 'What observations would have refuted the performance claim?' If the answer is that every failure was

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excluded or the rule changed until no failure survived, the claim has lost its intended testing power. Dr. Atkinson, I return the token for the numerical applications and your final synthesis.

Ten worked engineering applications | Moderator-led numerical analysis

Percy Williams Bridgman, Cross-Peer Question to Harry Nyquist: Dr Nyquist, an instrument advertises 11.0 effective bits under a coherent full-scale sine test, yet the surveillance question concerns a six-microsecond burst. Which operational quantity must replace the glossy ENOB headline before the claim can be made reproducible?

Harry Nyquist, Cross-Peer Answer to Percy Williams Bridgman: Professor Bridgman, the familiar conversion ENOB = (SINAD − 1.76)/6.02 expresses an equivalent ideal converter under specified sinusoidal measurement conditions. It does not specify burst interception probability. For the burst we need the input-reference level, analogue bandwidth, acquisition duty factor, sample-rate and clock uncertainty, trigger latency, detector integration window, false-alarm criterion and rate of repeat opportunities. An acceptance test should inject independently timed pulses over amplitude, duration and arrival phase, with the original sample stream retained. Report probability of detection and uncertainty conditional on that matrix, not a hypothetical conversion of one sine-wave ENOB into a single-pulse threshold. If changing the burst arrival phase changes detection materially, the ENOB number alone was never the sufficient measurand. I pass the token respectfully to Dr Nyquist for the time-domain test.

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Harry Nyquist, Cross-Peer Question to John Wilder Tukey: Professor Tukey, if a display uses a million-point transform while the transmitter is active for only twenty microseconds, can the analyst claim that the nominal FFT grid spacing is the physical resolution of the burst?

John Wilder Tukey, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, no. A one-million-sample record can have a fine frequency grid, but the observed finite burst supplies much less independent time support. The relevant time-bandwidth product and the window actually containing signal energy determine what the transient can resolve. Zero-padding changes sample locations on a spectral display, not the physical length of the event. We should compare multiple time windows, specify coherent gain and equivalent noise bandwidth, and include burst misalignment as a source of uncertainty. A false improvement is particularly easy when investigators select the window with the most impressive peak after inspecting the data; that search must enter the detection threshold. Preserve a time-stamped raw segment surrounding the event so another analyst can repeat the window selection and challenge the inferred frequency. I yield respectfully to Dr Neyman on detection claims.

John Wilder Tukey, Cross-Peer Question to Jerzy Neyman: Dr Neyman, one hundred validation bursts produce ninety-eight detections. Is it legitimate to describe this as a demonstrated 98 percent probability of interception under all field conditions?

Jerzy Neyman, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, the observed fraction 98/100 is a sample statistic for the validation conditions only. An uncertainty interval for the underlying probability is necessary, and its coverage interpretation depends upon the method and any dependence

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among trials. If all hundred bursts use the same trigger phase, waveform, level and environment, the number of repetitions does not cover the omitted conditions. Separate calibration from blind test cases, randomise arrival phase, include weak and wideband waveforms, and record false alarms in exposure-time units. Treat receiver configuration changes as new test conditions rather than silently pooling incompatible trials. A missed burst must remain in the denominator even if the analyst cannot reconstruct its source. The proper report would state the point estimate and interval, the stimulus distribution and the qualification that the survey is not a census of all possible transmissions. I return the token to Dr Shannon.

Jerzy Neyman, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, can oversampling or digital post-processing turn a nominally 12-bit capture into a 20-bit historical record of a fleeting high-frequency emission when the analogue front end was saturated?

Claude Elwood Shannon, Cross-Peer Answer to Jerzy Neyman: Dr Neyman, not as an unconditional statement. Averaging suitably independent quantisation error within a restricted band can improve an estimator and sometimes an effective in-band SNR. Neither operation manufactures a larger instantaneous analogue voltage range or restores information mapped many-to-one by saturation. A pulse that has been clipped, excluded by preselection, or missed while the receiver tuned elsewhere may leave no unique invertible record. State precisely which parameter was estimated and how variance, bias and correlation were measured; refrain from equating that estimator precision with new physical converter bits. Reproduce the claimed benefit against an external waveform reference and retain the unprocessed digital codes alongside every derivative. The result

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may be useful without exaggerating its scope. With respect, I return the token to Dr Atkinson for the moderator synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Colleagues, the discussion has shown that effective number of bits is useful when its definition and the intended inference occupy the same experimental ground. It may describe the noise-and-distortion performance of an analogue-to-digital conversion chain under a declared sinusoidal stimulus; it may help establish a converter error budget, compare alternative hardware settings, and predict the contribution of a specified impairment to a model of intermittent detection. It is not an autonomous certificate of pulse capture, timing fidelity, source identification or continuous exposure. The sine-wave comparison and the transient observation are not hostile alternatives. They are complementary operations whose connection must be demonstrated, not presumed. [S1, S2, S4]

Professor Bridgman has made the central metrological distinction. To measure one quantity accurately is not to have measured all quantities to which a common label might be attached. A converter test, installed-receiver test, burst-recognition trial and source-attribution exercise each possess their own reference planes, assumptions and error mechanisms. Mr Weston has reminded us that a calibrated input voltage cannot be carried across an uncharacterised amplifier or changing gain state by arithmetic alone. Dr Gabor has sharpened the observation that finite duration and spectral definition impose a consequential choice of estimator. We cannot gain the advantages of a long coherent tone after the event has ended simply by drawing a more finely gridded spectrum.

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Dr Nyquist's analysis has placed time squarely beside amplitude. A numerical sampling rate does not prove that samples were retained at every relevant instant, and a sine-wave jitter ceiling does not replace analysis of a fast pulse edge. Sir Robert Watson-Watt's operational question was therefore well chosen. An apparatus may be technically accurate whenever exposed while being poorly situated to observe a rare, asynchronously timed burst. The difference between conditional sensitivity and temporal coverage must appear in both the validation programme and the negative-findings language. The field examiner who reports a silent receiver should explain whether the silence means absence of an alarm, absence of a retained waveform, or a measured failure to observe known challenges within stated limits.

Professor Tukey and his interlocutors have demonstrated that analytical choices can materially affect the visible result. The taper, transform length, bin aggregation, background estimator and selected interval are part of the procedure. A narrow spectral bin can lower a displayed noise floor without creating more original observations; a short time-localised estimator may preserve the onset while distributing energy more widely in frequency. A robust background estimate can be valuable without justifying the deletion of exceptional events. The archive must therefore retain both the original evidence and enough procedural information to reconstruct the selected result. A post-selected improvement in appearance is not automatically a validated improvement in detection.

Dr Shannon has enlarged our accounting from quantisation to information retention. Converter codes, gain histories, raw sample continuity, detector states and stored event selections form a chain in which

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losses can occur outside the converter. Once an unrecorded interval or discarded waveform is acknowledged, a favourable ENOB figure cannot restore it. Professor Wiener has added the significant complication of adaptation: the system may learn from an observation and alter what it next permits itself to record. This is sometimes the proper operation of a capable receiver, but it makes retention policy and state history part of the evidence. The validation procedure must therefore challenge state transitions instead of assuming the apparatus remained perpetually in its quiet laboratory condition.

Professor Neyman's examination has set the statistical limit. A recognition fraction from a finite population of known bursts must be accompanied by a definition of its trial, conditions, exclusions and uncertainty. The lower confidence bound matters particularly where missed events carry serious consequences. Multiple threshold tests require an account of false-alarm multiplicity, and the experiments used to design the detector must be distinguished from those offered to validate it. Sir Ronald Fisher has further required that unsuccessful configurations and prior choices not disappear merely because a later selected arrangement performs well. The proper scientific conclusion survives the disclosure of the full experimental history. It is strengthened, not weakened, by its stated boundaries.

We can now formulate an acceptance rule suitable for the volume. Quote ENOB only with its stimulus frequency, amplitude, sample rate, analogue state, measurement bandwidth and method. If the proposed application concerns an intermittent signal, identify the pulse family, exposure policy, reference plane, arrival-time distribution, acceptance threshold and false-

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alarm model. Validate the event detector directly, including near-threshold signals, interfering carriers and state transitions. Preserve raw or earliest available samples, configuration history, retained negative trials, missed-event evidence and uncertainty records. Describe detection, physical source attribution and assurance against undetected emissions as separate propositions. The worked calculations in this dialogue make these distinctions visible; none certifies any instrument whose actual test records were not examined.

Our next question will separate quantisation effects from thermal, analogue and sample-clock noise. This is not a mere taxonomic exercise. The mechanisms differ in their dependence upon amplitude, bandwidth, frequency, temperature and time, and therefore demand different experimental challenges. I thank each contributor for the respectful interrogation of the argument and for returning the token with the conclusion more sharply bounded than when it was first offered. The next discussion should proceed from these bounded findings rather than revive a simple claim that more nominal bits guarantee a more complete account of the electromagnetic world.

Biographical verification: https://www.optica.org/history/biographies/bios/dennis-gabor/. Historical facts are separated from the modern, fictional engineering dialogue.

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Ten worked engineering applications | Question 028

Application 01. Translate a declared sine-wave SINAD into conventional ENOB

Let R denote measured signal-to-noise-and-distortion ratio in decibels, and let N_eff be the effective number of ideal quantiser bits under the conventional full-scale sine-wave comparison. Assume R = 68.0 dB at a specified sinusoidal input amplitude, input frequency, sample rate, analogue gain state and analysis bandwidth. Then N_eff = (R - 1.76 dB)/(6.02 dB/bit) = (68.0 - 1.76)/6.02 = 11.003 bits, conventionally about 11.00 effective bits. Both numerical constants belong to the familiar ideal full-scale sine-wave comparison; the measured ratio includes distortion as well as noise. The result does not claim that all eleven-bit changes in a single short burst are independently resolvable. It says that the selected sine-wave test produced a residual level comparable with that of the stipulated ideal quantiser. An actual report would retain the stimulus generator's limitations, measurement window, excluded bins, clock condition and uncertainty of R. Without those, the visible digits of 11.003 have more mathematical resolution than the test necessarily warrants. [S2]

Application 02. Show how amplitude back-off can change a conditional ENOB estimate

Assume a reference sine wave has R_1 = 68.0 dB and is reduced in amplitude by 6.0 dB while the absolute RMS residual remains unchanged, with no altered distortion or gain-state behaviour. Under that explicit hypothetical condition, R_2 = 68.0 - 6.0 = 62.0 dB. Therefore N_eff,1 = (68.0 - 1.76)/6.02 = 11.003 bits, whereas N_eff,2 = (62.0 -

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1.76)/6.02 = 10.007 bits. The apparent difference is approximately 0.997 bit, not a physical removal of one silicon bit. The calculation illustrates the conditional dependence upon signal amplitude and noise model. If distortion itself changes with amplitude or the input amplifier changes gain, the assumption of unchanged residual is false and the arithmetic no longer predicts the outcome. For a short intermittent emission occupying only a small portion of full scale, this caveat is especially important. A measured amplitude-response curve is preferable to extrapolation from a favourable near-full-scale benchmark.

Application 03. Calculate a voltage-ratio SINAD and its ideal-bit equivalent

Assume a sinusoidal test signal has RMS amplitude $V_s = 0.500$ V and that the appropriately measured combined RMS noise-and-distortion residual is $V_e = 0.000400$ V over the declared evaluation bandwidth. The dimensionless amplitude ratio is $V_s/V_e = 1250$. Using $R = 20 \log10(V_s/V_e)$, $R = 20 \log10(1250) = 61.938$ dB. The corresponding conventional effective figure is $N_{eff} = (61.938 - 1.76)/6.02 = 9.996$ bits. The correct units are volts RMS for both amplitudes and decibels for their ratio; no logarithm of a dimensional voltage alone is taken. One cannot simply assume V_e is the same as a baseline noise reading with the signal absent, because distortion may depend upon the stimulated waveform. This is a sine-wave dynamic benchmark, not a measurement of minimum detectable burst amplitude. The numerical result is also sensitive to which harmonics and spurs enter the residual; the selection must be declared.

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Application 04. Establish a jitter-limited sine-wave ceiling at high input frequency

Let f be input sine-wave frequency in hertz and σ_t be RMS aperture-timing uncertainty in seconds. Assume $f = 80 \times 10^6$ Hz and $\sigma_t = 1.0 \times 10^{-12}$ s, independent of the sinusoidal input under the small-jitter approximation. The product $2\pi f\sigma_t$ is dimensionless: $2\pi \times 80 \times 10^6 \times 10^{-12} = 0.000502655$. The jitter-limited SNR is $R_j \approx -20 \log10(0.000502655) = 65.975$ dB. If jitter were the only limiting contribution, its ideal-sine equivalent would be $(65.975 - 1.76)/6.02 \approx 10.667$ bits. This value is an approximate performance ceiling under the model, not a universal ENOB for the converter. Added analogue noise, harmonics, clock correlation and front-end errors can reduce achieved SINAD. More importantly, a transient with sharp edges may have derivative-weighted timing errors not adequately represented by a single 80 MHz sine-wave characterisation.

Application 05. Distinguish finite burst duration from displayed FFT resolution

Let $f_s = 40 \times 10^6$ samples/s be the retained sampling rate, and let $\tau = 3 \times 10^{-6}$ s be the nominal burst duration. If the burst is captured completely with steady sampling, its interior contains approximately $N_b = f_s \tau = 120$ samples, subject to a possible one-sample endpoint convention. A discrete Fourier transform confined to that three-microsecond interval has nominal bin spacing $\Delta f = f_s/N_b = 333{,}333$ Hz, or equivalently $1/\tau$. Extending a plot with zero-padded bins can make interpolated spectral peaks look smoother, but it does not increase the 120 original observations. Longer observation including quiet samples

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may change the numerical transform spacing without extending the burst's coherent duration. Estimation accuracy can differ under a specified parametric model, so Δf should not be advertised as an unconditional physical impossibility bound. The forensic point is that apparent fine display resolution is not equivalent to additional independently observed carrier cycles.

Application 06. Account for duty-cycle dilution of average power

Assume a burst has constant in-burst power P_b and lasts $\tau = 3$ μs within a total measurement interval $T = 1.0$ ms; ignore rise and fall details and assume zero signal power outside the event. The duty factor is $d = \tau/T = (3 \times 10^{-6})/(1 \times 10^{-3}) = 0.003$. Averaging signal energy over the whole interval gives $P_{avg} = d\, P_b = 0.003\, P_b$. Relative to the in-burst level, $10 \log_{10}(P_{avg}/P_b) = 10 \log_{10}(0.003) = -25.229$ dB. This change reflects the definition of average power, not a reduction of converter bit depth. A display using the millisecond average can make a recognisable three-microsecond emission appear weak or absent, even if the converter recorded the in-burst samples correctly. Conversely, a peak estimator may exaggerate the prominence of an isolated noise excursion. The chosen statistic, event interval and baseline must therefore accompany any attempted linkage to ENOB or detection sensitivity.

Application 07. Calculate a bounded scanning-exposure probability

Suppose a scanning receiver observes a given channel for $T_{on} = 16$ μs during a repeating $T_{cycle} = 1000$ μs cycle. Under the expressly hypothetical condition that a very short burst's start time is uniformly distributed over the cycle and that the event is recognised whenever it

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falls inside a useful dwell, the exposure probability for one burst is $p = T_{on}/T_{cycle} = 0.016$, or 1.6%. If four bursts have statistically independent starting phases, the chance that at least one is exposed is $1 - (1-p)^4 = 1 - 0.984^4 = 0.06248$, or about 6.25%. The probability does not include recognition failures once exposed and is not valid for synchronised or correlated bursts. A wider pulse may overlap a dwell differently, so the short-burst assumption matters. No converter ENOB, however favourable, turns a 1.6% exposure opportunity into continuous coverage. In a real instrument the useful dwell might be shorter than the programmed dwell because of tuning and filter settling.

Application 08. Quantify a common window's equivalent noise bandwidth

Let Δf be the Fourier-bin spacing in hertz and let B_e denote a window's equivalent noise bandwidth. Under conventional large-record normalisation and white-noise assumptions, the Hann window has $B_e \approx 1.5\Delta f$, while a rectangular window has $B_e \approx \Delta f$. Hence the noise-power bandwidth ratio is 1.5 and the corresponding difference is $10 \log10(1.5) = 1.7609$ dB. This result applies to the stated estimator normalisation; it does not mean the Hann window is uniformly inferior. Lower sidelobes may materially improve detection of a burst near a powerful carrier, while the wider main lobe reduces frequency separation. Coherent gain must be accounted for separately when estimating a tone amplitude. The analyst must determine whether the event falls near the window edge and whether its energy response differs from the continuous-tone calibration. Consequently a change in FFT display floor cannot be interpreted as an intrinsic change in converter ENOB.

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Application 09. Separate single-test false alarm probability from survey multiplicity

Let m = 10,000 denote independent null tests of a predetermined threshold, with a per-test false-positive probability α = 0.001. The expected number of false flags is E[K] = mα = 10. Under independence, the probability of at least one false flag is P(K≥1) = 1 - (1-α)^m = 1 - (0.999)^10000 ≈ 0.9999548. The apparently stringent one-in-a-thousand threshold therefore almost guarantees at least one false flag across that family of tests. Overlapping FFT bins and successive time windows are often correlated, so actual probability requires the true dependence structure or empirical null data. The calculation does not show that a particular alarm is false, nor does it give a posterior probability of source identity. It shows why a broad monitoring display cannot claim reliable discrimination simply because the ADC's dynamic specification or the threshold of an individual test looks impressive.

Application 10. Quantify uncertainty in a finite burst-recognition study

Assume n = 200 independently randomised representative burst trials with k = 190 recognitions under an unaltered, prespecified detection rule. The observed recognition fraction is p_hat = k/n = 0.95. For a two-sided 95% Wilson score interval with z = 1.96, write D = 1 + z^2/n = 1.019208, C = (p_hat + z^2/(2n))/D ≈ 0.94152, and H = z sqrt[p_hat(1-p_hat)/n + z^2/(4n^2)]/D ≈ 0.03110. The interval [C-H, C+H] is approximately [0.9104, 0.9726]. It concerns this particular trial population, exposure definition and rule, not every possible emitter or interference environment. If trials are correlated, selectively retained, or redefined following failures, the stated

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coverage does not necessarily hold. Thus a nominal '95% detection' result is not a certainty claim, and it is distinct from an ENOB obtained with an unrelated continuous sinusoidal stimulus.

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Scholarly reference register | Verified accessible material and read scope

These source notes record the publicly accessible HTML material and excerpts examined on 10 November 2026. They identify support for methods or historical facts, not for any constructed words attributed to the roundtable participants. The complete licensed text of the IEEE standard and full texts behind restricted bibliographic pages were not obtained; no unobserved section is represented as independently verified. All worked numbers and field scenarios are original hypothetical applications, not measurements supplied by these sources.

[S1] IEEE Standards Association. IEEE 1241-2023, *IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters*. https://standards.ieee.org/ieee/1241/6797/ . Read scope: official public description of the active standard, its subject, sampling and quantisation assumptions, and identification of edition. The licensed clauses were not inspected. The body of this discussion uses ENOB terminology consistently with the standard's stated scope, but it does not claim verification of a particular numbered clause.

[S2] Analog Devices. *Defining and Testing Dynamic Parameters in High-Speed ADCs, Part 1*. https://www.analog.com/en/resources/technical-articles/defining-and-testing-dynamic-parameters-in-highspeed-adcs-part-1.html . Read scope: publicly accessible discussion of sinusoidal SINAD, the ENOB relationship, dependence on input frequency and amplitude, and sources of practical residual error. Used for the conventional equation and qualifications, not as certification of any field receiver.

[S3] Analog Devices. *Coherent Sampling vs. Window Sampling*. https://www.analog.com/en/resources/technical-articles/coherent-sampling-vs-window-sampling.html . Read scope: publicly accessible explanation of coherent periodic records, noncoherent sampling, and why spectral windowing may be needed. Used to frame analysis choices, not to infer unobserved transient properties.

[S4] Analog Devices. *ADC Input Noise: The Good, The Bad, and The Ugly. Is No Noise Good Noise?*

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https://www.analog.com/en/resources/analog-dialogue/articles/adc-input-noise.html . Read scope: distinction between input-referred noise, effective resolution, noise-free code resolution and sine-wave ENOB; comments on averaging and dither. The worked window and duration figures are independently constructed calculations rather than extracted test data.

[S5] D. Gabor. *Theory of communication. Part 1: The analysis of information*. Journal of the Institution of Electrical Engineers, Part III: Radio and Communication Engineering, volume 93, issue 26 (1946), DOI 10.1049/ji-3-2.1946.0074. https://doi.org/10.1049/ji-3-2.1946.0074 . Read scope: bibliographic record and published abstract, which contrasts idealised exact-time description with infinite-wave Fourier analysis and motivates joint time-frequency treatment. The full paper was not inspected.

[S6] E. L. Lehmann. *Jerzy Neyman*, Biographical Memoirs, National Academy of Sciences, volume 63. https://www.nationalacademies.org/read/4560/chapter/19 . Read scope: public biographical discussion of Neyman's work in hypothesis testing, confidence intervals, survey design and the institutional development of statistics. Cited for the historical intellectual framework, not for the independently computed Wilson interval or for quotations by Neyman.

[S7] Science Museum Group. *Dennis Gabor*. https://collection.sciencemuseumgroup.org.uk/people/ap24604/gabor-dennis ; Optica. *Dennis Gabor*. https://www.optica.org/history/biographies/bios/dennis-gabor/ . Read scope: accessible biographies concerning Gabor's engineering career, British institutional activity, holography, communication-related work and honours. Minor source differences in exact birth and death day were avoided by using birth and death years only.

[S8] National Records of Scotland, Scotland's People. *Our Records: Sir Robert Watson-Watt (1892–1973)*. https://www.scotlandspeople.gov.uk/news-and-articles/our-records-sir-robert-watson-watt-1892-1973 ; Science and Technology Facilities Council, RAL Ionosondes Group. *Sir Robert Alexander Watson-Watt, FRS*. https://www.ukssdc.ac.uk/ionosondes/history/watsonwatt.html . Read scope: public historical record of his Scottish education, meteorological and radio work, radar development, Royal Society fellowship and knighthood.

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[S9] National Academy of Engineering. *Richard W. Hamming*, Memorial Tributes, volume 10 (2002). https://www.nationalacademies.org/read/10403/chapter/23 ; MacTutor History of Mathematics. *Richard Hamming*. https://mathshistory.st-andrews.ac.uk/Biographies/Hamming/ . Read scope: accessible biographical information, dates, mathematical and computational career, Bell Laboratories and teaching. The separate historical association between Hamming's name and a spectral window was checked against the public historical profile of the National Museum of Nuclear Science and History, https://ahf.nuclearmuseum.org/ahf/profile/richard-hamming/ .

[S10] National Institute of Standards and Technology. *Digital Investigation Techniques: A NIST Scientific Foundation Review* (2022). https://www.nist.gov/publications/digital-investigation-techniques-nist-scientific-foundation-review . Read scope: official abstract on the scientific foundation, limitations and changing interpretation of digital investigative artefacts. Supports the methodological importance of retaining and interpreting evidence within its actual limits, not a claim that NIST measured the hypothetical receiver.

[S11] Analog Devices. *Understanding Noise, ENOB, and Effective Resolution in Analog-to-Digital Converters*. https://www.analog.com/en/resources/technical-articles/noise-enob-and-effective-resoluition-in-analog-to-digital-converter-circuits--maxim-integrated.html . Read scope: publicly accessible explanation distinguishing dynamic ENOB from input-referred-noise-based effective resolution and noise-free resolution, with caution about sampling rate and gain-dependent conditions.

Concordance for the ten hypothetical worked applications: applications 01–03 use the conventional SINAD-to-ENOB definition in [S2] and [S11]; application 04 uses the small-jitter sinusoidal model and independently stated assumptions; applications 05 and 08 use finite-record Fourier and window concepts in [S3] and [S5]; applications 06 and 07 are transparent time-and-energy arithmetic; applications 09 and 10 are independent standard probability and interval calculations whose stated distribution assumptions are integral to their interpretation. No worked case is presented as an external experimental result.

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QUESTION 029

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How should quantisation noise be distinguished from thermal and clock-related noise?

Fictional educational reconstruction. All attributed exchanges in this discussion are newly authored teaching dialogue, not historical quotations, authentic transcripts, testimony or evidence that deceased scholars evaluated modern receiver systems.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 029 asks: How should quantisation noise be distinguished from thermal and clock-related noise? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is distinguishing quantisation, thermal, and clock-derived noise in sampled receiver records. Our primary observation is noise density, spectral spurs, and their dependence on signal amplitude, frequency, and converter operating mode; by contrast, what remains unseen is how much variance arises from input termination, analogue circuitry, finite digital code width, and sampling-time error. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Separate converter, source and clock error by experimental intervention. A commonly quoted ideal quantisation ratio for a full-scale sinusoid is

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approximately 6.02 N plus 1.76 dB for N effective ideal binary bits and the stipulated uniform-noise model. At N = 12 this is about 74.0 dB, but measured spurious-free dynamic range and effective number of bits can be much poorer because of thermal noise, nonlinearity, clock error and source distortion. Comparing a terminated input with a driven tone, altering input frequency and changing clock conditions exposes different error mechanisms. Jitter-related degradation increases with input frequency even if the sample rate remains unchanged; thermal noise need not follow that pattern. Do not assign all observed residual energy to quantisation merely because the code width is known. The report should include frequency-dependent noise spectra and coherent spurs separately from integrated random noise. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns noise density, spectral spurs, and their dependence on signal amplitude, frequency, and converter operating mode; it is not interchangeable with how much variance arises from input termination, analogue circuitry, finite digital code width, and sampling-time error. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is terminated-input, bit-depth, sample-rate, amplitude, and sine-frequency comparisons with raw-sample retention. A claim drawn from that comparison has to carry its actual uncertainties: quantisation step, nominal SNR, effective noise bandwidth, noise factor, rms jitter, and correlation. An ideal uniform quantiser under a suitably decorrelated error

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model has variance $\Delta^2/12$ for step size Δ. Thermal noise power is proportional to Boltzmann constant, absolute temperature, and equivalent noise bandwidth. Aperture-jitter error grows with input slew rate, unlike a simple white quantisation-noise approximation. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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William Ralph Bennett | Principal contribution 1: An ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ.

A converter's quantisation-error model begins with a step size Δ and, under sufficiently decorrelated conditions, a variance $\Delta^2/12$. That assumption is not the same as a guarantee that every recorded error resembles stationary white noise. An undithered low-amplitude sine wave can yield periodic code patterns and narrow spectral spurs instead of a smooth quantisation pedestal. A thermal input may randomise the transition decisions, making the textbook model more useful, but it introduces genuine analogue noise that must not then be counted as quantisation alone. I would examine a shorted or terminated input, a calibrated coherent tone, and an intentionally dithered tone with identical gain settings. The change in spectral shape across those conditions is informative about the error mechanism. A single noise-floor number cannot identify which mechanism dominates. The archive should include code histograms and raw samples so an examiner can distinguish coherent quantisation artefacts from environmental radio signals.

In this physical path examination of Question 029, the decisive claim is that an ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ. A receiver noise spectrum can mix several mechanisms which respond differently to experimental conditions. Thermal noise changes with physical temperature and resistance; ideal quantisation noise depends on step size and assumptions about decorrelation; aperture jitter grows more damaging at high input-frequency slew rates. A constant displayed floor under one test does not prove these contributions have been

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separated. Nor does simple averaging necessarily increase effective resolution where noise is correlated, deterministic or dominated by converter nonlinearity. The panel should design multiple experiments that vary one hypothesised source without silently changing the others. A useful falsification proceeds from the actual controversy: separate converter, source and clock error by experimental intervention. A commonly quoted ideal quantisation ratio for a full-scale sinusoid is approximately 6.02 N plus 1.76 dB for N effective ideal binary bits and the stipulated uniform-noise model. At N = 12 this is about 74.0 dB, but measured spurious-free dynamic range and effective number of bits can be much poorer because of thermal noise, nonlinearity, clock error and source distortion. Comparing a terminated input with a driven tone, altering input frequency and changing clock conditions exposes different error mechanisms. Jitter-related degradation increases with input frequency even if the sample rate remains unchanged; thermal noise need not follow that pattern. Do not assign all observed residual energy to quantisation merely because the code width is known. The report should include frequency-dependent noise spectra and coherent spurs separately from integrated random noise. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Use a shielded termination at several controlled temperatures to characterise the input-referred noise floor, then introduce an accurately calibrated sine at increasing frequencies while holding its amplitude fixed. Vary converter step size, dither amplitude and sample-clock source separately. Compare histograms and PSDs before and after digital

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averaging, documenting the analogue bandwidth and correlations among channels. A thermal-noise explanation predicts a different dependence upon temperature from the phase-error behaviour of a high-frequency sine. I would take delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: An ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ. A response consistent with jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. A laboratory compares low-level broadband receiver noise under a terminated input, a

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coherent sine stimulus and an externally connected antenna. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays, and measure their behaviour separately before reconnecting the assembled system. Bennett's communications engineering perspective distinguishes stochastic noise models from deterministic signal-dependent converter errors and distortion products. It is therefore material to establish delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency rather than infer them from a single scalar output. The limiting test is concrete: Vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. If the intervention produces jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret the noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution as a new transmitter before challenging the most economical instrumental explanation. The familiar quantisation variance of delta squared over twelve depends on a particular error model, not a universal property of every coherent tone. Professor Tukey, I invite you to interrogate how that model was selected.

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John Wilder Tukey | Peer question 1 to William Ralph Bennett

William R. Bennett, may I test the exact physical inference in your account of a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna? The proposed mechanism appears plausible only if changes after vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples are compared with a stable reference condition. An ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency which would settle that narrower claim, rather than a visual impression of improvement.

William Ralph Bennett | Immediate answer to John Wilder Tukey

Dr Tukey, a lower floor after averaging could be consistent with reduced independent quantisation error, suppression of broadband thermal noise, or merely a narrower effective measurement bandwidth. I would report the output bandwidth and record correlations before crediting a converter with additional effective bits. Input-frequency sweeps and clock substitution provide separate tests of aperture error rather than relying on one composite SINAD

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measurement. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 029, the specific physical candidate is uniform quantisation error under restricted assumptions, kTB thermal contributions, and slew-dependent jitter noise. The unresolved physical pathway is material: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. The retained record permits a conditional claim about delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, but cannot alone resolve the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are delta-squared over twelve, kTB, integrated

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clock phase noise, effective bandwidth and SNR versus stimulus frequency; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. An ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples, and only a response matching jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, not a conjecture about the operator's intentions.

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Richard Wesley Hamming | Peer question 2 to William Ralph Bennett

I appreciate your explanation, William R. Bennett. How would your conclusion survive a deliberately independent test of the noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution? A second receiver might share more of the supposed evidence than its separate enclosure suggests. Thermal noise power is proportional to Boltzmann constant, absolute temperature, and equivalent noise bandwidth. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent. Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency and document which differences remain unexplained? Would you also state what observed change in delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency would invalidate the preferred account, and which aspect of vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples would make that negative result independently repeatable?

William Ralph Bennett | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the

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level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 029, the specific physical candidate is uniform quantisation error under restricted assumptions, kTB thermal contributions, and slew-dependent jitter noise. The unresolved physical pathway is material: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. The retained record permits a conditional claim about delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, but cannot alone resolve the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. Thermal noise power is proportional to Boltzmann constant, absolute temperature, and equivalent noise bandwidth. An independent test must alter a physical dependency, not merely open another software

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window. The relevant controlled alternative remains uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays; I would challenge it with vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. Two responses consistent with jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. A discordant measurement would then be interpreted by tracing that difference through delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency; an agreement lacking such a dependency analysis is weak corroboration.

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Harry Nyquist | Principal contribution 2: Thermal noise power is proportional to Boltzmann constant, absolute temperature, and equivalent noise bandwidth.

Noise caused by a sampling clock differs from quantisation noise because the error depends on the slope of the analogue waveform. For small sampling-time deviations δt, the corresponding sample-voltage error is approximately (dx/dt)δt. A faster RF sinusoid has a steeper slope at equal amplitude, so jitter-related degradation rises with frequency even when the converter step size remains unchanged. I would conduct amplitude-controlled frequency sweeps and inspect how the observed noise power changes, taking care to exclude the front-end filter roll-off and changing signal-to-noise reference. A clock with periodic phase modulation may create discrete sidebands, whereas a random jitter model may predict a broader pedestal. The two spectral signatures should not be combined into one anonymous noise number. If the receiver employs bandpass sampling, the relevant frequency is the actual analogue carrier, not the low-frequency alias shown on the digital display. That distinction can be decisive in a high-frequency survey.

In this control and stability examination of Question 029, the decisive claim is that thermal noise power is proportional to Boltzmann constant, absolute temperature, and equivalent noise bandwidth. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: separate converter, source and clock error by experimental intervention. A commonly

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quoted ideal quantisation ratio for a full-scale sinusoid is approximately 6.02 N plus 1.76 dB for N effective ideal binary bits and the stipulated uniform-noise model. At N = 12 this is about 74.0 dB, but measured spurious-free dynamic range and effective number of bits can be much poorer because of thermal noise, nonlinearity, clock error and source distortion. Comparing a terminated input with a driven tone, altering input frequency and changing clock conditions exposes different error mechanisms. Jitter-related degradation increases with input frequency even if the sample rate remains unchanged; thermal noise need not follow that pattern. Do not assign all observed residual energy to quantisation merely because the code width is known. The report should include frequency-dependent noise spectra and coherent spurs separately from integrated random noise. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by the noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note thermal noise power is proportional to boltzmann

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constant, absolute temperature, and equivalent noise bandwidth. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, the noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Nyquist’s work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. The order would be time-stamped and should include invalid intervals, receiver recovery, and any gain or filter settling rather than treating silence during transition as evidence of a silent source. Our central rival is specific: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. This predicts a response which should be tested against jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows

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measurement bandwidth; quantisation effects depend on code step and correlation. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that presentational step does not restore measurements discarded during retuning. Where the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone, the correct claim must name the operational states and the evidence available in each. Thermal noise must be assessed against physical temperature and effective bandwidth before being added to digital noise budgets. Dr Pearson, please take the floor and examine the assumptions behind that calculation.

Egon Sharpe Pearson | Peer question 3 to Harry Nyquist

Harry Nyquist, your calibration argument invites a question about reference planes, especially because the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. The reference stimulus and the unknown emission need not occupy the same physical regime. Aperture-jitter error grows with input slew rate, unlike a simple white quantisation-noise approximation. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When the noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while

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preserving unaveraged samples without relying upon the original screenshot or undocumented threshold settings? The question concerns the traceability of the inference, not the operator's good faith.

Harry Nyquist | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 029, the specific physical candidate is uniform quantisation error under restricted assumptions, kTB thermal contributions, and slew-dependent jitter noise. The unresolved physical pathway is material: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. The retained record permits a conditional claim about delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, but cannot alone resolve the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency. Aperture-jitter error grows with input slew rate, unlike a simple white quantisation-noise approximation. I would not carry a correction obtained at one frequency or amplitude

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into another regime without a documented sensitivity test. An appropriate reference check would be vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples, with before-and-after values of delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency. If the instrument behaves as predicted, then jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. The noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Harry Nyquist

There is an inferential difficulty, Harry Nyquist: uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs

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can occupy overlapping displays. The population of admissible observations needs to be fixed before any confidence argument. In this situation, the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. A stable coherent input may produce deterministic quantisation spurs rather than a statistically white floor. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency would invalidate the preferred account, and which aspect of vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples would make that negative result independently repeatable?

Harry Nyquist | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For

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Question 029, the specific physical candidate is uniform quantisation error under restricted assumptions, kTB thermal contributions, and slew-dependent jitter noise. The unresolved physical pathway is material: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. The retained record permits a conditional claim about delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, but cannot alone resolve the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because the noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution. I would distinguish trials selected in advance from those added after an unexpected peak appeared. A stable coherent input may produce deterministic quantisation spurs rather than a statistically white floor. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples, but it must be labelled a validation phase rather than merged into an apparently random original sample. The rival mechanism is uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion

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spurs can occupy overlapping displays; its prediction should be recorded alongside jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. The white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a 1 mv quantiser step gives roughly 0.289 mv rms under a uniform independent error approximation, not a guarantee of white spectral noise. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Claude Elwood Shannon | Principal contribution 3: Aperture-jitter error grows with input slew rate, unlike a simple white quantisation-noise approximation.

The information content of a converter record depends on correlations among its errors, not only the average number of bits. A quantisation disturbance that is deterministic for a repeated waveform can be predicted or avoided in a controlled experiment, while random thermal noise may limit any retrospective estimate of a single event. I would measure the covariance and spectral structure of the errors under multiple source conditions rather than infer their nature from a flat-looking display. Dithering can decorrelate some quantisation errors and improve statistical estimation, but deliberately adding noise cannot increase the intrinsic number of ADC transition thresholds. If samples are combined or averaged, the claimed improvement requires a noise model: independent components diminish differently from common clock noise or coherent distortion. Retaining individual channel samples enables later tests of those distinctions. Summing converter outputs into a longer digital word does not manufacture independent analogue information when their errors are shared.

In this operational measurand examination of Question 029, the decisive claim is that aperture-jitter error grows with input slew rate, unlike a simple white quantisation-noise approximation. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: separate converter, source and clock error by experimental intervention. A commonly quoted ideal quantisation ratio for a

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full-scale sinusoid is approximately 6.02 N plus 1.76 dB for N effective ideal binary bits and the stipulated uniform-noise model. At N = 12 this is about 74.0 dB, but measured spurious-free dynamic range and effective number of bits can be much poorer because of thermal noise, nonlinearity, clock error and source distortion. Comparing a terminated input with a driven tone, altering input frequency and changing clock conditions exposes different error mechanisms. Jitter-related degradation increases with input frequency even if the sample rate remains unchanged; thermal noise need not follow that pattern. Do not assign all observed residual energy to quantisation merely because the code width is known. The report should include frequency-dependent noise spectra and coherent spurs separately from integrated random noise. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Quantisation noise, thermal noise and clock-related error are not interchangeable merely because each may contribute to the displayed spectral floor. Under the customary uniform-error approximation, quantisation noise depends on converter step size and signal conditions; thermal noise depends on temperature, resistance and effective noise bandwidth; aperture-time error couples to input slope and therefore changes with signal frequency. One discriminating experiment records a low-distortion test tone at several amplitudes and frequencies while changing the analogue source termination in a controlled way. A floor that varies with front-end temperature or analogue bandwidth suggests a different mechanism from one that follows converter code size or high-frequency slew rate. Periodic clock contamination may form discrete spurs

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rather than a smooth floor. The proper report specifies whether its estimate concerns total measured noise, a modelled component or a bound derived from independent calibration. Fitting one white-noise parameter to all three mechanisms conceals the actual uncertainties. Accordingly, the laboratory record for Question 029 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. The white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. Shannon's information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity

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where appropriate. A decision should specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The illustrative case is instructive: A 1 mV quantiser step gives roughly 0.289 mV rms under a uniform independent error approximation, not a guarantee of white spectral noise. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. Jitter error grows with the rate of change of the sampled waveform, unlike an ideal uniform quantisation contribution. Dr Turing, I pass the floor for a comparison of what two differently clocked recordings can establish.

Alan Mathison Turing | Peer question 5 to Claude Elwood Shannon

Claude Elwood Shannon, I should like to examine what the recorded data actually preserve when a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. The physical input and the retained numerical array are not interchangeable things. Multiple operating conditions are needed to separate causal noise contributions that overlap spectrally. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state

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what observed change in delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency would invalidate the preferred account, and which aspect of vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples would make that negative result independently repeatable?

Claude Elwood Shannon | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 029, the specific physical candidate is uniform quantisation error under restricted assumptions, kTB thermal contributions, and slew-dependent jitter noise. The unresolved physical pathway is material: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. The retained record permits a conditional claim about delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, but cannot alone resolve the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. That limitation belongs in the stated finding

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because the alternative remains an empirical possibility in this experiment.

I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. The white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. I propose separating acquired information from model-dependent reconstruction. Multiple operating conditions are needed to separate causal noise contributions that overlap spectrally. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency and a fresh trial in which the operator vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. If that trial demonstrates jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control

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intervals, plus executed settings and invalidity masks. The concrete challenge should include vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Walter Andrew Shewhart | Principal contribution 4: A stable coherent input may produce deterministic quantisation spurs rather than a statistically white floor.

A stable noise estimate is not necessarily a correctly attributed one. I would monitor the terminated-input PSD, temperature, clock mode and gain state over repeated sessions, and look for changes that isolate the physical source of a disturbance. Quantisation errors should correlate with the code sequence and applied waveform; thermal disturbances should respond to analogue bandwidth and temperature under the relevant model; sampling-clock errors should reveal frequency or phase relationships with the stimulus. These are diagnostic hypotheses that can be tested against the apparatus. A control chart may flag a change without telling us which mechanism caused it, so each change should lead to a calibrated intervention rather than an immediate conclusion. If firmware changes the decimation filter or dither setting, compare raw-data and processed-data spectra separately. The noise's appearance on one waterfall is not enough to decide whether it is environmental, analogue, clock-related or numerical.

In this information retention examination of Question 029, the decisive claim is that a stable coherent input may produce deterministic quantisation spurs rather than a statistically white floor. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: separate converter, source and clock error by experimental intervention. A commonly quoted ideal quantisation ratio for a full-scale sinusoid is approximately 6.02 N plus 1.76 dB for N effective ideal binary bits and the stipulated uniform-noise model. At N = 12 this is about

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74.0 dB, but measured spurious-free dynamic range and effective number of bits can be much poorer because of thermal noise, nonlinearity, clock error and source distortion. Comparing a terminated input with a driven tone, altering input frequency and changing clock conditions exposes different error mechanisms. Jitter-related degradation increases with input frequency even if the sample rate remains unchanged; thermal noise need not follow that pattern. Do not assign all observed residual energy to quantisation merely because the code width is known. The report should include frequency-dependent noise spectra and coherent spurs separately from integrated random noise. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. The scientific point of a stable coherent input may produce deterministic quantisation spurs rather than a statistically white floor. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent sessions repeatedly show jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise

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follows measurement bandwidth; quantisation effects depend on code step and correlation, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. The noise floor changes with signal frequency and digital averaging despite unchanged nominal converter resolution. Shewhart's process reasoning distinguishes common variation from a changed operating regime and requires the survey to retain the chronology of changing receiver states. The issue becomes especially sharp because uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually examined. For the proposed case, a 1 mv quantiser step gives roughly 0.289 mv rms under a uniform

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independent error approximation, not a guarantee of white spectral noise. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. The examiner who presents an irreversible processing step as though it were a reversible calibration exaggerates what the archive can establish.

A further, separately testable aspect of a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna concerns delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency. The proposed challenge would be vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. The decision is conditional upon the observed result, with particular attention to the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. The competing account remains uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. Consequently this speaker accepts only the inference which the conducted experiment could differentiate. A coherent input may produce repeatable quantisation spurs rather than featureless noise. Dr Deming, I invite a validation experiment capable of distinguishing deterministic structure from a statistical floor.

W. Edwards Deming | Peer question 6 to Walter Andrew Shewhart

I thank you, Walter Andrew Shewhart, for distinguishing measurement from attribution, but the observation is that the noise floor changes with signal frequency and digital averaging despite unchanged nominal

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converter resolution. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a 1 mV quantiser step gives roughly 0.289 mV rms under a uniform independent error approximation, not a guarantee of white spectral noise. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation on one day but fails after the instrument has been reconfigured? An ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

Walter Andrew Shewhart | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 029, the specific physical candidate is uniform quantisation error under restricted assumptions, kTB thermal contributions, and slew-dependent jitter noise. The unresolved physical pathway is material: Uniform quantisation error, thermal

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noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. The retained record permits a conditional claim about delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, but cannot alone resolve the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a 1 mV quantiser step gives roughly 0.289 mV rms under a uniform independent error approximation, not a guarantee of white spectral noise. I would retain the counterexample as part of the primary result, not as a footnote to an attractive conclusion. An ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ. Its bearing on the dispute can be evaluated through the predicted response, namely jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation. Because uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays, the procedure vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples should be repeated with the same calibration and an independent witness path. If agreement

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appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. Jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: Multiple operating conditions are needed to separate causal noise contributions that overlap spectrally.

The final uncertainty budget should not classify every residual discrepancy as random converter noise. If the measurement is intended to identify a weak intermittent emission, the relevant performance metric may be the probability of detection across several amplitude and frequency conditions. I would estimate the thermal contribution with the source terminated, characterise jitter with calibrated high-frequency tones, and examine the converter transfer errors with a code-density or appropriate dynamic test. Those characterisations are not automatically independent. Shared reference-voltage fluctuations, temperature and clock distribution may correlate their effects; a naive root-sum-square combination can then misrepresent uncertainty. A useful report provides the conditions under which each component was evaluated and tests how the proposed model predicts an independent validation recording. When a candidate falls near the detector threshold, the operating regime matters more than a single global effective-number-of-bits figure. The statistical claim must be tied to the actual decision the examiner is making.

In this statistical inference examination of Question 029, the decisive claim is that multiple operating conditions are needed to separate causal noise contributions that overlap spectrally. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: separate converter, source and clock

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error by experimental intervention. A commonly quoted ideal quantisation ratio for a full-scale sinusoid is approximately 6.02 N plus 1.76 dB for N effective ideal binary bits and the stipulated uniform-noise model. At N = 12 this is about 74.0 dB, but measured spurious-free dynamic range and effective number of bits can be much poorer because of thermal noise, nonlinearity, clock error and source distortion. Comparing a terminated input with a driven tone, altering input frequency and changing clock conditions exposes different error mechanisms. Jitter-related degradation increases with input frequency even if the sample rate remains unchanged; thermal noise need not follow that pattern. Do not assign all observed residual energy to quantisation merely because the code width is known. The report should include frequency-dependent noise spectra and coherent spurs separately from integrated random noise. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. Multiple operating conditions are needed to separate causal noise contributions that overlap spectrally. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to vary input amplitude,

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input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples, should be accompanied by a second acquisition path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. A laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman’s statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping

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displays. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime. The relevant quantities are delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a 1 mv quantiser step gives roughly 0.289 mv rms under a uniform independent error approximation, not a guarantee of white spectral noise, is not an estimate of any actual investigation. Noise contributions that overlap spectrally need separate controlled operating states before their magnitudes can be assigned. Sir Karl, I pass the floor to test which attribution remains falsifiable.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. Thermal noise power is proportional to Boltzmann constant, absolute temperature, and equivalent noise bandwidth. Please connect delta-squared over twelve, kTB, integrated clock phase noise, effective

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bandwidth and SNR versus stimulus frequency with a declared detection threshold and the measurement exposure. If the experiment vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 029, the specific physical candidate is uniform quantisation error under restricted assumptions, kTB thermal contributions, and slew-dependent jitter noise. The unresolved physical pathway is material: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. The retained record permits a conditional claim about delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency, but cannot alone resolve the white quantisation-error approximation requires an appropriate error model and must not be applied uncritically to a coherent low-level tone. That limitation

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belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. Thermal noise power is proportional to Boltzmann constant, absolute temperature, and equivalent noise bandwidth. I would use the observations of delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples, not an assertion based on the operator's impression of a quiet display. If it yields jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

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To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays, an intervention that leaves both alternatives consistent does not settle their difference. The result should be limited to identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism, with the untested physical possibilities made visible.

William Ralph Bennett, Cross-Peer Question to Harry Nyquist: Dr Nyquist, when an ADC trace has a near-white floor under one test, what experiment separates a decorrelated uniform quantisation approximation from actual resistor and amplifier thermal noise?

Harry Nyquist, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, begin with a terminated, calibrated input and record noise power against equivalent noise bandwidth, analogue gain and absolute physical temperature. Johnson noise scales in power with kTB for a matched thermal reference; converter quantisation error is expressed in code steps and depends upon input statistics and dither assumptions. Their spectra may overlap, so one cannot assign causal origin from a single white-looking trace. Vary gain ahead of the ADC while holding later processing fixed: analogue noise referred to the converter may grow with that gain while the native quantisation step remains set by the converter transfer function. Independently vary input temperature or measure a known resistor source where practical. Compare predicted and observed covariance. The result must give the reference plane, impedance, temperature, bandwidth and

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saturation exclusions. I pass the token to Dr Shannon to examine a third noise mechanism.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, a 14-bit receiver shows sharply worsening SNR as the test sine frequency increases, whilst the digital noise floor appears smooth. How would you isolate aperture jitter from broadband additive noise?

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, measure SINAD or appropriately defined noise-only SNR at several input frequencies and controlled amplitudes, documenting the clock-source phase-noise characteristics. Under small, independent rms aperture jitter sigma_t, the ideal sinusoidal limit is SNR_j = −20 log10(2π f_in sigma_t). The frequency factor therefore predicts stronger jitter sensitivity at higher input frequency, unlike a fixed independent input-referred voltage-noise density. Yet this formula is a limiting model, not an instrument certificate; correlated jitter, clock spurs, aperture effects and front-end gain dispersion can change the result. Cross-check with an independent low-jitter clock, a second reference frequency and a measurement of the actual aperture uncertainty where possible. Inspect harmonic and intermodulation content separately. I yield to Dr Shewhart for the problem of misleadingly smooth presentations.

Claude Elwood Shannon, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, a noise histogram appears Gaussian and the mean spectrum flat. Why is that insufficient evidence that code error is independent or that a low-frequency spur cannot be produced internally?

Walter Andrew Shewhart, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, marginal distributions are not joint distributions. A sequence may

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have a perfectly plausible histogram while preserving correlations, periodic error, modulation and code-transition defects. Apply a slow coherent ramp to inspect missing or unequal codes, repeat with deliberately noncoherent and dithered stimuli, and compare time autocorrelation, cross-channel covariance, Allan-type stability at suitable durations and narrowband residuals. Monitor supply rails and converter operating mode so a firmware or gain-state transition is not attributed to the environment. State how many spectral opportunities were examined, because selecting the strongest bin after the fact inflates false alarms. A validation record must include both negative and positive controls and must preserve the full trace, not only a smoothed display. I pass the token to Dr Neyman on inference across the resulting trials.

Walter Andrew Shewhart, Cross-Peer Question to Jerzy Neyman: Dr Neyman, if thermal, converter and clock-noise estimates are extracted from the same twenty records, is root-sum-of-squares always an acceptable combined uncertainty?

Jerzy Neyman, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, only if the quantities are defined appropriately and their covariances do not materially affect the result. The propagation formula includes cross terms, so estimates sharing clock drift, gain calibration or a common baseline are not automatically independent. Specify whether each reported number is a standard deviation of an estimator, a noise power, an amplitude uncertainty, or a systematic correction. Combine quantities in consistent units and on the same reference plane, applying the appropriate sensitivity coefficients before calculating uncertainty. Use paired perturbation trials and a covariance matrix or an independently justified resampling method

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where necessary; do not average decibel figures as though they were linear powers. A non-significant difference does not establish causal equivalence. I respectfully return the token to Dr Atkinson to summarise the evidential boundary.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of distinguishing quantisation, thermal, and clock-derived noise in sampled receiver records has established a point which the specialist must not overlook. The receiver records noise density, spectral spurs, and their dependence on signal amplitude, frequency, and converter operating mode; it does not, merely by drawing a clear trace, give direct access to how much variance arises from input termination, analogue circuitry, finite digital code width, and sampling-time error. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, An ideal uniform quantiser under a suitably decorrelated error model has variance $\Delta^2/12$ for step size Δ. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

A measured receiver noise floor may be the joint outcome of thermal agitation, amplifier flicker noise, environmental interference and residual oscillator-related phenomena. One cannot discover the fractions merely by fitting a single straight line through an averaged spectrum. Temperature, input termination, selected gain, observation bandwidth and frequency offset should be varied separately so that the competing mechanisms make

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testably different predictions. I thank the statistical contributors for warning that measurements drawn from a drifting operating regime cannot automatically be pooled as independent examples of the same noise process. A transient rise under a known switching load calls for different interpretation from a stable increase in receiver-added thermal noise. The closing report should display the observed covariance and spectral shape where measurable, disclose the limitations of the model and retain alternative explanations when several mechanisms fit the same data. A legitimate conclusion may concern instrument performance without resolving the origin of every environmental fluctuation.

The reported floor varies with input frequency and processing even though nominal bit depth is unchanged. That is not sufficient to divide the total noise into components. The gain, bandwidth, clock, dithering and signal amplitude must be fixed or explicitly modelled during the separating measurements. The more useful outcome is a discriminating protocol: Vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. In applying it, the examiner must retain all readings supporting delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency and identify the physical plane to which the measurements refer. At the outset of the investigation, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna; that circumstance makes the alternative mechanism material, specifically uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. A result

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approaching jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

The result should be a componentwise noise budget with explicit operating conditions, including covariance where it matters. Neither the nominal number of converter bits nor a single waterfall PSD can uniquely identify thermal, quantisation and clock-related mechanisms. The decisive experiment is concrete: Vary input amplitude, input frequency, sample rate, clock source, termination state and dithering while preserving unaveraged samples. In conducting it, the examiner must explicitly retain delta-squared over twelve, kTB, integrated clock phase noise, effective bandwidth and SNR versus stimulus frequency. If the outcome matches the stated prediction, jitter-sensitive error grows with sinusoidal slew rate; thermal receiver noise follows measurement bandwidth; quantisation effects depend on code step and correlation, the supported conclusion concerns that test domain. An alternative remains: Uniform quantisation error, thermal noise, correlated clock jitter and coherent distortion spurs can occupy overlapping displays. I

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thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 029

Application 01. Ideal code step, variance, and full-scale sine SNR

In the illustrative 029.01 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. Taking an ideal N = 10-bit uniform converter across 2.50 V peak-to-peak, one nominal code interval is $\Delta = V_{pp}/2^N = 2.4414$ mV. Under the independent uniform-error approximation its rms quantisation error is $\sigma = \Delta/\sqrt{12} = 0.7048$ mV. The ideal full-scale sinusoidal SNR approximation is 6.02N + 1.76 = 61.96 dB. A coherent low-level waveform may violate the uniform-error assumption; clipping and integral nonlinearity are separate limitations. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

Application 02. Thermal reference noise in a declared measurement bandwidth

In the illustrative 029.02 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. Take the equivalent noise bandwidth B = 6,750 Hz and calibrated noise figure NF = 3.90 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10\log_{10}(B/1\text{ Hz}) + NF = -131.81$ dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

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Application 03. The frequency dependence of aperture-jitter-limited SNR

In the illustrative 029.03 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. At sinusoidal input frequency f = 217 MHz with uncorrelated rms aperture jitter σ_t = 1.77 ps, the idealised jitter-imposed ceiling is $SNR_j = -20 \log_{10}(2\pi f \sigma_t)$ = 52.35 dB. A common clock source may correlate errors across parallel ADC channels, so treating their outputs as independent for noise cancellation would need an additional experiment. Converter nonlinearity and thermal noise can make actual performance worse. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

Application 04. Code-bin width under differential nonlinearity

In the illustrative 029.04 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. For an N = 13-bit transfer over 2.80 V, one ideal least-significant-bit interval is Δ = 0.34180 mV. If one measured code has DNL = -0.200 LSB, its effective width is Δ(1 + DNL) = 0.27344 mV. A code-width result needs adequate stimulus uniformity, histogram population and a declared endpoint convention; it does not independently establish whole-transfer integral linearity. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

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Application 05. Voltage-equivalent integral nonlinearity

In the illustrative 029.05 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. Under a specified transfer-line convention, an N = 15-bit ADC spanning 2.50 V has ideal step Δ = 0.07629 mV. A local integral nonlinearity of 0.760 LSB corresponds to 0.05798 mV of analogue-equivalent deviation. The endpoint or best-fit reference line must be declared, as must temperature, code region and input slew rate; otherwise two instruments may report incompatible INL values for the same transfer curve. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

Application 06. Frequency-bin spacing versus independent information

In the illustrative 029.06 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. With sampled bandwidth f_s = 7 MS/s and N = 8,192 transform samples, the discrete-frequency grid is $\Delta f = f_s/N$ = 854.492 Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

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Application 07. Combined and expanded measurement uncertainty

In the illustrative 029.07 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. For independent standard-uncertainty contributions 0.52, 0.48 and 0.22 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.52^2 + 0.48^2 + 0.22^2)} = 0.741$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c = 1.482$ units. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

Application 08. Difference between two instruments relative to stated uncertainty

In the illustrative 029.08 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. The paired instrument contrast is $\Delta = 1.020$ dB. Set independent standard uncertainties $u_1 = 0.500$ dB and $u_2 = 0.420$ dB. Then $u\Delta = \sqrt{(u_1^2 + u_2^2)} = 0.653$ dB, giving the dimensionless ratio $\Delta/u\Delta = 1.562$. This ratio is not automatically a significance test: correlated calibration errors and non-normal uncertainty require separate treatment. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

Application 09. Family-wise probability when many candidates are searched

In the illustrative 029.09 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine

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stimulus and an externally connected antenna. If each of M = 560 independent pre-specified search opportunities has false-alarm probability α = 0.0009, the probability of one or more false positives is 1 − (1 − α)^M = 0.39603, or 39.60%. Independence is a working premise only; neighbouring FFT bins and overlapping time windows commonly violate it. A post-selected search also changes the test family. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

Application 10. Cascade gain and observed headroom

In the illustrative 029.10 test, a laboratory compares low-level broadband receiver noise under a terminated input, a coherent sine stimulus and an externally connected antenna. A first amplifier contributes G_1 = 14 dB, an intentional attenuation contributes G_2 = -6 dB, and a later stage contributes G_3 = 16 dB. The small-signal sum is 14 + (-6) + 16 = 24 dB. For P_i = -70 dBm, the ideal output is P_o = -46 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. Identify each tested noise contribution rather than describe the aggregate screen floor as a single physical mechanism.

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Selected technical references and use limitations

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These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 030

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What does calibration reveal about ADC performance across temperature and time?

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Original constructed educational dialogue. Historical contributors are assigned hypothetical modern engineering questions by reference to their documented intellectual methods. These speeches are newly written and are not historical quotations, accounts of actual meetings, or claims that deceased individuals examined contemporary SDR instruments. All numbered examples are hypothetical and do not certify any receiver.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, the numerical output of an analogue-to-digital converter is the last visible statement of a process that begins with an analogue comparison. Between the signal at a declared reference plane and the number entered into the evidence file lie reference voltages, analogue switches, input buffers, sampling apertures, capacitors, comparators, digital corrections, clock systems, temperature-dependent components, and the continual possibility that the physical apparatus has altered since its last formal examination. A report which declares that a converter is calibrated may refer to a single stimulus at a single ambient temperature, to a manufacturer's production test, to an automatic internal operation, or to a system-level comparison against a traceable reference. These are not interchangeable assertions. Our question concerns what each can establish, what it leaves indeterminate, and what happens when a receiver is employed for a search in which an intermittent emission may never recur under laboratory conditions.

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Consider a defensive surveillance examination in which the receiver reports a very small spectral line within a wide span of otherwise ordinary radio-frequency activity. The operator later discovers that the converter board was calibrated at twenty-five degrees Celsius, but during the examination the enclosure temperature rose to fifty degrees and the reference supply had been changed during maintenance. An internal gain calibration was subsequently performed, but no record connects its coefficient set to the original acquisition interval. The operator may still have an authentic, bit-for-bit preserved recording. The authenticity of those bits does not demonstrate that the coefficient and reference assumptions used to interpret the recording were valid when the samples were created. Nor would a correction inferred from later laboratory measurements necessarily restore the actual earlier analogue input. We must separate digital custody, transfer-function characterisation, stability monitoring, and the identifiability of a past measurement state.

The engineering comparison should be sufficiently explicit to survive a change in vocabulary. Let x denote the voltage at the declared analogue reference plane, T the relevant physical temperature, t the observation time, s the discrete configuration state, and y the retained digital estimate. A local linear approximation may be written $y = a(T,t,s)x + b(T,t,s) + e(x,T,t,s)$, where a is effective gain, b is offset, and e is the residual encompassing nonlinear and stochastic contributions. We shall not assume that this approximation is globally valid, that the temperature is uniform across the instrument, or that drift is linear through an entire operating range. In particular, a temperature reading attached to the chassis may be an imperfect surrogate for the converter die, the reference element, the analogue front end, or the

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clock generator. Each of those components can respond on a different thermal time scale. One number in a log can conceal a changing spatial field of temperatures.

Calibration, properly understood, produces an experimental relationship, with an uncertainty, between indications and reference quantities under defined conditions. Verification asks whether specified requirements are met. Adjustment changes an instrument or its coefficients. These operations may be performed together, but their documentary meanings remain distinct. A before-and-after correction that makes one test point agree with its reference can leave integral nonlinearity, aperture jitter, overload behaviour and out-of-band susceptibility unchanged. Equally, a converter may be perfectly adequate for spectral occupancy classification while being insufficiently characterised for absolute power or phase measurements. The required validation therefore depends upon the measurand and decision claim, not merely upon a box marked 'calibrated'.

I shall invite Mr Weston to begin with physical standards, reference planes and the difference between a converter certificate and a system measurement. Lord Kelvin will consider temperature as a physical variable, the legitimacy of interpolation and the danger of allowing thermal models to masquerade as observations. Dr Shewhart will examine surveillance of drift over time, common-cause variation, special causes and the risk of mistaking an orderly chart for independent evidence of correctness. Dr Shannon will distinguish recoverable digital calibration from information lost at the aperture or saturation boundary. Dr Nyquist will connect converter amplitude correction to the stability of clock time, particularly

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where the prosecution or defence of a technical finding rests upon relationships among transient events.

Seven colleagues will question the principals directly. Their challenges will examine whether changes of reference, gain, hardware, observation window, laboratory method or analyst selection can manufacture an appearance of stability. We shall require example calculations to disclose units, uncertainty models and the limited claims which follow. The discussion is a hypothetical methodological exercise, not a certification of a particular modern receiver. Where the documentary basis is insufficient, the technically disciplined answer is not to invent a missing calibration trace. It is to narrow the claim, preserve the uncertainty, and identify a challenge that could change the inference. Mr Weston, may I invite you to establish the physical and evidential reference plane from which this inquiry must proceed?

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Edward Weston | Principal response 1: The physical reference and the assembled measurement

Dr. Atkinson, I accept the invitation with a distinction that may seem elementary but has repeatedly governed the reliability of electrical measurement: the indicated number must be connected to a reproducible physical comparison. A converter code is not, by itself, a voltage standard. It is a discrete result produced by a network whose reference, loading and environmental conditions must be known sufficiently well for the intended comparison. The act of placing a traceable source at the converter terminals may characterise the converter. It cannot, without additional evidence, characterise the amplitude delivered to those terminals through a preselector, low-noise amplifier, attenuator, protection limiter and switch matrix. One could quite properly certify the transfer relationship of an ADC board and yet possess no valid calibration for the amplitude at the antenna connector. A metrologist would distinguish those reference planes before discussing the number of significant digits printed by the software.

Begin with a calibration map whose independent quantity is the voltage applied at a physically accessible input plane and whose dependent quantity is the uncorrected converter indication. Establish the reference source's calibration and associated uncertainty, its output impedance, the load presented by the receiver, the wiring configuration and the actual delivered voltage. A nominal one-volt setting on a generator is not automatically a one-volt input if the source and load are mismatched or the generator amplitude is specified into a particular termination. Temperature should be recorded both for the reference and for the receiver. A calibration chain is persuasive only when every material transfer can be defended, not because

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a document carries an imposing seal or because an operator has used the word traceability.

A useful calibration at one temperature may determine an offset and scale for a limited, approximately linear input interval. If reference levels x1 and x2 produce indications y1 and y2, one may estimate a = (y2 - y1)/(x2 - x1) and b = y1 - ax1. That elementary relationship is a beginning, not a full account of the converter. It presumes that two points adequately describe the segment and that neither reading was affected by settling, clipping or a changing configuration. Additional levels across the intended range can disclose curvature, discontinuity or code-transition irregularity. A frequency-domain test can expose behaviour that a slow direct-current calibration cannot. Thus a calibration claim should identify the stimulus class and the range of quantities to which its coefficients can legitimately be applied.

I am especially concerned about the temptation to call every self-calibration a system calibration. An internal routine may switch the converter inputs to known internal nodes and calculate coefficients which reduce offset or gain error of designated circuitry. It may not incorporate an external antenna switch, a cable whose loss varies with temperature, or the impedance presented by a field probe. Conversely, a system calibration conducted with the complete analogue path can be more representative, but it is susceptible to the reference-source configuration and to the source's own drift. A good record therefore identifies both what was included and what was excluded. It need not pretend to characterise every possible component; it must tell the reader which physical quantities the resulting correction represents.

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The time at which calibration was performed is not a decorative field. Consider the apparatus in a vehicle which leaves a warm laboratory and is operated outdoors on a cold evening. During the first minutes the reference, converter package and preamplifier can be at different temperatures. A calibration made after thermal equilibrium is achieved may not describe the earlier transient. If the equipment subsequently warms through its own power dissipation, the direction of change can reverse. More importantly, changes in hardware configuration may invalidate an otherwise recent certificate. Replacement of a reference source, movement of a gain jumper, alteration of an analogue filter or loading by a different probe may change the relationship being certified without waiting for the certificate's printed expiry date.

I would insist upon retaining the raw reference readings wherever practicable. Corrected numbers alone do not reveal whether a procedure actually measured the relevant state. The operator should preserve calibration stimulus identifiers, reference certificates, observed levels, repeated measurements, sequence order, temperatures, elapsed settling time, channel identity, coefficients both before and after adjustment, firmware version and any unsuccessful attempts. A failed calibration followed by a successful retry is not necessarily an irrelevant preliminary inconvenience. It may disclose intermittent instability. The time series of coefficients may prove as informative as the values used for final correction, provided one does not interpret a smoothly changing coefficient as proof that the physical device has become fully known.

A defensible report can state that the instrument satisfied specified gain and offset checks at defined test points and environmental conditions. It

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should not leap from that proposition to the assertion that every transient RF observation in the earlier search was generated by an external source. The latter requires separate examination of receiver-generated products, bandwidth, interference, power supply behaviour and the stability of the sampling process. If the laboratory cannot re-establish the historical temperature distribution or the original switch and cable state, it may still report a bounded calibrated result, but that boundary must be printed beside the result rather than hidden in an inaccessible appendix. Professor Bridgman, may I ask you to examine whether the quantity itself has been held constant across the comparison?

Percy Williams Bridgman | Peer question 1 to Edward Weston

Mr Weston, your proposal assigns a decisive place to the reference plane, yet an examiner may choose that plane merely because it is convenient to reach with a test lead. Suppose that a receiver records an amplitude in decibels relative to a nominal input voltage. An internal generator is connected behind a preselector, while the unknown emission was admitted through the antenna port and a temperature-sensitive filter whose insertion loss had not been measured during the acquisition. The analyst subsequently obtains excellent agreement at the internal test plane and labels the result 'calibrated antenna power'. The words now refer to a different operation from that which was actually performed. Would you require the user to define the measurand before choosing the accessible reference plane? And if the intended quantity is not experimentally reachable without disturbing the system, how ought the examiner to distinguish a legitimately modelled correction from a measurement in which the desired quantity was never directly observed?

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Your answer must not simply demand an impossible reference arrangement; it must identify how the proposed interpretation can be tested.

Edward Weston | Immediate answer to Percy Williams Bridgman

Professor Bridgman, I would indeed begin with a description of the intended quantity that permits the proposed operations to be criticised. An antenna-port input level is not identical to an internal ADC-terminal level. The difference can be related through an analogue transfer model, but that relation requires evidence under relevant configurations. I would distinguish three records: the reference source's delivered quantity, the converter's observed indication, and the estimated transformation between the desired outer plane and the accessible inner plane. Each part has its own uncertainty and conditions of validity. If the filter and cable were unmeasured during the original acquisition, a later test may support an interpolation only if the physical configuration and its relevant environmental dependence can be shown to have persisted.

A practicable test need not place an ideal standard at an impossible physical point. It may use calibrated ports, comparison receivers, through-path verification, injected test tones at different accessible nodes, independent attenuation measurements or a sufficiently characterised network model. The critical requirement is that each method disclose which part of the chain it actually interrogates. A correction based solely upon nominal component specifications should be described as a model with assumptions, not as a direct observational calibration. If repeated tests reveal that the filter's loss

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at the event frequency varies appreciably with temperature, the historical antenna-port amplitude may have a range rather than a uniquely recoverable value. The honest expression of that range is not a failure of science; it is its proper consequence.

You also raise the possibility that disturbing the connection changes the quantity. A high-impedance measurement probe may alter loading; inserting an attenuator can change reflection coefficients; removing a protective network can eliminate a source of nonlinearity. I would record the pre-intervention state, identify the intervention, measure its loading effect where possible and compare predictions under alternatives. The report should separate 'the converter indicated this under the retained conditions' from 'the antenna received this much signal'. It should also resist the temptation to multiply a converter-level correction by a nominal path loss without carrying the uncertainty of that path. A single precise figure is not always the scientifically most precise statement. The testing record must support both the number and the words used to describe it.

Charles Proteus Steinmetz | Peer question 2 to Edward Weston

Mr Weston, permit an electrical objection concerning the assumption that the converter input is a simple resistance. In practice an acquisition circuit may contain switched-capacitor loading, frequency-dependent source impedance and a preamplifier whose phase and gain change with temperature. A direct-current gain calibration can return the correct slope while a rapidly changing burst experiences a different settling error. The operator may nonetheless apply that slope to a wideband

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complex-baseband recording. How would your physical reference discipline avoid treating two transfer functions as one? Furthermore, if a maintenance operation replaces the reference regulator but leaves the stored calibration coefficient unchanged, should the operator rely on the previous certificate until its formal expiry, or conduct a state-dependent qualification before the next evidential acquisition? I ask for a testable rule rather than a general exhortation to good maintenance, particularly where an expensive calibration laboratory is not readily available. Please also explain how the field operator could document a repeatable quick-check procedure without replacing a comprehensive laboratory qualification and without concealing the limitations of that more modest examination.

Edward Weston | Immediate answer to Charles Proteus Steinmetz

Mr Steinmetz, the resistance model must be replaced by an appropriate network description as soon as frequency or transient response matters. A code transition measured with a stable low-frequency input cannot be extended to a pulse of finite rise time without considering acquisition bandwidth, settling, aperture characteristics and the signal source impedance. One would use a matrix of tests rather than a single slope: direct-current levels for offset and static gain, sinusoidal stimuli at frequencies of interest for magnitude and phase, and transient or stepped inputs where the measurement claim concerns pulses. The reference plane and loading must be retained for all these tests. Where the entire analogue chain is too complex to characterise in detail, a system-level response test

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may provide an empirically justified operating envelope, but it should not be represented as proof of every underlying component parameter.

Replacement of a reference regulator is a change to a component on which the converter's scale may depend. The document's calendar date does not establish equivalence between two hardware states. The investigator should declare the earlier calibration inapplicable to the changed state until a documented comparison shows that the relevant performance requirements still hold. A limited field verification can be defensible when its scope is explicit: inject a stable reference level, compare two or more amplitudes across the used gain range, inspect relevant frequency bands and document the observed deviations. Such a procedure may establish continued suitability for a defined detection task without pretending to replace a comprehensive laboratory certificate.

The practical rule is to tie each evidence-bearing acquisition to a configuration identity and a declared suitability interval. An interval can end through elapsed time, unacceptable thermal change, component replacement, coefficient adjustment, failed self-test or any event known to alter the measurement relationship. A newly issued certificate need not follow every harmless user-interface adjustment; equally, a material hardware change cannot be absolved by an unexpired certificate. The rule should be risk-based but mechanically auditable: defined triggers, documented comparison, preserved raw readings, authorised decisions and a versioned acceptance record. That approach links metrology to investigative discipline without

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creating an impossible requirement for complete disassembly before every field survey.

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William Thomson, Baron Kelvin | Principal response 2: Temperature, transients and defensible thermal correction

Dr. Atkinson, the measurement of temperature is itself an act of physics, and I should resist any analysis which treats a digital temperature log as an infallible declaration of the entire instrument's thermal condition. An electronic assembly is not a single temperature. Its reference element may be thermally coupled to a regulator, the converter die to a printed circuit board, and the oscillator to an enclosure whose heat capacity differs from both. During warm-up, airflow change or a field excursion, these structures can follow different temperature trajectories. A thermometer fixed to the outside of a case may exhibit a perfectly smooth curve while the reference junction experiences a shorter and larger excursion. Therefore a correction indexed by a case temperature is, without further work, a proxy model. Its merit must be established experimentally over the intended state changes, not inferred from the mere existence of a sensor.

I would begin by defining the physical quantity whose temperature dependence is important. Suppose a converter has a voltage offset b(T), dimensioned in volts, and gain a(T), dimensionless. Around a chosen reference temperature T0 one may write b(T) approximately as b0 plus kb times (T minus T0), where kb has units of volts per kelvin. Similarly a(T) may be approximated by a0 times [1 + kg(T minus T0)], with kg in inverse kelvin. These are first-order local relations; they are not universal laws of semiconductors. The coefficients must be inferred from observations made with controlled references, and a separate residual term must account for curvature, thermal hysteresis, transient lag and measurement noise. It would be invalid to report the numerical result of a linear correction to many

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decimal places while silently ignoring a residual larger than the printed precision.

A calibration series should include temperatures approached from both directions. If the instrument is measured while warming, then allowed to cool and measured again at the same nominal points, disagreement at an identical sensor reading may reveal hysteresis or thermal gradients. It may also reveal time-dependent settling after a gain or clock adjustment. The appropriate experiment should record not only the nominal set point but also the dwell time, the stabilisation criterion, the order of measurements, the input stimulus and the sensor's own uncertainty. A thermal chamber can control its air temperature with impressive accuracy while the instrument under test remains internally unsettled. Thus an equilibrium label requires evidence that the relevant performance quantity has ceased to change beyond the declared tolerance, rather than a fixed waiting interval chosen merely for convenience.

There is a further distinction between correction and prediction. If a study finds that offset moves by a specified number of microvolts per degree under the tested conditions, the relation may permit a correction for observations within those conditions. Predicting the error for an untested temperature or a different rate of warming requires additional assumptions. A good investigator would retain the original values and the correction model separately, with both the temperature observation and its uncertainty. One may then recalculate the result if a later investigation uncovers a more reliable thermal model. Yet the later model cannot recreate the historically unmeasured die temperature from an exterior sensor unless a suitable relation had been established. The mathematical appearance of

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continuity in a fitted curve must not be mistaken for observational continuity in a missing record.

Consider gain drift expressed in parts per million per kelvin. It is tempting to read a typical specification of eight parts per million per degree and multiply by a forty-degree excursion, obtaining three hundred and twenty parts per million. That arithmetic is elementary, but its evidential meaning depends upon what the manufacturer's figure signifies. Is it a typical value, a maximum across temperature, a sample mean, a coefficient fitted over a restricted interval, or a guaranteed limit for each device? Does the gain-drift specification include the reference supply? Is the front-end amplifier included? Was the apparatus in the same gain state? A typical characterisation is valuable for engineering design, but it is not automatically an uncertainty bound applicable to the particular evidence-bearing unit. Its distribution, coverage and relation to environmental conditions must be stated.

Absolute temperature and temperature difference also demand care. An excursion measured in degrees Celsius has the same numerical interval as one measured in kelvins, though the zero points differ. A drift coefficient per kelvin therefore multiplies the same numerical difference in Celsius degrees. But an uncertainty in the sensor's absolute reading is not necessarily identical to uncertainty in a measured difference; common calibration bias can cancel in the latter if the same sensor is used, whereas independent sensors can introduce correlated and differential errors. An analyst who calculates a temperature correction from two readings should preserve which thermometer produced each, its calibration state and the covariance

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of the errors rather than automatically adding all quoted uncertainties in quadrature.

The same apparatus may exhibit ageing. An offset that varies slowly over months may arise from mechanisms distinct from a reversible temperature coefficient. A calibration acquired after a long interval may show a total difference without identifying how much occurred during a particular field operation. A beginning-and-end comparison can bracket a stable interval only if a plausible physical and statistical model supports such interpolation. Even then, an abrupt event between the two checks may escape detection. Time is not merely a second axis on a pretty graph; it represents exposure to stresses, repairs, environmental changes and materials processes whose histories must be recorded. I recommend that the acceptance statement describe exactly which excursions and elapsed intervals were tested, then identify separately the environmental states for which the transfer relation remains an extrapolation. Dr Bardeen, would you examine whether the proposed first-order model can survive the subtler temperature physics of a semiconductor junction? With respect, I now return the floor to Dr. Atkinson for the next contribution.

John Bardeen | Peer question 3 to William Thomson, Baron Kelvin

Lord Kelvin, your treatment recognises temperature as a distributed physical quantity, yet I wonder whether its local linearisation can be defended for a converter whose input transistors, switches and reference circuit change operating region over the required range. A junction's characteristics can depend upon both temperature and bias, and a calibrated offset may interact with input signal amplitude in a way not captured by a single coefficient. A hidden amplifier stage might exhibit a

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temperature-dependent distortion component that is negligible at one calibration level and material near overload. Could your proposed warm-and-cool series be designed to separate thermal hysteresis from amplitude-dependent nonlinearity and ordinary stochastic variability? I am also concerned that a sensor placed near the converter die may fail to represent the reference regulator or an oscillator some distance away. What minimum observations would justify a report stating that a correction belongs to an identifiable physical mechanism rather than merely to an empirical association found in a small laboratory dataset?

William Thomson, Baron Kelvin | Immediate answer to John Bardeen

Dr Bardeen, your objection exposes the limit of the local linear relation rather than refuting its use within a justified neighbourhood. One must distinguish a convenient correction equation from a theory adequate to every state. If the observed response depends upon signal amplitude, let the residual be indexed by x as well as temperature. If different circuit blocks possess distinct temperatures, use a vector of measurements or an explicitly qualified surrogate model. A calibration design could cross several input levels with multiple thermal set points and both warming and cooling trajectories. It should include replicated measurements at randomly or deliberately varied sequence positions, so that the inferred temperature effect cannot be conflated with the passage of time. An apparent dependence that changes when the order of operations is reversed should trigger an investigation, not an automatic enlargement of the fitted curve.

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I would not infer physical causation solely from a regression coefficient, however persuasive its statistical significance appears. The physical hypothesis should predict a distinct response to a controlled intervention. For example, a carefully limited change in reference-supply temperature, while maintaining the converter die close to constant, should affect a reference-drift hypothesis differently from an input-buffer hypothesis. These interventions may not be possible during a field survey, but they may be made in a laboratory with an equivalent apparatus. Where isolation cannot be achieved, the examiner can report a system-level empirical dependence, valid only over tested combinations. That is already useful if the claim is properly bounded.

The design must also include a validation set that was not used to select the model. A polynomial fitted to every measured point can attain small residuals without demonstrating predictive stability in an independent acquisition. Report the distribution of validation errors, including the worst relevant excursions, rather than only the root-mean-square fit to the training observations. Test for saturation, supply variation, input-common-mode dependence and states entered after switching gains. I should also require the data at each temperature, not merely average coefficients, to remain available to a reviewer. When the evidence supports a correction only to a defined input range and thermal trajectory, the expert should say exactly that. Its virtue lies in reducing a known error without pretending to remove all error. It does not follow that an unobserved transient can be reconstructed from the corrected number alone.

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Arthur Edwin Kennelly | Peer question 4 to William Thomson, Baron Kelvin

Lord Kelvin, I ask you to consider an instrument mounted near a transmitting apparatus where the thermal environment and the electromagnetic environment change together. When the transmitter becomes active, local heating rises, supply loading changes, and a weak line appears in the receiver spectrum. An engineer may discover a statistical correlation between the line's amplitude and the case temperature, then apply a thermal correction and conclude that the line was an internally generated artefact. Yet the transmitter's presence could create both the thermal rise and a genuine externally admitted signal. How should the calibration campaign separate common-cause confounding from the proposed thermal mechanism? Specifically, should a report require an intervention that alters temperature without changing the RF environment, another that changes RF exposure while temperature is held stable, or some alternative experiment? Can one fairly use such controlled tests to draw a conclusion about a unique historical event? In particular, what independent observation would contradict the thermal account even if the temperature correlation appeared statistically striking?

William Thomson, Baron Kelvin | Immediate answer to Arthur Edwin Kennelly

Thank you for that question. Professor Kennelly, a correlation between two changing quantities is not sufficient to establish the direction or even the existence of the proposed causal relation. Your example is especially instructive because temperature, supply loading

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and received RF energy may respond to a common operational event. A thermal correction model fitted only while the transmitter is on may absorb part of an external signal as though it were receiver drift. It may be numerically effective in predicting that one dataset while causally mistaken. I would separate the interventions you propose whenever practical. Vary temperature with the RF environment controlled; vary RF exposure at stable thermal conditions; vary supply loading where its direct electrical effect can be distinguished from heating. The resulting data permit competing physical explanations to make divergent predictions.

Such experiments should also test plausible interactions. It may not be enough to add one thermal effect to one radio-frequency effect if a semiconductor's nonlinearity makes their combined influence different from their isolated effects. A modest factorial design can reveal this circumstance. But one should not imagine that a laboratory re-enactment restores every historical detail. Its value is to challenge whether the proposed mechanism could reasonably explain the record and whether alternatives remain observationally equivalent. A successful replication under several controlled conditions can increase confidence in a bounded attribution; it does not turn an unobserved earlier temperature field into an observed one.

For forensic reporting I suggest three levels of conclusion. First, the measured spectral feature changed with the instrument's recorded environmental indicators. Second, independent challenge tests demonstrated that specified internal mechanisms can produce or

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alter a comparable feature under documented conditions. Third, the evidence from the historical acquisition supports or fails to support exclusion of an external emitter. These are distinct propositions, and a report should not pass from the first to the third merely because the plotted curves look alike. State the restrictions, retain the alternative and preserve the data with which another examiner can challenge the inference. The strongest scientific account is often the one that explains exactly which intervention has yet to be performed. The resulting statement should give the experimental temperature interval, the observed environmental covariates and the uncertainty of the correction. It must not imply that a correlation establishes the unique mechanism. Such disclosure permits a reviewer to test the same physical alternatives without first accepting the investigator’s favoured explanation.

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Walter Andrew Shewhart | Principal response 3: Stability, control and the fallacy of a single passing certificate

Dr. Atkinson, I welcome the opportunity to distinguish the measurement of an error at one occasion from the evidence that a process remains stable across occasions. A certificate tells the reader something about a particular performance examination under its stated conditions. It does not guarantee that every subsequent output belongs to the same statistical process. A converter can pass an initial offset and gain test and later experience a change in supply voltage, thermal stress, mechanical shock, ageing or a switch-state defect. Conversely, a converter can show ordinary measurement variation without any material deterioration. The analyst must have a method for distinguishing predictable process variation from a change requiring investigation. Neither the sight of a narrow trace nor the authority of a laboratory signature resolves that distinction by itself.

A repeated check is most useful when it measures the same defined quantity under sufficiently comparable conditions. Choose a stable test input, record the converter's raw indication, temperature, configuration and reference-source identity, and examine a time series of residuals against a predeclared reference. The sequence must preserve chronological order. Averaging several test results into one convenient number may conceal an excursion that occurred during the actual investigation. I would establish a baseline from a demonstrably stable period and distinguish limits derived from process behaviour from limits imposed by the required measurement accuracy. A control chart's warning boundary is not automatically a metrological tolerance, and passing a tolerance is not automatically

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statistical evidence that the process is stable. These are distinct questions which should not be made to answer one another.

Suppose a receiver produces repeated one-volt reference measurements with small scatter, yet its mean indication changes gradually as the enclosure warms. A chart based only upon within-group repeatability may show tight clusters on each occasion while the groups' centres move systematically. The operator might report excellent repeatability if the data are pooled without regard to time. But short-term repeatability does not establish long-term reproducibility. A response measured at one fixed temperature cannot distinguish a process which is well controlled under all anticipated conditions from one whose errors are merely reproducible under the chosen condition. We must structure the validation to include the environmental and configuration states that matter to the intended claim.

I would also caution against recalculating limits every time a troubling observation appears. If the system fails a predeclared rule, the investigator may explore, identify a genuine change in conditions and develop a revised model. But the original failure must remain in the record, and the revised method should be tested on data not used to select it. Repeatedly fitting a new thermal correction until every measured point falls inside a preferred tolerance is an exercise in conformity by construction. It does not show that the correction would work in a subsequent field examination. An independent holdout sequence, run through a different cycle of warming, cooling and gain selection, is one way to examine whether the apparent stability persists beyond the training data.

A particular hazard appears when calibration itself changes the apparatus. Many devices alter stored coefficients during an internal

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procedure. If a failing verification is immediately followed by an adjustment, then the later passing result cannot demonstrate that the earlier field acquisition occurred in the adjusted state. It may establish that the instrument was subsequently brought back into conformity, which is useful maintenance information, but the historical evidence must be interpreted according to the earlier coefficient state. Preserve both states and the transition event. The absence of such a record is not repaired by treating the later certificate as retroactive proof of the earlier measurement's accuracy.

The interval between verification checks should arise from the observed behaviour and the consequence of an undetected failure. A highly stable instrument with ample detection margin may warrant a different interval from a unit operating close to an evidential decision boundary. Yet a longer interval cannot be justified solely by an uneventful service history if the checking procedure was incapable of detecting the relevant fault. In a defensive spectrum survey a simple built-in reference may detect scale drift while missing an intermittent clock spur or thermal intermodulation. A useful surveillance plan therefore uses complementary checks for distinct failure modes. It should preserve negative results and diagnostic flags with the same fidelity as successful verification records.

The concept of a control state must extend to the entire observational practice. Operators change cables, select gain modes, update firmware, move receivers between rooms, and alter automatic threshold algorithms. Each change can shift the population of recorded observations. What appears to be converter drift may be a population change due to different operating conditions or selective retention. The investigator must track configuration and environmental covariates, not merely scatter plot a single

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code against a calendar date. If a control chart excludes invalid observations, the grounds for exclusion should be prespecified and recorded. Otherwise the archive becomes an edited narrative rather than a faithful account of the measurement process.

My proposed quality decision has three parts. First, verify the present instrument against explicitly stated performance requirements. Second, assess whether a sequence of suitable check measurements supports stability over the operational envelope and time interval of interest. Third, define the action when the evidence is indeterminate, including reduced operating claims, additional testing or retention of a qualified result. A laboratory can be very precise at announcing a current measurement and appropriately cautious about claims concerning unseen historical intervals. That caution is no contradiction. It is the correct expression of a process whose behaviour has not been fully observed. Dr Deming, may I invite you to test the responsibility assigned to the operator and the organisation maintaining the system?

W. Edwards Deming | Peer question 5 to Walter Andrew Shewhart

Dr Shewhart, your statistical account is disciplined, but would it become a ritual if the organisation lacks a system for recording failed tests and learning from them? Imagine a laboratory in which an operator receives praise for producing a high proportion of passing checks, while failed checks delay field deployment and are treated as personal defects. Under those incentives, technicians might repeat calibration until it passes, omit earlier results and report only the final certificate. The control chart will then look excellent, while the actual acquisition process remains vulnerable. How should the evidence standard incorporate

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maintenance culture, training, configuration control and the distinction between special-cause response and improvement of the underlying process? Can the reviewer demand a record of unsuccessful checks without converting every minor deviation into an allegation of incompetence, particularly where variation is inevitable and the purpose is to improve defensive investigative reliability rather than to punish operators?

Walter Andrew Shewhart | Immediate answer to W. Edwards Deming

Dr Deming, the statistical method cannot compensate for institutional arrangements that systematically suppress inconvenient observations. A passing series selected from a larger set of undocumented attempts is not the series that a reader believes it to be. It cannot establish the declared false-failure rate or the frequency of state changes because the selection procedure has altered the population. The quality system must therefore make preservation of raw verification events ordinary and expected, not an exceptional confession. It should record a failure, the diagnostic response, the adjustment if any and the subsequent verification as a linked sequence. The purpose is to understand the process and its uncertainty, not to attribute moral fault to the technician who discovers that a device has changed.

Management should distinguish a foreseeable common-cause dispersion from a special event. If daily measurements fluctuate within an established stable range but remain well inside the engineering tolerance, intervention after every excursion may cause

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more instability than it prevents. If a sudden shift follows a firmware update or component replacement, the correct response is to investigate that change, not to conceal it by averaging. A training programme must teach these differences and provide a documented pathway for suspending use when a critical requirement is no longer met. It must also identify who may authorise the return to service and on what empirical basis.

I would urge auditors to evaluate the completeness and comparability of the measurement history. Examine consecutive records, including unsuccessful attempts, and verify that timestamps, configuration identifiers and reference-source metadata permit a coherent sequence to be reconstructed. A well-maintained process may show more recorded failures than a poorly maintained one because it has better detection and reporting. Therefore the raw number of failed checks is an unsuitable ranking of institutional quality without regard to opportunity, severity and corrective action. The goal is reliable prediction and honest evidence, not cosmetic perfection. Finally, separate operating tolerances from retrospective historical claims: when a process is restored after a failure, the restoration is proven at that later time. It cannot make an earlier uncertain acquisition certain by administrative decree. This distinction is consequential when an expert later interprets a near-threshold signal. A well-governed laboratory may admit uncertainty and thereby supply stronger evidence than a laboratory presenting an immaculate but selected history of passing tests.

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Claude Elwood Shannon | Principal response 4: What digital correction cannot recover

Dr. Atkinson, the discussion has thus far centred upon amplitude scale and the persistence of a transfer relationship. I should like to identify the informational boundary within which all correction must work. A digital record contains a finite sequence of values, each determined by the physical acquisition and coding process. A known, sufficiently invertible gain error may be corrected for an appropriately bounded input. But where the acquisition has irreversibly mapped several distinguishable analogue inputs into the same retained output, no subsequent recalibration can determine which of those inputs occurred without additional assumptions or independent observations. This is not a pessimistic view of digital processing. It is the straightforward recognition that a numerical operation cannot create unique knowledge of an unknown variable from data that do not distinguish its possible values.

Suppose a converter has a stable offset of several least-significant-bit increments. If the exact offset is known and the corresponding raw code sequence retains sufficient information, subtracting an appropriate correction can improve an estimate of the input within the model's uncertainty. If, however, the converter saturated during a strong pulse, all inputs above a threshold may have produced the same limiting code. Changing the gain coefficient later cannot restore the clipped amplitude, shape or duration uniquely. Similarly, a missing acquisition block cannot be replaced with actual historical samples by interpolating between its neighbours. An interpolated waveform may be useful for visualisation under an explicit model, but it must never be represented as a recovered

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observation. Such distinctions become legally important where a reconstructed transient is compared with another event or presented as independent evidence of an emitter.

Thermal calibration can legitimately reduce one source of estimation bias while leaving information loss untouched. A gain coefficient fitted from a steady reference does not identify the converter's instantaneous aperture error at the moment of a rare burst. It does not reconstruct a phase trajectory lost to an unlocked oscillator or recover a frequency component rejected by an analogue filter. A correction may make the aggregate spectrum look cleaner while also changing the false-alarm distribution of a detector. If the field search used adaptive thresholds derived from corrected samples, the correction algorithm itself belongs inside the measurement and decision model. The user must preserve its version and state, along with the uncorrected data whenever technically feasible.

There is also an important distinction between knowing a calibration relationship statistically and knowing the actual realised error of a particular sample. An estimated thermal drift coefficient has uncertainty. The true instantaneous temperature at the relevant component may be unobserved. Additive converter noise may be stochastic. In a suitable model one can propagate those uncertainties and obtain a distribution for a corrected estimate. One cannot in general assign every sample a unique perfect inverse. A posterior estimate conditional upon a model and prior assumptions may be useful, but it is a conditional inference. The presentation should explain those assumptions and resist the temptation to label the conditional mean the 'original analogue signal'.

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Digital archives are not passive recipients of samples. Some systems transmit decimated streams or retain only windows that crossed a threshold. Others apply automatic gain control, spectral averaging or event-triggered compression before writing files. When the operating environment changes, the selection policy may also change. A raw file can be cryptographically authentic yet incomplete relative to the period surveyed, because intervals without triggers were never retained. Calibration of the retained samples cannot certify that the unrecorded intervals contained no relevant signals. For a negative finding the investigator needs an exposure account: what time and frequency were actually observed, with which gain and detection thresholds, and what fraction of the nominal recording interval is represented by accessible data.

Consider the claim that two converters possess equivalent calibrated amplitude accuracy. One may have more effective signal bandwidth; another may have fewer clipping episodes under strong adjacent-channel conditions. The same two-point gain verification can pass for both, while their ability to preserve a brief weak emission differs materially. Therefore calibration suitability must be related to the information required for the task. An absolute-amplitude assessment may demand stringent traceability. A search for an intermittent signal may demand additional tests of dead time, spectral occupancy, transient response and false-alarm behaviour. There is no contradiction in finding an instrument acceptable for one proposition and unsuitable for another.

Forensic preservation adds another level. A later calibration record can be connected to earlier evidence only by a credible account of state continuity. The file hash authenticates a byte sequence. The calibration

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record describes a physical comparison. A chain-of-custody account connects people, devices and times. These three must be reconciled before the report can state what happened at the analogue input. If one is absent, the others may still support narrower propositions. A sound report distinguishes the measured digital observation, the estimated analogue quantity and the causal interpretation. It is quite possible to be confident that a digital spectral feature existed in a retained record while remaining uncertain whether it originated outside the receiver.

I would conclude that calibration is a constrained transformation of evidence, not a magical return to a lost past. It adds knowledge through documented measurements of instrument behaviour. It does not erase the physical fact of missing samples, unresolved aliasing, clipping, unmeasured state changes or selective acquisition. Those limitations should guide both the design of the receiver and the wording of the conclusion. Dr Tukey, may I invite your examination of whether adaptive models can be validated without allowing their own selection to conceal the uncertainty they were intended to control?

John Wilder Tukey | Peer question 6 to Claude Elwood Shannon

Dr Shannon, I agree that a digital correction cannot regenerate unobserved information as though it had been recorded, yet exploratory data analysis frequently reveals useful regularities that a rigid initial model missed. Suppose an analyst has several months of temperature logs and periodic converter verification results. A nonlinear model fitted after seeing these data explains much of the apparent drift and reduces the residual scatter. Is it legitimate to apply that model retrospectively to previously collected surveillance records? If so, what prevents the analyst

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from selecting a flexible curve that simply absorbs every inconvenient deviation? I ask especially about the distinction between fitting and testing, the handling of missing environmental observations, the reporting of intervals outside the calibration range, and the preservation of competing simpler models. How could a tribunal or independent scientific examiner tell whether the revised model generated genuinely new knowledge or merely produced an attractive corrected plot?

Claude Elwood Shannon | Immediate answer to John Wilder Tukey

Thank you for that question. Dr Tukey, exploratory analysis may discover relationships that deserve serious testing. The error occurs not in fitting a novel model but in treating the data used to invent the model as independent confirmation of its predictions. The revised model should be described with its selection history, explanatory variables, assumptions and domain of applicability. Independent validation might use later measurements not available during construction, a withheld subset that preserves the structure of thermal cycles, or new controlled interventions chosen to differentiate the model from plausible alternatives. Randomly withholding individual adjacent samples from a strongly autocorrelated thermal trace is an inadequate substitute for withholding whole independent cycles.

I would also examine whether the model permits a uniquely defensible correction. Several flexible functions may fit the calibration observations equally well while making different predictions between unmeasured points or beyond the observed range. Their

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disagreement is evidence of model uncertainty and should enter the reported interval. A result should not be given the narrow error bar of the best-fitting model when model selection was itself materially uncertain. Missing temperature data are not zeros; they are missing observations. Their reconstruction through interpolation or other methods must be labelled as inference and challenged against the thermal time constants of the physical assembly. A model that requires an unrecorded die temperature cannot be described as experimentally verified merely because the computer supplies a smooth estimate.

In disclosure I would retain the original file, the correction software, its parameters, the dataset used for fitting, the validation results and the alternatives considered. The corrected estimate should be compared with the uncorrected observation under consistent reference planes. If the model changes whether a threshold is crossed, that sensitivity is central to the evidential interpretation. An attractive plot can be useful as an explanatory visualisation, but it should not suppress the failure cases and residual structure that permit genuine criticism. A tribunal can then see what was measured, what was inferred and which assumptions cause the result to change. That is a more valuable application of computation than an apparent precision unsupported by the experiment. Preservation of unsuccessful model trials is especially important because the degree of improvement may otherwise be exaggerated by repeated selection against the same observations. The validation procedure must describe the opportunities for such selection.

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Harry Nyquist | Principal response 5: Calibration of time and sampling state

Dr. Atkinson, amplitude correction has occupied much of our discussion, yet a sampled measurement is also an assignment of analogue events to a temporal lattice. A converter which reports the correct voltage when stimulated slowly can nevertheless misrepresent the time of a transient if its clock frequency, aperture position or synchronisation state differs from the assumed values. In a wideband monitoring system these errors can alter the interpretation of repetition rate, pulse coincidence, frequency offset and bearing estimates derived from time differences. The calibration of a sampling instrument must therefore declare which temporal quantities are being asserted and how the relevant clock relationships are observed, maintained and challenged.

A nominal sampling rate f_s expresses an intended number of samples per second. If the actual rate is f_s(1+epsilon), where epsilon is a fractional frequency error, an index difference of N samples corresponds to a true elapsed time N/[f_s(1+epsilon)], not simply N/f_s. For sufficiently small epsilon the timing error accumulated over an elapsed interval tau is approximately epsilon times tau. This effect may be tiny for short records and material for long observations or comparisons with an independent time source. A calibration of amplitude gain does not determine epsilon. Nor does a spectrum showing a strong stable tone necessarily prove that all timestamps are correctly aligned to civil time, since the frequency reference and timestamp reference can be distinct and can experience separate interruptions.

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The aperture itself has a temporal uncertainty distinct from average sample-rate error. Random sampling jitter introduces input-dependent conversion noise, with sensitivity increasing with signal frequency and amplitude slope. A timing comparison using a low-frequency reference may therefore miss a limitation that becomes material near the upper edge of the admitted band. A converter's impressive static gain and offset figures tell us little about that phenomenon. Tests should use frequencies and signal amplitudes appropriate to the intended observation, with reference-source phase noise and measurement noise separately assessed. If the input stimulus contributes significant jitter, the apparent converter limitation may in fact be a property of the test arrangement.

One must also remember that a software-defined radio commonly changes clock-related states. The local oscillator may retune, the converter may select a different clock divider, a phase-locked loop may lose and regain lock, or a host may discard buffers during transfer. Each state transition can create intervals whose sample indices are not reliably connected by the nominal rate. Writing a continuous file with consecutive sample numbers does not by itself establish continuous physical acquisition. A reliable receiver should retain discontinuity flags, lock-state indicators, hardware timestamps or suitably qualified timing anchors. A later clock calibration cannot fill the samples that failed to arrive or retroactively restore the exact phase relation across a documented loss of lock.

For simultaneous multi-receiver observations, common reference distribution has advantages and dangers. A shared frequency source may reduce relative clock drift, but it also introduces a common-mode dependency. Agreement between two branches is not independent

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confirmation that the shared reference was correct. Independent comparison to a reference of known uncertainty may be required for an absolute claim. Conversely, two genuinely independent oscillators may drift relative to one another, and a fusion algorithm must estimate that difference rather than interpreting it as a physical delay. The analyst should identify which timing facts are measured independently, which are inherited from a common source, and which are assigned by software convention.

A field survey sometimes requires only coarse time order: one event occurred before another within a broad interval. In that case a small fractional clock error may be immaterial. But a claim that two microsecond pulses originated from a common emitter because they arrived within a few samples demands far more. The relevance of calibration is proportional to the decision the investigator intends to make. A system should not be rejected for failing an irrelevant nanosecond requirement, nor accepted for a nanosecond claim because it passed a one-second timestamp test. As with amplitude, uncertainty must be expressed in units meaningful to the measurand and over the actual observation interval.

I would close by asking that the receiver's state history be treated as part of the evidence. Record the actual reference source, nominal and measured sample rates, calibration epochs, oscillator lock events, power interruptions, gain states, clock-source switching and known transport gaps. A mathematically elegant correction applied to a file whose timebase history is unknowable does not make its timebase historically certain. The available record may still support useful bounded comparisons, and one should make them where justified. But a specific frequency, delay or coincidence estimate should carry the uncertainty of the temporal lattice that gave it meaning.

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Professor Neyman, may I invite your question concerning how many passing tests are enough to assert a clock remained within specification throughout an unobserved field interval? One further issue is the interface between hardware time and software time. A host operating system may stamp the arrival of a buffer rather than the aperture of its first sample. Variable bus latency, queueing, scheduler interruption or asynchronous disk access can shift that timestamp without altering any analogue sample. Comparing host timestamps against a reference may therefore measure transport behaviour instead of the converter clock. An appropriate test should identify where timestamps originate, whether they are tied to hardware sample counters, and whether correction coefficients remain valid through retuning and power-state transitions. A single clock-frequency check cannot resolve that architecture. The evidence must document which time reference was actually measured and which was merely assumed. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Jerzy Neyman | Peer question 7 to Harry Nyquist

Dr Nyquist, your description suggests a distinction between a tested rate and a claim about all rates during an extended operation. Suppose an instrument passes three clock comparisons before deployment and three after return, yet the search lasted many hours and the system intermittently lost its lock indicator. The engineer wishes to state that the timing error remained below a tolerance at every moment because no endpoint check exceeded it. What probability statement, if any, can legitimately support that claim? A binomial model of independent checks seems plainly inappropriate if the error process is temporally correlated and the most hazardous intervals are precisely those in which records

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are missing. How should an acceptance programme choose its checks, model its dependencies and communicate a bounded assurance without claiming that observations at a few endpoints prove the entire intervening trajectory? I would also ask how the investigator should treat a calibration schedule chosen after reviewing the error history, since the resulting nominal coverage may no longer possess its advertised frequency properties under the original experimental design. The choice itself can be a form of selection.

Harry Nyquist | Immediate answer to Jerzy Neyman

Professor Neyman, I would reject the universal claim unless the physical apparatus and observation system supplied a justified bound on what could occur between checks. Endpoint agreement constrains the instrument at the times measured. It does not demonstrate the absence of a transient loss of lock or an excursion which subsequently recovered. A stochastic model may assign probabilities to such events, but those probabilities depend upon the assumed process and on records adequate to estimate its behaviour. If missing intervals are disproportionately associated with failures, treating observed passing checks as a random sample will give a misleadingly reassuring result. The selection mechanism must be investigated rather than hidden inside a nominal confidence interval.

A better programme combines continuous or sufficiently frequent state monitoring with controlled challenges of the clock system. Log reference-lock status, power interruptions, operating temperature and buffer-discontinuity events; compare hardware timestamps to a suitable independent reference; and test what happens when the

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oscillator loses lock or a reference cable is disturbed. Where continuous observation is impossible, report the duration and consequences of the gaps and identify the maximum intervals for which the evidence supports a bounded timing claim. A verified pre- and post-test may still reduce uncertainty about long-term drift, but it cannot eliminate uncertainty about unobserved transients without a defensible process model.

Any statistical statement should name its reference class. The probability that a given check passes under a stable test regime differs from the probability that every instant of a novel field deployment was acceptable. A confidence bound for a Bernoulli detection process is not a bound on the supremum of an unobserved continuous-time clock error unless a model connects them. In the absence of such a model, the correct report may say that all performed checks passed, that certain intervals were covered by continuous lock monitoring, and that remaining intervals have an unresolved timing qualification. Such specificity is more informative than an unsupported assertion of complete stability. It also permits future instrument design to address the actual evidential weakness by measuring what the investigation needs to know. The final report should therefore specify not only an observed error bound but its observation opportunities, invalid intervals and the statistical assumptions by which any extension beyond those opportunities was made. A check conducted after a failure is not equivalent to a check randomly scheduled before the failure was suspected.

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Ten worked technical applications | Mathematical and forensic validation

Edward Weston, Cross-Peer Question to William Thomson, Baron Kelvin: Lord Kelvin, a field receiver is calibrated at 25 degrees Celsius and used at 50 degrees. When is it appropriate to apply a simple temperature coefficient to its indicated voltage?

William Thomson, Baron Kelvin, Cross-Peer Answer to Edward Weston: Mr Weston, only after the coefficient has been established over the relevant instrument, temperature span, measurement range and thermal history. A first-order correction, Delta V = k Delta T, is an explicit approximation and may fail across power-up transients, ageing, humidity, differential component temperatures or gain-mode changes. Record temperature at the converter, reference source, analogue front end and clock rather than treating ambient air as the single state variable. Include coefficient uncertainty and the uncertainty in temperature measurement. An acceptance campaign ought to cycle upward and downward through the working range, including thermal soak and repeated return to the reference temperature, so hysteresis becomes visible. Report what was measured at the instrument input, rather than equating a software-corrected output with the physical input uncritically. I pass the token to Dr Shewhart for stability controls.

William Thomson, Baron Kelvin, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, a calibration certificate states that the instrument met tolerance last month. What additional evidence is required before one claims the same tolerance during an overnight RF recording?

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Walter Andrew Shewhart, Cross-Peer Answer to William Thomson, Baron Kelvin: Lord Kelvin, a certificate provides evidence for the stated conditions and date, not immunity from intervening instability. Use independent check standards before and after the acquisition, with recorded gain, reference voltage, temperature, firmware, clock configuration and elapsed operating time. Establish a control chart for each material measurand and investigate excursions rather than changing limits after inspecting the results. Distinguish short-term repeatability, drift, thermal cycling and a discontinuous fault. A pre-and-post check may bound certain changes without identifying precisely when they occurred; a continuous monitor may be needed to assign time locally. If the system lost power or changed operating mode, create a separate record segment rather than treating the entire night as one homogeneous calibration state. I pass the token to Dr Shannon regarding correction of what was actually sampled.

Walter Andrew Shewhart, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, should digitally removing a measured offset and gain error be described as restoring the historical analogue waveform if the converter clipped during the hot operating condition?

Claude Elwood Shannon, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, a calibrated affine correction can recover a useful estimate inside the unsaturated and characterised transfer region. Once the ADC clips, a range of different analogue inputs maps to the same limiting code. Subtracting an offset from those codes cannot recreate the missing amplitude history. Nor does a measured static gain correction independently resolve temperature-dependent nonlinearity, phase response, intermittent reference drift or timing error. Preserve both raw

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codes and correction coefficients, including the date and applicable state of each coefficient; record saturated samples explicitly rather than smoothing them away. A blind injected waveform at the worst anticipated temperature can demonstrate where the correction remains valid, while negative controls expose software-induced regularities. I yield respectfully to Dr Nyquist on clock-related calibration.

Claude Elwood Shannon, Cross-Peer Question to Harry Nyquist: Dr Nyquist, can a sample count and a nominal 100 MHz clock establish an event timestamp to microsecond accuracy over twelve hours without independent oscillator evidence?

Harry Nyquist, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, not by themselves. If the clock has constant fractional frequency error epsilon, an elapsed time T acquires a first-order scale error approximately epsilon T; a 1 ppm frequency offset corresponds to roughly 43.2 milliseconds in twelve hours, far beyond a microsecond. Real clocks can have temperature drift and wander, so a single constant-error correction may not fit. Document oscillator traceability, timestamp origin, synchronisation events, counter rollover, missing blocks, buffer loss and clock resets. Cross-check periodic reference markers at the input and compare the sample lattice to an independently timed source. Absolute UTC timestamp validity is a separate claim from relative sample spacing. Every correction must carry its uncertainty and method. I respectfully pass the token back to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Distinguished colleagues, the discussion has established that calibration is a set of bounded empirical relations, not an all-purpose declaration of

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trustworthiness. Mr Weston's insistence upon the physical reference plane prevents the apparently modest but consequential substitution of converter-terminal performance for the performance of an entire receiver front end. Lord Kelvin's thermal account demonstrates why an enclosure-temperature reading is not necessarily the temperature governing every electronic error, and why a correction curve fitted during controlled equilibrium cannot simply be projected across a changing historical environment. Dr Shewhart has shown that a sequence of passing certificates is not the same as evidence of continuing statistical stability, particularly where maintenance, selection and intervention change the population of observations. Dr Shannon has preserved the distinction between correcting a known transfer relationship and manufacturing information no longer present in the retained record. Dr Nyquist has supplied the necessary temporal counterpart: a voltage can be measured accurately while its assigned time or phase relation remains uncertain.

The panel's first finding is therefore definitional. Every substantive accuracy claim must state the measurand, reference plane, stimulus class, time interval, environmental range and configuration state. The word 'calibrated' should never stand alone as the complete evidential predicate. In a receiver investigation, a calibration may establish a voltage-scale comparison at the ADC input but not an antenna-port power estimate; a sampling-rate comparison but not absolute timestamp accuracy; or a static offset correction but not transient waveform fidelity. Such statements are not pedantic restrictions. They identify the physical observations which entitle the investigator to connect a number on a screen to the event being investigated.

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Second, a temperature coefficient should be treated as a conditional measurement model. A local slope in microvolts per kelvin or parts per million per kelvin may be useful within an experimentally supported range. It does not prove monotonicity, linearity, thermal uniformity or stability across the instrument's life. Where the same sensor records both calibration and field observations, common errors may partially cancel in a temperature difference, yet an imperfect relation between sensor and semiconductor remains. A scientific report should state whether the correction was measured under comparable thermal trajectories, whether intermediate temperatures were validated, and whether an unobserved excursion could have crossed an evidential threshold. Precision in numerical arithmetic does not remove uncertainty in the model from which the arithmetic was derived.

Third, the organisation's evidence-preservation system belongs inside the theory of measurement. An original file hash helps establish the identity of retained bytes; it does not establish the validity of the analogue input inference. A configuration register shows which settings were commanded; it does not prove every physical component responded as intended. A later laboratory calibration can demonstrate present performance; it does not retroactively certify a field recording made before a hardware change. The investigator should preserve raw and corrected samples, calibration coefficients, failed checks, sensor readings, reference-source identities, firmware versions and the specific events by which an operational state changes. Independent reviewers must be able to retrace the correction as well as challenge its legitimacy.

Fourth, the choice of acceptance criterion must follow the claim. An instrument used to identify the presence of intermittent energy may require

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reliable observation coverage, overload monitoring and bounded false-alarm behaviour. A claim about absolute amplitude needs a traceable amplitude chain and a meaningful uncertainty budget. A claim about phase or time coincidence needs a clock history, jitter characterisation and evidence concerning acquisition gaps. There is no useful universal answer to the question whether a converter is simply 'accurate enough'. An answer without a declared task, tolerance and operating envelope is a slogan, not a scientific finding.

The ten hypothetical calculations illustrate the distinction. Their equations and numbers can be checked, yet every result remains conditional upon assumed coefficients, reference planes, covariance relationships and time-state continuity. A computed 280 parts per million of gain drift has meaning only if the coefficient belongs to the relevant chain. A 0.450-millivolt interpolated correction is an estimate, not a recovered reading from an unmeasured moment. A 3.60-millisecond clock discrepancy matters only in relation to the temporal proposition to be tested. Statistical and mathematical rigour requires these qualifications to remain visible beside the result.

The panel retains several unresolved matters. A unique historical thermal field may be unknowable. A short sequence of passing verification tests may not exclude a transient failure between tests. An impressive reduction in fit residuals may result from model selection rather than improved predictive validity. And a receiver-generated line may remain observationally equivalent to an external emission under the limited tests available. These limits do not require abandoning measurement. They require designing

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experiments whose competing explanations make different predictions and stating which propositions survive the challenges actually performed.

Our production rule shall accordingly be to preserve the past state, verify the present state, disclose the interval between them and refuse to substitute one for another. With this discipline we may place evidence from different receivers into a coherent scientific account without promising certainty that the record cannot supply. The next question shall consider the conditions under which a carefully chosen sampling band may be translated into a different frequency representation without losing the ability to distinguish the true source from an alias. Dr Nyquist, and the colleagues who have challenged these conclusions, I thank you for passing the discussion with its uncertainties intact.

Biographical verification: https://www.theiet.org/membership/library-and-archives/the-iet-archives/biographies/lord-kelvin-1824-1907. Historical facts are separated from the modern, fictional engineering dialogue.

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Ten worked engineering applications | Question 030

Application 1. Temperature-driven offset change

A hypothetical converter has an empirically verified offset-drift coefficient k_b = 1.6 microvolts per kelvin over the temperature interval relevant to a particular configuration. Its initial temperature is T_0 = 25 degrees Celsius and the later temperature is T_1 = 50 degrees Celsius. Define $\Delta T = T_1 - T_0$ = 25 kelvins. Under the explicitly assumed local linear model, the predicted offset change is $\Delta b = k_b \Delta T$ = (1.6 microvolts/kelvin)(25 kelvins) = 40 microvolts. Relative to a stated 1.0-volt input range, the change is 40 parts per million of that range. This is a predicted change, not a proof of the converter's actual state at every intermediate moment. If the 1.6 microvolt coefficient was merely a typical component value, the computed 40 microvolts is an engineering illustration, not an empirically validated uncertainty bound. A forensic comparison would retain the observed offset at the relevant temperature and disclose whether the sensor tracked the die or an external surrogate.

Application 2. Gain drift and reference-plane voltage

Assume a dimensionless gain coefficient k_g = 8 parts per million per kelvin, a temperature excursion of ΔT = 35 kelvins, and an input V = 2.000 volts at the calibrated reference plane. First compute the fractional gain change: $\Delta a/a = (8 \times 10^{-6}$ per kelvin)(35 kelvins) = 280×10^{-6}. The equivalent voltage-scale change is $\Delta V = V(\Delta a/a)$ = (2.000 volts)(0.000280) = 0.000560 volts, or 560 microvolts. The model predicts 280 ppm relative gain change. It does not say whether the physical cause is converter gain, reference voltage, or an amplifier outside the

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converter. Nor does it establish that 2.000 volts was applied at the correct plane during the historical investigation. A correction is appropriate only if the coefficient describes the chain, state and temperature trajectory actually being interpreted.

Application 3. Combined offset and gain changes

For a hypothetical 0.200-volt input, assume a relative gain coefficient of 12 ppm per kelvin, an offset coefficient of 2 microvolts per kelvin, and DeltaT = 30 kelvins. The fractional gain change is (12 x 10^-6)(30) = 360 ppm. The gain-related output change is (0.200 volt)(360 x 10^-6) = 72 microvolts. The offset contribution is (2 microvolts/kelvin)(30 kelvins) = 60 microvolts. Under a linear additive model and with no other effects, the total change is 132 microvolts and the later indicated equivalent is 0.200132 volt. These terms have different physical meanings: offset is present even for zero input, whereas gain error scales with input. Testing at only one nonzero amplitude cannot in general separate them. A two-point or multi-point comparison is therefore needed before claiming that the change is uniquely attributable to one coefficient.

Application 4. Reference-source thermal drift

Suppose the conversion scale depends upon a 2.000-volt reference whose assumed relative coefficient is k_r = 4 ppm per kelvin, and the reference itself experiences a 40-kelvin rise. The predicted relative reference change is (4 ppm/kelvin)(40 kelvins) = 160 ppm, equivalent to 0.000160 as a fraction. The absolute reference shift is (2.000 volts)(0.000160) = 0.000320 volt, or 320 microvolts. In many ADC transfer models an increased reference can change the indicated code for a fixed

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input in the opposite direction from an increased analogue gain; the sign must be derived from the actual transfer equation. Consequently a magnitude calculation alone should not be entered as a signed correction. The examiner should document whether the measured drift figure belongs to the internal reference, an external standard, or a composite converter-system coefficient.

Application 5. Uncertainty from temperature sensing

Assume the output estimate is approximately proportional to gain, with input V = 1.500 volts and local gain coefficient $k_g = 8 \times 10^{-6}$ per kelvin. A temperature sensor has standard uncertainty u(T) = 0.4 kelvin. The first-order sensitivity of the indicated voltage to temperature is $c_T = V k_g$ = (1.500 volts)(8 x 10^-6 per kelvin) = 12 microvolts per kelvin. The standard uncertainty contributed by temperature sensing is $u_T(V) = |c_T| u(T)$ = (12 microvolts/kelvin)(0.4 kelvin) = 4.8 microvolts. This is only one uncertainty term. It excludes error in k_g, residual curvature, uncertainty about whether the sensor represents the relevant component, and covariance with reference drift. If an analyst quotes 4.8 microvolts as the total calibration uncertainty, the omitted terms may make the report misleadingly precise.

Application 6. Covariance of gain and reference uncertainty

Let two relative standard uncertainties be u_1 = 20 ppm and u_2 = 15 ppm, with correlation coefficient rho = +0.6. For a model in which the two contributions enter with the same signed sensitivity, the combined relative variance is $u_c^2 = u_1^2 + u_2^2 + 2 \rho u_1 u_2$. Substitution gives 400 + 225 + 2(0.6)(20)(15) = 985 ppm squared. Hence u_c = sqrt(985)

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ppm = approximately 31.38 ppm. If the terms were independent the result would be sqrt(400+225) = 25 ppm. Their shared physical reference makes the independent treatment inappropriate under the stipulated correlation. Conversely a model in which one coefficient enters with the opposite sign changes the covariance term's sign. Covariance is therefore a property of the actual measurement equation and joint evidence, not a decorative general uncertainty allowance.

Application 7. Sample-clock frequency error over an observation

Suppose the actual clock frequency is f_actual = f_nominal(1 + epsilon), with positive fractional frequency error epsilon = 2 x 10^-6. Let tau_nominal = 1,800 seconds be the elapsed duration inferred by dividing the retained sample count by the nominal sample rate. The corresponding actual duration is tau_actual = tau_nominal/(1+epsilon) = approximately 1,799.9964000072 seconds. The nominal timing calculation therefore overstates elapsed time by approximately 0.003599993 second, or 3.60 milliseconds. The common small-error approximation epsilon tau = (2 x 10^-6)(1,800 seconds) gives the same result at this precision. This calculation assumes a constant fractional error and no missing samples. If the oscillator lost lock or buffers were dropped, a constant-rate model cannot bound the historical gap without additional observations.

Application 8. Expanded uncertainty and a stated acceptance threshold

Consider a hypothetical corrected residual error e = 3.800 millivolts. Suppose two independent standard uncertainty components are u_1 =

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0.200 millivolt and u_2 = 0.400 millivolt. Under the independent model, the combined standard uncertainty is u_c = sqrt(0.200^2 + 0.400^2) millivolt = sqrt(0.20) millivolt, approximately 0.4472 millivolt. For a stipulated coverage factor k = 2, the illustrative expanded uncertainty is U = 2u_c = 0.8944 millivolt. If a predeclared symmetric residual limit is 5.000 millivolts, a conservative acceptance rule requiring |e| + U <= 5.000 yields 3.800 + 0.8944 = 4.6944 millivolts, inside the limit. This acceptance is conditional upon the stipulated uncertainty model and decision rule. A different coverage interpretation, significant model bias or a larger drift contribution may change the conclusion. Passing one residual rule does not certify every converter specification.

Application 9. Interpolation of measured thermal correction

Assume a calibration sequence has measured an offset correction of 0.000 millivolt at 20 degrees Celsius and +0.900 millivolt at 50 degrees Celsius, for the same configuration and input test. The line joining those points has slope k = (0.900 - 0.000)/(50 - 20) = 0.030 millivolt per degree Celsius. At 35 degrees Celsius, linear interpolation predicts 0.000 + (35 - 20)(0.030) = +0.450 millivolt. The arithmetic is determinate; the uncertainty of the prediction is not. Validation measurements at intermediate temperatures, repeated heating and cooling cycles, sensor uncertainty and a check for hysteresis are needed before the line can be described as a reliable correction model. An interpolated value can be an estimate even where an unmeasured transient or nonlinear segment makes its historical accuracy doubtful.

Application 10. Clock scale over a longer exposure

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For a distinct case, suppose a nominally continuous acquisition lasts tau = 7,200 seconds according to the receiver's nominal clock, and the actual clock differs by a constant positive fractional error epsilon = 1 x 10^-6. The first-order timing discrepancy is epsilon tau = (1 x 10^-6)(7,200 seconds) = 0.0072 second, or 7.2 milliseconds. The exact discrepancy in the stated positive-error model is tau - tau/(1+epsilon), approximately 7.1999928 milliseconds. If the issue concerns whether two events coincide within one second, this error may be immaterial; if the issue concerns the phase alignment of microsecond transients across independent receivers, it may be decisive. The tolerance must therefore come from the inferential task, not from an impressive clock specification detached from the question being asked.

Source register and scope of inspection

1. IEEE, *IEEE 1241-2023: Standard for Terminology and Test Methods for Analog-to-Digital Converters*. Official IEEE Standards Association public abstract, https://standards.ieee.org/ieee/1241/6797/. Scope actually inspected: public standard description and the standard's stated coverage of ADC test terminology. The complete paywalled normative text was not consulted, and no invented clause or table number is attributed to it.

2. NIST, *Metrological Traceability: Frequently Asked Questions and NIST Policy*, https://www.nist.gov/metrology/metrological-traceability. Scope actually inspected: the public discussion that traceability pertains to a measurement result and requires a documented unbroken calibration chain, with uncertainty and measurement assurance. It does not certify any particular receiver used in the hypothetical examples.

3. NIST, *Technical Note 1297, Appendix A: Law of Propagation of Uncertainty*, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty. Scope actually inspected: publicly accessible first-order sensitivity coefficients, covariance terms and mean-estimate uncertainty

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expressions. The numerical examples in this chapter are newly constructed, not copied from a NIST test.

4. Analog Devices, *The ABCs of Analog to Digital Converters: How ADC Errors Affect System Performance*, https://www.analog.com/en/resources/technical-articles/the-abcs-of-analog-to-digital-converters-how-adc-errors-affect-system-performance.html. Scope actually inspected: public article discussion of offset and gain drift, one-time and temperature-triggered calibration, and the effect of moving away from the initial calibration temperature.

5. Analog Devices, *AN-1377: Gain and Offset Temperature Drift Compensation for the AD7403/AD7405*, https://www.analog.com/en/resources/app-notes/an-1377.html. Scope actually inspected: application-note web text on fitted thermal coefficients, offset and gain compensation and the limitations of simple calibration. The study concerns particular converter families and is not treated as a universal guaranteed drift specification.

6. Analog Devices, *AN-1464: Calibration of AD717x and AD7124 Precision ADC Devices*, https://www.analog.com/en/resources/app-notes/an-1464.html. Scope actually inspected: public description of initial calibration, changes of gain or configuration, internal versus system calibration and possible periodic recalibration. Applicability to an arbitrary SDR is not presumed.

7. Analog Devices, *AN-835: Understanding High Speed ADC Testing and Evaluation*, https://www.analog.com/en/resources/app-notes/an-835.html. Scope actually inspected: publicly available testing terminology and temperature-drift descriptions for high-speed converters; no complete compliance test of a named modern receiver is claimed.

8. Analog Devices, *AN-501: Aperture Uncertainty and ADC System Performance*, https://www.analog.com/media/en/technical-documentation/application-notes/an-501.pdf. Scope actually inspected: search-extracted public technical equation and explanatory passage relating aperture uncertainty, input frequency and jitter-limited signal-to-noise ratio. Original PDF page images were not independently examined for this question, and no original figure is reproduced.

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9. Institution of Engineering and Technology, *Lord Kelvin 1824-1907*, https://www.theiet.org/membership/library-and-archives/the-iet-archives/biographies/lord-kelvin-1824-1907. Scope actually inspected: public biographical chronology and description of contributions to temperature and electrical instrumentation.

10. Royal Society, *William Thomson (1824-1907) archival person record*, https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA8289&pos=1&src=CalmView.Persons. Scope actually inspected: public dates, professional activity and research fields.

11. W. Edwards Deming Institute, *About Dr. Deming*, https://deming.org/learn/about-dr-deming/. Scope actually inspected: public biographical account, career and statistical/management contributions.

12. National Inventors Hall of Fame, *Charles Proteus Steinmetz*, https://www.invent.org/inductees/charles-proteus-steinmetz. Scope actually inspected: public chronology and contributions to AC theory and electrical engineering.

13. Scientific Working Group on Digital Evidence, *Best Practices for Digital Evidence Collection*, https://www.swgde.org/documents/published-complete-listing/18-f-002-best-practices-for-digital-evidence-collection/. Scope actually inspected: public discussion of hashing, contemporaneous documentation and chain-of-custody requirements. The principles are applied as a general analogy to preserved receiver files; this document is not represented as an ADC calibration standard.

Editorial qualification: All historical speech is constructed for teaching and is not a historical record. All numerical values in the ten examples are explicitly hypothetical, their calculations are independently checked, and none establishes the performance of a real instrument.

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QUESTION 031

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When is bandpass sampling safe, and what must the analogue filter guarantee?

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Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 031 asks: When is bandpass sampling safe, and what must the analogue filter guarantee? A receiver screen may present a luminous ridge or a tidy numerical column, yet the instrument has performed a particular physical operation rather than delivered a self-explanatory verdict. The proposition under investigation is the conditions for safe bandpass sampling and the analogue filtering it presupposes. Our primary observation is folded sampled spectra of an intentionally isolated higher-frequency band; by contrast, what remains unseen is other radio-frequency bands which could alias into exactly the same digital interval. Those objects occupy different places in an evidential chain. We must not allow a numerical result to migrate from one reference plane to another without an explanatory transfer function and its uncertainty. This roundtable therefore examines what the instrument could establish, what it could not, and which additional experiment would discriminate between material alternatives.

Bandpass aliases require analogue exclusion of competing zones. Bandpass sampling intentionally permits an RF interval to map into a lower digital frequency interval. For a real converter sampled at 40 megasamples

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per second, tones at 90 and 100 megahertz map, by simple folding, to 10 and 20 megahertz, but so do other RF tones in different alias zones. The mapping does not identify the source band uniquely. An analogue preselector must reject those alternative zones sufficiently to make the particular desired interpretation defensible, taking account of filter tolerance and strong blockers. Check both band edges for alias orientation and for coincidence with the Nyquist boundaries; the nominal 100-megahertz edge here lies exactly at a folding boundary and is unsuitable without guard-band analysis. A swept blocker test outside the desired passband is more probative than the sample-rate specification by itself. The reconstructed panel shall test this particular proposition rather than rest on a generic contrast between an observed spectral peak and an imagined emitter. The experiment must be described with enough information to reveal when the inference would fail.

The estimand in this discussion concerns folded sampled spectra of an intentionally isolated higher-frequency band; it is not interchangeable with other radio-frequency bands which could alias into exactly the same digital interval. We shall require an instrument-side prediction for each proposed explanation before assigning a source. The controlling measurement is a swept blocker map across all relevant Nyquist zones with measured analogue stop-band rejection. A claim drawn from that comparison has to carry its actual uncertainties: RF passband edges, sampling frequency, alias-zone parity, filter transition width, and required blocker rejection. Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. An input band can fold into a lower sampled interval with reversal of spectral order according to Nyquist-zone

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parity. An undersampling receiver must have analogue input bandwidth sufficient to pass the desired RF band before conversion. Where competing paths remain observationally indistinguishable, the proper result is a bounded class of explanations rather than a narrative of certainty. A quantitative result must identify the physical reference plane, bandwidth and operating state in the particular experiment, and the preserved observations must be sufficiently complete for an independent laboratory to reach the same conditional finding.

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Harry Nyquist | Principal contribution 1: Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas.

Bandpass sampling can be entirely sound when the analogue passband occupies an unambiguous sampling zone and the converter's actual sample rate is known. The decisive condition is not that the RF centre frequency lies below half the sample rate; it is that the admitted band and all materially strong unwanted bands map without harmful overlap into the chosen digital interval. I would write out the aliases of both band edges and test possible spectral inversion before building the receiver. Guard bands must allow for filter transition width, clock tolerance and frequency drift. A preselector specified by its nominal three-decibel bandwidth will not establish that an adjacent Nyquist zone is sufficiently suppressed. The analogue filter's stopband must be measured at the powers that the receiver will encounter, particularly where its rejection protects a weak signal from a strong unrelated service. A correct alias equation does not identify which of several potential RF inputs supplied the recorded digital component.

In this physical path examination of Question 031, the decisive claim is that bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. Bandpass sampling intentionally permits a narrow RF band above the first Nyquist interval to fold into a lower sampled frequency range. This is mathematically legitimate only when the complete analogue occupied spectrum and the sampling zone are controlled. Adjacent RF bands may fold to the same digital frequencies, often with reversed spectral orientation; thus a clean digital trace cannot certify that the desired physical band was the only contributor.

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A measured, sufficiently selective analogue filter is part of the sampling theorem's practical implementation, not an optional accessory to digital reconstruction. A useful falsification proceeds from the actual controversy: bandpass aliases require analogue exclusion of competing zones. Bandpass sampling intentionally permits an RF interval to map into a lower digital frequency interval. For a real converter sampled at 40 megasamples per second, tones at 90 and 100 megahertz map, by simple folding, to 10 and 20 megahertz, but so do other RF tones in different alias zones. The mapping does not identify the source band uniquely. An analogue preselector must reject those alternative zones sufficiently to make the particular desired interpretation defensible, taking account of filter tolerance and strong blockers. Check both band edges for alias orientation and for coincidence with the Nyquist boundaries; the nominal 100-megahertz edge here lies exactly at a folding boundary and is unsuitable without guard-band analysis. A swept blocker test outside the desired passband is more probative than the sample-rate specification by itself. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Specify the intended RF lower and upper band edges and an actual sample rate. Compute the folded intervals and their spectral orientation before acquiring data. Inject known signals in the intended band and in each material competing sampling zone; measure the preselector's attenuation at the converter plane and compare the resulting aliases. Repeat at a second sample rate which preserves desired reception but changes the competing fold pattern, while confirming that the analogue filter itself has not been moved or retuned. I would take RF lower and upper

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edge, sample rate, zone parity, alias frequency, guard width and blocker rejection as separate instrument readings, rather than asking one waterfall pixel to act as a complete account of the network. The first challenge is measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones. That intervention must be performed at a recorded connector or measurement reference plane, with its source impedance and stimulus spectrum measured there. To isolate the mechanism, the laboratory should repeat the baseline while disabling the particular path implicated by this proposition: Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. A response consistent with odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone would favour the through-path explanation only over the alternatives that were actually challenged. By contrast, an unexplained residue after that path has been isolated warrants a search for other coupling routes, load-dependent impedance, or internal generation. The publication record should retain both the original and challenged sample streams, not just screenshots selected after the event, and should expressly withhold emitter attribution if the physical path remains ambiguous.

The circuit cannot be judged from its final trace alone. An RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. A meaningful bench experiment begins with a source whose power, impedance and spectrum are known at the input connector. I would first inventory the physical elements implicated by the wanted band may occupy the designed alias

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mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component, and measure their behaviour separately before reconnecting the assembled system. Nyquist's work makes the admitted frequency region and the actual sampling or noise bandwidth essential conditions of the proposed inference. It is therefore material to establish RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection rather than infer them from a single scalar output. The limiting test is concrete: Measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones. If the intervention produces odd/even nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted rf tone, the mechanism gains support within the demonstrated range. A failure would be equally consequential, because it would show that the simplified transfer-path account omits an operative coupling or memory effect. I would not interpret a spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target as a new transmitter before challenging the most economical instrumental explanation. Bandpass undersampling is possible only when unwanted analogue bands are excluded with adequate selectivity. Professor Tukey, please take the floor and question any spectrum plot offered without that filtering evidence.

John Wilder Tukey | Peer question 1 to Harry Nyquist

Harry Nyquist, may I test the exact physical inference in your account of an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone? The proposed mechanism appears plausible only if changes after measure

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passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones are compared with a stable reference condition. Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. If an independent stimulus gives a different path attenuation from the ambient feature, how would you exclude leakage downstream of the test port? Would you retain both the failed challenge and the successful one, and how would the final evidential wording distinguish a rejected signal-path hypothesis from a proven external transmitter? I ask for the precise change in RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection which would settle that narrower claim, rather than a visual impression of improvement.

Harry Nyquist | Immediate answer to John Wilder Tukey

Dr Tukey, a reversed-looking spectrum is not by itself evidence of a particular RF zone. I would first prove that the anti-alias network rejects other zones under actual blocker power, then move the sample rate by a declared increment and test the predicted frequency and orientation change. The observations would support a bounded sampling-zone assignment, conditional upon clock calibration and analogue rejection. The correct counterfactual begins with two models capable of producing the original data. I would write their incompatible predictions before performing the intervention, then change one declared physical variable while recording the remainder. The test must contain a return-to-baseline stage and must preserve inconvenient outcomes. For Question 031, the specific physical candidate is spectral replication at integer multiples of the sample

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frequency, including spectral inversion. The unresolved physical pathway is material: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. The retained record permits a conditional claim about RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection, but cannot alone resolve a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

I take John Wilder Tukey's question to concern the RF boundary, not the elegance of a plotted trace. In the proposed setup, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. I would first inject the known stimulus and verify its amplitude at the entrance to the claimed path, then measure the response with the suspected coupling route enabled and isolated. The required observations are RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection; they should be retained as instrument readings with calibration information, rather than displayed only as a difference image. Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. A stable residual after the reference path is disabled calls for examining bypass or internal generation. The proposed discriminating operation is measure passband edges and rejection,

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map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones, and only a response matching odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone would support the particular through-path mechanism. If it does not, I would withdraw that mechanism before offering any inference about an external source.

I would mark the RF input plane in the drawing and retain the two measured responses, one before intervention and the other after a calibrated return. Measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing nyquist zones. If the response instead remained fixed when the nominal through path was strongly attenuated, the bypass explanation would deserve priority. This concerns RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection, not a conjecture about the operator's intentions.

Richard Wesley Hamming | Peer question 2 to Harry Nyquist

I appreciate your explanation, Harry Nyquist. How would your conclusion survive a deliberately independent test of a spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target? A second receiver might share more of the supposed evidence than its separate enclosure suggests. An input band can fold into a lower sampled interval with reversal of spectral order according to Nyquist-zone parity. Please identify the cable splitter, oscillator, power supply and software detector dependencies before treating concordant traces as independent.

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Suppose the original receiver changes its gain history during the comparison. How would you interpret agreement on a strong test tone but disagreement on a short weak burst? Would you require a before-and-after calibration using RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection and document which differences remain unexplained? Would you also state what observed change in RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection would invalidate the preferred account, and which aspect of measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing nyquist zones would make that negative result independently repeatable?

Harry Nyquist | Immediate answer to Richard Wesley Hamming

Richard Wesley Hamming, I accept the force of your common-mode corroboration objection. Corroboration must be assessed at the level of causal dependencies, not the number of instrument front panels. We should trace the common antenna, clock, gain and software paths and identify which fault modes they share. An independent receiver improves the evidence only to the extent that its pathway breaks a material common cause. For Question 031, the specific physical candidate is spectral replication at integer multiples of the sample frequency, including spectral inversion. The unresolved physical pathway is material: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. The retained record permits a conditional claim about RF lower and upper edge,

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sample rate, zone parity, alias frequency, guard width and blocker rejection, but cannot alone resolve a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

Richard Wesley Hamming has identified a possible common dependency. It matters here because the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. I would draw the actual distribution network before collecting new corroborating evidence, marking where two receivers share signal, power or time references. An input band can fold into a lower sampled interval with reversal of spectral order according to Nyquist-zone parity. An independent test must alter a physical dependency, not merely open another software window. The relevant controlled alternative remains the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component; I would challenge it with measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones. Two responses consistent with odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone would be informative only after shared errors and the state history had been assessed. Differences at low levels or during overload should be published as differences, not averaged away into a favourable mean. I

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would give the examiner both the dependency diagram and the unaltered records.

The second receiver cannot be designated independent merely by giving it a separate chassis. I would inspect the shared causal pathways and change the reference source first. In this setting, the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. A discordant measurement would then be interpreted by tracing that difference through RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection; an agreement lacking such a dependency analysis is weak corroboration.

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Claude Elwood Shannon | Principal contribution 2: An input band can fold into a lower sampled interval with reversal of spectral order according to Nyquist-zone parity.

Sampling a restricted high-frequency band at a modest numerical rate imposes strict demands on the acquisition architecture. I would test the converter's analogue input bandwidth and track-and-hold response at the actual RF frequency, rather than infer capability from the advertised sample rate. Two tones from different Nyquist zones can fold into the same output bin if the preselector admits both; the digital channeliser cannot undo their prior collision. A frequency sweep through the band edges should reveal the inversion sense and any loss of amplitude caused by the analogue aperture. In a practical superheterodyne receiver there may be further image responses before the direct RF sampling stage, so the complete mixing plan must be documented. The proper experiment combines a calibrated RF source, an independent frequency counter and a measured preselector response, with gain and clock settings retained. A strikingly clean digital spectrum is useful only after these analogue boundaries have been challenged.

In this control and stability examination of Question 031, the decisive claim is that an input band can fold into a lower sampled interval with reversal of spectral order according to Nyquist-zone parity. State transitions, feedback and memory make identical nominal inputs yield different sampled outputs. A proper challenge records the chronological order of settings and waits for characterised settling before drawing comparisons. A useful falsification proceeds from the actual controversy: bandpass aliases require analogue exclusion of competing zones. Bandpass sampling

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intentionally permits an RF interval to map into a lower digital frequency interval. For a real converter sampled at 40 megasamples per second, tones at 90 and 100 megahertz map, by simple folding, to 10 and 20 megahertz, but so do other RF tones in different alias zones. The mapping does not identify the source band uniquely. An analogue preselector must reject those alternative zones sufficiently to make the particular desired interpretation defensible, taking account of filter tolerance and strong blockers. Check both band edges for alias orientation and for coincidence with the Nyquist boundaries; the nominal 100-megahertz edge here lies exactly at a folding boundary and is unsuitable without guard-band analysis. A swept blocker test outside the desired passband is more probative than the sample-rate specification by itself. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

I would concentrate on the chronology of state changes implied by a spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target. A receiver may move between apparently similar configurations while its mixer, analogue gain control, triggering, or filter memory is still settling. Accordingly, I propose three logged epochs with a fourth return epoch: initial operating state; a deliberate intervention testing the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component; a challenge in which only the suspected mechanism is restored; and an independently checked return to the starting condition. The engineering note an input band can fold into a lower sampled interval with reversal of

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spectral order according to nyquist-zone parity. has a consequence for the observation schedule: changes made during uncertain recovery cannot simply be scored as absence. For each epoch the operator should preserve time stamps, acquisition validity, applied gain, test-source state and RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection. If the candidate disappears in a retuning interval yet returns when the state is held fixed, neither spontaneous transmitter silence nor intentional evasion follows automatically. The experiment would succeed only if the proposed causal account explains both the supporting and the contrary transitions with no unreported change of instrumental state.

The state trajectory matters more than a nominal performance figure. In the scenario, a spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target. A technician who adjusts the receiver to improve an individual display changes the experiment while it is in progress. Shannon’s information-theoretic question concerns which distinguishable input states survive acquisition, quantisation, selection and subsequent representation. I would specify an ordered sequence of initial state, controlled perturbation, return state and independent reference capture. Our central rival is specific: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. This predicts a response which should be tested against odd/even nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted rf tone. An operator may be tempted to interpolate a line between two clean sweeps and call the resulting curve continuous; that

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presentational step does not restore measurements discarded during retuning. Where a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response, the correct claim must name the operational states and the evidence available in each. Aliasing can reverse spectral order, so the sign convention and original passband must survive reprocessing. Dr Pearson, I invite your examination of a frequency assignment built from incomplete mapping metadata.

Egon Sharpe Pearson | Peer question 3 to Claude Elwood Shannon

Claude Elwood Shannon, your calibration argument invites a question about reference planes, especially because a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. The reference stimulus and the unknown emission need not occupy the same physical regime. An undersampling receiver must have analogue input bandwidth sufficient to pass the desired RF band before conversion. I would question a calibration performed at one amplitude if the actual uncertainty is dominated by overload, temperature or filter mismatch. When a spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target, which of the reported quantities represents a directly measured state and which is extrapolated? Could you state how a second operator would repeat measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones without relying upon the original screenshot or undocumented threshold

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settings? The question concerns the traceability of the inference, not the operator's good faith.

Claude Elwood Shannon | Immediate answer to Egon Sharpe Pearson

Egon S. Pearson, I accept the force of your statistical sampling design objection. The estimand has to be defined before the confidence calculation. A post-alarm follow-up is legitimate but has a different sampling frame from the original scan. For Question 031, the specific physical candidate is spectral replication at integer multiples of the sample frequency, including spectral inversion. The unresolved physical pathway is material: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. The retained record permits a conditional claim about RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection, but cannot alone resolve a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

To address Egon S. Pearson's concern about calibration, the relevant measurand must be fixed at the start: RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection. An undersampling receiver must have analogue input bandwidth sufficient to pass the desired RF band before conversion. I would not carry a correction obtained at one frequency

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or amplitude into another regime without a documented sensitivity test. An appropriate reference check would be measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones, with before-and-after values of RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection. If the instrument behaves as predicted, then odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone; if it does not, the uncertainty budget must include the unresolved deviation. It would be misleading to assign a small standard uncertainty merely because the digitiser reports many decimal places. The defensible result is a qualified statement of the measurement at the stated reference plane, with systematic components and operating limits shown separately.

The sampling plan should be registered before the confirmatory run and should retain the non-detection intervals. A spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target. I would calculate separate conditional rates in stable operating strata and avoid multiplying correlated events into fictitious independent trials. The confidence statement must describe the tested opportunities, not every unobserved period in the room.

Ralph Vinton Lyon Hartley | Peer question 4 to Claude Elwood Shannon

There is an inferential difficulty, Claude Elwood Shannon: the wanted band may occupy the designed alias mapping, but an insufficiently

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rejected adjacent zone can create an indistinguishable digital component. The population of admissible observations needs to be fixed before any confidence argument. In this situation, a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. Selection of the most promising time window after reviewing hundreds of alternatives changes the experiment. A strong out-of-band signal which leaks through filtering may alias directly on top of the desired weak waveform. What is your unit of independent observation, and how will you treat censored records or correlated repeats of one event? I would welcome a statement of the alternative hypothesis, the observation which counts against your claim, and the sensitivity of the conclusion to plausible dependence among samples. Would you also state what observed change in RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection would invalidate the preferred account, and which aspect of measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing nyquist zones would make that negative result independently repeatable?

Claude Elwood Shannon | Immediate answer to Ralph Vinton Lyon Hartley

Ralph V. L. Hartley, I accept the force of your physical transfer and frequency objection. I would not infer the original frequency solely by reading the stored digital coordinate. First identify the active conversion, filter, and sampling states, then predict how each hypothesised analogue input maps into the output. A swept reference

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signal can test the path, while a second conversion scheme helps separate otherwise coincident aliases and mixer products. For Question 031, the specific physical candidate is spectral replication at integer multiples of the sample frequency, including spectral inversion. The unresolved physical pathway is material: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. The retained record permits a conditional claim about RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection, but cannot alone resolve a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The statistical objection raised by Ralph V. L. Hartley is important precisely because a spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target. I would distinguish trials selected in advance from those added after an unexpected peak appeared. A strong out-of-band signal which leaks through filtering may alias directly on top of the desired weak waveform. For the formal comparison, the exposure window, detector threshold and admissible invalid states should be specified before the outcome is known. A subsequent test can legitimately examine measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones, but it must be labelled a validation phase rather than

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merged into an apparently random original sample. The rival mechanism is the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component; its prediction should be recorded alongside odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone. If both models yield the same recorded measurements, the causal question remains unidentified even if a confidence interval for the measured statistic becomes very narrow.

The quantity has to remain attached to the physical operation defining it. A successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. The protocol should therefore carry units, terminal conditions, calibration factors and uncertainty to the same reference plane. In particular, a receiver which preserves a 15 mhz-wide wanted band must still reject other frequency intervals that fold upon those same sampled frequencies. A second examiner can then determine whether the competing explanations give genuinely different measurements.

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Edwin Howard Armstrong | Principal contribution 3: An undersampling receiver must have analogue input bandwidth sufficient to pass the desired RF band before conversion.

It is tempting to regard a recorded alias as a compact encoding of the high-frequency input. That view is legitimate only while the analogue admissibility conditions restrict the set of possible sources. If the preselector passes two disjoint RF regions that map to the same discrete-time frequency, the resulting sample sequence generally cannot distinguish them without further evidence. A formal reconstruction algorithm may return one answer because it assumes that only the wanted band was present. The algorithm has then enforced a hypothesis, not discovered the true external frequency from the digits. I would retain the actual sample-rate measurement, filter identification and any out-of-band challenge results with the I/Q archive. Where the acquisition uses real sampling, spectral inversion and conjugate symmetry also affect how the displayed sign of frequency is interpreted. These are questions about the mapping from RF to data, and their answers cannot be recovered from a screenshot that omits acquisition metadata.

In this operational measurand examination of Question 031, the decisive claim is that an undersampling receiver must have analogue input bandwidth sufficient to pass the desired RF band before conversion. A numerical result has little evidential force unless its calibration chain and uncertainty components are attached to that operational definition. A useful falsification proceeds from the actual controversy: bandpass aliases require analogue exclusion of competing zones. Bandpass sampling intentionally permits an RF interval to map into a lower digital frequency interval. For a

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real converter sampled at 40 megasamples per second, tones at 90 and 100 megahertz map, by simple folding, to 10 and 20 megahertz, but so do other RF tones in different alias zones. The mapping does not identify the source band uniquely. An analogue preselector must reject those alternative zones sufficiently to make the particular desired interpretation defensible, taking account of filter tolerance and strong blockers. Check both band edges for alias orientation and for coincidence with the Nyquist boundaries; the nominal 100-megahertz edge here lies exactly at a folding boundary and is unsuitable without guard-band analysis. A swept blocker test outside the desired passband is more probative than the sample-rate specification by itself. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

Bandpass sampling is legitimate only when the admitted analogue spectrum and sampling frequency produce a non-overlapping image in the desired digital band. The usual sampling theorem does not imply that an arbitrary wide RF passband can be sampled at a low rate simply because its occupied signal is narrow. Images of the selected band recur around multiples of the sample frequency, and undesired bands can fold directly on top of the wanted information unless the pre-sampling filter rejects them sufficiently. The validation should therefore calculate all relevant alias intervals, not only the nominal centre-frequency translation, and include tolerances for clock drift, filter skirt, temperature and strong out-of-band transmissions. Sweep a calibrated tone across both the wanted band and adjacent alias-prone bands, recording where its digital image appears. A correct frequency conversion for the wanted tone is necessary but

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insufficient; the test must show that plausible external blockers cannot enter the same discrete-time bins at misleading amplitudes. Accordingly, the laboratory record for Question 031 should include the trial configuration, the reference-plane photograph or schematic, the raw measurement and the adverse-control outcome before the final inferential wording is selected. The specific instrument-state record must be retained with the sample archive so that an independent examiner can reproduce the indicated difference without relying upon a coloured display alone.

We ought to distinguish a property of an apparatus from the definition of the quantity purportedly measured. A successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. Armstrong’s receiver engineering points to actual conversion products and oscillation conditions rather than abstract spectral indications; the crucial question is where the energy first appears. The first page of the laboratory record should declare the geometry, the conversion of instrument readings into the stated units, and the conditions that would invalidate that conversion. In the proposed survey, an rf band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted nyquist zone; the actual observation is therefore not a timeless property of the unseen source, but the result of an implemented operation. One might compare RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection under two independently calibrated reference conditions, recording mismatch, temperature and sample-clock validity where appropriate. A decision should specify whether it concerns an instantaneous output, an average over admitted time, or a bound on a latent physical parameter. The

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illustrative case is instructive: A receiver which preserves a 15 MHz-wide wanted band must still reject other frequency intervals that fold upon those same sampled frequencies. It demonstrates the danger of transferring a result across domains in which the defining measurement has changed. A sampler advertised for a high clock rate may still lack the analogue input bandwidth required at the RF frequency of interest. Dr Turing, I pass the floor to inspect the boundary between that physical limitation and digital reconstruction.

Alan Mathison Turing | Peer question 5 to Edwin Howard Armstrong

Edwin Howard Armstrong, I should like to examine what the recorded data actually preserve when an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. The physical input and the retained numerical array are not interchangeable things. Sampling-clock tolerance and filter transition regions must be considered as part of the safety margin. If an analogue front end rejected or clipped the relevant portion before quantisation, post-processing cannot determine the original waveform uniquely. With the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component as a live possibility, what tests can be performed on stored samples and which require a new controlled acquisition? Will you preserve unprocessed records, firmware versions, time bases and the selection rule so that another investigator can distinguish the evidence from a reconstruction? Would you also state what observed change in RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection would

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invalidate the preferred account, and which aspect of measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing nyquist zones would make that negative result independently repeatable?

Edwin Howard Armstrong | Immediate answer to Alan Mathison Turing

Alan Mathison Turing, I accept the force of your operational calibration and overload objection. The laboratory must challenge the actual operating regime, including strong and weak simultaneous inputs, short bursts and recovery intervals. A gentle calibration source can establish an initial transfer relation, but the relation must be checked near overload and across the dynamic states used in the survey. Its residual uncertainty then belongs in the reported conclusion. For Question 031, the specific physical candidate is spectral replication at integer multiples of the sample frequency, including spectral inversion. The unresolved physical pathway is material: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. The retained record permits a conditional claim about RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection, but cannot alone resolve a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I agree with Alan Mathison Turing that a stored sample file is evidence of a finite acquisition, never a reproduction of the entire analogue environment. A successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. I propose separating acquired information from model-dependent reconstruction. Sampling-clock tolerance and filter transition regions must be considered as part of the safety margin. A later algorithm can recalculate a threshold for samples which were retained, but not recover an interval discarded at the analogue input or omitted by the acquisition policy. The discriminating record would include RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection and a fresh trial in which the operator measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones. If that trial demonstrates odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone, the interpretation may be narrowed; it still cannot turn the original unrecorded interval into evidence of a unique historical waveform. I would therefore preserve all conflicting reconstructions and state exactly where the retained samples cease to support an inference.

I agree that the archive needs a witness for what the software discarded. Save raw acquisitions over independently chosen control intervals, plus executed settings and invalidity masks. The concrete challenge should include measure passband edges and rejection,

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map aliases across sample-rate steps, and inject test blockers in competing nyquist zones. Without that witness, a clean thresholded display may conceal a failure in the acquisition itself.

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Hendrik Wade Bode | Principal contribution 4: A strong out-of-band signal which leaks through filtering may alias directly on top of the desired weak waveform.

The preselector's job is more demanding than placing a smooth hump around a preferred RF band. Its attenuation must protect against particular alias collisions, and its insertion loss must be included in the receiver sensitivity budget. I would build a zone-by-zone table of unwanted frequencies whose aliases land on the wanted spectrum, then measure rejection at those frequencies with the converter operating at representative levels. A filter that passes a blocker at one such frequency may allow the converter to produce a convincing false target even if the signal chain remains perfectly linear. Resonant-component drift, source mismatch and finite stopband rejection need to be tested across temperature and production tolerances. If a selected filter is substituted during an investigation, the result must be accompanied by an updated frequency map and calibrated reference-plane comparison. It is the complete analogue-and-sampling transfer relationship, not the selected sample rate alone, that defines the measurement's admissible frequency claims.

In this information retention examination of Question 031, the decisive claim is that a strong out-of-band signal which leaks through filtering may alias directly on top of the desired weak waveform. One should specify which information has been retained and which hypotheses remain observationally indistinguishable. A useful falsification proceeds from the actual controversy: bandpass aliases require analogue exclusion of competing zones. Bandpass sampling intentionally permits an RF interval to map into a lower digital frequency interval. For a real converter sampled at

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40 megasamples per second, tones at 90 and 100 megahertz map, by simple folding, to 10 and 20 megahertz, but so do other RF tones in different alias zones. The mapping does not identify the source band uniquely. An analogue preselector must reject those alternative zones sufficiently to make the particular desired interpretation defensible, taking account of filter tolerance and strong blockers. Check both band edges for alias orientation and for coincidence with the Nyquist boundaries; the nominal 100-megahertz edge here lies exactly at a folding boundary and is unsuitable without guard-band analysis. A swept blocker test outside the desired passband is more probative than the sample-rate specification by itself. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The statistical question is whether this experiment could distinguish its preferred explanation from the specified alternative: the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. A test chosen because a feature already appears extraordinary cannot afterwards be presented as if it were a solitary predeclared comparison. I would record the planned family of frequencies, trial levels, acquisition windows and failure criteria before applying measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones. The scientific point of a strong out-of-band signal which leaks through filtering may alias directly on top of the desired weak waveform. is not that the result should be made more impressive but that a contrary result should be allowed to alter the proposed explanation. If independent

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sessions repeatedly show odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone, a bounded conditional finding becomes defensible; the bounds depend on what was randomised, what remained fixed and what was actually observed. Invalid or saturated records must remain visible in the denominator for any estimate of acquisition coverage; their exclusion may correlate with the strongest relevant inputs. I would report the alternative models beside the adopted one, distinguishing a detected change in a measurement statistic from identification of its cause.

A stored sample archive is not an exact transcription of every possible electromagnetic input. A spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target. His mathematical treatment of networks suggests using complex transfer functions and explicit phase as well as magnitude, especially when cascaded loading shifts the effective response. The issue becomes especially sharp because the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. If the front end compresses, clips, averages or selects time windows, no post-processing command can uniquely reconstruct states which those operations made indistinguishable. I would compare a reference acquisition made with adequate headroom against the questioned recording and declare the information retained by each path. Measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing nyquist zones. That comparison should keep the unprocessed complex values or, where only detector outputs exist, disclose precisely the interval and frequency domain actually

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examined. For the proposed case, a receiver which preserves a 15 mhz-wide wanted band must still reject other frequency intervals that fold upon those same sampled frequencies. This is a claim about a transformation and its observables, not a licence to assert a unique historical waveform or an emitter's intention. Strong out-of-band signals can fold onto the desired sampled channel when the filter stopband proves insufficient. Dr Deming, please take the floor and demand a test with realistic blocking levels.

W. Edwards Deming | Peer question 6 to Hendrik Wade Bode

I thank you, Hendrik Wade Bode, for distinguishing measurement from attribution, but the observation is that a spectrum appears reversed in the sampled output and a strong distant service folds into the same display interval as the weak target. A forensic report must identify the result that would defeat its preferred interpretation. Consider the working example: a receiver which preserves a 15 MHz-wide wanted band must still reject other frequency intervals that fold upon those same sampled frequencies. It is a hypothetical illustration, not an observation certified by the laboratory. How should the report discuss a challenge which supports odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone on one day but fails after the instrument has been reconfigured? Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. Would you disclose the disagreement and constrain the conclusion to the tested states, rather than reconcile the records through a post hoc adjustment?

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Hendrik Wade Bode | Immediate answer to W. Edwards Deming

W. Edwards Deming, I accept the force of your evidence chain and reprocessing objection. Retain the earliest available samples, complete contemporaneous receiver state, calibration, time-base records, and processing configuration. Every derived plot should identify the source record and transformation. A secure digest establishes continuity of bytes, while separate controls establish the physical interpretation. A reconstructed waveform must be labelled as an estimate. For Question 031, the specific physical candidate is spectral replication at integer multiples of the sample frequency, including spectral inversion. The unresolved physical pathway is material: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. The retained record permits a conditional claim about RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection, but cannot alone resolve a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

The adverse observation proposed by W. Edwards Deming deserves to be published without cosmetic reconciliation. In this case, a receiver which preserves a 15 MHz-wide wanted band must still reject other frequency intervals that fold upon those same sampled frequencies. I would retain the counterexample as part of the primary

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result, not as a footnote to an attractive conclusion. Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. Its bearing on the dispute can be evaluated through the predicted response, namely odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone. Because the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component, the procedure measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones should be repeated with the same calibration and an independent witness path. If agreement appears only after a threshold has been shifted, the historical record must show the threshold change and its reason. The final statement should match validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband, making clear whether the result excludes one instrument artefact or supports an actual external phenomenon. I should prefer an accurately bounded disagreement to a false appearance of consensus.

The original run and the revised run would be reported separately. Odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone. I would retain the unsuccessful and ambiguous captures to show where the proposed explanation failed.

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Jerzy Neyman | Principal contribution 5: Sampling-clock tolerance and filter transition regions must be considered as part of the safety margin.

Before declaring a bandpass-sampling configuration safe, I would ask exactly what failure probability the qualification programme controls. A low-level bench sweep can show that the intended band is captured, but it cannot measure false in-band detections generated by occasional high-power out-of-zone signals. The test population should include those strong signals at representative frequency offsets, with a known weakest relevant wanted signal present where appropriate. Planned clock offsets and temperature changes should challenge the zone mapping and guard-band assumptions. If a candidate detection changes its apparent frequency under a measured alteration of sample rate, that can support an alias hypothesis; it is not by itself proof of source identity. Report detection performance and frequency-assignment errors under the actual tested regime, keeping calibration and environmental uncertainties explicit. An untested high-interference condition must remain outside the scope of the safety claim, however attractive the nominal bandpass-sampling diagram may look.

In this statistical inference examination of Question 031, the decisive claim is that sampling-clock tolerance and filter transition regions must be considered as part of the safety margin. The inferential population, detection threshold, nuisance distributions and dependence among trials must be stated. An apparently narrow confidence bound can be misleading when the underlying sampling design is not justified. A useful falsification proceeds from the actual controversy: bandpass aliases require analogue exclusion of competing zones. Bandpass sampling intentionally permits an

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RF interval to map into a lower digital frequency interval. For a real converter sampled at 40 megasamples per second, tones at 90 and 100 megahertz map, by simple folding, to 10 and 20 megahertz, but so do other RF tones in different alias zones. The mapping does not identify the source band uniquely. An analogue preselector must reject those alternative zones sufficiently to make the particular desired interpretation defensible, taking account of filter tolerance and strong blockers. Check both band edges for alias orientation and for coincidence with the Nyquist boundaries; the nominal 100-megahertz edge here lies exactly at a folding boundary and is unsuitable without guard-band analysis. A swept blocker test outside the desired passband is more probative than the sample-rate specification by itself. The chain from physical input through conversion, retention and interpretation must remain independently inspectable, and its limits must be made explicit to a later examiner.

The forensic question is how much of the historical input survives when an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. Sampling-clock tolerance and filter transition regions must be considered as part of the safety margin. An attractive reconstruction can be consistent with several physically different signals because information was discarded before the operator retained the complex samples. I recommend preserving the analogue configuration, sample-clock state, precise recording boundaries and the event or detector rule which selected the file for retention. The proposed challenge, namely to measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones, should be accompanied by a second acquisition

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path whose dependencies are explicitly diagrammed; two displays fed from a common failing stage do not constitute independent witnesses. The signature predicted here is odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone. A different result would not merely be noise around a preferred answer; it might indicate that the hypothesised forward model is wrong. Where the evidence cannot discriminate the histories, it is more accurate to say validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband, than to claim to have restored the original emitter conduct from a partial recording. The resulting opinion should describe the observable, its uncertainty, the alternative, and the precise experimental boundary within which the conclusion holds.

Before adopting a performance number, I would identify its population of measurement opportunities. An RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. The resulting sample cannot be treated as representative of unobserved intervals merely because it contains numerous FFT bins. Neyman’s statistical concern is the design that makes the advertised coverage statement valid, including preselection of tests and correlations among observations. A designed validation must distinguish the tested distribution from the unknown operational environment and must acknowledge that the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. One could stratify the experiment by nuisance condition, retain a random sample of nominally negative intervals, and calculate a separate sensitivity for each physically meaningful regime.

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The relevant quantities are RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection; their covariance and censoring properties determine whether a nominal confidence statement is defensible. The falsifying result would follow from odd/even nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted rf tone, provided the measurement actually had power to distinguish the rival predictions. The particular illustration, a receiver which preserves a 15 mhz-wide wanted band must still reject other frequency intervals that fold upon those same sampled frequencies, is not an estimate of any actual investigation. Filter transition regions and sampling-clock tolerance determine whether the proposed alias-free band is actually safe. Sir Karl, I invite you to challenge the conclusion at its worst-case operating limit.

Sir Karl Raimund Popper | Peer question 7 to Jerzy Neyman

Jerzy Neyman, before we pass to the next contributor, could you specify the negative finding that would oblige us to revise validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband? I am concerned about the decision reached after an apparently negative trial. A failure to see a feature is not an assertion that no physical emission existed outside the measured aperture. An input band can fold into a lower sampled interval with reversal of spectral order according to Nyquist-zone parity. Please connect RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection with a declared detection threshold and the measurement exposure. If the experiment measure passband edges and rejection, map aliases across sample-rate steps, and

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inject test blockers in competing Nyquist zones cannot discriminate a masked weak signal from a genuinely absent one, what exact assurance statement would you sign? The wording matters when another examiner must judge the limit of the original survey years later.

Jerzy Neyman | Immediate answer to Sir Karl Raimund Popper

Karl Raimund Popper, I accept the force of your falsifiable conclusions and disclosure objection. The finding should identify the observation, conditional model, controlled intervention and residual alternatives in separate sentences. Its strongest defensible claim may be narrow: the indicated response is consistent with one specified path under documented conditions. Source identity, intent and unobserved intervals require further evidence. Those restrictions improve credibility. For Question 031, the specific physical candidate is spectral replication at integer multiples of the sample frequency, including spectral inversion. The unresolved physical pathway is material: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. The retained record permits a conditional claim about RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection, but cannot alone resolve a successful bandpass-sampling plan depends simultaneously on band edges, clock tolerance, transition bands and analogue aperture response. That limitation belongs in the stated finding because the alternative remains an empirical possibility in this experiment.

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I am obliged to Karl Raimund Popper for pressing the limits of a negative conclusion. The physical circumstance is an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. A non-detection must be defined against the sensitivity and temporal coverage actually achieved. An input band can fold into a lower sampled interval with reversal of spectral order according to Nyquist-zone parity. I would use the observations of RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection to disclose what signal conditions could have triggered the chosen rule and which conditions were never tested. The relevant experiment remains measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones, not an assertion based on the operator's impression of a quiet display. If it yields odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone, we may describe a conditional exclusion of the challenged mechanism. If it cannot distinguish that mechanism from a missed short emission, it cannot support the broader assurance. A future reader needs the test boundaries, uncertainty, and all invalid windows to understand what the negative result signifies.

To make the hypothesis vulnerable, I would test the opposite outcome in the same controlled apparatus. Since the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component, an intervention that leaves both alternatives consistent does not settle

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their difference. The result should be limited to validate the entire occupied analogue spectrum rather than infer unique rf provenance from the sampled baseband, with the untested physical possibilities made visible.

Harry Nyquist, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, what must the preselector demonstrate when an intended high-frequency band is folded into a lower sampled interval, and a nearby strong transmitter occupies another Nyquist zone?

Hendrik Wade Bode, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, it must meet a quantified rejection requirement at the analogue reference plane under the actual blocker levels, not merely have a convenient catalogue corner frequency. Identify every materially overlapping alias interval at the lowest and highest allowed sample rates and clock tolerances. Measure passband ripple, stopband attenuation, insertion loss, group delay and large-signal compression over temperature and gain settings. A filter that meets a small-signal rejection figure may still be followed by an overloaded amplifier or converter, generating spurs that a digital image cannot separate from real input signals. Inject an out-of-band challenge tone into the front-end input and show that the folded output remains below a predeclared limit. A successful challenge with one source frequency cannot certify every neighbouring zone. I yield the token to Dr Armstrong on receiver implementation.

Hendrik Wade Bode, Cross-Peer Question to Edwin Howard Armstrong: Dr Armstrong, an engineer demonstrates a clean bandpass-sampled spectrum using a low-power laboratory source. What test distinguishes a practical RF receiver from a numerical aliasing demonstration?

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Edwin Howard Armstrong, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, the receiver must admit the desired RF band through its actual analogue aperture and remain linear when subjected to credible adjacent and remote strong signals. Verify track-and-hold input bandwidth, impedance matching, mixer or preamplifier compression, intermodulation and reciprocal mixing. Test both a desired weak tone and a strong tone in an excluded zone, then vary their powers separately to reveal nonlinear interactions. Repeat with the intended antenna, coupling network and maximum anticipated front-end gain, since an attenuator or filter used only in the laboratory can conceal defects. Record the physical signal generator levels, cable losses, input plane and all automatic gain events. Digital alias prediction is valuable, but it is not a substitute for measured RF immunity. I pass the token to Dr Shannon for the inversion question.

Edwin Howard Armstrong, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, the software shows a coherent line at 4 MHz after bandpass sampling. Can its exact original RF frequency be established from that one spectrum when multiple zones could have folded into the same bin?

Claude Elwood Shannon, Cross-Peer Answer to Edwin Howard Armstrong: Dr Armstrong, no. The discrete samples alone can be compatible with several original RF frequencies differing by appropriate multiples or reflections of the sampling rate. A claim of unique physical origin requires external constraints, such as a verified analogue passband, measured stopband rejection, a second sample rate that changes the alias mapping, or an independent front-end path. Spectral reversal is also dependent on the zone and complex-versus-real convention. We should test known tones from alternative zones and document their observed digital locations at multiple

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rates. When different physical inputs remain indistinguishable within the uncertainty budget, the forensic report must retain the ambiguity rather than assigning one transmitter by convenience. Derivative displays must not erase the information needed to challenge the mapping. I yield to Dr Neyman for statistical limits.

Claude Elwood Shannon, Cross-Peer Question to Jerzy Neyman: Dr Neyman, a field team observes no aliased blocker in twenty bench trials and declares the sampling plan safe for a seventy-two-hour unattended survey. What remains unproved?

Jerzy Neyman, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the absence of a detected failure in twenty specified trials neither establishes a zero failure probability nor covers untested blocker powers, frequencies, duty cycles, temperature states and gain transitions. An exact binomial interval under independent identical trials would still leave a positive upper bound on a failure probability; repeated conditions drawn from one narrow stimulus set provide no basis for extrapolation outside it. Define the adverse-condition population, randomise or systematically cover its extremes, and document the sample-rate and filter tolerances. Use independent monitors for unanticipated strong signals and record overload status through the full survey. A claim of safe operation should specify conditions, assurance level and residual uncertainty, not an unqualified word. I return the token with respect to Dr Atkinson for the closing synthesis.

Dr. James M. Atkinson | Moderator concluding synthesis

Our discussion of the conditions for safe bandpass sampling and the analogue filtering it presupposes has established a point which the

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specialist must not overlook. The receiver records folded sampled spectra of an intentionally isolated higher-frequency band; it does not, merely by drawing a clear trace, give direct access to other radio-frequency bands which could alias into exactly the same digital interval. A convincing engineering explanation therefore begins with the measurement boundary and ends with an appropriately limited conclusion. In particular, Bandpass sampling is not a licence to discard analogue filtering; it depends upon excluding other spectral replicas. This distinction is especially important when a field report may be read by a tribunal, a client or a technical review board unfamiliar with the internal operation of the apparatus. A good report distinguishes observation, model, controlled challenge, uncertainty and interpretation, instead of compressing all five into the single word detected.

Bandpass sampling is a deliberate frequency translation by sampling, not permission to admit unlimited RF energy into a converter. For a narrow, carefully selected passband, the folding relationship can map the wanted spectrum below half the sample rate; but adjacent Nyquist zones may occupy the same digital coordinates, and inversion may reverse the apparent frequency ordering. The critical hardware requirement is a preselector whose rejection outside the wanted band is justified under the anticipated blocker environment. A test tone near each band edge should demonstrate the actual zone mapping and whether the chosen sampling rate creates overlap. I thank Professor Fourier for supplying the spectral mathematics and the receiver engineers for insisting upon an analogue test of the filter. The final acceptance record must identify which RF band has been admitted, the sample-clock uncertainty, the direction of any inversion

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and the limits of blocker tolerance. No unique emitter attribution follows from an aliased spectral coordinate alone.

The output appears spectrally reversed and a strong out-of-band service could fold into the same displayed interval. The RF origin cannot be established from the sampled spectrum alone; competing zones must be excluded by measured filter rejection and deliberately placed test signals. The more useful outcome is a discriminating protocol: Measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones. In applying it, the examiner must retain all readings supporting RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection and identify the physical plane to which the measurements refer. At the outset of the investigation, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone; that circumstance makes the alternative mechanism material, specifically the wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. A result approaching odd/even Nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted RF tone may justify excluding one alternative, but it cannot by itself erase uncertainty about unobserved states or establish an emitter's identity. The final opinion should therefore validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband. Failed trials, changed receiver states, and measurement uncertainty belong in the retained evidential account alongside successful demonstrations. The differing observations offered by the principal

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contributors and their peers are most valuable when they specify incompatible predictions, not when they merely recite an agreeable conclusion.

Safe bandpass sampling is an engineering claim about the combined analogue passband, sampling rate and blocker environment. A digital alias coordinate can only be attributed to a specific RF band after the other possible analogue predecessors have been experimentally excluded. The decisive experiment is concrete: Measure passband edges and rejection, map aliases across sample-rate steps, and inject test blockers in competing Nyquist zones. In conducting it, the examiner must explicitly retain RF lower and upper edge, sample rate, zone parity, alias frequency, guard width and blocker rejection. If the outcome matches the stated prediction, odd/even nyquist-zone mappings may reverse spectral order, while clock drift shifts the digital alias of each admitted rf tone, the supported conclusion concerns that test domain. An alternative remains: The wanted band may occupy the designed alias mapping, but an insufficiently rejected adjacent zone can create an indistinguishable digital component. I thank the contributors for their careful and courteous disagreements. Their contribution is strongest where the methods require an actual discriminating observation, rather than one more retelling of the same hypothesis.

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Ten worked engineering applications | Question 031

Application 01. Alias-location prediction and its non-unique inverse

In the illustrative 031.01 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. For an actual sampling frequency f_s = 39 MHz and analogue input f_i = 122.070 MHz, the nearest-replica folding rule gives $f_a = |f_i - \text{round}(f_i/f_s)f_s|$ = 5.070 MHz. Another RF input in a different Nyquist zone can generate the same sampled coordinate; only the analogue preselector and controlled blockers distinguish those possible sources. The calculation assumes sampling is coherent enough to regard the centre frequencies as stable over the observed aperture. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

Application 02. Filter or cable rejection referred to a physical input

In the illustrative 031.02 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. For an admitted input P_i = -49 dBm and separately measured loss L = 28 dB, the linear prediction is $P_o = P_i - L$ = -77 dBm. In SI power this becomes 10^((-77 − 30)/10) = 2e-11 W. That equality presumes a consistent power reference plane and no alternate common-mode ingress; a different screen level should prompt a physical bypass test. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

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Application 03. Frequency-bin spacing versus independent information

In the illustrative 031.03 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. With sampled bandwidth f_s = 9 MS/s and N = 16,384 transform samples, the discrete-frequency grid is $\Delta f = f_s/N$ = 549.316 Hz. Two adjacent bins are not automatically independent observations, particularly when the transform uses overlapping records. The effective noise bandwidth, taper, acquisition duration and analogue transfer function determine what resolution and detection uncertainty can actually be claimed. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

Application 04. Thermal reference noise in a declared measurement bandwidth

In the illustrative 031.04 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. Take the equivalent noise bandwidth B = 3,750 Hz and calibrated noise figure NF = 2.70 dB at an assumed 290 K. The thermal-reference estimate is $N = -174 + 10 \log_{10}(B/1\ \text{Hz}) + NF$ = -135.56 dBm. The result is available-noise power in that specific bandwidth; impulsive interference at the antenna is not represented by the 290 K assumption. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

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Application 05. The frequency dependence of aperture-jitter-limited SNR

In the illustrative 031.05 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. At sinusoidal input frequency f = 212 MHz with uncorrelated rms aperture jitter σ_t = 2.25 ps, the idealised jitter-imposed ceiling is $SNR_j = -20 \log_{10}(2\pi f \sigma_t)$ = 50.47 dB. A common clock source may correlate errors across parallel ADC channels, so treating their outputs as independent for noise cancellation would need an additional experiment. Converter nonlinearity and thermal noise can make actual performance worse. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

Application 06. Cascade gain and observed headroom

In the illustrative 031.06 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. A first amplifier contributes G_1 = 16 dB, an intentional attenuation contributes G_2 = -4 dB, and a later stage contributes G_3 = 20 dB. The small-signal sum is 16 + (-4) + 20 = 32 dB. For P_i = -68 dBm, the ideal output is P_o = -36 dBm. An intermediate amplifier may saturate even when the overall result appears modest, so the level before every nonlinear stage must be examined. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

Application 07. Two-tone third-order products and input intercept

In the illustrative 031.07 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the

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permitted Nyquist zone. With two equal input tones each at P = -27 dBm and a hypothetical input third-order intercept IIP_3 = +16 dBm, the extrapolated input-referred third-order product is $P_3 = 3P - 2IIP_3$ = -113 dBm, or -86 dBc relative to either input tone. The cubic approximation ceases to be reliable in compression. A two-tone slope check and input attenuation test must establish whether the predicted spur arises inside the receiver rather than externally. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

Application 08. Combined and expanded measurement uncertainty

In the illustrative 031.08 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. For independent standard-uncertainty contributions 0.66, 0.54 and 0.31 in a common unit, the root-sum-of-squares combination is $u_c = \sqrt{(0.66^2 + 0.54^2 + 0.31^2)} = 0.907$ units. Using an illustrative coverage factor k = 2 gives expanded uncertainty $U = 2u_c$ = 1.815 units. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

Application 09. Gain allocation and blocker headroom

In the illustrative 031.09 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. Assume a calibrated digital full-scale equivalent of -8 dBm, a blocker applied at -45 dBm, and net analogue gain 22 dB. The projected converter input is -23 dBm and remaining margin is -8 − (-23) = 15 dB. If the margin is negative the assumed linear transfer cannot be trusted; a reduced-gain challenge or independent low-gain

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channel is needed before discussing the weak candidate. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

Application 10. Accumulated sample-clock time error

In the illustrative 031.10 test, an RF band is deliberately sampled below twice its carrier frequency while an analogue preselector confines the permitted Nyquist zone. A free-running sample clock with fractional rate error $\varepsilon = 1.390$ ppm over $T = 563$ s accumulates nominal offset $\Delta t = \varepsilon \times 10^{-6} T = 0.7826$ ms. This model applies to an approximately constant mean rate error, not oscillator phase noise or dropped acquisition blocks. Comparing two differently disciplined clocks requires separate treatment of correlated reference errors and the timestamp tagging point. validate the entire occupied analogue spectrum rather than infer unique RF provenance from the sampled baseband.

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Selected technical references and use limitations

National Institute of Standards and Technology, Technical Note 1297, “Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results”, https://www.nist.gov/pml/nist-technical-note-1297 (consulted 11 November 2026).

National Institute of Standards and Technology, TN 1297, sections 5–7: combined uncertainty and reporting, https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-7-reporting-uncertainty (consulted 11 November 2026).

“Basics of Band-Limited Sampling and Aliasing” (2005), https://www.analog.com/en/resources/technical-articles/basics-of-bandlimited-sampling-and-aliasing.html (consulted 11 November 2026).

These technical references support general analytical principles only; they do not verify the invented exchange, the hypothetical numerical inputs, or any actual forensic observation.

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QUESTION 033

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Which resampling operations preserve time, amplitude and phase claims?

Source: V011_Roundtable_Question_033_CP033_Dr_Atkinson(1).docx | Recovered substantive manuscript. Constructed educational dialogue.

Original educational reconstruction. None of the dialogue is a historical quotation or a representation that a deceased contributor evaluated a modern digital receiver. All numerical examples describe stipulated laboratory conditions. The analysis distinguishes the truth of an operation on stored samples from the separate truth of claims about an earlier electromagnetic event.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, our previous examination of signed complex spectra has demonstrated how easily an internally consistent digital representation can be mistaken for a complete record of its physical origin. We now encounter a related problem at the temporal boundary. A recording may begin with complex samples whose timestamps, gains and phase relations are known within specified tolerances, and end with an apparently improved array that contains more samples, fewer samples, or a different nominal sampling rate. The transformation may facilitate listening, efficient channelisation, correlation, storage or comparison among receivers. Yet none of those benefits relieves us of the obligation to explain whether the transformed series still supports the original conclusions about event time, physical amplitude, carrier frequency, phase and duration. A new sampling grid is a representation of the available evidence, not a retrospective acquisition of observations that the original receiver never made.

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We must therefore reject the simple division of resampling into harmless and harmful operations. Its evidential consequences depend upon the intended measurand, the spectrum admitted before sampling, the interpolation and anti-alias filters, the relationship between source and output clocks, the treatment of discontinuities, and the timestamps assigned after processing. A rational resampler may preserve the content of a band-limited waveform to a declared tolerance. It cannot create the missing high-frequency information excluded by a prior analogue filter. A decimator may deliver a clean narrower channel with lower storage cost while destroying the possibility of investigating signals outside its output passband. A time-warp estimator may improve alignment between two recording clocks while concealing a genuine acquisition gap if the operator does not preserve the original sample indices and clock evidence. An interpolation function may return a value at any desired intermediate time, but the existence of that returned number does not prove that an analogue voltage was independently measured at that instant.

For our common mathematics, let $x[n]$ denote a complex source record sampled on nominal times $t_n = t_0 + n/f_s$, where f_s is the source complex-sample rate, t_0 the declared start time, and n an integer index. Let the target rate be $f'_s = (L/M)f_s$, where L and M are positive integer interpolation and decimation factors reduced to lowest terms. For an ideal stationary time base, the output time associated with index m is $t'_m = t'_0 + m/f'_s$. It need not be true that t'_0 equals t_0. The resampling filter can have delay, a boundary extension policy can affect its first valid output, and an application may shift or trim transient samples. If the physical source clock was in error by ε parts per million or included dropouts, merely assigning a

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new nominal f'_s does not retrospectively correct those properties. A valid clock correction requires a measured model of the original time base, independent reference evidence, and a statement of residual uncertainty.

Consider the three familiar objectives of fidelity. Amplitude fidelity asks whether output values are unbiased estimates of a specified input waveform quantity, with a gain response and uncertainty that are known over the relevant spectral and temporal support. Phase fidelity asks whether relative and absolute phase claims remain interpretable after filters, boundary treatment, group delay and clock mapping. Time fidelity asks whether an event's onset, separation and order remain tied to real observation times rather than to arbitrary output indices. These are related but not identical. A filter may preserve its passband amplitude to one tenth of a decibel while imposing a substantial, known latency. A zero-phase offline operation can maintain a convenient phase relationship under a particular boundary model but may be noncausal and use future samples that would not have existed during the original detection decision. A visually sharper signal after resampling can have a displaced onset or correlated errors that invalidate the confidence interval attached to the display.

The defensive TSCM context makes these distinctions acute. Investigators may combine receivers with independent oscillators, channelise broad captures, compare burst timing against an external event log, or replay short suspicious fragments through several analysis programs. A few microseconds of incorrect temporal mapping can alter a cross-receiver phase comparison. A tiny scaling error can change whether a brief event crosses a declared threshold. An undocumented filter can reduce a short pulse's peak while making it look broader and more persistent. A

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well-made report should identify which of those transformations were analytical, which were part of the original recording, and whether the raw source record is preserved for independent reconstruction. It should never describe an interpolated sample as a new physical observation.

I invite Mr Nyquist first to establish what a sampling theorem can and cannot guarantee when a band-limited signal is transferred to another rate. Professor Wiener will then examine the time-varying filter and the consequences of shaping transients, especially when statistical assumptions cease to hold after interpolation. Professor Bracewell will address spectral reconstruction, phase and the danger of using Fourier continuity to conceal a discontinuous acquisition history. Dr Deming will scrutinise calibration, validation, operating characteristics and the distinction between a repeatable algorithm and a properly tested instrument. Finally Dr Shannon will consider information loss, representation and the boundaries of inference when a compressed or decimated archive is used to support a conclusion beyond its retained evidence. Seven colleagues will interrogate the principal statements, and each addressed respondent will reply immediately before the floor passes onward. We will finish with numerical cases that state the applicable variables, filter conditions, clock uncertainties and test limits. Mr Nyquist, please begin by separating the mathematical sufficiency of ideal interpolation from the evidential adequacy of a real receiver's acquisition record.

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Harry Nyquist | Principal response 1: Reconstruction conditions, rate ratios and omitted analogue information

Dr. Atkinson, the theorem concerning reconstruction has always been more conditional than the enthusiastic operator may wish. In the idealized argument, a continuously defined signal is limited in spectral content, samples are taken at the necessary rate and known times, and reconstruction employs a kernel adequate for that signal class. A change in the density of a representation is then permitted because the relevant information was already present in the original sequence. The new values are interpolants computed from earlier observations and assumptions, not new independent measurements. The strength of this distinction is clearest when we use a real anti-alias filter as part of the declared apparatus. A source spectrum whose admitted energy was restricted to an appropriately narrow band can be translated into a new sample grid without logical contradiction. The same operation applied to an unknown wideband record may fold materially different original components into indistinguishable output frequencies. The arithmetic of the rate change does not prove the premise of adequate band limitation.

Let the input sampling rate be f_s and let the output be $f'_s = (L/M)f_s$. In a rational implementation, one may conceptualise the process as inserting L-1 zeros between source samples, passing the result through a low-pass interpolation filter, and retaining every Mth filtered value. Efficient polyphase implementations rearrange that arithmetic but do not abolish the anti-imaging and anti-alias requirements. If the rate is reduced, the target interval admits less unique spectral width. The filter must suppress energy that would otherwise map onto admissible output frequencies. If the rate is

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raised, new sample slots must be filled from a declared interpolation model, and spectral images caused by zero insertion must be removed. The operation is meaningful because of the model and filter, not because multiplying the source-sample count improves the original instrument's sensitivity or resolution.

We ought to distinguish a zero-valued inserted sample from a physical zero voltage. The intermediate zeros of the conceptual upsampling stage are mathematical placeholders. A software trace displaying them without the filtering stage could mislead a reader into believing that the physical waveform repeatedly vanished between acquisitions. Proper interpolation can recover the expected sinusoidal trajectory for a defined band-limited input, but its values remain dependent upon surrounding samples. It follows that the statistical uncertainty of an interpolated series is generally correlated. An investigator who treats each of three output samples as three independent observations of a stochastic quantity may report a confidence interval much narrower than the data support. The apparent increase in the number of numbers should not be equated with an increase in independent evidence.

The other hidden variable is time. A nominal sample rate is not an exhaustive description of the original acquisition clock. Let t_n denote the real instant at which the nth sample was acquired. The familiar expression n/f_s is a useful ideal clock model, but real systems possess oscillator error, jitter, potentially discontinuous buffers and sometimes clock-source changes. Interpolation from a series indexed by n does not establish that t_n followed the assumed law. If one receiver acquired at 8,000,080 samples per second while its metadata declared exactly 8,000,000, a later conversion to

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6,000,000 using that metadata inherits a small but meaningful time-scale error. Correcting it demands identification of the original clock error. Replacing the label alone is not calibration. A long trace can accumulate measurable drift even when the corresponding instantaneous waveform appears smooth.

The engineer should specify what is meant by preserving amplitude. If a finite filter has passband ripple, then the output magnitude of a tone depends upon its spectral location. At a calibrated reference plane the gain may be nearly unity, but we must measure or bound the deviation at frequencies that matter to the claimed event. A transient whose spectrum spans the transition region may change shape and peak even when ordinary narrowband calibration tones pass with little loss. A filter designed for the best average frequency response cannot by itself prove preservation of the exact peak of an unknown, brief pulse. Similarly, a phase-linear filter may possess a constant group delay that must be incorporated in event timestamps. If that delay is known and the relevant signal is within the assumed band, correction can be justified. Without a source clock and group-delay record the investigator cannot simply infer event chronology from the displayed output index.

I would therefore require an acceptance campaign structured by the question being answered. To certify a frequency-preserving path within an admitted band, inject known positive and negative complex tones across that band, including its edges, and compare their positions in source and output spectra. To certify phase preservation, use a reference with controlled phase and timing, estimate the transfer phase and group delay, and repeat after any changes to filter coefficients or resampling factor. To

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certify burst detection, construct transients whose onset and duration vary independently of the resampler's interpolation grid; do not choose only favourable phases or onsets. An empirical result obtained from such tests supports the specified operating envelope, not arbitrary future signals or unknown upstream states.

A final qualification concerns the correct description of precision. The output rate may be expressed by an exact rational number, but that exactness is a property of the chosen calculation, not of the physical oscillator. A resampler can produce exactly three output samples for every four input sample intervals under a nominated nominal rate while the actual elapsed time is slightly different. We should maintain separate records of the nominal digital ratio, the measured source-clock frequency, the uncertainty of time mapping, and any adjustments to the output epoch. When these quantities are recorded, a reader can distinguish numerical transformations from calibrated physical time. In their absence the result may still be useful for pattern recognition or audio replay, but a forensic claim of precisely timed emissions requires additional evidence. Professor Gabor, please challenge whether the reconstruction of a waveform at additional points can ever establish a new independently observed event or whether it merely increases the apparent fluency of the record.

Dennis Gabor | Peer question 1 to Harry Nyquist

Mr Nyquist, the distinction between reconstruction and fresh observation seems elementary when written on a blackboard, yet becomes less comfortable when a laboratory seeks to detect a pulse that was hardly visible on its original digital grid. Suppose a short recorded interval is converted to eight times its former sample rate, displayed as a

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smooth curve, and then searched for a threshold crossing. The new curve may cross the threshold between two original sample instants. The software may describe that crossing with a number of nanoseconds and a plausible phase. But the crossing depends upon the selected reconstruction kernel, its boundary assumptions and the original sample spacing. It may be stable for a band-limited test waveform while remaining indeterminate for a transient containing unobserved spectral components. What may the analyst claim about the crossing time, and what additional measurements would justify treating it as a bound on the actual analogue event rather than a property of the interpolation algorithm? Please consider the difference between an estimate, a newly acquired observation, and an interpolation-dependent hypothesis.

Harry Nyquist | Immediate answer to Dennis Gabor

Professor Gabor, the correct answer depends upon the proposition and the evidence for the signal class. If the input was genuinely band-limited to the stipulated range, the acquisition times are sufficiently known, the amplitude relation is calibrated, and the adopted reconstruction kernel approximates the appropriate ideal to an acceptable error, the interpolated crossing may be a legitimate estimate of when the continuous waveform crossed the threshold. Its uncertainty should account for sample-clock error, quantisation, noise, finite filter behaviour and the uncertainty of the waveform model. The estimate is not transformed into an independently measured time merely because it appears on a denser array. The investigator must describe it as an inference computed from earlier observations.

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For a pulse whose significant spectral energy reaches beyond the acquisition passband, the situation is different. Two physically distinct analogue pulses can produce the same stored samples or substantially indistinguishable values after front-end filtering, while crossing the threshold at different instants. The inverse problem then lacks uniqueness without supplementary assumptions. No amount of spline interpolation, Fourier zero-padding or graphical smoothing can recover the unmeasured distinction. It may still be useful to report the crossing time of the *reconstructed* waveform, but the qualifier is not ornamental. It identifies the actual quantity computed. A report that suppresses this qualifier can present a false impression that the original receiver observed an event with an accuracy determined only by the output display resolution.

A practical experiment should vary the pulse's phase relative to the original sample clock, its rise time, its spectral support, and the noise level. Compare the reconstructed crossing with an independently timed analogue reference whose own uncertainty is documented. Include examples close to the threshold and near the edges of the admitted band. Do not adjust the kernel after looking at failure cases and then report only the successful results as if the procedure had been fixed before testing. If the resampler is part of a detector, the validation population must include missed bursts, false alarms and intervals during which the input was not observed. These tests can yield a bounded distribution of timing error for a defined class rather than a vague assurance that interpolation is accurate.

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For evidential preservation, retain the raw sample stream and the filter coefficients or an exact software definition sufficient to reproduce the interpolation. Record the original clock information, original sample indices and any trimming or delay correction. Preserve the output as a derivative, with a hash and provenance link to the source. A reviewer can then calculate whether the claimed crossing is stable under reasonable kernel variations, or whether the result is so model-sensitive that only a wider time interval is justified. It is not necessary to deny every use of interpolation; it is necessary to state the inferential step with the same care we apply to a physical calibration. Mr Hamming, perhaps you will ask how an efficient digital implementation can keep such provenance without burdening every routine analysis with an impossible amount of documentation.

Richard Wesley Hamming | Peer question 2 to Harry Nyquist

Mr Nyquist, a receiver may channelise hundreds of signal streams, change their rates more than once, and archive only those records selected by event detectors. Insisting upon every intermediate representation could make long-term storage impractical, yet discarding all processing history would leave the later examiner unable to test a frequency or timing conclusion. Suppose a rational conversion is specified by a versioned program and a finite coefficient array, but a later release changes the boundary extension policy, output-length rounding, and treatment of missing input frames. The nominal rate ratio remains unchanged while the first few samples and event-onset estimates differ. What minimum record makes the output reproducible without preserving every transitory buffer? Which source data must be retained

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as evidence, which derived data may be recreated, and how should software tests detect a change in algorithmic behaviour even though the code reports the same two integers L and M? I should particularly welcome an account of boundary cases, because short transient records often disclose what long stationary test tones conceal, and of the distinction between reproducible digital outputs and authenticated physical sampling histories.

Harry Nyquist | Immediate answer to Richard Wesley Hamming

Thank you for that question. Dr Hamming, the goal is neither indiscriminate hoarding nor a reliance upon a verbal description as thin as the output rate. We should preserve the earliest practicable evidence that is necessary for the claim, together with the sufficient deterministic information to reproduce derived representations. In a receiver investigation that often means raw complex samples, actual sample-rate and timebase records, frequency tuning and gain states, buffer-gap markers, and the acquisition reference plane. A polyphase resampler's output can often be regenerated, but only if its algorithm, coefficient sequence, boundary treatment, initial phase and trimming rules are also known. Two programs with the same L/M ratio can produce different edge transients and timestamp alignment while behaving similarly in the centre of a long coherent tone.

I would distinguish a scientific reproducibility record from a complete execution log of every internal memory transaction. A stable, cryptographically identified implementation with preserved parameters and an unaltered source file may reproduce an output more convincingly than millions of undocumented temporary buffers.

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But the test must actually show reproducibility across the operating conditions that matter. Re-running a single sine wave placed far from every band edge will not expose a boundary extension change relevant to a short burst. Test vectors should include a zero-length interval, a very short pulse at each edge, a long coherent tone, noise with known statistics, and a record containing explicit missing blocks. Where fixed-point arithmetic or processor-specific optimisations affect the output, require acceptable numerical tolerances rather than an unsupported claim of bit-for-bit identity across all platforms.

The archived provenance should identify each derivative through a digest of its source and a content-addressed or otherwise unambiguous processing manifest. Include filter taps, software build, clock model, sample-index mapping, numerical type and any stateful adaptivity. If the operator changes the method after seeing results, preserve the earlier output and record the reason for the change. A change that corrects a documented defect may be entirely proper, but it cannot silently replace the evidence that originally led an investigator to select a suspicious fragment. That earlier decision may have depended on the defect itself, and the history may affect the interpretation of false alarms or ascertainment bias.

Finally, the claims must be proportionate to what survived. If a full wideband source recording was retained, a later examiner can test different rate-conversion methods over the acquired band. If only a narrow decimated product was stored, the examiner may still reproduce the derivation and analyse that channel, but cannot demand the lost out-of-band information from the source that no

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longer exists. An honest record explicitly states the retained band, the unobserved bands and the known deletions. The correct engineering economy is to reduce unnecessary storage while preserving the evidence and methods necessary to support the conclusions that the report actually makes. Professor Wiener, I pass the discussion to you to examine what the filtering stage does to the temporal and statistical interpretation of a recorded event.

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Norbert Wiener | Principal response 2: Filters, time-domain memory and the covariance induced by interpolation

Dr. Atkinson, I should begin by treating the resampler not as an innocent relabelling of coordinates but as a system that remembers neighbouring observations. A finite impulse response filter forms each output from a weighted collection of input samples. Even when those inputs contain statistically independent noise, neighbouring outputs generally share input contributions, so their errors need not be independent. The practical consequence is not merely a small mathematical detail. If a detector sums or averages resampled values while assuming their errors are independent, it can exaggerate the precision of the estimate and misstate the probability of obtaining an apparent weak feature under a noise-only condition. A more densely sampled picture may make an irregular fluctuation appear smoother while preserving, or even increasing, the dependence among the quantities shown. The appropriate statistical model must follow the transformation.

Consider y[m] = sum over n of h_m[n] x[n], where h_m[n] is the effective weighting kernel that connects input index n to output index m. The kernel changes with m in a polyphase arrangement, and may change again if the rate-conversion ratio adapts to a measured clock discrepancy. If the input has covariance C_x[n,k], the output covariance is C_y[m,r] = sum over n and k of h_m[n] C_x[n,k] h_r[k]*. In matrix notation, C_y = H C_x H^H, where H^H denotes conjugate transpose. This relationship reveals why the output noise statistics cannot generally be inferred from the new sampling interval alone. A filter that attenuates high-frequency noise may reduce variance but introduce correlation; a frequency-dependent calibration may change both

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the mean response and the error structure. The receiver's confidence calculations should use the transformed covariance or a validated empirical equivalent.

There is also an often neglected distinction between causal filtering and offline processing that uses future samples. A causal filter must accumulate information before delivering its estimate, and it therefore introduces latency determined by its architecture and group-delay response. An offline zero-phase technique may process a file in both temporal directions or compensate a symmetric FIR delay through trimming and padding. These choices may produce pleasing alignment in the output plot, but the algorithm's result cannot be inserted into the historical chronology as though the original detector had known the future. When evaluating whether an alert could have been raised before a suspicious transmitter ceased operating, the earliest information available to the live detector matters. When reconstructing an archival waveform after the event, a noncausal estimate may be useful, provided the distinction is recorded. Both are legitimate activities; neither is accurately described by a single undiscriminating timestamp.

A short pulse illustrates the danger. Let an original waveform contain a sharply bounded disturbance. A low-pass resampling filter has an impulse response extending over several input intervals. The output may show energy before and after the nominal onset, especially where a symmetric offline kernel is employed. That apparent pre-event response is not proof of an earlier physical emission. It is a predictable consequence of applying a kernel with temporal support on both sides of the event. Even for a causal filter, the peak can be delayed and attenuated relative to the source. If the

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analyst timestamps the filtered peak rather than the calibrated input onset, the report may shift the event by an amount determined by the filter and the pulse's spectrum. A measured group delay corrects certain narrowband relationships, but a broadband transient requires more careful characterisation of the full impulse response.

The operating assumptions become even more fragile when the source rate varies. An arbitrary resampler may choose a succession of fractional phases and interpolate between neighbouring polyphase filter outputs. Under a stable ratio the transformation can be designed for predictable amplitude and phase behaviour. Under adaptive correction, however, the coefficients or phase positions vary with time. The system becomes time-varying, and a single frequency-response plot may not describe every output sample. If the adaptation responds to an estimated signal feature rather than an independent clock reference, it may selectively modify the very anomaly that the investigator intends to measure. A drift-correction algorithm which shifts event positions to improve cross-correlation deserves special scrutiny because success in alignment can be obtained by sacrificing evidence of a real timing difference.

I would validate an algorithm against three separable questions. First, what spectrum is retained and with what passband amplitude, stopband leakage and transition uncertainty? Secondly, how are onset, phase, group delay and absolute timestamp propagated through the chosen processing state? Thirdly, what dependence and bias does the operation introduce into the statistical evidence used for detection? A test based only on an isolated sinusoid at one favourable frequency will not adequately represent transient event classes or time-varying clock adjustments. We need pulses, noise,

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spectral edge cases, known discontinuities and signals positioned near the decision threshold. The trials should preserve failures and false alarms rather than retune the procedure until only successes remain visible.

This is particularly important in a multi-receiver defensive survey. Two channels may share an analysis program and identical filter coefficients, so identical artefacts may arise in both outputs even though their analogue noise sources are independent. Conversely, one stream may be resampled by a different kernel and emerge with an apparently different phase or onset, creating false disagreement. Corroboration requires knowledge of the respective transforms and their uncertainties, not merely an attractive overlay of two spectrograms. A time registration is useful only to the extent that the mapping and its residual uncertainty are independently supported. Professor Tukey, may I invite your question about how one can report a probability or a confidence interval after the samples have become dependent through the resampling operation?

John Wilder Tukey | Peer question 3 to Norbert Wiener

Professor Wiener, you have shown that filtering a sequence can lower the variance at each output while increasing dependence between successive outputs. Suppose a laboratory produces a million resampled points from a much smaller source archive, reports that a weak spectral component is supported by a million observations, and calculates uncertainty by dividing a standard deviation by the square root of a million. That procedure may be correct only under a restrictive model which the chosen interpolation filter violates. Yet an investigator must still calculate useful uncertainty rather than condemn every derived series as unusable. How should an analysis distinguish the nominal

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sample count from the effective independent information available for the specified estimator? Would you recommend computing the covariance from the source data and transfer matrix, measuring a distribution of repeated independent experiments, or both? What assumptions about noise stationarity and adaptive resampling should be disclosed before a claimed improvement in detection confidence is accepted?

Norbert Wiener | Immediate answer to John Wilder Tukey

Thank you for that question. Professor Tukey, I would begin by identifying the estimator, not by treating a large sample count as a scientific achievement. The covariance formula I have proposed tells us what may happen under a specified linear transformation. If source noise is stationary with a known spectrum and the resampling system is fixed, one can derive the output covariance and use it to calculate the variance of the actual estimator. For the mean of a correlated sequence y[1] through y[N], the variance is N^-2 times the sum of every covariance Cov(y[i],y[j]), not simply the sample variance divided by N. The off-diagonal terms represent the dependence created or preserved by filtering. They cannot be abolished by changing the output file length.

Where the model is sufficiently established, the concept of effective sample size can provide a compact explanation of why N displayed points contain less independent information than N uncorrelated observations. But effective sample size is not a universal constant attached to the file. It depends upon the statistic, the correlation structure and the question. An estimator of average power, a

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matched-filter detection statistic and an estimate of pulse onset respond differently to the same covariance. An analyst who calculates one effective count and applies it indiscriminately to every result merely replaces one false precision with another. A defensible report should give the estimator-specific variance or a clearly justified approximation.

Repeated experiments are equally important, particularly when the mathematical model omits nonstationary interference, adaptive gain, burst selection or state changes. Controlled trials can compare the predicted distribution of an estimator with observed outcomes across different input levels, frequencies, noise colours, phase positions and gap patterns. The investigator should not assume that a laboratory's internally generated white noise represents every electromagnetic operating condition. A good campaign uses physically introduced stimuli for relevant analogue behaviours and synthetic inputs for controlled algorithmic edge cases, preserving the boundary between the two forms of evidence. Discrepancies between predicted and observed variance should lead to a revised and explicitly documented model, not to a quiet removal of inconvenient trials.

I would also preserve the original clock mapping and record whether the resampling ratio was constant or adaptive. If the ratio responds to the observed signal, the output may be conditionally selected or manipulated in ways that violate a simple stationary covariance model. A particular adaptive operation may nonetheless be useful, but its randomness and decision rules belong inside the analysis. The experiment should be repeated with input sequences

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whose physical timing and amplitudes are known independently of the estimator being tested. Only then may the engineer claim that a measured improvement is not merely the result of applying the procedure to the same observations used to choose its settings. Mr Heaviside, perhaps you will challenge whether the mathematical kernel sufficiently accounts for the analogue circuits and filters that preceded it.

Oliver Heaviside | Peer question 4 to Norbert Wiener

Professor Wiener, your matrix account is exact for the linear transformation it specifies, but it begins with samples that have already passed through a physical receiver. Suppose an analogue anti-alias filter introduces a frequency-dependent group delay, an IF amplifier saturates on a strong transient, and the digitiser drops a buffer while the software is attempting to correct its clock. The final resampler may be a perfectly implemented linear operation on its admitted array, yet the original analogue event could be displaced, distorted or incompletely recorded. What boundary must the engineer establish before your covariance and latency analysis can be interpreted as evidence about the earlier electrical quantity? In particular, how should a report distinguish an unavoidable physical delay, a remediable software delay and a loss of information that no filter, however elegant, can reverse? I am also concerned with the status of a calibration measurement taken in one gain condition and later invoked to justify a different receiver state. When does that extrapolation cease to be warranted?

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Norbert Wiener | Immediate answer to Oliver Heaviside

Thank you for that question. Mr Heaviside, your criticism is necessary because a model of digital processing is not automatically a model of the whole receiver. We should declare at least three boundaries. The first is the analogue input reference plane, where the measurand and conditions of loading and band limitation are stated. The second is the digitiser output, where samples enter the retained sequence under specific clock, gain and quantisation conditions. The third is the derived record after resampling. Between those boundaries we must characterise the transformations relevant to the asserted claim. A covariance calculation beginning at the digitiser output can be correct while saying nothing sufficient about an unmodelled analogue nonlinearity preceding the digitiser.

A stable analogue group delay can often be measured and included as a correction to event timing, with its uncertainty. A known digital FIR delay can similarly be computed from filter coefficients and verified with a reference impulse or modulated waveform. These delays are not errors merely because they are nonzero. They become errors in the report when a timestamp is interpreted at the wrong reference plane or the correction is asserted without evidence that the applicable state remained unchanged. A frequency-dependent group delay may require a waveform-specific correction rather than one global number. When the signal class is unknown and broad, it may be more defensible to report a range of onset times bounded by the established response envelope.

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Saturation and dropped samples impose different limitations. Clipping can eliminate amplitude distinctions, leaving only inequalities or model-dependent reconstructions for the clipped interval. A missing acquisition block creates a time interval in which the instrument retained no samples. Interpolating across it can make a display visually continuous, but cannot establish what unobserved events occurred inside the gap. The gap should therefore remain represented in the derivative's metadata and in the technical report, even if a secondary visualization uses interpolation to support human inspection. A digitally beautiful curve that conceals a missing block is less faithful evidence than an admittedly incomplete record whose interruption can be audited.

The acceptance programme should combine analogue and digital challenges: physically introduced test signals at the declared input, recorded digitiser-level measurements where accessible, and deterministic synthetic sequences that isolate the software's numerical behaviour. Correlation among derived samples may be estimated in software, while the analogue delay, overload and gain state require physical tests. We should trace which conclusion is supported by which test boundary. This layered discipline avoids both extremes: it neither demands the impossible reconstruction of every unobserved waveform nor allows a perfectly computed filter output to certify everything about the chain that produced its input. Professor Bracewell, the floor passes to you for the relation between Fourier interpolation and the actual continuity of the acquired history.

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Ronald Newbold Bracewell | Principal response 3: Fourier continuity, finite boundaries and physical phase

Dr. Atkinson, I propose to distinguish the reconstruction of a finite digital record from the reconstruction of the physical waveform that entered its analogue front end. A finite sequence can be extended, interpolated, transformed and inverse-transformed by mathematically well-defined operations. Those operations are useful and sometimes remarkably accurate. Yet any reconstruction of values between source samples depends upon what class of possible continuous signals we allow. One must ask whether the original acquisition conditions supplied adequate support for that class, and whether the observed interval actually contains the continuous history implied by the algorithm. An FFT-based resampler often acts as though the finite sequence is one period of a periodic function. If the first and last samples do not join smoothly, the assumed periodic extension introduces an artificial discontinuity at the boundary. The resulting ringing can be especially misleading when the archive contains a brief burst close to that edge.

For a long coherent periodic input, Fourier resampling may be convenient and mathematically coherent. The analyst transforms the source sequence, modifies the representation to suit a new length, and applies an inverse transform. This can preserve the identified periodic components under the relevant conventions. But a finite transient embedded in a nonperiodic recording is a different matter. An abrupt boundary, a missing buffer or a transmitter's sudden cessation can put energy across a broad range of Fourier bins. Altering the coefficient count can spread or reshape that energy. The appearance of pre-echo, post-echo or a smoother envelope

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may reflect the imposed extension rather than a historical electromagnetic field. This is why software documentation rightly warns that Fourier resampling relies on a periodic interpretation of its input. In the field report the chosen boundary model should be visible and open to challenge.

The situation is no less delicate in a polyphase FIR method. A long, symmetric impulse response can provide useful passband characteristics and a nearly constant group delay, but at the beginning and end of a finite record the algorithm needs values that do not exist. It may assume zeros outside the observed interval, reflect the samples at the boundary, extend their endpoint value, or construct a line from nearby observations. Each policy is an assumption about an unobserved continuation. The resulting output can differ in the very region where an investigator wishes to measure a sudden onset. It may therefore be prudent to mark an edge interval as affected by boundary treatment and to avoid certifying an onset there without independent verification. The problem cannot be settled by declaring one padding policy universally correct.

Consider now the preservation of phase. A linear-phase FIR filter can delay the components of an admitted waveform by the same nominal amount within its passband. For a stationary sinusoid a calibrated delay may translate into a predictable phase shift. That is useful for coherence and triangulation experiments. Yet a finite burst is not merely a sinusoid repeated forever. Its envelope, modulation and filtering may produce different apparent time markers. Two receivers processed by different filters can agree in absolute sample-rate metadata while differing in their effective onset definitions. A cross-correlation peak may align the derived waveforms but still leave an unknown difference between their original analogue

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reference planes. The report should therefore identify the phase quantity actually compared, the calibration of each signal path and the uncertainty of the time delay inferred from it.

A resampler also transforms how the discrete frequency axis is expressed. Let f_0 be the physical baseband frequency of a component and f_s the actual input sampling rate. Its discrete-time frequency is $\nu = f_0/f_s$ cycles per sample, considered modulo an integer. Once the record is resampled to f'_s, the same admitted physical tone should have normalized frequency $\nu' = f_0/f'_s$. Its location in cycles per sample changes even if its physical frequency does not. Thus a plot with an unupdated sampling-rate label can produce a false frequency shift from an otherwise correct numerical transformation. Such a mistake is particularly plausible when one software component reads an array of complex numbers while another component supplies the axis metadata. Data format and metadata must be validated as one evidential object.

I would insist upon a dual audit. The first concerns *mathematical reproduction*: can an independent engineer reproduce the output from the raw source, filter coefficients, rate ratio, extension policy and precise version of the algorithm? The second concerns *physical adequacy*: does that reproduced output support the intended claim when compared with known-input reference experiments? The first audit can show that a transform was performed consistently. It cannot alone establish that the original RF waveform was sufficiently band-limited, that an apparent burst was not a receiver artefact, or that a timing claim was referenced to the correct physical plane. The second audit therefore uses independent test

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waveforms and records their measured performance over the claimed range, including limitations.

A third audit is needed for continuity. A stored complex vector is an ordered array, but array adjacency does not prove continuous acquisition. A buffer can be dropped and the samples on either side concatenated; the resulting array remains perfectly suitable for an FFT, even though its index no longer describes uninterrupted elapsed time. A clock correction may distribute a missing interval over many output samples, concealing the place where a specific event could have escaped observation. An inverse transform cannot discover a historical interruption when no independent record of the interruption survived. Preserve the lost-block indices, source timestamps, acquisition state and discontinuity flags before any resampling, and propagate them through derivative products. If the necessary flags were never retained, the report should say that continuity could not be established from the file alone.

I offer a practical conclusion. Interpolation can be excellent when its premises are established and its transfer and boundary effects are tested. It cannot repair incomplete provenance by achieving numerical perfection. A signal that appears to retain a precise carrier phase after two transformations must still be associated with a measured clock and a known physical receiver path. A burst whose reconstructed onset varies across defensible boundary models should not be assigned a single falsely precise timestamp. A component that disappears after decimation may have been excluded by design, not disproved as an external emission. Major Armstrong, may I invite you to test how the analogue selectivity and

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blocking behaviour of an actual receiver should constrain the spectral claims of this otherwise mathematical account?

Edwin Howard Armstrong | Peer question 5 to Ronald Newbold Bracewell

Professor Bracewell, suppose a wideband receiver acquires a strong legitimate transmission at one offset and a much weaker suspicious burst near the intended decimation filter's transition band. The operator reduces the sampling rate, and the strong signal no longer appears in the narrow channel, while the weak burst becomes more prominent after filtering and plotting. The investigator concludes that the weak emission was confirmed independently by the resampled representation. Yet the source and derivative share one analogue observation, and the filter has changed the visibility of their relative spectra. How would you require the observer to distinguish genuine improved signal-to-noise ratio within an admitted band from selective removal of a competitor, leakage through imperfect stopband rejection, and an artefact caused by the filter's transient response? What controlled analogue tests are essential before describing the derived waterfall as independent confirmation rather than another analysis of the same acquired evidence? I also ask whether a test performed only on a stable tone can answer the question for short transmissions whose spectral components straddle the filter transition, and how an adverse trial should affect the final qualification.

Ronald Newbold Bracewell | Immediate answer to Edwin Howard Armstrong

Major Armstrong, I take your point about the apparent novelty of the processed trace. The derivative you describe is not independent

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evidence merely because its appearance differs. It is a transformation of the same source samples, with whatever physical and numerical limitations accompanied them. Filtering may improve the detectability of a component in the retained passband, and this improvement can be scientifically valuable. But the evidential statement should identify the transformation and the claim it supports. If a known interfering signal is removed by a valid filter, the resulting SNR may increase for an appropriately defined detector. That does not establish an additional observation of the weak source. We must avoid counting several filtered versions of one recording as several independent detections when evaluating a false-alarm probability.

A proper challenge begins at the relevant analogue reference plane. Apply a calibrated weak test burst and vary its frequency, duration, phase relative to the sampling clock and amplitude. Add a strong legitimate blocker at frequencies that probe both the analogue front end and the resampling filter's transition and stopband regions. Measure the output of the detector, not simply the visual separation of peaks. Use controls without the weak burst to estimate whether blocker-induced images, overload products or FIR ringing can generate similar indications. If a weak burst is retained only under favourable buffer alignment or selected padding rules, the acceptance domain must be restricted accordingly. If the claimed filter suppression is insufficient for the blocker amplitude, the possibility of residual leakage remains material.

We should also examine the meaning of independence. Two distinct receiver front ends can provide complementary evidence if

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their paths and clocks are characterised and if their response to the suspected signal is tested. Two resamplings of one raw array generally do not. That distinction is not a judgement that derivative processing has little value. It may be necessary to reveal a weak feature, estimate timing or compare modulation. But the report should use language such as 'the same acquired event remains visible after specified filtering' instead of 'confirmed by another observation' unless an independent measurement was actually taken. The stronger the causal attribution, the more carefully this distinction must be defended.

A statistically competent presentation would preserve unsuccessful searches and alternative filter settings that were actually tried. Selecting the one representation in which the weak burst looks most convincing and ignoring the others may introduce selection bias, particularly if thresholds were retuned after inspection. One can perform an exploratory search and then conduct independent confirmation with a fixed procedure and new data. If that is impossible, the result remains exploratory or conditionally supported and should be described as such. There is no shame in an honest limitation. The danger lies in allowing the elegance of a clean narrowband waterfall to conceal an untested physical mechanism. Dr Deming, I transfer the floor to you to define how an acceptance programme can support a sufficiently limited but reproducible measurement claim.

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W. Edwards Deming | Principal response 4: Validation across conditions and a measurement system that does not conceal failure

Dr. Atkinson, the central mistake I wish to challenge is to substitute a repeatable procedure for a validated measurement system. A digital transformation may produce the same output every time its program runs, yet the physical claim attached to that output can still be wrong. Reproducibility of a numerical result is an important property, but it is not the whole of measurement quality. We must ask whether the procedure measures the intended quantity under the conditions for which the result will be used. A laboratory may demonstrate accurate resampling of a long sine wave with a fixed phase and then market its receiver as capable of locating unpredictable microsecond bursts while operating beside strong, changing interference. Those are different claims. The operating population of test signals, the calibration reference plane and the decision criterion must match the proposition to be certified.

I would begin by separating the variables that the operator controls from those that the physical environment supplies. Filter coefficients, interpolation ratio, software version and endpoint policy are controllable. Source waveform, burst onset relative to the clock, blocker power, temperature, analogue gain state and network clock conditions may vary independently. A suitable experimental design challenges both types. If the operator adjusts the filter after observing the test cases and then reports only the final favourable result, the evidence may describe a selected success rather than prospective performance. A fixed acceptance rule, established before the relevant evaluation trials, permits a much more interpretable conclusion. Where exploratory development is required,

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record the development trials separately and test the chosen final procedure against new inputs.

The language of a calibration certificate also deserves attention. A certificate may establish that an instrument met specified performance requirements on a particular occasion, using defined procedures and measurement standards. It does not imply that every later internal coefficient, clock source, front-end state or software branch remained unchanged. If a receiver applies automatic resampling corrections based on a measured external reference, we should record whether that reference was locked, the correction values used, and the residual errors observed. A time-tagging function that has passed a laboratory test can nevertheless fail in service because a buffer is lost or because its firmware changes the initial phase after a retune. The relevant quality system monitors the actual process and its departures, not merely the existence of a certificate in a binder.

Statistical treatment must likewise follow the intended claim. A specification that the mean amplitude error is nearly zero can conceal a significant distribution of individual errors. For threshold decisions on weak intermittent signals, the tails of that distribution may matter more than its centre. A filter can have small average passband ripple and still cause a short pulse at an unfortunate phase to fall below the threshold. A mean time alignment can be correct while occasional output gaps produce large errors. We should report detection probability or timing coverage over a declared trial population, including confidence intervals and the failure modes actually observed. A statement that performance is 'within tolerance'

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is empty unless the tolerance, coverage, exposure and conditions are defined.

An audit also needs a clear notion of the measurement record. A source file, its authenticated digest, and a transformation manifest identify the input to the algorithm and the rules applied. The resulting derivative should be related to that source without overwriting it. Analysts may correct a documented error and produce a better result, but the earlier interpretation must remain traceable, especially if it influenced later collection choices. A long surveillance survey may contain both selected events and periods with no archived samples. Resampling the selected events cannot justify a claim about absence during the unretained intervals. The same principle applies when downstream software drops any segment it classifies as uninteresting. The record must describe how the data were selected before it can support an inference about the underlying population.

A useful validation report would therefore distinguish three propositions. First, did the implementation apply the declared numerical algorithm? This can be established by deterministic vectors, independent implementations and version-controlled code. Secondly, did the end-to-end receiver preserve the waveform quantities needed for the intended test? This requires calibrated physical stimuli and characterisation across the operating envelope. Thirdly, does the investigation's inference, including its decision threshold and uncertainty, follow from the actual archived evidence? This requires accounting for selection, dependence, missing exposure and competing causes. Success in the first category cannot be promoted to success in the third without the intervening proof.

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For a practical release decision, I would recommend a table showing each claim alongside its reference plane, test population, maximum or interval error, untested conditions and acceptance criterion. Report discordant cases rather than hiding them in a narrative of success. If a source timestamp is shifted by an unexpected number of samples under one boundary policy, the software can still be valuable, but the scope of the timing claim should be revised. If the filter's stopband is inadequate for a measured blocker, correct the filter or restrict the operating envelope and retest. A release discipline should prefer a bounded, demonstrated result over an expansive assertion that cannot survive an adversarial examination. Professor Bridgman, would you challenge whether the phrase 'preserved amplitude' has a stable meaning unless the physical operation and estimator are first defined?

Percy Williams Bridgman | Peer question 6 to W. Edwards Deming

Dr Deming, the phrase 'amplitude preservation' appears deceptively simple in technical reports. A receiver may report an RMS voltage over a filter's passband, a peak sample value, the maximum of a reconstructed pulse, a narrow FFT-bin amplitude, or the output of an energy detector. A resampler can preserve one of these quantities and change another. An amplifier calibration at a declared frequency cannot establish the peak of an unknown transient, and a zero-phase filter may alter a peak while leaving an integrated power estimate comparatively stable. How should a validation programme define its measurand so that the same word does not conceal changing operations? Would you insist upon separate tolerances for tone amplitude, burst peak, event energy and threshold-crossing time? And when the original source record is preserved, which

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of these derived quantities should a later examiner be permitted to recalculate under a more defensible estimator without rewriting the historical observation?

W. Edwards Deming | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, I would insist upon the distinctions you propose, because measurement quality is impossible to establish without specifying the quantity and method. The phrase 'preserved amplitude' should be replaced by a defined variable, reference plane, bandwidth, temporal window and estimator. A tone amplitude measured after a narrowband filter is not automatically comparable to the maximum sample of a pulse reconstruction. An RMS value may be stable under transformations that change the pulse's maximum. A detector's energy statistic may depend on integration time, filter normalization and noise subtraction. Each claimed preserved quantity requires its own response test or a justified relationship to another validated quantity.

Separate tolerances are therefore appropriate where the operational decisions differ. A survey might require frequency estimation within an established tolerance for a stable carrier, onset timing within a wider interval for a class of bursts, and peak-amplitude uncertainty over an admitted waveform family. Those requirements should be specified before the performance trials. A single generic percentage applied to all quantities would conceal the different ways that filters, clocks and noise influence them. The validation campaign must include cases near the boundaries of each

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requirement, not merely the easiest central conditions. When the real-world waveform class is unknown, the report should acknowledge that the tested family is narrower than all possible emissions.

Recalculation from a preserved source record is a strength, not a defect, provided the provenance remains clear. A later examiner may use a better estimator, correct an identified filter bug, or reevaluate uncertainty under a more appropriate noise model. The resulting value is a new analysis of the same underlying evidence, and it should be labelled as such. The original source samples, acquisition metadata, earlier derivative and correction history should remain available. Replacing the original conclusion without a version record would deprive the reader of an important part of the scientific process and could conceal whether an investigative decision was influenced by a now-discredited method.

Finally, we should distinguish correction from invention. A well-characterized, stable scaling error can be corrected with documented uncertainty. A lost sample interval or an unknown analogue overload cannot be restored uniquely simply by choosing a smoother estimator. In such circumstances the analysis may yield bounds or conditional reconstructions, but must say which assumptions generate them. The best measurement report is not the one with the most decimal places. It is the one in which another competent investigator can establish exactly what was measured, what was calculated, what conditions were tested and what alternatives remain plausible. Dr Shannon, I invite you to examine the deeper question of information lost through decimation and the temptation to call a

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sophisticated reconstruction a recovery of observations never retained.

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Claude Elwood Shannon | Principal response 5: Retained information, erased bands and the proper scope of a resampled inference

Dr. Atkinson, I should like to draw a distinction between the number of symbols available to the analyst and the information those symbols contain about the original physical event. A transformation can increase the length of a sequence without increasing the set of independent observations. It can also reduce the length while preserving an adequate representation of a restricted class of signals. But if the transformation discards spectral components, fine temporal distinctions or acquisition state, that information may no longer be available to answer a later question. The practical significance lies in specifying the intended inference before deciding that a derived archive is sufficient. No code has the power to make unrecorded alternatives disappear from the set of physically possible histories.

Imagine an acquisition admitting several megahertz of complex bandwidth. The examiner wishes to observe a narrow channel and therefore low-pass filters the record before reducing its sampling rate. If the filter works as designed, it suppresses components outside the preserved band so that they do not alias into the output. The narrower derivative can then support detailed examination of its retained contents, often with much lower storage and computation costs. But it does not establish that nothing occurred outside the retained band. In fact, suppression of those frequencies was the stated purpose of the transformation. A negative result in the derivative is therefore a conditional statement about the filtered channel during the observed interval, not an assurance of silence across the original receiver's entire admitted spectrum.

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The same reasoning applies to amplitude and phase. A representation is sufficient for a particular task only if the distinctions required for that task have survived. A narrowband, coherently sampled tone may retain an identifiable phase trajectory under carefully designed resampling. A short saturated pulse may not retain its original peak because the clipping occurred before resampling. A channel whose timestamp was lost cannot be made absolutely timed merely by adding an output epoch to a new file. An apparently exact interpolation can be conditioned upon a band-limited model while several incompatible analogue inputs remain possible. The inference is legitimate when its conditions are stated; it becomes unsupported when the analyst treats the particular chosen reconstruction as the only conceivable physical history.

There is also a question about the effect of selection. A wideband survey might retain only segments that crossed a detector threshold, after which each selected segment is resampled and subjected to a more elaborate analysis. The resulting population is not an unbiased sample of the original observation periods. It is selected by an earlier decision rule whose false alarms and misses matter to any estimate of prevalence. An apparent agreement between an initial detector and a later resampled analysis is not independent confirmation when both decisions arise from the same selected data. A proper probability statement requires the sampling and selection mechanism to be included in the model, together with any conditions under which the detector's decisions influenced later acquisition.

To preserve the possibility of serious reanalysis, I recommend retaining the earliest practicable raw representation and its critical metadata whenever the investigation's questions are not yet fully known. Storage

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constraints may require selective preservation, but the constraints and omitted coverage should be declared. If only a derivative is retained, the report should document its passband, filter transfer, source-clock relation, output reference plane and the precise operations that formed it. It should distinguish what can still be tested from what is now unobservable. An investigator can report a weak feature in a retained narrowband channel with rigor while expressly declining to infer anything about a discarded neighbouring channel. Such intellectual restraint makes the useful finding stronger rather than weaker.

A common misconception is that improved numerical smoothness necessarily increases evidential content. Interpolation often creates samples that are highly correlated functions of earlier samples. They can help estimate a continuous band-limited signal within known assumptions, but the extra entries are not independent sightings. A Fourier zero-pad operation can make a plotted peak easier to localize without actually changing the physical duration or the independent data underlying it. A noise statistic can appear stable after filtering because the filter has removed a portion of the noise spectrum, yet the investigator must use the appropriate transformed noise model to calculate detection confidence. The right question is not how many samples exist after processing, but how much reliable information survives about the specified hypothesis.

A good report should therefore separate three statements. One identifies the stored sequence and its provenance. The second identifies a computed feature in that sequence with its method and uncertainty. The third identifies the physical explanation proposed for that feature, together with alternative explanations and the experiments used to test them. The steps

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between these statements require evidence. Without those steps the final conclusion may exceed the information retained. With them, a limited result may be entirely decisive for the investigative purpose. Mr Pierce, may I ask you to challenge the proposed retention policy in the difficult circumstances of a wideband receiver with finite storage, intermittent unknown signals and a legal obligation to disclose methods and material limitations? With respect, I now return the floor to Dr. Atkinson for the next contribution.

John Robinson Pierce | Peer question 7 to Claude Elwood Shannon

Dr Shannon, your preference for preserving the earliest practicable evidence is sound, but a defensive monitoring system may acquire many wideband channels continuously, producing far more raw data than can reasonably be stored or examined. One cannot simply declare unlimited retention to be the standard of scientific integrity. Suppose an investigator retains narrowband event snippets, a slower survey waterfall, and a log of the discarded intervals, but no full-rate wideband source stream. That archive can support some conclusions while foreclosing others. What minimum evidential architecture would allow the examiner to make useful, honest claims without pretending that retained products are equivalent to the discarded source? How should a later reviewer identify whether a questioned event might have been removed by a particular filter, missed during an acquisition gap, or distorted by a timestamp correction that is no longer reproducible? Please distinguish unavoidable resource limits from failures of experimental disclosure. In particular, what must be retained so the examiner can account for the opportunity of a weak, intermittent signal to have appeared during intervals that were never preserved at full rate?

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Claude Elwood Shannon | Immediate answer to John Robinson Pierce

Mr Pierce, a finite resource limit is a property of the real experiment and should be addressed through explicit design rather than concealment. If continuous raw retention is not feasible, decide which investigative propositions the system must support and design the acquisition and preservation policy accordingly. A hierarchy of products can be useful: limited high-rate source buffers around selected events, calibrated coarse survey summaries, receiver-state logs, clock-reference records, and explicit interval coverage masks. The resulting archive will not answer every conceivable future question, but it can answer the questions for which its coverage and methods were validated. The crucial discipline is to identify the omissions before making an assurance claim that the archive cannot sustain.

I would preserve an auditable account of the selection rule, including its software version, thresholds, integration windows, detection probabilities under tested conditions and the periods during which each receiver was actually observing. A log that says 'nothing detected' is not equivalent to proof that a detector was exposed to all relevant signals. If the record identifies which bands were filtered away, which time intervals were missing and which gain states were active, a later reviewer can determine whether the archived absence is genuinely informative or merely a consequence of not looking. A coverage mask may be no more glamorous than a

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waterfall, but it has substantial evidential value when a negative conclusion is considered.

Where the actual resampling derivative is retained but its raw source is not, the analysis should state the reproducibility that remains. If filter coefficients, output clock mapping, boundary policy and original interval identifiers are recorded, a reviewer can evaluate what the derivative would preserve for a controlled hypothetical input and test the algorithm's behaviour. However, the reviewer cannot verify the exact omitted original sequence or discover a real event that was excluded upstream. It would be improper to claim otherwise. A preserved source checksum can authenticate a retained block, but it cannot hash data never recorded. The document should separate a verified numerical transformation from the untestable historical details of a discarded input.

The policy can be improved by retaining representative untriggered source intervals for validation, by sampling the apparent noise-only population, and by preserving enough independent test records to monitor detector behaviour over time. Such practices help assess selection bias without requiring that every original bit be stored indefinitely. They cannot substitute for all possible evidence, but they can strengthen the reliability of limited claims. Where litigation or another formal inquiry requires specific disclosure, the record should accurately describe the algorithms, their versions, derivative histories, calibration conditions and known loss of information. A conclusion is not rendered invalid merely because storage was finite. It becomes

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scientifically fragile when the investigator refuses to specify what was lost.

Finally, I would resist the impulse to use the sophistication of a model as evidence of the completeness of its input. The most elaborate reconstruction can still rest upon an underdetermined source. Conversely, a modest retained fragment with clear provenance, known coverage and carefully bounded inference may be valuable. Our responsibility is to report what survived, why it survived, what transformations altered its form and which physical alternatives remain compatible with it. Dr. Atkinson, I return the floor so that the numerical cases and the final synthesis may place these distinctions into a reproducible engineering framework.

Worked mathematical and engineering applications

The following ten examples are constructed measurements, not instrument certifications. All filters, clock errors and test populations are stated rather than inferred from an unidentified receiver. A reported numerical result applies only to the specified quantity and physical or digital reference plane.

Harry Nyquist, Cross-Peer Question to Norbert Wiener: Professor Wiener, when rational resampling changes a 12 MHz I/Q stream to 8 MHz, what does a specification of the 3-to-2 rate ratio omit about the evidential timing of a short burst?

Norbert Wiener, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the rational ratio specifies the nominal sample lattice, not the physical timestamp mapping. The interpolation kernel, its state at the record

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boundaries, fractional delay, passband shape, start-time convention and the original oscillator drift all affect the output. I would preserve the source sample indices and acquisition timestamps together with the exact filter coefficients, version, arithmetic precision and treatment of leading and trailing transients. A calibrated timing pulse should enter before the ADC, not merely be fabricated in software after resampling. Compare the output timing with an independently observed event across several burst alignments and clock states; report both fixed algorithmic group delay and variable residual timing uncertainty. If the source lacked the analogue information needed for an unambiguous event, resampling cannot recover it. I pass the token respectfully to Dr Bracewell on phase continuity.

Norbert Wiener, Cross-Peer Question to Ronald Newbold Bracewell: Dr Bracewell, the output of a resampler has a visually continuous phase trace. Why is that insufficient to claim that the original emitter itself maintained phase coherence across a packet boundary?

Ronald Newbold Bracewell, Cross-Peer Answer to Norbert Wiener: Professor Wiener, phase continuity of the constructed output can reflect an interpolation rule. The original phase history may have been discontinuous, missing, noisy or altered by clock changes. Treat complex phase relative to a specified reference oscillator and compensate for any known frequency translation before comparing records. Calibrate the filter phase response and group delay across the entire admitted band, not solely at one centre tone. Include numerical phase wrapping conventions and the output sample time origin. Inject a known phase step near the record boundary at multiple positions and ask whether the processing preserves its magnitude and timing within a declared tolerance. In a forensic record, distinguish

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measured phase observations, model-dependent interpolations and the unobservable analogue interval between them. I pass the token to Dr Deming to test reproducibility.

Ronald Newbold Bracewell, Cross-Peer Question to W. Edwards Deming: Dr Deming, a developer demonstrates one perfect chirp after resampling. What controlled acceptance programme could expose spectral leakage, aliasing, or software-version dependence before deployment?

W. Edwards Deming, Cross-Peer Answer to Ronald Newbold Bracewell: Dr Bracewell, begin with a fixed source dataset and a predeclared acceptance matrix covering tone placement, chirps, short bursts, phase steps, band-edge stimuli, adjacent blockers and missing sample blocks. Test across rational conversion ratios, filter lengths, coefficient precisions and processor implementations. Record intermediate hashes and ensure that a known software version yields the same output under the same documented numerical settings; where floating-point reduction order differs, use a justified numerical tolerance rather than a visual judgement. Measure amplitude ripple, group-delay variation, alias rejection and event-time error at independently known locations. Reject the habit of adjusting the acceptance threshold after observing a disappointing result. If a filter is changed for better edge performance, rerun the complete relevant regression campaign. I yield the token to Dr Shannon regarding information lost in the operation.

W. Edwards Deming, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, if the original capture contained energy above the target resampler passband and the algorithm correctly removed it, what can a later investigator truthfully infer from the narrow output?

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Claude Elwood Shannon, Cross-Peer Answer to W. Edwards Deming: Dr Deming, the investigator may infer properties of the declared filtered representation within an established error and uncertainty model. The narrow output cannot by itself show that the eliminated frequency components were absent in the original analogue event. A many-to-one filtering operation has an equivalence class of input histories that map to the same output. Preserve raw samples or a demonstrably adequate parent representation where evidential duties require testing alternative hypotheses. Record the filter transfer function and its rejection, especially if a removed component could explain a transient otherwise attributed to an emitter. When only the derivative survives, say which questions it can still answer and which cannot be reconstructed. A reconstructed-looking waveform is not thereby a fresh physical measurement. I return the token respectfully to Dr Atkinson.

Dr. James M. Atkinson | Moderator's concluding synthesis

Colleagues, the panel has established that resampling is neither a surrogate for physical observation nor a process to be feared simply because it changes the density of a numerical array. Its value depends upon the measurand and the evidence supporting the relationship between source and derivative. Where an input was adequately band-limited, sampled at sufficiently known times, and transformed through a characterised filter, a new representation can preserve selected amplitude, frequency and phase information within declared tolerances. The same operation may be inappropriate for a short uncharacterised transient, a record containing missing blocks, or an investigation whose conclusion depends upon frequencies deliberately rejected by a decimation filter. The

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question is therefore not whether a software function is accurate in the abstract, but what specified physical claim it preserves under the conditions actually tested.

Mr Nyquist has reminded us that a changed sample rate is a relation among representations. Interpolation points are mathematical estimates from source observations, not additional independently acquired evidence. Decimation is safe for a defined band only when undesired components are sufficiently attenuated before the rate is reduced. The exact rational arithmetic of L and M does not convert an oscillator's nominal rate into an accurate physical time base. The original rate error, clock history and sample-index correspondence must remain in the calculation. A scientifically exact output frequency label can coexist with a physically mistaken time estimate if the analyst has confused these distinct quantities.

Professor Wiener has shown that filtering induces both temporal and statistical consequences. A finite response can displace a peak, change a burst's envelope, or make energy appear before a plotted onset when noncausal offline reconstruction is used. Closely spaced interpolated values may contain correlated noise rather than independent confirmations. A confidence interval based upon their sheer number can be misleading unless the covariance of the actual estimator is considered. The proper validation therefore includes noise statistics, event phases, gap conditions, transition-band signals, and the circumstances under which an adaptive resampling ratio was selected. The smoothness of a waveform is not an evidential substitute for those tests.

Professor Bracewell has brought Fourier interpretation back to the problem of historical continuity. A mathematically well-defined periodic

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extension can manufacture a discontinuity at the edge of a finite nonperiodic record. A boundary policy can shape the first and final values of a derived sequence. A digitally coherent record can conceal a dropped source buffer if the missing interval is not independently documented. A transform and its inverse may reproduce the array perfectly while leaving the original acquisition history unresolved. It follows that the receiver record must carry its intervals of actual observation, not merely a string of consecutive digital indices. An auditor needs the clocks, gap markers, algorithm version and earlier source if the timing conclusion is to be reproduced and challenged.

Dr Deming has insisted that numerical repeatability and measurement validity be tested separately. A resampler which behaves identically for every invocation may still distort the particular quantity that a field investigator intends to use. We must state whether amplitude means a narrowband voltage, an RMS value, the reconstructed maximum of a pulse or a detector energy statistic. We must state whether timing means the first sample above threshold, a calibrated onset, a correlation maximum or a time referenced to an independent event. These quantities can require different tolerances and different challenge populations. The acceptance plan should be fixed before the decisive test, and the unsuccessful trials should remain in the record. Correction of a demonstrated defect is proper, but silent substitution of a later analysis for the original decision history is not.

Dr Shannon has supplied the logical boundary. A narrow filtered derivative may be sufficient for a narrow question while being inherently inadequate for a question about discarded bands. The addition of interpolated samples does not increase the physical exposure of a receiver,

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and the elimination of samples does not prove that absent frequencies were silent. Source preservation is desirable, but finite storage can be managed by designing an auditable retention policy that reflects the questions the apparatus is intended to answer. Such a policy must disclose its coverage mask, detector selection rules, gaps and discarded spectral regions. We should prefer a bounded conclusion whose premises are visible to a larger but unjustified conclusion whose missing evidence has been hidden by sophisticated processing.

Our worked examples make these duties concrete. A twelve-megahertz complex stream resampled by five over eight has a new nominal rate of 7.5 megahertz, but a ten-part-per-million source clock error can accumulate nearly one hundred microseconds in a nominal ten-second interval. A strong blocker can alias into a retained channel if the digital filter lacks adequate attenuation. A symmetric 101-tap FIR at twenty megasamples per second possesses a nominal group delay of 2.5 microseconds. A one-tenth-decibel gain error becomes a measurable amplitude change. A one-microsecond misalignment can create a seventy-two-degree phase shift at 200 kilohertz. An interpolation model can give neighbouring outputs nearly ninety per cent correlation, and a lost buffer can create an unobserved interval of more than two milliseconds while the derivative remains visually smooth. None of these calculations proves that a particular receiver failed; each defines a mechanism that an appropriately designed challenge may test.

For the practical evidence record, the laboratory should preserve the earliest relevant complex samples, their hash and acquisition provenance, the sample-clock and local-oscillator references, the event and gap masks, the rational or adaptive rate mapping, numerical precision, filter coefficient

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identity, boundary extension policy, output timestamp alignment and derivation history. When retention limits prevent preservation of everything, they should be specified as limitations of the system's observation coverage. A derivative may legitimately be useful for listening, detection, analysis or comparison while still leaving some original source hypotheses unresolved. Each conclusion must identify the reference plane, the actual operation and the uncertainty that survives.

I therefore find that the panel has reached a clear position. **Resampling preserves claims only to the extent that their required distinctions survive the transformation and the associated physical and statistical conditions are established.** It does not manufacture independent evidence, erase acquisition gaps, or repair an unobserved radio-frequency event. The next question shall concern coherent time-interleaved digitisation, where several converter paths must be combined without mistaking their nominal alignment for a measured phase and timing relationship. I thank each contributor for the disciplined exchange and formally pass the token to the next discussion.

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Ten worked engineering applications | Question 033

Worked application 1. Rational conversion and exact output-rate arithmetic

Let f_s be the nominal complex source-sampling rate, L the positive integer interpolation factor, M the positive integer decimation factor, and f'_s the nominal output rate. The governing relation is $f'_s = f_s L/M$. Suppose f_s = 12,000,000 complex samples/s, L = 5 and M = 8. Then f'_s = 12,000,000 × 5/8 = 7,500,000 samples/s. The source interval is 1/12,000,000 = 83.333333 nanoseconds, while the nominal output interval is 1/7,500,000 = 133.333333 nanoseconds. For a ten-second ideal source interval, the expected output count is 75,000,000, subject to the convention applied to the first, final and filter-transient samples. None of these exact rational arithmetic relations establishes the actual source clock's physical rate; a real oscillator error must be propagated separately. The validation record should also retain the L/M ratio in reduced form, any output-phase offset, the filter taps and the rule for timestamping boundary samples.

Worked application 2. Clock error accumulated across a recording

Let f_{nom} be the stated source sampling rate, ε the actual fractional frequency error, N the number of acquired samples and T_{actual} their elapsed acquisition duration under a constant-clock model. Set f_{nom} = 8,000,000 samples/s, ε = +10 parts per million, and N = 80,000,000 samples. The actual frequency is $f_{actual} = f_{nom}(1 + \varepsilon \times 10^{-6})$ = 8,000,080 samples/s. The actual elapsed duration is $T_{actual} = N/f_{actual}$ = 80,000,000/8,000,080 = approximately 9.999900001 s. An analysis using

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the nominal rate assigns T_nom = 10.000000000 s. Its duration error is T_nom - T_actual ≈ 99.999 microseconds. Changing the output sampling-rate label does not remove this discrepancy. A defensible timing result needs a measured original clock model, evidence about possible rate changes and a residual uncertainty interval. The sign of the error matters where two independently clocked receivers are compared.

Worked application 3. Anti-alias attenuation for a strong unwanted component

Suppose an ideal resampler reduces a complex source rate from 12.0 to 6.0 MHz and is intended to retain a band within ±2.5 MHz, while a blocker at +4.0 MHz is present at -20 dBFS before the digital anti-alias filter. The target principal Nyquist interval is ±3.0 MHz. Without adequate filtering, +4.0 MHz is indistinguishable after sampling from +4.0 - 6.0 = -2.0 MHz. If the specified stopband attenuation at the blocker frequency is 70 dB in power, the residual level at the output is nominally -20 - 70 = -90 dBFS, assuming consistent reference scaling and no other nonlinearities. This may be below a declared threshold or may still matter in a very sensitive search. A certificate of 70 dB stopband attenuation alone does not determine the signal-to-noise ratio at the alias location; detector bandwidth, reference gains, quantisation and other interference must also be accounted for. Test the installed algorithm near the transition and for the maximum relevant blocker level.

Worked application 4. Linear-phase FIR group delay and timestamp correction

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Let K be the odd number of taps in a symmetric FIR filter and f_int the sample frequency at which the filter is implemented. Its nominal group delay is τ = (K - 1)/(2 f_int) for admitted components under the stated linear-phase model. Set K = 101 taps and f_int = 20,000,000 samples/s. Then τ = 100/(40,000,000) = 2.5 microseconds. If a filter output is tagged at its computational emission time without subtracting this delay, an analyst may assign an event onset 2.5 microseconds too late relative to the input sample reference. A noncausal zero-phase offline implementation can compensate alignment differently and may depend upon samples after the event. Therefore the documented filter architecture, padding and timestamp convention must accompany any asserted correction. This result applies to this hypothetical symmetric FIR, not automatically to an unknown IIR filter or waveform-specific detector peak.

Worked application 5. Amplitude ripple and the voltage error of a narrowband signal

Let g_dB be a filter's amplitude response in decibels at an admitted tone frequency and R the output-to-input voltage ratio. The relation is R = 10^(g_dB/20). For a stipulated passband gain error g_dB = -0.10 dB, R = 10^(-0.10/20) ≈ 0.988553. A calibrated 1.000 V tone at the filter input therefore appears at about 0.988553 V, a reduction of 0.011447 V or 1.1447 percent. This calculation does not establish how an arbitrary burst peak changes, because its spectrum may extend across several regions of the filter response. The relevant acceptance test should measure the declared estimator on the applicable waveform class and should

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distinguish stable gain correction from uncertainty caused by unknown spectral content, transient response and receiver state.

Worked application 6. Fractional delay and the phase of a coherent tone

Let f_B be the signed baseband frequency and Δt a time-registration error. Under a common phase convention, the magnitude of the induced relative phase shift is $|\Delta\varphi| = 2\pi|f_B\Delta t|$. For $f_B = 200{,}000$ Hz and $\Delta t = 1$ microsecond, $|\Delta\varphi| = 2\pi \times 200{,}000 \times 10^{-6} = 0.4\pi$ rad = 72°. Thus an error of just one microsecond may materially affect coherent summation even when the amplitude of each receiver output is unchanged. A fractional-delay filter may correct this difference where the actual timing offset is independently measured and the passband phase response is calibrated. It cannot prove that the two original acquisition epochs differed by the fitted offset when the fit itself was chosen to maximise coherence. Retain the independent timing reference and the uncertainty of the correction.

Worked application 7. Output covariance of a two-point interpolation

Let x_0 and x_1 be independent, zero-mean real noise samples, each with variance σ^2. Define interpolants $y_0 = (x_0 + x_1)/2$ and $y_1 = (3x_0 + x_1)/4$. The variances follow from independence: $\mathrm{Var}(y_0) = (1/4 + 1/4)\sigma^2 = 0.5\sigma^2$ and $\mathrm{Var}(y_1) = (9/16 + 1/16)\sigma^2 = 0.625\sigma^2$. Their covariance is $\mathrm{Cov}(y_0,y_1) = [(1/2)(3/4) + (1/2)(1/4)]\sigma^2 = 0.5\sigma^2$. Hence the correlation coefficient is $0.5/\mathrm{sqrt}(0.5 \times 0.625) \approx 0.894427$. The two displayed output values are strongly dependent even though the source noise samples were independent. Treating them as two independent experimental observations would make a statistical confidence statement unreliable.

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This small example is a matrix calculation of a defined interpolation rule, not a general model of all receiver noise.

Worked application 8. Converting an output sample index back to physical time

Let t_0 be the source epoch, m a nonnegative output index, f'_s the output rate, and τ a measured constant filter delay that remains in the output timestamps. The appropriate relation in this stipulated implementation is $t_{physical} = t_0 + m/f'_s - \tau$. Set $t_0 = 0$ as the chosen relative epoch, m = 75,000, f'_s = 7,500,000 samples/s and τ = 2.5 microseconds. Then m/f'_s = 0.0100000 s, and $t_{physical}$ = 0.0099975 s, or 9.9975 ms after the source epoch. Reporting precisely 10.000 ms would neglect the known delay in this implementation. Another implementation that explicitly centres its zero-phase filter and adjusts the output epoch would have a different relation. The equation must therefore come from the actual processing code and its timestamp specification, not from a generic resampling diagram.

Worked application 9. A dropped buffer does not disappear through interpolation

Suppose the input complex sample rate is f_s = 4,000,000 samples/s, and a block of N_{gap} = 8192 successive samples is lost. The missing exposure is $\Delta T_{gap} = N_{gap}/f_s$ = 8192/4,000,000 = 0.002048 s, or 2.048 ms. A later interpolation process may construct plausible values across that interval, but those values are conditioned on a model rather than recorded observations. If a suspicious transmitter emitted only within the missing period, the original receiver archive contains no samples from

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that event. Therefore a negative claim for the 2.048 ms interval is not justified by the interpolated output. The correct derivative should carry the gap in its provenance and coverage mask, and any visual filling should be labelled to prevent its mistaken use as evidence of uninterrupted monitoring.

Worked application 10. Fractional retention of a spectral channel

Let B_source denote the source complex-sampling bandwidth, B_keep the nominal width of a declared retained channel, and F_keep the ratio B_keep/B_source, assuming the stated complex rate corresponds to the nominal principal spectral interval and the filter transition is separately characterised. With B_source = 12 MHz and B_keep = 3 MHz, F_keep = 3/12 = 0.25, or 25 percent of the nominal spectral width. Thus a channel extraction retains only one quarter of the original nominal frequency interval; it cannot support a negative finding about the discarded three quarters. If the source receiver initially had additional analogue passbands or aliases, these require their own evidence and should not be folded into this simple fraction. The numerical calculation describes coverage, not detection probability, because detection also depends upon sensitivity, event duration, filtering, selection and actual time exposure.

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QUESTION 034

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What calibration is required for coherent time-interleaved digitisation?

Source: V011_Roundtable_Question_034_CP034_Dr_Atkinson(1).docx | Recovered substantive manuscript. Constructed educational dialogue.

Original constructed educational discussion. Historical participants are employed as intellectual personae. None of the speeches below is a quotation, a transcript, or a claim that a deceased expert examined a contemporary receiver. All numerical cases are stipulated educational examples, not measured instrument certifications.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, we have examined what is lost through careless resampling and what may be retained by a properly characterised mathematical transformation. We now approach a different, more treacherous boundary. In time-interleaved digitisation, several analogue-to-digital converter channels observe a common analogue programme at intended successive instants. Their digital words are interwoven to emulate a higher-rate converter, but the resulting sequence is not automatically the product of one ideal measurement instrument. The eye sees a single waveform marching across a display, while the underlying apparatus contains multiple apertures, gains, offsets, input networks and delay paths. The principal question is therefore what must be measured, corrected, preserved and challenged before this reconstructed sequence may support an inference about an external emission rather than an artefact arising within its own acquisition architecture.

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Let the nominal aggregate sample rate be F_s samples per second, the number of interleaved branches be M, the branch index be i in the set 0 through M minus one, and the cycle index be k. The ideal sample time assigned to branch i during cycle k is $t(k,i) = (kM+i)/F_s$. A more realistic time stamp is $t_{actual}(k,i) = t(k,i) + c(t) + \epsilon_i(T,f,state) + j(k,i)$, where c(t) denotes common clock phase error, ϵ_i denotes branch-dependent deterministic aperture displacement under temperature T, signal frequency f and operating state, and j(k,i) denotes residual random aperture variation. The expression is a working model, not a promise that all the terms can be measured independently. Likewise a branch output may be represented, while operating within its linear region, as $y(k,i) = a_i\, x(t_{actual}(k,i)) + b_i + d_i(x,T,f) + \eta(k,i)$. Here a_i is a gain factor, b_i an offset, d_i a residual deterministic error such as nonlinearity or bandwidth-dependent phase, and η a stochastic term. Those definitions already expose why a certificate saying only that each converter has a nominal number of bits is inadequate.

I ask that we distinguish several meanings of coherence. The converter branches may share a common frequency reference yet possess persistent relative aperture skew. Their individual clocks may exhibit excellent short-term stability but uncertain absolute epoch. Two separately mounted receivers may lock to the same laboratory reference while retaining unmeasured RF path delay, cable phase and local oscillator transients. A single apparatus may generate a highly repeatable interleaving spur whose phase remains steady over hours, precisely because the erroneous mechanism is coherent. It would be a serious error to interpret repeatability as proof of an external source. The defence investigator must instead articulate which physical variables are common, which are branch specific,

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which calibrations remain valid after switching gain or preselection, and which apparent signals survive controlled perturbations.

The historical and intellectual division of labour will be deliberate. Mr Nyquist shall address the timing lattice and the limits of nominal uniform sampling. Dr Shannon shall examine what can be learned about an unknown input from a corrected but finite representation. Professor Bode shall examine relative transfer functions and the limits of feedback-based calibration. Dr Bennett shall analyse periodic mismatch modulation and the spectral signatures by which an internal spur may masquerade as an emission. Dr Deming shall examine whether the laboratory's acceptance procedure actually challenges the system under the conditions for which a forensic conclusion is intended. Seven colleagues will test these propositions. Every question will be answered before the floor passes onward.

Our applications will use defined hypothetical rates, phases, uncertainties and signal levels. They will separate first-order engineering approximations from exact identities, and a model's mathematical neatness from its empirical validation. We shall not assert that averaging twelve-bit converters magically creates twenty-four truly independent physical bits. Nor shall we confuse shared-clock synchronisation with immunity from correlated errors. A corrected waveform is only as good as its calibration's admitted envelope, version history and preserved raw evidence. The final report must distinguish the physical input plane, the electronic sampling plane and the derived digital estimate. I invite Mr Nyquist to begin by identifying the measurement necessary to establish that successive words really correspond to the intended successive instants.

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Harry Nyquist | Principal response 1: The timing lattice, aperture displacement and its evidential limits

Dr. Atkinson, the first discipline is to distinguish a specified sampling schedule from the realised sampling instants. In an ideal derivation the schedule is uniform and the samples constitute evaluations of one band-limited function at known times. A time-interleaved apparatus replaces the assumption of one regular physical sampler with a committee of samplers. The aggregate mathematical grid may be perfectly uniform on paper even while the actual apertures follow a periodically perturbed grid. This is not a minor bookkeeping detail. At high input frequencies, a very small timing discrepancy is multiplied by the waveform's local slope. A sinusoidal input x(t) = A cos(2 pi f t + phi) has derivative -2 pi f A sin(2 pi f t + phi); for a small aperture error delta_t, its first-order voltage error is approximately x'(t) delta_t. Thus a picosecond cannot be judged small merely because a mechanical clock displays seconds in six figures. Its significance depends upon f, A, the required dynamic range and the intended inference. [T1, T2]

For M branches with nominal aggregate sample rate F_s, each branch ideally acquires once per M/F_s seconds, but with its phase displaced by i/F_s relative to a designated reference branch. Calibration should therefore establish the relative aperture of every branch, the uncertainty of that estimate, the conditions in which it was obtained, and the identity of the clock distribution configuration. Merely observing that all channels report the right average sample count is insufficient. A branch can accumulate the correct number of samples while beginning its aperture late by a fixed interval. Equally, a clock source may show excellent mean frequency over an hour while exhibiting short-term fluctuations relevant to a narrow coherent

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integration interval. These are distinct measurements. One requires a timebase accuracy statement, a phase-noise or time-deviation characterisation appropriate to the integration window, and a relative aperture-skew estimate at the frequencies to be admitted.

The subtle point is that deterministic skew and random jitter do not have interchangeable remedies. A reproducible delay epsilon_i can sometimes be measured with a suitable input, modelled across conditions and corrected digitally, provided the available samples contain the information required for the correction. Random aperture uncertainty j(k,i) is not retrospectively removable by subtracting one stored constant. It changes the analogue voltage sampled at each event, and its consequences depend on the instantaneous waveform. A statistical model may predict its contribution to signal-to-noise ratio, but a model is not a recovery of the particular unobserved analogue value. Common clock phase variation c(t) also differs from interbranch skew. If the common term affects all branches equally over a short interval, a relative interbranch comparison may suppress it, while absolute frequency or timing claims remain subject to that very same error.

To determine relative skew, I would not be satisfied with one sinusoidal frequency and one angular result. A tone-based phase comparison may infer delay from phase only after amplitude balance, channel phase responses and alias identities have been reconciled. Its phase is also periodic, creating ambiguity modulo an integral number of cycles if the delay is not otherwise bounded. A slow sine wave may scarcely excite the sensitivity necessary to diagnose a picosecond error at high frequencies. The campaign should test multiple frequencies within the admitted

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analogue band, include alternative amplitude levels, and identify where the acquisition chain's phase response departs from a pure delay. A branch input filter with dispersive phase may imitate a timing skew at one frequency but not another. Calibration that reports one delay number for such a path conceals the physical model's failure.

The investigator should conduct controlled state changes as genuine interventions. Vary input frequency, amplitude and the branch assignment if the architecture permits; operate at relevant temperatures; repeat after a gain-range or preselector change; and compare the raw aggregate with a separately characterised acquisition path. Where calibration estimates are obtained adaptively from live observations, freeze one version and test it on withheld challenge records. Otherwise the procedure may learn the very spurs it purports to eliminate and present self-confirmation as validation. The measurement record should preserve calibration data and the before-and-after representation so that another examiner can discover whether a correction accidentally suppressed a narrow real signal along with a branch artefact.

I must also caution against treating shared clock wiring as a guarantee of physical coherence. A reference may be divided into branch phases by components whose delay changes with temperature. Clock fan-out may introduce different rise times or threshold-crossing uncertainties, and a sampled input path may possess its own aperture uncertainty independent of the nominal digital clock edge. The responsible engineer measures the realised result at the relevant signal boundary, not merely the block diagram's promise. A receiver can be coherent with itself in one sense and incoherent with a second receiver because their reference epochs, RF paths

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or integration histories were never compared. Conversely, it can remain suitable for a bounded amplitude survey while lacking a verified absolute phase reference for geolocation.

The acceptance statement should therefore enumerate the claimed variables rather than use the unqualified adjective coherent. It might establish relative branch timing to a stated expanded uncertainty over a frequency, temperature and state envelope, and verify that a specified calibration suppresses internal artefacts without raising the false-negative rate beyond an agreed bound. A stronger statement of coherent phase recovery requires additional checks on reference epoch, input transfer phase, oscillator state and processing delay. A negative result during a scan requires its own exposure analysis. Whatever the instrument displays, the calibration must identify what the apparatus knew and what the historical analogue event left unknowable. I pass the discussion courteously to Mr Black, whose work on negative feedback prompts a question about whether internal compensation can disguise a drift it never truly measures.

Harold Stephen Black | Peer question 1 to Harry Nyquist

Mr Nyquist, your account distinguishes the true sampling instant from the schedule assigned by an engineering diagram. I wish to press the practical consequence when the receiving instrument uses a closed digital adjustment loop. Suppose a two-branch converter continuously estimates the spectral line thought to arise from aperture mismatch, adjusts fractional delay coefficients until that line disappears, and reports an attractively clean spectrum. The regulator has achieved a measurable result, yet it has used the observed programme to determine its own correction. If an external intermittent emission falls at the same

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frequency as the internal image, the correction may extinguish both, and the system may call the absence of a line a proof of successful calibration. In classic feedback engineering an apparently stable regulated output may coexist with an erroneous reference or inadequate measurement model. What independent observations should be required to establish that the loop corrects branch timing rather than enforcing the assumed absence of an inconvenient spectral component? Should the validation test be conducted with the loop frozen, deliberately disturbed, or challenged by an externally generated signal whose presence and absence are concealed from the calibration algorithm?

Harry Nyquist | Immediate answer to Harold Stephen Black

Mr Black, I accept the analogy, provided we do not overstate the identity between analogue feedback and a digital coefficient update. In each case the output is controlled by information selected through a measurement mechanism. If the measurement cannot distinguish the target defect from a legitimate signal bearing a similar signature, regulation alone cannot establish which cause has been removed. I would insist that the calibration signal, when practicable, be distinguishable from the unknown programme by its timing, frequency, branch assignment, injected code or carefully controlled stimulus schedule. The purpose is not simply to display a lower spur floor, but to acquire independent evidence of the parameter the algorithm claims to estimate.

A satisfactory trial should begin with the loop's definition. State its cost function, update interval, permitted coefficient range, initial conditions and response to a missing or changing reference. Save the

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coefficient trajectory. Then apply challenge signals which the adjustment algorithm did not use during training, including weak bursts placed near the known internal artefact, and verify both true-detection and false-alarm performance with correction enabled and disabled. Randomise the challenge placement in time and frequency so that the algorithm cannot succeed by repeating a prepared laboratory demonstration. The examiner must record every failed trial and any altered threshold, not simply the visually attractive run.

An external clock or independently characterised sampling device may help identify residual skew, although it also introduces its own delay and uncertainty. A second coherent reference is useful only to the extent that its path and dependence are disclosed. If both comparisons depend upon the same imperfect clock, their agreement is not wholly independent confirmation. Where the algorithm performs blind calibration using the programme alone, I would report its correction as conditional upon assumptions about signal statistics and artefact separability. Demonstrated suppression of a predicted image can be a valid restricted finding. It is not proof that the image had no external component, and it is not proof that another emitter would have survived.

Finally, freeze or version the calibration state before a forensic challenge and preserve the raw observations. If the coefficient update is essential during operation, reproduce the full update sequence with the test and require stability across a specified envelope rather than claiming universal immunity. A system that cannot expose its training record may still be useful for discovery, but its derived absence claims

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deserve a narrower evidential interpretation. I invite Dr Hamming to question how such disciplined measurement can be achieved without making every receiver impractically burdensome.

Richard Wesley Hamming | Peer question 2 to Harry Nyquist

Mr Nyquist, the examiner may discover hundreds of candidate signals across an extensive survey, while a high-speed receiver continuously adjusts gain, channel allocation, and clock calibration. Your demand for a preserved timing lattice and frozen challenge states appears reasonable for one academic experiment, but the forensic operator cannot stop the survey at every millisecond to measure the aperture of each branch against a metrology laboratory. Nor will a recording budget retain every raw sample indefinitely. I ask where you would draw the line between the variables essential to a particular claim and those that are merely desirable for an imagined perfect record. Would you preserve a complete sample stream, a sparse set of verified reference events, or a continuous parameter log? What evidence would support a limited statement that one detected line is receiver-independent if some of the calibration was adaptive and the source signal is too weak for a direct single-channel comparison? I also seek a principled response to the opposite problem: a cautious apparatus might produce an archive so large and complex that no independent examiner could realistically reproduce the analysis.

Harry Nyquist | Immediate answer to Richard Wesley Hamming

Dr Hamming, the difficulty is not solved by pretending every observation is equal in evidential importance. The required record should be selected according to the proposition that the investigator intends to defend. A frequency-and-time discovery log may support

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the proposition that the apparatus indicated a candidate during a specified interval, provided receiver configuration and exposure are sufficiently documented. A claim about the candidate's physical amplitude, phase coherence or external origin requires more. I would therefore define tiers of preserved evidence rather than impose an indiscriminate universal archive. At the first tier are time-stamped configuration changes, calibration identities, oscillator and clock status, detection-rule versions and any invalid intervals. At the second are raw signal intervals surrounding material candidates, together with sufficient pre-trigger context to distinguish event selection from continuous exposure. At the third are calibration challenge records and independent measurement paths needed for a stronger attribution claim.

Preservation may be selective without being misleading, but selection itself must be described. A triggered record is not evidence that nothing occurred during the unretained time. The operator should preserve the trigger rule, threshold, windowing, scan dwell and any dead time. This information permits an examiner to calculate a conditional detection probability or to identify where such a calculation is unsupported. Sparse reference events can diagnose clock drift when the drift model is validated, but they cannot reconstruct arbitrary unobserved phase excursions between references. A parameter log can document which correction was applied; it does not independently prove that the correction was physically valid.

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I should also distinguish an aggregate sequence from parallel corroboration. The same input sampled by several branches is not several independent observations of the same instant. Interleaving deliberately assigns different instants to branches. When the source is too weak for a single-branch measurement, a calibrated aggregate may improve a restricted detector's performance, but its evidence about external origin comes from additional interventions, such as changing the sample plan, receiver front end, or antenna while preserving the candidate's physical frequency and timing prediction. Those interventions must have competing outcomes for rival hypotheses; otherwise they merely produce more data.

Reproducibility should be achievable through a compact, content-addressed record of software, calibration constants, source digests and essential state transitions, not necessarily by storing each ephemeral memory transaction. Independent examiners need the ability to reproduce the resulting derivation and to test the stated uncertainties. Where the raw waveform is absent, a report must say so and limit its conclusion. A bounded finding is not evidence of incompetence. It is what precision means when the apparatus has finite memory and the original event cannot be observed a second time. I now pass the floor respectfully to Dr Shannon for the question of which corrections actually preserve information.

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Claude Elwood Shannon | Principal response 2: Information, calibration operators and the difference between restoration and invention

Dr. Atkinson, I begin with the proposition that a calibrated output is not equivalent to a newly observed input. Suppose an interleaved digitiser produces a vector y of recorded samples and a laboratory applies an operator C, chosen through calibration, to produce an estimate x_hat = C(y). The operator may be well justified, and it may substantially reduce a known error. Yet if the original physical acquisition is described by y = H(x) + n, then the adequacy of C depends upon properties of H, the uncertainty in its parameters, and the noise n. An elegant inverse does not rescue information that H has irreversibly discarded. If a branch clipped, a gain correction cannot uniquely restore the pre-clipping amplitude. If one aperture missed the relevant part of a transient, interpolation can offer a model-conditioned estimate but not a second physical measurement. And if the algorithm was calibrated with the event itself, the recovered structure may partly reflect the prior assumptions imposed upon it. [T1, T3]

In the ideal linear case, consider a fixed transformation matrix H that connects a finite set of input values to the observed vector. Where H has full rank and its conditioning is satisfactory, the experimenter may estimate the input under stated noise assumptions. If H is ill conditioned, small errors in the observation or in the estimated calibration coefficients may generate large errors in the reconstructed input. Where H lacks rank, distinct input vectors produce identical outputs. Adding channels cannot automatically remedy this when their responses are dependent or when they observe different instants and the signal class is unrestricted. The engineer should measure not merely the inverse algorithm's output quality on a familiar

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training waveform but also the range of admissible inputs on which it remains stable, and the statistical behaviour of the estimator for those inputs.

A time-interleaved converter imposes periodic structure upon its errors. A branch-specific offset can inject a line at a fraction of the aggregate sampling frequency, and a gain or aperture mismatch can translate a strong input component into other digital frequency positions. These errors have informational consequences beyond an untidy display. A narrow image can be mistaken for a weak transmitter, especially when a wideband screen compresses millions of samples into a small spectrum. Inverse processing must therefore be tested against its tendency to manufacture confidence. If the correction perfectly removes a calibration tone and its image, but an actual weak event near the same image is suppressed, the apparent improvement in noise floor conceals a loss in task-relevant information. The correct performance measure includes the distribution of missed events and false identifications as well as the residual spur height.

The term coherence requires equal care. Phase coherence means something only relative to a declared reference and a stated interval. Shared sampling clocks can provide a stable relation among branches, but do not of themselves establish the absolute carrier phase of an external signal at the antenna port. The path from antenna to digitiser includes filters, mixers, cables and physical propagation delay. Even if the clock has negligible random error, uncharacterised phase response along that path may defeat a claimed bearing or arrival-time difference. Conversely, a calibrated digitiser with imperfect absolute epoch can support useful within-record comparisons, such as the relative phase of two coherent components, when

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the common error cancels appropriately. The investigator should describe exactly what was compared rather than attach the adjective coherent to the entire recording without qualification.

Consider a proposed scheme to gang two twelve-bit converters against a common analogue input. If they sample nominally the same instant and exhibit partly independent noise, one may average their readings to lower a stochastic error under the right assumptions. But the result is not an ideal twenty-four-bit observation. The pair retains finite input range, differential nonlinearity, common clock error, and possibly strongly correlated analogue noise. If the two channels are instead time interleaved, they do not even measure the same instant, so their words cannot ordinarily be averaged as replicas. They extend the rate of sample acquisition at the cost of a larger mismatch-calibration problem. Any claim of additional effective bits must specify a waveform model, a noise model, bandwidth, acquisition duration, estimator and measurement reference plane.

The preservation of uncertainty is part of the representation. A single digital file may carry one sequence of nominal sample numbers while the true sampling times are estimates. Those estimates should be accompanied by a timing-calibration model and uncertainties, including correlation. If all branches follow one reference oscillator, a common frequency error can move their nominal timestamps together, and its uncertainty does not shrink merely because the number of samples increases. A covariance model for the reconstructed outputs may be necessary when a correction filter combines neighbouring words. Presenting a long list of corrected samples without its dependency structure invites subsequent analysts to calculate unwarrantedly narrow confidence intervals. The more

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sophisticated the correction, the greater the need for a reproducible description of how it modified the evidence.

I would design a task-specific acceptance experiment with hidden challenge events. Preserve the raw multiplexed words and calibration-state transitions. Select representative input frequencies and burst durations, including the portions of spectrum near expected mismatch images. Introduce both legitimate strong carriers and weak targets, and randomise the placement of the weak targets relative to branch phase. Require a fixed rule for identifying a candidate, with no adjustment after inspecting its answer. Record outcomes for each configuration, not only the best one. Then state a bounded result: for the signal class and operating envelope tested, the specified procedure preserved or detected events with measured performance and stated uncertainty. That is a genuine achievement. The broader assertion that the corrected sequence always reproduces the analogue past would be an inference the evidence has not earned. I pass the floor to Professor Gabor, who may properly question whether our sample-by-sample correction ignores the finite concentration of a transient in time and frequency.

Dennis Gabor | Peer question 3 to Claude Elwood Shannon

Dr Shannon, I wish to test the boundary between a waveform that is formally reconstructible and a burst whose effective evidence occupies a narrow region of both time and frequency. Suppose an instrument reports an unusually clean carrier after combining several converter branches, but its calibration was developed with long stationary sine waves and the suspected surveillance emission is a brief frequency-agile pulse. A long-tone phase correction can be excellent even though the

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transient encounters aperture distortion, filter memory and changing local oscillator phase. If the correction is represented by one frequency-domain function, the operator may be tempted to assign every output sample the same amplitude confidence. How would you define the information actually available for an event short enough to straddle only a few interleaving cycles? Is there a scientific way to quantify the loss introduced when we fit a stable calibration model to a nonstationary burst, or must the report describe a range of physically compatible pulses rather than one immaculate reconstructed line? I also ask whether a longer post-processing window can legitimately improve knowledge of a pulse that the front end never admitted.

Claude Elwood Shannon | Immediate answer to Dennis Gabor

Professor Gabor, the central fact is that information depends upon the question and the observation channel. A long stationary tone may allow very precise estimation of a small parameter because many nominally similar cycles contribute to the estimator. A short transient does not provide an equivalent collection of observations, even where the sample count is numerically large. The relevant channel includes the analogue front end, interleaving apertures, retained time interval and processing rule. If any of these is varying during the event, the stationarity assumed by the calibration must be tested, not silently imported from the reference experiment.

A useful practical representation is a family of input signals consistent with the measured samples within an uncertainty envelope. One may calculate a maximum-likelihood estimate or some other reconstruction, but should also examine its sensitivity to

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plausible timing skew, bandwidth-phase variation, gain state, and unknown onset within the sample grid. For a pulse occupying only a few nominal aggregate periods, a fixed aperture displacement can shift the apparent peak and alter its measured shape. When the true analogue rise time is shorter than the admitted bandwidth permits, no digital deconvolution can restore arbitrary lost high-frequency information without additional assumptions. Even with a powerful prior model, the resulting estimate is conditional upon that prior.

The engineer may quantify some losses by injecting characterised pulses over a grid of arrival phases and physical frequencies, measuring reconstruction error and uncertainty. Vary rise time, duration and amplitude independently rather than calling all short events equivalent. Compare the procedure on known tests whose waveform model differs from the one used to derive its coefficients. A worst-case or quantile performance bound over the intended signal class is often more relevant than the mean error of a stationary sine wave. If the bursts are selected by a trigger, the trigger mechanism's missed intervals must be incorporated into the performance claim.

Longer post-processing can reduce certain uncertainties where the raw record contains independent information, as when it averages noise over repeated transmitted symbols. It cannot recover observations never taken. A processing window that includes many post-event zero samples may change the appearance of a spectrum without changing the number of informative event samples. Likewise, a narrow Fourier bin can be useful for a lasting tone but may smear a brief event and misrepresent its timing. An appropriate report should

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identify which parameter was estimated, which signal model was used, what independent trials supported it, and which alternative pulse shapes remain observationally indistinguishable. A coherent but model-conditioned inference can be useful, but its conditions belong beside the result rather than hidden in the operator's memory. I invite Professor Bode to consider the analogue transfer functions whose imperfections may be mistaken for mere timestamp errors.

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Hendrik Wade Bode | Principal response 3: Relative transfer functions, phase dispersion and a calibrated operating envelope

Dr. Atkinson, the architecture of interleaving should be understood as a network of multiple input-to-output transfer paths, not simply as several ideal clocks waiting their turn. Branch i has an effective complex frequency response $H_i(f,T,s)$, where f is input frequency, T temperature and s the complete operating state. Its magnitude can vary with attenuation and gain settings. Its phase can vary through branch filters, buffers, sampling switch networks and physical routing. The familiar correction of one offset, one scalar gain and one scalar delay is justified only when these parameters adequately approximate the ratio of the true branch responses over the intended band. Where one branch has a frequency-dependent passband slope or group-delay ripple, forcing a single constant delay may improve one calibration tone while leaving substantial residual distortion elsewhere. [T2, T4]

A reference branch can supply a convenient phase origin, but no internal path is automatically an absolute physical standard. If $H_0(f)$ is selected as a reference and branch i is compared by $R_i(f)=H_i(f)/H_0(f)$, the measurement is relative. Its success in making the branch responses agree does not prove that H_0 has an accurately known absolute response at the antenna input. Nor does the act of dividing make the reference error disappear. Some systematic errors common to all branches cancel in R_i, while others survive in the final amplitude or phase of the aggregate record. If the report's claim concerns only interbranch image suppression, relative calibration may suffice. If it concerns absolute field strength, time of arrival or source

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location, the larger input chain must be characterised at the declared reference plane.

A useful diagnosis separates pure delay from dispersion. For a pure delay tau, phase is phi(f) = -2 pi f tau, and its slope with respect to frequency is constant. In a real network the group delay may vary: tau_g(f) = -(1/(2 pi)) d phi(f)/df, where the phase is unwrapped in a declared manner over a region where the transfer function is sufficiently well behaved. A two-point phase estimate gives an average delay over those points but can conceal fine ripple. Worse, phase wrapping can make two substantially different delay hypotheses appear equivalent at one tone. I would measure responses at a suitable grid of frequencies, check interpolated regions using withheld frequencies, and retain evidence of phase-unwrapping decisions. The residual mismatch after correction, not the elegance of its coefficient file, determines whether it can support the claimed result.

The correction itself may create new features. A finite-length fractional-delay filter has a passband error, endpoint response and transient length. A frequency-domain inverse can amplify noise around a notch of H_i, especially when a branch response approaches zero. If an equaliser is regularised to prevent that amplification, it no longer exactly inverts the measured response, and the remaining bias must be characterised. These are familiar engineering trade-offs. There is no virtue in calling one function a calibration if it merely transfers distortion from a visible spur into an obscure correlated error. The relevant figures are amplitude and phase residuals, noise amplification, introduced transients, and detection performance on the frequencies and times that the operator actually requires.

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Temperature and state changes are especially troublesome because they often alter the physical path without changing the software's nominal sample rate. A warm receiver may exhibit a branch delay shift due to clock distribution or input loading. A preselector change may introduce a different phase relationship. An automatic gain-control transition may alter analogue settling and the time in which a recorded pulse is valid. A calibration table indexed only by temperature may still be wrong if input frequency, full-scale range or firmware revision has changed. I propose an explicit configuration signature that associates every retained event with the coefficient version, gain/preselector state, clock status, calibration temperature range and any known invalid interval. When the state leaves the proven envelope, the system should flag uncertainty or demand a new challenge rather than apply a numerically plausible but experimentally unsupported correction.

One must also distinguish a channel's phase response from its sampling aperture. A measured tone-phase difference equals a contribution from aperture skew plus contributions from frequency-dependent analogue path phase, reference-path phase and possibly nonlinear distortion. If all those sources are forced into one timing coefficient, the correction may misrepresent a broadband transient. The separation can be approached by calibrated test fixtures, broadband excitation with independently characterised timing, and measurements at multiple frequencies and amplitudes. A constant slope across a substantial band supports a delay model more strongly than a single point. Disagreements between stimulus classes and environmental states identify where the simplified model fails. The investigator should resist describing those disagreements as nuisances to be suppressed; they are precisely the evidence that limits the claim.

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In a defensive surveillance survey, validation is most important where strong legitimate signals coexist with a small suspect feature. The branch transfer functions can be linear and accurate for low-amplitude laboratory tones yet depart under high common-mode power, input slew or near-overload conditions. A small mismatch spur can reside close to the target frequency. If the front end's dynamic range has been exceeded, digital equalisation cannot restore a valid linear measurement merely by removing the most recognisable spectral line. The acceptance trials should contain at least one representative strong interferer and should examine the target's detection probability while branch calibration is enabled, disabled and deliberately perturbed within a known bound. The report may then say what survived which physical challenges, not merely that the corrected spectrum looks quiet.

The useful end product is an uncertainty-bearing map from input conditions to corrected observations. It should describe the measured transfer ratios, residual errors, limits on inverse noise amplification, known thermal and state dependence, and the physical reference plane of every correction. A network is not completely described by the fact that its numbers can be divided. Similarly a multi-branch digitiser is not qualified for phase-coherent investigation simply because its streams are aligned to a display grid. I pass the token to Professor Wiener, whose analysis of correlated noise should illuminate what happens when equalisation makes an array of outputs appear cleaner but less statistically independent.

Norbert Wiener | Peer question 4 to Hendrik Wade Bode

Professor Bode, you distinguish the branch transfer functions from the clock offsets and warn that an equaliser may trade visible error for

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invisible correlation. I should like to examine a common validation practice. A laboratory measures a narrowband response, applies inverse filters separately to each branch, and subsequently estimates the noise floor of the combined record from successive FFT bins as though every displayed value were independent. But the equaliser may mix neighbouring time samples and magnify noise near its poorly conditioned frequencies. Furthermore the same reference tone may have driven every calibration estimate, producing common parameter uncertainty. Does agreement between corrected branches establish only that a chosen model has made them similar, rather than that the individual observations now contain independent evidence? What would a defensible uncertainty budget need to retain about calibration covariance, filter memory and shared reference error? I ask particularly how one might communicate this distinction to an investigator who sees a falling noise-floor trace and supposes that the instrument has thereby become more certain of the physical source.

Hendrik Wade Bode | Immediate answer to Norbert Wiener

Professor Wiener, the observed fall in a displayed noise floor is a statistic of a transformed representation, not an automatic declaration that uncertainty in the measurand has fallen. Let the input-noise covariance matrix be Sigma_x and let an applied linear calibration be C. The transformed stochastic covariance is Sigma_y = C Sigma_x C^H, where C^H is the conjugate transpose. If C combines neighbouring samples, off-diagonal covariance terms generally appear. If a calibration parameter theta is estimated with uncertainty, an additional term should be considered through the sensitivity of the

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corrected output to theta; where several parameters share a reference, their covariance must enter that calculation. A scalar formula that assumes independence can therefore understate uncertainty even when every standard deviation is individually estimated correctly.

The most defensible remedy is to define the actual estimator of the claimed quantity and propagate uncertainty through that estimator. For a specified input amplitude one might use an independently calibrated reference signal, repeat the full acquisition across several temperatures, and compare the corrected estimate with its known reference within a stated coverage interval. For spectral detection one must consider the distribution of the largest noise excursion across the bins and windows actually searched, not merely the variance of an arbitrary single bin. In both cases the equaliser may change the effective number of independent trials. The appropriate acceptance test uses the same search procedure that the field examiner will use.

Agreement among branches remains informative when interpreted correctly. It can show that relative mismatch is below a test threshold in a particular state. It cannot, by itself, establish that the common source oscillator is accurate or that the input antenna system has an unbiased transfer function. A common reference-tone error can be copied obediently into every branch. The calibrated agreement then remains genuine but the inference to absolute physical truth does not follow. That is why I would retain the raw record, reference source certificate, actual measurement uncertainty, algorithm version and

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the full schedule of control states, rather than merely a corrected output whose numerical neatness invites unwarranted certainty.

To communicate the result, the report should separate three statements: the relative branch mismatch was measured and reduced; the remaining uncertainty in a defined amplitude or phase measurand was evaluated; and a candidate external emission survived specified alternative explanations. Each statement requires its own evidence. A successful first statement does not guarantee the second or third. When those distinctions are explicit, the engineer may use sophisticated equalisation without concealing its statistical costs. I now invite Professor Bracewell to test our reliance upon smooth frequency-domain corrections when the event of interest is shorter than the filter's memory.

Ronald Newbold Bracewell | Peer question 5 to Hendrik Wade Bode

Professor Bode, suppose a correction operator has impressive steady-state performance, measured against a long sinusoid, while the laboratory's objective is to identify the arrival time and polarity of a short burst. A fractional-delay filter may be linear phase within its passband and nevertheless possess a substantial impulse response extending on either side of the nominal event. Its time-centred output can exhibit oscillations before the physical burst and continued ringing after it. Some examiners might call the first visible oscillation the beginning of the emission, especially when plotting at high magnification. Others might subtract a nominal group delay and declare the resulting timestamp absolute. How would you require the laboratory to test onset bias and its uncertainty, distinguish causal delay from offline acausal processing, and

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preserve the boundary treatment used near the beginning and end of a retained record? Would the same frequency-domain inverse be valid if the analogue branch response changed during an automatic gain transition that occupied part of the pulse?

Hendrik Wade Bode | Immediate answer to Ronald Newbold Bracewell

Professor Bracewell, a steady-state transfer function is a description of a linear time-invariant system only when the system is sufficiently stable over the observation. It does not become a universal account of a receiver that changes gain, loading or clock phase during a burst. I would accordingly use two families of challenges. The first would test stationary frequency response with tones and broadband signals across the admitted operating envelope. The second would test transient response using independently timed pulses of varying rise time, duration, amplitude and phase relative to the branch schedule. The distinction prevents an attractive long-tone calibration from masquerading as a verified time-domain onset measurement.

For a fixed linear-phase FIR correction of length L at sample rate F_s, nominal group delay is (L-1)/(2F_s) when the filter is symmetric and the conventional assumptions hold. That relation identifies a processing delay, not the entire uncertainty of a physical event timestamp. A pulse's apparent threshold crossing also depends upon bandwidth, threshold rule, noise and its unobserved analogue shape. If the implementation uses offline symmetric filtering, apparent pre-event ringing is possible in the displayed record. It must never be

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reported as a physical emission preceding the event merely because the plot contains nonzero corrected values there. The correction algorithm and its boundary-extension policy must be retained so that this behaviour can be reproduced.

I would compare measured onset estimates against an independently timed reference at the actual analogue input plane. Repeat with the pulse shifted through different interleaving phases. A single reference pulse arriving at a favourable phase is not adequate, because the artefact may vary periodically with branch assignment. Record the signed timing error distribution and its extremes over the intended pulse classes. Where the waveform model is uncertain, report a bound on onset position rather than a single absolute time. If analogue gain changes inside a pulse, apply a state-aware model if the transition has been characterised. If it has not, mark the affected interval indeterminate and preserve the raw samples instead of asserting that a stationary inverse recovered a uniquely defined input.

The same advice extends to phase. A correction that aligns stationary carriers can be valuable for coherent integration while still failing to reconstruct the start of a broadband transient. These are different measurands. We should certify only what the experiment has challenged: relative phase within a defined band and state, onset error for stated pulse classes, or amplitude response under a particular gain range. I pass the floor to Dr Bennett, whose study of unwanted modulation will connect branch mismatch to the spectral evidence from which the surveyor may infer an external emitter.

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William Ralph Bennett | Principal response 4: Mismatch as unwanted modulation, not merely an untidy conversion error

Dr. Atkinson, the forensic hazard of time interleaving is especially plain when one regards the branch sequence as a periodically time-varying system. Even if every constituent converter is acceptably linear in isolation, their periodically differing gains, offsets, apertures and bandwidth responses can modulate a legitimate strong input. The spectrum of the aggregate output may then contain lines that the analogue input did not contain. This is not a spectral illusion in the sense that the displayed computation is false. The digital sequence truly contains the modulation products. The false step occurs when the investigator assumes those lines must have existed at the receiver's declared external input plane. The distinction between an internal modulation product and an incoming emission lies at the heart of the experimental defence. [T2, T4]

Let the ideal discrete input be $x[n]$ and a simplified branch gain schedule be $g[n]$, periodic with period M. The aggregate observation is $y[n]=g[n]x[n]+b[n]$, where $b[n]$ is a periodic branch-offset sequence. Multiplication by a periodic gain function corresponds to discrete-frequency convolution with spectral lines at integer multiples of F_s/M. Consequently a sinusoidal input at frequency f_0 can generate shifted components at f_0 plus or minus qF_s/M, folded into the representable frequency band according to the recording convention. A branch-offset pattern can generate periodic lines even when the analogue input is nominally zero. The positions have a diagnostic relationship to the aggregate sampling rate and the branch count. They do not, however, prove internal origin without a physical test,

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since an external transmitter could happen to occupy a related frequency. The location is a clue which should motivate an experiment.

For two branches with actual gains 1.01 and 0.99, the mean gain is unity and the alternating gain perturbation is 0.01 times (-1)^n. If the input is a complex exponential at f_0, the principal shifted component has magnitude 0.01 relative to the unshifted carrier under this simplified model. The line therefore lies 40 dB below the carrier in power. That result is illustrative, not a general formula for every real-sine calibration case or every multichannel mismatch pattern. In a real ADC, gain errors may be frequency dependent and coupled with aperture displacement, and the shifted products can overlap, add or partly cancel. One must calculate or measure the actual branch pattern rather than declare one universal spur level from a nominal mismatch percentage.

Timing skew creates a related but distinguishable modulation. For a small branch-dependent sampling error epsilon[n], expand x(t_n+epsilon[n]) as x(t_n)+epsilon[n]x'(t_n), neglecting higher-order terms where justified. For a sinusoidal input the derivative contributes a factor proportional to 2 pi f_0. Thus the amplitude of timing-related distortion usually becomes more significant as input frequency rises, all else equal. An offset-related spur can exist without a carrier; a gain-related image scales approximately with carrier amplitude; a timing-related image also scales with input frequency under the small-error model. A calibration campaign that tests these distinct dependencies may discriminate among mechanisms more effectively than one that merely minimises total spur energy at one centre frequency. Nevertheless the mechanisms interact, especially at high slew rates and near nonlinear operation.

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The importance of interleaving calibration extends beyond an elegant single-tone spectrum. An investigative receiver may process multiple strong legitimate services simultaneously. Their images can fall within a band of interest, and their sum may resemble a cluster of weak transmitters. A frequency-agile instrument may shift its aggregate sampling rate, thereby moving internal spur families in a predictable manner. An external signal at a fixed radio-frequency coordinate will not ordinarily follow that digital branch-spacing prediction when the input path is properly accounted for. Retuning or changing the interleave mapping can therefore be a controlled challenge. But the test must preserve enough invariants to be interpretable: the antenna, RF path and gain state should be identified, and the change must not inadvertently move the analogue front end into a different response regime. Otherwise a disappearance can be explained by altered reception rather than by correction of an internal artefact.

One must also preserve the distinction between a spur and an estimated source probability. A spectral line at a predicted mismatch coordinate may have an internal mechanism, but the probability that a particular observed alarm corresponds to an external transmitter depends on the prevalence of relevant inputs, the detection rule, the number of searched opportunities and rival causes. Supposing the calibrated receiver produces one false candidate in a thousand reference trials does not make every individual alarm 99.9 percent likely to be genuine. Those statements concern different conditional probabilities. An analyst who sees a persuasive waterfall trace should not allow its visual regularity to replace a well-defined detection and attribution problem. The lines drawn by a digital plot have no knowledge of the path through which the physical energy entered the apparatus.

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A defensible bench test would start with a stable injected reference whose frequency and amplitude are known at the declared plane. Measure each branch's offset, relative gain and phase response over the intended frequency range. Deliberately vary sampling rate and interleave pattern if the hardware permits, looking for the predicted displacement of internal images. Introduce a weak independent target placed near, then on, then away from the predicted mismatch image, while keeping the assessment rule fixed. Evaluate false-positive and false-negative outcomes both before and after calibration. Repeat after thermal settling and after consequential state changes. Preserve the acquisition configuration and any rejected measurements. By this approach a claim of artefact suppression can be tested without suppressing the evidential record of legitimate weak events.

The key limitation is that no spectral pattern uniquely identifies its physical cause without the system boundary. A coherent mismatch line is internally generated only if the relevant causal tests support that explanation; a stationary external emitter could create a similar output under one set of settings. Conversely a physical emission may survive in the record despite some degree of branch mismatch. Engineering should not force every contaminated observation into the categories wholly false or wholly true. It should quantify the limitations that affect the question at hand, preserve potential alternatives and invite repeatable experimental challenges. I pass the token to Professor Tukey, whose criticism of selected spectral displays will sharpen this principle.

John Wilder Tukey | Peer question 6 to William Ralph Bennett

Dr Bennett, your proposed test changes an instrument parameter and asks whether the suspicious line follows the predicted internal spur

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coordinates. The design is attractive, but I wish to examine its statistical weakness. A spectrum analyser or SDR console may display thousands of frequency bins across hundreds of time windows, and the investigator may notice only a few apparently stable candidates. Suppose the analyst tries several branch mappings, calibration settings and FFT lengths and retains the one in which the candidate disappears most convincingly. The resulting demonstration may look causally decisive while its method has been selected after inspecting the desired conclusion. How would you distinguish a pre-specified, falsifiable discrimination test from an exploratory series of transformations whose unsuccessful members have been quietly forgotten? Should the investigator report a family-wise error rate, a false-discovery measure, or an empirical challenge frequency? And how should the conclusion address a candidate that persists in some conditions and disappears in others because the analogue passband, rather than the interleaving mechanism, has changed?

William Ralph Bennett | Immediate answer to John Wilder Tukey

Professor Tukey, the investigator should divide discovery from confirmation. Exploratory transformations may help identify a mechanism, but they cannot be treated as a pre-registered test whose success probability was known in advance. The record should retain the exploration history where it materially influenced the final choice of hypothesis, including the receiver settings, FFT windows, calibration versions and observed outcomes. A confirmatory challenge then states in advance which instrument parameter will change, the physical invariants expected of an external emission, the predicted internal-image displacement, the acceptable tolerance and

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the decision rule. The confirmatory data should be acquired independently of the trials that generated the idea, where practicable.

A family-wise error calculation may be appropriate when the analyst has tested a known number of statistically specified hypotheses, but it does not rescue a poorly defined experiment. The relevant trial count may include frequencies, times, receiver configurations and algorithm versions. Dependencies among those trials make a naive independent-bin approximation misleading. Empirical blank or negative-control trials using the entire search pipeline can be more directly relevant to an operational false-alarm claim, provided the controls represent the conditions actually encountered. The report must give the number and composition of the trials and must not convert a finite observed rate into a certainty about a specific line's cause.

When the analogue passband changes together with the branch mapping, the intervention is confounded. A disappearing signal cannot be attributed uniquely to the digital mismatch shift. I would either hold the analogue path fixed and alter a purely digital parameter, or perform additional controls that measure the change in analogue sensitivity. A dual-receiver comparison with separately characterised front ends may add evidence if the dependence between their paths is understood. Likewise a carefully injected candidate at the same physical frequency can test whether the system retains external signals during the proposed intervention. It is better to acknowledge that the first experiment was inconclusive than to preserve only its favourable image.

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The strongest statement after a successful campaign is bounded: the observed line moved in the manner predicted by the measured interleave mismatch under specified changes, whereas an independently injected physical tone obeyed the expected external-frequency mapping. That evidence supports the internal-artifact explanation and challenges particular alternatives. It does not prove that every future line at a similar frequency is internally generated, nor that all weak signals have been preserved by the correction. Statistical discipline gives the technical diagnosis a scope that can be defended. I pass the discussion to Dr Deming for the broader problem of calibration systems that declare themselves satisfactory by testing only the easy conditions.

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W. Edwards Deming | Principal response 5: Acceptance testing, traceability and a system capable of discovering its own failures

Dr. Atkinson, I shall distinguish the repeatability of a calibration procedure from the performance of the entire measurement system for its intended use. A trained operator may obtain nearly identical branch-skew numbers on successive mornings. That observation may demonstrate procedural stability, but it does not establish that the receiver correctly recognises intermittent weak emissions in the presence of strong legitimate activity. The standards of evidence must begin with the question being answered. Where an instrument is intended for discovery, a useful measure is detection performance across representative signals and conditions. Where it is intended for quantitative amplitude measurement, the measurand, input reference plane, correction model and combined uncertainty are central. Where it is intended to support source attribution, control of alternative explanations becomes indispensable. A single attractive laboratory certificate cannot answer all three claims. [T5, T6]

There are at least four populations to distinguish. First is the population of converter branches, which may differ in gain, offset, aperture, analogue response and nonlinearity. Second is the population of operating states, including gain ranges, sampling rates, preselector paths, clock-lock states, firmware versions and temperatures. Third is the population of signals that the investigation is meant to encounter, including weak bursts, large adjacent carriers, near-clipping transients and varying duty cycles. Fourth is the population of time intervals during which observations were actually possible, as distinct from the time intervals in which a triggered archive contains selected records. A calibration programme that samples only one

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convenient branch, one warm state and one strong continuous tone may be reproducible while almost entirely irrelevant to the claimed field task.

I recommend beginning with a declared acceptance matrix, not merely a list of calibration instruments. Every column should represent a physically meaningful factor, and every row should identify a trial or combination of conditions. The matrix should include the frequencies where interleave artefacts are predicted, as well as portions of the band where the calibration appears easy. It should challenge the receiver before and after warm-up; at the gain and attenuation settings used in practice; near, but not beyond, specified full-scale limits; and with both continuous and intermittent signals. It should include known-negative trials with no injected target, and known-positive trials whose presence and parameters are concealed from the person interpreting the results. The detection rule, tolerances and stopping criterion should be fixed before examining those confirmatory outcomes.

Variability itself is not a defect to be wished away. If repeated branch-delay estimates differ, ask whether the variation is attributable to routine measurement noise, temperature, state transitions or an unrecognised special cause. One can use control-chart reasoning to monitor a stable calibration parameter, but a control chart is valid only within the model and sampling assumptions supporting it. A visually flat trend may be produced by an algorithm that clips or over-smooths the parameter history. Likewise an adaptive correction may yield artificially stable residual images because its objective function has been tuned to hold that statistic steady. Independent checks are needed to establish whether the physical aperture actually remained within tolerance. One should not confuse the smooth sound of a servo with the accuracy of the device it controls.

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Traceability means more than possessing a sheet bearing an impressive institution's seal. A calibration result should be linked to appropriate reference standards through a documented chain with stated uncertainty. In this context the timebase reference and analogue amplitude reference may require separate chains, because time and voltage are separate dimensions of the waveform. Reference generators have their own cable delays, jitter, phase noise, loading and thermal characteristics. Their contribution to the uncertainty budget should be evaluated rather than excluded because their labels say standard. A small uncertainty in one carefully measured component cannot compensate for a large unmodelled error elsewhere in the receiver. The combined standard uncertainty of a derived quantity follows its measurement model, incorporating sensitivities and covariance where appropriate. [T5, T6]

An important consequence concerns the use of performance averages. A receiver might show excellent mean amplitude error across a broad collection of easy continuous-wave trials while failing a small number of intermittent signals that coincide with interleave image frequencies. If the intended field task is to find precisely such signals, the overall mean can conceal a critical weakness. I would report results by relevant signal class and state, including the tail of the error distribution and any conditions in which the correction could not be validated. A confidence bound derived from finite trials must state the number of independent opportunities and how independence was justified. A record of zero failures is not a mathematical assertion that the probability of failure is zero. It is evidence supporting an upper bound whose meaning depends upon the sampling design.

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The institution should also separate the person who builds the calibration from the person who evaluates its acceptance where resources permit. A fixed challenge suite with undisclosed event placements can expose overfitting and a tendency to adjust thresholds after unfavourable results. Where a small laboratory cannot separate personnel, it can still preserve the original rules, record deviations and use independent reference captures or blind replay. Negative results and invalid intervals belong in the technical record, not in a private collection of embarrassments. The report should distinguish corrective maintenance, calibration performed to characterise the apparatus, and validation performed to show that the whole instrument remains fit for a defined investigative purpose. Those are related activities but not interchangeable achievements.

Finally, the temporal scope of a calibration must be declared. An instrument measured in a controlled laboratory on Monday has not necessarily maintained those conditions throughout a field deployment on Friday. A field check immediately before and after the survey can provide evidence about drift, but may not reveal every unobserved transient during the interval. Continuous self-monitoring can help if its reference and diagnostic coverage are validated. When a loss of clock lock, gain transition or uncharacterised thermal excursion occurs, the correct response may be to mark the affected samples as qualified or invalid. It is not to hide the exception beneath a corrected amplitude scale. The system improves when it is designed to reveal its own weaknesses rather than to silence the indicators of failure.

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I would therefore accept a coherent interleaved receiver for a specified task only when the laboratory has shown, with independent challenges, that the combined branch response and correction preserve the particular quantities to be reported over a declared envelope. It should demonstrate relative timing, frequency response, uncertainty, false-alarm behaviour and weak-signal retention under representative stress conditions. Its limitations must be expressed so that the field examiner can recognise when a result falls outside the proven domain. The most impressive finding may sometimes be a justified declaration that the evidence is indeterminate. Such restraint prevents technical confidence from extending beyond its physical foundation. I pass the token to Dr Shewhart, whose question about detecting drift will bring the distinction between control and performance into sharper focus.

Walter Andrew Shewhart | Peer question 7 to W. Edwards Deming

Dr Deming, suppose the laboratory has characterised the converter's branch gain, offset and timing at a succession of temperatures and then installs a statistical monitor to detect departures from a stable calibration state. The reported control-chart points remain within the historical limits, yet a new firmware revision changes the internal order of fractional-delay filtering and gain correction, and a weak burst coincides with the next temperature transition. The chart looks reassuring because its monitored statistic is stable. But the relationship between the statistic and the actual physical measurement may have changed. How would you distinguish a process that remains under statistical control from one that remains valid for the desired electromagnetic inference? What evidence would justify transferring an earlier calibration certificate across

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a firmware change, and how should an investigator treat samples acquired during a state transition that was not represented in the original acceptance trials? I ask whether a failed challenge should cause merely another recalibration or a deeper revision of the measurement model itself.

W. Edwards Deming | Immediate answer to Walter Andrew Shewhart

Dr Shewhart, a control chart answers a question about the behaviour of a defined statistic under a stable process model. It does not supply proof that the statistic remains the right one after the process has changed. A firmware revision which alters correction order may change numerical transfer functions, effective latency, noise covariance and the interpretation of stored coefficients. The proper question is not whether the old line remains inside an old chart, but whether the changed instrument still implements the measurement model upon which the original validation depended. A version difference is itself a new state variable requiring technical assessment. Some changes may be shown, through regression tests and targeted characterisation, to leave relevant outputs invariant within tolerance. Others require a wider requalification.

I would demand a change-control record identifying the altered processing stages and their expected physical consequences. Retain both executable versions, calibration files and representative raw challenge records. Process the same immutable captures through the old and new implementations, compare residuals across the admitted band and transient classes, and examine whether differences exceed

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the previously accepted uncertainty. Such a comparison tests the digital change but not any simultaneous alteration of analogue hardware or clock conditions. Those need separate controls. When the revised firmware alters adaptive algorithms, test its response to challenge signals that were not available during development. Avoid defining success solely by the disappearance of one known spur, because a false-negative defect can also make that statistic appear better.

The weak burst acquired during a previously uncharacterised transition should receive a transparent qualification. Record the transition and retain the original samples and state log. If a separate, validated measurement path supports the feature, report the corroboration with its actual dependency. If no adequate evidence establishes that the timing and amplitude transfer remained valid, restrict the conclusion. The instrument may have indicated an event, but its quantitative amplitude, onset and source attribution may be indeterminate. A confidence interval calculated from stable-state trials should not be transplanted to an untested transition merely because the software can print one.

A failed challenge should initiate a study of causes before a recalibration becomes the convenient ritual. Perhaps the coefficient simply drifted and a validated correction suffices; perhaps the measurement model omitted temperature-dependent branch dispersion or a shared reference error. The distinction is found by experiments that force rival explanations to predict different outcomes. When the model is revised, its validation and historical

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applicability must be documented. We should not retrospectively certify old captures by applying a new model unless the old raw evidence supports the new analysis and its limitations are declared. The system's intellectual virtue is not the elimination of adverse points but the creation of a process in which the adverse point teaches us what remains unmeasured. I return the token respectfully to Dr. Atkinson for a final synthesis.

Harry Nyquist, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, four ADC branches nominally sample at 300 MS/s each to create a 1.2 GS/s stream. Which analogue mismatches must calibration measure before calling the combined output phase coherent?

Hendrik Wade Bode, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, each branch has a transfer function with gain, phase, aperture delay, offset, noise and temperature dependence; a single scalar amplitude correction cannot remove dispersive differences. Measure frequency-dependent complex gain at known injection planes across the actual admitted analogue band, then estimate relative aperture offsets independently of cable and fixture delay. Use several stimulus frequencies to distinguish a nearly constant time displacement, whose phase varies linearly with frequency, from filter-induced group-delay variation. Characterise the uncertainty and drift of the calibration coefficients as well as their numerical quantisation. Test at strong and weak input levels to reveal compression. Preserve original branch ordering and calibration state so an external analyst can reproduce the combined result. I pass the token to Dr Bennett to examine the spurious families.

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Hendrik Wade Bode, Cross-Peer Question to William Ralph Bennett: Dr Bennett, a stable 300 MHz spectral line appears without an injected RF signal, yet sidebands move when the test-tone frequency changes. What inference can be drawn from this different behaviour?

William Ralph Bennett, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, the branch-selection period is 1/(300 MHz) for a four-way system with 1.2 GS/s aggregate cadence; periodic offset differences can produce fixed spectral components at branch-rate harmonics. Gain, timing and frequency-response mismatch modulate the injected waveform and generate signal-following image families. Frequency movement offers a diagnostic distinction, not a unique identification of every cause. Perform input-open or matched-termination tests, vary the injected tone over a controlled grid and compare observed spur movement and amplitude with branch error models. A nonlinear amplifier or clock feedthrough could complicate the picture. Check phase and amplitude dependencies, and avoid labelling every line as an external emitter. I respectfully yield to Dr Deming for production controls.

William Ralph Bennett, Cross-Peer Question to W. Edwards Deming: Dr Deming, calibration succeeds at 20 degrees Celsius for a single input level. How ought a qualification matrix expose calibration failure during an unattended temperature excursion and gain change?

W. Edwards Deming, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, define a bounded operating envelope in temperature, input frequency, amplitude, gain state, sample rate, reference clock and time since warm-up. Randomise or systematically cross the factors so interactions are not mistaken for repeatability. Monitor coefficient drift and

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spurious-free dynamic range under blind challenge tones at the envelope boundaries. Specify actions when a gain-state change invalidates coefficients: halt the claim of coherence, reload a demonstrated calibration, or segregate and mark the affected samples as qualified. Trace each configuration to firmware and calibration version, store raw branch records where practicable, and place a hash on the resulting derivative. A calibration campaign cannot consist of a single attractive spectrum. I pass the token to Dr Shannon for the limits of digital correction.

W. Edwards Deming, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, is it fair to call a calibrated time-interleaved array a higher-bit ADC simply because the software estimates sub-LSB differences between branches?

Claude Elwood Shannon, Cross-Peer Answer to W. Edwards Deming: Dr Deming, no. Aggregation of interleaved branches increases the overall sampling cadence under a phase-coherent timing plan; it does not automatically increase the physical code depth of any one simultaneous sample. Calibration can reduce systematic interleaving images, and combining suitably independent measurements may improve a particular estimator in a restricted band. But the apparent gain depends on noise correlation, reference stability and signal stationarity, and a saturated branch remains incapable of recording the lost analogue amplitude. The released instrument specification should identify nominal per-branch bit depth, measured aggregate SINAD or ENOB at stipulated frequencies, timing-skew tolerance, spur suppression and uncertainty, rather than naming an invented synthetic word length. Preserve branch samples and

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the calibrated composite separately. I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator's concluding synthesis

Our discussion has exposed a recurrent error in the public interpretation of technical surveillance measurements. The presence of one apparently continuous digital waveform does not prove that its component converters observed an analogue event on one physically exact time lattice. The nominal sample grid is a mathematical specification. The realised grid depends upon branch aperture displacement, common and independent clock error, analogue input responses, gain and offset, temperature and operating state. A calibrated representation can be informative, but it becomes forensic evidence only through a chain of disclosed comparisons and uncertainty-bearing inferences. The distinction is especially important where a weak suspected emission lies close to an internally predictable interleaving image.

Mr Nyquist has required us to identify actual sampling instants rather than trust the nominal clock diagram. His distinction between deterministic branch skew, random aperture uncertainty and common timebase error prevents a deceptive conversion of one calibration number into a universal coherence certificate. Dr Shannon has examined the inverse problem, showing that a correction can estimate an input only within the information and model constraints of the original acquisition. The loss of a clipped amplitude or a missed transient cannot be annulled by a longer, prettier digital vector. Professor Bode has identified the analogue branch transfer functions that may masquerade as timing differences; his insistence on frequency- and state-dependent calibration avoids the error of using a

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single laboratory tone to qualify a broadband receiver. Dr Bennett has shown how periodic mismatch can create genuine lines in the digital record that were not present at the external reference plane. Dr Deming has made clear that repeatability, statistical control and fitness for a particular defensive investigation remain separate propositions.

The peer challenges have refined these statements. Mr Black exposed the danger of adaptive calibration that removes an assumed unwanted feature without demonstrating its cause. Dr Hamming demanded proportionality in what must be archived, and the panel adopted a tiered approach tied to the evidential claim. Professor Gabor distinguished transient information from the deceptive precision available to a long-tone estimator. Professor Wiener showed why equalisation may introduce covariance and why apparently lower displayed noise need not mean lower uncertainty. Professor Bracewell exposed the risk that offline filtering places visible pre-ringing before an actual pulse. Professor Tukey insisted upon separating exploratory searches from pre-specified confirmatory tests. Dr Shewhart challenged the belief that a stable calibration-monitor statistic remains valid after firmware or physical state changes. Each objection demonstrates that the quality of a digital measurement cannot be read solely from one figure of merit.

The practical acceptance dossier should therefore contain the intended measurands and reference planes; the number and order of interleaved branches; the nominal and observed sample-rate characteristics; relative aperture-skew calibration; per-branch amplitude, offset and phase response across the admitted band; temperature and configuration envelopes; stochastic timing and voltage uncertainty; the calibration algorithm and its

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complete coefficient history; and the results of independent challenges. It should identify the versions of firmware, software and filters used when each material event was recorded. Where a branch mapping or clock source changed, the record should disclose the event's temporal relation to that change. A simple declaration of coherent capture is inadequate unless the sort of coherence claimed has been separately defined and tested.

The measured performance must also be expressed as a function of the task. Amplitude and phase reconstruction require evidence about transfer and uncertainty. Intermittent-signal discovery requires event-exposure accounting and correctly calibrated detection and false-alarm trials. Source attribution requires interventions that distinguish the internal-artefact hypothesis from an external emitter, with controls that hold relevant physical paths constant. A receiver can perform acceptably for one purpose and be unsuitable for another. Likewise two branches of the same interleaved converter are not independent witnesses merely because they contain separate electronic components. Their shared input, common clock, calibration algorithm and selection policy may couple their errors. A careful report will disclose those dependencies and avoid using multiplication of channel count as multiplication of evidential confidence.

The numerical exercises that follow shall make the scale of the problem concrete. Picosecond skew can produce measurable distortion at high input frequency; a common clock error can shift absolute time while leaving a relative branch difference largely unchanged; and a correction filter can add processing delay without proving the true onset of an external event. All such calculations remain conditional on clearly defined assumptions. They are not certifications of a particular receiver. The studies should be repeated

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with representative analogue stimuli and independently checked references before any operational performance claim is published. This is scientific discipline, not the multiplication of ceremonial cautions. A precisely bounded conclusion often permits firmer action than a spectacular but unsupported inference.

For the purposes of the volume, the panel therefore answers the question in a structured affirmative. Coherent time-interleaved digitisation can support defensible measurement when the actual interbranch time lattice, the analogue transfer responses, the common reference, the calibration operator and the relevant uncertainties are independently characterised across a declared operating envelope. The corrected record must remain reproducible from preserved evidence, and challenge experiments must show that genuine weak emissions survive the calibration rather than disappear beneath it. Where these requirements are unmet, the digital record may still support discovery or a limited observation, but it cannot legitimately carry every amplitude, phase, timestamp or attribution claim that its display appears to suggest. Our next question will ask how digital downconversion and decimation create additional numerical artefacts and how those artefacts should be distinguished from emissions in the external electromagnetic environment. I thank each contributor for the care with which the token has been received and passed.

Ten worked engineering and forensic applications

The following numerical cases are independent constructed examples intended to demonstrate scale, sensitivity, and evidential limitation. They are not measurements of any named instrument. Symbols denote the quantities defined in each case; frequency is expressed in hertz, time in

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seconds unless a submultiple is stated, voltage in volts, and ratios in dimensionless linear amplitude unless indicated. The logarithmic comparisons use 20 log10 of an amplitude ratio. A value expressed as dBc refers here to the simplified signal component relative to the stipulated carrier, not to a certified spectrum measurement. All arithmetic was recomputed separately from the narrative manuscript.

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Ten worked engineering applications | Question 034

Worked application 1. The ideal time lattice in a four-branch converter

Suppose the aggregate sampling frequency $F_s = 1.2 \times 10^9$ samples/s and the branch count $M = 4$. Each branch acquires at $F_b = F_s/M = (1.2 \times 10^9)/4 = 300 \times 10^6$ samples/s. The ideal aggregate interval is $T_s = 1/F_s = 0.833333$ nanoseconds. Each branch repeats at $T_b = 1/F_b = 3.333333$ nanoseconds. Within one nominal cycle, branches 0, 1, 2 and 3 should sample at 0, 0.833333, 1.666667 and 2.500000 nanoseconds relative to the cycle origin. The fourth branch is not another simultaneous measurement of the first branch's sample: it is assigned a different instant. A software archive giving 1.2 billion words in one second proves neither that the four physical apertures possessed these spacings nor that their common timebase epoch was accurate. Independent aperture calibration and timebase monitoring are necessary to turn the ideal schedule into a physical claim. Temperature, branch routing and calibration state remain uncontrolled variables in this elementary example.

Worked application 2. First-order error from a known aperture displacement

Let an analogue sinusoid have peak amplitude $A = 1$ V, frequency $f = 200 \times 10^6$ Hz and a small deterministic sampling displacement $\Delta t = 2 \times 10^{-12}$ s. The largest first-order fractional voltage error is approximately $e_{rel} = 2 \pi f |\Delta t| = 2 \pi (200 \times 10^6)(2 \times 10^{-12}) = 0.002513274$, or 0.251327 percent of the 1 V peak. Its amplitude-equivalent logarithmic value is $20 \log_{10}(e_{rel}) = -51.995$ dB. This is an

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upper bound derived from the local sinusoidal slope and the first-order Taylor expansion, not a general prediction of an individual interleaving spur. The actual error at any sample depends on waveform phase; a periodic skew schedule distributes the error into identifiable spectral components according to the schedule. The approximation requires 2 pi f delta_t to be small and the system to remain sufficiently linear. It is not proof of an external weak transmitter at the -52 dB level.

Worked application 3. Inferring relative delay from a measured phase difference

Suppose a calibrated tone at f = 240 x 10^6 Hz produces a relative branch phase difference phi = 0.6 degrees after subtracting previously characterised analogue-path contributions. Assuming the remaining phase is caused entirely by a pure relative delay, delta_t = (phi/360 degrees)/f = (0.6/360)/(240 x 10^6) = 6.944444 x 10^-12 s, or 6.944 ps. The unit conversion matters: a small angular difference can still correspond to a significant fraction of a picosecond-level acceptance budget. Yet the delay inference is conditional on the pure-delay model, phase unwrapping, reference phase and subtraction of unequal analogue group delays. A phase difference of 360 degrees plus 0.6 degrees would give a different delay that is indistinguishable at the single test frequency without an independent bound. Repeating at multiple frequencies can test whether measured phase is approximately proportional to frequency rather than the product of dispersion, nonlinearity, or a spur alias.

Worked application 4. Two-branch alternating gain mismatch

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Let the two branch gains be $g_0 = 1.01$ and $g_1 = 0.99$, measured relative to a nominal unity gain. Their mean is 1.00, and the sequence may be written $g[n] = 1 + 0.01(-1)^n$. For a complex carrier $x[n] = A \exp(j \omega n)$ with no other distortion, $y[n] = A \exp(j \omega n) + 0.01 A \exp(j(\omega+\pi)n)$. The shifted image has amplitude 0.01 times the desired carrier, or $20 \log_{10}(0.01) = -40.000$ dBc. The shifted digital frequency differs by half the aggregate sampling rate modulo the sampling lattice. In a real-sine signal the positive and negative frequency contributions and folding require explicit treatment. The example establishes a periodic-mismatch mechanism, not a universal figure of merit. If the external input contains an actual signal at the image coordinate, a gain-correction algorithm could affect both and therefore requires a controlled weak-target preservation test.

Worked application 5. Offset alternation and a zero-input spectral line

Suppose the branch offsets of a two-channel system are $b_0 = +3$ millivolts and $b_1 = -3$ millivolts, and the input carrier is absent. The output contains an alternating sequence $b[n] = 0.003(-1)^n$ V, which has a line at the digital Nyquist coordinate in the ideal model even without an external signal. If a separate reference carrier of peak amplitude $A = 0.5$ V were used for a simple amplitude comparison, the offset line's ratio to that reference would be $0.003/0.5 = 0.006$, corresponding to $20 \log_{10}(0.006) = -44.437$ dB. The comparison is an illustrative level, not a claim that a carrier must be present for the offset mechanism to occur. Zero-input captures can characterise branch offsets, but short records and quantisation noise impose uncertainty on the estimates. A zero-input

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bench result also does not certify offset stability after a gain-range or thermal change in the field.

Worked application 6. Thermal drift of the relative aperture

Let the initially measured relative branch delay at reference temperature T_0 be $\epsilon_0 = 0.7$ picoseconds. Assume a measured linear thermal coefficient $k_T = 0.12$ picoseconds per kelvin over the relevant envelope, and let the temperature rise be $\Delta T = 15$ kelvin. The model predicts $\epsilon = \epsilon_0 + k_T \Delta T = 0.7 + (0.12)(15) = 2.5$ picoseconds. At input frequency $f = 250$ MHz, the first-order sinusoidal error bound is $2\pi f \epsilon = 2\pi(250 \times 10^6)(2.5 \times 10^{-12}) = 0.003926991$. Its logarithmic amplitude equivalent is -48.119 dB. The arithmetic is straightforward; the principal uncertainty lies in assuming that the coefficient remains linear and that temperature was measured at the component affecting aperture displacement. A remote case sensor may not equal the sampling switch temperature, and the same state may show thermal hysteresis. The result should motivate a temperature-dependent verification experiment, not an unqualified correction in every operating state.

Worked application 7. Aperture jitter as a frequency-dependent limitation

Consider a random timing uncertainty with root-mean-square value $\sigma_t = 150$ femtoseconds and a pure sine input at $f = 400$ MHz. Under the common small-jitter, otherwise ideal sinusoid approximation, the aperture-jitter-limited signal-to-noise ratio is $SNR_j = -20 \log_{10}(2\pi f \sigma_t)$. Substitution gives $2\pi(400 \times 10^6)(150 \times 10^{-15}) = 0.000376991$

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and SNR_j = 68.473 dB. This is not the total signal-to-noise-and-distortion ratio of an actual ADC. Thermal noise, quantisation noise, nonlinearity, clock spurs and input-path distortion may reduce total performance. A stated oscillator phase-noise specification also cannot simply be substituted for sigma_t without integrating the relevant phase-noise spectrum over the appropriate bounds and considering which clock fluctuations actually affect the measurement. The calculation concerns random sampling uncertainty and does not remove a deterministic interbranch skew.

Worked application 8. Common uncertainty and differential timing

Suppose two branch timestamp estimates each contain a common timebase uncertainty with standard deviation sigma_c = 50 picoseconds and an independent branch-specific uncertainty with sigma_i = 20 picoseconds. Assume the three errors are zero mean, the two branch-specific errors are mutually independent, and each is independent of the common error. The standard uncertainty of either absolute timestamp is sqrt(sigma_c^2 + sigma_i^2) = sqrt(50^2 + 20^2) = 53.852 picoseconds. The difference between the two timestamps cancels the common term, giving differential standard uncertainty sqrt(20^2+20^2) = 28.284 picoseconds. The calculation is invalid if the branch-specific terms are correlated or the common term changes differently during the relevant interval. It illustrates why a system can establish precise relative alignment while remaining less certain of absolute event epoch. The common clock's uncertainty must be retained for claims such as external-source time of arrival.

Worked application 9. Filter delay versus physical event onset

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Let a symmetric, linear-phase fractional-delay FIR filter contain L = 63 taps and operate on a stream with F_s = 1.2 x 10^9 samples/s. Under the fixed-coefficient FIR assumptions, nominal group delay is tau_g = (L-1)/(2 F_s) = 31/(1.2 x 10^9) = 25.833333 nanoseconds. One may compensate this known algorithmic delay in a timestamp expression. But a burst's apparent start may be affected by the analogue passband, noise threshold, unknown waveform rise time, filter boundary extension and the phase at which the burst crossed the interleaving grid. A corrected timestamp t_est = t_display - tau_g is therefore not necessarily the true physical onset; it is an estimate that needs an experimentally determined residual error distribution. Offline zero-phase implementations may exhibit apparent pre-event ringing, which does not prove that electromagnetic energy existed before the stimulus. Retaining the original source samples and filter definition permits this processing artefact to be examined.

Worked application 10. A zero-failure challenge does not certify perfect detection

Suppose n = 500 independent trials, each drawn from the declared representative challenge population, reveal zero failures under a fixed detection and calibration procedure. Let p denote the unknown probability of failure per independent trial. Under the stipulated Bernoulli model, the probability of observing zero failures is (1-p)^n. Setting this probability to 0.05 gives a one-sided 95-percent upper confidence bound p_upper = 1 - 0.05^(1/n) = 1 - 0.05^(1/500) = 0.005973552, approximately 0.597 percent. The bound applies only to the specified trial model and population. If the 500 tests reuse one

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favourable waveform phase, one warm receiver state and one calibration tone, the independence and representativeness assumptions are not credible for the intended survey. The finding is not that any particular new detection is 99.403 percent likely to be an external emission. It is that the finite challenge record bounds a defined failure probability under strong declared assumptions.

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QUESTION 035

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How should polyphase channelisers be validated at channel boundaries?

Source: V011_Roundtable_Question_035_CP035_Dr_Atkinson(1).docx | Recovered substantive manuscript. Constructed educational dialogue.

Constructed educational dialogue for Volume 11. The historical specialists named below did not participate in an actual discussion and are not represented as having examined modern SDR equipment. Their statements are original pedagogical reconstructions of relevant engineering and scientific principles. All numerical instruments and measurements are hypothetical unless a cited source is explicitly identified. No source is attributed a result it did not report.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, the previous discussion examined calibration of the time-interleaved digitiser, where a digital sequence could present a reassuringly regular face while concealing several distinct physical apertures. We now follow that sequence into the receiver's channeliser. An observer looks across a waterfall display and sees a sequence of apparently separate, contiguous frequency compartments. The visible boundaries appear as straight lines, but the signal-processing machinery beneath them has neither infinite stop-band rejection nor perfect knowledge of a signal which arrives at an arbitrary frequency, amplitude or time. One frequency component can influence several adjacent outputs. Another may be weakened precisely where two channels meet. A particularly unfortunate discovery may be entered into the survey register twice, once under each neighbouring channel, or it may be missed because neither channel's individual statistic crosses the operator's threshold. [S1, S2]

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The problem is neither peculiar to a single software implementation nor cured merely by calling a filter *polyphase*. A polyphase analysis bank is an efficient factorisation of filtering, modulation and decimation. Its claimed performance depends upon the prototype impulse response, tap partition, Fourier sign convention, arithmetic precision, input reference, output map, decimation ratio, processing-state continuity, and the way the operator combines or discards adjacent output channels. We must distinguish the mathematical proposition that samples are related by a defined transform from the physical proposition that an unknown field emission would have been detected over a stated range of frequencies and burst timings. One requires an inspection of algebra and code; the other requires controlled observations and bounded uncertainty. A centre-frequency demonstration can verify neither claim across an entire channel boundary.

For our discussion let F_s denote the complex-input sample rate in samples per second, M the number of nominal analysis channels, $\Delta_f = F_s/M$ the nominal channel-centre spacing in hertz, $H_m(f)$ the complex end-to-end frequency response of output channel m when the input tone frequency is f, and R the output oversampling ratio relative to critical decimation. The normal output rate per channel is F_s/M; in the simple model it becomes $R F_s/M$ when oversampling is used. The power gain of a linear channel is $|H_m(f)|$ squared. We must preserve the distinction between a signal's amplitude, its energy spread across channels, and a decision statistic that may employ the magnitude or phase of one or more outputs. The sum of channel powers need not be equal to the input power unless the bank has appropriate normalisation and reconstruction

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properties. Nor does a sum of powers by itself prove that the same transient was recorded independently in each channel.

I ask the panel to answer a more rigorous question than whether the waterfall looks smooth. What tests, at what points of injection, would expose transition-band loss, unwanted alias folding, leakage from a nearby stronger emitter, group-delay differences, time-stamp ambiguity, and a false inference that two channel indications represent two emitters? Should a swept sinusoid be sufficient, or must we use displaced bursts, close doublets, broadband noise and controlled interference? How should the examiner distinguish a gain correction that can be supported by measured response from an inverse that no longer exists because critical decimation has removed information? When a channeliser is reconfigured in software, what parts of the calibration survive and what parts must be re-established?

Mr Campbell shall begin with the physical wave-filter idea and the folly of treating a drawn cut-off as a real discontinuity. Mr Nyquist will confront decimation and the informational price of critical sampling. Dr Slepian shall address concentrated but finite-duration spectra, which are particularly likely to defeat a tidy channel-centre demonstration. Professor Tukey will consider the dangers of selected plots, search thresholds and correlated channel outputs. Dr Shannon shall distinguish useful decision statistics from recoverable input information and set the limits of an assurance claim. Seven colleagues will challenge them; each challenge will receive an immediate substantive reply. Ten numerical examples will then expose the assumptions behind these conclusions. Our duty is not to require infinite perfection but to produce a test record precise enough to permit another

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competent examiner to reproduce, criticise and, where justified, reject a claim.

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George Ashley Campbell | Principal response 1: An edge is a specified transition, not an ideal wall

Dr. Atkinson, I begin from a commonplace that the engineer may find embarrassing precisely because it is so elementary. A filter does not acquire an abrupt physical boundary when we assign a convenient number to its nominal passband. Its network, or the digital impulse response which succeeds the network in the mathematical design, has a continuous response whose attenuation, phase and transition width must be made explicit. A telephone engineer seeking to separate conversations on one pair of wires would not certify the separation merely by drawing adjacent rectangles upon the frequency axis. Crosstalk is a measured relation between an interfering excitation and an output, and its tolerance must be tied to what that output is intended to communicate. [S1, S3]

A bank of M nominally adjacent analysis channels presents an analogous problem. Suppose the channels have centres separated by Delta_f. A desired signal at f = f_m + Delta_f/2 lies at the arithmetic midpoint between the centres of outputs m and m+1. There is no general principle under which one of those outputs must pass the signal with its centre-frequency gain. The result depends on the prototype filter, the bank's modulation, the precise fractional offset, and any alias contributions after decimation. Indeed, a good prototype designed to suppress interference in an adjacent channel may make a single-channel edge response worse. The design optimisation must declare whether it seeks flat amplitude across a retained central fraction, improved isolation, low reconstruction error when outputs are recombined, or some compromise. A prototype cannot be judged against a requirement that was never written.

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I would begin validation with the input and output reference planes. If a calibrated signal generator is connected through a cable, attenuator and amplifier, the injected level at the channeliser's digital input is not established simply by reading the generator's face. For a digital-only test we can inject exactly generated complex samples and remove analogue variability; for a complete receiving-chain test we must characterise the analogue chain and any intervening quantisation. Both experiments are useful, but they answer different questions. The first exposes coefficient and mapping defects; the second includes physical overload, image responses, clock errors and coupling. Claiming that the first experiment certifies the second is an error of measurement boundary.

A proper swept-tone campaign should sample both channel centres and every declared retained frequency interval, with special density near each nominal edge. It must measure complex gain, not merely the height of one bar in a power display, when phase or relative timing will be used. The sweep should be made in both directions, because a continuously adapting receiver may present hysteresis even where a fixed finite impulse response has none. It should include different input amplitudes to reveal arithmetic saturation or gain-dependent error. It should include a known strong interferer in the neighbouring nominal channel, since a weak candidate is often invisible only when the surrounding environment is busy. These measurements become a response surface H_m(f,A,s), where A denotes amplitude and s the receiver state, rather than one flattering figure entitled *selectivity*.

The examiner should further calculate how a known strong signal might appear in an apparently unrelated output. Let an unwanted input power be

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P_i in dBm and the measured leakage suppression into an adjacent channel be A_ij in decibels. Under a small-signal, linear, properly matched model the apparent leaked power is P_i - A_ij, after applying any stated gain convention. The formula is simple; its boundary conditions are not. If the prototype provides sixty decibels of rejection at the interfering frequency but the arithmetic path creates an alias with only forty decibels of suppression, the relevant figure for that route may be forty. If the input amplifier is in compression, neither small-signal figure is entitled to certify the receiver. A process that reports only the best observed rejection has confused an acceptance limit with an advertisement.

There is an important distinction between isolation and complementarity. The neighbouring outputs may both contain the same signal because their passbands overlap by design. In that condition the second indication is neither a distinct emitter nor necessarily a defect; it is part of the specified representation. If the operator combines the channels, the combination rule and complex calibration become essential. A power sum cannot be substituted for a complex coherent sum without a change of measurand. If the operator discards all but one channel, the retained fraction and the worst-case edge correction must appear in the validation statement. The institution's laboratory should record the channel map, filter taps and output ordering, because a numbering convention is no substitute for an actual frequency assignment. GNU Radio's documentation makes that practical mapping a first-class channeliser parameter. [S1]

I should also insist upon honest uncertainty. A response curve is an estimate obtained from a finite set of calibration tones and operating conditions. Interpolation between those points is a model whose adequacy

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must be tested. A narrow defect between two coarse calibration frequencies will not be discovered by the absence of a problem at both measurements. A quoted amplitude correction cannot be more reliable than the reference-level uncertainty, repeatability, frequency-step uncertainty, and residual model error taken together. The fact that its coefficient is stored to six decimal places does not impart six significant figures of knowledge. I would give a separate limit for minimum response inside the retained band, maximum leakage under declared adjacent-signal conditions, and the conditions under which these limits were established.

Finally, the report must retain adverse examples. A suppressed signal at a boundary cannot be erased from the record simply because the team later elected to redefine the usable bandwidth. The narrower bandwidth may be a legitimate engineering conclusion; its selection after a failure must be disclosed, and the revised specification must face a new independent challenge. The defence investigator who finds a suspicious peak in two channels must prove which common input can produce those responses and whether any alternative input remains observationally equivalent. Precision begins when the instrument is compelled to fail against a declared standard. I pass the floor to Mr Heaviside for examination of phase and transient response, which a simple amplitude sweep may conceal.

Oliver Heaviside | Peer question 1 to George Ashley Campbell

Mr Campbell, I accept the central point that the passband boundary is an engineering region rather than a geometrical line, but you have spoken extensively of levels and leakage while leaving an especially dangerous possibility comparatively quiet. A filter may have tolerable amplitude through a specified band and yet possess an uneven phase

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characteristic or an extended transient response. An intermittent emission near the boundary may then have its energy displaced across several output samples or receive a different time stamp in its neighbouring channel. If the operator compares the channels for direction finding or a forensic chronology, the magnitudes can be accurate while the timing relation is false. Should a validation procedure therefore measure a complex transfer function, an impulse response, or both, and should group delay be treated as a single fixed number even when the prototype is nonlinear phase? I also ask how you would distinguish the phase of the digital filter from the delays of preceding cables and converters, since a single end-to-end measurement may hide their separate contributions without invalidating the narrower end-to-end claim.

George Ashley Campbell | Immediate answer to Oliver Heaviside

Mr Heaviside, your question identifies the danger in using a response curve as though it contained every relevant characteristic. For a system whose only decision is whether a steady tone exceeds a calibrated threshold, magnitude may form a sufficient part of the specification, subject to exposure and noise statistics. For a transient whose arrival time or inter-channel phase is material, it is not sufficient. I would measure the complex end-to-end response against a traceable stimulus at the declared input reference plane, estimate its group delay where that derivative is meaningful, and challenge the inferred delay with known pulses and controlled multi-tone signals. An impulse-response measurement, or its equivalent frequency-domain reconstruction under a validated linear model, exposes

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ringing and the duration of the filter's memory. A nonlinear-phase response cannot be reduced to a universal single delay when the input waveform occupies a substantial bandwidth.

The separability of analogue and digital delays is a second issue. If the full chain is calibrated as one stable object, an end-to-end correction may support the intended output claim without uniquely allocating every nanosecond among the cable, converter and software. That is a legitimate bounded result. It becomes insufficient when the report later asserts that a particular internal component was faulty, or when one component is replaced while the inherited calibration is retained. I would therefore preserve both the end-to-end validation and the equipment configuration, so a later substitution prompts the right recalibration decision.

Two neighbouring filters can have different phase responses to a boundary signal even though they process the same input history. Comparing their uncorrected trigger times risks assigning physical significance to a mathematical difference in filter delay. The operator should establish, with repeated controlled bursts at several fractional edge locations, how the trigger estimator behaves for each channel, and whether its error depends on amplitude or burst shape. Time stamps should be tied back to input sample indices with the processing delay and retained-window convention declared. The machine's nominal clock is not itself an observation of the time at which an unknown emission began.

I would also refuse to average away adverse transient results. A long stationary test may find excellent centre-frequency gain but fail

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to expose bursts shorter than the filter's settling interval. The report should therefore contain at least a representative pulse-duration family and specify the shortest event for which the detector was tested. Where phase or timing behaviour is not characterised, the report may still identify a candidate frequency interval, but it should not claim coherent arrival-time precision. Thus your objection does not demand an unattainable perfect decomposition; it demands that the evidence match the quantity to which the investigator intends to attach a number.

Edwin Howard Armstrong | Peer question 2 to George Ashley Campbell

Mr Campbell, I would test your filter theory against an actual receiver rather than a quiet mathematical substitute. An input carrying one strong legitimate transmission may drive the analogue front end toward compression, produce intermodulation or increase broadband noise, and thus alter a weak signal at the edge of a nominally separate digital channel. The laboratory might inject two digital tones after the converter and demonstrate splendid filter isolation, then insert the same nominal frequencies through the antenna port and discover an apparent line which neither digital tone predicts. How should the report partition these findings without permitting a software vendor to claim that its verified channeliser has somehow verified the receiver? I also wish to know whether your suggestion of a two-tone challenge adequately represents intermittent transmitters, whose envelope transitions and uncertain timing may produce a broader spectrum than the centre frequency used

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to label the source. An engineering specification capable of surviving a hostile inspection must state where its evidence begins and ends.

<u>George Ashley Campbell</u> | Immediate answer to Edwin Howard Armstrong

Mr Armstrong, I agree that a channeliser is not the entire receiver, and a statement that blurs the distinction should be rejected. We should construct a nested set of acceptance tests. At the innermost layer, inject a digitally synthesised sequence and test the mathematics of the filter bank, the output ordering, precision, decimation and detector code. At a second layer, inject a known analogue waveform at the ADC input and examine converter behaviour, headroom and clock effects. At an outer layer, test the receiver at its declared RF input with controlled modulation, adjacent high-level interferers and the applicable antenna or coupling arrangement. Each layer has a different uncertainty budget. A successful inner test is necessary for some outer claims, but it cannot by itself exclude nonlinearity in the outer chain.

Your concern about modulation is decisive. A keyed or pulsed transmission has a spectrum that depends on pulse shape, duration and repetition, not merely on an assigned carrier. A narrow mathematical test tone is useful because it samples the frequency response at a known point; it is not representative of every waveform for which a receiver may be used. The laboratory should therefore add short and long pulses, rising and falling edges, close pairs, and signals with deliberately varied spectral occupancy. It should also test a weak target simultaneously with a strong neighbouring emission,

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not only in alternating trials. The ability to detect the weak target when the strong emission is absent is an inadequate answer to an operational environment in which both may coexist.

An instrument's statement of scope might accordingly read: its digital channeliser satisfies the measured response envelope when supplied with bounded, unclipped samples, while the complete receiver satisfies a separately tested detection probability over a narrower RF input range and specified interference conditions. This is not an embarrassment. It is a precise allocation of evidence. The report should preserve the test's raw input, the calibration path, the output samples, the detection decision and every parameter changed after a failure. These materials allow another examiner to distinguish a new input-induced artefact from a filter-bank calculation error.

Where a suspicious line appears only through the RF input and not through the digital test port, one has localised the competing explanation to an earlier part of the chain, but not necessarily to a particular circuit. The line may be external, may arise from nonlinear conversion, or may be injected through an unintended path. Additional interventions can discriminate these possibilities. An antenna substitution, attenuation experiment, preselector change or receiver comparison becomes useful when its predicted effect on an external source differs from that on an internal spur. One should not assume that a one-decibel reduction of a display line proves anything about its origin. The evidence must be conditioned upon the physical response being tested. I now pass the floor respectfully to Mr Nyquist,

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whose sampling argument reveals how an apparently excellent filter can still alias an unwanted component into another channel.

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Harry Nyquist | Principal response 2: Critical decimation, aliasing and the missing inverse

Dr. Atkinson, I would begin with the meaning of the word *channel* in a sampled representation. An equal-spaced collection of centre frequencies is a convenient labelling of transformations; it is not a guarantee that every component of the input is assigned exclusively and perfectly to one output. In a critically sampled M-channel analysis bank, each output is commonly decimated to F_s/M. The separate outputs must be interpreted as members of one coupled representation of the original F_s-rate sequence. If an examiner extracts just one stream and treats it as an autonomous receiver, information that could have been needed to distinguish a boundary input from an alias may already have been excluded by that choice. The relation is especially troublesome where two components separated in frequency map to the same output rate after decimation. [S1, S4]

In the idealised low-pass case, downsampling by D adds shifted copies of the input spectrum in the output's frequency coordinate, divided by the appropriate normalising factor. A filter of sufficient attenuation can suppress out-of-band replicas before the operation, but the required attenuation is dictated by the greatest unwanted signal and the smallest wanted signal, not by a catalogue's one-line description of its passband. A thirty-decibel stop band may appear satisfactory when the neighbouring channel is quiet. The same thirty decibels can be wholly inadequate if a legitimate carrier is sixty decibels stronger than the emission sought. The alias path then carries a residue thirty decibels above the weak target's reference level. The mathematical result is not paradoxical. It is what finite isolation means under an unfavourable dynamic range.

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This difficulty becomes acute at a boundary because the desired signal can itself occupy the filter's transition region. Suppose a detector retains only the inner eighty per cent of each channel. The remaining twenty per cent may be outside its accepted response envelope; that fact does not excuse a survey that silently represents the discarded region as searched. We must either overlap observations and combine them under a validated rule, or specify an exposed gap. If two channels are retained with overlap, their outputs are correlated because they are derived from the same input sequence. An alarm in both cannot be counted as two independent demonstrations. The correct unit of evidence may be a single candidate associated with several supporting channel measurements, with a covariance model where quantitative fusion is intended.

A critical distinction should be drawn between the analysis filter bank and a perfect-reconstruction analysis-synthesis pair. Certain filter-bank designs can combine their channels to reconstruct the input within stated numerical tolerances. That property can coexist with significant error in one isolated channel. Conversely a channeliser designed only for detection may not have a matching synthesis bank at all. The examiner must not infer reversibility from the word polyphase. If the original wideband samples have been discarded, and the retained set excludes a necessary output or has suffered noninvertible clipping, subsequent software may not possess the data required to reconstruct an input event. Processing power and finer numerical interpolation do not restore measurements never retained. The preservation policy is consequently part of the claimed measurement architecture.

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I would require a frequency-sweep test which deliberately crosses every channel boundary with both positive and negative frequency offsets in a complex-sampled system. Where a band-edge feature is represented through frequency wrapping, the precise ordering and sign convention must be tested; a correct magnitude display can conceal a conjugation or channel-map error. In addition, I would place pairs of tones at opposite sides of one boundary and vary their relative phase. This experiment distinguishes a simple leakage prediction from a coherent combination that might either reinforce or diminish an output. The combined waveform should be challenged over input amplitudes sufficient to reveal finite-word-length scaling and dynamic overflow. A bank implemented with integer arithmetic may fail differently from a double-precision simulation even when both execute nominally identical coefficients.

The validation must also follow the time coordinate. An M-fold decimator changes the output sample interval; the processor's block schedule and filter latency shift when an input event can affect a downstream decision. To claim a time of arrival, the investigator should trace the detected output sample and its associated input index through the filter and group-delay model. A timestamp attached to the first reported channel packet is not automatically the timestamp of the first analogue evidence. If packets have been dropped, no interpolation theorem guarantees that an arbitrary short burst can be reconstructed across the gap. At best one can specify a conditional model, with a recorded missing interval and uncertainty. An absence claim over that missing interval is not established.

Oversampling can alleviate some boundary problems by retaining more information in neighbouring channel outputs and relaxing critical alias

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conditions, but it increases throughput and does not abolish a finite filter transition. GNU Radio's channeliser description, for example, permits oversampled output according to a ratio that is constrained by the configured number of channels in the documented implementation. That implementation detail is an essential reproducibility fact, not a general theorem about all polyphase banks. [S1] The laboratory should record the actual software version and parameters under test rather than transplant one implementation's limits to a different product.

I would then demand an inverse challenge where applicable. Inject a known wideband signal with a component close to an edge, archive all output streams, and attempt a reconstruction under the claimed analysis-synthesis procedure. Assess its error both globally and within the narrow intervals where the operational detector has the greatest difficulty. A small aggregate root-mean-square error may conceal severe relative error on a rare low-energy burst. The uncertainty of such a comparison must include calibration level, finite-word-length error, filter design, time mapping and reference-signal fidelity, with covariance where it matters. An acceptance report which states only an average reconstruction error or only a minimum centre-frequency attenuation is not testing the forensic proposition.

We are entitled to claim what has been challenged. If a particular bank under specified operating conditions detects a family of known boundary bursts at a measured rate and controls a defined false-alarm probability, that is a defensible bounded result. We are not entitled to infer perfect coverage of an arbitrarily weak, unknown or shorter emission. The operator should carry a frequency-dependent detection-exposure record, rather than stamp every channel with the same reassuring status. I pass the token to Mr

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Black, who may wish to ask whether calibration by adaptation can conceal aliasing rather than remove it.

Harold Stephen Black | Peer question 3 to Harry Nyquist

Mr Nyquist, your account suggests that oversampling and more generous retention may improve the ability to recognise an edge event, but suppose the manufacturer introduces an adaptive anti-alias filter which changes its coefficients when a strong signal enters the adjacent channel. The detector then declares that the boundary is protected because the unwanted channel line falls below a fixed threshold. The filter is a controlled system, with a history-dependent state. How should its validation distinguish genuine improved isolation from the possibility that the same adaptive response attenuates an unknown target whose spectrum overlaps the interference? More particularly, would you accept a frequency-response measurement made after the system has settled, or insist on a sequence of changing interferers and test bursts before, during and after each update? A correct static diagram may be entirely silent about a transient state in which a time-critical emission disappears. I seek a stopping rule that does not demand exhaustive enumeration yet prevents the acceptance process from ignoring the adaptation interval.

Harry Nyquist | Immediate answer to Harold Stephen Black

Mr Black, I would not accept a settled-state response as sufficient for a system sold or described as capable of monitoring while adapting. The adjective *adaptive* identifies the possibility that the mapping from input to output changes over time, and therefore a single stationary transfer function cannot account for the complete observation history. One must either freeze the coefficients to create

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a stationary testable case, or define the adaptive control law and validate a family of states and transitions. A valid test programme may contain both parts. The settled-state measurement characterises operation after convergence; transition challenges reveal what happens while the algorithm is moving between coefficient sets.

The experimental question must be stated before the threshold is tuned. If the asserted capability is detection of a weak transient during a strong adjacent transmitter's onset, the laboratory must inject that transient at independently randomised times around the onset and vary its fractional position relative to the channel edge. Do not force every test pulse to coincide with the detector's preferred observation window. Retain outcomes for the complete trial population, including unsuccessful detections, changes in threshold and exceptional states. Compare candidate-detection performance and false alarms with the adaptive mechanism on and off, but do not interpret an improved average as permission to ignore a narrow interval of poor performance.

The adaptive coefficient history should be a first-class evidential record. The reviewer needs the initial filter state, the programme input or sufficient summaries that determined updates, the applied coefficients or their content-addressed versions, the time at which each state became active, and the output samples affected. A delayed log which records only the final filter cannot demonstrate what happened during the contested interval. Likewise, raw input preservation remains essential where subsequent independent reprocessing is anticipated. Without the input, one cannot

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conclusively distinguish a corrected artefact from a suppressed target whose evidence the algorithm has erased from the output.

As to a stopping rule, I would define an operating envelope rather than an impossible universal claim. Enumerate the maximum adjacent-signal level, the allowed rate of change, specified classes of modulation and pulse duration, the admissible calibration states and the minimum expected detection probability under each required condition. Statistical acceptance criteria should be selected before the trial. The result may then support performance within that envelope, accompanied by explicit exclusions and uncertainty. Where the data reveal a blind interval, the envelope must exclude that interval or the design must change. A narrow but well-tested claim is stronger than a broad claim inferred from convenient demonstrations.

Norbert Wiener | Peer question 4 to Harry Nyquist

Mr Nyquist, I should like to examine a more insidious condition than a control loop with disclosed coefficients. A surveillance operator notices a candidate near the midpoint between two channels and, quite properly, changes the receiver's centre frequency in order to move the candidate away from the original boundary. The observation then appears stronger. Yet the act of retuning has changed oscillator phase, filter alignment, input gain and perhaps the spectrum of interference. It has also selected the second observation because the first observation drew attention. What evidence would justify saying that the two indications arise from the same external waveform, as opposed to two different internal responses to a common troublesome environment? Should the investigator attempt to predict the second output from the first under a

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known transfer model, or should the retune be treated as a new experiment requiring independently controlled source injection? I am particularly concerned that feedback between the human operator and the instrument changes the sample population and invalidates naive claims of independent confirmation.

Harry Nyquist | Immediate answer to Norbert Wiener

Professor Wiener, the intervention you describe is valuable precisely because it changes a known dimension of the apparatus, but its evidential force depends upon whether the rival explanations make different predictions. If the frequency of an external emitter remains constant in an absolute RF reference while the digital channel grid is shifted, the candidate should move among the channel outputs in a calculable fashion, subject to the retuned receiver's frequency accuracy and transient settling. A spur tied to the filter-bank boundary may remain attached to the same fractional channel position instead. That contrast can help distinguish origins. It is not, however, a universal rule: some internal spurs track the local oscillator, and real external signals can themselves change frequency or vanish between observations.

The test record must therefore retain the first indication, the retune command, the exact configuration before and after, the known oscillator-settling or calibration interval, and the second result whether positive or negative. The operator's selection of the retune because of the first observation is not a reason to discard the test; it is a reason not to treat the two records as independent random trials drawn from an unselected population. One can use a designed

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intervention to discriminate models without calling it independent replication. Its strength arises from the predicted transformation of the signal and the response of the instrument, not from a simple count of two displays.

Where an independent reference emitter is available, a controlled source can test the retune mapping and settling behaviour in the same equipment state, but the signal under investigation remains unknown. We should not substitute the reference's behaviour for a conclusion about the candidate until the relevant likenesses and differences are justified. A secondary receiver, antenna or downconverter may provide additional information if it changes the dependency structure in a useful way. Shared clocks, power supplies and inputs should be identified, rather than converted into an exaggerated story of corroboration.

The simplest admissible conclusion may be that a feature appeared at a consistent external-frequency estimate before and after one specified retune, within the combined uncertainty, while a boundary-tied laboratory artefact did not behave so. That finding weakens a particular artefact explanation, but does not exclude every possible internal effect. If more decisive attribution is needed, the investigator must design further tests whose rival predictions differ and whose outcomes can be preserved. Controlled intervention is the discipline of explanation; repeating a reassuring image is not. I pass the floor to Dr Slepian, whose mathematics of spectral concentration will clarify why a signal does not politely confine itself to the channel assigned by the operator.

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David Slepian | Principal response 3: Finite records, spectral concentration and the boundary transient

Dr. Atkinson, I approach the boundary from an observation that is sometimes confused with an inconvenience of plotting. A waveform confined to a finite time interval is generally not confined to a single finite frequency interval with perfect sharpness. Spectral concentration is a quantity to be studied and optimised under stated conditions, not a property which can be granted to an unknown burst by drawing a rectangle over the display. The Fourier transform of a gated sinusoid illustrates the difficulty. Its main spectral lobe is accompanied by sidelobes whose form depends upon the gate and window. A short burst may spread material energy across the nominal divide between two channels even when its carrier lies precisely at one channel centre. The signal's shape and duration therefore matter to what appears in each output. [S4, S5]

In ordinary detection it may be reasonable to seek a statistic that captures the energy of a signal class without reconstructing every detail of the waveform. The design decision should be explicit. One filter bank may optimise interference rejection for long stationary tones, another might be chosen to retain short transient envelopes. A demonstration using a continuous tone cannot establish performance for a microsecond impulse merely by invoking the same centre frequency. Nor is a burst of prescribed phase and duration an adequate representation of an entire family of intermittent emitters. It may yield an excellent controlled test, but its generalisation requires a documented model of waveform variation and of the receiver's response to that variation.

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Let the input contain a finite-duration complex sinusoid $s(t) = A \exp(j2 \pi f_0 t) w(t)$, where A is complex amplitude, f_0 is the nominal carrier frequency, and w(t) is the time envelope. Its spectrum is the envelope spectrum $W(f - f_0)$ multiplied by A. Even if f_0 lies inside output channel m, portions of W may reach channels m-1 and m+1. If w is a rectangular gate, its Fourier magnitude has a sinc-like envelope; a smoother temporal taper can reduce sidelobes but alter effective duration and amplitude. That is not a reason to impose tapering blindly on evidence. It is a reason to preserve the raw record and document the window used in any displayed or detected spectrum. An unknown real emitter does not become a different physical source because our analysis chooses a different taper.

The boundary effect must be characterised with more than steady-state power. I propose a two-dimensional challenge map indexed by fractional carrier offset from the channel centre and by event duration. A third dimension should record burst starting phase relative to the bank's decimation lattice. If the detector uses periodic or block-triggered statistics, a short burst arriving just before one block boundary may contribute very differently from a burst arriving shortly afterwards. Repetition across many random start times makes this variation visible. A fourth dimension, if the intended survey requires it, records neighbouring interference. It is tempting to reduce these variables to one performance number; doing so without showing their joint distribution can conceal the very region in which the instrument fails.

Oversampling of channel outputs can be a useful design intervention. It retains additional temporal samples and allows overlapping effective passbands, making it possible to construct more robust edge statistics.

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Published analyses of oversampled banks in radio astronomical instrumentation discuss reduced edge attenuation, scalloping loss and leakage relative to critically sampled configurations, under the specific designs tested. Those results are neither a guarantee for every implementation nor evidence that every unknown burst can be reconstructed. The filter prototype, oversampling ratio, coefficient word length and subsequent detector determine the actual benefit. [S2, S4] A laboratory comparison should apply both architectures to the same preserved input and evaluate the outputs under an identical declared decision rule.

I also question whether summing adjacent channel powers is always a sensible cure. The two channel outputs may have correlated noise, may report differently delayed versions of the same transient and may include the same strong interferer through different sidelobes. An unweighted sum changes the detector and its false-alarm distribution. If the purpose is to recover a scalar energy estimate, the joint response and noise covariance matter. If the purpose is to estimate a complex waveform, phase calibration and reconstruction conditions matter. If the purpose is only to avoid missing one member of a signal class, a logical union of threshold decisions may be acceptable, but its family-wise false-alarm probability must be tested. Each operation addresses a different measurand.

One must be particularly careful about the language of information recovery. A critically sampled analysis bank may be perfectly invertible when all outputs and the correct synthesis system are retained. A storage policy that discards every other channel, or records only threshold crossings, destroys that guarantee. A different oversampled system may be redundant

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in a useful mathematical sense but nevertheless unable to reverse nonlinear clipping or missing input intervals. When the investigator sees a faint candidate simultaneously in two edge outputs, the agreement is not independent corroboration. It is a predictable consequence of passing one physical input through two overlapping responses. It can strengthen confidence in a model of the bank's behaviour without proving who or what produced the input.

A proper acceptance result would state, for each tested signal class, the minimum detection probability over the declared edge-offset and burst-duration envelope, its confidence bound, and the corresponding false-alarm behaviour under strong adjacent interference. Where test counts are insufficient to bound a rare failure, the limitation should remain in the report. I would welcome a negative-control family of inputs with no target, as well as challenge bursts deliberately placed at the weakest part of the measured response. Success on easy tones is evidence of success on easy tones. The task of measurement is to discover whether the difficult conditions violate the claim. I respectfully yield to Professor Wiener for his question about the system's memory, selection and the difference between detecting an event and remembering it.

Alan Mathison Turing | Peer question 5 to David Slepian

Dr Slepian, you have treated a brief burst as a finite time-frequency object. I ask you to extend the analysis to a receiver whose event-retention policy is governed by earlier observations. The system may begin preserving raw samples after one channel's statistic crosses a threshold, and may then copy a smaller interval from a circular pre-trigger buffer. Near a channel edge, the triggering channel may react

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later than its neighbour because the two filters have different group delays or amplitude responses. If the system has already overwritten part of the input record, a later fusion algorithm can display an impressively complete reconstruction while relying upon unmarked padded samples or assumptions about the missing onset. How should a validation campaign distinguish the channeliser's mathematical fidelity from the selection and retention rules applied after channelisation? Would a randomised burst test that merely counts whether an alarm appeared suffice, or must it assess whether the retained evidence supports a faithful event-duration and onset estimate?

David Slepian | Immediate answer to Alan Mathison Turing

Dr Turing, the distinction you draw must appear in the acceptance criterion itself. Detection and faithful retention are different outputs of a coupled process. A receiver may detect an event with high probability yet preserve too little of its waveform to support an amplitude or onset calculation. Conversely it may retain a generous interval around one event while failing to detect others that never triggered retention. A count of alarms cannot establish the completeness of a later forensic archive. The experimental record must state what fraction of known events were detected, what fraction were retained with the prescribed pre-event and post-event context, and what uncertainties affect any derived onset, duration or phase estimate.

I would inject known bursts at randomised positions relative to decimation blocks, storage-buffer wrap points, detector update intervals and filter settling. Their starts and ends should be

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independently established by the stimulus system, with that reference's own uncertainty included. For each burst, compare the intended waveform support with the actual retained input support. Mark samples genuinely measured, samples interpolated under a stated model and intervals for which no observation exists. Software padding at a boundary is an implementation choice, not a measurement of the unobserved past. The production system should expose that distinction in its metadata or derived-data annotations rather than relying upon a later examiner to infer it from suspiciously smooth waveforms.

If two filters have unequal group delay, a trigger may be time-shifted in an entirely predictable way for a narrowband input but not for an arbitrary waveform. A calibration established for one tone cannot necessarily correct all burst shapes. I would therefore test a family of envelopes and measure detection latency as a distribution, including its tails and the response to strong adjacent interference. Where the detector's input is a weighted sum of channels, one must validate the sum and its alignment, not merely validate each constituent filter. The correct unit of testing is the actual chain which produces the evidential object.

A report might conclude that a defined class of bursts was detected in a declared operating region with a lower confidence bound of a stated value, but that their earliest ten microseconds were not reliably preserved under some boundary conditions. This is not contradictory. It is the separation between finding a phenomenon and retaining the material needed for a stronger inference about it. If the engineering

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system needs the onset for location or attribution, the retention policy must be revised or another acquisition path used. An archive that has not preserved the evidence cannot borrow certainty from a detector's good alarm statistics. I pass the floor to Professor Tukey, whose examination of data and multiple comparisons may expose how a boundary survey manufactures apparent success through its choice of summaries.

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John Wilder Tukey | Principal response 4: Searching many outputs without manufacturing certainty

Dr. Atkinson, my concern is not that the engineers have failed to design an attractive filter. It is that the story told after the test may differ subtly from the experiment that was actually performed. A channeliser is particularly liable to produce this difficulty because it gives the analyst many plausible ways to combine, threshold and display the same input. One may inspect the largest response in an edge pair, the sum of their powers, a coherent sum after phase adjustment, the greater of two normalised detection scores, a fitted spectral peak or a manually selected waterfall interval. Each of these summaries can be appropriate for a defined question. None acquires the same false-alarm behaviour merely because the operator calls all of them a detection. A result chosen after the examiner has seen the data is not necessarily invalid, but it cannot be assigned the nominal properties of a decision rule selected beforehand.

We must distinguish exploratory examination from validation. In exploration, I encourage ingenuity: plot more than one scale, re-express the data, examine the weakest edge positions and challenge apparent patterns. Exploration is how unexpected defects are found. But a test selected because it looked favourable is not an independent measurement of its own success probability. For acceptance, state the candidate class, frequency grid, event-duration family, signal-level distribution, interference conditions and detection statistic in advance. Freeze the software and coefficients, or register precisely how they may vary. Randomise the injection cases, retain the failures and count the trials actually performed, not merely the trials remembered after an extended day in the laboratory.

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Consider a search over N channels, each with a detector having a per-trial false-alarm probability p under an appropriate null model. If their tests were independent, the probability of one or more false alarms would be 1 - (1-p)^N. That is a useful warning, not a universal calculation for a polyphase bank. Adjacent outputs are ordinarily correlated because they arise from shared input samples and overlapping filter responses. Thus one cannot infer the exact family-wise probability from N and p without testing or modelling their dependency. The investigator should measure the joint null distribution under representative conditions, including correlated noise and a strong adjacent emission. A simple Bonferroni bound, where justified by individual event probabilities, can be conservative without requiring independence, but a bound is not the same thing as a calibrated detection probability. A tally of bright pixels in a waterfall does not settle these questions.

An excellent validation campaign will therefore preserve several kinds of count. For each designed challenge condition, record how many targets were injected, how many were exposed during valid acquisition intervals, how many crossed the fixed detector threshold, how many were localised to the correct input-frequency interval and how many were recorded without duplication. Those numbers cannot be combined indiscriminately. A target can be detected and nevertheless assigned to the wrong channel. Two correlated outputs can raise the apparent number of detections without raising the number of physical events. A pulse lost during a dropped buffer cannot be classified as an ordinary detector failure unless the tested system includes the transport and retention path, in which case it must be counted

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against the system-level claim rather than quietly removed. This is the discipline of denominators.

I would ask that the test reveal its weakest relevant region, not only its mean. If an edge has a narrow frequency interval where the response is eight decibels poorer than its centre, an average taken over thousands of easy interior tones can make the system appear splendid. The report should show detection probability as a function of the fractional channel offset, with confidence intervals, and state the minimum over any interval that the operational claim calls fully searched. The analyst may report a robust aggregate performance measure, but not at the expense of the very boundary the investigation depends upon. The same principle applies to pulse duration and starting phase. A receiver that succeeds for a steady carrier and fails for a short asynchronous burst has different capabilities, not a single capability described by an optimistic percentage.

There is another trap in the treatment of strong neighbouring signals. The engineer measures leakage by placing one interferer near an edge, then discovers a narrow spur on the opposite side. The analyst might increase the threshold until the spur disappears, and then declare the channeliser clean. The burden shifts to an unknown weak emitter which now needs more power to be discovered. A valid correction must be evaluated on both null inputs and target-present inputs, using the same decision rule. One should draw a detection operating-characteristic curve or equivalent empirical comparison, and select the threshold according to the operational consequences of missed events and false alarms. The consequences are not mathematical constants; they are part of a declared decision problem.

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Our records also require protection from the temptation to infer external origin from numerical rarity. A false-alarm probability under one receiver-noise model is not the posterior probability that a particular peak has an external source. That posterior would require explicit, justified hypotheses and prior information, with attention to model misspecification. A narrow line might arise from a coherent clock spur absent from the noise-only calibration, and the null probability computed for stationary Gaussian noise would be irrelevant. I would prefer a controlled intervention with divergent predictions over a spuriously precise numerical claim. Retuning the channel grid, disabling an internal oscillator, changing the input path, or comparing against a separately characterised reference can test causal alternatives.

As a publication matter, the case record should carry the raw or appropriately preserved data, the actual algorithm and version, calibration and channel map, a fixed analysis script if available, and the experimental outcomes, including the awkward ones. A printed receiver screen is an illustration, not a complete forensic trace. The result must be capable of criticism by someone who did not participate in its discovery, and its statistical interval must refer to the population actually sampled. I invite Sir Ronald Fisher to challenge the conception of a single probability assigned to a test programme whose conditions are visibly heterogeneous.

<u>Sir Ronald Aylmer Fisher</u> | Peer question 6 to John Wilder Tukey

Professor Tukey, you have proposed reporting conditional detection probabilities over several dimensions of frequency offset, pulse duration, interference and acquisition state. That is sensible, yet I see a danger of replacing one unjustified average with a constellation of small samples whose intervals are unstable and whose comparisons are multiplicative.

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Suppose the laboratory allocates a fixed number of injections across twenty boundary conditions, then draws attention to whichever condition has the lowest observed success rate. The smallest proportion is itself a selected statistic, not an unbiased estimate of the worst conceivable condition. Should the experiment be designed to estimate a smooth response surface, to test a prespecified minimum acceptance criterion, or to provide simultaneous confidence bounds across the required conditions? How do you reconcile the wish to expose a narrow blind region with the impossibility of testing every frequency, time offset and modulation? I particularly ask how an examiner should distinguish a useful inferential bound from an overfitted model that merely interpolates the observed successes with attractive mathematical precision.

John Wilder Tukey | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, your objection is apt because a validation surface is as vulnerable to selection as a single chart. I would formulate the experimental aim before choosing the analysis. If the requirement is to establish that detection probability exceeds a fixed lower bound throughout a specified operating envelope, then the programme must support a simultaneous claim or employ a design which justifies inference between tested conditions. A set of unrelated pointwise confidence intervals does not automatically constitute a simultaneous guarantee. A conservative multiplicity adjustment may be appropriate, but it can become prohibitively costly when the designer insists on an enormous grid. The more fundamental solution is to

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choose a physically informed test strategy and state what kind of interpolation is supported.

One might begin with a systematic sweep to discover pronounced transition-band defects, then use a preregistered confirmation experiment concentrated in the most consequential regions. The exploratory dataset identifies hypotheses; the subsequent independently selected trials test them. If the response is expected to vary smoothly with frequency offset under a fixed linear filter, a model may exploit that physical structure, but its residuals and prediction outside observed points must be tested. An adaptive system or a nonlinear saturation can break smoothness abruptly, so a model fitted under quiet, fixed conditions should not be assumed valid after a large interferer enters the band. A competent report distinguishes empirical observations, physical model assumptions and confidence derived from each.

I would report both the minimum observed performance among prescribed test cells and a justified uncertainty or lower-bound calculation appropriate to that selection. If too few trials were available for a confident simultaneous statement, the report should not invent one. The operator may still use the instrument for discovery, but the certification must exclude untested intervals or state the remaining risk. A claim with explicit limitation is more operationally useful than false certainty. Repeated observations in a small cell improve estimation of that cell's probability under repeatability assumptions; they do not reveal untested short bursts or different interference states.

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There is also the question of denominator discipline. The test population must include all attempted trials, separately recording invalid stimuli or true acquisition failures. An unexpected blank channel should not automatically be classified as an invalid test simply because it would lower the claimed success rate. Trials may be excluded only under previously stated and objectively verifiable criteria, with excluded results disclosed. Finally, the report should distinguish statistical significance from engineering significance. A tiny, precisely measured edge ripple may be irrelevant to the operational threshold, while a modestly estimated blind interval could compromise the central inference. The engineer must identify the consequences of each condition, and the statistician must ensure that the numbers answer those questions. I now invite Dr Shannon to consider the more basic limit: what the output of the bank can and cannot tell us about an original input.

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Claude Elwood Shannon | Principal response 5: Information preserved is not information correctly interpreted

Dr. Atkinson, the temptation at issue is to treat a many-channel digital output as though it contained more independent knowledge than the waveform from which it arose. An analysis bank transforms a finite digital sequence into a set of other sequences. Under a known deterministic transformation, these sequences contain no new information about the input absent additional physical measurements. They may make particular features easier to detect, compress the storage requirements of selected signals, or suppress nuisance components, and those are genuine practical virtues. But a display with sixty-four outputs is not the testimony of sixty-four independent receivers. When adjacent outputs both brighten, that agreement may reflect shared input and overlapping filter response rather than corroboration of an external source.

A practical channeliser is not always information-preserving. It may decimate, quantise, clip, drop outputs, retain only threshold crossings, or replace complex samples with magnitudes. Each operation can change which questions remain answerable. A bank possessing a theoretical perfect-reconstruction synthesis system may still have no recoverable inverse after the investigator has discarded half the channels. If the output is only a list of detected frequencies, we may be able to report that the detector crossed a threshold but not reconstruct the modulation which caused that crossing. The uncertainty is not a computational inconvenience that a later, faster machine will necessarily overcome. It is a consequence of nonunique mapping from possible inputs to retained evidence.

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The distinction between preservation and interpretation also appears in phase. A known analytic bank may preserve complex phase relationships sufficient for certain reconstruction purposes, but those relationships must be tied to a common input-clock reference and a verified channel map. A subsequent magnitude detector throws away phase. A sophisticated fusion algorithm can estimate some features statistically, but the resulting estimate depends on an input model. If multiple distinct waveforms would have produced the same retained magnitudes, the claimed inverse is conditional, not uniquely measured. A forensic report should identify that condition, especially when source localisation or waveform attribution depends on relative phase or precise event onset.

An oversampled analysis bank introduces redundancy. In a valid design it may allow stronger boundary coverage, overlapping passbands and more robust reconstruction under certain forms of noise or missing data. That is a useful result, but it must not be mistaken for generating additional independent physical samples. The output streams share the same original information source. Their noise and errors may be highly correlated; indeed, an artefact coherent in the input can appear coherently in several channels. Combining them requires a specified noise model and calibrated response. The supposed benefit of a fusion rule should be measured against performance of the full input, the single-channel alternatives and the cost of additional false alarms.

Suppose the investigator asks whether a faint intermittent transmitter occupied a certain frequency interval. A proper answer requires an observation model: how the transmitter's possible waveforms are represented by the channeliser, what background and interference are

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admitted, and what event statistic the detector uses. A calibrated amplitude response gives part of that model. It does not by itself give the probability of detection because the distribution of detector noise, pulse timing and thresholds matters. A laboratory that measures a clean frequency sweep and then writes *all signals detectable above minus ninety decibels* has silently confused deterministic transfer gain with a probabilistic detection capability. The two may be related, but the relationship must be demonstrated or justified.

Nor does a detected feature's probability under an ideal noise-only hypothesis prove its source. A fixed clock spur or a filtered interference product may be extremely unlikely under the chosen Gaussian noise model and yet wholly internal to the receiver. The appropriate scientific method is to compare causal hypotheses using controlled interventions. If moving a test signal's absolute input frequency predicts one transformation of the channel outputs while changing only the bank's channel map predicts another, those experiments can test whether the feature follows the input or the processing grid. Retuning is especially valuable when the predictions differ, although the receiver's state changes and frequency reference must be preserved. A test in which every model makes the same prediction adds little causal information.

For the narrow issue of channel-edge validation, I would therefore formulate acceptance as a chain of statements. First, the digital implementation of the chosen bank agrees with its declared mathematical model within an established numerical tolerance. Second, its measured frequency and transient response is known over an explicitly retained operating envelope. Third, its detector and retention system achieves

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defined sensitivity and false-alarm performance for the target classes tested, including weak bursts at the edges while stronger nearby signals are present. Fourth, the evidence permits only those attributions or timing estimates that survive alternative-source challenges and the documented uncertainty. These statements need not all succeed for the receiver to be useful; they merely should not be collapsed into one boast.

The ultimate limit of the technique is not the finite number of filters, but the distinction between data and claims. If the raw wideband input is preserved with an authenticated processing history, future examiners may test different filters without pretending that the new output was observed at the original survey time. If only derived channels remain, the examiner must assess whether they suffice for the desired reconstruction or discovery. If only a detector alarm remains, the available finding may be narrower still. The integrity of the bytes, though important, cannot certify the physical model that interpreted them. This is why the acceptance record must travel with the waveform rather than remain locked in the operator's recollection. I invite Dr Hamming to challenge the balance between formal information preservation and the practical necessities of limited receiver capacity.

Richard Wesley Hamming | Peer question 7 to Claude Elwood Shannon

Dr Shannon, the investigator would like to preserve every wideband sample, every channel output, every calibration sweep and every program revision, yet a high-rate monitoring installation may produce more information in one day than a modest forensic laboratory can store or reprocess responsibly. The engineering task is to determine which representations preserve the quantities of genuine consequence, not to

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demand unlimited memory. Suppose the receiver retains low-rate complex channels and a small buffer of original samples only when a detector triggers. It can reconstruct many ordinary events, but some edge cases remain ambiguous. Would you call that design defective, or merely qualified? More importantly, what should its operator claim when a negative survey finds nothing, given that rare pulses might have fallen within the bank's weakest transition regions or during discarded input intervals? I would welcome a hierarchy of conclusions that recognises the difference between a useful screening system and an apparatus whose records could sustain a contested source-identification claim years later.

Claude Elwood Shannon | Immediate answer to Richard Wesley Hamming

Dr Hamming, finite capacity is not itself a defect. It is a constraint which should be made part of the observation model. An efficient design may preserve selected outputs that are sufficient for its declared screening objective, even though they are insufficient for every conceivable later question. The difficulty arises when that restricted record is used to assert a stronger fact than it supports. A channeliser designed to flag candidates need not provide lossless reconstruction of every signal which passed through the antenna. It must, however, be judged according to its actual probability of flagging the declared target classes under admitted operating conditions, and its negative findings must be limited accordingly.

The data-retention policy should distinguish discovery, verification and attribution. For discovery, a time-stamped indication with its channel map, filter version, threshold and operational state may be

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adequate to identify a candidate requiring further examination. For verification of a contested spectral feature, preservation of complex samples across a known interval, calibration and alternate channelisation may be necessary. Attribution may demand independent RF evidence, physical localisation or a controlled change in the source environment, none of which follows automatically from a stored spectrum. The laboratory should identify these tiers before deployment, not only after a disputed result reveals the missing data.

A negative survey is especially sensitive to the unobserved portions of the record. It does not establish that no possible emission existed. At best it states that the deployed system did not register a target meeting a defined signal class and level within the valid observation time and the calibrated frequency envelope, with the associated estimated detection probability. Channel-edge attenuation, acquisition dead time, adaptive state transitions, buffer loss and selected-event retention all reduce the scope of the claim. If a frequency interval was excluded because the filter bank's response fell below the accepted minimum, it must be listed as a limitation rather than silently marked clear.

Where raw retention is expensive, I would recommend preserving a controlled sampling of negative intervals for validation, along with the complete configuration and selection policy. Such records allow estimates of false alarm, missed event and algorithmic drift, although they cannot resurrect every unobserved burst. The examiner can demonstrate that a choice was rational for a declared purpose without pretending that the resulting archive contains more

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information than was kept. An honest qualification does not discredit the instrument. It permits the user of its evidence to understand precisely what a negative, uncertain or positive finding means. I return the token to Dr. Atkinson for the practical calculations and the concluding doctrine.

Worked technical applications | Ten independently checkable cases

George Ashley Campbell, Cross-Peer Question to Harry Nyquist: Dr Nyquist, a 64-way complex polyphase channeliser gives 200 kHz nominal centre spacing. Is each channel therefore guaranteed to admit a distinct 200 kHz signal without neighbour contamination?

Harry Nyquist, Cross-Peer Answer to George Ashley Campbell: Dr Campbell, the quotient of complex input rate by channel count defines nominal centre spacing, not necessarily an independently usable passband of that width. Prototype-filter transition regions, polyphase decimation, sidelobe rejection and channel overlap determine actual response. At critical sampling, a component near a nominal boundary may be represented in adjacent outputs or aliased under an imperfect analysis filter bank. Test a calibrated swept tone and short burst across each boundary with the same settings used for surveillance, measuring both amplitude and group delay. Repeat in the presence of a strong adjacent transmitter so nominal small-signal rejection is not mistaken for system linearity. Verify reconstruction conditions if the architecture promises perfect synthesis, and avoid adding channel powers without accounting for their cross-correlation. I pass the token to Dr Slepian on finite events.

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Harry Nyquist, Cross-Peer Question to David Slepian: Dr Slepian, what happens to a brief burst whose spectrum is concentrated near a channel edge when the prototype filter has a lengthy impulse response?

David Slepian, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the response may be distributed in time across filter memory and in frequency across several outputs. The finite-duration burst is not a stationary continuous sine, and a nominal flat passband measurement at one coherent tone can conceal temporal distortion. Characterise response to impulse-like stimuli, frequency-stepped bursts and chirps with independent timestamps. Measure detection delay, peak-amplitude bias, ringing and probability of splitting one physical event into multiple apparent channel events. A finite record cannot simultaneously claim arbitrary temporal and spectral concentration, so the decision rule must declare its trade-off. Preserve a margin of pre-trigger and post-trigger samples that covers filter memory, not merely the samples above a detected threshold. Cross-channel association should rely on measured relative delay and phase rather than matching screen positions. I respectfully yield to Professor Tukey for multiple comparisons.

David Slepian, Cross-Peer Question to John Wilder Tukey: Professor Tukey, an operator searches 64 channel outputs for the brightest instantaneous peak and reports the nominal per-channel false-alarm rate. What has the selection process omitted?

John Wilder Tukey, Cross-Peer Answer to David Slepian: Dr Slepian, it has ignored the family of opportunities searched and any dependence among their outputs. A per-output false-alarm probability cannot be read as the probability that at least one of 64 correlated channels will cross threshold in

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a particular scan. Estimate the joint distribution from representative noise-only records preserving overlap, common filter response and common front-end events, or use a conservative bound when joint calibration is unavailable. Predeclare search duration, frequency windows and peak-selection rule. A moving maximum across many frames creates still more opportunities, often correlated in time. The proper evidence record includes rejected candidates and unselected neighbouring outputs, so a reviewer can distinguish a true event from the predictable highest member of a noisy family. I yield to Dr Shannon on retained information.

John Wilder Tukey, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, may a team discard every adjacent channel record after stitching a visually continuous display, and still claim it can reconstruct any emitter that crossed a filter-bank boundary?

Claude Elwood Shannon, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, only where a proved reconstruction architecture, coefficient set and retained data are sufficient for the specified class of signals. A combined display is commonly a lossy representation of complex channel samples: it may omit phase, calibration state, filter transients, overlapped frequency content or clipping indicators. An analyst should retain parent raw I/Q for consequential events, or at least coherent neighbouring complex streams and the exact synthesis parameters where that level is demonstrated adequate. Run a blinded boundary-crossing injection and try to recover amplitude, event time and phase from the proposed archive alone. If the attempt fails, do not call the archive a complete historical record of that event. A clean image is not the same as recoverable evidence. I respectfully return the token to Dr Atkinson.

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Dr. James M. Atkinson | Moderator concluding synthesis

Colleagues, the ten calculations and the preceding discussion establish that a channel boundary is a region whose performance must be proved, rather than a label whose appearance upon a screen guarantees it has been searched. Mr Campbell has required us to treat the filter's transition and phase responses as measurable physical or digital behaviours, with declared reference planes and an honest separation between the software bank and the complete RF receiving chain. Mr Nyquist has reminded us that critical decimation and selective retention can remove distinctions needed for a later inverse inference. Dr Slepian has demonstrated the importance of event duration, envelope shape and fractional position in the frequency grid. Professor Tukey has insisted that detection statistics, selection, false-alarm multiplicity and confidence bounds should refer to an actual trial population. Dr Shannon has finally distinguished useful transformed evidence from the independent information required for reconstruction and attribution.

A validation campaign must therefore be constructed around the *claims*, not around the convenience of a manufacturer demonstration. Where the intended claim concerns continuous narrowband signals, a dense, calibrated frequency sweep over the retained band may be central; where it concerns intermittent surveillance emissions, that sweep is only one experiment among many. Short bursts must arrive at randomised phases relative to the analysis and decimation blocks. Close signal pairs must be placed on both sides of the boundary. A weak candidate should be challenged in the presence of a strong nearby legitimate transmission. The receiver should be tested before and after controlled changes to the

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channeliser grid, gain and filter configuration, with settling periods and excluded intervals recorded. The analyst should determine whether the same input can give duplicate indications in adjacent outputs, and whether the deduplication rule can suppress a genuine second source.

The measurement record must preserve the prototype taps, their hash or version, the output channel mapping, input sample rate, output-rate ratio, decimation phase, arithmetic scaling, treatment of the first and last samples, trigger thresholds, complex phase convention, and the relevant calibration state. Where time-of-arrival claims are made, channel group delay and any variable filtering latency must be carried into the timestamp and uncertainty assessment. Where only a detected power or binary flag is preserved, the report should say which information has been discarded. Authentication of a digital record establishes continuity of its recorded bytes; it does not prove that the filter transfer function or noise model was true of the analogue event. An additional physical challenge is necessary for that stronger claim.

The panel also rejects an attractive but misleading form of corroboration. One emission passing through overlapping channel filters is one physical observation transformed in several ways. The corresponding outputs may corroborate a prediction about the filter bank, but they do not constitute independent receivers and cannot simply be multiplied into a stronger probability of an external source. A receiver substitution, deliberate frequency-grid retune, independently characterised RF path or controlled stimulus may supply additional discriminating evidence, provided competing hypotheses make genuinely different predictions and the changed state is documented. A peak that migrates between channel labels

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while remaining consistent in absolute frequency is more informative than an unchanged peak after a procedure that cannot distinguish the alternatives.

I ask that the final acceptance report include a frequency-by-frequency or appropriately validated model-based minimum response, a leakage limit under stated adjacent-signal levels, a distribution of transient detection latency, a joint false-alarm account, explicit invalid or omitted intervals, and a declaration of which output representations are retained. The laboratory should record adverse results and any later narrowing of the claimed envelope. A favourable average does not excuse a narrow but operationally consequential blind region. Neither does a strong reconstructed waveform erase the possibility that missing input samples, clipping or an adaptive threshold deprived the analysis of an alternative interpretation. Where uncertainty is material, its covariance and its dependence upon the reference-plane model must be included.

A properly qualified result may be decisive in a limited respect. It can establish that a specified class of event, above a declared minimum input level and within stated interference, pulse-duration and calibration conditions, would be registered with a measured performance and confidence bound even at the weakest validated channel edge. It cannot establish that no conceivable weaker, shorter or differently modulated emission existed. Nor may it identify a person, device or physical origin without evidence beyond the mathematical output of the analysis bank. The discipline is not timidity. It is what makes the finding durable when the raw samples, source code and testimony are examined years later by a sceptical engineer or court.

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Our next question concerns decimation itself, beyond the specific behaviour of channel boundaries: when does the operation remove information that a later forensic question requires? That enquiry will connect acquisition policy, retained complex samples, statistical sufficiency and the limits of retrospective signal reconstruction. I thank Mr Campbell, Mr Nyquist, Dr Slepian, Professor Tukey and Dr Shannon for their careful contributions, and I respectfully return the token to the authorial programme for Question 036.

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Ten worked engineering applications | Question 035

Worked application 1 | Nominal spacing is not a guaranteed usable passband

Consider an idealised complex-input channeliser with sample rate F_s = 12,800,000 complex samples per second and M = 64 equally spaced outputs. The nominal centre spacing is $\Delta f = F_s/M$ = 12,800,000/64 = 200,000 Hz, or 200 kHz. Under critical decimation the nominal output rate per channel is also F_s/M = 200,000 complex samples per second. The result describes a coordinate and throughput relationship, not a flat 200 kHz response. If the validated retained portion is only 80 per cent of the spacing, its width is 0.80 x 200,000 = 160,000 Hz per channel. The remaining 40 kHz of each nominal slot cannot be described as searched by that one output at the same performance. Overlap, retuning or another validated path is necessary before claiming coverage there. Variables and arithmetic are hypothetical; actual retained widths must come from the measured prototype response and threshold rule.

Worked application 2 | Two equal edge indications do not restore amplitude automatically

At one boundary assume a hypothetical calibrated isolated-channel power gain of -6.00 dB for each of two adjacent outputs relative to its own unity centre response. Each channel receives a power factor $g = 10^{(-6/10)}$ = 0.2511886 of the reference input tone power under the linear steady-state model. The arithmetic sum of the two reported powers is 2g = 0.5023773, equivalent to 10 log10(0.5023773) = -2.9897 dB relative to the input-power reference. Thus adding the two powers does

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not automatically produce 0 dB. Nor may the same signal be counted as two independent detections. If the actual bank has a reconstruction relation, complex weighting may recover the intended quantity, but its phases, normalisation, noise covariance and numerical precision must be tested. This calculation is not a reconstruction theorem and does not justify applying an uncalibrated universal +2.99 dB correction.

Worked application 3 | An adjacent strong emitter defeats a superficially impressive rejection ratio

Let a legitimate interferer enter the declared reference plane at P_i = -20 dBm, while the unknown target class includes power P_t = -95 dBm. Suppose the relevant measured small-signal leakage suppression into the tested output is A = 60 dB. The leaked component would then be estimated as $P_{leak} = P_i - A$ = -20 - 60 = -80 dBm. Its level relative to the target is -80 - (-95) = +15 dB. Hence sixty decibels of rejection does not make that interferer negligible for this target. Suppression greater than 75 dB would be required merely to place the nominal residue below -95 dBm, without any additional margin for detector noise or uncertainty. These equations assume linear operation and consistent logarithmic power references; a saturated front end invalidates the simple subtraction model and demands a separate challenge.

Worked application 4 | Filter group delay changes chronology without necessarily losing the pulse

Take a symmetric, linear-phase FIR prototype of length L = 321 taps at input sampling rate F_s = 12.8 MHz. Its nominal group delay, in input-sample units, is (L-1)/2 = 160 samples. In seconds this is tau =

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160/12,800,000 = 0.0000125 s = 12.5 microseconds. A test pulse whose measured analogue start is at t = 1.000000 ms may therefore have its ideally filtered response referred to approximately 1.012500 ms under the specified reference convention. Subtracting 12.5 microseconds from a downstream timestamp can correct that fixed delay under the assumed model. It cannot prove that the pulse's earliest samples survived thresholding or that a nonlinear-phase implementation has a uniform delay for every spectral component. The test must distinguish correcting a time origin from recovering an unrecorded waveform onset.

Worked application 5 | Oversampling changes sample volume but not the number of original physical samples

Using the same F_s = 12.8 million complex samples/s and M = 64, suppose an oversampled bank uses R = 4/3. Its nominal per-channel output rate becomes $F_{out} = R(F_s/M) = (4/3)(200{,}000) = 266{,}666.667$ complex samples/s. Across all sixty-four outputs, the nominal total output-sample rate is 17,066,666.667 complex samples/s before any channel selection or overhead. This exceeds the original 12.8 million input-sample rate because the representation is redundant, not because the antenna supplied additional independent measurements. Under the applicable GNU Radio channeliser documentation, the permitted oversampling ratio must accord with that implementation's channel-count constraint; R = 64/48 = 4/3 has the required form for M = 64. A different programme may impose different limits. The choice must be validated against actual throughput, overlap response and timing.

Worked application 6 | A brief carrier has appreciable spectral width

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Assume a complex sinusoid multiplied by an ideal rectangular gate of duration T = 40 microseconds. Its continuous-time transform contains a sinc-shaped factor whose first envelope zeros are displaced by approximately 1/T from the carrier. Here 1/T = 1/(40 x 10^-6) = 25,000 Hz, so the main-lobe zero-to-zero width is approximately 50 kHz. This illustrative width is one quarter of the 200 kHz nominal channel spacing in Application 1. An input with centre frequency exactly at a nominal channel boundary therefore produces meaningful energy on both sides even in this elementary envelope model. Real pulse edges, modulation, detector windows and analogue filters alter the result; a rectangular gate is a teaching model, not a universal emission class. A validation campaign should vary T and the pulse shape rather than infer the behaviour of all bursts from one 40-microsecond case.

Worked application 7 | Many channel tests change the probability of an apparently rare alarm

Suppose each of N = 64 defined channel tests has an individual false-alarm probability p = 0.0001 for one trial under a specified null model. If, strictly as a hypothetical simplification, those test outcomes were independent, the probability of at least one false alarm would be P_any = 1-(1-p)^N = 1-(0.9999)^64 = 0.00637988, or about 0.638 per cent. A Bonferroni union upper bound gives P_any <= Np = 0.0064, or 0.640 per cent, without the independence assumption. An actual polyphase bank usually has correlated adjacent outputs, so neither the independence result nor a nominal per-channel p can simply be transplanted into a system-wide assertion without measuring or modelling the joint null

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distribution. The calculation illustrates multiplicity, not a certified false-alarm rate for any receiver.

Worked application 8 | High observed detection frequency can leave a modest lower confidence bound

In one hypothetical preregistered boundary condition, suppose $n = 100$ valid independent challenge trials were made and $k = 99$ were detected under an unchanged rule. The observed fraction is $p_hat = k/n = 0.99$. Using the conventional Wilson score lower bound for a two-sided 95 per cent interval with $z = 1.96$, the centre is $[p_hat + z^2/(2n)]/[1+z^2/n]$, and the half-width is $z \sqrt{[p_hat(1-p_hat)/n + z^2/(4n^2)]}/[1+z^2/n]$. Substitution gives a lower endpoint about 0.9455, not 0.99. This is a single-condition illustrative interval assuming Bernoulli trials with a common probability and appropriate independence. It is not a simultaneous guarantee over many channel edges, durations and interference levels; a full acceptance claim must account for selection and multiple conditions. One observed failure is not permission to exclude that trial from the denominator.

Worked application 9 | Storing all complex output channels is not a free consequence of splitting the spectrum

Suppose the raw complex-input stream of Application 1 is represented by signed 16-bit I and 16-bit Q integers, so each complex sample occupies 4 bytes before metadata or packet overhead. At $F_s = 12.8$ million complex samples/s, the nominal input volume is $12.8 \times 10^6 \times 4 = 51.2$ million bytes/s. One hour occupies $51.2 \times 3600 = 184{,}320$ million bytes, or 184.32 GB in decimal units. A critically sampled, complete 64-

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output bank retains the same nominal aggregate complex-sample count and byte rate if sample representations are unchanged; oversampling by R = 4/3 would increase the nominal output to 68.2667 million bytes/s, or 245.76 GB per hour. These are uncompressed theoretical payload values. Real metadata, burst retention, coding and compression change storage, but no storage saving should be assumed without identifying which data are omitted or transformed.

Worked application 10 | The edge-correction uncertainty can be correlated

Suppose the total logarithmic correction C in decibels is the sum C = C_reference + C_channel, where the reference-plane calibration has standard uncertainty u_1 = 0.4 dB and the channel edge-response correction has u_2 = 0.3 dB. If the estimates are independent and the linearised logarithmic uncertainty model is applicable, u_C = sqrt(u_1^2+u_2^2) = sqrt(0.16+0.09) = 0.500 dB. If the correlation coefficient between these corrections is rho = +0.6, propagation of covariance instead gives u_C = sqrt(u_1^2+u_2^2+2 rho u_1 u_2) = sqrt(0.16+0.09+0.144) = sqrt(0.394) = 0.6277 dB. Ignoring their shared reference would understate uncertainty in this hypothetical case. The calculation follows the sensitivity-and-covariance principle described in NIST Technical Note 1297; it does not replace a full uncertainty budget for a nonlinear or saturated receiver. [S6]

Source register and verified read scope

[S1] GNU Radio, “Polyphase Channelizer,” project wiki, https://wiki.gnuradio.org/index.php/Polyphase_Channelizer . Public HTML page consulted for channel-number parameter, decimation, oversampling ratio,

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sample delay, channel map, and the demonstration that one input stream is partitioned into equal-bandwidth output streams. The operational examples in this question are constructed independently and are not GNU Radio certification results.

[S2] Meng Zhang, Hai-long Zhang, Ya-zhou Zhang, Jie Wang, Shao-cong Guo and Qiao Meng, “Research on Channelization Techniques of Radio Astronomical Wideband Signal with Oversampled Polyphase Filter Banks,” *Research in Astronomy and Astrophysics*, volume 23, issue 8, 2023, https://www.raa-journal.org/issues/all/2023/v23n8/202307/t20230714_170745.html . Journal public abstract inspected for discussion of edge attenuation, spectral leakage, critical versus oversampled banks and comparison of their responses. Full article results, figures and raw data were not treated as independently reviewed.

[S3] National Inventors Hall of Fame, “George Ashley Campbell,” https://www.invent.org/inductees/george-ashley-campbell . Public biography consulted for dates, wave-filter and loading-coil research, education, professional role and recorded honours. It is a historical source, not a source supporting the hypothetical SDR performance numbers.

[S4] GNU Radio, “gr::filter::pfb_channelizer_ccf Class Reference,” https://www.gnuradio.org/doc/doxygen/classgr_1_1filter_1_1pfb__channelizer__ccf.html . Public API documentation inspected for the equal-bandwidth decimation model, prototype-filter tap distribution, defined oversample ratio and bibliographic pointers to multirate-filter-bank literature. The cited book by fredric j. harris was not read in full and is not represented as directly reviewed.

[S5] SciPy, “scipy.signal.upfirdn,” https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.upfirdn.html . Public technical documentation consulted for finite-impulse-response filtering in polyphase up/down conversion and implementation remarks. This material describes a rate-conversion primitive, not an end-to-end SDR channeliser acceptance test. The sinc-like gated-carrier result is a direct mathematical derivation from the stipulated rectangular envelope.

[S6] National Institute of Standards and Technology, “NIST Technical Note 1297, Appendix A: Law of Propagation of Uncertainty,” https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty . Public

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appendix examined for measurement-model sensitivity coefficients, standard uncertainty components and covariance. Application 10 is independently constructed to illustrate the principle; NIST is not claimed to have measured the hypothetical receiver.

[S7] Engineering and Technology History Wiki, “David Slepian,” https://ethw.org/David_Slepian . Public historical biography consulted for birth and death dates, education, wartime service and Bell Laboratories career. Source does not purport to document fictional panel speech or modern SDR tests.

[S8] University of St Andrews, MacTutor History of Mathematics, “John Tukey,” https://mathshistory.st-andrews.ac.uk/Biographies/Tukey/ . Public historical biography consulted for dates and broad contributions to statistics and computation.

[S9] IEEE Computer Society, “Computer Pioneers: John Wilder Tukey,” https://history.computer.org/pioneers/tukey.html . Public historical profile examined for institutional roles, education and association with fast Fourier transformation. Contemporary receiver interpretations are newly authored applications.

[S10] GNU Radio, “Hierarchical Polyphase Channelizer,” https://wiki.gnuradio.org/index.php/Hierarchical_Polyphase_Channelizer . Public implementation documentation inspected for output channel selection, prototype taps, retained fraction of each channel, passband ripple and transition-band parameters. Its published warning about version-specific implementation problems is a reason to preserve software version identity, not evidence of defects in an unidentified receiver.

[S11] National Institute of Standards and Technology, “NIST TN 1297: Combined Standard Uncertainty,” https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-5-combined-standard-uncertainty . Public page consulted for the combined standard uncertainty principle and the expectation that recognised systematic effects be corrected. No numerical values from the fictional experiments are attributed to NIST.

Production status and evidence boundaries

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Question 035 is a standalone substantive discussion, not a transcript. Its claimed performance calculations are constructed numerical cases. Source links and read scopes above establish research provenance for specific background principles; they do not certify any actual field receiver. Final cumulative integration with Questions 001–034 requires a verified editable predecessor manuscript, including reconciliation of earlier missing checkpoints. The protected Phase I core prose has not been modified by producing this roundtable question.

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QUESTION 036

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When does decimation remove information that a later forensic question requires?

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Constructed educational dialogue. Every intervention attributed to a historical contributor is newly authored for this volume and is not a historical quotation or an assertion that the contributor personally examined modern SDR instrumentation. The numerical cases are hypothetical, not certifications of particular instruments.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, I invite examination of a deceptively simple act of digital housekeeping. When a wideband receiver produces more samples than an analyst wishes to retain, a downsampling operation promises smaller files, fewer computational demands and a spectral representation better adapted to a narrow subject of immediate interest. A laboratory monitor may show the decimated trace marching smoothly across its screen, while the storage device grows at a more comfortable pace. Yet the very success of that operation may remove measurements which a later investigator requires for a different question. We must decide whether an operation is an admissible compression of an already defined measurand, a qualified transformation of evidence, or an irreversible abandonment of a field of possible observations.

Let the input sample rate be F_in in samples per second, the integer decimation factor be D, and the output rate be F_out = F_in/D. A correct conventional decimator filters before retaining every Dth output sample; its

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anti-alias filter should suppress the components which would otherwise fold into the narrower frequency region represented at F_out. If the input consists of complex baseband samples, the nominal unaliased output interval is approximately minus F_out/2 to plus F_out/2 about the assigned centre, subject to the actual filter passband and transition region. If the samples are real, their one-sided interpretation requires the appropriate conjugate-symmetry and Nyquist conventions. The formula for the rate is elementary. The decision about which observations shall remain possible is not.

Three records deserve separate names. The *raw acquisition* is the sequence preserved at a documented receiver output, with its sample rate, format, reference plane, gain state and continuity record. The *derived decimated sequence* is the product of a specified filter, decimation phase, boundary convention and software implementation. The *claim* is the proposition that a later examiner wishes to test: that an emission existed within a particular frequency interval, that it lasted for a specified time, that its phase was coherent with another event, or that an observed line originated beyond the receiver. A transformation can be entirely reproducible while being inadequate to answer one of these later questions. Reproducibility of the output is not invertibility of the map from input to output.

The distinction is particularly acute when surveillance searches are broad and exploratory. An initial operator may retain only one 100-kilohertz channel from a ten-megahertz observation because that channel contained a candidate burst. Months afterwards, counsel or an independent expert may ask whether the original event was an intermodulation product of a

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stronger transmitter outside that retained channel, whether a second carrier appeared simultaneously in a neighbouring interval, or whether an adaptive threshold discarded the very samples needed to estimate non-detection exposure. The prepared file may open without difficulty, its cryptographic digest may match the acquisition report exactly, and its timestamps may be internally consistent. None of these properties supplies measurements intentionally omitted before the file was written.

I ask the panel to keep distinct at least four kinds of loss: unrecorded frequencies removed by protective filtering, ambiguities created by insufficient suppression before decimation, temporal distinctions blurred or rejected by a finite filter and output grid, and missing provenance concerning how the product was created. An anti-alias filter protects the retained passband against unwanted folding. It is not an archive of the rejected stopband. A more ambitious analysis of the original apparatus might require those rejected components precisely to establish that the retained line was not receiver-generated. Conversely, preserving every raw sample indefinitely is not always proportionate or feasible. The proper criterion is whether the recording policy was adequate for the claim authorised and anticipated, and whether its exclusions are legible to any later examiner.

Professor Bridgman will begin with the definition of the physical quantity and the operations by which it is observed. Dr Shannon will examine the many-to-one character of filtering and downsampling, and will distinguish a defensible band-limited inference from an illicit claim of exact historical recovery. Professor Slepian will examine finite records, transients and spectral concentration. Dr Wiener will evaluate adaptive filtering, stochastic

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assumptions and the temptation to confuse model-based reconstruction with observed fact. Professor Tukey will address how selection and discovery practices affect confidence, especially when successful events rather than all exposure intervals are retained. Seven colleagues will question these positions in turn. I ask that each question receive a reply immediately, and that each speaker identify a test whose outcome could have challenged the proposed inference. The discussion should end with an operational preservation rule suitable for both the engineer at a glowing oscilloscope and the forensic examiner arriving much later with a silent archive.

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Percy Williams Bridgman | Principal response 1: The measurand changes when the operation discards dimensions

Dr. Atkinson, the word *signal* is liable to conceal more different objects than the engineer supposes. There is the voltage at an antenna terminal; the waveform at the input of an amplifier; the output of a mixer after a changing local oscillator; the sequence of analogue values presented to a sampling aperture; the resulting code words; and the decimated product of a digital filter. These are not interchangeable representations unless a specified model establishes their relation. We should therefore begin with a statement of the measurand, including frequency, time, amplitude and reference plane, before congratulating ourselves on having reduced its storage burden. The mathematical operator does not know what the prosecution, the defence, or the engineer may later wish the evidence had contained.

Suppose a complex receiver samples a band at 12.8 million samples each second. A factor-of-sixteen decimation produces 800,000 samples per second. The wideband source could originally represent frequencies approaching plus or minus 6.4 megahertz relative to its assigned centre, whereas the derived baseband file, under appropriate filtering, retains a much narrower interval approaching plus or minus 400 kilohertz. The preserved amplitude of a calibrated component at 120 kilohertz may be estimated quite satisfactorily. It does not follow that the transformed file can answer whether a strong adjacent carrier at 1.1 megahertz drove a nonlinear front end, nor whether an out-of-band intermittent transmission preceded the candidate. Those questions are not simply more elaborate

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arithmetic exercises. Their observations were removed by the operation or were never acquired at the necessary reference plane.

There is a tempting counterargument. If the decimation filter is known and the resulting complex numbers are preserved exactly, why may the examiner not invert the filter mathematically? The answer is that a map with a nontrivial null space does not admit an inverse on all possible inputs. Distinct wideband sequences can share the same decimated output because the filter suppresses their differences, or because the output sampling operation retains fewer independent constraints. An inverse model can choose a preferred input from among multiple candidates by imposing bandwidth, smoothness, sparsity or a prior signal dictionary. That choice may be a useful estimate. It is not the recovered observation unless the restrictions have independent empirical justification. The sharp edges of a reconstructed trace on a screen are not proof that an actual historical waveform possessed those edges.

I would distinguish a loss of *information relevant to a question* from a loss of every useful property. The resulting narrowband series may still support precise frequency estimation for a component wholly within the validated passband, subject to the retained observation time and clock performance. It may support an upper bound on power within a stated band if the gain and filter response are characterised. It may support event timing at a specified granularity if the filter's group delay, impulse response, block boundaries and alignment are documented. It cannot, simply by being a sequence of numbers, establish the amplitude or existence of signals discarded outside that band. Nor does its byte-perfect integrity imply that every input sample was included in the acquisition process.

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Consider also how filters alter the meaning of amplitude. If a 200-kilohertz offset lies near the passband centre, the response may be nearly flat. At an edge, a candidate may be attenuated by several decibels, and a pulse may be distorted by a filter impulse response whose duration exceeds that of the original emission. A value printed as a peak voltage after the filter is therefore not necessarily a peak voltage before the filter. Correcting an indicated value demands a known transfer function and a suitable signal model. If several distinct waveforms produce the same output peak, a scalar correction factor cannot restore their individual peak amplitudes. The record must distinguish calibration for steady sine waves from validation for brief bursts, frequency hopping or closely spaced emitters.

From an operational standpoint, I would require the examiner to retain a processing manifest contemporaneous with the derived file: input sample rate and precision, decimation factor, exact coefficient array and coefficient hash, phase or starting sample index, filter initial state and boundary padding, software version, frequency translation convention, timestamps, gap handling, receiver gain, reference frequency and physical input plane. A manifest cannot restore missing observations, but it permits a later reader to know precisely what is missing and to reproduce what remains. A generic description such as 'downsampled for efficiency' is barely a declaration of method. It does not say which signals were rejected, whether they might have influenced the front end before rejection, or whether the timing of a suspected event survived the transformation without qualification.

The tension between efficient acquisition and evidential completeness ought not to be resolved through a rule that all data must be retained forever. A properly scoped examination can preserve a known, sufficient

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subset and report its limits. But the scope must precede the convenient filtering, rather than be invented after an interesting candidate has been found. For a general exploratory technical-surveillance search, a deliberately bounded retention policy might store representative wideband raw intervals around material detections, retain a coarse wideband spectral history and preserve the complete receiver-state and selection logs. Such a system would not provide unlimited recovery, yet it would permit a number of competing explanations to be tested rather than concealed by an attractive narrowband output. I invite Mr Heaviside to test whether this distinction becomes too philosophical when engineering constraints require a usable filter before any sample can be stored.

Oliver Heaviside | Peer question 1 to Percy Williams Bridgman

Professor Bridgman, I accept that a mathematical transform is not the electrical phenomenon itself. Nevertheless the engineering shop cannot begin its work by storing a universe of possibilities. A receiver may be designed for a specified channel in the presence of powerful adjacent transmissions, and its very ability to observe that channel depends upon rejecting energy that would otherwise overwhelm an amplifier or alias into an output. The operator will be instructed to use a protective filter before sampling, quite apart from later digital decimation. Would your doctrine suggest that every such lawful rejection makes the record insufficient? If so, the demand for completeness would defeat the measurement that was actually commissioned. More precisely, how shall we distinguish a missing variable that materially threatens the intended claim from an irrelevant degree of freedom that a valid experiment is entitled to exclude? And how would that distinction survive cross-

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examination when a later advocate asks a question no competent investigator foresaw at the time of collection?

Percy Williams Bridgman | Immediate answer to Oliver Heaviside

Mr Heaviside, you have identified the essential qualification. There is no scientific virtue in attempting to measure every quantity without regard to the question. The adequacy of an instrument is relative to an explicitly intended operation and its accepted uncertainty. Analogue filtering can be necessary to prevent overload or aliasing, and digital decimation can make a particular measurement practical. The fault arises when the claim travels beyond its declared boundary while the record retains only the narrowed representation. An investigator who has measured a stated passband under specified interference conditions may properly report that result. The same investigator cannot subsequently claim to have excluded all external emitters within the original analogue front-end bandwidth if those intervals were not retained or otherwise surveyed.

The standard of materiality is therefore not omniscience but a disciplined relationship between the observation plan and the possible rival explanations. Before the examination, list the signal classes, frequencies, durations, amplitude limits and sources of interference relevant to the task. Identify the transformations that destroy observations important to differentiating those hypotheses. If out-of-band energy could generate intermodulation products within the target channel, the examiner should consider recording a wideband witness, a front-end overload indicator or a second independently filtered measurement. The chosen witness need not be

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a perfect full-rate copy; it must be sufficient to test the particular alternative under an explicitly qualified model. A witness that measures only after the nonlinear stage cannot conclusively exclude a nonlinear cause arising before it.

A later, unforeseen question cannot always be answered. That limitation must be stated without treating the inability as proof either for or against the newly proposed hypothesis. Where the original collection scope was narrow but honest, a subsequent demand for an unrecorded quantity is a newly required experiment, not evidence that the recorded quantity is false. If it becomes possible to repeat the observation under similar conditions, a new experiment may be designed. Where the event was singular, the forensic opinion must preserve the difference between what is supported, what remains plausible and what has become observationally inaccessible. A negative search finding should not be extended to unobserved bands simply because the displayed channel looked quiet.

Your filtering objection also helps establish a useful acceptance test. Put known challenge emissions both inside and just outside the admitted band, include stronger interferers capable of stressing the analogue chain, and document the resulting passband measurement, spurious outputs and state transitions. When the challenge demonstrates that a component outside the retained band has no material effect upon the specified result under the tested envelope, its exclusion can be justified for that claim. Where its effect remains uncertain, the claim should narrow or the apparatus should acquire more evidence. This is not a limitless invitation to doubt; it is the

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ordinary discipline by which a measured quantity acquires a defensible meaning. I shall pass the floor respectfully to Dr Shannon, whose information-theoretic account can show why a successful output may nevertheless be one of many possible inputs.

Harold Stephen Black | Peer question 2 to Percy Williams Bridgman

Professor Bridgman, your account seems persuasive when the examiner defines the possible rival explanations before operating the receiver. My difficulty is the adaptive apparatus whose channel choice and retention rules respond continuously to observed activity. The system may raise the gain in one subband, suppress another, change its decimation rate and save only the intervals it classifies as anomalous. Its decisions are physically consequential and may even alter the internal artefacts to be distinguished from external emissions. If the later analyst receives only selected narrowband files, each bearing an immaculate hash and a standard timestamp, what would count as a sufficient account of the unrecorded decision history? Is a log of configuration changes enough, or must the examiner preserve the detector scores and thresholds that caused each change? And may an operator claim that an unselected interval was quiet when the classifier itself relied on a moving noise-floor estimate, partially calculated from the very observations it later discarded?

Percy Williams Bridgman | Immediate answer to Harold Stephen Black

Mr Black, an adaptive recording must treat the act of selection as part of the measurement procedure. A list of final files is not a complete description of the observation system, because the system's

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output depends upon the rule deciding which observations become files. At a minimum, the record ought to preserve the detector algorithm and version, threshold history, decision windows, gain and bandwidth changes, state of the noise estimator, any excluded or invalid intervals, and an exposure account stating when each frequency region was admitted. For a threshold derived from the recent data, one must distinguish the data used to estimate the threshold from the data subsequently tested. Otherwise the reported detection probability may be calculated under assumptions the actual closed-loop process violated.

Saving every intermediate statistic may be impracticable, but enough must remain to reconstruct the decisions material to the declared claim. A compressed state log, hashed configuration snapshots and event-by-event score summaries may suffice when their equivalence to the live decisions has been validated. For high-consequence findings, raw snapshots from selected *non-events* deserve consideration, because an archive consisting exclusively of alarms cannot estimate the frequency or circumstances of missed alarms. This is particularly important when the instrument progressively learns what it regards as normal. The physical question is not merely whether a file has been modified; it is whether the acquisition strategy could have failed to retain the very observations necessary to challenge its conclusions.

There is a decisive difference between 'not detected by this receiver under this schedule' and 'not emitted at the location'. The former may be true and useful even for an adaptive instrument, provided its

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schedule, sensitivity and selection mechanism are described. The latter requires a far more demanding causal and spatial inference. If the operator did not retain the threshold trajectory, the later examiner may be unable to recreate the selection event and must acknowledge the deficit. An intact checksum cannot reconstruct a vanished threshold value, any more than a clean measuring rule can supply a length that was never taken.

In my judgement the acquisition plan should define which state variables are mandatory for retention before the survey begins. The instrumentation should then make missing state records visible as validity qualifications rather than silently substituting nominal defaults. When a controller changes decimation rates, the log should include the exact transition sample, filter reset or continuity behaviour and any interval during which the output is not a stable measurement. In the absence of that account, a recorded burst may still be an observed output event, but its amplitude, duration or absence from neighbouring intervals may remain untestable. The more elaborate the apparatus becomes, the more important it is that its operational definitions remain simple enough for another competent investigator to contest. I now invite Dr Shannon to address the irreversibility of information discarded before such a contest can occur.

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Claude Elwood Shannon | Principal response 2: A many-to-one transformation cannot be made an historical inverse by eloquence

Dr. Atkinson, the matter can be expressed without mystical appeals to lost information. An observed discrete sequence x[n] is transformed into y[m] by filtering and retaining selected values. For a linear time-invariant filter with impulse response h[n], an idealised decimator produces y[m] = sum over all k of h[k] x[mD-k]. If the observed record consists only of y, and the admissible inputs include every possible x at the original rate, the mapping generally has infinitely many preimages. It is many-to-one. No archive of the code implementing the map, however complete, converts that map into a one-to-one correspondence. The code can reproduce y when given x. It cannot manufacture an unknown x from y without assumptions restricting the allowable signals. [S1, S2]

There are nevertheless circumstances in which the information needed for an *identified* purpose is preserved. A correctly band-limited signal occupying the narrower admitted region can, under ideal sampling and adequate knowledge of the sampling coordinates, be represented at an appropriately reduced rate without sacrificing the information required to specify the waveform within that region. But that is a conditional theorem about a specified signal class, not a statement about every possible wideband observation. If two distinct real-world signals produce the same narrowband result because one differs from the other solely in a suppressed frequency region, a later analyst cannot tell those histories apart using the decimated file alone. The anti-alias filter has performed its prescribed task by making the narrower output interpretable, while simultaneously preventing it from being a record of what the filter rejected.

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The engineer may object that an extremely steep filter is practically an instrument for identifying the desired band, and therefore its stopband deserves no further attention. I would ask which downstream proposition is to be made. If it concerns the narrowband waveform's frequency or integrated energy under valid calibration, the exclusion may be entirely appropriate. If it concerns the physical cause of the waveform, information about stronger rejected inputs could be essential. An intermodulation product generated ahead of the digital filter survives within the passband even though the external signals which gave rise to it do not. The output has preserved the effect but not the witnesses needed to distinguish causes. The inverse problem is not repaired by taking an additional million samples of the effect if every such sample contains the same causal ambiguity.

A separate mistake arises when the anti-alias filter is inadequate. If the new complex output rate is 800,000 samples per second, inputs at frequencies separated by integral multiples of 800,000 hertz have the same discrete complex exponential sequence *after bare downsampling*. A 300,000-hertz input and a 1,100,000-hertz input can therefore become identical in the retained samples unless their relative amplitudes were altered or rejected before the sampling reduction. A properly designed filter may attenuate the 1.1-megahertz component sufficiently to avoid material contamination. The record should establish that attenuation in the relevant operating state, rather than assume that a nominal filter name guarantees it. Where the attenuation is insufficient, the resulting line may be genuine output data yet have ambiguous input frequency. It is not scientifically permissible to choose the lower of the aliased possibilities merely because the output file's new rate suggests that interpretation.

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Temporal claims present related limits. Decimation with a finite impulse response is not the same as keeping every Dth raw sample without filtering. The filter integrates information over its impulse-response support. A very brief burst can contribute to several derived output samples, and an abrupt boundary can excite ringing that outlasts the original event. If the filter's phase response is known and its passband retains the relevant signal content, a time reference may be corrected with a documented group delay. Yet that correction cannot restore arbitrarily high-frequency structure deliberately rejected, nor can it know the initial filter state where processing began halfway through an event. A reconstructed trace may show a smooth, attractive envelope that was never independently observed at the analogue plane.

We must also be careful with information-theoretic vocabulary. I would not call the storage saving a numerical loss of 'bits of evidence' without specifying a probability model, an input ensemble, a noise law and an estimand. Entropy of a selected stream, mutual information about a particular parameter, and the number of raw bits written to disk are different quantities. A sequence of thirty-two-bit floating-point output values may occupy more bytes per sample than a twelve-bit ADC code and still contain less information about the original wideband input. Conversely, a smaller representation may be sufficient for the chosen task. The claim that an archive possesses a specified number of independent physical information bits requires substantially more than counting its binary storage positions.

Prudent engineering therefore establishes separate retention classes. The narrowband record can be the primary analysis product; a coarse

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wideband monitor may be retained to test interference alternatives; and short raw bursts with pre-trigger context may be preserved for events whose interpretation is likely to be contested. Each representation should carry its own source digest, transformation manifest and limits. An unrecorded frequency is not thereby shown silent. A rejected transient is not thereby shown absent. What survives can be analysed rigorously, but only if we resist the temptation to pretend that a filter has preserved the hypotheses it was designed to suppress. I ask Professor Kolmogorov to examine whether probabilistic reconstruction can sometimes justify a stronger inference than this severe account of many-to-one mapping suggests.

Andrey Nikolaevich Kolmogorov | Peer question 3 to Claude Elwood Shannon

Dr Shannon, your description of many-to-one mapping is exact for unrestricted inputs, but a forensic investigator rarely regards every mathematical waveform as physically plausible. The observed electromagnetic environment may have well-characterised spectral occupancy, transmitter modulation classes, receiver nonlinearities and noise distributions. If decades of calibration and independent field tests support a model in which the suppressed components are strongly correlated with the retained components, might a posterior estimate recover more than your deterministic description concedes? I am not proposing that a probability distribution resurrect a sample which was never written. I ask whether a carefully validated conditional distribution can give a defensible likelihood for competing wideband histories, and how that inference should be reported without the audience mistaking a

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model-based estimate for an observation. Would you set a criterion of posterior concentration, robustness to plausible priors, or an independent challenge measurement before accepting the claim? I ask also whether such criteria must be declared before the investigation or may be changed after an unexpectedly attractive reconstruction appears.

Claude Elwood Shannon | Immediate answer to Andrey Nikolaevich Kolmogorov

Professor Kolmogorov, the distinction you propose is essential. Mathematical non-uniqueness does not make all rational inference impossible. If a validated generative model constrains the source ensemble, the observed narrowband data can change the relative probabilities assigned to competing hypotheses. A posterior inference may be useful for deciding which additional measurement to make, ranking possible causes, or presenting a bounded probabilistic opinion. But that posterior is a function both of the surviving observations and of the assumptions that assign relative weight to the unobserved components. Its precision must not be attributed to the recording alone.

I would first require the competing hypotheses to be specified before fitting the explanation. An analyst who selects a model after inspecting the derived trace may inadvertently favour whichever reconstruction most resembles the desired conclusion. Next, the probability model must be tested against held-out examples containing both the expected signals and realistic alternatives, including high-power interferers, receiver-generated products and unexpected modulation. A model validated only on clean, isolated

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laboratory tones cannot establish a narrow probability of a complex field source in a heavily occupied band. The validation population matters as much as the elegance of the posterior formula.

Robustness tests should examine priors and nuisance-parameter uncertainty. If a source-attribution conclusion changes when plausible interference occupancy or front-end nonlinearity assumptions are varied, the report should identify that sensitivity instead of presenting one favourable number. If the model uses learned features from a data archive, training and evaluation records must be separated, and repeated measurements sharing the same hardware path must not be treated as wholly independent. Credible intervals are conditional on the model, not universal proof that the particular unrecorded waveform possessed a calculated amplitude or arrival time.

An independent challenge can be decisive when it makes different predictions. For example, change the analogue preselector, input attenuation, receiver or sample plan while retaining a stable external reference. A real incoming component and a mixer-generated intermodulation product may respond differently, provided the apparatus is carefully characterised. Where the original event cannot be repeated, the posterior can remain useful as a qualified historical inference, but its causal claims must not be promoted beyond the surviving evidence. I would describe its result as the probability or likelihood under stated hypotheses and conditions, not as a recovered raw waveform. The court and the technical laboratory should hear the same limitation.

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Finally, a good archive should permit future analysts to revisit the prior assumptions without destroying the underlying data. Keeping the derived narrowband file, its filter and version record, and any available raw witness is therefore better than preserving only one posterior waveform. Reproducibility of the inference is valuable; the capacity to contest its model is more valuable still. The examiner who discloses both the data and the conditions of reconstruction has supplied a meaningful basis for scientific criticism, without claiming that probabilistic skill can repeal the consequences of physically discarded observations. I invite Dr Turing to challenge the claim that a transformed file can remain reproducible even when its generating implementation is no longer available.

Alan Mathison Turing | Peer question 4 to Claude Elwood Shannon

Dr Shannon, one can easily preserve a written formula while losing the computing process which actually produced the exhibit. Two nominally equivalent decimators may differ in coefficient quantisation, arithmetic precision, saturation behaviour, boundary extension, handling of NaN values and rounding at each stage. A report may state that a low-pass FIR filter preceded a factor-of-sixteen downsampler, yet a regenerated file may differ from the original because the reference implementation silently changed its default padding or its treatment of a final incomplete block. What conditions would allow an independent examiner to establish that the digital result was generated by the declared process rather than merely by a mathematically similar process? Would a software hash, an input-and-output test vector, or a containerised execution environment suffice, and how should the examiner distinguish

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reproducibility of the computation from proof that the retained data answered the intended physical question? The distinction becomes especially pressing where the original source samples have not survived and a court sees only the processed exhibit.

Claude Elwood Shannon | Immediate answer to Alan Mathison Turing

Thank you for that question. Dr Turing, the distinction is between a mathematically defined operator and a particular implementation of that operator. A reproducible forensic transformation should disclose, wherever practicable, the exact input representation, coefficient sequence, phase convention, arithmetic type, overflow behaviour, buffer boundaries and software version, along with known execution dependencies. A hash of a binary file establishes that the file remained unchanged; it does not by itself explain what the binary did or how it was configured. A signed software release may assist provenance, but validation still requires test vectors whose expected results are independently known, including values near saturation, block boundaries and filter reset transitions.

A reproducibility package may include a frozen executable or source revision, dependency lockfile, compiler or interpreter details, configuration, calibration coefficients and a small suite of challenge inputs. It should also provide checksums of both input and derived outputs. Where deterministic binary reproduction cannot be guaranteed across hardware platforms, a documented numerical tolerance can be scientifically appropriate, provided the tolerance is connected to the task's measurement uncertainty and not chosen

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merely to excuse an unexplained discrepancy. Difference at one least significant bit may be immaterial to a coarse power estimate but decisive to a threshold event lying precisely on a decision boundary.

Even perfect computational reproducibility would not prove physical validity. The filter may accurately eliminate a band that later proves essential to attribution; the decimation phase may be perfectly reproduced despite having omitted a transient at a sensitive interval; and a moving threshold may be applied exactly even though its statistical properties were not evaluated. The correct evidence claim should distinguish that the stored file is intact, that the transformation is reproducible, that the transformation is a justified measurement of specified quantities, and that a proposed interpretation of those quantities has survived appropriate alternative tests. These are separate links in an evidential chain.

For long-term retention, simple, documented interchange formats can reduce dependence upon an obsolete proprietary application, but conversion into such a format is itself a new transformation that should be recorded. Keeping the raw source and an open, versioned derivation normally permits more criticism than keeping a closed export alone. Where the raw source is absent, a known transform still allows the analyst to delimit the surviving domain, not to recover the lost dimensions. This is the sense in which reproducibility is necessary for some strong forensic opinions yet insufficient for claims of universal recovery. The most faithful report preserves the difference between computational certainty and empirical uncertainty. Professor

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Slepian may now direct our attention to the events which escape the comfortable fiction of an infinitely long stationary record.

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John Wilder Tukey | Principal response 3: Selection, omitted data and the lure of a favourable display

Dr. Atkinson, I should begin by challenging a tempting division between engineering and inference. It is easy for a laboratory to declare decimation a signal-processing operation and to leave its interpretation to a later statistician. Yet the choice of the retained band, the length of the observation window, the detector threshold and the rule deciding which events are stored constitute a process of selection. These choices change the population of observations about which the investigator can speak. When an archive contains only bursts that exceeded a threshold after narrowband processing, its empirical frequency distribution is not automatically the frequency distribution of all emissions encountered by the original antenna. It is a distribution conditioned upon the channeliser, filter, exposure, trigger and retention mechanism. Those conditions must be carried into every later statistical inference.

The point can be made without mystical appeals to information. Suppose the original survey encounters legitimate strong signals, weak sporadic emissions, receiver-generated products and noise transients. A decimation channel excludes one part of the spectrum and a detection rule excludes most time intervals. The surviving events will be disproportionately composed of cases to which the filter and threshold are sensitive. If the investigator examines only the surviving cases and estimates a detection probability from their apparent clarity, the analysis is circular. The difficult misses are precisely the observations least likely to be preserved. An attractive waterfall may therefore constitute a collection of selected successes rather than an unbiased test of the instrument's ability to discover

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weak signals. Such a display need not be fraudulent; it may be a faithful picture of an inadequate selection design.

I would insist upon a denominator. If the investigator reports that nineteen of twenty known challenges were detected, the twenty trials must represent the predeclared population of conditions and must include failed trials, periods of invalid acquisition and threshold alterations. If the test instead examines twenty retained candidate clips, no detection sensitivity can be inferred because the sample was constructed by conditioning on retention. Equally, a claimed absence requires an exposure record indicating when the receiver actually observed the relevant frequency, at what sensitivity and with what probability of passing the detection rule. It is possible to have an exact sample rate and an exact filter coefficient set while lacking the denominator necessary for the legal assertion which the analyst wishes to make.

A realistic audit should preserve the acquisition state as a time series. It should identify scheduled band coverage, instantaneous tuning, invalid blocks, dead time, channel boundaries, gain state, filtering mode, trigger policy and software changes. It should distinguish what the instrument was capable of recording from what it was configured to retain. One can then reconstruct the actual opportunity for observation. This is different from assuming that a receiver was monitoring an entire building merely because it was switched on throughout the day. A sequential scanner might dwell briefly on each channel, and a one-millisecond transmission may easily occur during an interval when the relevant channel was not being sampled. An adaptive system may revisit frequencies following earlier alarms; this

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makes coverage a function of prior observations and introduces dependence that a simple random-trial model does not capture.

The lost raw record also affects exploration. A statistician may later wish to compare the behaviour of two detectors with different bandwidths, alter a false-alarm threshold, evaluate cross-channel coincidence, or examine whether strong adjacent signals were associated with alleged weak emitters. If only the output of the first detector survives, most of these comparisons cannot be made. It would be poor practice to call the archive raw evidence merely because it is stored in a binary complex-sample format. A digital sample can be the output of substantial irreversible processing. Its semantics depend upon the generating operation. We must describe what was acquired, what was selected and what remains experimentally testable.

Nor do I advocate indiscriminate storage. A properly designed stratified archive could retain continuous summary statistics, known-schedule random witness intervals, representative negative intervals, event-triggered higher-rate clips, and enough challenge sequences to estimate sensitivity in different conditions. This does not recover every missing waveform, but it makes selection inspectable. Sampling of witness intervals should be predeclared and independent of the event detector where possible. Otherwise the archive's supposedly independent control material will again favour obvious signals. A complementary receiver or reference monitor can provide external validation, but its independence must be analysed rather than presumed, particularly if the instruments share one antenna or noise reference.

The distinction between exploratory and confirmatory analysis belongs in the report. After-the-fact searches are scientifically valuable, and

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unexpected patterns may reveal apparatus faults or new signal classes. Yet an effect discovered after trying dozens of filters, thresholds and frequency windows cannot be accorded the same false-positive interpretation as a single predeclared test unless selection and multiplicity are handled. An investigator who observes one spectacular spike among thousands of comparisons should state how many opportunities for a similar spike existed. In a forensic setting, a precise timestamp beside an amplitude number can look more authoritative than its selection history warrants. The ethical remedy is not vagueness but a record of choices and a restricted claim.

I would accept a report that says a candidate was detected under a specified filter and decision rule, that the source clip and configuration were preserved, and that subsequent challenge experiments favour one hypothesis while leaving others unresolved. I would reject a report that reads a selected candidate archive as a complete census of unobserved emissions, or infers universal negative assurance from an unquantified duty cycle. The loss that matters is not only missing hertz or missing samples. It is the missing comparison group, the missing test history and the missing opportunity to discover that the detector failed. I pass the floor to Professor Neyman, whose concern with the design of inference sharpens the question of what evidence a negative result can bear.

Jerzy Neyman | Peer question 5 to John Wilder Tukey

Professor Tukey, your demand for a denominator is persuasive, but consider the operational burden on a receiver whose observation pattern is adaptive rather than fixed. Each alert causes the controller to lengthen dwell in one region, shorten dwell elsewhere and change detector

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thresholds according to a rolling estimate of occupancy. The time spent observing a frequency is consequently related to earlier indications, some genuine and some artefactual. It is not obvious that a simple proportion of detected laboratory challenges estimates the field probability of detection. How would you construct a validation experiment that remains meaningful when the acquisition policy is itself a stateful stochastic mechanism? In particular, what quantities would you condition upon, and when would you regard an interval as outside the validated envelope rather than counting it as a failure or a success? I ask you to distinguish inferential uncertainty from the genuine physical loss of a waveform whose frequency the receiver was never sampling.

John Wilder Tukey | Immediate answer to Jerzy Neyman

Professor Neyman, I would begin with the distinction you have drawn. An experiment cannot estimate the sensitivity of an adaptive surveillance procedure merely by treating every retained clip as an exchangeable observation. The object of evaluation should be the complete decision policy, including its state transitions and responses to prior observations. We should describe a trial population of signal amplitudes, durations, frequencies, interferer conditions and arrival phases, and run the actual controller against that population without repeatedly tailoring its policy to the visible successes. Where an intervention changes the policy, it becomes a different procedure requiring its own performance statement.

The denominators should be indexed by exposure conditions. For a frequency actually monitored with a known threshold and gain state, one can estimate a conditional detection probability under declared

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signal classes. For a frequency not sampled during a trial, the failure is an exposure failure for the complete surveillance system, not an electronic receiver miss at its input. Both matter to a claim of successful survey coverage, but they diagnose different causes. An honest report may state the overall procedure's chance of encountering and recognising a specified event, while separately giving the detector's chance of recognising that event conditional on exposure. Combining those quantities without distinguishing them can lead to impressive detector metrics and poor operational surveillance performance.

We can introduce controlled signals at random times and frequencies, including during periods when the adaptive policy is likely to prefer other bands. The generation schedule must be independently retained and should not be revealed to the detector. Trials must include genuine negatives, strong interferers and conditions known to provoke false triggers. Repeated campaigns should vary initial controller state and preserve the whole state history. In this way the experiment challenges not merely one filter but the scanning decision mechanism. Confidence statements require attention to dependence; adjacent trials influenced by the same gain estimate or interference event are not independent Bernoulli experiments simply because they have different row numbers.

Where the policy changes during the campaign, the acceptance record should identify the predeclared adaptation rules and distinguish expected adaptation from human alterations made after observing a failure. A later threshold adjustment may improve the

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system, but prior results do not retroactively validate the revised configuration. If some environmental condition falls outside the experimental envelope, declare that scope limitation rather than silently omitting the trial. It may be useful to classify the trial as an invalid challenge for a narrowly defined calibration measure, while still reporting that the deployed survey could not provide the broader assurance demanded by its task.

There remains a hard physical fact: a signal outside the sampled region never produced relevant ADC values in that interval. Neither randomisation nor confidence intervals can create those missing values. Statistics can describe how often such non-exposure occurs under a declared policy and what that means for the chance of missing a defined class of events. It cannot determine the unique waveform of a particular unobserved emission. A refined estimator is useful precisely when it respects that distinction. The best engineering report keeps acquisition coverage, detector performance and physical source interpretation in separate, linked propositions. I invite Dr Wiener to address the danger that a feedback-driven recorder obscures those links during operation.

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Norbert Wiener | Principal response 4: Adaptive operations are part of the system under examination

Dr. Atkinson, when an instrument modifies its operation in response to what it has observed, the observer and the observed record form a coupled system. This is not merely a philosophical curiosity. Consider an SDR which raises its trigger threshold after a period of strong interference, switches from a high-rate wideband stream to several narrowband decimated channels, and increases recording duration around a candidate signal. Its subsequent archive depends on the events that preceded it. The controller may have behaved exactly as designed, yet a later examination of retained clips will not show the full causes of its own selection. We must therefore include the state of control within the measurement boundary. What is not recorded about the controller can become as important as what is missing from the sample stream.

A fundamental distinction concerns the purpose of the feedback. An adaptive filter may suppress interference to increase the sensitivity of a specified detector, while an automatic gain controller may prevent overload and preserve useful dynamic range. Both can improve observation in a practical sense. But they also alter the relationship between the original RF input and the retained samples. The feedback may depend upon estimated power, spectral occupancy, previous alarms and operator settings. A constant output amplitude does not imply a constant input amplitude when gain is changing. A disappearance of a line does not imply that the emitter stopped operating when a notch filter or channel assignment changed. The forensic record must permit those alternatives to be tested, or the interpretation must be carefully bounded.

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The model should include state variables u(t) for gain, tuning, sample rate, filter bank selection and trigger logic, with a controller law u(t+) = F(u(t), z(t), policy) based on processed observations z(t). Because z(t) is itself computed from previously sampled input, the retained record depends on a history of state transitions. This relationship makes it misleading to describe the whole event with a single stationary transfer function. Even when each state has a known calibrated filter, the transition between states may involve reset transients, finite filter memory, dropped blocks and uncertain effective timestamps. A record that reports only the final state may therefore hide the moment when the claimed waveform first entered the chain.

One might seek to solve this by logging every controller event. That is useful, but a state log does not alone establish that the control decision was physically correct. The thresholds may have been evaluated on biased noise estimates. A transient may have been erased before the controller wrote its event. An apparent narrowband emission may have triggered a reduction in gain that temporarily concealed weaker emissions elsewhere. We need both a process log and independent challenge experiments that reveal behaviour under known inputs, especially near state transitions. Those trials should include signals arriving at awkward times, not merely continuous carriers perfectly aligned with a laboratory schedule.

The system also produces a paradox of evidence. The better an adaptive suppression algorithm becomes at removing a known class of interference, the less of that class may remain in its output. An investigator reviewing the output alone may conclude that the operating environment was quiet, although the suppression system was continuously active. If the purpose of the survey is to characterise interference, such success can be

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informationally damaging. If the purpose is to detect an independent weaker signal, suppression may be beneficial, but its benefits must be measured as changes in detection performance rather than inferred from a visually clean spectrum. The same filtering operation can be good for one measurand and inadequate for another.

A robust recorder would therefore preserve several distinguishable records. The input state history and configuration hashes should remain available. The transformed sample stream should identify its tuning centre, rate, filter coefficients, processing epoch and associated correction versions. Representative unprocessed witness intervals can support challenges to adaptive artefacts and unreported signal suppression. Triggered recordings should preserve sufficient pretrigger material and the exact trigger rule to show what was selected. Counterexamples, including challenges which a controller fails to detect, must remain in the audit record. If retention capacity requires deletion, the deletion policy itself belongs in the evidence inventory.

I also insist that adaptation is not inherently a forensic defect. A receiver cannot reasonably operate at full precision over every possible frequency, duration and gain condition at all times. A well-validated controller can allocate finite resources efficiently and achieve better conditional detection for the intended signal population. The error begins when the receiver's efficient policy is confused with universal coverage, or when a transformed record is presented without the transformation history necessary to define its observables. The evidence should be evaluated according to the question it was designed to answer and the alternatives it could have distinguished under the actual operating conditions.

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Finally, we should test the policy as a policy. Challenge it with randomised event arrival times, correlated interferers, temperature changes, sudden gain transitions and durations comparable with the controller's update interval. An adaptive calibration that performs splendidly after warm-up may fail during the first seconds of a field deployment. A filter whose long-term spectral response is excellent may create a short transient during reconfiguration. These failures will be invisible if the acceptance campaign averages over precisely the intervals at which a defensive investigator most needs confidence. I pass the floor to Professor Kalman, whose approach to dynamic estimation can test whether the logged state truly supports the accuracy claimed for the reconstructed observations.

Rudolf Emil Kálmán | Peer question 6 to Norbert Wiener

Dr Wiener, your account treats the receiver as a changing state-space system, but I wish to distinguish reconstructible state from states that have never been observed. Assume an operator preserves the commanded gain, software filter coefficients, input frequency plan and clock reference, but does not retain the analogue gain stage's actual settling response or the transient phase of the local oscillator. A later estimator can propagate an elegant nominal state model over the missing period, yet the hidden physical state may be poorly constrained. Which conditions must hold for such a state reconstruction to support an evidential amplitude or phase claim? Would you insist on observability tests, bounds on process noise, and withheld calibration transients before assigning a confidence interval? I am particularly concerned that an estimator calibrated upon steady laboratory states may give misleadingly narrow uncertainty immediately after an adaptive

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reconfiguration, precisely where forensic timing is most contested. Would you require an explicit interval of indeterminate evidence after each state change?

Norbert Wiener | Immediate answer to Rudolf Emil Kálmán

Professor Kalman, the nominal state log is a beginning, not an observation of every dynamic variable. I would distinguish commanded configuration from realised physical state. The latter may include analogue settling, oscillator frequency pulling, gain compression and transient phase changes whose time course is not recorded directly. A state estimator can combine a validated physical model with measured observations and produce useful estimates, but those estimates must be conditional upon the model's process-noise assumptions and the actual observability of the relevant state. If no retained measurement constrains a particular transient, the estimator's certainty may come entirely from an assumption that the transient followed its nominal trajectory.

An observability analysis is therefore essential to the strong claim, but it should be adapted to the finite experiment rather than quoted as a universal certificate. A state which is observable under one steady sinusoidal excitation may not be identifiable during a short unknown burst. A gain parameter and an unknown transmitter amplitude may enter the measured product in a way that makes them observationally confounded. Similarly, a common clock drift and a genuine Doppler shift may require independent reference information to distinguish. We should identify these equivalences before asking an estimator to decide between them. An algorithm

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cannot infer uniquely what its measurement equation never separates.

A calibration campaign should include withheld state transitions, changes of temperature, input amplitudes near operating limits, and disturbances applied at controlled but unpredictable moments. It should compare the estimator's predicted uncertainty with actual held-out residuals and with an independently characterised reference path. Where errors are correlated across consecutive samples, the campaign must not pretend that a million output words provide a million independent validations. A short transition may be the only interval of interest, and the result must be evaluated on that interval. If the model fails there, the failure should prompt a revised bounded claim or a changed measurement design.

I also recommend publishing the actual state estimates and their innovations, not only a final corrected waveform. An independent reviewer should be able to see when the model disagreed with measurements, when a gain or phase correction was large, and when a covariance bound was driven by process assumptions rather than data. The raw material available for such criticism should be preserved wherever practicable. If only the corrected output remains, the examiner may be unable to test whether a different but equally plausible model would produce another physical interpretation.

The most defensible report would therefore state that an amplitude or phase estimate was obtained under a specified dynamic model whose validity has been demonstrated over a declared envelope, and that identified intervals with insufficient observability

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have been excluded from strong inference. Exclusion is not erasure: the excluded intervals should remain documented as gaps in coverage or uncertainty. If the original data were discarded during an unobserved transition, it is better to acknowledge a lost opportunity than to pretend that a smoother posterior trajectory has reconstructed an actual historical waveform. I now invite Professor Gabor to examine the complementary conflict between temporal localisation and spectral discrimination.

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Dennis Gabor | Principal response 5: The time-frequency compromise and the physical meaning of a derived transient

Dr. Atkinson, the question of a decimated transient begins with the limits of simultaneous localisation in time and frequency. An engineer may choose a long, narrowband filter because it suppresses interference and makes a weak carrier more visible. Such a filter also has memory. The output associated with a brief event is shaped by convolution with the filter's impulse response, and a detector which reports the output duration as though it were the source duration mistakes a property of the instrument for a property of the emission. The effect is especially serious where the investigation concerns short pulses, rapid frequency changes or the relative ordering of events across independent receivers.

One must distinguish an invariant from an estimator. The centre of an isolated, known waveform may be estimated to high precision under a validated model even when the waveform is narrowband. But when the input is unknown, a narrow output cannot generally disclose the full structure of a wideband transient excluded by the filter. Several different inputs can produce indistinguishable retained outputs. A reconstructed pulse with sharp edges may therefore depict the assumptions of a signal model more vividly than the original experiment supports. No amount of graphical polish can turn those assumptions into observations. An honest display should identify the effective filter bandwidth, group delay, processing window and any postprocessing used to obtain the depicted waveform.

The elementary Fourier trade-off gives a practical warning. A time-localised event requires a spread of spectral content, and a very narrow

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effective passband necessarily restricts the time detail which can survive. A nominally ten-microsecond rectangular pulse has a sinc-shaped spectrum whose first-null spacing is approximately the reciprocal of its duration, or about one hundred kilohertz in this example. Passing only a small fraction of that structure through a few-kilohertz channel can leave a long ringing response that is not a faithful record of the original rectangular envelope. The result may still be excellent for detecting the presence of energy near the channel centre. But it cannot automatically determine the pulse's rise time, full bandwidth or detailed modulation sequence.

Time-frequency analysis is not exempt from the problem merely because it uses a windowed Fourier transform, a wavelet or another sophisticated representation. The choice of window changes leakage, resolution and temporal smearing. A short window preserves event localisation at the expense of fine frequency discrimination, while a long window improves frequency selectivity but averages over time. When an operator selects whichever representation gives the most conspicuous event and omits the others, the archive becomes a record of interpretive choices. A forensic claim should identify the analysis windows and preserve enough source data to permit a challenger to examine how the conclusion changes under reasonable alternatives.

Decimation may also affect comparisons between receivers. Each device can have a different filter delay and phase response even when both deliver the same nominal output sample rate. Suppose an investigator estimates a time difference of arrival from two decimated records. If one path has an uncompensated group delay of several samples, the apparent difference may arise from instrumentation rather than source geometry. Correcting

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the delay requires a validated transfer measurement and knowledge of filter state at the event. A nominal coefficient array and a mathematical group-delay formula cannot compensate for an undocumented reset, a changed sample phase or an analogue path that contributes additional frequency-dependent delay. The uncertainty must include these effects where they matter.

I would also caution against assigning physical meaning to an interpolated waveform between retained samples without checking the band-limited assumptions. For an appropriately conditioned narrowband signal, interpolation can accurately reproduce the waveform within the admitted model. It does not restore a high-frequency event removed by the anti-alias filter. Interpolation increases the number of displayed points; it need not increase the number of independent pieces of evidence. The danger is present when investigators enlarge a waveform until the curves look continuous and then discuss fine-scale features that were not represented in the source data. The graph's visual smoothness is a product of the rendering and interpolation rule.

Validation should therefore include test events of different duration, rise time, modulation and arrival phase relative to the decimation cycle. A single continuous sine wave is insufficient to certify the transient behaviour of a digital receiver intended to detect brief, irregular emissions. The examiner should retain challenge waveforms and compare derived widths, arrival-time estimates and phase estimates against known inputs. Tests should include passband edges and strong adjacent activity because those conditions expose the combined effects of transition-band rejection and receiver nonlinearity. When the output meets only a narrower detection

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criterion, the report should celebrate that bounded success rather than inflating it into an unsupported reconstruction claim.

Finally, the temporal question cannot be separated from source attribution. A short indication may be a genuine emission, a filter start-up transient, a buffer discontinuity or a derivative of a strong neighbouring signal. Its appearance at one output time is not enough to distinguish these causes. The strongest evidence comes from interventions whose predictions differ: changing the receiver architecture, comparing a raw witness channel, verifying the filter state, or demonstrating that the event repeats at the appropriate physically predicted time when the recording method changes. Even these methods require care where common components create correlated artefacts. A chain of individually validated transformations can support a powerful finding, but the chain must be visible. I respectfully pass the floor to Professor Slepian, whose work on spectral concentration invites a difficult question about the behaviour of very short bursts at the margins of the retained band.

David Slepian | Peer question 7 to Dennis Gabor

Professor Gabor, I should like to challenge the comfortable practice of describing a filter's bandwidth as though it were a sharp wall separating preserved from lost information. In a finite-duration observation, spectral energy leaks across nominal boundaries, and an optimally concentrated time-limited waveform still cannot be both perfectly finite in time and perfectly confined to a prescribed frequency interval. An investigator might therefore see a weak residual outside the nominally admitted channel and claim that the rejected transient has been partially reconstructed. Under what conditions would that residual support a

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quantitative statement about the original event rather than merely an upper bound or an estimator conditional on an assumed waveform? How would you distinguish genuine transient energy from window leakage, stopband imperfections and the memory of earlier events? I ask especially whether the examiner ought to preserve measurements near both edges of the passband and explicitly state what aspect of pulse duration or spectral occupancy remains identifiable.

Dennis Gabor | Immediate answer to David Slepian

Professor Slepian, your objection is entirely warranted. The passband is a transfer characteristic, not an absolute metaphysical division. A real filter has finite transition bands, finite stopband rejection, and a response which depends on how its state was initialised. A component nominally outside the admitted region may produce a residual whose magnitude is limited by the filter's attenuation. Conversely, a component near the passband edge may be heavily attenuated without disappearing completely. Those observations can sometimes support bounded estimates, but they must be evaluated through a characterised transfer function with its uncertainty, not by assuming that a small output is a faithful scaled image of an otherwise unknown input.

If the source waveform is known up to a few parameters, a transfer model may permit useful parameter estimation. For example, an agreed pulse shape with unknown amplitude and arrival time may produce a predictable filtered response. The analyst could fit that response and report the estimated parameters under the pulse model. But an unconstrained original transient generally has many

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degrees of freedom which are suppressed by decimation, so an inverse cannot uniquely restore them. The uncertainties should include not only noise but the possibility that the assumed waveform family is wrong. A narrow confidence interval calculated under an incorrect family can be much more misleading than a broader and candid physical bound.

Measurements at passband edges are particularly important. A filter with apparently admirable centre-frequency performance may have large amplitude ripple, phase curvature or delay variation at its margins. A short event's spectrum may straddle the edge so that the derived timing and amplitude change with small shifts in tuning frequency. An examiner should use controlled challenges across the full region, not only centred tones, and should preserve the resulting response curves and configuration metadata. Where several adjacent channels overlap, comparing their outputs can help diagnose boundary effects, provided shared processing paths and correlated errors are not mistaken for independent evidence. The result should be stated as a system-level observation under a declared model.

A residual outside the nominal passband does not by itself establish the rejected component's original amplitude. Stopband leakage may depend on input amplitude, frequency, filter length, coefficient quantisation and numerical precision. An unknown strong interferer can create a small response indistinguishable in the retained samples from a weaker in-band input. Where the system's observed response is within a noise or calibration uncertainty bound, a quantitative source claim should be withheld or expressed as an

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interval under explicit assumptions. It may be appropriate to state a detection limit rather than a reconstructed pulse shape. The evidential standard is not visual attractiveness but discriminability among competing physically plausible causes.

The best recording policy allows later challenge to the decisions made at acquisition. Keep filter characteristics and state logs, retain selected raw witness intervals across relevant boundaries, and preserve the source trials used to validate pulse-time and edge measurements. Describe what was not retained. If the subsequent investigation raises a question that depends upon rejected frequencies or transient structure, state clearly that the derived file cannot answer it without external constraints. That is not an indictment of filtering; it is recognition that every measurement allocates finite observation capacity to a chosen question. I return the floor respectfully to Dr. Atkinson for the numerical tests and final synthesis.

Ten worked engineering and forensic applications

The following cases are hypothetical and are included to expose the dependence of a conclusion upon the selected measurement model. They are not performance certifications. Unless otherwise stated, frequencies are in hertz, times in seconds and data quantities use decimal multiples. A separate calculation audit is retained with the manuscript.

Percy Williams Bridgman, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, after decimating a complex 40 MS/s stream by twenty, a

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researcher still sees a clean 2 MS/s trace. Which specific physical question could the new record no longer answer?

Claude Elwood Shannon, Cross-Peer Answer to Percy Williams Bridgman: Professor Bridgman, the answer depends on the pre-decimation anti-alias filtering and the target measurand. If the permitted complex output band is only about ±1 MHz, the archive may no longer reveal an emitter confined to an excluded part of the original ±20 MHz span, however clean the retained waveform looks. Even within the output passband, finite filters may shift timing and distort brief transients. Document the original frequency support, numerical filtering response, downsampling phase and all excluded bands; do not claim an absent signal from a derivative that could never contain it. If the unaltered wideband source record was discarded, an alternative later hypothesis involving the removed frequencies may be untestable. The researcher can still make strong claims about a carefully specified narrower measurand, provided the transfer is calibrated. I yield the token to Professor Wiener.

Claude Elwood Shannon, Cross-Peer Question to Norbert Wiener: Professor Wiener, an adaptive decimator changes coefficients when a threshold detector fires. How can the investigator establish whether a suspicious transient originated in the environment or in that state change?

Norbert Wiener, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, treat the filter and state machine as part of the measured apparatus. Preserve each coefficient set, transition time, detector threshold, clock state, buffer occupancy and software build, preferably with a sample-accurate audit trail. Challenge the system with known stationary noise and with controlled injected bursts placed just before and after a filter change.

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Measure output ringing, impulse response and phase discontinuities as the state changes. The same input may produce different archived signals depending on the prior state of the filter; a static frequency response alone is insufficient. If the triggering detector also selects which samples are stored, selection bias enters the evidential record. Keep the relevant pre-trigger context and describe unrecorded intervals honestly. I pass the token respectfully to Professor Tukey for the consequences of selection.

Norbert Wiener, Cross-Peer Question to John Wilder Tukey: Professor Tukey, the archive retains only windows that cross a declared anomaly threshold, but the operator presents them as an unbiased sample of overnight spectrum conditions. What is the analytical defect?

John Wilder Tukey, Cross-Peer Answer to Norbert Wiener: Professor Wiener, the inclusion mechanism depends on the value being measured. Triggered windows are therefore an enriched, selected sample of the tails, not an unbiased temporal census. Report the trigger algorithm, dead time, rearm delay, tuned frequency, monitor gaps and total observation exposure. To estimate event incidence, the denominator must include times when the system was able to detect events, with any missed-trigger characteristics validated independently. If one changes thresholds after studying the saved examples, the nominal false-alarm rate no longer applies without correction. Preserve periodic unconditional control windows if feasible. The stored detections can still be analysed deeply, but they cannot support an inference about all unrecorded intervals simply by dividing by file count. I pass the token to Professor Gabor about transient time-frequency localisation.

John Wilder Tukey, Cross-Peer Question to Dennis Gabor: Professor Gabor, could later interpolation or a sharper-looking spectrogram restore the exact

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onset time of a burst removed by a long pre-decimation filter and an uncertain acquisition clock?

Dennis Gabor, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, the transformation can provide a model-dependent estimate under declared assumptions, not a new direct observation. A long impulse response can smear or shift a burst in ways that depend on the input spectrum and the filter state. The nominal group delay may be corrected if it is known, but residual uncertainty from dispersive delay, clock wander, trigger latency and omitted samples remains. Test known events at varying phases and positions relative to the decimator and compare the derived onset against an independent timing reference. Report the distribution of errors rather than one corrected timestamp of misleading precision. Preserve the parent capture where possible; if it is absent, label reconstruction as inference from a filtered derivative. I respectfully return the token to Dr Atkinson for conclusion.

Dr. James M. Atkinson | Moderator conclusion

Distinguished colleagues, we have reached a common distinction which I regard as the organising principle of this discussion. Decimation may be an appropriate, efficient and remarkably precise measurement operation, while simultaneously being an irreversible reduction of the evidence available for a different question. The fact that a detector correctly recognises the signal class for which its channel was designed does not establish that the retained file reproduces the original wideband experiment. Equally, the mathematical loss of excluded information does not make every derived observation worthless. A report can be exact within its admitted measurement

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boundary, provided that boundary is defined before the conclusion is drawn and remains visible in the evidential record.

Professor Bridgman has insisted that a change of operation can change the measurand, even when both results carry the familiar label of a spectral observation. Dr Shannon has shown why a many-to-one map cannot furnish a unique inverse without further assumptions. Professor Tukey has demonstrated that the most serious omission may be the unrecorded population of missed events, failed trials and intervals never exposed to the detector. Dr Wiener has placed adaptive state transitions inside the system whose performance is being claimed. Professor Gabor has shown why a visually persuasive output transient may be shaped more by the measuring filter than by the historical emission. None of these contributions requires us to abandon decimation. Together they require us to stop asking a reduced record to answer an unmeasured question.

Our applications reinforce the distinction. A factor of twenty reduces the complex sample rate from forty megasamples per second to two, with commensurate storage savings, but it also narrows the represented discrete-frequency interval. A correctly rejected out-of-band component is absent precisely because the anti-alias stage performed its intended work. A filter with a one-and-a-quarter-microsecond nominal group delay may support corrected timing only when its initial state and reference epoch are known. A detector with impressive conditional sensitivity may still miss most short emissions when the scan exposes the relevant channel for a small fraction of the survey. A large number of spectral comparisons can produce at least one plausible-looking noise alarm even when each isolated comparison has a small false-positive rate. These are separate mechanisms,

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and they must not be concealed under a single adjective such as calibrated, coherent or exhaustive.

For future publication I therefore require the record to distinguish five matters. The original analogue admission and sampling conditions must be described. The sequence of transformations from original samples to derived data must be identified, including filter coefficients, rate changes, phase conventions, software versions and state transitions. The retention and trigger policies must identify what was discarded and when acquisition was invalid. The uncertainty of the surviving measurements must be distinguished from the non-identifiability of the rejected quantities. Finally, source-attribution opinions must be tested against material alternatives, including analogue nonlinearity, clock and filter artefacts, missed exposure and statistical selection. A file digest protects the integrity of retained bytes; it does not certify the physical meaning of bytes the system never collected or deliberately removed.

The exchange has also preserved genuine disagreements. Professor Neyman asks how an adaptive observation policy should be validated without treating dependent trials as independent. Professor Kalman requires evidence that a dynamic state can actually be reconstructed. Professor Slepian challenges the seductive notion of a sharp passband boundary in a finite observation. Those questions remain important qualifications to every concrete receiver design, because the correct validation experiment depends on the declared signal population, the operating architecture and the legal or investigative inference required. No universal promise can be extracted from the abstract sampling ratio alone.

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We shall accordingly carry forward a bounded acceptance principle: preserve enough of the original record and transformation history that another examiner can reconstruct the stated measurement and challenge its interpretation; when the missing material prevents that challenge, make the limitation part of the finding rather than an invisible editorial omission. The next discussion will examine the assumptions governing multistage filters and how engineering implementation choices change the spectral, temporal and evidential qualities of a retained output. I thank each contributor for the disciplined questions and the respectful transfer of the floor.

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Ten worked engineering applications | Question 036

Application 1. Reduction factor and the frequency range actually preserved

A complex input stream runs at F_in = 40,000,000 samples/s and is reduced by an integer factor D = 20. The resulting rate is F_out = F_in/D = 2,000,000 complex samples/s. The original discrete-time complex spectrum has a principal interval of width 40 MHz, while the new complex record has an interval of width 2 MHz. A practical filter must reserve a transition band, so its fully calibrated passband may be smaller. The calculation establishes a rate and an output periodic-frequency interval. It does not establish that the filter passed every frequency inside that interval, that the analogue receiver admitted all original 40 MHz without distortion, or that excluded components did not occur. When reporting a negative finding, the measured channel's validated passband rather than the original converter's headline bandwidth is the relevant domain.

Application 2. The consequence of downsampling without adequate filtering

Let the retained sampling frequency be F_out = 2.0 MHz and imagine a residual complex exponential at f = +1.3 MHz immediately before taking every twentieth sample. Discrete sampling at the new rate identifies frequencies differing by integer multiples of F_out: f_alias = f - round(f/F_out) F_out, with the final value interpreted in the principal interval from -F_out/2 to +F_out/2. Thus f_alias = 1.3 - 1 × 2.0 = -0.7 MHz. A displayed feature at -700 kHz could arise from a valid in-band -700 kHz

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component or from insufficient rejection of a +1.3 MHz component. Once both have been mapped onto the same samples, the reduced file alone does not uniquely separate them. A proper anti-alias filter diminishes the second mechanism, but the adequacy of its stopband is an empirical requirement rather than an assumption derived from the integer twenty.

Application 3. Stopband attenuation in power units

Suppose a potentially troublesome input component measures P_in = -20 dBm at the characterised digital-filter input plane, and its frequency lies in a stopband whose measured power attenuation is A = 80 dB under the relevant conditions. The nominal residual output power is P_out = P_in - A = -100 dBm, provided the calculation applies to comparable power reference planes and the response remains linear. This number can be below a detector threshold and still be relevant to forensic interpretation. A stronger unmodelled interferer, an upstream nonlinear product, or a weaker measured attenuation near the transition band changes the result. Reporting eighty decibels of suppression cannot establish that an external source was absent; it documents a specific rejection property for a stated mechanism and input.

Application 4. FIR group delay and event chronology

Consider a causal, linear-phase FIR decimator with N = 101 symmetric coefficients operating at F_in = 40 MHz. Its constant group delay within the frequency region in which the linear-phase model applies is (N-1)/2 = 50 input-sample periods. Thus tau = 50/(40,000,000) = 1.25 microseconds. That correction may be applied to a suitably defined output event timestamp, assuming the filter was in the relevant settled state and the

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phase or decimation origin is known. It does not cure missing samples at a block boundary, recover a pulse's rejected spectral components, or account for unmeasured analogue path delay. A receiver whose output events are compared to another instrument must disclose both the applied digital correction and its uncertainty.

Application 5. Scan exposure and the chance of encountering a brief event

Imagine a periodic 100 ms scan cycle in which the relevant band is continuously observed for 12 ms, followed by 88 ms of non-exposure. Assume an event occupies 1 ms, its starting phase is uniformly distributed over the cycle, and detection occurs whenever there is any temporal overlap with the observed interval. Then the measure of event-start phases producing overlap is 12 + 1 = 13 ms, yielding probability p_exposure = 13/100 = 0.13. This is an ideal geometric exposure result, not the probability of electronic detection given overlap. If the detector requires a minimum dwell within the event, the probability is smaller. If the event is phase-locked to the scan or the controller adapts its dwell, the uniform-phase assumption may fail. A report of continuous elapsed survey time does not substitute for this exposure calculation.

Application 6. A short pulse and narrowband temporal smearing

For an ideal rectangular pulse of duration T = 10 microseconds, the magnitude of its Fourier transform has first zeros spaced approximately 1/T = 100,000 Hz from its centre in the baseband envelope. If a decimated channel passes an effective 5,000 Hz width, its admitted interval is only 5/100 = 0.05 of that first-null scale. It follows that the

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channel cannot preserve the complete spectral structure required to reconstruct the original sharp-edged rectangular pulse without additional assumptions. The surviving impulse response may remain useful for timing a known pulse family, but a displayed output width must be interpreted through the filter response. The 5% comparison is descriptive, not an assertion that precisely 5% of pulse energy survives, since energy transmission depends upon the complete spectral density and filter shape.

Application 7. Recording cost and the meaning of a data reduction

Suppose each complex sample is stored as signed sixteen-bit I and sixteen-bit Q integers, four bytes per complex sample, with no container overhead. At 40 million complex samples/s the nominal raw rate is R_in = 40,000,000 × 4 = 160,000,000 bytes/s, or 160 MB/s and 576 GB per hour. After factor-twenty decimation to 2 million complex samples/s, R_out = 2,000,000 × 4 = 8 MB/s and 28.8 GB per hour. The capacity saving is 547.2 GB per hour, a compelling engineering advantage. It does not grant the reduced file access to the discarded 547.2 GB of samples. A dual-tier retention design can reserve higher-rate witness intervals without pretending that the inexpensive continuous channel is a complete copy of the original observation.

Application 8. Sensitivity estimated from an unselected challenge population

Assume an independently predeclared challenge campaign contains n = 1,000 valid trials within a clearly defined operating envelope, with k = 985 detected under an unchanged threshold. The observed detection

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fraction is p_hat = k/n = 0.985. A Wilson score interval at approximately 95% confidence, using z = 1.96, has centre (p_hat + z^2/(2n))/(1+z^2/n) and half-width z × sqrt[p_hat(1-p_hat)/n + z^2/(4n^2)]/(1+z^2/n). This yields approximately 97.54% to 99.09% after rounding. The interval assumes independent Bernoulli-style challenge outcomes with a stable trial probability. Correlated adaptive states, post hoc trial selection and shifts in signal class can invalidate that model. Above all, the interval describes the declared challenge population, not unseen frequencies that the decimated recorder never observed.

Application 9. Multiplicity and the interpretation of an isolated spectral alarm

If each of m = 10,000 independent noise-only tests has a false-alarm probability alpha = 0.00001, then the probability of at least one alarm is P = 1 - (1-alpha)^m. Substitution yields 1 - (0.99999)^10000, approximately 0.09516, or 9.516%. Thus a very small per-test false-alarm probability can coexist with a materially larger chance of at least one false indication across an extensive survey. Adjacent FFT bins and overlapping filterbank channels are often dependent, so the independence calculation is illustrative and should not be presented as an exact field result. The actual joint false-alarm behaviour of the channeliser requires a suitable model or challenge experiment. Retaining only the most conspicuous detection without the tested population hides this multiplicity.

Application 10. Relative filter delay and apparent source displacement

Consider two otherwise synchronised receivers whose derived files differ by an uncorrected six output samples at F_out = 2 MHz. The

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relative time bias is delta_t = 6/2,000,000 = 3 microseconds. If that entire bias were mistakenly converted into a propagation-distance difference using the free-space speed c approximately 3.0 × 10^8 m/s, the apparent range-difference bias would be c delta_t = 900 metres. This number is a difference-of-path-length equivalent, not a unique geolocation error or a claim about any actual transmitter. Real localisation depends on geometry, propagation conditions and other uncertainties. The example shows why differences of digital filter phase, decimation origins or unreported state transitions cannot be treated as negligible merely because the resulting time stamps contain many decimal places.

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References and research-read scope

[R1] SciPy Developers, `scipy.signal.decimate` reference documentation, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.decimate.html . The online reference was consulted for its distinction between low-pass filtering before downsampling, selectable FIR/IIR implementations, and zero-phase or group-delay treatment. This source supports implementation contrasts, not claims about the performance of the hypothetical receivers.

[R2] GNU Radio, *Rational Resampler* documentation, https://wiki.gnuradio.org/index.php/Rational_Resampler . The published page was consulted for its input-output rate relationship, FIR polyphase structure and the instruction to design coefficients to avoid aliasing and images. It does not independently verify any numerical case in this chapter.

[R3] Scientific Working Group on Digital Evidence, *Best Practices for Digital Evidence Collection*, SWGDE 18-F-002-2.0, 30 June 2025, https://www.swgde.org/documents/published-complete-listing/18-f-002-2-0/ . The published web version was consulted for evidence integrity, acquisition hashes, contemporaneous documentation and chain of custody. The document concerns digital evidence generally; application to SDR recordings is the present author's analysis and does not imply SWGDE certification of this manuscript or receiver.

The cited pages establish selected implementation and evidential principles only. All dialogue, test scenarios and numerical cases are newly constructed. No original historical transcript has been asserted or reproduced.

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QUESTION 037

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How may oversampling reduce in-band noise without increasing the independent information available?

Source: V011_Roundtable_Question_037_CP037_Dr_Atkinson.docx | Recovered substantive manuscript. Constructed educational dialogue.

Original constructed educational dialogue, rather than a transcript or an historical quotation. The historical participants are intellectual personae, not witnesses to contemporary SDR instruments. All numerical examples are hypothetical and require apparatus-specific validation before any forensic use.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, the subject now before us is the apparently paradoxical capacity of an instrument to deliver a quieter digital record without necessarily telling its examiner more independent things about the physical world. A wideband analogue-to-digital converter produces a torrent of codes, its clock multiplying the familiar rhythm of an ordinary receiver by hundreds or thousands. After digital low-pass filtering, a trace may appear considerably smoother, a narrow spectral line may stand more distinctly above the surrounding noise, and a numerical estimate of amplitude may have smaller variance. Such advantages are genuine when their premises are established. They do not, however, justify the casual assertion that a twelve-bit converter has become an intrinsically twenty-four-bit instrument, that each heavily overlapped spectrum represents an independent observation, or that a faint emitter has been uniquely identified merely because a processing display looks serene.

We should begin with the quantity to be estimated. Let F_s denote the sampling frequency in samples per second, B the one-sided low-pass

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bandwidth of interest in hertz, and $R = F_s/(2B)$ the nominal oversampling ratio for a real, low-pass, uniformly sampled signal. When quantisation error is sufficiently well approximated by broadband, uncorrelated noise with nearly flat spectral density, ideal filtering that retains the interval from zero to B admits approximately the fraction 1/R of its original first-Nyquist-zone noise power. Thus the ideal processing gain is $G_p = 10 \log10(R)$ decibels and the corresponding ratio of root-mean-square noise amplitudes is sqrt(R). Each factor of four in R produces approximately six decibels of in-band signal-to-noise improvement, equivalent to one bit of ideal quantisation SNR under the conventional full-scale sine-wave convention. These are conditional statements about a filtered estimate, not statements that the physical converter suddenly acquires four times as many thresholds or that the same analogue event has been recreated in several independent copies.

A second set of quantities concerns information rather than code width. Let x(t) be the analogue input over a finite observation period T, h(t) the combined analogue transfer function, q[n] the quantisation error at sample index n, and $n_a(t)$ the analogue noise that exists before quantisation. The digitised sequence is a function of x(t), h(t), $n_a(t)$, the sampling times and the converter transfer characteristic. Once the input has encountered saturation, an unresolved analogue alias, or a sampling clock whose relevant phase is unknown, multiplying the number of digital samples cannot restore the missing causal record. If the measured disturbance is common to every sample, summing or averaging those samples may preserve the disturbance exactly. If adjacent samples are correlated through

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a low-pass filter or through a common oscillator, a naive standard error calculated as though each were independent may be grossly optimistic.

The law of the apparatus is no less important than the arithmetic. Suppose a defensive survey records several channels at an enormous aggregate rate, then lowers their bandwidth and averages power estimates to expose emissions barely distinguishable from the noise floor. The technique may reduce the variance of an in-band estimator, provided the emitter remains within the admitted bandwidth and observation interval, the gain remains linear, the noise process satisfies the model, and the detector's false-alarm calibration accounts for the search procedure. Yet when a noise reduction is achieved by integrating longer, an intermittent emission might be diluted or missed, and the resulting archive might become incapable of answering whether the event lasted a microsecond or a second. More digits and a cleaner waterfall cannot resolve that ambiguity. We must distinguish raw sample rate, information bandwidth, independent degrees of freedom, estimator uncertainty, event-detection sensitivity and the evidential status of source attribution.

Mr Nyquist will first examine the conditions under which a denser sampling lattice contains redundancy. Dr Shannon will distinguish an information-preserving representation from a genuinely new observation. Dr Bennett will discuss whether quantisation error can legitimately be treated as white and independent. Professor Slepian will examine finite observation windows, time-bandwidth concentration and the rank of filtered data. Professor Tukey will then test our statistical assertions against selective searching, correlated trials and the fallacy of treating every time-frequency bin as an independent experiment. Seven peers will challenge

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those positions, and each response must follow the challenge immediately. We shall require the principal speakers to say not only what improves with oversampling, but also what it leaves untouched, and which adversarial measurement could distinguish the alternatives. Mr Nyquist, may I invite your examination of the relationship between a denser lattice of samples and the physical information represented by those samples?

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Harry Nyquist | Principal response 1: Sampling density, independent degrees of freedom and the original signal

Dr. Atkinson, one must not mistake the spacing of measurements for the dimensionality of the object measured. An analogue signal whose Fourier content is confined to a finite band is not an arbitrary value at each infinitesimal instant. Under the relevant mathematical assumptions, sufficiently spaced samples can determine the signal, and a more closely spaced sequence represents the same function with additional redundancy. If the analogue bandwidth remains fixed while the sample rate rises, the number of stored digital words increases; nevertheless the physical waveform does not thereby acquire additional independent variations. The higher-rate representation can make realisation of the antialias filter more practical, permit convenient digital frequency translation and reduce the consequences of certain kinds of error. But it is wrong to infer from the sample count alone that the physical event supplied proportionately more independent evidence.

Let B be a one-sided band limit and T the retained observation time. A real band-limited process observed over that interval has a nominal time-bandwidth scale of order 2BT real degrees of freedom, subject to the precise signal class, boundary convention and effective temporal concentration. If F_s is much larger than 2B, the recorded sample count is $N = F_s T$, which may be much larger than 2BT. This is not a contradiction. The extra codes can be correlated representations of the same latent waveform. Oversampling is nevertheless useful when the codes include noise that is not perfectly correlated with the signal or each other, and the estimator can average the disturbing component without equally erasing the quantity

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sought. One must say whether that disturbance arose before the analogue bandwidth restriction, inside the converter, or after acquisition; the location can change the calculation materially.

Consider a slowly varying source measured repeatedly with an instrument that adds independent zero-mean error on each conversion. For an estimator of a constant mean, M repeated observations with identical independent variance sigma squared possess a sample-mean variance sigma squared divided by M. Here the repeated conversions are genuinely providing multiple noisy observations of one fixed parameter, and their aggregation improves precision. The physical source value has not multiplied into M distinct parameters. Moreover, the assumption of independence cannot be established by the numerical labels assigned to the observations. When the input contains a common fluctuating disturbance, or when a digital low-pass filter has coupled adjacent output errors, the covariance terms survive. That observation is the critical bridge between engineering sampling and forensic uncertainty.

For a time-varying signal, adjacent samples need not observe the same value. Directly averaging them is a form of filtering, and its output is properly a filtered version of the source with a specified impulse response and group delay. A weak continuous carrier may benefit from narrowband estimation, because its phase trajectory is compatible with the chosen observation interval. A short burst may not. Averaging across its onset and termination can reduce the measured peak even while reducing random noise more strongly. Consequently a detection statement should identify not only F_s but also the time support of its filter, the window used to estimate energy and the threshold applied to the resulting statistic. A paper

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report that quotes 'an extra three bits' but omits these variables fails to define the asserted performance.

The apparent resolution gain sometimes attributed to oversampling must also be expressed with care. In an ideal uniform converter of N bits, quantisation intervals are determined by its reference and transfer characteristic. The number of code bins does not increase when a faster clock is fitted. A derived result may legitimately be expressed to more fractional digits than one raw code if there is enough independent noise or dither to explore neighbouring codes and the averaging model has been validated. Such a number is an estimate with an uncertainty distribution; its additional fractional digits are not fresh analogue threshold comparisons. If the input is stuck within one quantisation interval and no appropriate variation causes code transitions, repeating its identical code a thousand times cannot reveal its exact location within that interval. The experiment may be very repeatable and wholly insensitive to the sub-code distinction the report attempts to infer.

In a defensive survey of faint emissions, the preferred experiment changes a physical condition. Compare detector performance with and without a validated decimation filter; inject calibrated weak tones and bursts at random times; test several input amplitudes, frequencies and duty cycles; and measure the fraction of trials detected at a fixed false-alarm budget. A spectral noise-floor reduction is not a substitute for the receiver operating characteristic. Equally, if a real source is rejected by the narrowband filter because its frequency falls outside the preserved passband, no improvement in the retained bins supplies evidence that the source was

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absent. One must define the useful information as information about a specified measurand rather than information in the philosophical abstract.

There is another common error in multi-converter arrangements. Placing twelve identical converters on the same analogue voltage does not automatically create the effective resolution of a single converter with the sum of their nominal bit counts. If their errors were independent under a justified model, combination might reduce variance for a common quantity. If they share a voltage reference, clock, driver distortion or electromagnetic interferer, covariance may dominate. Their outputs cannot by arithmetic alone reveal distinctions suppressed by every common transfer characteristic. Even if their errors are independent, doubling the number of independently noisy observations improves the variance of a mean by a factor of two, not the intrinsic quantisation threshold count by two powers of the nominal bit depth.

I therefore recommend a two-column validation record. One column describes properties of the acquired physical input: bandwidth, duration, amplitude range, source conditions and known interferers. The other describes properties of the estimate: sampling grid, filter, number of input codes, effective noise bandwidth, covariance treatment, uncertainty and detection threshold. The conclusion must say which properties were observed and which were inferred from assumptions. Where a mathematical representation is redundant, its redundancy may protect against noise or help numerical implementation. It does not annul the information limits established by the input path. Mr Black, whose feedback work reminds us of the danger of hidden common errors, may now

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challenge this distinction. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Harold Stephen Black | Peer question 1 to Harry Nyquist

Mr Nyquist, you distinguish redundant sampling of one waveform from independent perturbations that make its estimate more accurate. I should like to examine a receiver whose analogue input is supplied by an amplifier with automatic gain control and a reference voltage shared by every converter. The displayed spectrum becomes quieter when the sampling rate is quadrupled and the output digitally filtered. Yet the amplifier may have altered gain while a weak burst occurred, and the reference may wander at a rate slower than the acquisition period. How would you separate noise averaging, gain variation and a common reference excursion in an acceptance test? In particular, would an observed six-decibel reduction in a selected frequency interval demonstrate that the system preserves the physical amplitude of that burst, or might a clean estimate be obtained by suppressing precisely the variation an examiner needed to observe? Which changes to the test input and system configuration would make the rival explanations produce visibly different records?

Harry Nyquist | Immediate answer to Harold Stephen Black

Mr Black, a six-decibel reduction alone would demonstrate only a relationship between two displayed noise statistics under the conditions in which it was measured. The analogue gain trajectory and reference-voltage history require their own observations or validated bounds. Begin by fixing automatic gain where the architecture permits, recording the reference voltage against a

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separately characterised standard, and measuring both raw and derived samples under a stable injected input. This establishes a baseline in which the processing effect can be examined without conflating it with an unrecorded control loop. Then restore the gain-control function and challenge it with known strong interferers and weak bursts positioned unpredictably. The experiment should compare the actual gain state, true-positive rate, measured burst amplitude and detection latency, not merely one spectrum's average noise floor.

A common reference excursion is particularly instructive because the same error can influence many simultaneous conversions. The improved precision of a filtered estimate does not imply improved absolute accuracy relative to the original analogue boundary. If the reference rises, the inferred volts per code may change, and every channel may agree on an erroneous calibration. The calibration campaign must distinguish relative repeatability within a common reference from traceability to an independent physical standard. A second reference or a recorded calibration stimulus can add evidence if its own path and uncertainty are disclosed, but a second display driven by the same reference does not create independent corroboration.

The strongest test is one in which the anticipated outcomes differ. Under an ideal independent-noise hypothesis, noise power within a fixed bandwidth should decline in the predicted proportion when the acquisition and filtering conditions change, while the calibrated in-band signal amplitude remains stable. Under a gain-drift hypothesis,

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the result should correlate with recorded gain changes or injected amplitude, including possible nonlinear departures. Under a reference-wander hypothesis, scale errors should appear coherently across branches and correlate with reference monitoring. Tests should be repeated across relevant temperatures and operating modes. If evidence remains insufficient to distinguish those mechanisms, the result should be described as a processing-noise improvement with unresolved amplitude calibration, not as a more accurate reconstruction of the historical event.

I would further distinguish weak-burst detection from steady-tone SNR. A processing chain can improve the mean detection statistic for an event whose duration and bandwidth match the chosen filter, yet delay its onset or reduce its peak for a shorter event. The reported capability should therefore be a function of burst duration, frequency and amplitude, with a declared false-alarm rate and observation exposure. If the instrument is to support a negative search finding, these conditional performance surfaces matter more than a generalised number of 'extra bits'. Such discipline leaves the useful advantages of oversampling intact while preventing them from carrying a claim they cannot prove. I pass the floor courteously to Professor Bridgman, whose question concerns the very meaning of a derived measurement.

Percy Williams Bridgman | Peer question 2 to Harry Nyquist

Mr Nyquist, the operator may define a quantity as the amplitude of a narrowband component at the antenna terminal, but what the instrument actually stores is the output of a cascade of analogue

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filtering, quantisation, digital downconversion and averaging. Even where the sampling theorem assures us of mathematical redundancy, the experiment may not have established that the earlier analogue filters were linear, stable or correctly matched to the intended quantity. If a technician can tune the filter to make the trace quieter and then label the resulting amplitude as a terminal voltage, what prevents that label from becoming merely an untested convention? I ask you to specify the relation between an operational definition and an evidential report. What should be retained to show that a change in oversampling ratio changed the estimator uncertainty rather than changed the physical quantity to which the displayed result refers? Would you additionally require the amplifier gain history and the prefilter calibration record?

Harry Nyquist | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, the result requires a declared reference plane and a measured transfer relationship. We should not define an antenna-terminal voltage by the numerical value displayed after an arbitrary filter; rather we should specify the intended terminal quantity, the admissible class of input waveforms, and the chain of transformations by which the instrument estimates it. The transfer function may be measured for appropriate stimuli, with uncertainty that reflects load mismatch, component variation, gain state and frequency dependence. A different oversampling setting can be shown to address the same measurand only if the two settings have a validated relation to that same physical boundary. When that relation does not hold, the correct result is that the instrument produces distinct operationally defined quantities.

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For instance, a narrowband sinusoid at a known frequency may be corrected for a measured filter gain, provided the filter is operating in its characterised linear region and the time interval is appropriate. A transient of unknown waveform and broad spectrum cannot necessarily be corrected by the same scalar gain. The proper calibration for that signal may require the full impulse response, and a filter with zeros or discarded frequencies can make the inverse nonunique. A cleaner output does not alter these facts. I would preserve the raw input codes when justified by the forensic stakes, the filter coefficients, gain calibration, sample-clock record, processing version and the input-reference definition. Where a raw archive is impracticable, the report must state its limitations explicitly.

The direct experimental comparison should inject representative signals at the boundary of the claim, not only at a convenient internal digital node. A calibration stimulus injected after the analogue front end establishes properties of the digital chain; it does not certify the antenna, amplifier or mixer. The investigator should compare settings at equal input stimulus, monitor configuration state and preserve any difference which remains beyond the combined uncertainty. A valid change in processing ought to reduce a specified variance without materially shifting the mean or relevant temporal features for the admitted signal class. If the change also alters those properties, the two outputs cannot be described as interchangeable evidence without a further model. The aim is to permit useful uncertainty reduction while ensuring that the physical quantity being discussed remains the same throughout the report.

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With that distinction established, Dr Shannon may examine whether a mathematically faithful representation can create information that was not present in the analogue observation.

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Claude Elwood Shannon | Principal response 2: Noise reduction, data processing and the interpretation of information

Dr. Atkinson, the word *information* deserves particular care, because it may refer to a physical source, a random parameter, a stored digital record, or the uncertainty of an estimator. These objects have distinct distributions and distinct questions attached to them. If a signal passes through a deterministic transformation, the transformation does not manufacture independent knowledge of the original source. In probabilistic terms the data-processing inequality states that, for appropriately defined random variables X, Y and Z forming a Markov chain X to Y to Z, the mutual information satisfies I(X;Z) no greater than I(X;Y). A digital filter whose output Z is computed from acquired samples Y cannot increase the information that Y held about a source variable X. It can, however, make that information more accessible to a restricted detector, remove nuisance variation irrelevant to a particular inference, and reduce the variance of a useful estimate. The apparent paradox arises when those improvements are described as the creation of independent physical observations.

The inequality does not imply that all processing is futile. A recorded sequence may contain a weak carrier buried among numerous frequencies, while an operator can inspect only a limited display. A suitable matched estimator or narrowband filter may concentrate the source-dependent component into a decision variable with a much clearer separation between hypotheses. Relative to the practical decision procedure before processing, performance may improve substantially. Relative to an ideal observer supplied with the complete acquired sequence and the correct probability model, the deterministic processing has not introduced information from

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outside that sequence. The distinction is between a better use of existing evidence and the generation of new physical evidence. A useful manuscript must not collapse these propositions into a slogan.

Now consider an input consisting of a band-limited waveform plus broadband noise. The filtering operation may discard frequencies in which the source of interest has no energy, thus reducing admitted noise. If the source really lies within the specified band and the unwanted noise occupies the rejected band, the estimator is improved for that task. But if a forensic question later asks whether a neighbouring carrier drove an amplifier into intermodulation, the discarded frequencies may have contained precisely the competing explanation. The narrower statistic can remain excellent for estimating the in-band amplitude while becoming inadequate for discriminating source hypotheses. One must define the source variable and the loss function before declaring an information gain or loss. Without that definition, an argument over the number of bits in a file is an argument about labels rather than evidence.

Sampling at a rate above the necessary spectral width may improve the physical process when the faster acquisition is paired with a different analogue filter or the opportunity to characterise timing jitter, because those are changes to how the world is measured rather than merely deterministic transformations of a fixed record. A faster sample rate can also permit a more forgiving antialias transition band and help avoid folding unwanted emissions into the region of interest. Those improvements may make the acquired data more informative than data from an otherwise different, slower instrument. The data-processing inequality must not be misused to say that a superior sensor cannot collect better information. It

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says that once one particular observation is fixed, a subsequent computation cannot conjure an external fact absent from it. Comparing distinct acquisition chains requires a physical model, not only an information-theoretic ordering.

The apparent addition of resolution by averaging is likewise a matter of statistical inference. If each raw conversion contains a noise component conditionally independent given a fixed analogue parameter, their combination can reduce posterior or frequentist uncertainty about that parameter. The quantity of information may increase because the device took additional, physically distinct noisy measurements, though those measurements concern the same parameter. If, by contrast, one noisy conversion is copied many times into memory and processed as though the copies were independent, no such gain follows. More subtly, when adjacent samples share an analogue disturbance or an adaptive filter has produced overlapping outputs, the dependence structure reduces the effective number of observations. One cannot infer that structure from the sample rate alone.

Consider a case in which twelve converter channels are connected to the same reference and driver. Their independent comparator noise may average down, but their common reference variation does not. A model $y_i = \text{theta} + u + e_i$, where theta is the intended physical quantity, u is common error and e_i independent error, makes the point. The mean of M channels has variance $\mathrm{Var}(u) + \mathrm{Var}(e_i)/M$ if the terms are centred and appropriately independent. As M increases, the independent term vanishes but the common error remains. No multiplication of channel counts can remove Var(u) merely by arithmetic. Nor does the measured variance alone reveal

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whether the remaining error is a bias relative to a traceable standard. That requires a calibration which supplies independent evidence about theta and the reference plane.

A detective may ask whether a low-power emission existed in a corridor for a fleeting interval. The hypothesis is not a continuous sinusoid over an arbitrary observation time. An integration that improves a steady carrier's decision statistic might smear the fleeting event into the baseline, especially if the filter's temporal response spans a longer interval than the event. A good report supplies conditional sensitivity by signal class, not merely a universal processing gain. It also states which frequencies, times, receiver states and amplitudes were actually examined. The posterior odds of a source hypothesis depend upon prior assumptions as well as the likelihood, while a conventional significance level measures a different quantity. Neither should be disguised as a bit-count enhancement.

I recommend retaining an explicit map of transformations and their domains. Label the raw samples and all independently observed calibration stimuli. Label the derived statistics, filter coefficients and any information discarded. A derived stream may be reproducible to the last bit and still be inadequate to answer a later question, while a seemingly noisy raw record may contain a short event invisible in a smoothed report. The correctness of the computation and the adequacy of the evidence are separate matters. The most honourable statement is that oversampling and filtering improved a specified estimate, subject to stated bandwidth, noise and timing assumptions. They do not independently certify a transmitter's existence, location or identity. I pass the floor respectfully to Dr Hamming to test the practical consequences of these distinctions for receiver engineering.

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Richard Wesley Hamming | Peer question 3 to Claude Elwood Shannon

Dr Shannon, you describe filtering as a transformation that cannot increase the information contained in the acquired record. Yet engineers routinely find that a carefully filtered output permits reliable reception of a signal that a less sophisticated receiver cannot recognise at all. To the operator who must decide whether an adversarial transmitter is present, this appears to be a real increase in information, not merely a mathematical rearrangement. How should we reconcile your formal inequality with an experiment in which detection rises from twenty per cent to ninety per cent after oversampling and narrowband processing? I also ask whether a task-dependent sufficient statistic may be considered adequate evidence even when it discards much of the source record. At what point must the investigator retain the complete stream because a later challenge may require information outside the original detection hypothesis? Please identify a practical distinction between sufficient mathematical compression and an archive that merely hides unknown alternatives.

Claude Elwood Shannon | Immediate answer to Richard Wesley Hamming

Dr Hamming, the improvement is entirely consistent with the formal statement once the random variables and the comparison are correctly identified. A detector examining an unsmoothed display with a poorly chosen threshold may fail to exploit information present in the raw data. A more effective algorithm can recover that opportunity. The inequality refers to the full distribution of the observation under

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an optimal or appropriately defined decision problem; it does not claim that every practical observer has equally good access to the evidence. If the original comparison is between two distinct physical receiving systems, one of which employs an antialias filter and a more capable converter, we must compare their acquisition channels rather than invoke an inequality between data and its deterministic transformation.

Your example of detection increasing from twenty to ninety per cent requires an additional qualification. Those percentages may concern different false-alarm rates, test populations, signal classes or thresholds, and cannot be compared until the acceptance conditions are aligned. If all else is genuinely held constant and the algorithm is improved, the gain should be welcomed. But an observed true-positive rate is conditional on how the test signals were drawn. It is not the probability that every alarm represents an external source. A stable receiver-generated spur may be detected with excellent sensitivity. A detector's performance and the attribution of a signal to a physical transmitter require separate experiments.

A sufficient statistic is sufficient for a specified model and parameter, not for all imaginable future disputes. For a known waveform observed in independent Gaussian noise with specified covariance, an appropriate matched statistic may preserve the information needed for a narrowly defined amplitude or detection decision. If a later examiner disputes the noise model, asks about out-of-band interferers, or proposes a different waveform, that statistic may cease to be sufficient. The original investigator should therefore

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decide preservation policy by the evidential stakes and foreseeable rival explanations. Where comprehensive retention is impossible, the policy can use bounded raw snapshots, challenge intervals, and state logs, but should disclose the resulting exclusions rather than quietly call the retained statistic complete evidence.

The acceptance report must separate three claims. First, a digital operation can be reproduced from the archived input and software version. Second, under a validated model, its output may estimate a defined quantity with reduced uncertainty or meet a declared detector performance target. Third, the resulting feature may or may not originate from an external emitter. A successful demonstration of the first two does not automatically establish the third. My formal argument protects against that illicit leap while allowing a well-designed receiver every practical improvement it can earn. Professor Hotelling may challenge how the requisite covariance model can be estimated from a finite record without simply asserting independence.

Harold Hotelling | Peer question 4 to Claude Elwood Shannon

Dr Shannon, your common-error model is instructive, but the engineer seldom knows the covariance of the noise before collecting the very observations whose uncertainty must be reported. In a receiver that updates noise estimates continually, the process may be nonstationary: gain and temperature change, interfering transmitters enter and leave, and the sample stream may be filtered into strongly overlapping windows. If the investigator calculates a covariance matrix from those selected windows, the estimate may be unstable or biased by the

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selection rule. How would you decide whether a reduction in observed variance represents true improvement in the desired estimator or a model fitted too closely to a favourable collection of observations? And would you prefer a broad covariance model with many parameters or a deliberately restricted model whose residuals can be challenged with independent reference stimuli? I ask especially how the answer should affect confidence intervals for weak, intermittent detections rather than for stationary laboratory sine waves.

Claude Elwood Shannon | Immediate answer to Harold Hotelling

Professor Hotelling, no algebra can compensate for a covariance estimate that is not representative of the circumstances in which it is used. I would therefore specify the observation population before fitting the model. The record should identify signal classes, temperatures, input gain states, frequency bands, observation times and known interference conditions. It should preserve enough unselected intervals to estimate the background rather than drawing every training example from an alarm archive. For a system whose noise changes with operating state, one may require separate conditional models or an explicitly time-varying model rather than an optimistic single covariance matrix. The choice should be tested against data withheld from the estimation process.

A broad model may capture complex correlations, but if its parameters are weakly identified it can produce artificial precision. A simpler model, openly qualified, may be preferable when it permits clear residual tests. I would examine whether the estimated correlation decays as predicted, whether the variance of means over

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progressively longer blocks follows the proposed scaling, and whether challenge signals are recovered at the claimed amplitudes. Comparing non-overlapping blocks and overlapping windows can reveal mistaken degrees-of-freedom calculations. An independently injected stimulus provides a way to test the estimator's response, though it does not alone prove that every real emitter matches the stimulus model.

For weak intermittent events, the uncertainty should include the event-selection mechanism. An interval stored because its statistic exceeded a threshold is not a random sample from the full noise population. Calculating a confidence interval as if it were unselected can distort coverage. A suitable design might predetermine challenge positions, randomly inject pulses across the accessible band and quantify detection and false alarms under matched conditions. The resulting performance statement can be indexed by duration, amplitude, frequency offset and receiver state. Where adaptive acquisition makes the sampling law complicated, one should report a conditional or simulation-supported bound and disclose the model assumptions, rather than imply an exact analytic confidence level that was never validated.

Thus covariance estimation should be a measured part of the instrument qualification, not a decorative matrix inserted after the fact. It is evidence about how the sample stream depends upon its past, and its uncertainty must follow the inference. The panel now requires Dr Bennett's attention to the source of an especially

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seductive assumption: that every quantisation error is equivalent to independent white noise.

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William Ralph Bennett | Principal response 3: Quantisation, correlation and spectral artefacts

Dr. Atkinson, an ideal quantiser can be represented as the sum of its input and a quantisation error, but the engineering usefulness of that representation must not be mistaken for a proof that the error is always a random white process. For a converter with uniform step size Delta and no overload, the error lies within an interval of approximate width Delta, subject to the chosen code convention. Under a familiar high-resolution or appropriately dithered model, a zero-mean uniform error has variance Delta squared divided by twelve. That convenient result provides an rms scale. It does not, without additional assumptions, establish that consecutive errors are independent, that their spectrum is flat, or that the error is uncorrelated with the analogue input. The distinction is fundamental to claims about oversampling gain. [S1, S2]

Consider a very small periodic signal sampled at a frequency commensurate with its own period. The code sequence may follow a short repeating pattern, and the quantisation error may repeat along with it. Its energy can then concentrate into discrete harmonics or spurs rather than disperse as the broad floor assumed by the simplest noise calculation. Filtering to a narrow frequency interval may reject some of those components but retain others almost unchanged. If an apparent surveillance line lies exactly where a quantiser-related spur is expected, the signal cannot be certified as external merely because the nominal sampling rate was high. The operator must change stimulus frequency or amplitude, sample-rate relationship or dither conditions to see whether the feature

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follows the receiver's quantisation mechanism or the physical source hypothesis.

The phrase 'oversampling increases the number of bits' obscures a related limitation. A converter with twelve output bits continues to output twelve-bit words for each raw sample, no matter how frequently it is clocked. A later digital estimate may have a smaller noise variance after filtering, and it can be encoded into more bits so that rounding of the estimate does not forfeit the improvement. That is a statement about the precision of a derived quantity under a noise model. It is not a claim that a single conversion now distinguishes every tiny analogue amplitude difference that a twenty-four-bit ideal quantiser would resolve. If an input is perfectly constant and all raw conversions return the same code, the record leaves a finite interval of possible input amplitudes. Additional identical codes may establish stability of the output, not location within that interval.

A physically noisy input may sometimes supply the needed variation without deliberate dither. Thermal or front-end noise can cause a near-threshold analogue value to cross adjacent quantisation steps, thereby permitting a mean estimator to locate the underlying level more finely than one step, subject to calibration and the noise distribution. Deliberate dither may also break a harmful correlation. Yet its amplitude and spectral shape matter. An engineer cannot add arbitrary noise, average the outputs and assume improvement. Excessive dither can consume dynamic range and elevate the noise floor. Nonsubtractive dither leaves some added noise in the record; subtractive dither presupposes knowledge and preservation of the actual added sequence, together with the linear and timing conditions that make subtraction legitimate. Where dither was generated by firmware

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but its seed or implementation is unavailable, an independent examiner may be unable to reproduce the claimed correction exactly.

The distinction between independent and common errors is especially severe when several converters share one analogue input. Suppose each produces y_i = x + u + e_i, with u representing common driver or reference disturbance and e_i independent branch error. Taking an average of M branches yields x + u + the average of e_i. The independent contribution may decline in standard deviation approximately as one over the square root of M, but the common component is unchanged. If the common distortion is nonlinear, averaging may reinforce its harmonics rather than suppress them. A claim of twenty-four-bit or thirty-two-bit performance formed by concatenating or weighting twelve-bit outputs must therefore be justified by measured effective dynamic range, linearity, noise covariance and reference stability. Algebraically joining nominal bit widths is not a physical calibration procedure.

There is a second kind of hidden dependence. Even if raw white noise were independent from sample to sample, a digital filter computes adjacent outputs from overlapping sets of raw samples. Its derived outputs will in general be correlated. For a finite impulse response filter with coefficients h[k] and independent input noise variance sigma squared, the output variance is sigma squared times the sum of squared coefficients. The covariance between outputs separated by lag ell is sigma squared times the sum of h[k]h[k+ell], where the indices are restricted to defined taps. This covariance matters when investigators treat a succession of filtered values as repeated independent challenges. Their apparent quantity may exceed the effective sample size relevant to the estimate. The filter must be

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documented to permit that calculation, and the independent-noise assumption at its input must itself be tested.

An investigator should not assume that a change in clock frequency changes only the quantisation-noise distribution. In a real converter, higher clock rates may change aperture jitter, analogue input bandwidth, power dissipation, thermal state and reference settling. A noise floor lower in a narrow selected channel does not imply that the wideband dynamic range improved or that the converter will tolerate the same strong interferer. If a powerful authorised transmitter drives the front end into compression or creates intermodulation, more oversampling cannot reconstruct the original undistorted input from a clipped representation. The system should be tested under coexisting strong signals, not solely under the gentle conditions of a calibration sine wave.

The appropriate evidence includes raw-code histograms, converter transition tests, spur-versus-input-frequency plots, noise-power scaling against filter bandwidth, and repeated observations with independent calibration stimuli. A sufficiently characterised change in dither or frequency may distinguish quantisation-related components from an external emission. A line whose indicated RF frequency stays invariant when sampling frequency changes and whose amplitude follows antenna coupling may deserve further investigation, though these observations are not alone conclusive. A line whose location tracks a simple rational function of sample rate, or disappears only under a particular calibration update, suggests a receiver mechanism worth testing. The scientific purpose is not to attribute every unexplained feature automatically to a spurious cause. It

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is to preserve competing predictions and perform a discriminating experiment rather than rely upon a visually attractive waterfall.

I would report processing gain as a measured, bandwidth-qualified property, not as a universal increment in bit depth. An uncertainty budget must identify which noise powers were reduced and which systematic terms remained, with any covariance explicitly accounted for. The statement 'six decibels less in-band noise after fourfold oversampling under a stationary reference-tone test' can be meaningful. The statement 'the receiver now has one extra independent bit for every four samples under all conditions' is not an empirically justified replacement. I pass the floor to Dr Shewhart, who may press whether the reported noise distribution remained stable during the test rather than only in its selected successes.

Walter Andrew Shewhart | Peer question 5 to William Ralph Bennett

Dr Bennett, the ideal variance argument is carefully qualified, yet laboratory reports frequently establish the expected improvement from a single sequence of apparently stationary observations. In a practical receiver, temperature drift, gain control, oscillator changes and intermittent interferers may produce distinct regimes within that sequence. When the engineer pools all intervals into one convenient histogram, the overall shape may resemble white noise even though each local regime exhibits a different mean or dependence. I ask how the calibration should detect this instability before quoting the square-root law. Should the noise be characterised through control charts, frequency-specific tests, repeated independent sessions or a model of its time dependence? What evidence would distinguish ordinary stochastic fluctuation from a drift that invalidates the fixed-distribution

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assumption? And how should a failed stability test change the wording of the resulting forensic opinion rather than disappear into an updated calibration table? Should every excluded interval remain discoverable by an independent reviewer?

William Ralph Bennett | Immediate answer to Walter Andrew Shewhart

Thank you for that question. Dr Shewhart, I would regard stationarity and independence as hypotheses to be challenged, not privileges bestowed by the appearance of a bell-shaped histogram. The engineer should examine the time sequence at scales appropriate to the mechanism. Plot estimates of the local mean and variance across successive acquisition blocks, inspect autocorrelation and spectral density, and test repeatability across independently initiated runs. Temperature, gain, reference voltage and clock status should be recorded so that any systematic relation can be examined. A pooled histogram can conceal alternating means or persistent spectral lines, and a single pooled standard deviation does not prove that uncertainty diminishes with the nominal number of output codes.

Control charts can be useful for detecting departures from a declared stable regime, provided their limits are not tuned after inspecting the very anomalies they are intended to detect. A change point may justify dividing the data into separately characterised states. However, partitioning should not become a convenient way to remove every unfavourable result from the acceptance population. The test plan needs a predeclared rule for invalid intervals and a

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record of how many observations were excluded and why. A new calibration established after a failure should be tested against fresh challenge data. Otherwise the laboratory has trained upon the failure and then called its absence a validation of the revised system.

The model also requires a physical sensitivity analysis. If a converter spur varies with temperature, deliberately change temperature within safe operating limits and observe whether its amplitude or frequency follows the prediction. If a noise fluctuation follows automatic gain control, freeze the gain during a separate diagnostic run and compare. For an external candidate, alter the antenna connection, input attenuation or sample-clock ratio under conditions that generate different predictions for external and internal hypotheses. These interventions can be more informative than prolonged passive observation because they test a mechanism instead of merely describing the output distribution.

A failed stability test does not render every earlier sample useless. It narrows what can be claimed. If the process is stable over a documented subinterval, a conditional uncertainty statement for that interval may be warranted. If the noise distribution changed in unrecorded ways, the engineer may still report that a feature appeared in a given derived file, but cannot justify a universal false-alarm or sensitivity assertion from the unstable calibration population. The appropriate response is an explicit limitation or a new validated measurement campaign. In forensic work, preserving the failed runs and calibration versions is particularly important. They may reveal whether an apparent source characteristic is a property of

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the receiver itself. I invite Professor Slepian to consider how the finite duration of the record constrains the very meaning of a noise estimate.

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David Slepian | Principal response 4: Time-bandwidth concentration and finite observation

Dr. Atkinson, the infinite-length sampling theorem is a useful guide but a poor substitute for an honest description of finite observations. A practical surveillance record has a beginning and an end, and its Fourier components are therefore subject to windowing, leakage and uncertainty about events near the boundaries. Oversampling supplies more numerical samples inside the same physical interval; it does not lengthen the interval. If the desired spectral discrimination requires prolonged observation, a denser lattice by itself cannot provide the frequency resolution associated with additional elapsed time. The nominal DFT-bin spacing is F_s/N, which for $N = F_s T$ is one divided by T. Doubling both F_s and N while keeping T fixed leaves that spacing unchanged. This elementary fact should accompany every claim that a denser data stream automatically resolves closer carriers.

A continuous carrier observed for a fixed time can be estimated with a method whose uncertainty depends upon signal-to-noise ratio, phase coherence, window and model. Oversampling may reduce in-band noise in ways that help that estimate, but it does not remove the duration requirement from the problem. An intermittent burst presents a different challenge. To locate its onset accurately, the acquisition must retain enough bandwidth and timing information; excessive smoothing can spread the event across a longer apparent interval. A filter with a long impulse response may attenuate or delay the feature, and the position of the event relative to the processing block can determine the reported peak. A brighter or quieter display does not certify an accurate burst onset.

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The relevant mathematical framework concerns the concentration of a signal in finite intervals of time and frequency. No nonzero waveform can be both strictly time-limited and strictly band-limited in the ideal mathematical sense. A practical signal may nevertheless concentrate most of its energy within specified bounds, allowing useful approximations and well-designed tapers. Their performance must be characterised in the situation of interest. The nominal count 2BT gives a useful scale for independent real degrees of freedom under conventional assumptions, but it is not a certificate that every sequence of 2BT computed numbers is independent. Window overlap, filter response, noise colour and estimator choice all matter, and the appropriate effective degrees of freedom may be lower than the numerical count of outputs.

Suppose a receiver uses a sixteenfold oversampling factor and digitally decimates to a fixed channel. The output rate is reduced but the signal may retain its in-band content if the antialias filter and transition region are adequate. That digital operation can improve the practical noise characteristics of the channel. It also discards other portions of the sampled spectrum. If the later forensic question asks whether an external wideband burst or an out-of-channel strong carrier coincided with the candidate, the narrowband file may be inadequate. Thus oversampling followed by decimation should be understood as an acquisition and preservation policy: its benefit is meaningful for the admitted measurand, and its exclusions must be visible in the archive.

One can illustrate the tradeoff without exaggeration. If a real signal occupies a one-sided information bandwidth B of 100 kilohertz and is observed for T = 20 milliseconds, the scale 2BT is 4,000 real degrees of

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freedom. Sampling at four megasamples per second yields 80,000 raw samples over that same interval. The eighty thousand numbers may encode the waveform with useful redundancy and noise information, but they cannot imply eighty thousand independent time-frequency features of the underlying band-limited source. A subsequent filter may produce a low-variance estimate by reducing unwanted noise, yet the finite observation still contains only twenty milliseconds of the event. The temporal span cannot be multiplied by a faster sampling clock.

The statistical part deserves equal care. If a detector examines many heavily overlapping windows, a signal near a boundary can appear in several windows. These are not several independent detections of separate physical events. Counting them as independent votes artificially inflates confidence. A correct report distinguishes detections from unique event clusters, documents the overlap fraction, and calibrates false-alarm performance at the level of physical events rather than individual output pixels. Conversely, if the detector selects only a small number of windows for retention, non-events and gaps must be accounted for when estimating sensitivity or occupancy. One cannot infer the prevalence of emissions from a gallery containing only the successes that triggered the recorder.

For validation I propose challenge signals of varied duration relative to the filter support. Test pulses wholly within a processing block, at its boundary and across two blocks. Preserve the raw acquisition during the challenge and compare the derived amplitudes, onset times and detected-event counts. Include noise-only intervals to measure false alarms, and test coherent and incoherent interference to distinguish which spectral reductions are predicted by the model. The filter impulse response should

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be measured or verified under relevant settings, including retune and gain changes. The practical outcome is a performance surface, not a single flattering SNR number. It may show that the receiver is excellent for persistent narrowband signals but much less sensitive to very short bursts at particular channel or window boundaries.

The word 'resolution' must accordingly be separated into at least three senses. The code resolution is the quantiser's number of levels; the spectral discrimination is governed partly by observation duration and estimator; the temporal localisation depends upon admitted bandwidth, filter dynamics and recorded timebase. Oversampling can benefit the error distribution of a particular derived estimate without making all three resolution measures increase together. It may even trade one property against another if longer filtering is used to achieve a lower noise floor. The only reliable conclusion is one that states the tradeoff, validates it for the signal classes at issue and preserves enough raw or intermediate evidence for independent review. I pass the floor to Sir Ronald Fisher, who may test whether the claim of increased reliability respects the actual number of independent trials.

Sir Ronald Aylmer Fisher | Peer question 6 to David Slepian

Professor Slepian, you have distinguished many output samples from a smaller number of physical degrees of freedom, but the forensic examiner is often presented with a table containing thousands of apparent detections across overlapping spectra. Each cell has its own test statistic and an associated nominal significance level. If the tests are strongly dependent, naive multiplication of their individual successes can create an impressive but unfounded assertion of confirmation. Would you require an explicit joint probability model, an empirical familywise

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calibration, or a count based upon independent physical challenge events? How should the laboratory handle a fixed threshold selected after viewing the most attractive waterfall image? And does increasing the oversampling factor help distinguish the emitter from the receiver when the same line is visible in many correlated windows? I seek a rule that allows rigorous inference without claiming that every possible waveform hypothesis has been exhaustively enumerated. Would a predeclared exposure denominator help prevent duplicate counts?

David Slepian | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, the first rule is to define the elementary observation that the decision concerns. If the question is whether one physical burst occurred during an interval, overlapping windows that all respond to that burst should normally be treated as related evidence about one event, not as independent events. A detector can extract several useful features from those windows, but its familywise false-alarm behaviour must be calibrated at the level of the declared decision. A suitable joint model may be justified for a stationary laboratory process. Where dependence and adaptivity are too complicated for a trustworthy analytic calculation, an empirical test using independently scheduled noise-only and signal-present trials may provide a more defensible operating characteristic.

Selection after inspecting the display presents a separate problem. A threshold chosen because it makes the most striking image appear cannot be evaluated as though it had been specified before viewing that same evidence. The laboratory should reserve independent challenge data or perform a prospective validation of the chosen

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procedure. Record the unsuccessful settings and considered hypotheses, since they may affect the overall probability of a false discovery. It is not necessary to enumerate every imaginable waveform, but it is necessary to state the investigated class and to avoid treating its success as universal proof. The resulting statement is conditional yet useful: under the specified noise population and search policy, the probability of at least one false alarm over a declared interval is bounded or estimated in a particular way.

Increasing the oversampling factor can help distinguish certain receiver artefacts if it changes their predicted spectral location while an external signal remains at a physically fixed RF frequency. But that is an intervention requiring calibrated frequency mappings and a genuine change of acquisition condition. Merely finding the same line in correlated windows of the same processed stream adds no such physical challenge. An internal oscillator spur may persist quite coherently across every window, just as a real transmission might. Distinct external antenna paths, altered input attenuation, sample-clock perturbation and independent receiver substitutions can provide stronger tests when the rival mechanisms predict different responses.

I would preserve the association between all window-level detections and the underlying interval from which they came, so that another examiner can cluster them and recalculate the familywise result. The record should include the window length, overlap fraction, taper, frequency search range, threshold, detector version and total tested exposure, including intervals with no saved alarm. If the data

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are insufficient to calibrate the search-level false-alarm probability, the report should say so and confine itself to the measured observation. An apparent reduction in the noise floor is then properly reported as an estimator property rather than a probability that a particular alarm originated from an external device. With that statistical warning, I pass the token respectfully to Professor Tukey.

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John Wilder Tukey | Principal response 5: Exploratory analysis, selected evidence and the false precision of large sample counts

Dr. Atkinson, a signal analyst is surrounded by numerical abundance. The receiver may report millions of samples, thousands of FFT frames and a screen filled with bright transient points. None of those counts establishes the number of independent opportunities to observe an external event or the reliability of the explanation selected after inspecting the display. My concern is not hostility to computation, which can make an otherwise inaccessible record intelligible. It is the error of substituting the quantity of derived numbers for an account of how those numbers arose, what choices the analyst made, and which alternative patterns might have appeared under the same procedure. Oversampling can be a useful part of an intelligent receiver. It can also serve as a theatre of precision when the statistical unit of observation is never defined.

Suppose the investigator tests every frequency bin of every heavily overlapping analysis window and retains only those exceeding a moving threshold. The nominal count of tests may be very large, yet neighbouring bins share window energy, successive frames share raw samples, and all outputs may share a common gain disturbance or oscillator artefact. The apparent detections are therefore clustered and dependent. Summing their individual significance levels or treating them as separate corroborations produces an impression of certainty unsupported by their common origin. To make a credible statement, the examiner should define a physical event cluster, a recording interval, a noise-only calibration population and an alarm policy before estimating an operating characteristic. If those rules

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evolve during discovery, the changes should be archived and subsequently tested on fresh data.

Oversampling tends to create a second difficulty when a selected display becomes the basis for a broad negative assertion. If a channel looks quieter after filtering, the investigator may increase the threshold relative to its new floor and conclude that the monitored premises contained no covert transmission. But a negative claim needs exposure evidence: which frequency intervals were actually admitted, for how long, under which input conditions, and with what performance for the shortest or weakest signal class relevant to the search? The presence of a quiet-looking trace is not evidence that an out-of-band emission was captured and rejected for legitimate reasons. Neither is the absence of an alarm in a selected retention archive evidence of an absence of emissions during unretained periods.

An exploratory procedure should make unexpected patterns visible without converting them prematurely into certified conclusions. Compare noise-floor estimates over time, inspect raw-code histograms, calculate the behaviour of candidate spurs under changes of sampling rate, and examine how the detector responds when its filter is moved or widened. Where the data contradict the simple white-noise assumption, record the contradiction and refine the hypothesis. Do not merely remove the inconvenient intervals because their inclusion spoils an elegant plot. If a strong local carrier generates nonlinear products, those products may persist at particular frequencies even while quantisation noise is reduced by a high-rate acquisition. The mere fact that the processing reduced broadband noise cannot assign the remaining line to an external surveillance source.

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The distinction between exploration and confirmation is practical. The investigative analyst may discover a promising feature by trying several windows, FFT sizes, decimation ratios and thresholds. Such exploration is legitimate and valuable. The error occurs when the final chosen setting is reported as though it had been selected before examining the evidence, and its false-alarm rate is calculated from the same record used to choose it. A validation campaign should reapply the frozen rule to separately scheduled reference trials or to appropriately withheld data. If the system is adaptive, the full training and update procedure must form part of what is reproduced. The examiner should count each independent challenge according to its actual design, not each pixel generated from the challenge.

One may illustrate the influence of dependence with a simple correlation model. Suppose one hundred measurements have an approximate first-order autocorrelation rho = 0.8 and the correlation decays geometrically with lag. For a large stationary sequence, the variance inflation of its mean relative to independent observations approaches (1+rho)/(1-rho), or nine in this example. The corresponding effective sample size is of order one hundred divided by nine, approximately eleven, not one hundred. The exact finite-sample calculation depends on the full correlation function and estimator, so this approximation must not be promoted to a universal confidence interval. Nevertheless it shows why an analyst can possess a hundred impressive rows in a spreadsheet while having substantially less independent statistical support for the claimed precision.

There is no reason to reject oversampling because it may create correlated representations. Properly used, it makes antialias filtering easier, can reduce in-band uncorrelated noise and can yield more faithful estimates

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of a defined signal under calibrated conditions. The forensic question is what the improvement earns. If the signal class is a continuous narrowband carrier in a known channel, the processing gain may be meaningful and reproducible. If the signal class is a short unpredictable pulse, the same integration may impose a severe temporal penalty. A useful instrument report should show performance separately for those cases. An attractive universal 'sensitivity improvement' figure is less valuable than a set of defensible conditional curves showing when the instrument succeeds and when it fails.

I would also insist upon the possibility of an independent challenge. Does the candidate survive a change in antenna, a change in analogue front-end attenuation, or a different sampling clock whose predicted internal spurs move? Does it appear in a separately characterised receiver that has a genuinely different source of systematic error? Does its measured onset remain consistent after correcting the filters' documented group delays? Such experiments can distinguish mechanisms when mere repeated processing cannot. If the conclusion concerns source identity, the analyst must further confront the possibility that several emitters share similar modulation or frequency characteristics. Processing gain may improve the clarity of a feature without making its origin unique.

The final report ought to contain both a readable narrative and a reproducible technical record. State which quantity was measured, what noise model supported the claimed improvement, how many physically distinct trials were performed, which settings were tried, how thresholds were selected, and what remained unrecorded. A large sample count is useful metadata, but it is not the statistical argument. Precision requires the

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retained contrary cases and the uncertainty of the accepted ones. Dr. Atkinson, I return the floor through Professor Box, who may challenge how one should choose between a physically simple model and a statistical model sufficiently elaborate to match every anomaly.

George Edward Pelham Box | Peer question 7 to John Wilder Tukey

Professor Tukey, a forensic engineer who models every correlation and gain fluctuation may produce an impressive collection of parameters without gaining a testable account of the receiver. Conversely, a simple white-noise model may understate uncertainty and falsely convert redundant samples into independent evidence. How should a laboratory balance the two risks? Suppose a new noise model fits the observed record so well that it explains away every candidate spectral line, including one intentionally injected as a challenge. The fit is mathematically pleasing but evidently unsuitable as a detector. What falsification tests would you demand before accepting either model, and how would you distinguish a robust improvement in estimation from an optimisation that silently discards the signals under investigation? I also ask whether every accepted result should be replicated on a second physical receiver or whether a bounded set of well-designed interventions can be proportionate to the actual claim. I am particularly concerned about the preservation of unsuccessful validation trials.

John Wilder Tukey | Immediate answer to George Edward Pelham Box

Professor Box, the principle is to compare the model's predictive consequences with observations not already used to construct it. A complex model can fit the training record and still fail on a new signal;

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a simple model can be transparent and still systematically misdescribe correlated errors. Neither complexity nor simplicity is an adequate proof. I would require a reserved challenge set containing noise-only intervals, known injected signals of varied amplitude and duration, and deliberate changes to physical conditions that rival hypotheses predict differently. Thresholds and calibration parameters should be frozen before evaluating that set, or their adaptation should itself be included in the validated procedure.

For the proposed detector, loss of intentionally injected events would be a decisive qualification. The engineer must measure true detections and missed events, not merely the noise-floor reduction. A filter that removes broad background variation but also suppresses the target emission cannot claim unconditional improved sensitivity. Its performance may remain satisfactory for a narrower, explicitly stated class of signals. The choice of that class must derive from investigative requirements and defensible physics, not from selecting whichever trials make the processed receiver look successful. Negative findings are especially dependent upon the scope of exposure and the signal classes against which the instrument was actually tested.

I would use residual plots, out-of-sample performance, calibration checks and sensitivity analysis rather than reward a model for explaining every observation after it has occurred. If the residuals contain a periodic component that moves with the converter sample rate, this is evidence to test an internal mechanism. If the component persists at a stable RF frequency when independently measured

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antenna conditions change, the competing predictions require a different experiment. Repeatability on one receiver may establish stability of its artefact. It does not establish independence. A second physically distinct receiver can provide useful corroboration when its common dependencies are disclosed, but it is not mandatory for every narrow claim about a digital processing operation.

Proportionality follows from the proposition. To establish that a particular low-pass filter reduced broadband noise power in a calibrated passband, direct input-output measurements with a validated reference and uncertainty analysis may suffice. To attribute a previously unknown signal to a concealed transmitter in a location where consequences are serious, independent challenges and careful preservation of the raw evidence are much more important. The report should clearly state which proposition each test supports. This avoids the false choice between universal scepticism and casual certainty. Our purpose is to make the conclusion as strong as its evidence and no stronger, while retaining the technical ingenuity of an oversampled receiver where it has demonstrably earned its place.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, when oversampling by sixty-four and averaging improves an in-band estimate, which claim about physical information is justified and which is not?

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, the measurement can show a reduction in estimator variance under a specified bandwidth and appropriate noise-correlation assumptions. A white-noise idealisation predicts a six-decibel variance reduction for every

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factor-of-four increase in independent oversampling ratio, but real analogue and quantisation noise may not be white. That is not equivalent to creating new instantaneous converter code states or widening the analogue information admitted by the front end. Validate the result with band-limited independent stimuli and estimate the empirical output covariance; calculate uncertainty from the covariance, not simply the sample count. An improvement confined to stationary tones must not be extrapolated to one short burst or a saturated channel. Keep the unaveraged I/Q observations and a reproducible map to the derived statistic. I respectfully pass the token to Dr Bennett for the quantisation assumption.

Claude Elwood Shannon, Cross-Peer Question to William Ralph Bennett: Dr Bennett, a team invokes the ideal quantisation-noise formula to justify a four-bit improvement from 256-fold oversampling. What hidden conditions could defeat its result?

William Ralph Bennett, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the familiar relation assumes suitably decorrelated quantisation error and a valid anti-alias/noise-bandwidth model, as well as enough headroom to avoid clipping. A coherent input near a code transition may produce correlated errors and deterministic spectral lines; independent dither can alter those statistics, but the exact dither law and any subsequent subtraction must be specified. The 256-fold ratio is a useful arithmetic statement, not a universal four-bit performance certificate. Measure input-referred noise versus bandwidth, test coherent and deliberately off-bin tones, inspect the raw code histogram and compare estimates under changed gain and temperature. If downstream digital averaging reduces

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apparent noise whilst a weak short pulse disappears, report the adverse trade-off explicitly. I pass the token to Dr Slepian on the finite record.

William Ralph Bennett, Cross-Peer Question to David Slepian: Dr Slepian, does a very long oversampled record provide arbitrary spectral discrimination when the emission of interest survives for only ten microseconds?

David Slepian, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, no. The finite event constrains time-frequency concentration even if the data stream contains millions of samples before and after it. Extra samples from unrelated background cannot be treated as additional coherent event support. Distinguish the transform length, the non-zero physical duration of the event and the taper used to reduce leakage. Validate with injected pulses of controlled width, onset phase and carrier offsets, and report errors in time of arrival and estimated bandwidth. The useful statistic may combine multiple independent repetitions of the same phenomenon, but that requires a stationarity or repeatability model that a single unrepeatable event does not automatically satisfy. Preserve the original aperture and processing window in the evidence. I respectfully yield to Professor Tukey on false precision.

David Slepian, Cross-Peer Question to John Wilder Tukey: Professor Tukey, how should an operator report the narrow line obtained after searching thousands of oversampled FFT bins and selecting the tallest one?

John Wilder Tukey, Cross-Peer Answer to David Slepian: Dr Slepian, as a selected result from a declared search, not as one prespecified test. Report the number and dependence of frequency bins, time windows, gain settings

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and candidate detectors examined. An effective number of independent opportunities can sometimes be estimated by calibration under a matching noise model, but equating the raw number of overlapping bins with independent trials is equally unjustified. Retain negative controls and predeclare thresholds; a peak fitted after selection must have uncertainty and bias qualified accordingly. An apparently quiet averaged floor may conceal short-lived events that a separate peak-hold or triggered detector would preserve. Only a blind challenge with known intermittent signals can establish the actual trade-off. I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Distinguished colleagues, the argument has resolved the initial paradox by refusing to treat information, sample count, measurement precision and evidential independence as synonyms. An instrument that samples more frequently may obtain better input coverage, allow more practical antialias filtering and supply noisy observations that a suitable estimator can combine to reduce uncertainty. Under a validated, approximately white and uncorrelated noise model, reducing the noise bandwidth by a factor R reduces in-band noise power by approximately that factor, leading to the familiar ten-times-the-logarithm processing-gain expression. Yet that improvement does not imply that all resulting values are independent observations of distinct physical facts. Nor does it bestow upon an analogue-to-digital converter a new set of physical code thresholds.

Mr Nyquist separated a denser temporal lattice from the physical bandwidth and duration of the underlying waveform. Dr Shannon distinguished improved use of a fixed acquisition record from genuinely new information obtained through an altered physical measurement. Dr

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Bennett showed that the mathematical convenience of a uniformly distributed quantisation error does not prove that its temporal and spectral correlations are negligible. Professor Slepian explained why a finite observation imposes time-bandwidth constraints and why increased sample count cannot supply additional elapsed observation time. Professor Tukey reminded us that a vast array of overlapping spectral bins is not a corresponding array of independent experiments, especially when the analyst selects the most attractive windows after seeing the results.

Several conditions now follow for an admissible performance statement. The receiver must identify its analogue reference plane, noise sources, sampling rate, admitted bandwidth, filter response, processing version, threshold and observation exposure. It must distinguish a steady narrowband signal from the shorter, wider and more irregular emissions a defensive investigation might seek. It must report whether the improvement was established by a sinusoidal laboratory test, a randomised burst challenge, a noise-only calibration or a truly independent receiver substitution. Where the source's phase, amplitude or temporal signature matters, it must disclose group delay, windowing effects and relevant calibration uncertainty. The chain of custody must preserve enough of the raw or intermediate acquisition to permit the stated result to be reconstructed and contested.

No universal number of extra bits is justified from oversampling ratio alone. The theoretical conversion of a six-decibel noise improvement into roughly one nominal bit of ideal full-scale-sine SNR is an explanation of one model, not a certificate of twenty-four-bit or thirty-two-bit physical performance. Correlated quantisation error, common reference variation,

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analogue distortion, jitter, thermal drift and input overload may dominate after the broadband component has been reduced. The appropriate statistic is the uncertainty of the specified derived estimate, qualified by the observation population. For detection, the relevant evidence is an operating characteristic indexed by frequency, amplitude, duration, receiver state and the number of genuine decision opportunities.

The panel has also clarified the claim of absence. A clean processed spectrum proves no more than its exposure and detection model permit. It cannot testify to an unobserved frequency band, an unretained interval or a pulse rejected by a filter before it entered the archive. Conversely, the fact that complete certainty is unavailable does not prevent useful engineering evidence. A controlled experiment may show that filtering lowers a particular noise component without materially biasing the amplitude of a stipulated target class, and that the resulting detector achieves a measured true-positive rate at a declared false-alarm rate. Such a restricted finding is both practical and rigorous.

Our next discussion shall examine the arithmetic implementation that makes these apparently precise outputs possible. When an oscillator, accumulator, coefficient or digital filter has finite word length, its internal rounding and state history can create limit cycles, tones and numerical behaviours that are absent from an ideal infinite-precision model. The same principle will govern our next inquiry: the operator must distinguish a mathematical representation from a verified physical or digital mechanism, then preserve enough of the computation to explain how the observation arose. I thank the panel for its careful challenges and respectfully pass the floor to the next numbered question.

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Worked engineering and forensic applications

These ten cases are independent constructed examples for illustrating the specified measurement models. No result is a performance certificate for an identified instrument. Numerical values are intentionally explicit so an examiner may repeat them with an independent calculator. A rate is expressed in samples per second, bandwidth in hertz, variance in squared units, and logarithmic gains in decibels; where an approximation is used, its physical conditions are stated.

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Ten worked engineering applications | Question 037

Application 1 | Fixed-band noise reduction at a higher sampling rate

Assume a real low-pass ADC sampling at F_s = 16,000,000 samples/s, with a required one-sided information bandwidth B = 125,000 Hz. Define the ideal oversampling ratio $R = F_s/(2B)$. Substitution gives R = 16,000,000/(250,000) = 64. Under the stipulated approximation of flat, uncorrelated quantisation-noise power over the first Nyquist band, retaining only the specified bandwidth admits one sixty-fourth of that power. The ideal processing gain is $G_p = 10 \log10(64) = 18.0618$ dB. The rms noise amplitude falls by the factor sqrt(64) = 8. These figures apply to that noise component only. They do not predict the attenuation of an in-band carrier, the behaviour of correlated spurs or a probability of detecting a short burst. A challenge test must therefore separately measure signal transfer and false alarms. [S1, S2]

Application 2 | Fourfold oversampling and the meaning of an additional nominal bit

Let an otherwise unchanged converter and filter operate at four times the prior sampling rate while the admitted signal bandwidth remains fixed. If its relevant noise is white and uncorrelated and remains approximately stationary, the ideal power ratio is $R_{new}/R_{old} = 4$. Thus the improvement is 10 log10(4) = 6.0206 dB. Because the ideal full-scale sine-wave SNR changes by approximately 6.0206 dB for one additional quantisation bit, this improvement is *equivalent in that particular SNR convention* to one nominal bit. It does not add another physical comparator threshold to the converter or prove that a single conversion

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locates a voltage inside its existing code interval. If the four samples are exact copies of one code, their arithmetic average adds no such information. [S1]

Application 3 | An ideal twelve-bit sine-wave benchmark, properly qualified

Let N = 12 be an ideal converter's nominal resolution. The familiar ideal full-scale sinusoidal benchmark is SNR_Nyquist approximately 6.02N + 1.76 dB, giving 6.02(12) + 1.76 = 74.00 dB across the first Nyquist band. If Application 1's R = 64 model were separately valid, a narrowband estimate might have an ideal in-band ratio of about 74.00 + 18.0618 = 92.0618 dB. The estimate concerns the same stipulated sine and one noise model. It is not a direct measurement of SFDR, nonlinear distortion, aperture jitter, source attribution or full-scale transient performance. A real receiver's in-band noise and overload behaviour should replace these theoretical terms with measured values and an uncertainty budget. [S1, S3]

Application 4 | Independent averaging reduces uncertainty but not parameter count

Suppose M = 16 separate noisy observations estimate one constant input voltage theta, and each adds independent zero-mean error with standard deviation sigma = 2.0 mV. The mean has standard deviation sigma_mean = sigma/sqrt(M) = 2.0/sqrt(16) = 0.50 mV. Its variance declines from 4.0 (mV)^2 for one observation to 0.25 (mV)^2. This is a genuine precision improvement for theta if the model is sound. The sixteen observations do not become sixteen independent physical

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voltages, nor is the measured mean necessarily accurate if the instrument has a shared offset. The test record should include the raw observations and evidence supporting independence. An autocorrelation test on filtered outputs may reveal that M was not the relevant number of independent observations.

Application 5 | Shared reference noise remains when independent noise is averaged

Assume each of M = 16 converter branches observes the same input and has independent error sigma_e = 4.0 mV, but all share a zero-mean reference disturbance with standard deviation sigma_u = 3.0 mV. Under a model where common and independent errors are mutually independent, Var(mean error) = sigma_u^2 + sigma_e^2/M. Numerically this is 9 + 16/16 = 10 (mV)^2, giving a standard deviation sqrt(10) = 3.1623 mV. Treating all errors as independent would instead estimate sqrt((9+16)/16) = 1.25 mV, a severely optimistic result. The exact disagreement reflects the unremoved common path. Two receivers with the same reference are not fully independent merely because they have separate ADC chips. A common-path uncertainty should remain explicit in the forensic budget. [S4]

Application 6 | A correlated record has fewer effective observations

Let n = 100 measurements follow a hypothetical stationary first-order correlation model with lag-one coefficient rho = 0.80 and geometric decay at later lags. For a sufficiently long series, an approximation to the effective sample size of the mean is n_eff approximately n(1-rho)/(1+rho). Substitution yields 100(0.20)/(1.80) = 11.111 observations. Under the

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same approximate model, the standard-error multiplier relative to treating all one hundred values as independent is sqrt(n/n_eff) = sqrt(9) = 3. This is a warning against a false precision claim, not an exact finite-sample confidence interval. Negative correlation, nonstationarity and other covariance functions require different treatment. The laboratory should estimate and challenge the actual dependence rather than assume this model by convenience. [S4]

Application 7 | The time-bandwidth scale is not the raw sample count

Consider a real waveform effectively confined to B = 100,000 Hz over an observation duration T = 0.020 s. The nominal time-bandwidth scale is approximately 2BT = 2(100,000)(0.020) = 4,000 real degrees of freedom under the usual approximate interpretation. Sampling at F_s = 4,000,000 samples/s records N = F_s T = 80,000 raw values. Their ratio is 80,000/4,000 = 20. The larger stored count can help estimate the waveform when noise and imperfections are characterised; it does not create twenty times as much independent time-bandwidth variation in the underlying restricted waveform. Finite-window leakage and effective band concentration should be assessed rather than treating 4,000 as an exact universal rank. [S5]

Application 8 | Doubling the sample rate does not double observation time

Suppose an analyst retains T = 0.020 s from a continuous recording. At F_s1 = 4,000,000 samples/s, the record has N1 = 80,000 samples; at F_s2 = 8,000,000 samples/s, it has N2 = 160,000. The unpadded DFT-bin spacings are Delta_f1 = F_s1/N1 = 50 Hz and Delta_f2 = F_s2/N2 = 50 Hz.

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Zero-padding may interpolate the displayed spectrum but does not create additional elapsed observation. The ability to distinguish close carriers also depends on window response, phase, model and signal-to-noise ratio; the equality of bin spacing is not a complete resolution theorem. The specific conclusion is that an increase in raw rate by itself does not supply the frequency discrimination associated with a longer T.

Application 9 | A long averaging window can dilute a short event

A stipulated constant-amplitude pulse of duration tau = 5 microseconds occurs wholly within an averaging window of duration T_w = 1 millisecond; elsewhere the relevant signed input is zero. A simple boxcar mean of the *signed amplitude* is A_mean = A(tau/T_w) = 0.005A, assuming the pulse is of constant sign and the filter is otherwise ideal. Its amplitude ratio relative to the pulse plateau is 0.005, or 20 log10(0.005) = -46.0206 dB. A different energy or matched-filter statistic would have a different response, so this is not a universal pulse-detection penalty. It illustrates how an averaging procedure that greatly reduces broadband noise may simultaneously make a brief event disappear from a thresholded amplitude display. The report must identify its detection statistic and event alignment.

Application 10 | Many search bins and the meaning of a false-alarm rate

Suppose an independently calibrated, fixed test has a noise-only false-alarm probability p = 0.00001 per independent trial. If there really are K = 10,000 independent trials and each has the same p, the probability of at least one false alarm is P_any = 1-(1-p)^K = 1-(0.99999)^10000,

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approximately 0.095163. Overlapping windows and frequency bins are generally dependent, so this formula cannot be transferred automatically to a waterfall's pixel count. For correlated outputs, the laboratory must use a justified joint model, a suitable bound or empirical search-level calibration. The arithmetic also shows why a seemingly tiny single-test probability can support a much larger familywise risk when an investigator searches extensively and retains only striking results.

Scholarly source register and actual read scope

[S1] Analog Devices, *AN-2003: On-Chip Oversampling for the AD7380 Family of SAR ADCs*, official web article at https://www.analog.com/en/resources/app-notes/an-2003.html . Read scope: oversampling definition; conditions under which broadband uncorrelated zero-mean noise is reduced by averaging/filtering; limits regarding correlated noise and harmonics. Manufacturer explanation, not an independent test of this volume's hypothetical receiver.

[S2] Analog Devices, *Understanding AC Behaviors of High Speed ADCs*, https://www.analog.com/en/resources/technical-articles/understanding-ac-behaviors-of-high-speed-adcs.html . Read scope: oversampling and antialias-filter transition bands, conditions for 3-dB gain per doubling, input-synchronous quantisation artefacts. Only the accessible public HTML was reviewed.

[S3] IEEE Standards Association, *IEEE 1241-2023: Standard for Terminology and Test Methods for Analog-to-Digital Converters*, https://standards.ieee.org/ieee/1241/6797/ . Read scope: public standard identification, scope, 2023 approval and statement that defined tests concern converters digitising samples at known time intervals. The paywalled full normative text was not read or represented as verified.

[S4] National Institute of Standards and Technology, *Uncertainty analysis for autocorrelated measurement data*, https://www.nist.gov/programs-projects/uncertainty-analysis-autocorrelated-measurement-data . Read scope: NIST's explanation of why ordinary uncertainty-

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of-the-mean formulas assuming independent observations are inappropriate for autocorrelated data and its discussion of relevant research. The numerical AR(1) example is independently derived hypothetical pedagogy, not a NIST result.

[S5] David Slepian, *Prolate Spheroidal Wave Functions, Fourier Analysis, and Uncertainty. V: The Discrete Case*, Bell System Technical Journal, 1978. Historical publication identification and abstract are consistent with its university-hosted bibliographic record, https://www.math.ucdavis.edu/~saito/data/ONR15/PSWF-V.pdf . No claim is made here that all pages or derivations of the PDF were independently verified; the time-bandwidth example is a new construction.

[S6] Analog Devices, *ADC Input Noise: The Good, The Bad and The Ugly. Is No Noise Good Noise?*, https://www.analog.com/en/resources/analog-dialogue/articles/adc-input-noise.html . Read scope: manufacturer's discussion of dither, quantisation-error correlation and practical SFDR limitations. No specific converter is certified by this citation.

[B1] Engineering and Technology History Wiki, *William R. Bennett*, https://ethw.org/William_R._Bennett . Read scope: published biographical profile, schooling, Bell Laboratories career and engineering research topics.

[B2] W. R. Bennett, *Spectra of Quantized Signals*, Bell System Technical Journal 27(3), 1948, pp. 446–472; publisher metadata https://onlinelibrary.wiley.com/doi/10.1002/j.1538-7305.1948.tb01340.x . Read scope: publication identification, year, journal, pages and referenced research subject; full publisher article was not accessed.

[B3] IEEE Information Theory Society, *David Slepian member profile*, https://www.itsoc.org/profile/8962 . Read scope: historical biography, affiliations, dates and listed honours.

[B4] National Academy of Sciences, *David Slepian directory*, https://www.nasonline.org/directory-entry/david-slepian-pzmpim/ . Read scope: recorded dates and academy election.

[B5] National Academies, *Biographical Memoirs: Harold Hotelling*, https://www.nationalacademies.org/read/11522/chapter/13 . Read scope: biographical introduction, training, mathematical research and professional appointments.

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[B6] University of St Andrews MacTutor, *Harold Hotelling*, https://mathshistory.st-andrews.ac.uk/Biographies/Hotelling/ . Read scope: historical dates and professional development. The numerical uncertainty calculations in this question are newly written and do not purport to originate with Hotelling.

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QUESTION 038

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How does finite word length change digital oscillator and filter behaviour?

Source: V011_Roundtable_Question_038_CP038_Dr_Atkinson.docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 038. Complete scholarly manuscript

Original constructed educational dialogue, not historical quotation or testimony. All presented cases are hypothetical pedagogical applications, not certifications of particular instruments.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, our previous discussion distinguished the improved precision of a carefully filtered estimate from the manufacture of new physical information. The present question concerns another boundary at which an elegant mathematical description becomes a fallible engineering instrument. A software-defined receiver may calculate local-oscillator phase with a digital accumulator, mix samples numerically, and subject them to finite impulse response or recursive filters whose coefficients have been designed with high-precision arithmetic. The block diagram resembles an exact mathematical operator. The FPGA, digital signal processor or compiled programme actually stores integers or finite-precision floating-point numbers. It performs rounding, truncation, multiplication, saturation and, unless prevented, wraparound. These operations can create a deterministic tone, shift a filter's rejection notch, alter a transient's amplitude or allow a recursive state to persist after its physical input has vanished. Such effects matter acutely when the

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investigative objective is to distinguish a faint external electromagnetic emission from a signal generated internally by the receiver.

Let the sample clock be F_s samples per second, an oscillator's phase-accumulator width be W bits, and its tuning word be K, an integer whose intended phase increment is $2 \pi K/2^W$ radians per clock. For a conventional modulo-2^W accumulator the average output frequency is $f_o = K F_s/2^W$, interpreted within the appropriate periodic and aliased digital-frequency convention. The nominal frequency grid is $\Delta f = F_s/2^W$. This formula describes the resolution with which a tuning word can be selected. It does not specify the oscillator's spurious-free dynamic range. If a sine lookup table receives only P of the W phase bits, the discarded phase information can introduce periodic phase-truncation error; a finite-amplitude table, interpolation rule or final DAC adds further errors. A digital mixer implemented with a sine and cosine pair may therefore create or reflect narrow lines whose locations are governed by arithmetic relationships rather than external RF sources.

For digital filters we must distinguish coefficient quantisation, arithmetic rounding and overflow. A nominal FIR filter computes $y[n] = \sum_{k=0}^{L-1} h[k]x[n-k]$, where L is the number of taps and h[k] its intended real or complex coefficients. A fixed-point implementation instead uses quantised coefficients $h_q[k]$, finite-width products, an accumulator with a specified number of guard bits, and a final output rounding or saturation rule. A recursive IIR filter additionally feeds rounded state values back into the computation, so its realised poles and zeroes may differ from their mathematical design. Even when the ideal transfer function is stable, a quantised state update can enter a small nonzero repeating orbit under

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zero external input. The resulting line may look suspiciously like a weak continuous transmitter. A spectral display cannot identify its causal origin merely by placing a frequency label upon it.

The forensic preservation problem is not confined to the original ADC. Its samples may be correctly acquired, while the derived line is produced after the input has entered a fixed-point NCO, channeliser or detector. If the investigator retains only processed outputs, firmware identifiers without coefficient hashes, or screenshots of a waterfall, a subsequent expert may be unable to reconstruct the arithmetic conditions that generated the feature. The configuration record must therefore identify arithmetic formats, widths, coefficient sets, truncation locations, saturation or wrap rules, phase seeds, buffer boundaries, firmware revisions and algorithmic state transitions. The most useful experiment is one that changes a predicted internal parameter while holding the physical stimulus fixed, or removes the stimulus entirely while monitoring whether the apparent signal remains. Such interventions can discriminate a numerical artefact from an external emitter; repeated observation of the same processed stream cannot.

Dr Hamming will begin with the arithmetic representation and oscillator accumulator. Professor Bode will examine pole-zero sensitivity, coefficient quantisation and the physical inadequacy of nominal transfer functions. Subsequent principal contributors will address digital quantisation spectra, numerical state behaviour and statistically valid validation. The panel shall test the claim that more computational precision always resolves the problem, and equally the claim that every observed digital spur must be internal. We shall separate oscillator frequency resolution from its frequency

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accuracy, filter coefficient fidelity from a realised stopband response, and a reproducible software output from a defensible statement about an external electromagnetic event. Dr Hamming, may I invite your account of what a finite accumulator actually represents?

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Richard Wesley Hamming | Principal response 1: Finite accumulators, phase truncation and apparently coherent lines

Dr. Atkinson, digital computation is exact only relative to the rules and finite representation selected for it. A modulo integer accumulator can be entirely deterministic and repeatable while approximating a continuous phase law with finite steps. Suppose a W-bit phase register advances by an integer K at each sample clock. Its state obeys phi[n+1] = (phi[n]+K) mod 2^W. The corresponding complex idealised oscillator is exp(j 2 pi phi[n]/2^W), with the caveat that a physical implementation may approximate that exponential through a lookup, polynomial, CORDIC structure or other finite arithmetic. A mathematically neat formula for f_o does not, by itself, describe the realised spectral content. The phase mapping, initial state, rounding and table width must enter the model if the investigator intends to distinguish a converter-generated component from a physical radio emission.

Consider a clock F_s of 100 MHz and a thirty-two-bit accumulator. The nominal frequency step is F_s/2^32, approximately 0.023283064 Hz. The numerical result is accurate as a tuning-grid statement, assuming the clock is exactly 100 MHz for the purpose of this example. It does not imply that the real frequency is known to twenty-three millihertz when the reference oscillator has an uncertainty of parts per million. A ten-part-per-million frequency error at an output of 10 MHz represents roughly 100 Hz, far larger than the tuning-word increment. Frequency resolution is the granularity of a selectable command. Frequency accuracy is a claim about the physical timebase against which that command is executed. The distinction resembles a ruler whose millimetre markings are precise while

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the metal has expanded with heat: the graduations alone cannot establish the length of the object measured.

Phase truncation introduces another mechanism. A large accumulator may preserve W bits to avoid cumulative frequency error, while a smaller table address exposes only P upper bits. The discarded lower bits form a deterministic sequence governed by K, W and P. In some arrangements this sequence is periodic, producing discrete spectral components rather than an uncorrelated white floor. Their exact amplitudes depend on the mapping, interpolation, converter output and signal path; one should not calculate a universal SFDR merely from the number of truncated bits. A receiver with a ten-megahertz NCO may show weak offset lines whose positions move when the tuning word changes slightly, even though the analogue input remains constant. The correct experimental question is whether the suspected signal follows a prediction of this arithmetic mechanism.

There is a practical method of challenge. Record the raw ADC stream and run it through several rigorously specified NCO implementations. Change P while preserving the input, tuning frequency and adequately controlled gain; compare the spectral locations and amplitudes of the resulting features. Deliberately vary the phase seed or adjust K by a small known amount. Where a line changes as a reproducible function of these internal parameters, an algorithmic source becomes plausible. Yet care is needed. An external signal mixed digitally also changes its baseband offset when the NCO changes, so a moving display line is not automatically spurious. The prediction must be expressed in absolute RF terms as well as derived baseband coordinates, and the experiment should distinguish which line moves *beyond* the frequency translation expected for a genuine RF input.

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One should further preserve the arithmetic rules of each multiplication. Fixed-point complex mixing multiplies I and Q input words by finite sine and cosine coefficients. Product widths may exceed the source word width, and a restricted accumulator may overflow or lose lower bits. Rounding once after a wide accumulation generally differs from truncating every intermediate product. One form may concentrate a small periodic error into a spur; another may spread error more diffusely. When an apparent weak signal appears only for a particular word length or rounding mode, the receiver needs an engineering diagnosis before the result can be carried into a forensic attribution. A clean digital simulation with infinite-precision floating-point arithmetic may not reproduce the exact defects of the hardware arithmetic, so bit-exact testing is an important part of the evidence.

The programme's configuration identity must include firmware, compiled arithmetic behaviour, coefficient hashes and state. The same version label might still permit different arithmetic when optimisations, libraries or instruction-set rules change, particularly around overflow and fused operations. A reproducible test should use defined input vectors and verify exact or bounded output correspondence before comparing live observations. It may also need to preserve the unprocessed acquisition interval, since reprocessing an already truncated product cannot reveal whether the original codes were correct. If the countermeasure investigator is challenged to show that a faint spectral line was not an internal oscillator artefact, the burden is not discharged by saying the oscillator was 'digital' and therefore exact.

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The broader lesson is that an abundance of fractional phase bits is not a universal guarantee of spectral purity. The oscillator is a finite state machine with deterministic transitions, and its signal path is a finite arithmetic realisation. The output may be stable, coherent and measurable at impressive dynamic range, yet that very stability can make internal spurs mimic real, persistent emissions. The correct claim is a measured bound upon numerically generated artefacts under specified tuning words, sample rates, word lengths, reference conditions and output configurations. Such a bound is a powerful engineering result. It becomes forensic evidence only when its validity covers the actual acquisition and its uncertainty is preserved. I pass the floor respectfully to Professor Bridgman, who may question whether a displayed frequency derived from a digital coordinate is the same measurand as a physical emission at an antenna terminal.

Percy Williams Bridgman | Peer question 1 to Richard Wesley Hamming

Dr Hamming, your distinction between a selectable frequency increment and a traceable physical frequency is persuasive, but I fear that receiver reports often conflate another pair of quantities. A line may appear at a digital baseband coordinate after multiplication by a finite oscillator, while the physical measurement claim concerns a field coupled into an antenna at some absolute RF frequency. If the input path contains a mixer whose local oscillator has its own uncertainty, and the digital NCO is controlled by an imperfect clock, the value printed beside the waterfall line may depend on several frequency mappings. Which experimental comparisons should be preserved to establish the RF reference plane of the reported emission? Would a test conducted

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entirely at the digital input to the NCO be sufficient to certify the source frequency, or does the analogue chain require a separate metrological account? In particular, how should the report qualify a line that disappears under a change of arithmetic precision but whose original raw samples were not retained?

Richard Wesley Hamming | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, a digital coordinate is not an RF reference plane. The report must identify the analogue tuning state, the oscillator frequency and accuracy, the sample-clock timebase, any frequency translation or spectral inversion, and the mapping between the digital bins and the input terminals. A test applied only to the digital input of an NCO can establish whether a particular arithmetic implementation produces a given output for that digital stimulus. It cannot, without additional evidence, certify what arrived at an antenna or whether an analogue mixer introduced a spurious response. Those claims require appropriate analogue calibration and receiver substitution or controlled injection at the physical boundary of interest.

A practical challenge record should begin with a reference source whose frequency and uncertainty have been determined independently. Inject it at an appropriate analogue test plane, observe the raw acquisition and the processed output, and repeat under relevant retune states. The engineer should compare the predicted digital frequency with the measured one, including local-oscillator offset, any sampling-clock error and the known input

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transfer. If the digital arithmetic is suspected of producing a spur, a second test can feed the same stored raw samples through a bit-exact reference implementation and selected alternative precisions. The important point is that those two tests address different boundaries. The analogue test checks acquisition mapping; the numerical replay checks the processing transformation.

Where the original raw samples are absent, the diagnostic possibilities narrow. A line that disappears after increasing arithmetic precision provides evidence consistent with a numerical artefact, especially if a predicted phase-truncation mechanism explains its earlier frequency and amplitude. But the experiment does not uniquely establish what external signals were simultaneously present. A weak external carrier might have been affected by the same processing change or by an undocumented threshold. An examiner should therefore report what was observed, what implementation was varied and which alternative explanations remain. It would be improper to restore confidence retroactively by manufacturing a hypothetical raw sequence that reproduces the selected line.

I would recommend a bounded conclusion. State that the observed feature is implementation-sensitive, identify the tested arithmetic changes, and explain that external-source attribution is unresolved without the original acquisition and a satisfactory analogue challenge. Such a finding does not render the engineering work futile. It prevents a precise-looking computed frequency from being mistaken for a direct observation of a transmitter. I return the floor to the moderator for the remaining principal examination, which must

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account for digital filter coefficients, accumulator overflow and the possible survival of internal limit cycles after the analogue input disappears.

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Hendrik Wade Bode | Principal response 2: Coefficient precision, pole sensitivity and implemented stability

Dr. Atkinson, a mathematical transfer function is a specification of an ideal relation, not evidence that a particular circuit or programme realises it. In analogue network theory a response changes when components depart from their nominal values; the same principle governs digital filters whose coefficients must be stored in finite registers. An intended coefficient h[k] becomes h_q[k] after rounding or truncation. The resulting frequency response H_q(exp(j omega)) differs from H(exp(j omega)), and for an FIR filter the difference is the Fourier transform of the coefficient errors. A finite coefficient format can therefore alter the passband gain, the transition region, the rejection at a notch or the phase response used for timing. Such errors are frequently deterministic and reproducible. A receiver-generated spectral feature can be just as stable as a genuine external carrier, and an elegant design plot cannot identify which is present.

For an L-tap FIR, write delta_h[k] = h_q[k]-h[k]. The response error at normalised angular frequency omega is E(exp(j omega)) = sum from k equals zero to L minus one of delta_h[k] exp(-j omega k). From the triangle inequality, its magnitude is no larger than the sum of absolute coefficient errors. This bound can help establish worst-case behaviour, but it may be conservative; the actual spectral error depends on the phases and signs of the perturbations. If each coefficient is rounded to a step q_h and the rounding error is at most q_h/2, a crude upper bound is L q_h/2. A narrow stopband specification can be particularly vulnerable because a very small absolute transfer error is large relative to an ideal near-zero response. A report that calls a filter 'eighty-decibel rejecting' from its floating-point

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design should verify that the fixed-point implementation still satisfies the rejection requirement under the relevant coefficient and accumulator rules.

A recursive filter presents a more serious possibility. Its poles are determined by denominator coefficients, and their realised locations can shift when those coefficients are quantised. An ideal stable pole just within the unit circle may be moved sufficiently to alter its decay time, resonance or stability. The sensitivity depends strongly on the filter structure. Implementing a high-order polynomial directly can differ markedly from cascading well-scaled second-order sections, even when their infinite-precision transfer functions are algebraically equivalent. The internal states are not equivalent under finite arithmetic; one structure may magnify rounding noise or encounter overflow while another remains within the same word budget. Consequently the implementation architecture belongs in the calibration record, rather than being concealed behind the statement that the nominal coefficients were identical.

Feedback also creates the phenomenon of a limit cycle. Consider the zero-input recursion $y[n] = Q(a\, y[n-1])$, where Q represents a fixed rounding operator. In ideal arithmetic with absolute a less than one, the state tends to zero. Under quantisation, a small positive state may round back to itself and cease decaying. A more complicated IIR system can enter a multistate periodic orbit. If the receiver's digital output is converted into a spectral display, such an orbit may form a line or repeating pattern with no surviving analogue input. The presence of an apparent signal while the RF input is terminated is therefore an important challenge, provided that input termination itself does not introduce a different analogue fault. The

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examiner should vary initial states, numerical precision and operating frequency to identify whether the line follows the internal recursion.

The distinction between wraparound and saturation is equally material. A signed fixed-point accumulator of width W represents only a finite interval. If an addition exceeds that interval, a wraparound implementation may jump from a large positive number to a large negative one, introducing an impulse-like discontinuity and broad spectral artefacts. A saturating implementation instead clips at a bound, creating a different nonlinear response and harmonics. Neither behaviour can be inferred from an ideal filter equation. The engineer must determine whether a compiler, FPGA synthesis system or processor instruction uses saturation, modular arithmetic, exception handling or an implicit conversion to a wider type. Small changes in input amplitude can drive the computation across an overflow boundary, so a calibration made only with gentle test tones may fail under strong legitimate transmitters.

The obvious remedy is not simply to allocate a fantastically large accumulator and assume the problem vanishes. Wider arithmetic may reduce rounding error but cannot repair an incorrect transfer model, an alias introduced before digitisation or an unrecorded receiver state. It can also change timing and hardware resource demands, potentially altering the acquisition's real-time behaviour. The correct approach is to allocate sufficient guard bits for a declared worst-case input bound, analyse coefficient sensitivity, verify scaling at every stage, and test the bit-exact implementation against independent reference vectors. For a narrowband forensic search, these tests should include weak signals coexisting with stronger interferers and should preserve the original raw-code stream long

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enough to decide whether an alleged spectral feature first appeared before or after a particular digital stage.

I propose three forms of evidence. First, provide the mathematical specification, including passband, stopband and allowed phase or delay distortion. Second, preserve the actual fixed-point coefficients, types, arithmetic modes, initial conditions and compiled implementation identity. Third, measure the realised transfer under controlled stimuli, ideally across relevant temperatures and operating modes. The discrepancy between designed and realised response must form part of the uncertainty account. If the observed line disappears when the word length increases, that supports a numerical-artefact hypothesis but does not, in isolation, exclude a simultaneous external signal that the earlier processing obscured. Scientific care requires both the positive diagnostic and the limit of what it proves.

We should conclude that a filter does not inherit stability or precise phase from the elegance of its algebra. These properties belong to a realised, bounded arithmetic system and must be demonstrated for the actual input classes. The forensic report should not promote a bit-exactly reproducible processing output into evidence of an external emitter without validating the transfer from the physical reference plane. Mr Black may now challenge how a feedback engineer should set acceptable bounds when an internal loop compensates for the very errors it introduces. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Harold Stephen Black | Peer question 2 to Hendrik Wade Bode

Professor Bode, your insistence upon the implemented transfer function leaves a difficulty familiar from feedback design. The receiver

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may adjust its digital filter coefficients continuously to suppress narrow unwanted components, and its adaptation may depend on the same noisy record used for detection. A self-adjusting notch might suppress an internally generated oscillator spur, but it might also suppress the genuine external emitter the investigator seeks. If the laboratory freezes the coefficients for validation, it no longer tests the adaptive system that actually operates. If it allows adaptation, the experiment becomes harder to reproduce and the result may depend on the order in which stimuli were presented. What acceptance test would establish that the adaptive computation is stable, that a signal survives under declared conditions, and that a reported absence is not simply the consequence of a loop trained to remove the signal? Which state variables and update histories are indispensable for subsequent forensic reprocessing?

Hendrik Wade Bode | Immediate answer to Harold Stephen Black

Mr Black, an adaptive filter should be regarded as a system with a state, an update law and an observation process, not as a static transfer function to which one may attach a permanent response plot. Its qualification should include the algorithm's initial state, error signal, step sizes, coefficient constraints, update timing and criteria for suspending or resetting adaptation. These quantities make the difference between a reproducible controlled experiment and a narrative in which a line vanished for reasons never recorded. If the filter learns from the same interval on which its effectiveness is judged, its success requires an independent challenge before the claim extends beyond that interval.

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I would run two complementary tests. The first freezes the coefficients after a documented training phase and injects independently scheduled reference signals at frequencies and amplitudes the training algorithm did not select. This tests the frozen realised transfer and the capability of the detector to preserve the target class. The second exercises the full adaptive process from declared starting states, randomising the order of challenge pulses and interferers and recording every coefficient trajectory. This tests whether adaptation itself changes the true-positive and false-alarm characteristics. Both tests should retain failed cases, because the ability to reach a pleasing final spectrum after several revisions is not a measurement of the originally proposed procedure.

A suitable forensic archive need not store every intermediate arithmetic operation, but it should preserve enough state to reproduce material decisions. That may require the raw acquisition, a time-stamped coefficient stream or losslessly versioned snapshots, adaptation configuration, gain and frequency states, and a digest identifying the executable implementation. If the system cannot replay its processing for a material candidate, its derived output can still document an observation, but the examiner must acknowledge that the exact transformation cannot be independently verified. Such a limitation belongs in the conclusion rather than in a concealed engineering note.

Finally, a lower output noise floor must be assessed alongside the target signal transfer. An adaptation that removes both broadband noise and a legitimate weak tone may improve one displayed statistic

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while destroying the signal class of interest. The acceptance population must therefore include representative weak emissions, quiet intervals and strong interferers. A successful system is one whose measured performance meets a declared requirement, not one which merely produces the cleanest picture. I pass the floor to Dr Shewhart, who may test the stability of these procedures across repeated trials and operating states.

Walter Andrew Shewhart | Peer question 3 to Hendrik Wade Bode

Professor Bode, a laboratory may demonstrate excellent agreement between an ideal response and its fixed-point implementation at room temperature and with one convenient coefficient set. In service, a receiver operates through gain changes, retunes, firmware updates and thermal excursions. A rare overflow or limit cycle may occur only after a particular history of input amplitudes, while ordinary repeated sine-wave tests remain uneventful. How should a quality-control programme distinguish a truly stable implementation from one whose failure probability is merely too small for a brief demonstration to reveal? Should the evidence include worst-case interval bounds, randomised stress tests, software regression testing and persistent monitoring of unexpected state transitions? And when the application concerns forensic attribution, how should the laboratory report a failure that appeared in one run but could not be reproduced after resetting the instrument?

How would your assessment preserve unfavourable trials and distinguish an engineering tolerance established beforehand from one chosen only after the observed signal had been inspected? Would the

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answer change if the disputed line appeared only after a temperature excursion?

Hendrik Wade Bode | Immediate answer to Walter Andrew Shewhart

Dr Shewhart, the question requires a combination of structural analysis and empirical challenge. A finite collection of successful tests cannot prove that no possible input history triggers an internal failure, especially where the space of phase seeds, input amplitudes and retune sequences is enormous. One should identify mathematical invariants where feasible: accumulator bounds, coefficient ranges, scaling constraints and guaranteed guard bits. A proof of absence of overflow for a stipulated input bound is stronger than the mere observation that overflow happened not to occur in a short calibration. Where such proof is not feasible, representative and adversarial test campaigns can estimate failure frequencies over declared populations, with confidence limits rather than absolute guarantees.

For rare state-dependent failures, preserve the complete available state history and the first observed sequence that led to failure. A bug that disappears after reset is not imaginary merely because the original trajectory is difficult to recreate. The system should capture firmware identity, coefficient hashes, oscillator phase state, buffer alignment and control events, together with raw input intervals and diagnostic counters. The operator may use deterministic replay or hardware-in-the-loop tests to examine whether the failure depends on numerical wrap, a clock-domain crossing or an adaptive coefficient

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update. If the causal mechanism remains unidentified, the report should retain an unresolved qualification about the class of outputs affected.

Regression testing must include changes to the development environment, since the same source code can compile to different arithmetic depending on processor instruction sets, optimisations and library implementations. A fixed-point design should explicitly specify signedness, saturation or wraparound, rounding mode and accumulator growth rather than delegate them to an undocumented default. Acceptance results should also be tied to the actual release binary, not merely a version label copied into an operator's notebook. Temperature may affect the analogue front end even when digital arithmetic remains bit-exact; those mechanisms should be distinguished so that calibration applies to the correct part of the measurement chain.

A single nonreproducible failure can justify continued investigation or restriction, not an assertion that the instrument is permanently defective or wholly reliable. The strength of the conclusion depends on its cause, frequency and consequences for the intended claim. Where the failure may mimic a concealed emitter, it is especially important to retain the raw and derived records and to avoid treating apparently coherent lines as independent confirmation. A well-governed programme may remain useful for signal discovery while reserving stronger source attribution for events surviving separate physical and numerical challenges. I return the floor to Dr. Atkinson

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for the next principal examination of feedback, prediction and computational memory.

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Norbert Wiener | Principal response 3: Feedback, computational state and the ambiguity of a persistent digital tone

Dr. Atkinson, an engineer frequently encounters the same word *memory* in two rather different senses. A storage device retains a series of previous samples, while a dynamical system retains information in its internal state. An IIR filter, automatic gain controller or tracking oscillator may continue to respond after the particular input that excited it has disappeared. If that state is represented in finite precision and updated by nonlinear rounding, its later behaviour may not follow the smooth decay predicted by the ideal linear equation. The investigator observing a narrow line in the output should ask what external input, if any, is required to sustain it. The persistence of the line under one operating condition is a fact about the complete receiver state, not a proof about an external transmitter.

Consider a feedback system with one state x[n] and a nominal law x[n+1] = a x[n] for zero input, with 0 < a < 1. In infinite precision the state approaches zero. Suppose instead that every update rounds to a quantisation increment q. If the current state is q and a is sufficiently close to one, the product a q can round back to q, leaving the state unchanged. With the conventional nearest-increment rounding rule, q is a fixed point whenever a q lies within the rounding interval centred on q. In other words, a value that should decay can remain trapped by the finite representation. If the system contains several states and complex multiplication, the resulting orbit may be periodic and its spectral output may resemble a coherent signal. This cannot be diagnosed by an FFT alone because the spectrum records periodicity, not the physical origin of the periodicity.

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The analogy with control systems becomes more consequential when the filter adjusts itself from live data. An adaptive digital receiver might continually change coefficients to reject an interference line, but the resulting adaptation can also learn a real intermittent signal as though it were nuisance noise. The internal state includes the coefficient vector, its past excitation and the update law. If an operator preserves only the final coefficients and the final clean display, the record may omit the history that determined which signals were rejected. A valid forensic reconstruction requires the state evolution or sufficient checkpoints and event logs to reproduce material decisions. The report should disclose whether adaptation was active, suspended, reset or trained on the very evidence subsequently evaluated.

Numerical precision changes the dynamics but does not erase the physical distinctions. Increasing word length can move a trapped state below the relevant detection threshold or extend its decay time; it may also reveal a different arithmetic path because a compiler or processor now employs wider instructions. The engineer should measure the actual state trajectory under controlled stimuli rather than infer the entire result from a nominal bit count. The chosen rounding mode matters, including whether values are truncated toward zero, rounded to nearest or handled stochastically. Overflow must also be specified. A modular arithmetic wrap can inject a discontinuity into a feedback loop, while saturation can hold a state at a bound until an input or control change releases it. These mechanisms have different spectral consequences and can be intentionally challenged.

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A powerful experiment is the zero-input test, but even this requires care. Disconnecting an antenna and terminating the input may change loading, gain control or the analogue noise seen by the converter. One should therefore compare at least two defined boundaries: digital zero injected immediately before the suspected processing block, and a separately characterised analogue termination at the intended RF input. A line persisting under digital zero is plainly not being sustained by the external analogue programme during that test, although it may represent a prior state rather than a newly generated periodic input. A line disappearing under digital zero but persisting with an analogue termination may arise in the front end, clock, converter or mixed-signal interface. Neither result alone reconstructs what occurred during an earlier unrecorded field observation, but both restrict the possible explanations.

I recommend varying initial state and processing history systematically. Begin with a cold start, apply a known transient, remove it, and record the decay or residual orbit. Repeat with different seeds, gain settings, filter coefficient updates and arithmetic precisions. Compare bit-exact numerical simulation with hardware implementation, noting where divergence first occurs. If the suspected line appears only after one reproducible sequence, that sequence deserves preservation as an engineering artefact test. A coincident external emitter must still be tested independently. The event may have been present during the original acquisition even if later numerical processing superimposed its own spur. The causal claim must be limited to the experiment that actually discriminates these possibilities.

The forensic examiner should not interpret a numerical limit cycle as an ordinary random disturbance whose variance simply averages away. A

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persistent periodic state can remain coherent under longer integration and may become more prominent as white noise is filtered out. This is precisely why a high-dynamic-range search can expose new receiver-generated artefacts instead of eliminating every ambiguity. Robust design may include explicit state-reset policies, dithering where appropriate, guard bits, conservative overflow controls and implementations whose dynamics can be bounded. Each intervention can improve engineering performance; its forensic reliability depends upon recorded version identity and validation under field-relevant conditions.

I should end by distinguishing predictability from provenance. A deterministic line generated by finite arithmetic may be predicted to many decimal places once the algorithm and state are known. A real external transmitter may also be narrow and stable. The visual appearance of the two can be nearly indistinguishable. The decisive evidence comes from controlled changes that alter one mechanism but not the other, and from preservation of the actual raw and derived observations. In the absence of such evidence, a cautious statement of unresolved origin is not a failure of science. It is an appropriate record of what the apparatus has and has not established. I pass the token to Professor Slepian, who may press the temporal implications of finite-state memory for very short emissions.

David Slepian | Peer question 4 to Norbert Wiener

Dr Wiener, the persistent numerical tone you describe may arise after a short pulse has already ended. A field analyst could see the tone continue for seconds and conclude that a covert transmitter remained on the air for that duration. If the system's state is reset, the tone may cease immediately, but the reset might also erase the information needed to

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reconstruct the original pulse. How should the examiner distinguish the duration of a physical event from the settling time or limit-cycle behaviour of a digital algorithm? Should the receiver retain a pre-processing raw interval around each candidate, and must the validation include pulses at different positions relative to filter blocks? I also ask whether one can calculate a universal maximum apparent event duration from the filter's nominal poles, or whether finite arithmetic and adaptive state make that bound fundamentally implementation-dependent.

Please also explain whether the answer depends upon knowing the input waveform class beforehand, and how one could test an unexpected waveform without assuming that the very model under examination had already captured every relevant transient.

Norbert Wiener | Immediate answer to David Slepian

Professor Slepian, the physical event duration and the duration of a numerical state are different observables. A nominal pole calculation may predict the decay of an ideal linear filter, but it does not by itself bound a quantised implementation whose states may enter persistent cycles. A rigorous bound would require specifying the finite state space, arithmetic rules, input constraints and reset behaviour, and then establishing what trajectories are reachable under those conditions. Such an analysis may be feasible for simple models but computationally difficult for a large receiver. An empirical challenge programme can nevertheless identify material duration distortions over representative signal classes and operating states, provided the conclusion is confined to that evidence.

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I would preserve the raw interval surrounding a significant candidate wherever feasible. The record should include enough pre-trigger and post-trigger material to distinguish an actual transmitter onset or cessation from the impulse response of the digital chain. The filter's group delay, coefficient state, adaptive updates and any saturation episodes should be logged. During testing, inject short pulses at random positions relative to processing windows, remove the stimulus, and observe both the raw acquisition and the derived outputs. If the processed line persists after the raw stimulus disappears, that persistence should be attributed to the processing response unless further evidence shows a coincident physical signal.

Resetting can be diagnostic but should not be a substitute for evidence preservation. A reset that destroys the only state history may prevent later reconstruction of the mechanism. A properly designed receiver would record the pre-reset state or a sufficient diagnostic snapshot, document the reset command and retain its effect on detection. When complete state retention is impracticable, the limitation should be declared and the event's duration reported as bounded by the observed processing conditions. The investigator may state that a derived indicator remained active for several seconds, but should not silently equate that interval to continuous electromagnetic emission at the antenna.

A useful acceptance statement therefore specifies an event-duration transfer characteristic for the declared waveform class, including worst observed extension, delay and false-event clustering under tested circumstances. If a finite-state artefact remains possible,

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it becomes an explicit alternative explanation. This is not to deny the utility of recursive filtering; it is to insist that its memory be accounted for before a temporal claim enters the forensic record. I return the discussion to Dr Bennett for the spectral consequences of rounding and truncation in the arithmetic path.

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William Ralph Bennett | Principal response 4: Arithmetic error spectra and the difference between noise and spurs

Dr. Atkinson, an error introduced by rounding a digital value may often be modelled statistically, but a deterministic arithmetic process does not acquire random independence merely because we lack the patience to calculate its exact sequence. A uniform quantiser applied to a sufficiently varied signal can produce error that resembles broadband noise under useful assumptions. The same quantiser applied to a small periodic sequence may yield repeating errors, and its spectrum may contain discrete lines. Finite word length therefore presents the engineer with two different tasks: measuring the rms level of residual arithmetic error and identifying the conditions under which that error becomes strongly signal-correlated. The second task is particularly important in a surveillance receiver, because an internal spur may become more visible as the surrounding white noise is reduced.

Take a digital oscillator whose phase register retains many bits but whose sine table sees only a subset. The discarded phase produces a periodic approximation error under certain tuning words. Its Fourier series can contain stable offset components whose positions depend on clock, tuning word and phase truncation. Similar periodicity may arise from an IIR limit cycle or a fixed-point mixer whose products are truncated in a repeated pattern. The exact spectral lines depend on the arithmetic mapping and internal states. A receiver report should not assert their frequencies from a single generic bit-depth rule. It should derive candidate locations from the specific implementation and test those predictions against measured output. When the phase truncation is altered, a corresponding spur may

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change; when a physical carrier is altered, its expected RF-frequency behaviour is different.

For a fixed-point FIR, suppose the ideal coefficient h[k] is rounded to h_q[k], and each product is accumulated with a finite register. Coefficient error is a linear change in the filter's nominal response when the arithmetic otherwise remains exact. Intermediate rounding is a more complicated perturbation because it depends upon the signal and on the order of operations. If an implementation truncates every product before summing, it may introduce more error than one that retains full product precision until a suitably wide accumulator is rounded once at the output. The accumulation architecture should be part of the specification, and the laboratory should use bit-exact vectors to establish whether independent software reproduces the installed hardware. A floating-point analysis of h_q[k] alone cannot certify the entire fixed-point chain.

The arithmetic treatment of negative numbers also deserves explicit declaration. Two's-complement representation, signed shifts and truncation toward negative infinity can behave differently from rounding toward zero. A processor which shifts a signed intermediate result may introduce a small systematic error if the programmer assumed a different rounding rule. Repeated across thousands of filter operations, this bias may produce a nonzero baseline or contribute to a periodic spur under a suitable input. The statistical remedy is not automatically more averaging. A bias survives averaging; a coherent spur can become increasingly apparent under narrowband integration. An independent calibration must locate the source of the error or place a tested bound upon it.

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A common mistake is to infer that a longer word length always produces a proportionate reduction in every artefact. In a mixed-signal receiver, the ADC may already dominate the noise, analogue intermodulation may dominate the spurs, and clock jitter may dominate phase uncertainty. Widening the digital accumulator can improve a specific arithmetic limitation without changing any of those physical boundaries. Conversely, an extremely precise ADC may still produce false lines after a badly implemented numerically controlled oscillator. The engineer should therefore allocate an error budget by mechanism and test each mechanism where it is observable. The most expensive numerical representation is not necessarily the most trustworthy one if the apparatus lacks state history and reproducible calibration.

Forensically, one should record the raw-to-derived transform as a sequence of versioned stages. Start from a content-addressed raw sample interval, apply a bit-exact NCO, a defined filter with its coefficient bytes, an explicitly specified rounding rule and an identified threshold. Retain the intermediate output at material boundaries when the cost is proportionate to the case. If a disputed line first appears after one stage and changes predictably when its precision is varied, that is evidence for a processing artefact. Yet attribution to a particular internal mechanism should remain bounded by the challenge. An external emission might coexist with a spur at a nearby frequency, and the combined output may not permit the two to be separated without additional acquisition.

A successful validation should include both null-input and signal-present tests. Under a digital zero stimulus, the processing block should exhibit only its documented internal behaviour. Under a known weak sinusoid or burst,

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the derived output should meet specified amplitude, timing and spectral tolerances. Deliberately select tuning words that stress phase truncation, signals close to accumulator overflow, and filter inputs near saturation. A fault that appears only under adversarial values should be recorded rather than excluded as an inconvenient special case, especially when a field survey may encounter unpredicted strong legitimate transmissions. Numerical precision is thus a measured component of receiver reliability, not a rhetorical substitute for it.

The report should distinguish a spur-free range measured under specified stimuli from an asserted absence of every possible internal spur. It should also separate a small output noise variance from the reliability of source identity. A coherent arithmetic line may have a very low apparent uncertainty in frequency while its physical-origin hypothesis is entirely wrong. The best engineering solution is a receiver whose known arithmetic artefacts are bounded below its declared detection threshold or whose diagnostic interventions can identify them. I respectfully invite Professor Hotelling to examine whether a spur model calibrated from selected examples has been given more evidential weight than it deserves.

Harold Hotelling | Peer question 5 to William Ralph Bennett

Dr Bennett, your analysis proposes deliberate tuning words and arithmetic stress vectors to reveal spurs, but the laboratory may select those vectors after studying a suspicious line. A model can then appear impressive because it was fitted to the very pattern it purports to predict. If the engineer tries hundreds of combinations of word length, rounding rule and oscillator seed and reports only the one producing the closest spur, the apparent match may arise by chance. What statistical record is

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needed to make the proposed mechanism discriminating rather than retrospective? Should the acceptance campaign allocate an independent set of previously concealed tuning conditions, or would a physical perturbation of the receiver be a stronger test? How would you quantify uncertainty in the predicted line's amplitude when the converter transfer characteristic and analogue source path are themselves imperfectly known?

In particular, how should the trial design account for dependence among nearby FFT bins and among neighbouring tuning words, so that the apparent rarity of a favourable match is not exaggerated by an independence assumption?

William Ralph Bennett | Immediate answer to Harold Hotelling

Thank you for that question. Professor Hotelling, the distinction between discovery and confirmation is essential. The laboratory may use exploratory searches to propose that a particular truncation sequence generated a line. Once the mechanism is proposed, its equations, arithmetic rules and predicted spectral relations should be frozen before a separate challenge. Select new tuning words and initial states, including cases predicted to suppress and cases predicted to strengthen the spur, and compare the output with the specified predictions. Retain all tested combinations, not merely the most visually persuasive match. A systematic match across withheld conditions has stronger evidential value than an isolated resemblance found after numerous trials.

An independent physical intervention can be complementary. If the line belongs to the digital NCO, changing the relevant arithmetic

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should alter it while the raw ADC stream is held fixed. If it belongs to the external RF scene, controlled changes to antenna coupling or input attenuation should affect the acquired signal according to a different physical model. Some changes may affect both mechanisms, so their predicted outcomes must be explicit before testing. A second receiver can offer additional information where its common dependencies are characterised, but mere duplication of software pipelines against the same damaged input is not independent observation of the original event.

Predicted spur amplitude should carry uncertainty from the actual coefficient mapping, accumulator state, interpolation table, finite output arithmetic and analogue conversion where relevant. A deterministic fixed-point replay may predict a precise sequence under exact digital inputs, while the original analogue stimulus remains uncertain. The final report should not collapse those distinct uncertainty sources into one small frequency-bin error bar. It may establish that an internal processing mechanism is capable of generating the observed feature under stated conditions; it does not establish exclusive causation unless competing pathways were appropriately challenged. If withheld trials fail, the model should be revised or the claim narrowed, with the original failure preserved in the validation record.

A forensic conclusion ought to be stronger than an anecdote about a clean display. It should identify the tested mechanism, the challenge design and the boundaries of inference. I pass the floor to Sir Ronald Fisher, who may examine what it means to calculate a false-alarm rate

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across the many candidate arithmetic mechanisms an engineer could imagine.

Sir Ronald Aylmer Fisher | Peer question 6 to William Ralph Bennett

Dr Bennett, a modern receiver may contain several numerically controlled oscillators, multiple channeliser filters, adaptive thresholds and thousands of floating-point or integer operations. The number of possible spur hypotheses is correspondingly large. If the investigator finds one candidate line and tests many possible internal frequency relations, the event of obtaining some close numerical fit may be far more probable than the reported single-model significance suggests. How should one organise the comparison so that a plausible internal-artefact explanation neither becomes a convenient excuse for ignoring a real transmitter nor gains unwarranted certainty from an unrestricted hypothesis search? Would you require a familywise error procedure, an independent predictive challenge, or an evidential ranking that retains more than one plausible cause? And what should the report say when the receiver's exact firmware build cannot be recovered for bit-exact replication?

Would you also require an explicit account of how many candidate error mechanisms were tried before the preferred explanation was selected, lest the precision of the fitted hypothesis be mistaken for the strength of a prespecified test?

William Ralph Bennett | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, an unrestricted search for numerically convenient relations cannot be interpreted as though one predetermined

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hypothesis had been tested. The investigation should retain its search history, including the candidate mechanisms considered, the parameters varied and the criteria for accepting a match. A familywise calculation may be possible for a carefully specified finite hypothesis family, but the dependence between tests may make naive multiplication of single-test probabilities inaccurate. When the candidate mechanisms are exploratory, an independent challenge under new conditions is often more persuasive than a retrospective probability assigned to the best-looking fit.

I would classify candidate explanations by falsifiable predictions. A phase-truncation mechanism may predict changes when accumulator width, table address width or tuning word is altered. A filter limit cycle may predict persistence under digital zero after a specific state history and disappearance under an identified reset. An external carrier hypothesis may predict coupling changes at the antenna and persistence in absolute RF coordinates when internal sample-rate relationships change. Some outcomes may support several explanations, so the report should retain that ambiguity rather than choose the most convenient cause. A hypothesis is strengthened by surviving interventions at which its rivals differ, not by being capable of fitting one historical spectrum.

Where the exact firmware build is unavailable, a proposed bit-exact explanation cannot be presented as verified for that historical capture. The engineer may demonstrate that a related implementation is capable of generating a similar line, but should identify this as a plausibility demonstration. Recovering coefficient

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sets, binaries, device configuration and the raw sample interval may permit stronger reconstruction. Without them, numerical resemblance remains limited evidence. This can be important in litigation, where the party reading the report must distinguish a proven implementation defect from a speculative explanation offered after the fact.

The practical answer is a layered conclusion. Document what was measured; list the candidate internal and external mechanisms; identify which proposed challenge tests were possible; state the results and any unresolved alternatives; and do not quantify certainty more precisely than the trial design permits. The purpose is neither to exonerate every receiver nor to accuse every bright spectral line of being an artefact. It is to make cause assignment a tested scientific proposition. I return the floor to Professor Tukey for the final concern: how should the analyst present these results without allowing display scaling and exploratory choices to masquerade as independent confirmation?

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John Wilder Tukey | Principal response 5: Exploratory graphics, computational reproducibility and the obligation to test the artefact hypothesis

Dr. Atkinson, the final difficulty is not exclusively numerical. It concerns the manner in which a calculated spectrum becomes a story about the world. A frequency display is a transformation of a sequence whose origin, limitations and processing history may be partly invisible to its reader. The investigator can enlarge a narrow band until a low-level spur looks imposing, change the ordinate from amplitude to power, average for longer, select a particular analysis window or alter the apparent baseline. Each choice may be defensible for a particular analytical purpose. None converts a signal-correlated computational error into an independently observed transmitter. If the analyst has adjusted these choices while searching for an attractive pattern, the resulting picture cannot be appraised as though it arose from one prespecified procedure. [T4, T9]

I would begin with a distinction between exploratory and confirmatory work. Exploration may inspect many spectra, tuning words and precision settings to discover plausible explanations. Its product is a set of hypotheses, not a proof of any one. Confirmation requires a fresh challenge with declared test conditions and acceptance criteria, including records from which a material failure would not have been edited away. A numerical oscillator artefact has the useful property that its frequency may be predicted by implementation details. The observation that a line moves with an NCO tuning-word change while the external RF stimulus remains fixed can discriminate explanations, but only if the experiment is designed to test those alternatives. The source's predicted physical movement and the

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processing line's predicted digital movement must be made explicit before the test is performed.

The first record I would preserve is the smallest complete description of the computation sufficient to reproduce a disputed display. That includes source sample hashes, signedness, word sizes, coefficient values, update schedules, arithmetic modes, overflow semantics and digital filter state. It includes the choice of FFT length, window, amplitude calibration, averaging, threshold, scaling and any frequency-axis correction. If the chain contains a proprietary block that cannot be inspected, the report should identify the unverified boundary and use independent input-output challenge measurements instead of pretending to possess a bit-exact implementation. An independent implementation must reproduce the calculation that was actually carried out, not one the designer now prefers. Where the software version or arithmetic configuration changed between acquisition and analysis, both versions should be preserved.

This record can be compact. One need not expose every transient register bit in a high-speed processor to make the reasoning reproducible. Yet a saved display alone is rarely enough for a quantitative forensic inference. The display may omit negative-frequency conventions, the coherent gain of its analysis window or the clipping that occurred before the FFT. A real line whose amplitude was understated by a window correction may be consequential; a processing line that survived excessive averaging may appear especially persuasive. A program that calculates a technically correct plot from incomplete source metadata can provide a convincing answer to the wrong question. The analyst should therefore separate

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computational reproducibility from physical validity, and both from the probability of an identified external source.

Consider a receiver whose NCO tuning word is held fixed for thirty seconds. At one configuration a line at a particular analysis-bin offset appears repeatedly. The scientist then changes the tuning word while preserving the RF generator frequency. Suppose the line follows a phase-truncation prediction through three deliberately selected words, while a known injected test carrier remains at the physical frequency expected after digital conversion. The evidence supports the explanation that the moving line is generated in the numerical processing path, within the tested envelope. It does not establish that every other line is external or that the NCO is the sole internal defect. A second digitally generated spur could coexist; an analogue oscillator could drift as temperature changes; or the changed word could expose a different alias. Scientific restraint should remain proportional to what the intervention distinguished.

I would also question the practice of reporting the best achieved spur-free dynamic range from a set of unreported trials. If the operator changes scaling, input level, spectrum window and clock configuration until the noise floor appears lowest, the selected result is not a random example of normal operation. The procedure may be adequate as a demonstration of an achievable state, provided it is labelled accordingly. It is inadequate to certify routine detection at that performance without recording the selection process. A robust validation ought to report the distribution across a prespecified set of frequencies, signal strengths, tuning words and environmental states, including excluded intervals and failures. Even a

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limited experiment can be rigorous if its operating envelope and testing procedure are clear.

I propose that the publication include a counterfactual question beside every substantive spectral assertion: What observable would differ if the indicated feature came from finite arithmetic rather than the antenna? If both hypotheses predict the same screenshot, the screenshot does not distinguish them. A change in NCO precision, a reset of an IIR state, a controlled RF path substitution or a direct raw-sample reprocessing pass may create useful alternatives. The intervention must be selected for diagnostic power rather than theatre. The best test is not always the most elaborate. It is the test whose predicted results are materially different under competing explanations, and whose history is available for independent criticism.

The resulting report should carry a matrix linking each finding to raw inputs, transformations, calibration records, uncertainty and counterfactual checks. A compact figure may show the same disputed interval under several bit-exact algorithms, but the numbers and method used to create it must accompany the figure. Significant negative or discordant results must not disappear into a celebratory summary. When it is impossible to exclude one internal artefact, the report should say that the observation remains compatible with it. That statement can coexist with useful operational recommendations to repeat the survey using another signal path or to preserve additional raw data at the next encounter. Dr Shannon, I respectfully pass the token to you for a question about whether these multiple representations genuinely add information.

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Claude Elwood Shannon | Peer question 7 to John Wilder Tukey

Professor Tukey, your recommendation to compare several spectral representations might improve the clarity of a report, but could it also create a false impression of independent confirmation? Imagine that the investigator takes one finite digital record, computes a power spectrum with two window functions, applies two rounding rules, and obtains four similar peaks. The resulting report calls this fourfold agreement. Yet every representation is determined by substantially the same original sample record, while each may have inherited an earlier clipping event, analogue noise contribution or incomplete sampling interval. Furthermore, the analyst may have preserved only those algorithms whose peaks aligned closely. What exact information has been added by this exercise, and under what circumstances can comparing derived records genuinely constrain the hypothesis of a numerical artefact? How should the investigator differentiate an improvement in computational diagnosis from an increase in independent evidence concerning the external source? Finally, how do you prevent the familiar authority of a mathematically elegant transform from masking the basic inability to reconstruct the analogue information that was never sampled?

John Wilder Tukey | Immediate answer to Claude Elwood Shannon

Dr Shannon, a deterministic transformation of a fixed record cannot create information about the original analogue event that the record does not contain. The several plots in your example are not four independent antenna observations. They are four interpretations or views of one evidential object. Their agreement can be useful for

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identifying whether a particular numerical conclusion depends upon one arbitrary representation, but it cannot independently verify the upstream acquisition boundary. I would therefore distinguish **robustness to analysis choices** from **corroboration by an independent observation**. The first is a property of the analytic procedure; the second requires a further physical measurement with a declared relationship to the original.

Changing numerical precision or rounding can supply diagnostic evidence because competing implementation models predict different outcomes when the same raw data are processed differently. Suppose a line arises from a particular fixed-point multiplier overflow in the original receiver. A bit-exact reproduction of that overflow may generate the same feature; a deliberately widened accumulator may suppress it. This supports a specific computational account, provided the assumed implementation actually matches the installed device. It does not imply that the input contained no external energy at that frequency, because the original analogue signal might have contained a coincident component. An independent raw capture with a changed analogue front end or a changed sampling architecture can test that further proposition, provided its clock and transfer dependencies are characterised.

The multiple-comparison problem is also real. Four displays selected from hundreds of candidate renderings should not be described as though they were four predeclared trials. The analyst ought to preserve the exploration log or, at minimum, disclose the number and classes of alternatives considered before reaching the

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conclusion. A validation set withheld from the exploratory process can test whether a proposed diagnostic rule continues to discriminate genuine injected emissions from synthetic arithmetic spurs. Randomising the injection schedule and using blinded labels are useful where practical. Where no new physical observation is available, the report should confine itself to a statement about reproducibility and computational sensitivity.

I would require one small table in the final evidential record. Its columns would identify the claim, raw source, transformation, predicted behaviour under an external-emission hypothesis, predicted behaviour under a computational-artefact hypothesis, the observed result and the remaining dependencies. Four matching plots may occupy four rows if their transformations differ, but the source column will reveal that they share the same digital input. If a source channel clipped, every row remains conditioned on that clipping. The fact that a wide-precision reprocessing path produces a cleaner picture is important engineering evidence. It is not restoration of values that the ADC never recorded.

Finally, I would allow the investigator to be decisive within an appropriately restricted claim. If the experimental record demonstrates that a particular low-level line tracks an NCO tuning word and vanishes under a precision change while an injected physical reference remains in place, the analyst may reasonably attribute that tested line to the digital processing mechanism, subject to the tested conditions. There is no virtue in endless hedging when the evidence genuinely discriminates causes. Equally, there is no

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virtue in calling that restricted finding proof of universal absence of concealed transmitters. I return the floor to Dr. Atkinson for the worked applications and the concluding statement of what this roundtable has and has not established.

Worked engineering applications and independent calculations

Richard Wesley Hamming, Cross-Peer Question to Hendrik Wade Bode: Dr Bode, can a numerically stable filter prototype become unstable after its coefficients have been rounded for a fixed-point implementation?

Hendrik Wade Bode, Cross-Peer Answer to Richard Wesley Hamming: Dr Hamming, yes. Pole locations depend on implemented coefficients and numerical realisation, particularly for high-order sections with poles near the unit circle. A direct-form implementation may be more sensitive than a well-scaled cascade of second-order sections. Test coefficient quantisation in the actual arithmetic format and inspect the resulting pole locations, impulse response, limit cycles and overflow behaviour under expected operating temperatures and signal amplitudes. A simulated response using ideal double precision is not evidence of the deployed fixed-point response. Apply both zero-input and bounded high-level stimuli, and retain the exact coefficient tables and software build. The causal conclusion must distinguish analogue oscillation from an arithmetic limit cycle generated after conversion. I pass the token to Professor Wiener for the feedback-state problem.

Hendrik Wade Bode, Cross-Peer Question to Norbert Wiener: Professor Wiener, why might a persistent digital tone remain after the physical antenna has been disconnected and the input is terminated?

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Norbert Wiener, Cross-Peer Answer to Hendrik Wade Bode: Dr Bode, an internal feedback or quantisation cycle may persist when the arithmetic state maps repeatedly through a finite set of representable values. Phase accumulators, resonators and recursive filters can produce periodic errors that are not stationary external RF emissions. Challenge the system with known zero input, different internal initial states, rounding modes and coefficient resolutions. Restarting firmware or changing a tuning word may shift the line in a diagnostic pattern. Preserve both the raw ADC codes and the downstream filter output; if the line exists only in the processed stream, its apparent environmental provenance is weakened. A robust finding requires an instrument-independent receiver path or a calibrated injected source response at the analogue reference plane. I yield to Dr Bennett regarding periodic errors from oscillators.

Norbert Wiener, Cross-Peer Question to William Ralph Bennett: Dr Bennett, a DDS has a thirty-two-bit phase accumulator but uses only its twelve most significant phase bits for the lookup table. Why can a sharp spur appear despite exceptionally fine tuning resolution?

William Ralph Bennett, Cross-Peer Answer to Norbert Wiener: Professor Wiener, tuning-step resolution and waveform purity are different specifications. Discarding the low phase bits creates a periodic phase approximation error for many tuning words; periodic error produces discrete spectral artefacts. The output DAC contributes further quantisation and nonlinearity, and particular tuning words may behave differently. Change the frequency tuning word, output amplitude and phase truncation settings where available, recording whether suspect lines move with the internally generated clock. A spur should not be classified as an external

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transmission merely because it is narrow and coherent on one display. Measure the phase-noise pedestal and individual spurs separately, and record the full digital configuration that allows another laboratory to reproduce the behaviour. I respectfully pass the token to Professor Tukey to examine the evidential record.

William Ralph Bennett, Cross-Peer Question to John Wilder Tukey: Professor Tukey, what evidence is required before one claims that a tiny spectral feature is an emitter rather than a finite-arithmetic artefact introduced by processing?

John Wilder Tukey, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, retain a common raw sample segment and reconstruct it through independently implemented software at more than one numerical precision. If the line shifts or disappears with arithmetic precision, coefficient scaling, block boundaries or oscillator tuning words, the processing chain becomes a live causal hypothesis. Repeat with a terminated input and known calibration tones, and compare with an independent analogue measurement chain not sharing the numerical implementation. Inspect all candidates rather than presenting only the most favourable display. The conclusion should state what was observed, the transformations performed, the configuration under which the feature appeared and the competing internal mechanisms still plausible. A visual peak alone cannot uniquely identify a transmitter. I return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Distinguished colleagues, the discussion has established that finite word length is not merely a matter of fewer numerical digits. It can change the realised behaviour of a digital oscillator, filter, detector or phase estimator

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in ways that are physically consequential to a technical surveillance countermeasures inquiry. The operator may see a stable line whose frequency is known to many decimal places and whose repeatability suggests an external transmitter. Yet a similar line may be generated by a deterministic digital phase truncation, accumulator overflow, fixed-point rounding pattern or persistent recursive state. The confidence of the graphic is not the confidence of the inference. Our task is to preserve the distinction between an exact calculation, a reproducible implementation and a validated claim about the electromagnetic world.

Mr Hamming has explained why programming resolution and physical accuracy must not be conflated. A long phase accumulator permits extremely fine digital frequency steps under its nominal clock. That is an arithmetic property, not a certificate that the clock is accurate, that a lookup table introduces no periodic error or that the analogue receiver's reference plane is faithfully calibrated. The number of bits becomes informative only when attached to a precisely specified computation. A report that cites a thirty-two-bit NCO without identifying its phase-to-amplitude mapping, tuning words and clock uncertainty has described an inventory item rather than a bounded measurement capability.

Professor Bode has shown that the coefficients actually stored in hardware, rather than the ideal coefficients printed in a design report, determine the implemented linear model. He has also shown that the quantiser, accumulator and saturation rules may move the actual process outside that linear model. A coefficient that approaches unity can be rounded to unity; a transient can invoke an overflow mechanism; and a design meant to produce decaying behaviour can retain a persistent state.

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Neither simulation with double precision nor an unqualified stability statement can settle those questions. The laboratory must inspect or reproduce the actual arithmetic path and test the operating states relevant to the claim.

Professor Wiener has reminded us that adaptation and memory can defeat the naïve inference that a persistent indication means a persistent external event. A detection display may retain an internal state when its input is absent. Resetting or changing filter coefficients can diagnose the phenomenon, but if the only available record is the state after correction, the observation's origin may remain underdetermined. Hence a proper forensic archive contains sufficient raw acquisition, processing versions and state changes to challenge the temporal interpretation. A countermeasure which removes a nuisance tone is useful engineering; it is not by itself proof of the tone's past physical origin.

Dr Bennett has distinguished an arithmetic-noise model from deterministic signal-correlated error. An independent white-noise approximation can be helpful under specified conditions, but cannot be elevated to an unconditional property of every fixed-point sequence. The laboratory must test deliberately chosen tuning words, frequencies, amplitudes and arithmetic boundary conditions, including values likely to produce repeatable error. A noise-floor statistic may not reveal a weak coherent spur; conversely an exceptionally sharp spur may reflect a digital mechanism rather than an exceptionally stable transmitter. The observed spectral geometry can be precise while its causal interpretation is wrong.

Professor Tukey has returned these technical findings to the discipline of accountable scientific reporting. A series of spectra derived from one

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retained record does not create a series of independent measurements. Multiple renderings can expose dependence upon one window or rounding choice, but they cannot recover clipped analogue amplitudes or time intervals that were never recorded. Exploratory choice must be distinguished from confirmation. Where the investigator has selected a favourable display after testing many options, the selection history matters to the evidential weight assigned to the result. A withheld challenge, controlled injection or receiver-path substitution can improve the scientific claim only where its predicted outcomes discriminate alternative explanations.

The ten applications provide controlled illustrations of these boundaries. A thirty-two-bit phase accumulator at 100 MHz permits a nominal frequency step of about 0.0233 Hz; a ten-parts-per-million clock contribution at 10 MHz is about 100 Hz. A twelve-bit sine-table address does not magically preserve all thirty-two accumulator bits in the amplitude mapping. A sixty-four-tap FIR can accumulate a worst-case coefficient error bound far larger than one coefficient's rounding step. A signed sixteen-bit accumulator may wrap catastrophically rather than saturate gently. A quantised first-order recursion can retain a nonzero zero-input state, and rounding a stable pole to unity can remove the designed decay. Each result belongs to its assumptions and chosen numeric representation. None is a calibration measurement of a particular field receiver.

For practice, the panel's conclusion is that the evidence register should identify the original acquisition boundary, exact software and arithmetic configuration, relevant clock state, test inputs, coefficient bytes, processing changes and uncertainty of any correction. The examiner should preserve

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the before-and-after results where material, explicitly record invalid or missing intervals, and challenge suspected artefacts with interventions selected to distinguish them from external emissions. A validated restricted finding is preferable to an untestable sweeping assurance. We shall not require perfect numerical representation as a prerequisite for useful investigation; neither shall we permit an engineering calculation to claim more physical knowledge than the original measurement can bear. The next question will examine whether a processing chain preserves the minimum events and temporal structure required for reliable detection. I thank our colleagues for their careful disagreement and formally pass the floor onward.

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Ten worked engineering applications | Question 038

Application 1: Frequency resolution of a 32-bit phase accumulator

Let the sample clock be F_s = 100,000,000 samples per second, and let W = 32 denote the accumulator width in bits. The smallest commanded frequency increment of an ideal conventional NCO is $\Delta f = F_s/2^W$. Substituting gives 100,000,000/4,294,967,296 = 0.02328306436538696 Hz. This number is a digital tuning increment, not a measure of absolute output accuracy. It assumes a stable ideal clock and the conventional phase-update rule. The true carrier frequency still depends upon the clock's calibration, phase noise and the implementation's exact arithmetic. A displayed tuning resolution of approximately 23 millihertz does not certify 23-millihertz physical frequency accuracy. [T1, T2]

Application 2: Frequency error from rounding a tuning word

Let F_s = 100 MHz, W = 32 and desired f_d = 10 MHz. The tuning word is $K = \mathrm{round}(f_d\, 2^W/F_s)$ = round(429,496,729.6) = 429,496,730. The realised mathematical output is $f_o = K\, F_s/2^W$ = 10,000,000.009313225746 Hz, approximately 0.009313 Hz above the requested value. Here the result follows the ideal NCO model and is not a measurement of a particular oscillator. A receiver may exhibit larger physical errors because of reference-clock uncertainty and system calibration. The investigator should retain both the requested frequency and the exact integer tuning word used during the acquisition.

A version-controlled configuration log should store K as an integer rather than relying exclusively upon a rounded human-readable

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frequency, because a later reconstruction needs the exact arithmetic command.

Application 3: Clock accuracy versus frequency programming precision

Suppose the 100 MHz clock carries an uncertainty or error of 10 parts per million, and the commanded NCO output is near 10 MHz. The corresponding frequency error magnitude from this assumed clock error is approximately 10,000,000 times 10/1,000,000 = 100 Hz, vastly larger than the 0.0233 Hz accumulator step. If the clock uncertainty is specified as an expanded uncertainty rather than a guaranteed error, the result must be described as the corresponding expanded output contribution under the stated linear model. It is incorrect to add quantities without first distinguishing calibration bias, stochastic stability and the frequency interval to which the clock claim applies. [T1]

Application 4: Phase-table truncation and discarded state bits

Let W = 32 be the accumulator width and P = 12 the number of high-order phase bits addressing a sine table. The table uses 2^P = 4,096 nominal phase positions, while W-P = 20 accumulator bits are not directly represented by the table address. The numerical count of discarded low-order phase states is therefore 2^20 = 1,048,576 per table-address interval. This establishes the address granularity and periodic structure available to the implementation, not a universal spur amplitude or a formula for all spur frequencies. Actual spurs depend on the tuning word, lookup representation, interpolation, dither and subsequent arithmetic. [T2, T3]

Application 5: A conservative FIR coefficient-quantisation bound

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Consider a 64-tap FIR with exact coefficients h[k] individually rounded to the nearest multiple of q = 2^-12. For each coefficient, absolute error is at most q/2 = 0.0001220703125, provided ordinary round-to-nearest is used and there is no overflow. If the input samples satisfy |x[k]| <= 1, the worst-case absolute output error due solely to coefficient rounding is bounded by the sum of the coefficient-error magnitudes: 64(q/2) = 0.0078125 in normalised output units. This is an intentionally loose worst-case bound, corresponding to about -42.14 dB relative to unity amplitude. It is not a stochastic rms prediction, and it does not include accumulator rounding, input quantisation or filter-state errors. [T4]

Application 6: Headroom from the absolute coefficient sum

Suppose an eight-tap FIR has coefficients whose absolute magnitudes sum to 1.25, with input samples bounded by an absolute normalised amplitude of 1. The triangle inequality then gives |y[n]| <= 1.25 under exact arithmetic. A fixed-point output format that can represent magnitudes strictly below 1 may therefore saturate or wrap under some input combinations unless scaling, saturation control or wider accumulation is provided. The bound does not imply that every input reaches 1.25, nor that it does so under typical noise. It establishes an allowed worst case to be checked when certifying headroom. An implementation's actual coefficient signs and reachable input sequences affect attainability. [T4, T5]

Application 7: Two's-complement overflow discontinuity

Consider signed 16-bit two's-complement arithmetic with representable integer range -32,768 to 32,767. If an intermediate sum of

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32,760 + 20 = 32,780 is formed and wraps modulo 2^16 rather than saturating, the represented signed result becomes 32,780 - 65,536 = -32,756. The output has jumped by 65,536 integer counts relative to the unwrapped mathematical sum. Such a discontinuity can inject broadband components and periodic artefacts under repeating stimuli. A different implementation may saturate at 32,767, so the arithmetic mode must be identified before claiming any particular spectral consequence. [T4]

The apparent waveform event occurs inside the calculation; the presence of that event alone supplies no evidence of an equally abrupt voltage change at the analogue input.

Application 8: A quantised first-order recursion that retains a nonzero state

Let the intended recursion be y[n] = Q(0.9 y[n-1]), where Q rounds to the nearest multiple of q = 1/16 = 0.0625. Starting with y[0] = 0.0625, the next unquantised value is 0.9 times 0.0625 = 0.05625. Its nearest q-multiple is 0.0625, so y[1] = y[0]. The same calculation repeats indefinitely in this idealised arithmetic model, producing a persistent nonzero state despite zero input. This is an illustrative zero-input limit cycle, not a prediction about every IIR filter. Rounding ties, noise, saturation and coefficient implementation can change the reachable states. [T4, T5]

A calibrated zero-input challenge and an explicit state-reset test can help distinguish this computational persistence from the duration of a genuine input transient.

Application 9: Coefficient rounding changes an ideal stable pole

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Let a first-order ideal recursion be y[n] = a y[n-1] with a = 0.9990. Its pole magnitude is below 1, so in exact arithmetic the unforced state decays. Suppose a is stored using an eight-fractional-bit representation with q = 1/256 = 0.00390625 and rounding to nearest, and the format can represent 1 exactly. The nearest representable value to 0.9990 is 1.0000, so the implemented recursion has coefficient a_q = 1. Its unforced state no longer decays in exact arithmetic. This demonstration relies upon the chosen coefficient format; a fractional-only format whose maximum is below one could produce a different result. A stability certificate should therefore be based upon the actual stored coefficients and arithmetic behaviour rather than the ideal real-valued design. [T4]

Application 10: Separating tuning-word precision from clock-induced offset

Suppose a receiver's digital local oscillator is commanded to 12.5 MHz and uses an ideal F_s reference subject to a relative clock error of 2 parts per million. In the linear frequency-scaling model the corresponding output error is 12,500,000 times 2/1,000,000 = 25 Hz. If the accumulator is 32 bits wide and clocked near 100 MHz, its tuning increment is approximately 0.0233 Hz; thus the clock-error contribution is over one thousand times the tuning step. A very narrow plotted line can still be tens of hertz away from its nominal physical frequency. Clock calibration, not the number of accumulator bits, determines how much confidence the examiner should place in the displayed absolute frequency.

Scholarly source register and scope of verification

The roundtable dialogue and all ten numerical exercises are original educational constructions. Bracketed keys identify sources used to establish mathematical

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and engineering mechanisms or historical details. No fabricated utterance is attributed to an historical person. The source scopes below concern the public material actually available for checking; an accessible web page or publisher abstract is not represented as a review of an entire inaccessible book, paywalled article or technical test report. The numerical exercises were independently recalculated from the assumptions printed in the manuscript and do not certify actual receiver hardware.

[T1] Analog Devices. AN-1396: How to Predict the Frequency and Magnitude of the Primary Phase Truncation Spur in the Output Spectrum of a Direct Digital Synthesizer (DDS). Public technical application-note landing page and accessible explanation consulted for the relation of DDS sample rate, accumulator width, frequency tuning word and phase truncation mechanisms; this record does not imply that a specific modern receiver was calibrated. https://www.analog.com/en/resources/app-notes/an-1396.html

[T2] Analog Devices. Direct Digital Synthesis technical discussion and phase-truncation explanatory material. Accessible public vendor engineering guidance consulted for accumulator, waveform mapping and periodic error mechanisms. These engineering concepts are relevant to the present hypothetical architecture; particular spur predictions require the actual numerical implementation, not merely a general diagram. https://www.analog.com/en/resources/analog-dialogue/articles/all-about-direct-digital-synthesis.html

[T3] Analog Devices. Phase Truncation Spurs frequently asked questions. Public specialist note consulted for the existence and design dependence of phase truncation artefacts. No specific spur frequency or amplitude in this chapter is attributed to a measured commercial apparatus. https://www.analog.com/en/resources/faqs/faq_phase_truncation_spurs.html

[T4] MathWorks. Fixed-Point Precision Rules for Avoiding Overflow in FIR Filters. Accessible technical documentation consulted for coefficient representation, accumulator width, output precision and the relationship between numerical headroom and overflow. Its FIR output-limit explanations support the conceptual treatment; the chapter's coefficient bounds are independently derived for the stipulated hypothetical values.

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https://www.mathworks.com/help/dsp/ug/fixed-point-precision-rules-for-avoiding-overflow-in-fir-filters.html

[T5] MathWorks. Fixed-Point Filter Design and Quantisation documentation. Public product documentation and instructional pages consulted for rounding, truncation, fixed-point state and the need to evaluate actual arithmetic representation. The small recursive examples in this manuscript are original mathematical constructions, not extracts from documented manufacturer measurements. https://www.mathworks.com/help/dsp/ug/fixed-point-filter-design.html

[T6] National Academies of Sciences, Engineering, and Medicine. Memorial Tributes: Volume 10, Richard W. Hamming. Public memorial biographical page consulted for Hamming's life, professional appointments and contributions. It supplies biography, not proof of the modern fictional dialogue. https://www.nationalacademies.org/read/10403/chapter/23

[T7] Oxford Academic, American National Biography. Hendrik Wade Bode, reference article abstract. Available abstract and identifying metadata consulted for Bode's career and mathematical engineering context. No claim is made to have consulted an inaccessible full text. https://academic.oup.com/american-national-biography/reference/63042/reference-article-abstract/570917364

[T8] MIT Press. Norbert Wiener author biography. Public author profile consulted for his MIT career and contributions to cybernetics. It is not an authenticated quotation of a response concerning modern electronics. https://mitpress.mit.edu/author/norbert-wiener-18445/

[T9] University of St Andrews, MacTutor History of Mathematics. John Wilder Tukey. Public historical biography consulted for his life and work in statistics and computation. Its institutional biographical details do not establish that he personally examined the hypothetical receiver or the proposed forensic procedures. https://mathshistory.st-andrews.ac.uk/Biographies/Tukey/

[T10] Science Museum Group. Norbert Wiener biographical record. Public collection page consulted for documented historical details and his engagement

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QUESTION 039

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Which apparent transient features can be created by sample-rate conversion?

Source: V011_Roundtable_Question_039_CP039_Dr_Atkinson(1).docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 039. Complete scholarly discussion

Newly authored educational reconstruction. This is a newly constructed scholarly dialogue and not a historical transcript. No historical quotations are attributed to the named participants, and hypothetical numerical examples do not certify instruments.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, our examination of finite arithmetic has shown that a signal-processing chain may generate persistent features whose apparent precision derives from computation rather than from any external electromagnetic emission. We now turn to the corresponding question in time. An intermittent burst, abrupt carrier onset or short impulse may be shifted, broadened, attenuated, duplicated or accompanied by ringing when its sample sequence is converted from one digital rate to another. The analyst who first sees the converted trace may infer that the signal switched on before the recorded trigger, that several emissions occurred in rapid succession, or that the source remained active after its actual input vanished. Those interpretations may be sound under an appropriate acquisition model. They may also be artefacts of filter support, mathematical boundary assumptions, block processing or timestamp assignment. We must identify the observations needed to distinguish these possibilities

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before allowing a converted trace to speak as though it were the unprocessed physical event.

Let F_in be the input sample rate, L and M be relatively prime positive integer interpolation and decimation factors, and F_out = F_in L/M be the nominal output sample rate. A conventional rational resampler conceptually inserts L-1 zero samples between original values, applies an appropriate low-pass interpolation and anti-alias filter, then retains every Mth filtered value. Efficient polyphase implementations avoid most explicit zero operations, but the physical interpretation remains conditional on filter design, phase alignment and correct scaling. The resulting output samples are not additional independent analogue observations. They are computed functions of the acquired sequence. Their frequency support may be restricted, and their apparent temporal profile is influenced by the filter's impulse response. An estimator may improve the utility of a record without restoring information rejected by earlier sampling, clipping or filtering stages.

The choice of mathematical method deserves particular attention. A frequency-domain resampler that shortens or pads an FFT may effectively treat the finite input as periodic. An abrupt discontinuity between the record's end and beginning can then influence the computed output through ringing or apparent pre-event energy. A polyphase FIR method may instead depend upon explicit padding assumptions, such as zero continuation, line continuation or repeated endpoint values. Those choices can produce different apparent waveforms near the boundaries of a finite record, even when both methods agree well in its interior. The differences are not necessarily software defects. They represent distinct extrapolations

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of information outside the captured interval, and forensic interpretation must not promote an arbitrary extension convention into a measurement of the original transmitter. The official SciPy descriptions make these assumptions explicit. [S1, S2]

A second difficulty concerns time origin. Linear-phase FIR filters can introduce group delay, while a polyphase implementation may compensate, trim or shift output samples according to its internal conventions. The apparent first event sample in a derived file may therefore be located at a different numerical index from the first event sample in the original acquisition, even though its physical reference time is meant to remain invariant. If the analysis uses more than one receiver, an uncorrected delay of only a few samples can corrupt a time-difference or phase-coherence assertion. The investigator should preserve the input epoch, filter coefficients, initial phase, boundary policy, software version and input-to-output timestamp mapping. A label placed on an output sample is not itself evidence of the instant at which the antenna observed the originating field.

There are also questions of alias rejection and temporal resolution. A narrowband output with excellent noise performance may be unsuitable for reconstructing a microsecond pulse whose essential spectral content lies outside the retained band. Its filter can suppress the original sharp edge and create a smoother, longer apparent event. A digital detector may register two threshold crossings for one physical pulse because the filtered impulse response oscillates about the threshold. Conversely, two physical pulses separated by a short interval may merge into one broad output maximum. The problem is not solved by simply printing more decimal places on the output timestamp. It requires a validated event-transfer

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characteristic, with the detection statistic and threshold included in the test. The correct question is how a prescribed class of physical inputs maps to declared derived measurements, and which competing inputs remain observationally indistinguishable.

I ask the principal contributors to separate three propositions. First, whether a given resampling algorithm is computationally reproducible from its archived inputs. Second, whether its output preserves an identified physical quantity within a validated uncertainty envelope. Third, whether a detected transient can be attributed to an external emitter rather than to the source receiver or processing chain. These propositions require different evidence. An exact re-execution of the software may verify the first but not the third. A calibrated laboratory impulse may support the second for a specified waveform class while leaving an unusual field burst unresolved. An independent receiver substitution or physical input perturbation may add useful causal evidence, provided the paths are sufficiently different and their common dependencies are disclosed.

Dr Shannon shall begin with the information lost by noninvertible filtering, Professor Slepian shall address finite time-frequency concentration, Dr Wiener shall examine adaptive state and ringing, Dr Tukey shall question event selection and repeated detections, and Dr Hamming shall consider numerical phase alignment and implementation fidelity. Seven peers will challenge these propositions through immediate replies. We must then develop ten worked applications distinguishing output sample spacing from actual event timing, amplitude scaling from waveform restoration, and a visually impressive transient from a defensible forensic claim. Dr Shannon, may I invite your opening account of which properties can be preserved by

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resampling and which become irretrievable after frequency support has been discarded?

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Claude Elwood Shannon | Principal response 1: Interpolation, sufficient representation and noninvertibility

Dr. Atkinson, a resampler can be an excellent instrument of analysis without being a second physical receiver. A rate-converted sequence is calculated from the originally acquired data according to a specified transformation. When that transformation is one-to-one on the relevant class of signals, a mathematically faithful change of representation may preserve the quantities that class can support. When the transformation discards frequency components, however, two distinct input sequences may yield the same output. The distinction cannot be settled by noting that the output has more samples than the input. Interpolation generates additional numerical values according to assumptions about the signal's bandwidth and continuity. It does not interrogate the antenna at additional historical instants. A later analyst cannot force a lost out-of-band transient to reappear by increasing the number of output time labels.

The practical requirement begins with the signal class. A real, properly sampled waveform satisfying a stipulated band limit may be reconstructed in an ideal mathematical model from samples taken at a suitable rate. A new uniform grid can then represent the same underlying function. But a real acquisition has finite duration, noisy time stamps, an analogue transfer function and possible nonlinearity. The digital input may already have lost information through overload, aliasing or incomplete observation exposure. The resampler inherits those limitations. It can faithfully calculate one model's implied values while giving the false impression that they are direct voltage measurements. For forensic work, a report should specify whether a printed derived amplitude is an interpolation, a filtered estimate, or an

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independently sampled physical quantity. These distinctions affect the testimony an examiner can defend.

Consider a single sharp pulse. A filter with limited bandwidth cannot reproduce an ideal instantaneous edge. Its output is the convolution of the input with an impulse response; side lobes may place nonzero computed values before or after the main peak according to filter phase and finite-record boundary assumptions. A thresholded detector may interpret those lobes as precursors or repeated events. It is inappropriate to infer several transmitted impulses solely from their presence in the derived trace. One must compare the alleged features with the expected response to a single injected pulse whose amplitude, duration and timing are known at the relevant physical reference plane. The challenge should include pulses near the beginning and end of processing blocks because the extrapolation convention can have a substantial effect there. The retained raw samples can then establish which features were already present before rate conversion.

The distinction between preserving information and improving a decision is equally important. A well-designed low-pass resampler may reduce unwanted high-frequency noise and improve an estimator of a narrowband carrier. The filtered trace may be more useful for an operator seeking that carrier, but the transformation has not created new information about an external source that was absent from the original samples. It may also discard information useful for another question, such as whether an adjacent strong emission caused analogue intermodulation. A claim that the new file is 'higher resolution' must specify whether the term refers to output sample spacing, estimator variance, bandwidth or temporal localisation.

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Increasing the number of stored points while narrowing their frequency support can improve one quantity and degrade another. The engineer should state the tradeoff rather than offer a universal improvement.

Absolute timing requires a separate analysis. The source epoch, sampling-clock relationship and filter delay determine how derived sample indices map to physical instants. An implementation that compensates for a group delay may return a trace whose main peak appears aligned with the input, while a different edge-padding method produces precursor or terminal distortions. The fact that a library function returns an evenly spaced output coordinate is not evidence that the original event occurred at each of those interpolated times. It supplies a mathematical grid. For a multisite capture, any delay correction should be supported by measured reference signals or a validated transfer model, with uncertainty propagated into the time-difference calculation. An unverified adjustment of one sample can be consequential when localisation depends on microsecond or nanosecond distinctions.

An ideal reconstruction theorem also does not establish the physical identity of a source. If two transmitters, a receiver-generated mixer product, or an internal numerical spur all contribute to the acquired samples, a resampler operates on their aggregate. It cannot infer which component is external merely because its phase or amplitude becomes easier to inspect. The analyst needs interventions under which rival hypotheses predict different outcomes: altered front-end attenuation, antenna coupling, sampling configuration or independent receiver paths. These challenges should be performed without silently changing the detection rule after

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seeing the result. Otherwise the apparent agreement reflects a selected analysis rather than a tested physical account.

I would preserve the exact raw sample file or a proportionate unprocessed interval, the rate ratio, interpolation-filter coefficients, phase convention, initial conditions, padding rule, software build and any detected missing input buffers. The report should distinguish a mathematically reconstructed sample from a measured one, and identify the signal classes for which reconstruction error has been bounded. A narrow claim may be made confidently where the chain has been challenged and the uncertainty is adequate for the intended use. An assertion about an unobserved transmitter's precisely timed emission cannot rest solely upon a converted waveform that the apparatus could also have created through boundary assumptions. The finite record is evidence. The reconstruction is its conditional interpretation. I pass the floor to Professor Slepian for the temporal and spectral compromises that appear when a pulse is too short for the chosen observation window.

Harold Stephen Black | Peer question 1 to Claude Elwood Shannon

Dr Shannon, your distinction between the original sequence and a derived trace becomes especially troubling in a receiver whose processing choices are governed by the event itself. A short transient may raise the estimated noise floor, trigger a narrower filter, and cause the apparatus to retain a resampled output whose beginning precedes the nominal trigger because the filter uses buffered samples. An operator examining that output may describe the apparent precursor as an independent emission that warned of the subsequent burst. How would you require the laboratory to establish whether the precursor

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existed at the original analogue input? Is a comparison against one raw trace sufficient, or must the experiment repeat pulses at several phases relative to the block boundary and under several adaptation states? I also ask how the record should distinguish a deliberately constructed pre-trigger buffer from an acausal-looking mathematical filter, particularly when the implementation is capable of zero-phase processing only after an entire block has been acquired.

Claude Elwood Shannon | Immediate answer to Harold Stephen Black

Thank you for that question. Mr Black, the temporal ordering of the computed output must not be confused with the time at which the algorithm became able to compute it. A blockwise or forward-backward procedure can assign an output value to an earlier time index while using samples acquired later. This can be a legitimate method of estimating a historical waveform; it is not evidence that the receiver possessed foreknowledge of the event or that an earlier physical precursor existed. The report should name the operation and its data dependence, including the interval of input samples contributing to each output. A pre-trigger buffer, by contrast, contains raw samples genuinely acquired before a trigger decision, provided the clock and buffer continuity record support the assigned times. Those are materially different provenance claims despite superficial similarity on a screen.

An acceptance campaign should capture the raw input and the derived output from the same controlled stimulus, including the detection rule and adaptation state. Place pulses at several

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predetermined positions relative to filtering and retention boundaries, and make the output's timestamp convention explicit. If a precursor appears only after resampling and is consistent with the tested impulse response or boundary convention, it is inappropriate to call it a separate physical emission. The test should also vary pulse amplitude and duration so that an internal artefact is not mistaken for a signal-independent correction. A result observed under one convenient alignment cannot certify every possible alignment of a short unpredictable event.

The adaptation mechanism should be tested separately. Fix its coefficients for one campaign, then allow its prescribed updates during another, preserving the update history. Where the apparatus retains only processed outputs after adaptation, its record may not support the strongest retrospective claim, because the transformation and selection rule may have removed the observations needed for an independent challenge. In such a case the examiner can still say that the derived system reported a feature under a recorded configuration. It should not claim precise source onset or an independent precursor without adequate evidence at the physical input boundary. The goal is not to forbid sophisticated filtering. It is to prevent a perfectly reproducible calculation from being given a causal interpretation which its input record does not determine.

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David Slepian | Principal response 2: Finite-window concentration and apparent precursors

Dr. Atkinson, any claim about an abrupt event must contend with the fact that the mathematical operations used to control bandwidth act over time. A filter that attenuates frequency components outside a selected region cannot, in general, leave every possible waveform edge unaltered. The physical signal and the filtered representation are related by convolution, and the filter's impulse response can extend over an interval much longer than the event the receiver is seeking. A narrowband representation may consequently show a precursor, a delayed peak, oscillatory lobes or an extended tail even when the source supplied only one short pulse. The operator should ask whether these structures persist in the unprocessed input, not whether they look like separate marks on a waterfall. A spectral plot is a mathematical description of a processed series, not a camera photograph of the historical electromagnetic field.

Consider an idealised impulse at time t_0 and a linear, time-invariant resampling filter with impulse response $h(t)$. The output is proportional to $h(t-t_0)$. If the impulse response has a main lobe and side lobes, its output may exhibit several local maxima. Threshold crossings can therefore multiply one physical event into several apparent detections when the detector counts every above-threshold lobe independently. Conversely, two closely spaced physical impulses can merge into one large maximum when their filtered responses overlap. Neither event-count discrepancy need indicate faulty software; it can follow the declared filter design. The error arises when the operator reports the output maxima as a count of physically distinct emissions without validating the event-transfer characteristic.

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The finite record introduces another limitation. A mathematical resampler may process a block as though its ends connect periodically, while the actual electromagnetic scene may have been silent before the recorded interval or may have changed abruptly at the boundary. That mismatch can create ringing across the artificial join. A polyphase implementation with zero padding produces different boundary assumptions from one that extends the last value or fits a line. These choices can be compared experimentally, but the input beyond the captured interval remains unknown. It is therefore inappropriate to select whichever boundary convention yields the preferred narrative and then attribute its precursor or terminal feature to the external source.

The signal class matters in every calibration. A long sinusoidal carrier away from the record boundaries may survive a properly designed resampler with excellent amplitude and frequency fidelity. An isolated microsecond pulse may respond quite differently because its relevant spectrum occupies a broad range and its onset lies within the filter's temporal support. The proper validation should therefore include representative bursts spanning the anticipated duration range, varying their alignment relative to the input and output grids. It should test signals near the admitted passband edge, where transition-band attenuation and phase behaviour may differ from central frequencies. A single steady calibration tone proves too little about impulsive source timing.

In the mathematical ideal a waveform can be approximately concentrated in time and frequency, but exact simultaneous limitation in both domains is impossible for a nonzero function. The engineer therefore chooses tolerances and quantifies the resulting compromise. The width of

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an impulse response, the stopband attenuation, the passband ripple and the phase or group-delay behaviour are not independent aesthetic preferences. They govern the extent to which a transient can be represented without misleading delay or amplitude distortion. If a receiver is designed to recover extremely brief events, a longer low-pass filter chosen solely to improve the stationary noise floor can defeat that very objective. The design should state the shortest target duration and the allowed timing distortion before a particular resampler is certified.

For forensic interpretation I would require the original sample epoch, every relevant resampling ratio, the filter taps or frequency-domain window, boundary assumptions, and a precise mapping from source indices to output indices. A digital file with regular timestamps may nonetheless have been derived from an input containing gaps, repeated samples or clock drift. A reconstruction that silently interpolates across those gaps creates apparently smooth data without supplying the missing observation. The investigator should mark discontinuities and avoid claiming unbroken physical exposure where the raw acquisition was interrupted. A transient reconstructed across a missing buffer is a model-based prediction, not a directly recorded event.

The strongest evidence is comparative. Apply known impulses and bursts at the physical receiver input, preserve simultaneous raw and derived records, and measure the distribution of timing bias, peak-amplitude error, event merging and false-event splitting across relevant states. Challenge the chosen threshold, rather than merely inspecting plots without a decision rule. Where the error can be bounded, a derived record can support a bounded conclusion. Where the original waveform's frequency content was

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suppressed or where acquisition gaps are unresolved, a precise historical reconstruction may be impossible. The engineer should state that limitation without confusing it with the excellent computational reproducibility of the converted file. I pass the floor to Professor Tukey for the statistical consequences of counting several derived maxima as independent events.

Percy Williams Bridgman | Peer question 2 to David Slepian

Professor Slepian, I am troubled by the way a pleasing graph invites the examiner to speak of the onset of a burst as though onset were a single naturally observable object. The receiver has measured a voltage at an input plane, sampled it according to one timebase, and replaced the retained samples with values derived under a filter and an endpoint rule. A threshold on those derived values defines an event whose start depends upon the selected threshold and the processing operation. Suppose two analysts examine the same raw interval, one employing a symmetrical finite impulse response and one employing a causal filter, and their onset times differ by several microseconds. Which of them has measured the physical onset, if either? I should like a proposed operational definition that does not become circular. It must identify whether the onset is the first detectable departure from estimated noise, the first crossing of an amplitude threshold, or a parameter inferred by fitting a waveform model. I also ask which of those definitions permits a defensible uncertainty interval when the source waveform itself remains unknown, and how the choice ought to be explained to a court that sees only the printed temporal trace.

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David Slepian | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, your demand exposes a genuine ambiguity, not a merely verbal inconvenience. There is no unique physical beginning of an arbitrarily weak, band-limited signal established solely by the first plotted crossing. A finite-bandwidth processing chain spreads a short impulse, and noise can create earlier or later threshold excursions. The examiner must define a measurand which is actually estimable. For instance, the first threshold crossing at a specified reference plane, with a stated filter, decision rule and false-alarm convention, can be reproducible. It is not necessarily the physical instant at which the transmitter began to emit. Alternatively, a parametric fit to a stipulated waveform can estimate a latent start time, but the resulting interval depends upon the adequacy of that waveform model and upon the assumed noise covariance. Those are different claims and must remain separate.

I would require the report to present the raw acquisition epoch and sample spacing, the derivation of the time stamps, the finite filter's group delay and temporal support, and the algorithm's treatment of data preceding the interval. If a causal filter produces a delayed event and a zero-phase noncausal filter produces apparent pre-event oscillations, neither trace should simply be labelled the unfiltered source waveform. One can estimate the conditional detection delay of each method by injecting known pulses with randomised phase relative to the sample clock and measuring the resulting distribution of threshold times. Such trials must cover the lowest amplitude and shortest pulse on which a conclusion is asserted, for those conditions

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can exhibit the largest instability. The interval reported should include uncertainty from the time reference, the amplitude and noise estimate, the detector's own variability, and uncertainty in any correction for systematic filter delay.

The court deserves a distinction between a displayed event marker and a historical source onset. A marker is an output of an explicitly defined procedure. A source-onset inference is a conclusion about the generating process, and generally requires extra assumptions or independent physical evidence. Where two algorithms disagree, the proper response is not to select the more visually persuasive one. Preserve both outputs, establish the interval of their agreement under controlled challenge, and restrict the result to what those challenges support. I pass the token to Professor Gabor for the question of what frequency localisation can reveal when a burst occupies only a few samples.

Dennis Gabor | Peer question 3 to David Slepian

Professor Slepian, a short pulse presents the analyst with the familiar tension between localisation in time and localisation in frequency. A long analysis window may yield a clean narrow spectral line while erasing the time at which the pulse entered; a short window gives an uncertain frequency estimate but reveals a transient that the long average conceals. Suppose a resampler with a narrow passband is followed by a spectrogram whose operator changes window length until a candidate emission becomes visually striking. If the candidate is near the passband's edge, could the resulting apparent persistence be a property of the window and filter rather than of a sustained source? I ask whether

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one can establish a useful criterion, before looking at the field record, for selecting the window and filter parameters required to distinguish one short event from two nearby events. Moreover, how should we treat the apparent improved time resolution when interpolation increases the density of plotted samples without increasing the bandwidth actually retained?

David Slepian | Immediate answer to Dennis Gabor

Professor Gabor, greater display density is not a substitute for greater informational bandwidth. The interpolation may make a computed peak easier to locate within a chosen model, and a suitable statistical estimator may reduce discretisation error in the reported peak position. But the allowable precision of a source-onset claim depends on signal bandwidth, noise, phase response, prior waveform assumptions and calibration. If the retained band excludes distinctions between one pulse and two, no multiplication of the output sample count restores that distinction. One can produce many values on an arbitrarily fine time grid from a smoothed waveform, but they are linked deterministically through the same finite collection of original observations.

The decision criterion should be constructed for the intended signal class. Define a minimum separation between two events that the instrument must resolve, a range of amplitudes and pulse durations, a bound on false splitting and false merging, and a permitted onset error. Generate trials over those conditions, including phases of the event relative to sample boundaries and placements near the edges of processing blocks. Apply the entire declared chain, not merely a

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textbook impulse response, because overlap handling, trigger logic and detector state may alter the result. A window that looks attractive at one input frequency can yield misleading estimates at another. This is especially important near the transition band of a rate-conversion filter, where attenuation and group delay may change appreciably.

I would resist the temptation to declare a universal window length. The choice is an engineering trade-off tied to the hypothesis being tested. A matched-filter detector can be powerful when a waveform template is justified, but its success is conditional on the template and noise model; it can also merge different physical inputs into one high correlation value. A shorter analysis window may reveal temporal irregularity while suffering poorer frequency discrimination. The record should therefore include a predeclared analysis plan or, where exploration is necessary, distinguish exploratory parameter choices from independently validated detection performance. A defensible figure can show the raw trace, filtered trace, detector statistic and parameter version side by side, with time alignment established by known challenges. The visualised widths should not be called intrinsic transmitter durations without a demonstrated inverse relation. I offer the floor to Dr Wiener to examine the additional complication of stateful processing.

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Norbert Wiener | Principal response 3: Filtering memory, adaptive state and false temporal continuity

Dr. Atkinson, an investigator examining a resampled trace must recognise that a signal-processing system can have memory. An output at one indexed instant may depend not only on an input at that instant, but on a sequence of earlier input values, filter initial conditions and coefficients selected during previous observations. Even when the underlying analogue field has ceased, the digital output can continue to move while stored filter state decays. The phenomenon is ordinary systems theory. It becomes a forensic problem when the analyst mistakes the computational aftermath of a real event for evidence of an additional transmitted event. A resampler implemented as a finite impulse response has a bounded support if its input continuation is appropriately specified; an infinite impulse response or adaptive estimator may possess a longer or state-dependent tail. These implementations can both be mathematically valid, while producing different event narratives from the same acquired samples.

We should begin with the elementary input-output model y[n] = sum over k of h[k] x[n-k]. In a linear time-invariant system, h represents the impulse response. If an input contains a unit sample at n=0, the output is a copy of h. Thus a positive leading lobe, negative side lobes and later ringing are possible even though the input consisted of one discrete event. If a threshold detector responds to absolute magnitude, several lobes may become several alarms. If an adaptive threshold updates after the first lobe, the later response may be suppressed, or the threshold may fall enough to label harmless residual motion as a second event. Neither outcome can be interpreted without recording both the filter and the detector state. The

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tempting phrase 'the receiver saw two pulses' obscures that the receiver acquired one sequence and the derived decision procedure produced two maxima.

A further distinction concerns causal and noncausal representations. A causal real-time filter does not literally respond before an unseen future event; its output depends on earlier and present input. A zero-phase offline procedure, however, may use samples on both sides of the displayed time, as occurs in forward-backward filtering or suitably centred FIR calculations. Its pre-event lobes are not a violation of causality. They are numerical values computed retrospectively from later observations. The investigator must avoid assigning a physical transmission time to those lobes. If the source recording is disclosed without its temporal processing history, a reader can easily mistake a noncausal reconstruction for evidence that the emitter began transmitting before the trigger. Correct annotation needs to identify the data dependence, not merely place the word 'filtered' beneath a chart.

Adaptive rate conversion introduces another layer. A receiver may estimate clock drift against an external reference and vary a fractional-delay phase continuously. The output then depends on a time-varying mapping, not a single rational factor. If the phase correction changes abruptly, a stationary carrier may acquire a short phase discontinuity or amplitude disturbance. If buffer availability forces a resynchronisation, samples may be duplicated, dropped or interpolated across a gap. A burst-like feature can then be a symptom of changing software state rather than an external emission. One should examine rate-control logs, buffer boundaries, time-stamp discontinuities and the residual between expected and actual sample

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counts. A mathematically neat interpolator does not absolve the surrounding scheduler or clock estimator of evidential scrutiny.

Consider a receiver whose digitiser is nominally clocked at ten million samples per second while its host clock is disciplined intermittently to a network reference. Software may declare a smooth output stream of a different nominal rate. Yet the input clock can drift relative to that declared epoch, and a correction algorithm can distribute accumulated timing error over many output samples. The resulting waveform may be suitable for listening or spectral occupancy estimates and still unsuitable for microsecond-level time-difference localisation. The question is not whether the rate conversion functions. The question is whether the reported event times map, with quantified uncertainty, to physical sample apertures. If the input epoch is uncertain, numerical timestamps cannot create an accurate one by interpolation.

The requirement for a valid evidence package is straightforward to state, although costly to implement. Retain the original capture or a validated lossless subset; record the actual input sample rate estimate, clock reference, buffer-gap events, algorithm build, coefficients, extension convention and mapping from original sample indices to output time labels. Keep logs of adaptive state where it influences material events. A replayer should be able to reproduce the numerical output from the same input, but a second test should establish whether the numerical output corresponds to the intended physical quantity. Replaying an artefact demonstrates computational repeatability. It does not prove external cause.

Our challenge campaign should include deliberately unhelpful trials. Inject a single pulse near an input-buffer boundary; repeat with the same

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pulse at different offsets inside a block; vary the fractional-rate correction, while holding the physical input fixed; and test cases of missing samples rather than covering gaps with plausible interpolations. Include constant or noise-only inputs so that a processing-state change cannot masquerade as an emission. Count events with the actual detector used in field service, not a simplified laboratory cursor. Failures should lead to diagnosed operating restrictions, not merely to new filter coefficients chosen after the troublesome trial has been seen.

I would also ask investigators to record the covariance or dependence among errors introduced by common processing. Two output representations derived from the same raw record cannot be counted as independent confirmations simply because they were obtained by different resampling packages. Their noise, missing-data gaps, amplitude anomalies and original timebase errors remain shared. The proper comparison is a conditional test of distinct algorithms on one input. Stronger corroboration requires a genuinely different physical observation or an intervention whose outcomes distinguish the rival explanations. An external antenna switch, a receiver substitution or a calibrated injected reference may provide additional evidence, although the influence of common equipment must still be disclosed. The aim is not perfect independence, but a dependency account sufficient to support the claim actually made.

A forensic report should therefore say not only that a transient was recorded, but whether it was present in the unconverted samples, how its appearance changed across the processing chain, and what operating states could have produced an analogous feature. Where the original record is unavailable, the examiner may establish reproducibility of the derived file

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and still be unable to determine the original number of physical emissions. That is a legitimate outcome. It is preferable to a vivid but unsupported account in which the filter's memory has silently become the transmitter's history. I now yield the floor to Professor Zadeh, whose question concerns the temptation to classify a poorly understood state transition as an ordinary signal event.

Lotfi Asker Zadeh | Peer question 4 to Norbert Wiener

Dr Wiener, a large monitoring apparatus may use adaptive filters, data-driven thresholds and rules for assigning uncertain events to categories. The algorithm might label an output feature as an isolated pulse with high numerical confidence even though its filter state was recently reset. From the operator's viewpoint the displayed label appears precise, and the preceding five seconds of streaming data may look uneventful. Yet the classification system might have been trained on recordings whose endpoints were extended in a different manner from the live instrument's endpoints. How would you require the designer to express the limits of confidence when the process being classified is itself affected by uncertain computational state? Is it enough to attach a general caveat to the receiver manual, or should every event preserve a trace of the transformations and state transitions that led to the class label? I also wonder how the committee would decide which uncertain examples must remain unclassified rather than being forced into an apparently exhaustive set of event types.

Norbert Wiener | Immediate answer to Lotfi Asker Zadeh

Thank you for that question. Professor Zadeh, the classifier's numerical confidence must be interpreted according to the

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experiment used to obtain it. A class probability estimated under a training distribution is not an automatic measure of the probability that a particular field event was physically transmitted. If preprocessing changes the training and operating distributions, the apparent certainty can be especially misleading. I would require the system to identify processing-state anomalies as separate conditions, not absorb them silently into the classes used for ordinary transmitter behaviour. A state reset, discontinuity, altered padding mode or coefficient replacement must be logged at a granularity appropriate to the asserted timing and causal conclusion.

This does not mean archiving every implementation instruction. A compact state record can preserve the versioned filter definition, update times, rate correction, buffer-gap flags and a cryptographic digest of the acquired interval. A later examiner can then distinguish a routine signal classification from an interpretation occurring during invalid or qualified exposure. Where the event depends on the unobserved interior of a lost buffer, a special unknown category is scientifically appropriate. Its presence is not a failure of professionalism. It records that the available evidence does not uniquely determine the asserted cause. Any assessment of classifier performance must count such outcomes instead of suppressing them from the denominator.

A robust validation should deliberately challenge the coupled system rather than merely the classification rule in isolation. For a known single-pulse input, vary the placement relative to buffer edges, and record how many detections appear. For a no-signal input, force

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representative resampler restarts and check whether the detector produces spurious alarms. For a pair of pulses, vary separation and relative amplitude and examine the rate at which the system merges them. The results should be stratified by state, not averaged into one flattering score. If the instrument is intended to operate under several allowed versions or update policies, those versions form part of its validated configuration envelope. A change in one can invalidate a previously satisfactory operating claim until the new combination is challenged.

The final inference remains conditional. A label may be useful for triage if its limits are recorded. A higher-stakes conclusion about external source behaviour requires preserved raw data or independent evidence sufficient to rule out important processing explanations. In particular, an attractive spectrogram after interpolation cannot show what occurred in samples that were never acquired. The examiner must speak plainly about that absence. I pass the token to Dr Shewhart, who can test whether the same processing system remains stable when challenged at apparently unimportant boundaries.

Walter Andrew Shewhart | Peer question 5 to Norbert Wiener

Dr Wiener, your proposed intervention tests may identify isolated defects, but the operating system faces a succession of temperatures, data rates, filter changes and input amplitudes. I am concerned that an engineer could run a dozen successful pulse tests at a single state and declare the apparatus stable over all its intended applications. A resampler might perform acceptably on stationary tones while a short

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high-amplitude transient near the end of a file creates ringing that crosses the detector threshold repeatedly. How would you distinguish common-cause process variation from a systematic defect in the rate-conversion method? Should the acceptance process examine event counts as a time series across operating states, or treat each configuration as a separate instrument? I ask especially how to avoid the familiar mistake of selecting a control limit after seeing the worst failures, thereby making the validation campaign appear stronger than it actually was. What constitutes a genuine warning that the corrected system is outside its established envelope?

Norbert Wiener | Immediate answer to Walter Andrew Shewhart

Thank you for that question. Dr Shewhart, the distinction begins with a defined process whose states and outputs can be compared meaningfully. A receiver that changes its resampling ratio, coefficient set, input bandwidth or buffer scheduler may no longer represent one stationary performance process. An average alarm rate over all these conditions can hide a severe defect confined to one boundary state. I would preserve a structured configuration identity and evaluate performance by the conditions relevant to the claim. Where a parameter changes continuously, such as a tracking correction to input clock drift, it may be more practical to validate a bounded region of parameter space with deliberately selected corner cases than to call each numerical coefficient a separate instrument.

For temporal anomalies the response variables should include time bias, spread of timing errors, rates of false splitting and false merging, and the duration of invalid acquisition intervals. These

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quantities can be monitored over representative environmental and operational sequences. A control chart may reveal changes within a continuing process, but it should not substitute for an independently specified acceptance criterion. The latter follows from the investigative use, such as a maximum permitted event-timing error or a maximum rate of missed pulses. We should declare the criterion before the final validation trials, retain failures and stratify by conditions so that a good average cannot conceal an unacceptable state.

The appropriate challenge includes pulses at many input phases and near every important processing boundary, not merely one convenient position. It also includes negative controls containing no injected event. If a processing restart under a no-signal condition generates an alarm, the system has demonstrated a possible internal cause for a field event. A correction may remove it, but it should then be tested on withheld trials, particularly on true weak signals near the artefact's position. Otherwise suppression of false alarms could come at the expense of suppressing legitimate signals. The validation should compare the raw data and derived decision record, with every threshold change logged.

I would distinguish an out-of-control state from a claim beyond validation. The first concerns evidence that a previously defined process has materially changed; the second occurs when someone asks the apparatus to support a question outside the conditions it has ever been shown to answer. Both deserve explicit qualifications, but their remedies differ. The engineer may recalibrate or repair the first.

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The second requires a new validation or a narrower conclusion. A report should not imply that a perfect-looking output waveform has certified either condition away. I invite Professor Tukey to examine the danger that the analyst's exploratory selection of windows and thresholds makes the evidence seem more decisive than the underlying trial population warrants.

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John Wilder Tukey | Principal response 4: Event selection, multiplicity and retrospective processing choices

Dr. Atkinson, I would begin with the distinction between exploratory examination and a procedure intended to establish a calibrated inference. Exploratory graphics can reveal that one processing choice produces a curious precursor while another yields a clean pulse. That observation is useful. It can reveal an unsuspected dependence upon a boundary assumption or a filter coefficient. But the same freedom to inspect many representations can make an arbitrary waveform look compelling. If twenty windows, eight filtering choices and several thresholds are tried, an especially striking shape is likely to appear somewhere, even when the underlying input contains no special cause matching the story subsequently told. An analyst should record which choices were made after seeing the data and should not pass the selected result off as though its test had been specified in advance.

A receiver might convert a million-sample field recording into several alternate grids for convenience. One output is processed with an FFT method that assumes periodic continuation; another uses a polyphase finite impulse response with zero extension; a third uses a phase-correcting estimator whose state follows a reference clock. Their differences near the record's endpoints are a valuable diagnostic. The error begins when the investigator chooses the version in which a hypothesised external transmitter appears most distinctly and then treats the chosen appearance as independent confirmation. The outputs share their acquired samples, input saturation, clock uncertainty and most physical interference. A larger

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collection of plotted representations is not a larger collection of independent physical events.

We need a plain numerical record of all event candidates and all selection rules. Suppose the detector scans K nominally independent windows, each having a false-alarm probability p under a declared noise model. The chance of at least one false alarm is 1-(1-p)^K, not p. If the windows overlap or derive from shared input, they are dependent and the expression is not automatically exact; it may nevertheless expose why reporting only the best looking window is hazardous. The appropriate null distribution must account for the actual dependence, including filter memory and adaptive thresholds. The investigator who counts every filtered side lobe as a new physical event has also inflated the apparent sample size. The resulting confidence interval may be narrow because its assumptions are wrong, not because the physical evidence is abundant.

A rigorous study should preserve the full trial population. It should include successful detections, failures, false splits, merged events, periods in which sampling was interrupted, and intervals excluded because the processing state was invalid. If the analyst discovers an unexpectedly severe effect of a block boundary, that discovery should lead to a revised hypothesis and a second challenge set. One should not merely replace the original boundary tests and report the second set as if no exploratory trials had preceded it. The history of a hypothesis matters when its claimed error probability is calculated from the same data used to construct it. The cleaner separation is to use one sample of trials to discover the defect and a distinct held-out sample to validate the proposed correction.

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I would examine amplitude and duration errors jointly with time errors rather than treat the position of a plotted maximum as the entire event. A polyphase filter can reduce peak amplitude while conserving other aspects of the retained waveform; a threshold then reports a later onset for a weaker event even when the actual input epochs are identical. A widened impulse can appear as two local peaks because of ringing; a detector with a refractory interval may report one event when two physical pulses are present. These failures depend jointly upon filtering and decision rules. The acceptance report should therefore present a matrix of input amplitudes, durations, separations and placements with both false-event and missed-event counts. One aggregate success percentage loses the important interactions.

The display should make the distinction between input and transformation visible. I would put aligned raw samples and converted samples on common, physically justified time axes, annotate acquisition gaps, and show the actual filter support. The original input index should remain recoverable from each derived timestamp or, where a one-to-one mapping is impossible, the interpolation mapping should be specified with uncertainty. A figure can include a theoretical single-impulse response, but it must be labelled as a model or measured calibration response, not an unseen historical waveform. The event marker should be accompanied by its construction rule and relevant state. Otherwise the eye is induced to see a crisp chronological episode where the instrument supplied only a model-dependent estimate.

One further temptation deserves resistance. If the analysis has discarded the original high-rate samples, an investigator may call a processed file raw

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because it is the earliest record still retained. Such language confuses custody with acquisition. The retained file may indeed be authentic and unchanged since collection; a cryptographic digest can demonstrate that limited property. Yet its derived nature determines the inferences it can support. To evaluate a disputed transient one may need the pre-conversion spectrum, pre-trigger context, input epoch or a filter state that was never saved. Evidence retention should be planned around foreseeable disputes rather than reconstructed apologetically when litigation makes the missing material important.

The appropriate final conclusion may be sharply bounded. We can say that the declared resampling method produced a transient under specified input and operating conditions, that several processing alternatives give differing apparent durations, and that a controlled injected challenge characterises that discrepancy over a limited range. We cannot infer from these facts alone that a transmitter emitted multiple pulses or that the first nonzero derived sample identifies its onset. The panel should also report discordant trials, because they show which interpretations remain uncertain. I now pass the floor to Professor Neyman, whose question concerns how to provide a confidence statement for an event count without silently counting dependent filter lobes as repeated observations.

Jerzy Neyman | Peer question 6 to John Wilder Tukey

Professor Tukey, suppose one physical pulse is passed through a resampler and produces three detector threshold crossings, while another pulse of the same nominal amplitude produces only one because its arrival phase differs relative to the input grid. A validation programme may report a high hit rate if any crossing within the trial

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interval counts as success, yet the forensic report may use the three crossings to infer a transmitter's emission cadence. These are plainly different decision rules. How should an examiner construct confidence bounds for missed events, false splits and timing errors when each physical trial can generate a variable number of derived detections? More particularly, what should be the independent unit of analysis for the confidence calculation? Is it a captured sample, a threshold crossing, a trialled physical pulse, or an operating session? I also ask how the laboratory should handle intervals when acquisition gaps make the truth indeterminate rather than merely negative.

John Wilder Tukey | Immediate answer to Jerzy Neyman

Professor Neyman, the experimental unit should correspond to the proposition being tested. If the claim concerns whether a physical pulse is detected, each controlled pulse presentation can be an appropriate unit, provided the presentations are independent under the designed trial conditions and dependence from shared sessions or adaptive state is accounted for. If the claim concerns the number of false splits, the response for each presented pulse is a count, not a collection of independently trialled threshold crossings. Treating three lobes produced from one pulse as three independent successes or failures would misstate the sample size. The report should therefore retain a trial-to-detection association: one known input event, the set of detector outputs assigned to it, the matching rule and any ambiguity.

For a miss-rate claim, define success before the test and count each eligible physical trial once. A Wilson or exact binomial interval may be

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useful when the assumptions of independent Bernoulli trials are justified, but repeated trials under shared thermal drift or identical calibration state may create clusters whose uncertainty requires a different treatment. For splitting, report the distribution of false extra detections per physical trial, including zero, one and several, with an appropriate model or empirical bounds. For time bias, retain the signed difference between known physical epoch and declared derived event time, not merely the magnitude of the error. A distribution of biases can reveal systematic phase dependence that a single root-mean-square value obscures.

Unknown exposure must not be counted as failure or success by administrative convenience. A buffer gap whose contents were never acquired gives no direct observation of whether a signal occurred there. Such an interval may be assigned an explicitly unassessable status, and the scope of any negative-search conclusion must exclude it or model it with clearly disclosed assumptions. Likewise, a pulse injected into a known invalid state should be retained in the audit, even if the primary acceptance statistic excludes it according to a predeclared rule. Readers need the denominator of every claimed performance rate and the number of trials the investigators omitted or reclassified.

The statistical result should be paired with a causal challenge. If the suspect multiple crossings disappear when the filter changes but the raw single-pulse record remains the same, that is evidence for a processing explanation. It is not automatically proof that every similar field event is internal, because real emitters may produce patterns

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that interact differently with the filter. A report can reach a strong limited conclusion while preserving its limitations: the apparatus demonstrated a false splitting mechanism under specified conditions, and the contested field recording is consistent with that mechanism. The stronger assertion that no external multiple emission occurred requires evidence capable of distinguishing the explanations. I invite Dr Hamming to address the final engineering question of reproducible sample indexing and numerical implementation.

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Richard Wesley Hamming | Principal response 5: Rate arithmetic, timestamps and implementation validation

Dr. Atkinson, a digital processing chain is often described by a few compact integers, yet those integers can be surrounded by software decisions of decisive evidential importance. Consider the rational relation $F_{out} = F_{in} L/M$. Provided F_{in} is the actual input rate, L and M are the intended factors and the implementation retains proper timing, the output nominal interval is $1/F_{out}$. But the input rate may be only the configured clock frequency, not a measured rate; the initial output phase may depend upon a filter polyphase arm; and an implementation may trim or pad its first and last outputs. A spreadsheet that multiplies the rate by L/M can be mathematically correct while the claimed event epoch is wrong. The investigator must know the initial index relation and any delay compensation, rather than trusting a formatted timestamp field.

The simplest validation is to inject reference events whose input epochs are known with adequate uncertainty. Distribute them across the acquisition block and repeat at different phases relative to the sample clock. Let n be an input index and m an output index. One may compute an ideal time $t_{in}(n)=t0+n/F_{in}$ and $t_{out}(m)=t1+m/F_{out}$. The reference epochs t0 and t1 must be related by a documented mapping; they are not guaranteed equal simply because a processing library returns its first output at the first input's nominal time. Some algorithms explicitly centre an impulse response, some maintain causal delay, and others compensate initial group delay. The correctness of each choice depends on what the application intends to preserve.

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Numerical arithmetic can also introduce a second error into the history. A rate converter operating for several hours may use integer counters and rational phase accumulators. If the implementation converts a large integer sample count to floating-point seconds too early, it can lose submicrosecond resolution after a sufficiently long interval. If it rounds each output time increment and accumulates the rounded result, a tiny error can grow over millions of steps. It is often preferable to keep an integer source index, a rational rate relation and a separately measured time origin, then convert to presentation units only when needed. This is a recommendation about preserving numerical meaning, not a claim that any particular floating-point format is universally inadequate. The limits must be calculated for the actual sample rate, counter width and operational duration.

Filter coefficients and their scaling need independent verification as well. An interpolation filter may use L times the conventional amplitude scaling when zero insertion is part of its conceptual implementation. If an investigator runs a software change in which this factor is applied differently, the peak of a derived impulse may change without any physical change at the antenna. Coefficients may be normalised to unit DC gain, unit energy or a specific passband metric, and those conventions are not equivalent for every signal class. A correct comparison should state the gain reference and the signal statistic used. For a short pulse, peak amplitude, integrated energy and threshold duration may respond differently to the same filter. The derived amplitude must not be interpreted as the directly observed antenna voltage without the full receiver and processing transfer function.

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Block boundaries merit a test of their own. A streaming polyphase converter maintains internal state across blocks in normal operation; an offline function called separately on each block may instead reset the state or apply an endpoint padding rule at every call. A physical signal crossing a block boundary may consequently be distorted or split. If blocks overlap and are later stitched together, the overlap-add or overlap-save convention should be disclosed, including any discarded guard samples. An apparently perfect output sample count can coexist with discontinuities at the joins. The validation should inspect an event continuously traversing several block sizes, not merely compare two methods on one static waveform file.

A further hazard is confusing a bit-for-bit reproducible output with a physically accurate reconstructed signal. Running the same code and obtaining the same values establishes one form of computational integrity. It does not tell us whether the chosen filter preserved the transient feature the examiner now cares about. An implementation can faithfully reproduce its own erroneous time origin. Its tests should therefore include independent, externally generated waveform challenges and controlled changes capable of discriminating an external-emission hypothesis from a processing-artifact hypothesis. For evidential work, one should archive the exact code version, parameter sets, software dependencies, filter taps and initial state. A common codebase used by two examiners can be a common error source, not two independent certifications.

We must not overestimate what validation can accomplish. It can establish error bounds for declared waveform classes and operating envelopes. It cannot certify the reconstruction of an arbitrarily short, arbitrarily broadband event after the relevant frequencies have been

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rejected. A useful test report may show excellent tone-frequency fidelity but poor pulse-width fidelity, or good pulse timing at moderate amplitude but unreliable detection near threshold. The right description identifies which intended use passed and which did not. This is not an argument against resampling. It is an argument for using a powerful digital method only for quantities that its demonstrated transfer can sustain.

I recommend that the examiner retain a clear distinction between chronological facts and processing facts. Chronological facts arise from a calibrated observation chain at the antenna and acquisition clock. Processing facts arise from transforming the stored observations under specified mathematical and software rules. Both may be valuable evidence. But when a derived pulse appears earlier, longer or more numerous than the input event, its significance cannot be settled by the smoothness of the graph. The underlying trial record and signal-processing definitions are the necessary witnesses. I pass the token respectfully to Professor Bridgman for a final question about how an engineer should identify a measurand when differing implementations produce incompatible but internally reproducible timestamps.

George Edward Pelham Box | Peer question 7 to Richard Wesley Hamming

Dr Hamming, a receiving instrument may give a single time reading for each detected transient, although that reading has passed through a rational resampler, a smoothing filter and a threshold decision. Suppose a software update changes the filter's compensation convention while leaving the analogue input and physical event unchanged. The displayed event time moves by several output samples, and both versions claim to

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be correctly aligned. A technician might say that the true onset is the time in the newest software, while the older report remains part of a court record. What operational definition would make the two results scientifically comparable? How can the laboratory determine whether the discrepancy is a fixed processing delay, a frequency-dependent bias, an amplitude-sensitive threshold effect, or an arbitrary endpoint convention? I am particularly interested in the distinction between correcting a known delay and claiming recovery of an onset whose waveform was never directly retained.

Richard Wesley Hamming | Immediate answer to George Edward Pelham Box

Thank you for that question. Professor Box, a comparable result requires a declared reference event and a declared algorithmic measurand. If the time is called the first upward threshold crossing in the filtered amplitude envelope, then the filter, threshold rule, noise estimate, input epoch and processing version belong to the definition. A change of filter may change that quantity. We should not call the difference a mere defect in precision without first asking whether the two versions still estimate the same property. If the intended measurand is the latent start time of a specified pulse model at the antenna input, each version is an estimator whose bias, variance and dependence upon waveform assumptions must be measured by challenge trials.

A fixed group delay can be corrected where it is actually fixed over the relevant bandwidth and processing state. A frequency-dependent delay calls for a more complex transfer model and a statement about

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what waveform class the correction serves. A threshold bias may vary with amplitude, noise and filter ringing, and one global offset cannot remove that variability. Endpoint conditions can create effects confined to the start or finish of an acquired block; such behaviour should be tested by moving a known event through the block and comparing interior and boundary placements. The validation record must not merely identify a mean offset. It should show the residual error distribution and the conditions under which the correction is justified.

If original samples have been retained, run both software versions against the same raw event, keep their full parameter records and calculate the numerical difference. Compare the outcomes with an independently timed injected reference. Where the input waveform has been rejected or the acquisition epoch was not recorded, neither software version can summon those absent facts into existence. One can sometimes bound the onset from the surviving band and a defensible model, but the bound must include model uncertainty and alternative inputs that yield the same retained output. A court should be told that an estimate was revised because the processing definition or calibration changed, not that a machine simply discovered a more precise historical fact.

The practical archive need not be extravagant, but it must be sufficient. Preserve file digests, sample-rate metadata, initial epoch, transformation chain, filter taps, state policy, software version and decision-rule settings. Show the raw and derived event locations on a common justified time axis, while indicating invalid or unobserved

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intervals. Distinguish a corrected timestamp from a directly measured aperture. If the difference between versions exceeds the stated uncertainty, the issue is substantive and should be reported, not hidden by retroactively regenerating older exhibits. Once this discipline is observed, rate conversion remains a valuable analytic instrument. Its numerical elegance no longer tempts us to mistake a computed event marker for direct testimony from the transmitter. I yield the floor back to Dr. Atkinson for the mathematical applications and concluding synthesis.

Worked engineering applications and independently testable calculations

Claude Elwood Shannon, Cross-Peer Question to David Slepian: Dr Slepian, a short impulse becomes a wider oscillatory feature after a rational sample-rate conversion. What measured attribute could establish that the ringing belongs to the filter rather than to the original pulse?

David Slepian, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, determine the conversion filter impulse response, including group delay, transition-band behaviour and finite-record boundary treatment. Inject impulses and calibrated short bursts before the same acquisition path, varying their onset relative to the input sample lattice. A post-resampling ringing envelope that tracks the implementation kernel and changes under a validated alternative filter is evidence of processing dependence. The physical input has its own bandwidth and uncertainty, so we must compare against an independent analogue observation rather than an idealised mathematical delta alone. Report both the original raw waveform and the derived trace, and avoid interpreting every output oscillation as an actual

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carrier ringing in the environment. A finite support signal cannot simultaneously be arbitrarily narrow in time and frequency. I yield the token to Professor Wiener.

David Slepian, Cross-Peer Question to Norbert Wiener: Professor Wiener, why can a filter with nominally constant group delay still produce misleading onset estimates near a dropped buffer or the beginning of a record?

Norbert Wiener, Cross-Peer Answer to David Slepian: Dr Slepian, a linear-phase finite filter has constant group delay within its relevant passband under stable coefficients, but its output also depends on the samples available to populate its memory. Near a boundary, missing or padded input changes the convolution and can create transients. The nominal delay correction removes a known average latency, not all uncertainty in the event onset. Preserve a history of sample losses, padding conventions, filter initial conditions and timestamp anchors. Test short pulses across buffer joins and change the offset of the join without changing the source. If an apparent transient follows the join rather than the injected pulse, label it as processing-related. Claiming perfect continuity from a resampled trace would disregard the unobserved original samples. I pass the token to Professor Tukey for selection bias.

Norbert Wiener, Cross-Peer Question to John Wilder Tukey: Professor Tukey, an analyst tests twenty interpolation kernels and publishes only the one whose waterfall most resembles a pulse train. How should the later evidential claim be qualified?

John Wilder Tukey, Cross-Peer Answer to Norbert Wiener: Professor Wiener, that result is conditional on a data-driven selection among twenty

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procedures. The effective number of tested patterns may be complex because the outputs are correlated, but the search must not disappear from the report. Define a precommitted feature measure and test the chosen kernel on held-out raw acquisitions with independent pulse-injection controls. Retain the alternative outputs and selection rationale. A resemblance that only emerges after adjusting interpolation ratios, edge padding and thresholds is not the same as a repeatable physical signature. For a consequential inference, I would require quantitative timing, amplitude and frequency agreement against an independently calibrated reference. Any apparent improvement should be weighed against false detections under negative controls. I yield to Dr Hamming on reproducible computation.

John Wilder Tukey, Cross-Peer Question to Richard Wesley Hamming: Dr Hamming, two machines resample identical archived I/Q but produce slightly different transient peaks. What must the release record contain to distinguish a numerical variation from an evidential discrepancy?

Richard Wesley Hamming, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, preserve source-file hashes, precise input sample format and endianness, all coefficients, interpolation and decimation factors, phase origin, arithmetic precision, saturation and rounding rules, software versions and the handling of gaps. Compare exact outputs where arithmetic is deterministic; otherwise predeclare a defensible numerical tolerance and measure how differences propagate into event detection. Verify that neither process introduced unrecorded interpolation through a missing block. A later investigator should be able to reproduce the derivative or at least bound its uncertainty, not infer from visually similar screens that the

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processes were equivalent. If the detected event changes classification across implementations, the result must be marked as software-sensitive, and original samples remain the evidential foundation. I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

The panel has separated a familiar convenience from an unfamiliar evidential danger. Sample-rate conversion is a legitimate mathematical tool for representing a retained signal on another sampling grid, but an output transient is not necessarily a second physical observation of an emitter. Mr Shannon has made clear why a many-valued interpolation can contain no more independent linear information than its input, and why filtering that eliminates relevant bandwidth may render different physical events observationally indistinguishable. Professor Slepian has explained how finite-duration and finite-bandwidth constraints affect the visual appearance of short events, while Dr Wiener has demonstrated how filter state, adaptive correction and buffer resets can create an apparent sequence of pulses from a single originating event. Professor Tukey has exposed the evidential inflation created when multiple windows or software versions are explored and the most persuasive-looking one is reported without the history of that selection. Dr Hamming has insisted that an arithmetically correct rate ratio is not sufficient to justify the time stamps or amplitude meanings presented to an examiner.

We should be precise about the many kinds of time discussed here. The input sample index identifies a position within the acquired digital record. Its physical time depends upon the sampling clock, reference epoch and any gaps. A filter's group delay describes a property of a specified system and

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frequency region. A detector's threshold-crossing time is a statistical or algorithmic decision based upon the filtered samples. A transmitter's physical onset is a claim about an external cause. The last of these cannot be established by merely printing any one of the preceding quantities as though its clock digits constituted direct physical testimony. A resampling routine may correctly compensate the nominal filter delay and still yield biased threshold time for a weak pulse whose amplitude differs from that of the calibration reference.

The practical validation must be designed around the claim. For an instrument intended to discover intermittent surveillance emissions, it should include a declared minimum burst duration, relevant frequency and amplitude range, measured noise conditions, acceptable onset error, and bounds on false splitting and missed-event rates. The whole detector, including the anti-alias filter and any later thresholding, should be challenged by physically injected events at different sample phases, near block boundaries and during representative state changes. Negative controls are essential. If a stream with no injected signal produces a false burst when a filter restarts, then a processing-origin explanation has been demonstrated and must be considered when a similar field event is interpreted. A successful calibration result applies only within the operating envelope actually tested; it is not an assertion that every imaginable physical emission has been reconstructed exactly.

The recorded evidence should permit a future examiner to distinguish the acquired from the derived. Preserve original samples when feasible, or at least validated raw intervals relevant to material events, together with the declared sampling rate and its measured uncertainty. Retain the input

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epoch, buffer-gap record, rational rate parameters, filter taps, coefficient scaling, boundary continuation policy, phase or group-delay treatment, software version and adaptive-state history. Record which original sample indices gave rise to the reported output event and the detector's decision rule. A cryptographic digest can help establish that a file is unchanged after collection, but it does not certify that the physical source was correctly represented in the first instance. Chain of custody and measurement validity are complementary disciplines, not synonyms.

The panel is equally clear about the limitations of negative findings. If a receiver discarded the spectral features needed to distinguish a brief pulse from two nearby pulses, the absence of those features in a derived record does not show that they were absent at the antenna. If the input capture contains gaps, a smooth interpolation across those gaps cannot transform them into verified observation intervals. If a chosen false-alarm probability was computed from a simplified model while the actual detector used strongly overlapping windows, its confidence claim must be revised. These are not reasons to abandon digital processing, but reasons to describe a result at the level warranted by the actual measurement and challenge record.

Our ten hypothetical applications demonstrate why the units and boundaries matter. The rate factor 3/5 changes nominal output spacing, not the input exposure duration; a causal filter's internal delay is not automatically a transmitter-onset correction; a four-sample indexing error can matter materially in timing analysis; and interpolation cannot increase the rank of an observation vector. We have deliberately distinguished each calculated quantity from a certification of real instrument performance.

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Where uncertainty remains, a bounded conclusion is often both useful and scientifically stronger than an unqualified assertion. I thank the contributors for their exacting questions and courteous responses. We shall carry this discipline into the next discussion, where the numerical construction of channel representations and their relation to the receiver's original physical measurements will require equally careful examination.

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Ten worked engineering applications | Question 039

Application 1: Rational conversion and the nominal output interval

Assume an actually measured input sampling rate F_in = 10,000,000 samples/s. Let L = 3 represent the integer interpolation factor and M = 5 the integer decimation factor; the numbers are relatively prime. The nominal output rate is F_out = F_in(L/M) = 10,000,000(3/5) = 6,000,000 samples/s. Therefore the nominal output interval is T_out = 1/F_out = 166.6666667 ns, whereas the nominal input interval was 100 ns. These are time coordinates of the derived samples, not 6,000,000 independent analogue measurements per second. A single physical impulse may contribute to several output samples because the FIR interpolation filter spans multiple input indices. The assertion that an event occurred at exactly one derived sample's printed time therefore requires a calibrated index-to-epoch mapping and a declared event estimator. If the input clock has unmeasured drift, multiplying its configured rate by 3/5 does not repair its physical timebase. Preserve the measured input rate, time origin, factors and filter state before making the temporal claim.

Application 2: Output count and finite record duration

For a hypothetical input containing N_in = 50,000 valid samples at F_in = 10,000,000 samples/s, the nominal captured duration is T = N_in/F_in = 0.005 s, or 5 ms. With L = 3 and M = 5, the expected approximate number of derived samples is N_out = N_in L/M = 30,000. The exact output count of a particular software routine may depend upon its endpoint convention, rounding, block segmentation and state, so 30,000 is a nominal arithmetic result rather than a claim about every

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implementation. If an analyst asserts 30,000 independent physical observations, the inference is wrong: the output values are dependent functions of the input record. Count the original exposure interval once. An output file that contains 30,000 values can represent a 5 ms portion of the original field without introducing any additional period of observation.

Application 3: Group delay of a causal linear-phase FIR

Assume a causal, symmetric FIR containing K = 101 taps and operating at an internal rate F_int = 30,000,000 samples/s. For an exactly symmetric odd-length impulse response, its group delay in the linear-phase passband is D = (K-1)/2 = 50 internal samples. Thus the delay is tau = D/F_int = 50/30,000,000 s = 1.6666667 microseconds. This number is a property of the stipulated internal-filter clock and the causal representation. A software routine may subsequently compensate the delay and assign the first output sample to the original epoch; one must inspect that implementation before adding 1.667 microseconds to a field event timestamp. A group delay is not necessarily an onset correction for an arbitrary broadband transient because the threshold-crossing time can depend on the filter's ringing and the event amplitude. Validate the entire event detector, not only the nominal linear-phase delay.

Application 4: The error caused by one output-sample indexing mistake

Using F_out = 6,000,000 samples/s from Application 1, an erroneous output index of one sample corresponds to Delta_t = 1/F_out = 0.1666667 microseconds. A misregistration of four samples corresponds to 4/F_out

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= 0.6666667 microseconds. These offsets may be small compared with a slow survey scan but material in a time-difference-of-arrival analysis. If the assumed propagation speed is c = 299,792,458 m/s in free space, one microsecond of timing error corresponds to about 299.792458 m of propagation distance. In a difference-of-arrival geometry that value is a path-difference error, not automatically a radial position error, because the source-location solution depends upon receiver geometry. The examiner should retain original integer indices and explicitly map them to the derived epochs instead of assuming that consecutive file indices constitute a physically calibrated chronology.

Application 5: Stopband attenuation of an aliased interferer

Suppose a rate reduction to F_out = 6 MHz has an output Nyquist interval extending to 3 MHz, and an unwanted input component has amplitude 0.1 V at a frequency that would alias into the retained band without suitable filtering. If the digital anti-alias filter attenuates that component by 60 dB in voltage, with the conventional voltage ratio A_out/A_in = 10^(-60/20), the residual amplitude is 0.1 V times 0.001 = 0.0001 V, or 100 microvolts. The result is an engineering expectation conditional on the actual filter response at that interferer frequency, its correct gain calibration, and operation within linearity. It does not show that all outside-band emissions have vanished, nor that the residual is an external signal. An interferer can also create nonlinear products upstream of the anti-alias filter. An evidential claim should distinguish digitally rejected components from analogue-generated in-band products that survive because their creation preceded the rate conversion.

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Application 6: Independent tests versus overlapping windows

Assume, solely for illustration, K = 100 statistically independent noise-only decision windows and a predeclared per-window false-alarm probability p = 0.001. The probability of one or more alarms is P_any = 1-(1-p)^K = 1-(0.999)^100, approximately 0.095208, or 9.52%. This is not 0.1% simply because each window individually has a 0.1% false-alarm probability. If the windows overlap heavily through a long resampling filter, the independence premise is invalid and the formula cannot be used without adjustment. Correlations may make the event-count distribution more clustered. For a real detector, use controlled noise trials processed through the same full chain to estimate the false-alarm law, and disclose whether the threshold was selected after examining these trials. A narrow confidence interval calculated from highly dependent outputs does not provide an independent physical basis for identifying a source.

Application 7: A bound on temporal splitting due to filter support

Consider a hypothetical FIR filter with K = 81 nonzero taps at an internal rate F_int = 20 MHz. The full nominal temporal support from first to last tap is (K-1)/F_int = 80/20,000,000 s = 4 microseconds. It is possible for a discrete unit impulse to influence output values within that interval in a causal implementation, although the duration of threshold crossings may be shorter and depends upon the actual tap values. A zero-phase representation could distribute support around a declared epoch, rather than entirely afterwards. The 4 microseconds is therefore not a measured pulse width. It is a useful bound on which output sample locations may depend on one ideal input impulse, given the stated filter

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and sampling clock. A detector reporting two subevents separated by 2 microseconds should be challenged with a known single-pulse input before those subevents are attributed to two physical transmissions.

Application 8: Clock-rate uncertainty accumulated across an interval

Assume an input rate F_{in} = 10 MHz whose fractional frequency uncertainty is u_r = 2 parts per million over a designated recording interval T = 20 s. If that uncertainty can be represented conservatively as a constant fractional rate offset during the interval, the corresponding first-order epoch error magnitude at the far end is approximately $\Delta t = T u_r = 20(2 \times 10^{-6})$ s = 40 microseconds. This is an illustration of one error model. A random time-varying clock process requires a more suitable uncertainty calculation and should not be reduced without evidence to one constant offset. Increasing output sample density by rational interpolation cannot shrink the assumed 40 microsecond uncertainty in the input chronology. A useful record therefore identifies the clock reference, the method and time window of its characterisation, and whether the event time is relative within a capture or absolute against an external reference.

Application 9: Peak-power and amplitude reporting after gain correction

Suppose an input sine wave has a measured peak amplitude of 0.2 V at a declared acquisition plane, and a fully characterised linear processing chain has a constant amplitude gain G = 0.8 at that tone frequency. Its output peak amplitude is 0.2 x 0.8 = 0.16 V. Dividing the derived value by 0.8 reproduces the 0.2 V amplitude estimate under the

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model. It does not justify applying the same scalar correction to a broadband impulse unless the amplitude and phase transfer are known across that impulse's relevant spectrum. A filter with frequency-dependent gain can alter peak height while leaving some integrated measures comparatively stable. The examiner must define whether the measured property is sine-wave peak, transient peak, root-mean-square voltage or an energy statistic. A correction formula can be exactly executed while estimating the wrong quantity because the measurand was never adequately stated.

Application 10: Physical observations versus computed output samples

Consider a 1 ms acquisition at F_in = 8 MHz with N_in = 8,000 valid input samples. A hypothetical 4:1 upsampling with L = 4 and M = 1 yields a nominal F_out = 32 MHz and approximately N_out = 32,000 computed output samples. The physical acquisition still contains 8,000 originally sampled values. Under an interpolation model y = A x, where x is an 8,000-component input vector and y is the derived output vector, the rank of A cannot exceed 8,000. Thus the 32,000 output coordinates cannot supply more than 8,000 independent linear degrees of freedom from those input data. This rank argument alone does not determine signal-detection quality; interpolation may improve a chosen estimator's numerical convenience. But it demonstrates why one must not multiply the forensic evidence count by four. If information was clipped, never acquired or removed by an earlier noninvertible filter, the conversion cannot restore it without additional assumptions or independent measurements.

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Scholarly source register and verified reading scope

[S1] SciPy, `scipy.signal.resample_poly` API reference, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.resample_poly.html . Consulted for the documented interpolation/decimation relationship, polyphase FIR filtering, zero-phase description, default zero continuation and selectable `padtype` boundary policies. The constructed receiver scenarios and forensic conclusions are original and not asserted to appear in this API documentation.

[S2] SciPy, `scipy.signal.resample` API reference, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.resample.html . Consulted for the Fourier resampling method, equidistant output samples and the practical treatment of a finite input as periodic. The hypothetical cases concerning external emitters are not attributed to the software authors.

[S3] GNU Radio Wiki, `Rational Resampler`, https://wiki.gnuradio.org/index.php/Rational_Resampler . Consulted for integer interpolation and decimation parameters, rational output rates, polyphase filter taps, and the engineering need to control imaging and aliasing. No claim is made that the documentation independently validates a particular forensic receiver configuration.

[S4] GNU Radio Wiki, `Rational Resampler Base`, https://wiki.gnuradio.org/index.php?title=Rational_Resampler_Base . Consulted for the conceptual relationship between the interpolation/decimation factors and the filterbank's anti-image and anti-alias requirements. This register does not represent every implementation detail or software version as inspected.

The biographical paragraphs above are educational summaries of established historical careers and require a separate final editorial check against archival biographies before publication. The mathematical examples are hypothetical and internally calculable; they are not original laboratory measurements or certifications. No source is claimed to prove the cause of any unexamined field recording.

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QUESTION 040

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How can the investigator reconcile different sampling clocks in one evidential timeline?

Source: V011_Roundtable_Question_040_CP040_Dr_Atkinson(2).docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 040. Complete Expert Roundtable Discussion

Original constructed educational dialogue, not historical quotation or testimony. Numerical examples are hypothetical.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, we have examined the distortion of an acquired signal when a resampler replaces one digital time grid with another. We must now confront a subtler difficulty. In a multi-receiver Technical Surveillance Countermeasures investigation, each apparatus may claim to have measured an event at a particular time, while the physical clocks underlying those claims differ in frequency, epoch, uncertainty, phase noise and historical calibration. Two receiver logs may each display a timestamp with nine digits after the decimal point. The extra digits are visually arresting; they cannot tell the investigator whether the two systems used the same time scale, remained synchronised during the relevant interval, or retained the instant at which each antenna's observation was digitised. A computer's file creation time, a host's packet-arrival time and an analogue sampling aperture are different events. Treating them as interchangeable can create the appearance of simultaneous emissions or implausible source movement that exists only in a defective chronology.

For an initial working model, let t denote an ideal reference time and let C_i(t) denote the reading of receiver clock i. Over a sufficiently short interval,

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we might write $C_i(t) = a_i + (1 + y_i)t + e_i(t)$. Here a_i, expressed in seconds, is an initial clock offset; y_i is dimensionless fractional frequency offset; and $e_i(t)$ includes time-varying wander, residual jitter and unmodelled measurement error. This model is intentionally simplified. A clock affected by a discontinuous correction, oscillator warm-up, state-dependent timestamping or a host scheduler may not be adequately described by one straight line. The examiner must identify the applicable interval and document whether the clock map was measured independently or fitted using the very event whose simultaneity is in dispute.

A time-difference measurement across two receivers requires the relative clock map, not merely two dates printed in the same calendar format. If receiver A reports a candidate at C_A and receiver B at C_B, the difference $C_B - C_A$ may include initial epoch offset, accumulated fractional-rate error, differing RF-path delay, analogue filter delay, digital group-delay handling, and host logging latency. Only after an appropriate correction can the residual difference be interpreted as a physical arrival-time difference. A common external reference can help. Yet two devices connected to the same reference may retain distinct divider phases, timestamp origins or cable delays, and a distribution network can introduce errors shared by several channels. A shared source can be an instrument of calibration without making the downstream observations statistically independent.

We must also distinguish accuracy, stability and resolution. A clock can produce extremely stable intervals while remaining several milliseconds behind the designated time scale. A system can be accurately synchronised at one instant and accumulate substantial error during an uncorrected later interval. A digital counter can resolve an increment to a nanosecond while

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the event it reports originated in a buffered stream whose packet delivery varies by milliseconds. The National Institute of Standards and Technology's metrological treatment distinguishes clock accuracy from stability and treats timing uncertainty over a given observation interval as an explicit measurement problem. We shall adopt that discipline rather than infer accurate chronology from the visual appearance of a precision-formatted timestamp. [N1, N2]

Our intended investigative environment is deliberately complex. Imagine a fixed wideband digital receiver, a scanning superheterodyne instrument, and a separate recorder collecting discriminator audio or baseband samples. The digital receiver's events may be timestamped at the ADC or field-programmable logic boundary. The scanner may identify an event only after tuning, filter settling and detector thresholding. The audio recorder may attach a host-computer timestamp to a buffer delivered after capture. All three may observe a related physical phenomenon, yet none may support the same submicrosecond timing proposition. The examiner should preserve the timing and acquisition definition of each observation and resist the temptation to shift traces until their peaks appear to align, then treat that aesthetically chosen alignment as independent proof of a common source.

I invite Mr Nyquist to consider whether the sample indices and their physical epoch are adequately defined, Professor Wiener to examine the dependence of timing maps upon estimated states, Professor Neyman to scrutinise uncertainty and the risk of overstating simultaneous detection, Dr Shannon to examine which information a synchronisation transform preserves, and Dr Hamming to discuss the construction of a reproducible

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common evidence timeline. Seven peer questions should challenge the assumptions that make each proposal attractive, and every question must receive an immediate answer. The numerical exercises will distinguish sample spacing from epoch accuracy, linear drift from stochastic wander, group delay from network latency, and propagation path difference from estimated location. We shall count the chapter complete only when all prescribed contributions, applications, biographies and citations are present and independently verified. Mr Nyquist, may I invite your first account of the relationship between sample index, realised clock frequency and the epoch required to interpret an observed transient?

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Harry Nyquist | Principal response 1: Index, epoch and the limits of syntonisation

Dr. Atkinson, a sampled waveform is organised by its indices, but an index alone has no absolute historical date. If a signal is acquired at a genuinely uniform rate F_s, the nominal interval between adjacent apertures is $T_s = 1/F_s$. Given a known reference epoch t_0, we can assign the ideal time $t(n) = t_0 + n/F_s$ to sample n. This simple relation becomes a claim about the physical world only when the sample clock and reference epoch are adequately characterised. A configured converter rate might be 20 MHz, but the actual oscillator can exhibit a fractional offset, and the phase of the first ADC aperture relative to an external trigger may remain uncertain. A report that prints $t_0 + n/20{,}000{,}000$ to nine decimal places cannot prove that the underlying aperture occurred within a nanosecond of the stated absolute time. It establishes a numerical conversion under premises that must be tested.

It is useful to distinguish two engineering tasks. Syntonisation makes clocks run at compatible rates. Synchronisation relates their readings to a common time or epoch. Two nominally identical oscillators can be syntonised within a narrow fractional difference while their time counters start from unrelated offsets. Conversely, two time counters may agree at one instant while their oscillators subsequently run apart. A careful investigator records both the initial offset and the rate uncertainty relevant to the entire observation. These differences become particularly important when a receiver observes one transmitter intermittently. A correction determined at the beginning and end of a long session may estimate

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average drift, but it need not reveal short-term excursions or discontinuous corrections occurring between those reference points.

Suppose, hypothetically, that receiver A's oscillator runs at its nominal rate, while receiver B has a fractional frequency offset $y_B = 1$ part per million. Over a 100-second interval, the first-order accumulated relative time error would be $T y_B = 100$ microseconds, assuming a constant offset. At an aggregate rate of 10 million samples per second, that represents one thousand sample intervals. Converting B's samples to A's nominal rate without measuring the actual offset may make the two plotted traces look compatible over a short interval while causing steadily increasing disagreement across the session. The example is not a prediction for a real instrument. It identifies the dependence of the conclusion upon the time interval and the clock's actual behaviour. If B's oscillator wanders irregularly, a constant-rate correction is not enough; an uncertainty account must cover the unobserved deviations.

A good time reference therefore requires measurements at a relevant boundary. A pulse-per-second signal, for example, can define reference events against which a sample counter is recorded, but only if the receiver establishes the aperture or latch relationship and its uncertainty. A host operating system may log the arrival of the reference pulse later than the physical edge. A network time protocol may estimate clock offset, yet variable path asymmetry, software latency and timestamp placement complicate the meaning of that estimate. A hardware timestamp near the acquisition boundary is often more appropriate for microsecond-level claims, but even it needs calibration of cable delay, fan-out phase and the

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input-to-counter relation. An engineering label such as 'hardware synchronised' describes an architecture, not an uncertainty budget.

We should also distinguish phase coherence from timestamp agreement. Two digital receivers may use frequency references derived from a common oscillator. That can support coherent processing under stated conditions, but the analogue mixers, sampling apertures, RF cables and digital filters may introduce different phase and delay responses. A short pulse can appear at different output sample positions because the filters and event selectors differ. A correct comparison must either place the claims at a common physical reference plane with validated corrections or explicitly acknowledge that only a weaker relationship has been established. A submicrosecond physical arrival difference cannot be extracted merely by subtracting two post-detection software event times unless those detection times have been related to the original antenna observations.

The investigator should maintain unrounded integer counters for each receiver and record the method by which each counter is mapped to the reference time scale. When possible, preserve the raw relation between observed reference edges and sample indices rather than replacing them immediately with interpolated absolute timestamps. This permits later analysts to refit a clock model, evaluate residuals, identify possible discontinuities and reproduce the adopted mapping. A straight line fitted through two reference points may be adequate for some interval estimates, but its adequacy must be challenged against independent references or residual measurements. A clock reset or loss of lock should create a documented break in validity, not a continuous timeline manufactured by interpolation.

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The final point concerns negative evidence. If receiver B did not detect the candidate at the time printed by receiver A, one must establish that B was looking at the correct frequency, with adequate sensitivity and known exposure, during the physical interval after allowing for the clocks' uncertainty. A mismatch of timestamps can produce a false assertion that the emission was absent from one receiver. Equally, an apparent coincidence within a generous matching interval may be weak evidence when hundreds of unrelated bursts occur. The clock map supplies one necessary condition for comparison; it does not, by itself, identify a common source. A bounded evidential statement should give the measured relative offset, its temporal variation, the calibration interval and the unresolved alternatives. I pass the token to Professor Bridgman, whose demand for an operationally defined measured quantity may reveal whether our shared time label conceals different physical event definitions.

Percy Williams Bridgman | Peer question 1 to Harry Nyquist

Mr Nyquist, your account identifies the danger of mistaking a sample index for a common historical epoch. I should like to press the definition of the event that is assigned an epoch. One instrument may timestamp the rising edge of an analogue trigger at a hardware latch, another may timestamp the strongest value of a digital envelope, and a third may timestamp the moment at which a scanning receiver's software first declares that a threshold has been crossed. A calibration can align their clock counters without making those event definitions equivalent. How, then, would you specify a measurand that allows investigators to compare these observations without silently inserting a source-waveform model? In particular, suppose a known impulse injected at a common

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distribution point produces a trigger timestamp that precedes the envelope-peak timestamp by several microseconds. Does one correct that observed difference as though it were a fixed cable delay, or retain two operational quantities whose relation changes with amplitude and filtering? I ask which challenge measurements would be sufficient to establish whether a constant offset is justified and when a time-difference claim must instead carry a more complex uncertainty interval.

Harry Nyquist | Immediate answer to Percy Williams Bridgman

Professor Bridgman, I would not begin by forcing the quantities to agree. A hardware trigger edge and a computed envelope maximum are different operational measurands. They can be compared through a validated transfer model if the intended physical quantity is identified, but they should not be treated as interchangeable merely because both are expressed in seconds. A controlled impulse provides one test of the relationship, not a universal constant, because the envelope maximum can depend upon input frequency content, filter bandwidth, signal amplitude, noise and the selected peak estimator. The hardware trigger may also have amplitude-dependent threshold walk or metastability effects. These should be measured rather than hidden inside a post-hoc time shift.

To calibrate the relation, define the physical injection plane and a reference pulse whose timing uncertainty is known. Record the actual hardware latch index, the raw acquired waveform and the downstream event declarations. Vary amplitude, duration, signal position within processing blocks and the receiver's relevant operating states. Measure the signed difference of each event

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timestamp from the reference epoch rather than simply fitting a constant to one favourable trial. If the difference remains constant within a defined uncertainty across the intended envelope, then a fixed-delay correction may be justified. If the difference varies systematically with amplitude or frequency, the report must use a conditional correction model or restrict its asserted timing precision.

The analyst should also preserve the independent input epoch for each instrument, the relevant filter and trigger versions, and the uncertainty of the common reference distribution. If two devices share the same cable or timing generator, a common systematic error may cancel in one relative comparison while still mattering to absolute UTC claims. One should not count two readouts derived from the same uncertain reference as independent evidence that the reference was accurate. The correlation belongs in the uncertainty model. A nominal 'time alignment' should therefore distinguish reference coherence, relative event calibration and physical propagation time.

In the field report I would permit a limited statement such as: the declared envelope-peak estimates were consistent to within a measured interval after applying a characterised delay model, over the specific range of test signals and receiver states. I would not permit the stronger inference that two transmitters necessarily emitted at the same physical instant solely from those aligned estimates. If the source waveform is unknown or the data were clipped, several histories may explain the same observed peaks. This is a limitation of the inverse problem, not an objection to using digital

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timestamps. The next speakers should address how clock-model updates and uncertainty enter an evidential timeline without suppressing this distinction.

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Norbert Wiener | Principal response 2: Clock state estimation and the danger of circular alignment

Dr. Atkinson, Mr Nyquist has provided the indispensable distinction between a mathematical coordinate and a physical observation. I would extend it by regarding each receiver clock as a dynamical system whose state is only imperfectly observed. The local counter does not merely carry a static error awaiting subtraction. It evolves under oscillator fluctuations, temperature, ageing, control commands and the occasional discontinuity in the programme responsible for disciplining it. The investigator's estimate of that state evolves too. A chronology created by mapping two receiver counters into a shared coordinate is therefore the result of an inference, and its evidential strength depends upon the observations employed in that inference and upon the dynamical assumptions admitted by the model.

Suppose a receiver clock has an offset state $x(t)$ and a fractional frequency error $y(t)$, so that a simplified continuous-time model is $dx/dt = y(t)$ and $dy/dt = w(t)$, where $w(t)$ is a stochastic driving term representing unpredicted frequency change. This is not a complete account of quartz physics; it is a tractable description over a declared interval. An external reference observation z_k may be represented as $z_k = x(t_k) + v_k$, where v_k includes reference-link delay uncertainty and measurement noise. The resulting estimate may be obtained by least squares, a sequential filter, or a more elaborate inference procedure. But whichever estimator is employed, the residuals must be examined. A filter that yields an elegant time series because its process noise was set artificially low may conceal genuine excursions. Another that is allowed to follow each transient with excessive freedom can absorb the anomaly that the investigator was trying to detect.

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One must not identify model prediction with observation. Between two reference measurements, the fitted clock state is interpolated or predicted according to specified assumptions. Its confidence bounds should expand with the length and uncertainty of that unobserved interval. If a receiver disconnects from the reference for ten minutes, the system may know that its counter continued monotonically without knowing the exact offset it acquired. Calling that interval synchronised merely because the final archive contains a smoothly corrected time column obscures the difference. This is especially important when an apparent event association depends upon tens of microseconds while the relevant holdover interval may permit much larger clock uncertainty.

Feedback adds a further complication. A clock discipline loop may apply frequency corrections gradually, step the clock under exceptional conditions, or replace the grandmaster when a reference becomes unavailable. The resulting control record is a physical part of the measurement system. A map that assumes one affine transformation, t = alpha + beta C, throughout a session crossing a clock step is not a correction but a false history. Preserve each segment, the measured offset at every reference exchange, the identity of the disciplining source, the control state and the time at which the correction took effect. If a system's wall clock is stepped backwards, two identical wall-clock labels can refer to two distinct chronological instants. A monotonic acquisition counter can help disambiguate them, but only if its relation to the corrected wall clock was recorded.

My concern is strongest where the observed radio events are themselves used to align the receivers. A common burst may legitimately serve as a

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relative timing marker if its physical relationship to the receiving sites is known or appropriately modelled. But a burst whose common origin is under investigation cannot also serve as unacknowledged independent proof of that origin. If the analyst shifts one trace until two peaks coincide, the fitted shift is the hypothesis-dependent alignment parameter. It must not be added to the dossier as an external confirmation that the events were simultaneous. The proper method separates training markers from challenge events, or jointly estimates clock offsets and propagation parameters while retaining the uncertainty and identifiability limitations of that joint model.

Even an external common-view reference carries dependence. Two receivers may obtain signals from a third clock and subtract them, suppressing portions of the shared reference error. That improvement is useful; it does not mean each receiver's individual UTC error vanished. A common disturbance can enter the corrected differences with either sign depending on the comparison being made. The covariance matrix should distinguish an error shared by both timing chains from errors private to each site. An investigator who squares two identical reference uncertainties and adds them as independent contributions may overstate one relative uncertainty, while an investigator who assumes perfect cancellation when propagation paths differ may understate it. Neither shortcut is faithful to the stated architecture.

I would therefore design the clock investigation as two related experiments. First, use independent reference events to determine the model's predictive performance across the expected observation interval. Record reference residuals, discontinuities, outliers and the uncertainty of

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drift extrapolation. Second, give the system concealed event challenges whose physical relationships are known, but whose times and propagation differences are not used to fit the time map. Examine whether the corrected timestamps recover those relationships within the claimed uncertainty. If the model succeeds only when evaluated upon the same reference pulses that trained it, it has established a good fit, not an independent validation of forensic performance.

A well-designed record should permit a future reader to re-estimate the clock state without destroying the original receiver counters or assuming that the original correction was inevitable. Preserve raw monotonic counts, reference records, filter settings, adjustment history and the software version that produced the displayed UTC labels. Where the raw record is no longer recoverable, a derived chronology may still support a weaker finding, but not every precision claim advanced by its printed decimal places. Engineering effectiveness, statistical inference and legal presentation must each respect that distinction. I pass the token to Mr Huygens, whose investigations of oscillation invite an examination of the difference between a regular mechanism and a reliable temporal reference.

Christiaan Huygens | Peer question 2 to Norbert Wiener

Professor Wiener, you describe the local clock as a hidden dynamical state, yet I should like to examine how the laboratory decides that its chosen state equations are adequate. An oscillator may appear regular over a short interval while its period shifts after heating, vibration or changes in mechanical loading. Equally, two clocks that appear mutually regular may share a common disturbance through their surroundings or reference source. Suppose an examiner measures a timing difference at

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the beginning and end of a survey, assumes a linear drift between those observations, and then uses that line to assert a precise ordering of two brief emissions near the middle. The residual at each endpoint can be exactly zero while the actual intermediate error is substantial. Would you require intermediate reference observations, a physical model of the disturbance, or a tested empirical upper bound on excursions? How can the examiner avoid the opposite temptation, which is to enlarge every uncertainty interval until even an observation supported by excellent clocks becomes incapable of distinguishing any practical event order?

Norbert Wiener | Immediate answer to Christiaan Huygens

Mr Huygens, the central error would be to regard agreement at the endpoints as evidence of a trajectory between them. Two point observations determine the affine line exactly in a numerical sense, but they provide no independent evidence about deviations from that line. The experiment must therefore ask which deviations remain physically possible under the admitted operating conditions. An oscillator's temperature, power state, control history and relevant stability measurements may constrain that possibility. A series of independent intermediate reference comparisons supplies stronger evidence because it can disclose curvature or abrupt changes otherwise invisible to an endpoint fit. The number and spacing of those comparisons should follow the accuracy needed for the actual claim, not a ceremonial requirement to collect as many readings as possible.

Where intermediate observations are absent, the examiner should propagate an uncertainty supported by the clock's known stability

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and operating envelope. The uncertainty may grow with the time since the last reference; its precise law depends on the noise model, not on an arbitrary rule that every clock drifts linearly. A validated oscillator model permits a narrower interval than an unidentified free-running clock because the former has evidence constraining its possible behaviour. Stability statistics should be reported with their averaging times and data-selection conditions. One Allan-deviation number cannot serve as a universal bound on every possible transient, and a manufacturer's nominal oscillator tolerance does not prove a field unit achieved that tolerance during a particular event.

I would design a test in which known reference events occur at irregular, concealed intervals during the receiver's actual operating programme. The analyst would fit a map without access to selected challenge events, then calculate prediction residuals on those withheld events. A persistent bias, excess residual variance or dependence on temperature would invalidate the proposed uncertainty budget. That result should lead to a revised or narrower model, with the revision itself documented rather than replacing the original experiment with an apparently inevitable success. In the absence of such a challenge, the report must be explicit that an interpolated estimate is conditional.

But bounded uncertainty is not a counsel of paralysis. If two events are separated by two seconds and the combined uncertainty is tens of milliseconds, their order may be secure for the intended purpose. If the separation is ten microseconds and the uncertainty is hundreds of microseconds, it is not. The correct choice is to match measurement

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effort to decision stakes. A relative ordering claim requires an interval for the corrected time difference; it does not automatically require national-standard absolute UTC calibration at each site. Conversely, an absolute chronology tendered to a court demands an identified time scale and a defensible mapping from the physical event to that scale. The issue is fitness for purpose, not the pursuit of unlimited precision. I invite Professor Michelson to challenge whether the act of measurement itself contributes a neglected delay.

Albert Abraham Michelson | Peer question 3 to Norbert Wiener

Professor Wiener, a time map constructed from recorded reference pulses may be internally consistent and yet fail to identify the physical arrival time of a radio transient. Consider two receivers sharing a master frequency reference but using antennas, transmission lines, analogue filters and digital detector algorithms with different propagation delays. The laboratories agree upon their counter epochs to far better than one microsecond. A source then produces a brief wideband pulse, and the two systems return envelope peaks that differ by several microseconds. Is it legitimate to correct the difference with cable-length estimates alone? An optical or electromagnetic measurement depends on its entire path, and the apparent delay may be affected by dispersive filtering, threshold walk and an uncertain definition of the pulse feature. How would you separate reference-clock error from the receiver transfer delays and from the physical propagation difference that might bear upon source localisation? Which observations would be required before a residual timing difference could serve as a geolocation constraint rather than a trace-alignment convention?

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Norbert Wiener | Immediate answer to Albert Abraham Michelson

Professor Michelson, no isolated clock correction can substitute for calibration of the signal paths. In the measurement equation, the observed event time is the sum, with appropriate signs, of a source emission epoch, propagation delay from source to receiving reference plane, analogue path delay, feature-extraction delay and timestamp-clock error. The last is only one component. If the investigator cannot identify the other terms, a very precise clock may generate very precise measurements of the wrong quantity. A cable-length calculation is admissible as a conditional estimate only if dielectric velocity, cable configuration and their uncertainties are known. It is particularly weak as a substitute for a system-level impulse response when analogue filters and nonlinear detectors contribute frequency- and amplitude-dependent effects.

I would therefore choose a common physical injection plane and a test signal family representative of the claimed emission. Feed the receivers with a calibrated distribution whose relative path delays can be independently measured. Preserve both raw waveform acquisition and event detector outputs. Compare the resulting counter-index differences for several pulse widths, centre frequencies, amplitudes and threshold states. A fixed offset model is justified only when its residuals stay within the specified acceptance bounds throughout the claimed operating envelope. When the detector feature changes its position with amplitude, the report must either define an amplitude-dependent timing correction or weaken its timing claim. The

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reference-plane definition should appear in the final statement, not be buried in a laboratory worksheet.

For source localisation I would include the geometry explicitly. Let the source coordinates be unknown, and each receiver position be measured with suitable accuracy. Propagation-time differences yield geometric constraints only after clock and instrument delays have been accounted for. A residual difference between two stations ordinarily defines a family of possible source locations, not a unique point. Obstacles, multipath and antenna response can produce apparent excess delay beyond simple line-of-sight propagation. The investigator must challenge the model with alternate receiver placements or a third site when practicable, or retain the ambiguity. If all stations rely on one uncertain reference, shared error may cancel in relative differences while remaining relevant to absolute event epochs. Covariance must be preserved through the transformation.

An evidential record should accordingly contain three layers: the raw acquisition coordinates, the calibrated instrument reference-plane estimates, and the geometrical inference. Each layer should have its own assumptions and uncertainty. Where only detector logs survive, one should not claim to have retrospectively measured the original analogue waveform's exact arrival edge. Where a well-characterised system does preserve calibrated timing information, one can make a useful bounded statement, perhaps excluding some locations while not distinguishing the remaining ones. These are competent uses of measurement, not a failure to achieve a more theatrical certainty. I return the token to Dr. Atkinson for the

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statistical examination of what the time intervals can actually establish.

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Jerzy Neyman | Principal response 3: Uncertainty intervals, clock-model selection and propositions of simultaneity

Dr. Atkinson, the preceding account has identified the instruments. I should ask what proposition their measurements are being offered to establish. A narrative that two radios emitted together may mean that their inferred source-emission epochs were identical, that their received pulses overlapped within a specified interval, or merely that two detectors declared alarms with similar display timestamps. These are not the same hypotheses. A precise statistical procedure cannot compensate for a claim that changes identity between calibration, examination and report. Before estimating a probability of coincidence, the investigator should specify the population of events, the time interval over which the instruments were exposed, the event-selection rules and the uncertainty of the clock transformations. Otherwise the number printed at the end of the analysis may be mathematically defensible for a different experiment from the one that actually took place.

Let t_A and t_B denote two estimates on a common defined time scale, referring to the same type of physical feature at declared receiver reference planes. Set D = t_B - t_A. If the estimates carry standard uncertainties u_A and u_B and a correlation coefficient rho, the linear covariance formula gives u_D squared = u_A squared + u_B squared - 2 rho u_A u_B. This equation follows from the variance of a difference and is not a universal guarantee of normality, stationarity or calibrated coverage. If both times depend on a common reference, their error terms may be positively correlated, and treating them as independent can overstate the uncertainty of one relative comparison. If a calibration error produces opposite-signed

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responses, the correlation may be negative, and an independence assumption would understate the result. The sign, magnitude and relevance of the covariance must be justified by the timing architecture and evidence.

Statistical claims require attention to the distinction between a confidence interval for a fixed but unknown parameter and a probability assertion about the truth of a hypothesis. Under declared regularity assumptions an interval constructed by a procedure may cover the parameter with a specified long-run frequency. That does not mean, after observing a single interval, that there is automatically a ninety-five per cent probability that the fixed physical event difference lies inside it. Nor does an interval including zero demonstrate that the events were simultaneous. An interval excluding zero may provide evidence of a nonzero difference under its model, while one including zero may simply indicate insufficient resolution. A claim of practical simultaneity often requires an equivalence criterion specified in advance, such as |D| being below a physically justified tolerance Delta, and evidence that the plausible interval for D lies within that tolerance. Failing to reject difference is not the same as establishing equivalence.

A forensic application should distinguish three uncertainties. The first concerns clock offset and rate estimates obtained from reference observations. The second concerns the acquisition and feature-definition process, including delay and threshold walk. The third concerns the interpretation that two declared features correspond to one physical source event. That last proposition may depend on signal classification, propagation and the number of unrelated events occurring during the survey. The probability that an unrelated event appears inside a matching

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window is affected by the search window and candidate-event rate. A chronology that contains hundreds of possible associations needs control of multiplicity; it cannot select the nearest pair after examining the entire archive and then report a single-pair probability as though only one trial had been conducted.

Consider the investigator who chooses a window of plus or minus five milliseconds after viewing the results and finds an apparently impressive match. If the window was selected because it included that match, the selection procedure alters the relevant chance distribution. A legitimate examination may explore several windows to characterise sensitivity, but it should record the exploration and reserve independent evidence for the final conclusion. Better still, declare the matching rule and acceptable timing uncertainty before the candidate events are exposed. Calibration residuals can support a justified window, provided the residuals represent the operating conditions and were not themselves selected for favourable behaviour. Where event rates are highly clustered or dependent on a common external stimulus, a homogeneous Poisson model may be misleading. The analyst should test alternatives rather than describe one assumed rate as observed fact.

The event population itself may be censored. A scanning receiver observes only the frequencies and intervals covered by its dwell schedule. A triggered recorder preserves only those bursts meeting its threshold and buffering rules. If one instrument did not report an event during the nominal coincidence period, that absence can support a conclusion only if its actual exposure and detection probability are known with sufficient confidence. The timestamp distribution of detected events is not generally

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the distribution of all emissions. Selection by threshold, pulse width and instantaneous noise conditions can shift the apparent event time. An amplitude-dependent detection delay must be characterised or included as a nuisance term. Likewise, if a clock correction is fitted only to those events that appear common to both receivers, the procedure selects agreement and may suppress evidence of its own errors.

Validation should consequently be split. In one set of trials, reference pulses determine clock maps and measurement-model parameters. In another, concealed challenge signals test the predicted timing differences under realistic gain, filter, temperature and acquisition conditions. The test set should contain false candidates and null periods, not merely known simultaneous pulses. Its performance measures should include missed events, false associations, timing outliers and invalid reference intervals. An examiner who excludes low-quality observations must preserve those exclusions and explain whether the claimed operating envelope also excludes such field conditions. Repeatedly retuning the algorithm until it passes the same test set converts the test into an extension of training; a new independent challenge is needed to assess general performance.

I would allow a technically useful conclusion where its premises remain clear. It might read that two detector features are temporally compatible within a specified corrected interval under a declared clock and path model. It might read that an observed difference excludes an event ordering claimed by one hypothesis, given an uncertainty budget supported by challenge tests. It should not leap from temporal compatibility to common source identity, nor from a failure to see an expected partner event to evidence of its absence without exposure analysis. The final report must

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preserve both the signed time difference and its uncertainty, because readers may be entitled to test alternative matching tolerances. I thank the moderator and pass the token to Mr Gosset, whose experience with finite samples will expose the practical danger of certifying clock performance from too few reference observations.

William Sealy Gosset | Peer question 4 to Jerzy Neyman

Professor Neyman, your argument places a properly defined confidence procedure between the raw observations and the final evidential statement. Yet the investigator's laboratory may possess only six independent timing-reference checks collected during the field session, and those checks may not span the thermal excursions or clock-state changes of the entire survey. Suppose the six residuals appear reassuringly close to zero. The operator is tempted to calculate their sample standard deviation, multiply by a familiar coverage factor, and publish a narrow error bar. The figure may impress a court because it appears quantitative. What safeguards would prevent such a small sample from concealing a skewed distribution, a clock step that occurred between checks, or systematic uncertainty common to every reference? Would you insist upon a particular interval method, or instead distinguish the repeatability that six observations support from the broader assurance that the entire investigation requires? I would also ask how the timing report should preserve a useful practical conclusion where the observations are too few for an elaborate distributional model.

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Jerzy Neyman | Immediate answer to William Sealy Gosset

Mr Gosset, six observations are not inherently worthless, but their information is finite and conditional. A small-sample calculation can be appropriate for a narrowly specified population with a defensible model, and your distributional work reminds us that estimating variance from limited observations introduces uncertainty of its own. But a calculation based solely on those six residuals cannot certify a clock trajectory during intervals never challenged. If the error includes a systematic delay common to all checks, repetition may reproduce the same biased answer with excellent precision. The sample standard deviation measures dispersion among the observed results, not necessarily uncertainty of the physical reference plane or correctness of the reference itself.

I would first enumerate the terms in the uncertainty budget. Residual repeatability from the six checks is one term. Reference-source uncertainty, cable and latch delay, model-selection error, clock drift between checks, and untested thermal states are separate terms. Those contributions need not all be treated as random draws from one normal distribution. Some may require physical bounds, prior calibration data or sensitivity analysis. Where a Student-style small-sample interval is used, its assumptions must be stated, particularly whether residuals are reasonably independent and approximately distributed as assumed. If the clock undergoes a discontinuous step, neither a small-sample t interval nor a Gaussian fit will discover the missing event unless the measurement procedure observed or otherwise bounded that step.

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The next safeguard is to retain the individual observations and their timing, rather than publish only a mean and a standard deviation. A sequence of residuals may reveal drift, dependence upon elapsed holdover time or a change coincident with equipment temperature. A six-point sequence sampled at widely spaced times has different evidential value from six measurements collected within a few seconds. The examiner should plot or tabulate the raw residuals, compare them with the proposed dynamic model, and report any failure to test the most consequential conditions. If independent records show reference-lock loss, an uncertain period should be designated invalid even when its nearest measured residuals were small.

Finally, I would match the statement to the evidence rather than disguise the deficit. If the six checks support only a millisecond-level bound under declared conditions, that may be ample for demonstrating the gross ordering of two transmissions separated by several seconds. It is inadequate for a microsecond-level time-difference localisation claim. The report should explicitly say which conclusions are robust under plausible alternatives for the untested intervals. A useful but limited finding is preferable to the false precision of a narrow interval whose coverage assumptions have not been challenged. I now invite Dr Shannon to address whether any digital transformation can supply the missing history or whether it can merely provide an orderly representation of what survived.

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Claude Elwood Shannon | Principal response 4: What synchronisation preserves and what an event archive omits

Dr. Atkinson, the decisive question is not whether a receiver's numbers can be rearranged into a common sequence. It is whether the retained observations contain the information needed to answer the proposed physical question. A clock correction assigns a different temporal coordinate to surviving samples. If the original counter positions and a validated mapping are available, that coordinate change may be reversible as a description of the observed data. It does not re-create samples omitted by a triggered archive, restore a clipped transient, or reveal the phase of a reference clock during an interval in which no appropriate measurement was made. The distinction between transformation and information acquisition is fundamental. One can draw a very fine time axis through sparse data, but the drawing does not fill the empty intervals with experimentally acquired evidence.

Consider a stream recorded at sample rate F_A with known counter n and a second stream recorded at F_B with counter m. A resampler may transform one numerical representation onto a common evaluation grid, provided its signal-model premises and filter design are appropriate. But an interpolation coefficient does not constitute a direct observation at the interpolated instant. The reconstruction assumes an admitted bandwidth and a sufficiently characterised acquisition system. When a detector has retained only peak times or log messages, its original waveform may be no longer available for any reconstruction. A later analyst cannot infer the actual onset edge from a single timestamp unless further assumptions

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about pulse shape, detector delay and threshold are independently justified. This limitation is not repaired by representing the log time in nanoseconds.

There are at least three coordinate systems in a modern receiving instrument. The analogue acquisition system has a physical time of contact between incoming signal and sampling aperture. A digital signal processing stage may carry an index referring to a window midpoint, the first contributing sample, the last contributing sample or the instant at which a detection decision is made. A software environment may append the time at which a buffer was delivered or written to storage. The metadata field called timestamp does not itself specify which coordinate system was used. A robust evidence schema records timestamp semantics, source clock, counter rate and the exact stage of acquisition at which the value originated. It should also record if an event time was estimated by interpolation or corrected for filter delay.

A phase-coherent combination poses a stronger question than a simple time-ordering comparison. If two receivers are to combine complex samples coherently, then the relevant unknowns include not only common event epochs but relative carrier phase, oscillator drift, mixer sign, sampling aperture and channel transfer phase. A shared ten-megahertz reference may stabilise frequency, but the resulting radio-frequency local oscillators can retain independent phase states and state changes. A common pulse-per-second edge may establish a counter epoch while leaving an unmeasured subcycle phase. These mechanisms can introduce a rotating complex factor between streams even when a pair of wall-clock labels agree. A calibration suitable for associating two bursts within a millisecond might

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be wholly unsuitable for coherent amplitude addition or radio direction finding from phase.

The information in an estimated clock map must be distinguished from the information in a common observed reference. If the two receivers independently measure the same designated calibration pulse, their relative time relationship can be estimated, subject to path delay and event-definition uncertainties. If they merely receive the same network time messages, the resulting agreement is governed by the protocol and network model. Each may be entirely suitable for a particular level of chronology, but neither supports a stronger conclusion without additional calibration. As the NTP protocol itself distinguishes offset, delay, dispersion and jitter, an application that records only a synchronised flag omits variables important to a later uncertainty assessment. In precision time systems, the timestamp point and network path asymmetry are physical components of the measurement, not incidental software details.

A useful archive should therefore contain at least two temporal descriptions for material events: the original acquisition counter and the derived time-scale estimate. These can be linked by a versioned clock model rather than allowing the derived estimate to replace its ancestor. If the clock model changes, the retained counters permit reprocessing with a revised map. The model record should include leap-second or other time-scale conversion tables where civil or satellite time is involved, because a label such as GPS time or UTC represents a defined scale rather than merely a string format. A conversion based on the wrong table can shift absolute times by whole seconds while preserving excellent interval regularity within each stream. In contrast, if the analysis concerns only the difference of two

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events close in time within one uninterrupted monotonic clock, an absolute UTC offset may cancel and a simpler comparison may be adequate.

The greatest danger is causal overinterpretation. A very strong spectral similarity and compatible event chronology can support a hypothesis of common activity; they do not logically compel a unique source history. Two devices may respond to the same external interference. Two independent emitters may be controlled by one upstream process. One receiver may generate a replica of an external signal through intermodulation or aliasing. An analyst must therefore specify what alternatives the evidence excludes and what it leaves unresolved. Timing measurements are particularly seductive because numerical alignment gives an impression of geometric necessity. The signal's content, antenna path, receiver state and calibrated propagation conditions must carry their own evidential weight.

My practical rule is to preserve the distinction between an original sample, a deterministic transformation, a probabilistic estimate and a causal inference. Label each stage. Retain the model, parameters, software, uncertainties and invalid intervals. Do not silently replace samples with a resampled product or treat a narrow output bin as an observed instant. When the underlying representation lacks the information for a desired future question, document that limitation and seek a different acquisition method next time. The next suitable experiment may require continuous raw baseband retention around a material event, a separate high-resolution time reference or two physically independent receiver paths. The desire to answer a forensic question cannot create evidence that was never measured. I pass the token to Lord Kelvin to inquire whether a derived time label can be considered traceable when the calibration chain is incomplete.

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William Thomson, Baron Kelvin | Peer question 5 to Claude Elwood Shannon

Dr Shannon, a common time coordinate lends great authority to a measurement report, particularly when the timestamp appears beneath a diagram resembling a precision scientific instrument. Yet a chain of conversions may begin with an instrument manufacturer's unspecified oscillator calibration, pass through network timing software, and terminate in a derived event label whose decimal places are abundant. In electrical metrology I should demand knowledge of the comparison standard, the transfer path and the uncertainty at the point of application. How would you distinguish an honest claim of relative timing consistency from an assertion of traceability to an international time scale? If a disciplined clock announces lock while the hardware timestamp belongs to a different oscillator domain, should the resulting timestamp be considered traceable at all? Moreover, must a field investigation always procure an international time standard, or can a properly compared pair of local clocks provide sufficient evidential support for a restricted difference measurement? I ask where measurement discipline ends and an unnecessarily expensive ceremonial appeal to standards begins.

Claude Elwood Shannon | Immediate answer to William Thomson, Baron Kelvin

Lord Kelvin, I appreciate your insistence upon traceable physical time. Traceability is a property of the measurement result and its documented chain of comparisons, not of the name affixed to a computer's clock source. If a timestamp must be represented as UTC,

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the examiner needs a defensible connection from the relevant physical event to a recognised realization of that time scale, with applicable calibration uncertainties and corrections. A locked status indicator may demonstrate that a control system accepted a reference. It does not establish that a different hardware oscillator domain remained phase-aligned, or that the delay from the antenna to the timestamp latch has been measured. The chain may contain an uncharacterised link, and the claimed uncertainty must not skip over that gap.

A relative time-difference result can nevertheless be rigorous without an absolute civil timestamp. Suppose two receiver counters are calibrated through a common injected event and a measured distribution path, and the question is whether two arriving pulses differ by more than a specified microsecond threshold. The relative comparison may be defended if its uncertainty and path assumptions are adequate, even if both devices are several seconds wrong against UTC. What would be unjustified is promoting that relative result into an absolute event date or source-emission epoch without the additional reference. The physical quantity being measured determines the required chain. Precision practice is not necessarily a request for a more expensive clock; it is a requirement that each asserted link be supported.

I would preserve a short provenance record with each derived time: counter identity, reference edge or protocol observations, correction version, event detector semantics, and any leap-second or UTC-offset convention. Where the reference is shared, mark that dependence so

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that future uncertainty calculations do not double-count or falsely cancel a common error. Where the calibration was checked only before and after the operation, identify the interval between checks and the model used to infer clock behaviour within it. Where the reference was lost, terminate the validity interval unless holdover performance has been separately established. Such metadata may be compact, but it makes the result reproducible and contestable.

This record also separates honesty from paralysis. A reported bound of several milliseconds may be entirely sufficient to establish that a sequence of transmissions occurred in a particular order, while an unverified nanosecond label could mislead a reader about far more delicate claims. The operative question is whether the evidence supports the chosen proposition at the required scale. It would be a mistake to discard useful relative observations merely because an absolute timing chain was unavailable; it would be worse to disguise their limitation behind the authority of the international standard. A good laboratory specifies which result is traceable, which is conditional and which remains unmeasured. I thank Lord Kelvin and return the floor to Dr Hamming, whose concern with reproducible computing can give these distinctions a durable evidential form.

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Richard Wesley Hamming | Principal response 5: A reproducible common timeline without destroying the raw counters

Dr. Atkinson, the apparatus has given us a collection of timestamps; our task is to develop a record that can be reproduced and challenged without needing to reconstruct the entire laboratory from memory. The worst approach would be to store only the final corrected UTC column and discard the original clock readings. A future examiner would then be unable to identify whether a surprising coincidence came from physical observations, a calibration revision, a change in timestamp semantics, or an interpolation algorithm. The correct data structure preserves the original acquisition index, counter domain, time-scale mapping, correction provenance and the uncertainty of the resulting physical quantity. It also records all discontinuities. In this sense a digital forensic timeline is a measurement model that has acquired a history of its own.

I would construct the record as a directed chain of transformations. The base record contains the raw sample index or counter tick, the receiver serial or other nonsecret stable instrument identifier, the sampling-clock domain and the acquisition-boundary event definition. An adjacent record contains reference observations, their own original timestamps, estimated cable and filter delays, environmental states and the applicable calibration versions. A transformation record specifies the fitted offset and rate, any piecewise changes, the residual statistics and the software algorithm. A derived record carries the interpreted epoch together with its uncertainty interval and relevant covariance identifiers. The complete chain can be cryptographically hashed for integrity, but the digest proves only that the

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preserved bytes have not changed since hashing. It does not certify that the clock or acquisition model was physically accurate.

A full programme must cope with several clock types. An ADC sample counter may be strictly monotonic but have no directly measured UTC epoch. A host clock may be disciplined by NTP and subject to adjustment or occasional steps. A network interface may insert a hardware timestamp closer to packet transmission than the operating system, yet still be separated from the antenna acquisition by buffering and processing delay. A GPS-disciplined reference may support stable frequency while its initial epoch, distribution cable and holdover behaviour remain conditional. These should not be flattened into one field called event_time before their distinctions are documented. A simple column for timestamp_type can help, but the data dictionary must explain the physical event represented and the clock scale used.

A practical timeline should also distinguish raw association hypotheses from accepted associations. Suppose instrument A reports candidate 7 at sample counter 381,450,000 and instrument B reports candidate 14 at counter 82,725,100. The candidate indices are facts about their respective archives; the assertion that they refer to the same emission is a hypothesis. The clock-model records may map them into overlapping time intervals, but that is only a consistency test. The report should retain alternative matches, unmatched detections, rejected comparisons and instances in which a receiver was not exposing the relevant band. It should not silently remove counterexamples when preparing a polished narrative. One goal of reproducibility is to permit another investigator to try a different, reasonable association rule and discover whether the conclusion survives.

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I would favour immutable source objects and versioned derived objects. For each source file, record its length, format, byte-order, sample structure, original digest, collection identity and custody events. The transformation manifest should include source object digests, exact reference files, filter and detector versions, timing parameters and any manual decisions. If a processing step changes sample rate or timestamp origin, the new object should declare the relation to the parent rather than merely reusing its name. A mathematically correct reprocessing operation can still produce a misleading historical statement if its output's time semantics are mistaken for the original event. The software must not conceal that distinction under a friendly user interface.

The design should include checks on impossible time behaviour. An input counter should not decrease without a documented wrap or reset. A map should not silently change its slope when a clock source switches. Event chronology should flag apparent backwards UTC motion, reference-age thresholds, invalid or uncertain leap-second interpretations, and timestamps whose uncertainty exceeds the decision window. Assertions of source motion derived from time differences should be checked against the receivers' known geographical geometry and propagation limits. A pulse difference larger than the maximum free-space arrival difference for two stations separated by a fixed baseline cannot be explained by ordinary direct propagation from a single source without an additional model such as multipath, receiver delay or faulty clocks. Such impossibility checks are valuable because they reveal when an elegant display is inconsistent with its own premises.

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Reproduction should be achievable by an independent examiner with the surviving data. The original raw objects must remain unchanged; the examiner should run a documented transformation against their preserved copies and obtain the same derived times within a defined numerical tolerance. The computation should record the time-scale library and any discontinuity-handling conventions. Where manual feature selection was necessary, preserve the chosen sample intervals and the decision criterion. Where adaptive thresholds or machine-learning detectors were used, retain the model version and event-selection exposure. Software that produces an answer only from a proprietary hidden state may still contribute to a search, but its unreviewable estimate is a weak basis for a strong forensic timing claim.

There is a temptation to treat an index-and-mapping archive as cumbersome compared with a convenient final event table. The objection mistakes reproducibility for redundancy. A relatively small manifest may preserve the essential lineage of many large recordings. If the full raw baseband cannot be retained indefinitely, prioritise preserved intervals around material events while recording which intervals were not retained and why. Store the detector state and duty cycle so that negative evidence can be bounded. A published report may be concise, but its underlying laboratory records should permit an examiner to see the actual distinction between a physical observation, a computer-derived estimate and an inferential claim. That hierarchy is worth the trouble precisely because an attractive coincidence plot can persuade before its hidden timing assumptions have been examined.

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I would conclude the engineering portion with a test plan: challenge the time mapping using withheld reference events, exercise resets and source changes, test the effects of actual filter delays, verify independent replication of all conversions, and compare the headline interpretation against the full set of candidate events including unsuccessful associations. These trials will not answer every conceivable historical question, but they provide a defensible boundary for those that matter. A time difference is a measured quantity only when its clock and path corrections are justified. A displayed timestamp can be accepted as a data value without accepting every story later attached to it. I pass the token respectfully to Professor Pearson and Dr Tukey, who may test whether the archive's statistical summaries are as faithful as its original measurements.

Karl Pearson | Peer question 6 to Richard Wesley Hamming

Dr Hamming, a complete data lineage is valuable, yet I fear that a laboratory may render it apparently authoritative by attaching a long list of numerical uncertainty terms without examining the dependence among them. Suppose two instrument logs obtain their times from one grandmaster and one packet network, but their reported clock errors are aggregated under an assumption of independence. A naive calculation might produce an uncertainty interval narrower than the effect of shared asymmetrical delay, or wider than is justified for a relative difference when common errors cancel. How would your schema prevent the analyst from confusing a catalogue of uncertainty components with a valid covariance model? Would you require every source of error to have its own shared identifier, and how would an external reviewer determine whether that identifier represents a measured physical dependence or

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an assumption selected for computational convenience? I should also like to know whether a pairwise correlation estimate based on a few favourable calibration intervals ought to survive without explicit qualification into an eventual legal report.

Richard Wesley Hamming | Immediate answer to Karl Pearson

Thank you for that question. Professor Pearson, a list of uncertainties is indeed not a model. The schema must represent dependencies among uncertainty terms, and the report must explain why the dependencies have the sign and magnitude assigned. Shared reference-source error, common distribution path delay and errors in a fitted drift model can enter several receiver timestamps together. A relative time difference may cancel portions of that shared error, but only where both measurements respond to the common term in the same way. The mathematics of a difference can subtract a shared term; the hardware may not. We need a description of the actual clock distribution and timestamp-latching path to know which algebraic cancellation is physically justified.

I would include explicit identifiers for clock domains, common references, calibration sessions and processing versions. Those fields are documentary evidence of possible common causes, not automatic estimates of statistical correlation. The covariance matrix is a separate analytical record whose entries must be supported by measured comparisons, physical modelling or defensible conservative bounds. If correlation estimates come from only a few observations, their sampling uncertainty should be retained rather than replacing it with a falsely exact coefficient. Analysts should be able to repeat the

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calculation with alternative plausible correlations and report whether the conclusion changes.

A good transformation programme should make dependence visible. It can link each corrected timestamp to the reference observations and software terms that contributed to it. A new examiner can then see that two apparently independent event times inherited the same disputed network offset. A pairwise difference can be recomputed using the appropriate covariance, and the analysis can be compared with a conservative interval model that does not assume a convenient Gaussian distribution. If a particular inference survives across those alternatives, its robustness is substantive evidence. If it fails, the failure should remain in the record.

The legal summary should avoid a single unqualified probability when the distributional premises are contested. It can state that the estimated arrival-time difference is consistent with a proposed physical relation across the validated range of correlation assumptions, or that its apparent precision relies materially on one untested assumption. As Mr Nyquist and Professor Wiener have insisted, source identity cannot be manufactured from two timestamps. The archive's role is to keep the physical observations and their changing interpretations distinct so that the scientific argument can be inspected. I now invite Dr Tukey to challenge whether this elaborate analysis may overlook a simpler graphical defect that invalidates the entire conclusion.

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John Wilder Tukey | Peer question 7 to Richard Wesley Hamming

Dr Hamming, you have designed a lineage capable of reproducing the calculation. But a perfectly reproducible calculation can be applied to the wrong segment of data, or to observations that disclose an obvious change of regime when plotted. Suppose a laboratory fits one offset and rate to an hour of reference measurements. Most residuals are small, yet the residual-versus-time plot contains a sudden jump coinciding with a receiver reboot and a slow curvature after the room temperature rises. The final table reports a pooled standard deviation and a reassuring confidence interval, with no visible distinction between the intervals before and after the reboot. Would you require visual and exploratory examination as a substantive validation step rather than a cosmetic plot? Which alternative displays would most readily expose a false coincidence between two receiver streams, and how would you prevent an examiner from manipulating axis limits, smoothing or sample selection until the chronology looks more coherent than the underlying observations justify?

Richard Wesley Hamming | Immediate answer to John Wilder Tukey

Dr Tukey, a reproducible pipeline is necessary but not sufficient. One can reproduce a flawed model exactly. I would require residual displays indexed against actual elapsed time, reference age, instrument state and temperature, together with numerical change-point checks appropriate to the claimed precision. A stepped clock should normally produce an explicit piecewise time map or an invalid interval rather than be absorbed into one pooled error estimate. A

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curved drift residual indicates that the affine model has omitted a term or that its validity interval is too broad. An attractive mean-square number can conceal both mechanisms, especially when a large population of ordinary residuals overwhelms a small but decisive set of failures.

The plots should be designed to expose the problem, not decorate the conclusion. Show the raw reference-minus-clock differences, the fitted correction, and the residuals on a common independently specified time axis. Annotate resets, loss of lock, filter changes and power interruptions. Display the uncorrected and corrected candidate-event differences, including unmatched events and excluded observations. A scatterplot of one clock's correction against another's can expose shared drift; a plot of residuals against temperature can reveal state dependence. When a confidence interval is advanced, show the empirical residual distribution and a sensitivity analysis to outliers and plausible correlation choices. Preserve the full axis scales and the numerical values used to construct each figure.

I would also require the investigator to state the selection rule by which candidate events entered the comparison. If a colleague manually selected the most convincing coincidences from several thousand detections, the archive must retain that choice and the rejected candidates. Apparent agreement may emerge even from unrelated events when the matching window is widened sufficiently. A plot centred on one chosen event can illustrate a phenomenon, but it cannot substitute for a declared association rule evaluated against

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the whole eligible event population. This is where statistical discipline protects the engineering account from confirmation bias.

Once the defects are visible, the laboratory may make a new, narrower analysis. Divide the observation into clock-validity segments, refit each with appropriate references, and test the result on withheld challenge events. Do not erase the first analysis; retain the history of correction and the reasons for it. If the new model is materially more complicated, identify the model-selection cost and any uncertainty arising from its added flexibility. The result may remain persuasive where the physical timing difference is large relative to all credible errors, and it may become indeterminate where the difference was minute. That is not inconsistency. It is what occurs when one stops asking a polished graphic to conceal the limits of the apparatus. I return the token respectfully to Dr. Atkinson for the worked cases and concluding synthesis.

Ten worked metrological and forensic applications

The following calculations use independently stipulated hypothetical inputs. They illustrate the difference between an arithmetically valid result and the additional observations required to justify a field conclusion. They do not certify a particular receiver, GNSS installation, network, time scale, source or person's action. Symbols are defined separately in each application; uncertainty categories must not be combined without a compatible distributional or bounding model.

Harry Nyquist, Cross-Peer Question to Norbert Wiener: Professor Wiener, two receivers use nominal ten-megahertz references, but their recorded

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sample indices diverge progressively. Which clock parameters must be estimated before their traces can share a timeline?

Norbert Wiener, Cross-Peer Answer to Harry Nyquist: Dr Nyquist, at minimum one must establish an epoch offset and a rate ratio over the interval of interest, then test for nonlinear drift, jumps and missing samples. A simple affine mapping from sample index n to reference time may be adequate over short stable periods, but long captures can require piecewise or stochastic models. Obtain physical calibration markers at both receivers where possible, rather than relying only on a host log written after buffering. Record the uncertainty and covariance of the fitted offset and frequency, because estimates derived from a common reference are not independent. A highly stable clock may have a fixed frequency error, while a clock with an accurate mean may wander rapidly. Preserve original indices and corrected time coordinates separately. I pass the token to Dr Neyman.

Norbert Wiener, Cross-Peer Question to Jerzy Neyman: Dr Neyman, if a single synchronising pulse appears in two streams, may the analyst calculate a unique clock-drift rate between them?

Jerzy Neyman, Cross-Peer Answer to Norbert Wiener: Professor Wiener, one pulse supplies a relative time anchor under a latency model but cannot uniquely determine both epoch offset and frequency drift. At least two separated timing references are needed for an affine fit, and additional references are essential to assess time-varying deviation, residuals and outliers. The fit should include uncertainties in the marker generation, cable propagation, detection threshold and instrument latency, with covariance if the references share sources. A very precise regression coefficient does not compensate for a biased marker or hidden sample loss. Test the mapping

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against withheld markers or an independently timed event. Report confidence intervals for each corrected event timestamp rather than one unqualified decimal time. I respectfully yield to Dr Shannon on the information lost through clock reconstruction.

Jerzy Neyman, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, two files display matching timestamps after retrospective interpolation. Does that prove that the receivers observed one physical pulse simultaneously?

Claude Elwood Shannon, Cross-Peer Answer to Jerzy Neyman: Dr Neyman, no. A timestamp is an estimated coordinate on a time scale, not a direct proof of propagation or shared source. Distinguish antenna arrival, analogue group delay, ADC aperture, digital filter delay, buffering, transfer and host timestamp. Correct each component at the relevant reference plane, retaining uncorrected values and uncertainty. Two systems may agree because they use the same mistaken host timebase or because a software alignment algorithm forced agreement. An independent timing channel or known stimulus injected at both analogue inputs provides stronger evidence. If the uncertainty intervals overlap, the finding may support temporal compatibility without uniquely establishing simultaneity or emitter identity. I respectfully yield to Dr Hamming for provenance controls.

Claude Elwood Shannon, Cross-Peer Question to Richard Wesley Hamming: Dr Hamming, what fields must an archive retain so that a later expert can reconstruct a timeline when the capture suffered one dropped buffer and an unnoticed clock step?

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Richard Wesley Hamming, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, retain monotonically increasing hardware sample counters where available, original clock-domain IDs, event epochs, synchronisation status, buffer sequence numbers, device resets, operating system clock changes and every known discontinuity. A missing block is a missing interval, not a run of legitimate zero samples. Preserve a change log for each correction, including independent timing references and transformation code. Test synthetic data with deliberately inserted missing buffers and clock steps, then verify that the timeline algorithm identifies rather than silently smooths them. A cryptographic file hash supports subsequent integrity, not original timestamp accuracy. The final report should distinguish absolute-time uncertainty, relative delay uncertainty and possible unobserved gaps. I return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Distinguished colleagues, the discussion has produced a coherent set of requirements for a chronology that can withstand technical cross-examination. Its foundation is modest but demanding: a sample index is an observation within a specific apparatus, while a timestamp expressed on an external scale is an estimate obtained through a chain of comparisons. That chain includes oscillator behaviour, reference distribution, timestamp placement, signal-path delay, event definition, and any transformations performed after acquisition. Treating one element as a substitute for all the others creates an apparently exact chronology without a reliable physical meaning. The question is not whether digital systems can record an event to many decimal places. They certainly can. The question is whether the

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underlying physical event has been adequately related to those numerical labels under the conditions that actually prevailed.

Mr Nyquist has shown why syntonisation and synchronisation must be separated. Relative sampling rates determine how event-index differences evolve; reference epochs determine where the resulting observations lie on a common time scale. Professor Wiener has explained why the clock map is a dynamical inference whose model and validity interval must be preserved. A two-point linear fit may look exact while failing an independent observation inside the fitted interval. Professor Neyman has insisted that the inferential proposition be defined before calculating an uncertainty or a chance-match probability. A clock difference is not a source identity, and an interval containing zero is not automatically proof of simultaneity. Dr Shannon has distinguished coordinate transformation from information acquisition. A correction can relabel surviving samples but cannot recreate an omitted pulse, missing buffer or unrecorded oscillator excursion. Dr Hamming has translated these principles into a reproducible evidence architecture that preserves counters, corrections, source digests and the decision history rather than only a polished final timeline.

Our peers have provided the necessary resistance to easy claims. Professor Bridgman has required the investigator to define whether an event time means an analogue threshold, a waveform feature or a software declaration. Mr Huygens has warned that clock regularity at two endpoints is not proof of a known path between them. Professor Michelson has placed the physical transmission line, receiver filter and propagation geometry back into the measurement model. Mr Gosset has examined the weakness of certification by a handful of residual checks. Lord Kelvin has distinguished

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a documented calibration chain from the mere visual appearance of traceability. Professor Pearson has prevented correlation assumptions from disappearing inside a reassuring root-sum-square formula. Dr Tukey has demonstrated how one graph of residuals against time or temperature can invalidate an otherwise reproducible arithmetic summary.

The practical doctrine is consequently tiered. For a discovery log, a bounded description of when an instrument indicated a candidate may suffice, provided the acquisition state, exposure interval and timestamp semantics are recorded. For an assertion that two receivers witnessed related events, the timing maps, event definitions and search-window selection must be challenged together. For a source localisation claim, the investigators must additionally account for physical reference planes, path delays, propagation assumptions and geometrical ambiguity. For a precise absolute date and time, the relevant UTC or other time-scale conversion must be documented, with the applicable reference chain and uncertainty. Each stronger proposition demands evidence not required by the weaker one. There is no benefit in demanding national-standard time for every routine observation, and no justification for using an unvalidated host timestamp as though it were a calibrated antenna-arrival epoch.

The ten hypothetical calculations reinforce the same distinction from different directions. A 25-ns sample interval can coexist with a 250-microsecond epoch uncertainty. A two-part-per-million oscillator discrepancy can accumulate 1.2 ms across ten minutes. A fitted clock line may miss a withheld intermediate observation by 35 microseconds. Nominally shared references can contribute covariance, while cable, threshold and network delays can dominate the error despite a numerically

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precise clock. A coincidence can occur by chance when enough events are compared; a geometrical time-difference estimate defines a constraint, not a unique location. None of these examples certifies an actual receiver. Their function is to expose the required observations, variables and competing explanations before a technical report employs the language of confirmation.

I therefore require the final evidential chronology to preserve the raw counter identity and values, reference observations, clock-model versions, invalid intervals, signal-path calibration, detector semantics, processed event estimates and their uncertainty dependencies. The report should distinguish what was observed, what was corrected, what was assumed and what could not be reconstructed. It should include unsuccessful associations, reference outages, clock steps and excluded trials. Where the relevant information is absent, the conclusion must be appropriately restricted. The panel has not proved a general method for recovering every historical clock offset; it has established a disciplined way to recognise where such recovery is justified and where it is not. That is sufficient progress for a rigorous investigator. I thank our colleagues for their courteous challenges and pass the floor forward to the next discussion, concerning whether a putatively coherent signal combination remains valid when its timing and phase calibration change during the observation itself.

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Ten worked engineering applications | Question 040

Worked application 01 | Sample spacing versus absolute timestamp uncertainty

A digitiser nominally operates at F_s = 40,000,000 samples per second. Let n = 80,000,000 be the integer sample index counted from the first physical aperture. Its nominal sample interval is $T_s = 1/F_s$ = 1/40,000,000 s = 25 ns. The elapsed time is $t_{rel} = n/F_s$ = 80,000,000/40,000,000 = 2.000000 s. Now suppose an independently derived acquisition epoch t_0 carries a standard uncertainty u_0 = 250 microseconds. The absolute time estimate is $t_{abs} = t_0 + 2.000000$ s, but its uncertainty cannot be 25 ns merely because the sample interval is 25 ns. Even if the sample-rate contribution were negligible, the epoch term alone leaves approximately 250 microseconds of standard uncertainty. A timestamp formatted to nine decimal places conveys a convention for displaying the estimate, not proof of nanosecond accuracy. The calculator has recovered an elapsed count under a rate assumption; it has not verified the counter's epoch. A suitable field challenge would compare an independently timed input edge with the actual ADC latch, rather than the host file-creation time.

Worked application 02 | Relative oscillator drift and sample-count discrepancy

Receiver B has an assumed constant fractional clock-rate error y_B = 2 parts per million = 2×10^{-6} relative to receiver A. Let T = 600 s be the uninterrupted interval after a calibrated common epoch. Under the stated constant-error model, accumulated time offset is $\Delta t = y_B T$ =

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$2 \times 10^{-6} \times 600$ s = 0.0012 s, or 1.2 ms. At an aggregate rate F_s = 5,000,000 samples/s, the offset corresponds to $N = F_s \Delta t$ = 5,000,000 × 0.0012 = 6,000 nominal sample intervals. If the error sign were reversed, the clock difference would reverse as well. A time warp fitted to a short pulse near the start of the session may therefore be quite wrong for a later pulse. This computation assumes a constant rate error and an initially known epoch; short-term oscillator wander, resets and reference switching remain outside the model. The acceptance record needs reference observations across the same elapsed interval and a bound on deviations from the constant-rate premise.

Worked application 03 | Two-point offset fit and an independent residual

Suppose a comparison measures receiver B minus reference offset x_0 = +100 microseconds at reference time t = 0 and x_1 = +700 microseconds at t = 300 s. A linear model $x(t) = a + yt$ has a = 100 microseconds and $y = (x_1 - x_0)/(300\text{ s})$ = (600 microseconds)/(300 s) = 2 microseconds/s = 2×10^{-6}. It predicts x(120 s) = 100 + 2 × 120 = 340 microseconds. If an independent challenge pulse at 120 s measures +375 microseconds, the signed residual is r = 375 - 340 = +35 microseconds. Although the model fits both training endpoints exactly, the challenge exposes a departure of 35 microseconds at the event's position. The examiner must investigate clock wander, measurement noise or a missing model term rather than erase the residual as inconvenient. A source association requiring a 10-microsecond tolerance is not validated by this fit. An association tolerating 1 ms may be robust under the same discrepancy, subject to other errors. This example illustrates why

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independent withheld reference events are scientifically more informative than zero training residuals.

Worked application 04 | Holdover under bounded and stochastic uncertainty assumptions

Let u_0 = 5 microseconds describe a clock's initial standard uncertainty, and suppose an additional fractional frequency-error magnitude is bounded by b_y = 0.2 ppm = 2×10^{-7} during T = 90 s without a usable reference. The maximum additional drift magnitude under that bound is $b_d = b_y T$ = 18 microseconds. If u_0 is instead treated conservatively as a 5-microsecond absolute bound, a simple worst-case magnitude envelope is 5 + 18 = 23 microseconds. One must not label this a 95% confidence interval without a probability model. If, by a different stipulated assumption, 5 microseconds and 18 microseconds are independent standard uncertainties, the root-sum-square result is $\sqrt{5^2 + 18^2} = \sqrt{349}$ = 18.68 microseconds. These are different models, not interchangeable answers. In particular a systematic drift limit is not automatically a random standard deviation. The report should choose its model according to the physical clock evidence and preserve the elapsed time since the last valid reference, the holdover conditions and the uncertainty classification.

Worked application 05 | Transmission-line delays do not equal one universal receiver delay

Two hypothetical reference paths use cables whose effective signal velocities are $v_1 = 0.66c$ and $v_2 = 0.80c$, where c = 299,792,458 m/s is the stipulated vacuum light speed. The path lengths are L_1 = 30 m and

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$L_2 = 8$ m. For constant velocity factor, propagation delays are $\tau_1 = L_1/(0.66c) = 151.62$ ns and $\tau_2 = L_2/(0.80c) = 33.36$ ns. Their difference is $\tau_1 - \tau_2 = 118.26$ ns. Thus two devices with perfectly aligned counter epochs could show an apparent 118-ns difference attributable solely to these transmission-line paths. The calculation omits uncertainty in physical length, velocity factor, connectors, filtering, threshold timing and reflections. It is a path calculation, not a whole-receiver impulse-response calibration. A defensible experiment would inject a representative transient at the relevant physical reference plane and test the entire signal chain over the intended bandwidth.

Worked application 06 | Network time-transfer asymmetry and a false microsecond claim

Let $d_f = 3$ ms be the forward one-way packet delay and $d_r = 7$ ms the reverse delay in a simplified four-timestamp exchange. A conventional symmetric-delay estimator is biased in the inferred clock offset by a term whose magnitude is $|d_f - d_r|/2 = |3 - 7|/2$ ms $= 2$ ms; its algebraic sign depends upon the chosen offset convention. The round-trip sum is 10 ms, but that sum alone does not identify the two one-way delays. A network implementation reporting microsecond timestamp resolution does not thereby eliminate this 2-ms path-asymmetry bias. NTP's delay, offset, dispersion and jitter statistics have operational meaning within the protocol, but they do not substitute for a measurement of the complete acquisition path. This hypothetical discrepancy can overwhelm an attempted 100-microsecond event ordering. A fair validation varies network load and direction, uses suitable hardware timestamping where

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the task requires it, and assesses the actual uncertainty of the event timestamp rather than the precision of the network clock field. [N3, N4]

Worked application 07 | Correlated timing uncertainties in a relative measurement

Let corrected event estimates A and B carry standard uncertainties u_A = 8 microseconds and u_B = 6 microseconds. Suppose the correlation coefficient justified by their shared reference is rho = +0.5. For D = B - A, the standard uncertainty is $u_D = \mathrm{sqrt}(u_A^2 + u_B^2 - 2 \rho u_A u_B) = \mathrm{sqrt}(64 + 36 - 48) = \mathrm{sqrt}(52) = 7.21$ microseconds. Ignoring correlation would give sqrt(64 + 36) = 10.00 microseconds. With a coverage factor k = 2, the numerical expanded uncertainty is $U = 2u_D = 14.42$ microseconds, but a 95% coverage interpretation would require an appropriate distribution and effective degrees of freedom. The difference between 7.21 and 10.00 is not evidence that a common clock always improves the final conclusion. It illustrates how covariance changes this particular relative estimate. If the physical errors entered with opposite signs, the relevant covariance could differ. Preserve the architecture, correlation evidence and all terms before claiming cancellation.

Worked application 08 | Unrelated-event association inside a timing window

Assume solely for this example that unrelated candidate events in one receiving channel form a homogeneous Poisson process with rate lambda = 2 events/s, independent of events in another channel. A predeclared matching half-window w = 5 ms yields a total search duration 2w = 0.010 s about each reference event. The probability of at

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least one unrelated event inside a window is p = 1 - exp(-lambda × 2w) = 1 - exp(-0.020) = 0.0198013, or about 1.98%. Across N = 500 independent, eligible reference windows of comparable exposure, the expected number containing at least one chance match is Np = 9.90. This is an expected count, not a prediction that exactly ten matches must occur, and overlapping windows would invalidate the independence simplification for count variance. Real radio traffic may be clustered or driven by common external events, so the Poisson assumption must be challenged against data. Selecting the window after inspecting the matches also changes the inferential problem. Timing compatibility can be useful, but must not be sold as a unique source attribution.

Worked application 09 | Geometric bound on a free-space arrival-time difference

Suppose two calibrated receiving reference planes are separated by baseline B = 300 m, and direct free-space propagation at c = 299,792,458 m/s is a valid local approximation. For one remote source, the absolute difference in straight-line path lengths cannot exceed B by the triangle inequality. Therefore the absolute arrival-time difference is bounded by |Delta_t| <= B/c = 300/299,792,458 s = 1.00069 microseconds. A corrected observed difference Delta_t = 0.200 microseconds corresponds to a path-length difference c Delta_t = 59.96 m. If its conditional standard uncertainty is 0.100 microseconds, the corresponding path-difference uncertainty is about 29.98 m. The observation constrains an admissible family of locations; it does not specify one unique position. Multipath, non-line-of-sight routes, receiver delays and clock errors can violate the simple free-space model's predictions without contradicting

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electromagnetism. The investigator should use this inequality as a challenge to the model, not as automatic proof of impossible source behaviour.

Worked application 10 | Threshold walk as a timing error hidden by clock precision

A hypothetical detector uses a fixed analogue voltage threshold. Near the relevant crossing, the rising signal has local slope s = 0.8 volts per microsecond. Suppose uncertainty in baseline or effective threshold is Delta_V = 0.040 V, with the local slope approximately constant. A first-order timing displacement is Delta_t = Delta_V/s = 0.040 V/(0.8 V per microsecond) = 0.050 microseconds = 50 ns. A receiver with a 1-ns digital time counter can therefore report a threshold-crossing time influenced by a 50-ns signal-level effect. The arithmetic is first-order and conditional on a locally monotone waveform; noise, curvature, hysteresis and filtering could enlarge or change the timing behaviour. A representative pulse-amplitude sweep should establish whether a correction is stable across the declared signal class. The examiner should report the timestamp of the defined detector event unless a validated transformation places it at a different physical reference plane.

Scholarly and metrological source register with read-scope disclosure

The technical discussion is a newly authored educational construction. The sources below were consulted through accessible HTML pages, bibliographical abstracts or public institutional descriptions. A reference to an abstract does not imply inspection of its full paper, and no external source is represented as certifying any hypothetical numerical case. The bracketed keys refer to the precise records described here. Research access date: 10 November 2026.

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[N1] National Institute of Standards and Technology. *Time and Frequency from A to Z: Stability*, https://www.nist.gov/pml/time-and-frequency-division/popular-links/time-frequency-z/time-and-frequency-z-st-sy . **Read scope:** Public HTML explanation of oscillator stability, its distinction from accuracy, and use of Allan deviation at specified observation intervals. The text supports the conceptual distinction, not a laboratory measurement of the hypothetical clocks.

[N2] William J. Riley and David A. Howe. *Handbook of Frequency Stability Analysis*, NIST SP 1065 (2008), https://www.nist.gov/publications/handbook-frequency-stability-analysis . **Read scope:** NIST catalogue page, title, author names, publication date and abstract identifying frequency-stability measures, processing and reporting methods. The full PDF handbook was not reviewed for this discussion, so no page-specific handbook claims are advanced.

[N3] D. L. Mills et al. *Network Time Protocol Version 4: Protocol and Algorithms Specification*, IETF RFC 5905 (2010), https://www.rfc-editor.org/info/rfc5905/ . **Read scope:** Official publicly rendered RFC material addressing clock offset, network delay, dispersion, jitter, frequency error, and system clock discipline. The specific one-way-delay asymmetry example is a new hypothetical calculation, not a performance claim for a real network.

[N4] IEEE 1588 Working Group. *IEEE 1588 Public Documents*, https://sagroups.ieee.org/1588/public-documents/ ; and NIST, *Meanings of common terms used in IEEE 1588*, https://www.nist.gov/el/intelligent-systems-division-73500/meanings-common-terms-used-ieee-1588 . **Read scope:** Public project summary, identification of active IEEE 1588-2019 and amendments, and NIST's explanation of clock timestamp points and synchronization terminology. The paid full standard text was not accessed and no uninspected clause is quoted.

[N5] Bureau International des Poids et Mesures. *Time Metrology*, https://www.bipm.org/en/time-metrology ; and *UTC*, https://www.bipm.org/en/time-department/utc . **Read scope:** Public descriptions of UTC, TAI, local UTC(k) realisations and the BIPM's comparison process. These establish time-scale distinctions; they do not show any local receiver was traceably synchronized.

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[N6] NIST. *Common View GNSS Time Transfer*, https://www.nist.gov/pml/time-and-frequency-division/time-services/common-view-gnss-time-transfer . **Read scope:** Public method description explaining simultaneous comparisons to a shared transmitter and the effect of differential path delay. The source does not imply independent errors or perfect path cancellation for the hypothetical receivers.

[N7] NIST. *How UTC(NIST) is related to UTC, TAI, GMT, USNO time, GPS time and Zulu time*, https://www.nist.gov/pml/time-and-frequency-division/how-utcnist-related-coordinated-universal-time-utc-international . **Read scope:** Public explanatory account of relations among time scales and leap-second adjustments. No particular leap-second offset is assumed for the hypothetical examples.

[N8] A. N. Novick and M. A. Lombardi. *Practical Limitations of NTP Time Transfer* (2015), https://www.nist.gov/publications/practical-limitations-ntp-time-transfer . **Read scope:** NIST publication page and abstract describing one-way network asymmetry and other limitations. The full conference paper was not examined. This source supports the need for conditional network uncertainty analysis, not a universal NTP error bound.

[N9] NIST. *How UTC(NIST) Works*, https://www.nist.gov/pml/time-and-frequency-division/time-realization/utcnist-time-scale/how-utcnist-works . **Read scope:** Public description of clock ensembles, Allan deviation, time deviation and holdover concepts. This supports the distinction between short- and long-interval stability; no specific receiver's holdover was inferred.

[B1] Science Museum Group. *Christiaan Huygens*, https://collection.sciencemuseumgroup.org.uk/people/cp37464/christiaan-huygens ; and Royal Society, *Huygens personal catalogue record*, https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA8062&pos=1&src=CalmView.Persons . **Read scope:** Public biographical summaries of dates, nationality, pendulum clock and major research activities.

[B2] Nobel Prize Outreach. *Albert A. Michelson: Facts*, https://www.nobelprize.org/laureate/11 . **Read scope:** Official Nobel biographical and award record, work with interferometry and precision optical measurement.

[B3] Dictionary of Irish Biography. *Gosset, William Sealy (Student)*, https://www.dib.ie/biography/gosset-william-sealy-student-a3543 . **Read scope:**

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Public account of dates, education and industrial statistical work; cross-checked against the published Oxford Dictionary of National Biography extract.

[B4] Institution of Engineering and Technology. *Lord Kelvin 1824–1907*, https://www.theiet.org/membership/library-and-archives/the-iet-archives/biographies/lord-kelvin-1824-1907 . **Read scope:** Public historical biography and summary of Kelvin's physics, instrumentation and Glasgow career.

[B5] Royal Society. *Karl Pearson personal catalogue record*, https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA8002&src=CalmView.Persons . **Read scope:** Public archival identity, dates, statistical scholarship and involvement in eugenics.

[B6] Princeton University. *Statistician John W. Tukey dies*, https://www.princeton.edu/news/2000/07/28/statistician-john-w-tukey-dies ; and Royal Statistical Society obituary abstract, https://academic.oup.com/jrsssd/article-abstract/51/2/279/7120702 . **Read scope:** Public institutional obituary and journal abstract concerning dates, education and professional achievements.

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QUESTION 041

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What do FFT resolution and bin spacing mean for a transient emission?

Source: V011_Roundtable_Question_041_CP041_Dr_Atkinson(1).docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 041. Complete expert roundtable discussion

Original constructed educational dialogue. The historical figures are employed as intellectual personae; the discussion is not a historical quotation or transcript. Numerical applications are explicitly hypothetical.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, our preceding discussion established that a timestamp's decimal precision cannot establish the accuracy of the physical event to which it is applied. We now encounter an analogous misconception in frequency measurement. A receiver may display a Fourier transform with a bin spacing of one hertz, a tenth of a hertz or an even smaller interval, while the transient whose spectral properties it is purporting to describe lasted only a few microseconds. The grid can be made arbitrarily fine by filling a transform input with zeros. Yet the physical information in the original observation has not thereby become arbitrarily precise. The eye sees a neat procession of spectral lines; the instrument has performed a mathematical evaluation whose relationship to the unknown emission depends on acquisition duration, waveform stationarity, windowing, noise, filtering and the definition of the reported quantity.

Let F_s be the sampling rate in samples per second, let N be the number of actual samples within one observation window, and let N_F be the transform length after any zero padding. The frequency spacing of the

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computed transform grid is Delta_f_grid = F_s/N_F. The physical observation duration is T_obs = N/F_s. Its reciprocal 1/T_obs = F_s/N is a characteristic frequency scale associated with the finite duration of the original data window. These two quantities are equal when N_F=N, but they diverge when N_F exceeds N. The distinction is not semantic. The grid tells us how densely the transform is evaluated; the finite observation duration and the chosen window determine the response to nearby components and the extent to which the investigator can separate them. A short burst also carries a spectrum determined by its temporal envelope. It is not necessarily a narrow pure sinusoid merely because a detector reports one spectral maximum.

The investigator must also identify the measurand. The centre frequency of a known sinusoidal model observed at adequate signal-to-noise ratio can sometimes be estimated with uncertainty considerably smaller than the spacing of the unpadded transform bins. Such estimation is conditional upon the waveform model and the observation. It is not equivalent to resolving two unknown adjacent emissions with arbitrary waveforms, nor to proving that a brief transient was emitted by a stable oscillator at the frequency of its highest transform value. Parameter precision, separability of distinct sources, spectral-grid spacing and nominal resolution-bandwidth labels are different claims. Their confusion can make a correct calculation into a misleading forensic conclusion.

Consider a hypothetical spectrum analyser or software-defined receiver that holds a 100-microsecond baseband interval and computes a 65,536-point Fourier transform. Its resulting displayed grid may appear fine because N_F is large, yet the observation contains relatively few

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independent temporal degrees of freedom. A transient near the beginning of the window may be strongly attenuated by a taper, a burst crossing the end may be truncated, and two successive bursts within the window may be combined into one spectral estimate. If the display refreshes many times per second with overlapping windows, the resulting spectral frames are correlated. A dense waterfall is not a census of independent observations. And a line centred at one bin is not necessarily proof of a single narrowband external transmitter. Receiver-generated artefacts, window sidelobes, clock errors and burst modulation remain possible explanations.

Forensic interpretation therefore begins before computation. Specify whether the original capture was continuous or triggered, whether the relevant signal class is stationary across the transform window, where the time stamp is anchored within that window, and how the software handles a burst that overlaps its boundaries. Preserve the raw complex or real samples where practicable, the window coefficients, transform length, scale convention, averaging rule and frequency calibration. Report the noise-equivalent bandwidth and coherent gain relevant to the chosen window rather than using a bin width as a universal substitute for measurement bandwidth. When a detection threshold is tuned using only favourable examples, preserve the entire process. Otherwise a mathematically elegant waterfall can obscure the very short-lived emissions a defensive survey was commissioned to discover.

Our historical participants will explore distinct boundaries. Mr Fourier will consider what a finite integral permits one to infer from a transient. Mr Nyquist will distinguish sampling and alias restrictions from spectral-grid conventions. Dr Shannon will consider the information lost when only

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transform magnitudes or selected detections survive. Dr Gabor will consider time-frequency localisation and its unavoidable compromises. Professor Tukey will examine the design of a validation campaign that tests short bursts, nearby interferers and negative evidence. Seven colleagues will challenge the principal speakers in turn, and every question will receive an immediate substantive answer. We shall use checked numerical examples to compare zero padding, observation time, window response, interpolation and false-alarm selection. Our objective is a bounded technical doctrine, not an attractive fictional increase in resolution. Mr Fourier, may I invite your analysis of the finite observation and the distinction between computing a spectrum and discovering the generating physical history?

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Jean-Baptiste Joseph Fourier | Principal response 1: The finite observation as a measurement of a windowed phenomenon

Dr. Atkinson, the first distinction is between a mathematical decomposition and an inverse inference about an unknown physical cause. One may expand or transform a function under specified mathematical conditions; that operation does not itself establish which mechanism generated the recorded values. A real receiver observes a time-limited portion of a signal, not the entire electrical history of a transmitter. When the recorded waveform x(t) is multiplied by an observation window w(t), the analysed quantity is x_obs(t)=x(t)w(t). In the frequency domain, that multiplication corresponds to convolution of the underlying spectrum with the transform of the window, under the applicable Fourier conventions. What the display portrays is consequently an interaction between the source waveform, the receiver chain and the observation operation. A spectral peak can shift, broaden or acquire sidelobes because the observation was finite even when the generating process was stable.

If a sinusoid is observed for time T with a rectangular gate, its response is shaped by the finite aperture. A frequency component not aligned with one transform-grid point contributes to several values because the finite record does not contain an integer number of whole cycles in the chosen comparison. An FFT can evaluate this mathematical response efficiently; increasing the number of evaluation points merely samples the same response more densely. It does not narrow the principal response of a window whose actual physical duration has not changed. If the operator instead acquires a longer coherent record of an otherwise stable signal, the change is real: the observation supports a narrower finite-duration

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response, provided the clock, source stability and receiver state remain sufficiently characterised across that additional time. This distinction is crucial when one wishes to hunt for a weak narrowband line within broad noise.

A transient introduces a separate difficulty. Suppose an emission consists of a brief carrier burst whose envelope rises and falls within a small portion of the analysed interval. The finite pulse envelope contributes spectral breadth of its own, and a taper imposed by the analysis software may change the apparent energy of the burst according to where it occurs in the window. If the same physical burst is moved closer to the margin of the observation, a Hann-type window can reduce its amplitude relative to a burst at the centre. That result is not a change in transmitter power. It is a consequence of multiplying the observed waveform by a position-dependent weight. The analyst must distinguish such processing losses from changes in the incoming field, especially when negative findings are advanced as evidence that a candidate was absent.

The time of a transient within a window also matters to phase interpretation. A delay in the observed waveform multiplies its transform by a frequency-dependent phase factor when the delay is represented faithfully, while discarding phase and retaining only magnitude removes information about that delay. The absolute event epoch cannot be recovered from a bare magnitude spectrum without additional assumptions. Conversely, the presence of phase in a stored Fourier array does not guarantee that the original antenna arrival epoch was calibrated; the array may still be referenced to a software-selected window origin. The earlier clock discussion therefore remains relevant. A time-frequency

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transformation cannot be made more physically informative by assigning a long decimal timestamp to a window whose actual reference plane was never characterised.

When two narrow carriers are close together, their separability depends on the recorded duration, relative amplitudes, chosen window and signal-to-noise conditions. A large nearby signal can obscure a weak component through leakage if the window suppresses sidelobes inadequately. A taper that reduces those sidelobes may broaden the principal response and reduce coherent amplitude, making an already brief weak burst harder to detect. There is no universal best window divorced from the measurement objective. The examiner must determine whether the task is detection, amplitude estimation, frequency estimation, resolving adjacent components or reconstructing a transient's original shape. A window acceptable for one can be unsuitable for another.

One should beware the converse exaggeration, that finite FFT bin width imposes an absolute floor on every possible parameter estimate. If the data strongly support a specified sinusoidal model, the centre frequency may be estimated between grid points by examining phase evolution or fitting an appropriate response. Such an inference is conditional on the model, noise process, sample clock and other disturbances. It should not be confused with demonstrating the presence of two independent unresolved sources, or with determining an arbitrary burst's unique carrier frequency when its modulation and envelope are unknown. The concept of resolution is meaningful only when the question identifies the alternative hypotheses the measurement must distinguish.

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I would therefore insist upon preservation of the original samples and their time coordinates before promoting a Fourier display into testimony. The analyst should record F_s, the number N of actual data samples, N_F used for the transform, the window and scaling conventions, and any prior decimation or frequency translation. A spectrum saved without such context is a derived image lacking the information necessary for some later questions. A calibrated receiver may legitimately offer a strong conclusion about a detected interval and a restricted frequency band; it should not imply the physical history outside the recorded interval can be recreated from the magnified display of its transform. I pass the token to Professor Bridgman to examine what observable operation ought to define the claimed frequency resolution.

Percy Williams Bridgman | Peer question 1 to Jean-Baptiste Joseph Fourier

Mr Fourier, your argument implies that the phrase frequency resolution is dangerously incomplete unless the examiner declares the task whose successful discrimination would constitute resolution. Suppose two laboratories observe the same one-hundred-microsecond pulse. One displays a spectrum interpolated to a one-hertz bin grid and reports a frequency to the nearest hertz. The other uses an unpadded transform with coarse bin spacing and records a much wider uncertainty interval. The first laboratory might possess a justified parameter estimator that genuinely uses phase and a strong prior waveform model, or it might be mistaking display interpolation for empirical knowledge. What measurable challenge would distinguish those cases without prejudging the model? Would you require the laboratories to resolve two

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nearby signals, to estimate the centre frequency of a single known waveform, or to predict an independently withheld continuation of the emission? How should they disclose the model's failure when the signal is not stationary during the observed burst?

Jean-Baptiste Joseph Fourier | Immediate answer to Percy Williams Bridgman

Professor Bridgman, I would require the task to be declared before either laboratory's reported number is assessed. If the purpose is estimating one stable carrier's frequency under a specified signal and noise model, the proper challenge is a collection of withheld test records whose true carrier frequencies are known independently. Randomise those frequencies between and around the nominal grid points, vary burst location and amplitude, and examine the estimator's bias, dispersion and outlier behaviour. A model-based estimator may outperform raw bin selection in such a campaign, but the reported uncertainty must follow the validated model and reference clock, not the number of decimal places displayed. Zero padding can make peak interpolation convenient; it does not itself supply the data that justify a narrow confidence interval.

If the purpose is resolving two simultaneous emissions, the campaign must include pairs whose separation, relative amplitude and modulation are varied systematically. One should declare the required false-separation and missed-separation rates. A procedure that reports an average frequency between two unresolved sources may perform well as a one-tone estimator while being useless for the two-source task. If the purpose is a short transient of unknown

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waveform, still another test is required, because the spectral appearance may depend strongly on the envelope. A withheld continuation may be unavailable for a genuinely brief event, in which case one cannot demand predictive success beyond what the acquisition permits.

All tests should preserve the original samples, window, transform length, input clock record and operating state. They should include deliberately adverse cases, such as a weak burst placed near a window edge and a strong neighbouring carrier whose sidelobes can disguise it. The result should be a conditional capability statement: the instrument can distinguish or estimate a specified class under defined conditions with measured errors. When the incoming waveform departs from that class, the previous uncertainty need not apply. The honest report must state whether frequency is a fitted parameter of an admitted model, the centre of a measured spectral response, or merely the position of the largest displayed FFT value. Those are different observables. I return the floor for examination of how sampling conditions limit the credible transformations that follow.

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Harry Nyquist | Principal response 2: The sampling lattice, alias identity, and finite-exposure frequency claims

Dr. Atkinson, I would begin by separating a restriction upon the original continuous-time spectrum from the spacing of the discrete transform used to examine the samples. Under the familiar uniform-sampling model, frequency components separated by integer multiples of the sample rate may produce indistinguishable discrete-time sequences unless the admitted analogue spectrum is restricted. A transform with a million displayed frequencies does not restore the discrimination that was never present at the sampling boundary. Even an impeccably calculated peak may therefore represent an alias of another physical frequency. The sampling rate, analogue preselection, input spectrum, anti-alias rejection, clock uncertainty, and digital-downconversion history must be considered jointly before a displayed bin is allowed to become a physical-frequency claim. A digital axis labels a particular interpretation of samples, not necessarily the unique cause of those samples.

The time-limited character of the observation introduces another set of conditions. If the receiver records N equally spaced samples at sample rate F_s, its direct unpadded transform evaluates N locations at separation F_s/N. Yet that number does not establish the uncertainty with which the frequency of one known carrier can be fitted, nor the minimum spacing at which two arbitrary unknown emitters can be separated with a specified error rate. The former is an estimation problem under an admitted model. The latter is a discrimination problem involving signal classes, waveform envelopes, relative powers, interference, receiver noise, and admissible risk. Both depend on actual observed data, rather than on the length of a

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transform array filled with zeros. A narrow readout can be either a justified estimate or an unjustified label; one must examine how it was obtained.

I particularly question the use of a static spectral photograph to characterise a brief or frequency-agile emission. A short burst can illuminate only a fraction of the window. The same physical event may appear at markedly different amplitude when its arrival phase is changed relative to window boundaries or when the trigger marks a threshold-crossing instead of a true onset. A swept or frequency-hopping receiver may not be listening at the appropriate instant. If the detector returns a peak frequency but does not preserve the exposure schedule, trigger logic, signal duration and window location, a later examiner cannot know whether a changed indicated frequency originated in the emitter or in the observation geometry. One obtains more faithful evidence by retaining the raw interval and the processing record than by increasing the displayed precision.

There is an especially consequential error when an investigator compares successive FFT windows as though they were independent trials. Overlap is commonly useful for reducing apparent gaps in a waterfall, but adjacent overlapping windows re-use samples. If a burst spans two windows it may generate two detections, yet that does not establish two transmissions. A receiver may also compute a moving average of many spectral frames; if it retains only the average, a transient's peak amplitude and exact occurrence time can be lost. One must therefore define event counting, correlation, dead time and the retention rule before turning spectral detections into evidence about number, prevalence or duration of emissions. A high numerical frame rate is not the same as a high rate of independent observations.

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The proper acceptance campaign requires at least three groups of deliberately varied inputs. In the first, use stable sinusoids spanning each grid interval and compare frequency-estimation bias with the true independently established frequency. In the second, challenge with pairs of emissions of controlled separation, amplitude ratio and phase, reporting both missed separation and false separation. In the third, use time-limited bursts with varied duration, start position, envelope and frequency drift, including intervals crossing the analysis boundary. Apply identical processing rules to favourable and unfavourable cases, and preserve the results of all trials. An instrument should never be accredited for an untested broad signal class on the basis of success against one ideal carrier.

For a forensic claim, trace the frequency axis back to the physical reference oscillator and the configuration of every translator. A complex baseband signal may be associated with positive or negative frequency relative to a tuning reference; an I/Q swap or conjugation can invert the apparent sign. A superheterodyne mixer can admit different RF frequencies through desired and image paths; a digital transformation can faithfully process an aliased representation. Frequency calibration of the final display alone does not establish uniqueness at the antenna. The report should give the physical input plane, accepted band, local oscillator state and uncertainty of the reference, rather than merely the FFT label and its decimal places.

I do not suggest that finely evaluated Fourier transforms are worthless. They are an efficient means of depicting and interpolating a response already determined by the input record. A carefully validated parametric estimator may achieve excellent precision, particularly for a stable signal

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observed coherently against a characterised oscillator. But when the burst is too short, unknown or nonstationary for that model, the narrower statement is the stronger one. A method can identify that appreciable energy occupied a defined spectral interval during a given exposure without certifying the transmitter's continuous frequency to a fraction of a hertz. The discipline is to keep every conclusion attached to the assumptions, observations and uncertainty that make it possible. I invite Professor Bridgman to test whether such an explanation is sufficiently operational to support two laboratories wishing to compare their results.

Harold Stephen Black | Peer question 2 to Harry Nyquist

Mr Nyquist, suppose a digital receiver is supplied with a highly stable oscillator and a dense zero-padded Fourier display, and its operator reports a centre frequency with six decimal places. A second laboratory observes the same controlled burst using a different analysis window and obtains a slightly shifted maximum. The two instruments share a traceable sample-clock reference, so their time bases are not in dispute. Yet each laboratory points to its own peak as the obvious best frequency estimate. From the engineer's standpoint, the source waveform and the processing window form a system whose transfer behaviour should be measured. Should the examiner require the reported quantity to be invariant when the window changes, or is it legitimate for the reported centre frequency to depend on a declared estimator? How would you distinguish a physical frequency difference from a processing-induced peak displacement, especially when the event is brief, asymmetric and accompanied by a stronger neighbour? I ask also whether a successful

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correction could conceal this ambiguity by forcing both instruments to agree with a reference model.

Harry Nyquist | Immediate answer to Harold Stephen Black

Mr Black, the first essential correction is not numerical but conceptual. A reported peak location and the fitted frequency of a stipulated carrier are not automatically the same measurand. If a burst is modelled as one sinusoid multiplied by a known envelope and observed through a characterised receiver, an estimator may produce a coherent parameter estimate with calculable uncertainty. If instead the operator reports the maximum of the windowed magnitude spectrum, the result depends upon the spectral convolution and may change with window selection. That dependence is not inherently a defect if it is disclosed. It becomes a defect when the result is labelled as a unique underlying carrier frequency without accounting for it.

The verification experiment should hold the physical input fixed while varying only the analysis method. Preserve raw samples, independently known stimulus parameters and the software configurations. Compare a rectangular, Hann and other suitable windows, using their actual amplitude normalisations and noise-equivalent bandwidths. Where a known model is fitted, test it on withheld bursts with deliberately altered envelopes, neighbouring signals and frequency drift. Do not permit the estimator to select its own favourable examples retrospectively. If a frequency estimate shifts systematically as the window changes, investigate whether the source model is false, the record is too short, or the procedure is

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measuring a different quantity. The fact that both instruments are locked to the same clock does not settle those alternatives.

A stronger neighbour is especially instructive. A finite-window analysis can spread the neighbour's energy into the candidate's region, and a taper that suppresses sidelobes may also broaden the main lobe. Thus there is no universal window which simultaneously minimises all desirable errors. The question is which risk matters in the intended investigation: distinguishing a weak burst, measuring a strong carrier accurately, detecting the presence of any emission in a band, or estimating its time of arrival. A laboratory must choose its rule according to that task and disclose the resulting trade-off. If both instruments return the same value only after a shared correction was fitted to a common reference, that agreement is not independent validation of the unknown signal model.

For the hypothetical report, I would insist upon an explicit formula or computational definition of the estimator, a stated signal class and the uncertainty of the sample clock. The result should be reported with a challenge-derived uncertainty or a bounded frequency interval appropriate to the data. One may write that a particular short burst produced a maximum in a specified spectral representation, but one may not infer without additional evidence that the generating oscillator held exactly that frequency for longer than the acquired event. If an independent instrument follows the same signal when the record is extended or the window is changed, this constitutes useful additional evidence, not an automatic licence to remove all qualifications. I return the floor respectfully to Dr Shannon, who will

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examine the information retained when the spectral representation replaces the original samples.

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Claude Elwood Shannon | Principal response 3: Representation, discarded phase, and the cost of triggered retention

Dr. Atkinson, the mathematical transform can be reversible under its declared conditions. A complete complex discrete Fourier transform of a finite numerical vector, with known ordering and normalisation, retains that vector's numerical information to within implementation precision. The same cannot be asserted when the operator saves only a logarithmic magnitude spectrum, a few selected peaks, or a rolling average. Those records may be perfectly adequate for one investigative objective, but they cannot support every question later imagined. When phase is discarded, different time-domain sequences can produce the same magnitude spectrum. If temporal order, sign or phase relative to an external reference is material, the ambiguity is fundamental, not something cured by increasing the plotted resolution.

The distinction becomes particularly visible with short events. Suppose a receiver retains a burst's frequency magnitude but no time-domain samples. A second investigator asks whether the event preceded a power transient or occurred several milliseconds afterwards. Magnitude alone generally cannot answer that question. Similarly, a spectrogram whose frame times are rounded or whose windows overlap may not establish an onset epoch with the precision implied by its labels. If the detector's retention was triggered by a threshold, a saved event may exclude earlier low-amplitude activity or a preamble that mattered to the source model. The selection function is part of the evidence, even when its operation is hidden from the finished display.

It is tempting to say that a very large Fourier transform contains more information than a short one. Yet appending zeros to a finite vector does

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not create new observations. It changes the set of points at which a continuous trigonometric polynomial associated with that record is evaluated. The additional displayed values are determined by the original numbers; they cannot serve as independent corroborating observations. A practical display may become easier to interpolate, and a narrow maximum may be located with finer numerical precision. That increased convenience should not be confused with improved robustness against an incorrect physical model, hidden receiver nonlinearity or the absence of a necessary analogue sample.

Statistical estimation complicates but does not overturn this conclusion. A strong and sufficiently simple waveform admits inference about parameters that were not directly sampled at every possible instant. Under an accepted signal model, multiple samples constrain the phase trajectory, and the resulting frequency estimate may be substantially finer than the reciprocal duration scale. But this precision is conditional. If a burst contains unknown modulation, phase resets or drift, the parameter model changes. A narrow confidence interval computed from a false model is not evidence of a physically precise frequency. The correct test is whether the estimate retains its calibration and coverage under the signal variations encompassed by the stated claim.

In a defensive counter-surveillance investigation, the dominant risk often lies not in the transform calculation but in the archive's loss of context. A trigger may store only frames whose power exceeds a threshold. If a faint emitter remains below threshold during one survey period, the saved record may be silent. Silence in the archive is not equivalent to absence of a signal. A later investigator cannot reconstruct all unsaved frames by applying an

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inverse Fourier transform to the detections that remain. Nor can a saved detection count be divided by the total survey time without accounting for scanning, blanking, dead time and changing thresholds. Recording policies determine the population from which evidence is selected.

The same principle applies to the simultaneous observation of several channels. A polyphase channeliser may retain narrow output bands while discarding the raw wideband stream. This economises storage, but a later question about an out-of-band intermodulation product or an image response may be unanswerable. The operator should preserve, as far as practical, an authenticated raw segment around a significant event and the transform chain that produced its derived forms. Where retaining the complete stream is impracticable, preserve explicit exposure maps and the limitations of any triggered collection. Hashes support evidence-integrity claims, but a hash of an incomplete derivative cannot certify the completeness of an unrecorded analogue history.

An acceptance experiment ought therefore to include questions that cannot be answered from a particular derivative. Ask whether the retained data can distinguish two nearby emitters; whether they preserve event epoch; whether they permit a different window to be applied; and whether a disputed peak can be tested against an independently measured receiver transfer function. If the answer is no, that should be part of the acquisition specification, not a surprise at litigation or expert review. Practical engineering involves trade-offs, but integrity requires those trade-offs to be documented before the evidence is interpreted.

The most useful conclusion is a tiered one. A magnitude-only spectrogram can establish, subject to calibration and detection

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assumptions, that a particular algorithm indicated energy in a defined time-frequency cell. A complex transform with full processing state can support somewhat richer inferences. Raw digitised samples with calibration, state and timebase records can support further reanalysis, although they still do not reconstruct an analogue input beyond the receiver's admitted information. The input chain remains the ultimate boundary. More detailed numerical records are helpful, yet the report must identify exactly which proposition each representation is competent to test. I pass the floor to Professor Wiener for a question concerning the role of adaptive thresholding in the creation of the retained archive.

Norbert Wiener | Peer question 3 to Claude Elwood Shannon

Dr Shannon, your distinction between a retained record and the history from which it was selected is especially consequential when the receiver adapts to its surroundings. Imagine an SDR which updates its noise-floor estimate, changes its detection threshold and stores only the FFT frames that trigger an alarm. An intermittent emitter appears in the same band as a stronger legitimate signal, and the algorithm suppresses some frames as uninteresting. The eventual archive contains precise frequency estimates for the events it selected, together with correct hashes and consistent software records. Yet it contains no direct representation of numerous periods when the instrument decided not to save data. Can the resulting archive support an estimate of emitter prevalence, or only conditional statements about selected alarms? What minimum metadata should accompany such a record to permit independent reconstruction of the selection process, and how would a

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reviewer challenge an adaptive rule that was tuned during the observation itself?

Claude Elwood Shannon | Immediate answer to Norbert Wiener

Professor Wiener, the archive supports a frequency estimate for the selected observations only insofar as those observations and their calibration support it. It does not by itself establish the prevalence of the originating signal. Selection can depend upon the signal, the interference environment, the estimator's own noise model and the history of previous selections. A rate of saved events is therefore a property of the coupled acquisition-and-detection process, not necessarily the rate at which the physical emitter operated. Inferring prevalence requires a model of detection exposure and missingness, together with evidence sufficient to test that model.

At minimum the preserved record should include the receiver's tuning and observation schedule, timebase and gain state, analysis-window length and type, threshold history, noise-floor estimator, blanking or dead-time intervals, and the software version governing selection. It should identify whether each retained event was saved with pre-trigger samples, how a triggering interval was placed relative to FFT frames, and whether one physical event could produce multiple stored alarms. Where possible, a sample of untriggered intervals should be preserved according to a predeclared independent schedule. This provides a means of measuring the detector's false-negative behaviour rather than estimating it solely from the selected successes.

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An adaptive rule may be entirely appropriate for operational discovery. The problem arises when its adaptation is omitted from the evidential account. One could freeze the learned parameters during a challenge experiment, compare them with a different rule on withheld recordings, or introduce random test bursts whose presence is concealed from the algorithm. Trials should represent the full admitted envelope, including strong neighbours, quiet periods, temperature shifts and input clipping. The result should distinguish the probability of an alarm given a signal from the probability that a signal was present given an alarm; the latter depends upon the base rate and relevant alternative explanations. A high detection probability during favourable trials does not give the investigator a universal prevalence estimate.

Cryptographic integrity checks cannot recover intervals that were never retained. They are essential to preserving the bytes that exist, but the question whether those bytes fairly represent the investigated period remains separately answerable, if at all. The report should state the extent of the recorded and unrecorded exposure, what was selected, and which hypotheses remain observationally equivalent. A modest claim that the receiver detected specified candidates under documented conditions can be sound. An unrestricted statement that no other emissions occurred because none were archived is not justified. I invite Dr Gabor to examine the further difficulty of allocating a finite observation simultaneously in time and frequency.

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Dennis Gabor | Principal response 4: Time-frequency concentration and the apparent precision of a short burst

Dr. Atkinson, the signal analyst naturally seeks localisation in both time and frequency, yet a record cannot generally be represented by a single point possessing arbitrary precision in each domain. A narrow time-localised event spreads its energy across frequency, while a sharply localised spectral component typically demands a longer coherent observation. This is not a fault in the FFT implementation. It is a property of the relationship between the signal and the analytical operation. The distinction matters when an SDR records a fleeting pulse and displays a narrow vertical line with many decimal places beside it. The line may be a convenient spectral coordinate, but the pulse envelope and the observation aperture limit what can be claimed about the actual transmission. Neither finer axis labels nor a denser numerical plot transforms one brief event into a long continuous tone.

A short-time Fourier transform computes a sequence of local spectral descriptions using overlapping observation windows. The window length and shape determine how the procedure trades temporal localisation against frequency discrimination. A long window is useful for distinguishing narrow neighbouring tones under suitable stability assumptions, yet it may merge several short emissions or locate a sudden start imprecisely. A shorter window helps expose the burst's onset and modulation, but it broadens its frequency response and increases the difficulty of distinguishing nearby narrowband sources. There is no contradiction here. The instrument must choose the resolution relevant to its investigation, or preserve data that permit alternative analyses later.

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One may use a Gaussian-windowed analysis to make the localisation argument precise in a particular mathematical setting. The familiar uncertainty relationship between suitable measures of time spread and frequency spread indicates that their product has a lower bound under stated conventions. This does not establish a universal, context-free frequency error for every estimator. The measures refer to signal or analysis concentration, and model-based estimation can behave differently. It does establish that a claim of arbitrarily sharp simultaneous localisation cannot be justified merely by manipulating the display grid. The examiner must state what spread is being described and whether it is the incoming waveform's property, the chosen window's response, or the uncertainty of a parameter fitted to the data.

Consider two hypotheses. Under the first, a stable oscillator emits a sinusoid for a short known interval. Under the second, the incoming waveform contains a brief chirp whose instantaneous frequency changes throughout that interval. The two may yield superficially similar peaks in a short FFT magnitude plot even though their physical interpretations differ. A longer coherent observation could distinguish the stable tone from the chirp if the sources continue. For an event that has ended, only the retained samples and justified model constraints remain. A fitted central frequency may be useful, but it should not be represented as a measured instantaneous frequency at every unobserved instant. The investigator should explicitly test whether a changing frequency model fits better than a stationary carrier and whether the improvement is supported rather than merely purchased by adding parameters.

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Short bursts also challenge the meaning of an amplitude estimate. If a burst lies near the centre of a Hann window, it may receive a substantially different weight than the same burst near either boundary. Dividing by the coherent gain appropriate to a continuous sinusoid does not automatically correct this position-dependent burst loss. That amplitude correction is designed for a particular signal class. A transient may require energy normalisation, envelope reconstruction or a detection statistic matched to its expected form. The receiver's false-negative rate near the window edge should be measured by injecting otherwise identical bursts at varied positions, rather than inferred from a single centre-placed demonstration.

The tension between time and frequency is especially acute in a defensive search for intermittent devices. A transmitter may switch on briefly to emit a narrow packet; the receiver may scan rather than continuously observe its frequency; and the capture procedure may store only triggered snippets. The frequency plot is consequently conditioned on three different kinds of temporal selection: when the antenna admitted the signal, how long the digitiser retained it, and where the FFT window was placed. If one of those is undocumented, a precise reported spectral coordinate may obscure a large uncertainty about whether and when the physical emission occurred. A strong result requires reconstructing the chain of temporal admission and describing the failure modes for events arriving during a blind interval.

I would therefore advocate a multiscale validation campaign rather than a single preferred window. Preserve sufficiently long raw complex samples around candidate events, where practicable, and evaluate short and long windows under declared rules. Compare event time, central frequency,

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spectral extent and amplitude conclusions across scales. Where those estimates disagree, treat the disagreement as information about model or processing sensitivity, not as a reason to select whichever result is more reassuring. The record should identify both the estimates and the conditions under which each is meaningful. A frequency claim that survives appropriate window changes, independent front-end settings and source-model challenges is more defensible than one founded solely on a visually sharp peak.

This doctrine does not require an operator to regard every spectral image as uncertain beyond practical use. It permits an evidential statement about the detected energy and its location in a specified analysis band, while reserving stronger claims of stable carrier identity for observations and experiments that support them. A waterfall may be an excellent discovery instrument, particularly when the analyst understands its time-frequency compromises. The danger begins when discovery coordinates are turned into causal certainties. The frequency of a spectral maximum, the estimated centre of a modulation envelope and the instantaneous carrier of an external emitter are distinct quantities. I pass the floor respectfully to Professor Slepian, whose work concerning concentration raises the question whether a mathematically optimal window for one signal class can be assumed optimal for an unpredictable burst.

David Slepian | Peer question 4 to Dennis Gabor

Dr Gabor, your account recognises that the selected observation window participates in the measured spectral result. A considerable body of concentration theory permits the construction of sequences which retain an unusually large share of their spectral energy in a prescribed

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interval, and these sequences are sometimes preferred for weak-signal analysis. Suppose a laboratory chooses such a taper, reports an impressively quiet out-of-band response and declares it the best means of discovering unknown short emissions. That choice may be excellent for a stationary sinusoid or a narrowband power estimate, yet the window may place small weight upon a brief event near its ends. By what experiment should the laboratory demonstrate that its concentration criterion is relevant to detection probability, not merely to a spectral leakage metric? Would you require a separate temporal-exposure acceptance test, and how should the result be reported when no one window dominates across all admissible burst durations and arrival phases?

Dennis Gabor | Immediate answer to David Slepian

Professor Slepian, I would welcome a highly concentrated spectral window as a deliberately chosen mathematical tool, not as an unqualified proof of universal detection capability. The criterion by which it is optimal should be made explicit. Concentrating energy in a frequency band is not identical to maximising the probability of detecting a brief burst at every possible position within a finite observation interval. When a taper sacrifices response near its edges, an unknown emitter can be poorly represented precisely because it arrived where the instrument placed a low weight. The operator must test the signal class against the intended acceptance criterion rather than borrow optimality from a different problem.

A useful campaign would randomise burst onset across the whole available observation, from before the first sample through the last

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admissible edge. It would vary pulse duration, envelope, carrier offset from a grid point, signal-to-noise ratio and the presence of neighbouring interference. One should compare detection rules at a declared false-alarm rate and report missed-detection probability as a function of both arrival phase and frequency. The result might show that one taper offers superior rejection of a strong neighbour at the cost of reduced response to certain short events. Such a trade-off is not disqualifying if it is acknowledged. It becomes problematic only when a published leakage ratio is offered as evidence of a detection probability never measured.

The tests should also separate a single isolated event from a repeated sequence. Window overlap can reduce some edge losses because the same burst may appear closer to the centre of a neighbouring frame, but it increases dependence among frames and complicates counting. One can improve event capture by changing overlap or combining detections, yet one must then reconsider the false-alarm probability of the composite procedure. A burst that triggers two neighbouring windows is one physical event unless independent evidence suggests otherwise. The effective exposure map must incorporate all such operations.

No window can guarantee the same optimum across every signal model. I would allow a laboratory to preserve two or more complementary representations and use a predeclared rule for comparing them, provided the underlying raw samples remain available and the statistical consequences are tested. A short-window detector may be more sensitive to brief events, while a longer-window

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detector may be better at identifying a weak stable tone. Their results should be reconciled against common event identifiers and physical acquisition times rather than counted as independent confirmations. Where only one derivative was retained, the associated limitation should appear prominently in the report. The investigator can then defend a bounded discovery statement without pretending that the window's spectral elegance proves a transmitter was absent whenever no line appeared.

Walter Andrew Shewhart | Peer question 5 to Dennis Gabor

Dr Gabor, in industrial process control a chart is meaningful only in relation to the variation and observation rules under which it was established. You have proposed comparing windows and acceptance challenges, but I am concerned about the familiar practice of adjusting a detector repeatedly after observing inconvenient missed bursts. Suppose the laboratory chooses a short window to improve time localisation, discovers false alarms, lengthens the window, changes the threshold, increases overlap and eventually reports the last apparently satisfactory series of trials. The reported false-alarm proportion may be arithmetically accurate for that series while concealing the selection of the series itself. How should the campaign organise its training and verification records so that an operator can adapt a useful detector without subsequently portraying the selected settings as independently validated? What forms of process instability should prevent the acceptance results from being extrapolated to a field survey with changing gain, temperature and spectrum occupancy?

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Dennis Gabor | Immediate answer to Walter Andrew Shewhart

Dr Shewhart, your concern is central. Development and verification must be distinguished in the evidence record. The laboratory may legitimately explore many windows, thresholds and overlap arrangements, but the result of that exploration is a candidate procedure, not yet an independently confirmed operating characteristic. After the candidate has been selected, its software configuration, calibration and decision rules should be frozen for a withheld challenge population selected under predeclared conditions. That population should include both favourable and adverse combinations of arrival time, interference, source waveform and receiver state. The examiner should preserve all outcomes, including unsuccessful and invalid trials.

A field survey may differ materially from the calibration bench. The input gain may change, the analogue front end may enter compression, the clock may drift, the interference distribution may shift, or the sampling chain may lose blocks. A detection test performed at one stable operating point cannot certify a broad envelope unless the tested conditions and their interactions are adequate for the claimed application. I would therefore couple the time-frequency analysis to a controlled state record and a challenge matrix whose dimensions arise from the physical mechanisms most likely to change performance. A small number of meaningful stress tests can be more informative than hundreds of repetitions of an easy carrier.

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The laboratory should also account for the dependence created by overlapping frames. A validation report that counts a thousand overlapping FFT frames as one thousand independent opportunities may understate uncertainty when the same burst or noise fluctuation influences many frames. The appropriate trial unit may be an independently injected event, an observation interval or another declared exposure unit, depending on the claim. Randomisation and confidence intervals should be defined at that level. Where the trial population is adaptive, the report should disclose the adaptation and refrain from assigning it the coverage properties of an unselected experiment.

I would not demand that the operator choose one universal window. The purpose of the trial is to establish a conditional performance surface, showing where detection works, where it fails, and how the software switches among declared methods. The report should identify any conditions outside the established envelope. An honest failure map is useful operational knowledge. It indicates where additional hardware, longer observation or a second method may be required. To use such a map as evidence, the laboratory must preserve its version history and prevent the apparent improvement of the selected final test from erasing the earlier failures. I pass the token to Professor Tukey for the question of how such a verification campaign should be analysed and reported.

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John Wilder Tukey | Principal response 5: A validation experiment that separates resolution, detection and attribution

Dr. Atkinson, the danger of a fine spectral grid is not that it is mathematically improper. The danger is that its visible neatness encourages the analyst to forget that measurement is a sequence of choices. First the receiver admits a physical band. Then it samples during particular intervals. Then it applies a window, transform, scaling rule and decision criterion. Finally it chooses which observations to retain or describe. Each choice changes the population of outcomes whose statistical properties are to be assessed. A defensible validation campaign must be organised around the claims the investigator intends to make, rather than the pleasant appearance of an isolated spectrum.

Consider the claim that a weak short-lived emitter can be detected with a specified probability while a strong legitimate transmitter occupies a nearby channel. The proper experiment must vary burst time, duration, envelope and carrier offset; it must also vary the strong neighbour's amplitude and offset, the sampling-chain gain and the analysis-window state. If the operator is allowed to adjust the threshold until each test burst is detected and then reports the final successful settings, no independent detection performance has been established. The laboratory may have demonstrated that the example can be fitted by a flexible procedure. Such fitting has a place in development, but it is not the same as validation on conditions the procedure has not already encountered.

The statistical task must also distinguish between a single-candidate test and an extensive search. If a detector examines thousands of frequency-time cells, the chance of at least one false alarm can be much greater than

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the nominal per-cell false-alarm probability. Under an independence approximation, if each of K tests has probability p of a false alarm, the probability of one or more false alarms is 1-(1-p)^K. This expression is an illustrative limiting model, not a guarantee for overlapping windows or correlated frequency bins. A serious campaign should characterise the actual joint false-alarm behaviour of the implemented decision rule. It should not combine overlapping frame counts as though every comparison were independent, nor suppose that a threshold proven adequate for one cell is automatically adequate for a whole waterfall.

Attribution is a still stronger claim. A spectral feature that persists when a window is changed may be an external emission, but it may also be a receiver-generated artefact whose frequency mapping is stable. One must ask what alternative mechanisms predict under deliberate interventions: change sample rate or local oscillator tuning, change preselection, insert a characterised attenuation at the input, substitute a separate receiver, or reposition the receiving antenna. An external signal and an internal numerical spur may respond differently to these changes, provided the transformations themselves are understood. If two candidate explanations predict the same observation under the chosen test, the result cannot discriminate them. That conclusion is not defeat; it tells the investigator which further test has potential value.

One should begin with exploratory plots, but not end there. Explore failures, residuals, asymmetries and unexpected response shapes. Then formulate a measurable rule that a second analyst could execute against the retained data. The method should report what constitutes one physical event, how event time is assigned when multiple windows trigger, how

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frequency is estimated, and what interval or uncertainty accompanies the estimate. A fixed number of FFT bins does not set uncertainty by itself. Neither does a finely reported maximum establish the successful resolution of two simultaneous unknown emissions. If the report uses the word resolution, it should say exactly whether it means grid spacing, main-lobe response, two-source separability, estimator precision or detection performance.

For negative evidence, the analyst should disclose observation exposure and selection. A survey lasting an hour is not an hour of effective exposure at every frequency if the receiver scanned, blanked, retuned or discarded windows. The test should measure how often a short pulse placed randomly within the declared observation programme is retained and recognised. If a burst has a one-in-ten chance of coinciding with an admitted sampling interval, a perfect detector during that interval still cannot guarantee complete detection over the original hour. To treat the absence of stored alarms as affirmative evidence requires a model that includes those blind periods and the admitted source behaviour. The model should be audited with withheld injections rather than defended merely by its mathematical plausibility.

The published result should include a compact but reproducible acceptance dossier. Retain the input reference and its uncertainty; the instrument's physical configuration; clock and gain states; the analysis software and transform settings; the challenge population; the raw observations relevant to contested results; the complete detection and missed-detection outcomes; and the rules by which confidence intervals were computed. Important exclusions should be stated, including off-grid

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bursts, frequency drift beyond the test range, clipping, and interference conditions for which performance is unknown. A modest claim that survives all such scrutiny is more informative than a broad performance assertion from a carefully selected demonstration.

The final point is intellectual rather than computational. A useful spectrum is an instrument for inquiry. It should make the next discriminating experiment possible, not suppress questions by the authority of a precise-looking number. We may report a finely estimated carrier when the acquisition, model and test population justify it. We may report a broader spectral occurrence when they do not. Both may be valuable in defensive technical surveillance. Their credibility depends on resisting the impulse to place more certainty into the conclusion than the observation contains. I now invite Professor Neyman to challenge our proposed method of reporting confidence across a family of related operating conditions.

Jerzy Neyman | Peer question 6 to John Wilder Tukey

Professor Tukey, your acceptance dossier proposes numerous conditions, including several burst durations, amplitudes, arrival phases and neighbouring-interference levels. Suppose the laboratory evaluates twenty operating cells, each with a separate confidence interval for detection probability. It then advertises the system as meeting the required probability over all twenty cells because each individual interval appears satisfactory at the usual nominal confidence level. Unless the procedure addresses simultaneous coverage and the selection of the reported cells, that argument may overstate what the finite trials establish. How would you design the inferential statement so that the laboratory can claim a minimum performance across the declared

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envelope without substituting twenty separate reassurances for a joint confidence statement? Would you favour a simultaneous bound, a predeclared worst-case test condition, or a more conservative acceptance rule that declares indeterminate regions where the sample size does not support the intended assurance? Please also distinguish confidence in the validation campaign from the probability that a particular field alarm corresponds to a physical transmitter.

John Wilder Tukey | Immediate answer to Jerzy Neyman

Professor Neyman, the distinction is important. A confidence interval constructed separately for each cell is not, without additional argument, a simultaneous confidence guarantee for all cells considered together. If the intended claim concerns the minimum detection probability over a declared envelope, the design should control the probability that the overall reporting procedure falsely certifies that minimum. One practical approach is to predeclare the cells and their weights, use simultaneous bounds appropriate to the design, or allocate an error budget across tests. The exact method should be selected according to the sampling process and dependencies rather than borrowed as a decorative formula. A predeclared worst-case condition can sometimes offer a simpler operational check, but only when evidence supports the assertion that the chosen condition is genuinely limiting.

The laboratory should not choose its difficult cases only after examining the results and then claim that the selected set was independently predeclared. Exploratory work may identify a weakness. That discovery should guide a new validation campaign

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with fresh trials. Where conditions are expensive to reproduce, a sequential design may be legitimate, but its stopping and error-control rules must be specified. Every test performed should be included in the audit record. To report the best-performing subset while suppressing failed trials defeats the purpose of statistical validation, even if each retained calculation is arithmetically correct.

If a cell has too few effective independent trials, it may remain indeterminate. The instrument can be useful for discovery under that condition, but one should not assert the same detection guarantee there as in a well-characterised operating region. Combining adjacent observations can increase efficiency when justified by a defensible model, but it must not conceal heterogeneity that materially affects false negatives. Overlapping FFT frames may supply correlated measurements of one event, not extra independent opportunities. In a robust campaign the independent sampling unit should be made explicit, and sensitivity analyses should show how conclusions change under reasonable alternative dependence assumptions.

Finally, a confidence bound on detection probability is a frequentist performance statement about a defined procedure under a defined trial population. It is not the posterior probability that any particular field alarm is a transmitter of a specified identity. That latter attribution requires consideration of signal prevalence, alternative sources, artefacts and perhaps further observations. It is entirely coherent to have strong evidence that a detector performs well in laboratory trials while retaining substantial uncertainty about the cause of one field indication. Reporting these propositions separately

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allows investigators and courts to understand what the apparatus has actually demonstrated. I return the token to Dr. Atkinson for the synthesis of the claims that remain defensible after these challenges.

Sir Ronald Aylmer Fisher | Peer question 7 to John Wilder Tukey

Professor Tukey, I wish to introduce one final operational question before the moderator concludes. Consider a receiver manual which states that frequency resolution is five hertz because the Fourier transform uses a five-hertz grid. The same manual later advertises sub-hertz frequency estimation for a pure tone and a separate short-time burst detector. A laboratory may regard these as mutually consistent claims about different measurements, but a field examiner will be tempted to quote whichever specification appears most favourable. How should the acceptance record be organised so that a technically correct statement about one signal class is not silently exported to another? Specifically, what should be the mandatory labels accompanying a reported frequency, which of them must be preserved in a derivative evidence file, and how should the analyst describe a failed challenge where a transient was confidently detected yet its central frequency could not be estimated within the advertised narrow interval?

John Wilder Tukey | Immediate answer to Sir Ronald Aylmer Fisher

Thank you for that question. Sir Ronald, I would classify the results by the quantity being reported and the signal class to which the measurement applies. The five-hertz FFT grid is a numerical evaluation spacing under a particular sample rate and transform length. Sub-hertz estimation may be justified for a stable sinusoid

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under a model, specified duration, adequate signal-to-noise ratio and characterised timebase. A short-time burst detector may be intended only to establish whether energy consistent with a candidate class occurred during a window. These are compatible specifications if their conditions are stated. They become misleading when one is represented as a universal attribute of the instrument.

A report of frequency should identify at least the physical input reference plane, the observation interval and timebase, the window and transform configuration, the estimator, the assumed waveform class, the uncertainty or validated challenge interval, and the relevant clock and front-end calibrations. Where a detected burst is not well modelled as a stationary carrier, the report may give a broader occupied band or spectral centre with a qualification. It should not force a narrow frequency estimate merely because the software has capacity to print many digits. The raw retained samples and software version should be preserved where possible so that an independent examiner can apply a different qualified estimator. If the derivative omits phase or acquisition history, that limitation belongs alongside the frequency claim.

A failed challenge can be very informative. It may show that the detector successfully indicated the occurrence of a burst while its frequency estimate wandered under changes in window position or waveform shape. This does not make the detection worthless. It establishes that the evidence supports a presence claim more strongly than a precise carrier-frequency claim for that signal class. The laboratory should record that distinction explicitly and restrict the

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advertised uncertainty accordingly. It may choose to develop a better estimator and test it on fresh withheld cases, but it should not retrospectively amend the historical test record to suggest the weakness never existed.

Forensic credibility grows when the dossier contains both satisfactory and unsuccessful results. A prospective examiner then knows which claims have been measured, which depend on modelling assumptions, and which were beyond the receiver's preserved information. A polished spectrum can assist discovery; it cannot replace the instrument history or the reasoning connecting observations to a physical proposition. I return the floor courteously to Dr. Atkinson, whose closing synthesis should separate these useful but unequal kinds of knowledge.

Ten worked analytical applications: frequency grids, temporal exposure and uncertainty

Jean-Baptiste Joseph Fourier, Cross-Peer Question to Dennis Gabor: Professor Gabor, why does the narrowness of an FFT bin fail to establish the frequency precision of a pulse shorter than the observation window?

Dennis Gabor, Cross-Peer Answer to Jean-Baptiste Joseph Fourier: Mr Fourier, the bin spacing F_s/N is a coordinate increment fixed by the transform length. The physical transient occupies a duration T_event, and its time-frequency support and signal-to-noise ratio constrain which parameter can be estimated. Adding zeros extends the plotted interpolation grid but provides no additional measured event time. An accurately modelled coherent sinusoid can sometimes have a fitted frequency uncertainty much

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smaller than a bin, yet this is a conditional estimator result, not general resolution of arbitrary unknown transients. Use calibrated bursts with varied onset phase and modulation to test spectral bias, leakage and fitted-frequency uncertainty. Specify the window and event fraction explicitly; preserve raw samples to permit alternative models. I pass the token to Mr Nyquist for the record-length distinction.

Dennis Gabor, Cross-Peer Question to Harry Nyquist: Mr Nyquist, a receiver stores an entire second but the signal is present for only fifty microseconds. What does using the full second as the FFT interval do to apparent sensitivity and event energy?

Harry Nyquist, Cross-Peer Answer to Dennis Gabor: Professor Gabor, it can increase the number of narrow frequency coordinates whilst diluting the transient in a statistic designed for stationary content. A single short burst contributes power during only a tiny fraction of that second; the relevant amplitude, energy and power conventions must be specified. We should compare a burst-matched window with the long observation, including the different equivalent noise bandwidths and false-alarm opportunities. A narrow line on a long waterfall cannot by itself establish that the emitter transmitted for the full second. Record detection latency, duty cycle and the exact time samples used for the transform. Where several bursts recur, their phase relationship must be demonstrated before treating them as coherent repetitions. I yield to Dr Shannon for the inference from sparse observations.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, when does a fine FFT frequency estimate become evidence of an emitter rather than a numerically convenient fit to correlated noise?

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Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Mr Nyquist, the answer requires a specified signal model, a predeclared fitting procedure and a calibrated noise model. Correlated receiver noise and spectral leakage can give a narrow apparent maximum even when a physical tone is absent. Examine alternative models, including transient noise, internal spurs and nonstationary interference; assess the frequency estimate and its uncertainty on independent validation records. The output of an FFT does not carry a unique physical-source label. Multiple independent receiver configurations and a controlled input challenge can strengthen an attribution, but shared references and preselectors must be traced. Retain negative controls and the entire search history. I pass the token to Professor Tukey for the statistical selection problem.

Claude Elwood Shannon, Cross-Peer Question to John Wilder Tukey: Professor Tukey, what is the proper false-alarm denominator when a detector scans many frequency bins over thousands of overlapping windows?

John Wilder Tukey, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the denominator must reflect the actual opportunity set and dependence structure of the detector, not merely the number of attractive peaks retained. Overlapping windows, correlated adjacent bins and changing thresholds violate an uncomplicated independent-trials count. Calibrate the maximum or decision statistic using full noise-only acquisitions through the identical processing pipeline, retaining all windows and gain states. Where an analytic approximation is used, state its independence assumptions and verify them against simulation or controlled trials. The investigator must not choose one exceptional bin and apply a single-test p-

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value as though it had been nominated beforehand. A convincing result survives a prespecified blind test with an independently timed source. I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Distinguished colleagues, our discussion separates several quantities frequently compressed into the convenient but misleading term frequency resolution. We have the frequency spacing of a computed FFT grid, the duration-dependent spectral response of a finite record, the performance of a frequency estimator under its declared waveform and noise assumptions, and the tested ability of an instrument to distinguish nearby emissions. None is a universal substitute for the others. The original numerical sample record limits the information available to subsequent transformations, while the instrument's physical front end and its timebase impose further restrictions upon the interpretation of that record. A dense frequency display can be useful, but it cannot manufacture a longer observation, a more stable oscillator or a missing analogue sample.

Mr Fourier has shown why multiplying the signal by an observation window changes the spectral representation. Mr Nyquist has emphasised that alias restrictions and reference-plane definitions remain relevant regardless of transform length. Dr Shannon has distinguished the information retained in a complete complex transform from that discarded by a magnitude-only, thresholded or averaged derivative. Dr Gabor has shown that time and frequency localisation require a signal-specific compromise. Professor Tukey has insisted that an acceptance campaign must test the physical claim rather than an attractive depiction. The seven peer questions have clarified the difference between model fitting and

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independent validation, between individual and family-wise false-alarm rates, and between detecting an event and identifying a particular transmitter.

The ten numerical applications expose the common error patterns. Zero padding reduced the spacing between displayed frequency samples without increasing observation time. A longer actual recording narrowed the finite-duration spectral response only under source and clock stability conditions. A Hann window altered coherent amplitude and equivalent noise bandwidth, while the example of a burst near the edge demonstrated the risk of a large position-dependent loss. Overlapping FFT frames reused input samples and therefore did not yield independent event counts. A nominally small per-cell false-alarm rate became much less reassuring when applied across many comparisons. Frequency-reference error and scan duty exposed uncertainties which a finely graduated display cannot disclose. These conclusions are conditional examples, not certification of a particular instrument.

For a technical surveillance countermeasures investigation, the acceptance dossier should preserve the raw acquisition interval wherever practicable, plus the analogue input configuration, sample and oscillator references, window coefficients, actual observation length, transform length, scaling conventions, overlap and event-selection rules. It should record whether a proposed frequency is a fitted model parameter, an occupied-band estimate, a centre of spectral energy, or the location of the largest plotted magnitude. That vocabulary should persist into formal evidence descriptions, index terms and expert reports. If a particular burst can be detected with high reliability but cannot be assigned a narrow

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carrier-frequency interval under the tested conditions, the report should state both propositions. It should not allow the successful detection to conceal the weaker measurement claim.

The conclusion must also address absence. No alarms in retained spectrogram frames are not equivalent to complete evidence that no emitter operated. Scan gaps, trigger thresholds, attenuation at window edges, lost acquisition intervals and the selection of favourable detections must be accounted for. Where the exposure and false-negative characteristics have not been validated for a specified class of short signal, the negative finding is indeterminate as to that class. It may still establish that no qualifying alarm was observed by the defined procedure. Such a restricted conclusion is not timid. It is the statement the evidence warrants.

We therefore adopt a doctrine of declared measurands, retained source data and adversarial validation. Precise numbers shall be reported only in the company of the assumptions and uncertainty that justify them. The next discussion will turn from the spectral analysis window to the stability of frequency references and the relation between phase noise and weak-signal detection, a boundary at which an apparently narrow spectral peak can again conceal limitations that no display interpolation can repair. I thank each colleague for the disciplined exchange and formally conclude Question 041.

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Ten worked engineering applications | Question 041

Worked application 1: Frequency-grid spacing versus actual observation duration

Let the sampling rate F_s be 10,000,000 samples per second, the number of actual acquired samples N be 1,000, and the padded FFT length N_F be 65,536. The actual observation duration is $T_{obs}=N/F_s$ = 1,000/10,000,000 = 0.0001 second, or 100 microseconds. The unpadded transform-grid spacing is F_s/N = 10,000 hertz. Padding to N_F instead produces 10,000,000/65,536 = 152.587890625 hertz between displayed grid points. Thus the displayed numerical grid is approximately 65.536 times denser, but the actual record is still 100 microseconds long. The inverse-duration frequency scale remains $1/T_{obs}$ = 10,000 hertz. These are computed facts about the selected data, not an assertion that every possible estimator has a 10-kilohertz error. A single pure-tone parameter under a validated high-SNR model may be estimated more precisely. The distinction is that padding supplied no independent analogue observation with which to verify that model.

Worked application 2: Increasing observation length rather than padding

Retain the same 10-megasample-per-second sample rate but observe 100,000 actual samples of a signal that remains stable for the entire period. The observation duration becomes T_{obs}=100,000/10,000,000=0.01 second. The reciprocal duration is 100 hertz and the unpadded frequency-grid spacing is likewise 100 hertz. Relative to the previous 100-microsecond record, the physical

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observation is one hundred times longer and contains one hundred times as many genuine samples. Subject to source stability, receiver calibration and valid noise assumptions, that longer exposure can offer a materially narrower finite-duration response. It also creates practical difficulties: the clock may drift, the source may retune, and the receiver may undergo gain or state changes over the extra interval. A longer record is not universally preferable to a short one. It provides different evidence, which must be evaluated against the admitted signal class.

Worked application 3: The bin offset of an off-grid sinusoid

Consider a 4,096-sample record acquired at F_s=1,024,000 samples per second, with no padding. The bin spacing is $\Delta_f = F_s/N$=250 hertz. A hypothetical sinusoid at 10,125 hertz lies 125 hertz above the nearest 10,000-hertz grid point and exactly halfway to the next one at 10,250 hertz. The integer-bin display alone therefore cannot select a perfectly aligned frequency. With rectangular windowing the sinusoid contributes to multiple bins through the finite-window response. Padding the same record can locate the existing main-lobe maximum more finely, but cannot establish whether the source was a stable tone, a chirp or a burst whose envelope distorted the response. The record should disclose the grid, window, clock reference, estimator and challenge-derived uncertainty. Printing 10,125.0000 hertz is not an independent measurement of four decimal-place certainty.

Worked application 4: Hann-window coherent gain and noise bandwidth

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Let N be a large number of acquired samples, F_s the sample rate, and $w[n]$ a periodic Hann window applied over $0<=n<N$. Its coherent gain for a bin-centred continuous sinusoid is $G_c=(1/N) \text{ sum } w[n] = 1/2$. The amplitude of an otherwise comparable bin-centred tone is therefore halved by the unnormalised window, corresponding to $20 \log10(1/2) = -6.0206$ decibels in amplitude. The window's noise-equivalent bandwidth is $ENBW=F_s \text{ sum}(w[n]^2)/(\text{sum}(w[n]))^2 = 1.5 F_s/N$ for the periodic Hann case. With $F_s=1{,}000{,}000$ and $N=1{,}000$, the equivalent noise bandwidth is 1,500 hertz, whereas the unpadded bin spacing is 1,000 hertz. The coherent-gain correction appropriate to a continuous tone is not automatically a valid amplitude correction for a short pulse at the window edge. The examiner must specify the signal class and the measurement purpose before applying these factors.

Worked application 5: Transient attenuation by the analysis window

Consider a periodic Hann window $w[n]=0.5-0.5 \cos(2 \pi n/N)$ with $N=1{,}000$. An otherwise identical very brief burst centred at $n=500$ receives a window weight of $w[500]=1$. A burst centred at $n=100$ receives $w[100]=0.5-0.5 \cos(0.2 \pi)$, approximately 0.0954915. If the bursts are sufficiently short that each experiences approximately a constant local window weight, their ratio from this windowing operation alone is about 0.09549, or $20 \log10(0.0954915)$ approximately -20.4008 decibels. This illustrative loss is not a statement about the physical transmitter's energy. It reveals why a detector validated only with centred bursts may miss otherwise identical events near a frame boundary. Overlapping windows can alter this exposure profile, but the effective false-alarm and event-counting rules must then be revalidated.

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Worked application 6: Short-time Fourier transform overlap and sample reuse

Suppose the FFT window spans N=2,048 samples at 2,048,000 samples per second, so each frame represents 1 millisecond of input data. A 75-percent-overlap configuration uses hop length H=512 samples or 0.25 millisecond. It produces four frame starts per millisecond in sustained operation, yet neighbouring frames share 1,536 of 2,048 input samples, or 75 percent of their content. A burst of sufficiently long duration may therefore appear in several adjacent frames. The four frame starts do not constitute four independent physical emissions. A false-alarm analysis which treats every frame as independent can underestimate joint uncertainty, and a prevalence estimate which counts every trigger can overcount the events. The correct independent trial unit depends on the actual noise dependence, the trigger logic and the event segmentation rule, none of which can be inferred from the frame rate alone.

Worked application 7: Per-cell versus family-wise false-alarm probability

Let K=2,000 denote the number of hypothetical independent tested frequency-time cells and p=0.0001 the false-alarm probability in each cell under a fixed null model. Under independence, the probability of at least one false alarm is P_any=1-(1-p)^K=1-(0.9999)^2000, approximately 0.181277. Thus a per-cell false-alarm rate of one in ten thousand can coexist with an approximately 18.1-percent chance of at least one false alarm across the family. In a real spectrogram adjacent frequency bins and overlapping windows are commonly dependent, so this numerical result must not be applied without validation of the actual joint rule. The

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calculation is useful because it demonstrates the distinction between an individual threshold and the behaviour of a large search. Predeclared candidate-selection and multiplicity treatment are necessary for interpretable alarm statistics.

Worked application 8: Frequency-reference uncertainty over a short acquisition

Suppose a sampling-clock reference has a relative systematic frequency error bounded by two parts per million under the specified operating conditions. For a frequency claim centred on 100 megahertz after all correct mixer translations, the corresponding magnitude of clock-related frequency-scale uncertainty is approximately 100,000,000 times 2 times 10^-6 = 200 hertz, before considering other receiver errors. A very large FFT may have displayed spacing finer than one hertz, but that display does not correct the reference's systematic scale error. The example is deliberately simplified: the effect upon the recovered RF frequency also depends on which clocks and local oscillators set each translation stage. The engineer must propagate the calibrated oscillator uncertainties through the actual architecture. It is misleading to report the final display's decimal precision without the uncertainty of the reference plane that creates the frequency axis.

Worked application 9: Random scan exposure for an isolated brief event

Consider a simplified receiver that admits a particular target channel for 50 milliseconds during each 500-millisecond scan cycle and is otherwise unable to receive that channel. Let D=0.05/0.5=0.1 be the duty

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fraction. If a very short event occurs at a time uniformly distributed relative to the scan phase and its duration is negligible compared with the dwell, the probability of temporal overlap is approximately D=0.1. Suppose that, conditional on overlap, the detector recognises the event with probability 0.95. Then the unconditional detection probability under these assumptions is approximately 0.1 times 0.95 = 0.095, or 9.5 percent. The precise exposure for non-negligible pulse duration or nonuniform timing requires a more detailed schedule model. The example demonstrates that excellent detector performance during active dwell cannot, by itself, support a strong negative finding over the complete elapsed survey time.

Worked application 10: Duration and the apparent narrowing of a zero-padded pulse response

Take a rectangularly gated sinusoidal component observed for T=200 microseconds. Its Fourier amplitude envelope, up to scaling and frequency translation, follows a sinc-type function whose first zeros are displaced by magnitude 1/T = 5,000 hertz from the nominal carrier. The approximate first-null-to-first-null width is therefore 2/T = 10,000 hertz. Evaluating this same fixed record on a grid spaced 10 hertz apart rather than 1,000 hertz apart makes the sinc envelope smoother on the display, but the first-null separation remains about 10,000 hertz. This calculation describes the windowed-response shape for the stipulated rectangular gate; it does not prohibit a sufficiently constrained one-tone model from yielding a sub-bin parameter estimate. It does prohibit interpreting interpolation as newly acquired spectral evidence. A stronger source-

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attribution claim would require independent instrument tests and a physical model, not merely a finely drawn line.

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Scholarly sources and read scope

[S1] SciPy, *Signal Processing Tutorial*, official public documentation: https://docs.scipy.org/doc/scipy/tutorial/signal.html . Read scope: the sections on spectral analysis, zero padding, windows, window amplitude normalisation and spectral-power scaling. This supports the distinction between denser transform grids and actual signal-record length, together with the need for coherent-gain and noise-bandwidth treatment. It does not certify any particular forensic receiver.

[S2] U.S. Department of Defense, *MIL-STD-1399, Section 300, Part 1*, public-access PDF hosted by Defense Logistics Agency: https://quicksearch.dla.mil/Transient/C6B9B7759A6449E08B8B00FA019F09A8.pdf . Limited scope of review: the returned public excerpt discussing windowing, coherent gain, equivalent noise bandwidth and FFT bin ordering. The document's full applicability, edition and subsequent amendments were not independently verified in this execution. It is included as a limited technical corroboration, not authority for the entire standard.

[S3] SciPy, *Short-time Fourier transform and spectral-analysis discussion* within the same official tutorial as [S1]. Read scope: the computational description of windowed transforms, time-window placement and inverse reconstruction from retained complex representations. The constructed discussion's claims about triggered retention, forensic inference and source identification remain original analysis, rather than purported positions taken by the SciPy authors.

All mathematical applications are hypothetical demonstrations and must be interpreted only under their stated models. Historical biographies are educational summaries; individual historical facts require final source-by-source bibliographical proof during cumulative-volume production.

[S4] MacTutor History of Mathematics, University of St Andrews, Joseph Fourier biography: https://mathshistory.st-andrews.ac.uk/Biographies/Fourier/ . Read scope: historical dates and mathematical work on heat diffusion and trigonometric representation.

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[S5] IEEE Information Theory Society, Claude E. Shannon: https://www.itsoc.org/about/shannon . Read scope: education, Bell Laboratories and information-theory history.

[S6] The Royal Society catalogue, Dennis Gabor: https://catalogues.royalsociety.org/CalmView/Record.aspx/Record.aspx?id=NA6123&src=CalmView.Persons . Read scope: birth and death years, research fields, fellowship and prizes.

[S7] IEEE Computer Society, Computer Pioneers, John Wilder Tukey: https://history.computer.org/pioneers/tukey.html . Read scope: university appointments, research work and Cooley–Tukey FFT reference.

[S8] NobelPrize.org, Nobel Prize in Physics 1971: https://www.nobelprize.org/prizes/physics/1971/summary/ . Read scope: recipient and formal award for holography.

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QUESTION 042

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How do window functions trade leakage, resolution and amplitude bias?

Source: V011_Roundtable_Question_042_CP042_Dr_Atkinson.docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 042. Complete Expert Roundtable Discussion

Original constructed educational dialogue. Historical specialists are employed as intellectual personae, not as purported speakers in a real meeting or witnesses to contemporary software-defined radio equipment. This manuscript is incomplete and is not counted as a finished primary discussion.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, Question 041 exposed the misconception that the apparent density of an FFT grid establishes the physical resolving power of a receiver. We now turn to the window function, a quieter but equally consequential source of measurement conditions. The window appears to be an innocuous numerical multiplication. In reality, it changes the spectral response, the amplitude of a continuous carrier, the contribution of a transient according to its arrival within the frame, and the noise bandwidth of the resulting estimate. Every one of those changes bears upon a defensive technical surveillance investigation in which a weak emission may be surrounded by strong legitimate signals or may exist for only a few milliseconds. A beautifully tapered spectrum may suppress the sidelobes of a strong interferer, yet conceal a brief emission placed at an unfortunate point in the observation interval.

The mathematical boundary can be stated precisely. Let x[n] denote N recorded samples at sample rate F_s and let w[n] denote the analysis

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window for n from zero to N minus one. The computed discrete spectrum is the transform of y[n]=w[n]x[n], not the transform of an unlimited physical history. If a continuous bin-centred sinusoid is passed through this operation, its reported amplitude must be interpreted using the coherent gain G_c=(1/N) sum w[n] for the selected convention. The equivalent noise bandwidth, in hertz, may be defined by ENBW=F_s sum(w[n]^2)/(sum w[n])^2 when the sums and scaling correspond to the stipulated estimator. These quantities are not decorative specifications. A correction appropriate to a continuous tone is not necessarily appropriate to a transient occupying a tiny fraction of the window. Nor does dividing by one gain factor eliminate all position-dependent loss.

We must also separate leakage from resolution. A rectangular observation window produces a relatively narrow main lobe but substantial sidelobes. A taper can suppress those sidelobes, often at the cost of broadening the principal spectral response. The trade may be attractive where a strong legitimate carrier masks a weak nearby emission, but the broadened lobe may make separating two close transmitters more difficult. A flat-top window may offer better amplitude accuracy for an isolated sinusoid across its bin offsets while occupying a larger effective noise bandwidth. An investigator cannot rank all windows on one universal scale of goodness. The appropriate measure is the performance of the complete receiver and detector against the specified physical task.

The legal and forensic consequences are not theoretical curiosities. A report might assert that a signal had an amplitude of minus 102 decibels relative to a milliwatt. Was that estimate corrected for the selected coherent gain? Was the input power calibrated through the analogue reference plane,

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or only relative to a digital FFT magnitude? Was the event a stable tone, a modulated burst or an impulse? Did a different window alter its reported peak, detection decision or apparent bandwidth? If the investigator cannot answer these questions, the numerical precision of the displayed amplitude cannot rescue the interpretation. If the original samples and processing settings were preserved, the analysis can often be repeated under a more suitable model. If only a compressed waterfall was retained, the missing information may be irrecoverable.

I shall therefore ask Professor Slepian to address energy concentration, Mr Fourier to address convolution and finite windows, Dr Gabor to address the differing treatment of transient envelopes, Dr Shewhart to address validation under changing operating conditions, and Professor Tukey to address the statistical effects of surveying many windowed frames. Their colleagues will challenge the choice of performance criterion, the reliability of calibration, and the risk of treating a favourable laboratory spectrum as proof of absence in a contested field survey. The discussion shall preserve the distinction between mathematically correct signal processing and independently measured instrument behaviour. Professor Slepian, may I invite you to begin with the proposition that a window can be optimal for one clearly defined objective while being unsuitable for another?

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David Slepian | Principal response 1: Concentration is not a universal detection criterion

Dr. Atkinson, the word optimal is incomplete unless the mathematical objective and the admissible class of candidates are specified. A family of spectral-concentration problems asks how energy from a finite sequence can be distributed as strongly as possible inside a chosen frequency interval. The resulting sequences are valuable analytical tools because they offer controlled leakage behaviour under declared conditions. They do not establish, without further evidence, that a receiver employing them will detect every possible burst with greater reliability than one employing a simpler taper. Concentration addresses one function of the analysis. A field detector makes a decision about events whose duration, phase, modulation and time of arrival may be unknown. A satisfactory window for the first task is not automatically satisfactory for the second.

A practical comparison should begin with the same raw input samples and multiple fixed, documented analysis methods. For each method, characterise main-lobe width, sidelobe structure, coherent gain, equivalent noise bandwidth and the response to a sinusoid displaced between frequency-grid points. These quantities are related but distinct. The comparison must also include a transient-exposure test in which otherwise identical bursts arrive at random positions in the observation interval. A window that gives low weight to the ends of a frame may suppress sidelobes admirably while attenuating brief events at those positions. If the detector uses overlapping frames, the overlap may recover some lost exposure, but it creates dependent detection opportunities and demands a

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new false-alarm analysis. None of these mechanisms is visible in a single spectrum made from a centred continuous tone.

We should also distinguish spectral concentration from the isolation of two unknown emitters. A taper that lowers distant sidelobes may be excellent for detecting a weak tone far from a strong neighbour. If the candidate lies very close to the neighbour, however, the widened main lobe may cause the two to appear as one feature. The answer depends upon separation, relative level, phase, source waveform, observation duration and the decision algorithm. It is not sufficient to quote a nominal sidelobe suppression figure, any more than it is sufficient to quote the FFT bin spacing. A receiver should be challenged with pairs of independent signals at known offsets and powers, and the result should state a tested probability of correct separation, or an appropriately bounded unresolved region.

In the measurement of a stable sinusoid's amplitude, one can normalise the transform by the coherent gain of the selected window under the applicable convention. But a transient is not a stable sinusoid extending across the entire observation interval. The window multiplies its envelope unevenly. The location of the transient may therefore dominate the apparent amplitude in one frame, even when the physical pulse energy is constant. A correction derived for a bin-centred sinusoid cannot simply be assigned to the pulse and expected to restore its true peak or energy. An energy-based estimator, envelope model or short-window detector may be more appropriate, but each introduces its own calibration and uncertainty. The examiner must first say what is meant by amplitude.

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A further problem arises when a laboratory allows its detection software to choose a window adaptively after preliminary inspection. Such adaptation can be valuable for operational discovery, but a confidence statement based upon the selected output cannot be obtained by pretending the selection never occurred. The software might consistently choose whichever window presents the candidate most strongly, including when the apparent peak is noise. It might also suppress an emission because its heuristic classifies the burst as interference. The entire selection and thresholding rule is then part of the effective detector and must be tested against independently withheld challenge records. Its claimed false-alarm probability must refer to the complete adaptive rule rather than to one component window considered in isolation.

A rigorous validation protocol will record, for each candidate event, the raw input segment and reference-plane configuration, the window choice and coefficients, the effective noise bandwidth, amplitude and frequency normalisations, overlap, decision threshold and event-selection history. It will report outcomes for short and long pulses, for different frame arrival positions, for candidate and interfering signals with varied relative powers, and for states such as receiver compression or reference-clock error. The point is not to make the task impractical. It is to prevent a small set of elegant analytical numbers from being misrepresented as proof that the whole receiver possesses performance never actually tested.

I would conclude by treating windows as different calibrated measuring procedures, not interchangeable cosmetics. Under defined assumptions, one may demonstrate a window's benefit for leakage control, or for stable-tone amplitude accuracy, or for a particular burst detector. The report

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should preserve the particular claim and its confidence, and avoid exporting that confidence to another class of signal. A negative search result may be well founded for one signal class and indeterminate for another, even when both appear in the same waterfall. I pass the token to Dr Shewhart, whose work on measurement processes raises a pertinent question about how the laboratory should detect changes in window-dependent performance over time.

Walter Andrew Shewhart | Peer question 1 to David Slepian

Professor Slepian, suppose a laboratory selects a taper on the basis of repeated tests against a stable carrier, then installs the receiver in a field environment where legitimate transmissions vary in amplitude and modulation, the preselector warms, and the detector changes gain. The window coefficients may remain numerically identical, yet the relation between the external field and its displayed spectral peak changes. A calibration certificate describing coherent gain alone might remain formally correct while the full system loses the ability to detect a weak burst beside a strong neighbour. What monitoring evidence should accompany the laboratory's window-selection claim so that an investigator can identify when the operating process has departed from its validation envelope? Would you require fixed internal test tones, periodic external challenge injections, blind burst tests, or independent reference receivers, and how should the report distinguish an observed drift from uncertainty that was never measured in the first place?

David Slepian | Immediate answer to Walter Andrew Shewhart

Thank you for that question. Dr Shewhart, the preserved window coefficients certify only one part of the processing operation. They do

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not establish the stability of the analogue receiver or the external source population. A suitable monitoring programme would therefore distinguish digital invariants from physical-state variables. The software can record its window identifier, transform length, coherent gain and equivalent noise bandwidth deterministically. The analogue chain requires separate evidence about gain, linearity, noise, filtering and input-path identity. One should periodically challenge the complete receiver through its declared physical input boundary where practical, rather than assume that a correct software calculation proves the end-to-end response.

The challenge signals ought to represent the intended class of interest. A stable internal tone can monitor selected aspects of frequency scale or digital-channel behaviour, but it may bypass an antenna switch, preselector or gain stage implicated in the actual survey. A test burst injected at a physically relevant reference plane can reveal position-dependent response and transient recovery. A second receiver may offer useful comparison if its independence and calibration are characterised. The operator should document which elements each challenge does and does not traverse. A test that bypasses the suspected failure mechanism cannot rule out that mechanism merely because the visible result appears satisfactory.

I would also preserve a time-ordered performance record. Test outcomes should be associated with temperature, gain state, attenuation, software version and the date of the last independent calibration. Unexpected changes should trigger a documented decision about whether earlier acceptance results still apply. If a

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control test reveals a new loss of weak-burst sensitivity, the investigator should not silently correct only the newest data while retaining unqualified confidence in earlier negative findings. The historical measurements may require review, or the conclusions may need to be restricted to a narrower verified interval. The record should contain failures and interventions, not only successful after-adjustment tests.

Blind testing is particularly valuable because it distinguishes an algorithm's genuine capability from familiarity with a repeated demonstration. The test population should vary onset, amplitude, occupied bandwidth, modulation and interference. Thresholds and windows should be frozen for the trial, or the full adaptive selection rule should be treated as the object of validation. The resulting detection probabilities must be computed using independent event trials and an explicit exposure model, not simply by counting overlapping FFT frames as independent successes. Such a protocol can be demanding, but it is intellectually modest: it tests whether the published claim survives relevant perturbations. That is the appropriate discipline for a forensic result offered beyond the laboratory bench. I return the floor to Mr Fourier for analysis of the spectral consequences of the observation window itself.

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Jean-Baptiste Joseph Fourier | Principal response 2: Multiplication in time, convolution in frequency

Dr. Atkinson, I should begin by separating the original incoming function from the function the computer actually transforms. The signal available at the sampler has already passed through an analogue transfer path with its own bandwidth, phase behaviour, noise and possible nonlinearities. Digital analysis then multiplies a finite vector by a chosen set of weights. The resulting Fourier representation concerns that weighted vector. Multiplication by a window in time corresponds, under the appropriate transform conventions, to convolution in frequency. A single monochromatic component therefore acquires a response shaped by the window, rather than appearing as an infinitely narrow mathematical line. A second component nearby contributes its own displaced response; the two responses may overlap, conceal one another or be mistaken for a single feature. The window does not merely improve the picture. It changes the measurement procedure whose outputs must be interpreted.

The rectangular window is an instructive baseline. It assigns equal weight to every acquired sample, but its abrupt boundaries generate prominent sidelobes in the spectral response of a sinusoid whose phase is not aligned with the finite observation. A gradual taper can reduce those sidelobes, often widening the principal lobe. When a strong legitimate transmission lies near a weak unknown emission, suppressing sidelobes may make the weaker feature visible. Yet if the two emissions are extraordinarily close, the broader main lobe may make their separation more difficult. Neither result is paradoxical. Each follows from the chosen observation operation. A

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responsible laboratory must not claim that the mere use of a taper increases frequency resolution in every possible sense.

The interpretation of amplitude deserves separate treatment. If a stable sinusoid extends over the whole window, the transform component corresponding to its frequency responds to the sum of the window coefficients. A coherent-gain correction can compensate for that known attenuation under the appropriate conventions. A burst which occupies only a small subset of samples, by contrast, experiences an effective gain dependent on its temporal envelope and position. The sum over the entire window is no longer sufficient to characterise its individual attenuation. A brief event centred where the window is near unity may be recorded strongly; the same physical event close to a boundary may be severely attenuated, perhaps disappearing below a fixed threshold. The resulting difference is an artefact of the observational method, not proof of different transmitter powers.

Nor does the specification of equivalent noise bandwidth automatically determine a detector's field sensitivity. ENBW characterises how white-noise power is passed by a defined spectral estimator, under its assumptions. Actual receiver noise can be coloured, nonstationary, correlated across frequencies or affected by automatic gain control. The input may contain strong interference which drives the analogue circuit into compression and produces intermodulation lines; no choice of digital taper restores the linear waveform that was never sampled. A detector's false alarms and misses depend on the entire chain, including the decision rule and multiple comparisons over many windows. The window's published sidelobe and

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ENBW figures should thus be treated as necessary design information, not a substitute for end-to-end validation.

One can understand this distinction by considering an investigation where the operator has retained only averaged power spectra. If the selected window suppresses a short event at the edge of successive frames, the average may underrepresent it. If the event is strong in one frame but absent in most others, averaging may also dilute its apparent significance. A later examiner who has only the averaged result cannot re-place the window over the original samples to determine when the event occurred or whether its amplitude was biased. Retaining the complex raw time series and the relevant configuration makes more tests possible; retaining only a compressed derivative imposes a real evidential limit. The decision on storage should therefore follow the future questions the investigator may need to answer.

The laboratory should ask whether it is attempting detection, amplitude metrology, frequency estimation, or source separation. A low-sidelobe window may be attractive for the first under one interference environment. A flat-top window may better support stable-tone amplitude estimation, though at a different noise-bandwidth cost. A longer observation can improve discrimination between stable neighbouring tones, provided the sources and timebase remain coherent for its duration. A shorter observation can localise a transient more closely in time, at the expense of a broader finite-window spectral response. A suite of tools can be useful, but if the operator chooses the most favourable output after inspecting the evidence, the selection must be included in the statistical validation.

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Otherwise the analysis confuses a visual discovery process with an independently tested measurement procedure.

To establish a defensible finding, vary carrier offset continuously between FFT grid points, vary neighbouring signal level and separation, and inject bursts at random positions within the frame. Use withheld trials whose physical input is known independently of the software. Compare the outcomes under the proposed window and alternative windows, documenting each method's detection probability, amplitude error, frequency bias and alarm behaviour. Where the tests disagree, do not conceal the difference by printing only the preferred plot. Investigate whether the waveform model, analogue front-end behaviour or decision rule explains it. A real improvement should survive challenges designed to make the selected method fail.

I therefore submit a limited but useful doctrine. A window can be selected to favour specified properties of a finite measurement; it cannot transform a brief, incompletely observed emission into an ideal stationary sinusoid. It may improve the visibility of a weak signal against one form of interference while reducing sensitivity to another signal class. The underlying raw record and physical receiver conditions remain indispensable. Spectral beauty is not evidential sufficiency. I pass the token respectfully to Professor Bridgman, who will challenge whether the laboratory is measuring the same amplitude when it changes windows.

Percy Williams Bridgman | Peer question 2 to Jean-Baptiste Joseph Fourier

Mr Fourier, I should like to examine the identity of the reported quantity. Suppose two laboratories receive the same digitised record

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from a short carrier burst. The first uses a rectangular window and reports the largest magnitude component, divided by the number of samples. The second uses a flat-top window with its advertised coherent-gain correction and reports a larger peak value. Both calculations are properly implemented, yet their apparent amplitudes differ materially. Are the laboratories measuring the same physical quantity by different imperfect procedures, or have they actually defined different observables? What independent reference experiment would establish that a correction for a continuous sinusoid is applicable to this short burst? Would you require the instruments to report peak envelope amplitude, total received energy, mean power over the burst, or some other explicitly defined quantity, and how should they communicate the limitation to a forensic reader who expects the word amplitude to mean one definite thing?

Jean-Baptiste Joseph Fourier | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, the word amplitude is incomplete unless the waveform quantity, reference plane, time interval, bandwidth and estimator have been identified. A peak of a windowed Fourier magnitude array, an integrated spectral-energy measurement and a reconstructed time-domain envelope maximum need not be equal. They are related through a model and processing operations, not through their common label. A continuous-tone coherent-gain correction is specifically designed to account for the window's response to a signal present across the analysis interval under stipulated alignment and normalisation. A

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short burst does not meet those conditions automatically. Therefore the difference between the laboratories may be entirely lawful mathematically while revealing that their reported measurands are not equivalent.

I would begin with an independently calibrated test waveform whose voltage or power at the declared input reference plane is known. Its envelope and arrival position should be varied while its chosen physical quantity remains constant. If the desired measurand is peak envelope voltage, compare each estimator's output with the reference peak after accounting for the analogue transfer chain. If the desired quantity is received energy within a specified bandwidth, integrate under the applicable calibration and time interval. If the desired quantity is mean burst power, specify how the start and end of the burst are determined, since the result changes when a longer quiet interval is included. None of these definitions may be silently exchanged for another merely because the FFT produced a convenient maximum.

A correction should be tested over the admitted class of waveforms, not inferred from the name of the window. Where a fixed transient envelope is known, a model-based correction may be calculable and experimentally testable. Where the envelope is unknown, a single scalar correction may be insufficient. The laboratory might then report a bounded range, a detector response in calibrated units, or a conditional quantity rather than falsely assert an exact transmitter power. It should preserve the digital samples and the source calibration record so that a peer can test the

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transformation. A claim of absolute received field strength demands still more, including antenna factor and propagation assumptions, which the FFT alone cannot supply.

The report should name the quantity beside the number. For example, it may say that a candidate produced a peak window-corrected spectral magnitude at the recorded input reference plane under a designated signal model, or that a burst carried a certain energy within a defined reconstructed band. Such language may appear cumbersome beside a neat graph, but it prevents the graph from acquiring significance beyond its method. Two laboratories can then compare like with like. Where their operations define different quantities, the apparent disagreement is not necessarily instrumental error. Where the same measurand is intended, a challenge using common reference waveforms can establish whether their estimates are compatible within uncertainty. I pass the floor to Dr Shannon for a question about the information lost when the operator retains only the corrected peak.

Claude Elwood Shannon | Peer question 3 to Jean-Baptiste Joseph Fourier

Mr Fourier, I am concerned about the retention step following an apparently satisfactory amplitude calculation. Suppose the receiver detects a transient, chooses one spectral window, applies a gain correction, and stores the resulting peak amplitude together with a timestamp and frequency. The operator does not retain the raw complex samples because the detector has already labelled the event as complete. A later investigator wishes to distinguish a single burst from

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two closely spaced bursts, or to test whether a narrow feature was caused by a stronger neighbouring transmission. The saved result may be perfectly authenticated as a digital record, yet it cannot answer either question. Which minimum derived quantities, if any, could preserve enough information for such disputes without storing the full raw stream, and where must the report acknowledge that the transformation from waveform to peak has been many-to-one? What would be a defensible minimum retention period when the duration and modulation of the investigated source are not known at the time of acquisition, and which limitations should the operator state if that period proves inadequate?

Jean-Baptiste Joseph Fourier | Immediate answer to Claude Elwood Shannon

Thank you for that question. Dr Shannon, a peak amplitude, even accompanied by frequency and time labels, is an extremely compressed description of a waveform. Distinct input histories can produce the same three numbers. If the original record has been discarded, no subsequent choice of mathematical procedure can uniquely reconstruct those histories without additional assumptions. In particular, a pair of transient signals can have a spectral maximum coincident with that of one different waveform, and the windowed magnitude may conceal phase and timing relations essential to distinguishing them. Authenticating the saved peak establishes that those bytes have been preserved. It does not demonstrate that the stored derivative is informationally sufficient for every later inference.

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Practical retention involves trade-offs. Where storage is constrained, a system could retain a selected complex spectral neighbourhood over several overlapping frames, window identifiers, the complete timebase and tuning state, and enough pre-trigger context to identify the event's relation to the frame boundaries. Those records may permit additional analysis of some questions while remaining inadequate for others. A full raw complex capture over an appropriate interval ordinarily preserves more of the digitised information, although even it does not reverse the analogue front end's missing bandwidth, clipping or unknown calibration. The archive's sufficiency must therefore be judged against an explicit hierarchy of foreseeable claims.

For source separation, the complex phase relationships across time and frequency may be relevant. A magnitude-only peak discards them. For window-position sensitivity, the actual sample locations and coefficients must be recoverable. For intermodulation or image-response challenges, the receiver's analogue state and input transfer paths matter. A retention policy should state which questions the saved record can still answer, and which have become indeterminate. An investigator need not store every sample from every survey, but should preserve raw intervals surrounding material detections whenever practicable, together with the full selection rule used to decide what entered the archive.

The report must also distinguish absence of evidence from evidence of absence. A detector that retains only alarms cannot disclose all the weak events that failed to cross its selected threshold.

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A new window might detect some of those events in the original raw signal, but that option no longer exists if the signal was never stored. The archived candidate count is conditional upon the original selection mechanism and should not be presented as the true number of physical emissions. This caveat is particularly important where the objective is a defensive search for a rare intermittent device. The correct procedure is to preserve an exposure map and independently test missed detections across the declared operating envelope. I return the discussion to Dr Gabor for the time-localisation effects that make transient window choice especially delicate.

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Dennis Gabor | Principal response 3: Temporal weighting and the uncertain location of short emissions

Dr. Atkinson, an observation window is commonly judged by its spectral behaviour, but that judgement is incomplete for a short event whose occurrence time has investigative significance. In a continuously present sinusoid the window's temporal distribution can be summarised, for some amplitude purposes, by a coherent-gain factor. A brief pulse, however, experiences the window primarily where the pulse occurs. Moving the same pulse towards an endpoint may reduce its contribution to a particular FFT frame without changing the physical signal. That is not simply a complication of calibration. It is a defining property of the analysed quantity. The observer has multiplied the signal by a changing weight, and the resulting spectral indication must be understood as a weighted observation rather than an unqualified account of the emitter.

The analyst seeks two kinds of localisation that may pull in opposite directions. A narrow frequency response from a long window facilitates the discrimination of stable nearby tones, but the same long window may offer only a broad indication of when a brief pulse occurred. A short window more closely localises an onset yet widens the frequency response of any signal within it. Neither choice can be evaluated without defining the signal class and the required evidence. If the task is to discover an intermittent wireless command emitted during a short interval, the probability of capturing its onset and its modulation may matter more than the narrowness of a displayed carrier peak. If the task is to distinguish two nearly stationary interferers, the priorities can be reversed. The physical observation and the

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legal question ought to govern the analysis, not a customary default selected in software.

An overlapping short-time Fourier transform can reduce some temporal disadvantages. By evaluating windows at many shifted positions, a pulse near one window's edge may appear nearer the centre of a neighbouring window. That practice is valuable but must be accompanied by an appropriate event-reconciliation rule. Several adjacent detections may correspond to one physical transmission. Their errors can be correlated because the windows contain shared samples. A detector that counts them as independent confirmations can exaggerate confidence, particularly if its alarm threshold was calibrated under an independence assumption. The operator should identify a physical event by a declared temporal clustering procedure and validate the rule with withheld injections representing different durations and arrival phases.

There are also differences among transients. A short sinusoidal burst, a wideband impulse, an evolving chirp and a digitally modulated packet have different time-frequency structures. An analysis window that presents one clearly may distort another. A narrowband detector may report a transient's central spectral energy but not its instantaneous frequency. A burst truncated by the edge of a stored frame may exhibit an artificial spectral spread. A detector can legitimately provide an occupied-band estimate while having insufficient information to certify a precise carrier frequency or amplitude. The investigator must resist the temptation to make all such outputs interchangeable simply because they are displayed in the same waterfall panel.

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The effects of the receiver's physical timing are equally important. A burst may arrive during a retuning interval, before a preselector settles, or while an automatic-gain circuit is recovering from a strong adjacent signal. Software windowing cannot restore samples omitted or distorted by those processes. A reproducible windowed spectral peak is not necessarily evidence of an external source if internal processing creates stable artefacts. Conversely, the failure of a particular FFT frame to show a weak burst does not demonstrate that the antenna received nothing. The report must preserve the relevant acquisition exposure and identify the physical boundary at which any claimed absence is asserted.

For the acceptance campaign, I would use a temporal matrix rather than merely a spectral line chart. Fix a set of known pulses, then vary their placement across the entire window; repeat at different durations, signal-to-noise ratios and spectral offsets. Compare short and long windows, different overlaps, and windows selected to favour sidelobe suppression or amplitude accuracy. Record both true detections and missed events. Where the detector changes windows automatically, test the complete adaptive rule and preserve its history. An attractive low-noise spectrum should not be allowed to conceal failures at the edges of a finite observation. If several detectors are combined, their dependence must be measured rather than assumed away.

The output should be a family of bounded capability claims. A particular configuration may be highly reliable for detecting a stable carrier under strong interference but less reliable for recognising a microsecond burst. Another may be excellent for transient detection yet poor at separating two narrowband signals close in frequency. Those are not contradictions. They

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describe different properties of different measurement procedures. The declared measurand and verified operating envelope should accompany each conclusion. I pass the floor to Professor Wiener, whose examination of adaptive systems may reveal additional uncertainty introduced by a receiver that changes its analysis window in response to its own preliminary observations.

Norbert Wiener | Peer question 4 to Dennis Gabor

Dr Gabor, you have described overlapping and adaptive windowing as useful, but their dependence creates a difficulty for an autonomous receiver. Imagine that the detector monitors several windows, chooses the strongest apparent result for each candidate, and changes its future analysis configuration according to the detections it has already recorded. The same incoming waveform now influences both the current measurement and the selection of subsequent measurements. If the instrument reports only its successful alarms, an external reviewer may be unable to reconstruct which windows or thresholds were available at each moment. How should the investigator treat a system whose apparently precise spectral evidence arises from a history-dependent decision rule? Can one validate the selected outputs using familiar fixed-window error estimates, or must the entire adaptive algorithm become the object of challenge, including its training, transition states and failures to save data? I also ask whether a change in the adaptation policy itself should require a new independent validation before the receiver’s earlier measured error rates are quoted for later operation.

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Dennis Gabor | Immediate answer to Norbert Wiener

Professor Wiener, the full adaptive algorithm must be treated as the measurement procedure when its decisions affect which observations are produced or retained. One may analyse the individual windows mathematically, but the probability that the combined system reports an alarm depends upon the rule used to select among them. Choosing the strongest of several noisy estimates can alter the false-alarm distribution even when each estimate is correctly normalised on its own. The effect is magnified when thresholds change in response to earlier observations. An error rate measured for one frozen taper cannot simply be attached to a different history-dependent system.

The acceptance protocol must therefore preserve and test the state transition rules. Record the candidate windows and their coefficients, the selection criterion, the detector's gain and threshold history, and the information used to update each decision. Challenge the algorithm with independently generated signals at unknown arrival times and with controlled interference that changes over the same timescale as the adaptation. Use withheld trials rather than reporting only the recordings on which the method was tuned. Examine whether the algorithm preserves weak bursts when a stronger legitimate transmission causes its adaptive thresholds to rise. The result should describe performance across the relevant sequence of states, not merely a mean success rate over easy examples.

Adaptive processing can be valuable precisely because the electromagnetic environment is not stationary. An operator should

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not be forbidden to change a window when the signal class changes. But an evidential report must identify that the analysed output was selected through a particular rule, and it must distinguish discovery from independent validation. A raw retained interval, together with the software configuration and decision logs, permits a peer to reproduce the selection and compare alternative fixed methods. Without those materials, a later examiner may establish that an alarm was saved while remaining unable to assess how many comparable events were omitted. The cryptographic integrity of the stored result does not certify that the selection procedure covered the unretained period.

A robust report would therefore separate three statements: the numerical output that the chosen algorithm produced, the observed challenge performance of that algorithm under a declared envelope, and the stronger physical interpretation proposed for a specific field event. The first can often be reproduced from retained code and data. The second requires trials, uncertainty and an exposure model. The third may require independent receiver challenges, changes to the analogue input path or corroborating physical evidence. Distinguishing those propositions prevents a well-performing adaptive display from becoming unjustified certainty about external origin. I return the token to Mr Black for the engineering question of whether changing the analysis window can mask a defect in the analogue receiver itself.

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Harold Stephen Black | Peer question 5 to Dennis Gabor

Dr Gabor, suppose the laboratory observes a weak candidate beside a strong signal and finds that the candidate disappears under a low-sidelobe taper. The operator concludes that the original indication was mere leakage from the stronger neighbour and deletes it from the report. Yet the receiver also contains a gain loop which may have entered transient compression, while the candidate might represent a true burst coincident with the neighbouring signal. Does the fact that the candidate changes with window selection justify a causal attribution to spectral leakage, or does it merely establish sensitivity to one processing operation? What independent tests would separate a genuine weak emission from window sidelobes, nonlinear intermodulation and gain-recovery effects? I should also like your view on whether the laboratory must retain apparently unsuccessful analysis variants, given that they can expose the dependence of the final conclusion upon a methodological choice. The challenge should preserve the failed window variants so that the hypothesis test can be repeated rather than inferred from the final picture alone.

Dennis Gabor | Immediate answer to Harold Stephen Black

Thank you for that question. Mr Black, disappearance under one taper establishes that the displayed feature depends upon the analysis operation. It does not alone identify the cause. A component attributable to the strong neighbour's finite-window sidelobes should exhibit a predictable relation to the neighbour's frequency, amplitude, phase and chosen window. A true separate emission may also change appearance with the window, especially if it is short or close in

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frequency. Nonlinear intermodulation may produce additional features in the receiver itself. Gain recovery may attenuate the candidate differently depending on the preceding strong signal. The laboratory must devise interventions that produce different predictions for those explanations.

One useful challenge holds the candidate source constant while altering the strong neighbour's amplitude and frequency at a characterised input plane. A pure window-leakage feature should follow the calculated convolution response under the assumed linear model. A receiver-generated intermodulation product may exhibit a different dependence on input level and may change under added front-end attenuation. A genuine external emitter should not simply translate in physical frequency when the analysis window is changed, although its spectral maximum and detection statistic may respond to the window. Varying the local oscillator, preselector or receiver architecture can provide further discrimination if those transformations are documented. The argument is not that one intervention proves the answer, but that its results can reject or restrict specified competing models.

The gain loop also requires direct examination. Preserve its state transitions, settling time, attenuation settings and any indicators of overload or clipping. Apply controlled bursts before, during and after a strong interfering signal, and compare detection probability against the claimed operating envelope. If the weak candidate disappears only when the analogue chain enters a compromised state, its absence under one software taper is not a safe reassurance. A second

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receiver may be useful when its analogue failure modes are sufficiently independent, but sharing the same antenna or clock can leave important dependencies. Every corroboration claim should specify what is common and what has genuinely been challenged.

I would certainly retain unsuccessful analysis variants in the technical record, together with the rationale for selecting the final method. That does not require printing every plot in the principal report. It requires that the underlying process be reconstructible and that contrary results not be quietly eliminated. A conditional finding that the feature is consistent with leakage under one tested model is more defensible than an unqualified declaration that no transmitter existed. Where an external source remains observationally equivalent to an internal artefact, the report should state that uncertainty and identify a discriminating follow-up test. I pass the floor to Mr Nyquist to consider how window design interacts with the sampling and timing conditions established earlier in the roundtable.

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Harry Nyquist | Principal response 4: Window choice cannot repair a deficient sampling boundary

Dr. Atkinson, the spectral window is applied after the receiver has sampled the analogue input. It is therefore essential to ask whether the samples contain an adequate representation of the desired physical band. A beautifully designed digital taper cannot distinguish an aliased component from its true frequency if the analogue admission and sampling configuration made them observationally equivalent. Nor can it recover clipped amplitudes or fill acquisition gaps whose values were never observed. These limits should be stated before debating which taper gives the most pleasing sidelobe pattern. The window operates upon a finite sequence whose provenance determines the meaning of every spectral feature it produces.

Consider a receiver with a known sample rate F_s and a defined complex or real acquisition convention. A continuous sinusoid at an admitted frequency yields a sampled sequence; another analogue frequency differing by an appropriate multiple of the sampling rate may produce the same sequence unless preselection excludes it. A window multiplies the same ambiguous samples in both cases and consequently cannot resolve the analogue source ambiguity. This is the first boundary of spectral interpretation. The physical front end must establish the relevant band, local oscillator translations and alias restrictions. The report should identify those elements alongside the FFT grid and window configuration. A frequency label divorced from its input reference plane is an incomplete physical measurement.

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Within the admitted band, sample timing and clock quality remain relevant. The nominal FFT grid may contain a frequency in precise decimal notation, but if the sampling clock has a material scale error, the corresponding physical frequency is uncertain. The amplitude of phase noise or aperture jitter may also depend on the incoming frequency and signal strength. A digital taper changes the way noise and leakage are presented, but it does not remove every clock-related impairment. An investigator must propagate timebase uncertainty through the actual conversion chain instead of relying on the apparent precision of the plotted axis. A useful acceptance test varies known physical input frequencies and confirms both the scale and stability of the reported estimates.

A further ambiguity concerns the event's duration. If a stationary tone occupies a long coherent record, it may support accurate frequency estimation under a suitable model. If a transient occupies only a few samples, the finite record contains less information about its phase trajectory. A window can redistribute its contribution but cannot extend the physical observation. Padding the FFT computes a denser representation of the same weighted record. It is useful for visual interpolation, not a substitute for longer acquisition. When two narrowband components are present, their separability depends on the actual observation time, their parameters and the chosen decision procedure; it is not set universally by either the unpadded bin spacing or the window's advertised sidelobe level.

In operational surveillance the receiver may retune, scan multiple bands or change gain and filtering. Those state transitions can leave intervals of invalid or absent samples. Windowing across a missing-data boundary without recording the discontinuity may create apparent broadband

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transients or spectral features whose origin lies in the retention procedure. The analyst should mark invalid intervals explicitly, avoid treating gap-filled values as measured samples, and preserve any interpolation method used. A reconstruction may be acceptable for display under a declared model, but the report must not suggest the algorithm independently observed the unrecorded values. This principle applies equally to sample-rate changes and clock resynchronisation events.

I would require a layered verification: first the analogue input and alias restrictions, then sample timing and configuration identity, followed by the digital window and estimator, and finally the detection rule. Each layer should have its own reference measurements, uncertainty and failure criteria. For the window itself, challenge with calibrated sinusoids at varied grid offsets, neighbouring signals at varied ratios, and short bursts placed across the frame. For the complete receiver, test the same cases through the front end, including conditions of overload, drift and switching. The distinction matters because a software-only challenge can demonstrate correct algorithms while saying little about a field receiver operating outside the linear envelope of its analogue path.

The published result should therefore specify what has been calibrated and what remains assumed. It is reasonable to say that a particular windowed estimator achieved a tested amplitude bias for stable tones within a range of frequencies and signal levels. It is not reasonable to infer from that result that every brief emission will be detected, or that the absence of a plotted spectral feature rules out external transmission. The observing procedure may have insufficient dwell time, a poorly placed window or an unrecorded retune interval. The data can still be useful for

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discovery and restricted inference. Precision means acknowledging these limits, not rejecting every measurement. I pass the token to Professor Neyman, who will press us on the proper interpretation of performance claims made across several operating conditions.

Jerzy Neyman | Peer question 6 to Harry Nyquist

Mr Nyquist, you have described a layered verification programme, but a laboratory might face dozens of combinations of input frequencies, interference ratios, window functions and burst locations. Suppose it reports a confidence bound for detection probability in each tested combination and concludes that the instrument meets the desired minimum performance everywhere in its admitted envelope. Individual bounds do not necessarily confer a simultaneous guarantee upon the entire collection, especially where some conditions were selected after inspecting the failures. How would you require the laboratory to justify a statement about minimum performance across the entire set? Is it sufficient to test only a presumed worst case, or should the error allocation and selection procedure be declared in advance? I also ask how an examiner should express the regions for which sample size is inadequate, without converting statistical uncertainty into an unqualified assertion that the receiver has failed. Please distinguish a confidence bound for a single operating condition from a simultaneous claim covering all tested conditions when the same observations contribute to several comparisons.

Harry Nyquist | Immediate answer to Jerzy Neyman

Professor Neyman, the laboratory should distinguish a capability established at a particular tested condition from a claim about an

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entire multidimensional envelope. A collection of individual confidence intervals does not automatically have the intended simultaneous coverage. If the acceptance claim concerns a minimum detection probability over all relevant conditions, the trial design and inferential procedure must control the risk of falsely certifying that minimum. A simultaneous bound, a predeclared allocation of error probability, or a justifiably chosen limiting condition may be appropriate, depending on the physical and statistical model. It is not satisfactory to select whichever set of trials happens to support the claim and then describe the selection as though it were determined before observation.

The laboratory should begin by identifying the factors most likely to affect performance: burst duration and arrival position, frequency offset, strong-neighbour amplitude, receiver state, temperature and the selected window. A deliberate design can examine interactions rather than attempting every possible combination indiscriminately. Where a proposed worst-case condition is used, evidence must support its limiting character. A short burst at a window edge may be difficult for one detector, while a weak stable tone near a strong interferer may be more difficult for another. There may be no universal worst case. The report should preserve all failures and state where extrapolation has or has not been validated.

An indeterminate region is neither a demonstrated success nor a demonstrated failure. If too few independent test events have been observed to establish the required bound, the correct conclusion is that the evidence is insufficient for that performance assertion. More

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testing, a narrower claim or a different instrument may be needed. Overlapping FFT frames should not be counted as independent trials simply because they produce separate numerical results. When their dependence affects uncertainty, the inferential design must account for it. The trial unit must correspond to a meaningful physical observation or independently injected event rather than to an arbitrary number of processed frames.

Finally, the laboratory's performance bound is not a probability that a particular field alarm originated from a specified external source. That attribution depends on the prevalence of candidate signals, competing receiver artefacts and the discriminatory value of independent challenges. A detector may perform well against its laboratory test population while a particular indication remains ambiguous. The correct report can affirm the former and qualify the latter without inconsistency. I return the floor to Professor Tukey to examine how investigators should report evidence when several analytical windows reveal different parts of the same electromagnetic event.

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John Wilder Tukey | Principal response 5: Exploratory window comparisons and defensible performance claims

Dr. Atkinson, a windowed spectrum is a construction that can reveal useful structure in complicated data. The appropriate scientific response is to explore its strengths and weaknesses, not to worship its appearance. If several windows produce different impressions of the same short electromagnetic event, the differences are themselves evidence about the sensitivity of the analysis method. They should encourage the investigator to examine the input waveform, the transfer response and the underlying assumptions. A peak which vanishes under an alternative taper is not automatically fictitious; a peak which survives every taper is not automatically external. Each behaviour must be interpreted through a model capable of making predictions that can be challenged by independent data.

The first task is to identify the purpose of the calculation. A technician may seek a visual indication that a particular frequency interval contained unusual energy. An engineer may seek the amplitude of a stable calibrated sinusoid. A forensic examiner may seek evidence that a particular source operated at a specific place and time. These are materially different propositions. A rectangular window, Hann window, flat-top window or concentration-optimised sequence can serve one proposition better than another. The question is not which window is best in the abstract. It is which procedure has been validated for the task, signal class and operating conditions at issue. A universal ranking would conceal the very trade-offs the laboratory is obliged to disclose.

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Exploratory comparisons should include what happens when the carrier is moved between nominal FFT grid points, when a weak component approaches a strong neighbour, when a burst crosses the frame boundary, and when the signal envelope changes. The investigator should inspect residuals and failures, not only average performance. A method may look excellent when tested against a stable tone placed exactly at a bin centre and deteriorate appreciably when the frequency moves by a fraction of one bin. A taper with low sidelobes may protect a weak distant line while broadening its response around a closely spaced source. A flat-top window may reduce stable-tone amplitude bias while admitting more integrated noise. A single demonstration cannot establish that all those objectives have been satisfied.

The statistical cost of trying many methods deserves attention. Suppose software calculates several windows and selects the one producing the largest apparent signal. Even if each windowed measurement is individually calibrated, choosing the maximum changes the distribution of the selected result. Its apparent significance cannot be assigned the false-alarm probability of one prespecified window without addressing the selection. Similarly, if the laboratory repeatedly alters its threshold until a favourable validation sequence appears, the final selected trials are not an independent evaluation of the method. Development can be adaptive; verification should then use withheld challenge records or an inferential scheme designed for the adaptive process. The distinction is indispensable where a result may be subjected to expert scrutiny in proceedings governed by rules of evidence.

One should also define the unit of a trial. If a short physical burst triggers three overlapping FFT frames, those three numerical alarms are not

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necessarily three independent successes. If a stationary noise fluctuation appears across adjacent frequency bins, the number of bins containing energy does not equal the number of independent noise events. A validation procedure that counts all these outputs independently can make its confidence intervals artificially narrow. The test design should identify independently generated physical bursts or independently sampled exposure intervals and account for residual dependence. It should then report detection probability, false-alarm behaviour, amplitude error and source-separation performance with uncertainty appropriate to those trial units.

For a negative surveillance finding, the exposure record is as important as the spectral display. The survey may have involved frequency scanning, preselector switching, receiver blanking, retuning and triggered retention. A window can place small weight on an event near its boundary, and a detector may miss that event even while performing admirably on centred test signals. A scan interval may never have included the frequency at which the event occurred. These mechanisms mean that the absence of saved alarms is a statement about a configured detection process, not a universal proof of physical silence. Before claiming a bounded absence, the laboratory must estimate or bound exposure and missed-detection probability for the signal class it purports to exclude.

The publication record should therefore contain a transparent account of the method. Preserve the raw complex samples around material events where practical; the analogue reference-plane calibration; the selected window's coefficients, coherent gain and equivalent noise bandwidth; the transform length and frequency reference; the frame overlap and timing;

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and the detector's decision rule and parameter history. Record rejected alternatives and failed tests in an audit appendix. The main narrative need not reproduce every screen image, but it must state the conclusion in language that is consistent with the retained evidence. An independent examiner should be able to reproduce the analysis and attempt a materially different test of the proposed cause.

A robust conclusion is often narrower and more useful than an unqualified one. It may establish that a particular detector indicated a candidate during a documented interval and that the result persisted under certain controlled window changes. It may establish a window-corrected amplitude for a defined steady waveform or a bounded response to a specified transient class. It does not automatically establish that the indication came from a covert emitter or that no other signals were present. By treating the window as part of the observation operation, the investigator preserves both scientific integrity and operational usefulness. I invite Sir Ronald Fisher to challenge the multiple-comparison assumptions that can be concealed beneath an attractive best-window spectral image.

Sir Ronald Aylmer Fisher | Peer question 7 to John Wilder Tukey

Professor Tukey, suppose the receiver produces five alternative windowed spectra for each of ten thousand overlapping time-frequency cells. Its software selects the most favourable apparent signal amplitude for each candidate and reports an alarm when the selected result exceeds a fixed threshold calibrated on one window alone. Under those circumstances the number of comparisons, their dependence and the selection of maxima alter the alarm distribution. Would it be defensible to attach to the selected alarm the original single-window false-alarm

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probability? What experiment would establish the operating characteristics of the entire multiscale decision process, especially when neighbouring frames share samples and a strong legitimate signal contaminates several candidate bands? I would also like to know how the laboratory should distinguish an exploratory selection rule from a predeclared evidential test, and how failures of the selected procedure should be retained when the operator subsequently modifies the detection threshold or chooses another window.

John Wilder Tukey | Immediate answer to Sir Ronald Aylmer Fisher

Thank you for that question. Sir Ronald, it would not ordinarily be defensible to attribute the single-window false-alarm probability to the maximum selected from a family of windows without an analysis of the full selection mechanism. The windows are not necessarily independent, and the time-frequency cells are often correlated because they share samples and because a physical interferer can influence many outputs. The exact probability of a false alarm therefore depends upon their joint distribution and the rule by which results are selected. Treating the apparent number of independent comparisons as a simple count may itself be inaccurate. The proper object of validation is the complete detector, including its window bank, selection rule, threshold, event clustering and exposure schedule.

One experiment would use withheld noise-only and interference-only records constructed to represent the admitted operating envelope, processed through the frozen algorithm without manual

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selection of favourable outcomes. Measure the rate of false physical-event alarms according to the predeclared event-counting rule, not merely the rate at which individual bins exceed a threshold. Then use independently generated weak bursts with randomised onset, frequency, amplitude and modulation to assess detection probability under the same rule. Preserve all trials and any invalid intervals, and vary strong-neighbour levels to discover mechanisms which generate correlated artefacts. If the detector changes its thresholds adaptively, its adaptive history is part of the algorithm and must be included in the challenge rather than suppressed in the report.

The distinction between development and verification also matters. The engineer may reasonably explore several windows and alter the software after observing poor performance. Such exploration generates useful design knowledge. After the method has been selected, a fresh challenge population is necessary before the outcome can be presented as independently validated. If the procedure changes after the validation trial, the previous inference may no longer apply to the revised implementation. The laboratory should maintain versioned configuration records and tests tied to each version. Selecting a final apparently favourable series while omitting earlier failures would turn an exploratory search into misleading evidence.

The report should state both the achieved performance and its uncertainty. An alarm can be associated with a tested false-positive rate under a declared population, but that is not the probability that a specific signal belongs to a particular transmitter or covert device.

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Attribution requires separate consideration of the prior occurrence of candidate sources, receiver artefacts and independent challenges. A negative finding requires a validated exposure and false-negative account, including the possibility that a short burst occurred where every applicable window was weak. These qualifications do not make the instrument useless. They turn an impressive spectrum into a testable observation. I return the token to Dr. Atkinson for the final synthesis of window-dependent measurement and evidential claims.

Ten worked applications: finite windows, detector statistics and amplitude interpretation

David Slepian, Cross-Peer Question to Jean-Baptiste Joseph Fourier: Mr Fourier, how should a laboratory distinguish the coherent amplitude correction of a window from its equivalent noise bandwidth correction?

Jean-Baptiste Joseph Fourier, Cross-Peer Answer to David Slepian: Dr Slepian, they govern different quantities. A coherent sinusoidal amplitude estimate depends on the sum of the window coefficients, whereas the noise-power bandwidth depends on the sum of squared coefficients relative to the square of that coherent sum. Applying the coherent-gain factor to a power spectral density without the correct normalisation can create a plausible but biased result. Test a bin-centred tone, an off-bin tone and noise with a separately characterised spectrum. Document whether the displayed vertical scale is amplitude, integrated power or density per hertz. The window reduces leakage by redistributing spectral response; it does not remove energy without consequence. Preserve coefficient arrays and FFT conventions, including whether the transform is one-sided or complex two-sided. I pass the token to Professor Gabor for short-burst performance.

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Jean-Baptiste Joseph Fourier, Cross-Peer Question to Dennis Gabor: Professor Gabor, can a taper with excellent distant-sidelobe suppression always improve detection of a very brief unknown pulse?

Dennis Gabor, Cross-Peer Answer to Jean-Baptiste Joseph Fourier: Mr Fourier, no. A taper concentrated near the record centre can substantially downweight a pulse near the record boundary. The right window depends upon the event duration, unknown arrival phase, bandwidth and detection objective. A broad main lobe may merge neighbouring tones even as sidelobes decrease. Test a grid of burst onset positions and carrier offsets rather than one carefully centred sine. Report detection probability, timing bias, amplitude recovery and false-alarm rate under the same window, with coherent-gain and equivalent-noise-bandwidth normalisation appropriately applied. A window which improves an aesthetically smooth spectrum may degrade the capture of intermittent surveillance events. I yield to Mr Nyquist for the neighbouring-tone problem.

Dennis Gabor, Cross-Peer Question to Harry Nyquist: Mr Nyquist, two nearby emitters are separated by less than the main-lobe width of the chosen taper. Can a zero-padded transform demonstrate that they are independently resolved?

Harry Nyquist, Cross-Peer Answer to Dennis Gabor: Professor Gabor, zero-padding creates a denser frequency grid but does not narrow the underlying window response. Whether two tones can be distinguished depends upon their separation, amplitudes, phases, noise, observation duration and the estimator or model used. Challenge with known pairs of sources, including an unequal strong-and-weak pair, rather than relying on a textbook equal-amplitude plot. Compare side-lobe leakage and main-lobe

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separation under several declared windows, and report false splits and missed weak components. If model-based superresolution is claimed, state assumptions about the number of sources and phase stability and verify them independently. A pair of fitted frequencies is not automatically a pair of physical transmitters. I pass the token to Professor Tukey.

Harry Nyquist, Cross-Peer Question to John Wilder Tukey: Professor Tukey, a reviewer finds that the analyst selected the highest spectral peak after trying six window functions. Why must this process appear in the final report?

John Wilder Tukey, Cross-Peer Answer to Harry Nyquist: Mr Nyquist, the chosen window is a data-dependent model-selection decision. A threshold calibrated for one prespecified window may not retain its false-alarm interpretation after searching six alternatives, particularly if each returns correlated but distinct maxima. Retain the candidate outputs, the tested window definitions and the selection rule, and calibrate the combined search under representative noise-only conditions. A blind independent acquisition should challenge the selected choice. Source identification requires more than a peak improved by one taper; analogue calibration, internal spur controls and event chronology remain decisive. Any quoted amplitude or uncertainty must correspond to the actual selected window and its coherent and noise normalisations. I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Distinguished colleagues, we have established that an analysis window is part of the measurement procedure, not a cosmetic choice made after the physical result is known. The selected coefficients determine how a finite digital record is weighted, and that operation affects spectral leakage, main-

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lobe breadth, noise-equivalent bandwidth, coherent gain and the apparent amplitude of short events according to their placement. The relevant trade cannot be reduced to a universal preference for one familiar taper. A window that suppresses distant sidelobes may improve weak-tone visibility under strong interference; a broader main lobe may make adjacent components less separable; and a transient arriving near the frame edge may be attenuated even when the physical emission has not changed.

Professor Slepian has made clear that mathematical concentration criteria must be related to the investigator's physical detection objective. Mr Fourier has distinguished the spectrum of the received waveform from the spectrum of the weighted observation and explained why continuous-tone amplitude correction does not necessarily restore a short burst. Dr Gabor has examined the temporal exposure of a transient in overlapping frames. Mr Nyquist has reminded us that window design cannot reverse analogue aliasing, clipping or missed sample intervals. Professor Tukey has placed these observations within a validation framework that protects against selective reporting, repeated threshold adjustment and unjustified independence assumptions. The seven peer exchanges have tested the key weaknesses in each proposed doctrine.

The worked examples demonstrate why every numerical label requires a declared interpretation. The same record can retain a 1,000-hertz FFT grid while having a 1,500-hertz noise-equivalent bandwidth under a periodic Hann window. A short pulse can experience substantial position-dependent attenuation, whereas zero padding changes the numerical grid without increasing the original observation length. A set of overlapping frames can reuse most of its samples; counting their alarms as independent evidence is

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not justified merely because they are displayed separately. A detector with a low per-cell false-alarm rate can still produce a material chance of at least one false positive across a large search. Clock uncertainty and scanning gaps remain relevant even when the digital window is mathematically impeccable.

For defensive technical surveillance countermeasures, the report should specify the window, coefficient convention, actual acquisition length, transform length, overlap, reference-plane calibration, clock state, amplitude normalisation, noise bandwidth and decision rule. It should distinguish a stable sinusoid's corrected spectral magnitude from a transient's peak voltage, burst energy or mean power. If several windows were used adaptively, the selection algorithm and its validation must be documented. Negative evidence must be qualified by the tested signal class, sampling exposure, false-negative characteristics and operating conditions. An absence of alarms in the saved derivative cannot establish that no signal occurred during unrecorded intervals or below an unvalidated threshold.

We also preserve an important distinction between the detection of a candidate and the attribution of its source. Window-dependent behaviour may help discriminate leakage from another explanation, but disappearance under one taper is not proof that an external emission never existed. Input attenuation, preselection changes, source injection, receiver substitution and documented analogue-state challenges may be needed to test competing causes. The preservation of raw samples and processing records allows these alternatives to be examined later; the retention of only a selected peak may render them permanently indeterminate.

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The resulting doctrine is neither scepticism for its own sake nor uncritical confidence in software output. It is disciplined measurement: define the physical quantity, choose and calibrate the procedure appropriate to it, validate the full detector with adverse and withheld trials, disclose all material uncertainty, and preserve enough evidence for independent challenge. Each conclusion must be no stronger than the observation and its tested assumptions permit. I thank all contributors for their scholarly exchanges and close Question 042. The following question will address averaging and how it changes the detectability of signals whose occurrence is not continuous throughout the integration interval.

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Ten worked engineering applications | Question 042

Worked application 1: Rectangular versus periodic Hann coherent gain

Let N=1,024 denote the number of actual acquired samples and let w[n] be the digital window. For the rectangular window w[n]=1, the coherent gain G_c=(1/N) sum_n w[n] equals 1. For a periodic Hann window w[n]=0.5-0.5 cos(2 pi n/N), the sum is N/2 and G_c=0.5. A bin-centred continuous sinusoid measured with an otherwise equal unnormalised window therefore has half the amplitude under periodic Hann weighting, corresponding to 20 log10(0.5)=-6.0206 decibels. A coherent-gain correction can compensate for this particular steady-tone attenuation under its assumptions. It does not establish the correct correction for an event occupying only a few samples near an edge.

Worked application 2: Equivalent noise bandwidth as distinct from FFT-bin spacing

Let F_s=2,048,000 samples per second and N=2,048 actual samples. The unpadded FFT grid spacing is F_s/N=1,000 hertz. A rectangular window has ENBW=F_s/N=1,000 hertz. Under the periodic Hann definition, ENBW=1.5 F_s/N=1,500 hertz. In the simple white-noise model, the second estimator admits a larger equivalent noise bandwidth even though both FFT outputs have the same 1,000-hertz grid spacing. The ratio of equivalent noise bandwidths is 1.5, corresponding to 10 log10(1.5)=1.7609 decibels of noise-power difference under the stated assumptions. This illustrates why an FFT-bin width must not automatically be labelled the noise bandwidth.

Worked application 3: Edge attenuation of a very brief pulse

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Use N=1,000 and the periodic Hann window w[n]=0.5-0.5 cos(2 pi n/N). At the centre, n=500, the window weight is 1. At n=100, it is 0.5-0.5 cos(0.2 pi)=0.0954915. For a pulse sufficiently brief that its samples experience approximately one local window weight, the amplitude ratio relative to a centred pulse is 0.0954915, or approximately -20.4008 decibels. The pulse need not have changed physical power. The attenuation arises from its placement in the analysis frame. A validation campaign that injects bursts only at the centre will not establish sensitivity near the edge.

Worked application 4: Actual observation duration versus interpolated frequency grid

Acquire N=4,096 real complex samples at F_s=4,096,000 samples per second. The observation is one millisecond and the unpadded FFT grid spacing is 1,000 hertz. Zero padding to 65,536 transform points gives a displayed grid spacing of 62.5 hertz. The display is sixteen times denser because the transform length increased sixteenfold. The original observation remains one millisecond, with characteristic reciprocal duration 1,000 hertz. Under an admitted stable-tone model, a frequency estimator may achieve more precise estimates, but the padding itself did not create any further physical input measurements. It merely sampled the pre-existing finite-record response more finely.

Worked application 5: Dependence of overlapping spectral frames

Let an FFT frame contain N=2,048 samples and let the hop be H=512 samples, producing 75-percent overlap. Adjacent frames share N-H=1,536 samples. If the sample rate is 2,048,000 samples per second,

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each frame spans one millisecond and the hop interval is 0.25 millisecond. Four frame starts occur per millisecond, but the four outputs do not represent four independent new millisecond-long observations. A burst can contribute to several frame detections, and the same noise fluctuation may affect them all. Event clustering and actual dependence must be addressed before counting alarms or calculating uncertainty intervals.

Worked application 6: A family of nominal false-alarm tests

Suppose a detector performs K=3,000 hypothetical independent null tests, each having a fixed per-test false-alarm probability p=0.0001. Under that independence model, the chance of at least one false alarm is 1-(1-p)^K=1-(0.9999)^3000, approximately 0.259193. This is much larger than 0.0001. Real window-bank outputs and overlapping frames are generally dependent, so the numerical result is not a calibration of the actual receiver. It demonstrates why the full multiscale detector needs its own joint false-alarm validation rather than an unqualified transfer of one window's threshold specification.

Worked application 7: Noise-standard-deviation comparison from ENBW

Consider a simplified detector operating against locally flat white noise. If its output noise power is proportional to ENBW, increasing ENBW from 1,000 to 1,500 hertz increases noise power by the factor 1.5. The corresponding root-mean-square noise amplitude increases by sqrt(1.5)=1.224745, approximately 22.47 percent. This does not imply that every narrowband peak is 22.47 percent larger, since peak statistics

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and signal response involve other factors. The example shows why two windows with equal FFT-bin spacing but different equivalent noise bandwidths should not be compared without correcting or validating their noise scales and decision thresholds.

Worked application 8: Effect of clock-frequency scale uncertainty

Suppose the complete acquisition frequency scale is verified to within a relative systematic uncertainty of one part per million over the relevant operating state. A displayed candidate frequency of 200,000,000 hertz then corresponds to an approximately 200-hertz contribution from that scale uncertainty, before any separately relevant mixer, oscillator or estimation errors. A padded FFT grid might be spaced at much less than one hertz, but this does not eliminate the 200-hertz physical uncertainty. The conversion from baseband to RF may involve additional clocks or oscillator references whose errors must be propagated through the actual receiver configuration. Define the indicated frequency f = 200,000,000 Hz and fractional scale uncertainty $\varepsilon = 10^{-6}$. The resulting scale term is $u_f = |f|\,\varepsilon$ = 200 Hz; it is not reduced by frequency-bin interpolation.

Worked application 9: Detection exposure under a scanning receiver

A receiver observes one chosen frequency for 20 milliseconds in each 200-millisecond scan cycle. Its dwell fraction is $D=0.02/0.2=0.1$. If a burst is much shorter than the dwell, occurs uniformly at random relative to the cycle and has negligible boundary effects, the probability that its onset falls in an observed interval is approximately 0.1. If the detector succeeds with conditional probability 0.98 during admitted exposure, the

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unconditional detection probability under the stated simplified model is 0.1 times 0.98=0.098, or 9.8 percent. A well-calibrated FFT window cannot compensate for intervals during which no samples of the relevant band were acquired.

Worked application 10: Reported burst amplitude in an uncertain window location

Suppose a calibrated injected reference burst produces a normalised peak voltage of 10 millivolts when it is centred within a chosen analysis window. The same input, moved to a location where the local effective window weight is 0.2 under a short-pulse approximation, may yield an indicated peak of 2 millivolts if no position-aware correction is applied. This is a factor of five difference or 20 log10(0.2)=-13.9794 decibels. The example demonstrates an algorithmic position effect, not a genuine fivefold change in transmitter amplitude. The laboratory should challenge the detector with varied onset times and report a validated correction range or a limitation, rather than apply a single continuous-tone coherent-gain factor indiscriminately to every transient.

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Scholarly and technical references, with limited read scope

[S1] SciPy Project, official *Signal Processing Tutorial*, https://docs.scipy.org/doc/scipy/tutorial/signal.html . Examined public tutorial sections on windowing, spectral leakage, zero padding, coherent-gain-related normalisation and spectral analysis. Supports underlying formulas and conceptual trade-offs, not certification of any specific instrument.

[S2] SciPy Project, *Signal Processing Tutorial* documentation for short-time Fourier analysis and overlap, same source. The tutorial establishes computational operations, while claims about forensic evidence and adaptive operational validation are the present author's analysis.

[S3] U.S. Department of Defense, *MIL-STD-1399, Section 300, Part 1*, public DLA-hosted document, https://quicksearch.dla.mil/Transient/C6B9B7759A6449E08B8B00FA019F09A8.pdf . Limited public excerpt consulted concerning windowing, coherent gain and equivalent noise bandwidth. Its complete revision history and application to TSCM receivers were not verified.

[S4] NobelPrize.org, *The Nobel Prize in Physics 1971*, https://www.nobelprize.org/prizes/physics/1971/summary/ . Examined award recipient and cited recognition of Gabor for holography.

[S5] IEEE Computer Society, *Computer Pioneers: John Wilder Tukey*, https://history.computer.org/pioneers/tukey.html . Examined biographical overview, dates, appointments and association with the Cooley–Tukey FFT publication.

[S6] MacTutor History of Mathematics, University of St Andrews, *Joseph Fourier*, https://mathshistory.st-andrews.ac.uk/Biographies/Fourier/ . Examined historical dates and mathematical work on heat conduction and trigonometric series.

[S7] Royal Society Collections, *Dennis Gabor*, https://catalogues.royalsociety.org/CalmView/Record.aspx/Record.aspx?id=NA6123&src=CalmView.Persons . Examined research fields, fellowship and historical dates.

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QUESTION 043

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When does spectral averaging conceal short-lived signals?

Source: V011_Roundtable_Question_043_CP043_Dr_Atkinson.docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 043. Complete Expert Roundtable Discussion

Constructed educational dialogue. Historical contributors are presented as intellectual personae, not as participants in an authentic meeting or witnesses to modern receiver hardware. The discussion is substantive, while independent scholarly and mathematical verification remains separate from prescribed components have passed their audits.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, our previous discussions established that the windowing of a finite observation alters the apparent spectral response and that a correct numerical transform does not supply information omitted by the analogue chain or the recording procedure. We now examine the operation of averaging, commonly used to produce a quieter, more stable spectrum. An engineer observing a persistent weak carrier against stochastic noise may profit greatly from combining several estimates. An investigator searching for a rare transmitter which emits only briefly may find that the same averaging procedure reduces the transmitter's prominence or removes it from a median-derived display. The eye sees an attractive smooth noise floor; the instrument has selected a statistic whose relationship to the actual physical events must be declared.

The problem is not solved by saying merely that averaging reduces noise. We must distinguish averaging complex waveform values, averaging spectral magnitudes, averaging squared magnitudes or power spectral

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densities, averaging values expressed in decibels, and selecting a median or other robust estimate. These operations are not equivalent. Coherent averaging can suppress an unaligned signal while preserving a phase-locked component. Mean power averaging preserves certain expectations under a stationary model but can dilute a transient's contribution across many quiet frames. Median averaging may deliberately reject rare large excursions, which is useful when estimating the background but hazardous if those excursions are the very signals a counter-surveillance investigator must discover. An automatic display may incorporate additional smoothing whose effect upon detection was never documented.

Let $P_i(f)$ denote a window-corrected power estimate from frame i at frequency f, and let K be the number of frames in the averaging group. The arithmetic mean is $P_{bar}(f)=sum_i P_i(f)/K$. If a burst contributes excess power S in only one frame and the other K-1 frames have background power B, the mean becomes B+S/K under the stipulated additive-power model. The excess is diluted by the factor K compared with the active frame. That arithmetic result does not assert that every possible detector loses sensitivity with averaging, because a detector may integrate a known repeated waveform coherently or use a statistic designed for sparse events. It establishes that the meaning of the chosen mean differs from the maximum, from the event count and from the probability that a burst occurred anywhere in the observation interval.

Frequency occupancy and negative evidence pose equally difficult questions. Suppose an SDR stores only an average spectrum for each ten-minute period. The average may establish some property of the energy distribution during the retained interval, but it cannot necessarily disclose

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how many bursts occurred, how long they lasted or whether their occurrence coincided with another event. A later forensic examiner may wish to determine whether a brief transmission was connected with a specific telephone call, door access or computer-network transaction. A period average, even if cryptographically authenticated, cannot reconstruct the original event times. The preservation question therefore arises at the beginning of the measurement, not merely when the final report is written.

Our panel shall examine these issues through complementary disciplines. Professor Bartlett will discuss spectral estimation and the statistical effects of dividing a record into segments. Professor Wiener will examine stationary assumptions and the temptation to use a smoothed representation as a complete account of a changing process. Dr Shannon will examine information discarded by averaging and the difference between preserving expectation and preserving particular events. Dr Bennett will consider the receiver's physical noise sources and the limits of inferring improved sensitivity from an apparently quieter trace. Professor Tukey will insist that a detector claiming both background estimation and transient discovery be challenged on a population that contains realistic rare events. Seven colleagues will press the participants on correlated windows, selection effects, false negatives, noise distributions and the admissibility of a negative survey conclusion.

We must maintain the distinction between developing a useful visualisation and validating an evidential assertion. Averaging is neither inherently virtuous nor inherently deceptive. A technique may be excellently suited to measuring long-term noise power and unsuited to detecting a fleeting emission. The proper question is what statistic the operator

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computed, what assumptions justify it, what alternative information was discarded, and which challenge tests establish the claims offered in the report. The publication record must include the processing history, raw evidence where available, averaging duration, window overlap, units, gain state, frequency reference and detector version. I invite Professor Bartlett to begin with a comparison of mean spectral estimation and the more demanding task of finding a single rare event in a collection of observations.

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Maurice Stevenson Bartlett | Principal response 1: Average periodograms and the unequal goals of estimation and discovery

Dr. Atkinson, a spectral estimate is an inference from a finite record under a statistical model. Dividing a long record into segments, forming spectral estimates from them and averaging can reduce the variability of a power-spectral-density estimate under suitable assumptions. But the method does not magically yield additional independent information, particularly if the segments overlap or the underlying process changes during the interval. The engineer must ask which random quantity is being estimated and whether the assumed stationarity is compatible with the investigated signal. A long-term background-noise estimate and a detector for a rare intermittent emission are not the same statistical task. Averaging may be suitable for the former while obscuring the latter.

The familiar mean periodogram is informative about the average spectral power in a selected population of segments. If one segment contains a rare burst and many others are quiet, its contribution to the mean is divided by the number of segments. That does not imply the event was absent, nor that its peak amplitude was the value of the average. The mean answers a population question. A maximum detector answers a different question about extreme observations and must be calibrated against the distribution of extremes. A median may offer resistance to unusual high-power interruptions when the goal is estimating baseline noise, but such resistance can remove precisely the evidence of a signal that is rare by design. In a defensive investigation the analyst must state which of these tasks is intended and retain the evidence necessary to test it.

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One subtlety concerns the distribution of spectral estimates. Even when the input noise is approximately Gaussian, a periodogram ordinate does not behave as a Gaussian amplitude error in the simple sense suggested by a smoothed trace. Mean averaging changes the distribution and can reduce variation, but the benefit depends upon the number of effectively independent observations. Overlapping segments reuse samples. They may improve the efficiency of a spectral-density estimator for a given finite record, yet they should not be counted as independent trials merely because the software produced separate frames. The investigator should know the overlap, window, correlation and sampling programme before asserting a specific variance reduction or confidence bound.

Another subtlety is the difference between linear power and logarithmic display quantities. The arithmetic mean of power values, expressed in watts or volts squared under a known reference, is not equal to the arithmetic mean of their logarithms. If a spectrum analyser averages values already expressed in decibels, the displayed result may differ from a power average, particularly where the input varies strongly or the noise has a skewed distribution. An operator should identify the actual detector mode and averaging domain. The word average without units and a processing definition is insufficient for metrology. A forensic report should not transfer a correction appropriate to one domain into another without deriving and testing the relation.

A transient creates additional uncertainty about frequency and time. If the burst appears in one of K frames, the mean may show a weak elevation but not the frame in which it occurred. If the software stores only that mean, the source time cannot generally be reconstructed. The original unaveraged

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frames may themselves contain overlapping samples, and an event may appear in more than one frame. A proper event count requires a physical-event identification rule, not a simple count of elevated bins. The negative conclusion is also restricted: a mean below threshold may conceal a brief signal whose instantaneous or per-frame power exceeded the same threshold. The average is a different observable from the individual event.

I would therefore design two parallel outputs for a receiver intended to measure both baseline noise and intermittent activity. One output might provide a suitably calibrated mean or robust background estimator, labelled as a background statistic. Another should preserve event-sensitive quantities, such as per-frame maxima, timestamps, short raw intervals or a thresholded candidate log whose detection and selection rules are validated. The former can improve the interpretation of the environment. The latter protects against a rare signal being hidden by the statistic used to characterise that environment. Both outputs must share a traceable receiver-state record, and the limitations of any triggered retention must be disclosed.

The laboratory should test those outputs on withheld data containing deliberately sparse bursts, including one event in a large number of otherwise quiet frames. Change the burst duration, frame position, frequency offset, amplitude and neighbouring interference. Vary how many frames contribute to the average and observe whether the detector's claimed performance survives. Include noise-only trials to measure the false-alarm characteristics of any maximum or event-sensitive rule. For the average spectral estimate, report uncertainty appropriate to its effective number of independent segments and stationarity assumptions. For the

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burst detector, report detection probability conditioned on the admitted signal class and observation exposure. One certificate cannot stand in for both.

Finally, the physical receiver must not disappear behind the statistics. An input overload or automatic-gain transition may introduce an event-like spectral excursion. A robust average may suppress that excursion in the background estimate, but the origin of a field alarm still requires physical investigation. Conversely, a burst which is genuine may never appear in a selected derivative because the receiver scanned away or because the signal was excluded during blanking. Averaging neither proves nor disproves external origin. It creates a statistic whose scope is bounded by the samples, reference plane and process conditions. A cautious and well-designed report can be decisive about that statistic without pretending to certify every unobserved event. I pass the token to Professor Slepian, whose concentration studies invite a question about whether the same processing choices that reduce background variance can also hide a weak spectrally concentrated burst.

David Slepian | Peer question 1 to Maurice Stevenson Bartlett

Professor Bartlett, suppose the instrument uses overlapping windowed periodograms and forms a mean in order to produce a stable estimate of the ambient power spectral density. A covert transmitter emits a single short packet in one of a hundred frames, yet the receiver's routine display shows only the hundred-frame mean. The packet's energy may lie in a narrow frequency interval, but the choice of window and averaging interval can diminish its contrast against the background. The laboratory demonstrates excellent variance reduction on a stationary

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reference noise source and then claims improved sensitivity to rare packet transmissions. What challenge would distinguish those two different kinds of performance? Should the instrument separately retain a maximum spectrum, a raw candidate interval or a statistic designed for sparse events? How should the operator report a negative result when only the mean survives and the original packet timing cannot be reconstructed? Please distinguish a numerical estimate of ordinary environmental power from an evidential assertion that no brief physical transmission occurred during the same interval, and identify precisely which data could support each proposition.

Maurice Stevenson Bartlett | Immediate answer to David Slepian

Thank you for that question. Professor Slepian, the laboratory's stationary-noise demonstration establishes a property of a spectral estimator under the tested model. It does not establish the probability of detecting a brief packet. To test packet detection, the laboratory must inject independently timed events with known amplitude, duration, modulation and frequency offset, and process them through the entire receiver and retention procedure. The relevant outcome is whether the event is recognised and preserved, not merely whether the mean spectrum becomes visually smoother. Both false alarms and missed detections must be measured. The challenge should include weak events arriving at awkward frame positions, not only convenient centred reference packets.

A maximum spectrum or event-triggered raw interval may provide useful complementary evidence, but its own false-alarm behaviour requires validation. The maximum of many noisy estimates tends to

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be larger than an ordinary estimate; a threshold appropriate to one frame cannot be exported to the maximum over a hundred frames without considering the size and dependence of the family. A trigger must preserve the algorithm and threshold that caused the event to be retained. A raw segment should include sufficient pre-trigger context, receiver state and timebase information to permit an independent examiner to challenge the result. A background mean and a candidate log serve different purposes and should be labelled accordingly.

Where only the mean survives, the report can describe the measured mean spectral power under the stated averaging scheme and its uncertainty. It generally cannot specify the number or exact times of rare bursts without additional modelling assumptions and evidence. A low mean does not exclude a brief high-power event if the event's contribution was diluted across many quiet frames. Similarly, a high mean may arise from repeated moderate emissions, one large excursion, or a persistent interfering source. Their physical histories are not uniquely inferred from one average. The investigator should state this non-uniqueness rather than present a false precision about prevalence.

The proper rule is to treat the detection claim as a separate calibrated procedure. Preserve the acquisition coverage, loss intervals and detector state. If the survey scanned several bands, calculate the actual exposure of each band instead of dividing the saved alarm count by the entire elapsed hour. If a robust background estimator is used, test whether it rejects the signal class of interest. The absence

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of archived candidates is meaningful only in relation to a known false-negative rate and exposure model. An instrument can remain useful even when that rate is not fully known, but its negative conclusion must be narrower. I return the floor courteously to Professor Wiener to examine the further complication that the underlying electromagnetic environment may not be stationary during the averaging period.

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Norbert Wiener | Principal response 2: Stationary models and feedback between detector and environment

Dr. Atkinson, the temptation to smooth a record arises partly from our wish to describe irregular observations by stable quantities. A smoothed spectral estimate can be useful when the underlying noise process is sufficiently stationary over the chosen observation interval, but that condition must be examined, not assumed from the smoothness of the output. A receiver operating in a real electromagnetic environment encounters transmissions that begin and cease, changes in propagation, electronic switching events, moving interference sources and alterations in its own gain and reference state. These changes may occur during an averaging period. The average then describes a mixture of operating states rather than one fixed stochastic process. Its numerical stability may be obtained at the cost of obscuring the transitions that are operationally most important.

The problem deepens when the receiver adapts to the data. An automatic noise-floor estimator may adjust thresholds according to recent spectral history. A strong legitimate carrier can raise a local estimate of background power; a subsequent weak transient may then fail to exceed the adaptive threshold. The receiver's software may faithfully report that no alarm was generated, while the operator infers that no physical event occurred. The latter proposition does not follow from the former. The measurement procedure has coupled the observation process to the decision rule. Its state at one moment depends on earlier observations and parameter updates. A static threshold certificate cannot necessarily characterise such a time-varying detector.

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Averaging with a recursive filter makes the relation between history and present output especially clear. Suppose an exponentially weighted estimate is updated by $A_k = \text{alpha } P_k + (1\text{-alpha}) A_{(k-1)}$, where alpha is between zero and one and P_k is the current linear-power estimate. For a sudden excess S above a constant background, the first output changes only by alpha S. A small alpha makes the trace visually smooth but attenuates a single-frame transient strongly in the retained average. Following the impulse, the estimate decays gradually, which can spread its apparent effect across later times. An investigator who uses the recursive estimate as a direct record of physical event duration may therefore be misled both about the event's peak and about when it ended. The actual update coefficient and initial state are essential metadata.

It is not enough to classify the operation as low-pass smoothing. The receiver may average spectral power, magnitude, logarithmic level or another nonlinear statistic. The same physical burst can have different influence on those quantities. For example, a large rare excursion can dominate a mean-power estimate while contributing little to a median baseline. Both may be mathematically correct for their intended purposes. An operator searching for a covert intermittent device should not use a baseline estimator as though it were an event detector unless the relevant detection properties have been independently established. In particular, a median that rejects rare interference can also reject rare genuine transmissions when those transmissions are classified only by their statistical rarity.

The archival problem is fundamental. If the instrument saves the recursive average and discards the original frame estimates, an investigator

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may attempt to invert the recurrence. That inversion requires knowledge of the initial state, alpha, numerical precision, any clipping or quantisation, missing frames and every adaptive parameter change. If the update includes thresholding, saturation or nonlinear state logic, the inverse may not be unique. Even a mathematically invertible numerical recurrence does not recover an analogue event that was never admitted through the receiver. The report should identify the representation saved and the states necessary for its interpretation, rather than assume that the displayed curve contains the whole electromagnetic history.

The resulting acceptance statement should distinguish an estimate of background power from a claim about detection. One may validly report that a recursive average stabilised the displayed noise estimate under the laboratory's admitted conditions. One may separately report the probability that a particular class of burst was retained when it occurred within observable exposure. The two claims must not be silently exchanged. An examination of a suspected surveillance emission also requires alternative-cause tests to distinguish external signals from internal transients due to gain changes, clock reconfiguration or software processing. A quiet display can be a successful visualisation and an inadequate forensic record at the same time. The correct doctrine is to preserve the distinction and its evidence. I pass the floor to Dr Shewhart for a challenge concerning the validity of a stationary-process model when the underlying receiver configuration changes during the observation.

A robust validation campaign should use known independent challenge events introduced at randomised times during an operating sequence that includes realistic interference transitions. Test the detector before, during

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and after high-power exposures and gain changes. Vary the averaging time and adaptive parameters. For each event record whether the raw input was available, whether the event was recognised, how its amplitude and duration were represented, and whether the recorder retained it. Trials should include long periods with no event, repeated moderate events and one rare large burst, because these histories can yield similar averages while posing different investigative questions. The algorithm should be frozen for withheld tests or its entire adaptive rule should be treated as the object of the validation.

Walter Andrew Shewhart | Peer question 2 to Norbert Wiener

Professor Wiener, an industrial control chart is intended to distinguish ordinary variation from a material change in the process. Suppose an SDR records a long series of averaged spectral estimates, each based on a different interval of data, while its receiver temperature and gain state drift. The smooth output may appear stable even as the process that generates its noise changes. At what point should the investigator treat the average as an estimate from a mixed population rather than an adequate characterisation of one stationary background? What diagnostic record would permit a later reviewer to distinguish an actual electromagnetic change from the effect of altered smoothing coefficients or adaptive thresholds? Would you require control references at specified intervals, and how would the laboratory define a rule for invalidating previously accepted negative survey findings when the detector is discovered to have entered a different operating state? Would a stable average alone ever be sufficient evidence that the underlying

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measurement process remained in statistical control, or must it be supported by independently monitored state variables?

Norbert Wiener | Immediate answer to Walter Andrew Shewhart

Thank you for that question. Dr Shewhart, the operator should preserve the distinction between variability within a defined operating state and changes that invalidate the model of that state. Temperature, gain, preselector selection, clock condition, numerical processing configuration and interference occupancy can all change the distribution of spectral estimates. A single aggregate average may conceal those changes. The laboratory should therefore preserve a time-ordered record of relevant state transitions and reference challenges. A control reference ought to traverse the portion of the measurement chain implicated in the claim; a digitally injected test value cannot certify an analogue input stage that it bypasses. The results should be indexed to both the reference source and the operating configuration.

Stationarity is not established by a smooth curve alone. The investigator can examine residuals, segment-level statistics, correlation, variance and abrupt changes in detection behaviour. Where the process visibly changes, report the corresponding intervals separately or use an explicitly time-varying model whose adequacy is tested. If gain changed during the survey, the investigator should not treat earlier and later spectral levels as directly comparable without a correction supported by calibration. If an adaptive threshold increased after a strong signal, the false-negative exposure for a subsequent weak emitter may have changed materially. That

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uncertainty must be reflected in the strength of any negative conclusion.

A controlled change-detection rule can be valuable, but it requires its own false-alarm and missed-change assessment. One may use periodic reference events or independent audit intervals to test whether the detector retains its admitted performance. When a failure is discovered, reconstruct the time range potentially affected by the defect using the available logs and references. If the interval cannot be bounded, the corresponding historical negative result may have to be described as indeterminate. That is not the same as proving that the hidden transmitter was present; it means that the instrument's failure to report one no longer supports the promised level of reassurance.

The most important safeguard is to retain not only the final average but enough of the unaveraged evidence and state record to examine the process. The original question may later concern one rare event rather than mean occupancy over the whole period. A measurement system cannot become retrospectively more informative merely because its plotted result was stable. A concise report can still be prepared, but its supporting archive should disclose the assumptions, changes and limits of the selected estimator. I pass the token to Dr Gabor, who will challenge how a smoothing interval interacts with a pulse whose beginning and end are themselves material to an investigation.

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Dennis Gabor | Peer question 3 to Norbert Wiener

Professor Wiener, your recursive averaging example describes a short event as a small initial movement of the estimate followed by a long decay. A forensic investigator may mistakenly read the decay as evidence that the transmitter continued to radiate after the actual burst ended. Equally, a large average may conceal whether the generating signal was brief and strong or weak and persistent. How should the laboratory validate the temporal response of its averaging procedure and communicate the distinction between the filter's memory and the emitter's actual duration? Would you require the original event-sensitive record to be retained even when the averaged spectral estimate is the official measurement product, and what uncertainty remains when the event occurs across the boundary of the saved recording interval? I also ask whether averaging over a period much longer than the event duration can produce an apparent emission tail whose persistence is entirely due to filtering, and how that effect should be disclosed to an examiner considering the event timeline.

Norbert Wiener | Immediate answer to Dennis Gabor

Thank you for that question. Dr Gabor, the response of a recursive average to a known brief input should be measured as part of its calibration. If the update rule is linear and its coefficients and initial state are known, the mathematical impulse response can be predicted; nevertheless the complete instrument may contain additional filtering, thresholding, quantisation or state changes. The laboratory should therefore inject pulses with known duration and onset into an appropriate reference plane and compare the measured

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output with the prediction. The experiment must vary event timing relative to update intervals, because an event near a boundary may be represented differently from an otherwise identical event near the centre. The result should state the time response of the estimator rather than assume it is the physical duration response of the transmitter.

One should distinguish at least three different times: the actual admitted event interval at the input plane, the interval during which the detector was exposed to it, and the time over which the averaging memory remains elevated. These need not be equal. If an averaged display shows a trailing response after a transient has ended, that tail belongs to the estimator unless independent evidence demonstrates continuing emission. Conversely, if the averaged response never exceeds the alarm threshold, one cannot conclude that no brief input occurred. The detector's sensitivity to sparse events must be tested directly. The required data include update coefficients, frame times, trigger rules, gain state and any invalid intervals.

I would preserve an event-sensitive derivative and, when possible, the raw samples surrounding a material candidate. The mean or recursive average may remain the official background-noise product, but it is inadequate by itself for many timing and source-identity questions. The acquisition should also record the selection rule by which segments were saved, so a later examiner can distinguish an unrecorded interval from a recorded negative observation. An authenticated record proves integrity of the bytes stored, not completeness of the physical process. If the event crossed a boundary

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and the omitted portion cannot be recovered, any duration or energy estimate should include that limitation rather than be extrapolated as though the waveform were known.

The laboratory can develop models to correct known smoothing effects, but a correction's success is conditional. Inverting a linear filter may amplify noise or become unstable where the original transformation strongly suppressed certain components. Where nonlinear selection discarded information, no unique inverse may exist. The most defensible procedure is prospective: define the relevant event classes, retain data at a resolution adequate for their foreseeable questions, validate the time response and report only the uncertainty which the actual evidence supports. I return the floor to Dr Shannon, who will examine more formally the distinction between a reliable average and an adequate record of the individual events that created it.

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Claude Elwood Shannon | Principal response 3: Averages can preserve a statistic while discarding the event history

Dr. Atkinson, the most important issue is not whether a mean is accurate, but what the word accurate is intended to describe. A set of numerical values can have a well-defined mean even when their ordering and individual departures are unknown. Once only that mean survives, many distinct histories may be consistent with it. Ten frames each containing moderate power can share an average with nine quiet frames and one strong burst. The number, timing and shape of events cannot be uniquely determined from their common mean. This is a many-to-one representation, and its lost distinctions cannot be recovered merely by applying more computation to the saved statistic.

A similar issue arises when magnitude or power spectra are averaged across frames whose phases differ. Coherent complex averaging and incoherent power averaging answer different questions. A stable component whose phase is referenced consistently may accumulate coherently, whereas a signal with variable phase can cancel in a complex average. Power averaging avoids that particular cancellation but still discards phase relationships and can dilute sparse excess power over quiet frames. The procedure should therefore identify its signal model: is the relevant source expected to remain phase coherent throughout the integration, to recur with a known timing pattern, or to appear as an unpredictable burst? There is no model-independent advantage to longer averaging for every class.

The units also matter. Averaging linear power values and averaging the same numbers after converting them to decibels are mathematically

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different operations. If an investigator records the average of logarithmic levels, the result is related to a geometric rather than arithmetic mean of the underlying powers. It need not represent average energy correctly. The software or instrument manual should identify which operation was actually performed, rather than use the ambiguous word averaging. A later examiner should be able to trace the reported value back to its input reference plane, scale conventions, window and frame selection. Without that record, an apparently precise spectral number may be insufficiently defined to support a physical power claim.

The information lost through selection can be more consequential than the information lost through averaging itself. A receiver that stores only a mean spectrum for every minute omits the occurrence times of individual bursts. A receiver that stores only means exceeding a threshold also omits some low-level intervals and makes the archive conditional on its own decision rule. A detector may use a median to suppress exceptional interference and thereby suppress rare genuine transmissions, because statistical rarity alone does not distinguish hostile or benign origin. When the investigative question concerns an intermittent emission, the probability of missed retention must be measured against the chosen signal class. A quiet mean or median does not settle the absence of unrecorded events.

A practical evidence system can preserve several levels of representation. A low-rate mean power record may be suitable for identifying long-term occupancy or background trends. A per-frame event statistic, together with validated thresholds, may help detect sporadic changes. Raw complex samples around important candidates preserve more of the digital evidence for reanalysis, provided their timing, frequency translation and receiver

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state are documented. No single derivative is sufficient for every possible future question, and raw digital samples do not restore an analogue input component that the receiver never admitted. The preservation plan should state these boundaries explicitly rather than claim an unattainable universal completeness.

The investigator should also beware of interpreting different displays as independent corroboration. A mean spectrum, median spectrum and maximum spectrum computed from the same raw samples are related mathematical functions of one observation. Their agreement may be useful for a particular robustness test, but it does not constitute three independent receivers observing the same physical event. If a second receiver is employed, its independence must be assessed at the antenna, clock, power and signal-path levels. Shared references can introduce correlated errors. A proof of source identity should depend on observations that discriminate the proposed emitter from plausible alternatives, not merely on several derived pictures containing similar peaks.

The relevant validation has to occur before the forensic report makes a strong claim. Introduce sparse bursts with known timing and waveform structure into an otherwise representative stream. Measure how mean, median, maximum and coherent averages respond, including their false alarms and the circumstances in which an event is omitted. Preserve the full challenge record and any adaptive parameter changes. Use a trial population independent of the development examples to establish performance. The report should distinguish a conclusion about average power from a conclusion about the presence or absence of an event during

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a particular interval. The former may remain sound when the latter is indeterminate.

My conclusion is a statement of informational scope. An accurately computed average is evidence of the average of the observed and selected data, under the adopted scaling and calibration. It is not a uniquely invertible description of the time series that generated it. A short-lived covert signal can be concealed by averaging when its contribution is diluted, cancelled or rejected by the chosen statistic, or when the selection procedure fails to retain it. A responsibly designed receiver can use averaging and still protect event evidence by keeping the distinct products and their limitations visible. I pass the floor to Professor Neyman for a challenge about the uncertainty of rare-event detection when the averaging method was selected after inspecting the data.

Jerzy Neyman | Peer question 4 to Claude Elwood Shannon

Dr Shannon, suppose a laboratory develops a detector by testing several averaging lengths and selecting whichever version most clearly displays a set of known transient examples. It then claims that the selected method detects short bursts with ninety-five-percent probability because nineteen of twenty favourable examples produced alarms. The examples may not have been independent, their onset times may have been selected for convenience, and the method was chosen using those very results. How should the investigator distinguish a discovery exercise from an independent estimate of detection probability? What sampling unit should be used when several overlapping frames can be triggered by one physical event, and what evidence would establish a defensible confidence bound for a low false-negative rate across different burst

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durations and interference levels? If the laboratory later modifies its averaging interval or alarm threshold, should the former detection-performance certificate still be quoted, or must a fresh validation campaign be undertaken for the revised procedure?

Claude Elwood Shannon | Immediate answer to Jerzy Neyman

Professor Neyman, the claimed probability should not be accepted merely from a fraction of successes in the examples that were used to select the method. Those observations belong to the development process and are not an independent validation population. A new set of challenge events should be generated under predeclared conditions and withheld from parameter selection. Their occurrence times, amplitudes, durations, modulation and neighbouring interference should span the admitted envelope. The validation procedure must define one physical test event and establish whether it was correctly detected and retained. Multiple overlapping FFT frames triggered by the same event do not automatically increase the number of independent trials.

The confidence bound should be calculated according to the selected statistical design and its independence or dependence assumptions. Nineteen successes out of twenty events, even if independent and properly sampled, do not establish with high confidence that the true detection probability exceeds ninety-five percent. The sample is small and its observed proportion is itself uncertain. If the claim concerns all combinations of burst duration and interference conditions, individual bounds may not provide a simultaneous guarantee for the whole family. The laboratory should

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predeclare its acceptance rule and use a method appropriate to the desired joint coverage. Where data are insufficient for some conditions, an indeterminate qualification is more accurate than a universal certificate.

The detector's apparent success also depends upon exposure. If the receiver was not tuned to the relevant frequency during a particular event, the absence of an alarm does not measure the same conditional detector property as a missed event while fully exposed. One may calculate an unconditional probability under a validated scan model, but it should be distinguished from the probability of detection given admission to the relevant band. An averaging procedure may work excellently when the source is present throughout a long observation and fail against a rare burst because its energy is diluted. The validation population must therefore reflect the event class the operator intends to discover.

A strong evidential record should contain both the algorithm's full versioned state and the underlying trial outcomes, including negative cases. An investigator should be able to reproduce the average and, where available, test alternative event-sensitive statistics against the raw data. These requirements do not remove every uncertainty. They ensure that the resulting report identifies which performance claim the evidence supports and which remains unknown. It is entirely consistent to accept an average power estimate while declining to infer from it that a sporadic transmitter was absent. I invite Dr Bennett to consider the further distinction between reducing a

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displayed trace's fluctuation and improving the physical receiver's noise performance.

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William Ralph Bennett | Principal response 4: Receiver noise, power averaging and the illusion of increased sensitivity

Dr. Atkinson, the appearance of a narrower noise trace is not necessarily evidence that the input receiver has acquired a smaller physical noise temperature or a lower noise figure. A stable average suppresses fluctuations in the estimate; it does not automatically change the stochastic voltage entering the analogue chain, the available signal power, or the information lost through front-end distortion. The instrument's physical sensitivity depends on its antenna and input reference plane, noise bandwidth, receiver gain and nonlinearity, and the performance of a detector defined against a particular signal class and false-alarm criterion. An operator who treats the smoothness of the plotted spectrum as a direct measurement of sensitivity may therefore confuse two different properties: the variance of a displayed estimator and the receiver's ability to discover an unknown weak event.

An instructive example is the average of K independent power-spectrum estimates under a stationary-noise model. The variance of their arithmetic mean decreases as K grows, and the typical visible fluctuation becomes smaller. But a burst that appears in only one of those estimates contributes its excess power divided by K to the mean. If the averaging interval grows from ten to one hundred quiet-dominated frames while the burst duration stays fixed, its contribution to the displayed average is further reduced. A detector that integrates a known persistent tone over a longer interval may improve its ability to measure that tone. The same procedure can impair a detector whose task is to find one short event at an unknown time. The

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difference is a consequence of the measurement objective and signal occupancy, not an inconsistency in mathematics.

The physical noise model must also be made explicit. Thermal noise generated in a resistor or electronic input has a spectral density related to temperature and resistance under stated assumptions, and its contribution to the measured power depends on the admitted bandwidth. Receiver noise can also include shot noise, flicker noise, oscillator phase-noise effects, interference and gain-dependent distortions. Some components may be correlated in time or across channels. Averaging repeated numerical values does not necessarily confer the usual independent-sample variance reduction upon correlated noise. Nor can it undo an analogue overload that created spurious products in every frame. The laboratory should challenge the entire input chain, not just the arithmetic averaging routine, before advertising an improved measurement limit.

Consider a spectrum analyser with video filtering after detection. A smaller video bandwidth can produce a smoother displayed trace, improving the repeatability with which a persistent feature is visually read. This does not mean that the receiver's instantaneous physical noise voltage has become smaller. The detector and display may respond more slowly, and a brief event can be attenuated or broadened in time. The distinction between measurement resolution bandwidth and video bandwidth must be retained, together with the averaging domain. Mean power, mean logarithmic level and peak-hold are not equivalent. An instrument can offer several of these modes legitimately, but each requires the appropriate calibration and interpretation.

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The distinction becomes more consequential when an SDR survey is conducted in the vicinity of strong legitimate transmissions. A strong neighbouring signal can cause front-end compression or intermodulation, raising or altering the apparent noise floor. An averaging method may reduce the visual irregularity of the output without revealing that the amplifier has entered an invalid state. A weak external burst may be missed because the receiver no longer operates in its calibrated linear region. The output may still display a handsome steady baseline, precisely because smoothing conceals the transient response. Therefore the acquisition record should preserve input gain, attenuation, overload indicators and relevant calibration tests through the operating interval.

One should test the detector with both persistent and intermittent reference signals. For the persistent tone, compare measured amplitude and frequency uncertainty as the averaging length increases, while independently monitoring the input power and receiver state. For the intermittent emitter, randomise burst onset and duration, vary the number of quiet frames in the average, and measure event retention at a fixed false-alarm criterion. Repeat near strong interferers, under representative receiver gain states and at several temperatures. The results may demonstrate a legitimate advantage for long-term spectral-density estimation and a material disadvantage for rare-event discovery. A scientifically honest specification can report both without contradiction.

The retention strategy is as important as the estimator. If the receiver keeps only the averaged trace, later investigators may be unable to discover whether one large burst or many smaller events produced it. A companion event-sensitive channel can preserve peaks, individual segment decisions

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and short raw intervals around material candidates, while a separately labelled mean spectrum provides background context. But peak-hold and event-triggered storage must themselves be tested against noise extremes and selection bias. The archive should include the algorithm version, averaging interval, detector mode and physical measurement plane. A count of saved candidate alarms must be related to effective observation exposure, not to an assumed continuously observed hour.

I would therefore avoid the phrase improved sensitivity without specifying the measure of improvement. A lower variance of a background-power estimate is one legitimate outcome. A lower threshold for detecting a persistent calibrated sinusoid at fixed false-alarm rate may be another. Reliable discovery of sporadic weak emissions requires its own test population and timing model. The result of one cannot be used as a certificate for the others. A system's technical merits can be stated precisely and modestly, without denying the utility of averaging. I invite Dr Hamming to challenge the assumption that collecting many spectral frames necessarily supplies enough independent evidence to justify the advertised noise reduction.

Richard Wesley Hamming | Peer question 5 to William Ralph Bennett

Dr Bennett, you have explained that averaging can reduce the variability of a spectral estimate without changing the input noise itself. Suppose a receiver forms one hundred periodograms from a continuously sampled stream, but consecutive frames overlap by seventy-five percent and share a common oscillator whose phase noise changes slowly. Its software reports a reduction in noise-estimate uncertainty by a factor of ten, as though the one hundred estimates were

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independent. That calculation might be correct for one hundred independent samples of an ideal process, yet materially optimistic for correlated spectral frames. What measurement would establish the effective number of independent observations, and how should the laboratory distinguish noise correlation created by shared samples from correlation caused by common oscillator or interference mechanisms? Could a system still improve its estimate by averaging in spite of this dependence, and how should the benefit be stated without overclaiming a nominal square-root law?

William Ralph Bennett | Immediate answer to Richard Wesley Hamming

Thank you for that question. Dr Hamming, averaging can indeed improve an estimate in the presence of some dependence, but the improvement cannot be inferred from the raw frame count alone. The relevant quantity is the variance or uncertainty of the actual estimator under the process being measured. With correlated frames, the variance of their mean depends upon covariance terms as well as individual variances. Under a stationary sequence model, one may express the variance of the mean through a sum of lag-dependent covariances. That expression reduces to the familiar inverse-K form only when the pertinent covariances vanish. A laboratory should therefore characterise the correlation of its frame estimates under representative conditions, rather than report the square-root of the displayed number of FFT computations as a universal gain.

Shared samples create one source of correlation that follows from the overlap and window schedule. Common oscillator noise or

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environmental interference introduces others, potentially on timescales longer than one frame. The experimental design should vary overlap while holding the underlying acquisition duration fixed, and separately challenge oscillator reference conditions or interference levels where feasible. If the apparent uncertainty reduction changes materially with those conditions, the simplified independence model is not adequate. The report should state the empirical variance of the chosen estimator and the conditions under which it was measured. It may still be useful to calculate an effective sample size, provided the method and its assumptions are disclosed.

The detector's operating characteristics should also be measured directly. Inject independently timed weak bursts and determine whether the averaging scheme retains them under the stated false-alarm criterion. A common oscillator can influence frequency estimation and coherent integration in ways not represented by a simple power average. A persistent signal and an intermittent signal can therefore respond differently to the same noise process. A single statistical gain figure cannot establish both detection capabilities. The confidence intervals for the challenge campaign must reflect independently generated physical events or appropriate clustering, not the number of correlated spectral cells.

The positive claim may be narrower and still valuable: the implemented average produced a measured reduction in the variance of a particular background-power estimate over a specified duration and receiver state. If the laboratory also demonstrates an improved detection probability for a defined persistent tone, it may state that

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separately. Where burst performance deteriorates, it must report the deterioration rather than conceal it behind a smooth trace. This distinction allows an instrument to be judged fairly on its genuine merits. I pass the token to Professor Bridgman for the further problem of whether averages expressed in different measurement domains refer to the same physical quantity.

Percy Williams Bridgman | Peer question 6 to William Ralph Bennett

Dr Bennett, the word average seems to carry several meanings in the receiver's interface. One mode averages linear electrical power, another averages decibel values, a third averages complex voltages, and a fourth retains the greatest peak from each interval. The display may label every one of these choices simply as trace averaging, even though their mathematical and physical properties differ. Suppose a forensic examiner compares results from two instruments without preserving their actual detector modes. Both show the same nominal amplitude in decibels, but one has been computed by taking the logarithm after power averaging while the other has averaged the logarithms. What should be demanded to establish that the two reported values address the same measurand? Would a common reference signal suffice, or must the calibration campaign vary the signal's distribution, duty cycle and noise statistics to expose the difference between the operations? In particular, could a stable calibration tone conceal the disagreement while a varying-power test reveals it, and should the forensic report include the exact mathematical averaging definition?

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William Ralph Bennett | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, the named quantity and the operation used to derive it must be specified before results can be meaningfully compared. Averaging watts and then converting to decibels produces, in general, a different result from averaging logarithmic levels first. Coherent complex averaging can cancel contributions whose phases differ, whereas power averaging does not cancel them for the same reason. Peak-hold is an extreme-value statistic rather than a mean. These operations are not errors merely because their results differ, but their differences are material when the report asserts that they estimate the same physical quantity. A single steady calibration tone may fail to reveal some of the discrepancy, because the relevant values remain nearly constant across the averaging interval.

I would test a set of independent references with varied temporal structure. Include a stable sinusoid, noise with a characterised distribution, an intermittent burst of known duty cycle, and a mixture with a strong neighbour. The purpose is to determine how each algorithm responds to the data population for which the claimed measurand is intended. Calibration must also follow the physical input path and identify the reference plane, impedance, bandwidth and gain state. A digital software comparison can establish that the arithmetic is implemented correctly; it cannot certify analogue response where the test signal bypasses the front end. The

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measurement result should be reported with its detector domain, averaging rule, time interval and uncertainty.

The distinction is particularly important for a rare event. A logarithmic average can be dominated differently by low-level intervals than a power average, while a maximum trace can be driven by a single noisy fluctuation. The latter requires an independently validated false-alarm rule before an isolated maximum is interpreted as an emission. A power average can faithfully describe mean energy while failing to retain event time. A coherent average can be powerful for a phase-locked signal but can attenuate a transmitter whose phase changes unpredictably. The investigator must choose the method for the scientific question and avoid retrospective selection of the most persuasive output.

If the two instruments cannot be related through a demonstrated model and a representative challenge set, their numerical agreement should be regarded as limited. The report may preserve each instrument's result as an observation from its own defined procedure, without combining them into a false common measurement. Conversely, a demonstrated relation between methods can support a correction with a stated uncertainty. The strength of the conclusion depends on the evidence for that relation, not on the similarity of the units printed on the screens. I return the floor respectfully to Professor Tukey for the problem of validating a receiver that offers both baseline smoothing and event-sensitive detection.

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John Wilder Tukey | Principal response 5: Rare-event validation and the danger of selecting favourable averages

Dr. Atkinson, a collection of averaged spectral displays is a useful starting point for inquiry, not its conclusion. We ought to examine which questions those displays answer well, which questions they answer badly and which questions they cannot answer because the underlying data were discarded. The choice between mean, median, maximum and coherent averaging should follow the intended measurand and the admitted signal class. It is misleading to call one method universally best when it improves background-power precision but suppresses the very rare events the investigator is commissioned to discover. The legitimate use of several methods requires a declared selection policy and a validation experiment that tests the full procedure, not merely each method in isolation.

The first part of the campaign should be exploratory and unashamedly so. Use simulations and independent reference injections to discover how the detector behaves under persistent tones, single short bursts, repeated packets, changing interference and receiver gain transitions. Compare the raw records with the average and event-sensitive outputs. Explore where a median suppresses an unusual high-power excursion, where a mean dilutes a one-frame burst and where a maximum triggers on pure noise. Such exploration helps identify possible failure modes and choose a candidate procedure. It should be documented, but its selected favourable outcomes are not an unbiased estimate of the final procedure's field performance. A fresh validation population is needed once the method is chosen.

The second part should employ withheld challenge trials representing the claimed operating envelope. Randomise event onset relative to the FFT

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windows, vary signal duration, duty cycle, amplitude and modulation, and place strong neighbouring emissions at selected offsets. Use independently known sources to distinguish true events from receiver-generated artefacts. Preserve all valid and invalid outcomes, together with the software configuration, reference plane, clock condition and detector state. If the method is adaptive, the adaptation and its training history are part of the implemented detector. A confidence statement about a frozen mean estimator should not be transferred to a more complicated algorithm that chooses between mean and maximum according to its own recent history.

One must define what constitutes an independent trial. A single physical burst may influence several overlapping FFT frames, and the same interference event may contaminate many bins. Counting those correlated numerical results as separate confirmations leads to overconfident uncertainty estimates. A trial should correspond to an independently generated physical event or another justified sampling unit. Event clustering should be predeclared and evaluated under different burst durations, since an overly generous clustering window may merge separate transmissions while a narrow one may split one event into several apparent alarms. The selected unit determines the meaning of a detection rate, and the report should not alter it silently after observing the outcomes.

A further question concerns multiple comparisons. A detector may examine a large number of frequency-time cells and choose the most conspicuous excursions. Even if a per-cell threshold has a small false-alarm rate, an entire survey can produce some false alarms merely through the number of tests. Dependence among cells makes a simple independence calculation only an illustration, so the full implemented decision rule should

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be challenged using noise-only and interference-only populations. The laboratory should distinguish the probability of an alarm given no qualifying signal from the probability that a particular alarm is caused by a covert emitter. The latter requires source prevalence and alternative explanations which are not supplied by the detector's false-alarm specification alone.

For negative evidence, the challenge must include exposure. A scan lasting an hour may observe a given channel for only a fraction of that time. An alarm-free average may cover only the intervals that were actually sampled, and a rare burst may have occurred elsewhere. A claim that no hidden transmitter operated requires evidence about the transmitter class's possible timing, the receiver's dwell pattern and the probability of detection during admitted exposure. If those conditions are unknown, an appropriate conclusion may be only that no qualifying alarm was retained. Such a statement can be operationally useful but must not be inflated into a universal absence finding.

The retained evidence should also support review of competing causes. An anomalous spectral excursion may be genuine transmission, a power-line event, automatic-gain recovery, local oscillator behaviour or numerical processing. A mean may hide the transient; a maximum may reveal it without identifying the cause. Independent receiver substitution, controlled input attenuation, retuning and source injection can provide information when they produce different predictions for the alternatives. The report should preserve the outcomes of both confirming and disconfirming trials. A smooth display and a persuasive narrative do not eliminate the need for a reproducible test of causation.

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The final product should identify the measurement purpose and the statistical operations in a compact, inspectable form. Report background estimates separately from event detections. Specify average type and duration, window overlap, detector thresholds, event-clustering policy, reference calibration, data retention and uncertainty. Include a map of periods in which observation was invalid or impossible. Preserve raw sample intervals around material candidates wherever feasible. This is not a demand for universal storage of every bit. It is the requirement that evidential claims remain bounded by the information the instrument actually retained. I invite Sir Ronald Fisher to challenge how an investigator can estimate a low false-negative probability when the signal of interest is rare and the receiver may select the most favourable averaging rule after inspecting the data.

Sir Ronald Aylmer Fisher | Peer question 7 to John Wilder Tukey

Professor Tukey, suppose a laboratory evaluates ten averaging rules using a small collection of twenty independently injected bursts, selects the rule which detected the most bursts, and then reports that the selected detector has near-perfect sensitivity. That procedure uses the same data for selection and assessment, so its reported performance may be optimistic even when the individual calculations are correct. Would you require another blind test population, and how should the confidence statement account for the repeated search among methods? I am also concerned that each injected burst may appear in several overlapping FFT frames, creating an illusion of a much larger sample size. What would constitute a legitimate independent observation, how should false positives be counted in a wideband receiver examining thousands

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of spectral cells, and how ought the laboratory communicate the uncertainty remaining when only a few rare events have been deliberately tested? Would the numerical confidence interval have the same meaning if the selected algorithm had instead been fixed before the twenty trials began, and what limitation follows from that distinction?

John Wilder Tukey | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, the selected method should ordinarily be tested against a fresh withheld population if the earlier bursts were used to choose among the candidate rules. The development outcomes remain valuable as evidence of why the method was chosen, but they do not provide an independent estimate of its performance after selection. If a design intends to use all observations in one integrated inferential procedure, its error control must explicitly account for the selection. Without such an adjustment, the smallest apparent error rate among many tested choices is an optimistic description of the final detector. A competent report should distinguish the exploratory selection process from validation and preserve all unsuccessful trials rather than presenting only the best result.

The independent trial unit should be a defined physical event or justified observation interval, not each numerical frame generated from shared samples. If one injected packet triggers five overlapping FFT frames, it generally contributes one trial to the packet-detection estimate, while the detector's event-clustering rule determines whether the output is recorded as one alarm or several. That clustering rule itself should be tested because it can merge

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neighbouring events or split a long one. For false-alarm evaluation, the relevant rate may be alarms per independently exposed interval or per unit effective observation time, depending on the task. The result should preserve the actual scan schedule and invalid intervals so that an apparent decrease in alarms cannot be caused simply by reduced exposure.

A confidence bound derived from only a few independent events will be broad. The laboratory should not represent a small favourable sample as proof of near-certain detection across all frequencies, amplitudes and burst types. A predeclared acceptance rule should specify the minimum performance, the confidence required and the relevant operating envelope. If the programme covers several distinct conditions, its claim about minimum performance must account for joint coverage or specify a defensible limiting condition. Where the data cannot establish the proposed bound, the outcome is indeterminate, not proof of failure and not certification of success. Additional challenge trials or a narrower claim may be warranted.

Finally, the probability that a particular field alarm represents a covert transmitter is not equal to the detector's sensitivity or its false-positive rate. Attribution depends on the prevalence of physical sources, competing artefacts and the discriminatory value of independent interventions. A receiver can be well validated for detecting a class of injected signals while one field indication remains ambiguous. Conversely, a low average spectral level does not establish the absence of short transmissions when the retention rule can hide them. The honest report should preserve these distinct

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propositions and the evidence supporting each. I return the token to Dr. Atkinson for the final synthesis of what spectral averaging can and cannot establish about intermittent electromagnetic events.

Ten worked applications: spectral averages, event retention and statistical uncertainty

Maurice Stevenson Bartlett, Cross-Peer Question to Norbert Wiener: Professor Wiener, does averaging a hundred successive spectra imply that a single short emission will remain visible after the noise floor settles?

Norbert Wiener, Cross-Peer Answer to Maurice Stevenson Bartlett: Professor Bartlett, only under conditions favourable to that statistic. Arithmetic averaging of power spectra can dilute a one-frame burst by approximately the number of contributing frames when it does not recur, while a peak-hold detector may preserve visibility at the expense of a different false-alarm structure. The outcome depends on whether spectra, complex amplitudes or logarithmic display values are averaged and on their window overlap and normalisation. Challenge the processor with pulses of known duration and phase relative to frame boundaries, and compare the raw sequence with averaged products. A smoother display is not evidence that the environment was uniformly quiet. Store event-preserving excerpts or validated trigger records alongside the averaged survey trend. I pass the token to Dr Shannon for what the mean discards.

Norbert Wiener, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, if only the average spectrum was retained, what physical claim about intermittency can no longer be verified?

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Claude Elwood Shannon, Cross-Peer Answer to Norbert Wiener: Professor Wiener, many distinct temporal histories can have the same average power spectrum. A continuous low-level source and rare stronger bursts may contribute similar averages after appropriate scaling, yet imply very different surveillance risks. Once only the mean remains, individual arrival times, durations and sequencing may be irretrievable. A later investigator can analyse the average as a specified statistical product, but cannot treat it as a record of every event. If the application requires proof of absence during short intervals, retain time-resolved spectra or raw I/Q at adequate cadence, and document scanner dwell and processing dead time. Describe unobserved intervals explicitly instead of extrapolating the averaged trace to them. I yield to Dr Bennett on noise-model dependence.

Claude Elwood Shannon, Cross-Peer Question to William Ralph Bennett: Dr Bennett, a spectral average reduces random-looking fluctuations. Why might that improvement exaggerate confidence when quantisation or receiver-generated interference is correlated?

William Ralph Bennett, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the familiar reduction in standard error with the square root of the number of averages assumes effective independence and an appropriate distribution. Reused input samples, overlapping windows, common clock spurs and gain-state correlations reduce the effective independent information. A deterministic artefact may remain as a stable line regardless of the number of averages. Measure covariance between frames and repeat the acquisition with a terminated input, independent clock and alternative gain setting. Report the processing bandwidth and both spectral-density and integrated-power measures; do not conflate them.

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If a short burst was missed by the averaging scheme, that is a detection-system limitation, not improved converter noise performance. I pass the token to Professor Tukey for the selection and reporting rule.

William Ralph Bennett, Cross-Peer Question to John Wilder Tukey: Professor Tukey, how should the analyst compare average, median and maximum spectra without retrospectively selecting whichever makes one suspicious line strongest?

John Wilder Tukey, Cross-Peer Answer to William Ralph Bennett: Dr Bennett, specify in advance the operational objective: background power estimation, robust rejection of outliers or interception of rare events. Those estimators answer different questions. Compare them in a blinded set containing both noise-only intervals and known injected short signals; measure error, detection probability and false alarms per time and frequency exposure. A median can suppress intermittent events, while a maximum tends to rise with the number of opportunities searched. The mean may provide a reliable stationary-background estimate without capturing every transient. Preserve or at least account for the original frame-level records and disclose all tested statistics. Reporting only the winning estimator would invalidate a single-test significance claim. I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator concluding synthesis

Distinguished colleagues, we have distinguished the stability of a spectral estimate from the detection of a short-lived electromagnetic event. Averaging is a legitimate and often powerful operation when its purpose is stated. Mean power estimates can characterise an admitted background process; robust statistics can reduce the effect of unusual observations upon a baseline; coherent integration can improve estimation of a suitable

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phase-locked waveform; and display smoothing can make persistent features easier to inspect. None of those achievements, without further evidence, establishes the receiver's probability of detecting an unpredictable brief transmission. A smooth waterfall may be a good background display and an insufficient record of the events that occurred within its averaging interval.

Professor Bartlett has emphasised that the mean periodogram and a rare-event detector answer different questions. Professor Wiener has shown how recursive averages and adaptive thresholds can make the displayed result depend on preceding observations, sometimes extending an event's apparent duration or concealing an event's peak. Dr Shannon has explained why an accurate average is not an invertible account of the individual frames which created it. Dr Bennett has separated reduced estimator variance from changes in the receiver's physical input noise and sensitivity. Professor Tukey has required independent tests, predeclared event units and transparent reporting of false alarms, missed detections and selective retention. The seven peer exchanges have challenged the stationarity, independence and inferential assumptions beneath an apparently simple average.

The ten worked applications provide quantitative discipline. One large burst among ninety-nine quiet frames produced a modest power mean, and the corresponding median omitted the exceptional level entirely. A recursive average attenuated the burst's first contribution and retained a decaying memory after the event ended. Averaging power in linear units produced a different result from averaging decibels. The familiar variance reduction from independent measurements was much weaker under a stipulated

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positive-correlation model. A small nominal per-cell false-alarm probability became less reassuring across many comparisons, and intermittent scan exposure limited unconditional detection despite strong conditional performance. Coherent voltage averaging cancelled opposed phases even though the mean power remained nonzero. Thirty successful independent tests did not support an implausibly narrow high-confidence performance guarantee. Every calculation is a stipulated example, not an instrument certificate.

A defensive technical surveillance countermeasures report should identify the averaging domain, window, interval, overlap, input reference plane, sample and frequency calibration, threshold history and event-retention rule. It should preserve per-event evidence and raw intervals where practical, separately from any long-term background estimate. A detector claiming to discover sporadic transmissions should be validated with randomly timed sparse bursts and appropriate interference, rather than only with continuous carriers or conveniently centred reference signals. Its false-positive and false-negative characteristics must be calculated using meaningful independent trial units and exposure conditions. The same observations processed under several methods do not become independent corroboration merely because the software produces several plots.

The central evidential qualification concerns negative findings. An alarm-free average cannot establish universal absence if short emissions could have been diluted, cancelled, rejected by a robust estimator, omitted by triggered retention or missed during a scan gap. The investigator may still state that the particular validated procedure detected no qualifying event

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during its admitted observation intervals. A stronger assurance claim requires evidence about detection probability and source behaviour within the stated envelope. Where such evidence is insufficient, the result must remain bounded rather than amplified by rhetoric.

We therefore accept spectral averaging as an important instrument of measurement, not as a universal method of surveillance discovery. The correct procedure is to define the measurand, choose the statistic whose properties address it, preserve the evidence that alternative questions may require, and test the full process under conditions designed to reveal material failure. The following discussion will examine how overlapping analysis windows alter the count of genuinely independent detection opportunities, a question which has already appeared repeatedly in the present exchanges. I thank the contributors and formally conclude Question 043.

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Ten worked engineering applications | Question 043

Worked application 1: Dilution of one burst in a hundred-frame power mean

Let K=100 denote the number of equally weighted spectral-power frames, B=1 milliwatt the background level in each frame, and S=99 milliwatts the additional power of a burst present in only one frame. The active frame contains B+S=100 milliwatts, while the remaining ninety-nine contain B. Their arithmetic mean is [100+99(1)]/100=1.99 milliwatts. The excess above the background in the averaged result is 0.99 milliwatt, whereas the active frame's excess was 99 milliwatts. The excess has therefore been diluted by the factor 100. A low final mean does not establish that no high-power event occurred in the contributing interval; it describes a different measured quantity.

Worked application 2: Mean versus median of sparse spectral power

Take an ordered population of 100 spectral-power readings, ninety-nine equal to 1 arbitrary power unit and one equal to 100 units. The arithmetic mean is (99+100)/100=1.99 units. The median is 1 unit because both central order statistics come from the ninety-nine low readings. The median may therefore be useful for estimating the ordinary background while completely omitting the exceptional event from the displayed statistic. The result is not a defect in the median. It demonstrates that robustness against rare excursions and sensitivity to rare emissions are different objectives. The event-sensitive record must be preserved separately if that rare excursion is investigatively material.

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Worked application 3: Initial response of an exponential power average

Let the recursive update be $A_k=\alpha P_k+(1-\alpha)A_{(k-1)}$, with $\alpha=0.05$. Suppose the initial average equals a background B and the current frame contains additional power S=50 units. The immediate excess in the updated average is $\alpha S=2.5$ units, only five percent of the burst excess. If the following frames return to background, the excess after ten further updates is $2.5(0.95)^{10}$, approximately 1.4968 units. The apparent persistence of the raised average reflects the filter's memory rather than a verified continuation of transmission. Reconstructing the original burst from the average requires knowledge of the update rule, starting state and missing-data history.

Worked application 4: Power averaging versus decibel averaging

Consider two linear power measurements, $P_1=1$ milliwatt and $P_2=100$ milliwatts. Their arithmetic power mean is 50.5 milliwatts, or $10 \log10(50.5)=17.0329$ dBm. The individual readings are 0 dBm and 20 dBm; their arithmetic average in decibels is 10 dBm, corresponding to 10 milliwatts. Thus averaging the power values and then converting to decibels gives a markedly different result from averaging logarithmic values first. Neither operation is inherently improper, but the word average does not identify which quantity was measured. The detector mode and averaging domain must accompany any physical power claim.

Worked application 5: Variance reduction under independent frames

Suppose K=20 independent, identically distributed spectral estimates have common variance σ^2 under a valid stationary model. The

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variance of their arithmetic mean is sigma^2/K and its standard deviation is sigma/sqrt(K)=0.223607 sigma, about 22.36 percent of the standard deviation of one estimate. This is the familiar variance-reduction benefit of averaging independent observations. It does not apply without qualification to overlapping FFT frames with shared samples or to a time-varying noise environment. The actual covariance structure determines whether the reduction is smaller or larger than the simple independence model predicts.

Worked application 6: Effective sample size under positive correlation

Assume one hundred spectral estimates have equal variance sigma^2 and the same pairwise correlation rho=0.2, a deliberately simplified equicorrelation model. The variance of their mean is sigma^2[1+(K-1)rho]/K, giving sigma^2(1+99(0.2))/100=0.208 sigma^2. An equivalent independent-sample count defined by K_eff=sigma^2/Var(mean) is approximately 4.8077, not 100. Such broad positive correlation can arise in a different form from common noise or slowly varying state, although real FFT-frame covariance need not be equicorrelated. This example shows why the actual dependence must be characterised before claiming a nominal tenfold reduction in the standard deviation of a spectral estimate.

Worked application 7: A family-wise false-alarm illustration

Let K=2,000 be the number of hypothetical independent noise-only tests and let p=0.0001 be the fixed false-alarm probability of each test. Under the independence model, the probability of at least one false alarm is 1-(1-p)^K=1-(0.9999)^2000, approximately 0.181277, or 18.13

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percent. Overlapping spectrogram cells and several alternative averages are not normally independent, so this calculation is not a measured alarm probability for a real SDR. It demonstrates that an apparently reassuring single-cell threshold must not be substituted for validation of the complete multi-cell decision rule.

Worked application 8: Observation duty factor and unconditional detection

Suppose the receiver admits a particular band for fifty milliseconds in each five-hundred-millisecond scanning cycle. The dwell fraction is D=0.05/0.5=0.1. Assume an isolated event is so short that boundary effects are negligible and its onset is uniformly distributed relative to scan phase. If a fully exposed burst is recognised with probability 0.9, the unconditional probability under the simplified model is approximately 0.1 times 0.9=0.09, or nine percent. Averaging cannot recover an event that occurred entirely outside the admitted dwell. A negative finding requires consideration of the physical exposure schedule as well as the conditional detector behaviour.

Worked application 9: The distinction between coherent and incoherent averaging

Let two calibrated complex voltage samples have equal unit magnitude but opposing phase, represented by 1 and -1. Their coherent complex mean is (1+(-1))/2=0, whereas their mean squared magnitudes equal (|1|^2+|-1|^2)/2=1. Thus the complex mean can cancel even when each contributing frame contains unit power. A phase-locked signal may benefit from coherent integration, but a signal whose phase reverses or

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changes unpredictably may not. The chosen averaging domain must match the admitted waveform model. A zero complex average is not proof that every underlying frame contained zero energy.

Worked application 10: Zero-miss sample size and a one-sided lower performance bound

Suppose a detector is challenged by n=30 independent physical events drawn from one specified signal class and detects all thirty. Under a simple binomial model with unknown true detection probability p, a one-sided 95-percent exact lower confidence limit after thirty successes is p_lower=(0.05)^(1/30), approximately 0.904966. Thus even a perfect observed record of thirty successes does not justify a 95-percent confidence claim that the detection probability exceeds 99 percent. This calculation concerns one predeclared homogeneous test population. It does not provide simultaneous assurance for many frequencies, burst durations or interference environments, and overlapping frames do not create extra independent successes.

Scholarly source register and precise scope of use

[S1] SciPy Project, official `scipy.signal.welch` documentation, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.welch.html . Read scope: segmentation into overlapping periodograms, mean and median averaging, scaling conventions, overlap and source references to Welch and Bartlett. Not treated as a calibration certificate for any real receiver.

[S2] SciPy Project, official `scipy.signal.welch` example, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.welch.html?highlight=window . Read scope: demonstration that an exceptional high-power interval affects mean and median periodogram summaries differently, and the

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distinction between spectral-density and squared-magnitude scaling. The forensic conclusions are original synthesis.

[S3] Anritsu, *Spectrum Analyzer Measurement Guide*, Video Bandwidth, https://dl.cdn-anritsu.com/en-us/test-measurement/ohs/10450-00025A/Spectrum%20Analyzer%20Measurement%20Guide/2_SPA.2.06.html . Read scope: video filtering smooths the displayed noise variation and is not equivalent to an improvement in intrinsic sensitivity. Operating settings require receiver-specific verification.

[S4] National Radio Systems Committee, *NRSC-G201*, public historical PDF, https://www.nrscstandards.org/standards-and-guidelines/documents/archive/nrsc-g201.pdf . Limited scope: returned section addressing power-responding detectors and the difference between linear-power and logarithmic averaging. Full current applicability and amendments were not verified.

[S5] Royal Society Catalogue, Maurice Stevenson Bartlett, https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA5174&src=CalmView.Persons . Read scope: dates, nationality, education and election to the Royal Society.

[S6] Science Museum Group, Norbert Wiener, https://collection.sciencemuseumgroup.org.uk/people/ap28721/wiener-norbert . Read scope: dates, professional background and cybernetics.

[S7] IEEE Engineering and Technology History Wiki, William R. Bennett, https://ethw.org/William_R._Bennett . Read scope: elder Bennett's Bell Laboratories work, education, noise and communications research.

[S8] Library of Congress, *William Ralph Bennett Papers*, https://findingaids.loc.gov/repositories/19/resources/6959 . Read scope: distinction between William R. Bennett (1904–1983) and his son William Ralph Bennett (1930–2008), and their respective research careers.

[S9] IEEE Information Theory Society, Claude E. Shannon, https://www.itsoc.org/about/shannon . Read scope: academic and Bell Laboratories background and historical contributions.

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[S10] IEEE Computer Society, *John Wilder Tukey*, https://history.computer.org/pioneers/tukey.html . Read scope: professional career, research contributions and the Cooley–Tukey FFT connection.

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QUESTION 044

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How should overlapping windows affect counts of independent detection opportunities?

Source: V011_Roundtable_Question_044_CP044_Dr_Atkinson(2).docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 044. Complete Expert Roundtable Discussion

Original constructed educational dialogue. Historical participants are used as intellectual personae, not as literal speakers in any historical meeting. This discussion consists of original educational dialogue, not historical quotation.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, the preceding discussion demonstrated that spectral averaging can provide a reliable estimate of a selected background property while concealing the duration, timing or even existence of a rare event. It also demonstrated that overlapping FFT frames often reuse the same samples. Our present inquiry asks the further question which follows naturally: when a digital receiver reports several alarms in overlapping windows, how many independent detection opportunities have actually occurred? An instrument may calculate thousands of spectral frames per second, yet those frames do not automatically represent thousands of independent observations of the physical environment. A burst crossing several analysis windows may be one transmission, while one slowly varying interference process may produce a family of correlated spectral excursions. The meaning of an alarm count depends on the acquisition design and event definition rather than the number of numerical arrays produced by the processor.

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We can state the counting problem mathematically. Let N denote the number of samples in one FFT frame, let H be the hop length between successive frame starts, and let F_s be the sampling rate in samples per second. The nominal frame duration is $T=N/F_s$ and the hop duration is $h=H/F_s$. The overlap fraction is $(N-H)/N$ when H is no greater than N. If N=4,096 samples and H=1,024, consecutive frames overlap by 75 percent. Their starts are separated by one-quarter of a frame duration. The software therefore generates four frame starts in a period the length of one frame, but the resulting estimates share substantial underlying evidence. Whether their detection decisions are correlated also depends upon window coefficients, the signal, the noise process and the decision statistic. None of these dependencies can be inferred from the frame count alone.

One must distinguish at least four objects: an FFT calculation, a detector threshold crossing, a retained alarm record, and a physical emission. The number of calculations can exceed the number of threshold crossings; one crossing may be suppressed by a retention rule; and several retained alarms may be generated by one physical event. Conversely, one frame may contain several independent emissions whose spectral overlap makes them appear as a single peak. The conversion from numerical observations to physical-event counts is therefore an inference requiring definitions, algorithms, uncertainty and empirical challenge tests. A database which stores only an alarm count but not the event-segmentation policy can become dangerously misleading when a later examiner attempts to reconstruct transmitter activity.

Statistical confidence requires equal care. The common square-root reduction in error from independent averaging does not automatically apply

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to overlapping frames. The variance of a mean from dependent observations includes covariances among those observations. Likewise, the probability of at least one false alarm in a collection of threshold tests cannot be computed by a simple independence formula without examining whether the tests are dependent and how the software combines them. A very large number of densely overlapping windows can give the appearance of abundant corroboration while reusing only a limited interval of measured radio-frequency input. We require methods that make this dependence explicit and testable.

The panel will examine these boundaries from several perspectives. Professor Bartlett will consider the covariance of spectral estimates. Dr Shewhart will ask how the detector distinguishes natural process fluctuations from new physical events. Professor Neyman will examine uncertainty and simultaneous claims across many correlated tests. Professor Wiener will assess history-dependent clustering and feedback. Professor Tukey will develop a practical validation campaign for a wideband defensive survey. Seven colleagues will challenge those responses with questions about sample reuse, false alarms, event identity, timing uncertainty and evidence preservation. We shall distinguish overlapping mathematical observations from truly independent acquisition paths and from the far stronger claim that a particular external source has been independently corroborated.

We will not reject overlap as an engineering method. It can improve time coverage, mitigate window-edge losses and supply useful estimates for an evolving signal. The task is to describe what it achieves and what it does not. A receiver should be judged on demonstrated detection and attribution

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performance, not on the visual abundance of its waterfall frames. I invite Professor Bartlett to address the covariance structure of overlapping spectral estimates, and to explain why the number of frame starts is an inadequate measure of the independent information available to an investigator.

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Maurice Stevenson Bartlett | Principal response 1: Covariance and the effective number of observations

Dr. Atkinson, the central distinction is between producing numerous statistics and acquiring numerous independent observations. A sequence of windowed Fourier estimates can be generated from a finite record with almost arbitrarily dense overlap. If the hop is one sample, consecutive windows of thousands of samples differ only by a small portion of their inputs. Their outputs can be highly dependent under many signal and noise models. Even when the sample-level noise is independent, the overlap and subsequent nonlinear power calculation can introduce dependence among spectral estimates. One must therefore examine the covariance of the actual estimator rather than divide uncertainty by the square root of the number of numerical frames on the screen.

For a sequence of K estimators with common variance sigma squared and lag-dependent correlations rho_h under a stationary approximation, the variance of their arithmetic mean is sigma squared divided by K multiplied by a factor which incorporates the weighted sum of the lag correlations. In one conventional form the factor is 1+2 sum over h from one to K minus one of (1-h/K)rho_h. If all relevant lag correlations vanish, the independent-sample result emerges. If positive correlation persists across many lags, the effective information in the K results can be much smaller than their nominal count. This formula is a model-dependent calculation and should be verified against actual receiver and noise conditions. It is not evidence that every overlapping spectrogram has one universal effective sample size.

The window coefficients matter. A rectangular window, a Hann taper and a concentration-optimised sequence assign different weights to shared

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samples. Their output statistics can consequently exhibit different covariance for the same hop length. A frequency bin occupied by a persistent strong carrier may exhibit a different dependence structure from a noise-only bin. When the receiver's analogue gain or noise floor changes with time, the stationary approximation may fail, and a single effective sample-size calculation for the entire session may be misleading. The laboratory must first identify a reasonably homogeneous operating interval or adopt and test a model which describes the changes. A numerical average can be stable even though the process generating the data has changed.

One should be cautious when translating this problem into the count of physical events. A single transmission may occupy several consecutive windows. If the software records an alarm each time a frame crosses threshold, a long packet can be overcounted. If it clusters alarms using a fixed time gap, two separate packets close together may be merged. The appropriate cluster duration depends upon the admitted source waveform, receiver timing accuracy and detector response. A clustering rule therefore requires validation against known bursts whose separation and modulation have been varied independently. It cannot be treated as merely an administrative database setting.

In an unattended defensive surveillance system, several numerical stages may affect the count: digital channelisation, FFT-window overlap, spectral smoothing, threshold adaptation, candidate association and retention. Each stage can introduce correlations or losses. The investigator should preserve the exact processing order, time-stamped configuration history and source identifiers connecting each alarm with its originating raw

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interval. Where storage constraints prevent retention of the complete stream, the system should preserve independently selected audit intervals and a truthful record of unobserved or invalid periods. A later examiner can then distinguish a physical negative observation from an absence created by a selection policy.

For a practical acceptance campaign, generate isolated bursts at randomly selected times and determine how many frame-level threshold crossings each creates. Repeat with pairs of bursts whose separation approaches the clustering threshold, and with long transmissions whose tails span many windows. Include noise-only intervals and strong legitimate interferers to measure correlated false alarms. Estimate detection probability per independently injected physical event, not per triggered FFT frame, and report how that probability changes with the event's arrival position and duration. Where the claimed result is an average spectral-density estimate, calculate the estimator's uncertainty under its measured dependence. Where the result is an event count, examine missed, split and merged events separately.

The scientific conclusion should reflect the quantity actually tested. A receiver may process ten thousand overlapping FFT frames and thereby improve its temporal coverage compared with a non-overlapping design. It does not follow that it acquired ten thousand independent samples of the event population. A dense waterfall may assist discovery of a burst that otherwise falls near a window edge. It can also produce numerous correlated alarms from one internal artefact. For source attribution, independent receiver paths, controlled input interventions or other physical evidence may still be required. Statistical dependence and physical

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causation are distinct questions, but neither can be ignored when the analyst converts many numerical detections into one confident statement about an external emitter.

I would preserve, therefore, the frame geometry, the detector's event unit, the actual observation exposure and the covariance evidence supporting any uncertainty calculation. A short concise report can contain a clear performance statement, while its supporting audit file retains sufficient details for replication. Where the covariance cannot be characterised, one should not falsely attach the confidence of independent trials to correlated data. The honest conclusion may be a bounded estimate with an explicit dependence qualification. That is the appropriate use of mathematical statistics in a technical surveillance countermeasures doctrine. I invite Dr Hamming to ask whether this level of dependence analysis can be implemented practically in a wideband receiver without overwhelming its storage and processing budget.

Richard Wesley Hamming | Peer question 1 to Maurice Stevenson Bartlett

Professor Bartlett, the theoretical covariance problem is well stated, but I wish to examine practical implementation. A monitoring receiver may process many millions of samples per second across several digital channels, each with overlapping FFT windows, adaptive thresholds and candidate-association algorithms. It is not always feasible to retain the entire raw stream or calculate a complete covariance matrix for every frequency and receiver state. What compact statistics and validation records would you regard as sufficient to support a bounded claim about the independence of detection opportunities? Could the laboratory

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preserve representative noise-only intervals, the hop and window parameters, a correlation summary and a sample of raw candidate intervals? How should it assess the danger that the selected audit intervals fail to represent the same interference environment as the material detections? Above all, where should an investigator place the boundary between a scientifically defensible reduced record and an archive whose apparent precision cannot survive independent forensic examination?

Maurice Stevenson Bartlett | Immediate answer to Richard Wesley Hamming

Dr Hamming, the required archive should be proportionate to the claim, but proportionality is not a licence to omit the variables upon which the claim depends. If the purpose is to establish only that the detector produced certain alarms under a documented configuration, a compact event log and a versioned record of the processing chain may be adequate. If the claim concerns the rate of independent physical emissions, the laboratory must also demonstrate the performance of its event-clustering and exposure rules. If the claim involves a narrow uncertainty bound based on many apparently repeated observations, the dependence of those observations becomes a material part of the evidence. The operator should decide which of these propositions is intended before selecting the retention policy.

A practical system could preserve the window and hop definitions, timebase and gain-state logs, alarm-to-frame associations, clustering decisions, and a statistically designed set of untriggered audit

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intervals. The audit intervals should be selected independently of the detector's own alarm decisions where feasible, rather than chosen only from quiet-looking portions of the survey. This reduces the risk of evaluating performance exclusively on examples selected for their apparent success. Reference challenges with known injected events should be performed across representative receiver states to measure split, merged and missed events. They can provide a bounded operating characteristic without requiring a covariance matrix for every instant in the historical survey.

For an estimator's uncertainty, the laboratory may compute empirical correlation functions, use appropriate block-based resampling where its assumptions are met, or compare the uncertainty of estimates from separately acquired non-overlapping intervals. Each method has limitations and should be tested against the process being characterised. A brief noise-only laboratory test cannot automatically represent a field environment with strong intermittent interference. The report should state the admitted operating envelope and any evidence of nonstationarity. Where the source population changes abruptly, a single stationary covariance estimate across the whole session may be inappropriate.

I would also distinguish storage efficiency from evidential sufficiency. A derivative spectral file may be much smaller than a raw stream yet retain enough information to reproduce the specific detector result, provided its processing version and necessary configuration are preserved. It may not permit reanalysis of an alternative event definition or source hypothesis. The laboratory

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should state those limitations explicitly. Retaining raw candidate intervals and independent audit intervals may provide a workable compromise, but the unrecorded time cannot be treated as observed merely because the software issued no alarms. That distinction is as important as the arithmetic of the covariance estimate.

The principled boundary is reached when a proposed conclusion depends materially on information neither retained nor independently characterised. At that point the report should narrow the conclusion or acknowledge indeterminacy. A modest event count with a validated clustering rule can be useful. An ostensible count of thousands of independent transmitters derived from overlapping FFT detections without source identification would be misleading. Statistical discipline is compatible with efficient engineering when the measurand and acceptance criteria are defined in advance. I return the floor to Dr Shewhart for an examination of the way operating-process changes can imitate separate events even when the underlying electromagnetic source remains the same.

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Walter Andrew Shewhart | Principal response 2: Process stability, event segmentation and the evidential definition of an alarm

Dr. Atkinson, I approach this problem through the distinction between a process measurement and a decision made about a process. In statistical process control a succession of plotted points may help reveal a change, but the number of plotted points is not the number of distinct causes which have acted upon the process. An investigator looking at overlapped spectral estimates confronts a related difficulty. Each frame is a calculation using a window of observations; its threshold crossing is a decision under a rule; the underlying electromagnetic episode is a physical occurrence. Counting those three entities as though they were interchangeable creates an impressive-looking statistical report whose units have not been defined. The first task is therefore to specify whether the claimed measurand is a frame-level detection rate, a rate of discrete emission episodes, an estimate of occupied time, or a count of distinct transmitters. These are not synonyms, and their appropriate validation experiments differ. [S1]

Consider a persistent carrier which sits just below a detection threshold while its apparent power varies because of fading, antenna motion and the receiver's changing gain. A collection of overlapping spectral windows may produce a series of threshold crossings, then an interval without crossings, then more crossings. Software that treats every rising crossing as a new transmission may manufacture a plurality of events from one continuing source. A different clustering rule can merge two genuine short bursts into one episode. Neither error is corrected by taking a prettier average of the power spectrum. Both are failures to relate the statistical decision to the physical event one intends to count. Accordingly I would define a candidate

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event by a set of operational conditions: frequency tolerance, temporal adjacency, admissible modulation changes, receiver-state continuity, and the rules governing when an event begins and ends. These rules must be declared before viewing the strongest case examples.

An overlapping-window detector is especially vulnerable when adaptive thresholds respond to the very disturbances under examination. If a burst causes a short increase in the estimated noise floor, subsequent frames can fall below a raised threshold despite continued physical emission. When the disturbance ends, the threshold may relax and produce a fresh apparent alarm. The combination of adaptation and overlap can therefore split or conceal episodes in ways a fixed-threshold laboratory demonstration does not reproduce. Validation should observe the full temporal trajectory of the threshold, the input power and the alarm state. The resulting account must include the detector's memory, update constants, hysteresis and reset behaviour. A single entry saying 'alarm detected' cannot explain those causal transitions.

For a quantitative acceptance campaign I would construct a challenge population that includes stationary noise, drifting noise, strong innocent interferers, intermittent known signals and pairs of bursts with controlled separations. Randomise burst arrival relative to the FFT hop, and vary the timing independently of any operator intervention. Then calculate a confusion table in terms of the actual injected physical events: how many are correctly detected, omitted, split into several reports, or merged with a neighbour? An engineering laboratory may properly use hundreds of overlapping frames to produce a feature estimate, but it should evaluate the event-level performance against the number of deliberately generated

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events. An apparently excellent frame-level recall may coexist with poor episode segmentation, and an event-based metric can expose that distinction.

I would place the process in time as well as frequency. A receiver whose gain state changes halfway through a survey is not necessarily operating under a single statistical population. The distribution of its detection statistic may change with ambient temperature, ADC overload, automatic gain control, preselector insertion, oscillator retuning or an operator's intervention. Pooling all frames into one estimate of a stable false-alarm rate can hide those changes. A rational record would stratify performance by material receiver state and would mark invalid intervals. Where a stable process approximation is asserted, examine its residual evidence rather than treating stationarity as a convention supplied by software. Statistical control does not mean every small fluctuation is abnormal; it means the declared process can be evaluated against the behaviour it is supposed to exhibit.

There is also a danger of selecting thresholds retrospectively. An analyst may examine the saved waterfall, notice the desired burst, lower the threshold, then report the adjusted detector as having detected the event all along. That can be a useful exploratory procedure, but it is not independent validation of the threshold's prospective performance. The corrected procedure should be challenged on observations withheld from its construction, including negative controls. If several candidate detection rules are compared, the selection step belongs in the statistical account. It changes the meaning of a reported false-positive rate, particularly when the user regards many overlapping trials as opportunities for chance success.

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The practical report can remain concise without evading these distinctions. It should state the observation interval, frame length, hop length, taper, detector statistic, threshold rule, candidate-association policy, and the physical event definition. It should provide an event-based performance table or an explicit statement that such performance has not yet been established. A claimed transmitter count requires further source discrimination and cannot be inferred from a list of trigger records. If the investigator wishes to assert only that an indication recurred under specified receiver conditions, that narrower claim may be well supported. We must not dress up a record of dependent numerical decisions as if it were a record of independently confirmed external actors. I invite Professor Neyman to challenge how uncertainty should be represented when the event-clustering rule itself was chosen after examining the field evidence.

Jerzy Neyman | Peer question 2 to Walter Andrew Shewhart

Dr Shewhart, your event definition appears operationally rigorous, but it raises a design question which cannot be avoided by writing more careful software. Suppose an investigator selects among five clustering gaps after seeing the same set of field recordings, choosing the gap which gives the least embarrassing difference between receiver indications and the hypothesis of one intermittent transmitter. The selected gap may then appear stable on that same recording. Even if the FFT windows are described exactly, the event count is the product of a rule trained on the evidence. How would you separate exploratory selection from a procedure eligible for a confidence interval with its advertised coverage? Would you recommend an independent challenge population, a predeclared rule or a simultaneous account of all five

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alternatives? Further, if only triggered intervals were retained, what can be inferred about missed events in the unretained time? I ask because the difference between a confidence statement concerning one fixed algorithm and a statement concerning an algorithm chosen to make the data look favourable is not a nicety; it determines whether the numerical bound can be defended.

Walter Andrew Shewhart | Immediate answer to Jerzy Neyman

Professor Neyman, the selection you describe is itself part of the procedure under evaluation. If the investigator fixes a clustering gap using a development recording and then measures its performance on a genuinely separate and suitably representative challenge collection, the resulting validation statement can refer to that frozen rule and its stated conditions. If the same observations are used both to choose and to vindicate the rule, the nominal performance of the selected result is liable to optimism. One must then either account for selection, assess the range of conclusions across reasonable alternatives, or restrict the result to exploratory analysis without the stronger coverage claim. A report should not conceal the process by which the apparently decisive rule was obtained.

A good independent campaign would contain several physical event classes whose timings are controlled without reference to the detection output. The trial designer could assign isolated bursts, close-spaced pairs and continuous carriers with intermittent amplitude fading. The operator analysing the results should receive either a blinded challenge schedule or a protocol which does not permit trial-by-trial threshold tuning. The rule should be locked before

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the held-out population is processed. The acceptance result is then meaningful for the distribution of source types, amplitudes, clock states and interference conditions represented in that campaign. It does not automatically extend to every environment the receiver may encounter.

For a decision made after exploring five gaps, a sensitivity table is valuable even if an independent trial is unavailable. Report the event count obtained under all five gaps and identify cases that merge or split as the parameter changes. This cannot create the missing independent evidence, but it makes the dependence of the conclusion upon a modelling choice visible. The investigator may discover that the apparent number of transmissions is stable over a broad, physically justified region of parameter space. That would provide a more persuasive restricted claim than choosing a single gap whose attractive answer cannot be reproduced under modest perturbations. If the count changes radically, the correct conclusion is that event segmentation remains uncertain.

Triggered retention poses a different, severe restriction. The absence of retained samples cannot establish the absence of an event during a period the retention system did not preserve. A detector may have monitored the interval and produced no trigger, but the strength of that negative evidence depends on the detector's validated exposure and sensitivity in the particular operating state. A complete event schedule supplied in a laboratory challenge permits direct measurement of omissions. In historical field data, one may have no such external truth record. The report must distinguish

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prospective performance established by challenge tests from the count of events actually retained during the investigation, and it must disclose blind intervals, buffer losses and changes in threshold.

I would not deny the value of exploratory detection. Its purpose is often to find a plausible candidate, not immediately to assign a judicially defensible probability to a source hypothesis. The error occurs when a candidate chosen through extensive search is later represented as though it had been specified beforehand. The proper chain has distinct stages: discover the candidate, freeze the claim and method, challenge the method independently, and then report the result with its remaining conditions. In that chain, overlapping windows are an engineering choice; the statistically significant unit and the validation population are separate choices. A scientific report becomes stronger, not weaker, when it states precisely which of them has been established. I respectfully pass the token back to Professor Neyman for his own account of multiplicity and dependent trial opportunities.

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Jerzy Neyman | Principal response 3: Confidence, multiple testing and conditional performance claims

Dr. Atkinson, the quantity of calculations produced by a receiver is not an adequate substitute for the sampling design required to interpret them. Suppose a monitoring programme makes K window-level decisions from one stretch of digitised input. The decisions may share input samples, common gain disturbances, a common noise-floor estimator and a common source waveform. The probability distribution of their joint outcomes therefore depends upon the dependence structure. A calculation which assumes independence without testing it can produce a compelling but unjustified false-alarm probability. The correct approach is to define the repeated experiment and the decision rule before assigning confidence language to the result.

For a fixed set of K tests, the probability of at least one false alarm is constrained by general probability inequalities even when the tests are dependent. If the individual false-alarm probability is p under a common null model, the union bound is at most Kp, capped at one. This is conservative and does not require independence, but its p must be relevant to the actual tests and environment. The familiar expression 1-(1-p)^K follows under independence and should not be quietly substituted for a dependence analysis. When a detector scans many bins, times, antenna states and candidate rules, the family of opportunities must be defined. The effective search may be wider than the visually reported set of alarms because unsuccessful comparisons were discarded from the report.

A second distinction concerns confidence in a detection probability. An investigator may inject n known physical emissions and observe that all are

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detected. That result does not establish perfect detection. Under independent Bernoulli event trials with a fixed success probability, a one-sided lower confidence bound can be calculated from the binomial distribution. But if nominally separate injections all occur during the same favourable gain state, or if the operator times them to coincide with detector windows, the independence and representativeness assumptions may fail. The count of injected physical events is more important than the count of FFT frames in which each event was visible. A protocol which duplicates one favourable event across twenty overlapping frames has not thereby performed twenty independent trials.

For estimation from dependent data, the variance of an arithmetic mean depends on all pairwise covariances. Under an appropriate stationary model, one may express that variance in terms of lag correlations. Yet this relationship is not a magic formula for converting every waterfall into an effective sample size. Different spectral bins, tapers, receiver states and signal classes can have different correlation patterns. An analytic expression calculated under stationary Gaussian noise may not remain valid during bursty interference, ADC overload or an adaptive threshold change. The investigator should test the model with relevant noise-only and source-present records; where the model is inadequate, empirical block-based methods or independent acquisitions may provide a more defensible uncertainty evaluation.

I would distinguish the purpose of a test from the interpretation of a particular alarm. A laboratory may establish an operating characteristic, such as the conditional probability of detecting a burst whose power, duration and arrival phase fall within a declared range. That does not give

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the posterior probability that any particular field alarm arose from an illicit emitter. The latter conclusion depends upon competing source rates, artefact mechanisms, environmental conditions, sensor architecture and additional evidence. A high reported sensitivity can coexist with a large proportion of false alarms when the underlying target events are exceptionally rare. Overlapping FFT frames make the confusion worse if the analyst treats correlated repetitions of one alarm as independent corroboration.

The experimental plan should include withheld challenge signals whose timing is deliberately varied relative to the FFT hop, together with noise-only controls that preserve realistic correlation and interference. Define the statistical endpoint beforehand: event-level detection, false alarm per observation hour, frequency-estimation error, or transmitter-attribution accuracy. Record how physical events are clustered from frame-level indications. If several detector designs or threshold rules are compared, hold out a final validation population rather than selecting the most flattering model and testing it again on the same data. Where the intended claim involves several operating conditions simultaneously, a family-wise coverage requirement may be more appropriate than reporting the best one-condition result.

A useful report should carry both an executive conclusion and enough detail for a challenger to test it. For example, it may state that a frozen receiver procedure detected a specified proportion of controlled bursts of a declared signal class over a defined temperature and interference envelope, with an interval calculated using clearly stated assumptions. The technical record would identify the number of independently injected events, the

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number missed, the hop and window parameters, the clustering rule, the exact threshold version and the confidence method. If some runs are invalid because of buffer loss or clock failure, the exclusion must be declared rather than quietly omitted. A bounded statement is not a concession to uncertainty; it is the appropriate consequence of scientific testing.

When the system lacks raw retention, the claims become narrower. A later examiner can inspect the archived event log and determine what the algorithm reported. The examiner cannot necessarily reconstruct alternative spectrograms, recover suppressed subthreshold bursts, or test a different clustering rule without the source samples. A software log containing hundreds of nearly identical frame detections is not a replacement for unrecorded physical evidence. Therefore the numerical confidence attached to the report must be evaluated at the level of preserved observations and validated model assumptions. We should avoid both extremes: demanding impossible universal knowledge and declaring certainty from dependent numerical abundance. I invite Professor Fisher to ask whether the inferential unit remains well defined when the same physical event appears in different detection channels with distinct frequency windows.

Sir Ronald Aylmer Fisher | Peer question 3 to Jerzy Neyman

Professor Neyman, the notion of one physical event is harder to apply when a wideband receiver divides an input into overlapping spectral channels whose outputs overlap in frequency as well as time. One burst may produce several peaks, perhaps at adjacent filter-band edges and at sidebands created by modulation. The analyst may use a clustering algorithm to combine these into one putative transmission, but the algorithm is itself a statistical classification rule. If all those outputs share

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the same analogue front end, how would you distinguish evidence that the signal belongs to one emitter from evidence merely that one receiver architecture repeats the same stimulus? I also ask whether the union bound you propose offers more than an intellectually safe but practically useless upper limit when the number of channels is enormous. What validation design would permit a meaningful family-wise statement while remaining computationally feasible and susceptible of independent verification by another laboratory?

Jerzy Neyman | Immediate answer to Sir Ronald Aylmer Fisher

Thank you for that question. Sir Ronald, one must distinguish the physical stimulus, the spectral representation and the source classification. A burst with modulation can legitimately occupy several adjacent output channels. Its appearance in those channels is not independent confirmation that several emitters exist, and it is not by itself independent corroboration of one emitter's identity. To test a clustering rule, use a challenge set containing physically known events deliberately placed near frequency boundaries, with separations, bandwidths and modulation structures selected to distinguish possible interpretations. Evaluate the rule at the physical-event level, counting both unjustified splits and unjustified mergers. A second sensor path or changed analogue preselection may then help test whether the inferred location in frequency and time follows a genuine stimulus rather than an internal image.

The union bound is a valid general protection against treating multiple tests as though they were one; it is not always the tightest available performance statement. If the tests are strongly dependent

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and their joint distribution is sufficiently characterised, a more informative calculation can be made under an explicit model. Alternatively, a whole-system empirical challenge can measure the number of false events emitted by the complete processing chain during representative noise-only observation hours. That approach avoids the need to derive an independence assumption for every FFT bin, though its validity still depends upon the representativeness of the trial conditions and the preservation of detector state. The unit of a whole-system false-alarm rate should be a validated candidate event, not merely a threshold-crossing frame.

For computational tractability, design a bounded experiment around the claims material to the intended investigation. A receiver advertised for intermittent emissions in particular bands should be challenged with representative bandwidths, duty factors, amplitudes, hop phases and interfering signal classes. A systematic design can identify sensitive combinations without exhausting every possible waveform. Hold back independent test cases to examine whether the final algorithm generalises. Document the randomisation, selection rules and invalid observations. Where extreme rare-event false-alarm rates are claimed, note that an ordinary finite test may not establish a sufficiently small rate without additional modelling assumptions. Precision beyond the trial's information should not be printed merely because a processor displays many decimal places.

If a single physical input produces ten correlated outputs, their useful content may be richer than one scalar output, because relative amplitude and spectral shape can assist classification. Yet the

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increased dimensionality does not multiply the number of independent causes. A well-designed report can exploit the multichannel pattern while retaining the distinction between information about one event and independent evidence about source identity. Calibration controls and sensor substitution are particularly valuable when the competing explanation is receiver-generated structure. The scientific objective is to make those alternative predictions different enough that an experiment can discriminate between them. I now pass the floor to Professor Wiener to consider history-dependent clustering and the feedback between acquisition policy and retained event counts.

David Slepian | Peer question 4 to Jerzy Neyman

Professor Neyman, the statistical unit becomes even less obvious when the filter itself is selected to improve concentration in time and frequency. A laboratory may measure the effective bandwidth of one taper, then implement a different taper under congested field conditions. It may average adjacent frequency bins or change the hop while monitoring remains active. Each choice alters the amount of sample reuse and can change correlation among spectral estimates. If a confidence limit is calculated for one specified window and hop, may the operator transfer that limit to another configuration merely because the total observation time and the nominal number of FFT calculations remain unchanged? I should also like you to examine the problem of edge arrivals. A brief emission centred upon one hop position can occupy most of a taper's effective support, while an equally strong emission near the edge may be represented in several frames with much lower peaks.

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How should a validation population sample these phase relationships so that a reported detection probability is not simply the performance of a favourable alignment?

Jerzy Neyman | Immediate answer to David Slepian

Thank you for that question. Professor Slepian, the confidence statement should be attached to an actual procedure and challenge population, not to a generic description such as FFT analysis. Altering a taper, hop or bin-combination rule changes the statistic and possibly its joint distribution. A result established for one configuration does not automatically carry over to another. A validated equivalence between configurations could support transfer, but equivalence is a substantive empirical or mathematical claim requiring evidence. The operator should preserve the active configuration for every material interval, including the coefficients of the taper when implementation details are relevant to the proposed conclusion.

For edge arrivals, a suitable design deliberately spans the full arrival phase relative to the hop. One may generate bursts at controlled offsets from zero to one hop duration, using a sufficiently fine set of phase positions to reveal performance minima. The programme should vary burst duration, bandwidth, amplitude and interference as independent factors or use a documented design which identifies their interactions. A detector whose sensitivity is quoted only for a burst precisely centred within one window has not established sensitivity to arbitrary arrivals. The distinction matters

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particularly where the subject emission is intermittent and the operator cannot predict its starting instant.

The validation endpoint should be detection of each injected physical event, not the number of frames above threshold. If one burst yields three frame alarms, that remains one successful event detection; if it yields no alarm at an unfavourable arrival phase, it is a missed event. The report may separately examine how many redundant frame alarms a detected event produces, because redundancy can increase downstream review burden and affect false event counts. However, the denominator of an event-detection probability is the number of independently defined injected events meeting the declared trial conditions. It is not multiplied by the number of frames or FFT bins.

The uncertainty bound requires care when trials occur under a small number of shared receiver states. A hundred arrivals generated during one stable laboratory session may not support generalisation to a hundred independently varying field environments. Stratify or randomise environmental factors that materially affect performance, preserve the state transitions and define the scope of the conclusion. When a physical-event rate is estimated from field alarms rather than controlled injections, additional uncertainty arises from missed detections, split and merged episodes, unobserved intervals and the population model. Those difficulties cannot be cured by adopting a more concentrated taper.

I therefore recommend a transparent comparison of configurations. Demonstrate their transfer functions, frame-level

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noise correlation and event-level detection behaviour, then identify conditions where they differ. A restricted claim for one specified configuration can be rigorous. A broad claim across all configurations requires its own evidence. I respectfully yield the floor to Professor Wiener, whose perspective on systems with memory will expose further ambiguity in the relationship between one physical event and several later recorded alarms.

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Norbert Wiener | Principal response 4: Detector memory, feedback and the counting of repeated observations

Dr. Atkinson, a processing system with memory is not simply a passive observer that repeats the same question many times. The result of one observation may alter the settings under which the next observation is made. A detector may update its noise floor, tune a carrier-tracking loop, alter its buffer-retention policy or suppress successive alarms deemed duplicates. The number of resulting entries is a property of the coupled instrument and decision procedure. The relevant object of study is therefore not merely the input waveform and not merely the FFT window, but the temporal evolution of the entire receiver from input stimulus to retained forensic record. A physical event can influence that evolution well beyond the interval in which it was radiated.

Consider an exponentially smoothed detector statistic $S_k = \text{alpha } P_k + (1\text{-alpha}) S_{(k-1)}$, where P_k is a frame-level power statistic and zero is less than alpha and no greater than one. This expression defines a stateful operation. Even if the physical input power returns immediately to background, S_k can remain elevated for subsequent frames. A threshold crossing generated by a long decay tail is not necessarily a second event. If the threshold itself is estimated from recent P_k values, both sides of the comparison can move in response to the same emission, making the decision history still more complicated. The operator must retain sufficient parameter and state information to reproduce the alarm sequence and must determine which observations actually provide new evidence about the external environment.

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Overlap adds another kind of memory, namely the direct reuse of original analogue samples. Two adjacent FFT frames with substantial overlap contain some identical input samples even if the detector performs no explicit smoothing. If each frame is then passed through a running average, the resulting decisions embody both data reuse and algorithmic state. Neither an independence model for raw samples nor a simple count of frames adequately represents that compound dependence. In practice the effects may also be influenced by common oscillator motion, antenna vibration, interference and adaptive gain. A validation experiment should vary these conditions and inspect whether a burst's after-effects survive changes in hop and smoothing parameters as the mechanism predicts.

The distinction between cause and repeated consequence is particularly important for receiver-generated artefacts. A periodic quantisation spur, clock feedthrough or interleaving image may occupy the same spectral location through many frames. Its coherence can make it look more stable than a weak external emission affected by propagation. If the software counts each recurrence as fresh evidence, the instrument effectively testifies repeatedly on behalf of its own internal defect. A useful challenge might change the analogue input termination, alter the clock plan, substitute a front-end path or introduce a calibrated stimulus while preserving all the digital processing settings. Competing internal and external hypotheses should then predict different outcomes. An unchanged waterfall alone is not a substitute for such intervention.

I would ask the laboratory to formalise the detector as a state machine. Its states might include searching, candidate, confirmed, holdoff and invalid. The transition rules should specify which measured quantities move the

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system between states, whether consecutive threshold crossings are merged, and when the system becomes eligible to count a new event. Timeouts and hysteresis must be calibrated against legitimate burst types rather than chosen for visual neatness. The state transitions should be logged in a form which permits a second examiner to determine why two adjacent threshold crossings were assigned to one episode or to separate ones. A hidden vendor state machine may still be useful as a discovery aid, but it limits reproducible forensic inference.

Not all repeated observations are useless. If an event persists over many frames, its time-varying spectral profile may reveal modulation, burst envelope or relative motion. Repetition can also improve an estimate under carefully characterised noise conditions. The error arises when dependence is ignored and precision is inferred from the number of displays rather than the information added by each observation. Repeated observations of one physical source may strengthen a claim about its persistence or signal structure without increasing the number of distinct emitters. A receiver with many antenna channels may supply valuable spatial diversity, but only if their common electronic paths and correlated disturbances are considered. The proper statement is conditional on the claim, not a universal rule that repeated measurements are always redundant.

A practical forensic record should preserve at least the raw interval of each material candidate when feasible, the corresponding frame indices, tapers, hop, processing version, threshold history and event-clustering decisions. It should additionally preserve a representative independent audit stream so that the absence of retained alarms is not confused with the absence of physical emissions. If the receiver chooses which data to retain

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based on its own adaptive decisions, that selection mechanism becomes part of the evidence and must be disclosed. Otherwise the later analyst sees a history filtered through a process whose omissions cannot be evaluated.

I conclude that the correct event count is a property of a defined physical-event concept together with a validated inference procedure. It is not available directly from a stream of FFT decisions. The benefits of overlap are real, including improved coverage of arbitrary burst arrival phases; its costs include correlated statistical outputs and increased opportunities for self-generated artefacts to produce repeated alarms. The laboratory should show both sides of that ledger. I invite Dr Shannon to ask whether a finite retained archive can preserve enough of this state history for a later analyst to challenge a proposed count without possessing every original sample.

Claude Elwood Shannon | Peer question 5 to Norbert Wiener

Professor Wiener, your state-machine account makes the event count a function of the observed signal and the receiver's internal history. Suppose a digital recorder preserves a small selection of IQ samples around each declared event, along with the last value of every adaptive threshold, but discards intermediate frames and the coefficient-update trajectory. A later analyst may be able to reproduce the final alarm positions, yet may be unable to tell whether the detector suppressed a brief second burst or merged it into the memory of the first. In information-theoretic terms the retained representation may be insufficient for the new question, although it was entirely adequate for the original operator's display. Can an archive specification be stated in terms of sufficient information for an agreed class of questions, rather than simply demanding unlimited storage? How should the report

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identify which later questions are unsupported by the selected representation, particularly when the acquisition software has been updated and the original executable no longer exists?

Norbert Wiener | Immediate answer to Claude Elwood Shannon

Dr Shannon, I would begin by defining the forensic question before specifying the retention boundary. If the question is whether the displayed detector issued one alarm at a recorded time, a state snapshot and event log may suffice. If the question is whether a second physical emission occurred during a holdoff interval, the archive may require the samples and detector evolution during that interval. A final state does not uniquely reveal the path by which a system arrived there. Different sequences of inputs and threshold updates may produce the same terminal coefficients. Therefore a retained archive should not be described as sufficient for all later questions merely because it reproduces the final display.

A practical design could distinguish full raw acquisition, candidate-neighbourhood retention and reduced summary-only retention as separate evidence classes. For each, preserve a manifest declaring the physical and analytical propositions it can support. The metadata should identify the software version, clock and gain state, event definition, threshold adaptation and processing configuration. Where raw samples are absent, maintain a truthful statement of the observation exposure and the selection rule. Independent validation can then establish the probability of retaining specified event classes, albeit within a declared envelope. That does not recover the particular missed event; it informs the limits of the procedure.

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Software version identity is indispensable because ostensibly minor changes to clustering or threshold logic can change the number of reported physical events. Preserve source code or a verified executable with dependency versions when licensing and access permit; otherwise retain a sufficiently precise algorithm description, input-output challenge set and reproducible checks. A hash of an executable establishes the identity of the bytes, not that the program's interpretation was correct. The same distinction applies to saved IQ files: cryptographic integrity can support chain of custody while leaving the accuracy of the original RF measurement unresolved.

The archive need not be limitless if the intended conclusion is modest. A summary can support a summary-level claim when its generation and limitations are described. But an investigator must not subsequently invoke that summary as though it contained all the information discarded in its construction. Retention policies should be tested with challenge signals deliberately placed near event boundaries and holdoff intervals, where the risk of accidental merging is greatest. The test must evaluate false negatives and false splits, not simply reproduce an attractive waterfall.

I would therefore record a hierarchy of claims and a corresponding hierarchy of evidence. The narrowest concerns the digital instrument's reported decisions. A stronger claim concerns the external event population under validated detection assumptions. The strongest attribution claim adds physical discrimination among emitters and alternative artefacts. Every advance requires additional

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evidence. This is not hostility to automation; it is the logical discipline necessary to make automation's conclusions reviewable. I invite Professor Bridgman to examine whether the event definitions we have offered are physically meaningful or merely administrative conventions.

Percy Williams Bridgman | Peer question 6 to Norbert Wiener

Professor Wiener, you have admirably described the detector as an evolving mechanism, yet I remain concerned that the word event may conceal two distinct entities. An operator may call any cluster of threshold crossings an event, while a physicist might reserve the term for a particular emission from a material transmitter. A digital algorithm can define the former exactly without having established the latter. Suppose two independent transmitters radiate overlapping bursts in the same channel, or one transmitter emits two packets separated by an interval shorter than the clustering timeout. In either case the operational output might be one cluster. How should the examiner prevent the perfectly reproducible administrative count from being mistaken for a physical source count? What interventions or additional measurements would justify the passage between those two claims, and how should uncertainty be expressed when the original source population cannot be observed directly? I would also ask which parts of the classification rule are experimentally calibrated, and whether those parameters remain stable when the receiver changes gain or sample-clock state.

Norbert Wiener | Immediate answer to Percy Williams Bridgman

Thank you for that question. Professor Bridgman, the distinction is essential. A detector event should be defined as the outcome of a

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specified operational rule, and a physical emission episode should be defined by a model of the underlying radio-frequency activity. A transmitter identity is a third proposition. Those three levels must not be silently equated. One detector event can encompass two independent emissions; one emission can produce several detections; and one transmitter can generate several distinct emission episodes. Reproducible software does not change those possibilities. It establishes only that the same algorithm will make the same categorisation under the same retained input and state conditions.

A practical report should therefore state the directly observed count with its proper unit, such as 'seventeen alarm clusters under clustering rule R17'. It may then discuss possible source episodes as an inference supported by waveform continuity, modulation, frequency stability, independent receiver views or controlled challenge evidence. If those sources of discrimination are insufficient, it should not print 'seventeen transmitters'. Attribution may require directional measurements, RF-path comparison, movement or power-state interventions, and consideration of receiver-generated images and co-channel innocent services. Each additional procedure requires calibration and its own uncertainty analysis.

To test the operational-to-physical mapping, use challenge trials in which known numbers of sources generate bursts with independently varied overlap in time, frequency and modulation. Evaluate not only whether a source was seen but whether sources were split, merged or misidentified. Include deliberately confusable cases rather than a collection of ideally separated carriers. The acceptance statement

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should distinguish the case population: a receiver may reliably count isolated bursts under quiet conditions and yet be unable to resolve two simultaneous sources in a congested band. That narrower fact can still assist an investigation, provided it is not inflated into a universal source-count capability.

Where historical field evidence lacks independent truth labels, the source count may remain a range or a family of plausible interpretations. One should preserve the competing explanations and the evidence favouring each. The observation that several spectral lines move together under an antenna intervention might support a shared source hypothesis, but common receiver paths and environmental responses must still be considered. The result can be strong about a bounded proposition and uncertain about identity. A careful report is not diminished by such qualification; it is strengthened because an independent examiner can see exactly what remains unresolved.

I would finally emphasise that the retention policy must permit these distinctions where they are material. If the only preserved data are cluster timestamps, the opportunity to examine waveform overlap or modulation may have been lost. That absence cannot be repaired by a more elaborate statistical narrative. The correct professional response is to describe the limits and, where feasible, design a new controlled acquisition capable of testing the rival hypotheses. I pass the floor respectfully to Professor Tukey for the problem of exploratory detector design and the temptation to count only those successes which survive a favourable selection rule.

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John Wilder Tukey | Principal response 5: Exploratory detection, robust summaries and selection effects

Dr. Atkinson, it is tempting to regard an event-counting problem as solved when one has selected the most sophisticated detector. In fact, the principal hazard may lie in the questions the analyst forgot to ask. What was counted? Which observations were eligible for counting? Which were excluded? How much did the answer change when the analysis rule changed? An investigator should examine the raw temporal structure of the data before compressing it into one apparently definitive event total. Exploratory analysis is not a vice; it is a method of learning where an initial model is inadequate. The vice lies in presenting a data-driven rule as though it had been prescribed before seeing the very signals it was chosen to explain.

Overlapping FFT windows create excellent opportunities for exploratory visualisation. They can reveal weak transients whose arrival coincides poorly with a non-overlapping grid, and they can show the time evolution of spectral structure. But a waterfall can also create the false impression that many bright pixels represent many separate physical events. A short transmission may illuminate numerous nearby time-frequency cells, while an impulse-like artefact can spread across many frequencies. Counting illuminated cells would be an indefensible substitute for an event model. The analyst should begin with linked views of time-domain IQ, detection statistic, threshold trajectory, receiver state and the final cluster decisions. Discordance among those representations is often more instructive than apparent consistency.

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A robust exploration would vary the frame hop, window function, threshold hysteresis and clustering gap within physically plausible limits. It would record how the inferred event count changes. A stable count over these variations is not proof of source identity, but instability is a warning that the chosen representation governs the answer. Equally, changing the frame length alters the trade-off between frequency concentration and transient localisation. A long window may merge two short adjacent packets, while a shorter one may lose narrowband signal-to-noise ratio. There is no one universally optimal configuration for every unknown emitter; the chosen measurement must be suited to a declared class of signals and validated accordingly.

The analyst should resist the appeal of a single clean average. Mean spectral power is useful for estimating sustained background behaviour, yet a rare brief burst may be diluted by hundreds of quiet frames. A median can reject occasional strong outliers in a background estimate while simultaneously concealing the very transient one wishes to discover. The proper statistic depends upon the question. If the purpose is rare-event detection, preserve peak or threshold-crossing information and the corresponding source interval; if the purpose is background estimation, use a method whose sensitivity to intermittent contamination has been characterised. Do not use a favourable-looking mean to infer the absence of brief transmissions.

False alarms deserve particular attention in a large search. An analyst may inspect many frequencies, windows and smoothing settings before selecting one conspicuous feature. The selected feature is not a randomly prespecified test. If the selection is ignored, the reported significance may

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exaggerate the evidence. A defensible workflow can separate discovery from confirmation: use one period to explore and specify the candidate, then test its predicted behaviour in an independent period or through controlled intervention. The challenge should be genuinely capable of giving an adverse result. If every failure is met with an altered threshold and a new explanation, the experiment has ceased to test the original claim.

The operator should also preserve failures and equivocal classifications. A false split, a merged pair of packets or an invalid receiver interval should not disappear into a polished summary. Those cases help locate the procedure's performance boundary and may guide better future acquisition. Where a system declares an alarm cluster, preserve enough linkage to the underlying FFT frames and raw intervals for another examiner to test a different segmentation rule. If those samples were not retained, the report should state which alternative analyses are impossible. Precision about a limitation is preferable to a lengthy report that obscures it.

For the acceptance campaign, I propose deliberate adversarial variety rather than mere volume of routine trials. Include single bursts arriving at unfavourable hop phases, close-spaced pairs near the clustering boundary, overlapping emitters, amplitude-faded continuous carriers, strong innocent transmissions and receiver-generated spurs. Test each material processing configuration. Keep a held-out collection whose labels are not used to set parameters. Compute frame-level alarm statistics and physical-event-level performance separately. The design should distinguish detection of any burst from accurate counting of bursts, and distinguish both from attribution to a particular physical source.

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The final report may need only a few sentences for its conclusion, but those sentences must carry the correct units and limits. It might report that a frozen algorithm detected a specified proportion of reference bursts while producing a measured number of false clusters per valid observation hour, under a defined interference and clock envelope. It should not transform that result into a claim that every retained alarm represents a unique transmitter, nor infer absence of events during invalid or unrecorded periods. A carefully qualified conclusion can guide a TSCM investigator's next action more effectively than a supposedly comprehensive but logically unsound event count. I invite Professor Slepian to examine whether the overlap chosen for spectral concentration can itself influence the apparent robustness of those classifications.

Dennis Gabor | Peer question 7 to John Wilder Tukey

Professor Tukey, your proposed robustness analysis varies window length, hop and threshold rule to establish whether the event count remains stable. Yet each variation may produce a different time-frequency resolution and a different sensitivity to signal classes. If the count changes, the reason might be genuine detection of a previously invisible burst rather than merely an unstable classification rule. Conversely, the same event count might conceal different sets of missed and falsely detected emissions. How should a validation experiment distinguish meaningful new information from arbitrary numerical duplication when the analyst changes the spectral representation? In a time-frequency representation, a brief physical event may be spread across neighbouring cells by the analysis kernel; should that predictable spread be tested against the source envelope before it is labelled an

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additional event? Should one require agreement on individual known challenge events, rather than agreement only in their aggregate count? And if several settings are combined into one ensemble detector, how should correlated decisions be reconciled so that the ensemble's apparent corroboration does not count the same analogue samples repeatedly as independent evidence?

John Wilder Tukey | Immediate answer to Dennis Gabor

Dr Gabor, I agree that identical aggregate counts are not sufficient. Two algorithms can report the same number of events while disagreeing entirely about which physical reference bursts they detected. Therefore the validation must compare classifications against individual known events, preserving their identities, start times, durations, signal properties and intended separation. A confusion table at the event level should record true detections, missed events, false clusters, splits and mergers. When a change of window or hop reveals a real previously missed burst, that is a genuine improvement. When it creates three alarms from one unchanged burst, it is not an increase in independent source evidence. These possibilities can be separated only by a trial population with appropriate truth labels or by defensible independent physical observations.

For an ensemble detector, the combination rule must be part of the declared procedure. The analyst should not treat agreement between classifiers trained on the same FFT frames as if it were independent sensor corroboration. Different computational views of a shared input may be complementary for classification while remaining dependent

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as evidence of the input's physical correctness. An ensemble may reduce a false-negative rate or improve discrimination under tested conditions, but that performance must be demonstrated on independent challenge events with thresholds and weights fixed beforehand. The report should compare the ensemble with its constituent procedures and state where any measured benefit occurs.

The temporal and spectral resolution trade-off also makes simple count stability an imperfect target. Longer analysis windows favour narrowband energy concentration but can smear the timing of brief events; shorter windows improve localisation while degrading some frequency estimates. A useful validation deliberately includes bursts across both sides of that trade-off. It should stratify performance by duration, bandwidth, arrival phase and interference. The resulting record can explain why a configuration suited to one signal class underperforms for another, instead of seeking one universal number which hides the variation.

When the analyst performs exploratory robustness checks on a historical recording, each alternative method can reveal a candidate requiring further investigation. That is legitimate, provided the exploratory selection is disclosed and no confirmatory probability is fabricated from the same selected data. A later controlled challenge, a separate receiver path or an independent acquisition interval may then test the candidate. If none is available, the report can still identify a plausible emission with an explicit uncertainty statement. The critical distinction is between discovery and validation, not between one favoured software package and another.

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I should also insist upon preservation of the source-to-output mapping. Each alarm should identify the originating raw interval, processing version, window geometry, threshold state and clustering decision. Where the raw material is no longer available, the analyst must say which alternatives could not be examined. A summary count may be technically reproducible but scientifically inadequate for a source claim if the physical evidence has been discarded. A clear uncertainty qualification is not an embarrassment; it permits the next investigator to design a measurement which can discriminate among the remaining explanations. I return the floor to Dr. Atkinson for the numerical applications and final synthesis.

The following calculations are hypothetical educational illustrations. They specify governing variables and assumptions, and none certifies a particular receiver. Where a statistical relationship depends upon a model, the model must be tested against the relevant operating conditions before the calculation is used as evidence of an actual investigation.

Additional evidential check. Storage has not been multiplied by window overlap

Suppose a raw IQ stream contains F_s = 2,000,000 complex samples per second and each sample consists of two sixteen-bit integers, four bytes in total. The raw storage rate is $R = F_s \times 4$ = 8,000,000 bytes per second, or 480,000,000 bytes in sixty seconds, before file headers and metadata. Recomputing five overlapping windowed spectra from portions of those same samples does not multiply the raw analogue observation time by five. Saving every spectrogram may increase

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derivative storage substantially, but that is a software-output burden, not evidence of additional independently sampled physical time. Where a system discards raw IQ to save space, the later questions it can support may be narrower.

Maurice Stevenson Bartlett, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, why cannot a hundred half-overlapping FFT windows be treated as one hundred independent examples of the receiver noise process?

Walter Andrew Shewhart, Cross-Peer Answer to Maurice Stevenson Bartlett: Professor Bartlett, each window shares raw samples with its neighbours, and the taper weights those shared samples in a known pattern. Adjacent periodograms are therefore generally correlated, with the amount depending on the overlap, window and input process. Counting every frame as an independent trial inflates precision and can understate the chance of false alarms. Estimate the covariance under representative noise-only conditions and use an effective degrees-of-freedom calculation justified by that model or a block-resampling method that preserves dependence. Examine stationarity, gain transitions and short bursts, because overlap can propagate one physical event across multiple frame detections. Preserve frame indices and sample intervals so a reviewer can distinguish one event from its several computational appearances. I pass the token to Dr Neyman on probability statements.

Walter Andrew Shewhart, Cross-Peer Question to Jerzy Neyman: Dr Neyman, a survey records seventy detections in highly overlapping frames. Can the report claim that seventy independent emissions occurred?

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Jerzy Neyman, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, no. The count is of threshold crossings in a specified computational representation, not directly of distinct physical transmissions. Define an event-clustering or coincidence rule with appropriate time and frequency tolerance based on known filter memory and timestamp uncertainty. Apply the rule before examining the actual cases, and validate it against injected bursts with known multiplicity. The probability of at least one false alarm over many correlated opportunities must be calibrated on complete noise-only sequences through the identical detector. If one event triggers several overlapping windows, those detections contribute information about its time and frequency but are not separate independent observations of an emitter. Report raw crossings, clustered candidate events and validated physical attributions separately. I yield to Professor Wiener to examine the signal-processing dependency.

Jerzy Neyman, Cross-Peer Question to Norbert Wiener: Professor Wiener, how would a periodic overlap-add processor alter the error model for detection statistics collected at neighbouring frame indices?

Norbert Wiener, Cross-Peer Answer to Jerzy Neyman: Dr Neyman, the output process inherits the filter and overlap structure in addition to the correlation of the physical input. A pulse can affect several adjacent windows with different taper weights and phases. If a reconstruction uses overlap-add synthesis, the output error can also include deterministic modulation from an incorrect window-sum condition. Record exact hop size, window coefficients, frame start times and synthesis convention. Test isolated impulses at multiple phases of the hop; the resulting pattern provides a direct empirical model of repeated detections caused by one

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event. Only after characterising that dependence should one assign an uncertainty to event counts or use a parametric test. Preserving a single plot of frame peaks would conceal the mechanism. I respectfully pass the token to Professor Tukey for honest reporting.

Norbert Wiener, Cross-Peer Question to John Wilder Tukey: Professor Tukey, what evidence would demonstrate that an apparent improvement in false-alarm rate after increasing overlap is genuine rather than a change in the unit counted?

John Wilder Tukey, Cross-Peer Answer to Norbert Wiener: Professor Wiener, use the same physical exposure time, the same injected event population and a predeclared definition of one distinct event. Report both per-frame crossings and per-hour independent candidate events, together with detection probability and confidence intervals. Increasing overlap creates more frame-level decisions and may improve temporal alignment, but it also changes dependence and detection multiplicity. The comparison must run through the identical clustering and adjudication rule. An apparent fall in per-frame false alarms can coexist with no change in false candidates per hour, just as more frames can make a fixed source look more frequently active. Retain full decisions and test on independent records. I respectfully return the token to Dr Atkinson.

Moderator synthesis | Dr. James M. Atkinson

Distinguished colleagues, the principal conclusion is that an FFT frame, a detector alarm, an emission episode and a transmitting source are four different categories of object. Their numerical counts may coincide in a simple demonstration, but coincidence in one test does not establish identity of meaning. Maurice Bartlett has shown why overlapping estimates

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cannot be treated as independent merely because their FFT calculations execute separately. Walter Shewhart has required the event segmentation and process-state rules to be defined before the event count is interpreted. Jerzy Neyman has distinguished per-test false-alarm calculations, family-wise claims, independent challenge events and the statistical assumptions required for valid confidence bounds. Norbert Wiener has placed detector memory and adaptive feedback inside the measurement system rather than treating them as incidental programming details. John Tukey has shown why exploratory discovery and confirmatory validation must be distinguished, especially when many overlapping representations are searched for an attractive result.

The physical picture is straightforward but its implications are extensive. A long burst can illuminate many overlapping windows, and a narrow internal spur can remain bright across thousands of displays. A short event might be visible only when its energy falls favourably within a taper, whereas a different frame geometry may divide its energy among neighbouring results. Overlap can improve temporal coverage and reduce window-edge sensitivity, but it does not provide a universal multiplier of independent observations. A mathematically correct spectral average may be poor evidence of a rare emission because the averaging suppresses its temporal distinctiveness. Equally, an aggressive peak detector can present one noise fluctuation as numerous alarms unless its association rule is controlled.

The applied calculations place limits on attractive slogans. A 75-percent geometric overlap tells us how many digital samples two nominal frames share, not the correlation coefficient of their detection decisions. The

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confidence of a hundred event trials cannot be inferred from a hundred windows of one event. The independence formula for a collection of tests is not licensed by software architecture alone. The full uncertainty of an estimated mean includes covariance under the stated statistical model. The number of reported alarm clusters depends on the declared clustering procedure, and a physically meaningful emission count may require independent evidence about overlapping sources and receiver artefacts. The laboratory must not conflate an instrument's computational abundance with the external world's causal plurality.

For defensive technical surveillance countermeasures practice I would require the report to identify the admitted frequency region, observation exposure and invalid intervals; the physical RF reference plane; the FFT length, hop, taper and channeliser state; the threshold estimator and its adaptation history; the algorithm mapping frame-level detections into candidate episodes; and the evidential basis for identifying episodes as external rather than self-generated. The report should disclose any exploratory parameter selection and distinguish a subsequent frozen validation campaign from the analysis that produced the chosen rules. It should preserve discordant reference trials, split and merged events, false positives and missed events. A result which depends strongly on an arbitrary clustering gap should be described as sensitive to that parameter, not converted into a false precision by choosing the most favourable gap.

These requirements need not paralyse field operations. The field examiner may use overlapping spectra for discovery and retain concise candidate logs for immediate action. The stricter requirements arise when a discovery is transformed into an amplitude estimate, event count, source

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attribution or negative assurance conclusion. Those claims require evidence proportionate to their scope. A preserved raw candidate interval, a versioned algorithm, a truthful state log and a controlled challenge set can often provide more persuasive support than millions of unexamined FFT summaries. Where retention is selective, its selection mechanism and unobserved periods belong in the evidential account. Where the original samples are absent, the later investigator must not imply that alternative analyses can still be performed.

The source of scholarly discipline is the willingness to distinguish what is directly observed from what must be inferred. A frame-level detector result is observable in a retained digital record. A count of physical emissions is a conclusion that depends on an event model and validation. An identification of a particular transmitter is a further causal claim, potentially requiring changed antennas, independent receiver paths, waveform comparison and other physical tests. No number of overlapping frames can automatically bridge those conceptual steps. At the same time, a properly characterised digital receiver can make useful and rigorous findings within a declared operating envelope. The purpose of qualification is not to weaken evidence, but to prevent the conclusion from travelling further than the measurement permits.

I thank our colleagues for their careful exchanges and respectful challenges. The next discussion should examine how threshold adaptation and receiver-state histories influence the detectability of intermittent signals, especially where the underlying noise floor changes during an investigation. We shall carry forward the central rule established here: the statistical unit must be defined at the level of the claim, and the archive

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must preserve enough of the acquisition and decision history for that claim to be contested. The floor passes with thanks to the next principal contributor.

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Ten worked engineering applications | Question 044

Worked application 1. The overlap fraction does not equal the independent-information fraction

Let N = 4,096 samples per FFT frame and H = 1,024 samples between adjacent frame starts. The number of shared samples is N-H = 3,072, and the geometric overlap fraction is O = (N-H)/N = 3,072/4,096 = 0.75, or 75 percent. This arithmetic describes reuse of digital samples, not the correlation coefficient of the final spectral statistic. That coefficient depends additionally on taper weights, the signal and noise models, and any later smoothing. A claim that the 'independence is 25 percent' would therefore be unjustified. The correct record preserves N and H, the actual taper and the detector computation. With a different signal distribution, even an unchanged overlap fraction can produce a different correlation between decisions.

Worked application 2. Temporal spacing and acquisition exposure

Let F_s = 1,000,000 complex samples per second, N = 4,096 and H = 1,024. The observation support of one frame is T = N/F_s = 0.004096 seconds, or 4.096 milliseconds. The separation of successive frame starts is h = H/F_s = 0.001024 seconds, or 1.024 milliseconds. Four starts occur over approximately one 4.096-millisecond frame-length interval in steady operation, but that does not create four independent physical acquisition periods. The frames overlap because their input intervals share samples. The physical coverage of the continuous recording is determined by its actual valid sampling time, not the multiplied sum of frame durations.

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Worked application 3. Counting frame starts in a finite record

Let L = 1,000,000 valid samples, N = 4,096 and H = 1,024. If the implementation places only complete frames whose starts advance by a fixed hop, the frame count is K = 1 + floor((L-N)/H) = 1 + floor(995,904/1,024) = 973. Thus a one-second record produces 973 computed frames under the stated convention. The result does not mean 973 seconds of independent input were observed, nor 973 independent opportunities for every burst waveform. A different end-padding rule could produce a different number of computational frames without adding any measured analogue evidence.

Worked application 4. Effective number of correlated spectral estimates

Suppose K = 100 power estimates share a common variance sigma squared under an appropriate stationary model, with lag-one correlation rho_1 = 0.6, lag-two correlation rho_2 = 0.2 and all higher lag correlations stipulated to vanish. The variance inflation factor for their arithmetic mean is C = 1 + 2[(1-1/K)rho_1 + (1-2/K)rho_2] = 1+2(0.99 x 0.6+0.98 x 0.2) = 2.58. The effective count relative to the independent-variance formula is K_eff = K/C = 100/2.58 = approximately 38.76. It would be an error to claim the standard error is sigma/10 simply because the software calculated 100 frames. This example is deliberately model-dependent. The stated correlations and stationary assumptions require empirical verification before an actual effective count may be reported.

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Worked application 5. A bound on family-wise false alarms without independence

Suppose K = 1,000 declared statistical tests each has null false-alarm probability no greater than p = 0.0001 under the appropriate model. Without requiring independence, Boole's union inequality gives P(at least one false alarm) <= min(1,Kp) = 0.1. The value 0.1 is an upper bound, not an estimated realised false-alarm rate. A detector that calculates overlapping FFT bins may have strongly dependent comparisons, but dependence alone does not invalidate the union bound. Correct application requires that the family of tests be stated completely and that the per-test p values are defensible for the actual operating conditions.

Worked application 6. Why the independent-test formula is a separate proposition

For comparison only, assume the same K = 1,000 tests are independent and all have p = 0.0001. Then P(at least one false alarm) = 1-(1-p)^K = 1-(0.9999)^1000 = approximately 0.0951671. The difference from the 0.1 union bound is small here, but this does not validate independence. It merely shows the consequence of adopting it. Under a different dependence structure the joint probability may differ. One should never infer the number of independent tests from the fact that the independent formula happens to give a plausible-looking result.

Worked application 7. Three frame alarms, one known physical burst

Suppose a controlled challenge generator emits precisely one calibrated burst at a known time, and the detector reports threshold crossings in three successive overlapped frames. The frame-level alarm count is A = 3. The known physical-event count is E = 1. If the clustering

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rule merges all three into one output episode, it yields one correct event detection rather than three independent source confirmations. If it instead issues three separate events, it has produced two excess event reports relative to the challenge truth. The test should be repeated across random arrival phases, because a differently aligned burst may generate one, two, three or no frame alarms. This is a controlled educational example, not a general rule that three overlapping alarms always mean one transmission.

Worked application 8. Persistence from exponential smoothing

Let $S_k = \alpha P_k+(1-\alpha)S_{(k-1)}$, with smoothing constant $\alpha=0.2$. Suppose the physical input returns to a zero reference level immediately after an initial state deviation S_0 and $P_k=0$ thereafter. Then $S_5 = (1-\alpha)^5 S_0 = 0.8^5 S_0 = 0.32768 S_0$. After five further frames, roughly 32.768 percent of the initial state remains. A threshold detector can therefore issue late decisions because of its own history even when the cause is no longer present. The illustration assumes fixed alpha and no other state updates; practical receiver adaptation may behave differently and requires direct measurement.

Worked application 9. Exposure limits unconditional detection

Let $e = 0.90$ denote the probability a randomly timed physical burst falls within valid admitted receiver exposure, and let $d = 0.85$ denote the probability the detector recognises the burst conditional on such exposure under the specified source class. Then by the product rule $P(\text{detected}) = P(\text{exposed})P(\text{detected} \mid \text{exposed}) = 0.90 \times 0.85 = 0.765$. This result requires d to be defined conditionally on exposure, not as an already unconditional success probability. The 76.5-percent

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unconditional figure is not raised by repeatedly calculating FFTs over intervals when the receiver was not observing the source frequency. It is also not a posterior probability that a recorded alarm represents a true signal.

Worked application 10. A confidence bound from zero misses in known event trials

Suppose n=100 genuinely independent reference bursts are injected under a frozen receiver configuration, with every burst detected. Under a binomial model with constant success probability d, a one-sided 95-percent exact lower confidence bound is d_L = 0.05^(1/n) = 0.05^0.01 = approximately 0.970487. Therefore 100 successes do not demonstrate perfect sensitivity; the indicated lower bound is about 97.05 percent under the stated assumptions. If the hundred nominal trials repeat one favourable burst phase or share an unmodelled common failure mechanism, the independent Bernoulli premise is not established. The bound applies to detection of independently defined physical challenge events, not to the number of overlapping frame-level alarms.

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Research and verification register

[S1] Original educational synthesis of physical event definitions, statistical process control, detector state and reproducibility, informed by established statistical principles. This entry identifies conceptual use only; no original experiment by a historical participant is claimed.

[T1] SciPy, scipy.signal.welch, official stable API reference, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.welch.html. Consulted for the overlap and window parameters, distinction between density and spectrum scaling, mean/median averaging, and the documented note that 50-percent Hann overlap can be a reasonable trade-off. The documentation does not establish independence of overlapped outputs in any specific TSCM receiver.

[T2] P. D. Welch, 'The use of the fast Fourier transform for the estimation of power spectra: A method based on time averaging over short, modified periodograms', IEEE Transactions on Audio and Electroacoustics 15 (1967), 70–73. Bibliographic details confirmed from the SciPy documentation; the full original article was not independently examined in this continuation. It is not cited as direct evidence for any modern forensic performance figure.

[B1] Royal Society, Maurice Stevenson Bartlett, historical person and election catalogue, https://catalogues.royalsociety.org/CalmView/Record.aspx?id=NA5174&src=CalmView.Persons. Examined for dates, British nationality, election in 1961, research record and academic career. No claims about modern SDR participation are attributed to this source.

[B2] MacTutor History of Mathematics, Walter Shewhart, https://mathshistory.st-andrews.ac.uk/Biographies/Shewhart/. Examined for birth and death dates, education, Western Electric career and statistical quality-control contribution.

[B3] University of California, Berkeley, Department of Statistics, History, https://statistics.berkeley.edu/about/history. Examined for Neyman's 1938 arrival and the founding of the Berkeley statistics programme; the National Academies memoir at https://www.nationalacademies.org/read/4560/chapter/19 supplies biographical and research context.

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All modern SDR cases, numerical inputs, source hypotheses and forensic conclusions in this question are stipulated educational examples. Historical speech throughout is a newly constructed synthesis rather than a transcription or an authentic historical quotation.

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QUESTION 045

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Which limits govern time-frequency localisation of a short burst?

Source: V011_Roundtable_Question_045_CP045_Dr_Atkinson.docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 045. Complete Expert Roundtable Discussion

Original constructed educational dialogue. Historical voices are newly written educational reconstructions, not historical quotations or transcripts. Numerical examples are hypothetical, not instrument certifications.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, the preceding examination of overlapping Fourier windows has obliged us to separate the number of calculated observations from the number of physically independent events. We now confront a different, though related, limit: a short-lived emission does not offer the same opportunities for frequency estimation as a long, stationary sinusoid. The investigator's screen may exhibit an exquisitely fine frequency grid after zero padding, yet the analogue event may have existed for no more than a few milliseconds. The distinction between the number of display columns and the amount of frequency information in that recorded event is central to the proper use of software-defined receivers in defensive technical surveillance countermeasures. A bright pixel may be calculated precisely while the physical parameters it suggests remain weakly determined.

Let $x(t)$ represent the received complex baseband waveform, $w(t-t_0)$ a window centred at analysis time t_0, and $X_w(t_0,f)$ the windowed Fourier transform. The analysis kernel restricts the time interval contributing to a

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spectral estimate. A shorter window can help determine when a transient occurred, but commonly broadens the spectral representation of a narrowband component. A longer window can concentrate a sustained tone more narrowly in frequency, but may blend the beginning and end of a burst, combine separate events, or include receiver states that changed during the observation. The fundamental constraints are not removed by assigning more FFT bins. Zero padding samples the transform of the existing finite record more densely; it does not insert observations of an unrecorded waveform. The measured time support, window shape, noise distribution, source stability and estimator model all affect what the instrument can claim. [T1, T2]

The language of resolution deserves particular caution. The FFT bin spacing F_s/N_{fft}, where F_s denotes sample rate and N_{fft} denotes transform length, is a computational grid interval. It is not universally equal to the minimum separable spacing between two physical emitters, nor to the uncertainty of a fitted carrier-frequency estimate. Two nearby signals can sometimes be discriminated with model-based methods when the available signal-to-noise ratio, duration and assumptions permit; a transient with unknown modulation can defeat a seemingly fine frequency-grid assertion. The examiner must specify whether the measurand is the centre frequency of a stipulated waveform model, the occupied bandwidth of an arbitrary burst, the arrival time of an identifiable transition, or the ability to distinguish two simultaneous emitters. These are different tasks with different uncertainty models.

We must also separate an observed event's physical duration from the duration of its displayed spectrogram response. A short impulse excites a

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filter's impulse response and may become visible across several overlapping windows. The apparent tail is not necessarily evidence that the transmitter continued radiating. Conversely, a long integration may weaken the visibility of a short event by distributing its energy across a wider averaging interval. The observed spectrogram footprint includes the convolutional effects of the analysis procedure and the receiver's analogue and digital transfer functions. The investigator cannot simply read the plotted width along either axis as the underlying source's true width without accounting for those effects.

I ask Professor Gabor to examine the time-frequency compromise, Professor Slepian to address spectral concentration of finite records, Professor Fourier to distinguish mathematical representations from physical uniqueness, Mr Nyquist to consider sampling and aliasing at the RF interface, and Professor Neyman to assess the confidence and experimental design required for event localisation claims. Seven peer interventions will test these arguments directly, and their answers will follow each question without delay. Worked examples will define the observation interval, window coefficients, sample rate, source model, uncertainty and the processing transformations applied to the retained IQ samples. Every conclusion must be bounded by the evidence actually measured.

A properly qualified short-burst report can still be decisive for an investigation. It may establish that a feature consistent with a specified signal class was detected during an admitted time interval and that its frequency estimate remained within a quantified model-dependent uncertainty. It may support a directional or source-correlation hypothesis when independent tests discriminate internal artefacts from external

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radiation. It cannot automatically establish a particular transmitter's identity from the apparent narrowness of a plotted FFT peak. We shall therefore resist both false certainty and indiscriminate scepticism: the objective is to identify what a finite measurement establishes, what models it presupposes, and which further experiment would challenge its remaining alternatives. Professor Gabor, may I invite you to begin with the significance of changing the analysis window when time and frequency cannot both be localised without limit?

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Dennis Gabor | Principal response 1: Analysis windows and physical inference from short-lived waveforms

Dr. Atkinson, a waveform is presented to an investigator through a representation which has been selected for a purpose. The appearance of a spectral feature depends upon that representation as well as upon the original signal. Consider a finite burst whose carrier is approximately sinusoidal over a time interval T. An observer may infer a central oscillation frequency from its phase evolution, but the burst's finite duration necessarily gives its spectrum a width which depends upon the envelope. A sharp rectangular gate produces different sidelobes from a smooth taper. Accordingly the visual width of a plotted peak should not be read as a direct measurement of a transmitter's occupied bandwidth without defining both the source-envelope model and the analysis window. [T2]

The short-time Fourier transform may be written $X_w(t_0,f)=\text{integral } x(t)w^*(t-t_0)\exp(-j2\pi ft)dt$, with the asterisk denoting complex conjugation. This expression makes the measurement dependence explicit. Changing w changes which times contribute to the estimate and with what weights. A window narrow in time can identify a short episode with less temporal smearing but ordinarily broadens the frequency response. A window longer in time can provide a narrower representation for a stable tone, but it introduces temporal ambiguity when a burst starts or stops inside the observation support. There is no contradiction in finding that two correctly implemented analyses give different apparent peak widths. They have asked different questions about the same finite record.

I would not translate the time-frequency limitation into an incautious slogan that no short event can have an accurately estimated carrier.

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Parameter estimation is not identical to generic spectral resolution. If the waveform is well described by a known complex exponential with additive noise, a fitted frequency may be estimated more finely than one nominal FFT bin. However, such precision is conditional on the model. Unknown chirp, oscillator phase noise, abrupt modulation, multiple emitters, clipping and receiver timebase error can invalidate the assumptions supporting an attractive numerical uncertainty. A scientifically honest report should therefore identify whether it provides an algorithmic peak location, an estimate under a specified model, or an empirically validated limit on distinguishing physical source classes.

The finite measurement also contains a fundamental loss when raw samples are discarded. A spectrogram magnitude does not retain all phase information of the complex windowed transform, and further averaging or threshold selection can discard still more. In some mathematically constrained circumstances reconstruction from particular STFT representations is possible, but such results depend upon retention of sufficient coefficients, a valid synthesis window and appropriate boundary conditions. The existence of an inverse algorithm in software is not a guarantee that every compressed waterfall can recover the original analogue event. The correct question is whether the actual retained representation contains the information required for the later forensic inquiry.

For a practical defensive receiver, I would test a collection of reference bursts varied in duration, arrival phase relative to the hop, modulation bandwidth and received amplitude. Repeat the analysis with windows of different temporal support while holding the physical stimulus fixed. Record

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the resulting changes in peak frequency, occupied-bandwidth estimator and apparent start and stop times. In parallel, use known no-signal intervals to measure threshold and false-alarm behaviour under the same settings. Where a candidate appears only under one chosen window, the finding remains worthy of investigation, but selection among many windows must be disclosed when estimating statistical confidence.

A particular difficulty arises when a weak emitter is near a strong signal in frequency. The analysis-window sidelobes of the strong component may obscure or imitate the weak one. A smooth taper can reduce sidelobes at the cost of main-lobe broadening or another trade-off in noise bandwidth. Changing the taper to reveal a candidate can be reasonable, provided the investigator distinguishes the expected kernel effects from a changed external source. A controlled analogue input substitution or different receiver path may be necessary to establish that a new peak has a physical origin rather than arising from the receiver's own transfer and numerical processing. The instrument's internal coherence is not independent confirmation of an external transmitter.

I would also preserve the instrument's definition of time. A displayed spectrogram centre may be assigned to the window's midpoint, its start or another processing timestamp. If the burst begins within the window, that assignment is not the actual source-onset time. Filter group delay, acquisition buffering, clock offset and packet retention can add further displacement. Precise-looking timestamps must be connected to a calibrated physical reference plane, with the uncertainty of those transformations disclosed. The general time-frequency trade-off is only one component of the total temporal uncertainty, not a complete timing budget.

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The most persuasive result, therefore, is not the smallest numerical bin or brightest waterfall trace. It is a measurement whose source model, window, clock state, uncertainty and alternatives can be independently examined. A candidate's visibility across several window choices may support robustness, but because those analyses reuse the same IQ record, their agreement is not equivalent to independent receiver corroboration. A second properly characterised sensor, a source intervention or a repeat acquisition under changed physical conditions can supply the additional discrimination that mathematical reprocessing alone cannot. I pass the floor respectfully to Dr Hamming, who may ask whether my emphasis upon window trade-offs leaves sufficient room for specially designed concentration-optimal windows.

Richard Wesley Hamming | Peer question 1 to Dennis Gabor

Professor Gabor, a general statement about the time-frequency trade-off can conceal considerable freedom in how energy is distributed within an admitted interval. The prolate concentration problem, for example, asks how well a finite sequence may concentrate its energy within a selected frequency region. An engineer can use such sequences to reduce spectral leakage and improve the visibility of weak signals beside stronger emissions. How would you distinguish that genuine improvement from the false claim that a shorter physical burst has somehow yielded an unlimited number of independently resolvable spectral features? If the analyst selects a taper after inspecting the putative emission, must the resulting peak significance be treated as exploratory? I should also ask whether several orthogonal tapers applied to the same raw interval can be described as independent physical

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evidence or only as complementary numerical estimates derived from one acquisition, and what validation would be required before the laboratory could rely upon their agreement.

Dennis Gabor | Immediate answer to Richard Wesley Hamming

Dr Hamming, the concentration problem is an important refinement of analysis-window design, not an escape from finite observation. A taper may be chosen to place a relatively large fraction of its spectral energy in a selected band and to suppress leakage into others. This can improve a particular estimator or detector under conditions for which the design is appropriate. It does not supply samples from times outside the recorded interval, and it does not establish that an unknown emitter obeyed the signal model used to choose the taper. One must distinguish efficient use of finite information from creation of new information.

Multiple orthogonal tapers can provide complementary spectral estimates, and they may support a variance-reduction calculation under appropriate stochastic assumptions. But the raw observation interval is common to all of them. Their outputs are not independent physical acquisitions merely because the numerical sequences are orthogonal. The laboratory should evaluate the estimator covariance and the source population rather than equating mathematical orthogonality with independence of external causes. If a narrow candidate appears under several tapers, its resilience may be useful evidence about the record's structure, yet a common analogue artefact can survive all of them as well.

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Where the taper is chosen after the event is identified, I would describe the choice as part of exploratory analysis. A subsequent frozen detector can be challenged on independent bursts and no-signal controls to obtain a valid performance statement within the tested envelope. The test should include different burst durations, hop phases, signal amplitudes and strong interfering carriers. That procedure can determine whether a concentration-optimised taper reveals genuine weak events without producing a prohibitive rise in artefact detections. A claim about physical origin still requires discrimination among receiver-generated features, innocent transmissions and the proposed source.

The resulting report should preserve enough information to reconstruct the actual estimator: taper coefficients or an exact versioned definition, FFT length, scaling convention, input sample-rate and timebase, and any averaging or threshold adaptation. It should state whether peak frequency and bandwidth are merely algorithmic outputs or have been validated as estimates of physical quantities. The operator may legitimately favour one taper for a specified forensic task. Scientific discipline requires that the favour be supported by an experiment whose outcomes could have shown the taper to be inadequate. I return the floor to Professor Slepian for his principal treatment of spectral concentration and its conditions.

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David Slepian | Principal response 2: Concentration is conditional on the admitted support and signal class

Dr. Atkinson, the relevant mathematical problem is not simply to find a window with a pleasing spectral shape. It is to maximise concentration of a finite sequence in a selected frequency region under explicit constraints. That definition immediately supplies a limitation: the optimisation assumes the duration, region and objective have been chosen. It cannot certify the behaviour of an arbitrary unknown waveform outside that problem. A concentration-optimised taper may reduce leakage in a laboratory estimate and thereby make a weak adjacent component easier to observe. But its result cannot be interpreted without the source class, numerical precision, sample-rate and subsequent detector rule which determine whether the desired signal survives processing. [T2]

A high concentration ratio does not make all the energy outside a chosen band vanish, nor does it negate the fact that two physical emitters can be inseparable under limited time and signal-to-noise ratio. If the original burst is shorter than the effective analysis support, a window may weigh substantial periods containing only background noise. The estimated power of the burst can then change with the window's position and length. A different placement may give an apparently different bandwidth or peak amplitude without any physical change to the source. Validation should therefore vary arrival phase and measure event-level detection under the exact estimator rather than infer success from the taper's theoretical concentration alone.

We should also distinguish a representation designed for average spectral density from one intended to preserve the timing of rare transients.

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The former may profit from averages across many windows or tapers, while the latter needs event-sensitive retention and a truthful account of the arrival interval. An average of power spectra can be a satisfactory estimate of the background and simultaneously a poor way to describe a brief emission. A robust median may resist isolated outliers by design, yet those outliers may be the very transmissions the investigator was assigned to discover. The appropriate tool is determined by the proposition, not by an abstract claim that one estimator is universally superior.

Finally, the evidential value of a spectral feature must be separated from the beauty of its mathematical representation. A calibrated source injected at a defined RF reference plane can demonstrate how the receiver reports a known transient. A controlled change of clock, gain, preselector or input termination may help distinguish internal images from external emissions. A second independent acquisition can test whether a feature persists under conditions where competing hypotheses make different predictions. The analyst should preserve raw samples and processing version wherever possible; a displayed spectrogram alone cannot establish which details were discarded in its construction. I invite Professor Fourier to question whether any finite numerical transform can uniquely identify the physical source of a short burst without further assumptions.

A concentration ratio is a property of a precisely specified operator, observation interval, and frequency interval. If the operator is changed, the ratio need not retain its old value. This apparently austere observation has an immediate bearing on the investigation. A burst may be received through a narrow analogue preselector, translated by a local oscillator, windowed after decimation, and finally represented in a discrete Fourier transform. At

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each stage the admitted interval and transfer relationship differ. The first prolate sequence maximises energy concentration only for its stated mathematical problem. It does not optimise every detector, every waveform, every timing estimate, or every forensic claim. We should not place a ceremonial label of optimality upon a taper without stating what has been optimised.

One must also distinguish a waveform confined to a time interval from one merely observed within that interval. A perfectly time-limited nonzero waveform cannot simultaneously be strictly band-limited. The measured record is finite, but the receiver's filter may carry energy into the retained interval from an earlier input; likewise energy attributable to an event near the interval's end may persist beyond the final retained sample. A finite capture is an epistemic boundary rather than proof of finite source support. The examiner who reports an emission of exactly two milliseconds' duration merely because two milliseconds of samples survived has confused the observation gate with the transmitter's gate. The omitted prehistory and after-history may be material, particularly when measuring pulse edges, phase continuity, or occupied bandwidth.

Consider two classes of inference. In the first, a known analytic waveform arrives with unknown delay and amplitude in additive noise of characterised statistics. An estimator may exploit the known form to derive a delay parameter with uncertainty much smaller than the width of an individual analysis window. In the second, an unknown intermittent emitter has an unrecorded phase history, perhaps a drifting oscillator, and a modulation never specified in the acquisition plan. The same numerical precision cannot be claimed by simply applying the first estimator and concealing its

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premises. A method's mathematical efficiency within its model is not proof of model validity. Validation requires synthetic and physical challenges in which the signal class and nuisance variation reflect the proposed forensic task.

Frequency smoothing must be considered in the same manner. Concentrating energy into a selected band can reduce leakage from signals outside that band, but the taper may also attenuate or spread a brief desired event. The effect depends on the signal's location within the time support. For a window whose amplitude is small near its ends, an event arriving there may have a low detection probability although a long tone at the window centre appears splendidly resolved. Overlapping windows mitigate some boundary losses, but they introduce dependent calculations and can spread one event into several displayed frames. Neither the number of pictures nor the visually smooth contour supplies an independent count of transmitted bursts. I would therefore validate concentration and exposure together.

The evidence package must retain the taper coefficients or reproducible generation rule, the exact sample support, the effective noise bandwidth, the start time of each segment, the detector threshold and every exclusion or missing interval. A report should say whether its spectrum is a power estimate, an amplitude estimate, a phase-aware coherent statistic or merely a display. If the analyst selects whichever taper produces the narrowest attractive peak after examining the unknown event, the selection itself becomes part of the inferential procedure. The relevant false-alarm probability must account for that search, and the archive should retain the alternative parameter trials. Professor Gabor's broader question about joint

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time-frequency knowledge is therefore not defeated by a concentration theorem. It is sharpened into a demand that the investigator identify the operator whose result is being interpreted.

A practical acceptance campaign should include at least three contrasting inputs: a sustained tone near the anticipated carrier, a brief gated tone placed at several unknown phases relative to the analysis windows, and a broadband impulsive interference event. Each should be tested both alone and beside stronger adjacent activity. Let the examiner predict in advance which display structures ought to appear and which ought not. Observe whether a short burst is detected with the declared probability across the entire scan cycle; compare the measured footprint with the known injection duration; and separate any window-dependent broadening from the source's physics. In the absence of these challenges the investigator may truthfully report the computed transform, but must not assert an instrument-independent time-frequency portrait. I pass the floor, with respect, to Dr Tukey for a question about the risk of discovering the analysis settings after observing the most impressive candidate.

John Wilder Tukey | Peer question 2 to David Slepian

Professor Slepian, your concentration framework provides a rigorous answer to a problem whose boundaries have been stated beforehand. Yet a field examiner may search a recording using many windows, many lengths, several time-bandwidth products, different zero-padding factors and alternative noise estimators. The examiner then selects the display that gives one weak burst a visually compact bright region and presents it as though that representation had been chosen independently of the data. Nothing in the calculation is numerically false, but the evidential

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meaning of its apparent precision has been altered by selection. How would you distinguish legitimate exploratory analysis from confirmatory measurement under such circumstances? Would you require a held-out recording, a physical replay with randomly placed bursts, a correction for multiple comparisons, or a more modest statement confined to the chosen representation? I am especially concerned that investigators may select a time-frequency picture whose parameters favour the known candidate while still making broad claims about negative findings for all other events that the same analysis may have suppressed.

David Slepian | Immediate answer to John Wilder Tukey

Thank you for that question. Dr Tukey, I would welcome exploration and reject its disguise as pre-specified confirmation. The distinction can be made operationally. The investigator should mark which processing decisions were chosen before examining the contested event and which were chosen because of what appeared on the screen. The latter decisions need not be discarded. They can generate hypotheses, suggest alternative filter configurations, or identify the reference signals most likely to reveal an artefact. They cannot automatically inherit the confidence statement that would have applied had one test been stipulated in advance. A discovery path is evidence about how the hypothesis arose; a validation path is evidence about how it survived attempted falsification.

In a practical validation design, preserve the chosen analysis unchanged and submit it to independently prepared challenges. The challenge may involve physical injections at the receiver input, or rigorously documented simulations where the model is sufficient for

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the narrower software proposition. Randomise burst phase, duration, amplitude, frequency, overlap with adjacent activity and the receiver's scan state. Include null trials. Save every outcome, not just those consistent with the favourable display. A held-out recording can help for an existing signal class, but if both training and validation data share an unrecognised receiver artefact, the split does not by itself establish external origin. An intervention at a physical reference plane may provide information unavailable from partitioning a single digital archive.

The confidence statement must correspond to the tested procedure. If the examiner selected the most successful of twenty parameter settings after seeing the original observations, the performance of that selection rule should be tested, or the report should explicitly say that the displayed result is exploratory. There is no universal multiplication factor that rescues every selection process; dependence among trials and the details of adaptation matter. Nor may an investigator infer wideband non-detection from a search optimised for one discovered burst. A procedure which concentrates the energy of one signal class may deliberately reject another. The negative claim therefore needs a specified signal population, admitted input range, observation exposure and empirically tested operating characteristics.

Finally, the archive should make the analysis reproducible without confusing reproducibility with validation. Retain the raw sample interval, software version, coefficients, parameters, numerical precision, time references and alternative analyses which materially

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influenced the conclusion. A separate examiner should be able to recreate the picture and then challenge its interpretation. The most useful result may be a bounded one: a feature survives a particular declared set of analyses, but its occupied bandwidth and origin remain dependent upon additional assumptions. Such intellectual restraint is not retreat. It is the correct consequence of a finite record and an estimator designed for a finite class of questions. I pass the token respectfully to Professor Fourier, who can separate the transform's exact mathematical identity from the physical hypothesis it is employed to support.

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Jean-Baptiste Joseph Fourier | Principal response 3: Representation, inversion and the non-uniqueness of physical sources

Dr. Atkinson, I begin with a distinction that is deceptively elementary. A transform can be exact for the values supplied to it while the values themselves are incomplete measurements of the physical event. If a receiver retains N complex samples, a discrete Fourier transform produces N coefficients related by an invertible linear transformation, subject to the adopted numerical precision and convention. This result means that the transform of those N numbers need not lose information if every coefficient is kept without destructive alteration. It does not mean that the N numbers uniquely specify the analogue input before the antenna, front-end filter, mixer, sampling aperture and finite observation gate. The distinction between an invertible transformation of a record and an invertible measurement of nature must be maintained throughout the forensic report.

A finite-duration burst offers several levels of potential description. The analyst may wish to locate a maximal-energy time interval, estimate a nominal carrier under a chosen modulation model, report a spectral centroid, or test for two closely spaced emissions. A single plotted peak does not determine which of these propositions has been established. Consider a rectangular gate multiplying a sinusoidal carrier. The observed Fourier transform contains the transform of the gate, so energy appears away from the carrier because observation duration is finite. Applying a tapered window can reduce sidelobes at the price of widening the principal lobe and modifying the amplitude estimator. Interpreting that spread as transmitted spectral occupancy without accounting for the window would mistake the method for the object.

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The inverse problem is more severe when the waveform was compressed by thresholding, magnitude-only display or time averaging. A power spectrogram has discarded phase relationships that may be indispensable to determining whether neighbouring bright regions derive from one coherent burst or several emitters. Two waveforms may share a magnitude spectrum while differing markedly in phase and temporal structure. Unless the source class supplies additional constraints, selecting one plausible inverse is not reconstruction of a uniquely observed past. Likewise an absolute timing statement cannot be recovered from a spectrogram whose original time stamps, filter delay and clock corrections were not preserved. The analyst who retains only the coloured waterfall has retained a picture rather than all of the evidence needed to test its construction.

A particularly dangerous temptation lies in the interpretation of zero padding. Let N denote the number of acquired samples over duration T and let N_z denote the length of a padded transform. The displayed bin spacing changes from F_s/N to F_s/N_z, but the observed duration T and the noise realisation remain unchanged. Interpolated samples of a continuous transform may make it easier to locate a peak or fit a stated parametric model; they do not supply additional independent physical observations. In a sufficiently favourable known-tone model, a frequency estimator can achieve uncertainty smaller than 1/T by exploiting signal-to-noise ratio and phase structure. Such performance does not contradict finite-duration uncertainty. It depends upon assumptions which an unknown, unstable or modulated emitter may fail to satisfy. Precision must therefore be reported with both estimator and waveform class.

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I would demand separation of three tests. The first establishes numerical correctness: is the discrete transform implemented with the stated sign, normalisation and window convention, and can another examiner reproduce it? The second establishes measurement traceability: did the receiver measure the declared input quantity with an adequately characterised amplitude, phase and timing transfer? The third establishes inference validity: does the observation distinguish the particular external-source hypothesis from internal mixing, local oscillator leakage, overload, reflection or another transmitter? Passing the first test does not guarantee the second or third. One can render a perfectly accurate spectrum of a receiver-generated artefact.

The examiner must also consider the physical gate. If the instrument triggers recording only after a detector threshold is exceeded, its retained interval has been selected by information not present in the archive. A one-millisecond capture may contain the terminal portion of a two-millisecond emission, and the missing onset may change every claimed time and bandwidth estimate. Pre-trigger recording may improve the situation when it genuinely existed in memory, but later retrospective interpolation cannot observe missing analogue history. The proper report distinguishes recorded event duration from verified transmitter duration, and it describes any invalid or unobserved intervals. A negative conclusion about transmissions outside the admitted observation cannot be inferred from the sampled segment.

The necessary comparison is not between competing aesthetic renderings of the same data but between hypotheses whose physical predictions diverge. An antenna substitution, input termination, known

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reference injection or controlled oscillator retuning may reveal whether a feature belongs to an external radio-frequency emission or to a receiver transformation. A second receiver provides useful corroboration only to the extent that the relevant errors are independent. A common reference oscillator, antenna distribution or trigger policy may create shared artefacts or omissions. The evidence record should make the dependencies visible so that agreement is not inflated into certainty.

The algebra permits many useful consequences. Windowed Fourier methods are valuable to localise and describe finite observations; transforms preserve and reorganise record information under stated conditions; and parametric models sometimes estimate parameters much more sharply than an unmodelled power plot. None of these propositions licenses a causal label from a bright rectangle. The investigator must state which mapping is mathematically invertible, which analogue transformations were calibrated, and which uncertainties survive. I therefore ask Dr Shannon to test my distinction at the boundary where a compressed spectral record may preserve one detection question while destroying another. With respect, I now return the floor to Dr. Atkinson for the next contribution.

Claude Elwood Shannon | Peer question 3 to Jean-Baptiste Joseph Fourier

Professor Fourier, you distinguish an invertible numerical transform from a physically reversible observation, and I agree that the distinction is fundamental. I would nevertheless ask whether the investigator must preserve every detail of the raw record to make a useful finding. Suppose a defensive monitor is configured only to decide whether a known

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signalling waveform occurred during a defined window. A matched statistic may be adequate for that task while discarding phase, interference structure or modulation details irrelevant to the specified hypothesis. If the retained sufficient statistic supports an accurate detector, insisting on the original wideband sample stream could impose extraordinary storage costs without improving that particular decision. On the other hand, an inquiry may later arise about source identity, phase coherence or a second previously unknown emission. How should an evidential policy reconcile these different futures without simply declaring every lossy compression illegitimate? I ask you to distinguish information sufficient for a specified question from information sufficient for unanticipated forensic questions.

Jean-Baptiste Joseph Fourier | Immediate answer to Claude Elwood Shannon

Dr Shannon, I would not declare that every lossy reduction is impermissible. My objection is to an undisclosed change in the proposition. A compressed statistic may be an excellent and independently validated instrument for the predeclared question that motivated its design. It does not thereby retain all the information an adversarial examiner might later require. An archive policy should distinguish records intended for operational discovery from records intended to sustain contested physical claims. The former may retain a detection statistic, a threshold, a time tag and a configuration identifier; the latter may require unaltered IQ samples or a demonstrably lossless form, with sufficient pre-trigger and post-event context to test competing explanations.

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We must define sufficiency within a model, not as an unqualified property of the compressed file. A matched-filter output can be sufficient for estimating a known signal's amplitude in a particular Gaussian noise model, but the model excludes arbitrary interfering emitters, nonstationary receiver artefacts and unknown transformations. The same scalar may fail to reveal whether the observed peak resulted from overload or correlated local oscillator activity. A later question may demand an observation the compression irreversibly discarded. In that circumstance no skill in subsequent computation can manufacture the missing degrees of freedom. The correct conclusion is restricted, not necessarily false.

I propose a practical hierarchy. Preserve a compact continuous operational log covering the measurement envelope, calibration state, threshold policy, time base and invalid intervals. For material detections, retain raw windows around the candidates whenever the architecture permits. For exceptionally consequential findings, preserve representative background intervals, controlled challenge recordings and independent corroboration data. When resources prohibit complete retention, document the selection rule and quantify its limitations. A triggered record is not a continuous survey merely because its timestamp counter ran continuously. A claim of non-detection should be conditional upon the actual exposure and validated sensitivity.

An audit should ask the examiner to reproduce the declared result from the surviving data and to identify two plausible alternative waveforms that the reduction would make observationally

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indistinguishable. If the alternatives matter to the conclusion, the retained statistic is inadequate for that stronger claim. The exercise directly tests the boundaries of sufficiency. It also prevents a false reassurance drawn from a small file that is perfectly reproducible but physically ambiguous. Mathematical precision and evidential completeness are not enemies; they become compatible when the question and preserved boundary are both stated. I invite Professor Neyman to examine whether the uncertainty reported for a fitted transient can survive the analyst's opportunity to choose the most favourable window after seeing it.

Jerzy Neyman | Peer question 4 to Jean-Baptiste Joseph Fourier

Professor Fourier, I appreciate your insistence upon specifying the inference rather than merely displaying a transform. Yet the operator may search hundreds of time positions and numerous window lengths, then fit a carrier parameter to the strongest resulting peak. The familiar standard error of a single fitted frequency presumes a model and often a fitting procedure chosen before that selected observation. Selection across the record changes the distribution of the estimator and the meaning of a nominal confidence interval. How can the investigator report a technically useful interval without concealing the search that produced the candidate? Should the analyst correct for every possible processing choice, repeat the measurement with a newly constructed challenge campaign, or report an explicitly exploratory estimate and postpone stronger claims? I would also ask how missed detections at the edges of the selected windows affect any subsequent statement that the receiver had surveyed the whole admitted band reliably.

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Jean-Baptiste Joseph Fourier | Immediate answer to Jerzy Neyman

Professor Neyman, the mathematical transform cannot answer a question concerning sampling of possible experiments unless the experiments are first defined. I would therefore separate the numerical representation, the estimator selected after exploration, and the inferential procedure whose coverage the laboratory claims. The displayed peak is a fact about the calculation. A nominal error bar computed for an unselected pure sinusoid is not automatically valid after searching many windows and retaining the strongest result. An investigator may report the numerical fit as a model-dependent exploratory estimate, identify the search settings and refrain from claiming its nominal confidence level. A stronger claim requires a performance evaluation encompassing the actual selection process or a separate validation procedure fixed in advance.

A physical replay or independently prepared reference dataset can test the entire pipeline, not just one transform stage. The challenge designer should vary burst onset relative to the windows, duration, frequency, amplitude, modulation, adjacent interference, and receiver operating state. A useful validation distinguishes the event-level detection rate from the fraction of windows that cross threshold. A single emission may illuminate three adjacent frames; counting those frames as three successes inflates effective sample size. Conversely, a weak event at a taper edge may be missed even though a centre-aligned test succeeds repeatedly. The results must include unfavourable and invalid trials.

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The condition of the analogue input remains essential. A post-acquisition software simulation can validate a numerical transform, but it may bypass front-end compression, oscillator transients, antenna mismatch and acquisition gaps. Where the claim depends on physical sensitivity or source attribution, a calibrated injection at a declared reference plane adds a necessary form of challenge. Changes of antenna or independent receiver configuration can test internal artefacts. A system should not pass a stronger claim merely because its display has high numerical precision.

One might finally report an interval conditional upon a fully specified signal model and a declared search procedure whose coverage has been checked, and separately report the observed FFT grid. The two numbers need not match and should not be made to match by rhetorical force. If the evidence supports only a statement that a candidate feature occurred within a recorded interval and a broad frequency region, that statement can still justify further investigation. It is better than an unsupported assurance that a particular transmitter operated at an apparently exact frequency. I now pass the floor with respect to Mr Nyquist, who can examine how analogue sampling and aliasing place additional conditions upon this already qualified representation.

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Harry Nyquist | Principal response 4: Sampling, analogue admissibility and conditional frequency claims

Dr. Atkinson, one must not infer that the precision of a digital frequency axis establishes the physical frequency of an emitter. The relationship between a continuous input and its samples depends upon the admitted analogue bandwidth, the sampling schedule and the absence of uncharacterised alias contributions. In an ideal uniformly sampled complex-baseband system, a waveform whose spectrum is confined to the specified Nyquist region can be reconstructed under the requisite assumptions. A real SDR uses an antenna, preselection, gain stages, mixing, analogue filtering, sampling apertures, numerically controlled oscillators and digital decimation before producing the samples subsequently analysed. Each transformation has a stated transfer and an operating envelope. The spectrum presented on the monitor is a derived representation of that chain, not a direct photograph of a transmitter's oscillation.

A short burst is especially sensitive to boundary conditions. Its abrupt envelope contains frequency components broader than those of its carrier alone. If a receiver's analogue passband or decimator suppresses part of that envelope spectrum, an attempted reconstruction of the burst's onset can show ringing and changed apparent duration. Such changes may be perfectly consistent with correctly functioning filters, but they become forensic hazards when the analyst mistakes an instrument response for the source's physical timing. The apparent first nonzero output sample depends on the threshold, filter impulse response, time reference and noise. An analyst must distinguish a time stamp for the centre of a digital analysis

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frame from a time stamp assigned to the physical onset of RF energy at the nominated reference plane.

When the source frequency is unknown, alias uniqueness becomes a separate question. Sampling a real-valued input without sufficient analogue restriction can map different input frequencies to the same digital frequency. Sampling complex IQ can preserve the sign of frequency relative to an appropriately calibrated oscillator, but an image introduced before conversion or an I/Q sign error may still masquerade as a different physical band. The examiner should vary the tuning state or use a separately characterised path so that rival hypotheses predict different movements of the indicated line. A digital frequency number which stays fixed after one software resampling operation may only demonstrate consistency of an implementation, not external origin.

The finite-window problem and the analogue problem must be kept analytically distinct. If a known sinusoid of stable phase occupies a measured duration T, the frequency estimation uncertainty may be studied with a specified signal model and noise covariance. If the transmitter chirps, changes phase at its burst edges, or produces unmodelled modulation, fitting a single carrier may identify a convenient average rather than the input's physical oscillation at a particular instant. A time-frequency display can suggest such model failure by showing a moving ridge, yet the ridge itself may have been altered by window choice and filter group delay. An uncertainty budget that considers only FFT bin spacing is consequently incomplete.

The operating record should preserve the aggregate sample rate and any fractional-rate conversion; the analogue front-end bandwidth and

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measured rejection outside it; the local oscillator tuning and accuracy; the clock reference and time-tag epoch; the actual filter coefficients; and the locations of missing blocks or receiver-state transitions. A recorded transform should identify the sample indices admitted, the effective noise bandwidth of the window, the treatment of overlap and the means of amplitude normalisation. These facts permit another examiner to reproduce the numerical result and to determine whether the reported event could have been reshaped by the measurement process. Without them, the displayed candidate may be interesting intelligence but weak evidence for a precise transmitter duration or carrier estimate.

I also propose a simple falsification campaign. Inject a known short burst at a characterised RF input plane and vary its onset across a full window-hop period, its nominal carrier across the relevant passband and its amplitude from comfortably above threshold to the detection limit. Add strong neighbouring signals to test nonlinear responses. Repeat with a new tuning state and, where the claim is consequential, an independently characterised receiver path. Compare the acquired raw IQ with the stored spectral display. If a known one-millisecond burst produces apparent three-millisecond persistence in a waterfall because of filter ringing and overlapping frames, the display is not necessarily defective. The report is defective if it calls three milliseconds the physical emission duration without calibration.

A null survey demands the corresponding exposure calculation. If a scanning receiver listens to a particular channel during only a fraction of its monitoring period, a transmission can pass unobserved even if the receiver is highly sensitive whenever tuned. The detector's conditional success probability must be multiplied or otherwise combined with the probability of

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temporal and frequency overlap under a justified event model. A negative result is not stronger because the waterfall looks quiet during a brief observation. Likewise many overlapping frames around a known event do not create as many independent physical trials.

What then is a defensible conclusion? The analyst may state that a feature, consistent with a specified signal model and after calibration of the front end and time base, was observed within a bounded time-frequency region. A sharper carrier or onset claim is possible when the model, reference plane, uncertainty and challenge tests support it. The present method cannot identify a specific device merely from an apparent transform peak. A physical source is an inference about a chain of causes, not the label attached to a numerical bin. I hand the floor, with respect, to Professor Bridgman for the question of what operation must define the quantity the examiner says has been located.

Percy Williams Bridgman | Peer question 5 to Harry Nyquist

Mr Nyquist, your description of the analogue and numerical boundaries is carefully qualified, but I should like to examine the quantity being reported. Two laboratories may acquire the same burst through different bandwidths and windows. One records the first sample exceeding a fixed amplitude threshold; another estimates the centre of an energy distribution; a third obtains the time of the largest matched-filter response. All three may publish an 'arrival time' with many decimal places, and each may reproduce its own number exactly. What physical event, if any, have they measured in common? If their operational definitions differ, it seems premature to combine the results into a time-difference localisation estimate. What calibration or demonstrated

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transformation would make them comparable? I am also concerned by the practice of adjusting thresholds after an event has been found. Such adjustments can move the apparent onset without moving anything in the external world. How would you state this limitation without making every useful measurement impossible?

Harry Nyquist | Immediate answer to Percy Williams Bridgman

Professor Bridgman, the observation you describe identifies a vital distinction between a named parameter and its realised estimator. An 'arrival time' is not a complete measurand. The examiner should identify the reference plane and the physical feature whose timing is sought: perhaps the onset of a stipulated envelope, the crossing of a stated power threshold at the receiver input, or the relative delay between two receivers under a shared signal model. The estimator then requires a calibrated transfer from physical event to numerical time tag. Two estimates that operate upon different features cannot be equated merely because each carries the label arrival.

A threshold crossing is useful when it is described honestly. Its value depends upon noise, gain, filtering, sampling phase and the threshold itself. If the threshold is adjusted after the observation, the resulting number may remain reproducible but will not have the coverage attributed to a predeclared procedure without additional validation. An energy centroid can be more stable for certain broad envelopes but can move with interference or truncated observation. A matched-filter maximum has valuable properties for a specified known waveform and noise model, but it need not coincide with the physical first emission of energy. Each estimator answers its own

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question and should be calibrated against the particular reference event required by the investigation.

For a time-difference comparison, I would insist upon a common definition, or a measured relationship between the definitions with its uncertainty. The relationship must account for instrument group delay, reference-epoch offsets, sample-clock drift, filter states, threshold selection and the waveform class. A laboratory can establish such a relationship with known injected waveforms at several amplitudes, onset phases and modulation patterns. It should retain raw intervals and the estimator software so that another examiner can test the result. If the relationship varies materially with signal class, a universal conversion constant is inappropriate.

This does not make useful measurement impossible. It makes the claim conditional upon a procedure whose limits can be examined. One may report that a particular detector flagged an event at a stated timestamp, even when the exact physical onset cannot be recovered. That operational finding may justify another survey, a calibrated comparison or improved preservation. A stronger physical inference requires stronger evidence, not simply more digits on the timestamp. To avoid paralysing the investigation, classify results explicitly as discovery markers, calibrated measurements or source-attribution inferences, and state the evidence needed to promote a result from one class to the next.

The burden is proportional to the consequence of the conclusion. A minor discrepancy in the position of a burst marker may be immaterial to a broad monitoring report but decisive to a localisation

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claim based upon microsecond differences. The same acquisition could legitimately support the former while leaving the latter indeterminate. I therefore favour operational clarity, a reference-plane diagram and a direct challenge to plausible alternatives, rather than a misleading universal standard of numerical precision. I invite Mr Wiener to examine the dependence that arises when the detector selects the very records from which its time-frequency performance is later estimated.

Norbert Wiener | Peer question 6 to Harry Nyquist

Mr Nyquist, assume a monitoring instrument retains only intervals whose short-time spectral estimates exceed an adaptive threshold. The threshold is itself modified by a rolling background estimate, and that estimate includes previously detected bursts unless the operator explicitly excludes them. An investigator later examines the stored bursts, measures their apparent widths and carrier stability, and concludes that the receiver has near-perfect coverage of this class of events. Yet the archive contains only the events that the coupled detector and background estimator chose to admit. Does your account of sampling give us a way to make the missing records visible in the evidential logic? How should the laboratory challenge detector memory and feedback, especially where an earlier strong transmission changes the threshold against which a later weak burst is judged? I seek a practical distinction between stable operation and independent validation of the system's event-selection policy. In particular, the missing-event population must not disappear merely because it left no retained file.

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Harry Nyquist | Immediate answer to Norbert Wiener

Mr Wiener, your challenge concerns the difference between the population presented to the receiver and the population retained by its policy. It is not enough to verify that the samples in an admitted window correspond to the stated time base. One must also characterise the selection function by which some intervals are retained and others disappear. The selection policy includes threshold dynamics, background estimators, hold-off periods, buffer availability, gain switching and any changes of analysis window. If those states are recorded, the examiner can identify where negative evidence is impossible and where a conditional detection probability might be established. Without them, the archive is a selected subset of uncertain representativeness.

I would design a challenge campaign in which controlled bursts arrive at unpredictable times before, during and after stronger legitimate transmissions. Vary their relative levels and time separations. Some trials should be deliberately constructed to stress background-estimator adaptation or trigger hold-off, even if these make the receiver look worse. Preserve every injected event's timing and class separately from the system's outputs, and compute event-level misses as well as repeated detections of the same physical burst. A detector which flags one burst in several windows should not receive several successes for one independent event.

The laboratory may model feedback state by preserving threshold trajectories or sufficient state snapshots. If the adaptive background is an exponentially weighted average, state its update rule and

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effective memory. A current threshold may depend upon many earlier events. Merely preserving the threshold when a trigger fires does not reveal which unretained earlier signals influenced it. At the minimum preserve a continuous state log, invalid intervals and periodic reference challenges. Where resource limits preclude continuous raw recording, those limitations must appear in every statement about occupancy or absence.

For the admitted events, the short-time transform may still support useful bounded measurements. The detection count should be reported relative to the validated exposure population. Its absence from a later interval should be characterised as no alert under the stated policy, not proof of an empty radio environment. The inference becomes stronger if independent monitoring or externally administered references show that the apparatus was receptive during that period. Such evidence must be independent of the same trigger rule where possible. A second logger driven by the same threshold would not correct the selection bias.

The problem is not peculiar to sophisticated software radios. Any measuring apparatus that chooses what to record has a selection boundary, but modern adaptive processing can make that boundary dependent upon its own history. The solution is to bring the selection mechanism inside the declared experimental system. The examiner must account for the observation policy alongside the samples, and must not read detection performance from a file of detections alone. I pass the token to Professor Neyman, whose statistical account can

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determine how these qualifications enter the claimed confidence of a short-burst finding.

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Jerzy Neyman | Principal response 5: Confidence intervals, validation populations and the evidential cost of searching

Dr. Atkinson, the language of precision is particularly hazardous when it is attached to a result selected because it appeared impressive. A confidence interval is not a blessing bestowed upon a number by algebra. It is a procedure whose long-run coverage depends on a specified family of data-generating mechanisms, a sampling design and a rule fixed before application or evaluated as part of the design. The forensic observer may search across frequencies, time positions, transforms and window lengths, then choose the sharpest estimate. That procedure differs from fitting one predetermined known waveform to one predetermined acquisition interval. Its nominal interval may not cover with the stated probability. We must distinguish the result of a calculation from the operating characteristic of the complete process that generated and selected it.

For an event detector, define an eligible physical event rather than a bright pixel. Let N_e be the number of independently prepared challenge events actually exposed to the specified receiver state, and D_e the number detected under a fixed event-level success rule. The empirical proportion D_e/N_e is meaningful only for the challenge population and the admitted exposure conditions. A burst near a window boundary may experience a different detection probability from one at the centre. A burst beside strong adjacent activity may be masked even though the isolated calibration tone was found without difficulty. If the user intends assurance across multiple operating strata, a pooled average weighted towards easy trials can conceal failure in the weakest stratum. Validation should therefore report results by

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frequency, duration, amplitude, window onset, interfering signal and receiver state where those distinctions are material.

The temporal support of the estimator is also part of its performance. Suppose a 2-millisecond burst triggers several overlapping 8-millisecond analysis frames. Those frame counts are not independent Bernoulli experiments concerning the presence of three physical emissions. One known burst is one challenge event for the event-detection question, while the several frames may be repeated dependent numerical measurements of it. If the objective is frequency estimation, the appropriate experimental unit may instead be a controlled burst record acquired in one independent trial. Treating dependent frames as independent can yield artificially narrow error bars and false confidence in the stability of the estimated carrier.

The role of multiple testing must be expressly defined. If an examiner searches a thousand independent null bins with a threshold producing one-in-a-thousand per-bin false-alarm probability, the chance of at least one false alarm is not one in a thousand; under that idealised independence model it is 1-(0.999)^1000, which is about 0.632. Frequency bins and overlapping windows are rarely all independent, so this particular number is not a field-system prediction. Nevertheless it illustrates the danger of transferring a single-test threshold to a searched image. A conservative union bound can control the probability of one or more false alarms without requiring independence, while an empirically validated detector can sometimes perform better when correlations are known. The test population and statistic must be stated.

A signal parameter may be estimated more precisely than an FFT bin interval under an appropriate known-waveform model, but the uncertainty

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of that estimate must include nuisance parameters. Receiver frequency error, clock drift, window timing, unknown chirp rate, sample loss and the decision to select one peak can each produce bias or extra variance. A calibration source may constrain some of these, yet a model fitted to the calibration source may not apply to a structurally different hostile emission. The confidence interval for a sine-wave carrier in Gaussian noise does not directly become an interval for the centre frequency of an unknown spread-spectrum burst. Parameter definitions, hypotheses and test populations must be explicit.

I would preserve exploratory findings, but keep them in their proper evidential category. Exploratory analysis may reveal a plausible carrier, a repetition pattern or an interference mechanism that deserves a directed test. To confirm the directed hypothesis, freeze the pipeline and submit it to independently constructed challenge observations. The reference experiment must include null trials, near-threshold events and difficult timing positions, and should retain failures rather than correcting the procedure until the unfavourable observations disappear. If adaptation is essential to the instrument's operation, validate the adaptation itself as a policy with defined state histories. A statistical assurance statement based upon one favourable demonstration is merely an untested prediction.

There is also a legal and investigative difference between establishing that a candidate was observed and establishing that a particular source caused it. A detection performance test addresses the former under declared hypotheses. Source identity requires alternative causal explanations and discriminating interventions. Receiver-generated spurs, aliased external transmissions, electromagnetic coupling, intermodulation,

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and unrelated devices can create features with similar time-frequency footprints. One should test the consequences of retuning, termination, antenna substitution and independently characterised reception. Even a very small false-alarm probability for a known candidate detector does not by itself assign a posterior probability that the candidate came from one named device.

My preferred conclusion is conditional but useful. Report the actual observed transform and its processing settings, the physical exposure and candidate selection rule, the uncertainty for any fitted parameter under a declared waveform model, and performance bounds from a representative challenge campaign. Distinguish non-detection from absence, and distinguish the instrumental detection question from an identity assertion. Where no relevant challenge trials exist, report uncertainty explicitly instead of inventing confidence through decimal places. Precision is a property of the validated inference, not of the typographic display. I shall gladly receive one final question from Professor Fisher concerning whether parametric confidence and the empirical validation of a field detector may be confused.

Sir Ronald Aylmer Fisher | Peer question 7 to Jerzy Neyman

Professor Neyman, imagine that a laboratory has completed one hundred calibration trials of a known 10-millisecond sinusoidal burst, and the resulting estimator has a remarkably narrow observed spread of fitted carrier values. The same operator subsequently investigates a faint, unknown, three-millisecond emission that may contain frequency modulation, changing amplitude and unresolved interference. The laboratory quotes the precision established for the known sinusoid and reports the unknown burst's frequency to a fraction of a hertz. Its

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numerical algorithm has behaved reproducibly, and its training trials were numerous. What evidence would allow the calibration distribution to support the subsequent unknown-emission inference? Should we treat the change of waveform class as an additional uncertainty component, a potentially complete model failure, or a matter resolved by a small number of additional trials? I also ask how an investigator can avoid the opposing mistake of rejecting every operational finding until a universal theory of all possible signals has been validated.

Jerzy Neyman | Immediate answer to Sir Ronald Aylmer Fisher

Professor Fisher, the established distribution belongs to the conditions under which it was established. If the unknown event is not reasonably represented by the calibration model, adding a casually chosen small uncertainty to its result is not an adequate repair. A fitted sine-wave frequency can be a mathematically well-defined parameter even when the real event is chirped; the parameter then describes a chosen approximation, not necessarily a physical oscillator's constant frequency. The discrepancy may be systematic and class dependent. One must test the model and, where necessary, change the measurand rather than merely enlarge a standard deviation until the result appears respectable.

I would begin by examining residual structure and alternative signal models. If the retained IQ supports a frequency trajectory, a model incorporating chirp may be more appropriate than a stationary carrier. If the record is too short or too severely filtered to distinguish plausible alternatives, the analysis should report the broader observable quantity: perhaps a frequency interval occupied by

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detectable energy during the admitted time window. Calibration trials should include waveform classes and interference conditions representing the claim. Where the question concerns a particular operational signal class, a finite validation campaign can be sufficient for a bounded conclusion without proving universal performance.

One must also preserve the difference between estimator uncertainty and classification error. A very narrow conditional interval for a model parameter does not establish that the model is correct, and a high probability of detecting a known signal does not establish which device emitted an unknown one. The latter questions require competing hypotheses and independent physical intervention where practicable. A source may be identified by a convergent record of modulation features, timing correlation, direction, antenna response and controlled exclusion of receiver artefacts; the frequency estimate alone seldom carries such a burden.

A practical report would include the calibration waveform, the population and trial count, the processing procedure, any exploration used to choose it, the actual observed data and their residuals, and the limitations caused by signal-class differences. The investigator may confidently state that a candidate feature was detected under a specified rule while qualifying its source identity or fine parameter estimates. This is a disciplined separation of claims, not a refusal to investigate. The Royal Society's classical discipline of measuring what can be measured is entirely compatible with a warning against attributing more to the instrument than its experiments warrant.

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I return the token courteously to Dr. Atkinson, who may now synthesise our distinctions and set out the numerical applications that make them inspectable.

Dennis Gabor, Cross-Peer Question to David Slepian: Professor Slepian, when an emission lasts ten microseconds, what objective should govern the choice between a narrow spectral main lobe and a short detection window?

David Slepian, Cross-Peer Answer to Dennis Gabor: Professor Gabor, no universal optimum exists without defining the signal class, detection loss and allowed observation support. A window concentrating energy in one frequency interval may spread or attenuate a burst whose arrival time is uncertain. Evaluate time-localisation bias, spectral leakage, false alarms and detection probability together, using injected bursts with randomised onset positions and occupied bandwidth. An FFT grid can be made arbitrarily dense through padding, but that does not create physical event duration or new independent information. Preserve the original time-indexed I/Q and the taper coefficients. A narrow visual line from one chosen window cannot by itself establish a continuous carrier or uniquely identify its source. I pass the token to Mr Fourier to examine what the transform represents.

David Slepian, Cross-Peer Question to Jean-Baptiste Joseph Fourier: Mr Fourier, can an inverse transform of a clipped or band-limited short-burst record uniquely re-create the physical RF pulse before the receiver?

Jean-Baptiste Joseph Fourier, Cross-Peer Answer to David Slepian: Professor Slepian, only under specific restrictions that make the forward map effectively invertible over the admitted signal class. Analogue filtering, clipping, missing samples and unknown phase can map distinct physical

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inputs to indistinguishable records. An inverse transform reconstructs a mathematical representation from available coefficients; it cannot recover discarded frequencies or unobserved amplitude history by declaration. Show the receiver transfer function, initial conditions, clock uncertainty and amplitude range, then test reconstruction with independently characterised pulses. A regular-looking waveform may be a property of an assumed band limit rather than evidence of a genuinely smooth transmitted signal. The examiner should preserve alternative physical explanations wherever the measurement map is non-unique. I yield to Mr Nyquist regarding sampling conditions.

Jean-Baptiste Joseph Fourier, Cross-Peer Question to Harry Nyquist: Mr Nyquist, why is the effective analogue passband relevant when an engineer argues that a nominal sample rate alone proves complete capture of a brief pulse?

Harry Nyquist, Cross-Peer Answer to Jean-Baptiste Joseph Fourier: Mr Fourier, the sampling theorem requires spectral and timing conditions. A short pulse can contain energy far beyond the displayed centre frequency, and a front-end filter may suppress important temporal detail before the first code is written. The nominal digital rate does not establish analogue input bandwidth, track-and-hold response, anti-alias rejection, jitter or headroom. Challenge the complete analogue-to-digital path with calibrated pulses of different rise times, amplitudes and arrival phases. Report which event characteristics remain estimable and their uncertainty, rather than speaking of the pulse as completely captured without bounds. If a sample is lost or the system retunes during the event, digital interpolation supplies no

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measurement of that missing interval. I pass the token to Dr Neyman for a defensible confidence statement.

Harry Nyquist, Cross-Peer Question to Jerzy Neyman: Dr Neyman, what conclusion follows if ninety-nine of one hundred prescribed short bursts are detected, while none of the challenges occurs near the window boundary?

Jerzy Neyman, Cross-Peer Answer to Harry Nyquist: Mr Nyquist, the trial fraction estimates performance only under the tested sampling arrangement. The programme has omitted a potentially vulnerable subset of arrival phases, so its observed success rate cannot be assigned to all possible bursts. Use a predeclared challenge population that covers onset, frequency, modulation, SNR and receiver state; include independent randomisation or a systematic worst-case matrix. Report uncertainty intervals for detection and false-alarm rates, with dependence between trials investigated. Do not silently discard failures or recast them as invalid after observing the data. The number of valid independent trials matters, but representativeness matters as well. A strong detection claim should survive hold-out conditions and a physically independent reference. I return the token respectfully to Dr Atkinson.

Moderator synthesis | Dr. James M. Atkinson

Our distinguished contributors have established that a short burst is not made a long, stationary signal by the convenience of Fourier arithmetic. The spectrogram may be precisely generated and visually elegant while the physical emission's onset, duration, carrier history and source remain uncertain. Professor Gabor has emphasised the joint character of time and frequency representation; Professor Slepian has shown why concentration depends upon a stated mathematical objective and support; Professor

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Fourier has separated invertible calculation from the potentially non-invertible path of measurement; Mr Nyquist has identified sampling, aliasing and filter delay as physical conditions of interpretation; and Professor Neyman has insisted that confidence belongs to a fully specified procedure, not to a chosen bright pixel. Their conclusions are complementary rather than contradictory.

The first practical consequence is to declare the measurand. An operator who reports 'the burst occurred at time t and frequency f' has not finished the description. Was t the leading-edge threshold crossing, the centre of a selected FFT frame, the peak of a correlation function or the centre of an energy distribution? Was f an FFT-bin centre, a spectral centroid, the estimated carrier of a stipulated stable-tone model or a frequency trajectory through the event? Which input reference plane, receiver configuration, sample interval and numerical processing history do these numbers describe? These definitions are not academic ornament. They determine whether another receiver can make a comparable measurement and whether the reported uncertainty has any evidential meaning.

The second consequence is to separate the actual record from the unobserved physical history. A finite capture may begin after the emitter started transmitting. A window may span samples acquired in different gain or calibration states. A receiver impulse response may extend a narrow event over several displayed frames. A magnitude-only archive may erase phase relationships indispensable to later questions. Zero padding can refine the presentation grid without creating new analogue observations. If the retained data do not distinguish two materially different possible inputs, no confident inverse should be claimed without naming the added

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assumptions. A bounded detection statement remains legitimate even when an exact source duration cannot be recovered.

The third consequence concerns the population of experiments. A handful of favourable, centre-aligned bursts does not establish coverage of difficult window-boundary cases or weak emissions beside strong activity. A thousand searched null locations do not inherit the false-alarm rate of one preselected test. Overlapping frames can measure the same event repeatedly but do not create independent emitted events. The proper campaign challenges the full acquisition and selection procedure, including its analogue front end, time base, filter state, scan exposure, thresholds and exclusions. Null trials and failed detections must remain in the archive; otherwise one has retained a success gallery rather than a validation record.

We have also preserved necessary qualifications. A known-waveform estimator may locate a frequency parameter more precisely than one FFT grid spacing, but only under its tested waveform and noise model. An optimal taper is optimal for the specified concentration criterion, not for every detection or attribution question. Agreement among receivers requires assessment of shared clocks, antennas and trigger dependencies. A frequency match alone is not an identification of a particular surveillance device. These boundaries are positive findings about what the record can and cannot sustain, not excuses to abandon useful instrumentation.

The final report should provide a concise chain of accountable propositions: the input and time reference planes; the retained raw observation and missing intervals; the window and transform parameters; the signal model and estimation rule; the uncertainties and nuisance variables; the population and outcome of relevant challenge trials; and the

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competing physical explanations not yet excluded. The investigator can then speak firmly where evidence permits and cautiously where several interpretations remain observationally equivalent. This is the foundation upon which an adversarial reviewer, a laboratory director or a court may test the conclusion without substituting rhetoric for reproducible measurement. Our next question concerns the use of multiple tapers and robust estimators, where reduced variance and leakage suppression must again be distinguished from the survival of rare events. I thank each colleague for the respectful passage of the token and close Question 045.

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Ten worked engineering applications | Question 045

Worked application 1. Computational bin spacing and acquired duration

Assume a complex-baseband sample rate F_s = 96,000 samples/s and a retained burst interval T = 0.004 s. Let $N = F_s T$ denote the number of samples actually acquired within that interval; N = 96,000 × 0.004 = 384. An unpadded N-point discrete Fourier transform has nominal bin spacing $\Delta f = F_s/N$ = 96,000/384 = 250 Hz. This is a property of the computational grid for the four-millisecond record, not a universal lower bound on parameter-estimation uncertainty and not a measurement of transmitter frequency stability. The calculation assumes uniform samples at the declared rate, no missing blocks and no change of oscillator state. Those conditions require evidence if the number is used in a forensic report. The uncertainty in a physical carrier must include the clock reference, analogue passband, waveform model and estimator procedure. [T1, T2]

Worked application 2. Zero padding changes sampling of the transform, not observation duration

Retain the same N = 384 observations, append zeros to form N_z = 4,096 Fourier inputs, and retain F_s = 96,000 samples/s. The plotted spacing becomes $\Delta f_z = F_s/N_z$ = 23.4375 Hz. This finer plotted interval is sometimes useful to interpolate the transform peak and to assist model fitting. It neither changes T = 0.004 s nor adds any independent observed phase history. The ratio between the grid spacings is 250/23.4375 ≈ 10.6667. Reporting 'frequency resolution improved by a factor of 10.7' without specifying that only the display grid changed would invite a false physical inference. A fair report calls it a zero-padded grid with 23.4375-

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Hz spacing and separately states the four-millisecond measurement support.

Worked application 3. A rectangular-gated tone exhibits a duration-dependent spectral envelope

Suppose a stable complex sinusoid of amplitude A exists for precisely T = 0.004 s and is zero outside that interval. Its continuous Fourier-transform magnitude has a sinc-shaped envelope centred at the carrier; the first zeros occur at offsets ±1/T = ±250 Hz, giving a null-to-null main-lobe width 2/T = 500 Hz. Here 'sinc' denotes sin(πu)/(πu), with u the frequency offset times T. The width follows from the stipulated rectangular gate and constant-frequency model. A physical transmission with shaped rise and fall, phase modulation, or filtering can have another spectrum. Observing a 500-Hz main lobe does not prove that the source radiated for exactly four milliseconds, because an acquisition gate or receiver filter can create similar spreading.

Worked application 4. A Gaussian time-frequency uncertainty product

For a continuously defined waveform whose time and frequency spreads are standard deviations σ_t (seconds) and σ_f (hertz) under consistent normalisation, the standard time-frequency uncertainty relation is $\sigma_t \sigma_f \geq 1/(4\pi)$. If $\sigma_t = 0.001$ s, the limiting standard-deviation spread is $\sigma_f \geq 1/(4\pi \times 0.001) \approx 79.5775$ Hz. The product is a property of the mathematical definitions, not an instrument noise specification, and it must not be conflated with FFT bin spacing or the occupied bandwidth of an arbitrary burst. An unknown modulation and measurement transfer may yield much broader observed energy. This example uses

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the ideal Fourier pair and does not certify the accuracy of any measured source parameter. [T1]

Worked application 5. An overlapping analysis window creates dependent frames

Take a window length N_w = 1,024 samples, hop H = 256 samples and F_s = 96,000 samples/s. The window duration is N_w/F_s = 10.6667 ms, while the hop duration is H/F_s = 2.6667 ms. The nominal overlap fraction is $(N_w-H)/N_w$ = 0.75, or 75%. A burst shorter than either interval may contribute to several successive frames because their supports intersect the same physical event. The exact frame count depends on event timing and window conventions. It would be erroneous to count those frames as independent emitted bursts or independent detector-success trials. The appropriate event identifier and clustering rule should be specified before validating event-level performance.

Worked application 6. Aliasing survives a beautifully computed time-frequency plot

Suppose a real-valued receiver samples at F_s = 24,000 samples/s while an insufficiently rejected analogue tone enters at f_a = 17,000 Hz. For the simple ideal real-sampling alias model, the observed positive-frequency alias is $|f_a-F_s|$ = 7,000 Hz, inside the 0–12,000-Hz Nyquist interval. A plotted 7-kHz line therefore cannot by itself establish that the physical input contained a 7-kHz tone. This example assumes a single tone, uniform sampling and negligible other analogue transformations. The investigator should demonstrate analogue rejection at the claimed reference plane or perform a controlled retuning or substitution test

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whose predictions differ between true 7-kHz content and a 17-kHz alias. [T3]

Worked application 7. Revisit exposure limits detection of brief events

Consider a receiver that observes a channel for dwell time $d = 4$ ms during every revisit period $R = 100$ ms, and suppose a physical transmission lasts $\tau = 1$ ms with an onset uniformly distributed across a revisit cycle. Assuming the instrument detects any positive overlap and has no additional latency, the onset interval producing some overlap has duration $d+\tau = 5$ ms, so the idealised overlap probability is $(d+\tau)/R = 0.05$, or 5%. This is not a measured detection probability: threshold sensitivity, filter transients, required integration time and the source-duration distribution can reduce it, and systematic event timing may invalidate the uniform-onset model. The example demonstrates that excellent within-dwell sensitivity does not establish continuous surveillance. The negative finding must state the actual exposure model.

Worked application 8. The cost of searching a thousand null opportunities

Let $K = 1{,}000$ statistically independent null tests each have single-test false-alarm probability $p = 0.001$ under a correctly calibrated threshold. The chance of one or more false alarms is $P_{FA,any} = 1-(1-p)^K = 1-0.999^{1000} \approx 0.632305$. A 0.1% false-alarm rate for one test does not imply 0.1% for a search over a thousand tests. Overlapping time-frequency coefficients and adjacent FFT bins are generally correlated, so this numerical value should not be applied literally to an arbitrary waterfall. Dependence-aware validation or a conservative union-bound

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argument is needed for a declared family of tests; the search and selection process itself must be included. [T4]

Worked application 9. What one hundred successful challenge events can establish

Suppose $N_e = 100$ independently prepared eligible bursts are injected under a fixed receiver state and all $D_e = 100$ are detected according to a predeclared event-level rule. The point estimate of detection probability is 100/100 = 1. With a two-sided 95% Wilson score confidence interval and $z = 1.96$, the lower endpoint in the all-success case is $N_e/(N_e+z^2) = 100/(100+3.8416) \approx 0.9630$. Thus perfect observed detection does not validate an unconditional 100% detection probability. More importantly, the interval is relevant only to the tested population and independence model. If all trials are easy centre-window bursts, it does not certify near-threshold edge events beside strong interference. The event population, state, selection rule and invalid trials must be preserved. [T4]

Worked application 10. Clock calibration may dominate the apparently fine frequency grid

Suppose a receiver estimates a carrier near $f_c = 500{,}000{,}000$ Hz, and its frequency reference has an uncorrected relative error of ±2 parts per million under the relevant operating conditions. The associated absolute error term is $\pm f_c \times 2\times10^{-6} = \pm1{,}000$ Hz. A plotted Fourier grid with 25-Hz spacing does not remove this 1-kHz reference uncertainty. The two quantities should be reported separately rather than added arithmetically without an uncertainty model. Other effects may include oscillator transients, sample clock errors and carrier instability. A traceable reference comparison or calibrated correction can reduce the

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uncertainty, but only its actually demonstrated scope should enter a forensic confidence statement.

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Research and verification register

[T1] Dennis Gabor, 'Theory of Communication. Part 1: The Analysis of Information,' Journal of the Institution of Electrical Engineers, Part III, Radio and Communication Engineering, 93(26), 1946, DOI 10.1049/ji-3-2.1946.0074. Read scope: publisher article metadata and abstract, consulted 10 November 2026. The present dialogue and SDR applications are original, not quoted from that paper. https://doi.org/10.1049/ji-3-2.1946.0074

[T2] SciPy, scipy.signal.windows.dpss documentation. Read scope: public documentation for discrete prolate spheroidal sequences, the NW time-bandwidth parameter, multiple tapers, concentration ratios and the reference to Slepian's 1978 discrete case, consulted 10 November 2026. This is implementation documentation, not an instrument certificate. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.windows.dpss.html

[T3] Standard Fourier transform and sampling relations as developed in the manuscript's mathematical exposition. Read scope: self-contained derivations and independent numerical recalculation; no external claim of a particular device measurement is made.

[T4] Numerical examples 8 and 9 use explicitly stipulated probability models and calculations verified independently in Python; the ordinary confidence and multiple-testing relations are not representations of measured trials. No field-system coverage or instrument performance has been established.

[T5] Nobel Prize historical record for Dennis Gabor, Nobel Prize in Physics 1971. https://www.nobelprize.org/nomination/archive/show.php?id=21810&mode= . Publisher official nomination/archive information verified in this continuation, including Gabor’s dates, electrical-engineering profession, Imperial College affiliation and the 1971 Nobel Prize.

[T6] Bell System Technical Journal bibliography: David Slepian, 'Prolate spheroidal wave functions, Fourier analysis, and uncertainty. V: The discrete case,' 57 (1978), 1371–1430, as identified in the public SciPy DPSS documentation. Full article text not inspected in this continuation; IEEE Information Theory Society biographical

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page consulted for Slepian's dates and Bell Laboratories background: https://www.itsoc.org/profile/8962 .

[T7] Fourier historical contribution to analysis and mathematical physics. Biographical details checked against the University of St Andrews MacTutor History of Mathematics biography, concerning his work in heat conduction, public life and the École Polytechnique: https://mathshistory.st-andrews.ac.uk/Biographies/Fourier/ . This is secondary historical scholarship, not an inspection of his original manuscripts. External verification is outstanding for final publication.

Editorial note: The dialogue is an original educational reconstruction, and the numerical cases are illustrative rather than measured field results.

Biographical scholarship records his work amid the tumult of revolutionary and Napoleonic France, his involvement in teaching and public administration, and his later position in the Académie des Sciences. Those circumstances place his achievements in their proper historical setting rather than allowing a modern author to transport his scientific career uncritically into the digital age.

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QUESTION 046

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What is the proper evidential use of multitaper and robust spectral estimates?

Source: V011_Roundtable_Question_046_CP046_Dr_Atkinson.docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 046. Expert Roundtable Discussion

Original constructed educational dialogue, not authentic statements or quotations by historical participants. Contemporary SDR case studies are hypothetical and numerical calculations do not certify a particular instrument.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, the preceding question established that a short observation has finite time-frequency content and that a mathematically refined picture cannot recover an unobserved analogue past. We now consider two methods which have transformed practical spectral estimation, multitaper methods and robust summaries. Both can be excellent tools for defensive monitoring, yet both can also conceal an intermittent transmission if employed without regard to the investigative question. The operator sees a quiet black trace below the monitor's spectral grid while a narrowly timed emission leaves only a momentary footprint. A method designed to estimate stable background power may treat that footprint as an outlier and suppress it precisely because it is unusual. Conversely, a method designed to detect every bright transient may yield a burdensome false-alarm population. The choice cannot be reduced to preferring a statistically smooth curve.

Let x[n] denote N retained complex samples, v_k[n] the kth taper in an explicitly defined family, and X_k(f) the complex transform of x[n]v_k[n]. A

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simple multitaper power estimate is $S_hat(f) = sum_k\ a_k(f)|X_k(f)|^2$, where the nonnegative weights a_k sum to one under the declared convention. A weighted spectrum can provide better bias-variance trade-offs for certain stationary processes and finite records, particularly when the tapers are chosen through the discrete prolate spheroidal concentration problem. Yet the output power estimates reuse the same analogue event. Their numerical orthogonality does not create several independent radio observations. This distinction is indispensable when an expert witness asserts that a signal was corroborated by six tapers. The statement might support robustness to the estimator's window choice, but it does not imply that six receivers observed six independent emissions. [R1, R2]

We must distinguish three related but separate propositions. First, the power spectral density of a background process is a population property estimated from an observation interval under assumptions about stationarity and covariance. Secondly, a narrow line or transient is a candidate feature whose detection probability depends upon its amplitude, timing, modulation and the chosen estimator. Thirdly, attribution to a particular external source requires evidence about the physical input, receiver transfer, competing artefacts and independent challenges. A good estimator for the first proposition need not be a good detector for the second, and neither settles the third. A smooth average can conceal sporadic energy; a robust median may suppress one anomalous burst; and a powerful line detector may mistake receiver periodicity for an emitter. The loss is not always mathematical error. It can be a mismatch between the statistic and the forensic question.

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The issue becomes acute in wideband software-defined surveillance where thousands of bins and many window starts are examined. The apparent precision of a threshold crossing depends on how many tests were attempted, whether the background estimate was adapted from the same record and whether successive windows or tapers are correlated. Data-dependent selection among taper numbers, time-bandwidth products, noise summaries and peak definitions introduces further conditionality. An operator who changes parameters after finding a suspicious peak can investigate intelligently, but cannot then cite a confidence level calculated for a single predeclared estimator without accounting for the selection process. The laboratory must record both the exploratory path and the frozen confirmatory procedure.

Professor Slepian will consider time-limited concentration and the conditions under which orthogonal tapers furnish useful complementary estimates. Professor Bartlett will examine variance and covariance, including the effective number of degrees of freedom. Professor Tukey will address robust summaries and the preservation of meaningful outliers. Dr Shewhart will consider detector performance as an operating process rather than a collection of attractive plots. Dr Shannon will distinguish task-specific statistical sufficiency from retention adequate for future forensic questions. Seven colleagues shall challenge these positions directly, and their replies shall follow immediately. All of our imagined participants speak as scholarly personae informed by historically documented mathematics, not as witnesses to instruments developed after their deaths.

Ten numerical applications will expose the assumptions beneath variance reduction, taper concentration, median selection, family-wise false

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alarms and missing-event claims. The examples are stipulated, not instrument trials. We shall retain the original samples as a reference where available, identify how tapers and robust summaries were constructed and distinguish the analogue passband and receiver state from the subsequent statistical operation. At the close we will ask what a laboratory could defend under cross-examination, not merely what a graph might make persuasive at first glance. I invite Professor Slepian to begin with the concentration criterion and the limits of the word independent.

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David Slepian | Principal response 1: Concentration, orthogonality and finite-data limits

Dr. Atkinson, I should begin by defining the optimisation question rather than with a general endorsement of multiple tapers. The discrete prolate spheroidal sequences are associated with the concentration of energy from a finite sequence into a specified frequency interval. Given a record length N and time-bandwidth parameter NW, one can obtain a sequence of orthogonal tapers with ordered concentration ratios. Their mathematics is precise, but its precision has a defined domain. The first taper concentrates energy according to the chosen criterion; subsequent tapers offer complementary ways of weighing the same observed samples. None changes the finite observation duration or the receiver's analogue history. One must never interpret the existence of K orthogonal vectors in an N-dimensional record as the existence of K independent acquisitions of one unknown physical event. [R1]

The practical benefit is real. A single rectangular window has conspicuous sidelobes and may leak power from a strong nearby carrier into the estimated spectrum of a much weaker component. Carefully selected tapers can reduce sensitivity to some leakage and stabilise estimates of stationary background power. A weighted average over several eigenspectra may balance leakage bias against variance. The useful number of tapers depends on the chosen NW, the concentration eigenvalues and the assumptions about the process. It is customary in some spectral applications to consider roughly 2NW well-concentrated sequences, but one must inspect the eigenvalues and estimator purpose rather than apply the expression as a talisman. Including more tapers without examining their

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concentration can broaden the estimate and obscure a line of investigative interest.

The weighting convention is itself part of the measurand. A simple unweighted average, an eigenvalue-weighted estimate and an adaptively weighted estimate need not produce the same output for a weak narrow signal beside strong broadband noise. The examiner should preserve the exact taper coefficients, window convention, transform normalisation, weighting algorithm and software version. If a window length is changed after examining a candidate, the resulting statistic is a different analysis of the same event. The analysis may be legitimate, but a report describing one unchanging method is incomplete. When a claim involves carrier amplitude, the distinction between a power-density normalisation and an amplitude-spectrum normalisation must also be stated. A spectrum which looks quieter after changing its scaling has not necessarily measured less physical noise.

I would insist that the physical record remain central. The tapers operate on retained IQ data, which have already passed through antenna matching, preselection, gain, conversion, sampling and buffering. A receiver-generated spur present in those samples may appear in many eigenspectra and survive averaging. Its survival is not independent confirmation of an external source. Conversely, an intermittent emission whose energy falls near the low-weight end of the record may be weakened in several tapers, particularly if their weights are chosen for a stationary background problem rather than event detection. A multitaper method can therefore be highly suitable for baseline noise estimation while being an incomplete detector of

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rare bursts. The detection function must be evaluated as a separate procedure.

An important subtlety concerns covariance. Orthogonality of deterministic window sequences is not equivalent to probabilistic independence of their estimated powers for arbitrary input processes. Under selected Gaussian and stationary assumptions, eigenspectral estimates may have tractable covariance structures and the familiar degrees-of-freedom approximations may be useful. Correlated interference, changing oscillator state, nonstationary emissions and gain switching can violate those assumptions. An uncertainty interval derived as though K spectral estimates were independent will be overly optimistic if their covariance is material. Rather than declaring independence on the strength of linear algebra alone, the engineer should measure or model covariance under representative operating conditions and retain the model's scope.

For the field laboratory, I would propose validation in two stages. First, characterise the numerical estimator with known synthetic data, including stationary coloured noise, narrow sinusoids and controlled transients whose onset phase varies relative to the retained window. Confirm that the implementation matches the declared taper definitions and scaling. Secondly, inject representative physical signals at the receiver's specified input plane to test interaction with analogue filtering, clock error, overload and source-independent receiver artefacts. Change the source class and compare the resulting detection probability. A software-only test can establish arithmetic correctness, but it cannot reproduce unmodelled front-end compression or missing analogue observations.

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The same discipline applies to a negative survey. If the system retains only the multitaper average, a future examiner may be unable to distinguish a weak burst from a temporary rise in background noise or a receiver state transition. A retained raw interval offers the possibility of alternative analysis; a scalar average may not. When storage limits demand reduction, the report should describe what was irreversibly discarded and what specific question the surviving statistic was designed to answer. No later change of taper can recreate phase information or transient detail that a magnitude-only average has removed. The limitation is a property of the archive and the hypothesis, not a defect in the mathematical concentration theory.

I therefore regard multitaper estimation as a powerful member of the laboratory's methods, not a universal verdict on spectral reality. It supplies useful control over leakage and variance within a stated population and weighting rule. It does not by itself determine physical origin, guarantee event detection or establish independent corroboration. Where the analyst uses different tapers to challenge one candidate, describe the resulting agreement as within-record estimator robustness. Where the claim concerns an external transmitter, perform the necessary physical discrimination. I invite Dr Hamming to ask whether my demand for exact coefficients is operationally practical across a large survey.

Richard Wesley Hamming | Peer question 1 to David Slepian

Professor Slepian, a field system may process terabytes of sampled data while using many taper families and adaptive weights. Your insistence upon preserving exact taper coefficients, normalisations and covariance models is mathematically admirable, but a complete archive of every intermediate calculation could dwarf the original signal record

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and make independent examination less rather than more practical. What minimum set of data, definitions and checks would permit another scientist to reproduce the material result? Suppose the software package implements a documented DPSS generator yet a later version changes its numerical conventions. Would preservation of a source-code revision, input parameters and a checksum of the resulting coefficients be sufficient, or is retention of the coefficient arrays essential? I would also ask how a laboratory should distinguish a source-level measurement error, which no amount of software provenance can repair, from a harmless numerical difference between two correct implementations. The evidential record should be economical but not so abbreviated that its critical transformations become untestable.

David Slepian | Immediate answer to Richard Wesley Hamming

Thank you for that question. Dr Hamming, the record must be sufficient for the inference, not an indiscriminate recording of every ephemeral processor operation. One workable scheme preserves the raw input interval or a verified lossless representation, the sample-rate and timebase metadata, the state of the analogue front end, the exact taper parameters and normalisation conventions, and a versioned software environment capable of recreating the coefficients. A checksum of the resulting coefficient array is useful because it permits an examiner to detect a silent change in generation or numerical precision. When the exact arrays are small relative to the raw IQ, retaining them directly is simpler than debating whether a later library revision produced identical values. The

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archiving choice should be determined by materiality and reproducibility.

The software test should compare the independently regenerated coefficients and outputs within declared numerical tolerances. A difference in the last floating-point bit may be immaterial to an amplitude conclusion with much larger receiver uncertainty, whereas a sign convention or scaling error could reverse a frequency axis or alter a threshold decision. The laboratory should specify what numerical precision is required for the claim and should not equate bit-for-bit identity with physical accuracy. A perfectly reproducible output can still derive from a clipped analogue waveform or an incorrect clock frequency. Digital provenance is necessary to test the computation but not sufficient to validate the measurand.

A practical intermediate record could preserve the input hash, key calibration identifiers, processing configuration, the computed detection statistic, a small set of validation reference outputs and a record of excluded or missing time intervals. When a contested candidate is found, the raw context should be retained for reanalysis whenever possible. For routine baseline statistics an aggregate record may be adequate if the report is explicitly confined to baseline power under its design assumptions. A claim that no brief emissions existed requires more: exposure, sensitivity and the retention policy must support that negative proposition. The absence of archived IQ cannot silently become proof that the unrecorded intervals were empty.

The most important safeguard is to distinguish the chain's different propositions. The first says that this code computes the stated

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multitaper statistic. The second says the receiver measured the nominated analogue quantity within a declared uncertainty. The third says the statistic discriminates a candidate signal class at an empirically established rate. The fourth concerns the external source of any detected feature. Each requires different evidence. Preservation should be designed backwards from the strongest conclusion contemplated, with a transparent account of what remains unobserved. That is more defensible than either perfect archiving in theory or a tiny file whose evidential scope nobody can reconstruct. I pass the token to Professor Bartlett to consider the covariance that makes apparently numerous eigenspectra less than a corresponding number of independent observations.

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Maurice Stevenson Bartlett | Principal response 2: Degrees of freedom, covariance and biased confidence

Dr. Atkinson, the central difficulty in spectral inference is not the ability to calculate numerous transforms but the relationship among the resulting estimators. If K tapered spectra reuse one random record, the resulting K estimates have a joint distribution that depends upon the input process and their weighting. For stationary Gaussian noise under defined conditions, certain orthogonal tapers can provide approximately decorrelated spectral quantities, and effective degrees-of-freedom approximations may become serviceable. That is not a statement about all random processes. A burst entering every taper through the same analogue front end is a common cause; its presence can correlate estimates strongly, and its effect cannot be dismissed by pointing to the taper vectors' algebraic orthogonality. The problem is one of covariance, not merely counting output arrays.

Consider a linear weighted estimate $S_hat = sum_\{k=1\}^K a_k S_k$, with weights a_k chosen to sum to one. Its variance is sum a_k^2 Var(S_k) plus twice the sum over distinct pairs of a_i a_j Cov(S_i,S_j). The covariance terms matter. If the estimates are independent with common variance v and equal weights, the variance is v/K. But if every pair shares positive correlation rho in the equicorrelation idealisation, the variance becomes v[rho+(1-rho)/K]. As K increases, the limiting variance is v rho rather than zero. A claimant who invokes K independent replicas when the noise floor includes common-mode receiver fluctuations will understate uncertainty. The algebra does not tell us what rho is for the field receiver. That quantity must be estimated or bounded using appropriate observations, and its stationarity must itself be considered.

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The same issue arises when overlapping windows and multitapers are combined. Forty outputs from ten heavily overlapping time segments and four tapers each do not necessarily represent forty independent physical experiments. The effect of overlap depends upon the time-series covariance, the taper functions, the segment hop and any adaptive weighting. If the underlying data contain a sustained carrier, each segment revisits much of the same energy. If the process changes during one segment, the stationarity assumptions that justify a conventional background estimate may be invalid. A report should not use the raw number of computed spectra as a substitute for an effective sample size. It should preserve enough structure to investigate dependence or evaluate performance empirically through independent challenge events.

One must distinguish variance reduction from bias. A spectrum estimator that has low variance can still be systematically wrong near a sharp line or an abrupt process change. Smoothing can broaden a narrow peak, leak a strong neighbour into the band of interest or conceal rare pulses. Several orthogonal tapered views may reduce one category of leakage bias while introducing a spectral smoothing width related to the selected time-bandwidth product. The point is not that one method is defective, but that the bias-variance trade-off depends on the parameter of interest. For a background noise-density estimate, reduced variance can be highly valuable. For the question 'did a 2-millisecond surveillance emission occur at an unknown onset?', a statistic biased against unusual transient energy may be a poor detector.

I would therefore demand independent control observations before interpreting confidence intervals. A laboratory can generate or physically

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inject noise and known signals within a declared receiver configuration, then measure the distribution of its spectral estimator under repeated independent captures. The captures, not the overlapping tapers within one capture, provide the primary experimental replication for the full-system performance question. Stratification by input amplitude, temperature, gain, strong adjacent carrier and onset phase is important because each may alter covariance or bias. A covariance matrix estimated solely from a handful of apparently quiet frames may fail precisely when the system faces the difficult signal class it was meant to discover.

A detection threshold should be distinguished from a background interval estimate. An interval for mean PSD under a stationary model does not automatically provide a false-alarm probability for the maximum of a searched time-frequency image. A thousand tested locations create a multiple-comparison problem, while the dependence among neighbouring estimates complicates the tail distribution. Empirical null trials and predeclared search statistics may be the most defensible route. If a specific family-wise bound is claimed, the analyst should state the exact null population and whether the bound assumes independence, uses a conservative union bound or comes from a validated resampling procedure. These are not typographic qualifications; they can change a surveillance conclusion.

Likewise the measured number of detections must not be confused with the number of emitted events. One physical burst may illuminate several consecutive overlapping frames, and four tapers may all show it. An event-level clustering rule should collapse dependent alerts into one candidate where the purpose is to count transmissions, while preserving frame-level

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data for signal-shape examination. The clustering rule itself requires testing: excessive merging can hide distinct closely spaced emissions, while insufficient merging inflates reported occupancy. Neither mistake is repaired merely by a better estimate of average spectral density.

For a courtroom or laboratory review I would present both the estimator definition and a bounded performance statement. The report could say that the multitaper procedure estimates stationary background power under the tested ensemble with a stated variance and bias, while a separate event detector was challenged on known bursts. It should not say that a candidate was independently confirmed K times merely because K windows revealed the same feature. The physical source remains a different inferential question, demanding intervention or appropriately independent observation. I invite Professor Fisher to challenge whether the covariance assumptions can be meaningfully tested when the field record is finite and the receiver environment changes.

Sir Ronald Aylmer Fisher | Peer question 2 to Maurice Stevenson Bartlett

Professor Bartlett, your covariance formula exposes a problem that many engineering summaries conceal. Yet a field laboratory may have only a small number of independent captures, each acquired under conditions that are changing with temperature, traffic and operator intervention. A covariance estimate from such observations can itself be unstable, while a conservative assumption that every result is fully dependent wastes real information in the orthogonal tapered calculations. What evidence would justify treating certain eigenspectral estimates as approximately independent for a defined measurement,

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and how would you communicate uncertainty in the covariance estimate? Suppose a narrow line is visible under six tapers but all six arise from one captured waveform. Is there any statistically defensible interpretation of that agreement other than the weak claim that six algorithms produced six similar numbers? I wish also to distinguish a test about stationary noise power from a claim that the observed line must have an external electromagnetic origin.

Maurice Stevenson Bartlett | Immediate answer to Sir Ronald Aylmer Fisher

Professor Fisher, covariance must be judged relative to the question, and its estimation uncertainty should not be suppressed. For a restricted stationary Gaussian noise model one can compare theoretical covariance predictions with repeated captures in a controlled, adequately characterised environment. The experiment should include checks of distributional form, stability across time and sensitivity to strong interfering activity. The assumption of approximate independence may be a useful engineering approximation for a particular estimator and population, but it should be tested or bounded, not asserted universally. In a changing environment the parameters can themselves vary; a pooled covariance may give false comfort if it averages incompatible receiver states.

Agreement among tapered spectra can be informative without amounting to independent physical corroboration. It may show that a candidate is not solely an idiosyncratic sidelobe of one chosen window and that the feature remains visible when weights are

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changed within the same data interval. This supports a narrowly phrased within-record robustness claim. The probability of such agreement under a null model can, in principle, be evaluated if the joint distribution is specified and validated. Its magnitude does not by itself identify an external source, because the same physical receiver artefact can enter every tapered view. Source attribution requires tests that perturb the physical pathway or provide observations with differently structured instrumental errors.

We can communicate limited covariance knowledge in several ways. Present confidence intervals conditional upon the stated covariance model; conduct sensitivity calculations over plausible correlations; and use independent controlled trials to assess the complete detector when theoretical assumptions are doubtful. If an equicorrelation model is used solely as an illustration, mark it as hypothetical. Where severe uncertainty remains, a conservatively bounded conclusion may be preferable to false numerical refinement. One may still report a feature's existence in the recorded data and the fact that it survived several mathematical analyses without pretending that a source identity was thereby established.

The experiments should also be designed to reveal bias, not only variance. A method may be highly stable while consistently broadening a narrow line or rejecting short impulses as outliers. The complete performance record must distinguish noise-background estimation, event detection, false-alert control and source discrimination. If one question requires extremely high sensitivity to rare transmissions, a separate detector on the raw or lightly

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processed data may be necessary even when multitaper estimates furnish a trustworthy baseline. More calculated estimates are useful only in the measure to which they support the proposition the investigator is actually making. I now invite Dr Neyman to question the effect of selecting the most favourable spectral representation after the candidate has been discovered.

Jerzy Neyman | Peer question 3 to Maurice Stevenson Bartlett

Professor Bartlett, assume that an examiner computes multitaper estimates with several time-bandwidth products and then chooses the one whose spectral line looks most convincing. The examiner subsequently uses the estimated variance of that chosen procedure to produce an apparently narrow confidence interval, as though the choice had been fixed before seeing the candidate. The experiments used to justify independence concerned quiet stationary noise, but the contested event is short and surrounded by legitimate intermittent transmissions. What becomes of the stated coverage probability? Is the most defensible course to repeat the entire selection policy on independently constructed null and signal trials, or can a conditional calculation on the chosen estimator suffice if its exploratory origin is disclosed? How should an adversarial reviewer distinguish a genuinely stable result from one which appears stable because the analyst repeatedly changed settings until an attractive picture emerged? The history of all unsuccessful parameter choices seems particularly relevant to such a comparison.

Maurice Stevenson Bartlett | Immediate answer to Jerzy Neyman

Professor Neyman, the act of selecting the estimator after observing the data changes the relevant experiment. An interval

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derived for one preselected estimator does not automatically retain its nominal coverage after choosing among many possibilities according to the same observed candidate. The selection can induce bias and alter the tail distribution of the chosen statistic. A conditional description of the final estimator is still valuable, but it cannot silently borrow the operating characteristic of an experiment that was not actually conducted. The examiner should record the search history and distinguish exploratory findings from independently validated conclusions.

For a confirmatory result, one can freeze the entire selection algorithm, including the candidate-search procedure, choice of time-bandwidth parameter, number of tapers, weighting, threshold and stopping rule. Then submit it to new challenge records under relevant conditions. That approach validates the procedure as used rather than a simpler idealisation. Another possibility is to limit the claim: describe the observed spectral feature and its stability under a stated set of parameter changes without attaching an unsupported false-alarm probability. It is better to state a supported qualitative result than to manufacture precise numerical assurance from an inappropriate distribution.

I would not insist that every spectral image be supported by an enormous universal campaign before the receiver can guide further investigation. Discovery, corroboration and final attribution are different tasks. A selected candidate may lead to a targeted physical test, perhaps retuning the receiver or exchanging antenna and termination states. A genuine external emission and a receiver

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artefact can make different predictions under these interventions. Such tests may add more useful discrimination than refinements to the variance of a selected spectral statistic. The report should explain why the alternative hypotheses would respond differently and preserve discordant outcomes.

Finally, the uncertainty calculation itself must not be reduced to a count of transforms. A candidate found by searching many times and bands requires consideration of the effective search population. A family-wise false-alarm bound may be established conservatively without independence, while an empirically calibrated max-statistic may be more efficient when the dependence structure is known. The appropriate method depends on the predeclared inference, not on the aesthetic compactness of the resulting confidence interval. A transparent audit trail is thus a component of measurement, not a bureaucratic burden. I now pass the discussion to Dr Tukey, who can examine the distinct problem of robust summaries that remove the very deviations a counter-surveillance investigator seeks.

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John Wilder Tukey | Principal response 3: Robust summaries, rare signals and the obligation to retain outliers

Dr. Atkinson, the attraction of a robust summary is that it resists the undue influence of observations that do not resemble the bulk of the population. This can be an admirable property when estimating a stable noise floor in the presence of occasional disturbances. Yet in a defensive survey the unusual observation may be the very object of the investigation. An isolated burst can be statistically exceptional and physically meaningful. A method that treats it as contamination can produce a better description of the ordinary background while delivering a worse answer to the question of whether an intermittent transmitter was present. The distinction between an estimator's robustness and a detector's sensitivity must therefore be made at the outset.

Suppose a spectral power bin is measured in ten separated time intervals. Nine values cluster near a common background level and one is greatly elevated by a short transmission. The arithmetic mean rises substantially; the median may remain close to the background. Neither result is intrinsically dishonest. The mean may be a poor description of typical background power, while the median may be a poor detector of the isolated emission. The correct procedure could preserve both: report the robust background estimate and flag the outlying interval as a candidate event. The fatal mistake is to retain only the median and subsequently infer that no short transmission occurred. Once the anomalous interval and its context are discarded, no mathematical sophistication can recreate its phase or duration.

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One should distinguish outliers caused by instrumental errors from rare legitimate physical events. A converter glitch, dropped buffer or transient overload may produce an isolated high-power record. A brief external emission can look similar in one numerical statistic. The distinction demands examination of raw time-domain data, receiver state logs, alternate frequency channels and physical interventions. Robustness alone does not identify cause. It may reduce sensitivity to both kinds of abnormality, which is valuable for one purpose and hazardous for another. The operator should state whether an outlier was excluded because of a known instrument fault, because it failed a predeclared signal criterion, or merely because it was numerically unusual.

Multitaper averaging introduces a related selection problem. A spectral line can appear with different amplitude under different tapers, particularly when its time support is brief or its frequency lies near a strong neighbour. Choosing the most consistent subset of tapered estimates may improve a robust background but suppress the candidate. Conversely, choosing the maximum among many tapers can exaggerate the false-alert rate. The data-dependent selection policy should be explicitly documented. If the method is adaptive, the system must preserve its coefficient history and evaluate performance over the adaptation process rather than pretending the estimator remained fixed during the observation.

I favour exploratory data analysis precisely because it can reveal structure not anticipated by a rigid single statistic. A waterfall, time-domain trace, robust PSD estimate and list of maximal transient deviations can be viewed together, with each supporting a different proposition. Exploration must not be confused with confirmation. If the analyst notices a weak

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repeated feature in several related calculations and then develops a new detection rule, that rule should be challenged on held-out or physically injected events with an independent null population. The apparent repetition of a candidate under several transformations of one record is not the same as the repetition of an external event under independently controlled conditions.

For event detection we should classify physical opportunities. Let a known injected burst count once as an eligible event, however many spectral frames, tapers or plots display it. Report the probability of detecting that event and the false-alert rate on independent no-event trials. In practice, a cluster of neighbouring alarms may be merged to avoid counting one burst repeatedly, but that clustering can also combine closely spaced separate emissions. Test both failure modes. A robust median can be used to estimate the background threshold while a separate trigger considers maxima or change points, provided the joint false-alarm distribution of the complete procedure has been examined. No universally optimal combination exists independent of the signal population.

I am especially wary of negative conclusions drawn from archives containing only successes or only summaries. If a receiver retains windows after its own detector fires, a sample of retained events cannot estimate the prevalence of the unretained events without a justified exposure and selection model. A smooth robust background may coexist with poor coverage during gain switching, preselector changes or adaptive threshold recovery. The record should identify invalid intervals and the conditions under which a signal would have been eligible for detection. Where resources prohibit continuous raw recording, preserve a candid statement

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of that limitation and representative control intervals that can test the policy.

My concluding proposal is to match the statistic to the decision. Use robust background estimators to characterise typical noise; use event-sensitive records to protect possible rare emissions from silent removal; and use controlled physical challenges to distinguish source hypotheses. A good forensic narrative should make both the ordinary distribution and the anomalous observations visible, with their different meanings intact. One may discard an outlier from a background estimate while preserving it in an exception register for examination. That is not inconsistency. It is the consequence of asking two legitimate questions of one finite record. I invite Professor Bridgman to inquire how such a distinction should be operationally defined before the investigation begins.

Percy Williams Bridgman | Peer question 4 to John Wilder Tukey

Dr Tukey, you propose that a laboratory retain both the robust typical background and the anomalous intervals. I agree in principle, but the category 'anomalous' can become a flexible word that conceals retrospective selection. One operator may define an anomaly by exceeding a power threshold in one channel; another may flag a spectral kurtosis increase; a third may rely on visual judgement of a coloured waterfall. All may claim to have preserved the important exceptions while using different measures of importance. What operational definition would you require before a forensic finding is offered? Should the exception register contain every threshold crossing, every state transition, or only candidates satisfying a specified waveform signature? How might the analyst document exploratory judgment without falsely

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presenting it as an algorithm whose false-alarm performance has been calibrated? I am particularly interested in whether a negative survey conclusion is even meaningful when the retention rule was modified during the survey and the earlier raw data were not kept.

John Wilder Tukey | Immediate answer to Percy Williams Bridgman

Professor Bridgman, a useful anomaly definition is necessarily linked to the purpose of the survey. A power excursion, a kurtosis change and a human observer's visual identification are different detection procedures. None should be described merely as a generic 'suspicious signal' without identifying the operation that produced it. The report should preserve the rule, its parameter state and the timestamped history of any modifications. If an operator changes a threshold after seeing a candidate, the change is an exploratory event and should be labelled as such. It may legitimately guide a new test, but its earlier performance cannot be retroactively established by the later settings.

I recommend keeping two distinct records. The first is a systematic machine-generated event log whose rules are versioned and whose opportunities for detection can be reconstructed. The second is an analyst annotation record explaining why certain events received additional scrutiny, including visual judgments and alternative hypotheses. The second record can be qualitative without pretending to possess a calibrated statistical false-alarm rate. The relation between them should be explicit. A human may observe a pattern that the original threshold missed, and that observation may be

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valuable, but the success should motivate a reproducible detector or directed physical experiment rather than a claim that the earlier monitoring system had always possessed the new capability.

An operational exception register need not retain all possible raw data forever, but its omissions must be described. Material state transitions, invalid intervals and trigger-rule changes should always remain visible if they affect detection opportunities. For severe allegations a raw IQ interval around a candidate is particularly important. If only the peak power value survives, later questions about phase coherence, modulation or receiver-generated artefacts may be unanswerable. A negative conclusion should therefore be bounded by the validated retention and detection policy and should not extend to time intervals or signal classes that the record never tested.

The distinction between machine events and analyst judgments protects both scientific rigour and creativity. The investigator is permitted to notice an unusual pattern and propose a source hypothesis. Confirmation requires observations capable of showing that hypothesis wrong. An antenna substitution, input termination, oscillator retuning or independent receiver measurement can be more decisive than reprocessing a signal through twenty variants of a robust estimator. The final report can distinguish a verified discovery, a candidate requiring further examination and a supported physical attribution without treating these as interchangeable categories. I pass the floor to Dr Hamming to question what happens when a

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median suppresses a burst but a numerical maximum introduces too many false alarms.

Norbert Wiener | Peer question 5 to John Wilder Tukey

Dr Tukey, your two-record proposal appears prudent, yet it leaves an engineering trade-off that cannot be evaded merely by adding storage. An extreme-value trigger can preserve short bursts, but the monitored bandwidth may contain millions of potential time-frequency cells, and an aggressive threshold could produce torrents of false alarms. A robust median supplies a stable background estimate but may delay adaptation to genuine changes in environmental noise. Should the detector combine a robust background with a maximum statistic, and if so how should its performance be evaluated when neighbouring bins are correlated and the background statistic is computed from many of the same samples? I also wish to know whether a mathematically impressive sensitivity estimate can remain meaningful once the host computer drops buffers, the gain range changes or the antenna front end saturates. Where would you locate the boundary between an algorithm that is correctly implemented and a surveillance system that is genuinely validated? In particular, should a time-dependent trigger policy be evaluated by replaying an entire input history rather than only a selected set of isolated examples?

John Wilder Tukey | Immediate answer to Norbert Wiener

Thank you for that question. Mr Wiener, I would not prescribe a universal maximum-plus-median formula. Such a procedure can be useful, but its false-alarm and detection characteristics depend on the monitored event population, the correlations among tested cells and

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the background-estimator update rule. The laboratory should define a family of candidate signals and an eligible physical-event rule, freeze the detector including its adaptation and clustering logic, then test it against independent signal and null trials. The test set should span bandwidth, duration, onset position, input amplitude, adjacent traffic and hardware state. If the detector is adapted during the test, that adaptive policy becomes part of the fixed procedure being evaluated; it cannot be tuned indefinitely until unfavourable trials disappear.

A robust background level and an extreme-event trigger answer different questions. The former estimates ordinary spectral power under a declared model, while the latter asks whether an unusual excursion occurred. They may share data and so their errors can be dependent. A nominal threshold derived under fixed known background variance cannot automatically be used when the variance is estimated adaptively from the same record. Empirical false-alarm calibration under representative null conditions may be safer, and the report should retain the fact that neighbouring cells or overlapping windows are dependent. The number of tests is not simply the number of plotted pixels if the detection rule clusters or combines them.

The host-computer problem is separate and material. A mathematically correct detector applied only to retained samples cannot find bursts that arrived during a buffer loss, clock invalidity or gain-change interruption. End-to-end validation must therefore measure exposure as well as conditional success during valid operation. A log of loss intervals and receiver-state changes should

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accompany every claim about quiet spectrum. A successful software unit test is valuable evidence of implementation, but it is not certification of the antenna, preselector, ADC, clock, transport buffers and retention policy. Each boundary has its own potential failure and required test.

A practical report might give two figures: a background-power estimate with a confidence qualification under its stochastic assumptions, and an event-level detection estimate with its challenge population and invalid intervals. It should also preserve examples of the strongest false alerts and known misses, because these often reveal unmodelled features. A system whose operators retain all successes while discarding failures cannot learn about its limits. The point is not to burden the reader with every internal computation but to document the few decisions that materially determine what the record could see and what conclusions the laboratory can defend. I now pass the floor courteously to Dr Shewhart for the governing question of process control and drift.

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Walter Andrew Shewhart | Principal response 4: A stable estimator is not a validated detection process

Dr. Atkinson, the success of a monitoring system should not be determined by looking at one favourable chart after the event. A process-control perspective asks whether the measurement system remains in a known state, whether its sources of variation are characterised, and whether a detected change is causally attributable to the process being monitored rather than the instrument. In the present case, the process under observation is electromagnetic activity arriving at a declared reference plane. The digital estimator is one stage of the measurement chain. A stable spectrum produced by a modern program is no assurance that the antenna, gain stage, oscillator or ADC was stable during the relevant interval. A smooth curve may equally result from aggressive suppression of abnormal observations.

Consider a receiver that estimates background noise by a robust median of recent spectral observations and updates its threshold at every window. After a nearby strong transmission, the background may rise or the front end may recover slowly from overload. A subsequent weak signal can be missed even though the routine PSD plot looks more stable than ever. The detector's statistical history has changed its sensitivity. If the laboratory validates the instrument using only isolated signals in a quiet state, it has not examined the circumstance that most threatens its mission. The controlled test should therefore include sequences of disturbances, recovery periods, threshold updates and deliberately placed weak events. The output should be evaluated as a time-dependent process rather than a bag of independent windows.

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The distinction between common-cause variation and a special physical event can be useful, but it must not be imported carelessly. In manufacturing control a rare large excursion may indicate an assignable process fault; in a technical-surveillance survey that same numerical pattern may be the target emission. The test objective determines whether the excursion is contamination or evidence. An investigator who excludes every outlier when estimating ordinary noise may be justified, provided the excluded observations remain in a separate exception register for inspection. If they disappear from all records, the resulting background estimate might be statistically robust while the surveillance coverage becomes scientifically unverifiable.

A complete validation needs two distinct operating characteristics. One describes the background estimator: its bias, variance, settling behaviour and susceptibility to strong neighbours under representative stationary or slowly varying conditions. The other describes the event detector: its probability of detecting specific physical bursts, its false-alert behaviour and its response to changing receiver states. The detector may use the robust estimate as an input, but that dependency must enter the experiment. An uncertainty interval for the background estimate does not, by itself, certify an event detection probability. The laboratory should retain known-miss examples, not merely plots displaying successful thresholds.

The same requirement applies to calibration. A receiver may have been characterised at one gain setting, one temperature and one clock discipline, yet perform differently after a preselector change or automatic gain adjustment. One cannot assume all versions of the signal path have one constant sensitivity merely because the software exposes the same

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spectrum window. The laboratory should declare operating envelopes and revalidation triggers. If coefficients adapt automatically, their update rules and state history form part of the measurement. If a software release changes the taper generator or threshold estimator, it may require a compatibility check against retained reference cases before earlier calibration claims are carried forward.

I would design a challenge matrix in which every known injected burst has a physical-event identifier and a declared opportunity for detection. Vary duration, carrier offset, relative onset to FFT hops, input amplitude, modulation and interfering traffic. Record each detector outcome, including invalid intervals and buffer failures. Count one known physical burst once, even if it appears in several tapers and successive frames. Where the investigation is concerned with two closely spaced bursts, verify that the clustering rule distinguishes them when justified. A process-control chart of the alarm rate may then reveal unstable periods, but it should not replace direct challenge of the detection rule.

False alarms should likewise be classified by cause where possible. Some arise from the assumed null noise distribution; others come from internal periodic spurs, network buffer artefacts, front-end nonlinearities or innocent external transmissions. Merely raising a threshold until the display looks quiet can suppress genuine weak emissions. A credible report should indicate whether the false-alert rate is measured under a specific null population, inferred from a statistical model or observed operationally without a complete ground truth. Those are different evidential grades. If uncertainty remains large, label it as such rather than reporting an unwarranted decimal probability.

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The end product is a calibrated process capable of being challenged and improved. Its logs preserve the applicable state, threshold, noise baseline and selection rule; its scientific record contains the trials which could have shown the method to be inadequate; and its conclusions are restricted to the signal classes and conditions examined. Robust background estimation can make the instrument useful and intelligible, yet it should never be granted responsibility for declaring every faint unrecorded emission absent. The receiver's silence is a conditional observation, not a pronouncement about the entire electromagnetic environment. I invite Professor Gabor to question how a method selected for spectral concentration may transform a physically brief event into a misleadingly persistent visual feature.

Dennis Gabor | Peer question 6 to Walter Andrew Shewhart

Dr Shewhart, suppose the system uses a broad analysis window and several prolate tapers to obtain a stable noise background. A known two-millisecond burst then affects several overlapped ten-millisecond windows, and the display marks a sequence of bright spectral cells extending beyond the source's true transmission interval. One examiner treats this as repeated detections, another as a single event lasting as long as the visual trace, and a third suppresses it as an anomalous contribution to an otherwise stable background. Each operator has seen a computational product of the same finite observation, but they report incompatible physical accounts. How would your process-control approach prescribe the event definition and preserve the distinction between measurement-response duration and physical emission duration? I also ask whether the laboratory should test changing burst onset across window boundaries, since a robust background scheme

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may be excellent for a centre-aligned test and poor for precisely the intermittent case of greatest investigative importance.

Walter Andrew Shewhart | Immediate answer to Dennis Gabor

Professor Gabor, the first step is to define the observed object at each stage. A spectral frame is a calculated statistic; a threshold crossing is an alarm; and a physical event is a transmission or interference episode defined by the experimental ground truth or, in an unknown survey, by an explicitly provisional clustering hypothesis. The three labels must not be interchanged. During validation the known burst has a recorded input onset and end time, independently measured at the chosen reference plane. The algorithm's several alarms may be associated with that single event, and its displayed duration can be compared with the calibrated receiver impulse response and window support. The presence of several bright cells is not by itself a duration measurement.

The challenge must vary onset phase relative to the window and hop, because that variation may determine whether a brief burst is represented strongly or attenuated by the taper. A fixed centre-aligned reference test is incapable of revealing a boundary-specific weakness. The experiment should also vary strong neighbouring activity, gain states and the duration of preceding interference to test the robust baseline's memory. Each injected physical event receives one eligible trial identifier, and the system is scored according to a predeclared event-level rule. Frame-level data remain available for diagnosing the shape of errors without being counted as independent successful transmissions.

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For operational unknown events, the archive should distinguish the measured threshold-crossing interval from the inferred physical duration. If the raw waveform survives, alternative timing estimators may be applied under stated models. If only multitaper power averages remain, precise onset reconstruction may be impossible and the report should say so. A laboratory may still use those summaries to direct further investigation, but should not claim that the source radiated continuously throughout the displayed response. Repeated candidate marks can be collapsed provisionally under a clustering rule whose known failure modes have been tested on closely spaced emissions.

I would also preserve exception records even when a robust background calculation excludes them. The laboratory can maintain a stable baseline for sensitivity control and at the same time document the transient observations that depart from it. A detector operated without a record of threshold state or invalid intervals cannot support a strong negative conclusion, however smooth the plotted spectrum. The engineering objective is not to make the trace look still. It is to create a process whose response to both ordinary background and rare material events is known within a declared envelope. I pass the token to Dr Shannon, whose information-theoretic account can clarify what a compressed spectral estimate necessarily loses.

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Claude Elwood Shannon | Principal response 5: Task-specific sufficiency and irreversible discard

Dr. Atkinson, the proper place to begin is with the question that the measurement system was designed to answer. A statistic can be sufficient for a parameter in a specified statistical model without preserving every detail of the original record. If an engineering mission is solely to estimate stationary background power under a tightly defined stochastic model, a properly calibrated robust or multitaper estimate may be an efficient summary. It does not follow that the summary is sufficient for unanticipated questions about transient duration, modulation, carrier phase, clock artefacts or transmitter identity. Sufficiency is conditional upon the hypothesis family, not a universal virtue belonging to one file format.

The irreversibility of a reduction can be demonstrated without any mystery. Suppose an estimator retains only a nonnegative average of squared transform magnitudes. Distinct complex waveforms can possess the same or very similar magnitudes while differing in their phase and temporal order. If those distinctions were never recorded, no later algorithm can guarantee recovery of the unique physical history. A future inquiry asking whether two receivers saw a coherent phase relationship may find that the original phase was discarded by design. An apparently reliable mean PSD can therefore support a background conclusion while leaving the timing or attribution question unsolved. The loss is a difference between tasks, not necessarily a numerical flaw.

Multitaper processing can also create an impression of independent corroboration because it yields several spectral views. But the physical acquisition is common to all tapers. A locally generated oscillator spur or an

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artefact of the input chain may be shared across the entire set, and a consensus among tapers does not expose that common cause. If a question concerns whether a feature was mathematically robust to taper choice, the multiple views are relevant. If the question concerns whether radiation arrived from outside the equipment, it requires additional physical evidence. Different antenna responses, controlled tuning changes, source interventions or independent instrument paths can discriminate alternative causal hypotheses in a way that reweighting the same samples cannot.

A robust estimator has another information boundary: it may intentionally diminish unusual observations. That can improve the stability of a noise baseline while suppressing the rare burst of investigative interest. The solution is not to prohibit robust statistics but to preserve a complementary event-sensitive path and its selection history. A receiver may retain a compressed continuous background summary together with raw windows around candidate events, trigger parameters, timebase information and invalid-interval logs. Such a two-tier architecture cannot answer every conceivable later question, but it makes the loss deliberate and reviewable. Silence in the candidate record should not be extended to unobserved classes or time intervals.

Time selection is as significant as amplitude selection. If raw IQ is retained only after the trigger fires, the archive's population is determined by the detector whose performance the investigator may later wish to assess. A file of detections cannot establish how many transmissions the system missed. Independent known-event challenges or a second observation channel are needed to estimate exposure and conditional detection probability. A high-level report must therefore include the

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observation duty cycle, the frequency coverage policy, threshold history and known invalid states. Without those facts an apparently quiet band is only a quiet record, not evidence that the band itself was empty.

I would also caution against deriving source identity from a highly refined detection probability. Suppose a calibrated matched statistic detects a known signal class with small false-alarm probability under a laboratory null model. The statistical result says something about the data's compatibility with the model. It does not establish that a particular named device produced the waveform when multiple emitters or receiver artefacts can satisfy the same signature. Attribution requires a comparison of competing causal explanations and often information beyond the spectrum: spatial direction, timing with other systems, electromagnetic coupling paths, modulation detail and controlled intervention. One can be confident a feature occurred without being confident of its source.

When defending a digital exhibit, preserve exact processing provenance. The source sample digests, taper parameters, window length, scaling conventions, robust estimator definition, software version and detected-event rule permit another examiner to reproduce the calculation. The analogue reference plane and clock calibration permit assessment of the physical measurement. The independent challenge campaign tests its operating characteristic. These layers should remain distinct in both the technical appendix and the summary, so that a legal reader is not invited to confuse digital integrity with physical accuracy. Cryptographic preservation of a PSD file proves that the file was not altered after hashing; it does not prove that the PSD represented the external input correctly.

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The proper recommendation is therefore conditional archiving and candid disclosure. If the investigation anticipates contested attribution, retain more of the complex time-domain observation and its context. If resource limits prevent this, narrow the claims to what the surviving statistics can support. No amount of elegant averaging will reproduce an unknown phase history erased by magnitude-only reduction or an event omitted by the trigger. A limited conclusion can be strong where it is precisely defined. I invite Professor Fourier to question whether an invertible transform before averaging can remedy information destroyed by the subsequent robust selection.

Jean-Baptiste Joseph Fourier | Peer question 7 to Claude Elwood Shannon

Dr Shannon, an unaveraged discrete Fourier transform is algebraically invertible when its complete complex coefficients and normalisation are preserved. A laboratory may consequently argue that spectral processing has not lost any information, even though it later stores only averaged magnitudes, threshold flags or a small number of prominent peaks. Where precisely does that argument cease to be valid? Suppose two different physical waveforms, one containing an intermittent weak emission and the other containing a receiver impulse, yield nearly identical robust background summaries. How should the examiner explain the resulting non-uniqueness without confusing the mathematical invertibility of the original transform with the information in the surviving archive? I would also ask whether preserving a hash of the original raw record, while destroying the raw bytes themselves, can support any later reconstruction. The questions are not merely

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philosophical, because a forensic report might cite the accuracy of a software transform while concealing the irreversible reduction applied afterwards.

Claude Elwood Shannon | Immediate answer to Jean-Baptiste Joseph Fourier

Thank you for that question. Professor Fourier, the distinction lies at the actual retained boundary. A complete complex transform of a finite sequence, under a known invertible convention and adequate numerical precision, can be mapped back to that finite numerical sequence. If the investigator subsequently squares magnitudes, averages across tapers, takes a median, thresholds peaks or discards most coefficients, the resulting operation is generally many-to-one. Different complex input sequences can produce the same retained summary. That loss cannot be repaired by invoking an inverse formula for an earlier stage which no longer survives in the record. A source hash can verify a candidate raw file if that candidate is later produced, but the hash itself is not a compressed reconstruction of the file.

The two waveforms in your example may be observationally equivalent under the retained summary even if the original complex samples would have distinguished them. The laboratory should not conceal that equivalence. It can describe the specific statistic and the signal classes against which it was validated, then state which later hypotheses cannot be tested because phase, timing or sample context were discarded. Such disclosure does not make the earlier statistic useless. It correctly confines the answer to its original

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purpose. A well-calibrated median noise floor remains an informative background estimate, while being an inadequate sole record for proving that a rare emission occurred or did not occur.

One should also distinguish an operational trigger from a forensic exhibit. The trigger can be optimised to use limited processor and storage resources, provided its missed-event characteristics and invalid intervals are understood. For a material candidate the apparatus should preserve the raw observation and the exact detector state, if technically feasible, so that alternative interpretations can be challenged. The fact that a detector fired is a historical fact about the instrument; the source of the input requires additional evidence. Multiple tapers or robust versions of the same data can test software robustness but cannot independently certify external origin.

Finally, a legal reader requires language at the proper level of abstraction. The report may say the stored spectrum was reproduced exactly from a preserved file, that the estimator showed specified performance on known challenges, and that an observed feature survived certain controlled receiver perturbations. Those are separate propositions with separate proof. A claim of device identity would demand more. It would be a serious confusion to allow a cryptographically intact, visually smooth spectral curve to masquerade as a complete record of an unobserved physical event. I return the token to Dr. Atkinson for the numerical cases and the panel's synthesis.

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David Slepian, Cross-Peer Question to Maurice Stevenson Bartlett: Professor Bartlett, orthogonal tapers are used to average spectral estimates. Does the number of tapers equal the number of independent physical observations?

Maurice Stevenson Bartlett, Cross-Peer Answer to David Slepian: Dr Slepian, not generally. Tapers applied to the same finite data interval are deterministic transformations of shared input samples. Under specified stochastic models their spectral coefficients can have useful orthogonality or approximate independence, but it remains necessary to calculate covariance and effective degrees of freedom for the estimator in question. Report the time-bandwidth product, number of retained tapers, individual eigenvalue concentration and weighting rule. Test correlated interference and short pulses, not only stationary Gaussian noise. A confidence interval derived from K independent exponential periodograms may not apply unmodified when the actual taper estimates are correlated or a few are heavily downweighted. Retain the original segment and the individual taper estimates. I yield to Professor Tukey on robust summaries.

Maurice Stevenson Bartlett, Cross-Peer Question to John Wilder Tukey: Professor Tukey, why might a median across spectral estimates suppress the very intermittent emission that a defensive survey is intended to detect?

John Wilder Tukey, Cross-Peer Answer to Maurice Stevenson Bartlett: Professor Bartlett, robustness to outliers and sensitivity to rare events are different objectives. If a weak emitter appears in only one or two of many segments, a median may successfully estimate ordinary background while intentionally rejecting the exceptional power observations. An arithmetic mean may dilute them, and a maximum may preserve them while increasing the expected height of noise extremes. Choose the statistic

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according to a predeclared measurand, and maintain a parallel event-detection stream when transient interception is required. Calibrate each rule on blind injected signals and noise-only records, accounting for the search over tapers and frequency bins. Describe what the retained statistic cannot reveal about event chronology. I yield to Dr Shewhart for process stability.

John Wilder Tukey, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, an algorithm shows excellent variance reduction during calibration, yet field performance changes when automatic gain control switches states. What control procedure is missing?

Walter Andrew Shewhart, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, the measurement system is not stationary across the switch. Maintain separate calibration and control records for each gain, filter, clock and detector state, with transition samples flagged rather than silently pooled. Monitor reference amplitudes and known internal noise markers over the same time scale as the survey. The acceptance campaign must include deliberate mode changes and strong blockers, since the estimator may react differently during settling. Check repeatability between instruments and after software revisions; improved precision under one stable state is not proof of correct decisions during state transitions. The operational report must preserve detector configuration and any samples withheld as settling artefacts. I pass the token to Dr Shannon on information sufficiency.

Walter Andrew Shewhart, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, can a compact multitaper PSD file replace raw I/Q as the sole forensic archive if a later dispute concerns the exact beginning of a pulse?

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Claude Elwood Shannon, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, a power spectrum estimator is a lossy summary. It ordinarily discards phase, time ordering within segments, portions of the input outside the reported frequency band and the unique original chronology. Many different short-burst histories can yield very similar multitaper PSDs. The PSD may be fully appropriate for background characterisation, but not for every future hypothesis about onset or waveform. Retain sample-indexed raw I/Q or a parent record demonstrably sufficient for the intended future questions, plus tapers, weights, software version and calibration records. If the original was discarded, state the limitations rather than presenting the summary as a transparent historical substitute. I return the token to Dr Atkinson.

Moderator synthesis | Dr. James M. Atkinson

The roundtable has demonstrated why a smoother spectrum may be either a better estimate or a poorer witness, depending upon the question. Professor Slepian's concentration analysis provides a mathematically disciplined family of windows; Professor Bartlett has explained how covariance governs uncertainty when several estimates share one source record; Dr Tukey has distinguished reliable background description from the detection of unusual but important episodes; Dr Shewhart has placed the entire detector inside its changing operating environment; and Dr Shannon has identified the irreversible limitations of preserving only a compressed summary. Their conclusions are not invitations to abandon multitaper or robust estimation. They are requirements to state precisely what the methods accomplish and what they discard.

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The first distinction concerns optimisation. A taper may be concentration-optimal for a selected time-frequency interval without being optimal for the discovery of every short surveillance emission. A robust median may estimate ordinary background faithfully while excluding an exceptional transmitter burst. The correct answer is not to choose between these procedures in the abstract, but to declare the signal population, estimator objective, decision rule and reference plane. If the laboratory intends to report noise density, validate noise density. If it intends to discover rare short bursts, validate event-level detection across duration, onset phase, amplitude, strong-neighbour activity and receiver state. If it intends to identify an external source, test competing physical causes.

The second distinction concerns the count of evidence. Six tapered spectra derived from the same IQ interval are six numerical perspectives on one acquired physical record, not six independent observations. Their covariance may be lower under selected stationary models, but the common analogue front end, oscillator and environmental history remain. Statistical variance calculations must include covariance when it is material, and an investigator should not infer independent corroboration from within-record consistency. The physical interventions capable of discriminating external radiation from receiver artefacts are of a different order from mathematical reweighting. A second receiver is useful only insofar as its path errors and selection policy have been characterised.

The third distinction concerns the fate of anomalous events. An elevated spectral value may be a legitimate source, innocent environmental activity or a receiver artefact. A robust estimator cannot decide this causal question merely by suppressing the value. The event should remain examinable when

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it may be material to the investigation. An exception register, selected raw IQ contexts and continuous configuration logs permit later examination, while a versioned baseline estimator can continue to provide a practical measure of ordinary background power. Where resource limits preclude such retention, the investigator must not later imply that absent raw evidence establishes an absent transmission.

The fourth distinction is statistical. Overlapping frames and shared tapers are dependent by construction, and an adaptive threshold has memory. A nominal single-test false-alarm probability does not automatically apply to the maximum over a searched waterfall, and a confidence interval for stationary background cannot automatically certify detection of bursts that violate stationarity. Laboratory trials should be organised around independent physical challenge events and a fixed, disclosed policy. Every miss and invalid interval is part of the evidence. A report may be decisive about a bounded proposition without claiming universal performance.

For publication I would require the complete estimator definition, taper parameters, exact numerical scaling, weighting and robust selection rule; the source reference plane and calibration state; a clear separation between raw and reduced records; representative validation across difficult signal conditions; a dependency account for corroborative observations; and a candid register of remaining alternatives. The scientific finding is strongest where independent scrutiny could reveal a material failure. We close by passing the token to the next question, in which cyclostationary features will be examined as potentially useful discriminators of signal classes without treating a recurrent modulation signature as a unique device identity.

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Ten worked engineering applications | Question 046

Worked application 1. Discrete prolate time-bandwidth scaling

Let N = 1,024 samples be acquired at F_s = 100,000 samples/s, with the DPSS standardised time-half-bandwidth product NW = 3.5. The record duration is T = N/F_s = 0.01024 s. The nominal half-bandwidth associated with the discrete concentration specification is W = NW/T = 3.5/0.01024 = 341.796875 Hz; the full selected band is 2W = 683.59375 Hz. The result identifies a mathematical concentration region, not the guaranteed physical bandwidth of any particular source. Changing the observation length or signal class changes the practical estimator problem. The actual concentration ratios for each taper should be obtained from the defined eigenproblem or the versioned implementation, not guessed from NW alone. [R1]

Worked application 2. The number of available tapers is not a number of receivers

With NW = 3.5, a rough engineering heuristic considers on the order of 2NW = 7 concentration modes, often using fewer tapers when the eigenvalues of the last modes are less satisfactory. Suppose K = 6 tapers are selected. They produce six spectral estimates from one retained record of N = 1,024 complex samples. This does not create 6 × 1,024 separately observed samples or six independent physical acquisition paths. The aggregate information remains constrained by the input record and the analogue measurement. Taper orthogonality must not be substituted for sensor independence in a statement about external corroboration.

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Worked application 3. The variance of correlated tapered estimates

Assume K = 6 power estimates each have variance v under a hypothetical common model and every distinct pair has correlation rho = 0.20. An equal-weight mean has variance v[rho+(1-rho)/K] = v[0.20+0.80/6] = v/3. With independent estimates, its variance would have been v/6. Thus the simplified effective independent count is K_eff = v/Var(mean) = 3, not six. This equicorrelation calculation is illustrative; it does not estimate covariance for a physical receiver. A laboratory requires measured or justified correlation estimates at its actual operating state before quoting the effective count.

Worked application 4. Common-mode fluctuation limits averaging

For K = 5 estimates with pair correlation rho = 0.40 and unit individual variance, the same illustrative model gives Var(mean) = 0.40+0.60/5 = 0.52. The independence formula would give 1/5 = 0.20. The true variance under the stipulated correlation is 0.52/0.20 = 2.6 times the independence prediction. Increasing the number of estimates cannot eliminate the common component. The covariance could arise from a shared receiver gain change, common oscillator state or physical nonstationarity; its cause must be investigated rather than labelled as mathematically independent noise.

Worked application 5. A rare burst changes the mean more than the median

Suppose ten power measurements in arbitrary but consistent linear units are [1,1,1,1,1,1,1,1,1,11]. Their arithmetic mean is (9×1+11)/10 = 2, while the conventional median is (1+1)/2 = 1. The median may accurately characterise the typical background, but it has not preserved the

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transient event which raised one observation to eleven. If the archive retains only the median, the exceptional physical occurrence is no longer individually recoverable. A robust baseline can be paired with an anomaly log whose performance and false-alert rate are separately validated.

Worked application 6. Why median spectral estimates require calibrated scaling

For an ideal exponential distribution of positive periodogram-power values with population mean μ, the population median is μ ln(2), approximately 0.693147μ. Consequently the population mean-to-median factor is 1/ln(2), approximately 1.442695. This factor illustrates a bias correction in a particular distributional model, not a universal calibration constant for all finite-sample robust estimators. The exact finite-sample median bias depends on sample size and implementation conventions; the receiver's physical noise statistics may depart from the exponential idealisation. The value of a median-derived PSD must therefore be interpreted under a stated model and actual software normalisation.

Worked application 7. A large set of searched null tests increases false alarms

Assume K = 2,000 mutually independent null tests, each with single-test false-alarm probability p = 0.0005. The chance of one or more false alarms is 1-(1-p)^K = 1-(0.9995)^2000 ≈ 0.6322. Overlapping windows, adjacent frequency bins and shared tapers are generally dependent, so the numerical result is not an actual prediction for a modern waterfall. It demonstrates why a per-bin false-alarm threshold must not be quoted as the false-alarm probability of the complete search. A valid search-level

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claim requires a dependence-aware model, a conservative bound or empirical null-trial calibration.

Worked application 8. Many frame-and-taper alarms may represent one transmission

Suppose one known physical 3-millisecond burst intersects three overlapping analysis frames, and four selected tapers exceed the threshold in every frame. The software emits 3×4 = 12 alarm records. Under an event-level definition there was one injected eligible event and, if successfully recognised, one detection. Treating the twelve alarm records as twelve independent confirmations of external radiation would misrepresent both physical exposure and the statistical dependence of the calculations. The raw alarm history remains useful to diagnose signal shape, but the validated event-counting rule should preserve the unit of inference.

Worked application 9. Overlapping frames do not multiply available time

Let an archive contain L = 10,000 contiguous samples, with FFT window length N = 1,024 and hop length H = 256 samples. The number of complete window starts is K_frames = 1+floor((L-N)/H) = 1+floor(8,976/256) = 36. These 36 frames reuse a common 10,000-sample record. The total observed analogue duration is L/F_s rather than 36N/F_s, and the effective number of independent spectral trials depends on the signal and estimator covariance. Counting 36 windows is valid for describing computations, not for declaring 36 independent observation periods.

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Worked application 10. Preservation cost of original IQ context

If a candidate interval contains N = 2,000,000 complex samples, stored as signed 16-bit I and signed 16-bit Q words, the raw payload is N×(16+16)/8 = 8,000,000 bytes, approximately 8 MB in decimal units, before metadata and container overhead. This is a feasible bounded retention choice for a material event even where continuous long-term wideband IQ retention is expensive. A 32-bit floating-point I and Q representation would double the nominal payload to 16,000,000 bytes. The calculation does not determine the correct retention policy, but it allows the investigator to distinguish actual storage constraints from an unsupported claim that raw evidence could never be preserved.

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Research and verification register

[R1] SciPy signal.windows.dpss official documentation. Read scope: public parameter description, DPSS concentration terminology, NW, Kmax and concentration-ratio output, consulted 10 November 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.windows.dpss.html

[R2] David J. Thomson, 'Spectrum Estimation and Harmonic Analysis,' Proceedings of the IEEE, 70(9), 1982, 1055–1096, DOI 10.1109/PROC.1982.12433. Read scope: IEEE publisher abstract and bibliographic metadata only. The full article was not independently examined in this continuation; numerical examples and dialogue are original. https://doi.org/10.1109/PROC.1982.12433

[R3] SciPy signal.welch documentation. Read scope: examples distinguishing mean and median spectral averages and treatment of an anomalous power interval, consulted 10 November 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.welch.html

[R4] The ten numerical applications are stipulated hypothetical cases, independently recalculated for the stated formulas. None represents an actual instrument-certification trial, source attribution or a measured survey outcome.

[R5] IEEE Information Theory Society, historical profile of David Slepian. Read scope: publicly available biography, education and Bell Laboratories association. https://www.itsoc.org/profile/8962

[R6] IEEE Computer Society, Computer Pioneers profile of John Wilder Tukey. Read scope: historical dates, education, professional affiliations, FFT collaboration and honours. https://history.computer.org/pioneers/tukey.html

[R7] University of St Andrews MacTutor History of Mathematics, Maurice Bartlett biography. Read scope: historical dates and principal research areas; full primary publications were not examined. https://mathshistory.st-andrews.ac.uk/Biographies/Bartlett/

Editorial qualification: Speech is constructed educational dialogue. All case measurements are hypothetical. Publication-stage reconciliation with the cumulative manuscript and earlier contributor register remains outstanding.

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Source-scope limitations and reproducibility protocol

The scientific references above inform selected definitions and documented examples, not historical quotations. The full text of the Thomson 1982 article was not obtained or independently audited for every proposition in this discussion; the IEEE abstract supports the described multitaper approach but not every modern forensic application. The SciPy pages establish particular software parameters and published behaviour, not performance certification of a receiver. No real surveillance instrument or physical emitter was measured while constructing the present numerical applications. Each is a stipulated model whose assumptions, variables and limitations are recorded alongside the calculation. Historical biographies are based on publicly accessible institutional records, and the fictional discussion must remain explicitly distinguished from those records.

For publication, the author or independent reviewer should verify every citation against the final source edition, inspect the actual software implementation used for any reproduced experiment, and preserve versioned taper coefficients and scaling examples where necessary. The input reference plane, clock state, analogue filtering, noise population and selection policy must remain available in the relevant technical record. A challenge campaign should retain both difficult null observations and known burst misses. The final editorial proof must ensure that the summary does not turn a conditional spectral estimate into an unconditional source attribution. These qualifications are part of the methods and evidence, not an editorial reservation that can be silently deleted without providing further validation.

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QUESTION 047

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How can cyclostationary analysis help without manufacturing a unique device identity?

Source: V011_Roundtable_Question_047_CP047_Dr_Atkinson(2).docx | Recovered substantive manuscript. Constructed educational dialogue.

Question 047. Expert Roundtable Discussion

Original constructed educational dialogue. The following speeches are newly written applications of historical intellectual traditions, not verbatim utterances or accounts of deceased scholars operating modern SDR equipment. Numerical examples are hypothetical.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, a receiver searching a complex radio-frequency environment often encounters signals whose ordinary power spectra resemble background noise while their internal timing exhibits conspicuous repetition. The packet clock, the framing structure of a communication link, the symbol transition rate or a repeated pulse envelope can leave mathematical structure that a simple energy detector may overlook. Cyclostationary analysis studies statistical properties which repeat in time, particularly periodic variation in second-order correlation. Properly applied, it can be a powerful aid to detecting or classifying modulated emissions. Improperly interpreted, it can transform a shared technological convention into a false claim that one particular device has been identified. The distinction is not subtle where forensic responsibility is concerned. Two unrelated transmitters may employ the same symbol rate, framing interval, oscillator family or protocol, and a receiver can manufacture a periodic artefact of its own.

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For a complex signal x(t), a representative cyclic autocorrelation at lag τ and cycle frequency α can be expressed as R_x^α(τ) = lim_{T→∞}(1/T) integral over T of x(t+τ/2)x*(t-τ/2)exp(-j2παt)dt. Its Fourier transform with respect to τ is a spectral correlation function S_x^α(f). Here f is ordinary spectral frequency, α is cyclic frequency, and the asterisk denotes complex conjugation. In a finite recording the infinite-time limit is replaced by a specific estimator, smoothing interval and normalisation. A significant nonzero cyclic component can be evidence of periodically varying second-order structure under a validated null model. It is not, by itself, a manufacturer's serial number, an address, a location or a unique source identifier. The distinction between a periodic signal property and a causal claim concerning an emitter must remain explicit. [C1, C2]

There is an additional peril peculiar to software-defined receivers. Parallel ADC mismatch, periodic buffer scheduling, automatic gain control, local oscillator leakage and time-interleaving calibration updates may introduce periodicity that survives ordinary spectral processing. A signal observed at cycle frequency α may be internally generated or reshaped. A two-branch converter, for example, can impose an every-other-sample pattern and corresponding spectral features even when its analogue input lacks that modulation. Similarly, a periodic scan schedule can shape the observed data population and produce cyclostationary artefacts if the examiner confuses observation gating with source gating. A candidate must therefore be challenged by changes of receiver state or by independent acquisition paths in which internal and external hypotheses make different predictions.

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The distinction between detection and identity will govern the proceedings. A cyclostationary detector may improve the visibility of a particular signal class in a specified noise population. A classification may recognise a family of modulations or framing rates. A device-identification conclusion is a considerably stronger proposition requiring evidence that discriminates between devices employing similar conventions and between receiver-generated and external features. Shared clocks, correlated processing and adaptive thresholds can invalidate the apparent independence of several detections. The investigative record should preserve the original IQ, clock references, cycle-frequency search limits, tested hypotheses, data-dependent choices and negative trials. A confidence interval derived for one preselected cycle frequency does not necessarily apply after searching thousands of candidates and reporting the strongest ridge.

Mr Nyquist will examine the sampling and aliasing of cyclic features. Professor Wiener will address the relationship between periodic statistics, feedback and adaptive receiver state. Dr Shannon will distinguish information about a signal class from information sufficient to identify an individual source. Dr Tukey will examine exploration, multiple testing and the temptation to select a striking cyclic peak retrospectively. Professor Bridgman will insist on an operational definition of what is being measured and on physical challenges which prevent an internal pattern from being attributed to an external device. Seven colleagues will interrogate these positions, and each response will follow its question immediately. Their speech is fictional educational synthesis, not historical testimony.

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We shall examine ten numerical cases, from symbol-rate aliases and finite observation resolution to multiple-test alarms and clock calibration. Every calculation will identify its assumptions and limitations. A useful result may be that a signal consistent with a given periodic modulation was present under a specified test, but the instrument cannot assign that modulation uniquely to a named device. Such a finding is not scientifically inferior to an extravagant attribution. It is a bounded proposition which another investigator can challenge at the physical reference plane. Mr Nyquist, may I first invite your account of what sampling can reveal, and what it can disguise, about a periodic structure in received data?

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Harry Nyquist | Principal response 1: Cyclic frequency, sampling aliases and physical reference planes

Dr. Atkinson, the existence of periodic structure in samples is not proof that an identical periodicity existed at the antenna input. A sample sequence is the outcome of a physical chain and a sampling operation. When a signal contains repetitive statistics, sample timing determines which patterns survive, which alias and which may be confused with periodic features introduced by the acquisition apparatus. A cyclostationary analysis that identifies a peak at some alpha should therefore begin by specifying the analogue input band, aggregate sample rate, converter branch structure, actual sample-time calibration and any digital rate changes. Without these facts the observed cyclic frequency is an estimate on an incomplete measurement coordinate system.

For samples acquired at nominal rate F_s, a continuous-time periodic correlation can map to discrete-time cyclic frequencies modulo the sampling rate under the relevant model. The exact alias relationships depend on whether the signal is real or complex, which correlation is used and how the receiver downconverts the input. If a researcher expects a symbol rate near 150 kilobaud but acquires a particular feature on a time axis sampled at 200 kilosamples per second, an aliased cyclic signature may occur in the digital analysis. It would be unsound to infer a different physical transmitter merely because the observed numerical cycle differs from the familiar symbol rate. The front-end filtering, sample-rate reference and estimation convention must be characterised before claiming an absolute physical cycle frequency.

Some periodicity may arise from the instrument itself. An interleaved converter with M branches has a repeating architecture every M samples.

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Offset, gain, bandwidth or aperture mismatch can create deterministic periodic errors; when the input is strong, some of the resulting products can grow and appear more signal-like. A receiver may be configured with a periodic automatic gain-control update or a fixed frame-based buffering schedule. Such systems can impose time-varying statistics even when the external source is stationary. These possibilities should be evaluated through input termination, calibrated injection, changed sample-rate settings or a separately characterised receiver, rather than assumed away because the cyclic spectrum looks structured.

The finite observation must be kept in mind. A theoretical cyclic autocorrelation is often defined using a time average over an indefinitely long record. A captured burst provides only a finite number of repetitions, and the resulting estimator's apparent cyclic-frequency resolution depends on observation duration and smoothing. One can interpolate an estimator grid by zero padding, but interpolation does not create additional independent cycles of the physical emission. A line appearing narrower after such padding has not thereby established a more stable source clock. The investigator should distinguish computation-grid spacing from measurement uncertainty, particularly when the emitter's timing may drift or reset between bursts.

Receiver retuning is a useful intervention, but its meaning requires care. An external signal whose ordinary carrier frequency changes position relative to the local oscillator should transform according to the known conversion mapping. An internally generated spur may instead remain at a fixed baseband offset or move with another relationship. The cyclic structure of an external modulation can remain invariant under a correct

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frequency translation, while clock errors and digital decimation can alter the reported numerical scale. The experiment must therefore predict both ordinary frequency and cyclic frequency under each hypothesis. Merely observing that some peak moves or remains still is not enough if the reference planes are not specified.

A strong adjacent emitter can create another deceptive result through nonlinearity. Suppose two legitimate signals pass through a front end near its compression limit. Their intermodulation products can inherit periodicity from one or both sources and appear at unexpected frequencies. A cyclic detector may identify the structured product correctly while the investigator mistakenly treats that product as an independent transmitted signal at the displayed frequency. Varying input attenuation, preselector configuration and RF source levels can help distinguish a nonlinear receiver product from a genuinely radiated emission. The output of a correctly calculated cyclic spectrum may still represent a distorted input.

The sampling clock itself contributes uncertainty. If the clock frequency differs from nominal by a fractional amount epsilon, a reported cycle frequency based on nominal timing differs from the true input value. A timebase may be stable yet wrong in absolute frequency, and two receivers may share the same erroneous reference. Their agreement would not constitute independent absolute calibration. For an evidential comparison among multiple sensors, record each clock discipline, the frequency reference, delay paths and any times when synchronisation was lost. A tiny numerical variance in a cyclic peak does not remove a systematic clock error.

I therefore recommend a layered conclusion. First establish that the retained data contain periodic second-order structure under the declared

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estimator. Then establish whether that structure survives appropriate physical and software challenges, with its ordinary and cyclic frequency mappings documented. Only after competing receiver artefacts have been addressed should the report infer an external emission class. Identification of one device among several employing the same modulation requires additional distinguishing evidence. A symbol clock is a common engineering property, not a personal identity document. I pass the token respectfully to Professor Slepian for the question of whether a finite number of apparent repetitions can support an extremely narrow cycle-frequency estimate.

David Slepian | Peer question 1 to Harry Nyquist

Mr Nyquist, your account rightly separates physical and sampled cyclic frequencies, but I wish to challenge the phrase 'narrow cycle-frequency estimate'. Suppose a finite record contains only a handful of repeated frames, while an engineer applies a very long zero-padded transform and obtains a sharply located cyclic peak. The resulting axis can be sampled to a fraction of a hertz, but the source may have transmitted only twenty frames in total, and its timing may have drifted within those frames. Under what signal model could such a frequency estimate possess meaningful accuracy, and how should the laboratory test that model? Does a concentration-optimised window help by suppressing leakage, or might it create a false confidence about the stability of a source clock? I also ask what role the actual sampling-clock reference plays when the instrument's own periodic branch schedule can generate a similar signature, particularly under gain or aperture mismatch.

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Harry Nyquist | Immediate answer to David Slepian

Professor Slepian, the answer depends upon what parameter is being estimated. For a stipulated periodic sequence with a stable period and a specified noise model, one can fit the periodicity to the observed data and obtain a model-dependent uncertainty. The frequency spacing of the padded transform is merely the grid used to display or search that estimate. A source whose frame interval drifts or resets violates the stable-period model, and a nominally narrow fitted peak may describe an average or an artefact of the fitting procedure. The examiner should preserve the actual number of observed cycles, the timebase calibration and the residuals of the fitted periodic model. A fine grid cannot stand in for those observations.

Concentration-optimised windows can reduce certain leakage effects and may improve estimation under an appropriately described signal class. They do not extend the observation duration or establish that the source oscillation remained stable beyond the measured interval. The laboratory should evaluate several known reference signals with controlled timing drift and burst lengths, varying the phase of their onset relative to the receiver's analysis windows. A model should be accepted for a claimed uncertainty only where its predictions survive relevant challenges. If a few observed cycles are compatible with materially different timing histories, the interval should remain wide or the reported quantity should change to one supported by the record.

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A separate test is required to exclude the receiver's periodic architecture. An interleaving spur may generate a repeatable cyclic feature even with no relevant external modulation. An input termination or known stationary noise source can reveal whether the feature persists without the suspected RF signal; changing the converter mode or clock reference may produce predictions different from an external modulation hypothesis. The test must consider that a receiver artefact can be input-dependent and thus disappear on termination while remaining internally generated under a strong legitimate signal. Controlled source injection at several levels can help expose that distinction.

Finally, a report should distinguish a measured cycle frequency from a device identifier. Multiple transmitters may share a nominal symbol rate, and one transmitter may vary its actual rate with temperature, oscillator correction or operating mode. A stable timing signature is useful for classification and for generating an investigation hypothesis, but source identity needs further evidence. The sound practice is to preserve the raw record, the clock model, estimator definition, validation outcomes and rival causal explanations. I now invite Dr Hamming to question how a practical implementation can search a broad range of cycle frequencies without turning computational flexibility into uncontrolled statistical selection.

Richard Wesley Hamming | Peer question 2 to Harry Nyquist

Mr Nyquist, an engineer may compute a two-dimensional spectral-correlation map across hundreds of ordinary frequency channels and

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thousands of cyclic-frequency values. A weak ridge appears, the analyst chooses a narrower search interval, adjusts smoothing and finally publishes the most convincing peak. A remarkable amount of computation may be involved, yet the displayed structure can arise from one chance fluctuation selected out of many. What minimum experimental history would make this result reproducible and statistically interpretable? Should the operator retain every parameter trial, or can one save a predeclared selection rule and the raw samples? I also wish to know how computation should be divided between a wide initial discovery search and a subsequent confirmatory experiment. A system may possess enough processing power to create infinitely many attractive representations of one finite input, but it cannot create a new electromagnetic observation merely by spending more machine cycles. What would count as a second physical test rather than a second rendering of the same evidence?

Harry Nyquist | Immediate answer to Richard Wesley Hamming

Dr Hamming, I would distinguish computational reproducibility from evidential validation. A complete raw input interval, a versioned executable description of the search, the tested frequency and cyclic-frequency ranges, the smoothing conventions and the reported candidate allow another examiner to reproduce the algorithm. For material findings, the history of exploratory parameter choices should also be preserved, at least to the extent necessary to reconstruct how the candidate was selected and how many effective opportunities were searched. Keeping a snapshot of every processor register is

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unnecessary; concealing the selection rule is unacceptable. The latter determines the appropriate null distribution for the strongest result.

A broad discovery pass can be useful even when its threshold is exploratory. Its output should be labelled as a candidate, not an independently validated device identification. One may then freeze a detector defined by the discovered feature and challenge it using independently acquired data or a physical injection campaign with null cases and alternative sources. The challenge should include signals sharing the same nominal modulation, receiver-generated spur conditions and state changes which could reveal a false causal attribution. A second mathematical pass over the same archive is a useful robustness check but is not a new physical observation.

Computation can reduce numerical error and explore more models, but it does not remove analogue uncertainty. If the receiver records samples with an uncalibrated clock or through a nonlinearity, many elaborate searches will faithfully analyse that imperfect record. An investigator who finds an apparently stable cycle should vary the RF conditions under which internal and external explanations predict different outcomes. A change in antenna or input attenuation, for example, must be interpreted with the instrument response measured, because both legitimate source strength and receiver artefacts may change together. The goal is a challenge capable of failure, not a demonstration constructed to keep the preferred signal visible.

I would also record the population of physical opportunities when interpreting negative findings. A scan that observes one channel

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intermittently may miss most bursts regardless of the richness of the cycle-frequency analysis applied during its limited dwell. The reported absence of a cyclic peak is conditional upon exposure, sensitivity and the tested signal class. For a selected candidate the final report should state the cyclic feature, the conditions of detection and the unresolved alternatives without asserting a unique device identity from an ordinary shared modulation property. I pass the floor courteously to Mr Wiener, whose work on stochastic processes and control may illuminate the hidden periodicity created by the receiver's own history.

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Norbert Wiener | Principal response 2: Observer feedback and the manufacture of periodic structure

Dr. Atkinson, I should begin by making the observation system part of the physical model rather than picturing a passive observer who merely reads a waveform. A software-defined receiver contains adaptive subsystems whose future operation depends on earlier measurements. Automatic gain control, frequency tracking, burst triggering, threshold adjustment, channel scheduling and even the decision to preserve a buffer can couple the apparent statistics of the retained record to the receiver's internal history. A periodic feature in that record may correspond to an external modulation. It may equally be the mathematical result of an observer which periodically opens and closes its window upon the world. The distinction is causal, not rhetorical. In my work on prediction and feedback, the observer was never exempt from the consequences of the mechanisms by which he acted upon the system.

Consider a front end that updates its gain every two milliseconds. Suppose an input of stationary noise passes through the front end, and the gain is periodically changed in response to a running estimate. If the gain update causes a deterministic alternation in output variance, the recorded process may have a periodically varying second-order moment even when the analogue process at the antenna was stationary. A cyclic-correlation estimator can quite properly report that the *recorded* sequence has structure at the update rate of five hundred hertz. It cannot legitimately conclude from this result alone that an unknown transmitter generated a five-hundred-hertz cyclic feature. The output observation is correct within its reference plane, while the alleged cause has been misplaced. A good

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technical report should preserve that distinction even if it makes the executive summary less dramatic.

One may go further. A recorder that stores samples only upon a periodic trigger may create a discontinuous archive in which the gaps are not incidental; they determine which events survive to be analysed. If an operator reconstructs the retained bursts on an artificial uniform time axis without preserving their true intervals, the apparent cyclic frequencies can reflect the archival process. If the correct time stamps are retained but the analysis ignores the gaps, an analogous mistake occurs mathematically. The observer must treat the observation mask as part of the data-generating model and distinguish a physical periodicity from one induced by sampling and selection. Merely producing an uninterrupted array of numbers does not demonstrate that the physical observation was uninterrupted.

Feedback can also create an apparently convincing confirmation loop. A detector identifies a spectral-correlation feature, a control law tunes the receiver to maximise it, and the resulting stronger feature is then offered as corroboration of the original identification. That procedure may improve sensitivity for a specific class of signals, but it is not an independent confirmation of a uniquely identified emitter. The system has deliberately sought the thing that makes its own decision variable largest. The correct comparison is between the predictions of rival hypotheses under interventions whose parameters were set before observing the challenge outcome. One might freeze the adaptation coefficient, inject a blinded waveform, alter the sample-rate plan, or compare a reference receiver which does not share the adjustment law. The resulting measurement can

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then test whether the periodicity belongs to the source, the receiver, or their interaction.

An adaptive receiver need not be disqualified from forensic work. Adaptation is valuable when the search environment contains strong varying signals and sparse weak emissions. Rather, the algorithm's history must be observable enough to support the particular conclusion. Save control-state changes, gain coefficients, trigger logic, timing references, affected acquisition windows and relevant firmware versions. Where the apparatus uses a closed proprietary calibration process, one may test its input-output behaviour across a declared operating envelope even when internal states are not available. That would establish a bounded performance claim. It would not prove that every subsequent feature was external in origin. The absence of introspection calls for more careful external validation, not an unbounded presumption either for or against the instrument.

My second concern is correlation among apparently independent detectors. Two receiver channels can use different physical ADCs and still share a clock, RF reference, antenna, synthesiser, automatic gain regulator or common software. Their agreement can arise from shared error. A second analysis pipeline over the same archived IQ data certainly can reveal processing mistakes, but it provides no independent view of the analogue input. Even two independently constructed receivers exposed to the same external interference can agree without proving the alleged source identity. Corroboration must be defined relative to a proposition and a dependency graph. It is possible to confirm the presence of a repeated spectral structure

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while remaining unable to distinguish two transmitters using the same waveform convention.

We should also take care with words such as *unique*, *stable*, and *persistent*. A cyclic ridge can persist over several acquisitions because the communications standard fixes a symbol rate or because a receiver always places its scheduler at the same interval. Stability is an empirical description. Uniqueness requires evidence that rival devices, receiver states and environmental processes do not produce an indistinguishable result within the stated measurement uncertainty. An investigator who has not tested this proposition must not transform persistence into identity. The proper intellectual discipline is to recognise an observation, define the model linking that observation to a cause, and devise an experiment likely to produce different outcomes if the cause is wrong.

The completed account should show the original evidence and the path of transformations. It should describe the estimator, the cycle-frequency search, the system state, the control-loop history and the physical challenge. It should preserve both successful and discordant outcomes, especially when a change of receiver state causes the feature to disappear. Such a disappearance can be diagnostically valuable, but it cannot by itself prove which part of the system changed the result. A final report may state that a periodically correlated component was present in the archived observations under particular operating conditions, and that controlled challenges support an external origin only within specified limits. That is a stronger scientific statement than an unsupported device-name assertion. I pass the token respectfully to Professor Shewhart, who may ask whether the

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receiver's ordinary monitoring charts have quietly become mechanisms for selecting their own exceptional results.

Walter Andrew Shewhart | Peer question 3 to Norbert Wiener

Professor Wiener, your account of an instrument participating in its own observation is persuasive, but a practical validation programme must distinguish common process variation from special causes without diagnosing every cycle as a failure. Suppose a receiver's gain-control coefficient changes periodically, yet repeated laboratory challenges show a cyclostationary feature whose estimated strength remains approximately constant. A monitoring chart may label the results stable, while a hypothesis test may call the peak significant. Would you permit the conclusion that the feature is external if the same apparatus is used to define the nominal range, the decision limit and the subsequent performance assessment? I ask also how one should treat the cases omitted from a validation report because they fell in an invalid acquisition interval. The excluded intervals may be precisely where the receiver state changed most, so the apparent stability may reflect the operator's selection rather than the physical behaviour. What experiment would separate ordinary operating variability from a systemic mechanism that has not been directly observed?

Norbert Wiener | Immediate answer to Walter Andrew Shewhart

Dr Shewhart, I would not condemn the use of monitoring charts. They are excellent instruments for detecting changes in a process defined with sufficient clarity. The defect arises when the chart's stable behaviour is offered as proof of a different proposition. The chart can establish that a particular detector statistic stayed within the

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observed reference distribution; it does not show that the distribution describes external transmitters rather than an internal periodic source. If the instrument generated both the candidate and its own acceptance limits, the comparison is conditioned on the mechanism being assessed. The result may be useful for measuring repeatability, but source attribution requires a physical intervention capable of separating alternatives.

I would start by recording the receiver state independently of the signal candidate wherever practicable. A log of gain coefficients, update intervals, temperature and sample-rate settings allows one to examine whether changes in cyclic strength coincide with control transitions. Yet correlation in such a log is not enough: a strong external signal can also cause a legitimate gain response. Introduce a known signal at the declared RF boundary, then terminate or attenuate the input while holding the internal programme fixed. Change the update period or the control law if the design permits, and record which peaks follow the internal setting and which follow an external frequency or modulation prediction. Randomise the order of challenges so that thermal drift and operator expectation are not confounded with the conditions being compared.

The invalid intervals are a matter of particular importance. If they are omitted according to a rule determined after viewing the results, the reported stability is conditional on a selected population. A proper record identifies when and why an interval was invalid, the fraction of observation time removed, and the intended relationship between that removal and the claim. One should not count invalid intervals as

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negative detection trials. Neither should one silently discard them to make a receiver appear better behaved. A separate category of missing or unusable observations is the correct scientific treatment, accompanied by a sensitivity analysis concerning plausible events during those periods.

Where full internal observation is impossible, a controlled external campaign can still provide a bounded answer. Establish fixed procedures using known injected modulations, independent null records, alternate receiver states and challenge data withheld from calibration. Report sensitivity and false alarms for the relevant signal and interference population. If the external-origin conclusion remains observationally indistinguishable from a known internal mechanism, say so. The chart may still support the narrower claim that the detector is stable under specified conditions, but it cannot resolve a causal ambiguity that the experiment never challenged. We should prefer one demonstrably limited conclusion to several impressive but untested adjectives.

Harold Stephen Black | Peer question 4 to Norbert Wiener

Professor Wiener, may I ask whether you have made dependence on internal state too comprehensive to yield a practical measure of signal information? Any receiver necessarily transforms the input, and even a fixed filter selects certain bands while suppressing others. A decision system could be accused of constructing the observed statistics merely because it defines a threshold and reports only selected events. Yet a properly characterised communication receiver can preserve enough statistical structure to distinguish a modulation class despite such

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transformations. Is there a principled boundary between ordinary, useful signal processing and observer-induced periodicity that defeats external inference? Specifically, should an investigator require full recovery of the analogue waveform, invariance under every possible front-end configuration, or only a demonstrable mapping of the relevant statistic across selected transformations? How would you specify a minimal retained record that permits a later examiner to challenge whether cyclic structure existed before the instrument modified the data?

Norbert Wiener | Immediate answer to Harold Stephen Black

Mr Black, I have no wish to demand an impossible untouched observation. A measurement is always an interaction with an apparatus, and every useful receiver imposes a transfer function, finite bandwidth and a convention for recording. What matters is whether the relationship between the desired input property and the recorded statistic has been sufficiently characterised for the claim at issue. If a linear time-invariant filter acts upon a cyclostationary signal, its effects on spectral correlation can be modelled under stated assumptions. An investigator can then make a qualified statement about the input signal class, provided the filter response, sample timing and estimator are known well enough. A periodically time-varying or adaptive path poses further questions because it can introduce the same category of structure being inferred.

The minimal record is therefore claim-dependent. A detection claim may require raw IQ around the event, acquisition settings, the calibration state, the selection rule and the portion of spectrum actually observed. A claim about transmitted symbol rate also

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requires a credible clock scale, alias model and stability information. A claim about a uniquely identified device would require much more: discriminatory features, reference populations, repeatability under environmental and receiver variations, and exclusion of credible alternative emitters. The term minimal must not become a means of withholding whatever would reveal a contradiction. It refers instead to the smallest sufficiently informative record for a specified testable proposition.

We should also distinguish invariance from predictability. A genuine external signal need not produce identical digital values after an antenna change, a gain change or a receiver substitution. Its amplitude and phase may differ greatly. What a valid experiment requires is a prediction for how the selected features should change under each hypothesis. If a receiver-generated spur follows sample-rate or control-update frequency while an external modulation's cycle rate follows its own physical clock, a controlled change can separate them. Conversely, if both vary together because of a common reference, an additional independent variable must be introduced. One does not win an argument by demanding that the signal remain visually unchanged under physically different conditions.

Finally, information lost at the instrument boundary cannot be recovered by retrospective mathematical sophistication. If only trigger-selected records survive, the unobserved periods are not negative trials. If input clipping destroys the waveform's peaks, a precise spectral estimate of the clipped series does not identify those peaks. But where the required property survives a known transfer,

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processing can extract it with useful uncertainty. The responsible report states the mapping, the evidence supporting the mapping, and the alternatives it cannot exclude. I pass the floor to Dr Shannon in his principal capacity to expand the distinction between modulation-class evidence and information sufficient for unique source identity.

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Claude Elwood Shannon | Principal response 3: Information about classes is not information identifying an individual emitter

Dr. Atkinson, the value of a periodic statistic depends upon the question the receiver is asked to answer. If the question is whether a recorded interval contains a modulation with second-order periodicity, the presence of a particular cyclic component may be highly informative. If the question is whether the modulation belongs to a specified family, a collection of cyclic components, their relative strengths and their behaviour under frequency changes may support useful classification. If the question is which individual transmitter, among many capable of producing the same waveform convention, emitted the signal, those observations may have almost no discriminatory value. The numerical complexity of the estimator cannot manufacture the missing distinction between objects that are physically indistinguishable under the chosen measurement.

Suppose a population includes a thousand transmitters adhering to one symbol-rate and framing convention. A detector identifies that shared convention without error. It has narrowed the source from an unrestricted population to a class, but it has not selected one member of that class. Unless additional validated features differentiate the members, any announcement of one serial identity would import information from outside the observed cyclic statistic. Such information might come from spatial measurements, independently authenticated transmissions, source-control tests, lawful metadata or a properly validated physical-layer fingerprint. None of those is automatically contained in an ordinary second-order cyclic spectrum. This distinction can be expressed without invoking a particular

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information-theoretic estimator: identical likelihoods for competing source hypotheses cannot yield a data-driven preference among them.

The term *feature* often conceals several different questions. A peak at cycle frequency alpha may indicate repeating second-order statistics within a finite observation. An estimator might report the magnitude and uncertainty of that peak. A detector compares some statistic with a decision limit to decide whether the observation is consistent with a selected null model. A classifier assigns a label among predefined classes. An attribution procedure evaluates competing causal explanations for an individual source. These operations require different reference data and carry different error rates. Confusing them allows an excellent detector to appear to be an excellent identifier, although the necessary source labels were never measured or verified.

It is particularly tempting to equate a large correlation magnitude with a highly probable identity. That is an error of conditional reasoning. A detection statistic may be improbable under a particular noise-only null hypothesis and entirely commonplace under thousands of different external transmitters or internal receiver defects. A small null probability says little about the relative probabilities of those alternatives without their likelihoods and relevant prior information. If the investigator reports a p-value after searching thousands of cycle frequencies, the selection procedure further affects its interpretation. The probability calculation must describe the entire decision rule that produced the displayed result, not the single selected line regarded in isolation.

The finite record also creates genuine statistical limits. A very short burst contains relatively few repeated symbol or frame cycles. Its estimated cyclic

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correlation can have substantial variance, and the relevant cycle-frequency resolution is related to the actual observation duration, not merely the apparent fineness of a zero-padded display grid. An estimate based on an interval selected because it exhibits a strong feature will be biased toward apparent significance unless the selection is considered. A repeat acquisition may reduce uncertainty if it provides a new physical observation under a sufficiently comparable signal model, but repeatedly transforming one archive does not multiply the physical evidence. One should never add the results of overlapping or correlated estimators as if they were independent transmitters.

There is an attractive practical use of cyclostationarity in difficult noise backgrounds. Under an appropriate model, stationary noise contributes no nonzero cycle-frequency coefficient in expectation, while a deliberately periodic communications signal may contribute such a coefficient. In a finite implementation, however, estimator variance, nonstationary interference and receiver-induced periodicity can create nonzero estimates even under an external-signal-absent condition. Therefore a claim of reliable detection must be based on measured null distributions and challenge trials representative of the operating envelope. The familiar observation that cyclostationary processing can exploit spectral redundancy is a principle requiring a test plan, not a blanket certification of every receiver or environment. [C1, C2]

One may improve the causal interpretation by designing complementary observations. An antenna substitution might change an external emitter's measured amplitude according to the propagation geometry while leaving some digital artefacts unchanged, although gain-control interaction

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complicates that prediction. A new sample rate can move certain internally generated periodic patterns on the recorded time scale, while the external modulation rate remains physically fixed subject to clock calibration. A second independently clocked receiver can test whether a candidate survives alternate front-end and timing mechanisms. None of these tests alone proves identity. They can nevertheless eliminate or restrict particular explanations and turn a descriptive spectral feature into a more credible external-origin claim.

It is also necessary to consider what a reference library of transmitters actually measures. If the library contains observations from only a few selected devices in one room on one day, a high classification accuracy within that library does not imply the same accuracy across all devices, temperatures, antennas and receiver settings. A system can learn room propagation, receiver gain, data-set artefacts or the chosen communications protocol rather than an individual device. Training and evaluation sets should be separated by device, acquisition session and relevant nuisance conditions according to the intended claim. Otherwise a classification exercise may show that a system remembers its own archive rather than identifies an unfamiliar external source.

My recommendation is to report three separate outcomes: the observed cyclic statistic, the tested signal-class decision, and the permissible source inference. Each should carry the appropriate uncertainty and alternative explanations. A result may support the phrase 'periodic modulation consistent with the specified class' while withholding any claim that an individual device was identified. In a defensive surveillance investigation that distinction is indispensable. The objective is to find credible signals and

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preserve evidence capable of later examination, not to convert the common mathematical grammar of communications into an unwarranted accusation. I invite Professor Neyman to challenge whether this cautious division of claims is compatible with an operational detector that must make decisions at a declared false-alarm rate.

Jerzy Neyman | Peer question 5 to Claude Elwood Shannon

Dr Shannon, a receiver deployed in a large building cannot defer every decision indefinitely while it waits for perfect source identification. It must decide which candidate signals warrant retention, additional sampling or a change of antenna. You have divided detection, classification and attribution admirably, but a practical operator still needs a threshold and an interpretable performance statement. Suppose the system searches a grid of many ordinary frequencies and cyclic frequencies, while the analyst allows an adaptive noise estimate to alter the threshold. Under what conditions may the false-alarm probability be assigned to the overall decision, and how should missed detections be measured for intermittent signals whose number of genuine opportunities is not known? Would it suffice to calibrate the test on simulated stationary Gaussian noise, or must the null population include real electromagnetic interference and internal receiver artefacts? Finally, can one speak responsibly of an unknown emitter's probability of being present when the available calibration establishes only the distribution of the detector statistic under selected laboratory conditions?

Claude Elwood Shannon | Immediate answer to Jerzy Neyman

Thank you for that question. Professor Neyman, an operational decision does not require a completed causal investigation. A detector

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can be assigned a threshold for preservation and follow-up, provided the meaning of its alarm is not inflated into a unique attribution. The relevant false-alarm probability is that of the *entire specified decision rule* under the defined null population. If the system searches many cycle frequencies and reports its maximum statistic, the threshold should reflect the distribution of that maximum, including correlations among the tested cells and any data-dependent smoothing or adaptation. Calculating the tail probability for one retrospectively selected cell is not equivalent. A practical approach uses independent null trials or a validated resampling model which reproduces the full search procedure, rather than merely multiplying a single-cell significance value by a guessed count of tests.

The null population must fit the claim. Gaussian-noise simulation may be useful for testing an algorithm's implementation or a deliberately restricted theoretical model. It cannot alone establish field false-alarm performance in an environment containing periodic digital interference, intermittent legitimate transmissions, switching power supplies and receiver-generated cycling. Such phenomena may be the principal causes of false external-origin alarms. The investigator should include them in the challenge population or explicitly restrict the field claim. Similarly, one cannot estimate missed-detection probability from an archive of alarms alone. Known-present challenge signals are required, with injection times and levels selected independently of the detector, so that opportunities are defined even when the receiver fails to report them.

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Exposure is fundamental for bursty signals. If a scanner visits a frequency for one tenth of each observation cycle, a narrow burst may never coincide with its dwell, regardless of how sensitive the cyclostationary estimator is during a visit. A valid report separates acquisition exposure from detector sensitivity conditioned on exposure. It identifies dead time, invalid intervals, sample-rate changes and adaptive threshold state. The system may report performance for specified burst duration, amplitude, modulation, interference and receiver schedule. It cannot claim universal detection probability for an undefined distribution of unknown emitters.

As for the probability that one particular unknown source is present, a false-alarm rate does not supply it. Such an inference requires additional probabilistic modelling of competing sources, their occurrence rates and the observed evidence. The alarm can still justify preserving a candidate and performing a physical survey. It should be worded as an operational trigger under a defined test, not as a probability of guilt or device identity. This is no obstruction to a useful instrument; it is the difference between an effective search policy and an evidential conclusion. I pass the floor respectfully to Dr Tukey, whose work on exploratory statistics may help us prevent an impressive picture from becoming an unacknowledged record of post hoc selection.

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John Wilder Tukey | Principal response 4: Exploration, selection and the arithmetic of attractive peaks

Dr. Atkinson, the first obligation in analysing an unfamiliar signal is often to discover what sort of question can sensibly be asked. Exploratory displays of cyclic spectral correlation are extraordinarily useful for that purpose. A two-dimensional map can reveal ridges, clusters, harmonic relations or suspicious receiver-state dependencies that no single preselected statistic would have exposed. I would not suppress exploration merely because it produces multiple comparisons. I would instead insist that the investigation distinguish exploration from confirmation, and that it preserve enough of the exploratory history to prevent the most attractive picture from being passed off as the inevitable outcome of a fixed test.

Imagine an analyst searches ten thousand cycle-frequency candidates, tries five smoothing widths, displays three colour scales and adjusts the ordinary-frequency interval until one ridge appears convincing. The published exhibit shows only the final graph and a p-value derived for a single chosen cyclic coefficient. This is not simply an innocent choice of presentation. The procedure selected a rare-looking outcome from many correlated possibilities, then evaluated it as though it were nominated in advance. The apparent precision is illusory. A complete description should include the candidate generation method, search ranges, resolution, smoothing, thresholds and any human decisions material to selection. The required level of detail is that needed to reproduce the decision rule and its selection bias, not every mouse movement of an operator.

A disciplined sequence is possible. First, use exploratory tools on discovery data to identify candidate features and plausible mechanisms.

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Second, freeze a limited confirmatory analysis, including its target frequencies, rejection conditions and permitted preprocessing. Third, assess that frozen rule on independent physical observations or properly constructed challenge records. If new results motivate changing the rule, label the changed analysis as a new exploratory candidate and test it on a fresh validation population. This avoids the sterile demand that the investigator never learn from data while preserving the distinction between learning and testing. It also gives the engineer useful feedback about which parts of the instrument or environment deserve a deliberate intervention.

The temporal structure of the recording complicates ordinary statistical shortcuts. Overlapping analysis windows are not independent trials just because their FFTs occupy different array indices. Several cycle-frequency cells can be correlated because they share samples, smoothing kernels or harmonic relations. A receiver scanning periodically may generate clusters of candidate peaks across many channels during one underlying event. A naïve count of all displayed cells exaggerates the number of independent physical observations, while pretending that the search involved only one cell understates the number of statistical opportunities for false alarms. Rather than assume either extreme, the analyst should measure the null distribution of the actual maximum or cluster-level decision over realistic acquisitions.

The strongest cyclical ridge may be the most stable but not the most causal. A signal in a receiver's local oscillator, a periodic clock fan-out defect, or a recurring automatic gain transition can produce an exceptionally neat pattern. An external emitter's modulation may be less neat because the receiver sees fading, frequency drift and interruptions. The investigator who

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ranks candidates only by visual regularity risks placing internal artefacts first. Comparative experiments should therefore change one relevant physical or processing condition at a time, and the prediction under each candidate hypothesis should be recorded before examining the outcome. The first scientific question is not which peak is prettiest, but what mechanism would make it appear and what observation could falsify that mechanism.

There is also a serious danger in unbalanced reference data. A classifier trained on a handful of modern signals may identify a particular communications protocol with high apparent certainty, because every sample from one device was recorded in one session and every sample from another in a different room. The model may learn session time, propagation geometry, receiver temperature, or data-file boundaries. Randomly dividing frames from the same acquisition into training and testing sets preserves these shared nuisances and makes the accuracy look stronger than a genuine independent-device test would. The split should reflect the intended use: different devices, days, frequencies, receiver states and environments where such generalisation is claimed. The method must be challenged by confusable technologies, not merely against easy negative examples.

An exploratory spectral map should carry the same evidential humility as any other diagnostic display. Colour scale, normalisation and interpolation can make a weak statistical fluctuation look like a sharp geometrical structure. A plot that suppresses the zero-cycle slice or clips large values may improve human perception of an interesting pattern, but it changes what the reader sees. Preserve the underlying numeric array and plotting

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settings. The headline conclusion should not depend upon a cosmetic choice which has no physical meaning. A defensible figure distinguishes observed sample statistics, computed uncertainty, rejected artefact hypotheses and remaining source alternatives.

The net result is not to abandon a powerful detector. Properly deployed, cyclic analysis can find modulated signals concealed in substantial stationary noise and can reveal structure that energy detection misses. The danger is the transformation of one real, limited success into several untested claims. One may discover a cyclostationary candidate, then independently validate a modulation-class finding, and only after additional discriminating evidence attempt source attribution. If an investigator fails to preserve that logical sequence, the original spectral data may still be sound, but the published interpretation will not be. I invite Dr Fisher to challenge how much a predeclared null model can realistically accomplish when the receiver's interference environment is too varied for one convenient probability distribution.

Sir Ronald Aylmer Fisher | Peer question 6 to John Wilder Tukey

Dr Tukey, you have rightly distinguished exploratory and confirmatory studies, but the division raises a further statistical concern. Even when the investigator freezes a rule after examining one discovery archive, the later challenge records may share the same receiver architecture, location and periodic interference mechanisms. Their numerical values are new, but their causes may not be independent of the discovery process. If a detector is validated only in the same room with the same clock and protocol mix, it may appear convincingly reproducible while its supposed modulation-class capability remains parochial. What should

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constitute an independent confirmation population, and how should we avoid declaring significance from a model whose nuisance factors were chosen retrospectively? More particularly, how would you report evidence when a conventional test of significance rejects a noise-only null, yet there remain several plausible receiver-generated and external-signal alternatives? I ask whether a significant cyclic coefficient has any sound meaning beyond the restricted model that gave rise to the significance calculation.

John Wilder Tukey | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, the word independent is too often treated as a magic charm rather than a property defined relative to a question. New samples from the same hardware may be independent in their thermal noise realisations while sharing an uncalibrated periodic spur. Fresh recordings on a different day may reduce some temporal dependencies while preserving the same antenna coupling. Independent validation of an external-origin inference must challenge those shared mechanisms. The experimental design should therefore specify which nuisance variables are varied, which are controlled and which remain unexamined. A split by file name or by random analysis window is not automatically sufficient.

For a frozen cyclic detector, I would choose validation records representing the intended population, with independently generated null and known-present cases. That population should include stationary noise, legitimate emissions with confusable modulation, receiver-state transitions, interleaving artefacts, power-supply

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periodicity and relevant interference. The rule's overall false-alarm and detection rates could then be estimated on those records, with confidence limits appropriate to the actual number of independent challenge units. If those units are not genuinely independent, report the clustered design and use the number of independent sessions or physical interventions rather than the impressive number of correlated FFT windows to describe the evidence base.

A significance rejection of one noise-only model can be worthwhile. It establishes that the observed statistic is unexpected under the specified conditions, assuming the calculation and selection correction are valid. It does not identify which alternative produced the result. A receiver defect and an external communications signal can both be inconsistent with stationary Gaussian noise. The next experiment must distinguish those alternatives through physical predictions rather than attempting to make the p-value speak a causal language it was never designed to speak. The more mechanistically informative test might be an input termination, sample-rate change or independent front-end substitution rather than a longer integration of the original record.

A scientifically mature report should therefore state the model rejected, the population against which the decision rule was tested, the scope of the confidence interval and the surviving alternatives. If the detector is exceptionally effective at discovering periodic structure but unreliable at attributing source identity, those are not contradictory findings. They describe different performance dimensions. The investigator may use the first strength to prioritise

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fieldwork while ensuring that the second weakness is explicit in any evidential conclusion. I now pass the floor to Professor Bridgman to examine whether the quantity called a device signature has been operationally defined at all.

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Percy Williams Bridgman | Principal response 5: Operational definitions, reference planes and the source-identity claim

Dr. Atkinson, we should examine what the phrase *device fingerprint* means before arguing about the confidence with which it is assigned. If it denotes a particular cyclic-frequency pattern measured in a received IQ record, then its definition is operational and reproducible once the estimator, acquisition window, clock reference and preprocessing are specified. If it denotes a stable physical property unique to one transmitter, the first operation is not sufficient to establish the second definition. An operation that measures a shared symbol rate cannot distinguish two individual transmitters using the same rate. The words unique and identifying must be justified by a discriminating experiment, not merely by the familiarity of the metaphor of a fingerprint.

Let us distinguish three reference planes. The first is the external electromagnetic field at the antenna location, shaped by propagation and interference. The second is the analogue input to the digitiser, after amplification, filtering, mixing, automatic gain control and possible nonlinearity. The third is the retained digital sequence after clocking, sampling and processing. A cyclostationary coefficient computed at the third plane is unquestionably a property of the retained record under its estimator. Inferring the first plane from it requires a validated transfer or an experimental challenge. Some receiver defects are shared by all acquisitions at the third plane and can thus appear extraordinarily stable. They may be excellent fingerprints of the receiver system and poor evidence about the source under investigation.

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A well-defined source-identity experiment would measure a population of candidate emitters with confusable modulation conventions under varied operating conditions. It would state what identifying feature is extracted and what reference class it separates. If devices share nominal symbol rates but differ in oscillator phase noise, modulation imperfections or clock drift, those additional properties might have discriminatory value. Yet their measurement may depend strongly on receiver frequency stability, multipath, temperature, gain and processing. The experiment must show that the claimed source property persists sufficiently under such nuisance changes and that the reference population contains credible alternatives. An identification statement exceeding that population is an extrapolation, not a measured fact.

There is a practical distinction between a natural feature and an authenticated identity. A lawful communication protocol may include an address or identifier inside decoded payload data. That identifier is not equivalent to a unique physical emitter, because addresses can be reassigned or imitated and decoding itself can fail. Conversely, a physical-layer feature may be repeatable but not unique. Combining several observations can strengthen an inference if the dependencies and error mechanisms are understood. It cannot erase the distinction between what a feature actually measures and the identity that the investigator wishes it to indicate. A careful report records both the observed information and the additional assumptions required for attribution.

The test apparatus can also create apparent device specificity through its training procedure. If every reference recording of device A used receiver gain state A and every reference of device B used gain state B, a machine

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classifier might identify the gain state with admirable accuracy. The operator may mistakenly interpret this as successful source identification. Cross-validation must separate acquisition sessions and deliberately vary receiver settings independently of source labels. Where the instrument cannot expose its processing, controlled substitution becomes particularly important. An independently characterised acquisition path can test whether the supposed feature follows the emitter or the recorder. The absence of such a test cannot be remedied by increasing the number of derived feature vectors from the same raw file.

An operational definition should also include rejection conditions. How large a difference in cyclic frequency or spectral correlation magnitude is sufficient to distinguish two classes? How much clock drift or filter response variation is admitted? What outcome marks an invalid acquisition, and what happens if the estimator produces no reliable peak? If these questions are answered only after seeing the data, the result is not a stable identification procedure. A valid procedure declares its comparison rule, uncertainty and abstention policy before challenge testing. It should allow an inconclusive result and should record it. An unqualified classifier forced to choose one label can make a misleading categorical claim when the evidence is inadequate to distinguish candidates.

Some assertions can be tested more directly by engineering interventions. Vary the sample rate while maintaining a calibrated physical carrier and compare the cyclic-frequency prediction for input and receiver artefacts. Terminate the RF input or use a calibrated load; test whether a candidate remains when no external signal can enter through the specified port. Change antennas and locations while tracking gain and propagation

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assumptions. Examine whether the candidate persists in an independent analogue front end with a different clock and processing implementation. Each change should carry a predeclared prediction under the competing explanations. The aim is not an impossible exhaustive proof that no other emitter exists, but a bounded inference supported by experiments designed to reveal material alternatives.

In a defensive technical-surveillance report the proper language might be that a candidate exhibits cyclic features consistent with a stated modulation class, that challenges of specified internal-artifact mechanisms were performed, and that the surviving alternative explanations include any transmitters sharing that convention. A stronger source-identification statement would require a documented discriminatory validation population and an uncertainty account for identity errors. It would not be justified by an appealing plot or a small p-value alone. Our duty is to preserve the relationship between the measurement operation and the proposition its words invite the reader to believe. I invite Professor Popper to challenge whether even a well-defined operational test can genuinely expose a preferred source hypothesis to possible refutation.

Sir Karl Raimund Popper | Peer question 7 to Percy Williams Bridgman

Professor Bridgman, your operational definitions are admirably exact, yet I fear they might permit an investigator to protect a preferred conclusion by continually narrowing the definition after each contrary result. Suppose a cyclic feature is first called a unique transmitter fingerprint. A rival device then produces the same pattern, so the analyst says the fingerprint identifies only the modulation class. A receiver spur

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then reproduces the class feature, so the analyst adds a condition that the receiver must have been in a favourable calibration state. Such qualifications can be legitimate, but they can also make the original claim impossible to refute. What predeclared experimental outcomes should require the investigator to withdraw an external-origin claim rather than merely append another explanation? How should source alternatives and receiver artefacts be presented so that a third party can distinguish a genuinely tested hypothesis from an interpretation continually rescued after adverse evidence? I also ask whether a narrow but falsifiable finding may be more valuable in forensic proceedings than a sweeping claim whose exceptions are never specified.

Percy Williams Bridgman | Immediate answer to Sir Karl Raimund Popper

Sir Karl, the concern is real. An operational definition becomes a discipline only when it fixes a comparison and admits a condition under which the comparison would fail. It must not be rewritten retrospectively merely to preserve a favourable label. An investigator may legitimately revise a scientific claim after new evidence, but the revision should be recorded as a revision. The first, stronger claim has failed to survive its challenge. A later, narrower claim requires its own evidential support and must not inherit the earlier claimed confidence as though nothing had changed. This is especially important when technical language is carried into a legal or administrative conclusion.

I would require the validation plan to state rival hypotheses and challenge outcomes before the experiment where practicable. If an alleged external modulation remains visible after a verified RF

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termination which excludes the implicated input path, that result contradicts the simple external-origin explanation and calls for an examination of internal generation or unintended coupling. If a second independently characterised receiver fails to observe a candidate under conditions in which its validated detection probability was high, the discrepancy should remain in the report and prompt further test. If many different known transmitters produce the same cyclic feature, the claim of uniqueness is defeated within that population. These are not mere inconveniences to be explained away. They are substantive observations limiting or rejecting particular hypotheses.

Some challenges will be indeterminate. A terminated input can still be susceptible to other coupling paths; a changed antenna alters propagation and sensitivity; a missing detection can result from limited exposure or a burst outside the observed interval. Therefore one should not transform every contrary outcome into decisive refutation either. The responsible interpretation defines the test boundary and its limitations in advance. If the result does not discriminate between alternatives, state that it is inconclusive rather than marking it as success for the preferred explanation. Confidence grows from interventions whose rival predictions differ and whose measurement uncertainty is understood.

A narrower conclusion may indeed be more valuable. It might establish that a reproducible nonzero cyclic feature occurred in the retained sample sequence; that specified receiver artefacts were challenged without producing the same outcome; and that the

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feature is compatible with a family of modulations, while individual identity remains unresolved. This statement is open to further test. An expansive accusation that one particular source necessarily caused the feature cannot be made robust merely by decorating it with more decimal places. The operational question is what another examiner can reproduce, where the original evidence ends, and which experiment could reveal a material failure. I return the token respectfully to Dr. Atkinson for a synthesis of the limited but valuable evidential role of cyclostationary analysis.

Harry Nyquist, Cross-Peer Question to Norbert Wiener: Professor Wiener, a spectral correlation detector reports a stable cycle frequency. What experiment establishes that this periodicity was emitted over the air rather than produced by buffering or interleaved ADC timing?

Norbert Wiener, Cross-Peer Answer to Harry Nyquist: Mr Nyquist, measure the suspected cyclic feature while deliberately changing internal scheduling, sample rate, interleaving mode and reference clock, keeping the analogue stimulus independently controlled. Periodicity in an internal switch or digital frame structure can create a cyclic signature even with a terminated RF input. Compare a second receiver path that does not share the same clock or software pipeline, and inject a known modulated signal to verify the expected movement of the cyclic frequencies. Retain raw I/Q and processing metadata so the analysis can be repeated under alternative filter and buffer conditions. A stationary cyclic line tells us something about the observed system; it does not automatically locate its physical source. I pass the token to Dr Shannon on the identification question.

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Norbert Wiener, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, can two transmitters that share a modulation protocol and symbol rate be uniquely distinguished by the same detected cycle frequency?

Claude Elwood Shannon, Cross-Peer Answer to Norbert Wiener: Professor Wiener, no. A cyclic statistic may characterise a class of modulation or repetitive structure without furnishing an individual physical identity. Two unrelated devices using the same waveform family can share cyclic features, and one device can change them under altered operating modes. Evaluate sensitivity and specificity against a population of candidate emitters, varying channel conditions, frequency error and receiver distortions. Report a likelihood or discrimination result only when the underlying reference populations and uncertainties are justified. Do not turn a class signature into a serial-number identification. Source attribution requires independent physical features, timing or spatial evidence, and a calibrated exclusion of receiver-created cyclic structure. I yield to Professor Tukey on the search over possible cycles.

Claude Elwood Shannon, Cross-Peer Question to John Wilder Tukey: Professor Tukey, the analyst searches thousands of cyclic frequencies and time lags before selecting the highest correlation. How should that search affect the reported confidence?

John Wilder Tukey, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the claimed probability of an extreme statistic must reflect the entire search procedure, including frequency, lag, window, filter and modulation hypotheses tested. Adjacent trial values are dependent, so neither the raw number of grid points nor a single predeclared-test p-value is automatically valid. Calibrate the maximum statistic on independent

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noise-only records processed identically and challenge the selected detector on hold-out signals. Preserve the search bounds and rejected candidates, not only the brightest peak. When the target modulation was hypothesised after inspecting the data, describe the result as exploratory until independent validation. A compelling graph cannot establish either a unique emitter or a controlled false-alarm probability. I pass the token to Professor Bridgman regarding operational definitions.

John Wilder Tukey, Cross-Peer Question to Percy Williams Bridgman: Professor Bridgman, what operational evidence must accompany the phrase “unique device signature” in a forensic report?

Percy Williams Bridgman, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, define precisely what is claimed unique: a cyclic modulation feature, a vector of calibrated RF emissions, a device family or one physical transmitter. A test must include a sufficiently broad and relevant comparison population, receiver configurations, channel perturbations, repeated operating modes and explicit error rates. The reference plane must be defined; the detector should be challenged with no antenna, calibrated stimuli and independent hardware. If the characteristic disappears when the acquisition software changes, its putative device specificity fails an elementary adverse test. Even a feature statistically rare in a limited laboratory set cannot be declared globally unique. The appropriate language may be “compatible with a class of signals” rather than “identifies this device.” I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator synthesis and concluding discussion

Colleagues, the discussion has produced a useful distinction between identifying a statistical property of recorded data and establishing the

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provenance of that property. Cyclostationarity provides a rich language for describing repeating second-order behaviour. It can reveal a class of communications signals whose ordinary energy spectrum is difficult to distinguish from a noise background, and it can guide a receiver towards further measurements. Yet the measured cyclic coefficient is first an attribute of the retained and processed sequence. It is not a physical address, a serial number, or a reliable declaration of one transmitter's identity. The investigator must make the further causal inference by reference to a calibrated acquisition boundary, competing hypotheses and experimental challenges capable of distinguishing them.

Mr Nyquist has reminded us that cyclic frequency is reported on a time axis whose calibration, alias relationships and sample selection must be understood. A nominal two-million-sample-per-second record can exhibit periodic structure that follows a four-branch interleaving schedule; a change in sampling rate may change the apparent cyclic coordinate without any corresponding alteration in an external emitter. The physical analogue frequency and the digital coordinate are related by a model. A scientifically correct transformation does not independently validate that model. Where the timebase is uncertain, the uncertainty belongs in every frequency and cycle-rate conclusion that depends upon it.

Professor Wiener has moved the boundary of the investigation through the receiver's feedback and retention mechanisms. Gain regulation, scan scheduling, adaptive thresholding and selective recording can generate or amplify periodic correlations. An internal coefficient may be stable for weeks and nonetheless tell us nothing about a particular external transmitter. It is therefore necessary to preserve a coherent engineering history of the

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receiver state and, where possible, to perform interventions for which an internal artefact and an external emission make different predictions. The record should not present two analyses of one IQ file as two independent physical detections, nor conceal the influence of a common clock or shared antenna path when several receiving channels agree.

Dr Shannon has separated detection, classification and identity. A cyclic ridge can be excellent evidence for one modulation class while being completely uninformative among a thousand devices that share the same convention. A classifier forced to choose one identity can conceal the fact that its evidence supports no distinction among several candidates. A credible source-identity study must establish its reference population, independence of training and test observations, nuisance conditions, alternative sources and abstention criteria. If those measurements are absent, the appropriate result is a bounded class finding, not an attribution dressed in the language of certainty.

Dr Tukey has restored the procedural history of discovery to its proper evidential place. An exploratory search across thousands of cyclic-frequency and ordinary-frequency coordinates is perfectly legitimate. Presenting the strongest peak as if it had been nominated before the search is not. Thresholds and confidence statements must be appropriate to the actual selection rule and to correlations among tested cells. Physical validation should use new acquisitions or deliberately independent challenge conditions where possible. A second attractive visualisation of the same samples has analytical value, but it does not create a second electromagnetic event. The archive must preserve the search ranges,

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smoothing rules, rejected candidates and invalid intervals sufficiently for another examiner to reproduce and contest the inference.

Professor Bridgman has made the report's language answerable to an operation. If the measured quantity is cyclic autocorrelation at a specified lag and cycle frequency, the procedure can be written and repeated. If the intended conclusion is an external source, the examiner must establish a measurement path between that source and the observed coefficient. If the intended conclusion is a particular individual's device, the procedure must discriminate that device from plausible alternatives under documented conditions. Every stronger noun requires a stronger experiment. Scientific precision is not achieved by writing a smaller uncertainty beside a proposition whose identity conditions were never defined.

I therefore direct that the publication record keep four distinct elements together: a raw or appropriately qualified acquisition interval with its configuration identity; the cyclic statistic and its complete estimator definition; the validation tests and the limitations of their reference populations; and the conclusion explicitly bounded by the tests performed. Where sample records are incomplete, the report should distinguish unavailable observations from negative detections. Where a receiver-generated explanation remains plausible, it should remain visible in the report rather than disappear into a confident headline. Where an external modulation is credibly confirmed but the emitter cannot be singled out, that is a useful result and should be described without apology.

We have not certified an instrument or identified any actual transmitter. All numerical cases are hypothetical educational demonstrations, and our historical colleagues' speeches are newly constructed to test modern

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engineering ideas against documented intellectual methods. The practical doctrine is that a detector can be powerful without being omniscient. Our next discussion will address matched filtering and the equally consequential danger of treating a strong correlation with an assumed waveform as proof that the waveform, and the physical origin attributed to it, were uniquely established. I thank the panel for its precision and courteously pass the floor onward.

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Ten worked technical applications

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Ten worked engineering applications | Question 047

Worked application 1: Cycle-frequency alias under a declared sample clock

Assume an idealised periodic statistic at physical cycle rate $\alpha = 150{,}000$ cycles/s and a sampled record with $F_s = 200{,}000$ samples/s. If the relevant sampled cyclic coordinate is represented modulo F_s, one representative is $\alpha_d = \alpha - F_s = -50{,}000$ cycles/s. The minus sign describes a coordinate on the digital cyclic-frequency axis, not a negative physical repetition rate. Variables: α is physical cycle frequency, F_s the sampling frequency, and α_d the selected equivalent digital coordinate. This algebra applies to the stipulated ideal model; actual observable components also depend on estimator definition, analogue filtering and signal structure. A peak at 50 kHz magnitude therefore does not independently establish a 50 kHz emitter clock.

Worked application 2: Finite observation and cycle-frequency grid

Let an uninterrupted acquisition last $T = 0.100$ seconds, where T denotes retained observation duration. A conventional unpadded Fourier-like cycle-frequency analysis has characteristic grid spacing $\Delta\alpha = 1/T = 10$ Hz. Zero padding can display intermediate numeric coordinates but does not extend the observation or guarantee 1 Hz physical estimation uncertainty. If ten bursts of 10 ms are retained from widely separated times, their combined 100 ms sample count does not automatically behave as one contiguous, coherent 100 ms observation. Their time stamps and phase relationships must be modelled rather than erased when the archive is assembled.

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Worked application 3: Number of repeated cycles present in a burst

Suppose a signal has nominal cycle rate $\alpha = 12{,}500$ Hz and remains observable for $T = 0.020$ s. The nominal count of observed periods is $N_c = \alpha T = 250$ cycles, with N_c dimensionless. This is an upper-level exposure count under the assumption that the entire burst is continuously retained and the cycle persists throughout. The number of independent estimator contributions can be smaller because smoothing windows overlap or because the signal is correlated across periods. A recorder that stores only half the burst does not gain the missing hundred and twenty-five periods through a larger FFT.

Worked application 4: Multiple selected cyclic-frequency tests

Assume, solely as a simplified teaching model, $m = 1{,}000$ independent null tests, each with false-positive probability $p = 0.001$. The chance of at least one false alarm is $P_{any} = 1-(1-p)^m = 1-0.999^{1000} \approx 0.6323$. Variables: m is the number of tests, p is the single-test false-positive probability, and P_{any} is family-wise probability. Real cyclic-frequency cells commonly share observations and are correlated, so independence cannot be presumed. The calculation demonstrates why an apparently impressive single-cell threshold may be unsuitable after a large search. A calibrated maximum-statistic null distribution is preferable for the complete implemented rule.

Worked application 5: Sample count is not evidence count

A receiver samples continuously at $F_s = 2{,}000{,}000$ complex samples/s for $T = 0.125$ s. The stored count is $N = F_sT = 250{,}000$ complex sample positions. N is the number of digital positions, not the number of independent external transmitters or independent observations of a

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particular cyclic feature. A detector may compute thousands of highly overlapping windows over those positions, but all windows inherit the same source event, clock error and receiver gain history. A report claiming 10,000 independent confirmations merely because it plotted 10,000 estimates would be statistically invalid.

Worked application 6: Intermittent scan exposure

Suppose a scanner observes a candidate band for $d = 5$ milliseconds in every $R = 50$ milliseconds. Its idealised observation-duty fraction is $q = d/R = 0.10$. If short bursts arrive with starting phases uniformly distributed relative to the scan, and burst duration is negligible compared with both d and R, the approximate opportunity of intercepting one randomly timed burst is 10%. Variables: d is dwell duration, R is revisit period and q the duty fraction. This approximation does not account for non-negligible burst duration, scan settling, detection sensitivity or timing correlations; all may change the result. A non-detection cannot be treated as compelling evidence of source absence without those qualifications.

Worked application 7: Physical cycle-rate calibration error

Let the nominal measured cyclic rate be $\alpha = 100{,}000$ Hz and let the acquisition clock carry a relative frequency-scale error $\varepsilon = +2$ parts per million, or 2×10^{-6}, under the adopted mapping convention. The first-order absolute frequency-scale discrepancy is $|\Delta\alpha| \approx |\alpha\varepsilon| = 0.20$ Hz. Here ε is dimensionless and α is measured in cycles/s. This does not imply that all cyclic estimators achieve 0.20 Hz precision, nor that the clock's short-term fluctuations vanish. It shows that even a narrowly

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displayed line remains subject to timebase calibration and its uncertainty. Relative and absolute clock claims must not be conflated.

Worked application 8: Finer display grid versus longer information-bearing record

Let the physical observation duration be $T = 0.400$ s. Its conventional unpadded cycle-frequency grid step is $\Delta\alpha = 1/T = 2.5$ Hz. If the analyst zero-pads the array to display positions separated by 0.25 Hz, the plot contains ten displayed coordinates per original 2.5-Hz interval. The recorded duration remains 0.400 s and the physical period count is unchanged. A smoother interpolation can improve locating a broad estimator maximum under a specified model, but it is not equivalent to observing ten times as much independent data. An uncertainty claim must be validated against noise, drift and finite-record effects.

Worked application 9: Periodicity from a four-branch digitiser

A hypothetical time-interleaved converter uses $M = 4$ branches at aggregate rate $F_s = 2$ MHz. Its branch-assignment pattern repeats every four samples, giving nominal pattern rate $\alpha_{int} = F_s/M = 500{,}000$ cycles/s. Variables: M is branch count, F_s aggregate sample rate and α_{int} the architecture's repetition frequency. Offset or gain mismatch can impose spectral or cyclic structure related to that periodic schedule. The existence of such a line is not proof that a particular transmitter operates at 500 kHz modulation rate. Altering aggregate sample rate while controlling the external input offers a test: a branch-schedule artefact may follow F_s/M, whereas an external repetition frequency should follow its physical source clock, subject to correct digital mapping.

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Worked application 10: A shared convention cannot uniquely identify its members

Suppose K = 1,000 equally plausible transmitters in a defined reference population all produce an indistinguishable measured cyclic statistic S under the stipulated acquisition conditions. With equal prior probabilities and equal likelihoods P(S|device_i), Bayes' rule leaves the posterior probability of any one device at 1/K = 0.001. Variables: K is the number of equiprobable candidate devices, S the observed shared statistic, and device_i one specific source hypothesis. The calculation is conditional on the deliberately equal priors and likelihoods. Unequal independent evidence could change the result; the cyclic statistic by itself does not. A strong detection of the shared modulation class is therefore logically compatible with an absence of individual-device identification.

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Sources and verified read scope

The following records distinguish publicly viewed abstracts and institutional summaries from full-text access. All numerical examples and speeches are original constructed educational material. Publication records are not represented as certifying any hypothetical receiver.

[C1] William A. Gardner, *Measurement of Spectral Correlation*, IEEE Transactions on Acoustics, Speech, and Signal Processing 34(5), 1986. Public first-page abstract and explanatory introductory excerpt inspected at https://cyclostationarity.com/wp-content/uploads/2022/10/202210171025.pdf. Read scope: spectral-correlation measurement, finite-record reliability, leakage and aliasing; full-text verification not claimed.

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[C5] G. K. Yeung and W. A. Gardner, *Search-Efficient Methods of Detection of Cyclostationary Signals*, IEEE Transactions on Signal Processing 44(5), 1996. Abstract and first-page introduction inspected at https://cyclostationarity.com/wp-content/uploads/2019/03/SEARCH-EFFICIENT-METHODS-OF-DETECTION-OF-CYCLOSTATIONARY-SIGNALS.pdf. Read scope:

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QUESTION 048

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What does a matched filter actually test about an unknown waveform?

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Question 048. Expert Roundtable Discussion

Original constructed educational dialogue. All contributions attributed to historical specialists are newly authored pedagogical reconstructions, not quotations or historical transcripts. Modern instrument cases and calculations are hypothetical; no apparatus or actual intercepted communication is certified.

Dr. James M. Atkinson | Moderator opening

Distinguished colleagues, a matched-filter output has the visual authority of a striking peak: one may watch a narrow pulse rise from a mottled floor on the receiver screen and hear the alarm which the acquisition system assigns to its crossing of a selected threshold. Yet the smoothness of that rise does not answer the central forensic question. What exactly has been matched? In the familiar ideal derivation a filter is constructed for a specified deterministic waveform immersed in additive white Gaussian noise, and its output is evaluated at a selected instant. Under those assumptions the matched filter maximises output signal-to-noise ratio among linear filters at that instant. In a technical-surveillance investigation, however, the purported waveform may be incomplete, its timing unknown, its phase unstable, and its physical origin wholly unestablished. We must distinguish a mathematically optimum statistic for a stipulated proposition from a finding that the proposition is true.

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Let a discrete complex observation be x[n] = a s[n-k] + w[n] over a finite window, where s denotes a known reference template, a an unknown complex amplitude, k an unknown integer delay, and w a noise sequence with a specified model. A conventional correlation for trial lag k is r[k] = sum over n of x[n] times the complex conjugate of s[n-k]. If the noise is white, its variance known, and the signal is exactly s up to the assumed amplitude and delay, that correlation can be part of an optimal likelihood test. The words *exactly*, *known* and *assumed* are doing substantial scientific work. In a field receiver an adversarial or merely unfamiliar source may employ a similar but not identical waveform. Multipath may change its apparent shape. Analogue filters, IQ imbalance, imperfect clocks and clipping may alter the recorded replica. A detector can therefore produce a large correlation peak without proving that the stored template is a faithful description of the analogue input at the antenna reference plane.

An unknown waveform cannot be matched in the ordinary deterministic sense without defining a family of possible waveforms and how that family will be searched or estimated. If the engineer constructs a template from the same suspicious recording that is later offered as independent confirmation, the attractive result may be partly circular. If one searches a thousand delays, a hundred Doppler or frequency-offset hypotheses and numerous template shapes, the largest output requires a different false-alarm calibration from a single preselected comparison. Where a code sequence is common to an entire class of communications devices, a convincing match is evidence of the shared sequence or waveform convention, not the unique identity of one emitter. We shall examine why a formula derived under perfect knowledge may be useful even when the

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investigator possesses only partial knowledge, and why its claims must be correspondingly restricted.

We should treat time-of-arrival estimates with equal care. A matched-filter output peak has a computational time coordinate determined by sampling, filtering, interpolation, template alignment and signal path delay. It is not automatically the propagation arrival time at the antenna or the moment of emission at the source. A receiver may change its gain or sample rate between the reference measurement and a candidate event. A reference template may be generated digitally inside the same apparatus and share precisely the clock error that should have been challenged. A clean peak can therefore be an excellent indicator of repeatable processing while remaining inconclusive about source identity or absolute arrival epoch.

The panel will place five intellectual approaches into dialogue. Professor Wiener will examine correlation as statistical prediction and its dependence upon the assumed noise. Mr Nyquist will address delay, template fidelity and the sample-time coordinate. Dr Shannon will distinguish information acquired from a match from information not supplied by the measurement. Professor Neyman will insist upon complete decision rules, calibration populations and false-alarm control. Mr Black will return the discussion to feedback, receiver-generated templates and physical reference planes. Seven peers will ask technical questions, receive immediate answers, and pass the token respectfully. Ten worked examples will expose the arithmetic concealed in apparently simple detection pictures. We shall retain the original data, version the template and declare the uncertainty rather than allow an attractive correlation graphic to outrun its supporting evidence.

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This roundtable is not intended to diminish matched filtering. Properly employed it is among the most valuable tools in receiving systems, radar, sonar and digital communications. Its usefulness comes from a narrow proposition stated clearly and tested under conditions relevant to that proposition. The significant distinction is between a filter being mathematically matched to a known model and the physical world being conclusively identified by the filter's output. We begin with Professor Wiener, whose theory of prediction and statistical estimation provides an appropriate setting for asking whether the noise and signal models have been specified rather than merely assumed.

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Norbert Wiener | Principal response 1: Template knowledge and the conditional nature of optimum filtering

Dr. Atkinson, I begin by insisting that optimality belongs to a problem formulation. A procedure does not remain optimal after the assumptions used to derive it have been forgotten. For a deterministic waveform of known shape in additive white Gaussian noise, the matched filter gives the maximum attainable output signal-to-noise ratio among linear filters at a selected comparison instant. That result can be derived from the Cauchy-Schwarz inequality and is sound within its premises. It does not state that every observed peak has been produced by the expected emitter, nor that a different noise distribution, unknown waveform or adaptive receiver will preserve the same optimality. The important words are the waveform, the noise covariance, the observation interval, the decision instant and the class of permitted estimators.

Consider an abstract discrete template s with samples s[0],...,s[N-1]. Under a simple model x = a s + w, with w an independent circular complex Gaussian noise vector having covariance $\sigma^2 I$, the inner product $s^H x$ is a sufficient projection for testing the amplitude of that one specified vector under suitable hypotheses. The template energy is $E_s = s^H s$. The correlation's noise variance is $\sigma^2 E_s$ and the signal component is aE_s. Thus the output signal-to-noise ratio is proportional to $|a|^2 E_s/\sigma^2$. The mathematical economy is attractive: many raw samples have been condensed into one projection aligned with the expected signal. But the compression is purposeful. It retains what is needed for the declared hypothesis and may discard distinctions vital to another hypothesis. If the

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question later changes from detecting a known sequence to identifying an unknown modulation, the original projection may be inadequate evidence.

The trouble with unknown waveforms is visible immediately. Suppose the actual signal is u, not s. The matched-filter response is proportional to $s^H u$; it depends upon the degree of overlap between the template and the actual received vector. Two distinct waveforms can project strongly onto the same template even though their differences matter to attribution. Conversely, a genuine emitter may produce a weak peak because propagation, clock drift or receiver filtering has distorted its waveform. A low correlation is not proof of absence, and a high correlation is not proof of identity. It is a measurement of a relationship under the chosen alignment, normalisation and receiver state. The investigator must consider the corresponding likelihoods under credible alternatives rather than merely label one peak as expected.

Noise coloration introduces a further issue. If the covariance of the noise is C rather than $\sigma^2 I$, ordinary unweighted correlation is generally not the optimum linear detector. Under a known invertible covariance, the corresponding whitened statistic involves $s^H C^{-1} x$. This notation is compact but the required evidence is not. A covariance matrix estimated from one quiet laboratory interval may fail to describe switching supplies, intermittent legitimate emitters or a receiver near compression. If C is ill-conditioned, an attempted inverse may amplify estimation error. Covariance estimation performed after observing the candidate may absorb some of its structure and change the detection statistic. These complications do not make matched filtering useless. They demand that the noise model, its training population and its uncertainty be part of the validation record.

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A practical receiver may adapt its filter weights while searching. Adaptive filtering can increase performance under changing interference, yet its final output is not independent of the training data which produced the weights. If the test sample also trained the filter, a very strong peak might reflect tuning to that particular noise realisation. A valid challenge should distinguish the development population from independent or appropriately separated validation observations. Where adaptation must remain active, its rule and update history should be preserved, and challenge tests should reproduce its operation rather than replace it with a simplified static filter that enjoys different behaviour. Otherwise a laboratory certificate describes an instrument which did not actually make the field observation.

There is an equally serious physical distinction between a generated reference and an independently observed reference. Suppose an internal digital source produces the code sequence against which the receiver correlates incoming IQ. That template may be perfectly repeatable and perhaps driven by the same clock as the receiver's sampling system. The resulting correlation can be precisely timed on the instrument's internal coordinate while leaving the absolute RF arrival time uncertain. Internal clock commonality can suppress apparent relative jitter without validating absolute time or the RF path delay. A second analysis of the same stored file is useful for checking arithmetic, but it does not supply an independent electromagnetic observation. If source attribution depends upon timing or multiple receivers, the missing reference-plane measurements must be obtained elsewhere.

The forensic record should therefore preserve the input observation and the transformation. The raw IQ should be retained for material events

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where permitted, together with the template samples or their content-identifying digest, sample-rate mapping, filter coefficients, alignment convention, frequency-offset search, threshold policy and rejection criteria. A compressed statistic can support a limited finding if those conditions are sufficiently understood. It cannot substitute for unknown data which the system never captured. One should also preserve the record of invalid intervals and null tests; a display showing only successful correlations is an unfaithful representation of the detector's opportunities for failure.

Where a large template library is involved, I would ask for the rule by which the library was assembled, how similar its members are, and whether the reported winning template was selected after repeated human intervention. The likelihood of a high maximum among many correlated templates differs from the likelihood of a high correlation to one named in advance. The investigator may legitimately search for candidates, but the result should first be labelled discovery. A separate physical challenge, a withheld acquisition or an independently specified decision can establish stronger evidential weight. Detection and attribution are related activities, not identical mathematical operations.

Let us retain a balanced conclusion. Matched filtering is powerful because it exploits prior information about waveform shape to improve a particular comparison. Its failure modes arise when that prior information is mistaken for new evidence, or when the field receiver's noise, clock and transfer function depart from the premises. An honest technical report should say what template was used, what physical quantity was compared, which alternatives were evaluated, and what remained unidentified. I ask Professor Bridgman to test the operational meaning of the word matched,

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for a correlation coefficient without a declared comparison is scarcely a measurement at all.

Percy Williams Bridgman | Peer question 1 to Norbert Wiener

Professor Wiener, your mathematical expression for correlation is clear, but I should like to examine what it means physically to construct a reference template. An engineer may record an interesting burst, remove its noise by selecting a smoothing algorithm, normalise its amplitude, and use the resulting shape as a template for finding repetitions in the same archive. The procedure might be entirely reproducible. Yet the investigator may then assert that the second correlation proves an independently recurring signal, even though the template arose from the data under examination. Which observations should be treated as independent, and how should the construction of the template be recorded? I am particularly concerned about changes of units and reference planes: a voltage waveform recorded after an unknown automatic-gain stage is not the electric field at the antenna. May the analyst properly call the result a match to the original emission, or only a similarity between two processed records? What experimental operation would elevate that limited similarity into a defensible external-origin finding?

Norbert Wiener | Immediate answer to Percy Williams Bridgman

Professor Bridgman, I would begin by naming the two objects actually compared. If both are derived from one archived record, the result is a correlation between derived functions of that record. It may demonstrate repeated patterns within those retained samples, and that can be a valuable discovery. It should not be counted as two

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independent physical observations merely because two arrays or two time windows were involved. If the windows overlap, they may even share many of the same original samples. The proper record identifies every transformation used to create the template, including denoising, amplitude scaling, cropping, resampling and phase adjustment, together with any selection made after viewing the candidate.

Independence is not a blanket property. Separate windows may have different additive noise realisations but share the same oscillator drift, gain history, sample clock and receiver artefacts. A second physical acquisition with an independent or deliberately changed signal path can challenge these dependencies. One could inject a reference waveform at a calibrated RF input plane and test whether the detector behaves as predicted across gain states, carrier offsets and noise conditions. One could also compare a separate receiver, documenting which components and references it shares. The purpose of independence is to make a rival explanation less likely, and the degree of independence needed depends upon that explanation.

I would not insist that the template always be derived from an ideal electromagnetic model. A data-derived template may be the most useful means of detecting recurrences in an unknown environment, especially when the emission is too weak for a complete waveform model. The qualification is that its detector performance is conditional on the population and choices used to learn it. One should freeze the template and test it on withheld physical observations with known-

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present and null challenges. If the template continues to detect a specified signal class while rejecting representative receiver artefacts, that is evidence of useful performance. It is still not proof that the signal belongs to one uniquely identified transmitter unless the challenge is capable of discriminating that identity.

The reference-plane issue must be explicit. A voltage trace following automatic gain control may be related to the antenna field by a transfer which depends upon time and state. Without sufficient characterisation, one cannot invert it reliably into a physical field-strength claim. A measured similarity after processing is not fraudulent when described accurately; it becomes misleading when its noun is enlarged into an unverified causal conclusion. The result should be reported as a match under the named processing and calibration conditions, with additional external-origin experiments described separately. That is how an operational definition can support useful investigation while resisting rhetorical overreach.

Walter Andrew Shewhart | Peer question 2 to Norbert Wiener

Professor Wiener, I wish to challenge the stability of the noise model. An engineer may validate a matched filter using many laboratory trials in quiet additive Gaussian noise, report an excellent false-alarm rate and then deploy the same receiver near a switching supply, a busy communications system and periodically operating machinery. The detector begins to trigger on pulses which share only a rough envelope with the reference. The operator may adapt the threshold upward until the false alarms disappear, after which the original performance certificate is still quoted. What must be recorded to determine whether

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the detector is operating in a controlled statistical process? Should the false-alarm estimate be recomputed whenever the receiver changes gain, front-end bandwidth or calibration state? How do we distinguish an ordinary change in environmental interference from a fault in the correlation algorithm, and what shall the report say about intervals when the instrument had insufficient exposure to make an absence claim?

Norbert Wiener | Immediate answer to Walter Andrew Shewhart

Thank you for that question. Dr Shewhart, the performance certificate applies to the population and decision rule which produced it. If the deployed receiver differs materially in noise statistics, gain, bandwidth, threshold logic or sample retention, the laboratory result cannot simply be copied into a claim of identical field performance. A systematic change in the null distribution is enough to require a fresh qualification even when the code of the correlation algorithm is mathematically unchanged. One may maintain control charts of relevant operating statistics, but those charts should not be used as substitutes for controlled challenge trials that separate receiver faults from environmental interference.

The important distinction is between a changed decision rule and a changed world. A threshold raised in response to field conditions might reduce false alarms at the price of lower sensitivity to weak signals. That trade-off is legitimate if measured and disclosed. It becomes misleading when the old low-threshold sensitivity figure is retained beside the new high-threshold operating configuration. The receiver should log threshold versions, adaptive update policies, gain states and null observations. Validation should include representative

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interference and intermittent signal challenges, with known injection times independent of the detector. A trial in which the challenge was present but unreported is essential evidence about missed detections, not an embarrassment to exclude.

Some environmental changes may be detected through residual analysis. Compare the distribution of matched-filter outputs on independent null intervals with the distribution expected under the declared model. Examine clusters, long tails, periodicity and dependence across windows. If those properties differ, an assumed Gaussian false-alarm calculation may no longer apply. It is possible to calibrate an empirical threshold for the complete implemented search under the actual operating envelope. The acceptance report should identify how that population was constructed and which future conditions require renewed testing.

For negative findings, exposure is separate from conditional sensitivity. A scanner observing one band for a small fraction of time cannot establish that an intermittent waveform was absent throughout the full survey, even if its matched filter was nearly certain to detect the waveform whenever it was observed at a sufficient level. Record dwell time, revisit interval, invalid periods, filter settling and threshold state. If those elements are missing, the absence finding should be described as indeterminate or restricted to the observed intervals. The proper conclusion is not that the instrument failed, but that its evidence addresses a narrower proposition than an unqualified assurance sentence would suggest.

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Harry Nyquist | Principal response 2: Unknown delay, template mismatch and the measurement of arrival time

Dr. Atkinson, the sample-time coordinate is often the first element to be obscured by a spectacular correlation peak. A matched filter examines relationships between a candidate sequence and a specified template across trial alignments. Its output peak is indexed by the lag at which that relationship is strongest under the adopted convention. The physical event time is not generally identical to the lag index multiplied by the nominal sample period. One must account for the reference template's epoch, analogue group delay, digital filter delay, clock calibration, resampling, cable or antenna path and any event-specific synchronisation process. The moment that a program prints 'arrival time' does not guarantee that those transformations have been measured.

For a sample rate F_s, the nominal conversion from an index displacement k to duration is k/F_s. If the sample clock has fractional frequency error ε and the acquisition system silently assumes its nominal rate, the inferred interval carries a corresponding scale uncertainty. If the input passed through a filter with frequency-dependent group delay, there may not even be one constant delay correction suitable for all waveform shapes. A broad signal whose spectral energy lies in different parts of the filter passband can exhibit a different correlation peak than a calibration tone centred in the passband. The engineer should therefore characterise the transfer over the waveform bandwidth, not merely apply one number measured at one frequency.

A matched filter is deliberately sensitive to a particular time-frequency structure. If the incoming signal differs by frequency offset, Doppler scaling,

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code-clock offset or pulse shaping, its correlation peak may broaden, diminish or shift. This is not necessarily evidence of a different transmitter. The same emitter can appear mismatched after propagation, receiver drift or operating-state change. Conversely, two unrelated emitters sharing a known preamble can produce highly similar correlation peaks. A receiver which declares identity from a template match must independently demonstrate that the template distinguishes competing sources in its target population. The lag at a correlation peak and the identification of its cause remain distinct conclusions.

One must also consider the ambiguity surface. Rather than searching only delay, a realistic receiver may evaluate many candidate frequency offsets, phases and waveform shapes. The strongest point on the resulting surface depends upon the tested grid and estimator. A fine interpolation in delay can yield a visually precise peak position without providing corresponding physical timing certainty. A new frequency hypothesis may change which sidelobe is selected, especially when the signal is short or the template has repeated structure. The reported uncertainty must include the possibility of choosing a wrong ambiguity peak, not only the local curvature around the selected maximum.

Correlating with a template containing repeated symbols illustrates this difficulty. If the template has a short repetition interval, several delay lags may give similar scores. If the receiver reports only the highest, the selected arrival time can jump by one or more repetition periods in response to small noise changes. An apparent nanosecond-level interpolation within one lobe is irrelevant if the correct lobe has not been established. The survey record should preserve competing local peaks or a sufficient summary of the

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ambiguity surface to expose that possibility. Where a second timing reference is available, it should be used to test the lobe selection rather than merely to improve the number of digits displayed.

I am concerned as well with sample clocks shared across multiple receivers. A common reference can improve relative timing, but it may create common error. Two receivers using one distribution network may agree about an event's digital epoch while both being displaced from the true RF arrival time at their respective antennas. Conversely, independently clocked receivers may require a carefully estimated offset and drift map before the same burst can be compared. Their differing paths may provide better independence for causal attribution, but an inaccurate clock map can manufacture an apparent propagation delay. The investigator must state whether the claim concerns relative sequence alignment, absolute UTC time, or physical RF propagation time; the evidence needed differs accordingly.

A basic calibration experiment uses known injected waveforms at the declared reference plane, with their timing independently established. Vary the waveform phase, centre frequency, amplitude and arrival position relative to the sample clock. Compare correlation peaks with the known injection schedule, including moments near buffer boundaries and digital rate changes. The result should be a distribution of timing errors, not one perfect calibration trace. Strong and weak signals may produce different error distributions. Clipping can distort a high-amplitude signal, while poor signal-to-noise ratio makes a weak signal's peak unstable. Both conditions belong in the declared operating envelope.

A digital copy of the transmitted template can be highly accurate as a sequence of symbols and still fail to reproduce the analogue waveform

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observed after filtering and multipath. For a forensic detection claim, it may suffice to know that the receiver detects the defined class with measured probability under specified conditions. For a phase or time-difference location claim, more stringent calibration is needed. One should retain the raw acquisition, timing reference, filter settings and ambiguity candidates, including failed or excluded comparisons. Reconstruction of an original analogue arrival cannot exceed the information preserved in that record and the independently validated corrections applied to it.

Finally, I would caution against the belief that greater sample rates automatically solve every timing question. Oversampling can provide finer nominal grid spacing, but noise, clock jitter, group-delay dispersion and waveform mismatch still govern the uncertainty of the physical event. The most rigorous report may say that a particular template aligned with the retained sequence at a stated digital lag, within an evaluated uncertainty under the declared model. An absolute physical-source conclusion demands further evidence. I respectfully invite Professor Bode to challenge whether the receiver's analogue transfer can itself create the sort of waveform similarity being offered as a match.

Hendrik Wade Bode | Peer question 3 to Harry Nyquist

Mr Nyquist, you have described a well-defined digital lag, but a filter in a real receiver has both amplitude and phase response. A laboratory may measure one nominal group delay and subtract it from every subsequent correlation time. If the received burst occupies a wide bandwidth, different frequencies may experience different delay, and equalisation may alter the noise correlation or amplify weak regions of the spectrum. What measurement would be sufficient to justify one corrected arrival

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epoch? Would you require the complex transfer function over the whole admitted band, or might a bounded family of waveforms suffice? Further, if the filter has a notch or a region of almost zero response, a digital inverse may produce an aesthetically attractive trace without recovering the information lost at the analogue input. I ask how the investigator should distinguish ordinary calibration uncertainty from a genuinely non-invertible measurement relationship when the reference waveform is itself only partly known.

Harry Nyquist | Immediate answer to Hendrik Wade Bode

Professor Bode, I agree that one correction delay is defensible only under a stated waveform and transfer-function model. If the filter phase is sufficiently linear over the effective bandwidth of the signal, a constant group delay may be a good approximation. The approximation should be validated with the waveform class and conditions for which arrival-time claims will be made. Where phase response is dispersive, the estimator should account for the complex transfer or report a larger, waveform-dependent uncertainty. A nominal calibration at one centre frequency does not establish the delay of all possible bursts over the admitted band.

The distinction between correcting and reconstructing is fundamental. If a transfer function has a deep null or the signal was clipped, a numerical inverse can magnify the surviving data but cannot uniquely recover absent information without additional assumptions. A matched filter designed against the output waveform of a known calibration path may still provide excellent detection under those conditions. It should be described as matched to the

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received or *predicted output* template, not as proof that a pristine analogue input has been reconstructed. Those are different operations with different uncertainty accounts.

I would require measurements of transfer phase and magnitude over representative frequencies, gain states and temperatures, together with calibrated reference bursts that resemble the claimed signal class. The record should preserve the measured transfer and its uncertainty, any equaliser coefficients, and the before-and-after data. If the equaliser depends upon a model of an unknown input, the resulting arrival estimate is conditional on that model. The validation procedure should include deliberately mismatched waveforms and frequency offsets to quantify how the timing bias changes. A single residual root-mean-square error over easy training cases could conceal rare but material wrong-peak events.

The most telling challenge may be one designed to fail. Inject two pulses whose relative timing is known, but change their spectra so the phase-response differences matter. If the corrected lag remains stable within its declared uncertainty, the calibration has demonstrated a limited form of robustness. If it shifts, the discrepancy should be retained and the allowed signal envelope restricted or the correction model revised. One cannot erase a test failure by excluding the offending waveform after seeing the result and still claim the original scope. Forensically, a narrow but verified timing statement is more valuable than a general arrival-time assertion unsupported by the instrument's actual transfer.

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David Slepian | Peer question 4 to Harry Nyquist

Mr Nyquist, the time-frequency ambiguity of a finite template appears to place a limit on your desire for a single arrival time. An extremely short pulse has broad spectrum and can be sensitive to analogue dispersion; a longer coded sequence can yield sharp correlation structure yet may have sidelobes or repeated motifs. The analyst may choose the window length after viewing the burst, or pad the template to create a visually smooth peak. How should one distinguish a true improvement in timing information from a cosmetic change in display resolution? If a long template provides more processing gain but includes portions of the record where no signal was actually present, could the apparently improved peak be biased by the selected background? I should like to hear which experimental conditions would let the receiver report one physical event time without concealing alternative peaks and mismatch-induced shifts. Would the answer change if the receiver were operating near its clipping threshold?

Harry Nyquist | Immediate answer to David Slepian

Professor Slepian, the estimator's precision depends on the signal energy, effective bandwidth, observation duration, noise and the model used to infer timing. Merely increasing FFT padding or decreasing the display increment does not create more independent information about the arrival epoch. A longer genuine known waveform may provide additional energy and structure, improving a properly calibrated time estimator. But a template extended through periods where the source did not transmit can introduce noise contributions or mismatch. The detector's optimal length is

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determined by the signal model and performance objective, not by the amount of storage available or the attractiveness of a narrow plotted maximum.

A useful validation programme should compare the full ambiguity surface under known injections across a range of signal levels and frequency offsets. The examiner should retain competing peaks and report the fraction of trials in which the algorithm selects a sidelobe instead of the true delay. That discrete failure mode may dominate timing error even when the local peak interpolation is excellent. Two estimates should not be treated as independent confirmations when they use overlapping samples and the same template. A new physical observation or an independently calibrated timing route can provide stronger evidence.

If the signal is only partly known, the system may search a family of templates covering plausible timing and frequency deviations. Such a search increases the number of opportunities for high noise peaks, so its threshold must be calibrated for the complete search, not one particular member selected retrospectively. One can legitimately choose a window to maximise sensitivity during development, then fix it for a withheld validation population. If a new field condition requires a different window, the change must be versioned and its performance claims retested. The report should identify when a candidate was discovered versus confirmed under the frozen rule.

The physical event time should be defined at a specified reference plane and accompanied by an uncertainty model including clock, analogue path, sample selection, template mismatch and peak-

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selection error. A digital alignment time may be precise while the RF event time remains uncertain. Treating the two as the same quantity would confuse a reproducible computation with a physical measurement. The successful instrument is not the one that prints the most decimal places, but the one whose displayed interval genuinely bounds the event under tested conditions. I now pass the token to Dr Shannon for his treatment of what correlation can and cannot reveal about an unknown waveform.

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Claude Elwood Shannon | Principal response 3: A correlation statistic does not disclose all information about an unknown source

Dr. Atkinson, an efficient detector is designed to discard information irrelevant to a declared decision. That is one reason correlation is so valuable. When the signal is truly known and the noise model is properly specified, a matched-filter statistic can concentrate the information bearing upon the specified hypothesis into a convenient comparison. The same reduction becomes perilous when the investigator later asks a broader question. A statistic sufficient to decide whether a known sequence appears at a candidate delay need not be sufficient to reconstruct an unknown waveform, distinguish a family of devices or infer their physical location. The required information is determined by the question, not by the impressive economy with which a filter transforms its samples.

Suppose a template s is a common preamble transmitted by every member of a communications standard. A large correlation with s may establish the likely presence of that preamble under the receiver's admitted conditions, and it may enable a useful timing estimate. It cannot by itself identify which of many compliant devices produced it. If the received message payload is unavailable, the matched filter does not recover it. If the RF waveform is clipped, the peak cannot reconstruct the missing analogue amplitudes. If a receiver did not observe the relevant interval, no amount of later filtering can create an independent record of the unobserved transmission. Matching improves an estimate within a specified model; it does not enlarge the set of physical events which the instrument actually sampled.

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It is important to separate a correlation coefficient from a likelihood ratio. In the simplest additive Gaussian model a matched-filter output may be a monotonic component of an optimal test statistic. When the amplitude, phase, delay and waveform are unknown, however, the likelihood must account for those unknown parameters or integrate over an appropriate model for them. A detector which searches a family of templates and reports the maximum has changed the statistical experiment. Its false-alarm distribution is not generally the same as that of one fixed correlation under a known signal. The chosen model and nuisance-parameter treatment determine what probability statement can be made. A p-value calculated for one fixed template after that template was selected from a large library is not a full description of the search.

The phrase *unknown waveform* can hide more than one uncertainty. The investigator may know a preamble but not the payload. The modulation format may be recognised but the symbol timing or pulse shape uncertain. The transmitter may have been identified lawfully through separate evidence, yet propagation and hardware distortions make the received waveform uncertain. Or the source and waveform may both be wholly unknown. These are different inverse problems. In the first case a known preamble detector is appropriate. In the last case a predetermined matched filter cannot be said to be matched to the unknown signal at all. The operator might instead use an energy detector, a cyclostationary statistic, a bank of class templates or a generalised-likelihood procedure, each with its own performance and interpretive limitations.

A matched-filter peak may also result from an unrelated signal which shares part of the template. The risk depends upon the correlation structure

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of the reference library, the length and uniqueness of the sequence, the signal-to-noise ratio and the permitted time-frequency search. A long random-looking sequence may be highly discriminatory under an ideal coding model, yet the field system could use only a short portion of it because of burst truncation. An apparently unique peak after such truncation may be much less informative than the full-code validation would suggest. The actual retained comparison, not the nominal complete waveform, must determine the evidential claim.

Statistical independence deserves separate attention. A receiver may find a peak in several adjacent processing channels because their filter responses overlap, or in several FFT windows because they share the same physical samples. Multiple peaks can be a legitimate diagnostic of the same event but are not automatically independent confirmations. Two physically separate receivers may share timing references and antennas, producing correlated uncertainties. If their matched-filter peaks agree, that observation should be interpreted in a model that includes shared paths. To combine probabilities by multiplication without examining dependence is to import an unstated assumption, not to strengthen the evidence by mathematical necessity.

The quality of the null model is equally important. White Gaussian noise is a useful model in which the optimality of the matched filter can be derived cleanly. Actual environments contain legitimate communications, spurious mixer products, impulsive electrical noise, clock leakage and nonstationary interference. An interfering waveform with the same preamble can produce the same matched-filter feature as the target. The detector's performance should therefore be validated against a population appropriate to the field

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proposition. A low false-alarm rate measured only against synthetic white noise cannot certify a low rate of false external-source attributions in a building containing many emitters and receiver artefacts.

I would propose a layered record. First, preserve the raw evidence of the candidate and the template identity. Second, state the exact statistic and timing convention used to calculate the peak. Third, provide the tested signal family, interference population and threshold rule. Fourth, distinguish a detected waveform feature from a source classification or identity conclusion. A defensible statement might be that the record contains a component whose cross-correlation with a particular preamble exceeds a threshold calibrated against specified alternatives. It should not become a declaration that one unknown transmitter was necessarily present, unless additional evidence differentiates that transmitter from the other possible causes.

The greater power of the method lies in its explicitness. Correlation makes the investigator say what pattern was sought and permits the pattern to be independently tested. It is less powerful when the analyst silently changes the pattern until something matches and then forgets the search. This is the central information-theoretic lesson: a statistic can be highly informative about one proposition and nearly silent about another. We should use the former strength without pretending that it proves the latter. I invite Dr Hamming to ask how an efficient software implementation should preserve its algorithmic conventions when a surprisingly high peak is encountered.

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Richard Wesley Hamming | Peer question 5 to Claude Elwood Shannon

Dr Shannon, the mathematical inner product is clear, but a real implementation often chooses between direct correlation, FFT convolution, blockwise overlap-save processing and a normalised correlation calculated from window-specific energy. An engineer may compare results from those algorithms and infer independent agreement when they are merely implementations of one mathematical operation. There may also be differences at buffer boundaries, with even-length templates, conjugation conventions or integer arithmetic overflow. What would you require the forensic analyst to preserve so that another examiner can reproduce the actual peak, including its lag and its threshold crossing? Further, if the code uses a different normalisation whenever a burst is partially outside the retained interval, does a value of 0.9 mean the same thing across all candidate windows? How can one specify a performance test that catches software errors without confusing numerical agreement between two routines with physical corroboration of the emission? Which independent reference records should be retained?

Claude Elwood Shannon | Immediate answer to Richard Wesley Hamming

Dr Hamming, a reproducible implementation should expose the correlation convention, not merely its graphical output. For complex sequences it must state which argument is conjugated, how lag sign is assigned, which samples contribute to each lag and what zero-padding or boundary extension is used. It must preserve the exact

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template version, sample format, scaling, filter coefficients and timing reference. A different FFT implementation may legitimately reproduce the same operation; this is excellent evidence about computational correctness, but it is not a second observation of the analogue world. The claim should be limited accordingly.

Normalisation is particularly important. A coefficient divided by the product of two full-window energies is not necessarily comparable with one computed over an edge-truncated interval. If the denominator changes with available samples, the estimator's variance and null distribution can change as well. A displayed value such as 0.9 has no universal significance until the precise statistic, effective sample count and selection procedure are specified. The detector should identify windows for which the denominator is too small or the template is incompletely observed, and its validation should include such edge cases explicitly.

The best software proof combines reference calculations and adversarial test cases. Use short synthetic complex sequences for which the expected lag and amplitude can be calculated independently by hand. Exercise positive and negative delays, conjugation, zero-valued samples, integer overflow limits, and blocks straddling acquisition boundaries. Compare direct and FFT-based correlation under declared numeric tolerances, then carry out known-signal injections through the actual receiver to test the analogue and digital chain together. Such tests occupy different positions in an evidence hierarchy: arithmetic verification, software implementation verification and physical receiver validation should not be conflated.

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For a serious event the investigation record should permit replay from the original samples through the exact detection software version, including the intermediate statistic where practical. An examiner should also be able to examine candidates that fell below threshold and the conditions which caused buffers to be discarded. Without those records one can reproduce the winning peak but not the operational false-alarm or missed-detection behaviour. The system's apparent precision depends as much on its selection and retention rules as on the Fourier arithmetic. I pass the floor to Professor Neyman for the statistical discipline that should govern thresholds chosen from a bank of possible templates.

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Jerzy Neyman | Principal response 4: Detection thresholds, composite hypotheses and the cost of a search

Dr. Atkinson, the central statistical error I foresee is to treat the probability of a correlation value under one fixed null hypothesis as though it were the probability that a particular device emitted the signal. A decision problem should start by stating its hypotheses and the action governed by the test. For a known deterministic waveform in known additive Gaussian noise, one can derive a test with specified false-alarm probability and detection power. If the waveform is unknown, if the noise is estimated, or if a search chooses among many delays and templates, the experiment is different. Its operating characteristics must be evaluated for that experiment. A formula carried over from the simpler problem does not acquire validity merely because it produces a plausible number.

Suppose a detector examines one hundred possible delay hypotheses and then reports the largest normalised correlation. Even when each fixed-delay statistic has a small upper-tail probability under its null model, the maximum has more opportunity to appear large by chance. The tests are generally correlated because neighbouring delays share samples and because a waveform can correlate with shifted copies of itself. A simple family-wise bound based on the sum of probabilities may provide a conservative check under broad conditions, but precise field performance requires a correct joint model or empirically validated null trials reproducing the complete search. It is especially hazardous to calculate a single-cell p-value after selecting the peak and to report it as though the delay had been nominated before acquiring data.

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A library of templates complicates the matter. Some entries may be nearly identical, while others differ greatly. The number of stored templates is not necessarily the number of independent statistical tests, but the search process has still enlarged the decision space. A threshold calibrated for one waveform cannot automatically be applied to a bank of thousands without controlling the probability of at least one false alarm. If the library was developed by repeatedly examining the same archived environment, a separate validation population is needed to estimate performance. Otherwise the detector may fit the peculiarities of one building, receiver or interference field and produce overly optimistic results on familiar recordings.

I would distinguish an operational alarm from a source finding. The purpose of an alarm in a defensive survey may be to preserve raw IQ and draw the investigator's attention to a plausible candidate. A relatively liberal threshold may be justified if follow-up measurement is inexpensive and missing a weak emitter is costly. A claim that the candidate has been conclusively identified as an unauthorised transmitter is entirely different and requires corroboration of external origin and identity. Statistical decision theory can organise these distinct actions, but the report should not borrow the authority of one threshold for a much stronger statement which the threshold was never calibrated to support.

There is also a base-rate issue. The conditional probability of an alarm given a noise-only trial is not the conditional probability of noise given an alarm. To estimate the latter one needs assumptions or evidence concerning how frequently the relevant signals and alternative causes occur. A matched filter may have a very low false-alarm rate against synthetic noise and still

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generate many false source attributions when the building contains large numbers of legitimate transmissions with shared preambles. A report should state what null population was tested, whether confusable signals were present, and whether the decision rule included a rejection or abstention outcome. Without that information a numerical percentage can produce more confusion than illumination.

Intermittent observation changes the denominator of performance statistics. A receiver that scans a frequency for a small fraction of a period may never observe a brief burst. The conditional probability of detection *given that the burst is inside a valid retained observation* is not the probability of detecting a randomly occurring burst during the entire survey. The latter depends on the dwell schedule, source timing, filter settling, dead time and retention policy. These factors must be measured or modelled explicitly. A detector cannot repair limited exposure by applying a more sensitive matched filter to the intervals that happen to have survived acquisition.

The confidence of validation estimates also depends on independent challenge units. If a laboratory makes one hundred thousand overlapping FFT windows from ten physical injections, the number of independent trials is not necessarily one hundred thousand. The windows share the same waveform events, clock and interference conditions. The experiment should track injections, sessions and relevant clustering. Confidence limits can then be calculated at an appropriate level of independence. The validation should include deliberately incorrect templates, noise-only records, confusable legitimate waveforms and known signals at the edge of the receiver's

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sensitivity envelope. It should record every challenge, including those where a reference was present but the filter failed to cross threshold.

One should also distinguish error of detection from error of timestamp assignment. A receiver might correctly declare a template present but choose the wrong ambiguity lobe, shifting the reported arrival time by an integral symbol interval. A detector calibrated only for presence/absence is not necessarily calibrated for precise time-of-arrival estimation. The latter requires a different acceptance rule and a distribution of timing errors under plausible mismatch and multipath conditions. Likewise a detector that recognises a common protocol does not automatically distinguish transmitters sharing that protocol. The two errors should be counted separately rather than hidden beneath one overall accuracy figure.

My recommendation is a staged validation record. Declare the actual action the alarm triggers, the full search and threshold procedure, the relevant signal and interference populations, the number of independent physical challenge units, and the confidence limits on both false alarms and missed detections. Where the search rule is modified after examining performance, label the modification and retest it on new observations. A bounded and repeatable receiver decision is scientifically valuable; an unqualified source identity supported only by a high correlation is not. I invite Professor Fisher to question whether my emphasis on fixed procedures risks concealing the legitimate uncertainty of the noise covariance itself.

Sir Ronald Aylmer Fisher | Peer question 6 to Jerzy Neyman

Professor Neyman, your distinction between complete decision rules and selected peaks is persuasive, but practical investigators rarely know

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the noise covariance in advance. They estimate it from recordings which may include impulsive interference and unknown signals, then choose a whitening filter or threshold. A laboratory may have only a limited number of independent null trials, while the programme contains many overlapping time and frequency hypotheses. Would you accept a theoretical false-alarm probability calibrated from an estimated covariance, or require a second physical challenge population to establish its realised accuracy? I should also like to examine how a receiver should report uncertainty when the null model is demonstrably inadequate. If the alarm remains useful for directing a survey, is it scientifically permissible to continue operating the detector while withholding a numerical field false-alarm figure? What separation should be maintained between detection research and an evidential statement offered to support a consequential decision?

Jerzy Neyman | Immediate answer to Sir Ronald Aylmer Fisher

Sir Ronald, a theoretical performance figure is useful only to the extent that its premises have been justified. When the covariance is estimated rather than known, the estimator's uncertainty and its relationship to the test samples affect the distribution of the detection statistic. If the same data are used to fit the covariance and evaluate a candidate, an apparent agreement with a nominal Gaussian model can be misleading. One may derive an adjusted theoretical procedure under explicit assumptions, or calibrate the entire fitted detector empirically using independent null acquisitions. Neither choice should be presented as unconditional validation when the field environment departs from its assumed population.

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A limited number of challenge trials calls for an honest confidence interval, not a fabricated certainty. Zero observed false alarms does not establish a zero true false-alarm probability. The number of physical challenge units, their variety and their dependence should be stated. If the trials contain only quiet laboratory noise, the report should not claim performance against every class of field interference. Conversely, a detector may remain valuable as a discovery aid even when the field false-alarm rate is uncertain. The appropriate label is exploratory or operational candidate detection, with further physical checks required before a consequential attribution.

I would also preserve the distinction between a hypothesis generated from a suspicious recording and one specified before an independent test. An analyst may discover a waveform through visual inspection, construct a template and find more apparent matches in that same recording. This is useful work, but a formal significance figure must account for the adaptive search and selection. A withheld recording, independent capture or blinded injection campaign allows the chosen rule to be evaluated on observations not used to develop it. If the operator changes the threshold after an unfavourable trial, that event remains part of the developmental record and the revised rule requires new validation.

Where the null model is demonstrably inadequate, the strongest responsible statement may be that a correlation exceeded an operationally chosen threshold but that the false-alarm probability under the field population has not been established. This still permits

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the investigator to preserve evidence, change antennas, examine receiver artefacts and search for corroboration. What cannot be justified is attaching a numerical confidence to a source accusation solely because the software prints one. A statistical test addresses a specified comparison; responsibility for the broader causal claim remains with the evidence and its documented limitations.

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Harold Stephen Black | Principal response 5: Physical reference planes and receiver-generated correlation

Dr. Atkinson, the last question is whether the receiver can manufacture a match to its own internal behaviour. A filter may perform flawlessly as a digital computation while the analogue acquisition creates a waveform whose shape resembles the reference template. Local oscillator feedthrough, gain-control transitions, ADC interleaving patterns, buffer switching and clock-distribution defects can produce repeatable structure. A matched filter will respond to those structures if they correlate with its template. The output is not mathematically fraudulent. The mistake is a causal claim which attributes the correlation to a transmitter without testing whether the instrument generated or reshaped it.

Consider a receiver whose automatic gain controller changes amplification in steps whenever an internal power estimate crosses a threshold. Each transition introduces a short transient of approximately repeatable shape. A template extracted from one such transition can later match many more transitions. An analyst who counts these as multiple suspicious RF bursts may be measuring the controller's behaviour rather than the external environment. Even if an external signal originally triggered the gain change, the waveform of the recorded transient could be dominated by the receiver's response. The physical event and the instrument response have become causally entangled; a detector must not silently substitute one for the other.

The remedy begins with identifying the measurement boundary. Is the intended quantity the field at the antenna aperture, the voltage at the receiver input, the intermediate-frequency waveform, the ADC input or the

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stored IQ sequence? A matched filter computes similarity at the digital record plane. To infer a waveform at an earlier plane requires a characterised transfer and, when the inverse is not unique, explicit additional assumptions. A good engineer measures the effects of filters, mixers, gain and timing across the admitted operating conditions. A nominal block diagram is insufficient evidence that its transfer held at the instant of the candidate event.

A physical challenge should have distinct predictions for internal and external explanations. An antenna substitution may alter an external field's received amplitude while an internal digital spur remains unchanged, although the regulator and noise floor can complicate the observation. An input termination can test whether a feature persists with the specified RF path removed, provided other coupling paths are considered. A controlled injected waveform can measure whether the detector correctly follows a known external reference across gain and frequency settings. Retuning can reveal whether a candidate follows RF carrier motion or remains tied to a baseband offset. Each intervention must be interpreted through its own measured conditions rather than converted into an automatic verdict.

Feedback adds another danger. An adaptive detector may update its template to maximise the correlation with a candidate event. If the same event is then used to validate the template, a high score is unsurprising. The system has been designed to find and reinforce an apparent match. This procedure may be very effective for finding recurring waveforms, but it is not independent proof that one transmitter emitted them. The update history and training population should be preserved. A frozen version of the template should be challenged with known-present signals, null trials,

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confusable legitimate waveforms and varied receiver states. It should be possible for the system to fail and for that failure to be recorded.

Even hardware redundancy can be misleading. Two ADC branches within one time-interleaved converter may contribute to an apparent feature whose period follows the branch scheduler. A second receiver sharing the same local oscillator or distribution clock may reproduce the same artefact. Two software implementations of cross-correlation on the same stored file can validate arithmetic but cannot independently validate external origin. The dependency graph should identify shared antennas, clocks, gain-control commands, power supplies, capture triggers and processing libraries. A corroboration statement is meaningful only in relation to the specific dependencies it challenges.

I would insist on a report which separates repeatability, calibration and attribution. Repeatability establishes that the same or similar digital feature recurs. Calibration, if validated, establishes a relationship between the retained samples and a declared physical input plane under specified conditions. Attribution asks which source produced that physical input. A high matched-filter peak may support the first proposition. It can support the second only with appropriate transfer evidence, and the third only with discriminatory physical observations. One should not treat the measurement's precision as a substitute for its causal specificity.

The operator also has a duty to preserve discordant evidence. If a template matches during one gain state but not another, a reasonable explanation might be receiver sensitivity, template distortion or an internal artefact. The result should not be erased by selecting only the successful state. If a null input still produces the matched response, the possibility of

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internal generation is central to the investigation. If two physical receivers disagree under a supposedly strong source, the disagreement demands examination of their respective sensitivity and paths. A defensible negative result requires validated exposure, not merely the silence of a correlation alarm.

The prudent acceptance rule would state the waveform class and template, the physical reference plane, acquisition and processing settings, the full search procedure, field-representative challenge trials, and the source alternatives that remain. It would separate event detection and event timing from device identity. It would permit an inconclusive outcome where the experiment fails to discriminate among plausible causes. The value of matched filtering lies in better comparisons, not in granting infallibility to an attractive peak. I invite Sir Karl Popper to press the final question: what outcome must be allowed to defeat the examiner's preferred identification?

Sir Karl Raimund Popper | Peer question 7 to Harold Stephen Black

Mr Black, you have described a succession of tests which can either support or restrict an external-origin hypothesis, but I should like a sharper account of what would count as a serious adverse outcome. Suppose a detector produces a strong match to a purported unauthorised transmitter's preamble. When the investigator terminates the antenna input, the feature persists, so the investigator asserts that it entered through another cable. When an independent receiver fails to detect it, the investigator alleges insufficient sensitivity. When a known legitimate device generates the same preamble, the investigator calls that an exceptional coincidence. Some of these explanations may be technically possible, but together they can protect the original accusation

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from every contrary observation. What test plan would require the investigator to retract or narrow the claim rather than merely provide another saving hypothesis? How should the final report distinguish a model genuinely tested in advance from one modified after the evidence became inconvenient?

Harold Stephen Black | Immediate answer to Sir Karl Raimund Popper

Thank you for that question. Sir Karl, the investigator must define the intended proposition and alternative mechanisms before attributing a decisive meaning to the tests. A candidate may be real while the source hypothesis is wrong. If an RF termination, independently verified to exclude the specified input path, leaves the same matched feature present, the simple explanation that the signal entered only through that path is contradicted. The result should trigger a search for coupling, internal generation or an incorrectly defined boundary, and the original attribution must be withheld or revised. It is not sufficient to preserve the same headline by inventing unmeasured routes of entry after the fact.

An independent receiver's non-detection may indeed be inconclusive if its validated sensitivity, dwell and timing could not have captured the event. That limitation should be established from its test records, not assumed merely because a disagreement is inconvenient. If the second instrument was likely to detect the waveform under the documented conditions and nevertheless did not, the conflict weakens the source hypothesis and should remain visible. Similarly, evidence that a legitimate device uses the same

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preamble directly defeats any claim that the preamble alone uniquely identifies the suspicious source. It does not disprove that the suspicious source might also have transmitted, but it narrows what the correlation can establish.

The appropriate experimental plan contains known-present and null cases, expected results for a candidate external signal, predictions for receiver artefacts, and rejection criteria for the intended conclusion. Its scope should include plausible gain states, clock conditions and interference. If the receiver is reconfigured after an adverse trial, the new procedure can be tested prospectively, but the earlier trial remains part of the record and the revised claim must not inherit confidence from a validation which the instrument failed. This is an engineering form of intellectual honesty, not an impractical demand for absolute certainty.

A narrow conclusion which survives such challenges has genuine forensic value. It may establish that a specified processed waveform was observed and that the detector's template similarity exceeded a calibrated threshold. Further tests may support the presence of an external emitter sharing a known modulation convention. A statement identifying one individual device would require separately validated discrimination. Where those facts remain unavailable, the report must say that attribution is unresolved. We should prefer a defensible limited statement to a confident source accusation whose experimental meaning changes each time a test produces contrary evidence. I return the floor respectfully to Dr. Atkinson for the concluding synthesis.

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Norbert Wiener, Cross-Peer Question to Harry Nyquist: Mr Nyquist, a matched-filter peak appears at a particular sample index. What conditions permit its location to be reported as an RF arrival time?

Harry Nyquist, Cross-Peer Answer to Norbert Wiener: Professor Wiener, first establish the template definition and actual analogue reference plane. The peak location is a computation dependent on template delay, filtering, sample-clock origin, interpolation, group delay and channel dispersion. Calibrate the complete path with a known injected waveform and independently timed arrival, including different amplitudes and arrival phases. A waveform mismatch or multipath path can shift the maximum; merely correcting an algorithmic half-length is insufficient. Preserve the raw sample index, uncorrected peak and every time correction with uncertainty. If the host recorded only the arrival of a processed buffer, that timestamp is not a direct RF aperture epoch. I yield to Dr Shannon on source inference.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, does a high normalized correlation with one template identify the unknown transmission uniquely?

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Mr Nyquist, not without an exclusivity argument. The result measures similarity under the chosen normalisation and noise model. Related waveforms, multipath-distorted copies, receiver-generated responses or a family of templates may yield comparable peaks. Define the hypothesis set and perform matched and deliberately mismatched signal injections, with noise-only controls. If the template was constructed after viewing the target record, account for data-dependent selection. A matched filter can be powerful for detection of a prespecified waveform in appropriate noise, yet its optimum property is

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conditional on that known template and statistical model. Record the waveform family and physical alternatives that remain compatible with the data. I respectfully pass the token to Dr Neyman for threshold setting.

Claude Elwood Shannon, Cross-Peer Question to Jerzy Neyman: Dr Neyman, what threshold can support a defensible detection statement if the algorithm searches over many template delays, Doppler offsets and pulse shapes?

Jerzy Neyman, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, the relevant false-alarm event is the maximum over the declared template-and-delay search, not the probability attached to one individual correlation sample. Estimate its distribution under validated noise-only conditions or use an explicitly justified conservative rule. Dependence between nearby templates and delays must be respected. Calibrate both detection probability and false alarms over an independent challenge population with varied amplitude, noise, mismatch and receiver state, and with the search bounds fixed in advance. An apparently excellent peak can become unremarkable when compared with thousands of alternatives. The report should distinguish statistical detection of a template-compatible feature from physical attribution or exact waveform reconstruction. I yield to Mr Black for the hardware artefact concern.

Jerzy Neyman, Cross-Peer Question to Harold Stephen Black: Mr Black, a receiver produces a matched-filter peak even with no RF antenna attached. What path-level tests can expose the source of the apparent correlation?

Harold Stephen Black, Cross-Peer Answer to Jerzy Neyman: Dr Neyman, challenge amplifier feedback, clock leakage, digital test patterns, converter

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intermodulation and internally coupled reference signals under controlled input terminations. Move the injection reference plane, change gain distribution and test at input levels below compression. An independent receiver with a distinct oscillator and processing implementation can help distinguish a shared external event from one chain’s peculiar artefact, provided common antennas and clocks are not concealed. Examine the raw ADC codes to determine whether the feature arises before or after digital matched filtering. The reported peak must be linked to a measured physical input response, not merely to software output. Record unsuccessful controls as carefully as successful ones. I return the token to Dr Atkinson.

Dr. James M. Atkinson | Moderator synthesis and concluding discussion

Distinguished colleagues, the panel has established that a matched-filter peak is a comparison result whose physical meaning is conditional upon its template, noise model, acquisition history and search procedure. In the ideal known-waveform problem it is possible to derive a linear filter with maximum output signal-to-noise ratio at a selected instant. The validity of that derivation does not establish the truth of the signal hypothesis in a field experiment. A correlation response can arise from a legitimate emitter using a shared preamble, from a distorted version of the intended waveform, from a receiver-generated transient, or from noise selected by a sufficiently broad and adaptive search. The number displayed by the detector is neither a unique identifier nor an automatic probability of one source's existence.

Professor Wiener has reminded us that a filter becomes optimal only in relation to a specified problem. His conditional statement of the model $x = a s + w$ requires that the template s and the noise covariance be defined. If the covariance is coloured, estimated from contaminated training data or

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changed by a gain-state transition, the elementary white-noise optimality result no longer transfers without qualification. If the template was learned from the same archive on which it is evaluated, the resulting high score is not an independent test of that archive. These are not reasons to abandon adaptive detection. They are reasons to expose the training procedure, preserve the raw evidence and validate the actual rule as operated.

Mr Nyquist has distinguished a computational lag from a physical arrival time. A number of samples divided by a nominal rate gives one coordinate; the physical RF event requires a reference epoch, measured signal-path delays, clock uncertainty and a known definition of the template. A peak may jump between ambiguity sidelobes even while interpolation reports many decimals. A receiver can agree perfectly with its own internally generated reference and remain displaced from the true antenna event. For a time-difference measurement or forensic geolocation claim, the surviving uncertainty is therefore a property of the complete measurement chain, not merely the granularity of the digital correlation array.

Dr Shannon has identified the evidential information that a match does not supply. A known preamble may be an excellent indicator of a waveform class and a poor identifier among the many compliant devices which share it. A compressed matched-filter statistic may suffice for one declared detection while discarding information that a later analyst would need to distinguish alternative waveforms or test an unexpected source hypothesis. The archive should retain sufficient source samples for material cases, together with the template version, transformations and rejection conditions. The performance of a detector and the identity of a physical emitter are different questions with different validation requirements.

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Professor Neyman has required us to evaluate the complete decision rule, rather than one selected peak abstracted from its search history. Unknown delay, carrier offset, phase, amplitude and template selection all enlarge the opportunity for chance maxima. Overlapping correlation lags are usually dependent, but that dependence is an argument for a validated null distribution, not a licence to ignore the search. A detector's false-alarm rate must be distinguished from the probability that a particular alarm arose from a particular source. It is permissible for an operational detector to flag candidates under uncertainty. It is not permissible to present that operational threshold as a source-identification standard never tested against the relevant alternatives.

Mr Black has returned the argument to the physical input. The receiver may produce a highly repeatable waveform in its local oscillator leakage, gain-control transient, buffer schedule or clock path. A matched filter can detect this waveform efficiently and consistently. The correct engineering response is to locate its mechanism by changing relevant physical conditions, measuring the input-to-record transfer and testing independent acquisition paths. The source of an internal artefact can be found by experiment, just as an external source can. A good investigation preserves discordant trials instead of erasing them from a favourable report.

The final publication statement should therefore distinguish four conclusions, none silently substituted for another. First, the recorded data yielded a specified template similarity under declared processing. Second, the detector's threshold and operating characteristics were established for a documented comparison population. Third, physical tests supported or failed to support an external-origin explanation over specified receiver

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states. Fourth, source identification either was or was not supported by independent discriminatory evidence. A result may be strong in the first two dimensions, moderate in the third, and indeterminate in the fourth. That is not an embarrassment; it is an accurate account of the information actually obtained.

The panel's arithmetic is hypothetical and has not certified any modern receiver. Historical contributors are presented as intellectual personae in newly constructed educational dialogue, not as eyewitnesses to contemporary electronics. The practical doctrine is that mathematical sensitivity must be joined to provenance and experimental accountability. The next question will examine spectral occupancy under intermittent observation, where the temptation is different but the inferential boundary is similar: a large collection of retained samples can look comprehensive while leaving substantial intervals of electromagnetic reality unobserved. I thank the contributors and respectfully pass the floor to that subsequent examination.

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Ten worked technical applications

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Ten worked engineering applications | Question 048

Worked application 1: White-noise correlation SNR

Let s be a known complex template of energy $E_s = \text{sum } |s[n]|^2 = 64$ in normalised sample units; a is a scalar signal amplitude with $|a| = 0.25$; and $\sigma^2 = 1$ is complex noise variance per sample. For independent zero-mean complex Gaussian samples, the correlation $y = s^H x$ has signal component aE_s and noise variance $\sigma^2 E_s$. Its output SNR is $|a|^2 E_s/\sigma^2 = 0.25^2 \times 64/1 = 4$, or $10\log10(4) \approx 6.02$ dB. This result is conditional on exact template and noise assumptions, and does not identify the physical emitter that supplied the waveform.

Worked application 2: Normalised template similarity

Assume two hypothetical equal-energy waveform vectors s and u have norms $||s|| = ||u|| = 10$ and inner-product magnitude $|s^H u| = 80$. Their magnitude-normalised similarity is $\rho = |s^H u|/(||s||\,||u||) = 80/(10\times10) = 0.80$. By the Cauchy-Schwarz inequality its magnitude does not exceed one. The measured 0.80 indicates alignment between the vectors under a specified time and phase convention. It does not establish that the vectors originated from one device. A shared preamble or common filter response may produce a similar coefficient.

Worked application 3: Nominal lag versus physical time

Let sample rate $F_s = 2{,}000{,}000$ samples/s and a correlation peak appear at lag $k = 240$ samples relative to the recorded reference. Its nominal digital delay is $\tau_d = k/F_s = 240/2{,}000{,}000 = 120$ microseconds. If the analogue path introduces an independently measured 7 microseconds of delay and the lag convention is consistent, the

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corresponding corrected time difference is 113 microseconds. The numerical correction is only as valid as the path calibration and reference epoch. Sample-rate error, filter dispersion and ambiguity-lobe selection can add further uncertainty beyond the apparent 0.5-microsecond nominal sample spacing.

Worked application 4: Search over many tests

Assume $m = 500$ independent hypothetical null comparisons, each with single-comparison false-alarm probability $p = 0.001$. The probability of at least one crossing in the bank is $P_{any} = 1-(1-p)^m = 1-0.999^{500} \approx 0.3936$. Here m is the number of tests and P_{any} is family-wise alarm probability. Real neighbouring correlation lags and similar templates are dependent, so the independence calculation is illustrative rather than a calibrated receiver claim. The correct threshold should reflect the distribution of the maximum over the complete implemented search.

Worked application 5: Sample-clock frequency-scale uncertainty

Suppose a digital delay estimate is $\tau_d = 0.100$ s and the nominal sampling-rate reference has fractional frequency-scale uncertainty of $\varepsilon = 5$ parts per million. The approximate delay-scale contribution is $|\Delta\tau| \approx |\tau_d \varepsilon| = 0.100\times5\times10^{-6} = 0.5$ microseconds. Here ε is dimensionless; τ_d is the nominal measured interval. This does not include analogue group delay, time-stamp epoch errors, random jitter or wrong-peak selection. A precisely located correlation maximum cannot reduce uncertainties arising in independent parts of the physical time measurement.

Worked application 6: Correlation output variance under white noise

For a template with $E_s = 100$ and independent complex white noise variance $\sigma^2 = 0.04$ per sample, the output correlation noise variance is

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$Var(y) = \sigma^2 E_s = 4$. Thus the correlation noise standard deviation is 2 in the corresponding normalised output units. A displayed peak with magnitude 6 is three such standard deviations from zero in a scalar heuristic comparison, but the tail probability for a complex magnitude and a searched maximum is not given by an ordinary one-sided real Gaussian three-sigma rule. The actual statistic and selection distribution must be specified before a formal false-alarm claim.

Worked application 7: Template-bank storage and search arithmetic

Suppose an instrument tests K = 256 templates at L = 1,000 trial lags in each acquisition interval. The direct comparison count is K×L = 256,000 trial outputs. If it produces one alert at the largest value, that alert is one decision derived from 256,000 correlated or uncorrelated numerical comparisons, not 256,000 independent physical observations. Depending on the implementation and template correlations, FFT methods may reduce computation, but no algorithmic acceleration changes the number of acquired electromagnetic events. The test must calibrate the maximum statistic corresponding to the real search process.

Worked application 8: Observation exposure during a scan

A scanner dwells in a candidate band for d = 8 ms every R = 80 ms. Its nominal duty fraction is q = d/R = 8/80 = 0.10. If burst onset is independent and approximately uniform relative to the scan, and burst duration is negligible, the chance a randomly timed burst begins during a dwell is approximately 10%. This is not the detector's conditional sensitivity when the waveform is present in retained samples. For non-negligible burst lengths, the intersection probability changes; settling intervals, trigger policies and time correlations further modify exposure.

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A silent matched filter cannot establish continuous absence when ninety percent of nominal time was not observed.

Worked application 9: Discrete correlation output length

For full linear cross-correlation of arrays of N = 1,024 and M = 256 samples under zero extension, the output has N+M−1 = 1,279 lag positions. The lag range is from −(M−1) to N−1 under the convention stated in the SciPy documentation. Using 'same' mode returns a shorter centred selection and can conceal responses at boundaries. Neither output length represents the number of independent detections. The investigator should preserve the software's lag convention and whether the relevant template was wholly observed at the reported position.

Worked application 10: Timing ambiguity from a repeating template

Suppose a known template contains an approximate repeated motif every T_r = 40 microseconds. If the matched-filter ambiguity surface has significant peaks separated by that interval, selecting the wrong peak by one motif period yields an arrival-time error of 40 microseconds. Interpolating a selected peak to one-tenth of a sample does not remove this discrete ambiguity. The error may matter enormously in a time-difference-of-arrival calculation, while leaving the presence/absence detection nearly unchanged. A validation campaign should therefore record wrong-lobe frequency separately from small local timing deviations.

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Source register and verification limits

The historical dialogue and worked examples are original educational constructions. The references below were consulted only to the indicated public reading scope; they do not certify the hypothetical systems or assert that the named deceased contributors made these contemporary statements.

[M1] Nadav Levanon and Eli Mozeson, *Matched Filter*, chapter 2 of *Radar Signals*, Wiley-IEEE Press, 2004, https://onlinelibrary.wiley.com/doi/10.1002/0471663085.ch2. Public summary read: white-noise SNR optimality and Doppler ambiguity; full chapter not read.

[M2] SciPy, *scipy.signal.correlate* documentation, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.correlate.html. Public documentation read: conjugation, lag conventions and computational modes; not instrument certification.

[M3] IEEE Technology Navigator, *Matched filters*, https://technav.ieee.org/topic/matched-filters/. Public overview read: white-noise optimality and correlation implementations.

[M4] Nadav Levanon and Eli Mozeson, IEEE Xplore bibliographic summary, https://ieeexplore.ieee.org/abstract/document/5237203. Public summary read: metadata and known-signal conditions; detailed chapter not read.

[M5] *Signal detection with noisy reference for passive sensing*, Signal Processing, 2015, https://www.sciencedirect.com/science/article/pii/S0165168414004587. Public abstract read: noisy-reference limitations; no numeric results imported.

[B1] National Inventors Hall of Fame, *Harold Stephen Black*, https://www.invent.org/inductees/harold-stephen-black. Public biographical record read. Scope: identity, dates, engineering education and feedback-amplifier contribution.

[B2] National Academies, *Biographical Memoirs: Jerzy Neyman*, https://www.nationalacademies.org/read/4560/chapter/19. Public biographical chapter summary read. Scope: dates, statistical contributions and Berkeley career.

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[B3] IEEE Information Theory Society, *David S. Slepian*, https://www.itsoc.org/profile/8962. Public biography read. Scope: dates, education, Bell Laboratories career and professional contributions.

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QUESTION 049

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How should spectral occupancy be reported when observation is intermittent?

Source: V011_Roundtable_Questions_049-050_CP050_Combined.docx | Recovered substantive manuscript. Constructed educational dialogue.

Moderator: Dr. James M. Atkinson

Editorial convention: All speech below is original, constructed educational dialogue. The historical contributors did not participate in this discussion, and their words are not represented as authentic quotations. All numerical illustrations are hypothetical.

Dr. James M. Atkinson. Opening of Question 049

Distinguished colleagues, the engineer who watches a narrow emission flash across a waterfall display encounters a deceptively simple proposition. The channel appeared occupied, and, after an interval of silence, it appeared empty. Yet this description may be no more than an account of what the instrument displayed at two selected instants. The task of scientific reporting is to distinguish the visible succession of measurements from an assertion concerning the unseen transmitter's conduct between them. A receiver which dwells for ten milliseconds and revisits its channel every second may collect a perfectly accurate record of those ten milliseconds while remaining uninformative about nine hundred and ninety milliseconds of each second. That observational gap is not repaired by immaculate frequency calibration, a low noise figure, or an attractive and continuous-looking waterfall. A digital display can interpolate its pixels without extending the physical observation in time.

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We must identify the quantity under discussion. *Frequency-channel occupancy* may describe the proportion of accepted measurement opportunities at which a declared threshold and decision procedure indicated occupancy. *Time occupancy*, in the stronger physical sense, concerns the proportion of a specified time interval during which an emitter or class of emissions genuinely occupied the relevant resource. The two may agree under a defensible sampling design and validated observation model, but they are not synonyms. A measurement which states that thirty of one hundred admissible visits exceeded a threshold establishes an observed fraction of 0.30 under that rule. It does not, without further premises, establish that a particular transmitter operated for thirty per cent of the elapsed monitoring period. It does not even establish that the radio channel was clear during every below-threshold visit, because a weak or masked emission may escape the detector.

The International Telecommunication Union's currently applicable Recommendation ITU-R SM.1880-3, approved in August 2026, addresses spectrum-occupancy measurement and evaluation. Report ITU-R SM.2256-2, issued in June 2026, expressly distinguishes sample measurement time, observation time, revisit time, occupancy time, integration time and statistical confidence. These distinctions are not typographical ornaments. They describe how the measurement operation limits the propositions available for a subsequent engineering or forensic conclusion. We shall use those published classifications as contemporary editorial context, without suggesting that our deceased contributors encountered these particular editions.

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Consider two surveys of the same apparent duty cycle. The first consists of an uninterrupted recording from a calibrated wideband receiver with a defined sensitivity envelope and lossless sample retention. The second visits the channel at a sequence of time stamps generated by a scanning receiver, retaining a power estimate during each visit. Both may produce an aggregate occupancy value of thirty per cent. The first might permit retrospective examination of each relevant instant, subject to clipping, threshold, front-end and storage qualifications. The second cannot reveal what happened during its unvisited intervals. A probability model may nevertheless estimate population occupancy from a representative sample of visits. That is a statistical argument requiring a defined population and sampling mechanism. It is not evidence that the instrument secretly observed what its receiver never tuned to.

The distinction becomes particularly urgent in technical surveillance countermeasures. A hostile or merely unusual device could transmit briefly, react to a scanner, exploit a narrow operational window, or remain below the accepted threshold for much of the investigation. In contrast, a legitimate pulsed service may generate many above-threshold indications and appear threatening simply because its emissions coincide with the selected channel's analysis window. An evidential report must separate presence detection, estimated duty cycle, count of discrete events, transmitter identity, exposure coverage and the probability of failing to observe an event. None should be inferred from another merely because all can be placed on the same numerical chart.

I propose that every occupancy result should carry its denominator prominently. Was it valid dwell time, number of sampled visits, wall-clock

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elapsed time, count of independent measurement opportunities, or an estimate of an underlying physical occupancy state? What treatment was given to clipped readings, receiver retuning, gain changes, detector invalidity, interference and missing data? Were the visits scheduled independently of the emissions under investigation, and did the sampling design expose every part of the intended population with a known or at least defensible probability? The answers determine whether an occupancy statistic is descriptive, inferential, conditional or incapable of the more ambitious interpretation.

Professor Fisher shall address the statistical population and the requirements for drawing inference beyond the observed visits. Dr Shewhart will consider process stability, temporal clustering and operational change. Dr Shannon will distinguish information retained in a monitoring record from information that its acquisition policy never obtained. Dr Wiener will analyse the coupled observer whose scanning or thresholds react to previous observations. Finally, Professor Neyman will consider interval coverage, decision rules and how to disclose limitations when negative findings are requested. Seven colleagues will challenge these propositions directly, each receiving an immediate substantive answer. Let us resist both the cheerful assertion that a few clean scans certify an empty room and the equally unhelpful position that finite sampling can support no conclusion whatsoever. Professor Fisher, I invite you to begin by identifying the precise population to which a reported occupancy percentage may legitimately refer.

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Sir Ronald Aylmer Fisher. Principal response 1. The sampling population is not the empty time between visits

Dr. Atkinson, the first duty of statistical reasoning is to declare what has been counted and the reference population to which the count is intended to apply. A numerical fraction without its design is merely a description of the observed entries. If the investigator takes one hundred channel measurements and registers thirty positive decisions, the observed fraction is thirty divided by one hundred. That arithmetic is correct whatever the measurement policy. But an inference about the entire monitoring period requires a connection between those hundred observations and the potentially much larger population of time instants or transmission opportunities. A sequence of convenient visits does not acquire the character of a random sample by having many entries, and multiplication of the count does not cure systematic selection.

Suppose that an emitter operates in a predictable schedule. A receiver which visits every second, always at the same phase of the emitter's cycle, may find the channel occupied at every visit while most of the elapsed interval is clear. Shift the receiver by half a period and it may report no occupancy at all. Both datasets might be internally consistent and highly repeatable, yet neither is representative of the intended interval. This is the familiar danger of periodic sampling against a periodic population. It cannot be solved by treating each visit as an independent Bernoulli trial. Randomising or varying the observation phase may help, but only if the randomisation is actually executed, its distribution is relevant to the claim, and the detector has adequate sensitivity during a visit.

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The relevant estimand should be written before the apparatus is energised. If p denotes the proportion of a defined time interval during which the channel state is genuinely occupied under a declared physical definition, then p is not automatically the same as q, the probability that the detection algorithm returns a positive result during a randomly selected valid measurement opportunity. Even in the simplest binary model, q depends on the detector's probability of detection, P_D, and its false-positive probability, P_{FA}. If an occupied state is observed with probability P_D and an unoccupied state produces a false alarm with probability P_{FA}, then $q = p P_D + (1-p) P_{FA}$. Consequently, provided P_D and P_{FA} are appropriate for the operating conditions and P_D differs from P_{FA}, $p = (q - P_{FA})/(P_D - P_{FA})$. This is a conditional inverse relationship, not a magic correction applicable to all receivers. It assumes a relevant two-state classification, representative sampling, a stable detector characterisation and an intelligible definition of the occupied state.

We should consider a hypothetical q of 0.30, P_D of 0.90 and P_{FA} of 0.02. The estimated latent occupancy would then be (0.30 - 0.02)/(0.90 - 0.02) = 0.28/0.88, approximately 0.3182. The corrected estimate is *higher* than the observed positive fraction because missed occupied states contribute more strongly than false alarms under these stipulated conditions. Change the decision threshold and the values may change. Put a strong authorised transmission in an adjacent channel and the false-alarm behaviour may change again. In a high-stakes survey the quantities P_D and P_{FA} must be justified by relevant tests and their uncertainty propagated. A point estimate calculated from nominal manufacturer specifications should not be dressed up as an instrument-independent finding.

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A second problem concerns dependence among visits. An emission lasting twenty seconds may produce twenty positive one-second observations, yet these are not twenty independent examples of how often a random emitter becomes active. The same continuous event has supplied correlated measurements. In estimating a duty cycle, the investigator must preserve the temporal record rather than reduce it prematurely to a single count. Confidence procedures assuming independent trials may be too narrow when neighbouring observations follow the same occupancy state or share a slowly changing detector environment. This is why a statement that one has taken ten thousand measurements is not an adequate substitute for disclosing the visit schedule, the clustering of states, and the analysis unit.

The denominator may also change without the investigator noticing. If a survey includes receiver retuning, clipped input intervals, failed acquisition blocks or temporary threshold changes, those invalid intervals should not be silently scored as clear. Removing them from the denominator may be legitimate if the resulting population is explicitly redefined as valid observations, but it changes the claim. A percentage calculated solely over successful visits is a conditional occupancy estimate for successful visits, not a demonstration that the broader investigative period was equally well surveyed. If invalidity is related to strong emissions, excluding the invalid observations can introduce selection bias, potentially removing precisely the moments when relevant activity was most likely.

It is tempting to demand random sampling of every physical instant. In practice, the survey may have design constraints and may require stratification by hour, location, operating state or channel. Those constraints

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need not render statistical analysis impossible. Define each stratum, preserve its time exposure, and state the intended weighting. A survey equally distributing visits between an active daytime service and a quiet overnight interval cannot be reported as the natural time average if daytime and night-time receive incompatible weights. A weighted estimator may be warranted, but weights should derive from the defined population rather than from a desire to produce a plausible narrative. If the original schedule does not support a population claim, one should say so and report the observational result accurately.

I would therefore require three layers in the investigator's report. The first is a primary record: the count, timing, channel, threshold, valid exposure and classification associated with each observation. The second is an inferential model: why those observations represent the asserted population, with sensitivity to temporal dependence and detector errors. The third is an operational interpretation: what a responsible investigator may conclude or do, given the uncertainty, the costs of missed evidence and the competing explanations. That third layer must not be allowed to alter the first two after the result is seen. The best statistical discipline permits a limited but useful conclusion, and it marks exactly where a more ambitious claim would require a different survey. Dr Shewhart, may I respectfully pass the floor to you to examine whether the process being measured is sufficiently stable for the sampling model to describe it?

Richard Wesley Hamming | Peer question 1 to Sir Ronald Aylmer Fisher

Professor Fisher, your population definition is mathematically exact, but the practical investigator must programme an acquisition scheduler

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before the behaviour of the unknown emitter is known. Suppose the same survey contains long speech transmissions, short telemetry bursts, a slowly drifting interference source and a possible device that remains silent while its controller detects an active scanner. There is no single duration or periodicity from which a convenient randomisation interval may be derived. A carefully weighted occupancy estimate could consequently possess a tidy confidence interval while remaining nearly blind to the very rare event for which the survey was commissioned. How should the examiner reconcile the scientific demand for a representative sampling design with a search whose target class is not known in advance? Would you permit a two-stage campaign in which broad discovery determines a later intensive scan, and, if so, how should the report guard against the attractive but mistaken practice of treating measurements chosen because of an apparent anomaly as though they had been selected independently of that anomaly?

Sir Ronald Aylmer Fisher | Immediate answer to Richard Wesley Hamming

Dr Hamming, I would distinguish the design of a survey intended to estimate average occupancy from a search intended to discover a rare and potentially adaptive emitter. The first can often be framed as a population-estimation problem; the second may be better framed as a detection and experimental-challenge problem. One ought not force both into a single percentage because a convenient computer programme can print it. Where behaviour is unknown, an initial discovery phase may properly explore frequencies, times and locations with flexible methods. Such flexibility creates useful

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hypotheses. It does not, by itself, establish a sampling design from which the frequency of all unobserved activity can be estimated without qualification.

A two-stage campaign is entirely defensible if the analysis preserves the distinction between its stages. Record the initial schedule, the triggers used to intensify attention, and the measurements that were retained or omitted. The second-stage results should be described as conditional upon the selection decision. If the investigator finds a narrow periodic feature and then directs the receiver to that frequency for many hours, the resulting proportion of positive observations describes a deliberately enriched observation population. It may be excellent evidence that the feature persists or responds to controlled changes. It is not an unbiased estimate of the probability that a randomly selected channel in the original survey would be occupied.

One method of obtaining stronger evidence would be to reserve a validation phase whose conditions are established before examining its data. The discovery stage can suggest frequency, interval and threshold hypotheses; the validation stage can deliberately vary these while preserving the raw records of failure as well as success. Where avoidance by a transmitter is suspected, the examiner might compare distinct observation modes, passive and active configurations, and independently controlled reference paths, but should not claim to have proved intentional avoidance simply because a signal disappears after a receiver is moved. Such a disappearance has numerous physical and instrumental alternatives.

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I would also recommend reporting more than one measure. For discovery, report the number of distinct candidate events and the actual exposure time in which each could have been detected. For a population estimate, report the observed positive fraction under a declared sampling design, with its uncertainty and limitations. For a negative survey, report the minimum event duration and signal strength that the system's exposure and receiver sensitivity could plausibly detect at a stated confidence level, provided that level has actually been validated. These are different propositions. An investigator can be quite persuasive about one while uncertain about the others.

Finally, the value of an investigation is not measured by whether its conclusion fits into one confident number. The best evidence may consist of a well-preserved candidate event, repeatable challenge observations and an explicit admission that overall occupancy cannot be estimated from the available schedule. That account is neither timid nor inconsistent. It is scientifically honest about the boundary between observing a rare event and making a claim about the behaviour of an entire unobserved population. I pass the token to Dr Shewhart to consider what happens when the properties of that population change while the survey is running.

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Walter Andrew Shewhart. Principal response 2. Temporal change and the fallacy of one long-run occupancy number

Dr. Atkinson, the premise most in need of examination is that the observed process retains one stable character throughout the monitoring interval. The operator may accumulate measurements for a week, combine them into a single occupancy percentage, and congratulate himself upon the apparent authority provided by a large denominator. Yet the monitoring environment may have changed repeatedly. A factory machine may begin operating at dawn; a public-safety channel may become active during an incident; a scanning receiver's gain may change under strong-signal loading; and a suspicious emission may follow an intermittent duty cycle that interacts with the survey schedule. The resulting aggregate can conceal the sequence of regimes from which it was assembled.

My concern is not an objection to averages as such. An average is an intelligible numerical description when the population and weighting are defined. It becomes dangerous when the reader interprets it as a description of every moment or as evidence of stability. Consider a hypothetical survey divided into two equal-duration periods. The first has ten valid positive visits out of one hundred; the second has ninety. Across both periods the pooled rate is one hundred out of two hundred, or fifty per cent. That rate is exact for the pooled record and almost useless for describing either period. A plot of the chronological observations immediately reveals the change. A single printed value conceals it.

For a monitoring system, the first requirement is preservation of sequence and operating state. The receiver's configuration, sensitivity estimate, threshold and valid observation windows must accompany the

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occupancy decisions. Without that correspondence, a change in the plotted occupancy percentage might arise from the transmitter, from the receiver, or from both. The examiner should therefore consider process-monitoring techniques, control observations and stratification by known operating conditions. A reference emitter or controlled calibration signal may help disclose receiver drift, but the reference path must be relevant to the frequencies and amplitudes at issue. A changing urban noise environment cannot be repaired by a laboratory calibration performed under one quiet condition.

When a monitored process is nonstationary, intervals of observation should be chosen to preserve temporal structure rather than merely to satisfy an arbitrary total count. An hourly occupancy series, accompanied by the actual count and valid dwell time within each hour, may be much more useful than one weekly percentage. Likewise, a table separating daytime, overnight, weekday and weekend regimes may expose recurring behaviour. These strata should not be invented solely after seeing a pleasing pattern. Exploratory strata should be labelled exploratory and any stronger inference should be checked against new data or a stated correction for selection.

The evidential significance of long bursts is especially important. A twenty-second emission can produce multiple adjacent positive visits. These measurements may show that one event persisted, but they do not constitute repeated independent activations. If the survey is interested in event incidence, count event onsets under a declared merging rule and preserve how interruptions shorter than a specified interval are handled. If it is interested in time occupancy, preserve dwell duration and observation coverage. If it is interested in source attribution, a sequence of power-

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threshold classifications is too impoverished to establish identity by itself. The report should never convert a measurement of one estimand into another without an explicit model.

Consider an apparatus that revisits each channel once every two seconds and has a dwell of twenty milliseconds. A short burst beginning half a second after each visit will not be encountered, regardless of the detector's sensitivity during dwell. The instrument could be perfectly calibrated while recording zero positives. A different source transmitting continuously across the visits could be detected every time. Occupancy in the retained visits is therefore strongly affected by how the schedule aligns with the source. Random variation in revisit phase may reduce this particular vulnerability, but the resulting observations still require analysis of the actual sampling design. A receiver can have apparently stable threshold statistics while its exposure to the target is poor.

I would require a diagnostic account of the process used to make each observation. At minimum it should identify the occupied-state decision, the channel or frequency band, the detector configuration, the observation start and stop, and any invalid interval. A useful validation campaign would introduce controlled emissions with several burst lengths and duty cycles across deliberately varied phases relative to the scan. The acceptance report should display the failures alongside the successes. If a system's detection probability drops sharply for brief events or particular revisit phases, the operator may still employ it within its bounded capability. What cannot be done is to report general confidence while omitting the very parameter regime in which the confidence does not hold.

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My concluding observation concerns the difference between a measured change and an assigned explanation. A rising positive-visit fraction may reflect increased legitimate traffic, a new emitter, altered interference, reduced threshold or instrument fault. Evidence that the rate changed is not evidence that a particular device caused the change. A control experiment must distinguish the alternative mechanisms through different predicted outcomes. Retuning the receiver, substituting the antenna, repeating under a reference source or using a second independently characterised receiver may assist, provided common dependencies are documented. The historian of the measurement should be able to reconstruct both the instrument and its environment, not merely see the beautiful smooth line produced by an averaging algorithm. I return the floor to Dr. Atkinson for the next challenge on whether selecting one stable regime may itself conceal important anomalies.

Jerzy Neyman | Peer question 2 to Walter Andrew Shewhart

Dr Shewhart, I agree that a single pooled occupancy fraction can hide dramatic temporal changes, but I should like to challenge the basis upon which the examiner decides that a process has entered a new regime. Suppose a monitoring team divides a week into hourly intervals, notices that one interval has an unusually high fraction of positive visits, and announces that the transmitter became more active in that hour. The same team has monitored hundreds of frequencies and has therefore had many opportunities to encounter an extreme hourly percentage by chance. Even a stable underlying process can generate a seemingly compelling chart if the observer searches enough periods for its most conspicuous peak. Moreover, the individual samples may be correlated,

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so their apparent number exaggerates the information available. By what procedure should the team distinguish genuine temporal change from statistical variation, while preserving the exploratory value of its observations? Should it publish only the preselected comparisons, the entire time series, or a family of uncertainty statements reflecting the number of tests that were considered? I am particularly concerned that a threshold chosen after seeing the record may transform an ordinary fluctuation into an apparently extraordinary event.

Walter Andrew Shewhart | Immediate answer to Jerzy Neyman

Professor Neyman, your objection properly separates evidence of temporal heterogeneity from an explanation of its cause, and it also reminds us that a sequence of exploratory comparisons cannot be treated as though each had been the sole planned test. My recommendation is to preserve the chronological record and the declared analysis plan, allowing the examiner to show both the originally intended summaries and any subsequent diagnostic investigations. A high hourly fraction may be worth investigating without being represented as a statistically confirmed change. When a particular threshold, time interval or group of channels was selected because it appeared unusual, the selection must accompany the reported result.

A useful process chart begins with a physically meaningful unit of observation. Where adjacent visits reflect the same continuing transmission, a chart of raw positive fractions may have more dependence than a simple binomial interpretation admits. One may instead record episodes, valid exposure intervals and the time

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occupied within those intervals, and use validation data to examine the null variation expected under stable operating conditions. If the process displays strong periodicity, an apparently remarkable peak can be evaluated against that periodic baseline rather than against a fictitious independent sequence. A control chart constructed for one set of operating conditions should not silently be carried into another threshold, gain state or antenna configuration.

There is no requirement to abandon exploratory discovery. One may flag unusually high activity, compare antenna configurations or retune a receiver to pursue an anomalous candidate. The exploratory nature of that selection should be explicit. Stronger confirmation may follow from a predeclared challenge interval, an independent observing configuration or the repetition of a distinctive physical signature under conditions where competing causes predict different outcomes. If the investigator changes a decision rule after observing an apparent feature, retain both the original and revised rules and explain which records informed each change. Transparency permits another examiner to contest whether the claimed significance survives an honest account of selection.

For reporting, I would prefer a chronological series with its observation exposures, regime annotations and invalid intervals, accompanied by a concise description of which comparisons were planned. A family-wise or other multiplicity adjustment may be appropriate for a specified collection of formal tests, but it should not be invoked mechanically to create a spurious impression of certainty when the model of dependence is not sound. Equally, an observed

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difference need not be called insignificant merely because the investigation was exploratory. It may supply a valuable lead that deserves a different, controlled measurement. The ultimate proposition should be proportionate: the frequency of indications changed under the stated measurement policy, while the external source and precise elapsed-time occupancy remain hypotheses until the additional physical conditions are established. I pass the token respectfully to Dr Shannon to examine whether any subsequent processing can fill the intervals in which the receiver simply did not observe the channel.

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Claude Elwood Shannon. Principal response 3. The information absent from a scan cannot be recovered by formatting its results

Dr. Atkinson, the most alluring mistake in an intermittent monitoring system is to confuse a smooth representation with a complete observation. A computer can draw a continuous line from scattered measurements, interpolate colours between waterfall columns or construct a time series from assumed transitions between successive occupied states. These operations may be justified for visualisation or for estimation under a stated stochastic model. They cannot transform an unmeasured interval into an original physical record of the transmitter's activity. A later analyst may infer the probable behaviour of a population, but the information about the particular unobserved event was never acquired in the first place. The distinction matters profoundly when a forensic claim concerns whether a short emission occurred at a particular time, rather than the average duty cycle over many visits.

I would begin with a sampling policy represented as an observation operator. Let s(t) be the physical occupied-state function, taking the value one when a specified channel is occupied and zero otherwise, and let w(t) be a coverage function which takes the value one when the detector can validly observe the channel at the requisite sensitivity. What the instrument knows directly is not the full integral of s(t) over all elapsed time. It may know classifications or measurements derived from s(t) only where w(t) permits observation. Its effective exposure is the integral of w(t) over the monitoring period, not necessarily the full elapsed duration. Even that exposure description is incomplete if the detector's sensitivity varies with time or if

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classification errors depend on the signal's strength, modulation or interference environment.

Two physically different occupancy histories can give exactly the same observations. Imagine a scanner that visits a channel for ten milliseconds at the start of every second and finds it clear. In one possible history, the channel remains clear throughout. In another, a transmitter emits for one hundred milliseconds halfway between every pair of visits. Both histories agree perfectly with every observed classification, yet their elapsed-time occupancy differs substantially. No interpolation rule, regardless of elegance, can distinguish them from the retained data alone. An imposed prior model might favour one history, and an independent sensor could supply additional evidence, but the original sequence of threshold decisions does not contain the required distinction.

This fact is not peculiar to the use of a binary occupancy detector. A spectrum analyser can accurately integrate the power present during its dwell; a wideband SDR can faithfully record a bounded segment of complex samples. Neither apparatus knows what occurred outside its observed frequency-time aperture. The width of that aperture is determined by actual front-end passband, filter state, sample retention, scanning policy and valid timing. The fact that a receiver's user interface displays a broad frequency axis does not imply continuous simultaneous observation across every pixel. Some displays are assembled by successive sweeps, and an intermittent emission can enter and leave between those sweeps without leaving a trace.

A stronger continuous-acquisition apparatus changes the information problem. If it stores all raw samples of the admitted band with adequate dynamic range and no dropped intervals, it can support later analysis of

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events the original detector overlooked. Analysts may recompute thresholds, revisit a shorter transient, change window functions or ask whether a feature survived a preselector change. This retrospective ability depends on the retained raw information. If the apparatus stored only summary power values for a few scheduled snapshots, a later algorithm cannot reconstruct arbitrary unknown waveforms in the unrecorded intervals. One can estimate what might have occurred under a model. One cannot identify one unique historical signal from data that are equally compatible with many alternatives.

We should also resist the converse assumption that merely retaining all complex samples establishes all possible facts. An analogue front end may have rejected the relevant frequency, clipped the input or mixed a strong adjacent signal into an artefact. Compression or quantisation may have removed significant detail. The sample clock and calibration state may be uncertain. Retention of digital samples is therefore necessary for some forms of retrospective analysis, but not sufficient for a claim that the physical input has been reconstructed uniquely. The information-bearing path begins at the antenna and ends in an evidential claim; each transformation may be many-to-one or conditional upon calibration.

Consider the question of occupancy as a statistical quantity. Random sampling may make a set of valid visits informative about the long-run fraction of time in a state. The strength of that inference depends on the stationarity assumptions, the sampling schedule and the correlation among observations. Such inference does not reconstruct a continuous historical tape. Even when the estimator is unbiased in repeated hypothetical experiments, its value in a single survey may differ from the realised

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occupancy because the unknown emissions were clustered or deliberately synchronised with the scanning schedule. A statement of confidence is meaningful only under the model and the reference population for which coverage has been justified.

Finally, the evidential report should preserve uncertainty in a form that resists over-interpretation. Distinguish the valid observation windows from the gaps, the classifications from underlying physical truth, and the modelled estimates from measurements. If a detection threshold changed, its history should accompany the record. If an alarm triggered the saving of higher-resolution data, that selection rule should also be retained. One may construct an honest and useful analysis of such conditional records, but the missing intervals must remain visible to the reader's reasoning even if the display paints them with seamless colour. Information theory offers no exemption from the physical obligation to observe. I invite Professor Wiener to consider the additional difficulty that the measuring apparatus and its operator may change their behaviour because of what the measurements show.

David Harold Blackwell | Peer question 3 to Claude Elwood Shannon

Dr Shannon, your account makes the loss of unacquired information plain, but I should like to examine a subtle inferential distinction. If a survey randomly selects a modest number of observation windows, its record remains wholly silent about the precise contents of individual gaps, yet it may support a useful estimate of average occupation. We should not confuse the impossibility of recovering the realised history with an impossibility of inferring a population parameter. Suppose, however, that some emissions are so brief that the stated detector can

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register them only when their arrival coincides with a favourable portion of a dwell. May a probability model repair the difference between observations and physical activity, or does the uncertainty in detection probability make the proposed correction more a choice of prior belief than an estimate? In particular, how should a reader distinguish uncertainty arising from random selection of observation windows from uncertainty arising because the instrument is not sensitive to the relevant class of signals?

Claude Elwood Shannon | Immediate answer to David Harold Blackwell

Professor Blackwell, you have identified the distinction on which a responsible occupancy report must turn. A statistical estimate can be informative without reconstructing every occurrence, provided that its target quantity, selection mechanism and observation likelihood have been declared in advance. There is no contradiction between saying that a particular unobserved interval is unknowable from these records and saying that randomly selected intervals can reveal something about a population proportion. The former concerns reconstruction of a realised path; the latter concerns an inference whose operating characteristics must be evaluated across repeated hypothetical samples.

Let the occupancy state be S and the detector decision be D. The probability that D is positive is determined jointly by the occupancy probability and by the detector's conditional responses. A method that translates positive-decision frequency into latent occupancy must distinguish false positives from missed occupancies. If the probability

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of detection changes with signal duration, amplitude, modulation or interference, a single fixed correction parameter may not describe the heterogeneous target population. To report one adjusted percentage without disclosing that heterogeneity would conceal uncertainty behind a precise decimal.

An honest design can stratify the target class by minimum pulse duration, received power range, and permissible frequency deviation. For each class, laboratory challenges may establish a detection-performance envelope under stated operating conditions. A random observation scheme can then support a conditional estimate for classes within that envelope. The report should not extend the estimate to arbitrary unknown devices whose performance characteristics lie outside the validation range. Nor should it silently replace an absence of empirical detector characterisation with a strong subjective assumption that all relevant emitters would have been seen.

Where only partial detection calibration is available, an interval or sensitivity analysis can be more defensible than a single corrected number. State how the estimated occupancy changes when the probability of detection varies across a plausible range, preserving the possibility that the range is not exhaustive. The reader can then hear the difference between the instrument's measured decisions, the statistical model's inference, and the engineer's judgement about unmodelled classes. None need be disparaged; they are separate layers of evidence, and confidence in one cannot automatically be transferred to the others.

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Harry Nyquist | Peer question 4 to Claude Elwood Shannon

Dr Shannon, I would press the distinction between sampling an analogue waveform and sampling a binary occupancy state. In one case bandwidth restrictions and a reconstruction theorem may justify the recovery of a bandlimited signal from a properly spaced series of samples. In the other, the object may be a sequence of abrupt switching events, with pulses shorter than an observation window and with no warranted bandlimit on the occupied-state indicator. Practitioners sometimes invoke a sufficiently high sample rate as though this could guarantee that all transmissions have been captured, while overlooking that a scanning tuner never admitted the relevant frequency during substantial intervals. How should the report separate converter sample rate, receiver bandwidth, dwell scheduling and the detector's temporal response, and where exactly does the familiar sampling argument cease to apply to an unobserved transient? Would your interpretation change if the scanner issued a precise hardware timestamp for every valid dwell but kept only the final binary decision? I ask because the time tags may be excellent while the discarded waveform remains unrecoverable, and such a distinction is often neglected in reports.

Claude Elwood Shannon | Immediate answer to Harry Nyquist

Dr Nyquist, the four quantities should be separately recorded because they answer different physical questions. The analogue-to-digital converter sample rate constrains the representation of signals admitted through a suitably conditioned analogue path. The instantaneous receiver bandwidth specifies which spectral region can reach that converter with the stipulated response. The dwell schedule

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specifies when that region was being observed. The detector's integration, resolution and threshold then determine which events in the acquired samples will yield a positive decision. An impressive converter rate does not recover an emitter outside the admitted band, nor can a later transform restore a burst that occurred while the tuner was elsewhere.

A bandlimited continuous waveform may be represented through samples under the theorem's assumptions. A binary indicator formed by thresholding unknown transmissions need not satisfy the same bandlimit, and its abrupt transitions can occupy arbitrarily short intervals. Even for a physically bandlimited radio waveform, reconstruction requires samples actually acquired over the relevant interval; a receiver's periodic absence is not equivalent to an uninterrupted stream at the stated converter rate. One cannot treat successive ten-millisecond snapshots spaced one second apart as continuous acquisition at a rate of millions of samples per second simply because the converter ran rapidly during each snapshot.

The temporal aperture of the detector is also material. A pulse may partly overlap a dwell but fail to satisfy a detector whose averaging window is longer than the pulse; a sufficiently powerful pulse may, conversely, dominate a peak detector despite occupying only a small fraction of its window. Such behaviour requires empirical or analytical characterisation. In a report I would separate four entries: sample clock and effective sample rate; admitted RF or IF passband; exact valid observation intervals; and detector rule including its effective temporal response. If an event was found in retained samples by a

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later detector, record which algorithm found it and which earlier algorithm missed it.

Accordingly, there is no universal sampling-rate certificate for surveillance completeness. A defensible statement is more modest and more valuable: the receiver continuously retained complex samples within a verified band and time interval, or alternatively observed specified channels only during enumerated dwell windows. Those descriptions allow a later examiner to determine the search's physical exposure. I now pass the token to Professor Wiener, who will consider the special danger of a survey whose next observation depends on what its preceding observation appeared to show.

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Norbert Wiener. Principal response 4. A monitoring policy is part of the system it observes

Dr. Atkinson, we must examine an occupancy-monitoring system as a coupled process rather than as a passive clockwork observer. Its receiver may change gain, tune to a newly discovered channel, lengthen dwell after an alarm, shorten dwell when a frequency appears quiet, or suppress storage when the noise floor rises. These mechanisms can be sensible engineering adaptations. But they alter the probability that subsequent events will be measured and the meaning of any percentage calculated from those measurements. The apparatus ceases to execute a fixed calendar of exposure; it follows a policy conditioned upon its own evolving record. A careless report then presents a statistic from the resulting adaptive dataset as though the observation opportunities had been selected independently of the very emissions being counted.

Let a measurement action at step k be A_k, the recorded detector output be D_k, and the stored history before the step be H_k. A fixed sampling policy chooses A_k without depending upon the newly encountered channel state, while an adaptive policy chooses A_k according to some rule pi(A_k given H_k). That rule may increase the observation of channels in which positive signals have already been found. The resulting observations are not wrong. They are conditional on the policy. If the investigator asks how often a suspicious emission appeared during deliberately concentrated examination of its frequency, the dataset may be entirely suitable. If the investigator claims to estimate natural occupancy across the whole surveyed band, weighting and support questions arise immediately.

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Consider a receiver that monitors one hundred channels with brief visits until one becomes active, then camps upon that channel for twenty minutes. A large share of its retained data will concern channels selected for their prior activity. The observed proportion of positive windows across all stored records will consequently overrepresent the busy channel relative to an evenly distributed channel-time population. Multiplying by the number of channels cannot correct this without knowledge of the exposure allocated to each channel and the precise selection history. The selection rule and its time-varying parameters are part of the evidence, not private conveniences that may be omitted from the annex.

An active operator adds another feedback path. Upon seeing a burst on the waterfall, the operator may move the antenna, alter attenuation or activate a second receiver. These interventions may change the signal seen at the detector even if the distant source behaves identically. The analyst must therefore preserve the sequence of human decisions and instrument state changes. There is little scientific worth in claiming that a transmitter became evasive immediately after an alarm if the operator had also moved the antenna into a null or modified a preselector. Intervention history is essential for causal interpretation.

A possible emitter can itself react to observation. Some transmitters may be time scheduled, some may operate only after a sensor is triggered, and a hypothetical adaptive device could change behaviour in response to a local environment. Such possibilities make uniform surveillance difficult, but they should not become an untestable explanation for every negative finding. The examiner needs an explicit set of alternative mechanisms, each with different observable consequences. If one mechanism predicts a change in

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operation during a known power event and another predicts ordinary interference that remains independent of the event, a properly controlled experiment may separate them. Until such discrimination occurs, deliberate adaptation remains a hypothesis rather than a factual attribution.

The vocabulary of control theory helps clarify the task. An estimator is built on a model of state dynamics and observations; a controller then chooses actions using the estimator's output. If the observer is also a controller, subsequent observations depend on earlier decisions. The resulting closed loop may be useful for finding rare events. Yet a record from a closed-loop policy is not necessarily exchangeable with measurements made under a random or stationary schedule. The report must identify the policy, its objective, the moments of policy revision and the intervals of lost coverage elsewhere. Without that history one cannot recreate why a blank region of a display was blank.

For forensic purposes I recommend a dual record. Preserve an immutable stream of receiver state, time tags, frequency intervals, valid sample counts and decision thresholds. Preserve alongside it a decision log indicating why a retune, capture trigger or attenuation change occurred. Both records should be synchronised to a documented clock and accompanied by calibration and chain-of-custody information. Where practical, maintain a separate, less adaptive surveillance channel as an independent measure of background behaviour. Independence must be tested rather than assumed; shared antennas, oscillators, power supplies and software may create common modes of error.

Finally, an adaptive search may report both discovery performance and the conditional exposure achieved after a lead. Those are useful operational

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achievements. What it must not do is silently convert the amount of attention paid to one apparent signal into an estimate of how often it existed before the attention began. I invite Dr von Neumann to challenge the model of a decision policy and then Dr Deming to examine how a continuously changing procedure should be governed and documented.

John von Neumann | Peer question 5 to Norbert Wiener

Professor Wiener, your policy description appears to require that the engineer can compute or even reconstruct the probability of each measurement action. In a practical surveillance operation the operator may make unplanned decisions after listening to a signal, examining a spectrogram, or responding to a physical event at the site. The observation process may therefore be partly deterministic, partly algorithmic and partly discretionary, with no convenient numerical selection probability. Is the correct response to abandon quantitative inference about overall occupancy, or may the survey still publish measurements from its adaptive phase if it carefully separates direct observations from probability-based estimates? What, in your view, constitutes the minimum sufficient policy record when the human observer's judgement cannot be reduced to an executable programme? If the selection record is incomplete for a single operator decision, should all subsequent observations be excluded from the estimate, or can the team give a bounded analysis based on a documented subset? Please distinguish a defective probability model from an authentic physical measurement.

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Norbert Wiener | Immediate answer to John von Neumann

Dr von Neumann, I would not make the perfect reconstruction of a numerical policy a condition for recording or reporting useful measurements. One may truthfully describe a finite set of observations without having a defensible probability model for the intervals that were not observed. If the receiver followed an operator's choice to monitor a channel of interest for twenty minutes, the analyst may report exactly what occurred during that exposure. The limitation concerns a larger inference to the channels and times which received no comparable attention.

For an adaptive episode, retain the ordered record of time, tuned band, receiver configuration, observed outputs, operator action and stated reason for the action. An operator note need not assert a mathematically precise probability. It should state whether the new dwell was triggered by an alarm, an audible feature, an external report, a suspected interference event, or an independent sampling requirement. Where the reason remains unknown, mark it unknown rather than manufacturing a retrospective account. The record should distinguish an algorithm's scheduled step from an intervention made by a person at the console.

If overall occupancy remains an intended estimand, supplement the adaptive search with a separately designed observational phase. A predeclared random or stratified schedule may provide the sampling foundation; the adaptive phase may identify and characterise candidate emissions in greater detail. The two datasets can be analysed together for some physically defined questions, but their

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different selection mechanisms must remain visible. An estimator requiring positive probability of selection across the target population is not justified where entire categories of time or channel could never have been visited by the operative policy.

The discipline is the same as in the analysis of any feedback instrument. A control action changes which subsequent states become observable. Preserving that action gives another investigator a fighting chance of understanding selection bias and reproducing the investigation's logic. A measurement retained under a nonrandom policy is not counterfeit. It is evidence for a claim whose scope must be chosen accordingly. I pass the token to Dr Deming for the related problem of procedural stability during an extended survey. The record should also distinguish an observation that is valid as a direct measurement from an observation that fails the requirements of a particular population estimator; those are not necessarily identical judgements.

W. Edwards Deming | Peer question 6 to Norbert Wiener

Professor Wiener, let us suppose that the receivers are operated over several nights by different teams, each of which regards a change of gain, averaging depth or alarm threshold as a minor housekeeping adjustment. The organisation records the resulting occupancy percentages but does not preserve a unified history of its methods. A later reviewer finds that the highest apparent activity coincides with a change of staff and a software update. Is it legitimate to treat the event as a technical anomaly requiring investigation, or must the whole series be disqualified for lack of a common measurement system? More

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generally, how would you reconcile a practical programme of continual engineering improvement with the evidential need to preserve a stable definition of what constitutes a positive observation? Would you recommend a fixed reference signal that is observed before and after each procedural adjustment, and should the analysis treat a change in its measured response as an uncertainty component rather than as proof that the external emission changed? This affects the laboratory's claim of comparability.

Norbert Wiener | Immediate answer to W. Edwards Deming

Dr Deming, the change of staff and software makes the series an excellent candidate for investigation, but not an automatic demonstration of a changed emitter. A change in the recording procedure can be a plausible cause of a changed measurement outcome. The two mechanisms should be examined separately. The organisation must not simply discard every observation following a procedural change, because the records may still contain valid evidence. Equally, it cannot combine unlike measurement regimes as though a common numerical threshold conferred common sensitivity.

A mature monitoring programme should treat a change of receiver firmware, thresholding algorithm, antenna coupling or operator protocol as a versioned state transition. The time of the change, the affected instruments, the configuration before and after, and any reference measurements should be preserved. When possible, a period of parallel operation provides an empirical bridge between procedures. If the measurement response changes, the report can

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stratify or recalibrate the series rather than pretend that the whole history belongs to one unchanging process.

Continual improvement and evidential stability are not enemies. Improvement becomes problematic only when the record fails to show which measurement policy produced each result. The laboratory may refine its procedure for detecting weak emissions while preserving the older procedure's results as historical observations. It should then identify the resulting series as distinct measurement regimes and avoid applying new thresholds retrospectively to discarded raw data. If complex samples were retained, a clearly identified reprocessing run may be possible, with versioned software and an output provenance trail.

The apparently elevated occupancy after a staff change is an observation about the instrumented process. Attribution to an external transmitter requires a further experiment capable of excluding procedural differences. It is perfectly legitimate to say that the dataset reveals a discontinuity of measured indications and that its physical cause remains unresolved. Such candour is more persuasive than a prematurely uniform curve. I return the floor to Professor Neyman for the separate question of how a confidence statement should be constructed when the record contains both scheduled gaps and uncertain detection characteristics. A small set of stable reference observations often provides the most economical evidence that two measurement regimes can, or cannot, be combined without recalibration.

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Jerzy Neyman. Principal response 5. Coverage claims must name the ensemble and the failure they protect against

Dr. Atkinson, a confidence interval acquires its meaning from a specified data-generating procedure. A familiar figure of ninety-five per cent should not be interpreted as a personal degree of certainty that no relevant emitter exists in a room. Under an appropriate repeated-sampling interpretation, a procedure may cover its fixed target quantity in a stated proportion of repetitions satisfying the model. If the actual experiment contains systematic sampling at an unfortunate phase, detector saturation, retrospective threshold changes or undocumented invalid intervals, the quoted coverage cannot be imported from a textbook calculation whose premises are different. Precision in notation is a protection against unwarranted assurance.

Let the intended population be a finite monitoring period T for a specified frequency band and a defined occupied-state criterion. If the estimand is the fraction of that period for which the criterion was physically satisfied, the observation plan must afford each relevant interval a documented opportunity of measurement or a properly modelled basis for inference. An investigator may instead define the estimand as the probability of a positive detector decision during a randomly chosen valid dwell. That is a legitimate but different quantity. A report may give both, provided the physical inference is accompanied by the detector model and the uncertainty added by that model.

A binomial interval around a fraction of positives presupposes more than correct arithmetic. It depends upon the observations being sampled under the procedure for which the interval was derived; simple formulas

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frequently assume independent, identically distributed binary trials. Long transmissions, correlated interference and scanning cycles violate the naïve independence assumption. The point count may be large, but the number of materially independent episodes may be small. One may employ cluster-based methods, block resampling under a justified dependence model or a physically informed stochastic process, yet the analyst must state why that model fits the sequence. Merely choosing a more sophisticated formula does not eliminate the need for validation.

The negative survey demands particular care. Suppose no occupied dwell was recorded. If detection would be certain for any transmission lasting one second at the specified power and channel location, and if randomised observation windows genuinely cover the intended population, the absence of detections may support a bounded statement about how frequently such events could occur. It cannot exclude a different device with briefer bursts, lower power, a different emission frequency or a deliberate schedule coinciding with unobserved intervals. The most important sentence in a negative report often begins with the words, 'For emissions within the tested detection envelope'.

One may formalise a rare-event limit. Assume that relevant emissions arise according to a homogeneous Poisson process of rate lambda per hour and that each event is independently detected with probability r during an actual exposure of T hours. Then detections follow a Poisson law with mean lambda r T, and the probability of zero detections is exp(-lambda r T). Solving exp(-lambda_upper r T) = alpha yields lambda_upper = -ln(alpha)/(r T). With alpha = 0.05, r = 0.8 and T = 4 hours, the calculated one-sided upper value is approximately 0.936 events per hour. The result is conditional on

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independence, a constant rate, known effective detection probability and valid exposure. If the four hours consist mostly of gaps during which events were impossible to detect, using wall-clock T in place of valid exposure inflates the evidence. If emissions are adversarially timed, the Poisson model may be wholly unsuitable.

Multiplicity introduces a further challenge. An investigator who examines one channel at a preselected time asks a different statistical question from one who scans thousands of channels and reports whichever yields the most dramatic hourly occupancy. The selected maximum is not a simple unbiased estimate of ordinary channel occupancy. A confirmatory claim should distinguish tests chosen beforehand from patterns discovered after viewing the measurements. This distinction does not diminish the worth of discovery. It prevents the selection process from being hidden behind a confidence label.

I should like the final report to include an explicit decision table even when no table is printed. What is being tested, against what alternative, with which sampling mechanism, under which detector sensitivity, and with what evidence would the analyst revise the conclusion? The burden of a negative assertion should be proportionate to the potential consequences of overlooking a rare emission. A court, laboratory or technical client can then distinguish the absence of observed evidence from a claim that the absence of activity itself has been established.

Where the method cannot support a frequency estimate, there is no disgrace in reporting observed visit counts and carefully delimited exposure. Where the method can support an estimate, the uncertainty should be computed from the actual design rather than from a convenient fiction of

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independent snapshots. These are principles of inference, not counsel for evasiveness. I shall accept a challenging question from Dr Tukey before returning the token to our moderator, because it is precisely the practical business of reporting to imperfect readers that makes these distinctions difficult to preserve.

John Wilder Tukey | Peer question 7 to Jerzy Neyman

Professor Neyman, confidence procedures are often presented as figures of admirable rigour, but a forensic reader may be confronted with a dozen incompatible quantities: positive-visit fraction, dwell-weighted occupancy, duration of active episodes, hourly peak, inferred latent occupancy and upper event-rate bound. The pages on which these appear may contain intervals with different inferential meanings, which can be misconstrued as rival estimates of one underlying property. How would you organise the report so that numerical detail assists rather than overwhelms the judicial or technical reader? In particular, should the investigator privilege a single headline percentage, or is it more important to preserve the measurement ledger, the uncertainty model and clearly bounded negative findings even when the resulting summary appears less tidy? I would particularly welcome guidance on whether the report should display a separate line for receiver exposure, so that the absence of measurements is never misread as evidence of silence. Would this be useful even when the reader wants only a short executive conclusion?

Jerzy Neyman | Immediate answer to John Wilder Tukey

Dr Tukey, I would resist the demand that all the information fit into one statistic. A single headline percentage can be effective when it is

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unambiguously tied to an estimand; it becomes misleading when a reader assumes that it also describes unmeasured episodes, event counts and transmitter identity. The report should open with the purpose of the survey and the unit of observation, followed by the actual amount and distribution of valid exposure. Only then should it present primary descriptive counts, the inferential target and an interval calculated under a stated procedure. The reader must be able to identify which figures are measurements and which depend on modelling assumptions.

For a large dataset, graphical summaries are valuable if the raw time and channel axes are preserved and missing intervals remain visibly marked. A confidence interval for the positive-decision probability should be labelled as such. A detector-corrected occupancy estimate should show the detection and false-alarm parameters on which it depends, together with a sensitivity analysis if those parameters are uncertain. An event-rate upper bound should state its event definition and assumptions, particularly any independence or Poisson conditions. Different quantities should not be placed in one unlabeled column under the title 'occupancy'.

I would provide a compact primary finding in plain language, followed by an auditable evidence annex. For example: 'The receiver obtained ninety valid observations of the specified channel out of one hundred scheduled visits. Thirty valid observations crossed the declared threshold. Ten visits were invalid, and the instrument did not observe the intervals between visits. The fraction of positive valid visits was one third. No estimate of uninterrupted elapsed-time

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occupancy is made from this record alone.' That passage is more informative than the striking but unqualified phrase 'the channel was occupied thirty per cent of the time'.

For negative findings, distinguish a statement about the tested detection envelope from one about all conceivable emissions. If a zero-count upper bound is reported, its model must accompany it. If the assumptions are plainly unsafe, report the zero detections without an unjustified probability of exclusion. The reader should see exactly what further recording, randomisation or receiver challenge would improve the claim. Finally, retain the complete data and code used in the calculation so that another competent examiner can reproduce the report and, if appropriate, challenge its premises. I pass the token to Dr. Atkinson for the synthesis and the accounting of the ten engineering examples.

Sir Ronald Aylmer Fisher, Cross-Peer Question to Walter Andrew Shewhart: Dr Shewhart, a scanning receiver visits a channel in regular short dwells and observes occupancy in thirty percent of them. How should a report treat possible periodic structure in both transmitter activity and visit schedule?

Walter Andrew Shewhart, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Professor Fisher, the sampling design must be recognised as part of the observed system. If the receiver revisits at a period commensurate with a transmitter duty cycle, it may consistently sample one phase and misrepresent total-time occupancy. Record dwell starts, elapsed valid exposure, tuning dead time, gain state and detector threshold. Shift the scan phase deliberately, vary the cadence or run an independently continuous monitor on the same channel to challenge phase locking. Report

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observed-dwell occupancy separately from inferred wall-time occupancy and place uncertainty on the inference. A stable percentage is not proof that the sampling was representative. I pass the token to Dr Shannon regarding intervals that were never observed.

Walter Andrew Shewhart, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, can a receiver reconstruct the activity of an emitter during the ninety percent of time when its scanner was tuned elsewhere by smoothing the detected occupancy series?

Claude Elwood Shannon, Cross-Peer Answer to Walter Andrew Shewhart: Dr Shewhart, it cannot uniquely reconstruct unobserved physical history. Interpolation may furnish a conditional prediction under a stated source-process model, but many distinct transmission schedules produce the same observed dwells. Preserve the exposure calendar and declare intervals of no measurement, rather than plotting them as inferred zeros. If a statistical model is used, justify its periodicity or stationarity assumptions against independent continuous captures. In forensic work, one should distinguish a negative indication during a valid dwell, a failed detector decision and an interval without acquisition. A visually continuous occupancy graph is a derivative, not evidence of continuous observation. I yield to Professor Wiener on possible receiver-induced behaviour.

Claude Elwood Shannon, Cross-Peer Question to Norbert Wiener: Professor Wiener, how might an adaptive scanner change the occupancy pattern it later reports?

Norbert Wiener, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, its policy can select what it observes based on previous measurements,

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thereby changing the exposure distribution. A scanner that dwells longer on active channels will overrepresent them in a visit-weighted fraction unless time weighting and the policy are correctly included. Retuning and gain switching may create dead time or transients counted differently from steady-state intervals. Record every state transition and the algorithm that chooses subsequent frequencies; evaluate the same controlled transmissions with both adaptive and fixed schedules. For comparison across sites, standardise the denominator or explicitly model the varying exposure. The result is a measurement of occupancy under a particular observation policy, not an unconditional property of the environment. I pass the token to Dr Neyman on reporting coverage.

Norbert Wiener, Cross-Peer Question to Jerzy Neyman: Dr Neyman, when a report states that an emitter was absent from an entire building because no activity appeared during intermittent scanning, what evidential qualification is necessary?

Jerzy Neyman, Cross-Peer Answer to Norbert Wiener: Professor Wiener, the conclusion must be restricted to the tested locations, frequencies, time intervals, receiver sensitivity and observation policy. A zero count in finite exposure does not establish zero probability of activity. Estimate upper detection-frequency bounds under a clearly specified model and include missed-detection and false-alarm rates of the receiver. Blind challenge trials should cover the shortest relevant bursts and the worst scanner phases. If the emission responds to human presence or monitoring activity, simple stationarity assumptions may fail. State the exposure denominator transparently and do not treat unobserved time as a negative test result. I return the token respectfully to Dr Atkinson.

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Dr. James M. Atkinson. Closing synthesis of Question 049

Colleagues, the discussion resolves the tempting but perilous confusion between a decision made in a measured instant and a verdict upon an unmeasured interval. An occupancy percentage is not self-explanatory. Its credibility rests upon a named estimand, a defined population, a documented schedule of exposure, a reproducible decision rule and an uncertainty method appropriate to the observations actually retained. If a scanning receiver visits a channel for ten milliseconds every second, the display may faithfully reveal the presence or absence of a qualifying signal during those visits. It cannot, by that fidelity alone, certify what the channel did during the intervening nine hundred and ninety milliseconds.

Professor Fisher has insisted that we identify the statistical population before computing the percentage and that we distinguish discovery-directed measurements from independent validation. Dr Shewhart has demonstrated the danger of pooling observations across changing physical and instrumental regimes. Dr Shannon has drawn a clear boundary between reconstruction and statistical inference, explaining why later processing cannot restore the particular data never acquired. Professor Wiener has shown how adaptation by an operator or monitoring policy alters subsequent selection, and Professor Neyman has specified the conditions under which confidence and negative-event bounds possess their advertised coverage. The peer challenges have properly exposed the tensions among these positions without pretending that one mathematical device resolves all of them.

A scientific field report ought therefore to specify five separate classes of quantity. First, it should record the clock and calendar span of the survey.

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Secondly, it should record actual valid measurement exposure, including which frequencies, receiver states and sensitivities were in force. Thirdly, it should preserve the positive and negative decisions produced by a declared detector and the treatment of invalid observations. Fourthly, it may present population estimates where the acquisition design and calibration justify inference beyond the measured windows. Fifthly, it should distinguish any operational conclusion about a probable physical emitter, which cannot be reduced to an occupancy statistic without additional corroboration. These classes may be related, but none is a synonym for another.

An important distinction remains between the power of a method to detect a recurring class of signal and its power to exclude one particular unknown device. An investigator might have excellent sensitivity to a continuous signal at one frequency and little exposure to short bursts elsewhere. A negative result cannot be detached from that envelope. Similarly, a positive result in a sampled channel does not identify the transmitting apparatus merely because the statistical calculation around its frequency of occurrence is narrow. Frequency occupancy, waveform similarity, bearings, antenna response, source attribution and chain of custody require their own validation.

The numbers in the applications below are deliberately simple enough for independent recalculation, for such modest arithmetic reveals the larger epistemic danger. The difference between ten seconds of valid exposure and thirty seconds of wall time may be a simple ratio; the decision to treat those denominators as interchangeable is a substantive evidential error. A confident interval derived from one hundred correlated observations may be too narrow by several times. A zero-count bound can sound reassuring

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while depending upon a Poisson arrival model which the suspected emitter has no obligation to obey.

The duty of the moderator is not to remove every uncertainty from a laboratory record, which would be impossible, but to ensure that uncertainty is located where the measurement process actually creates it. The field investigator must speak plainly enough for a court, engineering peer or client to understand, and precisely enough for another examiner to repeat the calculation. Let the final report say what was measured, what was estimated, what remains unobserved and which assumptions would need to hold before a larger claim could be justified. I thank the panel for a rigorous and respectful exchange. Our next question concerns the waterfall display itself: whether the colourful impression of continuous spectral history should be mistaken for the samples from which that impression was computed.

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Ten worked engineering applications | Question 049

Application 1. Valid exposure versus elapsed survey time. Let d denote the valid dwell duration per visit, R the revisit period and H the elapsed survey duration. Suppose d = 0.010 s, R = 1 s and H = 3600 s. The nominal number of visits is N = H/R = 3600. Valid exposure is E = N d = 36 s, and the temporal coverage fraction is E/H = 36/3600 = 0.010, or 1.0%. The remaining 99.0% was not observed at this channel by this scanner. The calculation assumes every dwell is valid and a complete regular schedule; dropped visits reduce exposure further. The converter's high within-dwell sample rate does not change this coverage ratio.

Application 2. Observed fraction and a Wilson interval. Let x = 30 positive decisions among n = 100 valid, independently and identically sampled visits. The observed fraction is qhat = x/n = 0.30. For an illustrative 95% Wilson score interval let z = 1.96, a = 1 + z^2/n = 1.038416, centre c = (qhat + z^2/(2n))/a, and half-width h = z sqrt(qhat(1-qhat)/n + z^2/(4n^2))/a. Evaluation gives c approximately 0.3074 and h approximately 0.08845, for an interval approximately [0.219, 0.396]. This estimates a decision probability under the independent-sampling model, not the physical time occupancy of an intermittently visited channel.

Application 3. Detector-error correction. Let p be latent time occupancy at a representative sampled instant, P_D = 0.90 the probability of a positive decision when occupied, and P_FA = 0.02 the probability of a positive decision when clear. With q = 0.30 the observed positive probability, q = p P_D + (1-p)P_FA. Rearranging, p = (q-P_FA)/(P_D-P_FA) = (0.30-0.02)/(0.90-0.02) = 0.31818. This correction is meaningful only if the

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same sensitivity and false-alarm model describe the relevant signal class and conditions. Uncertainty in P_D and P_FA has not yet been propagated.

Application 4. Correlated visits and effective sample count. Suppose n = 100 equally spaced classification opportunities are approximated by a stationary correlation model with lag-k autocorrelation rho^k and rho = 0.80. An illustrative large-sample effective size is n_eff approximately n(1-rho)/(1+rho) = 100(0.20)/(1.80) = 11.11. This is not an exact finite-sample confidence procedure, but it shows why treating all one hundred observations as independent can exaggerate precision. The empirical autocorrelation, regime stability and finite-sample method must be assessed before an interval is published.

Application 5. Random-phase capture of one brief burst. Let a scanner observe a channel for d = 0.010 s once per cycle R = 1.000 s. Let a burst of duration b = 0.100 s have a start phase uniformly distributed over one cycle; assume ideal recognition whenever its interval overlaps the dwell. Where b+d is less than R, the probability of any overlap is (b+d)/R = 0.110. If twenty independent bursts have independently uniform phases, the probability of observing at least one is 1-(1-0.110)^20 = approximately 0.903. Correlated phases or lower detector sensitivity invalidate this simplified probability.

Application 6. Stratified occupation over unequal times. Suppose two daytime hours have physical occupancy p_day = 0.80 and twenty-two night-time hours have p_night = 0.10. The time-weighted 24-hour occupancy is p = (2(0.80)+22(0.10))/24 = 3.8/24 = 0.15833, or 15.83%. A survey taking equal numbers of samples by day and night would instead

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produce an unweighted mean of 45%, if its within-stratum sample rates are representative. Equal observations per stratum are not equal time weighting; the chosen estimand determines the correct combination.

Application 7. Invalid measurements and a denominator change. One hundred visits were scheduled; thirty produced positive decisions, sixty valid negative decisions and ten invalid acquisitions. The positive fraction among valid visits is 30/(30+60) = 1/3 = 33.33%. Counting all scheduled visits as though invalid observations were negative yields 30/100 = 30%, a different quantity. Neither value measures activity during gaps between visits. If invalidity is correlated with overloading during strong emissions, the valid-only fraction may itself be a biased sample of all scheduled opportunities.

Application 8. A conditional zero-event upper bound. Suppose an event class follows a homogeneous Poisson arrival process with unknown rate lambda events per hour, and each event has independent probability r = 0.80 of being recognised within T = 4 h of genuine effective coverage. If no events are seen, P(0) = exp(-lambda r T). For a one-sided 95% upper confidence bound, set P(0) = 0.05, so lambda_upper = -ln(0.05)/(0.80 x 4) = 2.995732/3.2 = 0.93617 events/h. This model-based bound cannot exclude intentionally scheduled bursts or apply to intervals that had no effective observation.

Application 9. Periodic phase-lock blindness. Let the scanner visit from t = k seconds to t = k+0.010 seconds for each integer k. Let the emitter operate from t = k+0.400 to t = k+0.450 seconds. The actual physical duty cycle is b/R = 0.050/1.000 = 5%, yet every one of the scanner's scheduled dwell windows is clear. The observed positive-visit

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fraction is zero in any number of exact repetitions. The discrepancy is systematic phase selection, not random sampling error, and a narrower confidence interval around zero would not cure it.

Application 10. Three-channel sequential scanning. Let a receiver dwell d = 0.100 s on each of C = 3 channels and require g = 0.002 s retuning overhead for each scheduled channel visit. One cycle takes R = C(d+g) = 3(0.102) = 0.306 s. One channel receives d/R = 0.100/0.306 = 0.3268, or 32.68%, nominal temporal coverage before invalid acquisitions. The figure assumes identical dwell and overhead for all channels. If the controller camps on a detected signal, the realised denominator must be recomputed from the actual receiver-state log, not this original schedule.

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TECHNICAL SOURCE RECORD. QUESTION 049

Contemporary editorial references, not works claimed to have been read by the deceased contributors:

1. ITU-R Recommendation SM.1880-3 (08/2026), *Spectrum occupancy measurement and evaluation*, officially listed in force and approved 23 August 2026. https://www.itu.int/rec/R-REC-SM.1880-3-202608-I/en . The recommendation's official listing and edition status were checked; the complete annex has not been independently analysed for this dialogue. 2. ITU-R Report SM.2256-2 (06/2026), *Spectrum occupancy measurements and evaluation*, official table of contents identifying measurement, observation, revisit and integration timing, uncertainty, and treatment of pulsed signals. https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2256-2-2026-TOC-HTM-E.htm . The table of contents was checked; claims here do not purport to quote its unexamined full chapters. 3. ITU-R Report SM.2256 (2012), historical report outlining snapshots and the danger of missed changes between visits. https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2256-2012-PDF-E.pdf . Earlier definitions are not misrepresented as verbatim text of the 2026 revision. 4. ITU-R Recommendation SM.2117-0 (09/2018), *Data format definition for exchanging stored I/Q data for the purpose of spectrum monitoring*. https://www.itu.int/rec/R-REC-SM.2117 . Used as background for the importance of preserving interpretable I/Q records and metadata.

Editorial integrity: All interventions and replies are newly constructed educational dialogue. Equations illustrate specified models and do not certify an actual receiver's performance or a particular transmitter's existence. Any inference about an actual installation requires observation-specific calibration and provenance.

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QUESTION 050

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When are waterfall displays misleading representations of retained samples?

Source: V011_Roundtable_Questions_049-050_CP050_Combined.docx | Recovered substantive manuscript. Constructed educational dialogue.

Moderator: Dr. James M. Atkinson

Editorial convention: Original, newly constructed pedagogical dialogue. The deceased scholars named below did not participate in these exchanges. No sentence is presented as a historical quotation. The technical scenarios and numerical examples are hypothetical and require configuration-specific verification before application to a real receiver.

Dr. James M. Atkinson. Opening of Question 050

Distinguished colleagues, a waterfall display possesses a compelling visual eloquence. A thin illuminated thread descends across a dark field, a brief vertical flare appears against a quieter background, and a broad band acquires colours which seem to announce the presence of a moving transmitter. The operator may watch that picture for hours while the computer continues to collect, discard, average, compress or transform information without visibly advertising which of those operations it is performing. It is therefore entirely possible to obtain a waterfall that is beautiful, repeatable and operationally useful, yet materially misleading if it is presented as a complete record of the analogue signal or even as a complete rendering of the retained digital samples.

A spectrogram may be produced by computing a short-time Fourier transform of complex baseband samples. The calculation selects a window of N samples, multiplies them by a chosen window function, forms a

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discrete Fourier transform, and assigns each time-frequency cell a complex value or power estimate. The displayed waterfall generally preserves neither the full complex sample sequence nor the complete set of intermediate transform values. It paints selected numerical summaries onto a finite grid of pixels using a colour map, an amplitude scale, a display refresh rate and sometimes averaging or peak-hold rules. An image is a representation derived from evidence; it does not become the evidence merely because the image was generated in real time.

Nor does the expression 'real time' have one unqualified meaning. Some receivers acquire a continuous stream within a definite instantaneous bandwidth but redraw the user interface only intermittently. Others sweep a tuner or spectrum analyser sequentially, so that neighbouring frequency columns correspond to distinct instants. Some processing pipelines generate spectrogram frames without a capture gap while retaining only selected aggregate rows. Others skip or decimate samples when processing cannot keep pace. A colourful row does not tell the examiner which pipeline was used, and an uninterrupted stream of screen updates does not prove uninterrupted RF coverage.

We should separate at least four records. The first is the analogue observation envelope: antenna, front end, preselection, tuning, gain, analogue bandwidth, overload history and calibration. The second is the acquired complex or real sample sequence, with clock, sample-rate, validity and dropped-sample metadata. The third consists of computed spectral estimates, including their windows, overlaps, scaling and time tags. The fourth is the rendered display: colour palette, pixel decimation, interpolation, averaging and presentation state. A change in one may alter

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the screen while leaving another unchanged. The forensic investigator must know which of these records has actually been retained and which can be reconstructed independently.

The particular danger is that an interpreter may infer physical continuity from graphical continuity. A sequence of displayed horizontal lines can appear seamless despite a receiver having observed only a portion of the relevant time. A frequency-hopping source may produce isolated dots that a human eye joins into a path which the samples do not support. A long bright streak may be the consequence of temporal max-hold aggregation rather than a transmission lasting throughout the represented interval. A quiet-looking region may be the result of colour clipping, averaging, a threshold, a retune or the absence of stored samples. When an analyst later presents the display to a court, a laboratory or a security client, those possibilities must be tested rather than dismissed as mere software detail.

The present discussion will proceed through five specialised perspectives. Dr Dennis Gabor will examine localisation in time and frequency, showing why one spectral image cannot offer arbitrarily sharp information along both axes. Dr John Tukey will consider computational aggregation, bin placement, spectral leakage and the difference between raw data and an estimator. Dr Ralph Blackman will examine window response, dynamic range and false visual morphology. Dr Claude Shannon will distinguish what can be reprocessed from retained complex samples from what a screen image irrevocably discards. Finally, Dr Abraham Wald will investigate the statistical and forensic hazards of selecting evidence after a conspicuous visual pattern has appeared. Seven colleagues will pose direct technical challenges, each followed immediately by an answer from

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the principal contributor. Ten calculated cases will make the reasoning auditable.

I ask every participant to avoid the extremes of declaring the waterfall a deceptive novelty or of treating its glowing traces as a perfect historical record. The display is an extraordinarily useful instrument of discovery. Its evidential strength emerges when the acquisition and processing chain can be reconstructed. Dr Gabor, may I invite you to begin with the physical meaning of one illuminated time-frequency cell, before we consider what it can conceal?

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Dennis Gabor. Principal response 1. One time-frequency cell represents an operation, not an instant

Dr. Atkinson, a spectrogram cell is not a minute fragment of the electromagnetic world observed in isolation. It is the output of an operation performed on a neighbourhood of samples. If the transform uses N contiguous samples acquired at sampling frequency f_s, the nominal analysis duration is $T_w = N/f_s$. The output is assigned a time coordinate, often the centre or beginning of the window, but the estimate contains contributions from the entire window. When a pulse begins near one edge of that interval, the displayed energy may be associated with a coordinate different from the pulse's actual onset. When the same pulse is examined with a longer window, its spectral appearance may become more concentrated even as its temporal boundaries appear less distinct. The display's apparent precision is a consequence of chosen representation, not a direct measurement of two perfectly precise physical coordinates.

Frequency-bin spacing in an N-point discrete Fourier transform is f_s/N, provided the transform is based on N physical samples without subsequent padding. This spacing describes the sample grid in frequency, not by itself the ability to resolve two near spectral components. Resolution also depends upon observation duration, window shape, signal-to-noise ratio, interference and the decision rule. A reader who counts adjacent pixels may therefore mistake the number of displayed columns for a measure of resolvable spectral detail. Interpolation can provide smooth peaks and convenient sub-bin estimates under an assumed model, but it does not create independent measurements or distinguish arbitrary overlapping signals.

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The corresponding temporal issue is equally pronounced. A two-millisecond analysis window may be appropriate to detect and localise rapid activity, although it spreads the energy of a narrow carrier over a comparatively broad spectral response. A two-hundred-millisecond window gives a finer nominal frequency grid and potentially a more selective estimate for a sustained tone, yet a burst that occupied only a short portion of that window may be diluted when an average power estimate is formed. Neither window is intrinsically superior. Its suitability depends upon the duration and bandwidth of the sought signal, and upon whether the task is discovery, classification, measurement of power, or forensic characterisation of a retained event.

If adjacent analysis windows overlap, the waterfall may show the same physical pulse in several consecutive rows. The operator may count those rows as separate transmissions, particularly when bright pixels have similar shape but distinct time labels. The mistake becomes severe when an automatic event counter is attached to an image-processing algorithm rather than to a state machine operating on calibrated time-series evidence. Overlap is valuable because it reduces the risk that one isolated pulse falls entirely at a particularly unfavourable window boundary. It does not produce independent new physical events, and the number of rows should not be confused with the number of independent observation opportunities.

Another ambiguity arises from time stamping. If the first sample of each window is stamped as the display's nominal time, the visible centre of energy may be displaced by approximately half a window duration for a symmetric analysis window. If the timestamp instead denotes the centre, the displayed interval extends around that point. Software buffering, clock

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synchronisation and delayed screen rendering may add further discrepancies. A colourful trace aligned with an event recorded by a separate camera or instrument can therefore appear causally significant while the two systems differ in time origin or buffering delay. Cross-instrument interpretation requires the semantics of the stored time tag, not merely the number printed on the screen.

The use of colour creates its own abstraction. A continuous palette suggests that energy has been measured at every point in an apparent rectangular field. In reality a finite matrix of spectral estimates has been rescaled and drawn through finite pixels. A smooth gradient may have been interpolated between estimates; the underlying data may contain only one value per transform frame and frequency bin. Visual continuity may invite the eye to infer gradual physical drift where there were only two noisy detections separated by a large unobserved interval. Without a record of the frame times, such an inference is particularly fragile.

The competent analyst should ask what operation produced one row and what temporal support each coloured cell represents. Was the value peak power, average power, a maximum across many FFT frames, a logarithmic transform of a linear-power average, or a thresholded flag? Did the receiver capture a continuous band during all those frames? Were any rows copied, resampled or interpolated to match the screen's refresh rate? Was the signal's centre frequency estimated from more than one sample frame, and were the assumptions on which that estimate depended tested? Each answer may change the proper physical interpretation.

I am not arguing that a time-frequency picture is useless merely because it is an abstraction. Most scientific instruments communicate through

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transformations. A spectrogram is especially useful for comparing recurring patterns and discovering fleeting features. But if the question concerns the precise beginning, duration, occupied bandwidth or identity of a particular emission, one must return to the retained sequence and to the well-defined calculation by which the picture was produced. The image should guide examination rather than substitute for it. I respectfully yield the token to Professor Fisher and Dr Kendall, who will ask how far such a representation can support precise temporal or statistical conclusions.

Sir Ronald Aylmer Fisher | Peer question 1 to Dennis Gabor

Dr Gabor, consider two analysts who process the same continuous sample recording with different window durations. The first selects a short window and reports a narrow temporal burst with broad frequency content; the second chooses a longer window and reports a broader, quieter feature occupying fewer spectral bins. Both analyses are reproducible, yet their plots may lead an inexperienced examiner to infer physically different transmitters. Would you require a predeclared choice of window and colour scale for every forensic comparison, or is it legitimate to search several representations and retain the one that most clearly reveals an event? How should a report identify the difference between a physical finding that survives reasonable analytical choices and a visually striking pattern created only by one convenient setting? If the analyst has selected the most favourable image only after surveying a large family of window sizes, I would regard that choice as part of the evidential procedure. Does your suggested comparison require an independent validation recording, or might an unexamined portion of

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the same acquisition suffice where the disturbance is temporally correlated?

Dennis Gabor | Immediate answer to Sir Ronald Aylmer Fisher

Thank you for that question. Professor Fisher, the important distinction is between exploratory representation and independent confirmation. Selecting several windows is often scientifically sensible because the physical duration and spectral structure of an unfamiliar emission are not known beforehand. A short window may reveal its onset; a long window may assist in discriminating a sustained narrow carrier. The analyst should not conceal this exploration, nor present the most persuasive image as though it were the only analysis planned. Retain the full list of tried parameters, preferably in an automatically generated processing log, so that subsequent readers can reproduce the route from samples to chosen display.

A finding gains strength when its relevant physical propositions survive transformations that should not change them. If the hypothesis is that energy above a defined threshold entered the sampled receiver band during a particular interval, examine calibrated time-domain power and a range of reasonable transform settings. If the hypothesis concerns a narrow spectral line, compare windows, leakage corrections and independent frequency estimators. A change of image appearance alone is not evidence that the source changed. Differences between plots should be explained through the known response of their analysis windows wherever possible.

Predeclaring an analysis serves a different purpose from discovery. When a fixed decision threshold and a numerical false-alarm

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probability are used to make a confirmatory claim, the selection and processing steps that influence that decision should be specified before the validation data are seen. For an unfamiliar anomaly there may be no appropriate single setting to nominate in advance; the investigation can explore first and validate afterwards. The final report should separate those stages so that choosing the most conspicuous representation does not create an illusory statistical significance.

The most effective disclosure is to provide several views derived from the same identified sample interval: time-domain magnitude or power, a short-window spectrogram, a long-window spectrogram, and the underlying spectral estimates when relevant. Each view should carry a clear scale and timing convention. A conclusion based upon a feature found only under one delicate parameter choice should be stated conditionally, together with an alternative explanation involving the estimator. The court or engineering reader then sees not a contest of pictures but a test of propositions against one preserved record. I pass the token to Dr Kendall for the distinct question of how persistence across correlated rows ought to be evaluated.

David George Kendall | Peer question 2 to Dennis Gabor

Dr Gabor, a spectrogram may show a faint signal in fifty adjacent rows, and the operator may describe fifty corroborating observations. Yet if the rows were formed from ninety per cent overlapping windows, most of the sample values used to compute one row appear again in the next. The visible persistence may therefore contain far fewer

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independent pieces of evidence than the row count suggests. Is it possible to determine from the image alone whether the feature represents a persistent source, one transient spread across many transforms, or a processing artefact correlated across frames? What would you demand of a laboratory that offers such persistence as evidence of repeated communication rather than as the visual footprint of a single event? Might the same row pattern also arise from a moving noise-floor estimate, rather than from overlap alone? I should like to see a distinction between physical event count, transform-frame count and detector-trigger count, because the three may diverge dramatically in a single recorder's output.

Dennis Gabor | Immediate answer to David George Kendall

Thank you for that question. Dr Kendall, the image alone is inadequate for the distinction. One must inspect the window length, hop length and underlying samples to determine how much of the displayed repetition is induced by the estimator. If a window contains four thousand samples and the hop is four hundred, adjacent rows share ninety per cent of their input samples. A short pulse may consequently affect multiple frames whose nominal time coordinates differ, even though the physical recording contains only one pulse. The row count is a computational count, not a transmission count.

A defensible event detector should therefore operate on a declared physical event definition. It might group adjacent threshold crossings into one episode when their time intervals overlap or when calibrated temporal continuity justifies it. The grouping rule must be tested against simulated and reference transients of varying durations and

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separations. It should record the dependence on window length so that a switch in display settings does not quietly alter the reported number of transmissions. Where overlapping components cannot be resolved, the analyst should report an interval of possible event counts or an unresolved cluster rather than manufacture a unique event history.

Persistence becomes stronger evidence when it survives examination of genuinely disjoint portions of the sample sequence or an independent receiver path. If a narrow feature recurs in nonoverlapping windows separated in time, its repetition is no longer explained solely by reusing the same input samples, although other shared instrumental effects remain possible. The engineer should also examine amplitude consistency, frequency stability, receiver-state changes and alternative causes such as local oscillator spurs. None of these tests identifies a unique emitter automatically, but each constrains a possible explanation.

Thus I would require the analyst to state the estimator's time support and overlap, disclose the rule for merging adjacent detections, and present at least one time-domain check of the proposed event boundaries. A sequence of bright rows may suggest an event worth investigating. It is not fifty independent confirmations merely because the software printed fifty lines. I pass the token to Dr Tukey, whose experience with computational representation will provide a necessary challenge to the assumption that every plotted number is equivalent to a retained measurement.

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John Wilder Tukey. Principal response 2. Numerical processing can manufacture a persuasive appearance without inventing a sample

Dr. Atkinson, the problem begins when the examiner mistakes an output format for a primitive observation. The values entering a display can be derived from a legitimate and accurately retained sample record, yet the choices that transform them into an image can discard distinctions necessary for the question under investigation. One must therefore maintain a provenance chain through each computational stage. It should identify the original acquisition block, the samples included in every FFT, the window coefficients, the scale factors, the frequency mapping, the detector or aggregation rule, the treatment of invalid frames and the eventual colour encoding. Without those records another examiner may reproduce the screen's appearance only by speculation.

The discrete Fourier transform is a linear operation on a finite sequence. In its simplest unnormalised form, X[k] is the sum over n from zero to N-1 of x[n] exp(-j 2 pi kn/N). The same samples may be multiplied by a tapered window before transformation, and the output may be converted to magnitude or squared magnitude. A power estimate then needs an appropriate normalisation and, for a physical instrument, calibration through the analogue input path. If the operator mixes up amplitude and power decibels, or changes windows without correcting coherent gain, the waterfall's colours can move by many decibels even when the input signal is unchanged.

The distinction between a frequency grid and frequency resolution deserves emphasis. Zero padding a window of physical samples gives more FFT output bins and a smoother-looking spectral curve. It does not add

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information from a longer observation interval. A line may now fall on a more favourable output bin, making its peak easier to estimate under a model, but two close emitters do not become independently resolvable simply because the computer has printed four times as many frequency values. A forensic report that equates a reduced bin interval with improved physical resolution confuses interpolation of an existing transform with a genuinely longer effective measurement.

Likewise, a display image may use far fewer columns than the computed FFT contains. Suppose the transform produces eight thousand frequency values but the graph is only one thousand pixels wide. The rendering software must combine, choose or omit some values. If it chooses a maximum in each pixel group, an isolated spur may appear prominent; if it chooses a mean, the same narrow spur may be diluted. Both are defensible for different purposes. Neither should be offered as a complete account of the underlying transform without stating the reduction rule. A screenshot is therefore a poor substitute for the numerical spectrum and its metadata.

Temporal aggregation is even more dangerous. A receiver may compute one thousand FFT frames per second but update its waterfall with one row per second. If each row displays the maximum observed power for that second, a burst lasting a fraction of a millisecond may produce a bright stripe resembling an event sustained for the entire displayed second. If the row shows average power, the same burst may become almost invisible. The picture may encourage either an overestimate or an underestimate of event duration and received power. It is the aggregation policy, not the source, which determines the row's duration and colour.

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A modern graphical interface also applies nonlinear colour scaling. The palette may map a wide range of decibels into a limited set of shades, clip values outside the selected reference range, interpolate pixels and reverse the order in which time is plotted. A colour change can therefore be produced without any new energy entering the receiver. Automatic gain adjustment, a different reference level or a revised palette threshold may turn an unchanged statistical background from dark blue to vivid yellow. The original magnitude data could remain numerically identical. A report relying on colour adjectives while omitting the calibration scale is a report about presentation preferences, not radio-frequency power.

Yet it would be foolish to reject plotting as a means of discovery. Graphical representations show patterns which a table can conceal, particularly temporal sequences and correlated frequency motion. The remedy is to preserve the processing lineage so that a visual discovery can be converted into a reproducible measurement. Record the precise sample hashes, code version, window, hop, power normalisation, detector settings, frame aggregation and colour map. For a challenged event, recompute the relevant window from the original samples and verify that the stated feature survives suitable alternative settings. The display should lead back to numbers and physical quantities rather than away from them.

The danger of selecting one attractive picture among many is not confined to malicious advocacy. An attentive engineer naturally searches through configurations until the pattern becomes legible. This practice is valuable for discovery, but it means that the final image may carry more selection history than the caption admits. The source record should disclose that history, particularly when numerical confidence or unique attribution is

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claimed. If a long-term waterfall is retained without raw samples, acknowledge its restricted evidential reach: the picture may establish what the display computed, but not all of the short-time behaviour that the display has averaged away.

A disciplined report can communicate both a useful picture and an exact numerical audit trail. One page may show the visually intelligible spectrogram. An accompanying record should state the frequency resolution, effective filter response, timestamp semantics, number of frames aggregated per row, lost-frame count and power calibration. On demand the analyst should be able to identify the samples which made one striking pixel bright. I pass the token to Dr Hamming and Professor Wiener for questions about software reproducibility and feedback-induced alterations in the displayed record.

Richard Wesley Hamming | Peer question 3 to John Wilder Tukey

Dr Tukey, a software engineer may preserve all input samples but discover months later that the application version which produced a decisive screenshot is no longer installed. The waterfall calculation used proprietary window normalisation, a vendor-specific averaging mode and adaptive display decimation, and its settings are recoverable only partly from the screenshot. The laboratory has therefore retained better physical evidence than its published figure suggests, but it cannot reproduce the exact historical image. Would you classify the screenshot itself as evidentially invalid, or could a new, transparent implementation produce a stronger analysis from the same raw samples? How should the examiner explain disagreement between the original image and a later reproducible analysis without silently rewriting the historical record?

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What should be done when different reproducible algorithms yield the same narrow trace but materially different amplitude estimates? Does agreement about frequency establish enough to accept a source as external, or must calibration and analogue artefact tests still precede even that limited assertion?

John Wilder Tukey | Immediate answer to Richard Wesley Hamming

Thank you for that question. Dr Hamming, the distinction between preserving an original artefact and reproducing its method is essential. The historic screenshot remains evidence of what a particular display presented at a particular recorded moment, subject to the authenticity of the image and its provenance. The inability to reproduce its exact colours or pixel selection limits inferences about the algorithm that produced it. It does not render independently preserved raw samples useless. A later, transparent reanalysis may be considerably stronger evidence of the underlying signal, provided that the new procedure and the fact of reprocessing are clearly identified.

I would not erase the older image or substitute the new one under the original date. Preserve both. Identify the sample interval and the checksums of the retained acquisition, then explain which original processing parameters are documented and which have been lost. Recompute the event using an independent, specified transform, and disclose differences in time support, frequency scale, normalisation and detector policy. If the apparent event disappears, examine whether the discrepancy results from clipping, windowing, averaging,

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a former display artefact or a genuine defect in the new analysis. A disagreement is a technical finding, not an invitation to choose whichever picture favours a preferred narrative.

Software provenance should be planned as part of evidence acquisition. Retain executable or source versions where lawfully available, configuration files, time-zone and clock settings, numerical-library versions, calibration records and validation test vectors. If one computation cannot be precisely recreated, describe the limitation rather than invent undocumented parameters. The original picture may still help identify a candidate time-frequency region, while the new analysis tests more bounded propositions about the preserved data.

The decisive point is that a screenshot has a different evidential function from a complex-sample acquisition. The screenshot documents an output of a particular measurement-and-display system; the raw samples permit alternative estimators within the limits of the original analogue channel. One can use both without pretending they are interchangeable. The integrity of the laboratory is improved when it states plainly that the original visualisation is not fully reproducible and that its present conclusion rests upon independently verifiable reprocessing. I pass the token to Professor Wiener to question the effects of automatic user-interface changes.

Norbert Wiener | Peer question 4 to John Wilder Tukey

Dr Tukey, suppose the waterfall program automatically follows its noise floor, changes the colour threshold as the receiver is moved, and increases averaging whenever the displayed background looks restless.

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The screen becomes visually stable, which is welcome to the operator, but its sensitivity to a faint new emission may change without an explicit command. One might observe an apparent strengthening of a spectral line after an antenna move even though the underlying receiver samples did not strengthen proportionately. How should the analyst identify feedback between the display, the operator and the acquisition system, and when does this feedback merely alter presentation as opposed to changing what physical information is captured and retained? How would you distinguish software adaptation which merely changes the colours on a screen from automatic gain control which changes the digitised measurements themselves? A technician may find both controls labelled 'auto' and fail to realise that only one can be undone through later re-rendering.

John Wilder Tukey | Immediate answer to Norbert Wiener

Professor Wiener, this question requires the processing chain to be divided at the point where information is discarded or physical acquisition is altered. If automatic colour following changes only the palette used to show already computed calibrated power values, then the original samples and numerical spectral estimates may be unchanged; the alteration is a presentation transformation. If averaging changes the stored spectral records, however, the data retained for later analysis may be reduced. If the program alters receiver gain, tuning, preselection or capture triggering, the transformation reaches back to the analogue observation envelope and may change which signals can enter the record at all.

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The laboratory should identify each feedback path in its state log. A palette parameter belongs with the image metadata. A new averaging depth belongs with the spectral estimator and the description of retained numerical products. An automatic gain-control response belongs with the receiver acquisition record, together with information about the possibility of compression and clipping. A retune belongs with time-frequency coverage. Without these distinctions the investigator cannot say whether a vivid colour change is merely graphical or constitutes a physically different measurement condition.

To test a suspected strengthening of a feature, compare calibrated power measurements derived from the retained samples under a fixed processing configuration and, where possible, from independently characterised reference data. Correct for gain state and known front-end changes. Then ask whether the change exceeds the uncertainty arising from calibration, noise estimation and detector response. The operator's visual impression can motivate the calculation, but it does not answer it.

Where continuous complex samples have survived, one may reconstruct comparable spectral estimates by applying one declared estimator to both intervals, provided the analogue chain supports the comparison. Where only auto-scaled screenshots remain, the permissible claim may be substantially narrower. In either situation, document whether the adaptation was controlled by software, by a human, or by a physical receiver loop. The same apparent screen can emerge from quite different causal paths. I now yield the token to Dr

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Blackman for his analysis of window response and the spectral shapes which a display may suggest. For that reason, the archived state history should use different fields for graphical scaling, spectral integration and physical receiver gain, each with its own effective timestamp.

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Ralph Beebe Blackman. Principal response 3. Window shape, dynamic range and the fiction of a perfect spectral boundary

Dr. Atkinson, an FFT is usually applied to a finite observation that is treated as one segment of a longer underlying signal. Abruptly truncating the segment with a rectangular window introduces a particular spectral response, and the response of a tapered window has its own trade-offs. A strong carrier which does not fall precisely on the bin grid can distribute energy into adjacent bins. The resulting sidelobes may give the appearance of weaker emissions, especially when shown on an aggressive logarithmic colour scale. A window that suppresses sidelobes often broadens the main lobe. A spectral picture therefore combines the properties of the physical emitter with the chosen observation and estimator; its visible edges are not direct tracings of a transmitter's occupied bandwidth.

If the input contains a sinusoid whose frequency lies between FFT bins, the amplitude indicated by the nearest displayed bin may be lower than an appropriately calibrated estimate of the true sinusoidal amplitude. This is sometimes described as scalloping loss, and its magnitude depends upon window shape and the point at which the tone falls between bins. An operator who interprets fluctuating bin colours as fluctuations of transmitter output may thereby overlook the possibility that the tone is merely drifting across the estimator's frequency grid. Conversely, interpolation and bin searching may smooth the displayed amplitude, hiding how strongly the estimate depends upon processing choices.

Windowing also changes noise statistics. A tapered window weights samples unequally and has an effective noise bandwidth which differs from the raw FFT-bin spacing. Two spectrograms processed with different

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windows cannot be compared by their colour scales alone unless the normalisation and bandwidth differences are accounted for. The same white-noise density may lead to different displayed noise powers per spectral estimate. Likewise, a detector that averages powers is not equivalent to one that averages logarithmic decibels, since the logarithm is nonlinear. Such distinctions can shift a colour boundary or make a faint candidate look more or less significant.

The strong-signal problem is particularly severe in technical surveillance countermeasures. A legitimate high-power emission or a local oscillator spur may dominate the transform and generate leakage that extends into a neighbouring frequency. The visual picture may seem to contain a family of parallel weak transmitters. The investigator should compare window choices, attenuation, front-end filtering and dynamic-range behaviour to determine whether the faint structure is independent of the dominant source. This examination must begin with the possibility of analogue overload, because no digital window can recover an undistorted version of samples already corrupted by saturation or mixer nonlinearity.

A waterfall can also exaggerate spatial or temporal continuity through its chosen detector. Consider a one-second output row created from many individual FFT frames. A maximum detector preserves the strongest observed value at every frequency bin, even if those maxima occurred at different times within the second. The resulting horizontal row can resemble a broad simultaneous emission which never existed as such at any one instant. At one frequency the maximum may have occurred in the first millisecond, and at another it may have occurred near the end. Combining

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those maxima into one line is operationally useful for discovery, but it does not establish simultaneity across the plotted band.

A mean detector creates the opposite hazard. A brief pulse of large peak power may contribute very little to the average across a long period, particularly if the colour scale displays the result near the noise floor. In the simplest ideal case, a pulse present with duty fraction d and absent otherwise contributes average power d times its on-state power. The logarithmic display shifts that contribution by 10 log10(d) decibels relative to the on-state level when background can be neglected. A millisecond of activity in one second therefore appears thirty decibels lower as an average than as a peak. The source did not become thirty decibels weaker. The estimator answered a different question.

The problem of power calibration should therefore be stated in physical units and with the appropriate resolution bandwidth. It is not enough to say that an emission was 'bright' or 'faint'. State whether the plotted quantity is dBm in a defined analysis bandwidth, spectral density, a dimensionless normalised magnitude or a decision statistic. State the analogue reference plane and the attenuation or gain applied. If a later reader cannot translate the colours into an interpretable quantity, the image may still be useful as an investigative lead but is weak evidence for an exact emission level.

Finally, we should remember that each transform has finite time support, finite spectral selectivity and a noise distribution affected by the estimator. There is no uniquely truthful waterfall setting. A responsible analyst chooses a representation suited to the proposed physical claim, discloses its response and checks any material anomaly against the raw record and alternative explanations. A black-and-white numerical table may appear less

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captivating than a coloured spectrogram, yet it is often the table of exact parameters which allows an independent examiner to decide what the colours mean. I pass the token to Dr Nyquist for a challenge concerning apparently moving spectral lines and the limitations of a receiver's initial sampling chain.

Harry Nyquist | Peer question 5 to Ralph Beebe Blackman

Dr Blackman, a bright diagonal trace may appear to show a transmitter whose frequency is steadily changing, and a set of faint parallel lines may suggest several simultaneous signals. Yet each phenomenon might be influenced by a moving frequency-bin grid, front-end aliasing, local-oscillator instability or a receiver which swept several subbands in sequence. If the displayed samples have already passed through an insufficient anti-alias filter or a saturated mixer, changing digital windows will not correct the underlying defect. What minimum tests should be performed before the examiner reports a physical frequency sweep or multiple emitters, and what can a waterfall alone establish about these apparently coherent patterns? Please also consider a signal whose apparent diagonal slope changes when a different colour interpolation scheme is chosen. Would you require a direct estimate of instantaneous frequency from samples, with uncertainty, before permitting a statement that the emitter swept continuously rather than hopping between discrete frequencies?

Ralph Beebe Blackman | Immediate answer to Harry Nyquist

Dr Nyquist, a waterfall can establish that the selected processing chain produced a coherent time-frequency pattern. It does not, alone, establish that a unique external source produced the pattern or that

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the pattern has the physical interpretation suggested by its geometry. Before describing frequency drift, the examiner should confirm that the receiver observed the relevant band simultaneously, that its local oscillator and sample clock were sufficiently stable, and that frequency mapping did not change through retuning or interpolation. Check for image responses, aliases, spectral leakage and clipping. Each can create a shape that looks like a physical emission but follows the apparatus rather than an external source.

An instructive test is to change a controlled receiver parameter and predict how competing explanations should respond. A genuine external carrier, suitably within the admitted band and not disturbed by the test, should normally retain its external frequency when expressed at the correct RF reference. An internally generated spur may move with local-oscillator settings or persist with the antenna replaced by a properly terminated input. Such tests must be performed carefully because an antenna substitution or gain change can itself alter loading and interference. Their value lies in predicting distinct outcomes before performing the intervention.

For multiple apparent emitters, examine simultaneous complex-sample data if available and compare window functions and calibrated spectral estimators. Leakage from one strong tone should respond in predictable ways to window and bin placement. A front-end intermodulation product may change nonlinearly with attenuation. An alias may shift as the sample rate or receiver tuning changes. These differences can help distinguish hypotheses, but they require the relevant operating records and, ideally, independent

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measurements. A screenshot showing several coloured threads cannot provide those experimental controls after the event.

The conclusion should therefore be carefully bounded. 'The retained samples contain a feature whose centre-frequency estimate changed under a specified algorithm' is a narrower but stronger statement than 'the hidden transmitter swept its frequency.' Similarly, several displayed ridges may be described before they are attributed to several independent sources. I return the floor to Dr Shannon, whose concern is how much of this distinction can be recovered after only the visual product has survived.

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Claude Elwood Shannon. Principal response 4. The screenshot is a lossy communication channel from evidence to observer

Dr. Atkinson, one may consider the waterfall renderer as a communication channel whose input is a much richer technical record and whose output is a human-viewable image. This channel may be designed to convey operationally important patterns, but it cannot generally preserve all information in the complex samples. A pixel colour does not specify phase, and phase relationships may be essential for demodulation, direction-finding, fine frequency estimation or identification of sampling artefacts. Once complex spectral values have been reduced to magnitudes, an entire family of waveforms can become compatible with the same picture. Further reduction to an eight-bit colour index enlarges that ambiguity.

The loss is not necessarily an error. Engineers rightly compress and summarise data when the operational objective is to survey a large band for possible activity. The error appears when a later claim requires information which the chosen summary discarded. A spectrogram showing energy in a frequency cell cannot ordinarily establish the bits carried by a communication. A saved waterfall image cannot be reprocessed to recover arbitrary short transients below its temporal resolution. It may not even prove that the plotted neighbouring frequency bins correspond to energy present simultaneously if a maximum across several moments was used for each bin. The retained image is faithful only to the documented rendering operation.

We must trace losses along the chain. The analogue front end excludes frequencies outside its accepted passband and may distort those inside it. The converter quantises and samples the admitted waveform. A recorder

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may discard blocks, reduce precision or store only selected intervals. A spectral estimator multiplies finite windows, forms transforms and may retain powers while discarding complex values. A display processor selects and aggregates estimates, clips a dynamic range, maps the results to pixels and may add interpolation. At each stage different physical histories can map to identical downstream results. A later analyst cannot infer that those histories were identical at the receiver input merely because they share one final picture.

The distinction matters for reproducibility. If the full sequence of time-tagged complex samples is retained with adequate metadata, an independent analyst can regenerate several spectrograms, inspect transient amplitude in the time domain, compare windows, re-estimate centre frequencies and test whether an apparent feature remains under a different algorithm. Such retrospective work is still limited by original analogue selectivity, saturation, clock integrity and capture gaps. The samples do not grant an omniscient view of the antenna environment. Nevertheless they contain far more recoverable information than a picture of power alone.

Where only power spectral frames are retained, useful reanalysis remains possible within their boundaries. One can verify a threshold, examine a time series of computed powers or compare spectral shapes, provided the numerical frames, scale factors and timing are available. Where only a screenshot survives, one can examine its visible geometry and perhaps recover approximate pixel colours, but not a uniquely calibrated original power history unless the required mapping and processing metadata also survive. Reconstruction of a complex waveform from such an

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image is in general not unique. Many possible phase histories and many temporal distributions of energy fit the same displayed magnitudes.

A further problem is the false appearance of independence. Two images saved from the same source samples but rendered with different palettes do not constitute corroboration by two instruments. Two software algorithms may find similar features because they analyse the same artefact in the same digitiser. Two nominally separate receivers may share an overloaded distribution amplifier, common reference oscillator or harmful interference at the measurement site. Independent corroboration must be established through genuinely independent observation paths and a documented account of common dependencies. A duplication of display pixels is not a duplication of physical evidence.

A robust evidential package should therefore preserve the acquisition and processing layers in an ordered, checksummed archive. Include channel centre frequency, instantaneous bandwidth, actual sample rate, time-base quality, analogue gain and attenuation, saturation indicators, validity masks, dropped-sample counts, sample scaling, window coefficients, hop length, transform normalisation, aggregation policy and image palette. If one item is unavailable, record its absence rather than fill it with a later inference. A competent reviewer should be able to trace a selected pixel back to the transform values and sample ranges which contributed to it, where those underlying records remain.

This may sound demanding for a simple exploratory survey, but the required detail need not clutter every field display. Much of it can be captured automatically. The important point is architectural: a user interface meant for rapid human recognition should not be treated as the sole

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evidence store. Design the system so that the visual product points to a durable recording, not so that its graceful colours replace one. When an anomalous trace is later challenged, a preserved acquisition has the power to answer new questions that the original operator did not anticipate; a screenshot does not.

The appropriate forensic conclusion is not 'never trust a waterfall'. It is 'trust each layer for the proposition that layer can support'. The waterfall can be convincing evidence that a specified numerical pattern was displayed under a documented process. It can be an excellent signpost to a real radio-frequency event. It does not certify a complete physical history, the identity of an emitter or the continuity of an unseen transmission. I pass the token to Dr Blackwell for a question about inferential reconstruction from compressed records.

David Harold Blackwell | Peer question 6 to Claude Elwood Shannon

Dr Shannon, an investigator may have retained a timestamped matrix of power values, not the underlying complex samples, and may nevertheless estimate the likelihood of a particular class of modulation or transient event using a statistical model. It would be too sweeping to say that loss of phase forbids every meaningful inference. The question is how the inference should be qualified. If the power matrix is consistent with several distinct waveform histories, may the investigator still calculate a probability under an explicit prior or likelihood model, and what must be disclosed before presenting that figure as evidence? How does your distinction between missing information and valid inference apply when the model itself was selected because it made the displayed pattern appear familiar? If the analyst chose the prior distribution only

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after seeing the waterfall's shape, could the resulting posterior certainty be inflated by selection? I ask because the evidence must be capable of supporting a contested conclusion, not merely a model whose assumptions have been adjusted to flatter the observed picture.

Claude Elwood Shannon | Immediate answer to David Harold Blackwell

Professor Blackwell, loss of information does not make every further inference impossible. A known probability model can support classification or parameter estimation from a sufficient summary for the question at hand. The central requirement is that the claimed quantity be identifiable, or at least estimable with stated uncertainty, from the information actually retained under the model. If several physical explanations produce comparable power matrices, the posterior or likelihood comparison is conditional upon the candidate explanations, their modelling assumptions and any prior probabilities. It does not establish that the unmodelled alternatives were absent.

A statistical method using only spectral power can legitimately detect departures from a noise model, identify repeated energy patterns or estimate quantities that depend principally on second-order statistics. It cannot generally recover a unique phase history, and a claim about a specific transmitted message may require information never retained. The examiner should state the precise statistic used, the family of models compared, the manner in which its parameters were estimated and the validation data available. A calibrated classifier score is not a unique physical source identity merely because it is numerically close to unity.

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Where the candidate model was selected after viewing the waterfall, that discovery process must be distinguished from confirmation. The investigator can record the hypothesis, preserve the selected feature interval and test the hypothesis on independent sample blocks or later acquisitions, provided the validation procedure is appropriate to the claim. If only the original power matrix exists, a sensitivity analysis across plausible alternate models may still convey useful uncertainty. It must not be portrayed as an independent check of a model chosen to fit the same evidence.

Thus the correct position is neither that compressed data are worthless nor that elegant probabilistic inference replaces missing physical information. An inferential statement remains bounded by its model and the distinguishability of its alternatives. A reader should be told precisely what is directly visible in the retained power record, what additional features were inferred by statistical methods and which kinds of physical events could not be distinguished because phase or fine temporal structure was discarded. I yield the token to Dr Wald for the final examination of selection, thresholds and the hazards of a dramatic image.

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Abraham Wald. Principal response 5. A conspicuous picture can change the question after the evidence has been seen

Dr. Atkinson, the final hazard concerns not the Fourier transform but the decision process surrounding it. A security examiner begins with an objective: to determine whether a particular class of unexpected emission was present under specified search conditions. During the survey a striking waterfall feature appears. The examiner may then vary the threshold, frequency span, averaging depth, colour range and analysis interval until the feature looks more distinctive. This exploration may be entirely reasonable. Yet the resulting image is often presented as though those settings were selected independently of the outcome. If the number of examined representations is concealed, any later numerical claim of rarity risks severe distortion.

A decision rule cannot be assessed without its selection procedure. If an algorithm declares a positive event whenever a predeclared statistic exceeds a fixed threshold, the false-alarm probability may be estimated under a documented null model. If the human operator searches hundreds of images and chooses the most remarkable shape, the effective event is not 'a threshold crossing in one predetermined image'. It is 'the most conspicuous result obtainable among many searched settings'. The distribution of that maximum differs from that of one preselected statistic. A claim that a visual pattern is statistically extraordinary should therefore account for the search process or be tested with held-out data.

The familiar terms false alarm and missed detection are meaningful only for a stated event definition and observation envelope. What counts as one waterfall detection? Is it a bin above threshold, a connected group of bright

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pixels, a time-frequency ridge, or a transient with a particular duration and bandwidth? A detector that reports many overlapping bright cells as distinct alarms has a different false-alarm behaviour from one that consolidates those cells into one event. A change in colour palette may affect a human decision without changing numerical power, while a change in numerical threshold changes the detector itself. Both should be documented when a human judgement forms part of the evidential chain.

The same applies to the declaration of a negative result. An apparently empty waterfall may result from averaging which suppresses short events or from a display scale that paints low-energy features in the background colour. An acquisition with intermittent coverage may contain unobserved frequency-time regions which have nevertheless been filled by graphical interpolation. The report must distinguish 'the displayed map showed no qualifying feature under these settings' from 'the recorded samples contain no detectable feature under a specified validated analysis' and from 'no source emitted during the surveyed period'. These statements are not equivalent. Only the first may be justified by the image alone.

An examiner may improve the evidence by retaining both exploratory and confirmatory analyses. In the exploratory phase, allow varied window lengths, detection thresholds and display scales, but record the choices. Define a physical hypothesis from the observed pattern. In the confirmatory phase, apply a predeclared test to an independent portion of data or a genuinely new observation, taking care to preserve calibration and the relevant receive chain. If the pattern is a persistent internal spur, a controlled termination or attenuation challenge may distinguish it from an

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antenna-coupled external feature. The result should be reported with the limitations appropriate to the actual control.

Legal evidence should not be simplified beyond its strength. A clear, accessible figure can assist the reader greatly, particularly when combined with a calibrated axis and annotations showing the investigated interval. But the figure should not be detached from the samples, computations and instrument settings on which it depends. The chain of custody must include the digital recording as well as derived visual products. Hashes should identify the original files and subsequent derived versions. Reprocessing should leave an explicit record of software, parameters, input intervals and output identities. The purpose is not bureaucracy for its own sake; it is to preserve the possibility of an independent and adversarial examination of the result.

The investigator should take special care with a claimed source identity. A distinctive waterfall pattern can be generated by many radios sharing a modulation standard, by common environmental interference, by internal receiver processes and by deliberately constructed test signals. It may establish that a feature deserves directed inspection. It cannot uniquely attribute a transmitter without other physical evidence. Bearings, timing comparison, device response to controlled power events and independent receivers may narrow the possibilities, but each has its own uncertainties and possible common failures.

There is also a cost dimension. An overconfident declaration of an undiscovered transmitter may produce unnecessary expense or reputational injury, while a premature declaration that a room is clear may leave a genuine risk unexamined. Decision thresholds should therefore be

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connected to the intended use of the survey and the consequences of competing errors, without permitting those consequences to change the recorded physical observations. The evidential language should remain consistent: observed pattern, validated anomaly, plausible external origin and attributed device are different levels of claim. A waterfall is often useful at the first two levels and rarely sufficient alone at the fourth.

I would conclude that the strongest presentation is not the brightest screenshot but the one for which another examiner can reconstruct the path from RF input to retained samples, from samples to estimates, and from estimates to the displayed colours. Such a chain permits a challenge to the analysis without pretending that the analyst's original visual intuition had no role. Scientific integrity requires the intuition to be made accountable. I invite Dr Deming to test the practical requirements of that record before the moderator closes the question.

W. Edwards Deming | Peer question 7 to Abraham Wald

Dr Wald, many field teams operate under restricted time and equipment budgets. They cannot preserve every intermediate numerical array indefinitely, and their software may be designed primarily for rapid discovery rather than laboratory-grade archival recording. If we demand that every colour, transform and user action be reproducible for years, the resulting procedure may become too cumbersome to use in an ordinary protective survey. What minimum evidence package would allow a responsible engineer to distinguish an exploratory screenshot from a publishable finding? Is there a practical way to preserve the most valuable technical information without claiming a standard of completeness that the field apparatus cannot meet? Would you insist

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that the recorded summary include a test of the display's minimum detectable pulse duration, or is a calibrated threshold sufficient? A threshold may be measured accurately while the instrument remains blind to bursts that occur during processing dead time or between spectral frames.

Abraham Wald | Immediate answer to W. Edwards Deming

Dr Deming, proportionality is important, but proportionality must not be achieved through ambiguity. A field team can make a useful exploratory record with limited equipment, provided it does not claim that the record proves more than was measured. The minimum package begins with time, location, receiver configuration, frequency coverage, threshold and display settings, a record of valid and invalid observation periods, and the original digital artefacts actually retained. If a candidate event is found, preserve the highest-fidelity underlying acquisition available around that event, together with an independent description of the operator's observations and any subsequent interventions.

Where raw samples cannot be stored continuously, a system may maintain a rolling buffer and save the relevant interval on a trigger. The operator must document the trigger rule, pre-trigger interval, capture gaps and the possibility that events outside the buffer were discarded. A saved power matrix with full metadata is better than a bare screenshot; a screenshot with a calibrated legend and recorded settings is better than an undocumented image. These are graded levels of evidence, not interchangeable substitutes. The report should identify which level was achieved for each important finding.

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A practical validation procedure may rely on representative test vectors. Before the survey, process known signals of different durations, powers and frequency offsets to establish how the waterfall behaves. Preserve those results and the software version. After an apparent anomaly, use the same configuration to assess whether the displayed feature has a reproducible response. If the laboratory lacks the data required for one inference, mark that inference as unsupported rather than treating a more elaborate report as a substitute for missing acquisition.

This approach need not consume excessive resources. Automatic logging can record state changes and hashes without interrupting an operator. A system may archive full-fidelity data only for selected intervals while maintaining a continuous lower-resolution summary. The resulting report should distinguish coverage of the summary from coverage of the high-fidelity record and should not state that arbitrary waveforms can be recovered from the summary. A proportionate evidential package is one whose limits are explicit and whose important claims can be independently checked. I now respectfully return the token to Dr. Atkinson for the closing synthesis of the first fifty questions.

Dennis Gabor, Cross-Peer Question to John Wilder Tukey: Professor Tukey, a waterfall uses overlapping analysis windows and displays one short burst as five bright consecutive rows. What must the investigator do before counting five transmissions?

John Wilder Tukey, Cross-Peer Answer to Dennis Gabor: Dr Gabor, associate each row with its actual input-sample interval, transform window and hop

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size. The same physical samples can contribute to several rows, so the row count is a property of the display process, not a count of independent bursts. Examine the corresponding raw I/Q and group rows into candidate events using a predeclared rule validated against injected pulses. Report the graphical time support and group-delay convention, including any interpolation between rows. A visually sharp cluster may still represent a single transmission or an artefact triggered by an internal state change. Preserve the row-generation code and colour scaling so another analyst can reproduce the image. I pass the token to Mr Blackman on window response.

John Wilder Tukey, Cross-Peer Question to Ralph Beebe Blackman: Mr Blackman, how can a fixed colour scale and an unsuitable spectral window turn a weak intermittent signal into an apparently continuous bright line?

Ralph Beebe Blackman, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, the display may combine long integration, a taper with finite leakage, persistence, averaging or peak-hold rules. A strong nearby line can leak into adjacent bins; a slowly decaying maximum statistic can preserve colour after the input disappears. Conversely, adaptive autoscaling can make an unchanged noise floor appear to brighten or dim. Measure window coherent gain, equivalent noise bandwidth, display persistence and frequency response, and compare against a calibrated tone stepped on and off at known instants. Retain uncoloured power measurements and raw complex samples separately. A computer-rendered line should never be described as a continuously received carrier unless acquisition and temporal evidence support that chronology. I yield to Dr Shannon on information loss in a screenshot.

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Ralph Beebe Blackman, Cross-Peer Question to Claude Elwood Shannon: Dr Shannon, what information is lost when the only surviving evidence of a suspected emission is a compressed screenshot of a waterfall?

Claude Elwood Shannon, Cross-Peer Answer to Ralph Beebe Blackman: Mr Blackman, the screenshot may omit phase, unselected frequencies, time samples between redraws, absolute amplitude calibration, receiver mode, clipping indicators and the mapping from data values to pixels. Colour quantisation and image compression can further hide small differences. Many different underlying I/Q histories can generate visually similar pictures, particularly after averaging or interpolation. Preserve the original captures, spectral arrays, window parameters, timestamps and display settings, with checksums and a reproducible transformation chain. If only the image exists, limit conclusions to what the image actually depicts, with explicit uncertainty about source timing and amplitude. The apparent continuity of a line cannot repair missing acquisition intervals. I respectfully pass the token to Dr Wald on selection after viewing the image.

Claude Elwood Shannon, Cross-Peer Question to Abraham Wald: Dr Wald, the investigator has thousands of waterfall captures but publishes only the one exhibiting an unusually straight, bright line. What correction is required?

Abraham Wald, Cross-Peer Answer to Claude Elwood Shannon: Dr Shannon, report the selection process and the population of images examined. A conspicuous example may arise by chance when many correlated displays are searched. Calibrate a prespecified detection statistic using full representative acquisitions processed with the identical colour, window and persistence settings; do not assign a single-image probability to a frame

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chosen after inspection. An independent blind observation can test whether the physical signal recurs under controlled conditions. Keep rejected images and receiver state logs if evidential conclusions depend on comparison. The strongest single picture may be a useful lead, but it is not itself a frequency-standard measurement, a complete waveform record or a unique transmitter identification. I return the token respectfully to Dr Atkinson.

Dr. James M. Atkinson. Closing synthesis of Question 050

Colleagues, the fiftieth question concludes a significant foundational sequence in this programme, and its lesson ought to govern the treatment of every later receiver screenshot. A waterfall is a derived representation of a measurement process. It may be an excellent guide to anomalous radio-frequency activity, but it should never be mistaken for the complete record of what entered an antenna or even for the complete numerical content of the samples retained by the recording system. The question to be asked of each coloured pixel is not simply what it resembles, but which physical exposure, acquisition samples, numerical operations and rendering decisions produced it.

Dr Gabor has explained the joint limits on time and frequency localisation. A window spreads information across its duration, and overlapping windows may paint one physical burst across several rows. Dr Tukey has shown that zero padding, spectral scaling, frame aggregation and colour mapping affect appearance without necessarily changing the input signal. Dr Blackman has demonstrated how window sidelobes, scalloping, equivalent noise bandwidth and peak or average detectors may create false impressions of spectral multiplicity, temporal continuity or amplitude change. Dr Shannon has insisted upon the distinction between information

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preserved in a complex-sample archive and information discarded by a magnitude plot or screenshot. Finally, Dr Wald has exposed the selection bias that occurs when a particularly persuasive image is chosen from many unreported processing configurations.

A forensic report should document the complete time-frequency observation envelope. State the analogue reference plane, receiver passband, channel centre frequency, gain, preselector and any overload qualification. State the real sample rate, validity masks, clock reference and the exact intervals retained. For each spectral product, state window shape, effective duration, hop, normalisation, analysis bandwidth, detector, row aggregation and timestamp convention. For each rendered figure, state the colour scale, clipping, pixel decimation, interpolation and any automatic changes. Without such information, apparently similar waterfall pictures may represent different physical experiments.

The expert must also distinguish a recurrent signal from recurrent computation. One pulse can occupy several overlapping FFT windows, and multiple frequency maxima within one aggregated row need not have occurred simultaneously. A line appearing to move across the screen may be due to a genuine frequency sweep, but it can also follow a retune, oscillator instability, alias, bin-mapping error or display interpolation. The proper response is neither credulity nor dismissal. It is a sequence of controlled tests directed at the alternative mechanisms, using the highest-fidelity preserved acquisition when available.

Consider the moral weight of a negative report. When a waterfall looks dark, it is tempting to say that the monitored band was clear. Yet a dark region may represent a threshold, a clipped palette, averaged power,

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unobserved scanning gaps or a failure of the receiver to capture samples. A precise conclusion specifies that no qualifying display features were observed under a declared acquisition-and-detection policy. A broader assurance requires quantified coverage, characterisation of the relevant signal classes and an honest account of what would have escaped detection. A spectacularly high sample rate cannot by itself compensate for a narrow instantaneous bandwidth or missed acquisition intervals.

Consider equally the positive report. A bright trace does not identify a unique transmitter. An apparent burst count may depend upon window overlap and event grouping. Its apparent duration may reflect the time assigned to a peak-held row rather than the physical on-time of the source. Its apparent bandwidth may reflect a window's main lobe and leakage rather than the transmitted modulation alone. A reliable positive finding therefore proceeds from the preserved record through a reproducible analysis toward a bounded physical claim, with independent corroboration when attribution is sought.

The ten applications which follow are designed to separate simple arithmetic from the more demanding assumptions on which interpretation rests. A fourfold increase in FFT-bin count by padding is easy to calculate; whether the data can resolve two emitters depends upon the actual observation interval and estimator. A one-millisecond pulse spread across a one-second mean is easy to quantify; whether an operator should use mean or peak aggregation depends upon the detection objective. A time tag offset of a millisecond can be insignificant for one survey and decisive for a cross-instrument event comparison. Mathematical exactness is indispensable but does not excuse errors in defining the quantity being calculated.

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I therefore close this examination of the waterfall record with a rule fit for every advanced receiver laboratory: never allow the elegance of a representation to exceed the evidence supporting its interpretation. The original acquisition, the numerical transform, the visual display and the final inference must remain distinguishable and traceable. We have developed an account of what an instrument can measure, what an algorithm can show, and what a responsible examiner may properly say. Those distinctions also govern the earlier discussions of clock discipline, multisite observation and source localisation, where the accuracy of timing references may be far less secure than a persuasive display suggests. I thank each colleague for yielding and receiving the token with the careful courtesy appropriate to scientific disagreement.

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Ten worked engineering applications | Question 050

Application 1. FFT grid spacing versus analysis duration. Let f_s = 2.4 x 10^6 complex samples/s denote sample rate and N = 4096 the number of actual samples in a transform. The FFT bin interval is $\Delta f = f_s/N$ = 2,400,000/4096 = 585.9375 Hz. The window duration is $T_w = N/f_s$ = 4096/2,400,000 = 0.00170667 s, or approximately 1.707 ms. A displayed bin separation of 585.94 Hz does not alone establish the ability to resolve two nearby emitters; the chosen window and signal conditions also matter.

Application 2. Zero padding without added physical observation. Retain the same N = 4096 measured samples at f_s = 2.4 MHz, but append zeros to obtain an N_{FFT} = 16384-point transform. The new plotted bin interval is $\Delta f_{plot} = f_s/N_{FFT}$ = 2,400,000/16,384 = 146.484375 Hz. The physical observation duration remains 4096/2,400,000 = 1.707 ms. The grid is four times denser, but the observation carries no fourfold increase in independent frequency information. Zero padding can interpolate a spectral peak under a suitable model; it cannot recover an unrecorded interval.

Application 3. Overlap and distinct events. Suppose an FFT frame contains N = 4096 samples at f_s = 2.4 MHz, and the hop is H = 1024 samples. The nominal overlap fraction is (N-H)/N = (4096-1024)/4096 = 0.75, or 75%. Adjacent frame starts differ by H/f_s = 1024/2,400,000 = 0.000426667 s, or approximately 0.427 ms. One millisecond-long emission may influence several adjacent rows. Those rows are correlated

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summaries of overlapping input samples, not automatically separate transmissions or independent confirmations.

Application 4. Colour quantisation of a decibel scale. Let a renderer span L_{min} = -110 dBm to L_{max} = -30 dBm using 256 nominal evenly spaced colour levels. The total range is $R = L_{max} - L_{min}$ = 80 dB. If both endpoints are represented exactly, the nominal step between 256 level centres is $R/(256-1) = 80/255 = 0.3137$ dB. This number describes ideal uniform graphical quantisation, not instrument measurement accuracy. Actual palettes may be nonlinear or clipped, and power estimates carry calibration and estimator uncertainty independent of colour quantisation.

Application 5. Maximum aggregation hides duration. Suppose 1000 consecutive spectrum frames describe one second of genuine continuous acquisition, and only one frame contains a short strong pulse. If the software creates one waterfall row by taking a maximum over the 1000 frames, that row retains the pulse's high level. Its vertical height may correspond to one display second, yet the burst was present during no more than the particular short constituent frame. Without per-frame timestamps or raw samples, a reader cannot infer a one-second transmission from the bright row. Peak aggregation answers whether a large value occurred, not how long it lasted. For N = 1000 equally spaced frames spanning T = 1 s, each frame covers $\Delta t = T/N = 0.001$ s. One affected frame therefore supports millisecond-scale occupancy only, subject to its acquisition window and trigger resolution.

Application 6. Power averaging dilutes a short pulse. Let a signal transmit at on-state power P_{on} for b = 0.001 s within an interval T =

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1.000 s, with negligible power otherwise. The duty fraction is $d = b/T = 0.001$. The time-averaged contribution is $P_{avg} = d P_{on}$. In decibels, the difference is $10 \log_{10}(P_{avg}/P_{on}) = 10 \log_{10}(0.001) = -30$ dB. The thirty-decibel reduction is a consequence of averaging over silence, not a physical reduction in the signal's on-state power. Noise-floor and receiver response effects would modify an actual measurement.

Application 7. Temporal coverage with processing dead time. A monitoring instrument acquires a channel for $a = 0.015$ s, then cannot acquire relevant samples for $g = 0.085$ s, in a repeating 0.100 s cycle. Nominal coverage is $a/(a+g) = 0.015/0.100 = 15\%$. A randomly timed effectively instantaneous event has approximately a 15% opportunity to fall in an acquisition interval under ideal uniformly random phase and perfect sensitivity. A continuous-looking graphical update does not remove the 85% physical acquisition gap. The probability changes for finite bursts and nonuniform timing.

Application 8. Time tag semantics. Suppose an FFT uses $N = 8192$ real or complex samples at $f_s = 4{,}000{,}000$ samples/s. Its duration is $T_w = N/f_s = 8192/4{,}000{,}000 = 0.002048$ s, or 2.048 ms. If a plot labels the first sample time but a reader interprets the label as the centre of a symmetric window, the nominal centre discrepancy is $T_w/2 = 1.024$ ms. This is not necessarily the timing error of a detected pulse; precise estimation depends on its location and algorithm. It shows why time tag conventions must be recorded before comparing receiver events with external evidence.

Application 9. A clock-rate mismatch over a long capture. Let the receiver's assumed sample-clock rate be $f_0 = 10{,}000{,}000$ samples/s.

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Suppose its actual clock is higher by epsilon = 2 parts per million, so $f_{actual} = f_0(1+2 \times 10^{-6})$. If 600 seconds of actual samples are labelled using the nominal rate, the implied time-axis discrepancy at the end is approximately $600 \times 2 \times 10^{-6} = 0.0012$ s, or 1.2 ms, with sign depending on which axis is taken as reference. Clock error affects event alignment even when every waterfall row appears regularly spaced. Exact conversion must use the actual sample count and calibrated rates.

Application 10. Frequency pixel aggregation and simultaneous inference. Let $N_f = 8192$ spectral values be mapped into $W = 1024$ horizontal pixel columns. On average there are $N_f/W = 8$ spectral values per pixel. If the renderer uses maximum aggregation, the pixel reports the largest of those eight values, not their mean. If one plotted time row also takes per-bin maxima over 100 FFT frames, different frequency pixels may originate from different source times. Thus a colourful horizontal stripe can represent 8-to-1 frequency selection and up to 100-to-1 temporal aggregation without establishing simultaneous emission across the band. The actual implementation may distribute bins unevenly and requires the renderer's mapping log for reconstruction.

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TECHNICAL SOURCE RECORD. QUESTION 050

The following are contemporary editorial references, not works represented as known to the deceased participants:

1. ITU-R Recommendation SM.2117-0 (09/2018), *Data format definition for exchanging stored I/Q data for the purpose of spectrum monitoring*. Official identification and table of contents cover sample-rate, I/Q and scaling metadata. https://www.itu.int/rec/R-REC-SM.2117 and https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.2117-0-201809-I%21%21TOC-HTM-E.htm 2. ITU-R Recommendation SM.1880-3 (08/2026), *Spectrum occupancy measurement and evaluation*, in force at the time of drafting. https://www.itu.int/rec/R-REC-SM.1880-3-202608-I/en 3. ITU-R Report SM.2256-2 (06/2026), *Spectrum occupancy measurements and evaluation*. Its official table of contents distinguishes observation, revisit and integration times and addresses treatment of pulsed signals and measurement uncertainty. https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2256-2-2026-TOC-HTM-E.htm 4. National Instruments, *STFT Spectrograms VI* documentation, description of the time-resolution and frequency-resolution trade-off. https://www.ni.com/docs/ar-IQ/bundle/labview-api-ref/page/vi-lib/gmath/trans-llb/stft-spectrograms-vi.html 5. Tektronix, *Spectrum Analyzers* technical specifications, examples of trace detector and averaging choices, FFT lengths and displayed trace lengths. https://www.tek.com/en/datasheet/spectrum-analyzers

Evidence qualification: The worked calculations are hypothetical models, not measurements of any actual transmitter, antenna or receiver. Display and acquisition semantics must be verified against the particular system's firmware, processing implementation and retained metadata before a forensic conclusion is drawn. All five historical contributors' dialogue is entirely constructed.

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QUESTION 051

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When must RF arrival time be separated from a software timestamp at the host?

EDITORIAL CONVENTION: Original constructed educational dialogue moderated by Dr. James M. Atkinson. Historical contributors are used as intellectually situated analytical voices, not as actual participants in a later conversation or as sources of authentic quotations. References to modern SDR architectures, network protocols and software systems represent present-day editorial applications of their historically documented work. Every numerical example is hypothetical. All observational claims are conditional on declared instrument characteristics.

Dr. James M. Atkinson. Opening of Question 051

Distinguished colleagues, the problem before us begins with an apparently modest entry in a computer log. A screen displays the instant at which a receiver detected a brief emission, and the line appears to carry the precision of a metrological observation. Yet the timestamp may identify the moment a software routine copied an event record into memory, not the moment electromagnetic energy reached the receiving antenna. Between those occurrences lies a chain of physical propagation, analogue transformation, digital sampling, buffer allocation, device transfer, scheduler activity, clock conversion and file-system work. Every link has a chronology, and none acquires the chronology of its neighbour merely because the application presents one attractive number. A correctly synchronised host clock can state the host's time accurately while recording the wrong physical event.

The word *arrival* requires its own reference plane. An electromagnetic wave may intersect a defined antenna phase centre at time t_A. A voltage related to that field is then delivered through a feed line, filters, amplifiers

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and frequency conversion stages before an ADC samples the signal at some time t_S. Thereafter samples may enter programmable logic, cross a direct-memory-access boundary, join a ring buffer and wait for an application thread. The host may generate an indication at time t_H. The three quantities, t_A, t_S and t_H, are not interchangeable. If we assign t_H to the antenna event without knowing the intervening delay, the reported absolute time is potentially biased. If that delay varies with load, the reported time also carries jitter which an ordinarily stable RF source cannot explain. Importantly, a zero-delay assumption is itself a substantive measurement assumption and must appear in the uncertainty budget rather than conceal itself as a software default.

An appropriate measurement equation would distinguish known or estimated terms: $t_H = t_A + \tau_{prop} + \tau_{RF} + \tau_{acq} + \tau_{buf} + \tau_{host} + \varepsilon$, where τ_{prop} denotes propagation from a declared external reference to the antenna, τ_{RF} the group delay of the relevant analogue and digital front end, τ_{acq} the offset between the effective RF event and the chosen sample event, τ_{buf} the buffering and transfer delay, τ_{host} subsequent system and logging delay, and ε unmodelled error. Several of these quantities depend on frequency, receiver state or measurement definition; some are not independent. Conversely, if an acquisition unit records a hardware-anchored sample counter and trustworthy epoch reference, the chronology may be reconstructed from the sample index even when the host prints the event many seconds later. The document must say whether its time value was measured, calculated, inferred or simply copied from an application clock.

This question has a distinct bearing upon technical surveillance countermeasures. A narrow emission found simultaneously in two recorders

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might be used to suggest common origin, localisation or response to a controlled stimulus. An apparent delay of microseconds is physically meaningful only when the receiver chain is characterised at a comparable scale. A millisecond scheduling disturbance can dwarf the geometric delay across an ordinary building. Conversely, a continuously retained IQ stream can establish relative event order without providing trustworthy absolute UTC time. A well-founded chronology therefore requires two compatible descriptions: internal sample order and the means of relating that order to an external epoch. We must not inflate either description into the other.

I propose five complementary examinations. Dr David Lennox Mills will address clock synchronisation, protocol delay and the limitations of host time. Dr Edsger Wybe Dijkstra will examine the concurrent software system through which samples move. Dr Richard Wesley Hamming will test what digital signal analysis can and cannot establish about onset time. Dr Harry Nyquist will identify the distinction between sampling instants, timebase errors and analogue reception. Rear Admiral Grace Brewster Murray Hopper will close the principal discussion with software traceability, reproducibility and the evidential record. Seven colleagues will press specific objections, and each answer shall immediately follow its question. We shall conclude with a measurable acceptance test rather than a rhetorical assertion of accuracy. Dr Mills, I ask you to consider why an excellent network clock may nevertheless be a poor witness to the instant of RF arrival.

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David Lennox Mills

Dr Atkinson, the clock carried by an operating system has a real and essential purpose, but one must distinguish agreement between clocks from agreement between a clock reading and a physical occurrence. A synchronisation protocol exchanges information about selected transmit and receive events and estimates the relation of one clock to another. It does not, without further instrumentation, identify the time at which a voltage edge entered an arbitrary SDR front end. A software timestamp obtained in user space may occur after an interrupt is serviced, a packet is copied, a buffer is delivered and a thread is scheduled. Agreement of that clock with UTC, even to a fraction of a millisecond, leaves those intervals untouched. I would begin by drawing two axes: the clock's relationship to an external time standard and the measurement chain's relationship to the phenomenon. They are connected only by an observed or validated conversion.

The four-timestamp method familiar from network synchronisation illustrates the distinction. In the conventional exchange a client transmits at T1, a server receives at T2, the server responds at T3 and the client receives at T4. The offset estimate is $\theta = [(T2 - T1) + (T3 - T4)]/2$, while the round-trip delay estimate is $\delta = (T4 - T1) - (T3 - T2)$. Both calculations require assumptions about the meaning and placement of the timestamps. If transit is asymmetric, the inferred offset may be biased even when the arithmetic is flawless. If timestamps are generated after a variable software delay, they include that delay in the quantity being estimated. A receiver investigator who merely reads a host clock disciplined by such a protocol inherits its clock uncertainty and subsequently adds the SDR's own acquisition and

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processing uncertainty. Those are two separate budgets, not one number borrowed from the synchronisation display.

Contemporary network equipment may capture timestamps in a network interface or physical layer close to packet departure or arrival. Such hardware timestamping can reduce the variability introduced by software scheduling. However, a network interface's timestamp is still a timestamp of a network event, not automatically of an RF waveform crossing the antenna reference plane. The same distinction persists for a programmable receiver. Its FPGA may assert a counter value when an ADC sample crosses a hardware boundary; the utility of that value depends on the counter clock, its phase relation to the ADC, sample loss detection and knowledge of the analogue path preceding it. The instrument may provide a reliable local event index yet possess uncertain alignment to civil time.

A rigorous record should carry at least a sample-counter anchor, a declared clock domain, the time scale used for any epoch, the clock synchronisation state and the uncertainty in linking the anchor to that epoch. It should also preserve whether clock corrections were stepped or slewed. A host that changes its civil-time representation while samples continue arriving can yield apparently reversed timestamps or sudden gaps if software treats wall-clock time as a monotonic sample clock. An application may log the correction without correcting earlier events, or may rewrite historical display times under a revised offset. Either behaviour deserves disclosure. The physical samples do not travel backwards merely because a computer clock is adjusted.

Suppose an SDR acquires at two million complex samples per second and associates sample number zero with a properly captured hardware epoch.

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Sample forty-eight thousand occurs twenty-four milliseconds after that anchor, assuming the sample clock's mean frequency is exactly the stated value over the interval. A separate host log might be written twenty-nine milliseconds after the anchor. Subtracting the sample-derived interval from the host time provides an estimate of five milliseconds of cumulative latency for that observed event, provided the epoch paths share a legitimate reference. It does not prove that every subsequent event suffers exactly five milliseconds. A software transfer can be queued, a buffer can be resized and an operating-system interrupt can be delayed. One must study the distribution, its tails and its dependence on receiver configuration.

It is also useful to distinguish time accuracy, frequency stability, resolution and integrity. A clock can display nanosecond digits while possessing millisecond uncertainty; its resolution is finer than its defensible accuracy. A disciplined oscillator can hold excellent average frequency while undergoing an unrecorded phase step. A system may offer accurate ordinary timestamps while failing during a reference loss, leap-second transition, power interruption or holdover interval. These events must not be disguised by a single nominal specification. A confidence statement should be bounded to the exact reference state in which calibration occurred and should account for the period of the observation.

My recommendation is to make the measurement claim two-stage. First report the hardware sample chronology with its continuity evidence, including buffer sequence numbers and any missing-sample flags. Then report the mapping from that chronology to the external epoch, explicitly stating time standard, reference path, latency corrections and uncertainty. Where only host timestamps are available, label the value as the host's

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observation or logging time and refrain from retroactively calling it RF arrival. The resulting record is not weaker because it carries a qualification. It is stronger because the reader can distinguish a mathematical relationship that was tested from a timing assumption that remains provisional. I thank Dr Atkinson and invite Professor Kolmogorov to challenge the use of probabilistic models for the intermittent delay distribution.

Andrey Nikolaevich Kolmogorov

Peer question 1 to David Lennox Mills

Dr Mills, you distinguish synchronisation error from acquisition latency with admirable clarity, but your proposal to characterise the distribution of delay introduces a question of statistical population. Consider a host in which the overwhelming majority of buffers arrive within five milliseconds, while rare storage flushes or interrupt storms delay delivery by hundreds of milliseconds. An investigator collects ten thousand ordinary buffers and obtains a narrow histogram. That chart may look authoritative while excluding the very operating state in which the questioned event was captured. Moreover, the observed buffers may share a common scheduler regime, so treating them as independent repetitions will exaggerate the information. How would you bound the probability of a missed extreme delay without silently imposing a light-tailed probability law? Would you accept a direct hardware marker as an alternative, and how would you disclose those operating states that were not successfully exercised? If a small number of delayed transfers are themselves missing from the saved telemetry because the logging subsystem failed under stress, the empirical distribution would also be

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censored. How would your reporting method disclose such incomplete ascertainment, rather than quietly counting only those delays which software happened to record?

David Lennox Mills

Immediate answer to Andrey Nikolaevich Kolmogorov

Professor Kolmogorov, I would not infer a universal tail bound from a convenient run of quiet-host observations. The first obligation is to define the exposure: which processor loads, transfer modes, driver revisions, buffer depths, storage states and receiver gain configurations were represented? An empirical distribution is descriptive of those conditions. Treating it as a prediction for unobserved stressed conditions requires additional assumptions. A count of ten thousand deliveries may be valuable for estimating ordinary latency, but not for demonstrating that a rare hundred-millisecond delay is impossible. A zero count of a type of failure does not establish a zero failure probability.

For a forensic timing claim, I would prefer a direct physical marker that enters the acquisition stream at a declared reference point, coupled to an independently observed epoch. This can turn some uncertain software delays into quantities that are irrelevant to event time, because the physical marker and the questioned signal share the same recorded sample chronology. The design should still test for dropped samples and counter discontinuities, and must characterise any skew between the marker injection and the analogue signal path. A direct marker is not magic; it moves the calibration question to an earlier, more observable reference boundary.

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Where host time must be used, adopt deliberate stress experiments rather than relying upon random operating history. Apply processor and storage load, interrupt activity, receiver retuning and buffer saturation separately; preserve the raw timing measurements, not just their average. Report observed maxima as maxima of a specified trial, not as mathematical worst-case bounds. If a formal bound is wanted, define the model that produces it, state a confidence or coverage method appropriate to temporal dependence, and supply evidence for the assumptions. One may use quantiles or empirical extreme-value descriptions for exploration, but no such statistic warrants asserting an absolute limit on an adaptive or insufficiently observed operating system.

I would additionally protect the primary log from post hoc selection. A system which saves only events that exceeded a conveniently set threshold may contain a latency distribution conditioned on that trigger, and the resulting records cannot be treated as a random sample of all buffers. The number and timing of invalid acquisition intervals must remain visible. Calibration also needs separate acceptance criteria for ordinary operation and for disturbances; a system may pass one and fail the other. My conclusion is conditional and practical: direct acquisition-side timing is the preferred evidential basis; host timing may be used for a bounded proposition where the stated exposure, delay model and uncertainty permit it. I return the question to the moderator and invite Professor Jeffreys to test the logical leap from repeatability to accuracy.

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Sir Harold Jeffreys

Peer question 2 to David Lennox Mills

Dr Mills, imagine two acquisition systems which produce nearly identical host timestamps during a common injection trial. Their agreement may be highly repeatable, and a designer may call the result corroboration. Yet both systems could rely upon the same operating-system clock, the same trigger code or an incorrectly located physical calibration point. A shared latency would disappear in the difference while surviving in each asserted arrival time. From the standpoint of competing explanations, what observation would establish whether such agreement represents real temporal accuracy or a common systematic error? Should an investigator preserve a hierarchy of hypotheses, including clock bias, front-end delay, software timestamp placement and an actual propagation difference? I should also like you to distinguish the evidence required for absolute UTC accuracy from that required merely to rank the events chronologically within one recorder. A common external clock may likewise impart a systematic offset to both receivers, so apparent agreement could reflect common mode rather than independent validation. Please identify the independent physical reference that could expose this error without relying on the same network assumptions already under examination.

David Lennox Mills

Immediate answer to Sir Harold Jeffreys

Sir Harold, a pair of agreeing outputs provides evidence only about the relation between those outputs, until we identify the reference against which they are compared. Two instruments sharing the same

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mistaken epoch can agree to the last displayed digit and still misdate a physical event. A meaningful challenge must therefore change something that distinguishes the competing explanations. Compare an RF injection measured at the antenna reference plane with a separate hardware timestamp traceable through another path. Repeat with deliberately altered buffering, host load and clock synchronisation while keeping the physical injection fixed. If the reported time moves when the buffer depth changes, the software-timestamp hypothesis gains support. If it changes when the analogue filter is substituted, the front-end group-delay hypothesis deserves attention. If both systems shift together when their common reference changes, agreement alone has not provided independent corroboration.

I would not force all timing claims into the most demanding absolute-time standard. Within one continuous, uncompromised sample stream, the ordering of two event indices may be robust even though UTC mapping is uncertain. Their separation can be computed from the sample-index difference and the measured sample rate; its error then concerns clock rate, event-picking uncertainty and potential sample loss, not necessarily the host's absolute offset. A conclusion about whether an event preceded a door opening recorded in a separate system requires a cross-domain epoch relation. A conclusion about which of two RF bursts appeared first within one acquisition may require less, provided the same filter's delay and reference state apply to both.

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A report should therefore display a claim ladder. At the first level, there is an observed sequence of stored samples. At the second, the chronology of features extracted from those samples under a specified detector. At the third, a mapping from acquisition samples to an external epoch. At the fourth, comparison with independently clocked observations or a physical localisation model. Each step adds uncertainty and possible dependence, and none can be skipped by presenting a neat timestamp string. When the data support only the first two levels, the report should remain there without apology.

For each experiment I would preserve the rival predictions before the results are evaluated. Under a constant analogue delay, a filter replacement changes the apparent acquisition timestamp by a predictable amount; under a host-queue delay, changing the host load changes the logging time but not the sample-counter anchor; under a network offset fault, the displayed wall time shifts without altering the raw relative sample positions. Such separable predictions make the argument falsifiable. They also reveal when two explanations cannot be distinguished by the available instrument. My answer is that corroboration requires an independently placed reference and a discriminating intervention, not merely two similar numbers. I pass the discussion to Dr Atkinson and then to Dr Dijkstra, whose treatment of concurrency should clarify why a program's apparent order may differ from physical acquisition order.

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Edsger Wybe Dijkstra

Dr Atkinson, one of the most pernicious confusions in a concurrent acquisition system is to mistake the point at which a process becomes aware of an event for the point at which the event occurred. A well-formed program may be logically correct according to its specification while the specification quietly defines the wrong clock boundary. An interrupt handler is invoked after a hardware condition is asserted, but its execution is subject to priorities, masks and competing work. A user-space application may awaken only when a buffer or queue crosses a threshold. The resulting timestamp is an observation of software execution unless the data include an earlier hardware-anchored timing record. It may be consistent and entirely unsuitable for the physical claim imposed upon it.

I would begin with an explicit model of causality rather than a line of clock readings. The ADC samples the analogue waveform. A hardware controller commits those samples to a buffer. A bus transfer makes a descriptor visible to a driver. A driver informs an application, which processes and eventually writes a record. These operations are partially ordered by data dependence, yet their delays need not be constant. Modern CPUs may reorder certain operations subject to memory-order constraints; drivers may batch notifications; applications may share locks; and the file system may defer physical storage. The mere fact that a log entry appears after another entry does not prove that its associated RF event happened later. The definition of the chronological object must precede its logging implementation.

Consider a two-buffer acquisition. The sampling clock fills one block while software handles the preceding block. If each block holds 8192 complex

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samples at two million samples per second, acquisition of one block takes 4.096 milliseconds. A timestamp obtained when the block becomes available might represent its completion boundary, while a timestamp attached to a processing routine could occur still later. Assigning that one timestamp to the first sample introduces a nominal block-position error of 4.096 milliseconds even before queue latency. Assigning it to an event at an unknown position within the block creates an interval uncertainty bounded by the block duration only if the block indices and trigger placement are faithfully retained. Such errors are not repaired by a faster wall clock.

A correct design gives the samples a sequence identity independent of the host's handling of the sequence. Let block b contain samples $n = bN$ through $(b+1)N-1$, where N is the documented block size. If one knows the acquisition epoch associated with sample n_0 and the effective rate f_s, the computed time of sample n is $t(n) = t_0 + (n-n_0)/f_s$, before relevant cable, filter and detection corrections. Every processing routine should carry that identity rather than generate a new physical timestamp. Monotonic counters, overflow markers and sample-count checks are more useful than inferring continuity from file length. A purportedly seamless recording that silently loses one buffer shifts every later sample-to-time mapping if the software merely concatenates surviving bytes.

The investigator should distrust an implementation which cannot state whether its timestamp was assigned before or after a queue operation. Consider the familiar distinction between event-time and processing-time in data systems. The former belongs to a defined acquisition boundary; the latter to a stage of computation. In some applications processing time is exactly what the investigator wants, such as establishing when an alarm was

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presented to an operator. But it must not be renamed event time by an attractive display. A forensic report may legitimately show both: event at ADC sample index 3,400,000; alarm issued by the application at a later host timestamp. That paired account enables reconstruction of detection latency without contaminating the time of the underlying RF observation.

Concurrency introduces a second hazard: correlations between the observable delay and the phenomenon. A strong signal may trigger computationally expensive demodulation and therefore delay its own log record. High event density may increase queue occupancy, making later events appear still later. A filtering algorithm may examine a block of future samples before declaring an earlier event; its decision timestamp belongs to the completed calculation while the assigned event time should refer to the feature's independently specified position in the input. The distortion is then signal-dependent, not an additive constant. A single calibration performed with a simple calibration pulse may underestimate the latency experienced by complex or numerous events.

I would make the acceptance protocol adversarial in the engineering sense. Flood the processing queue without changing the RF injection schedule. Change buffer sizes while maintaining the acquisition clock. Induce a controlled driver restart, retune, sample-counter rollover and clock adjustment. The correct sample-derived event times should remain stable within declared tolerances, or a continuity fault should be explicitly recorded; meanwhile host processing and alarm times may change. An exception that silently supplies plausible output is more dangerous than a conspicuous refusal to issue a timestamp. The design should be capable of

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saying: *I do not know the epoch for this span*. That is a legitimate, and often necessary, state of a truthful measurement system.

Finally, reproducibility requires a precise interface contract. Define the semantics of every clock field, the conditions under which the value is valid, its resolution, units, wrap behaviour, clock corrections and calibration dependencies. Treat software versions and firmware hashes as part of the experiment. A later implementation with an unchanged display but changed buffering policy is not automatically equivalent to the previous one. A well-specified timing system should permit another competent engineer to rederive the event times from the preserved sample counters and anchors without relying upon the original graphical interface. I invite Mr Hewlett to examine the boundary between the hardware instrument and its software representation.

William Redington Hewlett

Peer question 3 to Edsger Wybe Dijkstra

Dr Dijkstra, the separation between event-time and processing-time is persuasive, but a designer may object that a hardware timestamp adds circuitry, complexity and potential new failure modes. Suppose a receiver supplies a free-running sample counter without a stable epoch, while a host keeps excellent time through an independently validated reference. Could carefully measured and repeated transfer latency establish a defensible mapping between the two clocks? Under what circumstances would the inexpensive architecture be adequate for a monitoring mission, and when would it be scientifically irresponsible to claim microsecond arrival times? I am particularly interested in hardware interface delays, retuning sequences and whether the clock-domain

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crossing itself becomes a source of uncertainty that cannot be removed by simply averaging more host timestamps. Suppose further that an application treats the timestamp of the most recently completed transfer as the acquisition epoch for the next one. This would create a deterministic lag even when the driver never loses a byte. What test would distinguish that implementation error from true sampling-clock drift?

Edsger Wybe Dijkstra

Immediate answer to William Redington Hewlett

Mr Hewlett, an architecture should be judged by the measurement claim it can support, not by whether one of its subsystems appears sophisticated. A free-running sample counter and a well-maintained host clock can be sufficient for many practical conclusions. They may establish the relative ordering of bursts and, with a measured sample-rate uncertainty, the separation between them. If the desired absolute time tolerance is loose compared with the observed distribution of transfer and scheduling latency, a calibrated host mapping may be useful. Yet the uncertainty statement must include the latency's systematic component, its dependence on operating state and the clock-domain translation. Averaging repeated transfers reduces uncertainty in the average only under a suitable stochastic model. It does not remove a fixed bias or an untested shift after a driver update.

The clock-domain crossing deserves a first-class place in the interface specification. An asynchronous event transferred into a synchronous counter domain may be observed on one of

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neighbouring clock edges; a synchroniser reduces metastability risk but can add finite, occasionally state-dependent latency. A sampled hardware flag may identify an event only to the resolution of a specified clock period. If an FPGA associates a sample counter with the ADC data path, its interpretation must be stated relative to the actual ADC aperture and data pipeline. These costs are often far smaller and more controllable than those of user-space scheduling, but they should still be measured rather than assumed away.

Retuning is particularly important. A synthesiser may temporarily lose lock, a front-end filter may change group delay, and an SDR driver may flush queued samples before accepting new ones. Even when the sample counter continues monotonically, its relation to the RF input may be invalid during such a transition. The correct response is to record the transition as a stateful measurement interval, perhaps with a validity mask, rather than to imply that continuity of counting proves continuity of observation. Where a receiver is not continuously observing the intended channel, a precise timestamp of what it did record cannot establish what occurred in the unobserved interval.

I would use a graded acceptance criterion. For minute-scale occupancy comparisons, the controlled host mapping may be adequate if the clock's drift, queue effects and acquisition coverage are bounded at a much smaller scale. For distinguishing two events separated by tens of microseconds, an architecture with millisecond transfer variability is inadequate absent a hardware sample chronology that removes that variability from the estimate. For time-difference localisation, both physical reference planes and every

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differential timing error become critical; the tolerance should follow the geometric accuracy required, not the software clock's number of digits.

Thus I do not insist upon one universal hardware design. I insist upon an explicit contract showing exactly which physical event a timestamp names, together with tests that can expose a false claim. A low-cost instrument may be excellent if its conclusions remain within its demonstrated capability. A costly instrument may be misleading if it labels the host's callback time as the instant energy reached the antenna. Thank you for the challenge, Mr Hewlett. I pass the discussion to Dr Hamming to examine the time introduced not by scheduling but by the signal-processing algorithm itself.

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Richard Wesley Hamming

Dr Atkinson, an investigator who asks for the time of a received pulse must first identify what feature of the waveform is intended by that word. The first nonzero sample, the crossing of a threshold, the maximum of a filtered envelope, the centre of an energy distribution and the estimated arrival parameter in a fitted signal model can occur at different times. Their differences are not necessarily instrumentation failures. They follow from the detection rule and the properties of the signal. One may faithfully sample a bandlimited waveform and still obtain a biased event time if the algorithm assigns a peak position without accounting for its filter, detection window or search procedure. I should therefore separate the acquisition clock from the estimator and ask what property each makes observable.

A conventional finite-impulse-response filter forms an output by combining present and earlier input samples. A linear-phase FIR filter of length L has constant nominal group delay (L−1)/(2f_s) seconds where f_s is the sample rate, provided we are describing the relevant passband and the ideal linear-phase operation. For an odd-length 75-tap filter at four million samples per second, the delay is 37/4,000,000 seconds, or 9.25 microseconds. The output may emerge later than the input feature in the indexed data even if the host processes every sample instantly. A real analogue front end may contribute additional frequency-dependent group delay. A zero-phase filter applied offline may appear to remove the delay in a plot, but its use of future samples means the resulting estimate is not a causal real-time detection and cannot be treated as such.

Time of arrival is often an estimation problem rather than a timestamp-reading problem. Let a known reference waveform s(t) arrive with unknown

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delay τ and amplitude a in additive noise. One can compare the recorded samples with shifted versions of s and estimate τ by the delay maximising a suitable likelihood or correlation criterion. Under stipulated noise and waveform assumptions, the estimator may perform well. But an unknown signal shape, clock mismatch, multipath, clipping or band limitation changes the inference. The peak of a correlation output is a property of the data and the assumed template. It does not certify a unique physical emitter, a single propagation path or a correct antenna epoch. Detection and attribution must be kept apart.

The sampling theorem should be applied carefully here. Sampling at frequency f_s establishes observations at intervals $T_s = 1/f_s$ in the selected sampling clock domain. It does not imply that every event's arrival is known only to one whole sample, because interpolation or model fitting may estimate a fractional-sample offset under appropriate bandwidth, signal-to-noise ratio and model assumptions. Equally, it does not entitle the engineer to report infinitely fine timing precision merely because interpolation can produce many decimal places. A fitted fractional delay inherits uncertainty from noise, bandwidth, template mismatch and clock calibration. A rate error of two parts per million over forty seconds accumulates an eighty-microsecond time-scale error if uncorrected. Such a bias can exceed the nominal fractional-sample precision by orders of magnitude.

The digital boundary may move with instrument configuration. A channeliser, decimator or resampler can change the mapping between input sample indices and output indices. If the output rate is $f_{out} = f_{in}/M$ for integer decimation M, the output's position cannot be translated into physical acquisition time without retaining the filter delay and the phase of

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the decimator. Some samples are discarded because their contribution has been represented in the filtered output; that is not the same event as accidental loss of an input sample or a broken chronology. An acquisition record ought to preserve the transform graph and its initial states, so that a later examiner can identify precisely which input interval contributed to a reported decision.

I would also require the detector's triggering rules to be documented. A rising-edge threshold may fire earlier for a large-amplitude pulse than for an otherwise identical weak pulse, a phenomenon often called time walk. A detector that integrates over a fixed block reports the interval within which the evidence accumulated, not necessarily the start of a brief event. An FFT-based transient detector may create a timestamp at the middle of a window, at its beginning or at the time a window is complete. All three can be legitimate bookkeeping conventions, but they differ and must not be mistaken for a physical observation in the absence of calibration. We should test each with a controlled injected waveform whose onset and spectral content are known at the stated reference plane.

For an investigative report I would preserve both a raw input chronology and a method-specific feature chronology. The raw record includes sample rate, counter continuity, acquisition epoch and instrument state. The derived event record includes the detector, its filter coefficients, analysis window, threshold, interpolation method and time-origin convention. If an independent analyst changes the detector, the derived event time may change, while the raw sample chronology remains a common basis for comparison. That is not necessarily a contradiction: two methods may estimate different features. The report should declare which physical

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question was asked. Was the examiner seeking the earliest measurable arrival, a representative centre, or the peak of a standardised reference waveform? These propositions have different uncertainty budgets.

Finally, let us not use a computationally impressive plot to conceal the location of the measurement. A signal-to-noise improvement through matched filtering may make a weak feature more detectable and allow better delay estimation under the model, but it cannot recover information never admitted by the analogue front end. If the receiver sampled an aliased or clipped representation, the filter may produce a clean-looking response to an erroneous observation. The decisive challenge is to vary the physical injection delay by known increments and verify that the estimated event time follows those increments within a stated uncertainty, across realistic signal strengths, receiver states and interferers. I pass the floor first to Professor Gabor, whose work on time-frequency representation provides a useful warning about the meaning of a plotted event centre.

Dennis Gabor

Peer question 4 to Richard Wesley Hamming

Dr Hamming, your distinctions are persuasive, but an investigator may ask for one timestamp from a spectrogram without possessing the reference waveform that your ideal correlation model assumes. The windowed transform assigns spectral energy to a sequence of overlapping time cells, and the time displayed for a cell may depend upon whether the software labels its leading edge, centre or final sample. A short event can colour several adjacent cells, particularly when a long window has been selected to resolve closely spaced spectral components. How would you formulate an evidential time interval from

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such a representation without implying a single objectively observed onset? If a later analyst selects a shorter window and reports a different onset, is that a measurement conflict or a predictable consequence of the representation? I ask especially how one should preserve and express the uncertainty caused by the window geometry. I also wonder whether two different amplitude thresholds should be represented as alternative measurement definitions rather than competing estimates of the same onset. Otherwise a signal-dependent time walk might be mistaken for a physical change in propagation, especially at low signal-to-noise ratios.

Richard Wesley Hamming

Immediate answer to Dennis Gabor

Professor Gabor, the time coordinate attached to a spectrogram cell is part of the representation's definition. If a window covers N consecutive input samples at rate f_s, its nominal duration is N/f_s seconds, and any single label must choose a convention. A centre timestamp is useful for plotting because it places a symmetric window near the middle of its support. It does not assert that energy first reached the input at that instant. If the detected feature was confined to one portion of the window, the centre can be substantially later or earlier than its onset. Spectral smoothing and leakage may colour neighbouring bins and frames, so the appearance of a coloured pixel cannot be read as a physical edge without a declared decision procedure.

I would distinguish the *support of observation* from the *estimate of onset*. The former is the interval of raw input samples that contributed

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to the visual cell, enlarged where necessary to account for filters or reconstruction windows. The latter is the output of a stated estimator that attempts to locate an event within or near that support. If the waveform is unknown and the instrument retains only magnitude spectra, the onset may be unidentifiable to a precision narrower than the observation interval. If the instrument retains the complex sample sequence, a later analyst can apply a family of onset detectors and report their sensitivity to threshold, model and noise. The revised estimate is not automatically a contradiction of the earlier display; it can be a refined claim made from richer evidence.

An example may clarify this. At f_s = 2,000,000 samples per second, a 4096-sample window spans 2.048 milliseconds. If the software labels its centre, the difference between the label and an event occurring at the earliest sample of the window is approximately 1.024 milliseconds. That is a coordinate convention, not a stochastic uncertainty. A claim that the onset is within a much narrower interval requires information from the sample data and a tested algorithm. If the window overlaps its successor by 75 per cent, the abundance of colourful frames does not create independent physical acquisitions. These frames depend heavily on common samples.

I would retain the precise window definition, hop size, sample-counter origin and the unaltered underlying IQ data where permitted. Every time coordinate should be accompanied by its convention. A forensic report might say that energy consistent with the declared detector was present in the sample interval from t1 to t2, and that a specified onset estimator returned t_hat with an uncertainty

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conditional on its validated model. The words *consistent with* matter because they acknowledge alternative interference or artefact explanations. If two models disagree, describe the disagreement and test it against known injected transients rather than averaging two incommensurable timestamps into an apparently precise number.

This approach preserves the useful distinction between frequency resolution and temporal localisation. A long transform window can improve discrimination of close spectral components while blurring the start and end of an event. A shorter window may resolve the event in time while reducing frequency selectivity. The best representation depends on which measurement question has priority. A conscientious examiner must resist allowing the visual smoothness of the display to dictate the meaning of the physical event. I return the token to Dr Atkinson and invite Sir Martin Ryle to question how these uncertainties affect observations from geographically separated receivers.

Sir Martin Ryle

Peer question 5 to Richard Wesley Hamming

Dr Hamming, consider a synchronised pair of receivers separated by a substantial distance, both observing the same brief emission and retaining their input samples. Suppose each receiver uses a different analogue preselector and a different digital decimation filter. Their software clocks are exquisitely aligned, and their spectrograms show apparently simultaneous peaks. Yet the effective group delays may differ by several microseconds, while an actual propagation difference of one microsecond would correspond to hundreds of metres of path

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difference. What would you require before interpreting the observed peak separation as evidence of geometry? Would an injection through the antenna connectors suffice, or would antenna phase centres, cable dispersion, multipath and direction-dependent response need separate treatment? I should also like to know when two apparently independent estimates share a common error source through their synchronisation system. The calibration may also depend on the direction from which the wave reaches the antenna and the frequency within its passband. Could you specify which terms are transferable across observation states, and which require a renewed calibration before the geometry is interpreted?

Richard Wesley Hamming

Immediate answer to Sir Martin Ryle

Sir Martin, the geometrical inference depends upon the difference between arrival times at declared physical reference planes, and an equality of software timestamps supplies no such guarantee. First reconstruct a time estimate in each instrument from hardware sample indices and valid clock anchors. Then correct the measured differential delays of their respective analogue filters, mixers, sample paths and event estimators. An injection at the receiver connector is useful for calibrating much of the internal chain, but it does not characterise antenna phase-centre displacement, cable lengths or the directional and frequency-dependent response of the complete receiving assembly. These must be included in the defined measurement system if the intended claim starts at the antenna.

For a simple far-field propagation argument, a one-microsecond time-difference error corresponds to roughly three hundred metres

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of differential path length in free space. This is not automatically a three-hundred-metre location error, because the geometry of intersecting arrival-time surfaces can amplify or reduce the resulting position uncertainty. It nevertheless shows why uncorrected microsecond-scale receiver delays cannot be ignored. A twenty-microsecond jitter in host logging would correspond to a six-kilometre difference in free-space path length before geometrical dilution. One ought not present a localisation derived from such a clock field as though the antenna arrival times had been observed with microsecond accuracy.

A carefully executed challenge would include both common-input and spatially defined tests. Feed a calibrated signal into each receiver through characterised injection cables, establish the relative delay of the electronic chains, and then use a known transmitter geometry to examine the assembled antenna systems. Introduce deliberate changes to one filter and then one clock source to identify whether the inferred time difference follows the predicted perturbation. Preserve the raw waveforms so that a common timing algorithm can be applied to both, and record where frequency-dependent delay corrections are evaluated. Multipath can produce multiple plausible correlation peaks, so the uncertainty statement should encompass alternative arrival paths where the data cannot resolve them.

Finally, shared clocks may create correlated error. If both receiver sample counters are disciplined by the same imperfect reference, an error common to both may cancel in a time difference, but a branch-specific delay or phase step may not. If the analysis uses absolute UTC

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events from different network paths, asymmetric delay and reference-state faults may reappear in the difference. A covariance term is warranted when uncertainties are dependent; blindly taking a root-sum-square of marginal uncertainties can give a misleading result. I would report the geometry, the calibration hierarchy, and the range of location solutions permitted by the remaining timing uncertainties. The physical claim should never exceed the measurement's actual reference-plane control. I pass the floor to Dr Nyquist for the clock and sampling perspective.

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Harry Nyquist

Dr Atkinson, our concern becomes more tractable when the engineer gives an exact definition to the sampling instant. A discrete data sequence is indexed according to the clock which controls conversion. The indices represent a succession of measurement apertures, and the interval between them is governed by the sampling timebase. They do not come pre-labelled with civil time. If the sample rate is f_s, the nominal period is $T_s = 1/f_s$, but the realised spacing contains frequency deviation, phase noise and perhaps a discontinuity from a clock reset or a lost sample. A display that assigns calendar timestamps to these indices must supply the relation between the sample clock and the chosen epoch. Without that relation, a beautiful digital sequence is internally ordered but not absolutely dated.

We should distinguish the centre of the ADC sampling aperture from an idealised instantaneous observation. In a sample-and-hold system the converter responds over a finite interval, and the aperture's precise relation to a trigger or external reference may vary. Aperture uncertainty can impair the amplitude fidelity of fast analogue signals and the timing of their sampled representation. The location of the effective sampling instant may be characterised, but should not be assumed equal to the location of a hardware trigger pin or the time a digital word is delivered by the converter. A pipeline ADC can deliver a word several clock cycles after the analogue aperture without altering the time at which the sample was physically formed. One must label the pipeline latency and avoid assigning delivery time to acquisition.

Clock frequency error is another independent quantity. Suppose an SDR uses a nominal sample frequency of four million samples per second but its

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realised rate differs by two parts per million. Over forty seconds the potential accumulated timing error relative to an ideal rate is approximately eighty microseconds, if the offset remains constant with that sign. The error does not grow because the host is slow. It grows because the conversion clock's scale differs from the reference scale. A timestamp derived from sample number n must either use the measured sample rate, track the timebase corrections or carry this drift as uncertainty. The sign and temporal behaviour of the error matter; a continuously disciplined sample clock may not have a constant offset across the interval, and a phase step can be more consequential than a slowly changing average frequency.

The analogue chain can change where an RF feature appears in the digital record. A narrow preselector may introduce dispersive delay that varies over the signal's bandwidth. The event's arrival at an antenna and the location of a pulse peak at the filter output can therefore differ in a waveform-dependent fashion. If the spectrum of a burst changes, the filter's effect on the temporal peak may change even though no physical propagation delay has changed. Inverting the estimated response may help under adequate signal-to-noise ratio and a properly identified model, but it may amplify noise and cannot recover information suppressed below the measurement system's sensitivity. The instrument's frequency response and group delay belong in the timing calibration of the relevant event class.

It is useful to have separate timing layers. At the first level, samples bear an integer index and an acquisition validity state. At the second, a clock model maps those indices into a continuous local time coordinate, possibly accounting for fractional delays and known clock drift. At the third, a measured reference relation maps the local coordinate into an external time

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scale. At the fourth, corrections place the estimated waveform event at the selected antenna or propagation reference plane. This layered method avoids the tempting, but erroneous, idea that because a receiver can label the hundred-millionth sample precisely it must know the time of its arrival in UTC equally precisely. Indexing, calibration and physical attribution are logically distinct.

A detector's latency also has two dimensions that should not be mixed. Its computational latency is the delay between the availability of sufficient input samples and the issuing of a decision. Its physical event-time bias is the difference between the declared feature's actual input time and the event time estimated from the processed data. A detector may spend a second performing offline analysis and still produce a defensible earlier event timestamp, because the underlying sample indices are retained. Conversely, an alarm generated within a millisecond may assign the wrong epoch if it mistakes callback time for a filtered pulse's onset. Speed of decision is not identical to accuracy of temporal attribution.

I would make continuity part of the reported evidence. If a 4096-sample block is missing at two million samples per second, a recording that closes the gap without a loss marker compresses the apparent time axis by 2.048 milliseconds. Later events will all appear too early relative to an unbroken sample counter. One may not repair this by resampling the surviving stream to fill the missing samples with interpolated values and then treating those as original observations. Interpolation may produce a useful display or estimation under a model, but it does not recreate the historical waveform uniquely. A gap should remain a gap in the evidential chronology.

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The decisive experiment must vary one timing factor at a time. Sweep signal bandwidth to reveal waveform-dependent filter delay, vary the sample clock under a measured reference to expose drift, change the block size to expose host-label bias, and introduce a deliberate dropped sample to test continuity detection. A valid system should either follow the predicted behaviour or declare that its timestamp is not supported under that state. The best acceptance standard is not an immaculate clock display, but a demonstrable mapping from physical input event to sample index and from sample index to the external epoch, with each uncertainty included. I respectfully invite Dr Ramsey to challenge the distinction between long-term timebase agreement and short-term phase continuity.

Norman Foster Ramsey Jr.

Peer question 6 to Harry Nyquist

Dr Nyquist, consider a receiver whose sample clock is disciplined by a highly stable frequency reference. Its measured long-term frequency error is exceptionally small, and the operator therefore asserts that every sample is accurately positioned in time. Yet a receiver may suffer a short phase step when a synthesiser reacquires lock, or an individual timestamp pulse may be transferred through a clock-domain boundary with one-cycle ambiguity. These defects can be almost invisible in an average-frequency figure. How would you frame a test which reveals them while preserving the distinction between oscillator stability, epoch accuracy and sample-clock phase? In a two-receiver comparison, under what conditions might a common reference conceal a correlated phase error instead of providing independent assurance? I should also like to know whether reporting Allan deviation alone would suffice for the

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forensic claim. If the oscillator has been steered, the instantaneous phase relationship during an individual burst may be poorly known even when the average frequency appears correct. Please address how calibration markers should bracket the event and how clock-state changes should be represented in the archived chronology.

Harry Nyquist

Immediate answer to Norman Foster Ramsey Jr.

Dr Ramsey, a good long-term average frequency is not a sufficient description of the temporal placement of every sample. Frequency stability concerns changes in the rate of phase accumulation over specified observation intervals; a sudden phase step may leave a small effect on a long-term average while corrupting the chronology around the discontinuity. A measurement intended to date short RF bursts must record or constrain the phase relationship at the moment of interest, not merely the fractional frequency averaged over hours. Allan deviation and related stability statistics provide valuable characterisation over different averaging times, but they are not a complete account of epoch alignment, discrete phase jumps or transfer-path errors. A statement of stability therefore needs separate tests of continuity and of traceability.

One approach is to distribute a reference event whose physical timing is observed independently of the receiver under test. Compare the sample counter at successive reference pulses with their independently measured epochs. Plot the residual versus time and retain the unaveraged sequence so that a phase step is not smoothed into an apparently benign drift coefficient. Then interrupt the

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reference deliberately, induce a synthesiser relock and observe whether the system flags the transition. The step magnitude, direction and duration should appear in the record. If the sample counter is reset, the mapping must explicitly identify a new segment rather than silently joining before-and-after indices.

In a two-receiver system, a common reference can reduce differential frequency error, but it also provides a common path through which faults can propagate. Suppose both instruments receive the same erroneous time pulse and their logged epochs shift together. A comparison of their timestamps may show excellent agreement while the absolute physical time is wrong. Alternatively, unequal cable lengths and distribution amplifiers can introduce branch-specific delays so that the two clocks are not even correctly aligned to each other. The calibration must characterise the common source, the distribution branches and the receiver timestamp path. When uncertainty components share a cause, the covariance should be retained rather than pretending that the two errors are independent.

I would therefore publish an observation-period-specific clock-state register. It should record the applied reference, lock status, loss-of-lock events, phase residuals, sample counter transitions and any clock steering operations. Where a discontinuity is detected, segment the record and refrain from assigning a precise absolute time across the unresolved boundary. Where the record is complete, construct the sample-to-epoch mapping from measured anchors and describe its uncertainty in each interval. A constant nominal frequency value may

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be retained as instrument metadata, but it should not silently substitute for the observed timebase history.

The practical benefit is that the investigator can defend both a positive and a limited negative finding. If the calibration proves that the phase remained within stated bounds during the relevant event, a time-difference claim may be justified. If an unrecorded reference interruption prevents the bound, a later calculation should not disguise the missing evidence with digits borrowed from an oscillator catalogue. The science concerns what the instrument actually measured. I return the token to Dr Atkinson and invite Rear Admiral Hopper to examine how the software and evidential record should retain these distinctions for subsequent reviewers.

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Grace Brewster Murray Hopper

Dr Atkinson, the most persistent danger in software-assisted measurements is that a program converts one kind of information into another without making the conversion visible to the user. A field labelled *timestamp* may carry an operating-system wall-clock read, an ADC counter value, an estimated arrival time, a processing-completion time or an exported file's creation date. Each is a legitimate datum for some purpose; none automatically answers every chronological question. The software designer's obligation is therefore not merely to store a number but to make the number's semantics reproducible. A forensic examiner should be able to ask what produced this value, which physical event it purports to describe, which transformations intervened and which software and firmware versions performed them.

I would insist upon a structured acquisition record. At a minimum, identify the receiver and channel, its tuning state, antenna and reference planes, the raw sample interval, the counter domain, the clock source and synchronisation state, the firmware version, the driver version and the mapping from sample index to the relevant epoch. Record the declared uncertainty and the calibration source in a machine-readable form. An application which offers only a formatted date and a frequency leaves too much to guesswork. Another engineer may reproduce the display yet be unable to reconstruct which sample actually supported the alarm. Good documentation must therefore preserve the chain from physical observation through digital representation to the evidential claim.

The distinction between event-time and log-time should be present in the data model rather than left to a user-interface convention. I would use

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separate named fields for sample_counter, sample_epoch, sample_clock_domain, derived_event_time, host_receive_time, host_log_time and time_uncertainty, together with the provenance of each field. A null or explicitly invalid value is preferable to a plausible invented timestamp. If the host was restarted, its clock stepped, the SDR retuned, or a buffer lost, a validity flag should survive every export. A database which permits a missing time value to be replaced silently by the current time is unsuitable for primary evidence unless that behaviour is prevented and verified.

Software revisions deserve scrutiny because the same data can acquire different timestamps when the algorithm changes. A matched filter whose coefficients are modified may shift its response peak. A driver which changes its block callback behaviour may alter host latency. A graphical program which changes from beginning-of-window to centre-of-window labels may move every displayed waterfall event by a half window even though the input samples are identical. These transformations must be treated as part of the instrument's measurement function. A reproducible record includes an algorithm identifier, parameter set and versioned processing history, so that an independent examiner can apply the same operation and obtain the same output or explain a difference.

The preservation policy should distinguish raw evidence from derived material. The original IQ blocks, counter anchors, reference-state logs and discontinuity records should be protected against undetected alteration using suitable integrity controls. Derivatives such as threshold detections, time-frequency displays and revised clock mappings should be linked to that original record without replacing it. A cryptographic digest can establish that retained bytes have not changed since the digest was created, but it does

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not prove that the original measurement was accurate or that a timestamp's reference plane was correctly declared. Chain of custody governs who handled the evidence; measurement traceability governs what the evidence means. The two should support one another without being conflated.

Consider an observation in which a short burst is visible in the original samples at index 1,200,000, and the software log records an alarm some milliseconds later. If a later analyst reconstructs the event time using a corrected sample-clock model, the revised time should be stored as a new derived claim, with its method, inputs and authorisation. The original log entry should remain available for comparison. If the corrected mapping changes a previously issued report, record the change and the reason rather than silently replacing the earlier value. A system which cannot distinguish current interpretation from original observation is difficult to audit even when its numerical calculations are correct.

I would test the software by deliberately presenting it with abnormal data and operating states. Give it a counter discontinuity, an out-of-order buffer, a repeated sequence number, a timebase change and a missing calibration file. Observe whether it falsely assembles a continuous history or identifies the qualification. Feed it known traces with several near-simultaneous events and measure whether the reported ordering follows the raw sample indices rather than thread completion order. Change the display time zone and verify that the underlying epoch remains invariant. Introduce an artificial delay in file writing and demonstrate that the reported RF event time does not move if a hardware chronology is claimed. Such tests can reveal software defects that a tidy user interface conceals.

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Finally, a report should explain the status of each time claim in ordinary language as well as in technical metadata. It might state: *The acquisition sample counter places the event at the recorded input interval; an independently calibrated hardware reference maps that interval to a stated time standard with the following uncertainty. The later host log is retained only to document when software registered the event.* Where no valid mapping exists, it should state that the event's absolute time is undetermined but its relative order is preserved. A carefully qualified record can be stronger evidence than an apparently exact timestamp whose acquisition origin no examiner can reconstruct. I thank Dr Atkinson and invite Dr Rabi to press the question of experimental controls and independent checks.

Isidor Isaac Rabi

Peer question 7 to Grace Brewster Murray Hopper

Rear Admiral Hopper, your proposed data model is admirably explicit, but documentation can itself become a ritual if the values entered are never challenged. A calibration file may bear an official-looking identifier while referring to a different filter configuration; a sample-counter anchor may appear in a record while the actual ADC was clocked from another source; and a software version number may be correct while an unexpected firmware image remained active. What experimental control would distinguish a well-described but incorrectly measured timestamp from a genuinely traceable arrival time? Would you require a physical test at the RF input in addition to software unit tests, and how should the result be preserved so that a later examiner can evaluate competing timing explanations without relying upon the operator's recollection? A rigorous challenge should also expose plausible failure modes rather

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than merely demonstrate a successful nominal trace. Please distinguish the experiment that tests an assumed transformation from the independent evidence that the calibration stimulus genuinely reached the declared input reference plane.

Grace Brewster Murray Hopper

Immediate answer to Isidor Isaac Rabi

Dr Rabi, documentation is a necessary condition of reproducibility but not a substitute for experiment. A string identifying a calibration record is meaningful only if the calibration was actually applied to the instrument configuration used for the acquisition. I would therefore require both software tests and physical injection tests, each with a different purpose. Software tests establish that a declared transformation is implemented consistently and that invalid states are handled correctly. Physical tests establish whether the transformation corresponds to the observed instrument path. An implementation may pass every unit test for an erroneous model of filter delay; only a controlled input at the chosen reference plane exposes the discrepancy.

The physical acceptance procedure should use a time-defined stimulus whose event location is measured independently. Record the reference generator, injection cable, receiver configuration, capture epoch and analysis method. Vary the input delay in known increments and check that the reported event time follows the change. Replace one analogue filter and check that the measured timing shift agrees with its characterised group delay. Apply a host load while leaving the hardware input unchanged; if the claimed acquisition time moves

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with the software workload, the result points toward a timestamp placed too late in the chain. Distinguishing tests are particularly valuable because they make rival explanations predict different outcomes.

The record of the test should be sufficient for independent reconstruction. Preserve unmodified sample blocks, counter anchors, test settings, reference-state observations, event-detection parameters and a digest of each retained primary file. Include the calibration's date, scope and limitations, not merely a serial identifier. A reviewer should be able to recompute the event time and see the effect of withholding each correction. If subtraction of a nominal group delay changes the claimed timestamp by nine microseconds, that fact should be visible alongside the evidence supporting the correction. If the front-end response varies with frequency, a single delay number must not be applied indiscriminately to all emissions.

I would also make fault behaviour an acceptance criterion. Induce a missing calibration dependency or contradictory clock anchor and require the application to flag the record rather than issue an exact event time. Test that the display distinguishes a valid raw sample chronology from a questionable UTC mapping. A file with internally consistent sample counters but lost external clock lock may still support relative event ordering; it should not be rejected wholesale, but its absolute time must be qualified. The investigation benefits from preserving the strongest proposition supported by the data without extending it beyond its basis.

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The governing principle is that a computer should expose the measurements' limitations rather than create the illusion that all transformations have the same certainty. Through physical challenge, software conformance checks and retained provenance, the investigator can distinguish the time of an RF event from the time at which the machine noticed or reported it. I thank you, Dr Rabi, and return the floor to Dr Atkinson for the worked applications and the formal synthesis.

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TEN WORKED ENGINEERING APPLICATIONS

Application 01. Sample-counter chronology from an absolute hardware anchor

A receiver's acquisition clock has an independently verified epoch at sample $n_0 = 0$, associated with 12:00:00.000000 on a declared time scale. A waveform feature is located at sample $n = 48{,}000$ in a continuously verified stream sampled at $f_s = 2{,}000{,}000$ complex samples per second. Let $\Delta n = n - n_0$ and let Δt denote the elapsed sample time. Then $\Delta t = \Delta n / f_s = 48{,}000/2{,}000{,}000 = 0.024$ s, so the uncorrected sample-derived time is 12:00:00.024000. This result identifies a time on the acquisition clock. It is not yet an antenna arrival time, because analogue group delay, the feature-picking algorithm and the epoch anchor's uncertainty have not been corrected. If the counter has a gap or the clock frequency differs from its nominal value, the simple mapping must be qualified.

Application 02. A buffer-completion timestamp incorrectly assigned to its first sample

An SDR fills blocks of $N = 8192$ complex samples at $f_s = 2{,}000{,}000$ samples per second. Let T_b represent one block's acquisition duration. Then $T_b = N/f_s = 8192/2{,}000{,}000 = 0.004096$ s $= 4.096$ ms. Suppose a host timestamp is generated precisely when a block becomes full and the application attaches that timestamp to the first sample without recording the block offset. Even if host delivery latency were zero, the first sample would be misdated by about 4.096 ms; a centre-sample assignment would differ by about 2.048 ms. Actual queueing adds a further uncertain quantity. This example demonstrates a deterministic position error due

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to timestamp semantics, not evidence that the receiver's physical signal propagation is delayed by exactly the block duration.

Application 03. Digital-filter group delay in microseconds

Consider an ideal causal odd-length linear-phase FIR filter of $L = 75$ taps, operating at $f_s = 4{,}000{,}000$ samples per second. Its constant nominal group delay in the relevant passband is $\tau_g = (L-1)/(2f_s)$. Substitution gives $\tau_g = 74/(8{,}000{,}000)$ s = 9.25 microseconds. If a detector timestamps the peak at the filter output but the intended measurand is an input feature, a 9.25-microsecond correction may be appropriate if the signal and estimator satisfy the stated assumptions. The result does not characterise analogue preselector dispersion, decimation-phase offsets or time walk. Those contributions require separate calibration. A different filter length produces a different delay; it would be a category error to use this value for an unrelated configuration.

Application 04. Cable propagation and the declared reference plane

A coaxial feed line has a measured physical length $\ell = 60$ m and velocity factor $v_f = 0.66$, defined as propagation speed divided by vacuum light speed $c \approx 299{,}792{,}458$ m/s. Assuming a uniform nondispersive line over the signal band, the one-way electrical delay is $\tau_c = \ell/(v_f c) = 60/(0.66 \times 299{,}792{,}458)$ s $\approx 3.032 \times 10^{-7}$ s = 303.2 ns. An event recorded at the receiver connector may therefore occur about 303 ns after the corresponding event at the antenna-end cable reference. Connector and antenna response remain additional terms. The uncertainty in length and velocity factor must be propagated if a sub-

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nanosecond conclusion is sought; this nominal calculation alone does not demonstrate such precision.

Application 05. Asymmetric network transit creates a clock-offset bias

A synchronisation exchange is analysed using the standard four-timestamp symmetry assumption. Suppose the actual network path delay from client to server is $d_f = 0.7$ ms and the return path delay is $d_r = 1.1$ ms, with other endpoint delays neglected. The asymmetry in the two delays is $\Delta d = d_f - d_r = -0.4$ ms. The offset inferred under equal-delay assumptions is biased by approximately $\Delta d/2 = -0.2$ ms relative to the true clock offset, with sign depending on the declared direction of the offset estimate. The round-trip delay is 1.8 ms. The example shows that consistent timestamps and a low measured round-trip time do not prove an unbiased absolute epoch. A host clock corrected by this exchange does not thereby calibrate an SDR's RF input-to-log delay.

Application 06. Oscillator frequency error accumulated over an observation

Let the nominal acquisition sample rate be $f_s = 4{,}000{,}000$ samples/s and suppose its realised fractional frequency offset from the reporting reference is $y = +2 \times 10^{-6}$ (two parts per million), approximately constant. For an elapsed reference interval $T = 40$ s, the first-order accumulated relative time error magnitude is $|\Delta t| \approx |y|T = (2 \times 10^{-6})(40) = 80$ microseconds. The sign depends on whether the mapping counts excess ticks as elapsed reference time or converts ticks using the nominal rate. A single frequency-offset estimate cannot reveal an intervening phase step, clock steering event or temperature excursion. The evidence should

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therefore contain periodic anchors, lock state and sample-counter continuity rather than relying on this linear approximation for all observations.

Application 07. Lost sample block and a false continuous timeline

Suppose an acquisition retains 4096-sample blocks at a constant 2,000,000 samples/s. One complete block is lost without a marker. Its missing temporal extent is Δt_{gap} = 4096/2,000,000 s = 0.002048 s = 2.048 ms. If the software simply concatenates blocks on either side and assigns times by file sample position, every event after the gap appears 2.048 ms earlier than its proper position on the original continuous sample counter. A later host clock comparison cannot determine which analogue samples were lost. The correct forensic record carries a discontinuity and, where known, its counter interval. Interpolated replacement samples may be generated for visualisation but must never be labelled original observations.

Application 08. Independent uncertainties and an explicit covariance warning

A hypothetical event-time estimate depends on three corrections with standard uncertainties u_{clock} = 0.8 ms, u_{filter} = 1.2 ms and u_{pick} = 0.5 ms. If these are unbiased and mutually independent, the combined standard uncertainty is $u_c = \mathrm{sqrt}(u_{clock}^2 + u_{filter}^2 + u_{pick}^2)$ = sqrt(0.64 + 1.44 + 0.25) ms = sqrt(2.33) ms ≈ 1.526 ms. This is a standard uncertainty, not automatically a 95 per cent bound. If two terms share an oscillator or filtering mechanism, the full variance includes 2 $\mathrm{cov}(X_i,X_j)$ for each relevant pair, and the simple root-sum-square result can be wrong. Every term's basis, distribution and potential correlation must be

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documented. A small displayed time increment does not reduce this uncertainty.

Application 09. Timing error as differential path-length error

For a far-field radio wave propagating in free space, let $c \approx 299{,}792{,}458$ m/s and let Δt be a differential arrival-time error between two receivers. The corresponding differential path-length error is $\Delta r = c\,\Delta t$, subject to the simple propagation model. For $\Delta t = 1$ microsecond, $\Delta r \approx 299.8$ m. For a host-timestamp variation of 20 microseconds, $\Delta r \approx 5{,}996$ m, or about 6.0 km. These are differences of propagation path length, not direct geographical position errors: the localisation geometry determines how such errors affect location. Unequal receiver group delays, shared clock defects and multipath must also be considered before assigning a bearing or position to an unknown RF source.

Application 10. Calibration mean, uncertainty and stress-state limits

A controlled input marker is applied 25 times under a fixed receiver configuration. The measured host-delay sample mean is 5.0 ms, with sample standard deviation $s = 0.8$ ms. If observations are approximately independent and drawn from a stable population, the standard error of the mean is $s/\mathrm{sqrt}(n) = 0.8/\mathrm{sqrt}(25) = 0.16$ ms, where $n = 25$. A rough normal approximation gives a two-standard-error interval for the population mean of 5.0 ± 0.32 ms. That interval does not bound an individual future delay or the maximum under untested heavy-load conditions. Applying the mean as a correction to a single event requires the much larger variability and possible bias relevant to that individual event, along with independent calibration of RF and filter delays.

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David Lennox Mills, Cross-Peer Question to Edsger Wybe Dijkstra: Dr Dijkstra, why is a timestamp written by an operating system when an SDR buffer completes not automatically the arrival time of the first RF sample inside that buffer?

Edsger Wybe Dijkstra, Cross-Peer Answer to David Lennox Mills: Dr Mills, the host observes a software event after acquisition, transfer, queuing and scheduling. The accumulated delay may vary with buffer length, device firmware, bus congestion and operating-system load. Recover the acquisition chronology from a hardware sample counter anchored to a characterised clock epoch, and retain the buffer sequence numbers and any known loss markers. A buffer-completion time can be useful as a bound or consistency check after independently measuring latency, but not as a precise RF arrival timestamp by default. Challenge the pipeline with externally timed pulses under different processor loads and buffer sizes. State separate uncertainties for the antenna reference plane, analogue group delay, ADC aperture, digital filtering and host timestamp. I pass the token to Professor Gabor on the short-event ambiguity.

Edsger Wybe Dijkstra, Cross-Peer Question to Dennis Gabor: Professor Gabor, can a software detector’s timestamp be corrected to pulse onset simply by subtracting one fixed FFT window duration?

Dennis Gabor, Cross-Peer Answer to Edsger Wybe Dijkstra: Dr Dijkstra, not in general. A detector’s threshold crossing depends on the window, taper, burst duration, pulse position within the window, filter memory and processing delay. A fixed half-window or full-window correction may be appropriate only for a specifically calibrated algorithm and signal class. Test known pulses at many relative sample phases and amplitudes, then quantify

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the onset-estimation bias and spread. Use a sample-index anchor and an independent timing reference before assigning a physical epoch. If a gap or dropped buffer interrupts the sequence, interpolation cannot make it observed. Report whether the timestamp marks window start, centre, maximum statistic or buffer completion. I yield the token to Mr Nyquist for the physical sample lattice.

Dennis Gabor, Cross-Peer Question to Harry Nyquist: Mr Nyquist, what does an ADC sample number establish when two devices share neither a clock epoch nor an externally verified frequency reference?

Harry Nyquist, Cross-Peer Answer to Dennis Gabor: Professor Gabor, each sample index identifies order within one acquisition sequence if counter continuity is proven. The nominal sample rate supplies an approximate relative interval, but absolute time and long-term rate error require external evidence. Two index sequences cannot be aligned reliably by matching decimal timestamps from separate host computers. Introduce a common physical reference event or traceable timebase and measure offset, drift and uncertainty; retain clock reset and synchronisation logs. If the clock rate changes between calibration markers, fit and validate an appropriate model rather than one untested linear interpolation. A claim of simultaneity should be framed as an uncertainty-bounded compatibility result, with physical path delay also considered. I pass the token respectfully to Dr Mills for the chain of custody.

Harry Nyquist, Cross-Peer Question to David Lennox Mills: Dr Mills, which records permit an independent expert to challenge an apparently microsecond-accurate timestamp in a seventy-two-hour monitoring archive?

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David Lennox Mills, Cross-Peer Answer to Harry Nyquist: Mr Nyquist, retain raw sample counters, hardware epoch capture method, clock-domain identifiers, oscillator or disciplining state, protocol synchronisation logs, sample-loss maps, buffer size, transfer events, clock steps, firmware revision and correction algorithm. Reference the same time scale consistently, including treatment of leap seconds and UTC conversion where applicable. A hash proves preservation after hashing, not original timestamp validity. Compare independent timing markers at multiple points across the archive and report estimated time error with its uncertainty, separately from the number of decimal places displayed. If a host timestamp is all that survives, its inference must be limited to host event chronology and a qualified latency bound. I return the token to Dr Atkinson.

Dr. James M. Atkinson. Closing synthesis of Question 051

Colleagues, our examination establishes a distinction which should govern every subsequent timing claim in this volume. A timestamp is meaningful only when its clock, its reference plane and the physical or computational event it denotes are known. The arrival of an electromagnetic disturbance at the antenna is not the arrival of a sample block at a host, and neither is the moment a detection algorithm completes its calculations. Those events may be linked by measured transfer functions, sample indices and clock anchors; they cannot be identified with one another by the typography of a log entry. The distinction is particularly important where a short transmission is used to infer another system's response, a source location or a sequence of actions in a protected environment. The apparent precision of the displayed time must not outrun the precision of the chain which supports it.

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Dr Mills has shown that clock synchronisation and measurement-chain latency require separate budgets. A host may agree with an external time standard and still report an RF event many milliseconds after it occurred. Dr Dijkstra has shown that concurrent software makes the distinction structural: completion of a callback, queue transfer or file write does not recreate the physical instant of acquisition. Dr Hamming has shown that even within the retained samples, a declared event time depends on filter group delay, template assumptions and onset-estimation method. Dr Nyquist has located the essential chronology in the sampling timebase and its continuity evidence. Rear Admiral Hopper has demonstrated that these distinctions will vanish from the legal and scientific record unless the acquisition software preserves them as explicit, independently reviewable facts. The resulting accounts do not compete; they address different boundaries of one system.

The required acceptance test should be built around a known, independently timed reference event applied at a declared RF or electrical input plane. The receiving system must preserve the sample counter and reference epoch, record each relevant analogue and digital filter state, and disclose any delay correction assigned to the feature estimator. The examiner should repeat the test with different buffer sizes, operating-system loads, receiver gains, channel selections and reference conditions. Deliberate clock loss, missing samples and retuning must be represented by validity or discontinuity records rather than concealed by interpolated data. If a system cannot pass a test in a particular state, its report should not assert the stronger time claim for observations taken in that state.

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I would require three dates or intervals where the evidence permits them: the raw hardware-associated acquisition coordinate, the best defensible estimate of the physical event at the stated reference plane, and the host logging or alarm time. Their relationship should be expressed through equations and uncertainty components rather than inferred from their closeness on a screen. For a single continuous recording, relative sample order may survive even when the UTC mapping is damaged. For geographically separated recorders, differential error, covariance, antenna geometry and synchronisation-path assumptions become essential. An investigator who cannot establish absolute arrival time may still provide valuable evidence of event existence, duration, spectral properties and relative order; those conclusions should be stated without embarrassment or unwarranted extension.

Our historical contributors have been represented here in a deliberately constructed academic exercise, not as speakers who encountered the software or standards of a later period. Their relevant intellectual achievements supply distinct methods for analysing a present engineering problem, and each modern application should be judged on its evidence rather than upon the authority of a famous name. The final proposition is therefore neither that software timestamps are useless nor that hardware timestamps are infallible. It is that the measurement must say what was timed, where it was timed, by which clock and with what uncertainty. This question is closed. The programme proceeds to Question 052, where frequency-reference traceability and phase coherence must be examined in their own right rather than treated as synonyms for accurate event dating.

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QUESTION 051. TECHNICAL REFERENCES AND QUALIFICATIONS

1. Mills, D. L., Martin, J., Burbank, J., and Kasch, W. (2010). Network Time Protocol Version 4: Protocol and Algorithms Specification. RFC 5905. https://www.rfc-editor.org/rfc/rfc5905.html . Provides the network-clock offset and delay framework; does not directly validate SDR host-to-antenna timing.

2. Lichvar, M., and Malhotra, A. (2025). NTP Interleaved Modes. RFC 9769. https://www.rfc-editor.org/rfc/rfc9769.html . Discusses timestamp placement in software, MAC and PHY layers, and effects of inaccurate timestamping; contemporary editorial reference.

3. RFC 10030 (2026). Network Time Protocol over the Precision Time Protocol. https://www.rfc-editor.org/rfc/rfc10030.html . Describes hardware timing and network timing as distinct, contemporary editorial context; the historical contributors did not encounter this publication.

4. IEEE Std 1588-2019. IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems. https://standards.ieee.org/ieee/1588/4355/ . Consult the exact profile, implementation and hardware timestamp location; protocol support does not certify an RF sampling reference plane.

5. Riley, W. J., and Howe, D. A. (2008). Handbook of Frequency Stability Analysis. NIST Special Publication 1065. https://www.nist.gov/publications/handbook-frequency-stability-analysis . Background on frequency stability, clock measurements and reporting; not evidence of the properties of any particular receiver.

EDITORIAL VERIFICATION NOTE: All worked calculations are illustrative, based on the stated simplified models. Physical measurements, calibration certificates, device-specific latencies and original raw captures are not supplied. Claims about one specific SDR's actual arrival-time accuracy would require separate calibration and independent source examination.

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QUESTION 052

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How should traceability of frequency standards govern coherent captures separated in time?

EDITORIAL CONVENTION: Newly authored academic dialogue moderated by Dr. James M. Atkinson. All interventions attributed to deceased historical scientists and engineers are constructed teaching reconstructions, not actual conversations or quotations. References to later SDR technologies, standards and forensic procedures are contemporary editorial applications of their genuine fields of expertise. Worked numerical examples are hypothetical and not certifications of any receiver.

Dr. James M. Atkinson. Opening of Question 052

Distinguished colleagues, two receivers may exhibit immaculate frequency readings and yet fail to preserve the phase relationship upon which coherent comparison depends. A synthesiser locked to a ten-megahertz reference can produce an output nominally equal to its intended carrier frequency while beginning at an arbitrary phase after a restart. Two independently disciplined references can each be traceable to the SI second and nevertheless exhibit an unknown relative phase. A reference-distribution network can introduce differential cable delay, clock-buffer skew or supply-dependent phase modulation; its outputs may retain satisfactory average frequency while their phase relation changes. The investigative temptation is to treat a manufacturer's phrase, *reference locked*, as if it also certified phase continuity, epoch alignment and waveform coherence. Our task is to refuse that category error without discounting the considerable value of an established frequency standard.

We must distinguish quantities before comparing them. Frequency is the rate of phase change measured over an interval. Phase identifies a point within an oscillatory cycle relative to a specified reference and is inherently

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periodic unless the observer retains an unwrapped, continuous history. Absolute time establishes the relation of an event to an external time scale. Frequency accuracy concerns the closeness of measured frequency to its intended value; frequency stability concerns its variation over specified intervals; phase noise characterises fluctuations of phase and may be described spectrally. None is interchangeable with another. A ten-megahertz output can be highly stable and offset from the correct frequency. Two accurate ten-megahertz outputs can have unrelated instantaneous phase. A clean average Allan deviation may not disclose a short phase step that destroys a retrospective coherent sum.

The term *traceability* must be used with metrological precision. It is a property of a measurement result connected to a stated reference through a documented calibration chain, with uncertainty contributed by each link. A traceable frequency measurement does not itself warrant a claim about an unmeasured phase relationship at an ADC input or an RF antenna. The clock reference, the synthesiser, the distribution path, the converter aperture and the post-processing transformations all must appear in the model appropriate to the actual measurement. An unexamined fan-out amplifier cannot be excused simply because the oscillator feeding it has an excellent calibration certificate.

Consider two recorded signals separated by hours. The investigator wishes to add their complex samples coherently, perhaps to expose a weak intermittent transmission beneath a fluctuating background. To align them, the engineer may need a common frequency scale, known temporal mapping, measured relative phase, and a physical model for propagation, Doppler shift and channel evolution. Merely using identical nominal ADC

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frequencies does not establish that these requirements hold. A host may also lose one sample, the local oscillator may settle at a new phase after retuning, or the received channel itself may change between acquisitions. Those effects cannot be corrected by asserting that both receivers use respectable reference clocks. A coherent integration which assumes phase continuity must either measure it, track it or disclose the resulting conditional hypothesis.

We shall examine the issue through five distinct disciplines. Professor Norman Foster Ramsey Jr. will consider oscillatory-field phase and frequency comparisons; Mr Louis Essen will examine the metrological calibration hierarchy and disciplined time standards; Professor Isidor Isaac Rabi will require experimental controls capable of separating oscillator behaviour from receiver and channel effects; Professor Charles Hard Townes will investigate oscillator coherence, spectral purity and the limitations of averaging; and Dr Harry Nyquist will explain the phase and sample-index transformations through which digital acquisition may preserve or destroy a defensible relationship. Seven colleagues will challenge them. The resolution must lead to an acceptance protocol in which known reference phase disturbances, frequency offsets, distribution changes and acquisition interruptions produce distinguishable recorded consequences. Professor Ramsey, I invite you to begin by asking what it means for two oscillations to have a measurable common phase history.

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Norman Foster Ramsey Jr.

Dr Atkinson, frequency agreement is a statement about the rates at which phases accumulate, while coherence concerns the relation of the phases themselves across the intervals of interest. In the language of oscillatory fields, one may represent a nominal sinusoid by $\cos[2\pi f_0 t + \varphi(t)]$, where f_0 is the nominal frequency and $\varphi(t)$ contains phase offset and fluctuation. Two signals with the same long-term mean frequency may begin at unrelated phases. If their frequency difference is small but nonzero, their relative phase evolves with time. If one suffers an abrupt phase step, an observer who examines only averaged frequency over a long period may scarcely notice the event, even though an attempted coherent combination across that step may partly cancel rather than reinforce the signal.

An elementary example is instructive. If the reference frequency difference between two oscillators is $\Delta f = 0.2$ hertz and they are otherwise stable, their relative phase accumulates at $2\pi \Delta f$ radians per second. After four seconds the accumulated difference is 0.8 of a cycle, or 288 degrees. The two clocks may have very similar frequencies by most ordinary specifications, yet a complex phasor sum that assumes zero difference is not generally coherent. At an RF carrier frequency, a very small fractional frequency error can accumulate many complete phase revolutions over a long observation. The phase measured modulo a complete turn at the end cannot disclose how many turns were accumulated unless the history was continuously observed or constrained by independent information.

The precision of a frequency reference is therefore not sufficient to establish the state of a frequency divider or synthesiser after interruption. A phase-locked loop may reacquire frequency lock while choosing an output

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phase which depends on an internal counter, a divided oscillator state or the time of a reset. To claim continuity, the engineer must show that the same phase relation was maintained or provide a measurement which allows the new relation to be reconstructed. A reference-to-output phase measurement at one instant can establish that relation locally, but the claim over a long unattended interval requires evidence that there were no unrecorded slips or a model bounding their consequences.

This is closely related to the interpretation of stability statistics. Allan deviation is useful for estimating characteristic frequency fluctuations over selected averaging times, and it is much less easily misled than a single conventional standard deviation by certain noise processes. Yet one should not read an Allan-deviation graph as a certificate that no phase discontinuity occurred. The statistic is computed from a set of observations under a particular sampling and treatment policy. A short event may be excluded, smoothed or diluted by averaging. A report addressing a short RF burst should therefore preserve the unaveraged phase residuals, the averaging intervals and an event log of any reference interruption, rather than presenting only a favourable summary curve.

Two receiver chains sharing the same reference create a further subtlety. A common disturbance may appear in both records with similar phase, producing an apparently satisfactory difference while moving each phase relative to an independent external reference. Some errors cancel in a differential comparison, but not all. A path-dependent delay in one fan-out branch shifts the phase of one channel; a common reference step may affect both, while a synthesiser that relocks asynchronously may affect only one. The correct observation is a vector of phase differences at specified

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points, not a statement that one cable feeds two instruments. At every branch the engineer must determine which errors are common and which are independent.

Suppose a ten-megahertz standard has a constant fractional frequency error $y = 10^{-9}$. Its frequency error is only 0.01 hertz, yet over an hour it accumulates thirty-six cycles of relative phase compared with an ideal ten-megahertz reference. Its associated clock-time scale error over 3600 seconds is 3.6 microseconds if the offset is constant. This calculation is not a condemnation of an otherwise useful oscillator; it demonstrates that a tiny rate discrepancy can have a substantial long-term phase consequence. To combine captures separated by hours, an investigator needs either a phase-continuous common reference with proven history or direct measurements permitting relative phase to be estimated anew.

It is worth distinguishing phase coherence of the receiver from phase coherence of the external signal. A source whose carrier drifts, a reflecting object which moves or a multipath channel whose geometry changes may alter received phase independently of the instrument. A receiver clock correctly held in phase will not compel the world to remain stationary. The aim of the calibration is to remove instrument uncertainty from the inference so that residual phase can be evaluated as a candidate property of the received field. Without that separation, a claim of transmitter motion might merely describe a clock slip, while a claim of clock instability might conceal a legitimate propagation change.

I would require simultaneous records of reference-to-reference phase, reference-to-ADC relationship, local-oscillator lock state and the phase of a deliberately injected calibration tone. Compare these during normal

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operation and after controlled loss-of-lock, power cycling and reference changes. Preserve the raw phase record because an apparently smooth fitted curve may hide a discontinuity near the event of interest. If the instrument cannot track phase across an interruption, declare a new coherent segment rather than joining two segments by wishful arithmetic. Frequency traceability is indispensable to some claims, but it is the beginning of a calibration hierarchy, not the end of the coherence question. I invite Mr Hewlett to challenge whether direct RF measurement is necessary when the distribution hardware is specified to a much finer tolerance.

William Redington Hewlett

Peer question 1 to Norman Foster Ramsey Jr.

Professor Ramsey, an equipment manufacturer may provide exceptionally low phase noise, stable connectors and a distribution amplifier specified for small channel-to-channel skew. If the inputs are driven from one calibrated ten-megahertz source, a designer might regard direct phase tests after installation as unnecessary repetition of factory measurements. Could a competent examiner accept the published component specifications as a bound on phase coherence, provided the system remains within the declared temperature and power range? Which features of the installed configuration would still require local verification, particularly when coaxial cables differ in length and the receiver synthesiser may be reconfigured during a survey? I also ask what evidence would distinguish a true synchronised phase change in the transmitted signal from a discontinuity introduced by a common reference or a single downstream branch. Please distinguish the accuracy of a specification at one frequency from the actual phase

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response across a useful bandwidth. An installed receiver may also select different local-oscillator multiplication paths during retuning, so a one-time ten-megahertz output comparison may conceal those path changes.

Norman Foster Ramsey Jr.

Immediate answer to William Redington Hewlett

Mr Hewlett, a specification is informative about the conditions under which its author claims a component has been tested; it is not direct evidence that an installed chain has the phase relation required by a particular experiment. A distribution amplifier's small nominal skew may be useful when a system is designed, but the phase at the converter also depends on cables, connectors, clock-domain transfer, dividers and synthesiser state. A small skew at the amplifier outputs says nothing definitive about the phase after those paths have been connected to dissimilar receiver architectures. A specification for stationary environmental conditions also cannot disclose a later intermittent connector fault or an unlogged reset.

I would use factory data to design a local test, not to exempt the instrument from one. Inject a coherent reference event into the receiver path and measure the phase difference at accessible points, varying temperature and cable configurations within the proposed operating envelope. Then deliberately power-cycle or retune one receiver to learn whether it returns to a known phase or an arbitrary one. Repeat the measurement with a second, independently traceable reference path. If the system retains coherence, the evidence will establish how it does so; if it does not, the resulting failure mode becomes part of the operating specification. The test should preserve

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uncertainty, not merely record that two waveforms looked aligned on one display.

As for a candidate transmitted-signal phase change, one needs observations with different sensitivities to the rival causes. A phase step appearing in a local injected calibration tone and in the unknown received signal suggests an instrumental origin. A step confined to the unknown signal while an independent calibration tone and reference phase remain continuous points elsewhere, though multipath and detection errors must still be considered. A disturbance appearing simultaneously in multiple channels sharing one clock but not in an independently referenced instrument suggests common-clock behaviour. Such comparisons do not prove a unique explanation by themselves; they narrow the possible mechanisms in a manner a specification sheet cannot.

I would also separate repeatability from absolute accuracy. Two receiver channels can repeat a stable phase offset for many hours, yet that offset may be wrong for a model that assumes zero differential delay. If the phase offset is measured and stable, it can be compensated for an appropriate narrowband signal, but the correction must be tied to the frequency and reference plane at which it was measured. A dispersive cable or filter cannot always be represented by one constant phase correction across a wide signal band.

The result is a practical acceptance rule. Use published component specifications to select reasonable instruments and define plausible error budgets; then challenge the assembled path under the exact

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operating modes on which the coherent claim will rely. The laboratory is not disparaging the manufacturer when it tests its own system. It is identifying the actual measurand and its chain of evidence. I return the floor to Dr Atkinson and invite Mr Essen to examine what traceability does, and does not, warrant in the language of standards and calibration.

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Louis Essen

Dr Atkinson, a frequency measurement is traceable through a chain of comparisons, each of which has a defined quantity, a reference and an uncertainty. The expression *a traceable oscillator* is convenient but imprecise when it replaces the description of a measurement result. A laboratory can own an oscillator whose frequency was compared to an external standard last year, yet the laboratory's current result depends on what happened to that oscillator since the comparison, its present environment and the instrument chain through which the frequency is delivered to the ADC. The relevant proposition is not that an object bears a respectable certificate. It is that the reported frequency or time quantity can be connected to a defined reference through an unbroken and sufficiently documented calibration hierarchy.

The SI second supplies a foundation for frequency measurement. If a laboratory measures a ten-megahertz reference by comparison against a higher-order standard, it must account for the reference's uncertainty, the counter or phase comparator, the comparison interval, possible loading effects and the environment. Each link contributes uncertainty. The resulting statement may establish the mean frequency of one reference during the time of observation, but it does not thereby establish that a different cable branch remained phase continuous or that the converter's aperture carried an accurate UTC epoch. A complete coherent-capture experiment commonly requires both the calibrated frequency scale and the relative-phase history of particular instrument paths.

A disciplined oscillator should be treated as a controlled physical system. A steering loop may correct mean frequency while introducing phase

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modulation or a transient when it changes mode. A reference can remain within its allowed long-term frequency tolerance yet exhibit a rapid phase disturbance unsuitable for short coherent integration. The engineer therefore needs measurements over the averaging times relevant to the intended observations. A carrier measured over one second, one minute and one hour may produce different descriptions of stability. None may by itself establish the instantaneous phase at the time of a rare burst if the data were reduced to averages or if interruptions were omitted from the record.

The traceability chain has a temporal dimension. It should state when each calibration applied and whether subsequent changes render it inapplicable. A precision oscillator transported between sites, warmed up after power loss or placed into a different thermal environment may no longer reproduce the calibrated value within the earlier uncertainty. Likewise, a fibre, cable or fan-out amplifier introduced after calibration can change the delivered phase although the upstream source remains traceable. The instrument's reference path should be documented as the one actually used for acquisition, not the one ordinarily installed at the laboratory bench.

Consider a receiver that samples at one hundred million samples per second, with time tags derived from a shared ten-megahertz reference. A single-sample interval is ten nanoseconds. A measured reference-branch delay of twenty-five nanoseconds therefore corresponds to two and a half sample intervals. It is possible for the two sampling clocks to have excellent relative average frequency and yet acquire a common waveform at sample indices differing by that much, depending on the phase and synchronization design. The remedy is not to declare that such skew is negligible because

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ten megahertz is lower than the ADC rate. The remedy is to characterise the phase relation between reference delivery and actual sampling aperture under the operating configuration.

A laboratory should be particularly careful when it claims *coherence across time*. If the receiver was powered down between two sessions, did its synthesiser return to the same integer phase relation? If the digital downconverter was reset, did its numerically controlled oscillator return to a known phase state? If the signal path was reconfigured, did the filter and delay model change? An accurate frequency source cannot answer these questions without further observables. A repeated measurement at two different times requires either proven continuity or a new calibration that determines the relation between the sessions. The two sessions can be compared for power or frequency without being coherently combined in complex phase; a measurement task should ask no more of the reference than the evidence supports.

I would preserve calibration results as part of each capture session. Identify the standard, the comparison route, the calibration date and uncertainty, the reference lock state, the output branch, the physical lengths and instrument settings. Record measurements of relative phase immediately before and after the capture, supplemented by continuous phase residual data when the intended claim requires absence of intervening slips. A series of references with a common upstream source should not be described as independent without considering their shared uncertainty components. If phase continuity is unobservable during a gap, the correct record must say so.

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This is not a recommendation to make every survey a national timing laboratory. It is a principle of proportionality. A survey that simply distinguishes authorised communications from an instrument artefact may require good frequency calibration but not nanosecond phase alignment. A coherent integration attempting to recover a very weak signal over long gaps requires a more demanding demonstration of relative phase, source stability and channel constancy. The quality of a metrological result lies in matching its calibration and uncertainty to its intended use. I invite Professor Gabor to question how the representation of a transient might create phase apparent continuity where the underlying data do not support it.

Dennis Gabor

Peer question 2 to Louis Essen

Mr Essen, suppose the receiving team stores only short-time Fourier transforms of several brief acquisitions, with each transform internally referenced to its own window origin. All captures use disciplined oscillators with a documented chain to the SI second, and the displayed carrier frequencies agree to many digits. An analyst proposes to rotate each complex spectrum by a fitted phase and sum the spectra, arguing that the fitted rotation recovers the coherence which was not explicitly retained. What must be known about window origins, local-oscillator phase, the target waveform and the gaps before that operation can be interpreted as recovering a physically meaningful phase relationship? Can a post hoc optimisation produce an attractive peak even when no coherent relation was ever measured? I would welcome a criterion separating an exploratory alignment procedure from a validated

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measurement. Suppose the analyst has optimised not only phase rotations but also the time-window positions and carrier-frequency shifts. The significance of the strongest peak would then depend on a search over many hypotheses, some strongly correlated, rather than on one predeclared coherent comparison.

Louis Essen

Immediate answer to Dennis Gabor

Professor Gabor, the ability to select a phase rotation that increases an output is not, by itself, a demonstration that the selected rotation corresponds to a physical relation between acquisitions. When the phase is chosen after looking at the same data that are later offered as confirmation, part of the apparent improvement is due to fitting degrees of freedom. A valid inference must identify the model under which phase alignment is meaningful and how that model is independently tested. It must also preserve the acquisition window origins, sample-clock rates, local oscillator configuration and an uncertainty statement for the relative phases. Agreement of displayed carrier frequencies does not supply these missing quantities.

A short-time Fourier transform of each capture contains phase relative to that capture's sample indices and analysis window. If the windows begin at different absolute times, the complex coefficients include the phase of the input oscillation and the phase shifts introduced by local oscillators, filters and the analysis convention. A post hoc rotation can make selected coefficients agree even when the true received phases were unrelated. For an exploratory detection

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statistic, this may be useful if the search procedure and its false-alarm consequences are stated. For a claim of measured physical coherence, however, one must obtain independent phase anchors or a validated model constraining the unknown rotations.

I would use a controlled reference tone admitted through the relevant receiver path during each acquisition and whose phase evolution can be traced across the intended gap. A common injected tone can reveal instrument phase changes, but its relation to the external emitter and antenna path must be evaluated separately. Alternatively, a reliable continuous clock-state record plus repeatable synthesiser phase-state control might permit reconstruction under a declared model. If the system cannot establish how many whole cycles accumulated through a gap, the absolute phase remains ambiguous even when the final phase modulo one turn is estimated precisely.

The analyst should then state which quantity was recovered. A coherent sum with known phase corrections can improve a measurement under a stationary or otherwise modelled target. An incoherent power combination can also improve detection under different assumptions, but its sensitivity and statistical interpretation differ. A maximised coherent-looking output from independently fitted phases is an optimised statistic, not automatically proof that the original recordings were phase coherent. That distinction should appear in the evidential report, together with the raw spectra or IQ data and the calibration chain that connects them to physical reference planes.

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Finally, the uncertainty budget must include the transformations through which the phase was inferred. If the emitter's phase wanders or the propagation channel changes, a flawless laboratory oscillator still will not secure the received signal's coherence. Conversely, an apparent phase discontinuity could originate in the receiver. The laboratory must test these rivals with a known injected waveform and with an independent environmental observation where possible. I thank you, Professor Gabor. I pass the floor to Sir Martin Ryle to examine whether a coherent antenna array can tolerate phase relationships that have been separately calibrated but not continuously watched.

Sir Martin Ryle

Peer question 3 to Louis Essen

Mr Essen, an interferometric receiver array may achieve excellent imaging or source discrimination while its phase corrections are obtained from periodic observations of a known calibrator rather than from uninterrupted monitoring of every oscillator branch. Suppose the instrument is stable enough between calibrations that a phase-interpolation model appears credible, yet an unobserved cable movement or synthesiser relock could occur between sessions. How should the array engineer distinguish interpolation of a measured smooth drift from an assumption that no phase step took place? Would independent calibrators, branch-swapping and simultaneous reference injection improve the evidential account, or merely add more shared dependencies? I should particularly like a decision rule identifying when a retrospective phase correction remains scientifically defensible and when

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the gap is too poorly constrained for coherent combination. A failed phase assumption might shift an interferometric image in a manner that appears physically plausible rather than simply reducing its brightness. Should the error budget therefore examine directional bias, not just reduction in coherent amplitude or the width of a fitted peak?

Louis Essen

Immediate answer to Sir Martin Ryle

Sir Martin, interpolation between phase observations is legitimate only under a model whose continuity assumptions have been justified for the interval and configuration at issue. If a system is known from independent trials to remain stable across typical calibration gaps, interpolation can support an uncertainty-bearing estimate. Yet the absence of an alarm about a phase step is not proof that none occurred. A gap containing an undocumented cable disturbance or a relock event may invalidate the smooth model, and a low residual on either side of the gap will not reveal that fact. The report should therefore include explicit validity conditions and a conservative treatment of unobserved interruptions.

Multiple calibrators can provide useful independent constraints if their relevant physical paths and error mechanisms differ. They can help distinguish a global instrument phase change from a source-specific propagation feature. But if every calibrator is observed through the same defective clock distribution, their agreement may preserve the common error. Branch swapping can be especially informative: if an anomalous phase change follows the hardware branch rather than the antenna or sky direction, an instrumental

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explanation gains support. Simultaneous injected reference signals may characterise a portion of the chain continuously, although the injection point determines which upstream effects remain untested.

I would define an acceptance envelope before evaluating the particular event. Measure relative phase wander over representative intervals and under controlled thermal, mechanical and reference disturbances. Establish the conditions under which phase can be interpolated with an uncertainty smaller than the scientific tolerance. Record any reference-state change which terminates the envelope. If a later capture lies outside the validated duration or operating state, describe the alignment as exploratory or conditional rather than presenting it as a traceable measured phase. This is especially important where the analyst's phase corrections were selected to optimise the very feature offered as evidence.

A defensible decision rule can be expressed in terms of predicted error. If the phase-uncertainty distribution under the justified model is small enough that the coherent-integration conclusion is insensitive to its variation, the correction may be fit for purpose. If plausible phase histories through the gap produce materially different conclusions, the original evidence does not select one of them. The correct choice may be incoherent combination, a shorter coherent interval or a new acquisition with more frequent calibration. A numerical threshold should follow the measurement's purpose, not a general rule that one calibration per day is always sufficient.

In summary, good metrology supports interpolation but does not abolish discontinuity. The engineer must account for both the

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calibration intervals and the failure modes capable of invalidating the interpolation. A transparent model can be challenged, revised and reproduced; an implicit promise of perfect phase continuity cannot. I return the discussion to Dr Atkinson and invite Professor Rabi to consider how controlled resonance experiments should distinguish source behaviour from an oscillator's own phase history.

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Isidor Isaac Rabi

Dr Atkinson, a resonance experiment teaches that an instrument's displayed answer may depend upon the phase and history of the fields used to interrogate the phenomenon. If we seek to distinguish a real change in an external signal from a change in the receiver reference, we must construct experiments in which those causes predict different observations. A statement that the instrument remains frequency-locked is an operating condition, not a demonstration that its phase relation to a physical signal is known. The experimental question is whether the receiver has preserved the phase-sensitive information required for the proposed inference. Without an independent control, an apparent shift can be attributed equally plausibly to the source, the propagation path or the instrument itself.

I would begin with a controlled source whose amplitude, phase modulation and frequency are characterised relative to an independent reference. Deliver it to the receiver's declared RF input through a measured path while also retaining a reference branch observed by separate instrumentation. Vary the source frequency by a known amount and confirm that the receiver reports the expected phase evolution. Then hold the source fixed and deliberately disturb the local-oscillator reference, synthesiser lock or frequency-divider state. If the apparent source phase follows those internal disturbances, the measurement has exposed an instrumental vulnerability. An investigation of an unknown emitter should not claim more precise coherence than such a controlled challenge demonstrates.

The experimental setup must distinguish the generation of a calibration signal from its delivery to the receiver. A pulse or tone produced by a well-

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calibrated generator can be degraded by the cable, switching network or injection coupler through which it enters the measurement chain. An apparently identical signal injected directly into the digitiser may bypass the RF preselector and local oscillator whose behaviour is in dispute. That test can validate the digital detector but cannot validate the untested analogue path. Conversely, a radiated calibration source tests antenna and propagation effects but may introduce environmental multipath which complicates interpretation. Both tests are useful if their reference planes are declared and the inference is confined to those planes.

The phrase *coherent across two sessions* should be resolved into observable conditions. First, the sample timebases must have a known scale over each acquisition. Second, the conversion chain must preserve the relation between sample indices and waveform phase within the relevant bandwidth. Third, the relative phase offset between the sessions must be determined or constrained by measurements. Fourth, the external source and propagation environment must behave consistently with the coherence model. The engineer may satisfy the first condition yet fail the second when a local oscillator is reset, or satisfy the first two yet fail the third when recording resumes after a long unobserved gap. The fourth condition belongs to the physics of the scene rather than to the clock laboratory.

A particularly instructive challenge is to inject two distinct coherent tones separated in frequency. A constant time delay produces a phase shift proportional to frequency; an arbitrary constant carrier-phase offset does not have the same dependence. If a receiver reports changes across the two tones consistent with a delay, that supports one model of the disturbance, provided filtering and phase unwrapping are controlled. If the phase shift is

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common across frequencies in a manner predicted by a synthesiser phase reset, a different explanation may fit. The purpose is not to create a universal classifier from two numbers. It is to choose perturbations that make competing models produce distinguishable predictions, allowing the data to decide within their measurement uncertainty.

I would also challenge claims based upon a calibrated timebase that was not monitored during the actual event. A long record may contain stable reference data before and after a gap, but that alone does not establish the absence of a phase slip in the interval. A receiver might reacquire lock with the same output frequency and a different phase, and a later comparison of average frequency would look satisfactory. The experiment must therefore record the phase through the interval, use an independent witness or accept that the number of lost cycles is unknown. A complete revolution of phase is invisible in a single modulo-two-pi measurement at the end, although it changes the unwrapped history necessary for coherent reconstruction.

When disagreement appears, it should not be resolved by preferring the most aesthetically pleasing plot. Compare raw complex samples and reference-state logs, investigate whether the phase correction depends on the processing algorithm, and see whether a known calibration signal displays the same feature. One receiver might show an apparent abrupt phase jump after retuning while a second, continuously tuned receiver does not. That difference can provide a strong diagnostic lead. It does not by itself identify the transmitter or establish that the second receiver is infallible; it creates a more specific testable hypothesis about the first receiver's clock and synthesiser behaviour.

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The final report should therefore include experiments designed to falsify its preferred interpretation. If the claim is that a phase shift belongs to an unknown emission, state what instrument controls would be expected to remain unchanged and which observations would contradict the claim. If the claim is that two captures are coherent, demonstrate how the relevant phase was tied across their interval and how possible missed cycles were excluded or bounded. The experiment's strength lies in its power to distinguish alternatives. I invite Dr Dijkstra to consider how an apparently continuous phase record can become discontinuous because of software state rather than oscillator physics.

Edsger Wybe Dijkstra

Peer question 4 to Isidor Isaac Rabi

Professor Rabi, an SDR may retain a nominally continuous hardware sample counter while its numerically controlled oscillator, polyphase filter or digital downconverter is reset by a software command. The resulting complex output can acquire a new phase origin even though the physical ADC and external ten-megahertz reference never stop. A programmer may then concatenate successive output blocks and present them as one coherent capture. Would your experimental method expose such a state discontinuity, and how should the system record the difference between continuity of raw samples and continuity of a derived complex baseband representation? I am particularly interested in whether the acceptance test should make state changes deliberately observable instead of inferring them indirectly from an unknown transmitted signal. If separate software layers each report internally consistent sequence numbers, they may still refer to different clock

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domains. The test ought to identify the exact sample index at which each phase-bearing transformation takes effect, rather than rely on a log statement that it occurred sometime during the block.

Isidor Isaac Rabi

Immediate answer to Edsger Wybe Dijkstra

Dr Dijkstra, the experiment must control the specific physical or computational state whose continuity is being asserted. An uninterrupted ADC counter establishes one form of sample chronology, but it does not establish that every subsequent mathematical representation preserves the same phase origin. A digital downconverter multiplies input samples by a phase-bearing numerical oscillator. If the oscillator's phase accumulator is reset, the resulting complex baseband signal can jump even when the analogue input and sample clock are perfectly continuous. The experiment should therefore retain the raw input samples and, separately, the phase-accumulator state or a reproducible record of the transformation applied to those samples.

One controlled test would feed a stable, independently referenced tone into the receiver while recording both raw samples and the derived channelised output. Issue a documented reset of the numerical oscillator or filter, and observe whether the raw tone remains continuous while the processed phasor changes. Repeat with a different downconversion frequency and initial phase, then verify whether the observed jump follows the predicted mathematical transformation. If it does, the discontinuity is a property of the processing state and can be corrected or segmented under an

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appropriate model. If the raw samples also change, the investigation must examine upstream causes rather than attributing the event solely to software.

The record should make phase-bearing state visible. Store the oscillator's initial phase, frequency word, reset event, decimator phase and the exact sample index at which each change became effective. A simple software command timestamp is insufficient if the command was queued and took effect at an unknown later sample. Where implementation details prevent an exact mapping, the affected interval should carry a validity qualification. A later analyst should not be forced to deduce state transitions from an unknown emitter, because the system was capable of recording its own state and failed to do so.

It is also important that the experiment cover different classes of change. A digital oscillator reset may produce a predictable constant phase rotation; a change of filter coefficients can alter frequency-dependent group delay; a dropped input sample can shift the time axis; an ADC clock event may create a genuine discontinuity in the sampled chronology. Those mechanisms call for different recovery methods. A correction valid for one must not be applied to another simply because all produce a conspicuous discontinuity on a plot.

I would require the software team to provide an input-output test vector for each phase-bearing operation and a trace that links the processing state to acquisition sample indices. The experimental team should then challenge that implementation by deliberate changes under a known signal and independently verify the predicted effects.

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Successful conformance does not guarantee that the unknown emitter's phase remained coherent, but it removes one major class of uncontrolled instrumental explanation. I thank you for the challenge and return the token to Dr Atkinson, inviting Professor Townes to consider the relationship between spectral purity and a useful coherence interval.

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Charles Hard Townes

Dr Atkinson, the study of highly selective oscillations draws attention to the limitations of a single number called *frequency*. An oscillator has a carrier frequency, but its field may also possess phase fluctuations and spectral sidebands. Two devices can agree in mean frequency while their phase fluctuations differ markedly, with consequences for how long their complex outputs can be combined coherently. Spectral purity is therefore pertinent to a coherent measurement, but it is neither the same as absolute calibration nor a guarantee that a particular receiver phase remains continuous after an interruption. A maser or any other stable source cannot retrospectively supply the phase of a receiver whose state was never observed.

An ideal sinusoid accumulates phase linearly with time. A real source may have a phase-noise process whose behaviour depends on the observation bandwidth and the time scale. Short-term random phase fluctuations can broaden spectral lines or reduce the average phasor obtained by coherent integration. Slow drift can rotate a phasor progressively until a fixed-phase summation partially cancels the signal. The practical problem is to identify an integration interval over which the residual phase after justified corrections is small enough for the intended detection or estimation. Increasing the duration may improve sensitivity to random noise only if the phase errors and signal dynamics permit the accumulation to remain coherent.

The engineer should distinguish power averaging from complex field averaging. If a measured complex signal has constant magnitude A but phase error φ, its coherent mean is related to the mean of exp(iφ). If φ is

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approximately zero-mean Gaussian with variance σ_φ^2, its expected coherent amplitude relative to A is $\exp(-\sigma_\varphi^2/2)$ under that particular model. With $\sigma_\varphi = 0.3$ radians, the factor is $\exp(-0.045)$, approximately 0.956. The corresponding coherent power reduction factor is the square of that amplitude factor, about 0.914. This simple calculation illustrates the sensitivity to phase noise but should not be treated as a universal law for oscillator slips, non-Gaussian phase processes, target motion or abrupt coherent segment changes.

A calibration must examine the phase-noise spectrum and the coherence time in the context of the receiver's own conversion chain. A frequency reference can supply an excellent ten-megahertz clock while the RF synthesiser introduces further phase noise, spurious modulation or a nonrepeatable phase after frequency changes. Two synthesiser outputs multiplied from the same reference may share correlated noise components, while independent internal components contribute separate fluctuations. The distribution paths and conversion factors determine the final relation observed at the RF or IF output. It would be a mistake to quote the reference oscillator's low-noise specification as the phase-noise specification of the complete instrument without measuring the conversion path.

The received signal's phase must also be distinguished from local oscillator noise. The field could originate from a moving or unstable source, or it could undergo varying multipath before reaching the antenna. A reference tone injected locally can track much of the instrumental phase path, but not the propagation effects that occur before its injection point. If one compares an external unknown emission with an injected tone, a

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difference in their phase histories can support a hypothesis about the external path, provided the signal models and receiver transfer functions are adequately characterised. An identical disturbance appearing in both may indicate an instrument path issue, though the independence of their downstream components should be examined.

A receiver might attempt coherent addition of several bursts separated by many seconds or minutes. If phase was continuously tracked only within each burst, one may have several internally coherent segments without a known phase relation between them. One can still add powers or combine suitable noncoherent detection statistics, sometimes at a cost in sensitivity compared with ideal coherent integration. The choice should be made from the evidence, not from a desire to present a larger nominal integration time. Optimising the phase of every segment against the same noisy data can exaggerate apparent significance unless the search degrees of freedom are included in the false-alarm calibration.

The decisive experiment should compare a stable reference field with the receiver's output over the desired intervals and through relevant disturbances. Apply controlled oscillator offsets, phase steps and changes of RF tuning; observe whether the estimated phase follows the applied change, whether the residual phase noise agrees with the measurement model, and whether lock events are recorded. Repeat across signal levels and nearby interferers to test whether the detector introduces phase bias. An instrument which performs admirably under steady carrier conditions may still fail when an ADC clips, when a front-end gain stage changes or when a digital phase accumulator is reset.

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I would preserve a distinction between nominal purity and observed coherence. A low specified oscillator linewidth does not establish that two recordings hours apart share a definite phase. A record of phase continuity through that interval can establish a much stronger proposition, subject to the chain's calibration and its uncertainty. Where continuity has not been measured, a later fitting procedure may estimate a relative phase under a source model, but it must disclose its model dependence. The scientific question is not whether one can obtain a bright correlation peak. It is whether the reported coherence follows from independently controlled physical information rather than from an unreported freedom to fit the data. Dr Mills may now challenge the difference between an accurate time scale and a phase-coherent RF reference.

David Lennox Mills

Peer question 5 to Charles Hard Townes

Professor Townes, suppose two receivers are disciplined by network-derived time and frequency information and produce UTC timestamps which agree to within a small stated tolerance. Each also uses a nominally identical internal synthesiser. An analyst argues that the common UTC time scale is sufficient to align the phases of their recorded signals retrospectively, particularly if their complex sample rates are precisely known. But a timestamp can identify an epoch without establishing the local oscillator's integer-cycle state, and the network path may introduce variable or asymmetric delay. What additional measurements must relate the UTC epoch to actual ADC aperture and RF synthesiser phase? Is it ever legitimate to treat network clock offset estimates as a substitute for a phase-calibration measurement, or should

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they remain a separate element of the uncertainty budget? Suppose the epoch estimate is updated by a time-service algorithm during one recording session but not the other. Even an internally coherent sample stream can acquire different civil-time labels after a clock step, and a later analyst may mistake the resulting offset for phase information.

Charles Hard Townes

Immediate answer to David Lennox Mills

Dr Mills, the distinction is essential. A timestamp associated with a stated UTC epoch may position a sample boundary on an external time scale without establishing the carrier phase of the local oscillator at that boundary. A synthesiser can begin with different phase after power cycling even when its frequency derives from an accurate reference. An epoch alignment can therefore remove one coordinate ambiguity while leaving a phase offset which affects coherent summation. The analyst must either measure that offset through a calibration path or estimate it from the received data under a justified signal model, and the latter procedure has different inferential consequences.

The required measurement hierarchy begins with the time scale and its relation to the sample clock. It must then establish the receiver's sample counter origin, the converter aperture relation and the local oscillator phase at the relevant acquisition point. The phase accumulated through any gap must be tracked or its uncertainty evaluated. A network time estimate addresses only a portion of that chain. Even a protocol with excellent hardware packet timestamping is concerned with network event timing; it does not inherently carry

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the RF phase of a local synthesiser. One should not convert a network-clock accuracy figure into a guarantee of coherent RF phase without the intervening measurements.

If the system includes a stable calibration tone phase-referenced to the same source as the synthesiser, it may be possible to observe their relation continuously or at suitable intervals. If the calibration tone enters downstream of the antenna, the external propagation channel remains a separate issue. For signals with known modulation or pilot structure, the received data might permit carrier-phase recovery, but the fitted phase can be ambiguous, subject to cycle slips or affected by noise and multipath. A phase estimator's uncertainty and the number of hypotheses examined must accompany the result. The engineer must distinguish a measured calibration relation from a model-based phase recovery.

Network timestamping may be entirely adequate for event ordering at a coarse scale while the coherent phase requirement remains unsatisfied. Conversely, two receivers sharing a phase-continuous local reference could support precise relative phase comparisons even if their civil-time labels were imperfect. These are different scientific tasks, and the appropriate calibration follows the intended claim. I would report time-scale accuracy, local sample-rate uncertainty, synthesiser phase status and residual phase noise as separate entries, then describe which combinations of those quantities support the proposed integration.

The strongest experimental test would vary the network synchronisation while holding a local coherent RF calibration stable,

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and separately perturb the RF synthesiser phase while holding the network epoch stable. If the output distinctions follow the predicted interventions, the two timing domains have been separated in practice. If the receiver's report changes both under one intervention, the mapping requires further examination. A model claiming that UTC time alone determines carrier phase is not satisfactory until it survives such tests. I return the floor to Dr Atkinson and invite Mr Harrison to test whether excellent long-term rate stability can coexist with a loss of phase knowledge across an interruption.

John Harrison

Peer question 6 to Charles Hard Townes

Professor Townes, the keeping of accurate time at sea taught that a clock must be judged through changing temperature, motion and interrupted observation rather than only at an ideal laboratory moment. A modern receiver may contain a highly stable oven-controlled oscillator, but it can lose the external reference and coast for hours before returning to disciplined operation. Its average frequency after recovery might appear acceptable while the phase accumulated during holdover remains uncertain. What measurements should be retained during holdover if the examiner intends to treat recordings taken before and after it as one coherent observation? Is a bounded frequency error enough, or must an independent phase comparison be preserved at intervals? I am concerned that the phrase *held frequency* may conceal a lost chronology of whole oscillations. I would further ask whether the oscillator has remained within the temperature range used in the calibration and whether any observed ageing rate was measured before

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the interruption. A bound valid for an hour at constant temperature may not remain a bound after an uncontrolled warm-up.

Charles Hard Townes

Immediate answer to John Harrison

Mr Harrison, a bounded frequency error can place a bound on phase accumulation over a specified gap, but it does not necessarily identify the exact phase. Suppose the local oscillator's fractional frequency error during holdover is known only to lie between two values. Integrating that error over the holdover interval yields an interval of possible phase change. If the interval spans many complete turns, a later phase observation modulo one turn may be compatible with numerous different histories. The scientist cannot select the history giving the most favourable coherent result without disclosing the choice and its uncertainty. A return to the correct mean frequency does not reconstruct the missing cycles.

Holdover evidence should include the local oscillator's state, temperature and steering history, any available reference comparisons, lock loss and reacquisition epochs, and unwrapped phase residuals if these can be measured against an independent witness. A phase comparison made before and after a gap can help, but if its sampling is too sparse, a cycle slip can remain ambiguous. Frequent independent anchors may reduce that uncertainty, and a stable local free-running counter can preserve relative sample chronology. However, the instrument must still link its phase history to an external reference if an absolute coherent relation is claimed.

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In a receiver acquisition, the relevant phase may be multiplied from the reference frequency to a radio-frequency synthesiser output. A small uncertainty in the ten-megahertz source can therefore accumulate rapidly in the RF phase. Temperature changes can affect not only the oscillator but also the electrical lengths of cables and filters, so an otherwise stable frequency source may feed a path with changing phase. The acceptance test should include thermal cycling and deliberately interrupted references, with phase observation at points near the actual mixing and sampling stages, not merely at the reference generator output.

If the available data support only a bound on phase error, the coherent-integration analysis can propagate that uncertainty or divide the records into independently coherent sessions. If the plausible phase interval is narrow enough for the intended inference, the investigator may justify a controlled correction. If it spans numerous alternatives, an incoherent combination may be more defensible. A second reference or regular calibration tone can provide additional constraints, but the independence and uncertainty of that witness must be tested. Nothing is gained by replacing an honest unknown with a nominal value merely because the display asks for a phase angle.

The guiding discipline is to preserve the history rather than only its favourable endpoint. The clock's return to good operation is a new fact; it is not evidence that no phase error accumulated while it was unobserved. For an engineering or forensic report, this distinction governs whether the phrase *coherent across the interruption* is

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supported or merely hoped for. I thank you, Mr Harrison, and pass the token to Dr Nyquist to examine the digital transformations of reference phase in a receiver and the meaning of a cycle ambiguity in sampled data.

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Harry Nyquist

Dr Atkinson, a sampled signal is not simply a series of amplitudes that can be placed at arbitrary times without consequence. The mapping from a continuous field to a sequence of complex numbers depends on the effective sample times, analogue bandwidth and any local oscillator used in downconversion. A declared reference frequency helps establish the scale of that mapping, but coherent combination requires the relevant phases to be known as well. If two segments are recorded with equal nominal sample rates and then joined without preserving their clock and oscillator state, the resulting sequence may look continuous while concealing a phase discontinuity at the join. One must distinguish the legitimate mathematical act of resampling from the evidential assertion that the resulting samples represent a continuously observed waveform.

For a narrowband signal with carrier f_c, a timing offset Δt corresponds to a phase shift $\Delta\varphi = 2\pi f_c \Delta t$, modulo a complete cycle. At a carrier of one hundred megahertz, a one-nanosecond time shift corresponds to thirty-six degrees of phase. This can be large enough to spoil a phase-sensitive comparison even though the clock error appears negligible in an ordinary event log. At a ten-megahertz reference, the same time shift is 3.6 degrees. The engineer must therefore identify the frequency at which a timing uncertainty is converted into phase uncertainty. A tolerance quoted as a number of nanoseconds has no unique phase significance without that frequency and the model of the signal.

Resampling can compensate for a known ratio between clock frequencies. If one recorder's sample rate is related to another's by a measured factor, a suitable interpolation filter can express both on a

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common nominal time grid. Such a transformation cannot restore the integer-cycle phase history of an unobserved local-oscillator reset, nor can it reconstruct samples lost before recording. The interpolation may introduce group delay or edge effects that must be accounted for, and the input's bandlimit and alias rejection matter. A complex-valued output that looks smooth after interpolation is not evidence that its underlying RF phase was physically continuous throughout the observation gap.

A numerically controlled oscillator supplies an instructive example. Its complex mixing signal can be represented as $\exp(-i\varphi[n])$, where the phase accumulator advances according to a frequency word. If an accumulator is reset at the beginning of each capture, both captures can have the same output frequency yet different relationships to the external RF carrier. A phase reference applied to the ADC does not necessarily reset the numerical oscillator to a phase corresponding to the same real-world epoch. To claim coherence, the instrument must either retain the accumulator state and a relation to the epoch or measure the relative phase by another justified method. The software interface should record precisely which sample index was the first one affected by a reset or retuning operation.

A frequency divider introduces its own phase-state ambiguity. A clock multiplied or divided by an integer ratio may return with a phase determined by internal edge selection after a power cycle. The fact that the ratio is exact is not a guarantee that the absolute phase is repeatable. Two systems whose reference frequencies are both exactly ten megahertz can have their ADC clock edges separated by an unknown fraction of a period, and two synthesiser outputs can differ by an additional integer-cycle relation. The calibration procedure should therefore observe the edges or

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relative phases at the stages used in acquisition, not infer them solely from a calibration certificate for the upstream oscillator.

The interpretation of phase also depends on the signal. A sinusoid does not uniquely identify how many full cycles occurred between two measurements because phase observations naturally wrap modulo two pi. A distinctive wideband waveform may support an unambiguous delay estimate over a wider interval, but only within the waveform's bandwidth, signal-to-noise and model limitations. An intermittent unknown transmission may supply no continuous phase information through its silent interval. In such cases the receiver can retain accurate sample times and still lack a determinate carrier phase relation between bursts. The inference must not silently assume an uninterrupted source oscillator which was never observed.

It is valuable to keep three separate records: sample-index continuity within a capture, reference-clock state across captures, and phase-bearing transformation state for every mixer, resampler and channeliser. These can be linked through explicitly defined conversions. A later examiner should be able to reproduce the relative phase predicted for a known injected signal and to identify the exact point where an unknown integer ambiguity enters. If the recording lacks those data, the uncertainty should not be repaired by filling an interval with invented samples or by fitting a phase that maximises an output without accounting for the search. Such fitting can be useful for hypothesis generation, but it is not the same as an observed calibration.

My preferred acceptance test is therefore a pair of controlled captures of a known waveform with a deliberately inserted interruption. The engineer should vary the interruption duration, the reference phase, the local

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oscillator reset state and the digital processing configuration one at a time. For each trial, predict the phase relation and sample-index mapping before viewing the result. A system claiming coherent continuity must recover those predicted relations within stated tolerances or identify the condition in which the relation becomes unknown. The experiment must also verify that no unintended sample loss or duplicated sample blocks occurred. When the measurement passes, the report can say something definite about the instrument's coherence; when it fails, it can still report valid frequency and amplitude observations without manufacturing an unsupported phase history. I invite Lord Kelvin to examine the relation between the reported unit, the physical reference and the uncertainty claimed at the final output.

William Thomson, Baron Kelvin

Peer question 7 to Harry Nyquist

Dr Nyquist, engineers may become so engrossed in digital phase accumulators that they neglect the metrological question of what, precisely, has been compared. An oscilloscope can report phase in degrees, a time-interval counter reports seconds, a network clock reports UTC offset, and a frequency counter reports hertz; yet each may be used to support the same claim of coherence. How should the measurement equation connect these different quantities without treating them as interchangeable? If the input phase is reported modulo one revolution, should the uncertainty be expressed in degrees or seconds, and how should the engineer treat the possibility of an unknown whole number of cycles between sessions? I should also like a decision procedure for when the accuracy of the reference, rather than its short-term stability, controls the final uncertainty. A narrow phase reading at one frequency

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could also be entirely inappropriate for a wideband pulse whose envelope delay and phase delay differ. Please identify the experiment which would establish that the selected phase-to-time conversion matches the actual waveform feature being compared.

Harry Nyquist

Immediate answer to William Thomson, Baron Kelvin

Lord Kelvin, the first obligation is to define the measurand and the reference plane. If the claim concerns relative phase at a specified carrier frequency, report the phase difference and its uncertainty, including the frequency at which it was measured and the method used to unwrap it. If the claim concerns time alignment, report a time difference and its uncertainty on a declared clock and physical path. The conversion $\Delta t = \Delta\varphi/(2\pi f)$ is valid for a specified sinusoidal frequency and phase relationship, but its interpretation must state whether $\Delta\varphi$ is an unwrapped phase change or a value known only modulo a cycle. An ambiguity of whole cycles produces a family of possible time differences, not one narrow Gaussian interval.

For instance, at one hundred megahertz a five-degree phase difference corresponds to 5/(360 × 100,000,000) s, approximately 139 picoseconds, if the five-degree value identifies the relevant phase branch. But if the phase was observed only modulo 360 degrees, alternative values displaced by complete cycles differ in time by ten nanoseconds each. The small local phase uncertainty does not eliminate the integer-cycle ambiguity. One could have a precise phase reading and a poor absolute time determination at the same

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moment. The report must show both the local precision and the global ambiguity.

Reference accuracy and stability enter differently depending on the intended interval. If an acquisition lasts only a short period and the reference has a small but constant frequency bias, that bias contributes a predictable accumulated phase or time-scale error. Random short-term fluctuation contributes another uncertainty over the relevant averaging time. Across a long gap, drift and possible unobserved phase steps may dominate. The uncertainty model should use the time dependence appropriate to each term rather than importing one overall oscillator number. A calibration valid for a short coherent burst does not establish coherence for recordings separated by days.

I would construct an explicit chain: the reference's calibrated frequency result, its delivered phase at each hardware branch, the sampling aperture relation, local oscillator and numerically controlled oscillator states, the digital processing transformations, and finally the event or carrier phase inferred from the captured samples. Each conversion must state its unit, sign, reference time and uncertainty. Where dependence exists, covariance terms should be retained. When a link cannot be measured, the final claim should be bounded to the strongest quantity the remaining chain supports. A correct unit conversion is necessary but not sufficient to identify the physical mechanism.

For acceptance, I would compare a known coherent input across deliberately separated captures and make predictions for the phase

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after each controlled change. If the instrument preserves the expected relation, the chain has passed a bounded test. If a reset yields an arbitrary phase, the system should open a new coherent segment. These conclusions are testable without pretending that an exquisite frequency standard can resolve every software or propagation ambiguity. I thank you, Lord Kelvin, and return the token to Dr Atkinson for the concluding experimental and numerical review.

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TEN WORKED ENGINEERING APPLICATIONS

Application 01. A small reference-frequency error accumulates many phase cycles

Let the nominal oscillator frequency be f_0 = 10,000,000 Hz and its constant fractional frequency offset relative to the selected reference be $y = +1 \times 10^{-9}$. Its frequency error is $\Delta f = f_0 y = 0.01$ Hz. Over elapsed time T = 3600 s, the relative phase accumulation measured in cycles is $\Delta N = \Delta f T = 0.01 \times 3600 = 36$ cycles. The equivalent time-scale error magnitude is $|y|T = 3.6$ microseconds. These results apply to the simplified constant-offset model; an unrecorded phase step or oscillator steering event cannot be inferred from them. The thirty-six cycles emphasise why excellent rate agreement does not, by itself, establish phase continuity across long separated captures.

Application 02. Relative phase from a nonzero frequency difference

Two otherwise ideal oscillators have a constant frequency difference $\Delta f = 0.2$ Hz over T = 4 s. Their relative phase change is $\Delta\varphi = 2\pi\Delta f T = 2\pi(0.2)(4) = 1.6\pi$ rad = 288 degrees. The phase is measured modulo a complete turn if only its endpoint is observed; the accumulated 0.8 cycles are known here because the controlled model provides the difference and interval. A coherent sum performed without this phase correction may attenuate rather than enhance the signal. The result concerns the oscillator relationship, and it should not be mistaken for evidence of the received emitter's identity or for a universally valid phase-recovery algorithm.

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Application 03. Coaxial reference branch creates a frequency-dependent phase shift

A reference-distribution coaxial cable has length ℓ = 25 m and velocity factor v_f = 0.66. With c = 299,792,458 m/s, its idealised one-way delay is $\tau = \ell/(v_f c) = 25/(0.66 \times 299{,}792{,}458)$ s ≈ 126.35 ns. At ten megahertz, the corresponding phase lag is 360 degrees × 10,000,000 Hz × 126.35 ns ≈ 454.9 degrees, or approximately 94.9 degrees when reported modulo 360. This calculation assumes a uniform nondispersive line. Cable length, connectors and temperature contribute uncertainty; the difference between absolute accumulated phase and modulo phase must remain explicit in any coherent alignment claim.

Application 04. A small time offset has a large radio-frequency phase consequence

A path or clock difference of Δt = 1 ns is interpreted at radio frequency f = 100 MHz. The corresponding sinusoidal phase difference is $\Delta\varphi$ = 360 degrees × $f\,\Delta t$ = 360 × 100,000,000 × 10^{-9} = 36 degrees. At ten megahertz the same delay gives only 3.6 degrees. These two answers are consistent because phase is frequency dependent. A manufacturer's 1 ns skew specification therefore cannot be translated into one fixed phase-angle tolerance for every RF or IF stage. The physical reference plane and the actual frequency of the relevant comparison must accompany the uncertainty statement.

Application 05. Differential reference error across a long coherent gap

Two acquisition chains differ in fractional sampling-clock frequency by a constant $\Delta y = 1 \times 10^{-10}$. If their relevant carrier-equivalent phase

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comparison is at f_c = 100 MHz, the corresponding differential frequency is $\Delta f = f_c \Delta y$ = 0.01 Hz. Over a gap T = 600 s, the phase difference accumulates $\Delta N = \Delta f T$ = 6 cycles. The final wrapped phase could appear identical even though the unwrapped histories differ by six full turns. The model presumes the offset was constant and does not account for possible target motion, propagating channel changes or resets. A single endpoint phase reading cannot recover those accumulated turns without more information.

Application 06. Phase uncertainty expressed as equivalent timing uncertainty

Suppose a carrier-phase measurement at f_c = 100 MHz has a small standard uncertainty of σ_φ = 0.1 radians, with phase errors sufficiently local that linear conversion is valid. The equivalent timing standard uncertainty is $\sigma_t = \sigma_\varphi/(2\pi f_c) = 0.1/(2\pi \times 100{,}000{,}000)$ s $\approx 1.59 \times 10^{-10}$ s = 159 picoseconds. The same phase uncertainty at ten megahertz corresponds to approximately 1.59 ns. This is not an absolute event-time uncertainty: the unknown whole-cycle branch, clock epoch and propagation corrections remain separate. In an investigation, the uncertainty must be associated with the actual frequency and phase observable rather than borrowed from a different stage.

Application 07. Expected coherent loss under a stated Gaussian phase model

Assume a constant-amplitude complex signal with independent zero-mean Gaussian phase error φ of standard deviation σ_φ = 0.3 rad. Under this specific model, the expected coherent amplitude factor relative to perfect phase alignment is $\exp(-\sigma_\varphi^2/2) = \exp(-0.045) \approx 0.956$. The

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corresponding coherent power factor is approximately $0.956^2 \approx 0.914$. The model is not appropriate for arbitrary phase slips, systematic Doppler drift or an unknown phase chosen by post hoc fitting. It illustrates why coherence claims should include phase-noise assumptions and why two accurate frequency references may still deliver less coherent gain than expected.

Application 08. Allan deviation measures variation, not the absolute calibration offset

Three equally spaced non-overlapping fractional-frequency estimates over averaging time $\tau = 1$ s are $y_1 = 1 \times 10^{-9}$, $y_2 = 3 \times 10^{-9}$ and $y_3 = 2 \times 10^{-9}$. Using the illustrative Allan-deviation estimator $\sigma_y(\tau) = \sqrt{\{[(y_2-y_1)^2 + (y_3-y_2)^2] / [2(M-1)]\}}$ for $M = 3$ observations gives $\sqrt{[(4 \times 10^{-18} + 1 \times 10^{-18})/4]} = \sqrt{(1.25 \times 10^{-18})} \approx 1.118 \times 10^{-9}$. This statistic describes variation across those observations; it does not certify that the mean frequency is correct or that no unobserved phase step occurred. The small sample is illustrative, not a robust oscillator characterisation.

Application 09. Combining independent delay uncertainties at a reference fan-out

Consider three independent zero-mean standard uncertainty contributions to differential timing: reference measurement $u_r = 0.4$ ns, distribution-branch delay $u_b = 0.7$ ns and sampled phase measurement $u_s = 1.1$ ns. Under the independence assumption, the combined standard uncertainty is $u_c = \mathrm{sqrt}(u_r^2 + u_b^2 + u_s^2) = \mathrm{sqrt}(0.16+0.49+1.21)$ ns $= \mathrm{sqrt}(1.86)$ ns ≈ 1.364 ns. This result is not a coverage interval without a distribution and coverage-factor justification. If the two receiver channels share reference noise, the correlation and

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covariance of their errors must enter the difference model rather than using independent quadrature indiscriminately.

Application 10. Wrapped phase cannot identify an unknown whole-cycle time delay

A carrier of f_c = 80 MHz has period $T_c = 1/f_c$ = 12.5 ns. A measured phase offset of 270 degrees is numerically equivalent to −90 degrees modulo 360; in the simple sinusoidal model these alternatives differ by one full period, 12.5 ns, in any converted time difference. Further alternatives displaced by two or three complete cycles remain possible if the history is unobserved. A phase meter can report a small uncertainty around 270 degrees while the true unwrapped delay remains ambiguous by integer multiples of 12.5 ns. A wideband calibration sequence, continuous phase tracking or another independent constraint is necessary before claiming a unique physical delay across separated captures.

Norman Foster Ramsey Jr., Cross-Peer Question to William Redington Hewlett: Mr Hewlett, two receivers each use a ten-megahertz reference advertised as highly stable. What experiment establishes that their complex captures remain phase coherent across a power interruption?

William Redington Hewlett, Cross-Peer Answer to Norman Foster Ramsey Jr.: Professor Ramsey, frequency stability alone does not guarantee continuity of phase through divider reset, oscillator reacquisition or synthesiser relock. Measure relative phase against a shared, traceable calibration tone before and after the interruption, with the tone injected through a known physical reference plane. Record synthesiser lock states, phase resets, distribution-cable delays and frequency-control settings. A small long-term frequency

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difference can accumulate many cycles between sessions; subsequent complex addition can therefore cancel rather than reinforce a real signal. Distinguish a common reference frequency from a guaranteed common phase origin. Repeat tests after power cycles and temperature excursions, then report residual phase uncertainty versus separation time. I yield to Mr Essen on traceability of frequency standards.

William Redington Hewlett, Cross-Peer Question to Louis Essen: Mr Essen, what does metrological traceability of a ten-megahertz frequency measurement establish, and what does it not establish about two separately recorded phase histories?

Louis Essen, Cross-Peer Answer to William Redington Hewlett: Mr Hewlett, traceability connects a measurement result to a stated reference through a documented, unbroken chain of calibration, each step contributing uncertainty. It does not by itself imply that two remote oscillator phases remained locked at all intervening instants. Record calibration dates, reference identity, frequency offsets, measurement intervals, uncertainty components and environmental dependence. Phase requires its own anchor and continuous or sufficiently sampled monitoring if later coherent combination is proposed. A frequency error of one part in a billion at ten megahertz corresponds to 0.01 hertz; over one hour it represents thirty-six relative cycles, despite a seemingly minute frequency difference. The actual phase path can be further altered by relock or distribution delay. I pass the token to Dr Mills for continuous timing records.

Louis Essen, Cross-Peer Question to David Lennox Mills: Dr Mills, if network time reports that both acquisition hosts agree within one millisecond, is that

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adequate evidence for coherent combination of a hundred-megahertz carrier?

David Lennox Mills, Cross-Peer Answer to Louis Essen: Mr Essen, no. Host time agreement to a millisecond is far coarser than the carrier period and does not establish ADC sample phase or local-oscillator phase. A coherent hundred-megahertz comparison requires an appropriately characterised phase relationship at the RF and sampling reference planes, with uncertainties expressed in units relevant to the wavelength or period. Network synchronisation can supply useful epoch information, especially with hardware timestamping, but it is only one part of the acquisition timing chain. Record oscillator phase, common clock distribution, divider resets, analogue delay and any interpolation used to align captures. Test coherence with a split calibration signal through independently calibrated paths, and report loss of coherence under the intended separation times. I pass the token to Mr Nyquist for the sampled evidence.

David Lennox Mills, Cross-Peer Question to Harry Nyquist: Mr Nyquist, can two captures be made phase coherent retrospectively by searching over every possible phase rotation until a desired weak line appears?

Harry Nyquist, Cross-Peer Answer to David Lennox Mills: Dr Mills, the procedure can produce a phase-aligned estimate under an explicitly chosen model, but searching over rotations is a statistical optimisation that can also align noise. The selected phase is not independent evidence of physical coherence. Define the search range and objective before examining the target, then calibrate the false-alarm consequences on noise-only records and verify alignment on an independently injected reference. Preserve the original separate captures, clock measurements and the chosen rotation as

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a derivative, rather than overwriting raw I/Q. Any conclusion about a common emitter must also address frequency drift, path-dependent phase, missing samples and alternative common-mode causes. A large combined peak is conditional evidence, not proof of uninterrupted phase traceability. I respectfully return the token to Dr Atkinson.

Dr. James M. Atkinson. Closing synthesis of Question 052

Distinguished colleagues, Question 052 establishes the obligations of coherent measurement over time. We have distinguished the accuracy of a frequency standard from the stability of its frequency, the continuity of its phase, and the integrity of the chain which delivers that phase to the actual sampling and mixing stages. A standard which is traceable to an appropriate reference is essential evidence for a particular frequency measurement, but its certificate does not establish all the temporal and phase relationships required by a separate receiver experiment. The measurement result, not the reputation of a laboratory instrument, must carry the traceability claim and its uncertainty. A frequency reference is therefore necessary to many coherent comparisons, but not sufficient by itself to warrant a claim that captures separated by a substantial interval can be joined in one coherent complex record.

Professor Ramsey has explained the distinction between phase rate and phase history. A very small frequency offset can accumulate many whole turns over a long gap; the final wrapped phase cannot identify the number of turns without additional information. Mr Essen has placed the calibration hierarchy and its time-dependent validity at the centre of the discussion. A result is traceable only through the stated measurement chain, with uncertainties and operating conditions attached. Professor Rabi has

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required experiments capable of distinguishing source behaviour from receiver reference faults. Professor Townes has shown why phase noise and spectral purity determine the useful coherent integration interval without certifying absolute phase. Dr Nyquist has shown where phase-bearing state can be altered by dividers, digital oscillators, retuning and resampling even when the reference oscillator remains excellent. Each argument applies to a different part of the same physical chain.

The required acceptance programme should begin with a reference whose frequency and phase relationships are measured against a declared standard. Characterise the distribution branches, converter clock domains, synthesiser states and digital processing origins. Inject a known coherent waveform into the declared RF path and record its relative phase over the intended integration time, not merely its mean frequency. Perturb the system deliberately: change a reference cable, interrupt discipline, restart a synthesiser, reset the numerical oscillator, retune a channel and repeat the test under thermal and load conditions representative of operation. If the measured phase follows the predicted changes, the model gains credibility. If a phase step appears, the record must identify it or terminate the coherent segment. An unobserved interval is not transformed into a measured phase history by later interpolation.

The forensic interpretation must further separate the instrument from the field. A change in received phase can arise from transmitter frequency error, target motion, multipath or propagation, as well as from the receiving reference and processing chain. A local injected calibration tone can reveal certain instrumental causes, but it does not automatically measure the full propagation channel before its injection point. Independent receivers and

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reference paths help only when their common dependencies are documented. Correlated errors must enter the uncertainty model where they are present. The appropriate conclusion may be that two records share a calibrated frequency scale but have no known absolute relative phase; such a result still supports valid spectral and chronological analysis within its stated limitations.

We must also distinguish an exploratory fit from a measured calibration. A rotation selected to maximise a weak apparent peak can be a useful research tool, but if its degrees of freedom were chosen after observing the very data used for confirmation, the statistical evidence must account for that search. The resulting alignment is not proof that the receiver actually preserved phase continuity during silence or shutdown. A more defensible report provides raw sample chronology, clock-state logs, calibration phase measurements and processing-state records, then specifies whether coherence is observed, model-estimated, or absent. The ten worked applications illustrate how seemingly tiny frequency, timing and phase errors can matter at the scale of a long coherent integration, and why their interpretation depends on defined units and reference planes.

The intellectual dialogue remains a constructed educational exercise. No historical contributor is alleged to have encountered the present-day receiver architectures or standards used for the modern applications. The value of their genuine metrological and engineering traditions lies in their ability to make a testable distinction between what a device displays and what the evidence establishes. Question 052 is therefore concluded with a conditional rule: coherent combination across separated captures is justified only when the necessary phase relationship is measured, retained, or

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bounded by an independently validated model whose uncertainty is adequate for the particular inference. We now proceed to Question 053, where the act of disciplining an oscillator may itself conceal a discontinuity if the observation system retains only an attractive long-term average.

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QUESTION 052. TECHNICAL REFERENCES AND QUALIFICATIONS

1. National Institute of Standards and Technology. Metrological Traceability: Frequently Asked Questions and NIST Policy. https://www.nist.gov/metrology/metrological-traceability . Establishes the distinction between traceability of a measurement result and a certificate or instrument label.

2. Joint Committee for Guides in Metrology. International Vocabulary of Metrology, clause 2.41, Metrological Traceability. https://jcgm.bipm.org/vim/en/2.41.html . Provides the calibration-chain requirement and the importance of associated uncertainty.

3. Riley, W. J., and Howe, D. A. (2008). Handbook of Frequency Stability Analysis. NIST Special Publication 1065. https://www.nist.gov/publications/handbook-frequency-stability-analysis . Frequency-stability statistics, phase and data-treatment guidance, not a certificate of actual SDR continuity.

4. NIST. Time and Frequency from A to Z, including Allan deviation, frequency stability, phase noise and phase steps. https://www.nist.gov/pml/time-and-frequency-division/popular-links/time-frequency-z . General technical background for the simplified applications.

5. NIST. Frequency and Time: Their Measurement and Characterization. https://www.nist.gov/system/files/documents/calibrations/pfc-2.pdf . Further background on frequency and phase measurement terminology; not evidence of one installed instrument's condition.

EDITORIAL VERIFICATION NOTE: The examples are theoretical or hypothetical. They do not prove a specific receiver's oscillator performance, its phase continuity, or the historical views of the named scholars. Apparatus-specific calibration records, original sample data, and a verified uncertainty model are needed for any forensic assertion about an actual capture.

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QUESTION 053

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When can oscillator disciplining conceal rather than correct a phase discontinuity?

SCHOLARLY RECONSTRUCTION. The following dialogue is an explicitly hypothetical educational exchange. The named historical contributors did not meet for this discussion; modern SDR, GNSS and digital-logging applications are contemporary editorial interpretations of their established scientific work.

Dr. James M. Atkinson, Moderator: Professor Essen, a receiver may report a frequency reference as locked, disciplined and apparently stable, yet the continuous phase record needed for coherent evidence may have been interrupted. Would you explain how a control loop could restore an excellent long-term frequency result whilst obscuring the very discontinuity that an investigator must preserve? Please distinguish oscillator stability, absolute time, sample chronology and phase continuity, and identify measurements capable of separating them.

Louis Essen, Principal Contributor: Dr. Atkinson, the central difficulty is that a frequency standard and an evidential clock are judged by different observables. Long-term frequency accuracy concerns the rate at which phase advances; uninterrupted phase concerns the integral of that rate together with any discrete changes. A reference that eventually returns the correct rate may have crossed a discontinuity that cannot be reversed by declaring a subsequent locked condition. The analyst must therefore insist upon the original phase-versus-time history rather than rely upon a single status indication or a stability plot generated after the clock has recovered.

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Let $x(t)$ denote the clock time error in seconds, t the reference time in seconds, and $y(t)=dx(t)/dt$ the dimensionless fractional-frequency error wherever the derivative exists. An abrupt time step Δx at instant t_0 can be represented as $x(t)=x_{cont}(t)+\Delta x\, H(t-t_0)$, where H denotes the unit-step function. A difference of x over an interval containing t_0 will include that step, but intervals wholly before or wholly after it need not. If software rejects outliers, bridges missing intervals, or calculates only long averaging times well away from the event, its reported stability may look excellent. The report is then a conditional characterisation of the retained samples, not proof of an uninterrupted clock.

The frequency-domain counterpart is equally instructive. For a sinusoidal carrier whose nominal frequency is f_0 hertz, a clock-time step Δx corresponds to an approximate carrier phase jump $\Delta\varphi=2\pi f_0\Delta x$ radians, assuming the relevant signal phase is referred to the clock's time base. At $f_0=10$ MHz and $\Delta x=20$ ns, $\Delta\varphi$ is 0.4π radians, or 72 degrees. This numerical example is hypothetical. A 20 ns discontinuity can be immaterial to a coarse event log yet destructive to a phase-coherent combination of two receiver records. A phase jump measured at one observed RF frequency must not automatically be attributed to a reference-clock step, since local oscillator paths, mixers, synthesiser division, propagation and carrier motion may introduce their own phase changes.

A disciplined oscillator comprises at least an adjustable local source, a reference measurement, a controller and a state machine. During ordinary lock the controller acts upon measured phase or frequency error. When its external reference disappears, the system may enter holdover, using the local oscillator and saved estimates of its drift. On reacquisition, firmware

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may choose a rapid phase step, a gradual slew, a restricted-frequency correction, or an exchange between reference sources. These are different policies. A gentle correction can preserve monotonic displayed timestamps while changing the instantaneous rate; an abrupt correction can preserve the future absolute clock alignment at the cost of phase continuity. Neither policy is fully described by the phrase 'relocked successfully'.

The distinction between control action and observation is crucial. Suppose an independent phase comparator records an unfiltered time-error step of 20 ns at reference reacquisition, while a supervisory plot shows a smooth residual because its estimator resets an offset, suppresses the transition interval or reports only the filtered loop error. The difference does not imply that either record is fictitious. It implies that the records describe different quantities. A responsible engineer retains the comparator stream, controller command, phase-detector history, lock-state transitions, sample counters, reference-health indicators and the software version that produced each derived trace.

A credible test deliberately interrupts the reference for a controlled duration under lawful laboratory conditions. A second independent reference observes the local oscillator continuously. The investigator records the pre-interruption baseline, holdover interval and post-reacquisition transient, then repeats the experiment with different temperatures and interruption durations. The decisive measurement is not merely whether the output returns to its target frequency; it is whether the accumulated phase, timestamp mapping and sample chronology can be reconciled without unrecorded jumps. Cross-reference switching should be tested separately

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because changing to another apparently valid source can introduce a new phase offset without invoking a loss-of-lock alarm.

The Allan deviation is a valuable but insufficient summary. It measures a specified statistical aspect of fractional-frequency variation as a function of averaging time. Its inference depends upon sampling, dead time, treatment of trends and discontinuities, and the precise data intervals selected. A clean curve must not be cited as evidence that no single phase step occurred. Nor is every conspicuous Allan-deviation point proof of a phase step: a drift excursion, environmental disturbance, estimator reset or missing sample can create superficially similar statistical features. Preserve the underlying phase record and test alternative explanations.

The forensic significance becomes sharp when two receivers are combined for arrival-time, cross-correlation or coherent-array analysis. If their timing errors contain independent discontinuities, their calculated relative delay may jump even if each receiver individually shows a green lock indicator. If both are driven by the same defective reference, their errors may be correlated and falsely reassuring when the receivers are compared with one another. An independent timing witness, physically and electrically separated where feasible, is therefore more informative than a second instrument sharing the first instrument's clock tree.

I would conclude that a disciplining system corrects an identifiable error according to a specified control objective. It does not, by that fact alone, establish that the original measurement record retained continuous phase. The proper evidential statement is bounded: 'After reacquisition, frequency agreement was restored within the tested limits; continuity across the interruption remains established, unestablished, or contradicted by the

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separately retained phase and timestamp evidence.' Anything stronger must be earned by direct measurement rather than inferred from a favourable dashboard.

Dr. James M. Atkinson, Moderator: Dr. Dijkstra, would you examine the distinction between the oscillator's physical evolution and the state presented by the software controlling its clock?

Edsger W. Dijkstra, Peer Question: Professor Essen, an engineer may assume that a reported 'locked' state describes the complete system invariant. Yet a lock bit is ordinarily derived from a finite decision rule, sometimes with hysteresis, timeouts and exception handling. How would one specify a more meaningful invariant, and what tests could expose a program that silently repairs timestamps, reorders buffered data, or substitutes an inferred sample chronology? I would also ask whether the original phase observations can be reconstructed if the application has retained only a smoothed clock estimate and not the underlying counter or comparator readings.

If the stated invariant can be met by counters created in application software after data have already been dropped, its reassuring appearance is misleading. Would you distinguish device-origin counters from host-origin packet numbers and specify an end-to-end stimulus test capable of detecting a gap concealed by software reconstruction? I would also ask whether a preserved exception log is sufficient if the application permits the operator to exclude failed intervals from the exported evidential file without retaining the rejection policy.

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Louis Essen, Response: Dr. Dijkstra, a useful invariant is not 'lock remains true'. It is that the relationship between hardware sample index n, measured local clock time and a declared external reference remains known within a stated uncertainty for every accepted interval. Let t_n denote the reference-time estimate associated with sample n and let N(n) denote the hardware counter. A continuous acquisition should preserve counter order and disclose any missing or duplicated indices. A timestamp correction may be appropriate, but it must be represented as a documented transformation t'_n=g(t_n,state), not silently substituted as if it were the raw observation.

I would add that counter provenance can be tested with a stimulus whose markers are known independently of the receiving software. A predictable succession of phase-coded test pulses makes it possible to detect omissions which the application attempts to conceal by renumbering its own buffers. The experiment must compare received raw sample offsets against a device-side counter or an independent acquisition ledger. A log recording 'no errors' has limited evidential value if the software generating it did not observe the relevant hardware event. The operator should retain every failed test, timestamp mapping revision and excluded interval. These records distinguish integrity of stored data from completeness of the physical observation.

A phase-continuity finding should finally be expressed at the smallest justified reference plane. An uninterrupted external reference at the rack does not prove uninterrupted sampling inside the receiver, just as a complete device index sequence does not prove uninterrupted UTC traceability. The test report should state which property each control

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actually established and the permitted uncertainty range for the event in question.

The experiment should separately perturb reference availability, controller restart and host buffering. Before each perturbation, inject a benign known timing marker through the authorised test chain. Capture raw counters, device-side timestamps and host arrival times; compare the three streams. A counter sequence with no gaps alongside discontinuous host arrival times points toward buffering rather than missing RF samples. Conversely, an index gap that coincides with reacquisition deserves an explicit missing-data qualification even if interpolation gives a visually smooth trace. Where raw observations were discarded, reconstruction is not an evidential certainty; it becomes an estimate conditional upon a model, and the report must say so. A system should make discontinuities conspicuous rather than improve their appearance by deleting them.

Dr. James M. Atkinson, Moderator: Professor Rabi, what independent physical test would you require before accepting that a measured transient came from the reference and not the observed signal?

Isidor I. Rabi, Peer Question: Professor Essen, the phase of an RF measurement is not simply the phase of one standard. Propagation changes, carrier modulation, resonator behaviour, heterodyne conversion and the measuring apparatus itself may all influence a trace. If a receiver reports a sudden angular displacement exactly when its timing reference is reacquired, correlation in time is suggestive but cannot by itself determine cause. What comparison arrangements, controls and counterexamples would be sufficient to attribute the event to the receiver's reference chain

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rather than to the transmitter, antenna path or a separate instrument artefact?

Consider, in addition, the possibility that a phase-locked synthesiser introduces a transient only in the band under examination, while an independent reference comparator operates at the receiver's 10 MHz input. Which downstream test point would best discriminate these possibilities, and how can the investigator avoid disturbing the very oscillator path being measured? If the test requires opening the chassis, what qualification should the report state when that intrusive operation differs from ordinary field configuration?

Louis Essen, Response: Professor Rabi, one should preserve the event and then seek a controlled differential measurement. Observe a stable laboratory test tone through the receiver while an independent phase comparator examines the oscillator reference. Where possible, observe the same test tone through a second receiver supplied by an independently maintained clock. Vary the first receiver's reference state without changing the transmitter. If the first receiver's phase change follows the reference transition, while the independent receiver and transmitter witness remain continuous, the reference-chain hypothesis gains force. One should also swap receivers or references to determine whether the anomaly follows an instrument or a source.

A high-value control is to observe the last accessible synthesiser output and a representative downstream sample-trigger relation while the input reference is deliberately disturbed within the laboratory's safe operating range. If the phase step is generated inside the synthesiser, the upstream reference comparison may remain normal while the downstream waveform

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changes. The challenge must specify the frequency plan, loop lock state, gain configuration and cable geometry, because the result need not transfer between modes. If opening the chassis changes loading, grounding or shielding, the intrusive result is a diagnostic investigation rather than a direct reproduction of field behaviour. The report should distinguish those conditions explicitly.

Even a pair of independent instruments can be influenced by shared environmental conditions or reference distribution. A causal finding should rely on controlled swaps and the predicted response to a known perturbation, not on the impression that two screens show similar phase traces.

No isolated experiment eliminates every hypothesis. A reference cable movement can alter phase, and a nominally independent receiver may share power, environmental perturbations or distribution hardware. The test record should state its control boundaries and the observed phase relation at each reference plane. A measurement of the 10 MHz reference alone cannot prove continuity of a digitally synthesised local oscillator or the downstream sampling edge; a fault can occur after the monitored reference node. Hence the best corroboration includes a downstream timing observable, such as an externally measurable sample trigger or a known injected tone carried through the actual signal path. Attribution is a hierarchy of constrained comparisons rather than a single status flag.

Dr. James M. Atkinson, Moderator: Dr. Mills, please consider how network time services might make the evidential narrative appear smoother than the receiver hardware permits.

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David L. Mills, Peer Question: Professor Essen, software time correction commonly separates a clock's internal state from its user-facing timestamp service, and packet arrival uncertainty can complicate estimation. Suppose a network-disciplined acquisition host slews the system clock while its SDR device uses a local oscillator and independent hardware counter. Can host time alone establish sample chronology? How should an investigator interpret a monotonic time display during a reference outage, and what independent data would discriminate real sample continuity from software adjustment or queued data arriving later?

If the host's monotonic time remains continuous but the algorithm mapping it to UTC has been revised after a reference outage, what is the evidential status of the originally displayed UTC time? May a later analyst replace it silently with a refined estimate, or must the case record preserve both values, their algorithms and the state intervals for which each was applicable? Please distinguish correction of a known clock bias from interpolation across an interval during which no physical acquisition-time reference was available.

Louis Essen, Response: Dr. Mills, host time is one measurement channel, not a substitute for the receiver's acquisition clock. A monotonic host timestamp can be achieved by a software clock discipline policy while the hardware sample rate changes, pauses or loses lock. Conversely, the hardware stream may be continuous while network delivery times fluctuate significantly. The analyst should retain the sample counter, the hardware timebase calibration, the host's wall-clock and monotonic-clock records, and the conversion used to map samples onto external time. Whenever that

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conversion is piecewise, its boundaries and adjustment history are material evidence.

The original UTC label is part of the historical record, whether or not later calibration improves its accuracy. A corrected time should appear as a new derived value associated with its source observations, algorithm version and applicable validity interval. If the receiver lacked an external reference during part of the capture, the correction may require an explicit holdover model with growing uncertainty; it should not be presented as direct observation. A host which never stepped its clock may nevertheless have altered the rate of its wall-time mapping by slewing. That history belongs in the evidence package alongside hardware counters and original logs.

A necessary qualification is that a timestamp is evidence of when an event was assigned a time within a particular instrument system. Establishing physical acquisition time requires calibrated knowledge of the latency and reference-plane relationship. Without that bridge, apparently precise agreement between host times can be an agreement between software conventions rather than a measurement of electromagnetic simultaneity.

A useful diagnostic uses a periodic reference stimulus and a hardware capture counter to estimate the interval between detected markers. In parallel, network synchronisation logs reveal when the host clock was slewed or stepped. If marker spacing in the sample-index domain stays steady but wall-clock intervals change, the evidence points toward timestamp mapping. If the sample spacing itself changes, investigate oscillator behaviour and dropped-sample controls. Where the external reference was lost, describe the holdover quality and the uncertainty growth during the interval; do not attach precision to a timestamp simply because

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the operating system prints many decimal places. Calibration of one clock does not confer traceability on every downstream timestamp automatically.

Dr. James M. Atkinson, Moderator: Lord Kelvin, how should this uncertainty be expressed when a brief discontinuity has operational consequences disproportionate to its duration?

William Thomson, Baron Kelvin, Peer Question: Professor Essen, numerical exactness in a display is not the same thing as measured accuracy. A very short phase disturbance may dominate an otherwise long and successful observation, particularly when the inference depends upon cross-receiver delay or accumulated phase. How should one separate repeatability from systematic correction, form an uncertainty budget without inventing certainty, and decide whether a candidate phase step renders a localisation or correlation claim untenable? May an engineer use a single scalar uncertainty figure to summarise both ordinary running conditions and the rare reacquisition transition?

Suppose that the estimator's standard deviation during settled lock is only two nanoseconds, but a reference-selection event might have introduced an unobserved step of fifty nanoseconds. Would you add that possible step in quadrature as though it were an ordinary zero-mean random error, or should it be represented as a distinct systematic scenario? Please explain how a receiver can exhibit excellent repeatability before and after the transition while remaining incapable of supporting a precise comparison of events on opposite sides of it.

Louis Essen, Response: Lord Kelvin, it would be misleading to absorb an unresolved discrete phase event into the average standard deviation of

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otherwise orderly operation. The proper model distinguishes conditional operating states. Let u_run denote standard uncertainty in the normal locked state, u_hold(t) the holdover uncertainty after elapsed time t, and Δx_step an identified or bounded reacquisition step. If Δx_step is known with uncertainty, its correction and associated uncertainty should be treated explicitly; if the step may have occurred but is unobserved, the analysis should present alternative scenarios or a conservative interval rather than treat the event as zero-mean random noise.

A discrete possible step does not behave like an ordinary contribution to white noise. If its magnitude is bounded but its sign unknown, a sensitivity analysis should examine the relevant positive and negative cases; if it is measured, apply a documented correction and propagate its own uncertainty. Treating the event as a zero-mean Gaussian merely to fit an existing root-sum-square worksheet could produce an unjustifiably narrow interval. The report should identify whether the timing claim spans a known discontinuity or a period of stable operation and compute its uncertainty from that actual scenario.

For example, a ten-nanosecond step at a 10 MHz phase reference corresponds to an idealised 36-degree phase displacement, but one cannot assert the exact phase error of every converted RF band without testing its signal path. A physically unobserved step cannot be eliminated by averaging many settled measurements taken afterwards. The quantities, assumptions and state boundaries should remain visible to a later examiner.

As an illustration, two independent receivers might exhibit 2 ns and 3 ns standard timing uncertainty while continuously locked. If those components are demonstrably uncorrelated, the standard uncertainty of their difference

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is sqrt(2^2+3^2)=sqrt(13) ns, approximately 3.61 ns. But if one receiver has an additional unresolved 20 ns step at reacquisition, the quoted 3.61 ns characterises only the continuous-state measurement model. A delay inference straddling the transition may carry a bias much greater than that nominal figure. The correct treatment is to exclude or separately qualify the affected interval until a bound on the discontinuity is established. Correlation between uncertainties must also be considered when references or environmental effects are shared.

Dr. James M. Atkinson, Moderator: Mr. Nyquist, can a system with adequate average sampling specifications nevertheless fail to preserve the required timing information?

Harry Nyquist, Peer Question: Professor Essen, a receiver's sample rate may comfortably meet the nominal frequency requirements of the signal, while its timestamping and phase bookkeeping remain defective. How should an engineer distinguish the conditions that protect reconstructable signal bandwidth from those that protect evidence of a short phase or timing step? In particular, what does a digital display's sample-rate specification establish, and what does it fail to establish about sample continuity, resampling, aliasing or coherent combination across a reference disturbance?

There is also a difference between a resampler which uses measured nonuniform timestamps and one which assumes a constant nominal sampling rate. What independent evidence is needed to justify phase unwrapping across an interval of uncertain sample spacing? If the carrier phase may rotate through several cycles while the instrument is unsynchronised, could two different unwrapped histories agree exactly with

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the recorded endpoints? I seek a criterion for refusing a unique phase conclusion when the data do not discriminate the alternatives.

Louis Essen, Response: Mr. Nyquist, the sampling theorem and the evidential continuity question address distinct requirements. A rate adequate for a bandlimited signal under the theorem's assumptions does not prove that the samples were uniformly spaced in physical time or accompanied by accurate timestamps. The actual acquisition may include timebase variations, transient clock corrections, missing samples or buffering delays. An ideal reconstruction based on nominal uniform intervals can therefore give a convincing waveform whilst shifting the timing of its components. One must establish actual clock behaviour and sample-index continuity independently of the configured sample rate.

A phase unwrapping decision requires a bound on phase advance between consecutive trustworthy observations. In an idealised continuous single-tone model, any phase interval greater than π radians between samples can create ambiguity in the simplest nearest-neighbour unwrapping rule. When the true sampling interval is itself uncertain or samples are missing, the method's condition may fail even though the saved endpoints look orderly. Independent phase markers or a credible bound on frequency excursion may reduce the set of compatible histories, but the exclusion of alternatives must be demonstrated rather than assumed. If several cycle counts remain possible, report that ambiguity explicitly.

The key distinction is between a data-processing convenience and a physical assertion. A resampler may produce a uniformly spaced estimated sequence for later spectral analysis, but it cannot prove that the instrument collected a sample at every synthetic time. When a phase-coherent forensic conclusion

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depends on an absent interval, the correct scientific result may be that continuity is indeterminate.

For test purposes, send an authorised reference tone, pulse marker or phase-coded sequence through the complete receiver chain and retain both raw samples and hardware counters. Compare marker phases and interval estimates across the suspected transition, including their uncertainty. A resampler may compensate slow oscillator error without restoring information lost during an unsampled interval. A phase-unwrapping routine can likewise choose a continuous mathematical branch without proving that the physical oscillator had no jump. The engineer should report whether the reconstructed sequence is an uninterrupted observation, a calibrated time-warp of an uninterrupted observation, or an interpolation over absent measurements. Those three statements must not be conflated.

Dr. James M. Atkinson, Moderator: I shall now pass the principal token from Professor Essen to Dr. Mills. The question is no longer whether the oscillator returned to lock, but whether an external time label can be reconciled with the surviving hardware acquisition chronology. Dr. Mills, please offer an independent principal assessment rather than merely repeating Professor Essen’s account.

Dennis Gabor, Peer Question: Professor Essen, I should like to distinguish an actual phase discontinuity from the apparent discontinuity produced when an analyst joins two observations made through different finite time windows. A short acquisition interrupted by a clock-reference switch can be displayed as adjacent spectrogram columns whose phase estimates each depend upon a window, filter and chosen carrier model. The analyst may

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then subtract two wrapped phase angles and announce an abrupt change although a continuous oscillator with a transient change of frequency could explain the same samples. Conversely, a phase reset might be smoothed by window overlap or by a postprocessing algorithm that enforces phase continuity. How would you construct an experiment that distinguishes these possibilities? I particularly ask how the hardware sample counter, the analogue waveform reference, the transform-window boundaries and the uncertainty of the comparison should be preserved. Would an apparently satisfactory reconstruction of the central carrier frequency have any evidential power concerning a brief discontinuity that was not actually resolved?

Louis Essen, Response: Professor Gabor, the first requirement is to state what was observed and at which stage a discontinuity might have arisen. The continuous input is not directly available after it has passed through a band-limited analogue circuit, a sampler, a buffering system and an estimator. I would preserve the original complex samples together with a hardware counter, the local reference-state log, and a chronology of every software operation that changed the sample-to-time map. A spectrogram, by contrast, is a derived representation. It is valuable for displaying changes in energy and local frequency, but adjacent displayed estimates are not independent measurements of instantaneous phase unless the underlying windows and estimator warrant that interpretation. The raw index sequence supplies a different kind of continuity evidence from a timestamp column: it can show that samples are consecutive in stored order, while leaving their exact physical acquisition times uncertain. Both facts should be reported separately. To test the competing hypotheses, construct an authorised

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reference experiment using a source whose phase evolution is observed independently at a second instrument. Keep a known unmodulated carrier and a controlled pulse or modulation marker in the reference input. Deliberately perturb the disciplined reference while recording the independent phase comparator, the SDR's physical sample-counter events and the actual acquisition state. Repeat with a deliberately introduced phase step, with an interval of frequency offset but no step, and with a known omission of samples. A blind analyst should examine those records using the proposed processing chain without being told which perturbation occurred. Preserve rejected interpretations as part of the validation evidence. In each case compare sample-domain phase differences, cross-correlation lag, and windowed frequency estimates, but do not use a common fitted model as though it were an independent witness. The mathematical distinction is elementary but decisive. If carrier phase is phi(t), instantaneous frequency offset is the derivative of phi divided by twice pi. A genuine phase jump is a discontinuity in phi that need not correspond to an ordinary bounded frequency offset. A finite frequency excursion instead accumulates phase continuously, although a narrow analysis window can make its boundary appear sharp. A sliding transform with overlapping windows can smear either phenomenon, and a reconstruction algorithm that interpolates across missing samples may favour whichever hypothesis it was designed to recognise. Record the window function, width, overlap, unwrap rule and reference comparison, and vary them during sensitivity analysis. A stable numerical frequency estimate after reconstruction confirms only the behaviour of that estimator on retained data. Where the independent reference cannot resolve the disputed interval, the final finding

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should say that phase continuity is unverified over that interval. It may still be possible to bound the maximum time or phase departure under additional explicitly justified constraints, but the boundaries must come from measured inputs rather than from the pleasant appearance of a waterfall. A phase-aligned display is never proof that an instrument experienced no reference interruption.

Claude Elwood Shannon, Peer Question: Professor Essen, a frequency-control loop can make the currently displayed frequency error small while having transformed or erased information concerning the trajectory by which the loop obtained that state. Imagine two acquisition histories. In the first a reference remains continuous; in the second the reference is lost, an acquisition buffer is filled with an alternate clock and subsequent firmware silently interpolates timestamps or discards duplicate counters. The final sample file may have the same nominal rate, the same size and an indistinguishable averaged spectrum in both histories. A reviewer who receives only that file cannot tell which history occurred. What minimal auxiliary record would allow the two experiments to be distinguished? Does a cryptographic digest of the postprocessed file establish the origin of its timestamps? Please explain the limits of reconstructing an unobserved phase history from frequency-domain summaries, and specify how an engineer should report the loss of relevant information without assuming that a strong clock-discipline algorithm can manufacture an independent observation.

Louis Essen, Response: Dr. Shannon, the two histories may indeed map to the same retained file. Once a transformation has mapped distinguishable physical histories into an identical stored representation, no later inspection

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of that representation alone can determine which history preceded it. This is not an allegation about a particular manufacturer's software; it is a statement about the information available to an inference. The defensible response is to change the acquisition record before the information disappears, not to invent a correction after the fact. In an SDR that must support coherent timing claims, the preserved evidence should include a monotonic hardware sample index at the earliest reliable boundary, identifiers and timestamps for reference changes, a record of phase-lock and holdover states, observed counter resets, and an explicit mapping between hardware counts and the reported external time scale. Those records should be sampled or captured with enough temporal resolution to expose the transient under examination. A host clock and a reference-frequency indicator are useful but cannot substitute for a direct record of sample continuity and phase behaviour. A cryptographic digest offers a narrower proposition. It can demonstrate, subject to the hash algorithm and custody process, that the bytes subsequently examined match an earlier recorded set of bytes. It does not demonstrate that the acquisition hardware operated correctly, that the encoded timestamps marked the true sample apertures or that a software programme never discarded and re-created data before the hash was calculated. The acquisition system needs an independently reviewable configuration record and an event log whose source and failure modes are characterised. A second counter with a different failure mode, or a simultaneous observation of a known RF reference, may provide additional discrimination. Where both rely on the same clock-distribution fault or the same firmware transformation, their apparent agreement is not independent corroboration. The limitation also

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has an instructive quantitative expression. A frequency-domain average is a many-to-one mapping: it commonly loses the time order or phase history required to reconstruct a transient event. Even a complex spectrum of one fixed-length transform does not necessarily identify events omitted by the recording system. If the samples themselves were lost, the uncertainty is not merely a larger least-significant-bit error. It is uncertainty about the existence and duration of an interval whose physical values were never observed. A defensible report should therefore distinguish observed sample coverage from nominal file duration, and verified phase continuity from continuity imposed by software. It should present alternative histories where both remain compatible with the evidence, rather than issue one preferred reconstruction as fact. I would require the qualification test to include injected clock failures and file-path faults whose start and end times are known to an independent controller. Test recording continuity with deliberate counter jumps, duplicated packets, phase resets, reference holdover, slews and reacquisition. Reproduce all derived displays with the disclosed algorithms and versions. The objective is not to obtain a perfectly smooth spectrum; it is to ensure that a reviewer can identify where the system observed, where it inferred, and where the surviving evidence cannot decide.

David L. Mills, Second Principal Contributor: Dr. Atkinson, a frequency-discipline system and a timestamp service have different control objectives. A clock can continuously advance its internal monotonic counter while a conversion layer applies a revised offset between the counter and a civil timescale. Conversely, a counter might stop, wrap or lose continuity while the visible wall-clock service remains superficially orderly. The practical test

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is to preserve an immutable map from sample index to the raw counter, plus each version of the later mapping to external time. I would obtain the exact pre-reacquisition and post-reacquisition counter readings, identify the oscillator and synthesiser nodes actually controlling sample acquisition, and measure an independent calibration pulse before and after reference recovery. I would not accept a computer time-service log as proof that an RF phase path remained uninterrupted. When the mapping is corrected after an outage, report the original record and the revised estimate separately, including the interval for which the correction is underdetermined. I invite Dr. Dijkstra to challenge the software implications rather than assume that the recorded chronology is immutable.

The hardware-to-UTC conversion should be documented as a succession of measured relationships, not as one eternal coefficient. Let n be a receiver's sample counter and C(n) the receiver-clock time represented by that counter. Define U_j(C) as the correction to external time accepted during validity interval j, with its independently justified uncertainty. A reproducible UTC estimate is t_UTC(n)=C(n)+U_j[C(n)] only when n falls in interval j and both mappings were actually observed or validly calibrated. If the oscillator reacquires a source and the correction model changes abruptly, the indices on opposite sides of the change belong to different intervals. A program that recalculates the entire file with the last known U_j can create a deceptively smooth chronology while concealing the historical change in the relationship between clocks.

This distinction is especially important during reference holdover. A disciplined oscillator ordinarily estimates its frequency and perhaps its drift from previous reference comparisons. Once the reference disappears, those

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estimates are predictions whose error may increase with time. For a simple constant fractional-frequency error y, the clock-time error accumulated over holdover duration T is approximately $\Delta t = yT$. If the unknown bias is one part in ten million, a 600-second holdover can accumulate approximately 60 microseconds of time offset. The arithmetic is illustrative. Actual drift is influenced by temperature, ageing, noise and controller history; an interval error bound must reflect those influences rather than simply multiply a catalogue specification by elapsed time. The quality of the estimator's previous lock does not remove the uncertainty created after the reference vanished.

A clock's ability to keep time monotonically should likewise be separated from its ability to represent an external timescale accurately. If the software clock is slewed, it may display an ever-increasing timestamp while advancing it at a rate slightly different from the hardware counter. If it is stepped, it may assign two adjacent stored events unexpectedly different UTC labels. Either policy may be acceptable for a particular computing service. The forensic requirement is to preserve the raw counter sequence and the clock-control decisions so that a later examiner can reconstruct the mapping applicable at the precise moment of acquisition. Host arrival timestamps introduce an additional queueing term and do not remove the need for hardware counter provenance.

Suppose the receiver delivers 4,000,000 samples per second with a hardware counter, and an external pulse-per-second marker is captured alongside the IQ stream. Before an interruption, successive markers occur 4,000,000 counters apart. After reacquisition one interval is only 3,999,980 counters, while the host's displayed timestamps remain separated by

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exactly one second. This hypothetical observation might reflect a temporary rate change, loss of twenty samples, a marker-detection fault or a counter mapping error. The correct conclusion is not yet that any one mechanism occurred. Counter overflow diagnostics, marker phase, simultaneous independent clock comparison and a known reference signal must be examined to discriminate them. A smooth host-time column is insufficient evidence of continuity.

When the reference path is shared by several receivers, common errors can survive comparisons between their UTC labels. Two instruments may agree because both used the same inaccurate time source or the same recalibration model. Their agreement does not establish independent evidence of absolute timing. A separate oscillator or timing witness with independently maintained traceability should observe at least one downstream point in the acquisition chain. The investigator must also consider whether the supposedly independent clocks share power, thermal environment, cabling or software. The evidential claim should identify which dependencies have actually been tested, rather than invoke independence simply because the instruments have separate serial numbers.

My recommended acquisition ledger therefore contains the device identity, original sample index, receiver frequency and gain configuration, raw clock status, reference selection, holdover and relock indicators, phase or frequency comparator measurements, host monotonic time, wall-clock time, hardware event markers and any subsequent calibration revision. No later transformation may overwrite the original values. A correction record should carry its effective range, algorithm version, source observations and uncertainty assumptions. The reviewer can then state whether an event was

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captured, whether its relative timing was preserved and whether its external UTC label remains supported across the reference transition. Those are different findings, and each deserves a separate evidential conclusion.

Edsger W. Dijkstra, Cross-Peer Question to David L. Mills: Dr. Mills, your proposed map is only useful if the software refuses to silently rewrite it. Suppose the application originally associated device counter 9,000 with a time estimate, then replayed the capture after reacquisition and produced a corrected UTC label. The operator sees only the latest view. What invariant must remain inspectable so that the post-hoc correction does not masquerade as contemporaneous observation? I am also concerned about the boundary of an overflow: a continuous sequence of host-assigned packet numbers does not prove that the instrument produced a continuous series of actual samples. Please distinguish provenance of the labels from provenance of the observations.

Would you also specify the minimal independent test that would catch a host which regenerates plausible UTC labels from the final clock state, thereby hiding the precise index at which the reference changed? I am concerned that a record may be cryptographically intact whilst its original time mapping was never preserved. An excellent digital signature authenticates retained bytes; it does not retroactively prove the scientific adequacy of the data model encoded in them.

David L. Mills, Cross-Peer Answer to Edsger W. Dijkstra: Dr. Dijkstra, store original hardware sample indices, the observed device-counter values, the device clock state and the exact transformation that generated each external timestamp. A later correction should be appended as a new

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mapping, never substituted in the raw acquisition ledger. If the device does not expose a counter that survives overflow, explicitly state that the host packet sequence is not an independent continuity witness. In laboratory qualification, inject known pulse markers while provoking both a reference interruption and an acquisition backlog; inspect which underlying records distinguish the two. A genuine clock correction may improve external-time agreement after the fact, but it cannot restore physical phase observations or samples never acquired. The contemporaneous record and the correction belong to separate layers of evidence, and an uncertainty interval should cover the unresolved transition rather than conceal it with numerical formatting.

A two-path timing witness makes the weakness observable. Capture a laboratory pulse-per-second marker and its device counter indices in the receiver, while an independent recorder timestamps the marker from a separately maintained reference. Interrupt the primary source, permit reacquisition and compare the raw hardware chronology with the host's corrected timestamps. Where the software silently reassigns the prior UTC values, the revised mapping can be compared against the preserved independent record. A cryptographic signature of the final file proves that the saved bytes were not later modified; it does not prove those bytes record what the operator saw before correction. The original and revised mappings must both survive, with evidence of the state transition which caused the change.

Louis Essen, Response to David L. Mills and Edsger W. Dijkstra: I accept that distinction and add a metrological qualification. Even a flawlessly preserved original counter is only a sequence until its time scale is independently

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established. A frequency standard may calibrate the interval between counts; a phase comparator may establish a transition step; neither substitutes for the other. The peer exchange therefore narrows the claim to what was observed at the relevant hardware node and separates it from subsequent clock estimation. I pass this additional question to the moderator: have we retained an independent downstream witness across the recovery interval?

Dr. James M. Atkinson, Moderator: Dr. Dijkstra, the previous exchange established that corrections to clock labels do not reconstruct lost observations. Would you develop the necessary software invariants, after which Mr. Nyquist may examine their sampling consequences?

Edsger W. Dijkstra, Third Principal Contributor: A clock transition is a state transition, not just a different numerical estimate. A well-specified acquisition program should preserve both raw and derived states and announce when a mapping loses validity. A robust design assigns one hardware index to each actual sample and never backfills missing observations with invented source data. An epoch boundary is a substantive event: subsequent timestamps may be accurate while the phase relation across that boundary remains unknown. My test would restart the acquisition software with a reference disturbance and compare the raw stream against a separately observed calibration marker. An invariant should fail conspicuously if evidence has been lost, rather than be restored cosmetically by a smoothly displayed clock.

One additional acceptance test should deliberately force an acquisition restart at the precise instant the reference state changes. The

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implementation passes only if it preserves both the prior and subsequent counter epochs, identifying which samples have no supported continuous-time correspondence. A restart concealed by renumbering constitutes a documentary defect even if the stored data remain syntactically valid.

I would specify the invariants before building the application. The first is order preservation: for any accepted sequential samples, the hardware index either increases according to the declared device contract or a gap, restart or wrap event is explicitly recorded. The second is provenance: a derived timestamp must be linked to its raw counter, source observations and conversion version. The third is state completeness: every transition between locked, holdover, reacquiring, unsynchronised and fault conditions must be represented with effective boundaries, including transitions that occur during a host communications outage. An ordinary status indicator cannot prove these invariants. They should be expressed as testable properties of the acquisition record and challenged under deliberate fault conditions.

Consider a state variable q with possible values LOCKED, HOLDOVER, RECOVERING and UNTRUSTED. A transition from HOLDOVER to LOCKED may require the controller to reacquire phase. The software must not infer that an earlier range was continuously valid simply because q now equals LOCKED. Instead, a transition event records the last index verified under the previous state, the first verified under the new state, and any unresolved interval between them. A state transition may leave the sample sequence intact while invalidating absolute timestamp mapping; another transition may invalidate both. Those outcomes should have different error codes.

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Collapsing them into a single Boolean is equivalent to discarding evidence needed to distinguish the competing physical explanations.

One verification rule could assert that every accepted IQ packet names a first sample index n and a declared sample count m, and that a following packet begins at n+m unless a documented exception is present. Yet an implementation might manufacture its own sequence numbers after discarded device packets; in that case the rule would merely certify software bookkeeping. The relevant counters must originate as near as practicable to the acquisition hardware and be qualified against known stimulus events. Packet duplication, reordering and counter wrap must be separately tested because an apparent arithmetic discontinuity may result from a legitimate wrap or a driver bug rather than missing physical samples. The verification report should identify the origin and integrity protection of every field used.

A second rule concerns transformation monotonicity. It may be valid to map a hardware counter sequence into corrected physical time using a piecewise function, but every change in mapping belongs to an explicit version. If a resampler creates synthetic samples on an even time grid, those samples are derived values with lineage to the original observed indices and an interpolation kernel. A missing segment cannot be silently filled by a filter prediction and then counted as an observation. In machine-readable evidence metadata, distinguish observed, resampled, interpolated and predicted states. A waveform that looks continuous after processing may still contain an interval in which the instrument was blind.

There is a profound distinction between checking program syntax and validating its scientific meaning. Unit tests can prove that an index field increments as designed, while the hardware actually stopped sampling for

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an interval. A fault-injection programme should therefore disrupt the physical reference source, hardware data transport, host processing queue, time-conversion process and storage path independently. For each disruption, a separate trusted recorder should establish what the device actually observed. The expected software result is not always successful continuity: sometimes the correct result is a conspicuous, bounded declaration that the record has become incomplete. An honest failure state is an essential product feature, not an embarrassment to suppress from the interface.

Finally, the evidential process must be reproducible. The analyst should retain a protected original file, event ledger and calibration configuration, then document each computation with a versioned executable and declared parameters. A checksum can detect later alteration of recorded bytes, but it does not prove that the bytes corresponded to correctly sampled RF at the time of acquisition. That requires instrument challenge tests and hardware provenance. A well-engineered archive consequently distinguishes integrity of storage, completeness of acquisition, validity of timing and support for physical attribution. These are independent propositions. None should be inferred solely from the attractive appearance of a retrospective phase plot.

Harry Nyquist, Cross-Peer Question to Edsger W. Dijkstra: If the device retains every index but varies its actual sample rate during recovery, may software still declare the acquisition sequence continuous? What happens to an inferred signal phase when a nominal constant sampling rate is imposed on the physically irregular clock?

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Please distinguish a sample-counter gap caused by lost transport packets from a genuinely irregular hardware sampling interval, since both may give the same discontinuity in an application's index series. Would the independent reference marker you propose make that distinction observable, and which records must survive to substantiate the result?

A variable-rate clock may also be accompanied by packet reordering or host buffering, so an index sequence which appears consecutive after software repair is not necessarily the original hardware sequence. How would you require the acquisition device to testify, in an engineering sense, to the generation time of the samples? Could a calibration marker expose a missing interval which a plausibly renumbered buffer conceals? And must every such correction be disclosed even if the final spectral picture appears unchanged?

Edsger W. Dijkstra, Cross-Peer Answer to Harry Nyquist: Physical sample continuity is not equivalent to calibrated temporal continuity. A retained sequence can be complete in index order while its mapping to elapsed time changes. The program must retain clock state or independently measured rate corrections. Resampling can construct a useful uniform representation of the recorded observations, but its interpolation model and uncertainty should be declared. If a discontinuity makes the phase path ambiguous, the system must preserve alternative plausible reconstructions rather than claim the missing phase was observed.

A hardware-time marker supplies a test of actual chronology only if its origin and capture method are independently characterised. A packet gap can occur downstream of a complete device capture, whereas irregular

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hardware sampling changes the reference marker relationship even when the transport delivers every packet. Compare both the hardware index and marker phase against an independent acquisition witness. When the driver hides its own errors, the software must disclose that the counter cannot certify acquisition continuity. A formally tidy index stream cannot substitute for the physical challenge test.

The capture protocol should require a hardware-origin counter or time marker whose generation precedes transport through the host, and each stored buffer should retain its relation to that origin. A separate test marker injected through the receiving path can expose a lost interval even if software creates a continuous index sequence. A driver that does not expose any such information must have its limitations documented; a post hoc software counter is weaker evidence. During a controlled reference fault, compare the count and phase of expected markers against the preserved raw stream, then challenge the record under packet reordering and host queue stress. If the gap was filled by interpolation, each derived sample must be tagged as such and excluded from a direct-observation count.

There is also an important reason to preserve failures that do not visibly alter a waterfall. An investigator may later ask a question about burst timing or coherent phase that was not contemplated during acquisition. A seemingly harmless interpolation for a spectral average can therefore destroy the evidence needed for another scientific inference. A complete acquisition record retains original samples, exception events and transformations so later experts can make that distinction themselves.

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Dr. James M. Atkinson, Moderator: Professor Rabi, may I pass you the token to examine the physical reference planes and the possibility of a synthesiser-origin transient? Professor Essen will then challenge the scope of the proposed measurement.

Isidor I. Rabi, Fourth Principal Contributor: The reference itself must be challenged as a physical component of the measuring apparatus. A phase jump in the displayed carrier may arise in a synthesiser, a mixer, a cable or an external field, even if it coincides with a clock status change. I would compare the oscillator output at the point of distribution with a second comparator monitoring a downstream sample-related event. A known local stimulus passing through the full receiver should be observed in parallel with the unknown RF signal. Switching only the external source, or only the receiver reference, supplies evidence about where the anomaly originates. The timing of coincidence is merely a clue until causal controls show which physical pathway produces it.

An independent phase comparison should also be repeated at more than one carrier frequency and over different receiver gain states. A transient seen only after frequency conversion may depend upon a particular oscillator or mixer path, and a successful test at the reference input alone cannot establish its absence. The conclusion must identify which downstream nodes were physically challenged.

A reference node is a physical measurement point, not a metaphor for the entire instrument. In a receiver containing a frequency synthesiser, analogue mixer and ADC, the input reference can be processed by several control loops and dividers before it influences the measured carrier phase

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or sample edges. A test that observes only the external 10 MHz terminal can miss a discontinuity generated inside an intermediate loop. It can also falsely assign an external phase change to the reference simply because the two events occur at similar times. The analyst must identify the complete transfer pathway, including any buffered control updates, phase-detector operating ranges and reference switching procedures relevant to the instrument's state at the contested event.

For an ideal frequency multiplier with ratio N, a deterministic input phase excursion may appear multiplied by N at the output under an appropriately coherent relationship. The familiar phase-noise power-density scaling of 20 log10(N) decibels is likewise conditional on the architecture and how noise is referred. A practical phase-locked synthesiser shapes input-reference noise differently across offset frequencies, while the local oscillator contributes its own independent noise. A sudden phase step is a transient rather than a stationary noise process, so one must not infer its exact waveform from a single catalogue phase-noise figure. The correct procedure measures the actual transient response of the deployed synthesiser or bounds it through a justified dynamic model.

An illuminating laboratory arrangement monitors three points simultaneously: the reference input, a downstream synthesiser or sample-edge witness, and a benign injected RF test tone traversing the receiver's full signal path. Introduce a controlled, small reference phase perturbation within component ratings, and record the response in all three channels with independently maintained time. Then repeat after substituting an external reference of adequate quality and after changing any authorised synthesiser mode. If the upstream reference is continuous but the

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downstream witness steps, the impairment lies beyond the monitored input plane. If both step together, further comparison is needed to distinguish source-origin phase from distribution or measurement-chain error.

A carrier burst complicates the comparison because it may not be present during every sampling interval. Suppose a fixed calibration tone remains visible while an intermittent external carrier shows a phase jump. A shared reference event should ordinarily leave some trace in the calibration path, subject to differing frequency conversion and channel transfer. If only one received carrier exhibits the disturbance, a propagation or transmitter hypothesis gains plausibility, but selective receiver artefacts remain possible. The calibration injection should span relevant frequency bands and avoid overloading the front end. One fixed test tone does not validate every receiver setting, filter path or gain state across a complex SDR's complete operating range.

The examiner must also preserve the chronology of switching. An instrument may report a relock time based on its control processor's status polling rather than the precise first hardware sample affected. A reference selection command might initiate a transient before the operating-system log acknowledges the change. Record both commanded and observed state changes and compare them with a hardware counter or event marker. A loss-of-lock indication after the suspected event does not necessarily exculpate the reference, just as a perfectly timely status flag does not prove the physical waveform of recovery. Discriminating evidence requires time correlation between independent physical observables, not timestamps read from the same control interface.

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My concluding evidential standard is a set of refutable alternatives. Could an input-reference interruption explain the observed phase? Could a synthesiser control transient do so while the reference remained stable? Could antenna-path motion, multipath or a carrier-origin phase change account for the pattern? State an observation that would favour each explanation and conduct as many lawful, reversible challenges as necessary to narrow them. If the relevant downstream sample phase was never recorded, say plainly that continuity remains unestablished. A proposed correction inferred from stable behaviour afterwards cannot retroactively create the missing observation. The proper outcome of an experiment may be a bounded uncertainty, not a reconstructed certainty.

Louis Essen, Cross-Peer Question to Isidor I. Rabi: Can the investigator use a single 10 MHz reference comparator to establish the phase continuity of a synthesised receiver that samples at an unrelated rate and translates several RF bands? How should uncertainty be transferred between nodes?

I would further ask whether the relevant phase transfer function is known at the moment of reference switching, rather than merely at settled lock. A recovery transient can briefly drive the synthesiser outside its usual linear operating regime, so a small-signal measurement conducted under normal operation may fail to predict the event. What qualification follows?

If different synthesiser paths derive phase from the same input through distinct division and loop-filter settings, a discontinuity may be suppressed at one monitored output and amplified or delayed at another. Would you require a matrix of tests across the relevant frequency plans rather than one successful check at the nominal band? And how should the investigator

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qualify a transient recorded through a probe whose capacitance or grounding potentially changed the oscillator under test?

Isidor I. Rabi, Cross-Peer Answer to Louis Essen: A comparison at 10 MHz measures that particular node. A synthesiser can introduce its own phase transients and a sampling clock can behave differently, depending on divider ratios and loop dynamics. One should measure or bound the relevant transfer function from the tested reference to the actual sample edge, including internal phase locking. The result must specify the observation node and state; otherwise it is a statement of reference-source stability, not of the whole receiving chain.

That qualification is essential. A linearised transfer function around settled lock describes only a local approximation. During acquisition or switching, a controller may saturate, reset an accumulator or engage an alternative divider. Such behaviour needs direct transient measurement or a bounded state-dependent model. The investigator must distinguish observations made under stable operating conditions from observations made during the transition and should retain any control-state records defining that interval. If the internal transition cannot be observed, one cannot claim that a quiet external reference terminal establishes the downstream phase history. The finding must identify this untested causal path.

A test matrix is appropriate because the transient transfer depends upon the frequency plan, lock state and internal configuration. At minimum compare representative synthesiser modes and downstream sample-edge observations, with traceable calibration at the chosen reference planes. A probing arrangement which changes the circuit loading cannot be assumed

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to reproduce untouched field operation. Its influence should be characterised using a non-invasive witness where possible, or by comparing operation before and after insertion of the diagnostic probe. The report must distinguish measurements under the diagnostic configuration from conclusions about the normal configuration.

One should also avoid treating absence of a transient at a reference input as evidence that every derived oscillator was phase-continuous. An internal state reset or loop reacquisition can occur independently of the source, and those pathways require separate challenge. Where the complete receiver architecture is unavailable, the investigator may be unable to eliminate all such alternatives. The conclusion should state the established range and the unresolved portions of the signal path rather than conceal them behind one reference certificate.

Dr. James M. Atkinson, Moderator: Mr. Nyquist, our final principal perspective concerns what sampling can preserve across a discontinuity. Dr. Mills will test whether retrospective timestamp repair supplies any missing phase evidence.

Harry Nyquist, Fifth Principal Contributor: Sampling theory concerns how a bandlimited waveform may be represented under specified acquisition conditions. It does not attest that every intended sampling instant occurred or that the instrument retained an unbiased phase record during a controller transition. The investigator should use a known phase-coded test signal to detect discontinuities that a pure steady tone might conceal. I would evaluate time-tag uncertainty, index gaps and the frequency-dependent consequences of a possible clock step separately. A receiver with

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excellent average rate accuracy could still be unfit for phase-continuous combination of bursts separated by reference reacquisition.

For each reconstructed interval I would retain the estimated sampling times, their stated uncertainties and the original observed indices. The analyst should compare a constant-rate model with a measured piecewise timing model and report any material difference in inferred phase and correlation. If the alternative models remain compatible with the reference markers yet support different conclusions, the case has not established a unique phase history. This condition is a reason to narrow the claim, not to suppress the contradictory analysis.

The mathematical conditions for reconstructing a waveform must not be mistaken for a historical assertion about the clock which sampled it. An ideal uniformly spaced sampling grid has instants $t_n=nT_s$, where $T_s=1/f_s$ and f_s is the actual sampling frequency. During a reference recovery, actual instants may instead be $t_n=nT_s+\varepsilon_n$, where ε_n denotes sampling-time deviations. A reconstructed sequence evaluated as though every ε_n were zero implicitly assumes away the problem to be investigated. The departures can introduce phase errors increasing with signal frequency. They can also reduce the validity of correlation and direction-finding measurements that depend upon coherent phase across channels. The signal-processing method should state its assumed time grid as a scientific premise.

For a sinusoid $x(t)=A\cos(2\pi f_0 t+\varphi_0)$, a small sampling-time error Δt produces an approximate phase error $\Delta\varphi=2\pi f_0\Delta t$. At a 100 MHz RF-equivalent signal frequency, a ten-nanosecond error corresponds to an

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entire cycle of phase, so a phase-only estimator would be unable to distinguish that offset from an integer-cycle ambiguity without additional information. In practical SDRs, analogue frequency conversion may reduce the frequency at the sampler, while local-oscillator phase and timing error add other contributions. The calculation must be performed at the relevant frequency and with a coherent model of all conversion stages. It demonstrates why a precise host clock label cannot alone guarantee phase coherence.

A different challenge arises when the receiver actually loses samples. If the hardware counter jumps from n to n+m but the recording contains only the endpoints, there is no measured sequence in the missing interval. No mathematical interpolation can establish whether the external carrier underwent an abrupt phase change while the receiver was blind. A prediction algorithm can produce one plausible continuation under its model, but several different physical histories may remain compatible with the same retained samples. This is a question of identifiability, not of processor speed or the elegance of a resampling algorithm. The final evidence record must distinguish observations from predictions and state where the latter are unsupported by direct measurements.

A controlled phase-coded reference sequence can test both the clock mapping and sample continuity. Choose a known finite-bandwidth waveform with clear correlation markers and inject it through the authorised receiver path while an independent instrument records the source. Compare observed sample indices and marker phase before, during and after a deliberate reference interruption. Change the gap duration, signal level and receiver gain state to reveal whether the apparent

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continuity depends upon favourable conditions. A successfully tracked marker constrains the sample-to-time relationship for that waveform and configuration. It does not automatically validate all frequencies, especially if an analogue path or synthesiser mode changes between test and operational measurement.

When no independent time witness exists, cross-channel comparison can still provide useful but limited information. Two sample streams driven by one source may preserve excellent relative phase while both accumulate an undetected absolute time error. Channels with separate clocks may exhibit relative drift even when each has good individual long-term stability. An investigator should compute a covariance model for the measurement quantities actually used, including reference sharing and calibration uncertainty. Apparent cancellation of a common error in a differential estimate is beneficial for one defined inference but cannot prove that the common error was physically absent. The choice of estimator must follow the intended question: relative delay, absolute UTC time, or phase history.

I would conclude by requiring three separate acceptance tests. First demonstrate the receiver's data continuity through counter and transport challenge tests. Secondly measure the correspondence between sampled indices and physical elapsed time through known markers and independent reference comparison. Thirdly test the stability of the derived scientific inference under alternative calibrated timing mappings. Only then can one claim that a phase difference or time-of-arrival estimate survived oscillator reacquisition within a stated uncertainty. A receiver can be excellent for broad-spectrum detection while unsuitable for submicrosecond attribution

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across an unmonitored clock transition. That limitation should guide the report, not become an inconvenience hidden by a smoother plot.

David L. Mills, Cross-Peer Question to Harry Nyquist: If the receiver corrects its host timestamps after the acquisition, can a retrospective calculation recover the relative phase between the first and second halves of the record, or does the claim demand a simultaneous downstream observation?

If a second receiver supplies an independent phase witness, how should its own timing uncertainty, analogue group delay, and possible loss of samples enter the reconstructed bound? I would not accept a corrected waveform merely because the second receiver produces a smoother-looking picture. Which specific observations rule out otherwise compatible cycle counts across the missing interval?

If a phase-preserving resampler assumes a recovered clock model fitted to samples on both sides of a gap, how would you distinguish a justified conditional estimate from a false claim that the missing interval was observed? Would a strong narrowband signal make it safe to interpolate even if a phase jump might have occurred while the carrier was below threshold? Please give a condition under which a multiple-cycle ambiguity remains even if the reconstructed graph looks perfectly smooth.

Harry Nyquist, Cross-Peer Answer to David L. Mills: A timestamp correction can improve the alignment of known events in external time, but cannot supply a phase observation missing from the data. If independent timing markers constrain the boundary sufficiently, a retrospective estimate may be justified with a measured uncertainty and a clear phase-ambiguity statement. Without that evidence, a smooth mapping is a model

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assumption. The investigator should retain both the original counter chronology and the adjusted labels so that neither is misrepresented as an observed physical phase.

The independent receiver should first be qualified for sample completeness and clock uncertainty over the same disputed interval. Its known waveform feature must be matched to the original receiver through calibrated propagation and analogue delay paths. A phase-continuity claim can then be supported only to the extent that the independent record constrains phase advance strongly enough to exclude alternative integer-cycle histories. If the reference record itself contains a gap or its relative delay is uncertain by more than the separation of plausible phase histories, the ambiguity survives. One should report the set of compatible reconstructions rather than choose the smoothest as if it were an observed truth.

A strong signal can help estimate phase where actual samples exist, but it does not directly observe an interval during which samples were lost or the carrier was undetectable. If an unknown phase step of an integer multiple of two-pi radians can occur within that gap, different physical histories may agree with the same endpoint phases. Interpolation selects one history by model assumption; it does not measure away the ambiguity. The analyst should mark the interval as prediction-only, retain the unmodified endpoint observations and provide sensitivity bounds over plausible phase steps or frequency changes.

A conditional reconstruction can nevertheless be useful when the assumed signal dynamics have independent support. One might, for instance, constrain frequency deviation using a second continuously operating

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channel with genuinely independent timing, then propagate that constraint across the gap. The result would be an estimate with an explicit uncertainty and a statement of the external evidence on which it depends. Its status is entirely different from an uninterrupted acquisition. No number of additional digits in the corrected timestamp can convert a prediction into a physical observation.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has distinguished four questions too readily collapsed into the word 'stable': whether the frequency converged to a reference; whether the clock's phase remained continuous; whether sample indices and hardware acquisition persisted without gaps; and whether external timestamps remained traceable through state changes. A control loop may improve the first while disrupting or obscuring one or more of the others. Controlled reference interruption, independent downstream phase observation, retained counters, loop-control records, explicit uncertainty budgets and challenge testing across reacquisition are therefore required before a continuity-dependent forensic conclusion is justified. The panel's dialogue is a modern scholarly reconstruction, not a historical record of its participants.

QUESTION 053. TECHNICAL REFERENCES AND QUALIFICATIONS

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2. NIST, Time and Frequency from A to Z, entry P (phase-locked loops, phase shifts and phase steps), https://www.nist.gov/pml/time-and-frequency-

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division/popular-links/time-frequency-z/time-and-frequency-z-p . Supports the underlying terminology, not any hypothetical instrument result.

3. NIST Computer Security Resource Center, 'holdover' glossary, https://csrc.nist.gov/glossary/term/holdover . Defines clock operation following loss of controlling reference.

4. D. A. Howe and N. Schlossberger, 'Characterizing Frequency Stability Measurements having Multiple Data Gaps' (2022), https://www.nist.gov/publications/characterizing-frequency-stability-measurements-having-multiple-data-gaps . Supports the importance of gap handling in frequency statistics.

EDITORIAL QUALIFICATION: Worked values and experiments above are illustrative, not measurements of a deployed SDR. Historical contributors' speech is fictional reconstruction. Verify instrument-specific sample-counter semantics, hardware clock topology and measured correlations before applying the conclusions to an actual engagement.

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QUESTION 054

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How can common-reference distribution create correlated errors in supposedly independent receivers?

SCHOLARLY RECONSTRUCTION. The exchanges below are fictional instructional dialogue among deceased specialists, not actual conversations or statements. Contemporary receiver-array applications are editorial extrapolations from historically documented scientific principles.

Dr. James M. Atkinson, Moderator: Professor Townes, an investigator may deploy several receiving channels and take comfort when they report the same phase excursion, the same short-duration event or the same bearing solution. Yet the channels may derive frequency and time from one reference oscillator, from one distribution amplifier, and even from the same mains or battery supply. What exactly remains independent in such a configuration, and by what measurements might the investigator distinguish a genuine external radio-frequency phenomenon from a disturbance introduced simultaneously into every receiver?

Charles H. Townes, Principal Contributor: Dr. Atkinson, the word 'independent' is incomplete unless we specify the random variables, physical pathways and inferential purpose. Two antennas occupying separate locations may encounter independent local interference, yet their receivers may share one frequency standard. Two frequency references may be nominally separate while being disciplined to the same higher-level source. An instrument can therefore possess diversity in one portion of its measurement chain and common-mode dependence in another. Apparent agreement is evidence of reproducibility only for the elements genuinely

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made independent; it is not automatically two independent demonstrations of an external emitter.

For a simplified phase measurement from channel i, write $\theta_i(t)=\varphi_i(t)+c(t)+e_i(t)$, where θ_i is observed phase in radians, φ_i is the external signal phase as transformed through the antenna and propagation path, c is a common reference-induced phase term, and e_i represents channel-specific measurement error. All quantities must be brought to a declared common reference plane and the model is only an approximation: frequency conversion and sampling may scale or filter the reference contribution differently in each channel. If the same c enters both observations identically, the difference $\theta_1-\theta_2$ cancels c. That cancellation is useful for differential phase but dangerous as a diagnostic of reference health, because two channels can agree while both remain wrong relative to an independent time or frequency standard.

Conversely, a sum or common-mode estimate can emphasise c. If the independent errors e_1 and e_2 are zero-mean, each with variance σ^2, and c is zero-mean with variance σ_c^2 and independent of them, the individual observed error variance is $\sigma_c^2+\sigma^2$, and the covariance between channel errors is σ_c^2. The correlation coefficient is $\rho=\sigma_c^2/(\sigma_c^2+\sigma^2)$. For a hypothetical $\sigma_c=4$ degrees and $\sigma=3$ degrees, $\rho=16/25=0.64$. The mean of two channel errors then has variance $\sigma_c^2+\sigma^2/2=16+4.5=20.5$ square degrees, giving standard deviation approximately 4.53 degrees; the naive independence model yields sqrt((16+9)/2)=3.54 degrees. Both computations are conditional on the model. The naive calculation promises more information than the experiment actually collected.

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A shared source creates several distinct coupling mechanisms. Its short-term phase noise may propagate through each phase-locked loop with different transfer functions, so perfect cancellation cannot be presumed. Its slow frequency drift can bias absolute-frequency estimates while remaining nearly invisible in a channel-to-channel comparison. A reference distribution amplifier can introduce additive phase fluctuations and amplitude-to-phase conversion. Cable length, temperature and mechanical strain can shift phase differentially. A shared power supply may modulate several oscillators, mixers or converters in a recognisably synchronous fashion. Finally, a common software timestamp authority may correlate nominally separate records even when the front-end oscillators are physically independent.

The time and frequency scales of each coupling must be examined. A reference cable whose electrical length changes by $\Delta\tau$ seconds produces a phase change approximately $2\pi f_{ref}\Delta\tau$ at the reference frequency f_{ref}, but a synthesiser's response at the final receiver frequency depends upon its multiplication ratio, loop dynamics and architecture. It would therefore be improper to multiply the cable phase change by a nominal ratio and declare the exact downstream error without a transfer measurement. A 10 MHz reference is a reference signal, not a guarantee that every receiver's 1 GHz local oscillator inherits exactly the same phase transient at the same instant.

A credible experimental design uses at least three controlled conditions. First, both receiver channels operate from the shared reference, and a benign, known test signal is injected through a documented splitter or an over-the-air source whose geometry is controlled. Second, each channel operates from its own independently monitored reference, with the test

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signal and receiver gain settings otherwise held constant. Third, the reference connections are exchanged or switched under logged conditions, preferably with an independent phase comparator watching the reference nodes before and after the distribution network. At each condition, retain raw samples or hardware phase outputs, instrument state, counter values and reference health, not simply the resulting bearing or correlation summary.

The perturbation should be innocuous, calibrated and traceable. A small programmed phase modulation of the distribution source may reveal whether apparent simultaneous receiver transients follow the clock network. A thermal or mechanical change to one reference cable can reveal sensitivity to differential delay. A carefully bounded supply perturbation may test supply rejection, subject to equipment ratings and safety, but should never be applied to operating evidence equipment without authorisation. The investigator must not confuse an intentionally introduced test condition with evidence from the environment, and must preserve untouched observational records for comparison.

Spatial evidence introduces an additional complication. Two antennas can observe the same genuine remote carrier with strongly correlated propagation phase. Such correlation is not automatically artefactual; it may be the property being measured. A reference perturbation can be distinguished from propagation by using channels with deliberately different clock trees, by monitoring a local injected calibration tone alongside the external signal, and by changing antenna geometry while leaving distribution wiring fixed. If the anomaly moves with the antenna, the propagation or antenna hypothesis becomes stronger; if it follows the

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reference line, the clock hypothesis becomes stronger. But coupling and cross-sensitivity mean each test is probabilistic rather than absolute.

Correlation also affects estimates of detection confidence. Suppose an operator treats four coherent receivers as four independent confirmations of an event and multiplies four false-alarm probabilities. This would be justified only if the relevant false-alarm mechanisms were independent under the null hypothesis. A shared digitiser clock or jointly generated interference can instead produce a coincident false event, defeating that multiplication. The relevant null distribution should be measured using the actual multichannel configuration and includes common-mode artefacts, not a mathematical fiction of four independent instruments.

For an evidential report I would require a covariance or dependence description, a clock-tree diagram, a list of common power and data pathways, the method by which relative and absolute phases were calibrated, and an explanation of which errors the processing cancels and which it cannot detect. It is perfectly respectable to use a shared clock for coherent relative measurements. The failing occurs when that deliberate architectural choice is disguised as evidential independence. A properly limited claim might say that the receivers independently observed RF energy at distinct antennas while sharing a timing and frequency source; that statement conveys what was actually corroborated.

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Dr. James M. Atkinson, Moderator: Dr. Mills, you have particular expertise in disciplined timing systems. What is lost when a common reference network is described simply as a stable source?

David L. Mills, Peer Question: Professor Townes, a central reference can distribute a disciplined frequency while each receiver derives its timestamps through a separate host, buffering layer or internal counter. Some shared failures will appear as simultaneous phase events, whereas others may produce a correlated timestamp correction without any change in the RF waveform. How should a field examination distinguish physical oscillator coherence from software synchronisation and a merely common external time label? Would you also explain why matching timestamps issued by two systems administered through the same network synchronisation service are not by themselves independent confirmation of event time?

There is a practical discontinuity between frequency discipline and the timestamp imposed by an acquisition program. Assume that the host uses a network clock which is temporarily slewed, while hardware sample counters remain monotonic and the local synthesiser is locked to the common RF reference. The two time scales could describe different events with ostensibly compatible timestamps. Would you require a separately stored counter-to-external-time mapping at each station, and how would you test the mapping during an interrupted time service? I am seeking a procedure that distinguishes a genuine physical phase excursion from an administrative clock correction without assuming that all labels generated by one host are trustworthy.

Charles H. Townes, Response: Dr. Mills, trace the reference all the way to the measurement primitive. A physical RF phase observation may depend on a

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reference oscillator that determines mixer phase or sample-edge placement. A timestamp depends on the mapping from sample counter to external time, which may be updated through software. The two mappings can have different state transitions. Ask whether the clock signal actually controls the acquisition front end, whether it only labels a completed buffer, or whether a host discipline algorithm estimates the offset after data collection. The test should log each stage and introduce perturbations into one stage at a time.

The crucial operational requirement is to retain at least two distinct chronologies. The first is an immutable account of sample acquisition from the device's hardware counter, including its rollover and lost-block indicators; the second is the dated sequence of mappings to external time, including each offset, drift estimate, step and holdover transition. If a network time service slews the host clock while the receiver samples continuously, no missing RF phase observation follows merely from the host adjustment. Conversely the host may show continuous civil time while the synthesiser undergoes a phase step. Measure a common laboratory pulse at the RF input and, separately, a timing marker at the downstream clock edge before and after a deliberate permitted service interruption. The two measurements permit different diagnoses. Record original and corrected labels side by side. A post-processed timestamp that makes multiple stations look consistent is an inference which must be independently assessed, never a replacement for the actual event-counter record.

If two hosts consult the same time service, their apparent agreement may indicate that the service produced a consistent answer, not that the receivers experienced the event at precisely that external instant. Retain the

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hardware counters and a locally generated timing marker alongside network-clock offset estimates and adjustment logs. Repeat with independent timing supervision and separately measure network path asymmetry where relevant. A common time label is not evidence of a common physical acquisition edge, just as a shared clock does not prove that the software stored every sample. These dependencies must be mapped and reported rather than hidden under an ambiguous synchronised status.

Dr. James M. Atkinson, Moderator: Mr. Harrison, what would a practical clockmaker ask before trusting the distribution apparatus?

John Harrison, Peer Question: Professor Townes, a central source of excellent intrinsic quality must still reach each instrument through a physical connection. Cables warm, connectors loosen, vibration changes strain and different paths acquire different delays. Is it possible for the standard itself to remain stable while the distribution makes the receiving channels disagree? And how ought one distinguish a slowly changing cable delay from a sudden fault in a connector or distribution buffer, especially when the observed radio signal is also affected by environmental motion?

Let us consider temperature and mechanical stress rather than an abstract perfect source. One station has a reference cable routed through a warm equipment rack, another passes through a draughty service duct, and their connectors have been disturbed by transport. Both instruments nevertheless report nominal lock. What measurements at the delivered clock input would show whether the electrical path length changed? Would you examine return loss, connector repeatability, thermal expansion, and load sensitivity as separate mechanisms, and how would you prevent the act

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of attaching a phase comparator from changing the state being investigated?

Charles H. Townes, Response: Mr. Harrison, intrinsic quality and delivered quality are separate measurements. A stable source at its output terminals does not establish stability after twenty metres of cable, a switching device, and a receiver's internal phase detector. Record a reference-plane diagram and use an independent comparator at the point of use. Measure delay or phase at the distribution outputs over the expected temperature and mechanical conditions. A gentle, reversible temperature dependence may suggest cable propagation effects; an intermittent step associated with movement or re-termination suggests a discontinuous contact or switching phenomenon. Neither inference is conclusive without a controlled test.

One should measure delay at the delivered reference plane under representative thermal and mechanical conditions, then repeat the measurement after a controlled cable exchange. A nominal ten-megahertz reference source does not constrain the exact phase at the end of every cable: the output phase can change with propagation delay even while frequency remains locked. Use a phase comparator with a characterized loading effect, a matched input and stable reference routing, and record the cable's termination and signal amplitude. Vary temperature within a safe laboratory range while logging at least one sensor along the cable and at each connector. If a temperature excursion causes a reproducible phase shift that follows the cable, it favours a physical path-length explanation. Yet the same manipulation can alter a buffer amplifier's operating point, so compare the complete network against a calibrated through-line and

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examine insertion gain. A conclusion about the cause must specify where the variation first appears and what components remain untested.

The RF antenna system must be challenged independently. A local injected tone carried through a fixed electrical path can establish whether the receiver reports a phase change even when the external propagation channel is removed from the experiment. Next vary the cable path while keeping the antenna path constant; then vary antenna geometry while keeping the reference cabling stable. The diagnostic power lies in changing one causal pathway at a time. When changes cannot be isolated, report the confounding factors and enlarge the uncertainty bound. The humble connector can frustrate an elaborate array, and its effect must not be dignified as a discovery about a remote transmitter.

Dr. James M. Atkinson, Moderator: Lord Kelvin, what does common error do to the asserted precision of an averaged multichannel finding?

William Thomson, Baron Kelvin, Peer Question: Professor Townes, an analyst may compute a standard error that decreases as the square root of the number of receivers, supposing that each contributes an independent observation. If the common reference induces a shared component, what does increasing the number of channels actually accomplish? Please distinguish a shared random contribution from a fixed calibration bias, and consider whether measuring excellent repeatability across many channels can ever be sufficient to establish external accuracy.

Suppose the operator shows me four displays whose excursions agree within a fraction of a degree, then presents a quoted uncertainty divided by the square root of four. I ask what was independently measured rather than

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how many readouts were printed. What model would distinguish a stable common bias from a fluctuating common disturbance, and how would you estimate their different effects on the mean and on each channel difference? Would the confidence interval change if all channels shared a fan-out amplifier with a switching supply that occasionally produced deterministic phase steps?

Charles H. Townes, Response: Lord Kelvin, take n observations, each with a shared zero-mean error c of variance σ_c^2 and an individual zero-mean error e_i of variance σ_e^2. Assuming the e_i are mutually independent and independent of c, the arithmetic mean has error $c+(1/n)\Sigma e_i$. Its variance is therefore $\sigma_c^2+\sigma_e^2/n$. As n grows, the independent contribution decreases, but the common contribution remains. If n=8, σ_c=4 ns and σ_e=3 ns, the standard uncertainty of the mean is sqrt(16+9/8)=approximately 4.14 ns, not sqrt(25/8)=approximately 1.77 ns as under the incorrect all-independent model.

The number of displayed traces should not appear in an uncertainty formula until the dependence model has been justified. I would compute the covariance of phase residuals from a controlled common injected tone, separately for stable operation and for declared reference transitions. If the random common component has variance σ_c^2 and each channel has independent variance σ_e^2, four channels yield a mean variance $\sigma_c^2+\sigma_e^2/4$. A stable bias b_c is different again: it shifts every result without producing repeat-to-repeat random dispersion and must be calibrated or bounded as a systematic uncertainty. In a switching episode the stationary covariance approximation can be invalid because a coherent step is a conditional event, not one more sample from the quiet random process. Retain its magnitude,

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timing and response in each branch. A truthful confidence statement will specify the operating state, the estimator, the evidence of dependence and whether a systematic-bias allowance or separate transient scenario is included.

A fixed bias presents a different problem: it does not appear as an across-run random spread and cannot be removed by averaging repeated measurements. If the bias is known, apply an appropriate correction with its own uncertainty; if it is unknown but bounded, retain a systematic uncertainty term or a scenario limit. Repeatability concerns agreement under specified conditions. Accuracy concerns relation to a defined reference or truth, to the extent this is measurably available. Several instruments sharing one defect may exhibit superb repeatability, but they do not thereby validate the asserted absolute time, phase or frequency. The uncertainty budget must reflect the shared design and the actual evidence for correlation.

Dr. James M. Atkinson, Moderator: Professor Poincaré, would you consider whether a convincing agreement is sometimes an artefact of the analyst's model?

Henri Poincaré, Peer Question: Professor Townes, a common disturbance may be mathematically removed by differencing, and a differenced measurement may look exceptionally clean. Yet the discarded common component might be precisely the evidence that the absolute clock or reference was wrong. How should an investigator decide which transformation preserves the quantity of interest? Is it legitimate to interpret low residuals in a differential fit as proof that both channels

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correctly measured the external event, especially where phase unwrapping and filtering have already imposed assumptions of continuity?

There is an inverse problem hidden in this subtraction. If the comparison software removes an estimated common trace from each receiver, it may also remove the genuine phase evolution of a common transmitter illuminating every antenna. How can the analyst specify the subspace that is discarded, identify the physical parameters which can no longer be recovered, and establish whether the retained differential measurement answers the claimed forensic question? What independent information would allow separation of a common environmental carrier event from a reference-phase event when their predicted channel vectors happen to agree?

Charles H. Townes, Response: Professor Poincaré, every transformation answers a particular question. If our objective is the relative phase between two antenna paths at the same instant, subtracting an exactly common phase term can improve that relative estimate. If our objective is the event's absolute time or carrier phase relative to a traceable external reference, subtraction destroys necessary information. The original observations and the applied transformation must therefore both remain available. The quantity of interest should be written before the processing algorithm is selected, and the report should avoid transferring a conclusion from one estimand to another.

A practical way to preserve this distinction is to archive the original full phase series alongside the residual after subtraction, with the numerical transformation, its reference conditions and the physical estimand explicitly recorded. Otherwise an audit of absolute continuity becomes impossible.

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Before subtraction, write a forward observation model with separate external-signal parameters and internal-reference parameters. Determine whether the channel vector induced by a possible common transmitter event can resemble the vector caused by a reference step. If so, no difference-only representation can discriminate them. Preserve both original channel phases and the common-mode residual, and measure their responses to independently controlled antenna-path and clock-path stimuli. A difference operator is legitimate for an estimand such as relative delay when its assumptions hold, but it can annihilate the common component essential to a claim about simultaneous carrier modulation. Mathematical identifiability must be tested by the rank of the sensitivity matrix and by the condition number under the actual station geometry and noise levels. Where two hypotheses remain observationally equivalent, report that equivalence. Adding more channels driven by precisely the same clock and receiving the same highly correlated signal may add almost no discriminating information.

Low differential residuals establish only that the chosen model fits the particular differences well. They cannot prove the absolute correctness of each channel, nor can they establish that filtering was harmless. Phase unwrapping may resolve an ambiguity by continuity assumptions that break down during discontinuities or missing samples. Independent phase monitoring and known challenge transients test these assumptions. Where more than one unwrapping or calibration history is compatible with the data, disclose the alternatives and their consequences. A mathematically elegant residual is not a replacement for a physically identifiable reference plane and an independently tested observation chain.

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Dr. James M. Atkinson, Moderator: Professor Wiener, what do covariance and spectral structure reveal about a common impairment?

Norbert Wiener, Peer Question: Professor Townes, in practice neither the external radio signal nor the reference noise is guaranteed to be stationary, and different receivers may filter a shared disturbance in dissimilar ways. Can cross-correlation or cross-spectral measurements still provide useful evidence of a common source? What limitations arise when the operator estimates covariance from a short record containing one brief event, removes a trend before analysis, or incorrectly treats coherent environmental signals as independent noise?

Suppose coherence is computed over a long interval containing several minutes of quiet operation and one brief common timing discontinuity. The windowed spectral estimate may represent the transient poorly, and a simultaneous legitimate RF event may itself produce strong coherence. What joint time-frequency controls would you demand to test whether the correlation follows the reference path? Could a controlled modulation be used to estimate a transfer function, and how should the analyst handle phase wraps, nonstationary epochs and finite-window bias before assigning a causal interpretation to the coherence display?

Charles H. Townes, Response: Professor Wiener, cross-spectral measurements are useful diagnostic descriptions, provided they are interpreted conditionally. For two error channels e_1 and e_2, a prominent cross-spectrum at a disturbance frequency can suggest shared modulation or coupling, but it does not uniquely locate the physical source. A coherent remote RF signal, correlated antenna propagation, electrical interference and reference distribution can all create spectral coherence. Controlled

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interventions are needed to distinguish those possibilities. Record the raw time series, segment selection, windows, smoothing bandwidth, and any detrending operations used to compute the cross-spectrum.

The analyser should also examine whether the measured coherence varies with the chosen window and data subset. A causal explanation that survives reference swapping and controlled stimulus changes is stronger than a high coefficient calculated from one selected stationary-looking interval.

I would first split the record into physically meaningful states: normal lock, a reference-transition interval, and recovery or holdover. Analyse each with explicit windowing and retain the underlying phase samples so that the spectral average cannot erase a one-off step. A stable injected tone provides an independent path to measure the reference-to-output transfer function; a known RF input modulation measures the separate antenna-to-output response. Compare magnitude and phase at several modulation frequencies and test whether the model predicts a controlled disturbance at a frequency not used in fitting. High spectral coherence is not an attribution. A common external emitter, shared clock, supply coupling and even common DSP interpolation can generate correlated signatures. If phase wraps occur, document the unwrapping algorithm and verify it against raw complex samples. For an episodic event, report the time-domain response directly and avoid compressing a rare transition into a Gaussian noise floor derived from quiet intervals.

A short interval containing one transient is particularly vulnerable to overstated spectral inference. Frequency-domain averages assume some meaningful repeatability or local stationarity; an isolated event may instead be more informatively compared in the time domain with known controller-

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state transitions. Preserve its amplitude, duration and relative timing at every monitoring point. Coherence between receivers should be measured before and after reference swapping, with independent local signals where possible. The ideal is agreement between a physical intervention and the predicted change in the cross-channel statistics. Without such intervention, correlation is evidence of dependence, not a certificate of cause.

Dr. James M. Atkinson, Moderator: Professor Kálmán, how might a state estimator conceal a shared disturbance while presenting credible output covariances?

Rudolf E. Kálmán, Peer Question: Professor Townes, digital receiving instruments frequently estimate clock offsets, drift and phase from noisy observations. Several channels may be processed through one shared reference model or one common prediction step. Under what conditions may a filter's stated uncertainty become overconfident because the model omits correlated process disturbances? How should one assess the resulting innovation sequence and distinguish a genuine phase disturbance from a change introduced by model resetting or covariance tuning?

I am concerned that the software model used by both receivers might itself manufacture agreement. If the two filters share a common clock prior and the same smoothing routine, their small reported innovation variance may say little about physical independence. What innovation cross-correlation and leave-one-channel-out tests would you require? If the clock undergoes a discrete transition that the linear process-noise model does not permit, could the estimator redistribute it into transmitter state or location, while returning misleadingly small posterior uncertainty? Please specify which underlying data must remain inspectable.

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Charles H. Townes, Response: Professor Kálmán, an estimator's covariance is only as trustworthy as its state and disturbance model. If two channels receive a common process perturbation but their filters treat errors as independent, the resulting joint covariance matrix is incorrectly diagonal. Subsequent fusion can overstate information and yield a narrow uncertainty interval despite correlated residuals. One remedy is to augment the state with an appropriately modelled shared disturbance and estimate its covariance; another is to use measured cross-covariance or conservative bounds when a full state model cannot be justified. The appropriate choice depends upon identifiability and available calibration data.

This challenge is especially important at the instant a controller changes reference states. The filter may remain numerically stable while its assumptions about process noise, measurement independence or source continuity cease to hold. Such transitions belong in the validity register.

A state estimator can conceal a physical failure if its model attributes every observed residual to the parameters it was designed to estimate. Inspect raw pre-filter phase and timing observations, the innovation sequence at each receiver, and the innovation cross-correlation between receivers. Under a correctly specified model those innovations should exhibit the expected covariance and temporal structure; coherent excursions suggest a missing common state, incorrect input disturbance, or shared processing error. Conduct leave-one-receiver-out and independently clocked control runs. Introduce a known laboratory reference phase step and require the estimator to flag the state change rather than silently move the estimated emitter. Verify the provenance of all clock-correction data and retain the actual gain matrices, noise assumptions and transition flags. A small

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covariance reported by software is only a conditional mathematical output. It does not certify that its process model included the correct physical fault.

Innovation sequences should be inspected for synchronised transients, nonzero cross-correlation, state-dependent bias and unexplained variance changes. A covariance reset may make later error bars look small without establishing that the unobserved reference transition was continuous. Maintain a controller-state log and compare raw observations to filtered states across deliberately introduced reference changes. Sensitivity tests varying process-noise assumptions may reveal that a claimed localisation or timing result depends heavily on an unvalidated model. Do not describe an internally consistent estimator as externally accurate until an independent check supplies that missing evidence.

Dr. James M. Atkinson, Moderator: Professor Michelson, what test of physical independence would you accept before relying upon simultaneous observations?

Albert A. Michelson, Peer Question: Professor Townes, interference measurements can detect exceedingly small changes, but they also inherit the behaviour of mirrors, supports, temperature and reference paths. Modern receiver arrays likewise promise precision while sharing their physical surroundings and engineering infrastructure. Which controls would distinguish a common environmental disturbance from a genuine radiation-field effect, and how would you design a reference-swapping trial whose results could be reproduced by a second laboratory rather than depending upon an operator's interpretation of one attractive display?

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When one swaps reference branches between receivers, the operation changes cable stress, contact impedance and sometimes the relative timing of analogue and digital stages. How can a laboratory experiment establish causality rather than merely produce a new configuration with a new noise floor? I would like a repeated intervention plan that includes a known good reference, a known imposed defect, fixed RF calibration inputs and an independent observer. What result would distinguish the genuine common-clock contribution from a receiver fault, and what inconclusive outcomes must be reported rather than interpreted opportunistically?

Charles H. Townes, Response: Professor Michelson, design the experiment around explicit competing explanations and a set of interventions whose outcomes would differ. A genuine incoming-wave phase change should depend predictably on antenna geometry, source direction and propagation conditions. A clock-network phase event should correlate with an independently observed reference perturbation and remain when the antenna input is replaced by a documented local test signal. Common mechanical vibration may disturb both antenna cables and reference distribution, so vibration, temperature and supply measurements should accompany the comparison rather than be treated as irrelevant background.

The same trial must preserve the source waveform, detector settings and receiver reference clock for later independent reanalysis. Only then can a negative result be judged against the actual sensitivity of the experimental configuration rather than an unstated assumption that the equipment must have observed every relevant event.

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The purpose of an intervention sequence is to seek different predictions from different causal hypotheses, with the test conditions recorded before examining the results. Under a common-source defect, a deliberately imposed source phase modulation should propagate through both receivers according to their calibrated transfer functions. Under a single-branch defect, swapping branches should move the anomalous signature with the branch, subject to documented cable and connector conditions. Under a receiver-local impairment, the disturbance should remain more closely attached to the receiver when the same reference and RF calibration inputs are exchanged. These are conditional predictions, not guaranteed binary outcomes. Repeat A-B-A tests with a sham manipulation and monitor the reference source, fan-out ports, power supply and RF inputs simultaneously. If the manipulated system also changes dynamic range or noise floor, report that as a limitation. A single falling spectral peak does not establish the absence of an external signal.

For reproducibility, publish the connection diagram, component identities and firmware versions, the calibrated source and comparator configurations, stimulus amplitudes, trial schedule, environmental limits and unedited time series. Randomise or blind the order of reference configurations if observer expectations could influence event classification. Include negative controls in which no perturbation is applied. Independent reproduction should seek the same causal distinction, not merely a similar-looking chart. If the perturbation follows a particular distribution module when moved between systems, that is more informative than two reports generated from the same unchallenged apparatus. The report should say

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exactly which faults have been excluded and which shared pathways remain untested.

Dr. James M. Atkinson, Moderator: I pass the principal token to Lord Kelvin for an independent examination of multichannel uncertainty, and then invite Professor Wiener to challenge that model.

William Thomson, Baron Kelvin, Second Principal Contributor: Dr. Atkinson, agreement between receivers should be expressed in a model that distinguishes common errors from individual errors. An average of n channels does not suppress a disturbance copied identically into every channel; it suppresses only those variable contributions that are suitably independent. More importantly, one must specify whether the desired measurement is absolute time, differential phase, received field strength or location. A perfectly shared reference phase might cancel from a relative-phase estimate while remaining fatal to a claim about the absolute time of the event. I would demand a clock-tree drawing, comparisons of source and branch phase, and intervention tests in which one reference path is replaced while the RF stimulus is held fixed. The resulting covariance should be derived from observations, not guessed from the number of receivers. I invite Professor Wiener to examine whether a static covariance can describe a transient switching event.

I would begin the uncertainty budget at the physical reference plane, not at the end of a spreadsheet. Consider four phase observations $y_i=\theta_i+c+e_i$, for channels i=1 through 4. Here θ_i is the receiver-dependent phase of the intended signal, c is an additive common-phase disturbance in radians, and e_i is channel-specific error. In a calibration experiment with identical

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applied signal phase, we may investigate the statistical properties of c and e_i. If their variances are σ_c^2 and σ_e^2, and all e_i are mutually independent and independent of c, the variance of the four-channel mean is $\sigma_c^2+\sigma_e^2/4$. Increasing to sixteen channels changes the second term to $\sigma_e^2/16$, while the common component remains untouched. The inference is conditional upon independence and stationarity. It is not a theorem that four receivers necessarily produce a twofold improvement in total measurement precision.

A numerical illustration should make the issue visible. Suppose a shared reference produces a random standard deviation of 0.8 degrees of phase at the measurement offset of interest, while each individual receiver contributes an independent standard deviation of 1.2 degrees. A single channel then has root-mean-square uncertainty $\sqrt{(0.8^2+1.2^2)}=1.442$ degrees, under the stated zero-mean and independence assumptions. The mean of four has $\sqrt{(0.8^2+1.2^2/4)}=1.000$ degrees. A naïve analyst who divides the single-channel figure by $\sqrt{4}$ reports 0.721 degrees and materially understates the variance. The difference is not an administrative dispute over significant figures. It is the consequence of a physical conductor carrying one perturbation into several apparently distinct observations.

It would be equally incorrect to insist that a shared term always corrupts the measurement. Define a differential estimate $d_{ij}=y_i-y_j$. If the shared disturbance enters both measurements with precisely the same coefficient and at exactly the same event time, c cancels, yielding $d_{ij}=(\theta_i-\theta_j)+(e_i-e_j)$. This cancellation is an advantage in a well-designed coherent experiment, but it is not an absolute-time calibration. If two distribution branches have different phase transfer functions, c enters as h_i*c-h_j*c, where the asterisk denotes convolution. Their unequal gain, delay, or loop

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bandwidth may prevent full cancellation even though both are connected to the same reference oscillator. A diagram of a common source therefore cannot replace a measurement of the two delivered clock edges.

The covariance matrix reveals this architecture more faithfully than an isolated accuracy certificate. Under the simplified model, $\Sigma=\sigma_c^2 \mathbf{1}\mathbf{1}^T+\sigma_e^2 I$, where 1 is the vector of four ones, I is the identity matrix, and the superscript T denotes transpose. Its diagonal elements are $\sigma_c^2+\sigma_e^2$, while each distinct off-diagonal element is σ_c^2. The common direction, represented by 1, has variance eigenvalue $4\sigma_c^2+\sigma_e^2$. Each of the three differential directions has eigenvalue σ_e^2. These are the modes which different estimators emphasise or reject. Before applying them to the field record, establish that the measurement quantities have compatible units, that a linearised phase model is justified, and that finite sample covariance has not concealed a deterministic step.

Consider what a station operator means by the phrase independent confirmation. A second antenna may independently intercept a radio wave but share the first antenna's conversion oscillator, ADC sampling edge, mains supply, trigger service and software timestamp mapping. For an amplitude-only question the common ADC clock may be less consequential than the analogue front-end; for a frequency excursion it may be decisive. For a source-location question the spatial separation matters, yet the shared timestamp origin and any calibration offsets remain germane. I would insist that each evidential assertion specify the particular random variables claimed to be independent and the controls by which that claim was challenged. Counting independent housings, vendor serial numbers, or separate on-screen traces does not answer a statistical question.

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A second difficulty is the possibility of systematic rather than stochastic error. A fixed branch delay of forty nanoseconds will not be revealed by the apparent scatter of repeated timing measurements if the delay remains stable. At a nominal electromagnetic propagation speed of 299,792,458 metres per second, forty nanoseconds correspond to approximately 11.99 metres of path-difference equivalent. It does not follow that the position estimate is wrong by precisely twelve metres, because the inverse geometry changes the mapping between delay and position. The correct report carries the delay bias as a bounded or calibrated term and propagates it through the actual geometry. Statistical averaging does not repair a measurement whose reference plane was misidentified.

Finally, the calibration must include more than the distribution source in isolation. Measure the source, each fan-out branch, and the relevant receiver output against an independent standard where practicable, preserving the chain of uncertainties. Record each instrument's detection bandwidth and noise contribution so that a sub-floor comparison is described as a limit rather than a measured physical absence. A repeatable shared transient may warrant a deterministic intervention model rather than a covariance estimate derived from quiet operating minutes. Lord Kelvin's problem, in modern analytical language, is to prevent an elegant algebraic uncertainty from acquiring authority beyond the physical observations that support it. I therefore pass the token to Professor Wiener to examine the temporal model itself.

Norbert Wiener, Cross-Peer Question to Lord Kelvin: Lord Kelvin, the common disturbance is unlikely to be stationary throughout an investigation. When a distribution amplifier switches supply mode or a

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phase-locked loop reacquires lock, its errors may be episodic, and covariance computed across many quiet minutes could dramatically understate the event interval. Would you distinguish the ordinary-operation covariance from a state-dependent or bounded transient model? What record would permit a later analyst to decide whether several simultaneous spectral detections came from one underlying reference disturbance, rather than independent emissions arriving at several antennas?

You have proposed a covariance structure that distinguishes common and independent terms, yet it presumes a defined operating regime. Consider a fan-out system in which a shared oscillator is stable, but one supply switching event imposes a short step on all receiver phases. If a long calibration record contains that event only once, a stationary covariance estimate may be highly sensitive to where the analyst placed the windows. Would you treat the episode as a separate state, represent it by a bounded timing or phase discontinuity, and calculate its effect on each estimand individually? If an instrument later filters or smooths the record, what original evidence would remain necessary to prevent the model from portraying the transition as ordinary random noise?

William Thomson, Baron Kelvin, Cross-Peer Answer to Norbert Wiener: Professor Wiener, one covariance matrix cannot be presumed valid across different physical states. Divide the record at documented reference changes and estimate the dependence within each genuinely comparable operating regime. For an isolated transition, retain its measured amplitude and duration and formulate a bounded scenario, rather than force the event into an inappropriate Gaussian noise assumption. Simultaneous independent observations are useful only if independent reference controls

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were present. A stable local injected tone may exhibit a common step when the clock tree changes, while external spatial observations should be separately challenged by antenna geometry and propagation. The point is to use interventions that discriminate hypotheses. A low steady-state variance is not a warrant to ignore a large unmodelled discontinuity.

A change of operating state should be modelled as a change of the experiment, not hidden within an average. I would retain a state-labelled time series, with the transition time established by an independently witnessed reference-plane measurement. Within a stable state, a covariance estimate may describe the random part of the error; for the transition, a measured or bounded phase step may be more honest. Suppose the shared step is 0.03 radians at each of four channels, while their individual random-phase uncertainty is only 0.001 radians. Treating the step as one more draw from the random distribution would grossly misrepresent its importance during the actual event. An absolute phase estimate inherits the near-common step; a true differential estimate may cancel it if the branch transfer functions match, but a difference between unequal filtered versions of the step can produce a transient of its own. Thus the propagated error must be computed using the transfer functions for the actual channels and the exact estimator. Repeated quiet measurements do not establish that the transition will be benign.

I would require four complementary records. The first captures source and port phase during the reference transition. The second preserves downstream receiver phase or sample-timing observations. The third records control states and supply disturbances that might explain the change. The fourth specifies the data-processing transformation that the

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operator used to display the result. A reconstructed event should be compared against those records without discarding the unprocessed phase stream. If the transition occurred only once, a probability distribution inferred from that single occurrence is weakly supported; the report may instead state an observed bound under an explicitly defined configuration. Where multiple events exist, their dispersion can be estimated but only after checking whether they belong to one physical population. I agree with Professor Wiener that a stationary model cannot be transferred across a reference switch without experimental justification.

Charles H. Townes, Response to Lord Kelvin and Norbert Wiener: Their exchange identifies why cross-channel coherence is both the benefit and the forensic risk of the shared reference. Its cancellation in differences must be demonstrated experimentally for the exact measurement functional. I would retain both differential and common-mode phase streams, because deliberately discarding one may make the other appear more conclusive than the evidence warrants.

Dr. James M. Atkinson, Moderator: Professor Wiener, please examine the shared disturbance as a dynamic multichannel process rather than a single covariance coefficient. Professor Townes may then test the causal interpretation.

Norbert Wiener, Third Principal Contributor: The common reference should be analysed as an input to a multichannel system with frequency-dependent transfer paths. A disturbance may be shared at its origin yet appear with distinct amplitudes, phases and delays at individual receiver outputs. Correlation estimated during quiet operation does not characterise a rare

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re-lock transient. I would examine cross-spectra and time-domain responses under deliberate safe source perturbations, keeping the antenna stimulus unchanged. The inferred dependence belongs to a specified configuration and state, not to a permanent universal coefficient.

To call the common reference a single number conceals a process with memory. Let $c(t)$ denote the reference-induced phase variation at the source, and let $g_i(t)$ represent the impulse response of the entire distribution and conversion path serving receiver i. An observed perturbation may be expressed as $z_i(t)=(g_i*c)(t)+u_i(t)$, where u_i includes unshared receiver noise and other unmodelled terms. In the frequency domain, $Z_i(f)=G_i(f)C(f)+U_i(f)$. Two receivers may therefore display similar narrowband disturbances while disagreeing in phase and magnitude because their distribution paths differ. Even the sign of a time-domain excursion can be transformed by filtering, AC coupling, phase wrapping or derivative-like tracking loops. No one should infer a simple contemporaneous common cause from a pair of coloured spectral traces without checking those transfer paths.

A cross-spectral measurement offers one avenue of inquiry. If the reference perturbation is wide-sense stationary over the selected interval and the unshared noises are independent of one another and of the reference, $S_{ij}(f)=G_i(f)G_j^*(f)S_{cc}(f)$, where the star on G_j denotes complex conjugation and S_{cc} is the reference phase-noise power spectral density. A normalised magnitude-squared coherence can then be written $\gamma^2_{ij}(f)=|S_{ij}(f)|^2/[S_{ii}(f)S_{jj}(f)]$, provided both denominator spectra are nonzero. A value near unity means that variation at that frequency is linearly related between the channels under the estimator's assumptions. It does

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not reveal whether the relation arises from a genuine common transmitter, shared reference modulation, a local supply line, or a shared processing artefact.

The engineer should distinguish a stochastic fluctuation from an episodic state change. A slow random-walk phase component, a supply-related periodic spur, and a reference switch that occurs once in twelve hours produce markedly different statistical records. The first may be modelled with an appropriate low-frequency spectrum; the second may be studied as a deterministic periodic disturbance, with harmonics and load dependence; the third is a transition event whose amplitude, duration and exact sequence should be preserved in the time domain. If one long record is partitioned into short segments for spectral averaging, the lone switching event may influence only one or two segments and be submerged in an overall average. A smooth plotted curve can therefore be a poor account of the episode most relevant to the forensic question.

Time lag matters as much as amplitude. Suppose the fan-out produces a common short phase step, but one local synthesiser reacts after ten microseconds and another after thirty. The correlation of their phase records may be highest at a twenty-microsecond lag rather than at zero lag. If the investigator assumes identical time stamps for the plotted events, the displacement may masquerade as propagation between antennas. To diagnose the situation, simultaneously inject a controlled reference-path challenge while supplying the RF inputs with a stable known signal, and measure the downstream response of each synthesiser. A separate antenna-path challenge then tests whether the observed delay belongs to reception or to local clock recovery. Neither test alone can establish all

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relevant causes, but together they reduce an otherwise broad class of explanations.

One may also make a useful two-condition comparison. In condition A, channels one and two share the same ten-megahertz source, and a weak line near a known injected carrier appears in both spectra. In condition B, channel two takes a second low-noise reference with verified stability while the RF stimulus and analogue signal paths remain as unchanged as practicable. If the line moves, weakens or decorrelates, reference dependence becomes a plausible explanation. But the intervention has itself changed local-oscillator noise, PLL settling and possibly receiver sensitivity; those changes must be measured with a retained calibration tone. A feature that falls below the altered detection floor has not thereby been proved absent. Causal attribution rests on whether the entirety of the altered response fits an independently tested transfer-function model.

A further danger lies in spectral leakage and estimator tuning. Finite windows spread the energy of a discrete component across neighbouring bins; overlapping segments may make adjacent spectral estimates statistically dependent. Coherence can rise artificially if a deterministic carrier dominates both channels, even though their random noise sources are genuinely independent. One should estimate and report the window, resolution bandwidth, number of statistically informative averages, confidence limits, and the effect of subtracting or retaining common calibration tones. If the signal occupies a frequency range where a receiver's phase tracking saturates, linear cross-spectral reasoning becomes dubious. We may need a nonlinear or state-dependent response model, or may have to restrict the claim to carefully bounded operational conditions.

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The result of these tests should be expressed as a model challenge rather than a triumph of correlation. I would ask whether a measured reference-path perturbation predicts the phase, amplitude and timing of a receiver artefact within stated uncertainty. If the same model predicts the response to a distinct challenge amplitude and an altered branch configuration, its credibility improves. If it predicts only the data from which its parameters were fitted, then the apparent fit may be overfitting rather than explanation. A quiet comparative trace can coexist with a shared bias; a high coherence can coexist with a genuine remote emission. I pass the token to Professor Poincaré, for the remaining question is which physical quantities are identifiable after the observations have been transformed.

Charles H. Townes, Cross-Peer Question to Norbert Wiener: Could high coherence in a cross-spectrum be sufficient evidence that the receivers share one defective reference, or could a coherent external RF source produce the same mathematical appearance?

Your coherence model depends on the channel transfer functions and on treating the disturbance as a process with an appropriate spectral description. Suppose a legitimate narrowband transmitter is itself coherent across both receiving antennas and the shared distribution reference develops a sinusoidal spur at the same offset frequency. Their contributions occupy the same spectral bin. Can phase-coherence magnitude alone distinguish these physical sources? Which controlled interventions would change the clock contribution without systematically attenuating the genuine RF contribution, and how would you guard against the misleading conclusion that a feature which diminishes after changing a reference must have been wholly internal? In particular, what negative-control

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measurement would reveal the simultaneous change in receiver sensitivity or local-oscillator noise floor caused by the replacement reference?

Norbert Wiener, Cross-Peer Answer to Charles H. Townes: The coherence describes shared variation, not unique causation. A real transmitter, a common disturbance carried through antenna paths and a reference-network spur can each produce coherence. Controlled changes of reference source, antenna geometry and injected calibration tones are needed to distinguish them. The analyst must also retain the frequency plan and the synthesiser transfer functions because an internal reference spur may appear at several translated frequencies.

No magnitude-squared coherence statistic can, by itself, identify the physical origin of a common sinusoidal component when both hypotheses predict the same coherent line. One must force their predictions apart. I would preserve a fixed known RF calibration input while varying the reference perturbation, recording whether the line's complex amplitude follows the calibrated clock-to-output transfer function. Independently, I would change the RF input through a controlled attenuator or reference-plane injection while leaving the reference network fixed, then examine whether the relevant component behaves as an externally received signal. A second receiver using a demonstrably independent clock and separate analogue path can provide a valuable contrast, but even that channel may observe the same legitimate emission and therefore remain correlated. Its evidence must be interpreted under its own sensitivity and timing model. A feature that vanishes only after an alteration which also raises the detection floor cannot be assigned to the changed clock with confidence.

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I would also measure phase, not merely spectral amplitude. The clock-induced component often has a predictable phase relation to an imposed reference modulation, while a genuine remote component's relation depends upon its own waveform, propagation and acquisition configuration. If the two mechanisms coincide at one offset frequency, challenge the clock at a second offset and test whether the predicted response transfers. In a small-signal linear regime the different paths may be represented with separate transfer functions, but the model should not be extrapolated through PLL unlock, cycle slips or saturation. The analyst should retain the complex spectra with their window conventions, state labels and calibration uncertainty. Coherence is a diagnostic observable, not a declaration of source. I return the token to Professor Townes with the qualification that discrimination, not mere numerical agreement, is the standard of a convincing investigation.

Dr. James M. Atkinson, Moderator: Professor Poincaré, I invite your attention to the distinction between the quantities preserved and discarded by differential processing. Lord Kelvin will ask whether the resulting error bounds remain meaningful.

Henri Poincaré, Fourth Principal Contributor: The inferred result depends on which difference the analyst regards as meaningful. Subtracting receiver phases may cancel a common error and thereby support a relative measurement; the same subtraction can conceal a defect relevant to absolute timing. A shared reference improves the definition of one coordinate system while reducing independence of the observations used to validate it. I would specify the estimand, reference plane and transformation before interpreting the residuals. If an unexplained common component

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was removed, the report should still show it to the examiner rather than present only the aesthetically cleaner differential trace.

We should begin with the geometry of the inference. Let the vector y contain the measured phases from n receivers, x contain the desired external signal parameters, a contain unknown common-reference disturbances, and ε contain residual errors. A local linear model may be written $y=Hx+Ba+\varepsilon$. Here H is a sensitivity matrix for the external field, B describes the reference perturbation's effect on the receivers, and the rank of the combined matrix [H B] governs whether different parameter combinations can be distinguished. If one column of H is a linear combination of columns of B, the relevant external parameter is not identifiable from the available observations. No increase in computational precision, receiver count with identical geometry, or number of decimal places can restore information that the experiment did not record.

To clarify, suppose every receiver reports a common small phase rise, and the sought external model permits a simultaneous phase rise of equal magnitude at all antennas. A model with a genuine transmitter phase event and a model with a common reference jump then produce the same phase vector. In the simplified observation space they are indistinguishable. A differential projection D with $D1=0$ eliminates an exactly shared disturbance, but it also eliminates a genuine common-mode component of the received field. One can improve sensitivity to relative phase while losing the very external parameter that one hoped to establish. The projection may be optimal for one estimand and destructive for another. The analyst must therefore state the quantity that remains observable after every subtraction, normalisation, detrending and reference correction.

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An apparent solution can be unique numerically without being unique physically. Imagine an optimiser that estimates transmitter direction, reference offset and branch delays, and returns a single set of parameters with a negligible residual. If the associated Jacobian is poorly conditioned or rank deficient, a family of nearly equivalent parameter sets may fit within the noise. A regularisation penalty can select a tidy member of that family, but the chosen value inherits the penalty's assumptions. A report should separate the directly observed data, the constrained model solution and the conclusions induced by priors or regularisation. Where the result concerns a possible covert emitter, this distinction has forensic importance: an algorithmically stable output is not equivalent to scientifically identified cause.

Calibration signals offer a means of increasing observability, provided their pathway is selected intelligently. A tone injected after the antenna and before the analogue receiver tests some internal conversion steps but not antenna coupling or feeder-current pickup. A radiated calibration field tests a different portion of the chain and may introduce multipath. A reference-input phase perturbation probes the clock transfer function, while a controlled variation in cable route probes an external conductor pathway. Because the interventions enter at different locations, they create new equations with different sensitivities to external and internal parameters. A carefully designed set of interventions can increase the rank of the effective problem. Merely repeating the same measurement at greater precision cannot.

I would distinguish structural identifiability from practical identifiability. Structural identifiability asks whether an ideal noiseless experiment can

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uniquely determine the parameters under the model. Practical identifiability asks whether the actual geometry, bandwidth, instrument noise and time coverage allow a useful estimate. A parameter might be structurally identifiable yet too weakly excited to estimate at the observed signal level. For example, a branch delay can in principle be measured from phase slope across frequency, but a single narrow carrier gives phase only modulo 2π. Several frequencies or a suitably wideband calibration waveform may unwrap ambiguity, subject to the stability of the response during the measurement. A local single-frequency phase match alone should never be reported as an absolute cable delay without the necessary ambiguity analysis.

An explicit counterexample is often more instructive than a general appeal to uncertainty. Construct two candidate mechanisms: A is a legitimate transmitted phase change applied to the same RF source observed by all antennas; B is a reference-clock phase change introduced upstream of every local synthesiser. Calculate or simulate their predicted observations with the actual phase and frequency conversion conventions. If they coincide under the measurement chosen, the evidence does not discriminate them. Then propose a measurement, such as a separate independent-clock receiver or direct source-reference comparator, on which their predictions differ. The new test should be planned before seeing its outcome, and its sensitivity and rejection criterion recorded. Otherwise the investigator can always invent a post hoc explanation for whichever result occurs.

One must also resist treating the absence of an anomaly in a transformed variable as proof that the underlying physical event was absent. Averaging may eliminate anti-correlated contributions; differencing may eliminate

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exactly shared contributions; thresholding may omit weak excursions; and phase unwrapping may inadvertently classify a genuine discontinuity as a computational reset. Preserve the untransformed complex samples where permitted and maintain a reversible transformation record. The very same measurement can support a strong statement about relative channel consistency and only a weak one about whether an external emitter existed. I invite Professor Michelson to devise physical tests that make these alternative predictions observably different.

William Thomson, Baron Kelvin, Cross-Peer Question to Henri Poincaré: If common-mode subtraction yields a small differential residual, may it justify a correspondingly small uncertainty interval for a source position or an absolute phase observation?

You have explained that a common-mode projection may remove both an internal defect and a physically real external component. Consider three receivers in which a location solver uses only relative phase and time differences. The residuals are small after subtraction, but the original channel records contain a simultaneous step. What precise inference remains justified by the residual fit, and what would you require before alleging that the step came from the room rather than the reference network? Can the conditioning of the source-location geometry and the rank of the augmented reference-error model show that the apparent solution is unidentifiable despite a persuasive residual statistic? Would your judgement differ when independent reference-plane measurements show that the common phase step persisted with the antenna input electrically terminated?

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Henri Poincaré, Cross-Peer Answer to William Thomson, Baron Kelvin: Only where the desired quantity truly depends upon the difference and the common contribution demonstrably cancels. An absolute phase inference retains the omitted common uncertainty. A localisation model also includes differential branch delay, geometry, propagation and waveform identification. A small residual under one transformation does not validate those other terms. The declared uncertainty must follow the measurement equation, not the visual attractiveness of the transformed trace.

A small residual after differencing establishes that the measured channel differences are consistent with the chosen model, to the precision and under the conditions tested. It does not establish that the common component of the original observation was a physical emitter or an instrument defect. Formally, if the external model and the common-reference model possess a shared column direction in the sensitivity matrix, their effects are not separately identifiable from those observations. An augmented matrix with deficient rank discloses the structural ambiguity; a matrix with a very large condition number discloses practical sensitivity to small uncertainties. If the location solver ignores branch timing biases, it can produce an apparently tight coordinate whose uncertainty budget fails to include the relevant unknown. A meaningful location claim must include the receiver geometry, correlated timing errors and calibration path delays, then show that independent evidence constrained those effects.

Consider a hypothetical three-receiver system. Each reports a common phase rise of 0.02 radians while their differences remain almost constant. One model attributes this to the emitter's instantaneous phase, a second to a shared synthesiser reference. The difference data alone cannot

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discriminate the two. A separate reference comparator, a receiver independent of that source, or an intervention that modulates one reference branch while holding the RF stimulus fixed introduces additional information. Where such evidence is absent, the proper finding is that relative phase relationships were stable across the event, not that a specific emitter was identified. I would preserve the original common-mode record precisely because it documents the phenomenon erased by the differential transformation. The evidence must not be made more certain by deleting the terms which make its interpretation uncertain.

Dr. James M. Atkinson, Moderator: Professor Michelson, please turn our discussion from inference to experiment, examining what controlled branch-swapping can actually demonstrate. Professor Wiener will challenge the limits of one unrepeated transient.

Albert A. Michelson, Fifth Principal Contributor: A good physical experiment is designed so that explanations compete under controlled changes. For a reference network I would retain a known tone through each receiving path, swap the distribution branches, and then substitute an independently monitored clock while leaving the antenna environment fixed. If the feature follows one branch, examine that branch; if it follows the source, examine the reference; if it follows a cable or antenna orientation, examine coupling. No one swap is conclusive because reconnecting apparatus may itself alter impedances or thermal conditions. Replicate with appropriate controls and record every departure from the original state.

The experimenter should demand a physical arrangement that can be deliberately rearranged without losing sight of what is held constant. Let the

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initial configuration employ two receivers, a common ten-megahertz reference, identical injection cables and matched known RF calibration tones. Record phase at the output of the central oscillator, at each fan-out port, at the synthesiser-derived sampling clock when accessible, and in the stored complex I/Q data. The measurement is not complete because the display shows a sideband: it is complete only when the disturbance has been traced to the earliest plane at which it becomes detectable. Each added probe, however, changes loading and possibly shielding. Record termination and instrument insertion effects, then compare the result with a probe-free control.

The first intervention should move a component, not merely turn it off. Exchange the two distribution branches at their receiver inputs, leaving the receivers and calibration-tone injection unchanged. A fault that follows a branch output suggests a path-specific contribution; one that remains with a receiver suggests its local circuitry or software. Yet an exchange may simultaneously alter cable strain, contact resistance and temperature. The experiment therefore requires repeatable geometry, connector inspection and a subsequent return to the baseline configuration. The observed result should be an A-B-A sequence, and ideally a replicated B-A-B sequence, rather than one change recorded as decisive evidence. Repeat the comparison while documenting supply ripple and thermal conditions.

The second intervention challenges a common impairment directly. Apply a small authorised phase perturbation to the laboratory reference through a characterised injection path. Measure whether the phase excursion at each receiver matches the independently measured distribution transfer function. Suppose the imposed test modulation has 0.02 radians peak at a

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particular offset and receiver one transmits it with gain 0.8 while receiver two transmits it with gain 0.5, both in the small-signal regime. Their predicted peak responses are 0.016 and 0.010 radians. If the measured response departs from these values, the discrepancy may reveal additional branch gain, conversion error or an invalid linear model. The numerical figures are illustrative, not product specifications or evidence from an actual survey.

The third intervention must protect the possibility that a genuine radio emission is present. Perform an antenna-path measurement with the reference unchanged, using a calibrated local radiated stimulus only where lawful and suitable. Compare it with a direct electrical injection made at a defined front-end connector. A remote signal may be seen by a portable independent-clock receiver even where a shared-clock spur moves when the reference distribution is altered. Conversely, a cable carrying common-mode current may collect real external energy and be altered by moving the cable. A decreased receiver display after an RF choke or branch reconfiguration cannot be taken as an assertion that the environment became silent. The apparatus and the environment must remain conceptually separate even when physically coupled.

An instrument's own phase-noise floor should be established before asking it to certify a better source. When two correlated analysis paths share a reference or calibration tone, cross-correlation can reduce uncorrelated measurement noise but does not remove fluctuations common to both channels. A dedicated phase comparator may provide a lower floor than a general swept analyser, though its advantages depend on the actual measurement architecture. Document offset frequency, phase-noise units,

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calibration power, detector settings and the number of independent averages. Challenge the result with a through connection or a low-noise substitute. A floor-limited absence of detected sidebands is not a measurement of zero sidebands.

The sequence of observations should be blind where practical. One investigator may change a branch, inject a calibration challenge or restore the baseline while a second reviews the anonymised output, records the resulting hypothesis classification and states a confidence bound. The withheld condition is then revealed and compared with the pre-registered prediction. This protects against confirmation bias in interpreting very small spectral differences. The test matrix must include quiet controls, known injected reference defects, known RF stimuli and combinations of both. A system that correctly recognises only pure cases but fails when the two causes coexist is not adequately qualified for a field investigation in which such combinations are entirely plausible.

Finally I would describe the evidential deliverable as a traceable set of experiments rather than a bare assertion that the receivers are independent. The investigator should identify which functions share an oscillator, distribution amplifier, clock cable, power rail, acquisition host or timestamp service, then supply the measurements which justify treating a subset of their errors as independent for a particular estimand. If the evidence does not separate a common-reference transient from a real simultaneous emission, the finding should be reported as unresolved. Physical integrity of the apparatus and integrity of the inference are two different tasks. I pass the token to the moderator with that limitation, for it is the proper boundary of the experiment.

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Norbert Wiener, Cross-Peer Question to Albert A. Michelson: How can we distinguish a transient appearing only once from a genuine causal effect if the act of exchanging cables and references changes the ambient environment?

A controlled intervention may itself change the system that we are trying to understand. Suppose the cable exchange requires opening the enclosure, the temperature of the distribution amplifier changes slightly, and the common spur disappears for several minutes before returning. How would you design repeated sham and genuine interventions to discriminate causality from thermal recovery or mechanical settling? What records should be captured at the oscillator, individual ports, receiver input and digital output before, during and after the manipulation? If the result cannot be replicated, would you treat it as evidence of a transient mechanism rather than pretend to identify a specific defective component? What observations would distinguish a temporary contact restoration from the normal warm-up history of a phase-locked loop?

Albert A. Michelson, Cross-Peer Answer to Norbert Wiener: Retain a baseline and use repeated interventions with negative controls. Record temperature, supply ripple and local interference simultaneously. Where a transient cannot be reproduced, present its time association as an observation rather than assign a unique cause. Source substitution can give valuable evidence but an isolated coincidence has limited discriminating power. The final finding should state which competing explanations were challenged and which remain unexcluded.

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The procedure should distinguish a reversible intervention from an uncontrolled disturbance of the apparatus. Before opening the enclosure, record a baseline with the same antenna stimulus, reference source, termination, temperature and analyser settings, including raw complex samples where possible. Perform a sham intervention that mimics the delay, movement and environmental exposure without exchanging the target branch. Then perform the planned exchange, restore the original arrangement, and repeat the sequence on a different day or after sufficient thermal settling. A simple before-and-after comparison cannot separate cable effects from warming, contact movement or a change in power-supply load. An A-B-A-B design offers more evidence of reproducibility, although it is not immune to long-term drift. Monitor source phase and fan-out branch phase with an independent comparator, and document probe loading so that the act of measuring does not create the suspected anomaly.

A positive finding would mean that the measured effect follows the predicted intervention across repeat trials within the measurement uncertainty. For example, if a spur consistently follows the physical fan-out port while receiver identities, calibration inputs and software settings are exchanged, a port-associated mechanism becomes more plausible. It does not mean that a remote emission was necessarily absent, since the defective path may modulate genuine received energy. Conversely, if the spur appears only during one warm-up interval and never repeats under a controlled challenge, the data support an intermittent event but do not identify its microscopic cause. Retain the unsuccessful trials and avoid selecting only the clearest graph. The final report should disclose precisely which hypotheses the experiment distinguished, which were not tested, and

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what measurement floor limits the negative results. This is the difference between an experimental diagnosis and a persuasive anecdote.

Dr. James M. Atkinson, Moderator, Closing Synthesis: A shared reference does not invalidate multichannel reception. It establishes a defined dependence which can be an advantage for coherent differential measurements but a material limitation for independent corroboration. The proper analysis separates antenna-path phase, common reference noise, distribution-path delay, host time mapping and correlated processing assumptions. The panel requires independent reference supervision, deliberate reference swapping, retained raw observations, an empirically defended covariance model and transparent uncertainty statements. Agreement between channels supplied by one defective reference remains agreement; it is not two independent demonstrations that the external event was correctly timed or attributed. This dialogue is a constructed modern pedagogical exercise.

QUESTION 054. SOURCE AND VERIFICATION REGISTER

Candidate primary references for editorial verification: NIST Special Publication 1065, W. J. Riley, Handbook of Frequency Stability Analysis (2008); IEEE Std 1139, definitions of physical quantities for fundamental frequency and time metrology; NIST guidance on time and frequency distribution, clock comparison and measurement uncertainty. Exact editions, relevant pages and applicability of individual clauses require verification against the source copies before final acceptance.

EDITORIAL QUALIFICATION: Every numerical example is hypothetical; no field receiver, distribution module, correlation coefficient or measured

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phase error is represented as independently tested. Contributor speech is fictional educational reconstruction. Formal lengths of individual peer questions and responses remain subject to final editorial checking.

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QUESTION 055

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Which observations discriminate clock drift, sample loss and delayed receiver buffering?

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SCHOLARLY RECONSTRUCTION. This dialogue is a modern educational fiction involving deceased historical contributors. It is not a transcript. Contemporary SDR and software references are editorial applications of their documented concepts.

Dr. James M. Atkinson, Moderator: Dr. Hopper, a receiver operator notices a sudden absence of samples on a waterfall, followed by a later burst of apparent detections. The temptation is to infer either that the transmitter stopped or that the receiver oscillator failed. But the acquisition clock may have drifted, the receiver may have lost samples, or samples may have accumulated in a host buffer and arrived late. Which contemporaneous observations are indispensable to discriminate these mechanisms, and how should an examiner preserve the chronology without mistaking a visually continuous graph for a continuous physical measurement?

Grace Murray Hopper, Principal Contributor: Dr. Atkinson, the first responsibility is to separate events at the antenna from events in the instrument, transport, operating system and display. A waterfall is a derived presentation, not an acquisition ledger. It may update at an irregular rate even when hardware samples are steady; it may also display a smooth interpolated picture across an interval in which no samples were collected.

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The examiner must identify which subsystem owns each clock, which counter advances when a sample is produced, which counter advances when a packet is delivered, and which timestamp marks an observation rather than its later processing. These distinctions are part of the evidential model, not optional engineering housekeeping.

Let n be a hardware sample index, f_s the nominal sample rate in samples per second, t_0 the acquisition start time, and $\varepsilon(t)$ the fractional sample-clock frequency error. Under an ideal fixed clock, the time assigned to the nth sample is $t_n=t_0+n/f_s$. With a slowly varying actual rate $f_s[1+\varepsilon(t)]$, the elapsed time for N samples instead approximately equals the integral of $dn/[f_s(1+\varepsilon)]$, and for small constant ε it is $N(1-\varepsilon)/f_s$. Drift changes the mapping between sample index and physical time even when all samples survive. A missing group of samples produces an index or sequence discontinuity. Buffering delay changes when the host receives or presents samples but does not necessarily change their acquisition order or physical sampling interval. Each mechanism can create a similar disturbance on a graphical display while leaving a different signature in the raw records.

Suppose a receiver nominally produces 2,000,000 complex samples per second and its clock runs fast by ten parts per million. The actual rate is 2,000,020 samples per second. During a 60-second interval the difference in accumulated sample count relative to a perfect two-megasample clock is 1,200 samples. That does not mean that 1,200 samples have vanished; it means a nominal-rate timestamp inferred from the count would differ in its time mapping. By contrast, a genuine missing segment of 1,200 samples at the nominal rate corresponds to approximately 0.6 milliseconds of unobserved acquisition time, provided the loss occurred in a continuous

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hardware stream. These numerical examples are hypothetical, and clock models must be corrected for the actual receiver architecture.

The third case is host buffering. Imagine that a device continuously acquires and numbers every sample while the host processor is momentarily occupied with a disk operation. The delivery process may stall for 200 milliseconds and then issue several packets rapidly. If the hardware index sequence remains intact and device timestamps follow the expected acquisition cadence, there has been a delivery delay but no evidence of missing RF samples. However, an unbounded host queue can eventually overflow, turning delay into genuine loss. Thus a correct report must differentiate backlog without loss from backlog followed by loss, and must not treat queue length alone as proof that every intermediate sample was recorded.

A robust acquisition record should retain, where the apparatus exposes them, monotonically advancing sample counters; first-sample timestamps at the device; packet sequence identifiers; receive error codes; out-of-sequence and overflow indications; device and host buffer utilisation; start, stop and retune commands; clock-lock transitions; and the operating-system monotonic times at which packets were received. Not all devices expose each field. The analyst must explicitly state which safeguards are absent. A host-created counter incremented only after successful delivery does not independently establish how many samples the hardware generated and discarded before delivery.

Distinguishing tests should be designed as a small factorial experiment. First perturb the acquisition clock by a safe, calibrated amount while maintaining a sufficiently capable transport and record reference-marker phase versus

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hardware index. The expected signature is a continuous index stream with a changed relationship between sample number and independent reference time. Next inject controlled packet loss or reduce host throughput without altering the device clock; the expected signature is a discontinuity in sequence identifiers or missing hardware-time intervals, accompanied by error metadata where supported. Finally impose host load that creates queued delivery while remaining below overflow; the expected signature is delayed packet arrival with continuous counters and acquisition timestamps. The three outcomes should be recorded separately and then challenged under combined conditions.

To avoid confusing a transmitter dropout with acquisition loss, observe a known benign reference tone or time marker through a parallel independent measurement chain. If the disputed signal disappears but the local reference marker persists continuously in the same receiver samples, a receiver-wide sample gap becomes less plausible, although selective front-end artefacts remain possible. If both vanish from the raw record, one must distinguish a common RF path interruption from acquisition loss using counters, a second receiver and input-chain controls. If packet indices are missing, reconstruction cannot restore the unmeasured waveform by merely drawing a line between the last and next displayed points.

The hierarchy of evidence matters. The strongest claim of uninterrupted acquisition requires agreement between a trustworthy hardware sequence, measured timing behaviour and raw sample integrity. A green application status, a steady average throughput counter or a smooth spectral trace is weaker evidence. The chain of custody must preserve original files, hashes, buffer-error records, calibration and clock configurations, application

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versions and every derivative transformation. Later resampling and interpolation may serve analysis, but they must be labelled as computations over a possibly incomplete record. An expert witness should describe what the instrument observed, what its software estimated and what the investigator inferred as three separate propositions.

Dr. James M. Atkinson, Moderator: Professor Nyquist, would you address how a drifting clock affects spectral inference without necessarily causing lost samples?

Harry Nyquist, Peer Question: Dr. Hopper, analysts often associate samples with an exact configured sampling frequency and thereby treat the displayed frequency bins as invariant. Yet a drifting acquisition oscillator changes the physical spacing of those samples in time, even when their number and order are perfectly preserved. How would you distinguish a sample-clock frequency error from packet loss using a precisely known tone, and why must one avoid treating a narrow spectral displacement as conclusive evidence that the external transmitter changed frequency?

A drifting sampling clock changes the physical time represented by each recorded index, even though the acquisition stream need not lose one sample. Please distinguish a known fractional frequency error from sample-rate jitter, a phase-step event and a true absence of data. If the investigation contains only a stable RF test carrier which was derived from the same reference as the receiver, could its apparent frequency remain unchanged when both drift together? What independent signal or timing marker would you use to expose that circular calibration, and how would you state the relevant measurement interval?

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Grace Murray Hopper, Response: Mr. Nyquist, the known tone becomes an independent ruler for the time base, provided its source is itself characterised and its path is controlled. Record raw samples, compute the tone's phase increment per sample and compare it with the phase increment expected from the externally measured source frequency. A gradual change in the increment, accompanied by continuous counters, supports a changing sample-clock map. A sudden index discontinuity with no intervening samples points to loss or a device restart rather than a mere frequency offset. The operator should also inspect the local oscillator and digital downconverter, because their frequency errors may resemble sampling error. Frequency-bin displacement is an observation; attribution to the transmitter requires an instrument challenge and a reference trace.

The instrument's frequency translation must also be checked. A measured frequency offset in the saved baseband samples may come from an RF input shift, local-oscillator drift, or a sample-clock scale error, and these explanations do not predict the same behaviour when the centre frequency or decimation ratio changes. A second calibrated reference tone and a record of the synthesiser settings can separate the hypotheses. The investigator should test more than one tone, because an offset at one frequency cannot by itself identify the mechanism. When the second instrument shares the suspect clock, the comparison may conceal rather than expose the original fault. The result belongs in a bounded uncertainty analysis, not a claim of absolute truth.

A separate, independently clocked calibration waveform is the proper instrument for testing the relationship between hardware sample index and elapsed physical time. If the receiver and test tone inherit the same

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defective reference, a proportional change can cancel in the apparent frequency estimate. Record the known tone's source oscillator and measure its frequency against a separate standard, while preserving the acquisition device's raw counters. A progressive error in the index-to-time relation points toward rate calibration, whereas a missing counter interval indicates an omitted sample range if the counter was assigned at capture. A reference switch may produce a phase discontinuity with no omitted indices, and random sample-time jitter requires a different short-term analysis from fixed frequency offset. The report should distinguish the observed sample sequence from the inferred elapsed seconds, and avoid attributing every suspicious waterfall gap to a clock defect. One physical waveform may contain a real burst exactly when the display stalls; only the stored acquisition record can show which parts were actually observed.

Dr. James M. Atkinson, Moderator: Professor Wiener, how would you analyse the irregular delivery sequence without confusing transport time with signal time?

Norbert Wiener, Peer Question: Dr. Hopper, a host records bursts of packets, some separated by large gaps and others arriving almost simultaneously. An investigator might treat the packet-arrival intervals as samples of the incoming radio field or infer discontinuity from their variance. How should a statistical analyst separate queue-induced arrival jitter from actual acquisition timing, particularly when there is no direct observation of every device clock edge and the transport path itself may re-order packets?

Suppose the transport path has a temporary service interruption and then delivers a densely packed cluster of blocks, all with apparently valid host

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timestamps. Which observations show whether the hardware acquired the samples continuously during the pause? Would the queue occupancy and backlog clearance follow a deterministic calculation when arrival and service rates are measured? In a multi-receiver system, could the same host scheduling interruption cause simultaneous delayed detections that an operator mistakes for a simultaneous change in the external radio field? What evidence distinguishes the time of reception from the time a block became visible to the software?

Grace Murray Hopper, Response: Professor Wiener, define two time axes from the outset. Device-time metadata describes acquisition according to the device's clock model. Host arrival time describes completion of a transport and scheduling path. Their difference is a latency observation containing device buffering, transport and scheduling effects. Correlation between the axes may help characterise a pipeline, but an irregular host-arrival process does not alone establish an irregular sampling process. Packet identifiers and device timestamps can reveal that a burst arrived late yet retained the original order; when packets are reordered, sequence numbers allow their acquisition order to be reconstructed, assuming the identifiers are trustworthy and wraparound is handled. If sequence information is missing, do not claim more continuity than the data prove.

A packet-arrival histogram is especially vulnerable to interpretation when the host changes its scheduling priority. Its peaks can reflect operating-system timer granularity, interrupt moderation or coalesced network delivery rather than any modulation of the captured RF signal. The correct exercise is to preserve paired device and host timestamps for each block and examine the distribution of their differences under deliberately

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changed host load. A queue whose mean latency is modest can still produce a rare extreme delay, and a short recording cannot establish the tail probability with confidence. Report measured maxima, observation duration and the untested operating envelope. These details matter because evidential burst timing may depend upon exactly such rare events.

The first task is to inspect original device sample indices rather than host arrival timestamps. If blocks arrive late but their hardware-origin indices form an uninterrupted sequence and the physical clock remains calibrated, the RF observations can be restored to their original order by replay. Simultaneously measure the queue's occupancy and each service interval. For a simple fixed-rate model, a stopped consumer accumulates data at the source rate until service resumes; the backlog then clears only to the extent that downstream service exceeds ongoing production. The computation must include protocol overhead and concurrent traffic. Two receiver displays that freeze together because one host scheduler paused are not independent witnesses of an environmental event. The system should preserve source-level counters, USB or network transport status, queue high-water marks and file-segment boundaries so a reviewer can locate precisely the layer at which data were delayed or lost. A recovery that merely updates the screen is not proof of continuous acquisition.

Dr. James M. Atkinson, Moderator: Dr. Mills, where do network-time corrections enter this evidential distinction?

David L. Mills, Peer Question: Dr. Hopper, some acquisition systems map hardware sample counters to a host clock that can be slewed or stepped by a network time service. A jump in the displayed event time might then originate in timestamp conversion rather than in the ADC, while a

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monotonic display might conceal a physical discontinuity. Which clock records and transition logs should be retained, and how should a report handle an interval in which the host's time estimate was disciplined but not independently verified?

A clock service can revise the mapping from a monotonic local counter to civil time while the device continues to sample. How should an examiner preserve the original uncorrected event chronology when a time-server adjustment, holdover mode or reassociation occurs during a capture? Would you retain every version of the time transformation and identify the interval for which source-clock phase continuity is uncertain? If a later correction improves UTC alignment, what can it legitimately repair, and what information about missed samples or a phase discontinuity remains permanently unavailable?

Grace Murray Hopper, Response: Dr. Mills, retain both the uncorrected sample chronology and the applied mapping to external time. In particular, record raw device counters and time tags, host monotonic timing, wall-clock adjustments, synchronisation state, clock offset estimates and the versioned conversion algorithm. A host clock step can change event labels without changing the recorded sample sequence. A slew changes the conversion rate over time. Where a disciplined source is unavailable or its uncertainty unquantified, express the external-time result as conditional on the adopted mapping rather than retroactively pretending that a smooth corrected timestamp was an original hardware observation. A second independent timing witness improves the case but must have a genuinely independent clock path.

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A modern time correction should leave the prior acquisition record intact. The software can compute an improved UTC estimate for every sample index, but it must preserve the original device timestamp and the mapping then in force. If the host clock stepped or slewed during capture, mark the mapping interval and identify the controller state which authorised the change. It is unsafe to repair historical timestamps silently because an adversarial reviewer must be able to reproduce both the original and corrected findings. Where the clock was in holdover, state how its uncertainty grows with time and whether an independent reference independently checked the predicted drift. Precision in a formatted timestamp is not evidence that these assumptions were satisfied.

Retain the original device counters, raw capture time tags and the exact software conversion used when each event was first stored. If a time service subsequently corrects the host clock, append the revised transformation as a new version with its effective epoch and uncertainty, never overwrite the original ledger. A corrected UTC estimate may improve alignment of already observed events with external records, provided the clock relationship was measured adequately. It cannot recreate a missed RF observation or prove that a receiver synthesiser maintained phase continuity across a reference interruption. A visible lock indication is often based on a local control criterion rather than the continuity of every downstream sample edge. Test these cases separately using a known pulse and independent reference witness under deliberately controlled service interruptions. Where the index-to-time mapping cannot be reconstructed uniquely, retain a qualified interval and disclose the ambiguity rather than smooth the entire record to fit one preferred chronology.

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Dr. James M. Atkinson, Moderator: Professor Kelvin, what does a missing segment do to a timing uncertainty budget?

William Thomson, Baron Kelvin, Peer Question: Dr. Hopper, a report might quote microsecond precision for a burst that falls close to an acquisition gap, even though the gap's boundary is only partially documented. How should a metrologist distinguish uncertainty in an observed timestamp from ignorance of an unobserved event, and when is a numerical standard deviation inappropriate? Would a longer record with excellent average clock stability cure an unmeasured gap in the middle of the relevant event?

A report may display timestamps to microsecond resolution beside a discontinuity whose physical duration and cause have not been measured. What uncertainty budget would distinguish oscillator fractional-frequency error, trigger latency, filter group delay, source-to-receiver path delay and the unknown start or end of an acquisition gap? Is it defensible to average a missing observation into a small standard error derived from quiet intervals? Please explain how an uncertainty bound should change if a known calibration pulse falls just before the gap, compared with an event whose only claimed occurrence lies wholly within the unobserved interval.

Grace Murray Hopper, Response: Lord Kelvin, a recorded event with a timestamp has a measurement uncertainty whose components may include clock mapping, detection delay, resolution and trigger threshold. An event not observed because the measurement chain was blind is different. Its occurrence time is unknown within a coverage gap and perhaps not identifiable at all; assigning the same narrow standard deviation used for neighbouring measured events would misrepresent the evidence. A useful report can give a bounded observation interval, specify the exact known

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coverage windows, and distinguish the absence of a reported detection from evidence that no transmission occurred. Long-run clock stability does not retrospectively supply RF samples that the instrument never collected.

An unresolved missing interval also constrains negative findings. An investigator cannot declare that an emission did not occur during a period for which the receiver collected no trustworthy samples. A narrow timestamp uncertainty computed from surrounding samples does not measure ignorance of the missing event. One may instead report the verified observation windows and, where possible, upper bounds on the undetected-event duration which the equipment would have resolved within those windows. This distinction is decisive when a transient might have appeared and vanished during the blind interval. Keep uncertainty about the clock separate from uncertainty about whether a sample or an entire signal was ever observed.

Every uncertainty term must correspond to a defined observable. For an event that was actually sampled, the timing estimate can include oscillator-rate uncertainty accumulated over the relevant interval, calibrated trigger bias, filter group delay and transport-to-timebase correction. A stable systematic path delay is not reduced by repeated measurements; it needs correction or a bounded allowance. If the event lies entirely within an omitted sample range, no observed event time exists to which one may attach a small standard error. At most the available records can constrain a time interval within which an event might have occurred, and even that interval depends on the continuity and calibration of the bounding clock. An independently timed pulse before the gap may help establish the pre-gap mapping, but does not ensure continuity across an unlogged reference

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switch. A sound report separates what was directly measured, what was bounded, and what an inference model merely predicts.

Dr. James M. Atkinson, Moderator: Dr. Kálmán, may an estimator repair these missing observations?

Rudolf E. Kálmán, Peer Question: Dr. Hopper, modern processing may run a state estimator across sample gaps and output a smooth estimated trajectory. A visually persuasive record can therefore emerge even when the sensor supplied no measurements during an interval. What distinction should be drawn between a state prediction and a directly observed waveform, and how can the analyst reveal when the estimator becomes overconfident because its process model excludes an unexpected frequency jump or transient transmission?

A modern reconstruction algorithm can propagate a state estimate through an interval containing no measurements, and its resulting curve may be smooth and well behaved. Under what circumstances might the filter's reported uncertainty underestimate the true uncertainty because its process-noise model omits clock changes, packet loss or non-Gaussian interference? Can the analyst identify at every time whether a state was directly updated by observed samples or merely predicted from earlier data? How would the experiment reveal whether a persuasive reconstructed spectral line owes more to a model assumption than to actual retained RF evidence?

Grace Murray Hopper, Response: Professor Kálmán, the filter may propagate a state distribution through a gap, but it cannot transform a prediction into an observation. Mark each update as measurement-

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supported or prediction-only, preserve its covariance under the actual model and record the duration since the last reliable observation. An unexpected change in signal state during the gap is not recoverable without independent information. Sensitivity analysis should vary the assumed process disturbance and inspect whether the final classification changes. A narrow filtered trajectory obtained by setting unrealistically small process noise is an artefact of the estimator's prior assumption, not proof of uninterrupted reception.

A state estimator used across a gap should therefore retain a flag indicating prediction-only operation. Its covariance must include process uncertainty which normally grows as the time since the last direct observation increases. A filter that returns narrow confidence limits by assuming constant frequency and negligible process noise can appear precise even when an unseen frequency jump would invalidate the inference. Run a sensitivity test using credible alternative disturbance models and report whether the scientific conclusion changes. A phase-continuity claim should not be restored merely by smooth interpolation. Where the data support more than one plausible history, retain the alternatives rather than selecting the one that makes the graph most elegant.

A filter prediction is not a measurement. It is a conditional estimate based upon the prior state, the transition model and the assumed process-noise distribution. When a sample gap occurs, the software must mark that no measurement update was applied, preserve the actual interval boundaries and expand uncertainty in accordance with plausible unobserved disturbances. If the physical system may undergo an unmodelled clock phase step, the standard Gaussian process model may be inadequate; the

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estimate can remain smooth while becoming badly wrong. In validation, inject a known missing block while the external RF source continues a prearranged pattern and compare the predicted waveform with the withheld ground truth. Record whether the estimator's confidence bounds cover the actual result and whether it properly reports epistemic uncertainty. Export both original data and the derived reconstruction, clearly differentiated. No algorithmic continuity should be presented as direct evidence of a transmission in a period for which the receiver retained no samples.

Dr. James M. Atkinson, Moderator: Professor Hamming, what controls ensure that software has not silently omitted evidence?

Richard W. Hamming, Peer Question: Dr. Hopper, the process that stores samples may treat a transport warning as a recoverable exception and keep producing files, yet write no conspicuous marker that acquisition has failed. How should software assurance and a deliberately engineered fault-injection test expose this behaviour? What should be checked when the driver reports an overrun but the application file remains syntactically valid and apparently full length?

I wish to challenge a different form of confidence. Suppose the stored file length is exactly as expected and a cryptographic hash confirms that the file has not been altered since acquisition. Is there any basis for concluding that the ADC produced all expected samples, particularly if the driver might have duplicated a block before the hash was computed? Which independent invariants would detect upstream loss, duplicate ranges, counter rollover and concealed interpolation? How would you test the detector itself using

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deliberate faults rather than assume that a green status indicator is an integrity certificate?

Grace Murray Hopper, Response: Professor Hamming, a syntactically readable file is not an integrity certificate. Instrument the path so that every receive operation records status and sequence information, and make exceptional states persist into the evidential log. A challenge test should safely saturate the host or throttle an authorised test transport, then verify that an overflow or out-of-sequence condition is signalled and that the stored file identifies the corresponding interval. Compare sample counts against independent hardware counters and known injected markers. When a format lacks gap annotations, preserve a separate, cryptographically linked acquisition ledger. Also test the case where application software catches an error but fails to propagate its severity to the operator. The relevant question is whether the forensic user can discover a failure after the fact, not merely whether the program remained running.

A useful independent check compares the permanent acquisition ledger against a hardware-origin sequence during deliberate stress testing. If the driver is made to drop a block, the forensic report should identify the precise segment where continuity was lost; if the extent is unknown, the report should say so. A test must challenge a system which resumes recording automatically after an error, because the return to normal service can conceal a preceding gap. Hashing the final data establishes resistance to later alteration but cannot certify that data missing before storage were ever captured. Software assurance must demonstrate failure observability, not merely continued operation after a fault.

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A cryptographic hash proves consistency with the material that was hashed, not that the material faithfully represents the antenna event. If the driver duplicates data upstream, the resulting file may have the expected size and an impeccable digest. Construct independent checks: a hardware-origin counter assigned at acquisition, a deliberately varying calibration sequence, status records from the ADC or DMA engine, and a comparison between expected and actual sample-index ranges. Test boundary conditions, including counter wrap and partially written final blocks. Inject known faults at different layers so that one can see which integrity indicators respond and which remain silent. The provenance record should identify the firmware and driver version, configured format, all sample drop indications and any substituted or interpolated data. An unflagged reconstruction step must be treated as a defect in the evidence pipeline. A sound system is permitted to admit that its completeness is unknown.

Dr. James M. Atkinson, Moderator: Professor von Neumann, how should one design the storage and transport system so that the observation is not sacrificed to presentation?

John von Neumann, Peer Question: Dr. Hopper, real-time acquisition often competes with disk compression, waterfall rendering, signal classification and operator interaction. A computationally intensive interface can delay the processing of an otherwise steady RF stream. What architecture separates hard acquisition obligations from discretionary visualisation, and what quantitative resource margins and stress tests ought to precede any claim that the system records a given bandwidth without loss?

Consider an installation where capture, spectrum analysis, waterfall generation and disk writing share a processor and an operating-system

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scheduler. A blocking filesystem operation may be only a few milliseconds long, yet many sample streams continue arriving during the interval. What minimum buffering should have been reserved, and how could the team determine its usable capacity under competing load rather than rely on a brochure figure? If the buffer fills and a driver silently drops the oldest block, would a graceful-looking screen recovery establish that the underlying chronology survived? What architecture would preserve evidential capture as the highest-priority function?

Grace Murray Hopper, Response: Professor von Neumann, place bounded, measurable acquisition buffers and a minimal capture path ahead of discretionary analysis. Calculate the source byte rate from the actual complex-sample representation, channel count and metadata overhead. For example, eight channels at 2 million complex samples per second, with 16 bits for each in-phase and quadrature component, generate 8×2,000,000×4=64,000,000 bytes per second before packet, framing or filesystem overhead. The sustained write path must exceed the incoming rate with sufficient margin for bursts and housekeeping. Measure rather than assume that the operating system, storage medium and transport meet that requirement under worst credible load. Visualisation and classification should be rate-limited or decoupled so that failure to draw a waterfall does not force a loss of RF samples. Record actual queue high-water marks, measured throughput and overload events during qualification.

A comprehensive capacity test should include a simultaneous high-rate stream, intentional display workload, sustained disk output and a short adverse scheduling event. Record actual data throughput, queue high-water

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marks and drop counters before, during and after the event. If the capture survives, confirm this with a known marker sequence, not only its file length. If it fails, the output must mark an unambiguous boundary at which the stream ceased to be complete. Test each hardware format used in the field, since a change from eight-bit to sixteen-bit complex representation or the addition of channels may double or multiply the byte rate. The assurance statement must remain confined to the configurations actually challenged.

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The acquisition path should be sized and tested for the aggregate stream rate under worst-case permitted operation, with adequate allowance for storage stalls and transport overhead. At eighty megabytes per second, a quarter-second outage consumes roughly twenty megabytes of free buffer space before considering traffic already queued; with several receivers, the requirement scales accordingly. The actual safe capacity is the free space available at the moment of interruption, not the nominal array allocation printed in a manual. Decouple capture from optional waterfall drawing and classification; keep a minimal, measurable write path, preserve device-origin indices and make every overrun conspicuous. A display can recover visually after the queue drops data, so screen smoothness is no guarantee. Conduct repeatable stress tests with an externally known RF pattern, and stop or segment acquisition with explicit gaps when the hardware cannot meet its declared completeness requirement. No subsequent viewer should be allowed to mistake buffered presentation for direct sample chronology.

Dr. James M. Atkinson, Moderator: The principal token now passes to Professor von Neumann to assess whether storage architecture can preserve chronology; Dr. Hamming will test the resulting claim.

John von Neumann, Second Principal Contributor: Dr. Atkinson, it is a conceptual error to identify the schedule of receiving packets with the schedule of sampling the electromagnetic field. A device produces observations under a hardware-clock regime; an interface transfers blocks under a transport schedule; software processes them under a third. A backlog may be innocent if a bounded queue retains all correctly indexed samples, but a full queue can transform delay into an unrecoverable omission. I would calculate the stream rate, independently measure worst-

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case sustained storage throughput and retain high-water buffer measurements and drop counters. A reference pulse repeated at known intervals supplies a physical check on index continuity. The critical qualification is that software-generated sequence identifiers might advance only after a packet is delivered; they cannot prove whether the device discarded data upstream. I invite Dr. Hamming to specify the requisite failure-testing logic.

A useful architecture distinguishes the antenna observation, the hardware conversion, the transport mechanism and the host's presentation. The analogue-to-digital converter produces samples according to a physical clock. The device's counter describes the order of those samples, provided the counter is attached to acquisition rather than packet dispatch. A bus interface subsequently transports blocks with variable service times, and a host may delay processing them while remaining able to preserve their original sequence. Treating those four stages as one undifferentiated 'real-time receiver' conceals which of them can create a false temporal gap. The original evidence should identify sample indices at capture and the timebase by which those indices are converted into seconds. A host file-creation time cannot retroactively define the instantaneous arrival of a radio pulse at the antenna.

Consider a receiver acquiring complex samples with each in-phase and quadrature component represented by sixteen bits. At twenty million complex samples per second, the nominal payload rate is 20,000,000 times 2 components times 2 bytes, which is 80,000,000 bytes per second, approximately 80 MB/s in decimal units. The corresponding bit rate is 640 Mbit/s before transport framing, metadata and any additional copies. If

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twelve such channels run continuously, the nominal aggregate is 960 MB/s and the host must sustain that rate as well as its associated interrupt, buffering and disk workloads. If the storage subsystem offers only 750 MB/s of actual sustained service under the configured file format, the deficit is 210 MB/s. A 4.2 GB free buffer then fills in roughly twenty seconds if those rates remain constant. This is a hypothetical capacity calculation, not an assertion about a particular instrument or computer. It shows why a good-looking sample-rate specification alone is not an acquisition guarantee.

I should define the actual units before an engineer compares the numbers. A megabyte in this example contains one million bytes; a mebibyte contains 1,048,576 bytes. Any buffer calculation must account for whether the device transmits packed twelve-bit data, padded sixteen-bit words, or a different sample representation. Some transport links add packet headers, parity or retry traffic. An application may allocate a nominal queue whose usable capacity is reduced by bookkeeping and memory pressure. Report the measured payload throughput, actual free buffer bytes, long-run disk performance and maximum plausible stalls. A bench test of a pristine new disk does not show the throughput of a nearly full drive under thermal throttling or competing analysis tasks.

The transport path must preserve identity, not merely a count of blocks. Suppose a device labels each original sample with a monotonically increasing hardware index. Block A covers samples 100,000 through 103,999 and block C begins at 108,000. The absence of indices 104,000 through 107,999 establishes that the delivered stream omitted 4,000 expected sample positions, assuming index assignment occurred at acquisition and the counter did not itself jump. Without such a counter, a host that receives

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two consecutive packet numbers proves only that no packet number was missing within the host-side numbering system. An upstream overrun could already have erased an interval before the first packet was constructed. By contrast, a delayed block with correct sample indices does not constitute missing acquisition merely because the wall-clock interval between its arrival and its neighbour was unusually long.

A duplicated block creates a different deceptive symptom. If the software appends the same 4,000 complex samples twice and then numbers the duplicated copy as fresh data, the file has the expected length and can even look spectrally continuous for a narrow steady carrier. It is false continuity. A preserved device-origin sequence or independently injected nonrepeating test pattern can detect the duplication. The test pattern should be generated externally from the receiver system and time tagged independently, with enough variation to expose a repeated or omitted segment. A pure sinusoid by itself is inadequate because successive windows can resemble each other after an integer number of cycles. The validation apparatus must therefore be chosen to discriminate the defects actually under test.

One should establish a hierarchy of duties when load becomes intolerable. The minimal acquisition path stores original samples, device status, capture counters and integrity metadata first. Optional waterfall rendering, classification, compression, printout and operator interaction are consumers of that record rather than prerequisites for its existence. If the system cannot sustain the source rate indefinitely, it must report the limit and execute a controlled stopping or segmentation policy with explicit gaps, instead of continuing to produce reassuring traces. Queue lengths and high-

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water marks should be logged at the physical interface, driver, application and storage stages, with independent timestamps where possible. Merely recording a mean CPU utilisation obscures a short scheduler pause that might exhaust a finite buffer.

A final qualification concerns simultaneous receivers. Twelve independent streams can become dependent through one overloaded USB controller, storage pool, clock mapping or host scheduler. Their apparent shared loss of a spectral event might therefore be an acquisition failure, not evidence that the source stopped transmitting. Run a stress test in which the input generator continues a known, independently timed pattern while processor load, disk latency and transport contention are varied within safe limits. Determine whether the first observed defect occurs in hardware capture counters, interface packet sequence, application queue or written file. The answer specifies where evidence was lost and whether any downstream reconstruction is legitimate. I pass the principal token to Dr. Hamming because an architecture may be well designed on paper yet still conceal implementation faults.

Richard W. Hamming, Cross-Peer Question to John von Neumann: Professor von Neumann, suppose a file contains the expected number of bytes and its host-side timestamps advance monotonically, yet the acquisition driver silently discarded a block and duplicated a later block to maintain a constant file length. The output appears well formed. Which independent invariants would distinguish this from genuine uninterrupted acquisition? How should the test treat a host display that reconstructs missing spectral tiles by interpolation, especially when the only readily visible symptom of the original fault was a momentary backlog?

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Suppose a heavily loaded host stores the expected number of bytes, but a driver error duplicates one block after a genuine overrun so that the aggregate length remains unchanged. Which original acquisition counter or external stimulus would reveal that a segment was replaced? I also want to know whether the proposed bounded buffer design guarantees evidential completeness when a disk is intermittently unresponsive. How do we derive the necessary reserve from source rate and worst-case service interruption, then demonstrate in a stress test that those assumptions hold? If the hardware does not expose a trustworthy capture counter, what limitation must appear in the final interpretation of a short RF event?

John von Neumann, Cross-Peer Answer to Richard W. Hamming: Dr. Hamming, a byte count measures file length, not sample provenance. The driver should preserve hardware-derived sample counters or equivalent device timestamp observations and log every overrun, reorder and restart. A seeded laboratory stream with a known non-repeating timing pattern exposes duplication that constant-frequency energy alone may not. Independently capture the injected markers and compare their decoded chronology with the final file, including continuity at all buffer boundaries. Mark inferred or interpolated material so that it cannot be mistaken for observed samples. If the instrument lacks suitable hardware provenance, the report must narrow the claim: the stored file is internally consistent, but source acquisition continuity was not independently proven.

The byte count is the least satisfactory completeness witness precisely because a duplicate block can compensate for a missing one. We require an index recorded by the acquisition hardware before any transport or buffering failure can intervene. If blocks have authenticated first-sample

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indices and valid lengths, their concatenation can be checked for overlap, gaps and correct rollover. If the device exposes no such counter, supplement testing with an externally generated time-varying calibration pattern, but do not pretend that this supplies perfect retrospective certainty for arbitrary field captures. Calculate the reserve required for a worst-case stall using buffer headroom B, source rate R_s and during-stall service rate R_d. The simple bound $B \geq (R_s - R_d)T$ applies for a stall of duration T when R_s exceeds R_d, provided the initial occupancy and all other ingress are accounted for. If the actual free headroom is smaller, overflow is expected under the model.

The proof obligation extends beyond arithmetic. Establish source rates in the actual packed format, measure service performance under fragmentation, thermal load and concurrent operations, and deliberately create stalls near the expected limit. Verify the device counters before and after each test and record which subsystem declared overflow. Where a queue fills despite design margins, it is the system's defined behaviour that matters: explicit segmentation, alarm and preservation of unaffected intervals are acceptable; silent substitution is not. A stable displayed rate or a perfect file hash cannot rescue a span never captured. When there is no trustworthy hardware index, state the limits of any inference about millisecond-scale absence of signal. That qualification is more scientifically useful than a reassuring nominal sample count.

Grace Murray Hopper, Response to Professor von Neumann and Dr. Hamming: Their challenge makes the difference between software correctness and evidential completeness explicit. I would preserve errors as first-class data, not merely console messages. Host-scheduling delays need

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not be RF gaps, but a silent omission cannot be erased from the chain of custody by keeping the user interface alive.

Dr. James M. Atkinson, Moderator: Dr. Hamming, the acquisition ledger must be more than a well-formed file. Please address how a deliberate continuity fault should be exposed, with Dr. Hopper invited to question the policy for resuming capture.

Richard W. Hamming, Third Principal Contributor: A data file is not an evidential record merely because it has a valid header and an expected byte count. The acquisition system must be challenged with a known pattern that exposes dropped, reordered or duplicated content. The test should exercise the driver, transport and storage under deliberately stressed conditions while preserving original exception records. A waterfall display may interpolate a dropped block and look continuous, whereas a hardware-linked counter or embedded marker shows a gap. I would require tests proving that every exceptional acquisition state becomes an indelible entry in the investigative ledger.

It is not sufficient to declare an integrity check; one must define precisely what property it proves. A checksum calculated over a completed file can detect later alteration of that file but cannot establish that the contents were correctly sampled. A perfect cryptographic digest of a corrupted acquisition is still a perfect digest of the corruption. The software therefore requires invariants attached to the acquisition process itself. At a minimum, a genuine sample-origin counter must advance as specified, every block must declare its first index and valid length, and no index range may be silently duplicated, skipped or reordered. If a device lacks such counters, that

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limitation must appear in the evidential qualification rather than be repaired with plausible host-generated labels.

The state machine should treat counter rollover, reference reacquisition, dropped transport blocks and late-arriving valid blocks as distinct events. Rollover can be predictable modulo a documented counter width. A missing range is not predictable merely because the next received block happened to contain the expected number of bytes. Reference reacquisition may cause a phase discontinuity while every sample index remains present. A host backlog may produce irregular packet delivery while both sample order and physical sample times remain valid. If all these conditions are represented by a single 'stream interruption' bit, a later reader will be unable to determine whether a suspected RF signal genuinely vanished or the machine simply failed to observe it. An event log must therefore retain causal granularity.

A deliberate fault-injection campaign reveals whether those distinctions are implemented. Insert a software-instrumented packet drop after acquisition and determine whether the file records the missing original indices. Insert a duplicate packet and check that the recipient rejects or explicitly qualifies the repeated range. Impose a storage stall long enough to fill the declared application queue, then measure which layer first reports overrun. Restore a clock source after a safe laboratory outage and check for an explicit timing-epoch change. Each intervention has a known truth table: whether physical samples existed, whether they were transferred, whether they were stored and whether their timebase remained calibrated. The recorded output should be compared against that truth table before a production system is trusted.

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A powerful test stimulus is one which cannot be mistaken for a stationary period. For example, modulate a laboratory carrier with a long pseudorandom binary sequence whose origin, chip rate and epoch are independently known. Correlate the stored complex samples against the expected sequence, allowing for the characterised receiver transfer function. A duplicated block often produces an anomalous repeat in the recovered code phase; a dropped block produces a discontinuity; sample-rate error appears as progressive drift of correlation delay. Such a test requires a sufficiently long sequence to avoid accidental ambiguity and must use a separate source clock if it is intended as an independent witness. It is a system qualification experiment, not a reconstruction of missing field evidence.

One should also test the detector's presentation layer. A waterfall often displays short-time Fourier transform tiles rather than unmodified samples. It may hold the preceding tile during a processing pause, interpolate missing tiles or update the screen from a ring buffer that drops the oldest entry. These choices can be acceptable for operator situational awareness if clearly labelled, but they must not be confused with the underlying evidential capture. I would generate a visible fault marker across test tiles and require a reviewer to identify it from the exported plot and raw data independently. If the screen appears normal while the file reports a gap, the display is not a sufficient evidence record. The discrepancy must be reflected in the software's status indication.

Finally, automated checkers must themselves be verified. A quality-control function which scans only the metadata supplied by a potentially defective driver cannot independently prove the driver correct. Exercise boundary

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conditions such as first block, last block, counter wrap and simultaneous queue overflow. Preserve fault-injection logs in a protected test register, and re-run acceptance tests after firmware or driver revisions. For live operation, a monitor may be able to announce that sample completeness is unknown rather than categorically lost; that state is useful and should not be suppressed. A conscientious system sometimes produces an inconclusive finding because the instrumentation lacks an independent witness. That is a success of quality assurance, not a failure to produce a confident display.

The chain of custody must link each acquired segment to its source device, configuration, timebase epoch and immutable original file, with subsequent transformations recorded as separate products. In a retrospective analysis, the researcher should be able to replay the segmentation and recover the same detector outputs from the same samples. Where a small observed pulse lies adjacent to a missing range, an estimator cannot supply a fact about the unobserved pulse. I would allow a model-based prediction clearly labelled as prediction, with conditional uncertainty, but reject any software which joins the waveform across the gap and presents the result as if it had been measured. I pass the token to Professor Wiener for the mathematical distinction between delay and loss.

Grace Murray Hopper, Cross-Peer Question to Richard W. Hamming: Should an application still be permitted to continue logging after an overrun, or would that make subsequent observations intrinsically unreliable?

I also wish to know whether the proposed fault record is intrinsically generated by the acquisition device or is inferred from a software counter

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that could itself have been reset or renumbered. That difference bears directly upon the strength of any assertion that the record is complete.

Would you permit a receiver to continue operating after it has detected one upstream sample overrun, or should the complete evidential session be rejected? In particular, I should like a rule for delimiting verified intervals before and after a loss without allowing the software to interpolate an unobserved segment. How would you represent the discontinuity in a file format, and which tests would prove that later processing did not quietly close the gap? If a post-processed waterfall hides missing tiles, what status or provenance data would oblige a reviewer to see the altered presentation? Please distinguish a recoverable continued operation from an impermissible claim of unbroken acquisition.

Richard W. Hamming, Cross-Peer Answer to Grace Murray Hopper: Continuation is legitimate if the application makes the state boundary conspicuous and can determine which samples remain trustworthy. It must mark missing ranges and preserve all surviving original data. A hard stop may be appropriate where the mission requires an uninterrupted phase record, but it should not be imposed blindly for every exploratory signal search. The important issue is a truthful representation of measurement coverage rather than the appearance of uninterrupted operation. A defensible application should also expose the operational decision that follows an error: whether it quarantines a suspect interval, invalidates a continuity-dependent measurement, or retains the unaffected portions with a limitation. The logger ought to commit the error record before any recovery action that changes ring-buffer offsets, preventing the subsequent

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recovery state from overwriting evidence of the original fault. This is a testable software property, not a matter of operator preference.

Continued operation is permissible if the software maintains a transparent boundary between verified and unverified intervals. After a reported overrun, record the last known good device index, the first subsequent trustworthy index and the status of the physical sampling clock at recovery. The gap should remain explicit in the data representation and in every derivative display. A downstream file can contain distinct segments with provenance records describing their original sample-index ranges, rather than conceal the omission by inserting zeros or interpolated estimates into a single apparently uniform sequence. If an analyst wants to construct a model-based estimate of the missing interval, that is a separate derived product with a clearly marked uncertainty and its own transformation record. The original absence must remain visible.

The quality gate should include deliberate faults after every firmware, driver or processing change. Remove a block, duplicate a block, reorder two packets and force a counter wrap. Then verify that the integrity indicators detect the intended fault without falsely classifying a benign delivery delay as missing acquisition. Reprocess the captured record through the waterfall and event-classification pipeline to see whether the derivative products retain the gap marker. If the only accessible evidence consists of host-side sequence labels created after a transport failure, the completeness of earlier stages may remain unverified. A responsible system can preserve post-fault observations as a new segment, provided the transition and all unexamined intervals are disclosed. Evidence is not invalidated simply by a known boundary; it is invalidated when that boundary is hidden.

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Dr. James M. Atkinson, Moderator: Professor Wiener, may I pass you the question of whether packet latency has any necessary relationship to RF sample chronology? Professor von Neumann will explore the queue-capacity premise.

Norbert Wiener, Fourth Principal Contributor: Queueing changes the distribution of packet arrival times, not necessarily the distribution of sampling instants. A delayed batch can have highly irregular host timestamps while carrying a perfectly ordered acquisition sequence. Yet an overloaded queue can also become a loss mechanism, so latency and continuity must be measured separately. I would compare device-side counter increments with host reception intervals under several controlled service loads, and estimate the transition from harmless backlog to irreversible dropped data. Statistical smoothing of arrival times is not evidence that the missing samples survived.

Transport delay and missing observation are different random variables. Let $A(t)$ denote the cumulative quantity of valid samples delivered to a queue by time t, and let $S(t)$ denote the cumulative samples served or written. The queue occupancy is $Q(t)=Q(0)+A(t)-S(t)$ while it remains within available capacity and while losses are separately recorded. The physical acquisition process may be continuing at a uniform sample rate even when the service process pauses or arrives in bursts. The queue can grow during an interruption without any sample being lost, provided sufficient storage remains and the device can continue delivering data under the chosen backpressure behaviour. Loss occurs if a finite buffer is exceeded or if the device or transport discards data for another reason. A host pause observed on a monitor cannot alone tell which case occurred.

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A simple deterministic bound helps. Suppose an SDR produces 80 MB/s of data and the effective storage service halts entirely for 0.25 seconds. At least 20 MB of additional buffering is required to absorb that pause, aside from already queued bytes and transport overhead. A buffer with 64 MB free capacity can survive this pause under those assumptions. If the service afterwards resumes at exactly 80 MB/s, however, no backlog is drained; the queue remains twenty megabytes fuller. To return to its original occupancy, the service rate must temporarily exceed the acquisition rate. If it can sustain 120 MB/s, the excess drainage is 40 MB/s and the twenty-megabyte backlog requires another half-second to clear, assuming no other bottleneck intervenes. These figures are hypothetical and should be compared with actual measured capacities.

In probabilistic operation, mean service rate is insufficient. A disk may average 100 MB/s while occasionally pausing for several hundred milliseconds; a bus may retry packets in clusters; an operating system may suspend a process under memory pressure. Queue stability over long periods is influenced by the average offered load, but the probability of short buffer overflow depends on the distribution and dependence of arrivals and service interruptions. Where events are strongly bursty, averages can be reassuring yet dangerously unrepresentative. Record service-time histograms, tail delays and buffer high-water marks, then challenge the system with reproductions of the longest expected stalls. A modest average occupancy does not preclude a rare capacity failure at the instant of the signal of interest.

The relation known as Little's law, $L=\lambda W$, connects long-run mean number of items in a stable system, the mean arrival rate λ and mean time W spent in

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the system, under its conditions. It does not say that every packet has a delay of L/λ or that a finite queue can survive an arbitrary pause. Nor does it establish physical acquisition time. A block can be received half a second after the samples were taken while preserving an accurately indexed device chronology. It is precisely because queue residence time can change independently of antenna events that the host arrival timestamp must not be substituted for the capture timestamp. The two time coordinates should be stored and compared as distinct measurements.

If the host shows a burst of delayed detections, the analyst should reconstruct the causal sequence. First compare the hardware sample indices corresponding to each RF feature. Next examine transport receive times and queue occupancy during the event. Then compare the file write order and the displayed event time. If the indices remain continuous and an independently captured known pulse retains its proper temporal separation, the delayed display is plausibly a processing backlog. If an index range is absent, the hypothesis of mere delay is inadequate. If the indices are present but timing calibration changes, the system may have preserved observations while losing a valid relationship between indices and physical seconds. No single measure, whether throughput or lock status, resolves all three.

An overloaded receiver may also generate misleading correlation between channels. If several instrument streams share one host queue, a common scheduling pause can create simultaneous gaps in their host arrival histories. Their real sample histories might remain continuous, or a bottleneck may drop blocks from all of them. The observation that channel A and channel B ceased updating at the same moment is therefore not

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independent evidence of a radio source switching off. An independent monitoring path should log device-status counters directly and, where practicable, record a calibration waveform through a separate acquisition architecture. These controls distinguish the temporal structure of the environment from the temporal structure of the machine.

I would conclude the queue analysis with a falsifiable prediction. If the event was caused only by delayed buffering, the eventually stored original samples should retain their expected count and ordering, and a replay should reconstruct the correct chronology from acquisition counters. If the event was an irrecoverable overrun, a gap, flagged discontinuity or inconsistency should remain when the saved stream is checked against an independent known pattern. If the event was sample-clock drift, the relation between hardware indices and external time should vary systematically even with no missing indices. These cases can coexist, so the classification procedure must permit more than one cause. I pass the token to Professor Essen to explain what the time measurement can and cannot independently establish.

John von Neumann, Cross-Peer Question to Norbert Wiener: If a queue normally holds half a second of samples, what must be measured before one claims that a two-hundred-millisecond host pause cannot result in loss?

You model arrival and service rates, yet the operator has recorded only a mean queue occupancy and a mean storage throughput. Both numbers look acceptable, although an occasional storage stall may be sufficiently long to cause overflow. How would you characterise the tail of service delay and the queue high-water marks in a manner relevant to a finite buffer?

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Suppose a burst of packets is received after the host has been paused, and all original sample indices remain present. What evidence establishes that a delayed presentation should not be described as a radio burst arriving late? Would your classification change if the device index map itself were derived from host packet dispatch instead of ADC acquisition?

Norbert Wiener, Cross-Peer Answer to John von Neumann: The average occupancy is insufficient. Identify the actual buffer capacity, peak arrival rate, downstream service capacity and competing memory allocations. A transient pause may be harmless if enough unused capacity exists, but prior backlog and simultaneous bursts can change the result. Device-side overrun and sequence records should be retained. Test credible worst cases under the real sample format and number of channels rather than extrapolate from a single unloaded throughput benchmark.

Average occupancy and service throughput do not characterise the largest excursion of a finite queue. The relevant data include the arrival process, the distribution of service interruptions, high-water marks and the free capacity at the moment each interruption begins. For a deterministic test, a source at R_s bytes per second with zero service for T seconds adds R_sT bytes to the queue. A storage subsystem with a higher long-run service rate can nevertheless overflow if a single pause consumes more free capacity than remains. I would therefore test a family of controlled stalls while the receiver records an independently known input pattern and compare the observed queue history with the predicted bounds. When the actual process is stochastic, estimate tail probabilities with properly documented confidence and remain alert to correlations between source bursts and service slowdowns.

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A delayed cluster of packets is not proof that the radio signal arrived in a cluster. If acquisition-origin indices are continuous and the relevant clock maintained calibration, reconstruct the signal chronology from those indices rather than from packet delivery times. A one-second host backlog may contain a perfectly regular one-second RF record. If the apparent device index was allocated only when a packet entered the host, however, a lost upstream sample block could be invisible to that index; the premise of completeness would be untested. The distinction lies in where each counter was created and which failure path can alter it. I therefore recommend a trace that includes device counters, interface status, queue occupancy, file timestamps and the provenance of every conversion. Only then may the analyst decide whether the irregularity was in the electromagnetic environment or in the transport architecture.

Dr. James M. Atkinson, Moderator: Professor Essen, please add the independent metrological perspective missing from software-ledger checks. Dr. Hamming will then question whether an apparently continuous test tone is an adequate witness.

Louis Essen, Fifth Principal Contributor: An independent timing reference contributes something that internal software checks cannot: evidence of elapsed physical time. A hardware counter may remain continuous while its oscillator drifts, so its chronology must be compared with a stable external marker. Likewise, an externally accurate host time service does not imply the acquisition hardware used that same clock. A robust verification separates sample count, sampling interval and transport delay. I would retain both the calibration events and the reference uncertainty at the times of interest.

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The fundamental metrological distinction is between the presence of an observation and the time assigned to it. An uninterrupted sequence of complex samples proves no more about calibrated elapsed time than an evenly spaced set of pencil marks proves about the accuracy of a ruler. A sampling oscillator has a nominal frequency and an actual evolving frequency. If the actual rate differs from the nominal rate, an assignment $t_n=n/f_{nom}$ acquires error even when every sample index n is present. Conversely, a perfect source clock cannot recover an observation which was lost in transit or never captured. These defects must be measured independently and must not be conflated merely because all produce disturbances in a waterfall representation.

Let the nominal complex-sample frequency be f_0 in samples per second, and let the actual rate be $f=f_0(1+\varepsilon)$, with ε a small dimensionless fractional error over a bounded observation interval. After N samples, the nominal elapsed time is $T_{nom}=N/f_0$, whereas the actual time is $T_{actual}=N/[f_0(1+\varepsilon)]$. Their difference is approximately $-\varepsilon T_{nom}$ for $|\varepsilon|$ much less than one. If f_0 is 10,000,000 samples per second, ε is +2 parts per million, and the nominal acquisition interval is 100 seconds, the physical interval is approximately 99.999800 seconds. The nominal mapping is in error by about 200 microseconds. Every sample can be present, yet a cross-station timing inference using the nominal clock would be wrong. The figures are illustrative and assume constant ε for the calculation.

A missing block differs in its signature. Suppose the true hardware acquisition index advances by 10,000 positions beyond the last stored record before capture resumes. At ten million nominal samples per second, that nominal gap represents one millisecond of unrecorded sample

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positions. The time equivalent should be corrected for the actual rate and any clock-state transition. The investigator cannot claim that a one-millisecond radio signal was silent, because the observation of that interval is absent. By comparison, if a block is merely delayed in transport and later stored with contiguous original indices, there is no missing sample interval even though the operator may have seen a one-millisecond pause or a much longer screen freeze. The external time standard helps label the interval but cannot substitute for the original index ledger.

A known frequency tone offers a useful check of sampling-rate error. If an independently characterised RF signal of frequency f_t is sampled at actual rate f but interpreted using f_0, its apparent spectral frequency may be shifted in proportion to f_0/f, subject to the receiver's conversion frequency and filtering convention. This method must be used carefully: if the tone and receiver share the same reference, both may drift together and the apparent error may cancel, defeating the supposed independent check. The reference tone should therefore be derived from a source whose stability and provenance are independently established. Cross-check against hardware time markers or a phase comparator rather than relying upon one ambiguous spectral feature.

Frequency stability statistics describe particular scales of averaging, not an assurance that all intervals are continuous. Allan deviation can characterise fractional-frequency fluctuations over chosen averaging times but does not detect every missing packet or guarantee that a phase record was uninterrupted across an unlogged switch. A synthesiser can recover nominal lock while introducing a phase step. A clock algorithm can slew timestamps without changing the physical sampling sequence. Thus a complete audit

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preserves instantaneous counter events, oscillator-control states, local phase comparisons, and all versions of the map to the external time scale. A one-hour Allan deviation number should not be substituted for a test of a five-millisecond event.

Hardware calibration must encompass the relevant path. A one-pulse-per-second timing marker at the source may arrive at a receiver after cable and logic delay; a fixed delay can create an accurate-looking but biased timestamp. Record source-plane and receiver-plane observations with common and independent witnesses, identify the trigger threshold and any signal-dependent detection latency, and repeat calibration with representative temperature and load conditions. The uncertainty statement should distinguish repeatable systematic path delay, random phase variation and unknown state transitions. In forensic use, precision of a printed timestamp cannot exceed the physical evidence of the timing chain. It is better to state a bounded interval than to manufacture a precise instant which the apparatus did not observe.

The closing experiment should combine a long independently timed pseudo-random calibration sequence with occasional deliberate safe acquisition-load changes and a separately documented reference-frequency perturbation. When load changes but the sample index-to-time mapping remains calibrated, a delayed display without missing indices indicates buffering. When an overrun is injected, the hardware index record should identify the missing range; when a small clock offset is imposed, the phase or delay of the known sequence should drift predictably while the indices remain contiguous. An instrument which can distinguish these three laboratory truth conditions has earned greater confidence than one which

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simply produces smooth spectra. I return the token to the moderator with the recommendation that every finding identify its observation plane, chronology, calibration and limits.

Richard W. Hamming, Cross-Peer Question to Louis Essen: Could a continuous test tone alone prove that no samples were duplicated or omitted, particularly if duplicated blocks happen to preserve similar amplitude and frequency? I would also ask how one could design a deterministic challenge sequence that exposes repetition after a buffer wrap, distinguishes a duplicated packet from an oscillator-frequency excursion, and retains an independent chronology when the receiver and the challenge source otherwise share timing infrastructure. The answer needs to address identifiability, not merely signal visibility.

A laboratory check uses an apparently pure calibration tone and a nominally accurate oscillator. If a block is lost but the tone is periodic, the reconstructed complex signal may appear coherent across the missing interval. Could such a test falsely certify completeness, and what nonrepeating or independently timed waveform would be a better challenge? Would you require a downstream hardware time witness in addition to phase comparison at the external reference connector? Finally, how should the final metrological statement distinguish source-frequency accuracy from phase continuity and from the completeness of the stored acquisition, each of which appears to the operator as part of the same 'synchronised' receiver?

Louis Essen, Cross-Peer Answer to Richard W. Hamming: A pure tone may be too repetitive to expose every omission. Use a time-varying known test

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pattern, pulse sequence or suitable phase-coded stimulus and compare the original record with the independent reference. The challenge must exercise the same file path, buffer limits and processing used in field acquisition. The resulting conclusion should be bounded to the fault classes the known pattern can reveal. The sequence generator must not rely upon the same drifting or interrupted reference under test, since a common failure could leave its test pattern and receiver equally wrong. Test distinctive block boundaries, deliberately introduce separately identified loss and duplication, and compare reconstructed ordinal positions rather than only a spectral average. Record any ambiguity where different failures could reproduce the same observed pattern.

A periodic pure tone is not a sufficient completeness witness because an omitted or repeated segment may join at nearly the same phase after a whole number of periods. A more discriminating test uses an independently timed sequence with nonrepeating or suitably long-period phase and amplitude structure, together with markers whose positions are measured outside the receiver under examination. A pseudorandom code or designed pulse sequence can distinguish a skipped interval from a rate error when its ambiguity properties and signal-to-noise ratio are known. Compare recovered marker positions against sample indices and against a separate calibrated timebase. Do not derive the generator and the receiver from the same questionable reference when seeking an independent check of their relative drift; a common defect could cancel in the comparison. The testing arrangement should itself have a documented calibration and uncertainty.

I would separately report frequency accuracy, time offset, short-term phase behaviour and the completeness of the observed sample sequence. A clock

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with small long-term fractional-frequency error can nevertheless undergo a brief phase step; a system with an uninterrupted sample counter can still have an inaccurate mapping to external time; and a system with a magnificent external reference can still lose samples through buffer overflow. Measure at the receiver's actual sampling edge when possible, not merely at the external oscillator connector. Known cable and logic delays require correction or uncertainty allowance. If the experiment establishes only that the external reference remained stable, that finding must not be extended to an unmeasured synthesiser or acquisition driver. I return the token to Dr. Hamming with the distinction between a calibrated clock and a complete record firmly preserved.

Dr. James M. Atkinson, Moderator, Closing Synthesis: Clock drift, sample loss and delayed buffering are different defects with potentially similar graphical appearances. Clock drift alters the relationship between sample index and physical time; loss removes observations and should appear in trustworthy counters, device timestamps or error metadata; and buffering delays delivery without necessarily changing the underlying acquisition. The panel therefore requires independent timing stimuli, raw sample and sequence records, driver-status logs, host arrival timestamps, controlled stress tests and explicit preservation of gaps. The forensic distinction is between what was physically sampled, what reached storage and what a later display or estimator made visible. None of these categories should be silently substituted for another.

QUESTION 055. VERIFIED TECHNICAL SOURCES AND LIMITATIONS

W. J. Riley and D. A. Howe, Handbook of Frequency Stability Analysis, NIST Special Publication 1065 (2008),

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https://www.nist.gov/publications/handbook-frequency-stability-analysis . NIST identifies phase and frequency analysis, data preparation, statistical methods and reporting as relevant elements of a stability assessment.

Ettus Research, USRP Hardware Driver and Device Manual, General Application Notes, https://uhd.readthedocs.io/en/latest/page_general.html . Receiver overflow is associated with a host failing to consume device samples sufficiently rapidly, and outcomes depend upon the device, transport and streaming mode.

Ettus Research, USRP Hardware Driver and Device Manual, rx_metadata_t reference, https://files.ettus.com/manual/structuhd_1_1rx__metadata__t.html . Documents receive metadata including time information, overflow errors and out-of-sequence indications. These are examples of product-specific metadata, not assertions that every SDR exposes the same fields.

Editorial limitations: All numerical examples are hypothetical. This constructed historical dialogue is not an actual transcript. Instrument-specific error semantics, packet ordering and the evidential adequacy of a particular capture must be tested with the deployed hardware and software. Individual word targets and the whole-book duplicate-text audit remain outstanding.

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QUESTION 056

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What can network time synchronisation establish about an RF acquisition chronology?

SCHOLARLY RECONSTRUCTION. The following fictional instructional dialogue brings deceased historical specialists into a modern discussion. No statement below is an actual historical quotation; applications to network timing and contemporary SDR instruments are editorial extrapolations.

Dr. James M. Atkinson, Moderator: Dr. Mills, an RF monitoring console might display timestamps ostensibly synchronised to a national time standard, yet the underlying samples may have passed through an analogue signal path, an independent ADC clock, a device buffer, a transport interface and a host processing queue. What can a network synchronisation record establish about the original electromagnetic event, and where does the inference from computer time to the instant of physical acquisition become unwarranted?

David L. Mills, Principal Contributor: Dr. Atkinson, network time synchronisation is a means of estimating and correcting differences between clocks. It is not a direct sensor of when electromagnetic energy reaches an antenna. That distinction should govern every subsequent inference. A remote time server may help establish the host operating system's time relative to a recognised timescale. It does not automatically calibrate antenna propagation delay, analogue group delay, frequency-conversion latency, ADC aperture timing, USB queueing or the interval between an acquisition command and the first physical sample. An examiner must describe these transformations explicitly rather than treat a displayed timestamp as an observation made at the antenna terminals.

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Consider the four timestamps of a conventional request-response exchange. Let t1 denote the client's transmit timestamp, t2 the server's receipt, t3 the server's transmit timestamp and t4 the client's receipt. Assuming the timestamps have been interpreted consistently in the respective clock domains, the familiar offset estimate is $\theta=[(t2-t1)+(t3-t4)]/2$, while estimated round-trip delay is $\delta=(t4-t1)-(t3-t2)$. These equations are documented in RFC 5905. Their significance is conditional: symmetric outbound and return network delays make the offset estimate comparatively well behaved, but unequal path delays can cause an offset bias. Neither equation contains a measurement of the RF receiver's antenna-to-digital-sample delay.

For an illustrative asymmetric path, assume the server's clock is otherwise ideal and the client's true offset is zero. A forward network delay of 1 millisecond and a return delay of 3 milliseconds produce $\theta=(1-3)/2$ milliseconds, or minus 1 millisecond, under the usual sign convention. The four-timestamp estimate therefore appears to indicate a clock offset even though the assumed clocks coincide. This is not proof that any particular system will show precisely this error, because actual clock-discipline algorithms combine repeated measurements and use filtering, selection and other safeguards. The example demonstrates a limitation of single-exchange identifiability. A low numerical scatter in repeated measurements cannot establish that a constant path asymmetry has vanished.

The instrument chronology requires a different chain of evidence. First establish how the sample-producing hardware defines time: by a free-running ADC counter, a sampled pulse-per-second marker, a synchronised device clock, or a host-issued command. Then document the relation

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between this hardware timebase and host time. Let n denote sample index, f_s the actual sampling rate and t_a the actual time corresponding to the first retained sample at a declared electrical reference plane. For an ideal uniform stream, $t(n)=t_a+n/f_s$. If the acquisition hardware clock drifts, or if samples are dropped, a nominal constant-rate relation can become inadequate. Separately, if a host labels a packet at its arrival, the label is $t_{host}=t_a+\tau_{analogue}+\tau_{device}+\tau_{transport}+\tau_{host}$, where each τ refers to a declared latency component and the decomposition is illustrative. None of those terms can simply be set to zero by enabling a network-time client.

A disciplined operating system may maintain a monotonic clock and an externally referenced wall clock with distinct purposes. Slewing a wall clock changes the mapping between a time label and a physical interval. Stepping it may create an apparent discontinuity in recorded event times. A carefully designed acquisition system should preserve its monotonic hardware counter, clock-adjustment state and timestamp conversion alongside the externally presented clock label. Records should distinguish measurement time, device packaging time, network receipt time, processing time and final display time. A single column named 'timestamp' is a poor foundation for a forensic conclusion unless its origin and error bounds are unambiguous.

A useful experiment captures a known, lawful laboratory timing marker along the complete receiver chain while independently measuring the marker at a calibrated upstream reference plane. Record simultaneous device sample counters, device-provided timestamps, host monotonic and wall clocks, time-synchronisation logs and network-delay measurements. Then introduce a controlled asymmetry into the network time path while keeping the RF marker and acquisition wiring unchanged. If displayed host

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event times change but the hardware sample-index relation to the independent marker does not, the evidence points toward timestamp mapping rather than a change in the sampled event. Repeat the converse experiment by altering a documented analogue delay or the device sampling clock while leaving the network synchronisation unchanged.

A two-way network timing system also inherits a network topology. Server hierarchy, reference selection, authentication, operating-system timestamp placement, and routing can all influence the meaning of a reported offset. A server's claimed upstream relationship to a standard must be supported by a traceability or configuration record if that relationship is material to the case. Authentication may help establish message provenance but does not by itself improve propagation-delay symmetry or make a receiver's sampling clock accurate. Moreover, two hosts consulting the same timing hierarchy may share a systematic error, so their agreement cannot automatically be counted as independent corroboration.

What, then, can the network record support? It may provide evidence about the host's estimated clock offset, delay and synchronisation state within a specified period, subject to the protocol model and observed network conditions. When a properly instrumented calibration bridges host and hardware clocks, it may support a traceable estimate of sample acquisition time with an uncertainty statement. Without that bridge, the network service describes computer time, not directly the antenna event. For an adverse forensic interpretation, this is not a semantic distinction but the boundary between a defensible timestamp and a derived figure whose precision is unearned.

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Dr. James M. Atkinson, Moderator: Professor Poincaré, does the four-timestamp exchange uniquely identify clock offset when path delays are unknown?

Henri Poincaré, Peer Question: Dr. Mills, simultaneity and clock convention acquire operational meaning through the signals and procedures by which clocks are compared. If the forward and reverse propagation times are unknown separately, might different combinations of clock offset and delay asymmetry explain the same four recorded times? How would you demonstrate this ambiguity without making the unwarranted leap that synchronisation is impossible, and what supplementary evidence could narrow the family of compatible explanations?

For a legally consequential RF chronology, I ask that the time-transfer convention be written in a way an independent examiner could challenge. Suppose a route is asymmetric by an unknown constant amount while the client's clock is stable, and another experiment produces the same four timestamps by changing the clock offset. What observation would distinguish these cases? Please specify the reference plane at which you would obtain that observation, and state whether adding servers through the same provider network truly creates a new constraint. Otherwise the displayed offset may be an apparently precise solution to an equation having several physically admissible answers.

David L. Mills, Response: Professor Poincaré, the observations determine a round-trip interval and an offset estimator under stated assumptions, not the two one-way delays individually. Write the outward delay as d_f and the return delay as d_r. If the server and client clock offset is Δ, the measured estimator contains $\Delta+(d_f-d_r)/2$, with signs depending on which clock is

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defined as positive. An unmeasured change in $d_f - d_r$ can therefore imitate a change in Δ. Multiple exchanges, minimum-delay filtering and path characterisation improve practical inference, but they do not logically measure an unknown constant asymmetry in isolation. Independent clock comparison, calibrated symmetric paths, or direct physical timing links can help constrain it. The report should disclose which assumption makes the desired timing estimate identifiable.

One can begin by keeping the relevant variables visible. Write the measured offset as the clock difference plus one half of the path-delay asymmetry, with the sign convention specified. Additional packets on the same asymmetric route can refine an estimate of changing jitter while leaving a constant asymmetry unidentified. What changes the inference is an intervention or observation whose dependence on the unknown delays differs from the original exchange. An independently calibrated local pulse, a physical comparison against a third clock, or a carefully characterised bidirectional link supplies such information. The reference plane must be stated, since a calibrated signal at a network interface does not establish the analogue receiver's internal latency. A second server adds useful independent evidence only to the extent that its transport and reference dependencies differ; two addresses may share the same timing source and network infrastructure. I would retain a diagram showing upstream services, forward and reverse paths, timestamp placement, and each expected delay uncertainty. I would then compare all clock-offset hypotheses compatible with the records rather than choosing the one that gives the neatest UTC labels. If a bounded asymmetry of ±0.8 ms remains, for example, the event-time claim cannot responsibly advertise an absolute

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uncertainty of 0.02 ms merely because the filtered offsets vary by that amount. A laboratory may develop a stronger result by replacing the unknown path with a measured local reference. But until it does, it must describe the bound honestly. This is the difference between using an operational time service and certifying the instant of a physical RF event.

Dr. James M. Atkinson, Moderator: Professor Wiener, what does repeated statistical agreement prove about a timing service?

Norbert Wiener, Peer Question: Dr. Mills, an investigator may obtain thousands of closely clustered offset values and report a very small standard deviation as though it were the absolute timing uncertainty. Yet a deterministic delay asymmetry could persist through the entire series. How should measurement statistics separate short-run fluctuation from fixed model error, and what dangers arise when filtering selects only apparently favourable low-delay samples from a changing network environment?

A further issue concerns the independence of repeated samples. The clock algorithm may select those exchanges with the smallest observed round-trip delay, but successive exchanges on one route can inherit the same bottleneck, physical asymmetry, server load or timestamp implementation. If hundreds of retained observations look similar, how should a researcher decide whether their uncertainty reflects genuinely fresh information? I ask especially about hidden dependence after outlier selection and about the difference between statistical confidence in the filtered estimator and confidence that it estimates the correct physical quantity.

David L. Mills, Response: Professor Wiener, precision within the selected observations is not equivalent to accuracy against an external standard.

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Repeated low-scatter estimates can coexist with a persistent systematic error, and the selection rule can materially affect the distribution reported. Preserve all candidate exchange timestamps, not only the accepted offsets, together with network path changes, chosen peers, filter parameters and rejected observations. Evaluate the residual variation conditionally on routing and load, and include an uncertainty or bias qualification for unmeasured asymmetry. A clean statistical plot is evidence of repeatable behaviour under the selected conditions, not an automatic certificate of traceability to the RF sample instant.

The samples are informative about different things. A low-dispersion series can indicate that the estimator's observable is stable under the present conditions, yet that observable may contain a persistent asymmetry. Repeated packet exchanges should be examined as a time series containing shared route and server states, not counted as independent trials merely because the clock software printed new numbers. I would retain all candidate offset and round-trip-delay pairs, including the values rejected by the filter, together with peer changes and time-of-day or routing context. A conditional analysis might show that a congestion episode increases both delay and variance; excluding that episode can improve operational synchronisation but changes the population being described. If a persistent return-path bias survives in the selected low-delay subset, there is no statistical means to identify it from those same exchanges alone. Its influence needs an independent test or a conservative bound. Nor should uncertainty shrink as the inverse square root of the raw sample count when correlations make effective sample count smaller. Autocorrelation, common server disturbances and change points must enter the assessment. An

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attractive mean is not a calibration certificate. For RF evidence the estimator should additionally be tested against a hardware timing reference near the receiver acquisition chain. The resulting report can distinguish three conclusions: the host clock's short-term consistency, its conditional time-transfer accuracy, and the entirely separate accuracy of mapping a physical sample index to an external timescale. Each has its own source of uncertainty and cannot simply inherit the strongest number from the other two.

Dr. James M. Atkinson, Moderator: Professor Kálmán, how should a receiver behave when its host clock is corrected during ongoing capture?

Rudolf E. Kálmán, Peer Question: Dr. Mills, a state estimator may smooth offset and frequency measurements before issuing host-clock corrections. During a server change or transient packet delay, the estimator may change its state without a corresponding event in the hardware acquisition stream. How can an investigator distinguish measured clock evidence from the filter's prediction, and why should a very narrow estimator covariance be treated cautiously when an unmodelled shared network disturbance is present?

The usual filter reports a predicted clock state and a covariance that depend upon an assumed dynamical model. Suppose an alternate upstream time server is chosen abruptly, a network route changes, or the host oscillator is commanded to slew while acquisition continues. Can the filter become overconfident during that transition because its state-space model assumed smooth frequency wander? How should the measurement record distinguish the pre-transition estimate, raw packet observations, control actions and revised conversion of hardware sample indices? It would be

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insufficient to present a post-transition covariance ellipse without exposing the state reset that created it.

David L. Mills, Response: Professor Kálmán, maintain the observation and state-estimate streams separately. A correction issued by the discipline loop is a control action based on measurements and model assumptions; it is not an RF observation. The hardware sample counter should remain the primary order record, while a versioned conversion relates counter positions to external time. A clock-source change, reset or unexpected network asymmetry warrants an explicit boundary in that conversion. Correlated measurement errors can render an assumed diagonal covariance model overconfident. Test residuals, retain the raw exchanges and compare the resulting mapping with a separately monitored timing reference. If the hardware-to-host relation was never measured during a gap, mark the external event-time estimate as model-dependent rather than claim continuity from estimator output alone.

A discipline loop is a controlled estimator, and its error statement rests on a specified process model. If that model treats oscillator drift as smooth while an upstream server switches, the innovation sequence may contain a disturbance too abrupt for the assumed process noise. The filter can respond by a state jump, a temporary slew or an increased uncertainty interval depending on its implementation. The stored state covariance immediately after a reset describes the revised model, not necessarily the unmeasured error immediately before the transition. An acquisition report should preserve the raw four-timestamp tuples, clock-selection and system-state changes, and both old and revised counter-to-UTC mappings. It should never silently rewrite the timestamp that was first attached to a sample. A

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useful test introduces a known path-delay change while an independently monitored device clock continues to produce a periodic test marker. If the software labels shift while marker intervals in the device sample domain remain stable, the disturbance belongs to the mapping. If the device counter and physical marker also change, investigate the hardware clock. When the evidence cannot discriminate those cases, enlarge the uncertainty statement or quarantine the interval. Model checking should examine cross-correlations, innovation outliers, state-dependent residuals and the effect of alternative process-noise assumptions. A narrow filter covariance obtained from an overly certain model is not proof of narrow measurement uncertainty. The resulting record should explain every clock-state boundary relevant to the claimed event order.

Dr. James M. Atkinson, Moderator: Dr. Hopper, how should software retain the original chronology when several timestamps compete?

Grace Murray Hopper, Peer Question: Dr. Mills, a logging application can quietly overwrite a packet's arrival timestamp with a later corrected timestamp, and a database can sort records by a wall clock that has stepped backwards. Both decisions can make the chronology appear inconsistent or conceal what the operator initially observed. What minimal provenance fields and transaction rules would allow a later examiner to reconstruct acquisition order while distinguishing genuinely absent samples from an altered timestamp mapping?

Consider a computer program that preserves only its latest corrected UTC time, discarding original device counters, earlier wall-clock labels and the raw synchronisation transactions. It may produce a beautifully ordered event list after the analyst changes the correction model. What audit trail

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would prove which events were physically captured and which times were computed after capture? Please address the possibility that processing threads reorder blocks, a failed transport duplicates records, and a host's wall clock steps backwards. Which identities must remain immutable to make a later courtroom or laboratory replay genuinely possible?

David L. Mills, Response: Dr. Hopper, preserve immutable source records: acquisition-device identity, stream and packet sequence numbers, hardware sample indices, device timestamps, raw host monotonic arrival time, contemporaneous wall-clock label, clock-discipline state and the method used to produce corrected UTC estimates. Do not overwrite a raw timestamp with the result of later calibration. Store the transformation separately, with its version, assumptions and uncertainty. Sort by a reliable acquisition sequence when reconstructing sample order, then annotate how that order maps to external time. Hash the original acquisition data and the associated event ledger, documenting any missing identifiers or counter resets. Such controls distinguish what was stored and when from what an improved clock model later inferred.

The acquisition device should produce an identity that remains valid when every wall-clock label is recalculated. A hardware sample index or unambiguous monotonic sequence is preferable when supported, coupled with the receiver identifier, channel, configuration epoch and raw device timestamp. Retain host monotonic arrival time and the original wall-clock time separately. The network synchronisation subsystem should preserve the selected server, source of calibration, raw exchanges, offset estimate, applied adjustment and any reference changes, permitting reconstruction of the time conversion applicable when the file was written. A later corrected

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UTC estimate belongs in a new field or derived table with its transformation version and uncertainty; it should not overwrite the original. The pipeline also needs explicit exception records: dropped and duplicated packet identifiers, queue overflow, counter wrap, device restart, retune and filter-latency changes. If parallel workers produce records out of order, use the device sequence to restore acquisition order, documenting any unresolvable gap. Hash or otherwise integrity-protect the raw records and retain provenance sufficient to reproduce a calculation rather than merely replay a picture of the waveform. For a challenge test I would induce an authorised host-clock step while a stable marker and counter stream continue, and separately induce a controlled transport loss. A correct logger should preserve the different signatures. What the programme can prove after this test is not that its receiver is always correct, but that the configured faults remain visible to a later examiner and cannot be mistaken for a real change in the radio environment.

Dr. James M. Atkinson, Moderator: Professor Michelson, could a carefully repeated laboratory calibration validate the complete timing chain?

Albert A. Michelson, Peer Question: Dr. Mills, the host reports accurate time to within a small estimated interval, but the RF input passes through filters and cables of unknown group delay. Can an end-to-end challenge reveal the true acquisition latency without relying upon the network estimate alone? How should a laboratory ensure that the calibration target is the same reference plane and event definition used by the field report?

I should like the calibration described at the actual RF measurement plane. A time protocol can characterise a computer clock, but a received pulse may experience cable delay, analogue filtering, frequency conversion and

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feature-dependent trigger latency before it is logged. How would the laboratory design an end-to-end challenge that distinguishes those contributions without relying on the same computer clock to judge itself? If the input amplitude changes and the timestamp shifts, what test establishes whether the physical event changed or the event detector moved its threshold crossing?

David L. Mills, Response: Professor Michelson, inject a sharply defined but bandwidth-appropriate, non-damaging timing event at a known physical reference plane. Observe it with an independent calibrated timing instrument while the SDR records the corresponding feature, raw samples and hardware counters. Repeat to characterise trigger jitter, algorithmic detection latency, front-end group delay and the hardware-to-host time mapping. A filter's delay can depend upon frequency and settings; a detection algorithm's timestamp can depend upon threshold and signal-to-noise ratio. The calibration should therefore match the relevant bandwidth, gain, firmware and processing configuration. Report both a correction and its residual uncertainty, and distinguish a laboratory result from a deployment claim unless continuity of configuration is established.

An end-to-end calibration must begin at a declared physical reference plane, such as the RF connector with a properly characterised calibration path or an antenna measurement point. Introduce a waveform with a defined feature and observe its generation time independently of the receiving host. The recorder should capture raw samples and hardware counters while the host simultaneously logs its network-time discipline. Compare the physical marker with the sample index of the detected feature, then repeat through variations of frequency, bandwidth, level, filtering and environmental state.

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Those variations expose group delay, threshold walk and trigger jitter that a single fixed-point calibration would conceal. A correlation peak and a threshold crossing need not coincide: each detection rule has its own bias and variance, especially when signal amplitude changes. We should therefore define in advance the feature whose time is asserted in the field report. The measured correction might be decomposed into path, acquisition, algorithmic and clock mapping components only where sufficient controls render them distinguishable. Otherwise an end-to-end delay with a defensible uncertainty is preferable to an unjustified breakdown. When the host timebase is compared against itself, the experiment is circular; independent hardware counters and a calibrated timing witness break that circularity. A blind confirmation trial, in which a second operator introduces an unknown controlled delay, tests whether the complete processing chain recovers the expected time difference. These procedures support a bounded claim about a particular configuration. They do not automatically certify a different receiver, firmware build or antenna path in the field.

Dr. James M. Atkinson, Moderator: Professor von Neumann, what resource constraints can corrupt a nominally precise chronology?

John von Neumann, Peer Question: Dr. Mills, a receiver system may timestamp samples in device hardware but subsequently experience finite buffer capacity and variable transport throughput. If host scheduling delays create a queue, which evidence proves that each sample survived? And if a clock service and an acquisition program share the same processor, might heavy computation affect observed packet-timing statistics even when the external reference remains stable?

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A high-throughput receiver can accumulate gigabytes of samples while a host system performs network synchronisation, writes to disk and produces a display. Heavy computation may delay host timestamps or cause queue overflow without changing the ADC's oscillator. Can system resource records distinguish an observation that was sampled promptly but received late from one that was never acquired? Please specify the minimal hardware counters and queue telemetry, and explain why matching output file sizes or a consistently updated waterfall cannot be treated as proof that all expected sample indices survive.

David L. Mills, Response: Professor von Neumann, separate acquisition continuity from arrival punctuality. A valid sequence of hardware sample indices, device-side overrun indicators and a verified uninterrupted raw file can establish a strong case that samples survived an arrival delay. Host packet arrival timestamps alone cannot. Record buffer occupancy, dropped-packet counters, transport error states and scheduler load, then perform worst-case stress tests with a known calibration stream. Heavy host load can change software timestamp placement and queue latency without changing the reference oscillator, and can ultimately provoke overrun when buffers fill. A system that merely shows a green synchronisation icon while dropping RF samples has met neither a forensic continuity requirement nor a meaningful full-chain timing requirement.

The receiver must distinguish three events: hardware sampling, device or driver delivery, and durable storage. A hardware counter that advances for each generated sample may show continuity even when delivery is delayed; a transport sequence may reveal reordered packets; and a device overrun flag may disclose the loss of samples before the host could read them. None

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of these guarantees is available by assumption, since some receiver models expose fewer counters than others. The acquisition record should describe the actual fields used and the limitations of their semantics. A test should operate at the maximum intended streaming rate while background storage, interface rendering and clock synchronisation are stressed. Track queue occupancy, high-water marks, receive error codes, consecutive sample indices, host arrival intervals and disk write completion. If the queue temporarily accumulates ten buffers and later drains without index gaps, the condition is delayed delivery, not demonstrated sample loss. If the hardware or driver reports a missing range, the interval must be marked as unobserved even when the final file retains an expected overall byte count through duplication or padding. A waterfall that updates uniformly proves only that its rendering loop continues. It may repeat, interpolate or omit data in ways irrelevant to the source. The strong evidence is a known challenge sequence recorded end to end, with raw sequence reconciliation and a separately observed timing marker. Every throughput claim should be tied to the actual configured complex sample size and channel count, because processing throughput calculated from an advertised nominal rate may underestimate overhead and transient workload.

Dr. James M. Atkinson, Moderator: Professor Jeffreys, what conclusions may a court properly draw from agreement between two synchronised receivers?

Harold Jeffreys, Peer Question: Dr. Mills, two receivers report the same short signal at nearly identical UTC times. Both consult the same upstream synchronisation service, though their antennas and front ends are separate. Does such agreement count as two independent pieces of timing evidence, or could a shared timing error explain part of the agreement? How should

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the analyst describe this evidence without falsely claiming either complete dependence or complete independence?

Two independent antennas register a short emission, and their hosts report the same corrected UTC timestamp within a narrow tolerance. Both hosts select a common network server, use the same timestamp conversion software and share a network path for at least part of the route. What evidential weight should be assigned to that agreement? I would ask for an explicit decomposition between independent evidence of radio energy and potentially correlated evidence of time. How ought a report express the competing explanations where no independent clock witness was available during the particular event?

David L. Mills, Response: Professor Jeffreys, the analyst should decompose the proposition. Distinct antennas and front ends may provide separate evidence of RF-energy occurrence. Their external time labels, however, are not wholly independent when a common upstream hierarchy or timestamp-conversion method contributes to both. A covariance model or conservative bound should reflect common components, and independent timing supervision is needed to corroborate absolute event time. The evidential conclusion can therefore say that two acquisition paths detected an event whose respective timestamp estimates agree within stated uncertainties, while both share a specified synchronisation dependency. That is more precise than treating their agreement either as useless or as independent proof of a particular UTC instant.

There are two hypotheses that must not be collapsed. The separately placed antennas may corroborate the physical occurrence of a signal, subject to their own RF artefacts and environmental dependence. The host

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timestamps, however, may be correlated because both systems use a common upstream time service, routing infrastructure or conversion algorithm. The likelihood of matching time labels under a shared failure can be much greater than it would be under independently calibrated clocks. Without data sufficient to estimate these dependencies, multiplying two nominal timing confidence levels is not justified. The analyst should document the clock-source diagram and preserve original device counters so that arrival-time differences can be reassessed after later calibration. If each receiver was separately calibrated at its antenna reference plane and had an independent physical timing witness, that would support a stronger absolute-time inference. If not, the defensible statement is that two receiver paths observed a corresponding event and their host-derived labels agreed within the stated tolerance, with a disclosed common synchronisation dependency. Where a source-location conclusion relies upon the same labels, a sensitivity analysis should show how a plausible shared or station-specific timing bias changes the solution. A common bias may cancel in a differential estimate; a branch-dependent bias need not. The location inference must therefore be tested with the appropriate error covariance, not an assumption that each instrument is a statistically unrelated witness. This approach preserves valid corroboration while refusing to invent independence that the installation did not provide.

Dr. James M. Atkinson, Moderator: I now pass the principal token to Henri Poincaré to examine the identifiable limits of network-based clock comparison. Professor Wiener will cross-examine his account.

Henri Poincaré, Second Principal Contributor: Dr. Atkinson, the four-timestamp clock comparison illustrates an identification problem rather

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than a magical determination of absolute simultaneity. An unknown clock offset and unknown one-way network delays can produce the same observed exchange timestamps in several configurations. The familiar estimator is useful under explicit assumptions concerning path symmetry and delay dynamics; without an independent measurement of asymmetry, its numerical output does not establish the absolute error of the client clock. More importantly, correcting the host clock says nothing without a measured relationship to the receiver sampling counter. I would distinguish three propositions in the report: that a host was disciplined according to a specified protocol; that the counter-to-host mapping was measured and retained; and that antenna-to-counter latency was characterised for the waveform and detector under test. The latter two require laboratory experiments beyond the network protocol. A crucial final safeguard is to write the estimator's assumptions beside its result. A client-server exchange alone does not reveal its forward and reverse delays separately, even with perfect timestamp arithmetic. When the stated application requires a stronger physical assertion, the investigator must demonstrate what independent observation supplies the missing information. An explicit boundary of inference is an accomplishment of metrology, not an admission that all time comparisons are worthless.

The underlying question is not whether the clocks display the same hour, but whether the measurements determine the relative time at which two physical processes occurred. A convention for assigning time to distant events can be operationally sound while still depending on a specified communication mechanism. In an RF investigation the analyst must distinguish a convention used to coordinate civil time, an experimentally

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realised time-transfer relationship, and a physical delay inferred for a signal travelling from the transmitter to a receiver. The latter requires its own propagation and instrument model. None of these descriptions is refuted by the others; the error occurs when one is treated as an interchangeable measurement of another.

Let a client's clock read $C(t)=t+b$ relative to an ideal reference time t over a brief exchange, with b a constant offset. Let the forward propagation delay be d_f and the reverse propagation delay be d_r, each measured in seconds. The request departs at physical time t, reaches the server at $t+d_f$, and the server answers after a measured processing interval. Algebraically the standard offset estimator contains the true clock offset and one half the difference between the propagation delays, with its sign defined by the selected clock convention. Thus one set of timestamps admits a family of explanations: increasing b by a small quantity while changing the path asymmetry appropriately can leave the recorded exchange unchanged. There is a degree of non-identifiability that no additional decimal place removes.

One must then ask what extra observation breaks that ambiguity. A separately monitored local timing connection can compare the client against a common calibrated electrical marker, though it too has a finite cable and threshold delay. A deliberate reversal of the network path can test whether a presumed asymmetry changes sign or magnitude. A fibre loop or symmetrical laboratory connection might constrain rather than eliminate asymmetry. Each intervention creates a different set of observables, and the resulting uncertainty should be calculated in units of time, not represented by the subjective confidence of the operator. For a physical emitter-time

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inference, a comparison at the network interface is still one reference plane removed from the ADC aperture and the antenna.

The terms accuracy and simultaneity are therefore best treated as statements about named events at named reference planes. A packet transmitted from a host interface, a sample clock edge, and a threshold crossing in a processed waterfall can be associated by calibrated relationships; they are not identical occurrences. Record the event definitions, the time transformation used between them and the uncertainty of that transformation. A replay of captured data through later software must not silently change the original event definition even when a more sophisticated estimator improves the displayed chronology.

For a hypothetical laboratory system, suppose the host offset estimate repeatedly reads +0.2 milliseconds with a variation of 0.02 milliseconds, while a comparison against a locally wired independent standard reveals a persistent -0.6 millisecond path-related bias. The tight clustering indicates repeatability; the independent comparison reveals a discrepancy in the absolute mapping. Those stipulated figures are not empirical measurements and their signs depend on the chosen offset convention. A report that quotes only the observed standard deviation would omit the larger systematic uncertainty affecting the event-time claim. Conversely the discovery of bias does not make the original recorded packets disappear: it changes what can responsibly be inferred from them.

I would invite the other contributors to identify the physical and computational boundaries at which each comparison is made. A field team may legitimately use network time to coordinate observation logs, schedule equipment checks and place approximate detections on a common timeline.

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Stronger conclusions, such as nanosecond-level time difference of arrival, require a chain of independent checks extending to the sampling hardware and signal feature. Where that chain is absent, the proper assertion is a qualified correspondence of computer clocks, not a verified correspondence of electromagnetic arrival times.

Norbert Wiener, Cross-Peer Question to Henri Poincaré: Professor Poincaré, your statement permits a large systematic bias to coexist with thousands of nearly identical offset estimates. If a laboratory obtains a smooth histogram of client offsets, how should it describe the repeatability without misrepresenting the accuracy? Would a minimum-delay selection rule remove the ambiguity if the preferred path had a constant, unequal forward and return delay? What independent measurements would establish that the improvement was physical rather than merely statistical?

My concern is that the practical estimator chooses among many packet exchanges and thereby changes the apparent symmetry problem. Suppose the low-delay subset comes from one stable but asymmetrical route and the rejected high-delay samples come from a second route. Does the convergence of the accepted-offset histogram identify the clock bias, or does it merely describe one conditional transport state? Please state a concrete, falsifiable experiment that would show when the network-delay model is wrong. In particular, would reversing the link, introducing a known asymmetry, or comparing against a local hardware time standard discriminate the two explanations? The manuscript should distinguish a test that constrains constant bias from one that only reduces random scheduling variation.

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Henri Poincaré, Cross-Peer Answer to Norbert Wiener: Professor Wiener, the histogram can support a statement about variation conditional on the sampled network states. It cannot quantify a fixed asymmetry that is not observable from those records alone. Minimum-delay selection can reject some variable congestion but does not necessarily eliminate a constant directional difference. A calibrated direct timing link, independent time-transfer apparatus or characterised symmetric path offers additional evidence. The same distinction applies downstream: a host whose clock is accurately aligned may still label packets after variable buffering delay. Preserve the independent device counter and experimentally determine how its indices map to the timing reference. A report should not substitute reduced scatter for a bias bound, nor should it confuse a corrected software label with the instant the electromagnetic event reached the antenna.

Professor Wiener, the convergence of a conditional histogram establishes only that the chosen estimator is repeatable within its selection rule. The accepted samples are not a new physical clock reference. I would begin with two different hypotheses: a stable true clock offset accompanied by variable path asymmetry, and a changing true offset accompanied by path compensation. I would then design a measurement capable of breaking the observational equivalence. Swapping the physical forward and return paths in a controlled laboratory test, where possible, predicts a reversal of the asymmetry contribution but not of the underlying clock offset. Injecting a known one-way delay predicts a calculable change in the four-timestamp estimator even while the oscillator remains unchanged. A locally cabled independent time comparison provides a third constraint, subject to its own separately calibrated electrical delay. A successful experiment need not

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prove universal symmetry; it should provide a bound over the conditions actually tested. If the route changes, repeat the comparison or enlarge the uncertainty statement. The accepted-offset histogram might remain narrow before and after the change, yet both clusters can be displaced by different systematic terms. A report should state that its estimator approximates clock offset under the tested path model, not that it has directly measured the absolute arrival time of an RF event. To connect the estimator to that event, we need a second chain of measurements extending through the host, the acquisition device and the analogue signal path. Otherwise the apparent precision belongs to the timing service, not to the electromagnetic event under investigation.

David L. Mills, Response to Professors Poincaré and Wiener: Their exchange correctly restricts the four-timestamp model. Practical filtering does improve estimates in appropriate network conditions, but no choice of display precision removes an unmeasured physical asymmetry. The ultimate acquisition chronology remains a chain of measured mappings rather than one host-time label.

Dr. James M. Atkinson, Moderator: Professor Wiener, would you distinguish statistical repeatability from the unobserved path asymmetry in network clock estimates? Dr. Mills may challenge your proposed boundary.

Norbert Wiener, Third Principal Contributor: The offset estimator is a statistical object conditioned by a physical network. A cluster of similar values demonstrates repeatability under observed path conditions; it cannot identify a constant forward-reverse asymmetry. Delay selection and averaging may improve performance under congestion, but the model

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uncertainty remains. I would preserve rejected as well as accepted packet exchanges and compare alternative routes and independent timing witnesses. A timestamp applied after an SDR buffer arrives is especially susceptible to being mistaken for the actual capture instant. I would additionally require the uncertainty assessment to distinguish aleatory fluctuation, systematic path bias, and the uncertainty introduced when a model is selected after the data have been viewed. A stochastic estimator whose parameters are tuned until its residual trace becomes quiet may understate its uncertainty. Preserve competing candidate models, compare them against held-out timing challenges, and check whether the inferred RF chronology changes across defensible filtering rules. For example, a fit that assumes identical forward and reverse delays might yield a much smaller variance than one admitting route-dependent asymmetry; that difference is not a triumph of the first estimator but an indication that the measurement alone cannot decide the question. A network with infrequent topology changes also violates the naïve assumption of one stationary stochastic process. Time-tag each change, stratify the observations, and report intervals where calibration cannot bridge the transition. These practices make the resulting probabilistic statements conditional, transparent and capable of being tested by an independent laboratory.

A sequence of network offset measurements is a selected statistical record. It is produced by a noisy physical channel, a packet scheduler, server processing and an algorithm that decides which observations deserve weight. The algorithm may reject delayed exchanges precisely when a network is congested, so the apparent stability of accepted observations can depend strongly on which samples were discarded. We should not attribute

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a single distribution to the errors until we have inspected their time dependence, their common causes and their conditional relationship to the network state. The most dangerous interpretation is that a hundred nearly identical outputs must represent a hundred independent experiments.

Suppose the observed offset estimates obey $z_k=b+a_k+n_k$, where b is the desired clock offset, a_k is an asymmetry-induced bias and n_k is random timing noise. If a_k remains constant over the test, repeated averaging can suppress a zero-mean n_k but cannot recover b separately from a_k. If a_k changes with route or congestion state, the observation distribution may be a mixture rather than a single bell-shaped curve. An apparently heavy tail could be the trace of occasional route switching, a burst of server load or another reproducible physical mechanism. It is preferable to study these states than to remove unusual values merely because they interfere with an attractive plot.

The record should retain the measured round-trip delay, the individual request and response timestamps, the selected server, the clock filter state and the date of each network-route change. With these observations a researcher can plot conditional offset versus delay and examine whether a low-delay subset is more stable. Even the minimum observed round trip has a limit: it may reduce transient queueing while preserving fixed directional asymmetry. The lower envelope of delay is therefore an estimator under a model, not a direct measurement of the unknown forward and return times. It should not be sold as a calibration by itself.

A small theoretical experiment is useful. Let the two one-way delays in a reference state be 1 ms and 1 ms. Now suppose a route change increases only the outbound path to 3 ms. The additional asymmetry can shift a four-

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timestamp offset estimate by approximately 1 ms even while the actual client oscillator is unchanged. If only the low-scatter measurements after the change are retained, a post-change time series may look stable and still be displaced relative to the earlier one. A change-point analysis that includes route evidence can explain the discontinuity, but only an independent reference can establish which portion arose from clock motion rather than path alteration.

Correlations among instruments matter no less than correlations within one instrument's record. If two receiver hosts consult the same upstream server, its bias can enter both time mappings. Their event labels may agree within a small difference because the shared error cancels, whilst neither label is independently traceable to the asserted external timescale. The covariance must represent this common mode. A simple model for two timing estimates $x_i=s_i+c+e_i$ includes a common error c and independent errors e_i; their covariance contains the variance of c. Treating c as two unrelated noise sources can make combined timing uncertainty artificially small.

The conclusion of a statistical analysis should therefore be phrased as an inference conditional upon observed transport states and acknowledged assumptions. We can assess stability, outlier rates, dependence, and whether known controls predict measured changes. We cannot infer from statistical smoothness alone that the physical packet paths were symmetric or that the RF sample clock shared the host's estimated time. I would pass the question of preserved evidence to Dr. Hopper, because a satisfactory statistical model is useless if the original observations were transformed or overwritten before anyone could examine them.

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David L. Mills, Cross-Peer Question to Norbert Wiener: Is a minimum-delay estimate ever sufficient for a receiver report when the host time service is carefully monitored and has remained stable for many days? Please address how you would prevent a genuine clock correction from being misclassified as a route change solely because both produce a shift in a filtered offset trace. The existence of an independent timing witness seems central to that distinction.

Consider a long receiver acquisition during which the network clock appears stable according to the filter, but the route changes without an application alarm. The new path has a different outbound-versus-return delay, and the operator keeps only filtered offsets. What diagnostics would reveal a systematic change when the retained offset series remains quite smooth after the transition? Could a change-point test on the raw four-timestamp tuples identify the transition even if the host's control loop gradually slew through it? And what independent observation would be needed before describing the resulting shift as a true change in the physical RF event chronology rather than a change in the host clock mapping?

Norbert Wiener, Cross-Peer Answer to David L. Mills: It supports a bounded assertion about host synchronisation under the tested path conditions. It does not alone establish the receiver hardware-to-host mapping or the absolute one-way delay from antenna to timestamp. Those require additional calibration. The report should show the network contribution separately from the acquisition-chain contribution and avoid implying that long monitoring eliminates fixed asymmetry. A useful safeguard is a paired hypothesis test supported by observations from different physical domains. If a host offset changes while a locally monitored hardware marker and an

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independent clock comparison remain constant, the network-path explanation becomes more plausible. If the independent comparison records the same actual host-clock motion, one must investigate the discipline action itself. Neither a lone filter residual nor the mere date of a route change is sufficient. Record the expected signature under each explanation before inspecting the intervention result, and repeat the experiment at least across a few deliberately varied path conditions. A statistical change-point result should therefore be presented as evidence of a transition, not as proof of its underlying cause. Only a discriminating physical observation supports that attribution.

Dr. Mills, the first diagnostic is preservation of the original candidate measurements and their context, including delay, timestamp asymmetry proxies, peer-selection history and route-change evidence. The output of a state estimator alone is not sufficient, because it can remove much of the transient by changing the host clock. A change-point procedure could look for shifts in the joint distribution of offset and round-trip delay, but it must be assessed against actual path conditions and the risk of false alarms. A route can change asymmetry while leaving total delay nearly constant, so the absence of a visible delay jump is not conclusive. Conversely, a host oscillator drift can change the offset series without any route change. An independent timing witness is needed to distinguish these mechanisms credibly. For example, a stable local pulse or hardware clock comparison unaffected by the packet route can show whether the physical host offset moved when the network estimator changed. If that witness remains stable while network estimates shift, the path hypothesis gains force; if both move together, the host-clock hypothesis becomes stronger. The report should

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include the selected and rejected packets and a sensitivity analysis showing the consequences of alternative asymmetry values. It should not claim a unique cause from a filtering residual. Only after the host-to-device timing bridge has itself been established can one discuss a corrected RF acquisition chronology. We must also acknowledge the separate effect of buffering: a host's packet-arrival time can shift even when neither its wall clock nor the receiver's sampling time changes.

Dr. James M. Atkinson, Moderator: Dr. Hopper, the token now passes to software provenance and the preservation of original event order. Professor Poincaré will address the implications of a revised UTC mapping.

Grace Murray Hopper, Fourth Principal Contributor: Software architecture must preserve the distinction between raw acquisition order and a later computation of civil time. A transaction that replaces original device timestamps with revised UTC labels creates an avoidable evidential ambiguity. I would keep immutable hardware indices, device counters, the contemporaneous host-clock state and a separately versioned mapping for all corrections. When clocks step backwards, sorting records by wall time alone can reverse the original observation order. An operator must be able to reconstruct the original sequence without trusting the latest user-interface view. The acceptance test should be formulated as a falsifiable software requirement: after any supported synchronisation adjustment, every preserved RF sample must remain associated with its original device index and acquisition epoch, and no derivative timestamp may be presented as an unmodified hardware observation. Construct test cases in which a known timing marker crosses a host-clock step, a buffer overflow and a receiver retune. Inspect the stored record for unambiguous event

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boundaries and verify that a reviewer can reproduce both the original and revised UTC mappings. A good design also preserves conversion uncertainty in a machine-readable field rather than burying it in a narrative footnote. This matters when several institutions exchange evidence and one later reprocesses a recording under a different time-transfer model. The integrity of the original acquisition ledger should permit divergent analyses while still exposing which data were truly observed and which quantities were inferred. Such a separation makes a computer system scientifically useful even when an earlier conclusion requires correction.

Software must preserve the distinction between facts captured by hardware and times calculated later. A receiver can acquire an uninterrupted indexed sample stream while the host clock is stepped; it can also lose samples while a host clock remains impeccable. A logging format that stores only one generic timestamp for both circumstances destroys useful evidence. The solution begins with an explicit data model, not merely a more elaborate clock routine. The operator should be able to inspect which record came from a device register, which from a driver callback, which from an operating-system clock, and which from a later conversion to coordinated time.

I would organise the acquisition ledger around an immutable observation identity: station identifier, receiver and channel identity, hardware sample counter or documented substitute, packet sequence, device timestamp if available, host monotonic arrival time, contemporaneous wall-clock label, configuration epoch and cryptographic checksum or other integrity control. A separate clock-state ledger would store network peer selection, raw four-timestamp exchanges when available, estimated offset, delay, jitter,

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reference changes and each commanded clock adjustment. The linkage between the two ledgers should be a recorded rule with a version number. These fields do not make a faulty measurement accurate; they make its failure and later correction discoverable.

Consider the case in which a host wall clock jumps backwards by 40 milliseconds while its receiver continues to acquire blocks numbered 5000, 5001, 5002 and 5003. Sorting the resulting records solely by wall-clock label could present the blocks in the wrong order. Retaining their hardware counters preserves acquisition order, while the original wall-clock labels preserve the contemporaneous report. An updated timestamp mapping can then produce corrected estimates, with the discontinuity and uncertainty prominently annotated. The original labels must not be quietly replaced, because that would make it impossible to reconstruct what the system actually asserted at the time of collection.

Another case involves buffering. An RF packet may be captured at a device, reach a driver after a variable interval, and be written to disk after further delay. A timestamp taken during file writing is therefore a transaction time, not necessarily an event time. Different software threads can observe packets in a different order when processing runs concurrently, especially if a queue is split across workers. The system should preserve explicit acquisition ordering and document any reordering transformation. Its test suite must deliberately introduce queue load, loss, duplicate delivery and clock discipline changes, then confirm that each condition is observable in the saved evidence.

A provenance system should also distinguish facts about the source from facts about the tool. A server's asserted time and its digital authentication

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evidence are not measurements of propagation delay. A receiver manufacturer's clock-quality indicator is not a calibration of an analogue filter. The immutable ledger should contain those outputs as outputs, with provenance and known limitations, rather than treating them as unquestioned assertions. An examiner can then ask which assumption each subsequent conclusion required and whether a different assumption would change the result.

The public-facing report should be built from the raw ledger and contain a precise description of the event time: for instance, 'UTC estimate assigned to the rising edge of a calibrated injected marker, derived from device sample counter and reference comparison, with specified uncertainty'. That is quite different from 'timestamp written by the logging host'. Both may be useful; neither should masquerade as the other. A trustworthy computer system helps future investigators examine the original observation even when the contemporary interpretation later changes. The quality of its evidence is revealed not by the elegance of its display, but by what remains demonstrably reconstructable after an error.

Henri Poincaré, Cross-Peer Question to Grace Murray Hopper: How should one describe two events whose displayed UTC order reverses after a clock correction, even though their hardware counter order is unequivocal? In particular, how would you preserve the uncertainty of translating those counter epochs into external time without allowing a later analyst to convert that uncertain ordering into a falsely precise legal chronology?

An electronic record can show two events with UTC labels that reverse their acquisition order after a clock correction. The operator may prefer the

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corrected UTC ordering because it agrees with an external narrative, but the original hardware counters say otherwise. Which ordering is evidentially primary, and under what assumptions might either ordering fail? I ask you to define an invariant strong enough to protect the raw sample sequence while allowing later scientific correction of its external time mapping. The answer should also confront counter reset and missing sample intervals, because a merely monotonic counter is not a sufficient guarantee when its provenance is unknown.

Grace Murray Hopper, Cross-Peer Answer to Henri Poincaré: The hardware counter supports their acquisition order within that clock domain. The external-time relationship remains conditional on the calibration used. A corrected UTC estimate might legitimately change the inferred spacing or absolute placement, but it should not erase the observation that one sample preceded the other in the physical device sequence. Keep the original and corrected representations and specify their uncertainties. Where two hardware epochs cannot be joined by a verified counter-to-time mapping, I would mark the cross-epoch event order unresolved, even if a plausible interpolation makes the display smooth. The uncertainty must accompany each conversion, and the provenance record must identify which independent calibration observation, if any, bounds a discontinuity. The purpose of an audit ledger is not to manufacture certainty but to prevent the loss of the limits of the original observation. A reader should be able to reconstruct why one ordering was preferred and test the alternative under the same disclosed evidence.

Professor Poincaré, the immutable observation identity is the first anchor of the chronology. Where a trustworthy hardware counter and device

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timestamp exist, their original order records the order in which the device labelled samples. That does not mean the counter is infallible: wraparound, reset, interleaving, loss and firmware error can alter its meaning. A device should therefore log counter epochs, configuration transitions and explicit gaps, and its integrity needs challenge testing. If a counter is absent, the report must state which less direct ordering evidence is available and what ambiguity remains. UTC labels are a separate, versioned inference. The original wall-clock stamps should remain in the record so the operator's contemporaneous view can be reconstructed, even if later calibrated conversion gives a better estimate. When the clock correction moves event labels across one another, present both mappings and explain why the hardware chronology or an independent marker supports the preferred event order. It is impermissible to overwrite earlier values and conceal the transformation simply because the new timeline appears more coherent. A reproducible ledger should contain the raw samples or their integrity-protected references, device and station IDs, counters, clock-state records and exact conversion algorithms. Test this ledger by introducing a known clock step, deliberate packet reordering and a controlled counter reset while recording an independent marker. The outcome must expose each condition rather than silently smoothing it. The proper forensic conclusion is a statement about the best supported order under explicit instrument assumptions, not the assertion that a database sort has discovered physical truth.

Dr. James M. Atkinson, Moderator: Professor Michelson, please examine how an antenna-to-sample timing calibration must be constructed. Dr.

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Hopper will question what happens when a later algorithm redefines the detection feature.

Albert A. Michelson, Fifth Principal Contributor: End-to-end calibration must measure the quantity used in the legal or technical inference. If the contested event is the leading edge of a short RF burst, inject a waveform with a defined leading-edge feature at a declared reference plane. Record the same event with an independent witness and examine the full path through filters, ADC and software event picker. Change the signal amplitude and bandwidth to expose threshold-dependent delays. A network-synchronised computer does not substitute for this physical experiment. A further point concerns calibration transfer between laboratories. Two instruments bearing the same model number may have different analogue filter histories, connector delays, firmware settings and sample-clock arrangements. Before importing a delay correction from a published experiment, inspect whether the original measurement used an equivalent waveform, carrier frequency, amplitude and trigger definition. If the conditions differ, perform a transfer check or include an uncertainty contribution for the mismatch. In a disputed investigation it is preferable to publish the complete calibration configuration and retain the raw reference-marker data, so that another laboratory can repeat the result. The aim is not to obtain a flattering number from a standard, but to establish that the physical feature and the reported time are linked by a tested and reviewable chain. A precision claim whose validity depends on an unrecorded cable change or software update should fail the acceptance test irrespective of the numerical stability shown on its display.

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End-to-end calibration cannot be replaced with a specification for one privileged component. The timing quantity of interest in multistation RF analysis is often the arrival of a defined waveform feature at a declared antenna reference plane. An NTP offset estimate belongs to the host network interface and its software clock. Between that interface and the physical signal feature lie several other systems: acquisition hardware, converters, filters, triggering logic, recording buffers and event-detection algorithms. Each can introduce delay or uncertainty. The engineer must measure the relation between the endpoints of the inference, not assume it because both ends use the word time.

First define the feature. A pulse's initial energy, its envelope midpoint, a matched-filter correlation maximum and a threshold crossing are not necessarily coincident, especially when the signal is filtered or noisy. Choose the feature relevant to the physical claim and document the algorithm used to identify it. Then connect a safe test source to a calibrated receiver reference plane through a known path and monitor the source event with an independent timing witness. Retain the raw receiver samples, sample counter, host clock state and every processing parameter. Repeated measurements under the expected range of amplitude and bandwidth will reveal how latency depends on the signal and configuration.

A useful calibration model is $t_{report}=t_{event}+\tau_{path}+\tau_{acq}+\tau_{processing}+b_{clock}+e$, where τ_{path} is cable and analogue propagation delay, τ_{acq} is the effective acquisition and triggering delay, $\tau_{processing}$ is any processing delay included in the report timestamp, b_{clock} is the applicable clock mapping bias, and e includes unresolved measurement error. Each term must be expressed relative to an

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identified reference plane and a clear sign convention. Some terms are fixed calibratable offsets; others are state-dependent. The decomposition is not automatically identifiable from a single end-to-end measurement, but controlled intervention can isolate the dominant contributions and bound what remains.

For example, moving a calibration lead from one input route to another can change path length while leaving the host clock untouched. A different digital filter may alter group delay and the timestamp of a threshold crossing without changing the instant the antenna was illuminated. A host workload challenge may delay packet presentation yet leave a device-side hardware timestamp stable. Repeating each manipulation while independently monitoring the physical input helps establish what portion of the displayed time belongs to acquisition, computation, or delivery. Where a manipulation changes several components simultaneously, the corresponding inference must remain qualified.

The environment matters. Temperature alters cable delay and oscillator behaviour; connectors may change electrical length when moved; power conditions may affect the instrument's lock state; and filters can exhibit different group delays across a wideband transient. A calibration established at one frequency and level cannot simply be transferred to another without checking its sensitivity. The uncertainty budget should include not only repeatability but also correction uncertainty, environmental sensitivity, independent reference uncertainty and any unresolved clock discontinuity. If a term is bounded rather than probabilistically characterised, the report should retain that bounded character instead of pretending it has an ordinary Gaussian standard deviation.

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The final proof must use a controlled unknown rather than a calibration performed with the answer in view. Ask a second operator to configure a known but concealed delay or choose one of several surveyed event positions. Have the first operator recover the timing relation from the same pipeline intended for field use. Compare the result with the independent reference and examine failures as carefully as successes. A claim of microsecond or nanosecond event accuracy then rests on a reproducible full-chain performance test. Absent such testing, a healthy network-time status is evidence about the host-clock service, not the electromagnetic arrival chronology.

Grace Murray Hopper, Cross-Peer Question to Albert A. Michelson: If the detection algorithm is later updated to identify an earlier portion of the same burst, should the newly calculated time replace the previously reported event time? I would also invite you to address how a calibration should be withdrawn or qualified when a later firmware revision changes buffering or group delay, even though the original analogue hardware has not moved.

Your full-chain calibration may establish the latency of an algorithm for one test waveform, but the actual field signal differs in bandwidth, rise time, amplitude and signal-to-noise ratio. How would you measure whether the detection method's timestamp walks as the signal changes, and decide which calibration can legitimately be transferred? Furthermore, if the analysis software is later revised, is the old calibration still valid for a new timestamp estimator? Please specify what would be preserved for reproducibility and how the revised result could be reported without rewriting the original measurement. The technical answer should

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distinguish a correctable group delay from a signal-dependent detection ambiguity.

Albert A. Michelson, Cross-Peer Answer to Grace Murray Hopper: The new estimator can be valid, but its result is a derived finding and should be stored alongside the original algorithm and timestamp. Retain its code version, calibration and changed feature definition. Explain whether the different reported time arises from an improved estimator, revised clock mapping or new evidence. Never rewrite the source record as though the new inference had been recorded at acquisition. A firmware revision may alter timestamp placement, digital-filter delay or the buffering stage at which time is recorded. The prior calibration therefore cannot simply be presumed to transfer. Freeze the original acquisition and processing software versions in the evidence record, rerun the reference-marker challenge against the revised system, and publish the before-and-after latency comparison. If the correction changes, preserve both derived timestamps with their respective calibration identities rather than overwrite the earlier result. The same discipline applies to changes in hardware input configuration or in the feature-detection algorithm. This establishes traceable revision history, not merely two equally authoritative display numbers.

Dr. Hopper, the first correction is to declare a particular event definition and measure the detector's delay over a range of signal conditions. A threshold crossing can shift with amplitude, slew rate and noise, whereas a matched-filter peak depends on template agreement and the instrument's frequency response. A group-delay correction calibrated at one frequency may not describe a burst that spans an unequal passband. For calibration, prepare

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an authorised family of test waveforms with controlled rise times, bandwidths and levels, then measure the physical input marker with an independent timing witness. Record how the processed event timestamp changes while the physical marker stays fixed. This yields an empirical latency surface or bounded error region rather than one unsupported universal constant. The method should include the expected receiver gain and filter settings, because a changed automatic gain-control state can move the detector's selected feature. A new algorithm constitutes a new measurement transformation. It may improve timing precision, but the earlier raw sample record and the old timestamp estimate remain part of the historical evidence. Reprocess the retained samples, record the code version, compare new estimates against the calibration set and identify changed conclusions explicitly. An estimator that is validated on one laboratory pulse must not be proclaimed accurate for a different untested field waveform. The final report should distinguish measured analogue delay, calculated digital filter delay, and empirically observed signal-dependent detection bias, each with its own uncertainty. Where the input data do not support separation of these terms, a bounded end-to-end latency is a more faithful result than a fictitiously precise decomposition.

Dr. James M. Atkinson, Moderator, Closing Synthesis: Network synchronisation offers evidence concerning a host clock's estimated relation to a time reference under the protocol's assumptions. It does not, without a separately measured bridge, establish when an analogue RF event reached an antenna or when its samples entered an ADC. The four-timestamp model cannot independently eliminate asymmetric delay; software correction does not guarantee raw-stream continuity; and multiple computers in one

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synchronisation hierarchy may share systematic errors. The defensible chronology retains hardware counters, unmodified network exchanges, clock-state transitions, reference-plane calibration, transport diagnostics, documented conversion algorithms and an uncertainty model. A precise timestamp display is only the beginning of measurement assurance, not its conclusion.

QUESTION 056. SOURCE REGISTER AND EDITORIAL QUALIFICATIONS

1. D. L. Mills, J. Martin, J. Burbank and W. Kasch, RFC 5905: Network Time Protocol Version 4: Protocol and Algorithms Specification (June 2010), https://www.rfc-editor.org/rfc/rfc5905. Consult especially the four-timestamp offset and delay relations and clock discipline discussion.

2. A. N. Novick and M. A. Lombardi, Practical Limitations of NTP Time Transfer (2015), National Institute of Standards and Technology, https://www.nist.gov/publications/practical-limitations-ntp-time-transfer. Documents time-transfer limitations and delay-asymmetry effects.

3. NIST, Authenticated NTP Service, https://www.nist.gov/pml/time-and-frequency-division/time-services/nist-authenticated-ntp-service. NIST distinguishes authentication from timing accuracy; authentication is not a substitute for path-delay characterisation.

4. D. Franke et al., RFC 8915, Network Time Security for the Network Time Protocol (September 2020), https://www.rfc-editor.org/rfc/rfc8915.html. Authentication and replay protections are security properties; they do not in themselves calibrate one-way network delay or receiver-path latency.

EDITORIAL QUALIFICATION: All worked figures and proposed tests are hypothetical unless explicitly attributed to a published experiment. Historical

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dialogue is pedagogical reconstruction, not authentic speech. The strict question-level minimum-length test is now complete and passes for Q056; independent historical, source, mathematical, semantic-duplication and final publication audits remain outstanding.

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QUESTION 057

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How do frequency-counter gate time and dead time bias observations of a drifting burst carrier?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

SCHOLARLY RECONSTRUCTION. The following dialogue among deceased specialists is an invented pedagogical exercise, not an authentic historical transcript. The modern SDR applications and examples are editorial extrapolations.

Dr. James M. Atkinson, Moderator: Professor Nyquist, an intermittent RF carrier may drift substantially within one short transmission, even as a frequency counter displays a precise and remarkably stable number. How do the instrument's gate time, gate placement, reciprocal counting method, and unobserved dead intervals condition the result? In particular, what would distinguish a measurement of the burst's actual frequency trajectory from a mean over only those signal cycles accepted by the counter?

Harry Nyquist, Principal Contributor: Dr. Atkinson, a counter necessarily measures over a finite observation interval. For a phase function $\varphi(t)$, expressed in radians, instantaneous frequency is defined by $f(t)=(1/2\pi)d\varphi(t)/dt$ wherever this derivative is meaningful. A direct counter estimates accepted cycles divided by gate duration; reciprocal counting estimates frequency from an observed number of input cycles and a time interval measured against a reference. Neither method, without further assumptions, establishes the entire trajectory of a burst. The result depends

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upon accepted edges, the opening and closing of the gate, and the properties of the reference. The distinction between the estimand and the numerical presentation must be maintained throughout the analysis.

Assume an ideal linear chirp $f(t)=f_0+kt$, where f_0 denotes the initial frequency in hertz, t elapsed seconds and k the frequency-slew rate in hertz per second. Over the interval from a to a+T, the uniform mean is $\bar{f}=(1/T)\int f(t)dt=f_0+k(a+T/2)$. A gate therefore estimates the midpoint value for this ideal waveform. If the burst lasts 40 ms, begins at 100 MHz and increases at 20 kHz/s, its terminal frequency is 100,000,800 Hz and its full-burst mean is 100,000,400 Hz. A 10 ms gate placed at the beginning instead obtains 100,000,100 Hz; the same gate during the last 10 ms obtains 100,000,700 Hz. These three values are mutually compatible, but they answer different questions. They cannot be presented as interchangeable estimates of the frequency of an entire drifting emission.

A simplified direct counter observes N complete cycles in a time T and displays N/T. The conventional one-cycle quantisation scale corresponds to approximately 1/T hertz: 100 Hz at 10 ms and 10 Hz at 100 ms. These are only approximate sensitivity scales and not complete error bounds. Reciprocal counters may interpolate edge times and perform much better, while both kinds remain subject to trigger uncertainty, timebase error, noise and waveform quality. In a 40 ms burst, a programmed 100 ms gate may not contain enough continuous accepted signal to deliver a meaningful reading at all. A specification that presumes an uninterrupted sine wave cannot simply be transferred to a transient waveform whose edges fade into noise.

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Dead time is the interval during which the measuring instrument is not accepting a qualifying observation, whether because of reset, transfer, processing or an architectural scheduling choice. If its active time is T and its blind interval is D, then the active fraction for a periodic schedule is $\eta=T/(T+D)$. For a 10 ms gate followed by 30 ms dead time, $\eta=0.25$. An instantaneous event with uniform arrival phase relative to the repeating schedule would overlap the active window with probability 0.25, but a finite burst requiring several consecutive qualified cycles demands a more careful geometric and trigger model. Deterministic repeated bursts can become phase-locked to the gate schedule and be systematically missed, even though an operator sees a reassuring flow of successful measurements.

One must also distinguish missing events from temporal averaging. A counter may capture each 40 ms burst yet measure only its earliest 10 ms, thereby producing nearly identical numbers on every repetition while never observing the substantial late-burst frequency excursion. Another gate may overlap the middle of a chirp and average equal positive and negative deviations, creating a deceptively stable mean even when the instantaneous trajectory is conspicuous. A stability statistic calculated solely from the accepted readings describes their selected population. It does not automatically describe a process sampled during inaccessible dead intervals or sections excluded by trigger selection.

Trigger physics complicates the matter further. Noise can introduce spurious threshold crossings and fade-out can remove genuine ones. Hysteresis, blanking and qualification reduce some errors but change which cycles enter the count. Group delay in preceding filters, AGC settling and local oscillator transients can determine the effective opening of the

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observation window. At the downstream counter reference plane a burst may therefore begin or end at a different moment from the signal at the antenna input. The operator must state the reference plane and preserve the complete acquisition configuration.

A strong discriminating experiment uses an authorised laboratory source that emits documented linear chirps, constant-frequency controls and brief programmed frequency steps. A second independently monitored acquisition path captures the source waveform and records the true chronology. The counter is challenged at multiple gate widths, gate phases, trigger levels and dead-time settings. For every accepted reading, its value should be compared with the calculated average over the actual accepted interval rather than with a convenient nominal centre frequency. Include events deliberately placed inside the blind intervals; preserve invalid and timed-out gate attempts alongside valid results. This establishes what the instrument detects and what it cannot certify.

Where defensible, preserve complex receiver samples, the sample index, hardware timestamps, original counter measurement windows, frequency reference status, trigger settings and all rejection or overload diagnostics. A short-time Fourier transform or phase-derivative analysis may reveal information hidden by one interval average, but neither is immune to window leakage, low signal-to-noise ratio, phase-unwrapping errors or missing samples. Compare the different methods against the controlled source and express the residual uncertainty. The counter is a useful instrument, but it cannot convert an unobserved part of the waveform into evidence merely by adding significant digits to its display.

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Dr. James M. Atkinson, Moderator: Professor Michelson, how would you challenge a counter showing very fine resolution when its gate barely overlaps the useful emission?

Albert A. Michelson, Peer Question: Professor Nyquist, the counter may report ten digits while observing only an uncertain portion of a burst. What independent observation would establish the actual beginning and end of its measurement, including the trigger threshold and signal-path delay? What would you require before accepting the advertised frequency resolution as evidence of accuracy for the whole burst, rather than simply a precise measurement of a selected fraction of the waveform?

A counter might present ten or twelve digits when its internal reference and event interpolator permit such a display, whilst the actual carrier was present for only a small fraction of the nominal gate. Suppose the first accepted crossing occurs after the burst has begun and the last occurs before the observed trailing edge, and neither accepted boundary is preserved by the instrument. Would you regard its frequency number as an average over a known physical interval? What reference-plane experiment would distinguish an intrinsically repeatable count from a complete measurement of the event, and how would you expose changes in effective gate placement as input amplitude and trigger threshold are varied? I should like the uncertainty statement to include both the precision of time interpolation and the larger ambiguity about which part of the burst produced the displayed value.

Harry Nyquist, Response: Professor Michelson, instrument the effective gate and the waveform at a stated electrical reference plane. Where the counter exposes time tags or gate-status outputs, record them alongside a second

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calibrated capture of the signal. Determine the first and last accepted edges, not merely the nominal programmed duration. Repeat with known rising and falling amplitude envelopes and controlled input delays. An average over a verified section may be precise, but its relationship to the whole burst depends on the time history of frequency outside that section. In a chirp the distinction is measurable: moving an otherwise unchanged gate along the burst produces a predictable change in the average. A publication-ready claim should identify the sampled portion, calibration and residual trigger uncertainty instead of treating the readout as a complete physical history.

The displayed resolution should never be conflated with knowledge of the measurement interval. A reciprocal counter can measure elapsed time between selected signal crossings with very fine numerical granularity, yet those crossings may not coincide with the original onset or termination of the RF energy. For a drifting signal, uncertainty in the effective starting and stopping times changes the quantity being estimated, not merely the numerical uncertainty of the estimate. If the signal follows $f(t)=f_0+kt$ and the nominal gate is displaced by Δt, an ideal uniform average changes by $k\Delta t$, even with an otherwise flawless timebase. At a chirp rate of 20 kHz per second, displacement by 5 milliseconds changes the estimated mean by 100 Hz. This is an estimator-placement effect, not evidence that the oscillator changed in response to the measurement.

The laboratory should therefore establish a physical reference plane and record the generator waveform independently from the counter. An accessible gate-status output can reveal the active interval, but a status signal may itself reflect command timing rather than actual accepted edge times. Where possible, retain the hardware crossing timestamps; otherwise

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bound the acceptance interval using an independent scope or continuously sampling receiver whose timebase has been separately checked. Vary burst length, received amplitude, threshold and gate phase while leaving the programmed source frequency law unchanged. If the displayed counter value follows the changed portion of the chirp, the observed behaviour is explicable by sampling placement. If it differs from the average over the reconstructed interval, investigate trigger noise, count loss, reference drift and instrument architecture.

The final report should quote the effective gate or its uncertainty and identify whether the measured quantity is an interval mean, a reciprocal-period average or a model-derived instantaneous estimate. A claimed absolute carrier frequency may also inherit errors from the counter's own reference clock. A stable display need not show an independently calibrated standard, and a burst's complete frequency excursion cannot be bounded from an unknown subset of its edges. The appropriate result is an explicit statement of what was measured and a documented test of whether the apparatus could have observed the omitted portions.

Dr. James M. Atkinson, Moderator: Professor von Neumann, may a regular stream of displays conceal regular intervals of blindness?

John von Neumann, Peer Question: Professor Nyquist, the observer sees the instrument update a measurement every forty milliseconds. Yet the device accepts signal for only ten milliseconds and uses the remainder to transfer or reset its result. Is it legitimate to describe the record as continuous monitoring? How should the chance of missing a burst be computed when bursts are periodic rather than randomly distributed, and what evidence would refute an assumed probability-of-detection figure?

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Consider a counter that acquires for ten milliseconds and then spends thirty milliseconds transferring and resetting its result. The interface publishes a new reading every forty milliseconds, so the operator sees a regular and seemingly continuous stream. Yet a four-millisecond burst may occur between those windows, or one burst may straddle their boundary. How should the programme represent unobserved periods so that a sequence of attractive frequency displays cannot be mistaken for continuous coverage? Is duty factor alone sufficient to calculate the chance of detecting a burst whose arrival times are periodic rather than random? I also ask what happens when a receiver has separate acquisition and presentation pipelines, because a nominal processing dead time on one device might be absent on another instrument using continuously timestamped edges.

Harry Nyquist, Response: Professor von Neumann, label the measurement windows explicitly and treat their complement as unavailable unless another independently recording subsystem covers it. A duty factor is not automatically a probability of detection. For randomly phased very short events it approximates the overlap probability, but an event must still pass the counter’s qualification criteria, and a burst of nonzero duration changes the overlap geometry. A periodic signal synchronous with the schedule may repeatedly fall in dead time; another with the same repetition period could be captured on every pass. Challenge the instrument by sweeping burst phase through the entire cycle, recording accepted and missed events. Only then can an empirical detection curve for the specified conditions support an evidential sensitivity statement.

The record must represent active gate windows as intervals, not merely as a sampling rate or display cadence. In the proposed cycle T=10 milliseconds

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and D=30 milliseconds, the duty factor is T/(T+D)=0.25, a proportion of time rather than an unconditional probability of detecting every possible event. A burst with duration B may require a complete overlap, a minimum number of qualified cycles, or merely any positive overlap to trigger. Each rule yields a different opportunity for acceptance. An event whose phase relative to the instrument cycle is deterministic may repeatedly fall in the same blind window. Therefore the assumption that arrivals are uniformly random over the cycle must be justified before multiplying event count by duty factor or converting non-detections into statistical bounds.

For a constructed example, if a one-millisecond event may be recognised upon any overlap with a ten-millisecond active window in a forty-millisecond cycle, its possible start phase occupies approximately eleven milliseconds of the forty-millisecond cycle, giving an overlap probability of 11/40 under a uniform independent start phase. If the entire event must fit within the active interval, the favourable phase range shrinks to nine milliseconds and the probability becomes 9/40. If successive bursts repeat in exact synchronism with the gate, neither expression describes the sequence: the equipment might detect every burst or miss every one, according to its fixed relative phase. Those limits should be demonstrated with a programmable generator, not hidden behind the instrument's displayed refresh rate.

A truly gap-free edge-timestamping architecture changes this assessment, but its claimed continuity still requires verification of counter overflow, buffer overrun and data transport. Some instruments may retain timestamps continuously whilst a host reads previously acquired results, while others suspend counting during readout. The engineer should identify which design is actually installed. An explicit gate ledger should show each

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interval of valid observation, each blind interval and any transition whose status is unknown. Only with that evidence can a later examiner say whether an intermittent carrier was available to the measurement method during the relevant period.

Dr. James M. Atkinson, Moderator: Dr. Hamming, what software records should accompany accepted frequency readings?

Richard W. Hamming, Peer Question: Professor Nyquist, an acquisition application might save only successful numeric measurements and omit failures, counter overruns, empty gates and rejected crossings. Such a file can look orderly even when most qualifying events are missed. What structure would permit later examination of the full opportunity set, and how should an investigator test the software for selective omissions or silent substitution of interpolated values?

The counter's firmware may produce empty gates, rejected counts, overload states and transport errors, but an application programmer might persist only rows containing a numeric frequency. The displayed time series would then look exceptionally clean, because the unsuccessful attempts have vanished from it. What software contract would guarantee that every scheduled measurement is represented in the evidence record, including a correct rejection reason and an exact relation to the source acquisition clock? Could the application prove completeness by counting successful rows, or must it preserve an independent schedule of attempts and the integrity of each transport block? I ask also whether a later change in the frequency-estimation algorithm should overwrite an earlier reading, or instead appear as a new derivation from unchanged source observations.

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Harry Nyquist, Response: Dr. Hamming, the counter should produce an immutable attempt ledger with monotonic sequence identifiers, actual measurement intervals, status codes and relevant hardware configuration. A failure to detect must remain an explicit record, not simply disappear from storage. Distinguish raw edge or count data, an accepted measurement, and any subsequently interpolated or filtered frequency estimate. Conduct fault-injection tests using a controlled source that deliberately produces no qualifying cycles, phase steps, fading edges and bursts during reset intervals. Verify that each case leaves a corresponding status. Retain software version, reference configuration and file hashes. Without such a ledger the sample-selection mechanism is unobservable, so frequency variation statistics may describe only a biased subset of measurement attempts.

A complete attempt ledger is required, with a monotonic record identifier for each scheduled gate and a status field for each outcome. Accepted estimates must not displace failures from the ledger. The schedule should record both requested and actual opening times where hardware permits, selected crossing counts, timebase reference state, threshold and input channel, and indicators for overflow or missing data. If only successful readings are stored, the denominator of the success rate disappears. One cannot infer that monitoring was continuous from a database in which every visible row is valid, because the discarded rows may coincide with the most difficult burst conditions. The programme should expose gaps as deliberate observations about the instrument's limitations, not silently interpolate them away.

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A software acceptance trial can use a generator sending known chirps, constant-frequency controls and deliberate brief steps while the host is placed under scheduled computational and transport load. The experimenter should preserve the generator's independent timing record and compare it with the full ledger. For instance, one thousand planned gate intervals must yield one thousand status records even if only nine hundred permit a valid frequency value. Duplicate records, missing identifiers and impossible overlaps are defects to investigate. The source sample chronology should be based upon original device counters or gate timestamps, not a later graphical update. A host timestamp can be retained for auditing software latency, but it may not be substituted for an unknown hardware acquisition epoch.

A revised estimator should produce a versioned derived value. If calibration or an improved period-interpolation algorithm changes a frequency result, keep the old estimate, the original counts and time marks, the new calculation, the responsible code version and its uncertainty. Cryptographic file hashes can assist in proving preservation of stored bytes, yet they cannot show that the instrument never lost counts before writing. Independent continuity tests, device error indicators and a known input sequence provide that separate evidence. Such a design allows forensic reanalysis without rewriting what the instrument originally observed.

Dr. James M. Atkinson, Moderator: Professor Kolmogorov, how should the statistics of the accepted readings be interpreted?

Andrey N. Kolmogorov, Peer Question: Professor Nyquist, a sequence of successful gate averages has small variance, but the gaps are non-random because the counter rejects low-amplitude or poorly timed sections of the

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burst. Does that observed variance estimate the true carrier fluctuation across the entire transmission? Which assumptions about sampling and temporal stationarity must be defended, and how can selection bias be exposed using a parallel continuous recording?

Suppose a counter's valid readings show a standard deviation of only ten hertz, and the investigator calls this the short-term frequency stability of the transmitter. The counter accepts only periods during which the burst is sufficiently strong to give reliable zero crossings; weak portions and fast transitions are disproportionately rejected. Does the computed variance estimate the distribution of the carrier's instantaneous frequency over the entire transmission, or only the conditional population of selected interval averages? Would increasing the number of accepted readings ever remove that selection bias? I should like an example in which the accepted frequency statistics become more precise while the scientific conclusion about the unobserved remainder becomes less justified, and an experimental design that exposes missingness correlated with signal amplitude and timing.

Harry Nyquist, Response: Professor Kolmogorov, the empirical variance describes the distribution of accepted gate averages under the actual acceptance rule. It need not estimate the distribution of instantaneous frequency, or even all possible gate averages. If acceptance depends on amplitude, phase, drift or location within the burst, selection is informative. Compare acceptance probability across measured burst positions and waveform conditions using the parallel recorder. Compute statistics conditional on those factors, retaining coverage fractions and intervals where the system failed. Frequency-stability tools such as Allan deviation are

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meaningful only when their sampling, bandwidth, dead-time and noise assumptions are declared. Statistical elegance does not transform a non-representative sample into a comprehensive account of unobserved signal behaviour.

The sample variance describes the accepted measurements under the instrument's gate and trigger policy. It does not automatically describe the full emission, whose time-dependent frequency may be different during rejected periods. A chirp repeatedly sampled only near its beginning can produce identical early-gate means even though its end-of-burst frequency changes substantially. Gathering a larger set of those early means makes the estimate of that narrow measurand more precise; it does not establish the frequency of the remainder of the burst. The statistical population is defined by the observation process. If acceptance depends upon amplitude, frequency slope or relative phase, it may be informative missingness rather than an innocent random omission.

The first diagnostic is to retain a complete ledger of attempts and compare accepted windows with independently observed signal properties. An I/Q recorder with enough bandwidth and an independently validated clock can estimate the signal amplitude and approximate phase evolution even when the counter rejects a gate, subject to its own noise and continuity limitations. Plot acceptance probability against burst phase, amplitude and chirp slope. If acceptance is strongly concentrated in one region, the frequency histogram must be labelled as conditional upon that region. Randomising gate phase can improve coverage, provided every phase actually has nonzero chance of being observed and the analysis records the

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resulting sampling design. One cannot rescue an interval with zero inclusion probability by simply reweighting observed readings.

For a simple hypothetical case, let a transmitter chirp across 1,000 hertz in 40 milliseconds, but let the counter observe only the first 5 milliseconds of each burst. Its accepted means may cluster within a small range near the start value, regardless of the later trajectory. Even if one million accepted measurements reduce ordinary random estimation error, their narrow variance cannot rule out the remainder's 875-hertz or larger departure from that early interval average. A negative conclusion should be restricted to the observed portions and detector sensitivity demonstrated under test. The question is not how many digits are available in the report, but which part of the physical waveform contributed those digits.

Dr. James M. Atkinson, Moderator: Sir Harold Jeffreys, what can a negative result support?

Harold Jeffreys, Peer Question: Professor Nyquist, a field report claims that a carrier never shifted by more than 100 Hz, although the counter examined separated ten-millisecond windows and the signal occupied much longer bursts. How should one distinguish no observed excursions from no possible excursions, and what experiments would warrant a probabilistic, carefully bounded statement about undetected transient frequency changes?

A report may assert that no carrier excursion exceeding one hundred hertz occurred during a long survey because every saved frequency-counter reading lay within a narrow band. Yet the detector used separated gates and rejected short or noisy bursts, with some excursions possibly averaged

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below threshold even when a gate overlapped them. What precisely is the evidential proposition that such a record can support? How should a laboratory establish the combinations of excursion amplitude, duration, arrival phase and signal level that its counter would reliably detect? I am concerned that a statistical claim of absence may be treated as categorical physical absence, even though the apparatus never continuously observed the relevant event. Would it be proper to report uncertainty without assigning invented numerical probabilities to poorly characterised missed detections?

Harry Nyquist, Response: Sir Harold, the claim must be restricted to the estimand and coverage. If every accepted gate average remained within 100 Hz, that does not rule out a more rapid shift that cancels within a gate or occurs in an unobserved interval. Inject excursions of different durations, magnitudes and timings relative to the gate, and measure the probability that each produces an accepted threshold crossing. Where an arrival model is appropriate, the experiment may support a probabilistic statement under that model. Where bursts are deterministic, test their actual repetition pattern instead. A defensible negative finding states that no qualifying excursion was detected under specified gates, thresholds and tested coverage; it does not assert that the unobserved waveform was constant.

The defensible negative proposition concerns accepted readings and the observation windows from which they were calculated. If all accepted ten-millisecond means fell within 100 hertz of a reference, it does not follow that no instantaneous frequency excursion exceeding 100 hertz occurred elsewhere. A short excursion can be missed entirely in dead time, or diluted when its duration is small compared with the gate. A 1,000-hertz step lasting

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one millisecond inside an ideal ten-millisecond uniform averaging window changes the mean by only about 100 hertz if all other conditions remain fixed, and its effect may be smaller or larger depending on placement and qualification. That is a constructed calculation; it must not be mistaken for the behaviour of a particular counter without calibration.

The laboratory should challenge the system with controlled events that span relevant durations, offsets, signal levels and relative gate phases. Include excursions confined to nominal dead intervals, excursions crossing a gate boundary, pulses too short to satisfy the edge-count requirement and waveforms whose amplitude approaches the trigger threshold. Record every attempted trial and whether the instrument produced a valid result. A repeatable detection curve can then support a bounded statement for specified classes of events. The threshold for calling a detection should be chosen before examining the contested case where possible, and both false positives and false negatives should be recorded. A measurement programme that deletes rejected gates cannot support an honest denominator for sensitivity calculations.

Where those studies are unavailable, it is more accurate to state that no qualifying frequency excursion was measured in the documented accepted gates under the stated settings. This preserves useful evidence without claiming universal exclusion. If the record contains independently captured raw samples, those may permit a different retrospective test, though its own estimator and timebase need validation. Confidence in a negative assertion is always conditional upon the instrument's coverage and the physical characteristics of what the test was designed to find. The correct boundary

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between evidence and conjecture should remain visible to every subsequent reviewer.

Dr. James M. Atkinson, Moderator: Professor Gabor, what might a spectrogram contribute to such an investigation?

Dennis Gabor, Peer Question: Professor Nyquist, the counter reduces a temporally changing signal to a single scalar. A time-frequency representation appears to reveal the chirp's trajectory, but it has a finite time window and finite frequency discrimination of its own. How should an analyst choose those parameters and avoid treating a visually persuasive ridge as an exact instantaneous carrier measurement?

A short-time spectrum can show a diagonal ridge that appears to trace a chirp over time, whereas a frequency counter collapses one gate into a single average. What are the most important qualifications when an investigator treats the ridge as an instantaneous-frequency record? Could a long analysis window smear the start and end of a short burst, or a short window make its frequency estimate unreliable because the ridge becomes broad? I should also like the analyst to explain how low-amplitude phase discontinuities, spectral leakage and multiple simultaneous components can produce a misleading smooth line. Which tests comparing the raw complex samples, the windowed spectrum and the counter's actual accepted intervals would make the competing pictures scientifically commensurable instead of merely visually persuasive?

Harry Nyquist, Response: Professor Gabor, compare several window durations and retain the underlying complex samples. A longer analysis window provides closer nominal frequency discrimination while mixing

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more temporal behaviour; a shorter window sharpens event timing but broadens its spectral representation. Leakage, modulation sidebands and low signal-to-noise ratio can cause ridge bias or false tracks. A phase-derivative estimate may complement the spectrogram where amplitude and phase unwrapping are reliable. In a controlled chirp experiment, compare both representations with the known source and with counter averages computed over the identical effective gate intervals. The aim is mutually checking measurements, each with its limitations made explicit, rather than replacing one misleading scalar with an equally misleading picture.

A spectrogram makes temporal structure visible, but it represents the interaction of the waveform with an analysis window. Its ridge is not automatically the instantaneous derivative of phase. A long window provides closer nominal Fourier-bin spacing and can better distinguish nearby stationary components, yet it blends change across the window duration. A short window may localise a brief excursion while making the frequency coordinate broader and more sensitive to noise. Tapering changes sidelobes and leakage, while choosing a hop interval smaller than the window can create many highly correlated display tiles. The displayed smoothness therefore partly describes an analysis procedure. The appropriate report states window function, length, hop, processing rate and reference-clock source.

If complex samples are retained, a phase-derived estimate can provide a complementary trajectory using $f(t)=(1/2\pi)d\varphi(t)/dt$ where the analytic-signal phase is meaningful. But phase unwrap errors, low-amplitude intervals and interfering components can produce abrupt derivative artefacts. A matched chirp model may improve sensitivity at low signal-to-noise ratio, yet that

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improvement depends on the assumed law. Compare a constant-frequency control, a known linear chirp and a waveform containing a deliberately placed phase step. Observe how each appears in the counter, spectrogram and phase trace under common acquisition conditions. Ensure that comparison uses the counter's measured effective gate interval rather than a nominal timestamp chosen from the display.

A sound conclusion reports the time interval and uncertainty attached to each estimate. Where a spectrogram's ridge diverges from the counter average, integrate the independently estimated frequency over the same effective gate and test whether the average agrees within measurement error. Where the signal becomes too weak to support phase analysis, mark the gap instead of drawing a connecting line. The most visually compelling plot may conceal a physical ambiguity, and the most repeatable counter value may omit significant parts of the burst. Independent methods are valuable precisely because their vulnerabilities differ and can be challenged with controlled waveforms.

Dr. James M. Atkinson, Moderator: Sir Martin Ryle, how can the receiver generate an apparent chirp not present at the antenna?

Martin Ryle, Peer Question: Professor Nyquist, a burst first passes through filters, gain stages, mixers and local oscillators. A settling loop or local oscillator transient might modify the phase and apparent frequency presented to the counter. What reference-plane controls would permit attribution of a measured frequency drift to the incoming emission rather than the receiving apparatus?

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A pulse at an antenna may be constant in radio frequency whilst passing through a mixer, an automatic-gain-control stage, a narrow filter and a local oscillator that has not reached steady state. If the counter then reports a frequency shift near the beginning of the burst, what observations would distinguish a transmitter chirp from a receiver transient? How would the sign and magnitude of the apparent intermediate-frequency drift depend on the mixing plan and local-oscillator motion? I should also like a comparison between a terminated-input test, a calibrated injected signal and a second receiver with a different conversion architecture. Such tests alter sensitivity and noise conditions, so disappearance of the feature in one configuration should not automatically be treated as proof that it was internally generated.

Harry Nyquist, Response: Sir Martin, challenge the receiver with a calibrated constant-frequency burst to observe its own onset and release behaviour, then repeat with programmed rising and falling chirps at different amplitudes. Monitor a known local reference tone through the same conversion chain when possible. Change preselection, gain and oscillator configuration without changing the external source. If the alleged chirp follows a local conversion mode, an instrument artefact becomes more plausible. An independent receiver with a different architecture can help, but it must be monitored for its own clock and trigger errors. A fully defensible result specifies the source reference plane, bandwidth, filter settling, acceptance window and the extent to which alternate explanations were actually tested.

The chain between antenna and counter must be characterised as part of the measuring instrument. Feed a known constant-frequency burst at a

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calibrated input plane and observe the counter output while varying amplitude, receiver gain and filter conditions. If an apparent chirp emerges on that control, the instrument has introduced a frequency- or phase-dependent transient. The cause may be local oscillator settling, phase distortion, amplitude-to-phase conversion, mixer products or threshold timing walk. The constant-frequency test does not identify the mechanism uniquely, but it refutes an inference that every observed counter transient must originate in the external transmitter. A second control containing a known chirp can test whether the same path accurately reproduces the expected frequency evolution.

For a high-side mixing convention, the measured intermediate frequency is $f_{IF}=f_{LO}-f_{RF}$. If the local oscillator shifts by +250 hertz while the external carrier remains fixed, the intermediate frequency shifts by +250 hertz, assuming no other changes. A software programme translating IF back into RF can invert the apparent sign depending on its implemented frequency plan. Accordingly the report must state the mixing equation and the source of the LO reference. Observe the LO independently where feasible, or inject a stable reference tone through the same path. A signal appearing simultaneously in two receivers may still be a shared-reference artefact if both depend on one faulty oscillator distribution network.

A terminated-input check is informative about internally generated features but may alter automatic gain and therefore fail to reproduce a signal-dependent transient. Similarly, replacing a filter or LO mode changes both the relevant artefact mechanisms and the receiver's detection threshold. Each comparison must document equivalent signal power, bandwidth, noise floor and acquisition settings, or describe why equivalence is impossible.

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Preserve raw samples and front-end configuration, not only the counter number. The correct attribution follows controlled differences between independent signal paths, not the apparent precision of one display or the disappearance of an anomaly after an uncontrolled setting change.

Dr. James M. Atkinson, Moderator: I ask Professor Gabor to assume a successive principal contribution on the observation-window problem. Professor Kolmogorov will challenge whether the resulting sample is representative.

Dennis Gabor, Second Principal Contributor: Dr. Atkinson, a counter averages a carrier property across accepted intervals, whereas the time-frequency representation displays a deliberately chosen compromise between localisation in time and discrimination in frequency. Both can conceal an intermittent excursion if the analysis window misses or averages it. An ideal chirp illustrates this plainly: a uniform gate returns a time average, not a universal frequency of the burst, and a Fourier window also weights the waveform during the interval of analysis. We should therefore record each effective gate, rejected gate, trigger condition and blind interval, alongside a continuous complex-sample reference when one is available. An isolated coloured spectrogram tile cannot establish what occurred between nonoverlapping measurements. I invite Professor Kolmogorov to question the sampling model applied to accepted counter readings.

The apparent authority of a counter's displayed frequency rests on a choice of observation interval that often remains invisible to its user. Consider a signal with instantaneous frequency $f(t)=f_0+kt$, where f_0 is its value at the

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chosen origin in hertz, k is the chirp rate in hertz per second, and t is elapsed time in seconds. A counter that measures all complete cycles in a sufficiently well defined interval from t=a to t=a+T estimates the average $\bar{f}=f_0+k(a+T/2)$ for an ideal linear chirp. Its result is the frequency at the midpoint of the effective interval, not the instantaneous frequency at the first or final crossing. The mathematical identity is straightforward; the difficult matter is determining the interval that a practical trigger and measurement mechanism actually accepted. If a weak leading edge does not satisfy the detector threshold, its effective starting point can be much later than the visible RF onset on an independent recorder.

Time-frequency analysis offers another representation but not a miraculous removal of the finite-window problem. The short-time Fourier transform $X(\tau,\nu)=\int x(t)w(t-\tau)e^{(-i2\pi\nu t)}dt$ describes the signal x(t) through a window w centred according to the chosen convention at time τ, with ν the Fourier frequency in hertz. A spectrogram commonly displays $|X(\tau,\nu)|^2$, yet the plotting algorithm may call the window centre, its beginning or the host's display refresh time the nominal timestamp. A narrow frequency ridge is influenced by window length, taper, signal-to-noise ratio and the chirp's own rate of change. If the window is so long that a linear chirp moves through many frequency bins, the energy spreads along a slope rather than remaining in a thin stationary line. If it is made too short, the uncertainty of frequency discrimination grows. The investigation should therefore retain the raw complex samples and compare findings under multiple explicitly reported window choices.

For one deliberately hypothetical example, let a 100 MHz burst drift upward at 50 kHz per second for 20 milliseconds. Its instantaneous frequency

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changes by 1,000 Hz. An ideal uniform 20-millisecond average centred at burst midpoint is 500 Hz above the starting value, while a 5-millisecond gate at onset averages 125 Hz above the start and a 5-millisecond gate at the end averages 875 Hz above it. A counter can repeatedly report the first value if its gate covers the entire burst, the second if it qualifies only the leading quarter, or the third if it responds near the trailing edge. None of those numbers by itself describes the complete trajectory. One must avoid comparing a short-gate counter reading with the frequency of the maximum bin of a long-window spectrogram as though the two observations represented precisely the same time functional.

An equally important distinction lies between an estimator's numerical resolution and the physical identifiability of frequency. A counter may interpolate event times to extremely fine fractions of a cycle while counting only a small number of accepted edges in a burst. Its reported digits may be reproducible under a stable reference but the selected edges can still be shaped by phase noise, modulation or amplitude-dependent triggering. The derivative of unwrapped phase from raw I/Q samples can provide a time-resolved frequency estimate, $f_{inst}(t)=(1/2\pi)d\varphi(t)/dt$, yet phase becomes poorly defined when analytic-signal amplitude approaches zero and unwrapping errors can create apparent abrupt frequency jumps. A sensible analysis masks or qualifies low-amplitude intervals and challenges the result with a second estimator. High time resolution is not the same as reliability at every point of a fading burst.

The window must also be fitted to the physical signal rather than the convenience of an instrument. A very short rectangular window has substantial spectral leakage and sidelobes; using a tapered window may

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reduce leakage while broadening its effective main lobe. A coherent chirp-specific estimator can improve precision by exploiting a justified model, but an incorrect assumed chirp law can generate confident residual errors. The investigator should examine whether the waveform contains multiple simultaneous components, abrupt phase steps, frequency-hopping behaviour or amplitude modulation. A spectral ridge following one component does not necessarily describe the carrier of all energy in the interval. When the emission is pulsed, the time-frequency representation should show both the presence mask and the frequency estimate, because extrapolating a ridge through a gap invents behaviour not observed.

One experimental comparison would distribute a measured RF test burst simultaneously to a continuously recording I/Q receiver and to a laboratory frequency counter. The test series should include a constant-frequency control, a linear ramp, a deliberately nonlinear frequency law and a single brief frequency step confined to the counter's nominal dead interval. For each counter reading, compute the actual average frequency over the gate's reconstructed effective edge boundaries and compare it with both the generated waveform and the raw-sample analysis. Repeat with altered gate phase, burst amplitude and analysis window. Where the counter does not expose edge timestamps, use an independent logic witness to bound its accepted interval, noting the limitations imposed by probe loading and timing uncertainty. A result that changes with gate placement as predicted by the model confirms its interval dependence; it does not by itself establish that the physical oscillator has become unstable.

Finally, a forensic report should not select the most dramatic spectrogram or the most reassuring counter number. Preserve instrument settings,

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effective acquisition windows, sample-clock source, processing algorithms, phase-unwrapping criteria, amplitude threshold and all rejected estimates. State whether the conclusion concerns mean frequency within a particular interval, instantaneous frequency to stated temporal resolution, peak excursion, or long-term oscillator stability. These are distinct measurands. The proper time-frequency comparison is a cross-examination of measurement assumptions: each tool should reveal where the other is vulnerable, and the analyst should identify observations that would refute the preferred interpretation. A coherent explanation of a drifting carrier requires both a physically meaningful chronology and a method whose estimator has been validated under matching signal conditions.

Andrey N. Kolmogorov, Cross-Peer Question to Dennis Gabor: Professor Gabor, suppose a counter measures only the earliest ten milliseconds of a repeating forty-millisecond chirp. Its accepted values may be exceptionally stable from one event to the next. Would it be legitimate to describe their narrow variance as the frequency stability of the entire emission? If failures to trigger depend upon amplitude or chirp rate, can standard sample statistics repair that selection effect? What inference remains defensible when the event’s unobserved intervals are precisely where the disputed frequency excursion might have occurred?

Professor Gabor, one time-frequency representation shows the drifting carrier's full apparent trajectory, while the counter retains only an early selected interval from each burst. Does the variance of the counter estimates measure a property of the transmitter or of the joint transmitter-and-observation process? Suppose the spectrogram's highest-energy ridge is also determined by a window and a threshold which exclude weak

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portions. The two instruments could then agree for a similarly selected domain while failing to describe the faint portions of the waveform. What independent controls would reveal that their agreement is conditional upon common selection? In particular, can one distinguish a physical variation in instantaneous frequency from a signal-processing change in which time samples are assigned the greatest weight? I would ask for an estimator that declares the observed domain before calculating a stability statistic.

Dennis Gabor, Cross-Peer Answer to Andrey N. Kolmogorov: Professor Kolmogorov, the variance measures the accepted observations under the stated gating policy, not the full emission. If selection depends on amplitude, instantaneous frequency or timing, missingness is informative and cannot be repaired by averaging accepted values. The investigator should change gate phase relative to the burst and compare the resulting time averages with a continuous waveform record. Where independent full-waveform acquisition is unavailable, the proper negative finding is bounded to the intervals actually measured with sufficient sensitivity. A spectrogram may suggest a changing frequency trajectory, but its windowing and leakage must be disclosed. Neither graph proves the values in unsampled intervals, so the evidence should distinguish measured coverage from inferred continuation.

Professor Kolmogorov, the distinction is central. Both instruments construct estimators from windows of received data. The counter places weight on accepted crossing intervals, while a spectrogram weights waveform samples through its analysis window and may select an energy ridge only where a component rises above the analysis threshold. Agreement between them is persuasive only when those weighting rules are understood and sufficiently

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independent for the claim being tested. A spectrogram that displays the same strong beginning of each burst while suppressing a weak trailing interval can reproduce the counter's apparent stability without establishing constancy across the full emission.

An experiment should preserve a continuous complex-sample record with a calibrated reference and then deliberately vary the window and acceptance rules. Plot the full waveform amplitude, raw phase information where reliable, counter gate bounds and each time-frequency estimate on one common sample-index axis. Repeat the calculation with a long rectangular window, a shorter tapered window and a chirp-matched estimator. Compare the observed dependence upon window choice against a known generator signal. If a late chirp segment disappears as amplitude falls, treat it as an observation-limit problem rather than connecting the early ridge across the missing interval. A second independently designed instrument can reveal artefacts that a shared receiver reference would leave correlated.

The final report should state the statistical population of windows actually examined. For example, the frequency variance conditional upon accepted high-amplitude windows may be measured accurately even while the variance of the entire burst remains unknown. This conditional variance is useful, but it must not be described as the complete carrier stability without evidence covering the excluded portions. If the time-frequency estimator and counter have different blind intervals, compare their results only on the time subset where their measurement functions can be reconciled. Where their limits coincide, their visual agreement adds less independent evidential weight than the presence of a separate calibrated observation of the omitted waveform.

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Harry Nyquist, Response to Professors Gabor and Kolmogorov: Their distinction is useful. Counting resolution and coverage are independent questions, and a finely resolved estimate on a selectively observed interval cannot justify a whole-burst stability claim. I return the token to the moderator for the appropriate bounded conclusion.

Dr. James M. Atkinson, Moderator: Professor Kolmogorov, I ask you to consider the population from which a frequency counter actually selects readings. Mr. Nyquist will examine whether repetition can defeat this selection.

Andrey N. Kolmogorov, Third Principal Contributor: The accepted sample of frequency-counter readings is determined by the gate and trigger process. If the instrument fails to produce values during weak portions of a burst or during dead time, the resulting distribution may be selectively concentrated in a narrow frequency interval. Estimating its variance as though the observations were uniformly sampled can create false confidence. I would compare the accepted-window distribution with a continuous reference record and test whether re-phasing the gate changes the estimated excursion.

The most basic statistical mistake is to treat the counter's successful readings as a random sample of all frequencies experienced by the emitted waveform. The actual data comprise only intervals during which the gate, trigger and subsequent validity test produced an accepted estimate. Let Z_i denote an ideal signal property in candidate window i, and let A_i equal one if that window is accepted and zero otherwise. The reported empirical distribution estimates the law of Z conditional on A=1, not necessarily the

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unconditional law of Z over all candidate intervals. If a frequency excursion also changes amplitude or interferes with edge qualification, the acceptance process depends on the variable of interest. Discarding rejected windows then creates selection bias, even before considering ordinary noise or finite counter resolution. One should document A_i for every attempted acquisition and investigate whether its probability changes with measured amplitude, gate position, slope or waveform class.

A further source of selection arises from periodic sampling of periodic signals. If a 40-millisecond chirp repeats every 100 milliseconds and the counter opens its gate every 100 milliseconds at a fixed phase, it can observe the same early portion of every burst indefinitely. Thousands of nearly identical results establish excellent repeatability for that early average, while leaving a late excursion wholly unmeasured. This is not a random failure that disappears with more data; it is a design defect caused by synchronisation between the observation schedule and the waveform. Deliberately shifting the gate phase can test the problem. Under an instrument able to observe the burst independently, the schedule may be randomized or swept so that coverage extends across the full period, but the analysis must still report the resulting sample weights and intervals.

The simple duty factor $\eta=T/(T+D)$, with T the active gate duration and D the dead interval, describes the proportion of scheduled time during which the detector is observing. It does not, without additional assumptions, give the probability of detecting a burst. For an instantaneous event whose arrival phase is uniformly distributed relative to a stable schedule, η approximates the probability that its occurrence coincides with an active gate. A finite burst has a duration B, and qualifying detection may require more than

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mere overlap, perhaps a minimum number of cycles, sufficient amplitude or the presence of a complete gate. If an event of length B happens wholly inside a dead interval, it cannot be detected by that counter at all. The investigator must use the actual overlap and acceptance criterion, not automatically equate duty factor with detection efficiency.

A numerical example sharpens the distinction. With T=10 milliseconds and D=30 milliseconds, the gate duty factor is 0.25. A 1-millisecond event with a uniformly random start phase is not necessarily detected with probability 0.25, because the relevant event might only need partial overlap, which increases the geometrical window, or might need a complete uninterrupted 1-millisecond observation, which decreases it. In the simple periodic case, if any overlap suffices, the phase interval leading to detection has length T+B out of T+D, giving 11/40=0.275 for B=1 millisecond, so long as B is shorter than D and the interval does not require more elaborate qualification. If complete containment within the active gate is required, the favourable start range is T−B, giving 9/40=0.225. Both figures differ from η=0.25 and both rest on explicit physical assumptions.

Uncertainty of the accepted average itself must be separated from uncertainty caused by incomplete coverage. A counter's event-time jitter may produce an approximately zero-mean random error on each selected interval, while an unknown dead-time excursion produces no reading from which to infer its value. A narrower confidence interval for an accepted frequency average does not bound the maximum frequency excursion in an unobserved interval. Nor is the Allan variance calculated from a set of irregular, gapped samples directly comparable with the corresponding statistic for contiguous sampling unless the dead-time model and associated

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noise processes are accounted for. NIST work on distributed dead time shows that measurement schedule influences frequency-comparison uncertainty, especially when correlated low-frequency noise is present. The conclusion must state which stability statistic has actually been estimated and which unobserved processes could still affect it.

The strongest remedy is a design that makes missingness explicit and tests alternative explanations. Each scheduled gate should have an identifier, planned and actual boundaries, acceptance status, detection threshold, received amplitude estimate and any processing fault. Independent monitoring provides a witness for intervals with no accepted counter reading; it may reveal that RF energy existed but that the counter could not qualify sufficient edges. One can then compare the pattern of rejection with amplitude, frequency slope or burst phase and assess whether a statistical correction is justified. If an inclusion probability can be defensibly estimated for a specified regime, weighted estimators may support a population-average inference. However, inverse-probability weighting is not a remedy when some events have zero chance of observation under the actual schedule. For those intervals the apparatus supplies no direct evidence.

In courtroom use, an apparently stable counter trace should be accompanied by an explicit coverage diagram. The report ought to give the total monitoring interval, number of attempted gates, accepted and rejected windows, measured dead-time distribution, sample timing reference, and validation trials including programmed excursions not known to the initial analyst. It should also distinguish a negative result from a measurement failure. The statement “no accepted reading differed by more than 100 hertz” may be accurate while “the carrier never differed by more than 100

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hertz” remains unsupported. A scientifically responsible negative inference specifies the duration and amplitude of excursions the system was shown capable of detecting, at a quantified confidence appropriate to its calibrated operating conditions. Data incompleteness cannot be concealed by presenting a long series of precise numbers.

Harry Nyquist, Cross-Peer Question to Andrey N. Kolmogorov: Could many thousands of repeated readings overcome selection bias when the counter always samples the same phase of a periodic chirp?

Professor Kolmogorov, suppose that a counter measures precisely the same early portion of a periodic chirp ten thousand times and every accepted result falls within a few hertz of the same value. Is there any number of additional repetitions that makes this observation sufficient to bound an excursion during the unobserved latter half of each burst? Might a randomised gate phase, coupled with an independent burst-onset trigger, alter the inferential position? Please distinguish statistical independence of measurement noise from independence of the underlying coverage schedule. I am concerned by the common practice of quoting a narrow uncertainty on the sample mean while leaving the sampling process itself undiscussed. How should a negative claim be reformulated when an event class has zero probability of being included by the actual instrument?

Andrey N. Kolmogorov, Cross-Peer Answer to Harry Nyquist: The number of accepted readings improves precision for the quantity actually observed but does not change the unobserved domain. A systematic gate-phase preference remains regardless of sample size. The experiment must shift gates across the burst and compare to continuous acquisition, or state that

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the inference is confined to the accepted portions. More observations of the same incomplete segment do not supply evidence about omitted intervals.

Professor Nyquist, additional repetitions under the same deterministic schedule improve the estimate of the repeated early-gate mean, not the unobserved late-burst frequency. If the gate is phase-locked to the beginning of each emission, its inclusion probability for a late event can be exactly zero. No finite or infinite number of repeated early measurements supplies a direct observation of that late interval. The law of large numbers does not create information about a variable that the sampling mechanism never admits. The relevant statistical parameter is the conditional mean or variance over the accepted gates, not the full temporal range of the transmitter's instantaneous frequency.

Randomising gate phase can enlarge coverage, but it does not automatically cure every problem. The investigator must record the randomisation mechanism and its actual realised phases, demonstrate that all relevant portions of the burst have a nonzero inclusion probability, and account for changes in trigger success as the signal's amplitude and frequency slope vary. A counter may fail even when a gate nominally overlaps the event, because too few qualified crossings occur or the phase comparator becomes unreliable. An independent capture of the burst envelope and a controlled generator challenge can estimate these acceptance probabilities within a specified operating range. Such a design permits a defensible statistical population statement, whereas a fixed-phase schedule cannot justify extrapolation into regions never observed.

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For a negative finding, state exactly which class of excursion the test could have seen. The report may say that no accepted early-window mean departed by more than a given amount, or that in laboratory validation an excursion with specified duration, amplitude and timing relative to the gate was detected with a measured sensitivity. It must not infer that all frequencies in all unobserved intervals were within the same bound. The uncertainty interval attached to the sample mean and the uncertainty about observation coverage should be described separately. The first may narrow as independent accepted samples accumulate; the second may remain fundamental until the measurement design changes.

Dr. James M. Atkinson, Moderator: Dr. Hamming, please analyse the fate of rejected or unreported counter gates. Professor Gabor may then question what happens when gate boundaries are timestamped only in software.

Richard W. Hamming, Fourth Principal Contributor: A counter logger should treat every attempted gate as an event even when no numerical frequency results. Without the failed attempts, the analyst cannot distinguish an intermittent transmitter from intermittent instrument availability. In my view the critical software invariant is an immutable attempt sequence recording intended gate timing, actual accepted edges, trigger state and rejected measurements. A program producing only attractive numerical rows is an unreliable witness to temporal coverage.

A computerised counter is not merely an instrument followed by a passive notebook. Its software decides which hardware events survive as structured records, and that decision may alter the evidence as thoroughly as a faulty electrical connection. I would assign a monotonic identifier to every

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scheduled measurement attempt, not merely to each successful frequency reading. The record should contain the requested gate duration, actual gate opening and closing hardware timestamps where available, reference-clock status, trigger threshold, input channel, accepted cycle count, counter overrun flags, firmware version and a status enumerating success, timeout, rejection, overflow and communication failure. Each measurement record also needs the identity of the processing algorithm that converted raw event counts into a displayed frequency. If the logger writes only rows containing plausible numbers, it creates a record that falsely suggests continuous successful observation.

The distinction between real gate timing and host presentation time is especially important. Suppose an instrument opens a 10-millisecond gate at time 100.000 seconds and obtains a valid mean frequency by 100.010 seconds, but its USB interface transmits the result at 100.070 seconds and the application updates its graph at 100.100 seconds. These three times describe acquisition, transport and presentation, respectively. Labelling the frequency with the graph refresh time shifts its apparent position by 100 milliseconds from the beginning of the gate. Even recording only the completion time loses the information required to locate the effective observation interval when the measurement is a chirp. The software schema should expose all clocks separately and retain a calibrated mapping between device-specific counters and the external time scale. A display timestamp is never a substitute for a missing hardware gate witness.

The apparatus also needs to preserve unsuccessful evidence. An invalid gate can reveal that a burst was too short for the required cycle count, that the threshold was not reached, or that an internal processor did not service the

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measurement in time. Those explanations have different forensic consequences. If no RF waveform existed, the counter's silence may be expected. If the independent recorder shows a clear burst during a counter timeout, the absence of a frequency reading is instrument failure or a qualification problem, not evidence that the signal lacked a carrier. Therefore the attempt ledger should remain linked to a continuous observation record, ideally raw I/Q samples or an independent detector with its own chronology. The system must be able to describe what was attempted as well as what succeeded.

Reconstruction requires transaction-level integrity. A successful counter reading should be associated with immutable gate identifiers and their source bytes. If firmware later changes the way reciprocal averaging rounds an interval, the original recorded periods and time marks should remain available. A corrected frequency can be stored as a new interpretation with the algorithm and calibration version. A timestamp correction should likewise be applied as a versioned mapping rather than overwriting the original device time. The associated evidence file should be hash-verified after capture, but hashing cannot prove that no samples were omitted before the file was written. Continuity requires sequence-number analysis, counter-overrun indicators, expected-byte-count checks and deliberate fault-injection trials against the real acquisition path.

A specific software stress test should generate a burst schedule containing known gaps, deliberately overlapping gates, rapid frequency changes and intervals in which the host process is overloaded. The challenge input should be independently recorded so that the operator cannot infer the answer merely from the counter's successful output. With a 1-kilohertz gate-

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update rate, one million scheduled gates correspond to 1,000 seconds of requests if every interval is nominally one millisecond. The audit should count exactly one result or explicit failure for every request. Missing sequence identifiers, repeated result identifiers or impossible overlaps must be treated as anomalies. A logging programme that discards timeouts may appear to have a low error rate simply because it has deleted the hardest measurements from its denominator.

The criterion for correctness is not that every requested reading succeeds. A trustworthy system can fail honestly and still be useful. Its quality gates should reject estimates whose effective observation interval is unknown, whose timebase suffered an unverified transition, or whose signal did not satisfy the qualification rule. It should preserve those rejections, however, because they may determine whether a negative finding was possible. A reviewer ought to be able to query the record for every millisecond of the intended monitoring period and obtain a direct observation, a suitably described lower-quality observation or a marked interval of noncoverage. Concealing the latter transforms a measurement limitation into apparent silence.

The final software proof should compare the exported report with the raw event ledger and an independent test controller. The reviewer selects a displayed frequency, traces it backwards to the accepted cycle count and actual gate interval, then computes the estimate afresh. A second check selects an attempted gate with no number and verifies that the corresponding nonacceptance is still visible. A third check deliberately changes the system clock while the counter continues recording, proving that the event's hardware chronology survives any alteration in wall-clock

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representation. These tests are not mere programming conventions. They are the means by which the measured portion of the electromagnetic event remains intelligible and challengeable long after the original apparatus has been disconnected.

Dennis Gabor, Cross-Peer Question to Richard W. Hamming: What if a frequency estimate was computed correctly but its gate boundaries were associated with a buffered display timestamp rather than actual hardware time?

Dr. Hamming, suppose a reciprocal counter correctly estimates an average frequency, but the software associates that result with the time its USB buffer reaches a host rather than the instant its accepted crossings occurred. A later time-frequency plot might then place the counter estimate beside an unrelated portion of the burst. How should the original gate boundaries, device counter epoch, host arrival time and graphic display time be represented so that another examiner can recover the actual chronology? If the counter exposes only a display cadence and never discloses the underlying measurement interval, should the programme assign a nominal midpoint or explicitly leave the temporal alignment unresolved? I should also like to know how a revised timestamp calibration should coexist with the original time labels in the evidence record.

Richard W. Hamming, Cross-Peer Answer to Dennis Gabor: The frequency average may still be valid over some unknown physical interval, but its placement in the burst chronology is unverified. Preserve hardware gate or edge timestamps, and calibrate their relation to the host display. If only display-update time survives, do not locate the estimate precisely within the

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burst. Test a known phase-coded source to reveal the actual offset and variability of the presentation delay.

Professor Gabor, the original time fields must be kept distinct. A device's gate-open and gate-close records, if present, belong to the acquisition clock. A USB transfer completion and host receipt belong to transport and scheduling. A screen refresh belongs to presentation. Conflating those fields turns a valid average into an incorrectly located observation. The software should store the counter's original gate identifier, accepted edge count, clock source and raw timestamp data alongside host transport records, then place the result on a common chronology only through a separately documented mapping. Where actual gate boundaries are unavailable, the application may display a qualified time interval or uncertainty range, but it should not manufacture the nominal midpoint as if it had been observed.

If a calibration subsequently improves that mapping, preserve the earlier derived timestamps and the original source measurements. The corrected time belongs to a new versioned derivation record naming the calibration method and its uncertainty. An examiner should be able to select one frequency reading and trace it back to the same gate and source bytes through either mapping. That property depends upon monotonic sequence identifiers, explicit epoch transitions, and unaltered raw counts. It also requires clear handling of gaps: a packet that was lost before logging leaves information absent, not merely delayed. A dashboard can show an estimate with an appropriate qualification, but its visual order cannot supersede the recorded source order.

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A practical audit introduces known bursts at recorded hardware times while deliberately delaying USB transfers and graph updates. If the displayed time remains tied to host arrival, it will move; if the programme correctly uses acquisition timestamps, the inferred burst time should remain stable within its calibration uncertainty. Repeat with a counter reset and with lost transport blocks. The purpose is not to force a successful timestamp under every failure, but to prove that the system records the failure and refuses unsupported temporal claims. A frequency estimate may be accurate in its own interval and still lack a defensible position on the absolute acquisition chronology.

Dr. James M. Atkinson, Moderator: Sir Martin Ryle, the counter sees the receiver output rather than the external carrier directly. May you examine instrument-created transients, followed by Dr. Hamming's challenge concerning weak-signal ambiguity?

Martin Ryle, Fifth Principal Contributor: The receiver chain can generate its own apparent frequency transient. A mixer local oscillator may settle after a gain or band change, and an intermediate-frequency filter can ring at burst onset. A frequency counter downstream may thus faithfully measure the receiver output while misrepresenting the external transmitted frequency. Challenge the system with both constant-frequency pulses and programmed chirps at calibrated input levels. If the reported drift appears during a constant-frequency control, its origin lies somewhere in the instrument chain or test arrangement.

The counter measures the signal delivered to its electrical input, not the field directly at an antenna. Between those points stand cables, preselectors, low-

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noise amplifiers, mixers, intermediate-frequency filters, gain-control loops, reference oscillators and threshold circuits. Each stage can change the amplitude or phase characteristics of a short burst, particularly during settling. A local oscillator whose frequency is recovering from a switching event may impose an apparent chirp on an otherwise constant external carrier. A narrow filter can ring after a short pulse and cause its effective envelope to persist after the antenna has ceased receiving the emission. Consequently, when the counter shows a drifting carrier, the survey must distinguish a source phenomenon from a receiver-generated transient by experimenting on the complete signal path. A valid counter calibration at a direct electrical input is insufficient to validate the upstream converter and filters.

A controlled measurement uses at least two waveforms: a well characterised constant-frequency burst and a known chirp with similar bandwidth and duration to the questioned emission. Feed both at a calibrated input plane, retaining a separate direct observation of the generator output. Repeat through the same gain, preselection, conversion and detection settings used in the field. If the constant-frequency control develops a transient at the counter output, the receiver is contributing to the measured phase evolution. One should vary burst amplitude, repetition period, filter bandwidth and gain-control state to identify the dependence. The transient may arise from local-oscillator settling, amplitude-to-phase conversion, limiter recovery or threshold effects; a single trace rarely identifies its cause uniquely. The response of the complete chain must be characterised before the carrier's measured frequency motion is attributed to the transmitter.

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The local oscillator is a particularly subtle source of bias in a frequency-converting receiver. For a high-side heterodyne with $f_{IF}=f_{LO}-f_{RF}$ under the declared sign convention, a transient change Δf_{LO} in oscillator frequency changes the measured intermediate frequency by the same sign if f_{RF} remains fixed. If the LO moves by 400 hertz while the RF source is truly constant, the IF may move by 400 hertz. Depending upon how software translates an IF estimate back to apparent RF frequency, that motion can be assigned an incorrect sign or interpreted as a source chirp. Any report should define the frequency plan and mixing sign. Observing a stable reference tone through the same conversion path, or independently comparing the LO phase against a separate reference, can expose this mechanism. The test must be performed at relevant gain and tuning settings rather than at a convenient unrelated frequency.

Input amplitude also matters. A weak burst rising through a detector threshold presents later qualifying zero crossings than a strong burst whose leading edge remains above threshold. Noise may insert false crossings or cause missing cycles, and an automatic gain control may change phase or frequency estimation dynamics while settling. If a counter employs a prescaler, its divide ratio and start-up behaviour can add further qualification delays. A spectrum analyser can help reveal the full transient, but its own local oscillator and analysis windows can impose different artefacts. Independent observation is genuinely informative only when the instruments do not share the relevant potential failure mode. Two receivers using the same unstable frequency reference may corroborate a common internal disturbance rather than an external emission.

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Group delay and impulse response deserve quantitative attention. For a linear time-invariant receiving path with frequency response $H(\omega)$, the group delay is $\tau_g(\omega)=-d\arg H(\omega)/d\omega$, measured in seconds. A bandpass filter with appreciable delay variation across a pulse's spectrum can reshape the observed envelope and move the time at which a trigger becomes valid. A narrowband sinusoid may traverse the same hardware with little evident envelope change, so a continuous-tone acceptance test may miss the failure that appears on a short burst. Repeat calibration with signals that exercise the relevant bandwidth and duration, and document filter state, analogue gain and temperature. If the path contains nonlinearity or time-varying control, a single group-delay number does not completely describe its behaviour; its transient response must be measured directly.

A useful two-receiver test places one receiver at a different architecture or independently maintained clock and preserves both channels' raw samples. Both observe a known source at an appropriate common reference plane. If the apparent frequency excursion follows one receiver when its LO configuration changes, the receiver hypothesis gains weight. If the frequency evolution follows the source and persists across different conversion plans within validated uncertainty, an external origin becomes more plausible. Cable and antenna substitution can further expose common-mode coupling, whereas a terminated-input experiment identifies some internally generated features. Every substitution changes sensitivity, so any disappearance must be assessed against the new noise floor and detection threshold. A missing trace is not proof of an absent signal if the substitute configuration could not have detected it.

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The final technical record must contain more than a centre-frequency number. Preserve the field receiver path, tuned frequency, LO reference, filter selection, gain state, detector settings, counter gate schedule, software time mapping and independent control waveforms. For each unexplained frequency excursion, compare what the external-source hypothesis predicts with what receiver-settling and triggering mechanisms could produce. A source attribution can remain indeterminate even after a precise frequency estimate has been obtained. The appropriate forensic discipline is to localise the point in the measurement chain at which the anomalous phase evolution first appears, then quantify what inference survives the known limitations. The distinction between an observed intermediate-frequency transient and a demonstrated external transmitter property must remain explicit throughout the report.

Richard W. Hamming, Cross-Peer Question to Martin Ryle: If the constant-frequency control shows a transient only at weak signal levels, does that automatically identify threshold noise as the cause? Please also describe how a second, independently monitored receiver would constrain competing causes, rather than merely reproducing the original threshold-setting error or a shared clock artefact.

Sir Martin, a constant-frequency control may show a spurious transient only when its amplitude is near the detector threshold. Is that sufficient to identify simple random threshold noise as the cause, or could other receiver processes become amplitude-dependent under the same conditions? Please consider automatic gain control, filter settling, limiter behaviour, mixer conversion and the local oscillator's response to a changed signal environment. How would you distinguish each possibility while keeping the

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observation comparable to the original disputed waveform? I am also concerned that changing gain or filter bandwidth to make a feature disappear changes the very sensitivity required to observe it. What experimental design would preserve both a valid source reference and a complete account of the receiving chain?

Martin Ryle, Cross-Peer Answer to Richard W. Hamming: No. A weak signal can interact with gain control, phase estimation and filtering as well as trigger threshold. Repeat with varied amplitude, known injected signal and independently monitored local oscillator state. The result should identify which controlled changes affect the anomaly, and preserve plausible mechanisms until the data discriminate them. A single correlation with level is a clue rather than complete attribution.

Dr. Hamming, amplitude dependence is a clue, not an identification. Near threshold, noise may add or remove accepted zero crossings, but a gain-control loop may also be changing, the filter's transient response may depend on how long a weak pulse excites it, and a mixer or limiter may introduce amplitude-to-phase conversion. A receiver whose local oscillator undergoes phase settling after a tuning or gain-state change can produce a chirp-like frequency trace without any external source drift. The test should distinguish those mechanisms by altering one documented condition at a time while keeping the source waveform under independent observation. If several internal stages change together, an observed difference cannot be attributed confidently to just one.

Begin with a known constant-frequency burst delivered through a calibrated electrical path at relevant power and bandwidth. Capture the original

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receiver I/Q samples as well as the counter estimate, and monitor gain-control state, reference lock and local oscillator where accessible. Repeat through a set of amplitudes including well above threshold, near threshold and below reliable qualification. Substitute a fixed-gain condition only as a separate declared experiment, not as though it were the same field configuration. Reverse the chirp direction of a second programmed source, then use two different local oscillator frequency plans to see whether the observed motion follows source frequency or conversion architecture. Each control should have a predicted signature under the rival hypotheses before its result is examined.

If an anomaly disappears under a new setting, measure the sensitivity of that setting to the same signal. A wider filter may lower the observed peak relative to noise; a gain change can move the detector away from its previous operating regime. An independently clocked receiver with a distinct architecture and known RF reference can corroborate an external signal under properly matched sensitivity. The report should include the complete comparison matrix: waveform, input power, gain state, filter setting, local oscillator configuration, trigger threshold, gate boundaries and any observed receiver transient. The final conclusion may identify a receiver-origin component, bound an external drift, or remain indeterminate. It should never convert the failure of one altered instrument to display a feature into proof that the original field had no such emission.

Dr. James M. Atkinson, Moderator, Closing Synthesis: Gate time estimates frequency over a finite interval; dead time excludes intervals altogether. A counter may be precise for its accepted gate average while failing to characterise the underlying burst trajectory. The panel therefore requires a

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measured acceptance schedule, input-reference-plane controls, calibrated chirps and constant-frequency challenges, retained rejected gates, and comparison with independently recorded phase and time-frequency data. Numerical resolution must not be confused with temporal coverage or with a bounded claim that no unobserved excursion occurred. All examples are hypothetical and the historical dialogue is pedagogical reconstruction.

QUESTION 057. SOURCES AND EDITORIAL QUALIFICATIONS

1. National Bureau of Standards, Frequency Standards and Clocks: A Tutorial Introduction, revised edition, Technical Note 616, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote616r1.pdf. Discusses averaging time and counter dead-time effects.

2. National Bureau of Standards, Time and Frequency Users Manual, revised Special Publication 559, https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication559r1.pdf. Discusses counter accuracy, triggering and measurement intervals.

3. National Institute of Standards and Technology, Time and Frequency from A to Z, entry F, https://www.nist.gov/pml/time-and-frequency-division/popular-links/time-frequency-z/time-and-frequency-z-f. Definitions of frequency counting, drift, standards and stability.

4. International Telecommunication Union, Handbook: Selection and Use of Precise Frequency Systems (1997), https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-31-1997-PDF-E.pdf. Discusses sampling time, averaging and counter dead time.

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EDITORIAL QUALIFICATION: Calculations and programmed chirp experiments are hypothetical. The sources support physical measurement principles but do not validate an unspecified real receiver or imply actual historical statements. Full duplication, historical attribution, per-speaker length and publication proof remain outstanding.

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QUESTION 058

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What Do Phase-Noise Sidebands Reveal About Defects in an RF Reference Distribution Network?

SCHOLARLY RECONSTRUCTION. This is fictional teaching dialogue among deceased historical specialists. Modern electronic instruments, numerical tests, and SDR applications are present-day editorial extrapolations, not historical quotations or documented statements by those individuals.

Dr. James M. Atkinson, Moderator: Professor Townes, consider an RF survey in which several nominally independent instruments display comparable sidebands around their frequency references and occasionally report narrow spectral features near received carriers. The laboratory source itself may exhibit phase noise, a fan-out amplifier may contribute residual modulation, its power supply may impose periodic ripple, and the measuring instrument may have a noise floor sufficiently high to conceal all three mechanisms. What can the shapes and correlations of sidebands establish about these competing causes, and what experimental controls would distinguish an external electromagnetic signal from an artefact common to a receiver system?

Charles H. Townes, Principal Contributor: Dr. Atkinson, a sideband is an observation of spectral energy displaced from a nominal carrier, not a certificate of its physical origin. The complete reference chain deserves examination: source oscillator, filtering and discipline loops, distribution amplifiers, dividers, switching devices, cables, connectors and individual instrument clock inputs. Phase variation originating in an oscillator is inherited by the following network, subject to its transfer characteristics. Additive fluctuations introduced after the source enter only the affected

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branch or branches. A power-supply disturbance may make several branches agree if they share the supply, or may remain local to one receiver. Consequently the question is not whether a sideband exists, but where along a defined signal path its phase modulation first becomes measurable.

A distribution-network investigation should first formalise what the measurement physically represents. In a small-noise approximation an output may be written $v(t) = A[1+a(t)]\cos[2\pi f0t+\varphi(t)]$, where A is its nominal peak amplitude, a(t) its dimensionless fractional amplitude variation, f0 its nominal carrier frequency in hertz, t elapsed time in seconds, and φ(t) its phase error in radians. The two perturbations must not be conflated. A square-law power detector predominantly registers amplitude variation, whereas a properly biased quadrature phase detector is primarily sensitive to phase fluctuation. Nevertheless neither instrument is perfect, and any nonlinearity or quadrature error permits cross-conversion between the two. If a distribution network generates a discrete 100 Hz offset pair around a 10 MHz reference, the frequency separation supplies a useful clue about periodic influence. It does not, without coherent demodulation, identify its modulation type or establish which cable, fan-out amplifier, power converter or oscillator generated it. A technician should report the relative amplitude of the two components, the instrument resolution bandwidth, the reference offset convention, and the uncertainty of the inferred modulation index.

A principled test programme must distinguish an absolute measurement of the oscillator from a residual measurement of a distribution component. For the latter, compare the phase of the signal before a characterised two-port component with that after the component, allowing for nominal delay and frequency translation. If φin(t) is the upstream phase fluctuation and ε(t) the

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additive phase error imposed by the branch, an idealised output relation is $\varphi_{out}(t)=\varphi_{in}(t-\tau)+\varepsilon(t)$, where τ is delay. Subtracting the delayed source phase isolates ε, provided the two observation paths have sufficiently matched transfer functions and independently characterised detector errors. One must not simply subtract two plotted decibel curves. The spectra may contain correlated and anti-correlated contributions, and power spectral densities add only under the relevant independence assumptions. This is especially important when low-level sidebands are compared between receivers sharing a master reference.

A sound conclusion should therefore have three layers. The observational layer states what sideband was present and with which calibrated amplitude and offset. The mechanistic layer records which interventions changed it while leaving the measuring system sufficiently stable. The evidential layer identifies whether the feature survives a change of reference topology, receiver input termination, and independently referenced measurement. When these layers disagree the proper result is not a forced diagnosis but a qualified uncertainty. For example, a line that vanishes after replacement of the common reference, while remaining absent from an independent receiver operating from its own timebase, favours a reference-distribution explanation. It does not exclude an external signal whose demodulation became undetectable after frequency planning or sensitivity changed. The inference must preserve the measurable differences between these explanations.

Let the output be $v(t)=A\cos(2\pi f_c t+\varphi(t))$, where A is nominal amplitude, f_c the carrier frequency in hertz and $\varphi(t)$ residual phase in radians. For sufficiently small phase excursions, the one-sided phase-fluctuation power

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spectral density $S_\varphi(f)$ in radian-squared per hertz is related to single-sideband phase noise $L(f)$, conventionally expressed as carrier-relative power density, approximately by $L(f)=S_\varphi(f)/2$ in linear units. The logarithmic presentation is $10 \log10[L(f)]$ dBc/Hz. This relation must not be applied without qualification to large, discrete modulation or large phase excursions, where the familiar small-angle approximation breaks down. One should always state the carrier, offset frequency, resolution bandwidth or phase-demodulation method, and whether the trace is of phase, amplitude or combined spectral noise.

A narrow pair of symmetrically spaced sidebands can result from sinusoidal phase modulation, but may also involve amplitude modulation or mixed mechanisms. Suppose $\varphi(t)=\beta \sin(2\pi f_m t)$ with modulation frequency f_m and small modulation index β radians. Expansion of the complex exponential gives first-order upper and lower phase-modulation sidebands with voltage amplitude approximately $\beta/2$ times the carrier voltage. Their individual relative power is therefore approximately $\beta^2/4$, or $20 \log10(\beta/2)$ dBc, provided β is small and detection preserves the corresponding sidebands. At $\beta=0.01$ radians this example gives about -46.0 dBc per first-order sideband. The calculation is hypothetical and does not prove that measured sidebands at that level arose from a specified clock defect.

For a reference at 10 MHz with a 100 Hz sinusoidal phase perturbation, symmetric sidebands displaced by 100 Hz are unsurprising; that displacement identifies the modulation frequency, not necessarily the component responsible. Ripple from an internal switching supply, an external power system, a control-loop limit cycle, mechanical strain, or coupling from an adjacent circuit could all introduce a similar offset. An

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oscilloscope or spectrum analyser viewing only the final distribution output cannot distinguish them without additional measurements. The investigator must sample the oscillator output before fan-out, the buffer inputs and individual branch outputs with reference-plane calibration and without allowing the probing arrangement to create the anomaly being investigated.

Noise shape is informative when interpreted with appropriate restraint. Close-in flicker-related phase noise, far-out approximately white-phase-noise floors, and discrete spurs may suggest different physical mechanisms, but their slopes are not unique fingerprints. A phase-locked loop also shapes source and voltage-controlled oscillator noise differently inside and outside its control bandwidth. A distribution amplifier can contribute broadband residual noise and low-frequency flicker terms of its own; division and frequency multiplication change carrier-referred phase relationships under specified coherence assumptions. The analyst should therefore compare measured input and output spectra and measure transfer functions before alleging a defective part from a single curve.

If two independent phase-noise sources contribute as statistically independent small fluctuations, their linear spectral densities may be added. They cannot be added directly as negative dBc/Hz numbers. For example, if the reference source contributes $L_{source}=-130$ dBc/Hz at a particular offset and a distribution branch contributes $L_{additive}=-140$ dBc/Hz referred consistently to the output carrier, their combined linear densities correspond to $10^{(-13)}+10^{(-14)}=1.1\times10^{(-13)}$, giving approximately -129.6 dBc/Hz. This illustrative calculation assumes independent contributions, the same offset and measurement reference, and no omitted

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filtering or correlation. A measured value nearer −125 dBc/Hz would demand inquiry into additional noise, coupling or instrument limitations, not an automatic declaration that the fan-out device is faulty.

Measurement-system limitations can imitate both excessive noise and excellent performance. An ordinary spectrum analyser has local-oscillator phase noise, detector behaviour, resolution bandwidth and dynamic range of its own. If its displayed floor exceeds the reference network's true noise, the instrument reports an upper bound rather than the device's intrinsic phase-noise spectrum. Dedicated phase-noise analysers may use two measurement paths with independent oscillators and cross-correlation, suppressing uncorrelated internal noise as averages accumulate. However, anything common to both paths, including the signal under test and some shared instrument impairments, remains. Cross-correlation must be understood as a noise-separation method with explicitly stated independence assumptions, not as a universal truth filter.

The distribution experiment needs a branching protocol. First, measure the source at an accessible, properly terminated point while all outputs are connected in their operational configuration. Second, measure every branch at its receiver input with its actual cable and load. Third, exchange cables and loads between branch outputs, preserving the path labels. Fourth, operate the network with a safe substitute reference of known phase-noise performance. Fifth, independently monitor the distribution supply and the local environment for ripple, vibration and temperature change. A spur that follows a particular output port suggests an internal distribution-path issue; one that follows a cable suggests cable or connector effects; one that

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persists on every output and exists at the source demands investigation upstream.

A safe supply-modulation challenge can be especially illuminating where the equipment rating and the test plan permit it. Apply a small, measured test modulation to the distribution amplifier's laboratory supply and compare the phase-demodulated output with the known test waveform. Distinguish amplitude modulation from phase modulation using an appropriate phase-sensitive measurement and examine whether the spur amplitude scales with the injected disturbance. Remove the perturbation and verify return to baseline. Tests on an operational evidential recorder require authorisation and separate preservation of the original observations; a laboratory challenge must not be confused with a field observation.

Correlated spectral defects create a particular forensic hazard. If several receivers share the same reference network, a phase or frequency spur may propagate through their synthesiser and sampling structures. They may then show simultaneous low-level spectral features, apparent carrier shifts or degraded weak-signal discrimination. Their agreement is not independent corroboration of an external transmitter. Yet one must avoid the opposite error: a genuine external signal may also be observed simultaneously at several receivers. A local injected calibration tone and independently clocked observation channel provide a means of testing the reference hypothesis without asserting a cause prematurely.

The conclusion should be a set of bounded findings: at what offset a component was observed; its amplitude relative to carrier and the instrument floor; how it changed between the oscillator, fan-out input and outputs; whether it tracked supply intervention, cable exchange or a known

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test source; and which physical explanations remain viable. No single spectral slope or pair of sidebands establishes intentional surveillance, the source of an external emission, or a legal attribution. The distribution apparatus is part of the measurement system, and its own spectral behaviour must be documented before claims about the surrounding RF environment are treated as reliable.

Dr. James M. Atkinson, Moderator: Professor Essen, what distinction must be drawn between the source oscillator and noise introduced after it?

Louis Essen, Peer Question: Professor Townes, a reference source can be exceptionally stable when measured at its own output, but a distribution branch may add phase fluctuation after the original oscillator. If an engineer compares only the absolute noise spectra at two points, the two curves might resemble one another because the common source dominates. What method would reveal residual branch noise under those conditions, and why is it important to distinguish the noise inherited by both measurements from the noise added in the component under test?

My difficulty is not simply whether the branch contains extra noise, but whether the selected experiment has enough independence to reveal it. If the source and reference arm are derived from the same oscillator, propagation delay will make some source fluctuations appear as residual error even without a faulty branch. If I shift the cable length or change a digital compensation setting, the observed spur may respond merely because the differential phase transfer function has changed. Which reference-plane definition would allow laboratories to reproduce the result? Should we determine the complex transfer function of each branch before claiming additive phase noise? And how should we handle a spur that

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remains fixed in hertz but changes in dBc when amplifier gain is altered, knowing that ratio measurements can disguise a changed carrier amplitude?

Charles H. Townes, Response: Professor Essen, the proper approach is to measure the residual phase difference between appropriately matched input and output references, with the relevant carrier frequency and delay accounted for. The inherited phase fluctuation may largely cancel in a differential measurement, exposing additive noise that an absolute spectrum obscures. That cancellation depends on coherence, equivalent path delay and the measurement bandwidth; imperfect delay compensation can leave apparent residual source noise. The device may also alter phase in response to amplitude, temperature or load. Consequently the residual measurement should be repeated with a low-noise substitute source and a reference through-connection, not reported as a direct property of the amplifier without accounting for the measuring apparatus. For multiple outputs, compare each branch both against the common input and against another branch. Agreement between two outputs can hide shared input noise but disclose differential additive noise; the two results answer different questions. Neither should be substituted for the other.

A reproducible report should define its reference planes at physical connectors and identify which voltages are being compared, not merely which menu option was pressed. Establish a traceable source measurement at the upstream connector, follow with a measurement at the downstream branch connector, and record both carrier power and complex modulation response. A time-domain phase comparison requires either matched delay or explicit compensation: if the upstream phase is evaluated at time t and

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the downstream record samples a delayed version at $t-\tau$, the residual includes $\varphi_{in}(t-\tau)-\varphi_{in}(t)$ in addition to branch error. For a periodic perturbation at offset f_m, the magnitude of that unwanted difference depends on $2|\sin(\pi f_m \tau)|$, so delay must enter the uncertainty model. The formula refers to equal-amplitude phase terms and does not excuse neglecting detector mismatch or cable dispersion.

One should next swap physically equivalent branches whilst keeping the instruments and source unchanged. If the anomaly remains attached to a port, a port-specific hypothesis gains plausibility; if it follows a cable, mechanical or shielding influences deserve attention. A gain change also requires recalibration. A sideband-to-carrier power ratio may remain approximately constant for pure linear amplification, but additive noise or saturation can change it. Record power in absolute units and the sideband ratio together, with bandwidth-normalisation explicitly stated. The result must include a test of detector linearity, since an overloaded analyser can manufacture spurious products. An independent reference is particularly valuable as a check, although independence must be established rather than inferred from a separate chassis.

Dr. James M. Atkinson, Moderator: Professor Ramsey, how would you establish the physical meaning of a pair of discrete sidebands?

Norman F. Ramsey Jr., Peer Question: Professor Townes, a symmetric sideband pair appears on the spectrum analyser at a fixed displacement from a reference carrier. It is tempting to label the feature as a phase disturbance, and perhaps to assign it to a particular power-supply frequency. What further observations separate amplitude modulation from phase modulation, identify the relevant phase relationship, and distinguish

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an actual periodic perturbation of the reference from an analyser-generated response or mixer product?

A reader may overlook the role of coherent phase in the apparent symmetry of the two modulation sidebands. If a converter's rail ripple drives both gain and propagation delay, then amplitude and phase perturbations share a periodic cause, potentially adding constructively on one side of the carrier and destructively on the other. Suppose a spectrum screenshot contains a spur at plus 200 Hz but little energy at minus 200 Hz. Can we conclude that it is not phase modulation, or is that conclusion equally unjustified? Which IQ calibration, sign convention and image-rejection tests would you demand before taking asymmetry as evidence of a physical one-sided emitter? I also ask whether the presence of correlated AM and PM is a defect of the oscillator itself or can originate solely in distribution-stage nonlinearity.

Charles H. Townes, Response: Professor Ramsey, retain the complex modulation information when an instrument is capable of measuring it. A phase demodulator and an amplitude demodulator should examine the same signal at the same reference plane. For small, coherent sinusoidal modulation, amplitude and phase contributions can be decomposed from the quadrature components, but their estimated separation depends on calibration and phase reference. Change the analyser's reference source or frequency-conversion configuration to see whether the spur follows the tested signal or remains associated with the instrument. A second receiver architecture with an independently maintained local oscillator can offer corroboration. Frequency displacement alone is not a unique cause: two equal-magnitude sidebands can arise from several combinations of modulation and measurement artefact. A phase-difference measurement

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across the distribution device, simultaneous recording of supply ripple, and controlled removal of the suspected source provide a more persuasive causal test.

One-sided appearance does not exclude phase modulation because coherent AM and PM can interfere in the complex sideband coefficients. In the first-order analytic-signal model, the component at a positive offset combines the relevant Fourier components of a(t) and jφ(t), while the negative-offset component involves their conjugate relationships. A special relative phase can enhance one and suppress the other. The test therefore must preserve both IQ channels and calibrate the sign of the quadrature axis. Inject a known pure amplitude modulation at a specified offset, then a separately characterised phase modulation; the recovered components should track the intentional perturbations with measurable cross-leakage. The observer must also test image rejection and carrier leakage, since imperfect quadrature creates false spectral imbalance.

If calibrated AM and PM components remain correlated, inspect the points at which gain and delay are both susceptible to the same disturbance. A fan-out amplifier can convert supply ripple into gain modulation through amplitude response and into phase modulation through voltage-dependent delay. A synthesiser can do likewise through its control loop. Rotate the load matrix and measure the oscillator directly before inferring the responsible stage. When correlations are strong, report a measured cross-spectral relationship rather than describing the amplitude and phase curves as independent. The normal teaching simplification of separate AM and PM is useful for first-order calculation, but it is not evidence that the physical mechanisms are separate.

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Dr. James M. Atkinson, Moderator: Mr. Hewlett, what ought the engineer to infer from a spur that grows when the fan-out amplifier is loaded?

William Redington Hewlett, Peer Question: Professor Townes, changing the number of connected receivers alters termination conditions and supply demand. If a sideband becomes larger as another branch is enabled, one explanation is output-to-output coupling; another is supply modulation; still another is a changed impedance or a receiver injecting energy back into the distribution network. Which experiments isolate the pathways without risking damage, and why is a comparison of one arbitrary loaded and unloaded condition inadequate?

Let us examine the loading experiment as an engineering intervention rather than a suggestive visual demonstration. Switching a second receiver onto a fan-out output changes more than terminal impedance; it can alter supply current, chassis potential, cable layout, the thermal condition of nearby buffering stages and even the operating state of the receiver's own digital electronics. In a field installation there may be no safe means of removing ground bonds, nor would doing so be acceptable merely to prove a hypothesis. What controlled sequence would separate direct reverse coupling at the carrier from power-rail coupling at the offset frequency? How would you prevent an increase in measurement sensitivity caused by changed gain from being mistaken for a newly appearing spur? Please distinguish a diagnostic observation from an intervention that merely suppresses the display of the problem.

Charles H. Townes, Response: Mr. Hewlett, map the changes systematically. Establish a correct termination at each port and measure output power, amplitude modulation and phase modulation before and after connecting a

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characterised load. Replace the receiver temporarily with a safe equivalent load to separate receiver feedback from a mere change in demand. Monitor supply rail ripple and current simultaneously. Enable branches in different orders, measure each affected output and repeat with physically separate supply arrangements where the apparatus permits. If the spur follows a specific receiver, investigate reverse coupling and isolation; if it follows aggregate power load, investigate regulation and supply rejection; if it follows one port regardless of load, investigate that branch. Every manipulation requires a written configuration record because a narrow improvement can result from a changed impedance rather than repair of the original mechanism. In particular, no unqualified claim of additive phase noise should be made from a measurement that has silently changed carrier power or detector operating point.

Begin with a topology diagram listing every active output, cable length, termination, chassis bond and supply rail. Keep protective earthing intact. Create the baseline using a calibrated source, known load and documented output power. Then change one factor while repeating controls: substitute a matched termination for the receiver, substitute a known isolated distribution buffer for the branch, vary the number of correctly terminated outputs, and finally compare alternative supply arrangements within safe electrical design. At each stage record the carrier power, sideband ratio and, when possible, residual phase. Reverse-coupling hypotheses predict that disturbances injected into an output port can affect another output in a frequency-dependent way; supply-coupling hypotheses predict a relationship with rail ripple or load current. Those predictions should be tested by benign, calibrated perturbations below equipment safety limits.

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Detection thresholds deserve an independent verification at each state. Inject a small reference spur of known modulation index before the receiver or through a characterised calibration port and determine whether the instrument still reports it with equivalent sensitivity after an architectural change. If the test spur vanishes as well as the suspect spur, the evidence is compatible with simple desensitisation. Make a before-and-after uncertainty budget for the receiver gain and analyzer floor. A narrow line that diminishes while the test line remains stable is more informative, but it still does not identify the component without corroborative tests. This distinction should be explicit in the engineering report, for otherwise a successful suppression experiment will be mistaken for successful causal diagnosis.

Dr. James M. Atkinson, Moderator: Professor Kolmogorov, can a low noise floor established by many averages justify a narrow confidence statement?

Andrey N. Kolmogorov, Peer Question: Professor Townes, phase-noise measurements often involve averaging many spectral estimates. The displayed trace may become visually smooth, but the data may contain a discrete spur, nonstationary switching event or correlated disturbance present in both analysis paths. What assumptions about random processes and independence are required before the reduction of an averaged floor is interpreted as improved sensitivity? May the analyst represent the remaining uncertainty by the count of averages alone?

The words 'noise floor' and 'confidence' often acquire authority merely because a digital analyser displays many significant digits. Yet a narrow coherent spur is not distributed as the surrounding stochastic bins, and repeated overlapping transforms may not constitute independent

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observations. If a recording programme reports four thousand averages, how should the investigator estimate an effective sample count when every second window overlaps half of the previous one? What if a slowly changing thermal process makes successive records dependent over minutes rather than milliseconds? Can an apparently remarkable decrease of displayed phase-noise density be an artefact of the measurement method itself, particularly when the two correlation channels share a splitter or bias network? I ask for a test that would make the uncertainty statement falsifiable.

Charles H. Townes, Response: Professor Kolmogorov, averaging reduces the variance of a chosen estimator under specific stochastic assumptions; it does not guarantee that systematic components disappear. For independent spectral records, the variance may decrease as the number of informative averages increases, but overlap, shared noise, slow drift and correlated detector errors reduce the effective amount of independent information. A coherent spur remains because it is not a zero-mean random fluctuation under the relevant averaging operation. In two-channel cross-correlation, uncorrelated measurement noise can be progressively suppressed, while correlated noise survives. The uncertainty assessment must therefore distinguish repeatability, instrument floor and systematic error, and must retain information about the spectral estimator, windows, bandwidth, data exclusions and nonstationarity. Counts of averages alone do not specify a defensible bound. Repeating a comparison under deliberately changed instrument configurations is often more informative than adding further averages to one unchallenged architecture.

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An average count is not an effective independence count. The statistician should estimate the covariance among spectral estimates under the actual acquisition protocol and determine an effective sample size suitable to the estimator. If the per-record variance is σ^2 and the correlation between records separated by lag k is ρk, an approximate effective number for a sufficiently long stationary series is $M_{eff} \approx M/[1+2\Sigma\rho k]$, where M is the record count and the sum is over meaningful positive lags. This is a practical approximation, not a universal theorem for every overlapping spectral estimator. A defensible uncertainty interval can use appropriately blocked resampling or independently repeated experiments, while disclosing the overlap, window and correlation assumptions.

To make the claim falsifiable, add a known modulation tone of specified amplitude and demonstrate that the analyser recovers it when the supposed floor is very low. Repeat the measurement with an independently characterised splitter and, where practicable, a different cross-spectrum topology. A cancellation in one configuration but not another signals instrument dependence, even if both traces are pleasingly smooth. Cross-spectrum subtraction can be affected by anti-correlated thermal noise introduced in a common power divider; the risk is experimentally documented in later metrology work, which must be cited editorially rather than attributed to our historical speakers. For coherent discrete spurs, track tone power and temporal persistence separately from random phase-noise density. Finally disclose the number of conditions and offsets examined so that the claimed false-alarm or non-detection probability is reproducible.

Dr. James M. Atkinson, Moderator: Sir Harold Jeffreys, what does a shared sideband imply about the probability of an external emission?

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Harold Jeffreys, Peer Question: Professor Townes, imagine that three receivers report a faint spectral line displaced by the same amount from their reference-related signals. The investigator may be tempted to multiply three nominally small false-alarm probabilities and announce overwhelming corroboration. What assumptions fail when all three receivers share a reference distribution module, and how should competing hypotheses such as genuine external emission, common reference modulation and instrument artefact be compared without invented probabilities?

A Bayesian statement requires a proper set of hypotheses and a likelihood that acknowledges dependency. Suppose three receivers display an offset line at the same time. Under a simplistic model in which each has a one-in-a-thousand chance of a spurious result, an analyst might multiply those probabilities and advertise an implausibly small false-positive rate. However, if all three receivers use one reference source, a single reference fault can produce three observations together. What conditional probability structure would avoid that elementary error? How should prior probabilities be stated when the suspected external transmitter is extraordinary but the electrical distribution network is known to contain switching electronics? And how can a report communicate the strength of evidence without converting an assumption-dependent probability into a courtroom certainty?

Charles H. Townes, Response: Sir Harold, the events are not independent simply because three displays exist. Their false indications may be conditionally dependent on one shared impairment. A useful analysis specifies hypotheses and seeks observations expected to differ among them. A source-related line should persist under a controlled independent-clock check, subject to the actual receiving conditions; a reference-network

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spur should respond to safe substitution or perturbation of that network, though complicated coupling may prevent a perfectly binary result. The researcher should not assert numerical likelihood ratios without empirical models, calibration or defensible prior information. Instead report the test conditions, evidence of dependence, and any remaining uncertainty. The strength of the finding comes from discriminating experiments, not from counting redundant instruments as if they were separate witnesses.

Represent the evidence E as a collection of observations with their shared conditions, rather than as three independent scalar events. Let Hext denote an external emitter and Href a reference-distribution artefact. The posterior odds equal prior odds multiplied by the likelihood ratio P(E|Hext)/P(E|Href), but each conditional probability must include the common reference configuration and relevant measurement uncertainty. A graph that places the reference fault as a parent of all three receiver observations shows immediately why their indications can be dependent. If one shared spur has high probability under Href, the three coincident displays may provide little discrimination. Under Hext the amplitude and spatial phase predictions may differ, making antenna relocation or independent clock replacement more valuable than a fourth identical display.

Do not smuggle certainty into the prior. Report a sensitivity analysis over plausible prior odds and explain which conclusion depends on which values. Better still, design an intervention that creates a large likelihood contrast regardless of moderate prior disagreement. One might compare the suspected line under an independent reference with calibration injection and unchanged antenna geometry, then under antenna termination with the original reference restored. The joint outcomes, not the number of

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screenshots, form the evidence. An honest report must also acknowledge unmodelled hybrid mechanisms, such as a strong external signal mixed with internally contaminated local-oscillator noise. The evidence may not distinguish all conceivable causes, and the written conclusion should say so.

Dr. James M. Atkinson, Moderator: Professor Gabor, how does a time-frequency representation assist when a spur appears only intermittently?

Dennis Gabor, Peer Question: Professor Townes, an analyser may show a weak offset line averaged over an observation window, yet the disturbance may actually be a periodic switch event or a brief transient associated with the clock system. Can time-frequency methods help distinguish persistent random sidebands from intermittent deterministic modulation, and what limits arise from the temporal window, signal-to-noise ratio, or interaction between a measurement filter and a short event?

A long Fourier transform can make a transient switching event appear as a faint but persistent neighbouring spectral component, while a very short analysis interval sacrifices the ability to separate close frequency offsets. The temptation is to adjust the window until the waterfall tells the most compelling story. How should an examiner select the window duration and overlap before inspecting the anomaly? If a fan controller switches at intervals related to a 70 Hz spur, what measurements would reveal a repeating time-domain mechanism rather than a continuously present oscillator impairment? I am also concerned with a false absence: a spur may be intermittent and therefore invisible in an average, although it remains causally important to a receiver's momentary false alarm. What should be preserved?

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Charles H. Townes, Response: Professor Gabor, an appropriately calibrated time-frequency record may show whether the feature persists, follows a supply-switching schedule or appears only at control-loop state changes. A shorter analysis window localises transients while broadening frequency discrimination; a longer window can sharpen the offset estimate at the expense of temporal detail. Neither representation alone establishes the circuit responsible. Record the supply waveform, controller logs and reference amplitude or phase simultaneously, and align them using an independently checked clock. If a transient occurs at a reference switch, inspect the phase trajectory directly rather than infer continuity from an averaged sideband trace. Cross-compare results obtained with different window lengths to expose smearing or spectral leakage. The measurement should state its observation coverage, since an intermittent spur can evade a sweep or appear diluted by an average over long quiet periods.

Choose more than one predeclared analysis scale and retain the raw IQ or phase-error samples so the choice can be reviewed. A transform over T seconds has characteristic Fourier-bin spacing 1/T hertz, though the actual resolving power depends on window shape and signal-to-noise ratio. A 0.1-second window yields 10 Hz nominal bin spacing; a 10-second window yields 0.1 Hz. Neither is inherently superior. The shorter view may reveal the onset of a switching event, while the longer view may resolve an offset line accurately if the process is stationary over the interval. Report the window function, overlap, equivalent noise bandwidth, and the threshold procedure used to detect an event.

A useful experiment records fan-control command signals, rail-current measurements and clock phase synchronously, then tests whether the

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spur's onset follows control transitions. If no causal command trace can safely be acquired, at least record power and thermal states without altering the device. A periodic event can produce a comb of lines with spacings related to its recurrence, but such a comb is not unique proof of a controller fault. Measure the reference at its upstream and downstream planes to locate the onset of modulation. Keep raw records around nominal and anomalous episodes, rather than only averaged displays. When a claimed absence is based on a long average, supplement it with an event-detection threshold and a stated duty-cycle sensitivity; otherwise an intermittent interference mechanism can be diluted beyond visibility.

Dr. James M. Atkinson, Moderator: Sir Martin Ryle, how should the investigator prevent the receiving apparatus from being mistaken for the physical environment?

Martin Ryle, Peer Question: Professor Townes, in a multi-receiver survey, an apparent carrier artefact can travel through local oscillators and frequency-conversion stages, which are ultimately referenced to the same distribution network. A genuine external signal may also appear coherently across receivers. Which changes of frequency plan, antenna path or reference source can test these alternatives, and how should the examiner avoid assuming that a line which disappears on changing a receiver setting was necessarily fictitious?

When a local oscillator derives from the suspect reference network, an internally generated modulation sideband can be translated along with a genuine external RF input. It may even produce a spectral component that follows a plausible frequency trajectory when the operator retunes the receiver. How can an investigator tell the difference between a spur entering

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after the antenna and a line radiated from outside, especially when digital frequency re-mapping fixes the displayed frequency axis? Would terminating the antenna suffice if the instrument automatically changes gain upon removal of the RF input? How could geographically separated receivers strengthen a spatial claim when they still share a synchronised timing service or comparable internal oscillator architectures? I ask you to distinguish independent information from merely repeated equipment.

Charles H. Townes, Response: Sir Martin, an appropriately controlled change of architecture provides evidence but also changes sensitivity. Replace an antenna input with a known terminated or injected-signal condition, while preserving the relevant receiver operating state. Change the local oscillator or translation plan, monitoring how a true fixed RF signal should move in the intermediate-frequency representation compared with internally generated spurs. Independently substitute the reference clock and record whether the suspicious feature follows the reference or remains associated with the incoming field. The test must also account for front-end gain, filtering, noise floor and dynamic range so that disappearance is not merely a loss of detectability. A genuine signal can vanish from one configuration because the receiver's transfer function changes. The final attribution should therefore rest on a coherent set of instrument challenges, not a single toggled setting or a plausible-looking spectral display.

Treat antenna termination as one intervention, not a conclusive verdict. First disable or explicitly record automatic gain control, preserve the noise-equivalent sensitivity, and verify the receiver with a calibrated injected signal before and after the termination. A line persisting under a sound matched termination is evidence for an internal or conducted contribution, although

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leakage around the termination is still possible. A line disappearing with the antenna may be external, but removal of a strong carrier can also remove reciprocal-mixing products generated internally. Retuning should be analysed in absolute RF coordinates as well as displayed baseband coordinates; the transfer of an internal reference spur through each mixer or digital numerically controlled oscillator must be calculated.

Spatial discrimination becomes stronger when receivers have independently verified oscillator paths, different front-end architectures and known antenna positions. A real transmitted wave may exhibit position-dependent field strength and phase, subject to multipath and near-field qualifications. A common measurement artefact need not follow the same geometry. However identical electronics operated in separate buildings can still share mains-related interference or an external timing system. The report should identify what was genuinely independent, including power source, clock, antenna path, software processing and calibration injection. A mere increase in the number of receivers is not sufficient. Construct competing hypotheses and predict how each should respond to receiver retuning, reference replacement, antenna relocation and test-signal injection, then document the results without cherry-picking the best-looking traces.

Dr. James M. Atkinson, Moderator: Dr. Dijkstra, what software metadata are needed to reconstruct a distribution fault years later?

Edsger W. Dijkstra, Peer Question: Professor Townes, automated monitoring software often stores the phase-noise trace but discards supply states, exact reference-port assignments, correlation settings and instrument firmware versions. The graph may remain attractive yet become difficult to reproduce or challenge. What minimal provenance rules would establish whether a

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later reviewer can reconstruct the measurement, including the treatment of branches deliberately disconnected or rejected as noisy?

The programming system may be the last and least examined part of a reference-distribution investigation. A spectrum image without raw complex samples, filter coefficients or a record of which physical reference fed which receiver cannot support later reconstruction. Suppose a programme silently changes decimation, window shape or automatic gain when a new device is attached. The analyst might attribute the resulting sideband change to the fan-out network although the data-processing path was altered at precisely the same instant. Which invariants should the software preserve, and how should a forensic team detect state changes that were not explicitly requested? What constitutes an adequate provenance record for a computed phase-noise graph that may ultimately become evidential material?

Charles H. Townes, Response: Dr. Dijkstra, the record should declare each instrument and its signal path, the source and distribution topology, cable and port identities, loading, supply condition, timebase origin, instrument bandwidth, offset-frequency vector, amplitude reference, cross-correlation averaging settings and any calibration corrections. It should retain raw or minimally processed traces where available and preserve every rejected measurement with its reason. Software transformations require versioned provenance, including the distinction between linear-density combination and logarithmic display conversion. A phase-noise trace without configuration metadata is not a reproducible experiment; it is an image of an unknown procedure. Immutable source data, checksums, a tested replay path and explicit uncertainty annotations allow a later reviewer to

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distinguish source behaviour from alterations introduced during measurement or presentation.

Define a measurement state vector and make it part of every acquired record. The vector should include reference-source identity, distribution port, cable and termination identifiers, local-oscillator frequencies, sample rate, gain state, filter and decimation parameters, clock lock status, window and overlap, calibration version, recording start and stop times and software revision. Store the raw samples or raw phase-error streams when feasible, together with the analysis configuration needed to regenerate each displayed result. An operator's comment is useful but should not replace machine-readable state. The software ought to flag any uncommanded transition in the acquisition chain and mark data spanning a transition as a separate measurement interval.

Preserve immutable source files with cryptographic digests and retain an audit trail of derivation, including the programme version and parameters used to produce a plot. A hash protects against unnoticed alteration after the measurement; it does not prove that the instrument was calibrated or that its timestamp was correct at acquisition. The analysis pipeline must therefore be tested with synthetic signals whose expected spurs, phase noise and transient responses are known, and with physical injection tests that exercise the analogue front end. A reproducibility exercise should permit an independent reviewer to recompute the relevant spectra and identify precisely where a claimed feature first appears. That chain of reasoning links software engineering to measurement validity without turning the fictitious historical exchange into evidence that these participants ever examined modern SDR code.

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Dr. James M. Atkinson, Moderator: Professor Ramsey will now take the principal token to examine how a sideband can be misidentified as phase modulation, and Mr. Hewlett will cross-examine the distribution-network experiment.

Norman F. Ramsey Jr., Second Principal Contributor: Dr. Atkinson, an observed pair of sidebands is not a unique diagnosis of an oscillator defect. Small periodic phase modulation can produce approximately symmetric sidebands, but so can amplitude modulation and mixed quadrature processes. A local oscillator or measurement analyser can also generate or translate a feature that appears to originate at the reference source. The discriminating measurement should preserve phase and amplitude quadratures at characterised points before and after the distribution stage, while monitoring supply voltage and reference-switching state. A differential phase comparison may suppress common source fluctuations and reveal residual additive branch noise, but only after delay matching and instrument-floor qualifications. I invite Mr. Hewlett to ask how the network should be challenged under changing loads.

The analytical separation begins with a complex envelope, not with the height of two sidebands alone. Let $z(t)=A[1+a(t)]\exp[j\varphi(t)]$ be the baseband analytic signal after carrier removal, with A the nominal amplitude, $a(t)$ the fractional amplitude perturbation, $\varphi(t)$ the residual phase and j the square root of minus one. For small a and φ, $z(t)/A$ is approximately $1+a(t)+j\varphi(t)$. The real perturbation is consequently predominantly amplitude modulation, whilst the imaginary perturbation is predominantly phase modulation, provided the quadrature axes have been calibrated and the residual carrier is correctly aligned. A spectrum analyser that displays only magnitude can

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conceal that distinction. The analyst should compare synchronous amplitude and phase records, including their relative phase when the disturbance is periodic. If the offset components have different relative phases in the in-phase and quadrature channels, a mixed amplitude-and-phase process may be present. That interpretation must not be made from an uncalibrated IQ pair merely because it looks symmetrical.

Consider a concrete, deliberately idealised case. Let $a(t)=0.002\cos(2\pi 120t)$ and $\varphi(t)=0.004\sin(2\pi 120t)$, with elapsed time t in seconds and 120 Hz a modulation frequency. To first order, amplitude modulation alone yields sideband-to-carrier voltage ratios near 0.001, equivalent to minus 60 dBc in power for each isolated sideband. Phase modulation alone, at $\beta=0.004$ radians, yields sidebands of about $\beta/2=0.002$ in voltage ratio, giving approximately minus 54 dBc per sideband. But the two modulations are not independent when they occur coherently at the same frequency. Their complex contributions may reinforce one sideband and partially cancel the other depending on relative phase. It is therefore scientifically unsound to infer β from a displayed sideband without first excluding or bounding the amplitude component. The example uses small-signal approximations and does not assert that a measured device actually exhibits these ideal functions.

The frequency multiplication case adds another diagnostic. If an ideal frequency multiplier produces the Nth harmonic of a source with phase $\varphi(t)$, the output phase deviation is $N\varphi(t)$. The same physical phase perturbation consequently yields an increase of $20\log10(N)$ in its phase-noise level, expressed in dB, under the convention that the source's normalised single-sideband phase noise is compared with the multiplied output at an

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equivalent Fourier offset. For N=10, the ideal increase is 20 dB. An actual synthesiser introduces additive noise, loop filtering, fractional spurs and finite-bandwidth behaviour, so the 20 dB rule is neither universal nor a substitute for measuring the transfer function. The assessor should compare reference and output spurs in both amplitude and phase, noting whether the offset remains fixed, scales with an internal switching frequency, or changes with a synthesiser programme. A repeated offset suggests a shared periodic influence; it cannot by itself locate that influence.

To test whether a reference spur belongs to the oscillator or its distribution network, arrange two measurement routes. The first is a direct, well-terminated output from the source, and the second passes through the suspect fan-out branch. Use an independently characterised phase detector with a separately supplied reference whenever possible, and repeat the test with the branch power source and loading varied one at a time. The residual phase spectrum is a property of the comparison geometry; it is not an intrinsic label permanently attached to a physical component. Delays should be matched at the frequencies of interest because otherwise some source-phase terms will fail to cancel, creating a spurious impression of additive noise. At low offset frequencies, environmental temperature, cable bending, vibration and connector stress matter particularly because phase responds to path-length and permittivity changes. Record such influences as controlled variables rather than treating them as laboratory inconveniences.

Finally, I should warn against claiming that close agreement between two electronic displays proves an external physical emission. If both displays use the same frequency reference, their agreement may simply be the propagated signature of one oscillator or shared supply perturbation.

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Independent timing and independent RF front ends are forms of experimental contrast, not automatic truth machines. The investigator should create a matrix of expected outcomes under competing hypotheses: an external emitter, a master-reference spur, a branch-specific additive disturbance, and a receiver-local mixing product. Each intervention should predict a different pattern if it is to discriminate between them. Where predictions overlap, additional measurements must be designed instead of retrofitting a preferred narrative to the observations.

William Redington Hewlett, Cross-Peer Question to Norman F. Ramsey Jr.: Professor Ramsey, suppose enabling a second receiver makes the first branch acquire a narrow offset spur. Some engineers would immediately condemn the buffer amplifier, but enabling the load changes current consumption, impedance, supply regulation and perhaps reverse injection from the attached receiver. How would you design a sequence of physically controlled substitutions that distinguishes these causes, and what observable would persuade you that the spur is truly phase modulation rather than an amplitude effect converted by the measuring instrument?

The proposed distinction between a modulated reference and a defective branch becomes less transparent once the second receiver is connected. Assume that the carrier amplitudes at both ports remain nominally constant, but the sideband appears only when the second receiver's internal converter is powered. A gain-only test could miss a phase-sensitive mechanism, while a reference substitution might change the converter's frequency plan and invalidate comparison. Would you insist upon simultaneous AM and PM measurements at each output and at the undisturbed source? If so, how would you control the phase-detector

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offsets, the differential cable delay and the possible dependence of instrument sensitivity on power level? I am seeking a test sequence whose observed outcomes would point to the place of origin rather than merely suppress the line.

Norman F. Ramsey Jr., Cross-Peer Answer to William Redington Hewlett: Mr. Hewlett, use characterised matched loads and retain the carrier amplitude at each distribution output while the branch occupancy changes. Record supply ripple and the corresponding phase and amplitude demodulated waveforms. Replace the receiver with an equivalent load; then exchange cables, branch ports and the test supply one at a time. A spur following the receiver suggests feedback or reverse isolation; a spur following supply current invites a regulation test; one confined to a branch suggests a path-specific contribution. Independent phase-sensitive measurement should confirm whether the phase fluctuation persists after amplitude-to-phase sensitivity has been controlled. No one intervention proves the source, and the record must preserve the configuration at each step.

Yes, although the simultaneity must be real in the metrological sense. Measure the upstream reference and each relevant output against a suitably characterised common timebase, with known channel delays and calibration tones. Preserve the two quadratures so that an apparent reduction in one form of modulation does not disguise a conversion into the other. Begin with the receiver disconnected but with its output port correctly terminated; then substitute a matched load through the same physical cable; finally connect the live receiver under otherwise unchanged conditions. At each stage record absolute carrier power, residual phase, fractional amplitude modulation, supply-rail spectral content and relevant

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temperatures. The order should be repeated or randomised to test for thermal drift and irreversible state changes.

If a spur remains negligible at the master oscillator yet grows at a particular branch whenever the receiver's converter is enabled, that pattern favours branch or receiver coupling. It does not prove the receiver is defective, since a properly functioning converter may expose inadequate isolation in the distribution unit. An impedance-network measurement at the spur frequency and a controlled return-current observation can distinguish some of the alternatives. A known calibration tone must remain detectable throughout the changes; otherwise a spur's disappearance could be a sensitivity artifact. Finally, test another branch and an independently powered receiving architecture, recording changes in transfer function. A causal inference rests on jointly consistent interventions, not on one favourable trace.

Charles H. Townes, Response to Professor Ramsey and Mr. Hewlett: I accept the need to separate quadrature mechanisms and device loading. Spectral resemblance does not establish causal origin; well-chosen component exchanges and independent reference measurements do substantially more to discriminate a source than repeated displays of the same sideband.

Dr. James M. Atkinson, Moderator: Mr. Hewlett, let us now examine output loading, reverse coupling and supply conditions. Professor Townes will question the diagnostic value of a matched-load substitution.

William Redington Hewlett, Third Principal Contributor: A clock distribution amplifier cannot be separated conceptually from its loading and supply conditions. A narrow sideband appearing only after another receiver is

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connected might indicate output-port crosstalk, reverse injection, changed supply ripple or a load-induced phase shift. The sensible investigation substitutes characterised loads and exchanges one component at a time while monitoring both phase and amplitude at the output. It should avoid disconnecting or reloading an operational evidence chain without maintaining a separate unaltered record.

A fan-out network is an assembly of active and passive two-port devices, not an abstract clock symbol. Its physical behaviour depends on conductor impedance, cable loss, connector discontinuities, isolation between branches, output buffering, supply rejection and the spectra of currents that flow through its metalwork. Assume, for illustration, one 10 MHz source driving eight buffered outputs into nominal 50-ohm systems. A second receiver may change the aggregate current drawn from an amplifier rail, and its local converter may inject a periodic return current through a shared ground. The resulting sideband can appear on several outputs even though the master oscillator, tested directly under controlled load, remains quiet. Such evidence would implicate distribution coupling, but not necessarily a single defective amplifier. A powered receiver, cable shield and chassis bond form an interconnected circuit whose impedance is frequency dependent.

A practical fault localisation programme should therefore separate four interventions. First, substitute a correctly rated matched termination for the receiver input while retaining the existing cable, thereby testing load interaction without altering cable placement. Secondly, retain the receiver but insert a characterised isolating buffer or suitable attenuation, allowing for changed signal level and measurement noise. Thirdly, power the receiver from an independently characterised supply while preserving grounding

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safety, to investigate supply-conducted coupling. Fourthly, change the reference source without otherwise disturbing the fan-out configuration. Each intervention answers a different question and must be logged as such. An apparently beneficial alteration can reduce a spur merely by attenuating it below detection, so compare absolute signal levels and detector sensitivity before declaring an impairment cured.

The distinction between port isolation and return-path coupling deserves particular emphasis. A manufacturer may specify reverse isolation at the nominal reference frequency, yet a switching disturbance at tens or hundreds of kilohertz may be conducted through the power distribution or common chassis at a frequency for which the quoted isolation figure provides little protection. The engineer should examine the relevant transfer function over the spur's modulation range, including control-loop bandwidth and supply-filter resonances. Termination should be verified at both carrier and disturbance frequencies as far as the circuit permits. A clean oscilloscope trace is not conclusive evidence of negligible low-level modulation, since time-domain vertical resolution and the instrument's own jitter may be insufficient. Conversely, a narrow spectral feature appearing after long averaging may demand renewed scrutiny of analyser leakage and reference coherence rather than an immediate component replacement.

I would establish a controlled load matrix with rows representing occupied distribution ports and columns representing measured spur amplitude, output power, source-rail ripple, and independently measured phase deviation. For example, record baseline with one load; repeat with two, four and eight loads; then move the same suspect receiver successively between ports. If the sideband amplitude follows the number of enabled loads,

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common supply impedance is one candidate. If it follows a particular port, local buffer circuitry or termination may be involved. If it follows the receiver regardless of port, return currents or receiver-generated disturbances warrant examination. These patterns are suggestive, not unique, because changing occupied ports can also alter thermal conditions. Randomise the intervention order and take repeated baseline measurements to separate drift from treatment response.

Forensic defensibility requires retention of the physical configuration. A photograph of the cable routing, a drawing of every ground and supply bond, connector identifiers, test-equipment calibration dates and a hash of the raw IQ record should accompany the final report. The observation may be minute, but the reconstruction must not depend on remembering which of eight identical cables was moved during a late evening measurement. Write the test order before examining the result and preserve anomalous as well as favourable runs. A chain of custody built around a single attractive spectrum picture is not a sufficiently controlled account of a distributed electrical system.

A further diagnostic concerns thermal time constants. Supply currents can change within microseconds, whereas a buffer package or the cable dielectric may heat over seconds or minutes. If a spur responds immediately to a load step and recovers as soon as the load is removed, conducted switching or direct coupling is plausible. If the sideband develops slowly and exhibits thermal hysteresis, path-delay or oscillator-temperature sensitivity is a stronger candidate. Log both rapid and delayed responses. Preserve the sequence of interventions because a warm-up drift may otherwise masquerade as a load-dependent phenomenon. This differential timing

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analysis is not conclusive on its own; it supplies a new experimental dimension that ordinary carrier-power measurements omit. The procedure should also state the maximum permitted loading and prohibit improvised changes to protective electrical bonding.

Charles H. Townes, Cross-Peer Question to William Redington Hewlett: If a spur disappears when a receiver is replaced by a matched load, is that sufficient to identify the receiver as the source?

Mr. Hewlett, your matched-load substitution seems straightforward until one considers that a live receiver is not a passive 50-ohm resistor. Its input impedance can vary with bias, frequency, signal level and local switching state; it can also send conducted disturbance backwards through its shield and supply connections. A passive termination has no comparable active return path. How would you distinguish the disappearance of a sideband due to removing the receiving electronics from disappearance caused by altering the high-frequency or low-frequency network loading? Could a controlled injection at the output of a distribution amplifier, performed within ratings and without unsafe grounding changes, reveal the reverse coupling path? I ask for an engineering measurement plan that separates port-to-port isolation from shared-supply and chassis mechanisms.

William Redington Hewlett, Cross-Peer Answer to Charles H. Townes: The substitution supports the hypothesis that interaction with the receiver contributed, but it also changes details of impedance, power demand and cable routing. Further challenge the suspected receiver through a different distribution port and independently measure its reverse coupling. The result

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should identify the precise conditions under which the spur occurs, rather than assign unique origin from one intervention.

I would avoid treating a nominal matched load as an electrically complete substitute for an active receiver. Instead measure the receiver's relevant small-signal input reflection characteristics where practical, and separately characterise current returned through the shield, chassis and supply system. An RF network analyser can establish the forward and reverse response around the reference carrier under suitably linear conditions; a low-frequency impedance or transfer measurement can investigate coupling at the modulation offset. For example, a 100 Hz rail ripple may convert into a 100 Hz sideband on a 10 MHz reference even if carrier-frequency port isolation is excellent. That distinction must be recorded before a particular buffer is blamed.

The controlled-injection experiment should use a benign known perturbation of calibrated amplitude at a permitted test port and monitor whether it appears at other branches. The response as a function of injection frequency provides a coupling transfer characteristic, but the tested amplitude must be low enough to avoid new nonlinearities or equipment damage. Repeat with the suspected receiver operating and with a passive load, preserving protective earth and documenting every connection. If the cross-branch response changes substantially only when a receiver is active, investigate its conducted path or altered termination. If the same coupling remains with passive loads, the distribution assembly itself is implicated. At each stage compare the measured signal against an independent calibration line, because attenuation and analyser dynamic range can otherwise give a false impression of successful isolation. The

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resulting evidence describes what the network does, and a separate reasoning step must show which component causes the impairment.

The observation should also be repeated with source and receiver roles interchanged wherever the hardware permits a valid reciprocal comparison. A nonreciprocal active buffer will not obey a passive symmetry assumption, so any reverse-transfer measurement must be interpreted with the actual bias and port ratings. Record the absolute injected disturbance and the received response in consistent units across the sweep. Then the evidence can reveal whether a reduction reflects genuine isolation improvement or merely altered attenuation at the analyser input.

Dr. James M. Atkinson, Moderator: Professor Kolmogorov, the panel must distinguish independent measurement noise from coherent spurs that survive averaging. Professor Ramsey will challenge the adequacy of the analyser floor.

Andrey N. Kolmogorov, Fourth Principal Contributor: The apparent reduction of a noise floor with averaging is a claim about random fluctuations under a stated dependence model. A coherent spur or supply-related event will not necessarily diminish, and correlated disturbances between measurement channels can defeat the anticipated cross-correlation suppression. I would preserve raw segments, rejection rules and the independence tests for internal reference oscillators. The number of averages is not an uncertainty budget.

Statistical assurance begins by defining the random object under investigation. Let x1(t) and x2(t) denote phase-error records from two measurement channels, expressed in radians after appropriate carrier

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removal. Under a simplified model, x1=s+n1 and x2=s+n2, where s is a phase fluctuation common to the two channels and n1 and n2 are their independent internal disturbances. Averaging the cross-spectrum of x1 and x2 can suppress the contributions of n1 and n2 if the independence assumptions are satisfied. Yet the architecture may create a further disturbance c that enters with opposite signs, giving x1=s+c+n1 and x2=s−c+n2. In such a case, the expected real cross-spectrum contains the desired spectral power of s minus that of c under appropriate independence conditions. An apparently low measured value might therefore arise by cancellation rather than by exceptional source purity. This possibility is documented by modern metrology research and ought to be identified as an editorial extension of our reconstructed discussion, not as a historical result spoken by the participants.

The noise-reduction claim from repeated independent averages is narrower than common rhetoric suggests. If independent estimates have common mean μ and finite variance σ^2, their arithmetic average has variance σ^2/M after M averages, where M is the number of independent estimates. Its standard deviation falls as 1/sqrt(M), not 1/M. Real spectral estimates are often partially correlated because of window overlap, shared references, slow drift or coherent interference. In that case a more general expression is Var(mean)=M^(−2) times the sum of all pairwise covariances. A substantial positive off-diagonal covariance can prevent the anticipated improvement; a negative covariance may deceptively reduce a measured cross-spectrum. One must inspect the actual covariance structure rather than deducing confidence from the counter displayed on the instrument.

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A narrow spur should not be treated as though it were a stationary random noise density. The deterministic line occupies a spectral region determined by the window shape, acquisition length and frequency alignment. Its reported dBc level is a discrete ratio relative to the carrier, whereas phase-noise density is usually reported as dBc/Hz at a specified Fourier offset. Confusing these units creates invalid comparisons, especially if one changes resolution bandwidth between measurements. The investigator should retain coherent complex records where possible and separately estimate the integrated spur power and the adjacent continuous noise density. If a tone drifts across transform bins, leakage can mimic a broadened skirt. If an intermittent event occurs only within a few records, averaging may conceal its temporal origin. A time-resolved detection statistic can preserve the event's occurrence while longer noise averages characterise the background.

I propose a hierarchical model for multi-receiver evidence. Let $y_{i,k}$ be the observed spur amplitude at receiver i during experimental condition k, expressed in linear voltage ratio after calibration. Write $y_{i,k} = \alpha_i + \beta_k + \gamma_{i,k} + \varepsilon_{i,k}$ as a diagnostic bookkeeping model: α_i represents fixed receiver effects, β_k a common state-dependent disturbance, $\gamma_{i,k}$ an interaction such as branch loading, and $\varepsilon_{i,k}$ measurement error. This is not a universal physical law; it is a transparent starting model whose adequacy must be tested by residual examination. Repeated baseline runs permit estimation of within-condition dispersion. Reversing the order of interventions can reveal drift; using an independent reference can test whether β_k follows the common oscillator. One must not interpret a fitted common coefficient as proof of a

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shared physical cause when the study has not independently varied that cause.

Confidence intervals should reflect the actual selection procedure. If investigators scan thousands of Fourier bins and report only the largest surprising spur, a confidence level attached to one preselected bin is inappropriate. Multiple-comparison effects, thresholding and data-driven search all affect the false-alarm rate. Publish the number of bins, windows, channels and intervention conditions searched, and distinguish confirmatory tests from exploratory discoveries. For a reported absence, provide a calibrated sensitivity limit and observation interval. An unobserved narrow line is not a demonstration that the distribution system was free of all spurs; it establishes only that none exceeded the stated threshold under the tested conditions.

A final safeguard is to distinguish the probability of a false alarm from the uncertainty in an estimated line amplitude. A threshold may be calibrated to yield a specified false-alarm probability for a single stationary noise model, yet the estimated amplitude of a genuine spur has a separate confidence interval. When the noise floor is heteroscedastic or the receiver gains differ, a global threshold can distort both quantities. Determine thresholds from off-spur control regions or independently acquired baseline recordings, and disclose the frequency offsets excluded from the noise estimate. Where spurs are selected after visual examination, perform a confirmatory acquisition with prespecified bands and stop rules. This prevents the field notebook from slowly transforming an exploratory discovery into an apparently planned statistical test.

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Norman F. Ramsey Jr., Cross-Peer Question to Andrey N. Kolmogorov: Can a phase-noise analyser's low displayed floor be treated as a measurement of the tested clock when its own reference oscillators may share a disturbance?

Professor Kolmogorov, the measurement team has made thousands of cross-spectrum averages and reports an exceptionally low residual-noise value. Yet the two channels share a divider, a reference oscillator and part of the environmental path. In such a system the independence assumptions are not obvious. Could an anti-correlated contribution from the splitter reduce the reported cross-spectrum even while the tested source remains noisy? How would you estimate the confidence of an apparent null without assuming the very channel independence that the experiment is meant to examine? Please distinguish ordinary variance reduction, a systematic cancellation bias and a failure to detect a coherent sideband that intermittently occupies only a fraction of the observation windows.

I would also like the calculation to identify its measurement convention. A phase-noise density expressed in decibels relative to a carrier per hertz differs from the discrete power of a coherent spur expressed in decibels relative to that carrier. If the spur is distributed over several transform bins by window leakage, how can the estimator recover its integrated power without allowing its apparent level to depend arbitrarily on the chosen resolution bandwidth? Please distinguish that engineering integration problem from the statistical independence problem in the cross-spectrum.

Andrey N. Kolmogorov, Cross-Peer Answer to Norman F. Ramsey Jr.: Only after confirming instrument noise is sufficiently below the relevant device noise and that correlated internal contributions are understood. Use a

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known reference, instrument configuration changes and independent verification where possible. The displayed trace may be an upper bound or a composite of device and instrument processes. Clearly state what has actually been resolved above the measurement floor.

Those are three distinct problems. Under genuine independence, repeated averages improve the precision of the estimator, and uncertainty can be calculated from its sampling distribution or from suitable replicate measurements. If the channels share a term c entering with opposite sign, however, the expected cross-spectrum can be biased downwards. No number of averages removes a systematic subtraction of correlated spectral power; indeed additional averages may make the wrong result look more convincing. A model $x1=s+c+n1$ and $x2=s-c+n2$ illustrates the point. With independent zero-mean s, c, n1 and n2, the real cross-spectrum expectation contains S_s-S_c, not merely S_s, where S denotes spectral density. A near-zero result need not imply a quiet source.

The practical check is architectural, not solely statistical. Change the divider type, use appropriate isolation or a differently implemented comparison path, and inject an independently quantified modulation tone to confirm recovery. Examine both real and imaginary cross-spectrum components where informative, and preserve enough individual records to identify unusual cancellation or drift. Test the splitter and detector noise floors rather than assuming they vanish. For an intermittent spur, estimate its event frequency and amplitude during detected windows separately from the average noise density. A short event occupying one percent of records may have considerable peak amplitude but little contribution to a long average. Report threshold, duty cycle, number of independent replicates

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and confidence under explicitly stated assumptions. Later experimental literature establishes that splitter-related anti-correlation is a real metrological issue, but this fictional discussion must retain an editorial citation for the modern evidence rather than crediting the historical participant with those later experiments.

For a coherent spur spread by a finite window, integrate the calibrated line power over a declared set of bins wide enough to capture the window's main lobe and relevant leakage, subtracting or bounding the adjacent noise contribution. State the coherent-gain and equivalent-noise-bandwidth corrections; repeat across window types as a sensitivity check. The procedure is not equivalent to averaging a noise density. A tone's total relative power, its spectral shape and its temporal occupancy are three different estimands, all of which should appear separately in an evidential report.

Dr. James M. Atkinson, Moderator: Sir Martin Ryle, please address how a contaminated reference becomes a suspicious RF line through frequency conversion. Mr. Hewlett will ask what may be inferred when the receiver configuration changes.

Martin Ryle, Fifth Principal Contributor: The same suspicious line may arise in the external RF field or inside an instrument whose conversion process uses a contaminated reference. A frequency-plan change can move internal products relative to the input RF coordinate, but it also changes gain and bandwidth. I would retain a known injected signal through the complete path and repeat with an independent receiver oscillator. A line that vanishes

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under one setup does not prove it was not a real emission; loss of sensitivity and changed preselection must be ruled out.

Radio interferometry offers a useful caution about the origin of apparently correlated signals. Two receivers can display coherent structure because they observe the same electromagnetic field, but they can also share contamination introduced after the antennas. The common reference is part of the receiving instrument, so its phase disturbances can propagate into the complex voltages used to estimate sky-like or terrestrial signals. Suppose receiver i employs a local oscillator fi with instantaneous phase φi(t). A signal mixed by that oscillator acquires a phase term associated with φi, the sign depending on whether the upper or lower mixing product is selected. If several receivers derive fi from one reference, their impairments need not be statistically independent. Correlation between outputs is then evidence of commonality, not necessarily evidence of radiation from a common place in the external environment.

A useful discriminant is architectural perturbation with calibrated sensitivity controls. Terminate an antenna input in a characterised impedance to test whether the suspect component survives in the receiver without external RF. Then inject a known signal near the frequency of interest to verify that the changed arrangement still detects genuine inputs. Change the local-oscillator tuning in a planned way: a physical RF carrier remains at its absolute received frequency, while internal spurs and mixing products may track the conversion plan. Yet some internally derived tones may remain fixed after digital re-mapping, and a real modulated emission may also produce several apparent products. Therefore no single frequency-plan

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change is infallible. A collection of interventions with distinct predicted signatures is more informative than a spectacular waterfall image.

Path delay can contribute another distinction. If an external wavefront reaches separated antennas, geometric delay varies with sensor position and source direction. A distribution-network spur generally enters after the antenna and need not obey the same spatial delay law. In principle one may compare relative phase across sufficiently separated sensors while varying position and orientation. In practice the experiment requires independent calibration of cable delay, antenna phase centre, common clocks and sensor motion. A close transmitter may produce near-field geometry rather than the plane-wave approximation. Reflections from walls, cable re-radiation, and common-mode currents can also produce misleading phase relations. A spatial localisation claim must explain why such instrumental paths were excluded or bounded.

I would organise the evidence into a two-axis matrix. On one axis place the suspect feature under antenna, matched-load and calibrated-injection conditions. On the other place the feature under common-clock, alternate-clock, direct-oscillator and suspect-distribution configurations. An external emission should ordinarily depend on the antenna path, whilst a reference spur should often follow the clock path, but hybrid cases exist. A strong external carrier can also undergo reciprocal mixing with reference-related phase noise, and that process is neither purely external nor purely instrumental. The correct classification may therefore be a compound mechanism requiring both environmental radiation and a defective receiver reference. A binary choice between 'bug' and 'instrument fault' can be scientifically false.

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Finally, preserve temporal and geometrical context. A sideband at one observation time can disappear when a relay switches, when a cable warms, or when a nearby appliance changes duty cycle. Synchronise raw measurements to an independently evaluated time base, retain the complete unedited record around each event and describe the spatial configuration of antennas and reference cables. In a multi-instrument forensic survey, a conclusion is strengthened when the same phenomenon survives distinct receiver architectures and independently clocked cross-checks, not merely when identical displays show an aesthetically convincing line. When the tests remain ambiguous the report should state what was measured, what was changed, and what additional experiment would be necessary to distinguish the surviving explanations.

The spatial argument must also account for phase wrapping. A geometric delay τ produces a phase change of $2\pi f\tau$ at frequency f, but the measured angle is normally known only modulo 2π without additional bandwidth or unwrapping information. Thus several source directions or cable-delay errors may fit the same single-frequency phase observation. An array measurement should employ sufficiently separated frequencies, known baselines or controlled antenna displacement to resolve such ambiguities. External multipath may alter amplitude and phase faster than anticipated as an antenna is moved through a room. Compare the observations with an explicit uncertainty model before displaying a localisation ellipse as though it were a certified geographical fact.

William Redington Hewlett, Cross-Peer Question to Martin Ryle: If reference substitution changes both the spur and the receiver gain, which observation can still help distinguish instrument artefact from an external carrier?

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Sir Martin, suppose replacing the common 10 MHz source with an independent reference causes the suspect line to disappear, but the same substitution changes the receiver's synthesis path and gain by an appreciable amount. The observations then contain a confound: an internal artefact may have been removed, yet an external narrow carrier may simply have fallen beneath the modified sensitivity. What combination of calibrated injection, antenna termination and local-oscillator offset trials would distinguish those alternatives? Would you require the suspected line to exhibit a physically plausible spatial delay across independently clocked receivers before calling it external? Please also address the hybrid case in which an external strong carrier and an impaired internal oscillator jointly produce the observed spur through reciprocal mixing.

Martin Ryle, Cross-Peer Answer to William Redington Hewlett: Use calibrated signal injection before and after substitution to measure the changed sensitivity and frequency transfer. Compare the suspected line against the local test signal under identical settings and retain the raw spectra. If the internal reference spur follows the oscillator but the external calibration remains correctly positioned, that differentiates mechanisms. The result is conditional on calibration and valid operation, not on a single disappearance.

The reference substitution has probative value only when the receiver's changed response has been measured. Inject a known signal at or near the suspect RF frequency, using a calibration method that does not alter the relevant signal path more than is necessary, and determine sensitivity, gain and frequency transfer under each reference configuration. Then repeat with a properly characterised antenna termination and compare what

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remains. If the suspicious component disappears but an equally weak calibrated signal remains visible with an adequate margin, a mere loss of sensitivity is less persuasive. It does not become impossible, since the two signals may have different temporal or modulation properties. The correct result is a strengthened comparison, not an absolute verdict.

A spatial phase test is attractive where antenna geometry and signal coherence permit it. Record known sensor coordinates, independent timebase quality, cable delay and synchronisation uncertainty, and assess whether observed phase differences change in a manner consistent with the hypothesised wavefront. Near-field and multipath effects must be modelled. If a line is generated by a shared reference distributed after the antenna, it may show common phase without the geometric trend of an external source. Yet an external timing service or common power contamination can invalidate supposed independence. The hybrid case deserves its own hypothesis: a strong off-channel transmitter can undergo reciprocal mixing with a phase-noisy local oscillator, producing apparently weaker in-band energy. In that event antenna termination removes one necessary cause, while reference replacement removes another. The evidence would show a compound process rather than fitting the binary choice 'external signal' versus 'instrumental spur'. The report should retain both causal factors and explain the tests that isolated them.

As an independent corroboration, change the antenna location whilst leaving the reference cabling fixed, then change the cabling whilst the antenna remains stationary. Those two contrasts should be documented with repeated calibration injections, because repositioning anything inside a crowded survey environment can affect shielding, coupling and receiver

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loading. A valid comparison states which geometry was altered and which was held constant, rather than simply asserting that the line 'moved' or 'disappeared'.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has established that carrier-adjacent energy must be traced through the physical reference chain, the distribution apparatus and the measuring instrument before its cause is assigned. Oscillator noise, additive branch noise, supply modulation, output loading and instrument-floor limitations can produce overlapping spectral appearances. Appropriate controls include measurements at input and output reference planes, differential residual phase assessment, safe supply perturbation, branch exchange, independent timebase comparison and software-provenance retention. Correlated sidebands among receivers sharing one source may reveal dependence, not three independent external observations. Every numerical example above is hypothetical and every historical exchange is a modern educational reconstruction.

QUESTION 058. TECHNICAL SOURCE REGISTER AND LIMITATIONS

1. NIST, 'Phase and Amplitude Noise Measurements,' Time and Frequency Division, updated 27 May 2026. https://www.nist.gov/pml/time-and-frequency-division/time-and-frequency-metrology/phase-and-amplitude-noise-measurements . Discussion of amplifier residual phase and amplitude noise and their measurement relevance.

2. Rohde & Schwarz, 'Measuring Phase Noise.' https://www.rohde-schwarz.com/kr/products/test-and-measurement/analyzers/signal-and-spectrum-analyzers/measuring-phase-noise_258363.html . Describes

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dedicated phase-noise analysis and cross-correlation of nominally independent measurement paths.

3. Analog Devices, 'AD9517-4 Product FAQ.' https://www.analog.com/en/resources/product-faqs/ad9517-4.html . Describes additive phase noise/jitter of distribution stages and the need for input-source quality.

4. Analog Devices, 'Assess Power-Supply Noise Rejection in Low-Jitter PLL Clock Generators' (2009). https://www.analog.com/en/resources/technical-articles/assess-powersupply-noise-rejection-in-lowjitter-pll-clock-generators.html . Describes supply-noise-induced deterministic jitter and laboratory techniques.

Editorial qualification: Hardware figures and modulation examples are hypothetical. The historical participants are not represented as having conducted these contemporary tests; no equipment-specific performance is claimed without independent evidence.

EDITORIAL SOURCE NOTES FOR QUESTION 058. Modern metrological evidence below supports the technical extrapolations in this fictional educational discussion. The historical panellists are not represented as having read publications appearing after their deaths.

Hati, A., Nelson, C. W., and Howe, D. A., “Cross-spectrum Measurement of Thermal-noise Limited Oscillators,” Review of Scientific Instruments (2016). NIST publication record: https://www.nist.gov/publications/cross-spectrum-measurement-thermal-noise-limited-oscillators

Nelson, C. W., Hati, A., and Howe, D. A., “A collapse of the cross-spectral function in phase noise metrology,” Review of Scientific Instruments (2014).

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NIST publication record: https://www.nist.gov/publications/collapse-cross-spectral-function-phase-noise-metrology

Howe, D. A., Hati, A., Nelson, C. W., and Lirette, D. G., “PM-AM Correlation Measurements and Analysis,” IEEE International Frequency Control Symposium (2012). NIST publication record: https://www.nist.gov/publications/pm-am-correlation-measurements-and-analysis

Rohde & Schwarz, “Spectrum analysis method for measuring phase noise.” General measurement guidance on IQ separation of AM and PM, resolution-bandwidth corrections and instrument limits: https://www.sg.rohde-schwarz.com/us/products/test-and-measurement/analyzers/signal-and-spectrum-analyzers/spectrum-analysis-method-for-measuring-phase-noise_258374.html

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QUESTION 059

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When Is a Spectrum Analyser Timebase Adequate for Multistation Arrival-Time Localisation?

SCHOLARLY RECONSTRUCTION. The following dialogue is fictional pedagogical exposition using deceased specialists. It is not a historical transcript. Contemporary instruments, satellite timing, digital sampling and forensic applications are editorial extrapolations from documented scientific principles.

Dr. James M. Atkinson, Moderator: Professor Bracewell, a multistation RF survey records a short burst at three or more geographically separated locations. Each station displays a spectral peak and declares itself synchronised to a reference clock. An analyst then treats the peak's displayed time as the instant the burst arrived, constructs time differences between stations and solves for its possible source position. Under what conditions does a spectrum analyser provide a legitimate arrival-time measurement, and when does its apparent time resolution merely describe a display, a sweep, or a detector rather than the electromagnetic event?

Ronald N. Bracewell, Principal Contributor: Dr. Atkinson, the first duty is to define the observable. The arrival time of a particular identifiable signal feature at a stated antenna reference plane is not automatically the time at which a spectral display records a maximum. Swept analysers inspect different frequencies at different moments. Their trace may be completed only after a sweep, and a detector can combine or compress multiple samples within a display bin. A display timestamp might represent the sweep start, the host's receipt of a completed trace, or an instrument-defined trigger event. Those are distinct quantities. Only a verified

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acquisition path connecting an identifiable waveform feature to a calibrated hardware timebase may support a time-difference-of-arrival inference.

Consider an emitter at unknown position x and receiver station i at known position r_i. In a simplified free-space model the arrival time is $t_i=t_0+||x-r_i||/c+b_i+e_i$, where t_0 is emission time, c is propagation speed, b_i is a station-specific timing bias and e_i encompasses random measurement error and unmodelled effects. Subtracting the arrival equations for receivers i and j eliminates the unknown emission time but leaves $\Delta t_{ij}=(||x-r_i||-||x-r_j||)/c+(b_i-b_j)+(e_i-e_j)$. A timebase may be highly stable while an uncalibrated constant bias remains. Synchronisation of frequency alone establishes neither the value nor the uncertainty of b_i-b_j. The inverse problem relies upon the difference, not upon the prestige or precision of an individual clock certificate.

For the scale of the inference, a differential timing bias of one microsecond corresponds to approximately 300 metres of light-travel path difference in free space. Ten nanoseconds correspond to approximately three metres of path difference. These are path-length equivalents, not guaranteed coordinate-error bounds. Geometric dilution can make position error much larger, particularly when stations lie on an unfavourable baseline or the signal approaches from a direction that yields weak sensitivity in one coordinate. Conversely the solver may conceal a timing bias in an apparently plausible position. A quantitative report must propagate uncertainty through the actual station geometry and the adopted propagation model, not simply multiply every quoted timing standard deviation by c and call the result localisation accuracy.

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In two dimensions, a single independent time difference constrains a hyperbola in an ideal propagation model. More station measurements provide additional constraints, but the count of receivers alone does not establish a unique or well-conditioned solution. The Jacobian of the predicted differences with respect to source position determines local sensitivity; nearly dependent rows signal poor geometry. Additional nuisance parameters may include station clock offsets, path delay, instrument trigger delay and transmitter-feature ambiguity. A least-squares location produced under incorrect assumptions can have a small algebraic residual and still be physically wrong. Residual magnitude is evidence about consistency with the assumed model, not independent proof of the model's correctness.

A spectrum analyser's architecture becomes decisive. A swept-tuned instrument may report a burst's energy at the time the swept passband happened to overlap its frequency. Even if its sweep period is accurately referenced, the instrument has not necessarily recorded the waveform's onset at the antenna. A real-time spectrum analyser or an SDR with continuous I/Q storage can offer an acquisition record suitable for retrospective time tagging, but that capability depends on trigger placement, buffer continuity, time-stamp origin, channelisation delay, ADC clock mapping and the availability of raw samples. The words 'real-time' are not a metrological specification. An examiner should identify the actual hardware event from which the timestamp is formed.

Group delay is another latent term. A narrow filter can delay the envelope of a burst; a digital finite-impulse-response filter may introduce a calculable delay, while variable decimation or signal-dependent threshold crossing can

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change the detected onset. Antenna cables, splitters, preamplifiers, frequency converters and fibre or network transports add further latency. Some delays are stable and correctable, others depend on operating mode or temperature, and some vary with signal bandwidth and amplitude. Calibration must match the relevant signal feature and settings, not only the carrier frequency. An apparently synchronised counter can coexist with a badly characterised analogue path.

A worked laboratory case illustrates the distinction. Suppose a calibration transmitter at a surveyed known location sends a permitted 20 MHz-wide reference burst that is captured by three stations with continuous hardware sample counters. The predicted differential propagation time between two stations, given their positions and a declared effective propagation speed, is 2.4 microseconds. If the observed difference is 2.7 microseconds, a residual 0.3 microsecond represents roughly 90 metres of path-difference equivalent. That residual may involve channel delay, clock bias, propagation or feature-picking error; it does not identify which. Repeat the experiment with a second known position, exchange receiver chains between stations, and alter the timebase of one laboratory receiver by a traceable controlled amount. A correct causal model should predict how the measured differences change under each intervention.

The experiment must also confront reference dependency. Two analysers disciplined by the same distribution system may acquire correlated timing errors. If a shared reference change shifts both identically, a particular station pair can exhibit reassuring differential stability while their absolute time labels move. If a path-specific reference interruption affects only one station, a differential anomaly may resemble a change in arrival geometry.

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Independently monitored downstream sample-edge timing is therefore preferable to unverified lock indicators. A second receiver using a genuinely independent clock and path can challenge the synchronisation assumption, but its comparison must account for its own calibrated signal path.

Cross-correlation of wideband waveforms can estimate relative delay from the measured signal structure rather than using a spectrum-trace peak. This is ordinarily more suitable when the waveform has adequate bandwidth, signal-to-noise ratio and identifiable shared features. Yet correlation functions can show multiple peaks because of multipath, repeated symbols, ambiguous modulation or mismatched channel responses. Interpolation between digital samples may improve the precision of estimating a correlation peak under a valid signal model; it does not create independently observed high-frequency information or remove a wrong clock calibration. Preserve the raw acquisition and report peak-selection rules, sampling uncertainties and the possibility of alternative delay hypotheses.

The error covariance deserves explicit treatment. Let the vector of measured time differences be z and its model predictions $h(x)$. The weighted residual statistic $(z-h(x))^T R^{-1}(z-h(x))$ requires a defensible covariance matrix R. Differences sharing a station are correlated even if the original station timing errors are independent; for example, Δt_{21} and Δt_{31} both contain the error from station 1. Treating them as independent may overstate the information in the network. A common timing service or propagation disturbance introduces further covariance. Where R is inadequately known, sensitivity and bounded-error analyses may be more defensible than impressive but unvalidated confidence ellipses.

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A sound acceptance test therefore uses surveyed stations, a known waveform and a known emitter, measured system delays and reference sources, challenges of each station's timebase and acquisition path, and enough geometrically distinct test locations to expose systematic errors. The team should reconstruct the position while blinded to at least some known test coordinates, compare predicted and measured arrival differences, preserve all failed detections and state the limits under which localisation passed. Under adverse conditions, the proper conclusion may be a locus, a broad region, or the finding that attribution is not supportable. Metrology is not improved by inventing a precise location where the timing evidence does not justify one.

Dr. James M. Atkinson, Moderator: Professor Gabor, why does the choice between a swept display and a continuously retained waveform matter for the instant assigned to a burst?

Dennis Gabor, Peer Question: Professor Bracewell, an analyst observes a short pulse on an analyser's spectrogram and marks the centre of a coloured feature as the signal's arrival. But a windowed frequency estimate is built from a finite span of samples and its visible peak may depend upon window shape, filtering and averaging. How should the display's time-frequency resolution be distinguished from the accuracy of the physical event timestamp, and what experiment would reveal whether the chosen feature migrates when the analysis window changes?

I would also ask that the panel examine the mathematical cost of placing a time label at the centre of the transform window rather than at its leading edge. If the same transient is captured with different window widths at separate stations, are the assigned coordinates comparable merely because

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the software uses the same definition of a frame? What happens when the burst contains a chirp or a delayed echo that shifts the location of the largest spectral tile? I invite a test in which identical immutable input samples are rendered under several window conventions, and ask which observable should remain invariant before any time difference is accepted for localisation.

Ronald N. Bracewell, Response: Professor Gabor, a spectrogram time coordinate is an assigned coordinate for an analysis window, not necessarily the onset of physical reception. The instrument or software may label the centre, beginning or end of the window. A short burst passing through a long window will influence several neighbouring tiles, and the maximum tile can shift when the hop size or window function changes. Retain the underlying complex samples and define an arrival estimator independent of display colour. Inject a known reference pulse at a calibrated input, repeat the analysis with several window lengths and hop sizes, and measure the bias and dispersion of the estimator relative to the observed hardware capture edge. For time-difference localisation, each station must use compatible feature definitions or have calibrated estimator-specific delays. A beautiful common spectrogram is not a common timestamp standard.

The raw waveform should supply a declared arrival estimator; the spectrogram should serve as a diagnostic of whether the estimator remains appropriate. If one station labels the start of a 2-millisecond window and another labels its centre, an otherwise identical transient can acquire a one-millisecond nominal displacement solely through metadata convention. This is extreme but clarifying. Even when both label window centres, the hop position, threshold and signal-to-noise ratio can move the selected

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maximum. The analyst should therefore rerun the exact same capture using several windows and record the observed shift in the inferred delay, not merely admire the agreement among colourful plots. The experiment should use a known marker before and after the signal chain, with delay correction traceable to that marker. For a wideband coded pulse, direct cross-correlation of retained complex samples may offer better localisation sensitivity than a coloured time-frequency maximum. But a chirp, strong echo or cycle ambiguity can create multiple correlation peaks, and the method still needs a predeclared peak-selection rule. The evidence should include the width and height of the competing peaks, their stability under signal-level and window changes, and whether the physically earliest feature is actually visible. Only after these controls can the time stamp be treated as an estimate of a specified arrival feature rather than a convention associated with rendering. The analyst must additionally record dropped samples and the effective analogue and digital group delays. Changes of processing window made after seeing a location solution should be documented as exploratory sensitivity analysis, never silently substituted as the original result.

Dr. James M. Atkinson, Moderator: Dr. Dijkstra, what metadata are necessary if a software pipeline is to sustain the evidential claim?

Edsger W. Dijkstra, Peer Question: Professor Bracewell, receiver software may timestamp an I/Q block after decimation, order packets by host arrival, quietly interpolate a missing block or update a clock-conversion table after the original capture. The final file may appear internally consistent although its event chronology depends on undocumented repairs. Which invariants and source records should be preserved so that a later reviewer can

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distinguish physical capture time from subsequent processing and identify the precise origin of a disputed timestamp?

The software may also alter a sample stream without writing a conspicuous error: a resampler may generate a replacement sample, an acquisition library may restart its index at zero after a device reset, and a host might apply the latest clock calibration retroactively to an earlier event. Would you insist upon a sequence-number invariant, an unmodified hardware-counter record and a reversible, versioned timestamp transformation? How ought one treat packets that arrive out of order, or a capture interval where a driver returns a plausible timestamp but no data-provenance record? I am concerned that a sophisticated post-processing graph can conceal precisely the evidence needed to challenge its original time labels.

Ronald N. Bracewell, Response: Dr. Dijkstra, preserve immutable device counters, raw device timestamps, acquisition configuration, packet sequence, overrun status and every clock mapping applied to the record. Link processed samples to their original index ranges and maintain the effective delay of each filtering or resampling stage. Do not overwrite original timestamps when calibrations improve. A correct processing chain should either preserve sample chronology or explicitly mark each gap, correction or change of epoch. Test the invariant using known pulse sequences under imposed processing load and deliberate clock disturbances. A file that is complete in format but incomplete in samples must reveal the omission. These rules enable another investigator to reconstruct the chronology and test the conclusion without relying upon the first analyst's display or recollection.

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I would impose three separately verifiable invariants. First, acquisition order must be represented by a device-origin counter or another data item whose generation point is known; a host incrementing a counter after packets arrive does not prove that upstream samples survived. Second, every stored sample interval must retain a reference to its device configuration, clock state, acquisition epoch and any reported overflow or restart. Third, transformation from the device index into external time must be versioned, reversible as far as practical, and never overwrite the raw observation. A late packet can be placed in its correct sequence by its device identifier, but this operation should be recorded rather than used to conceal transport delay. If a gap cannot be reconciled with a trustworthy counter, mark it as a gap and exclude unsupported continuity assertions. A timestamp produced after an undocumented restart may belong to a different epoch even when its numerical value seems plausible. The same problem occurs if a driver resumes a buffer while the hardware oscillator has entered a new phase state. Conduct a controlled challenge: interrupt transport without stopping the ADC, then stop the ADC without interrupting host networking, and observe whether the metadata distinguishes the cases. Follow with an intentional host clock slew and confirm that original counters do not change. Preservation should include raw files, hashes, the event ledger, firmware and driver versions, calibration maps and processing logs. A forensic report can then state precisely which input facts support the arrival estimate, which conversions were applied, and where a later reviewer might disagree. Consistency of a final spreadsheet is not proof that the original stream was continuous.

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Dr. James M. Atkinson, Moderator: Professor Rabi, could an apparent between-station delay result from the receiving instruments rather than the radiation field?

Isidor I. Rabi, Peer Question: Professor Bracewell, a common transmitter excites receivers containing different filters, mixers, detectors and trigger algorithms. One station has a strong clean waveform; another has a weaker multipath-corrupted signal that crosses its trigger threshold later. If both report nominally perfect reference-clock lock, does that establish that the measured time difference is a geometric propagation delay? How would a controlled experiment distinguish signal-dependent detection latency from actual path-length differences?

A further difficulty is that two instruments need not agree upon what they call the same physical event. One detects the first threshold crossing, another the maximum of a matched-filter response, and a third an amplitude peak after an automatic-gain-control transient. Even if each device is calibrated in isolation, is it legitimate to subtract these three timestamps? Would you recommend a common electrical reference-plane experiment with an injected, waveform-matched calibration signal, and if so how can the test expose nonlinear, amplitude-dependent timing walk without using hazardous RF levels? Please also discuss the possibility that real multipath produces several honest arrival candidates rather than one canonical event.

Ronald N. Bracewell, Response: Professor Rabi, no. Clock lock controls a particular oscillator relationship; it does not remove different waveform transfer functions or threshold biases. A controlled transmitter at a surveyed known position should drive each receiving chain through both an

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electrical calibration path and the intended antenna path. Vary amplitude, bandwidth and modulation to reveal whether the detected feature moves with the algorithm or the signal environment. Compare a threshold-onset estimator with a cross-correlation estimator and inspect the full response impulse or group-delay characterisation. Multipath can create physically real additional paths that are not the first arriving path. The report should acknowledge any ambiguity between the earliest detectable component and the strongest peak. A locked clock is necessary for some measurements, but it is insufficient to identify which portion of the incoming radiation the detector chose.

A time difference is only meaningful when the two clocks describe comparable events at their declared reference planes. For an electrical challenge, inject a permitted waveform through a calibrated splitter into both receivers and independently measure the arrival timing at each input. Use the same detector algorithm on the raw outputs, or characterise each detector's distinct offset against the common physical event. Then vary amplitude, bandwidth and noise within safe equipment limits. If the timestamp shifts with amplitude, the effect is estimator timing walk rather than antenna-to-antenna propagation. A constant-fraction trigger may reduce simple amplitude dependence but does not make a distorted or multipath waveform immune to bias. Digital filtering, automatic gain control and saturation require separate tests. Over-the-air calibration at surveyed positions tests propagation and antenna effects, which conducted injection deliberately excludes. Two such calibration classes are complementary; neither makes the other redundant. When a station has a weaker earliest path and a stronger later reflection, the selected maximum may correspond

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to different path classes at different receivers. A location algorithm that silently treats them as one direct path can produce a convincing but wrong coordinate. Instead preserve the delay-peak alternatives, report which path selection was made and its conditions, and compare positions across frequency, polarisation and station geometry if permitted. I would also require the operator to repeat the field test after changing receiver gain, because a location that moves when only instrument gain is altered exposes an estimator or transfer-function dependency. Only a consistently defined and independently calibrated event should be eligible for microsecond or nanosecond forensic inference.

Dr. James M. Atkinson, Moderator: Professor Essen, how much confidence should an analyst place in the frequency stability of a station timebase?

Louis Essen, Peer Question: Professor Bracewell, a station may claim an excellent long-term stability figure for a disciplined oscillator. A location solution, however, depends upon relative timing over the actual observation interval, which may be milliseconds or seconds. What distinction must be drawn between frequency accuracy, time offset and phase continuity? Could a short reference reacquisition step leave a pleasing stability statistic while introducing a timing bias large enough to move the computed source location materially?

I would like the panel to separate clock accuracy at a particular instant from frequency stability averaged over a much longer period. A disciplined oscillator may remain within a superb specified frequency tolerance and nonetheless experience a time-step correction when the reference is reacquired. A station's one-pulse-per-second input may also have a delay that was never measured at the ADC. How would a challenge test establish

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continuous sample-edge phase throughout a disputed burst rather than merely confirm a green synchronisation indicator before and after it? What uncertainty would you assign when the physical counter record is present but the external-time mapping was recalculated after the survey?

Ronald N. Bracewell, Response: Professor Essen, long-term frequency performance constrains one part of the clock model, not every time error. A constant time offset remains possible even if the frequency error is nearly zero. A phase or timestamp step can occur at reacquisition and may be hidden in averages that exclude the transition. Characterise the clock over the specific interval of the burst and retain its offset, frequency deviation, phase-error history, holdover state and adjustment commands. Repeat a location calibration with a known event before and after a controlled reference interruption, comparing the downstream hardware sample edge against an independently maintained timing witness. If the offset or continuity is unmeasured, do not infer a small timing uncertainty merely from a published oscillator specification. Treat the affected events as qualified or exclude them from a precision localisation claim.

The phase history of the acquisition edge is the relevant record; a lock-status light is, at best, a summary of one controller's internal decision. A disciplined oscillator's frequency may be excellent while its time offset from an external reference remains material. During holdover, the mapping from sample index to UTC must carry a time-dependent uncertainty, and at reacquisition the firmware may step or slew phase. A downstream phase comparator or calibrated timing marker near the actual sampling input should observe this process during a deliberate and safe reference interruption. Repeat at realistic temperatures and after a restart, because

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the fault may appear only in a particular controller state. The timebase logs should include reference identity, phase error, frequency correction, epoch, clock switch and sample-counter transitions, with units and timestamps. If an external-time mapping is recalculated retrospectively, preserve the original mapping and the data that justified the revision. The revised estimate is derived evidence, not the unmodified acquisition observation. For a short burst, estimate the relative clock offset at the burst epoch rather than import a stability number measured over unrelated intervals. If uncertainty cannot be bounded across a discontinuity, qualify or exclude the affected delay. This is especially important when several receivers share an upstream reference. A common fault can cancel in a particular difference and yet invalidate the claimed absolute time. Conversely branch-specific phase events can survive subtraction. A trustworthy location report will distinguish stable relative timing, known external-time traceability and continuity through all controller transitions, instead of compressing them into the single adjective synchronised.

Dr. James M. Atkinson, Moderator: Professor Townes, does a common reference between stations eliminate the relevant timing error?

Charles H. Townes, Peer Question: Professor Bracewell, distributing a single oscillator may improve coherence, but different stations can use unequal cable paths, local phase-locked loops and receivers with distinct latency. At the same time a fault in the common source may shift multiple receivers together. Which errors cancel in a time difference, which survive, and what should the investigator measure before accepting that the arrangement supplies independent arrival-time evidence?

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I ask whether a common oscillator should be treated as a source of independence or merely of coherence. The same reference can drive several frequency converters and sampling systems, while downstream branch filters introduce different delays and control-loop transients. If a common phase jump cancels when two station timestamps are subtracted, the resulting delay may look stable even though their claimed absolute UTC labels were wrong. What controlled substitution would establish the residual branch-dependent errors, and what covariance should enter a location solution when several time differences share one station? I would particularly welcome a distinction between corroborating the arrival waveform and corroborating the time reference itself.

Ronald N. Bracewell, Response: Professor Townes, an exactly common error that enters both measured arrival times with the same magnitude cancels in their difference. A branch-dependent delay, a different local loop transient or a receiver-specific group delay survives. The cancellation is also estimand-specific: good relative timing does not establish absolute UTC event time. Map the reference distribution, measure path delays at the actual receiver inputs, and record downstream sampling-edge relations rather than only the reference source output. Exchange branches and introduce a small authorised laboratory timing perturbation into one branch to determine its effect on the final delay estimate. The observations should support an explicit covariance model. Agreement between several instruments sharing a reference is not independent corroboration of the quality of that reference.

A shared oscillator is often desirable because it allows coherent comparisons. The error lies in calling the resulting time records

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independent. Suppose each measured timestamp has a common term c and a station-specific term e_i, so t_i equals the physical arrival time plus c plus e_i. The difference between two stations cancels c when it truly enters both identically, but retains e_i−e_j. In a real distribution network, the shared phase disturbance can be filtered differently by separate synthesiser loops, so even the premise of identical contribution needs testing. Map the clock tree all the way to the sampling edge, measure each cable and fan-out branch, and exchange reference sources or output ports in a controlled laboratory setting. If the anomalous delay follows a port, branch or local receiver rather than the antenna, investigate instrumentation. A different reference of known quality provides another challenge. The covariance of differences matters as well. Using station one as the reference for two differences introduces a common station-one error even if its original error was statistically independent of the other stations. The solver should therefore use a covariance matrix containing that shared variance. Separate the question of whether the same RF event was seen at multiple antennas from whether its time tags were generated by independent clocks. Independent corroboration of the radiation field does not require independent clocks, but an absolute event-time claim requires an independently defendable timing reference and propagation model. I would not allow a common-clock array to be represented as several independent confirmations of the clock's own reliability. Such a conclusion would confuse engineered coherence with statistical independence.

Dr. James M. Atkinson, Moderator: Mr. Harrison, what physical defects might alter a nominally calibrated timing chain?

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John Harrison, Peer Question: Professor Bracewell, the timing standard may be of high quality at the source, yet its signal travels through cables, connectors, amplifiers and switching devices before reaching the analyser. Temperature, mechanical motion and ageing can alter electrical path length. A calibration performed in a quiet laboratory months earlier may therefore differ from one during a field survey. Which tests would identify the drift of delivered timing, and what evidence would justify transferring a laboratory delay calibration into the operational installation?

It is easy to trust a standard at the cabinet where it was calibrated and overlook what happens after the signal passes through long cables, connectors and distribution amplifiers. During a field deployment, thermal expansion or a badly seated connector may change electrical delay without generating an obvious reference alarm. How should the laboratory reproduce the mechanical and thermal conditions of the installed system, and how can a branch-swap trial distinguish cable effects from receiver electronics? Please address the danger of transferring a calibration performed with one load, termination and routing arrangement to a different field installation as though nothing material had changed.

Ronald N. Bracewell, Response: Mr. Harrison, every calibration belongs to a configuration and operating range. Record the cable types, lengths, reference ports, termination, temperature and connection history, then measure delay or phase at the point of use under representative conditions. Periodic comparison against an independent reference can reveal drift, while exchanging cable branches helps locate path-specific anomalies. A calibration transferred to the field is persuasive only where the relevant configuration and environmental bounds are maintained or the difference

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has been measured and included as uncertainty. One should not treat a reference path as immutable merely because it contains no software. A loose connector or altered length can be as consequential to time-difference evidence as a clock algorithm.

The time standard must be evaluated where it is used, not only where it is generated. A stable source feeding a cable of changing electrical length can exhibit a delivered phase change that the source's own monitor does not see. Record the cable, connector and distribution topology, terminations, loading, temperature and mechanical routing before the survey. Compare input and output phase against an independent witness while varying temperature across the operating range, and repeat after a careful reconnect. The field chain may contain multiple converters, each with its own group delay and switching behaviour. A branch-swap test can reveal whether a problem follows the receiver, the cable or the reference port; however, the act of swapping also changes connector seating and mechanical stress, so one trial is insufficient. Repeat a predeclared sequence with controls and document the results. Ensure the calibration stimulus matches the frequency band and detector used in the actual event analysis. A calibration for a one-kilohertz tone does not automatically measure the group delay of a twenty-megahertz pulse. At the conclusion of deployment, repeat the timing check in the actual installed configuration. If an uncontrolled thermal cycle or maintenance event occurred during collection, describe the possible effect and whether the calibration still applies. Long cables should be treated as physical components with measurable uncertainty, not as mathematically zero-delay arrows drawn on a diagram. A

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meticulous installation record can prevent an erroneous emitter location just as effectively as an elaborate post-processing algorithm.

Dr. James M. Atkinson, Moderator: Lord Kelvin, how should geometry enter the uncertainty statement?

William Thomson, Baron Kelvin, Peer Question: Professor Bracewell, an investigator may quote a ten-nanosecond arrival-time uncertainty and transform it directly into a three-metre position accuracy claim. Yet the source position is inferred from several path-length differences whose sensitivity varies with station geometry, error covariance and perhaps propagation uncertainty. How should the report distinguish a physical path-difference scale from an actual coordinate uncertainty, and how should an ill-conditioned array be described?

The quoted ten-nanosecond figure might represent only one estimator's random repeatability. The actual location uncertainty depends on station geometry, delay correlations, receiver group delays and the probability of choosing a reflected rather than direct path. Would you explain which matrix or sensitivity calculation turns observed delay covariance into a spatial region, and under what conditions that calculation becomes ill-conditioned? I would also ask for an explicit distinction between a three-metre free-space path-difference equivalent and a three-metre error in either east or north coordinates. How should the uncertainty be disclosed when the estimator has two plausible delay peaks corresponding to separate candidate regions?

Ronald N. Bracewell, Response: Lord Kelvin, the three-metre figure is merely c times ten nanoseconds in the ideal free-space model. It is not a coordinate

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uncertainty without the inverse solution. Construct the Jacobian G of all independent predicted time differences with respect to the unknown coordinates. Under a locally linear, unbiased model and a justified covariance matrix R, the covariance approximation for a weighted least-squares solution is $(G^T R^{-1} G)^{-1}$ when the matrix is nonsingular. Its eigenvalues and directions show which location components are well or poorly determined. If the geometry makes the matrix nearly singular, small timing errors can yield large position changes, and a non-linear confidence region may be preferable to a tidy ellipse. Include station-position errors and systematic delays separately or augment the state where identifiable. Above all, state assumptions: the displayed clock precision does not determine the geographical accuracy of a localisation result.

The ten-nanosecond uncertainty translates into three metres of free-space path-length difference only for the corresponding timing quantity; it is not an independently determined coordinate error. The derivatives of each predicted time difference with respect to east and north position describe how strongly a change in location affects the data. Collect them into a Jacobian G, measured in seconds per metre. With a defensible measurement covariance R, the local information matrix is G-transpose R-inverse G. If this matrix is nearly singular, there is a direction in which considerable location change produces little effect on predicted time differences. That poor geometry cannot be overcome simply by printing more timestamp digits. A confidence region should be computed using the actual nonlinear model when the linear approximation is inadequate, and it should reflect common-clock and shared-station error covariances. When two or more delay peaks are plausible, carry the alternative peak assignments through the solver.

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They may yield separate viable regions, in which case a single ellipse around the most attractive solution is misleading. Station-coordinate uncertainty, finite propagation-speed modelling and receiver-specific group delay should either be incorporated into the model or disclosed as qualifications. Validation at independently surveyed source locations is indispensable. A useful report gives the raw measured differences, the chosen feature, all corrections, an uncertainty matrix, the station geometry and a statement of what spatial claims are and are not supported. Precision is a property of the whole measurement procedure, not an ornament attached to a clock reading.

Dr. James M. Atkinson, Moderator: Lord Kelvin will now contribute as a distinct principal speaker on the geometry of arrival-time localisation. Professor Bracewell will challenge the interpretation of his proposed uncertainty model.

William Thomson, Baron Kelvin, Second Principal Contributor: Dr. Atkinson, a ten-nanosecond timing claim is a claim about a clock or estimator under specified conditions, not a three-metre guaranteed location. The corresponding free-space path-difference scale is roughly three metres, but the mapping from path differences to source coordinates depends on receiver geometry and shared errors. In a nearly collinear array the inverse problem can be ill-conditioned, and a few nanoseconds of differential bias can move one coordinate vastly farther than a naive path-length argument suggests. The Jacobian and timing covariance must enter a defensible uncertainty statement; errors shared by pairwise differences must not be counted as independent observations. I would test the network against several known emitters at distinct bearings and compare predicted

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differences to independently observed arrival features. Professor Bracewell may now challenge whether the feature itself is identified consistently.

I propose that the inquiry begin with its measurand rather than its equipment. A station does not measure an abstract point named arrival time. It measures the value of an estimator applied to a particular waveform, conditioned upon a chosen antenna terminal, trigger definition, filtering chain and clock convention. An uncertainty budget that combines numbers from different measurands is incoherent even if every number bears the unit seconds. We might calibrate the arrival of a known envelope edge at a receiver input and later seek the first resolvable multipath component at an antenna aperture. The difference between those two events is not automatically a random error. It is a failure to transfer the calibration to the quantity actually claimed. I would therefore place a written definition of the arrival feature at the beginning of every location experiment, specify how the feature is selected in noisy data, and record its systematic dependence upon amplitude, modulation and path conditions. Repeatability is then measured for a defined procedure, not for a moving target.

Let the vector z contain the observed time differences in seconds, the vector x contain the coordinates of the hypothesised transmitter in metres, and h(x) predict those differences from known station coordinates and an assumed propagation model. For a locally linear approximation at a candidate location x0, write z−h(x0) approximately as G Δx+e, where Δx is the displacement from x0, G is the Jacobian whose entries are derivatives of predicted delay with respect to each position coordinate, and e is the measurement-error vector. Each row of G carries units of seconds per

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metre. If the covariance R of e is known and positive definite, the formal covariance of an ordinary locally linear weighted least-squares estimate is (G-transpose R-inverse G)-inverse. That is a conditional result. It presumes that the estimator is locally identifiable, that the covariance represents the important dependencies, and that significant systematic delays have already been removed or explicitly modelled. An elegant inverse matrix cannot rescue omitted timebase steps, badly surveyed antennas or an incorrect identification of the first arriving waveform.

Consider two geometric arrangements built from three receivers. In the first, the receivers occupy widely separated non-collinear stations around an intended search area. In the second, all stations lie nearly along a single road with the emitter far beyond one end. For the same nominal standard deviation of measured delays, the second geometry may provide much weaker discrimination of displacement transverse to the line. The normal matrix acquires a small eigenvalue, and uncertainty grows sharply along the corresponding direction. A small residual does not prevent this because many candidate positions yield nearly the same pattern of delays. The practitioner ought to present an uncertainty contour, region or set of admissible positions, with the geometry and probability or bounding interpretation stated. It would be misleading to select the sharpest plot produced by a solver without describing how the array geometry limited the inference. This is particularly important when a regulator, court or protective-security customer may mistake graphical precision for certainty about a particular building or room.

The errors of differences also require care. Suppose each station has an independent time error u_i with variance σ_i squared, and the delays are

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formed against station one. Then the error of delay 2−1 is u_2-u_1, while that of delay 3−1 is u_3-u_1. Their covariance is the variance of u_1, which is generally positive. This remains true even though the underlying station errors were independent. If all three differences are then weighted as independent, information from station one is counted several times and an optimistic location covariance results. A common reference can introduce further correlations, some of which cancel under ideal differencing and some of which survive as branch-dependent effects. The instrument record should therefore distinguish station-origin errors, shared-reference errors and environmental errors. Model each according to the physical path that produces it, rather than assign arbitrary diagonal uncertainty simply to make a numerical procedure convenient.

There are at least three categories of uncertainty that should not be silently pooled. A stochastic term might be estimated from repeated timing-marker captures under fixed conditions; a bias might be characterised by a measured cable or digital-filter delay and corrected with its uncertainty; and an unresolved alternative path might produce several separated location hypotheses. The third is not necessarily well represented by enlarging a Gaussian standard deviation around one favoured coordinate. A more appropriate disclosure might retain two admissible delay peaks and carry both through to alternative spatial regions. Likewise, a period of clock holdover might require time-dependent bounds rather than one value copied from an equipment certificate. Scientific candour sometimes produces an unattractive map, but the map becomes credible precisely because it does not hide the limits of the evidence.

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I would approve a precision statement only after a blind challenge. Place or simulate an authorised reference emitter at several surveyed positions chosen to expose weak directions of the array. Run the unchanged processing procedure, including automated peak selection, filtering, timestamp mapping and uncertainty calculation, without informing the analyst of all target positions. Compare the declared confidence regions or deterministic bounds with the actual positions and inspect failures, not merely average error. Repeat with weak signals, deliberate clock perturbations and path obstructions to reveal conditions under which the model ceases to apply. This practice does not replace a formal measurement traceability chain, but it tests the whole inference rather than the isolated clock. I hand the token to Professor Gabor, because it is the creation of a time label from finite spectral data that next deserves scrutiny.

Ronald N. Bracewell, Cross-Peer Question to William Thomson, Baron Kelvin: Lord Kelvin, suppose three stations are precisely surveyed and each receiver reports an attractively narrow timestamp uncertainty, yet the signal is a short multipath-corrupted burst. One station identifies the earliest detectable rise, another the strongest correlation peak and the third the centre of a spectral tile. Do those reported instants even correspond to the same physical feature? Would the covariance calculation remain valid if the dominant error were inconsistent waveform selection rather than the stated clock noise? How should a known-source trial expose the discrepancy?

Let us press the distinction between data residual and validated geographical error. Suppose an array produces nearly zero residuals for several delay differences, but two stations share a clock correction that is not represented in the weighting matrix. The solver may make the residuals

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even smaller by shifting the source into a region favoured by the mistaken reference assumption. What independent diagnostic would demonstrate that the reported confidence ellipse reflects the underlying experiment rather than only the chosen covariance and a favourable geometry? Could an array's observed calibration results at surveyed locations expose a systematic bias that persists despite a low residual? I would also ask you to address the near-field case, where a plane-wave approximation may be tempting but geometrically unjustified.

William Thomson, Baron Kelvin, Cross-Peer Answer to Ronald N. Bracewell: Professor Bracewell, the model fails at its definition of the measured quantity. Its timing covariance cannot compensate for three stations applying incompatible feature rules. Establish a common arrival estimator or calibrate the state-dependent bias of each method over a representative waveform family. Record raw samples, compare alternative correlation peaks and use test emitters at surveyed positions to assess whether the chosen feature follows the predicted geometric delay. If multipath makes the earliest arrival unresolvable, the result should be an interval or set of candidate loci rather than a single overprecise coordinate. The timing model and the propagation model must be challenged together; a well-conditioned numerical solver cannot repair a misidentified physical event.

I should first insist that the low residual belongs to the fitted model, not to the physical propagation field. A location solver might use a point x that minimises the weighted squared difference between measured and predicted delays, yet if the reference-clock covariance is wrong, the weights are wrong even when the algebra has been executed impeccably. A shared offset that cancels between some station pairs can be invisible to those

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differences; a branch-dependent error can imitate an additional path-length difference. The correct challenge is to predict measurements for known emitter locations that were not used in fitting the calibration. Compare the resulting position errors with the reported confidence regions and ask whether the claimed coverage holds over the relevant geometry and signal conditions. It is not enough to quote the mean localisation error across favourable tests. Examine the worst cases, rejected events and the station arrangements for which the inverse map is poorly conditioned. To distinguish covariance error from geometry, repeat using independent clock monitoring and physically exchange an instrument between station positions where practicable. If the inferred location follows the receiver rather than the surveyed station, an unmodelled instrument term is implicated. The near-field case adds another model question: the arriving wavefront need not be approximated as planar across a sufficiently large aperture or close emitter. Use the geometric range-difference model appropriate to station separations and source distance, with any antenna phase-centre issues declared. An approximate plane-wave solution may be a useful initial guess, but it should not be reported as a validated coordinate unless its approximation error is bounded. A confidence region should be conditioned upon the waveform, clock state, propagation model and array geometry tested; otherwise it is a formal mathematical object with uncertain physical meaning.

Ronald N. Bracewell, Supplementary Commentary to Lord Kelvin: The distinction is decisive. It is the arrival of a specified waveform feature at a declared reference plane that must be measured. A spectrum analyser

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timebase is only one component of that observation, and a cross-station solution is no stronger than its least justified waveform-timing assumption.

Dr. James M. Atkinson, Moderator: Professor Gabor, I invite you to examine the timestamp implicit in a spectrogram window. Professor Bracewell will challenge whether that display feature supports an arrival-time difference.

Dennis Gabor, Third Principal Contributor: A spectrogram is a representation formed from finite analysis windows, whereas an arrival-time claim refers to an identifiable physical feature of a waveform. A burst may influence several spectral tiles and a maximum tile can move with window length and overlap. I would preserve original complex samples and compare event pickers with known arrival markers injected at a defined input plane. Different stations must measure the same feature or correct for their differing response delays.

The decisive difficulty in time-frequency analysis is that the timestamp on a spectrogram tile is a convention attached to a window of observations. Let $x(t)$ denote a measured complex waveform, $w(t)$ an analysis window, τ the window's nominal time coordinate, and f an analysis frequency. The short-time Fourier transform is $X(\tau,f)=\int x(t)w^*(t-\tau)\exp(-j2\pi ft)dt$. This expression uses an integral over a neighbourhood of τ, not an ideal measurement at a singular instant. Even in a digital implementation, where the integral becomes a sum across sample indices, the result depends on the window support, its centring convention and the effective filter response. A spectral peak therefore inherits a temporal footprint. A reviewer who reads the label of the tile as the arrival of the first electromagnetic energy has imported an assumption the transform itself does not supply. The distinction is visible

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even for a noiseless artificial burst: move the analysis-window origin by half a hop, and the brightest tile may be assigned a different time without any change in the underlying event.

A familiar trade-off follows from finite observation duration. A long analysis window offers finer nominal frequency discrimination and may assist detection of a nearly constant narrow carrier. It also spreads the influence of a brief onset over a larger time neighbourhood. A short window confines the burst more tightly in time while producing broader spectral energy, so that weak adjacent emissions may become difficult to distinguish. Neither trade-off constitutes a universal uncertainty product that can be applied to arbitrary estimators without checking window definition, sampling, signal model and threshold. A chirp whose instantaneous frequency traverses several bins during the window can displace the maximum away from the physical onset. A multi-component waveform may furnish several plausible ridges. The question for arrival localisation is not which picture looks sharpest, but which feature is sufficiently invariant between stations that a relative delay can be estimated and validated.

It is advantageous to separate three possible estimands. One is the earliest detectable departure from noise, typically sensitive to threshold and false-alarm policy. Another is the time of a selected amplitude maximum, often biased by fading and group delay. A third is the relative alignment that maximises a correlation between two known or observed waveform segments. Cross-correlation can exploit the modulation over a broad bandwidth and may have smaller variance than onset thresholding in favourable conditions, but this need not identify the first physical path. A strong delayed reflection may dominate the correlation maximum while a

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weaker direct wave arrives first. The analyst must therefore record whether the location solution is based on earliest-path delay, strongest-feature delay or composite waveform alignment. Switching among these definitions after looking at the answer invites selection bias and can move the estimated emitter across a material boundary.

For a quantitative illustration, take a sampled waveform with sampling rate f_s equal to 20 million complex samples per second. The nominal spacing between adjacent samples is $1/f_s$, or 50 nanoseconds. Multiplying by the speed of light gives approximately 15 metres of path-length equivalent for one interval. A fitted correlation maximum may be estimated at a fractional-sample position, so the 50-nanosecond spacing is not a universal lower bound on timing estimation precision. Yet interpolation creates no missing bandwidth, and the variance and bias of that estimate still depend upon signal structure, signal-to-noise ratio, phase coherence, clock error and multipath. The estimate might be much better than a sample interval under a clean known-waveform experiment or much worse under weak distorted reception. Precision must be shown by repeated calibration and a signal-specific model, not by asserting a clever interpolator's nominal resolution.

I would test an algorithm with a collection of controlled waveforms rather than one convenient pulse. Include a narrowband burst, a wideband coded sequence, a swept-frequency event and a two-path signal with adjustable relative amplitude and delay. Inject them at a measured electrical reference plane and preserve the source timing independently. Vary receiver signal level and filter bandwidth while keeping the reference feature definition fixed. The resulting bias curve, plotted against conditions, will expose whether the estimator's selected time follows the physical input or changes

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with spectral emphasis. Reprocess the same immutable samples with altered window sizes and hop intervals; any migration of the inferred arrival time is an analysis dependency that must be included in the uncertainty or excluded by a justified fixed configuration. A second laboratory should be able to reproduce the challenge without knowing the desired location answer.

A special danger lies in animations and continuously refreshed displays. The human eye sees the waterfall as a continuous theatre of motion, yet the underlying system may decimate data, retain only selected events or draw smoothly across time gaps. A coloured patch that appears to arrive simultaneously at three stations is not a substitute for the three sample-index records and their verified clock mappings. I would require the report to state the acquisition duty cycle, time-stamp origin, transform window, overlap, smoothing, trigger algorithm and retained raw-data coverage. The resulting documentation may be less elegant than a single colourful image, but it allows the inference to be examined. The discussion now properly passes to Professor Essen, because the reference clock itself determines how time-frequency features at separate stations can be compared.

Ronald N. Bracewell, Cross-Peer Question to Dennis Gabor: Can a set of spectrogram tiles with apparently simultaneous maxima across stations supply an adequate time-difference estimate for a short broadband burst? In addition, I would require the selected feature to be predeclared before the field record is inspected; otherwise a retrospectively chosen window invites biased localisation.

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I have a more precise concern about the peak chosen for localisation. A real-time analyser may label each frequency-time tile with millisecond or microsecond precision, although the analysed window spans far more time than the printed digits suggest. If a burst contains a direct signal and a delayed echo, changing window length or overlap can alter which tile becomes brightest. Can you identify an arrival estimator whose definition remains stable across such changes, or explain how the changes should enter the timing uncertainty? How should one check whether a chirp's moving frequency and a receiver's time-varying filter shift the plotted peak for reasons unrelated to physical propagation time?

Dennis Gabor, Cross-Peer Answer to Ronald N. Bracewell: Not without verifying the time coordinate assigned to each tile, the window placement, and the response of each instrument. Analyse the underlying waveform directly and establish the relation between a chosen correlation feature and the physical arrival. A shared processing convention can reproduce an error in every station. Calibrate with a known emitter and vary window configuration to quantify the possible bias.

The timestamp for a tile is a property of the windowing scheme. The earliest arrival of a specified waveform feature, by contrast, must be defined against the underlying samples and an electrical reference-plane calibration. When a spectrogram uses a window of N samples and a hop of H samples, the displayed tile time may refer to its first, centre or last sample; merely altering that convention shifts its label by a fraction of N/f_s even though no incident radiation changes. To test invariance, apply the same raw waveform to several documented window lengths, hop sizes and spectral thresholds. The feature that is eligible for a TDOA estimate should either remain stable

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within a stated tolerance or carry a measured processing-dependent bias into the uncertainty budget. A chirp can distribute energy over successive bins; one frequency tile may brighten earlier than another simply because its centre frequency is crossed at a different moment. Accordingly the maximum tile is not a universal onset. In a multipath environment, a later stronger path can dominate the short-time spectrum while the earlier direct component is weak. If the analysis objective is first-path timing, retain a model capable of detecting that component and report when the signal-to-noise ratio is insufficient to establish it. If the objective is strongest-path correlation, name it as such and use a propagation model reflecting that choice. A reproducible inference should preserve the exact estimator code, filter coefficients, sampling clock calibration, peak-selection thresholds and alternative candidate peaks. Vary the settings only as a documented sensitivity study, not to select retrospectively the location that best fits a preferred narrative. Spectral displays are invaluable for diagnosis, but the physical arrival claim must rest on a separately validated observation of a common signal feature.

Dr. James M. Atkinson, Moderator: Professor Essen, the problem now turns to clock continuity during the precise observation interval. Lord Kelvin will test whether a stability summary can justify the proposed uncertainty.

Louis Essen, Fourth Principal Contributor: A highly stable oscillator may still carry a time offset or experience a phase step at reference reacquisition. A localisation inference depends on the relative state of the station clocks during the actual burst. The engineer should observe each downstream sample-edge timing relationship to an independent reference, not merely

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rely on the oscillator’s long-term frequency-stability figure. A shared timing service creates common dependencies that need covariance treatment.

A frequency reference and an event-time reference perform related but distinct tasks. Frequency stability concerns the rate at which clock phase changes; synchronisation for arrival-time measurement concerns the offset and continuity of the clock's actual time tags across stations. A system can possess a superb short-term frequency standard and nevertheless have a fixed time offset from the system with which it is compared. It can also be disciplined to a reference and then suffer an unrecorded step when the disciplining source is lost and recovered. An equipment specification expressed only as parts in ten to the minus twelve, or as an Allan deviation at a selected averaging time, cannot certify a ten-nanosecond coincidence claim without an event-specific timing calibration. The operator must observe the clock state over the exact capture interval, particularly near holdover transitions, reference switching and software restarts.

Let $x_i(t)$ be the time error in seconds of station i against a common declared timescale and $y_i(t)=dx_i/dt$ be its fractional-frequency error wherever the derivative is meaningful. Over an observation interval of length T, a nearly constant frequency error y produces an accumulated timing error approximately yT. At y equal to two parts per million and T equal to ten seconds, that accumulation is 20 microseconds, corresponding to about six kilometres of light-travel distance. This is an intentionally exaggerated hypothetical oscillator error, not a specification for an actual metrology installation. The calculation illustrates why one must distinguish a measured oscillator rate error from the elapsed interval over which its correction is applied. A frequency error of ten parts per billion over ten seconds instead

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yields 100 nanoseconds, already approximately 30 metres of path-difference equivalent. Constant calibration offsets and discrete jumps are separate terms, not captured by the continuous drift calculation.

A useful hardware arrangement gives each sample stream an immutable counter and supplies a traceable mapping from counter value to an externally measured reference event. A pulse-per-second reference can mark an epoch, but the timing of the pulse at the actual receiver input and the uncertainty of synchronising it to the ADC sampling edges must be measured. Cable delay and jitter matter. A station can record a recognised satellite timing signal and still mislabel samples if its driver interpolates between pulses using an oscillator that slipped or if a buffer was restarted without a corresponding discontinuity marker. The metrology belongs to the full path from reference arrival to sample edge and stored timestamp. The words 'GPS locked' or 'network synchronised' are not descriptions of that complete path. One must also distinguish timing from absolute location and recognise that external reference reception itself can be obstructed, disturbed or unavailable.

To establish phase continuity I would place an independent time-interval counter or phase comparator at a point as near as practicable to the acquisition clock. It should record before, during and after controlled interruptions of the disciplining reference. The experiment ought to distinguish an instantaneous clock step from a gradual slew and from a change in the mapping between sample indices and host wall-clock time. A slew may preserve monotonic labels while altering their rate. A step can alter time labels abruptly while the RF samples remain physically uninterrupted. Conversely a sample drop can occur without any recognised

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clock error. These are distinct fault mechanisms requiring different evidence. Repeat the tests under temperature change and after system restart because drift and reference-state recovery are often dependent on conditions that a single steady laboratory run fails to exercise.

In a distributed array, the reference architecture creates correlated errors. If two stations are driven from the same source through different distribution paths, the source's common component may cancel under subtraction while unequal cable delays and branch-phase perturbations survive. If separate clock sources are disciplined through a shared higher-level network or satellite service, their errors may remain statistically dependent. The uncertainty of $t_i - t_j$ is the sum of the two variances minus twice their covariance; it is not invariably the square root of the sum of two squared independent uncertainties. The examiner should preserve the clock topology, reference-selection records and every change of master source. An apparent agreement among stations cannot verify the shared timing standard when the same defective element supplies their estimates.

I would calibrate a multi-station receiver network by transmitting a permitted known waveform from several surveyed locations while measuring the emission epoch with independently supervised equipment. The calibration should be repeated before and after the field survey and whenever a receiver clock, synthesiser or digital processing configuration changes. Retain a closure record in which time differences around multiple station pairs are compared; an inconsistent closure can reveal a timestamp or estimator fault even before a location is computed. Yet a closed set of differences does not establish absolute event time, for common errors can disappear from all differences. The strongest report is explicit about which

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quantities were independently measured and which were inferred from a shared clock model. I pass the token to Professor Rabi to consider whether the observed event feature is, in fact, the part of the radiation field we intended to time.

William Thomson, Baron Kelvin, Cross-Peer Question to Louis Essen: If a clock’s Allan deviation is exceptionally small, what additional evidence could establish a valid ten-nanosecond interstation timing uncertainty during a specific short event? Please also distinguish an event whose sample counter is continuous from one whose physical time reference has discontinuously changed; the two cannot be inferred from one status bit.

Suppose the station operator reports an exceptionally small Allan deviation over a thousand-second averaging time. Yet the particular emission lasted only twelve milliseconds, and the hardware had switched references just beforehand. What observation would connect the stability statistic to a time offset at the actual burst epoch, and how would the uncertainty budget represent an unobserved reference step? Please distinguish the continuous frequency-error integral from an instantaneous time discontinuity and address the possibility that host software maps sample indices to UTC by retroactively smoothing a clock correction. Could two clocks agree in their present frequency while retaining different accumulated phases from an earlier interruption?

Louis Essen, Cross-Peer Answer to William Thomson, Baron Kelvin: Direct clock comparisons during the relevant state, calibrated distribution delays and reference continuity are required. Stability statistics do not determine the initial phase offset and may fail to expose an isolated step. Evaluate both

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station-specific and shared uncertainty terms, then propagate them through the arrival-difference model. The ten-nanosecond claim cannot be inferred from a single stability summary. That evidential distinction is essential: measurement continuity cannot be inferred solely from a restored lock indication, even when the clock rate thereafter appears excellent.

A frequency-stability statistic at one averaging time cannot alone constrain the time offset at a particular epoch. Let $x(t)$ be the station's time error relative to a reference and $y(t)$ its fractional-frequency error wherever differentiable. Over an uninterrupted interval, $x(t_2)-x(t_1)=\int y(t)dt$. This relates phase accumulation to rate error and permits a bound if y is actually observed or bounded over the interval. A discrete step at reacquisition contributes an additional jump that is not recovered by integrating only the smooth rate. The analysis must therefore retain phase-comparator readings, lock-state transitions and any controller command that steps or slews the local clock. If the twelve-millisecond event straddles an unobserved step, a confident timestamp is not warranted simply because the long-term Allan deviation was excellent. The measured sample-index record may remain contiguous while its UTC mapping changes. Host software can generate a smooth revised mapping retrospectively, but that algorithm is a reconstruction whose uncertainty must be justified from independent evidence; it must not silently replace the raw device timestamps. Two clocks can agree in frequency today yet retain quite different accumulated time offsets because of earlier interruptions, cable delays or initial phase settings. The appropriate field test captures a known timing marker before and after the clock transition using an independently maintained reference, and repeats the transition under representative

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holdover and temperature conditions. Where no independent witness covered the disputed epoch, the report must give a bound or qualification rather than assume the phase was continuous. A common upstream clock does not settle this question if downstream branches can experience different switching or sampling events. It is the observed relation between each station's actual ADC edge and the claimed external time that must be certified.

Dr. James M. Atkinson, Moderator: Professor Rabi, please explain why the detected waveform feature may not be the first physically arriving component. Professor Gabor will question the interpretation of the strongest peak.

Isidor I. Rabi, Fifth Principal Contributor: The arrival feature may be an artefact of the receiver response rather than a direct measure of radiation-path length. A wideband pulse can be delayed or reshaped by filters and threshold detectors; multipath can displace the strongest peak from the earliest arrival. I would calibrate each receiver with a known pulse of appropriate bandwidth and then test it at several amplitudes to expose signal-dependent bias.

A receiver's reported arrival time is influenced by the physical signal and by the apparatus used to select it. A pulse entering a band-limited filter emerges with its envelope reshaped; a narrow filter can ring for a finite interval, and its group delay can vary with frequency. If two receivers use different intermediate-frequency filters or digital decimation chains, the same incident waveform need not generate the same threshold-crossing time. A high-level carrier might also push one front end toward gain

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compression or activate automatic gain control, altering the envelope and changing which part of the burst triggers the timestamp. These effects are not repaired by disciplining the receivers to an excellent common clock. The measured event must be defined at a physical input plane and then related through an experimentally characterised transfer function to whatever internal point the instrument records.

Consider a known short pulse observed through two causal filters. Suppose receiver A has an effectively flat group delay of one microsecond across the relevant band, while receiver B has three microseconds. If an algorithm timestamps the filtered envelope peak without removing the differing delays, the two estimates show a two-microsecond offset even when both instruments receive the field at the same instant. That offset corresponds to approximately 600 metres of free-space path difference, but the inferred extra distance is entirely instrumental. This is a hypothetical demonstration, not a property of a specific device. A calibration made for a narrow carrier at one frequency may not transfer to a wideband pulse whose energy occupies parts of the filter response with different delays. Therefore the timing calibration must cover the actual waveform class and receiver settings.

The external propagation channel presents an additional selection problem. A direct path can arrive before several reflected paths, but may be weak because of shadowing, antenna polarisation or destructive interference. A stronger later reflection might dominate a correlation peak or energy threshold. The earliest detectable component is not necessarily the earliest physical component, and the strongest component is not necessarily the shortest propagation path. In an indoor or urban security survey, walls, windows, metal structure and moving machinery can change the channel

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during a measurement. A credible location analysis should test stability across time, antenna geometry, polarisation and frequency where practicable, with lawful passive measurements and authorised calibration sources. If several competing delay peaks remain, preserve them as alternative hypotheses instead of selecting only the one that yields a convenient coordinate.

Signal-to-noise ratio also changes the apparent onset of a burst in threshold detection. When the waveform is strong, an early low-amplitude precursor may cross the criterion; when weak, only the later high-amplitude portion is admitted. A fixed voltage threshold can therefore introduce amplitude-dependent timing walk. Constant-fraction discrimination may reduce some forms of amplitude dependence but is not an automatic cure for multipath, filtering or changing pulse shape. For each receiver, vary injected signal level while holding the source waveform and the physical timing fixed. Plot estimated delay against level and record both bias and dispersion. This response curve can be used to qualify field measurements or to reject claims outside the validated envelope. A high numerical timestamp resolution is of little value if the estimator moves by microseconds as the input amplitude changes.

A robust challenge compares at least two estimators applied to the same immutable I/Q record. One can use a defined correlation template derived from a reference capture; another can examine a predeclared envelope onset criterion. The disagreement is itself diagnostic. Next substitute a stable conducted laboratory path for the antenna, preserving equivalent levels and respecting impedance and equipment safety. If the dispute persists under conducted injection, investigate the receiver transfer function

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or algorithm. If it emerges only over the air, investigate the propagation and antenna system, while recognising that both mechanisms can coexist. It is essential that the operator retain the raw waveform and all processing settings so that a later examiner can determine whether a claimed location depends on a fragile peak-selection rule.

I would not grant an exact emitter attribution from three tidy time stamps when the signal paths and feature definitions have not been challenged. A logically stronger inference may be the assertion that the observed burst is consistent with several possible source regions under specified path hypotheses. That is neither indecision nor a failure of the instruments. It is an honest recognition that inverse propagation can be ambiguous. The panel can then identify which additional lawful observation, station relocation or independent calibration would resolve the ambiguity most efficiently. Precision becomes persuasive only when the signal event, the receiver and the propagation channel have each been examined rather than collapsed into one number on the screen.

Dennis Gabor, Cross-Peer Question to Isidor I. Rabi: If the earliest physically arriving signal component falls below one receiver’s threshold while a later multipath component is stronger, should the analyst report the later peak as the propagation arrival? Would two calibration waveforms of different bandwidth expose the ambiguity more decisively than repeated processing of one narrowband pulse alone?

Suppose the earliest physically arriving wavefront at one station is strongly attenuated, whilst a delayed reflection is the first component to cross the chosen detection threshold. A second station sees the direct component

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clearly. If the location algorithm subtracts the two detected onsets, the estimand is no longer the same at the two stations. How could the field investigator distinguish this mixed-path explanation from a genuine timing fault, using lawful changes in antenna polarisation, bandwidth or station geometry? When correlation yields two plausible peaks, what reporting practice would preserve both possibilities without allowing a reviewer to mistake a preferred strong peak for an independently established first arrival?

Isidor I. Rabi, Cross-Peer Answer to Dennis Gabor: Only if it is explicitly called the detected feature and the estimator’s bias and ambiguity are included. The first arriving physical component may be unresolvable with the available sensitivity. Multiple delay hypotheses should be retained where the waveform permits them. A highly precise timestamp for the strongest peak cannot be silently equated with first arrival. Repeated calibrated experiments are needed to establish the proper observable.

The mixed-path hypothesis should be tested by asking which observable changes with propagation geometry and which changes with receiver configuration. A reference-clock fault may affect all waveform components in a station's time record in a characteristic common manner. A propagation change can alter relative path amplitudes, delays and polarisation, causing the selected correlation peak to move between physically different paths. Record the entire complex baseband sequence and its correlation surface, not only the location chosen by a maximum-selection routine. A narrow pulse may resolve multiple peaks if its bandwidth and signal-to-noise ratio support the separation; a narrowband waveform may show an ambiguous periodic correlation structure even when the true direct and reflected paths

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are present. Changing antenna polarisation or modestly relocating an authorised station may change the path amplitude distribution. If a reported delay jumps when the strongest path changes but independently monitored clock phase remains continuous, the multipath explanation gains weight. Conducted injection of a known waveform through the receiver can separately test whether the timing algorithm and filter produce a similar jump without any outdoor propagation. Neither test should be treated as an absolute discriminator; their joint pattern is more persuasive. If two peaks remain plausible, propagate both delays into separate location hypotheses and describe their relative support without fabricating probabilities. If the earliest wavefront lies below detectability, the statement should be 'earliest resolved component under stated sensitivity' rather than 'first physical arrival'. The report must also record antenna reference planes, phase-centre corrections and frequency-dependent group delays. Otherwise the examiner might confuse an instrumental or channel-dependent feature with a new geographical fact. We should prefer a defensible region of uncertainty to an exquisitely printed but unjustified coordinate.

Dr. James M. Atkinson, Moderator, Closing Synthesis: A spectrum analyser timebase is adequate for multistation arrival-time localisation only as part of a calibrated acquisition and inference chain. The panel distinguishes a spectral display time from a sampled signal's physical arrival, a frequency-stable oscillator from a traceable and phase-continuous event clock, and a time-difference precision from a geographically supportable location. The required evidence comprises raw timing records, known reference planes, quantified receiver and transport delays, controlled reference challenges, a propagation and geometry model, appropriate error covariance and tests

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against sources at surveyed positions. Where those conditions fail, the proper finding is a bounded delay observation or an indeterminate location, not an invented coordinate. This is a fictional scholarly reconstruction.

QUESTION 059. TECHNICAL SOURCES AND EDITORIAL STATUS

1. International Telecommunication Union, Report ITU-R SM.2211-2 (06/2018), Comparison of Time-Difference-of-Arrival and Angle-of-Arrival Methods of signal geolocation. Official report record: https://www.itu.int/pub/R-REP-SM.2211-2-2018 . The report provides a relevant methodological foundation; no numerical field result in this constructed dialogue is attributed to it.

2. NIST, W. J. Riley, Handbook of Frequency Stability Analysis, Special Publication 1065 (2008), https://www.nist.gov/publications/handbook-frequency-stability-analysis . Use for frequency and phase-stability interpretation, not as proof of the hypothetical TDOA field cases.

3. International Telecommunication Union, Recommendation ITU-T G.8271/Y.1366 (2020), Amendment 1 (08/2024), Time and phase synchronization aspects of telecommunication networks, https://www.itu.int/epublications/publication/itu-t-g-8271-y-1366-2020-amd-1-2024-08 . Consult relevant sections on timestamp granularity, path asymmetry and timing noise, with applicability verified before publication.

EDITORIAL QUALIFICATION: All scenarios and numerical examples are hypothetical. Historical dialogue is a fictional pedagogical reconstruction. Structural tests are separate from final source-to-claim, historical-participant, mathematics, semantic originality, and pagination review. NOT PUBLICATION APPROVED.

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QUESTION 060

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How can oscillator ageing be separated from thermal cycling in long-duration RF surveillance?

HISTORICAL RECONSTRUCTION NOTICE. These exchanges are constructed for modern instruction. The deceased participants never held this discussion; contemporary SDR applications are editorial extrapolations of established scientific principles.

Dr. James M. Atkinson, Moderator: Lord Rayleigh, a frequency reference may appear to drift monotonically during a long RF surveillance deployment, yet its enclosure warms by day, cools by night, and recovers imperfectly after power interruption. How can an investigator distinguish irreversible oscillator ageing from reversible temperature sensitivity, delayed thermal equilibration, and hysteresis? In particular, what experiments, observation intervals and models would justify an evidential claim that the observed drift originated inside the reference rather than in the environment or the measurement apparatus?

John William Strutt, Baron Rayleigh, Principal Contributor: Dr. Atkinson, we must first identify the measured quantity. Let f(t) be oscillator frequency in hertz at elapsed time t, and let f_ref be its declared nominal frequency. Its fractional-frequency deviation is y(t)=[f(t)−f_ref]/f_ref, a dimensionless quantity. An observation of y increasing slowly is not by itself an observation of material ageing. Its trajectory may reflect several causal mechanisms acting together. The observer who fits a straight line to an uninterrupted environmental record has measured the resulting trend, not isolated the internal mechanism that produced it. A day-to-day temperature cycle may be correlated with calendar time; so may ageing, gradual changes in supply

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loading and the progressive settling of a newly energised oscillator. The explanatory variables cannot be distinguished from their common result unless the experiment provides independent variation.

A practical working model is $y(t)=a(t)+g[T_r(t)]+h[T_r(t),q(t)]+w(t)+e(t)$. Here $a(t)$ is the slow ageing contribution; T_r is the resonator temperature rather than merely the external air temperature; g is a reversible equilibrium temperature-response function; h describes history dependence through an internal state q such as stress, thermal gradient or prior temperature trajectory; w represents warm-up or recovery after power interruption; and e contains measurement noise and unmodelled disturbances. This equation is a decomposition for experimental design, not a claim that all oscillators possess uniquely separable additive mechanisms. A more realistic model may couple ageing and temperature. Without intervention, the decomposition can be non-identifiable, because several combinations of terms reproduce the same frequency record.

Thermal lag deserves particular care. A sensor fixed to the instrument housing may report the temperature T_h while the resonator experiences T_r, which responds with a delay. A simple first-order approximation, $\tau(dT_r/dt)+T_r=T_h$, uses a thermal time constant τ measured in seconds. If the case temperature rises rapidly, the resonator may remain cooler for an appreciable interval. A compensator using the wrong temperature variable can overcorrect or undercorrect. On a cooling ramp of equal magnitude, the sign of lag reverses. Thus a plot of oscillator frequency against housing temperature can form a loop even when the underlying equilibrium function $g(T_r)$ is single-valued. A genuine memory or stress hysteresis may create an additional loop that persists after the temperature gradients have relaxed.

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Only sufficiently slow ramps and dwell periods can help distinguish these possibilities.

Ageing is conventionally the frequency change associated with internal changes in the oscillator over time. Such changes may arise from resonator material, contamination, electrodes, mounting stress or sustaining circuitry; the sign and rate may themselves vary. In a narrow observation interval, one may approximate $a(t)=a_0+A\,t$ with ageing rate A measured per second, but its apparent linearity must not be extrapolated indefinitely. A controlled experiment should compare the same oscillator after sufficient thermal equilibrium at a fixed reference temperature on successive dates, using an independently characterised measurement chain. This comparison reduces, though never entirely eliminates, reversible thermal contributions. If the supposedly constant-temperature control drifts, the experiment requires a second reference or a traceable comparison hierarchy rather than blind confidence in the control.

For a numerical illustration, suppose a 10 MHz oscillator has a measured fractional ageing trend of 2×10^{-9} per year, under otherwise constant conditions. Its corresponding nominal frequency change would be 10^7 Hz $\times\ 2\times10^{-9} = 0.020$ Hz over a year. Suppose a temperature excursion of 5 °C introduces a reversible fractional shift of 1×10^{-8} under the tested conditions. That shift corresponds to 0.10 Hz, five times the illustrative annual ageing change. The numbers are hypothetical and do not describe a particular instrument. They show why a short field regression without independent temperature control can misattribute a daily reversible variation to long-term ageing. The exact coefficient, signs and slopes of a real oscillator must be measured.

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Consider an especially deceptive case: the site gradually warms during a six-week survey because an air-conditioning control set-point changes, while the oscillator undergoes ordinary long-term ageing. A linear regression of frequency against calendar time will combine both effects. A polynomial fit may appear statistically excellent yet still be causally ambiguous. Repeating the record at a deliberately reversed temperature schedule, within equipment ratings, supplies discriminating information. If the frequency trend reverses promptly as the thermal stimulus reverses, at least some component is temperature-sensitive. If a residual difference remains when the resonator and supporting circuitry have returned to a verified common reference temperature, that difference may reflect ageing, retrace, stress memory or instrument drift; further controls are necessary before assigning it exclusively to ageing.

The ideal experiment uses multiple oscillators and independent metrology. Select one device under test, a second oscillator of similar construction held at stable temperature, and a comparison reference whose own stability and traceability are documented. Measure the phase or fractional-frequency difference with appropriate counters or phase comparators, retaining original phase data, gate durations and dead-time information. Log resonator or oven temperature when accessible, ambient and enclosure temperatures, humidity, supply voltage, load and power-cycle state. Cycle only the test oscillator through controlled heating, dwell and cooling stages, keeping the comparison reference thermally isolated. Alternate the ramp direction and repeat the programme across different days. The reference should not share the thermal intervention, power supply or distribution fault under investigation.

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Two different comparisons are needed. First, examine frequency at the same adequately equilibrated temperature before and after a prolonged interval, whilst preserving the device's power state and environmental history. That gives evidence concerning secular change. Secondly, inspect frequency at the same recorded temperature on heating and cooling trajectories; a difference reveals path dependence, which may originate from hysteresis, lag or control-loop dynamics. To isolate lag, hold the device at selected temperatures until the measured frequency and internal temperatures approach equilibrium, and repeat at different ramp rates. A difference that shrinks as the ramp slows indicates a dynamic contribution, although it does not by itself rule out all material hysteresis. An offset surviving long equilibrium dwell requires further investigation of persistent memory, retrace and measurement bias.

A controlled power interruption is a separate intervention, not merely an extension of a temperature ramp. It may reset a temperature controller, remove heat, change mechanical stress and produce frequency retrace after restart. Record the last pre-shutdown stable observation, the cooling path, elapsed off-time, the warm-up frequency trajectory and the ultimate stabilised state. If the RF survey requires continuous phase evidence, mark the interrupted interval as unobserved rather than reconstructing the phase as though the oscillator had run without interruption. Distinguish the clock's recovered frequency from the accumulated phase or time error, because a good post-restart frequency number cannot recover chronology lost during a reference outage.

The statistical treatment must respect dependence over time. White measurement noise, flicker noise, random-walk frequency behaviour,

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deterministic thermal cycles and genuine ageing can coexist. Ordinary residual variance after subtracting a linear drift may conceal periodic terms; merely increasing the number of observations may create false confidence if samples are strongly correlated. Estimate a noise model from the phase record, check Allan or related time-domain stability measures at the relevant averaging times, and state how missing intervals and imposed control cycles affect those estimates. Compare alternative causal models using held-out thermal cycles or independently supervised devices, not only goodness of fit to the data used for model construction.

The practical consequence for a defensive RF survey is that the timebase cannot be certified from a single headline long-term drift or ageing figure. If a receiver combines a drifting local oscillator, temperature-sensitive synthesiser and changing reference distribution, its reported carrier frequency may move even while the external transmitter is perfectly stable. Conversely, a reference that performs well in a laboratory oven may experience transient gradients and mechanical strain in a vehicle or temporary installation. A known injected signal and a second independently clocked receiver help identify instrument-generated motion. Ultimately the report should give the time window, the test range, reference state, estimated drift and temperature response, thermal-history qualifications and uncertainty. The strongest conclusion is often a bounded conditional statement: ageing-like secular change was detected under controlled thermal equilibrium, while specified thermal-cycle and retrace effects were measured separately.

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Dr. James M. Atkinson, Moderator: Professor Essen, what is the minimum metrological comparison needed before we name a slow drift ageing rather than reference error?

Louis Essen, Peer Question: Lord Rayleigh, the counter under test and the alleged independent reference might themselves be ageing. A long comparison will show a slope, but differences cannot identify which oscillator changed without another standard. How would you design a reference hierarchy that does not falsely transfer the control oscillator's own drift into the test oscillator's ageing record? Please address calibration, comparison duration, and the risk that disciplining both sources to one master conceals their separate histories.

I would also ask what independent event would reveal a change in the shared distribution network rather than in any one resonator. If the comparison counter and every surveillance receiver derive their timing from the same reference, their excellent mutual agreement could conceal a common bias. Would you require a free-running witness that was never disciplined by that master? Please explain whether the three-source comparison is valid when the environmental controls, power supply or phase comparator are shared, and identify a diagnostic procedure that would expose reference-path contamination without interrupting the surveillance evidence. The distinction between a genuinely independent clock and an additional display channel is indispensable.

John William Strutt, Baron Rayleigh, Response: Professor Essen, a difference measurement establishes difference, not individual blame. If two sources have fractional deviations y_A and y_B, the measured series is approximately y_A−y_B plus instrument contributions. A fitted trend estimates

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d(y_A−y_B)/dt; it does not independently identify dy_A/dt and dy_B/dt. A third characterised source can support a three-corner comparison, but its utility depends on the independence and covariance assumptions. Where an external traceable reference is available, repeat comparisons before and after temperature cycles and retain each source's discipline commands and phase record. Two devices locked to the same master may display correlated behaviour that cannot independently establish the master's accuracy. The uncertainty budget must include reference drift, comparator response, connection changes and all breaks in measurement continuity. Only after those pathways are addressed should a slope be attributed to ageing of the device under test.

Begin with the topology, not the instrument catalogue. Trace each signal from its physical oscillator to the point at which the measurement is digitised, including distribution amplifiers, cable runs, multipliers, transfer oscillators and automatic reference selection. A counter powered from the same external 10 MHz standard as the device nominally under test is not an independent frequency witness. If an independent witness is unavailable, record that limitation and stop short of an absolute ageing attribution. A differential result may remain entirely useful for assessing relative stability, provided the conclusion is restricted to what the comparison establishes.

I would perform three checks. First, inject an independently known test tone at the receiver input and measure whether its recorded frequency moves with the suspect reference. Secondly, compare the oscillator output directly at its connector and after the distribution network, using a path capable of exposing temperature-dependent cable delay. Thirdly, test a second oscillator with a different thermal and electrical history. The comparisons

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should be made at matched averaging intervals, with environmental and power records aligned to the same time base. If an apparent secular slope follows a cable swap or power-supply reconfiguration, the causal inference must be revised.

A useful numerical illustration concerns a difference of two slopes. Suppose source A is estimated to change by plus 4 parts in 10 to the tenth per day relative to B, while A changes by plus 1 part in 10 to the tenth per day relative to C. If the comparisons are simultaneous and their conventions are consistent, B and C differ by 3 parts in 10 to the tenth per day. That finding says the references are not interchangeable. It still cannot, without further evidence, tell us whether A is intrinsically stable. Report sign conventions, clock ownership and correlated calibration error, or the reader may mistake subtraction of measurements for discovery of a physical ageing mechanism.

Dr. James M. Atkinson, Moderator: Professor Ramsey, what experimental distinction matters most between ageing and retrace?

Norman Foster Ramsey Jr., Peer Question: Lord Rayleigh, after power is removed and the oscillator cools, the frequency on restart may differ from its pre-shutdown value even after the enclosure reaches the same indicated temperature. Is this a secular ageing step, an effect of internal stress or a controller-memory change? What repeated experiment would separate retrace from a steady ageing process without assuming that the same panel temperature guarantees the same resonator state?

A related difficulty appears when the laboratory report mentions a single temperature, usually that of the outer case, although the oscillator contains several bodies cooling at different rates. Can the claimed retrace be

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represented by one scalar correction if the resonator mount, electronic control board and heater have separate time constants? Please address whether elapsed off-time, the rate of preceding cooling, and the position of the thermometer must all be recorded. What minimum repeated-startup experiment would permit the analyst to distinguish a genuinely persistent offset from a slow transient that has merely not finished settling by the nominal observation time?

John William Strutt, Baron Rayleigh, Response: Professor Ramsey, the critical point is to define retrace as a measured change associated with a power and thermal history, rather than automatically classifying the post-cycle offset as ageing. Compare long uninterrupted operation at controlled temperature with a matched sequence that includes known power-off intervals. After each restart, record both time to stabilisation and the eventual steady offset. Use internal oven temperature or an independently measured resonator proxy where possible, because identical housing temperatures may coexist with different gradients or stress states. Repeat the procedure with different off-times and controlled return-to-equilibrium dwells. A difference correlated with cycling is evidence of retrace or history dependence; a trend observed across undisturbed long-term baseline intervals supports an ageing component. Both mechanisms may coexist, so the method should estimate them rather than force a single exclusive label.

The common error is to substitute the recovery of one visible parameter for the recovery of an entire physical assembly. If the enclosure sensor is back at its nominal reading, the crystal support and regulating components may still be warmer or colder than before shutdown. Consequently I would define the initial state by more than temperature alone: the previous

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operating duration, off-time, environmental exposure, supply condition and the control circuit's recent history should be preserved. At each return to operation measure the full time series, not a single frequency value at a predetermined minute after power restoration.

For a numerical test, suppose the first start after a ten-minute outage reaches its apparent stable plateau after forty minutes, while the first start after a six-hour outage takes four hours. If a technician samples both at the one-hour mark, the apparent difference could be a settling artefact. Fit separate transient responses and test whether their predicted frequency trajectories converge within the stated observation uncertainty. Then repeat the outages in alternating order under approximately equal ambient conditions. An effect that follows cooling depth and recedes with dwell time supports a transient explanation more strongly than a secular ageing conclusion.

Even a final offset after extensive dwell must be interpreted cautiously. It may reflect changes in package stress, heater calibration, compensation voltage or reference path rather than an irrecoverable defect in the resonator. To claim physical retrace one must define the pre- and post-cycle operating points and the tolerance within which they are considered the same. The final report should preserve both recovered frequency and elapsed recovery time, because a receiver may have recorded many hours of evidence during a period in which its timing reference had not recovered.

Dr. James M. Atkinson, Moderator: Professor Wiener, how can one prevent a sophisticated regression from giving an attractive but misleading causal answer?

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Norbert Wiener, Peer Question: Lord Rayleigh, temperature cycles are often approximately daily, and ageing is a slow function of time. A data analyst can obtain an impressive fit by adding trends, sinusoidal terms and enough delayed predictors. How could the model be tested for identifiability and independent predictive power? What should be done when the residuals are strongly correlated and the study contains no deliberate reversal of the thermal schedule?

Suppose the deployment exhibits an apparent weekly frequency trend after subtracting a fitted annual temperature curve. How would you test whether the residual follows changes in work patterns, supply loading, humidity, air-conditioning schedules or a slowly varying reference clock? Please distinguish a parameter estimated from one season from a law capable of predicting another season. I would particularly welcome an explanation of how strongly autocorrelated observations alter the weight of evidence, and how a random-walk process might masquerade as linear ageing when the trial contains only a single long stretch between calibrations. What withheld experiment would you demand before trusting a correction?

John William Strutt, Baron Rayleigh, Response: Professor Wiener, a model that describes one realised trajectory need not identify its cause. Examine whether the predictors span sufficiently different experimental conditions: repeated temperatures at different elapsed ages, multiple ramp rates, opposite thermal directions and stable-temperature dwell periods. If time and temperature move together, the regression columns may become nearly dependent, inflating coefficient uncertainty even when the fitted curve is smooth. Use blocked validation on entire held-out thermal cycles, not a random scatter of adjacent samples that share nearly the same

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history. Examine lagged residual structure and compare alternative models with and without path-dependent terms. If the experiment never changes the thermal schedule independently of elapsed time, report that ageing and temperature drift remain confounded. Model complexity cannot manufacture independent information absent from the measurements.

First, inspect whether the residual contains systematic structure. A plot of daily means can make correlated noise resemble a steady slope, whilst a plot of independent stable-temperature baselines may reveal abrupt shifts after power events. Record the residual autocorrelation across short and long lags, and compare models with thermal forcing, environmental periodicity, step changes and stochastic frequency wander. I would withhold an entire thermal excursion from the fitting process, rather than use random individual observations from the same excursion as the validation set. Such random partitioning gives the algorithm almost identical neighbouring observations on both sides of the nominal validation boundary.

As an illustrative calculation, consider 120 hourly observations with a correlation near 0.90 between successive hourly errors. An approximate effective sample size for a simple first-order correlated process is $N_{eff}=N(1-r)/(1+r)$, giving 120 times 0.10 divided by 1.90, or approximately 6.3 independent observations. That estimate rests on a restrictive model, and should not be presented as a universal adjustment. Yet it shows why the confidence implied by 120 rows can be deceptive. The analyst should quantify uncertainty under an appropriate covariance model and examine how conclusions change under more than one plausible noise description.

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A further challenge uses reversed experimental forcing. If a winter heating regime produces one inferred ageing slope, deliberately vary the thermal schedule in a subsequent controlled interval whilst preserving a separately characterised reference. A real material-ageing contribution may remain, but a temperature-aliasing component should change according to the imposed thermal response. If the model predicts only its original record, it is a description rather than an independent explanation. I would classify each conclusion according to the intervention that actually tested it, and not according to the sophistication of the regression software.

Dr. James M. Atkinson, Moderator: Mr. Harrison, how might packaging and mechanical stress defeat the assumption that the oscillator is at a single temperature?

John Harrison, Peer Question: Lord Rayleigh, an oven thermometer may indicate a stable set-point whilst the supporting electronics, enclosure and resonator mounting points continue to change temperature. Could an oscillator exhibit an apparent memory effect entirely because its internal parts approach equilibrium at different rates? How would you observe this without opening or disturbing the resonator enclosure and thereby changing the very mechanism under examination?

I would be uneasy if the same sensor were used both to regulate the oven and to certify that it has reached thermal equilibrium. Its control point can look unwavering whilst heat flows through the metal support and electrical connections. Could you describe a nondestructive way to estimate those gradients and establish whether a frequency change follows mechanical mounting or ambient changes rather than time itself? Please specify what should be done when an investigator cannot place a thermometer directly

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on the resonator. How should we interpret frequency differences between heating and cooling at equal indicated case temperature, particularly when the instrument has been moved or mounted differently?

John William Strutt, Baron Rayleigh, Response: Mr. Harrison, treat the instrument as a thermal system with distributed states. Measure multiple accessible surface and oven-control indicators, the ambient airflow and supply dissipation, and look for differences in the frequency response when ramps of equal final temperature have different rates. Without disassembling the instrument, repeat long dwell intervals until accessible temperatures and frequency become stable within declared criteria. If frequency-versus-temperature loops contract with slower ramps, thermal lag is implicated. If a persistent difference survives adequate equilibrium, investigate stress hysteresis, retrace or ageing rather than inferring them immediately. The observation strategy must acknowledge that inaccessible resonator temperature remains a latent quantity. Using several external sensors improves a model but does not establish a unique internal state unless supported by independent calibration.

The first principle is to observe several accessible locations instead of trusting a single convenient dial. Monitor enclosure temperature, air intake, power-supply temperature and oven-control effort, with sensors whose calibration and response time are known. Where direct resonator measurement is impossible, treat its temperature as a hidden state with an uncertainty, not a value secretly identical to the case reading. Compare responses after gentle changes in airflow or enclosure temperature, keeping the experiment within the equipment's declared operating limits. A frequency excursion that follows a controlled change in cooling airflow is

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evidence of environmental sensitivity, not of the calendar's capacity to age metal.

One experiment would fix the oscillator in its installed orientation, hold the ambient temperature until a stable baseline is observed, then introduce a modest thermal change and return to the original condition. Repeat the sequence at two ramp rates. If the enclosed assembly retains the same equilibrium characteristic, the apparent frequency-versus-case-temperature loop should contract as the ramp is made slower and the dwells longer. If a persistent offset remains after carefully documented equilibration, repeat the sequence without moving the mount. A change that appears only after moving the unit calls for a separate orientation or stress investigation, rather than an automatic ageing label.

A practical measurement must include load conditions. Driving an unusually long reference cable or additional distribution amplifier can alter output current, internal dissipation and possibly the frequency setting of a sensitive oscillator circuit. Record the connected load before and after each trial, and use a monitored buffer where appropriate. The final record should show the sensor placements, mounting method, time of every intervention and uncertainty of the frequency comparison. Without that physical account, an attractive graph can conceal the entire cause it purports to establish.

Dr. James M. Atkinson, Moderator: Lord Kelvin, how should the measurement uncertainty be presented when the dominant correction is history-dependent?

William Thomson, Baron Kelvin, Peer Question: Lord Rayleigh, a laboratory report may assign a small standard uncertainty to the oscillator’s frequency

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at 25 °C, while the device reaches that temperature through markedly different paths. A single-valued calibration table may then provide inconsistent corrections. How should the engineer communicate uncertainty when temperature alone is insufficient to determine the state, and what quantitative bounds are more honest than an unduly precise correction?

When the published uncertainty budget gives one combined number, it may hide fundamentally different contributions: calibrated reference offset, short-term counter noise, long-memory oscillator wander, temperature calibration, and the choice of ageing model. Can you specify which of these are random within one comparison and which are systematic across many observations? If a laboratory repeatedly measures the same oscillator against a shared reference, can the uncertainty decrease as the square root of sample count? I should also like to hear whether an ageing rate quoted per day or per year remains meaningful across changes of power state, because the time coordinate itself may be operationally ambiguous.

John William Strutt, Baron Rayleigh, Response: Lord Kelvin, define the operational state in the calibration, including approach direction, ramp rate, dwell time and power history, or acknowledge that those variables remain uncontrolled. Where the difference between heating and cooling observations is repeatable, it can be modelled as a path-dependent effect with its own uncertainty. Where histories are unknown, a bounded envelope across tested histories may be more defensible than a conventional small standard deviation at a nominal temperature. The uncertainty from the comparator, reference, environmental sensors and drift estimation must still be included. An example: if a calibrated frequency correction at 25 °C varies between −3×10^−9 and +4×10^−9 over observed histories, the analyst

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should not conceal that spread by reporting only the scatter within a single heating pass. No coverage probability follows merely from the endpoints; it needs an explicit probabilistic model or a conservative interval statement.

An uncertainty statement must match the measurand and the observation interval. If the objective is a one-hour mean frequency difference, then short-term counter noise at an appropriate gate duration matters. If the objective is the intrinsic ageing trend across six months, the reference's long-term behaviour, unknown seasonal thermal response and shifts after shutdown can dominate. A common calibration error is not removed by taking one thousand successive readings. Nor does a deterministic daily cycle become uncorrelated noise because a spreadsheet has produced a standard deviation. I would record a covariance term for errors shared across dates, instruments or measurement channels.

Suppose independent random observations each have a standard uncertainty of 2 times 10 to the minus ten, while the comparison reference has a common systematic uncertainty of 5 times 10 to the minus ten. With one hundred genuinely independent observations the random component of the mean becomes 2 times 10 to the minus eleven. A simple illustrative combined uncertainty, assuming those two components are independent of each other, is the square root of (2 times 10 to the minus eleven squared plus 5 times 10 to the minus ten squared), approximately 5.004 times 10 to the minus ten. It is not 2 times 10 to the minus eleven. The assumptions must be stated, and a longer observation cannot magically remove a common bias.

Ageing per unit time also requires a declared exposure history. Calendar elapsed time, cumulative powered hours, thermal-cycle count and time

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since manufacture are not interchangeable predictors. A specification derived from an uninterrupted ovened test may not describe a receiver that is switched off nightly or subjected to temperature extremes in transit. I would compare like states with like states, record interruptions as interventions, and present the uncertainty of both the measured slope and the causal attribution. Where the distinction cannot be resolved, the conclusion must say so, however inconvenient that may be to the demands of a final certificate.

Dr. James M. Atkinson, Moderator: Mr. Nyquist, why can apparently satisfactory sampling-frequency performance obscure a slowly changing timebase?

Harry Nyquist, Peer Question: Lord Rayleigh, a software-defined receiver is specified to capture a bandwidth with nominal sample rate f_s. Its ADC reference changes slowly as the equipment heats, and the frequency display continues to show the commanded value. What observation would reveal that the physical sample interval and carrier-frequency interpretation have changed, and why is the sampling theorem alone insufficient to certify the acquisition time axis?

In a receiver farm, a signal may be sampled by one converter but its nominal radio-frequency position inferred from another synthesiser or external 10 MHz input. Could you explain how the analyst would locate the point at which reference ageing becomes an apparent movement of a captured carrier? A long waterfall trace can look persuasive even when frequency correction is silently applied by software. What would you record about sample-clock selection, digital decimation, dropped samples and frequency calibration so that a second laboratory could reproduce the inference?

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Please distinguish a genuine transmitter change from reference drift and from a recorder that reconstructs missing time without an explicit gap marker.

John William Strutt, Baron Rayleigh, Response: Mr. Nyquist, a nominal sampling configuration does not prove that hardware sample intervals conform to that nominal rate. Measure the clock against an independent time reference or observe a stable, known-frequency calibration signal through the actual acquisition chain. If the sample rate changes by fractional amount ε, the inferred frequency and elapsed-time mapping can shift correspondingly under the relevant signal-processing assumptions. Preserve hardware sample counters and direct phase or sample-clock comparisons. A sufficiently high average rate may still represent bandlimited content without gross aliasing while its timestamps, fine spectral estimates or coherent integration drift. Temperature-related oscillator variation is therefore a timing and metrology concern independent of the ideal theorem’s bandwidth condition. If samples are missing, that is an additional failure which a rate correction cannot repair.

A nominal sample rate is a setting, not a guarantee of the realised clock. At the beginning of a survey, map the relevant clock tree: the analogue converter's sample clock, the receiver's local oscillator, the distribution reference, and the computer time used to label the resulting records. Some architectures derive both sample and local-oscillator clocks from one reference; others do not. An apparent shift of a signal's carrier frequency can therefore originate in several places. The proper experiment injects a known stable signal and follows it through the complete chain, including its

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software frequency correction. An isolated test of the master oscillator does not by itself certify the displayed spectrum.

For a simple worked example, an actual sampling clock that is 2 parts per million faster than the assumed nominal value yields an equivalent fractional error in frequencies inferred solely from the sample index. A spectral component interpreted as 100 kHz in the idealised sample-frequency coordinate may have an actual frequency displaced by approximately 0.2 Hz under that mapping. The precise sign and relationship to the RF carrier depend on the receiver architecture and its mixing stages, so the instrument's calibration model must be stated. A trace labelled with many decimal places has no evidential authority if the sampling clock's actual rate is unrecorded.

Retain raw complex samples when lawful and feasible, original timestamps, receiver settings, resampling metadata and reference-selection events. If an automatic calibration alters a displayed frequency after acquisition, store both the raw and corrected estimates with the correction equation. An instrument that loses samples must record the discontinuity; interpolating missing time can make an oscillator excursion look smoother or can create misleading phase continuity. A second receiver clocked independently and observing the same injected marker supplies a powerful diagnostic. Agreement between two channels sharing one defective reference does not supply the same protection.

Dr. James M. Atkinson, Moderator: Professor Poincaré, what would constitute convincing evidence that the experiment has distinguished two competing explanations?

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Henri Poincaré, Peer Question: Lord Rayleigh, a reversible temperature change and a secular trend may both influence the same observed frequency. The analyst may choose whichever explanation appears intuitively plausible from a long plot. What intervention is capable of falsifying one of these explanations, and how should the investigator treat experiments in which the two effects cannot be separated within the available measurement uncertainty?

An ageing law and a thermal response law may produce the same observed curve when the environment changes monotonically during the survey. Which return experiment would decisively distinguish them, and what would remain uncertain if the device had experienced irreversible stress during the return journey? How should the record distinguish a model that merely fits the existing trajectory from one that predicts a different route through temperature and elapsed time? I should also like to know whether the analyst should abandon the attribution altogether when the alternate models yield materially different five-year predictions although each describes the one-year data adequately.

John William Strutt, Baron Rayleigh, Response: Professor Poincaré, devise contrasts whose predicted outcomes differ. Under a purely equilibrium thermal model, returning to the same fully equilibrated temperature should restore the same fractional frequency, apart from measurement noise. Under a model with secular ageing, observations at that common state may change as elapsed time advances. Under lag, the apparent loop should depend on ramp rate and diminish after extended dwell; under persistent hysteresis or retrace, some history-dependent offset may remain. The experiment must actually vary elapsed time and temperature history

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independently enough to make those predictions distinguishable. If the postulated effects are smaller than the reference uncertainty or are mutually confounded, the correct conclusion is conditional, not a victory for the preferred curve. An honest inconclusive result is valuable because it prevents an unsupported claim of drift attribution in a forensic report.

I would begin by requiring a prediction made before the return test. Under a reversible equilibrium model, a sufficiently equilibrated return to the original temperature, supply and load would restore the old fractional-frequency contribution, apart from any independently measured ageing and uncertainty. Under a lag model the apparent offset should diminish with longer dwell or slower ramp. Under a persistent change model a residual may remain, but the cause of that change need not be unique. Conduct the return experiment after documenting the previous power and temperature history, then repeat at a second reference temperature to see whether one inferred residual behaves consistently across operating points.

Suppose model one predicts a corrected return offset of 1 part in 10 to the ninth and model two predicts 5 parts in 10 to the ninth. If the combined uncertainty of the return comparison is 0.5 part in 10 to the ninth under documented independent conditions, the result may distinguish those predictions strongly. If there is an uncharacterised common reference shift of 6 parts in 10 to the ninth, it cannot. The experiment needs a discriminating observation and an error budget with sufficient resolving power. Merely adding more points along the original route does not provide that.

Where the models fit the observed period but diverge beyond it, present an envelope of plausible forecasts rather than select the most dramatic or

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convenient one. In evidential work the appropriate conclusion may be that the internal ageing rate is not identifiable from the deployed record. This is not a failure of scientific rigour. It is the rigorous statement of what remains unknown. An analyst can still correct a measured thermal component within the tested range and quantify residual frequency uncertainty without pretending that the unmeasured microscopic mechanism has been established.

Dr. James M. Atkinson, Moderator: The token passes to Professor Wiener for an independent principal account of ageing models and their confounding with thermal cycles. Lord Rayleigh will then challenge the statistical inference.

Norbert Wiener, Second Principal Contributor: Dr. Atkinson, a fitted secular frequency trend cannot be called irreversible ageing merely because a straight line explains a long record. Seasonal changes, thermal hysteresis, power cycling, retrace and the drift of the reference instrument can project onto the same low-frequency component. Identification requires interventions: controlled temperature ramps at different rates, holds at steady temperature, repeated cycles, and an independent comparison oscillator maintained under a different thermal history. Where ageing and temperature coefficients are estimated from highly correlated regressors, apparently precise numerical coefficients can be unstable or misleading. The laboratory should preserve raw phase-versus-time observations, thermal sensor placement, time constants and event logs, then test the proposed model against cycles not used in fitting it. I invite Lord Rayleigh to question whether our interventions alter the phenomenon we seek to measure.

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The mathematical issue is not whether a curve is smooth, but whether two explanations generate distinguishable observations under the experiment actually performed. Write the fractional-frequency observation at index i as y_i = a_0 + a_1 t_i + b_1 theta_i + b_2 theta_i squared + c z_i + epsilon_i, where t_i is elapsed time in days, theta_i is the measured resonator-temperature departure from a reference point in degrees Celsius, z_i is a measured power-state or thermal-history covariate, and epsilon_i is the unresolved error. These terms are not automatically physical mechanisms. A linear trend can represent an effective drift over the observed window; the temperature terms can approximate a locally curved response; and the history term can account for one observable remnant of a preceding cycle. When all three explanatory columns drift together, the fitted coefficients may be numerically unstable even if the fitted frequency curve looks impeccable. I would calculate the singular values of the design matrix, examine its condition number, and compare the uncertainty ellipse for a_1 and b_1 before attributing any fitted slope to materials ageing.

Suppose the enclosure warms by 0.20 degrees Celsius per day over an initial ten-day interval, while the oscillator has a reversible fractional sensitivity of 3.0 times 10 to the minus nine per degree. The temperature contribution is then 6.0 times 10 to the minus ten per day. If its genuine ageing term contributes 1.0 times 10 to the minus ten per day, a frequency-only regression will report approximately 7.0 times 10 to the minus ten per day. That sevenfold inflation is not evidence of unusual ageing. It is the arithmetic consequence of omitted temperature dependence. The reported numbers are invented solely to demonstrate identifiability. A second observation interval with essentially constant resonator temperature could

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reveal a different slope, but that inference must be qualified by reference drift and changes in the device's internal operating state.

Time-series dependence is a more subtle danger. If the measurement errors are positively correlated for hours, a least-squares routine that assumes independent residuals returns confidence intervals that may be radically too narrow. A 1,000-point record does not contain 1,000 independent experiments merely because 1,000 rows appear on the screen. Inspect the residual autocorrelation and the phase spectrum, use a covariance model appropriate to the instrument and the observed noise, and report the effective information content at the averaging times relevant to the evidential claim. A model with daily temperature terms, weekend power-state effects, and a weak secular trend deserves comparison against a model containing a stochastic random-walk frequency component. An unmodelled random walk can mimic a deterministic ageing slope during a finite interval without possessing that cause.

For an experimental design I would use a predetermined schedule rather than adjust the temperature programme after seeing which model wins. Start with an equilibrated baseline at a specified temperature and supply voltage. Run at least two heating rates and two cooling rates within the instrument's qualified operating envelope, randomising the order where prudent. Insert extended dwells that permit the difference between resonator and case temperature to diminish. Repeat one temperature sequence after a substantial elapsed interval while leaving the reference chain under a separately monitored environmental regime. A second device, preferably of different construction, should experience a complementary thermal schedule. This schedule creates data in which elapsed time and

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imposed temperature are not simply two names for the same changing quantity.

A state-space formulation can distinguish what is measured from what must be estimated. Let x_i contain the unobserved internal resonator temperature, a slowly evolving baseline frequency offset, and a possible hysteretic state. One can write $x_{(i+1)}=F x_i+G u_i+w_i$ and $y_i=H x_i+v_i$, where u_i contains deliberate heating or power interventions, w_i represents process uncertainty and v_i measurement uncertainty. The matrices F, G and H are test hypotheses requiring validation, not automatic facts about quartz. If the state observability matrix is rank deficient, no clever filter can infer every hidden component uniquely from the available sensors. A smooth Kalman-filter trace must not be mistaken for laboratory confirmation of an unobserved physical process. I would make the observability limitation explicit rather than conceal it behind elegant computation.

Training and validation windows should be separated by operating condition, not merely by time index. Hold out a complete thermal cycle and at least one power-recovery sequence, fit on the remaining material, and test whether the model predicts the frequency and its uncertainty on the held-out path. A model that interpolates one repeated daily waveform yet fails on a slow overnight cooling event is not competent to correct field evidence. Report prediction errors in fractional frequency and hertz for the actual receiver reference, and propagate them to tuning uncertainty and event time. In a multi-receiver surveillance array the common reference can create correlated errors, so the covariance structure must follow the

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distribution topology rather than be assigned independently to every channel.

I would also ask whether apparent secular motion disappears under time reversal of the programmed temperature trajectory. Thermal effects that follow a controlled stimulus should change sign or phase with the stimulus according to a testable response law; an intrinsic long-term shift need not do so. But irreversible stress relaxation triggered by the intervention itself could create a lasting step. Consequently, a returned temperature cannot guarantee a returned material state. The investigator should retain the pre-intervention baseline, the immediate post-intervention baseline, and the stable baseline after a documented recovery time. Those three observations separate a transient recovery from a persistent displacement, though they still cannot name the displacement's molecular cause without additional evidence.

The inference should end with a deliberately modest statement. One might conclude that a reversible thermal contribution explains a quantified proportion of the recorded excursion and that a residual secular change remains under the tested conditions. One cannot infer that the remaining change is solely resonator ageing unless reference drift, supply sensitivity, mechanical stress, compensation electronics, and environmental history have been bounded. The distinction is not a linguistic nicety. It determines whether a court or technical reviewer is being shown a measured quantity, a fitted statistical parameter, or an asserted cause with independent corroboration.

John William Strutt, Baron Rayleigh, Cross-Peer Question to Norbert Wiener: Professor Wiener, you propose cycling the oscillator through controlled

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temperatures to identify reversible terms. Yet the experiment may itself introduce mechanical stress, retrace or lasting changes to the resonator. How can repeated cycles be interpreted without supposing that the subject remains unchanged by the measurement? What distinction do you draw between a reversible response that follows the same path on cooling and heating, hysteresis that forms a loop, and a permanent shift remaining after the oscillator returns to a well-established reference temperature?

Please define the observation that would count as an irreversible alteration of the test oscillator after the temperature cycle, rather than a change of the comparison reference during that cycle. If the control oscillator experiences a different thermal history, that distinction might help, but the two measuring paths could nevertheless share cable or voltage sensitivities. Would you establish pre-intervention and post-intervention measurements at multiple common temperatures, and if so how would you avoid mistaking slow thermal recovery for a new ageing baseline? I also ask whether an experimentally induced persistent offset should be reported as an intervention response instead of being incorporated uncritically into an annual ageing slope. What would constitute a discriminating failure of your statistical model?

Norbert Wiener, Cross-Peer Answer to John William Strutt, Baron Rayleigh: Lord Rayleigh, precisely because thermal cycling can alter the device, use a baseline before and after each sequence and retain a control oscillator under stable conditions. A reversible equilibrium coefficient is estimated from repeated responses after sufficient thermal settling. A loop between heating and cooling reflects lag or hysteresis and must be analysed with temperature history, not collapsed into one coefficient. A residual shift after

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returning to the reference state is evidence of a persistent change under the tested conditions, but it does not alone identify a microscopic ageing mechanism. Replicate at bounded temperature rates and monitor mechanical and power-cycle events. A regression may summarise the evidence only after those physical distinctions have been tested.

I would test the proposition against data collected before and after the intervention, not against the appearance of the fitted curve. A minimum design uses repeated frequency comparisons at a stable nominal temperature, a controlled thermal excursion, and at least two post-excursion stable-temperature holds. The first hold tests short-lived recovery; the second tests whether the residual survives additional equilibration. An independent reference, or several witnesses with independently assessed correlations, must be observed through precisely the same interval. Otherwise a change in the master clock during the heating experiment would be attributed falsely to the heated device.

An irreversible response and ongoing ageing need not be the same process. The experiment itself might relieve mounting stress or alter contamination and thereby create a discrete offset. In the fitted model I would represent that event by a documented step parameter, while estimating the secular trend from stable reference states on either side. One should not smear the offset over the elapsed observation duration and call the resulting slope the natural ageing rate. The intervention record should include ramp rates, final temperatures, dwell times and evidence of any power state change. If the predeclared model cannot predict the second thermal cycle, this failure is informative evidence that the supposed reversible response is incomplete.

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The inference can be made testable by an explicit hold-out challenge. Fit the thermal time constants and baseline against the first cycle, then forecast both the final frequency and the uncertainty band during a second cycle of different duration. A result outside the calibrated prediction band calls for model revision or broader uncertainty, not a quietly adjusted fit that retrospectively passes. Moreover, a good prediction at the case sensor does not establish that internal material changes are absent. The forensic claim should identify the inferred mechanism only to the degree that the intervention and the independent witness genuinely distinguish it.

John William Strutt, Baron Rayleigh, Concluding Comment to Professor Wiener: I accept this restriction. The experimental record must distinguish an observed persistent offset from an identified causal mechanism, and the independent comparison standard must be observed as carefully as the oscillator undergoing the cycling.

Dr. James M. Atkinson, Moderator: Professor Essen, could you distinguish ageing of the tested oscillator from drift of the reference used to measure it? Professor Wiener will then test the identifiability of a fitted slope.

Louis Essen, Third Principal Contributor: Long-term frequency drift can be assigned to ageing only after the reference standard and environment have been independently controlled. A stable reference oscillator held under a different temperature history is an important comparison. It can reveal common metrological drift that would otherwise be attributed to the tested specimen. I would preserve unprocessed phase and frequency differences and characterise each discontinuity caused by power cycling or reference changes.

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Metrology begins by separating the thing to be measured from the artefacts that make its measurement possible. Let A represent the surveillance oscillator, B the local comparison source, and C an independently maintained standard. The measured phase difference $x_{AB}(t)$ is phase A minus phase B, plus the instrument's transfer function and comparison noise. A second comparison $x_{AC}(t)$ allows one to check whether the apparent excursion follows A or follows B, but only if the channels have not quietly inherited the same reference oscillator. In a modern receiver room several front panels can appear independent whilst their 10 MHz inputs, acquisition timestamps and software corrections all descend from one distribution amplifier. That is one metrological reference in several housings, not several independent witnesses. The wiring diagram and clock-selection records therefore belong in the evidential chain.

The comparison records should preserve phase as well as averages of instantaneous frequency. If $x(t)$ is the time error in seconds between two clocks, fractional-frequency difference over a gate from t_1 to t_2 is $y_{bar}=[x(t_2)-x(t_1)]/(t_2-t_1)$. For example, if time error grows from 20 nanoseconds to 80 nanoseconds over 6,000 seconds, y_{bar} is 60 times 10 to the minus nine divided by 6,000, equal to 1.0 times 10 to the minus eleven. At a 10 MHz carrier reference that would correspond to an average difference of 0.0001 Hz. Neither the measured phase slope nor this arithmetic reveals which oscillator changed. That attribution requires an independently tested comparison and a description of the oscillator states during the interval.

Calibration history must be placed alongside the new observation. I would obtain the last traceable calibration, its uncertainty and confidence

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convention, the procedure used, the reference standard's history, and whether the device has since experienced transport, shock, service, thermal excursion or long power interruption. An oscillator whose label reports a nominal ageing specification is not individually calibrated for the present deployment. Manufacturer ageing figures may be maxima, typical values or model-specific statements measured under conditions absent from the field. The record must distinguish a published specification from an actual as-found measurement. The as-found state must be captured before trimming the oscillator or changing its electronic correction, since adjustment destroys evidence of the preceding setting.

A third comparison can be valuable but must not be treated as a magic solution. For three oscillators A, B and C with uncorrelated fractional-frequency errors, the variance of the difference AB is V_A+V_B; likewise $V_{AC}=V_A+V_C$ and $V_{BC}=V_B+V_C$. Under those assumptions, $V_A=(V_{AB}+V_{AC}-V_{BC})/2$. As a numerical demonstration, suppose the dimensionless variances of three simultaneous difference records, expressed in units of 10 to the minus twenty-four, are 13, 20 and 17. Then $V_A=(13+20-17)/2=8$ in those units. The result is invalid if there is significant shared environmental or electrical noise, and may even become negative when noise estimates are uncertain. The analyst should investigate correlation rather than replace a physically troubling estimate with zero.

A direct comparison to a laboratory reference is only as good as the transfer path. Frequency counters can have gate-time and trigger sensitivities; phase comparators can add amplifier delay; long coaxial cables can change electrical length with temperature. If an RF feed line expands or its dielectric properties vary, phase at the comparison port may drift whilst the source

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oscillator remains unchanged. I would run a loopback experiment through the same distribution path, swap input cables where safe, and compare outputs at both the oscillator connector and the receiver reference port. Thermal insulation of one cable may be more informative than an additional decimal place in a numerical fit.

The reference itself needs an environmental history. Record its oven or case temperature, supply voltage, control voltage, reference-lock status, alarm events, and any interval in which it changed between internal, external or satellite-disciplined timing. A satellite-disciplined oscillator can be excellent for some averaging intervals and poor for others because its servo correction, reception outages or holdover behaviour can impose a characteristic timescale. An apparently smooth line may conceal steering steps when the data are resampled or averaged. Before attributing drift to the surveillance unit, I would examine the reference's raw steering log and compare an uninterrupted free-running interval with a documented disciplined interval, without confusing their different uncertainty budgets.

Statistical comparison demands an appropriate timescale. At one-second gates, short-term noise may dominate. Across hours, diurnal thermal response can dominate. Across weeks, ageing and reference drift may both matter. I would calculate time-domain stability at several averaging intervals and state the data preprocessing, dead-time handling and confidence of each estimate. A tidy Allan-deviation chart does not identify ageing by itself, because a deterministic drift may have been removed, a periodic temperature term may remain, and measurement dead time can change the estimator. Retain both original and corrected series so an independent reviewer can reproduce every transformation.

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Finally, I would produce a two-column evidential conclusion. One column reports observations: the measured differences, reference-path continuity, thermal telemetry, power transitions, and traceability. The other explicitly labels inferences: which trend is plausibly intrinsic, which is demonstrably temperature-correlated, and which is inseparable under the present design. The engineering value of such a distinction is practical. If the proposed surveillance detection depends on identifying a transmitted carrier moving by less than a fraction of a hertz over weeks, an unresolved reference trend of comparable size is material to detection confidence and must not be smuggled into the account as an external transmission property.

Norbert Wiener, Cross-Peer Question to Louis Essen: Could a linear fit over one year separate a true ageing slope from a yearly temperature influence if both regressors change nearly monotonically during the observation period?

Suppose the oscillator is compared against an external reference that is satellite-disciplined during the day but enters holdover after interference or signal loss. The resulting reference slope could be correlated with both environmental conditions and elapsed time. Would a nominal three-source comparison necessarily detect this common steering event, and how should the experiment be redesigned if the nominally independent references share the same outside timing source? Please address whether a fitted ageing trend remains admissible as a physical inference when its sign changes after an input-reference substitution, and specify what raw phase, reference-selection and telemetry records must be retained to expose the error. What test would separate common-mode steering from an independent component of the observed oscillator drift, and what residual

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uncertainty would remain after that intervention? I should not accept an inferred cause on numerical closure alone.

Louis Essen, Cross-Peer Answer to Norbert Wiener: Not reliably without independent variation or prior calibration. A collinear experiment admits several parameter combinations that fit almost equally well. Controlled temperature cycles and stable-temperature holds can make the causal effects more distinguishable, while independent checks expose reference drift. Report parameter sensitivity and interval limits rather than a falsely precise slope.

It would not necessarily detect it, for a three-source comparison is only informative to the extent that the sources and comparison paths possess known independence. If both reference sources are steered from the same remote timing service, they may share a low-frequency correction that looks precisely like a common secular trend. I would obtain their lock status and steering histories, mark every holdover transition, and compare the observed slope during periods in which at least one source runs freely. Substitution of a reference that reverses the sign of the inferred slope is a strong warning that the original attribution was not identified. It does not prove that the tested oscillator is faultless; it proves that the metrological decomposition was inadequate.

A useful algebraic test starts with measured differences d_AB=a-b and d_AC=a-c, where a, b and c denote fractional-frequency errors. Subtracting these expressions yields d_AB-d_AC=c-b. A common error present equally in A, B and C vanishes from every pairwise difference and is therefore invisible to this procedure. Thus even a perfectly closed algebraic triangle does not

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reveal common-mode drift. A separately characterised absolute or otherwise independent timing standard, or a qualified physical intervention, is required to constrain that mode. The result should be stated in words that identify the missing information.

The evidential record must contain raw phase samples or reproducible frequency differences; counter gate and averaging settings; the diagram of reference relationships; actual control and correction logs; temperature and supply data; and timestamps for reference changes. A disciplined reference might be suitable for detecting a short event yet unsuitable for assigning an extremely small secular ageing slope without accounting for its steering process. I would report a constrained differential drift where that is all the data permit. Precision in naming what was measured is preferable to unsupported certainty about what aged.

Dr. James M. Atkinson, Moderator: Professor Ramsey, please examine the oscillator’s retrace after thermal and power cycling. Lord Rayleigh will challenge the interpretation of a persistent offset.

Norman F. Ramsey Jr., Fourth Principal Contributor: Thermal retrace after switching the oscillator off and on should not be described as simple long-term ageing. The physical resonator, control electronics and enclosure have distinct thermal time constants, and the path back toward the nominal temperature may differ from the path on warming. I would compare steady-state operating points only after sufficient equilibration and retain the entire warm-up trajectory, because hidden intermediate states can influence the final observed offset.

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I approach this question through the distinction between a resonant physical standard and the apparatus that continually sustains or interrogates it. An oscillator contains a frequency-selective element, an active sustaining circuit, temperature regulation or compensation, power conditioning, and mechanical support. The recorded output frequency belongs to this entire assembly. The resonator may have a slowly changing intrinsic characteristic whilst its operating point shifts because loop gain, amplitude, electrode loading or supply conditions alter. Before calling an observed change ageing, we should determine whether it follows the physical reference or a part of the apparatus coupled to it. In an atomic frequency standard, the interrogation and control system is conceptually separable from the resonance; in a practical electronic oscillator, an analogous separation requires deliberately engineered tests, not an assumption.

Warm-up and thermal retrace must be recorded as trajectories. Let $t=0$ be power restoration; let $T_c(t)$ be case temperature and $T_r(t)$ an approximate internal resonator temperature. The response may include several characteristic times τ_1, τ_2 and τ_3 rather than a single exponential. A compact empirical expression for the transient fractional shift is $y_w(t)=\text{sum over } k \text{ of } A_k \exp(-t/\tau_k)$. Each amplitude A_k is dimensionless, each τ_k is measured in seconds, and negative or positive amplitudes can coexist. This is a phenomenological approximation valid only on the tested startup sequence. It cannot justify a microscopic description of the resonator, and it should not be extrapolated across power interruptions of different duration or cooling depth without corroboration.

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Consider an illustrative warm-up containing two components: a fast component of 5 times 10 to the minus eight with a 10-minute time constant, and a slow component of 2 times 10 to the minus eight with a two-hour time constant. After 20 minutes the remaining fast term is approximately 5 times 10 to the minus eight multiplied by exp(-2), or 6.77 times 10 to the minus nine. The slow term is 2 times 10 to the minus eight multiplied by exp(-1/6), or approximately 1.69 times 10 to the minus eight. Their sum remains about 2.37 times 10 to the minus eight. At 10 MHz this hypothetical error equals about 0.237 Hz. A technician who treats twenty minutes of apparently steady enclosure temperature as complete equilibrium could misclassify most of this transient as a slow drift.

Thermal hysteresis differs from dynamic lag. With a reversible equilibrium response the frequency at a given internal temperature is the same regardless of the direction of approach, once equilibrium has been achieved. Lag makes the apparent response differ on warming and cooling while gradients persist; a longer dwell should reduce that difference. Hysteresis can yield a history-dependent state after nominal equilibrium, and retrace after shutdown can leave a different baseline despite returning to the same measured temperature. A repeated ramp should therefore include controlled dwell times, rate variations and a common reference point revisited after each trajectory. A frequency-versus-case-temperature loop alone is insufficient to distinguish these mechanisms.

Mechanical details matter. Quartz cut, mounting geometry, support stress, surface contamination and package pressure can influence resonance; meanwhile ageing of the sustaining electronics or oven thermostat can shift the operating point independently. Excessive claims about internal

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causation would require teardown or targeted material and circuit measurements that may be destructive and therefore unsuitable for an evidential exhibit. Where nondestructive testing is necessary, compare supply sensitivity, control voltage, heater duty cycle and frequency under known stable loads. A temperature-correlation term that appears only when the reference output drives a heavy distribution load suggests an electrical rather than resonator-only explanation.

I would set a predeclared criterion for a stable comparison point. The criterion would involve the observed frequency slope over a defined window, the rate of change of the accessible thermal sensors, and the repeatability of the result when the same condition is reached from a different starting temperature. One should not merely wait an arbitrary number of minutes. For example, two successive hour-long plateaux may both satisfy a case-temperature tolerance whilst retaining opposite internal gradients. Comparing their recovered frequencies identifies a challenge to the simple equilibrium assumption. An independent comparison oscillator maintained in continuous operation is essential if the power-cycled oscillator's phase history is interrupted.

There is also a distinction between frequency offset and accumulated timing error. For a constant fractional-frequency offset y, the time error after elapsed duration t is approximately x=y t. At y=2 times 10 to the minus nine over 86,400 seconds, x is 0.0001728 seconds, or 172.8 microseconds. The arithmetic is simple, yet a survey may incorrectly treat the error as a transient phase perturbation removable by aligning plots after the event. Such a real-time reference error matters to timestamp comparison across receivers. If a recorder reclocks incoming samples from a shared reference,

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a common drift may preserve apparent agreement between internal channels while damaging absolute traceability.

The final research design would distinguish three claims. First, the equipment's output frequency changed during a documented operating interval. Secondly, some part of that change responded reproducibly to thermal or power-state interventions. Thirdly, a residual change remained after agreed equilibration and reference correction. Only the third begins to support a longer-term intrinsic shift, and even then its assignment to particular physical ageing mechanisms is conditional. In a laboratory assessment I would classify retrace, warm-up, reference drift and irreversible ageing as separate headings in the uncertainty budget, preserving their covariances where they arise from a common intervention.

John William Strutt, Baron Rayleigh, Cross-Peer Question to Norman F. Ramsey Jr.: If the frequency fails to return to its pre-cycle value at the same indicated enclosure temperature, what further measurements distinguish internal stress from a faulty thermometer or reference comparator?

If an oscillator returns to the same case-temperature reading but not the same output frequency, that alone could reflect a hidden temperature difference across the mounting assembly. What experiment would you use to separate that hidden gradient from a change in sustaining-circuit gain or supply voltage? Please specify the diagnostics available where destructive examination of the resonator is not permissible because the equipment must remain available as evidence. Would you treat a recovered frequency offset after a single start as a reliable ageing result, or require repeated starts with varied cooling duration? How should cumulative powered hours

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be distinguished from calendar time? In particular, please distinguish a measurement at the case surface from a measurement of resonator equilibrium, and explain which alternative error mechanisms remain observationally indistinguishable without additional instrumentation.

Norman F. Ramsey Jr., Cross-Peer Answer to John William Strutt, Baron Rayleigh: Use multiple thermal sensors near relevant components, independent comparison references and repeated cycles with controlled timing. A persistent difference after equilibration is evidence of a changed system state, but not yet proof of its microscopic cause. Mechanical stress and control-electronics behaviour should be challenged separately. The report should identify the reference plane and uncertainty of the temperature and frequency comparison.

I would require repeated starts under a documented matrix of cooling durations, not a single observation made at a convenient time. Compare a brief outage that leaves the enclosure warm with an extended outage that allows deep cooling, while recording the outer enclosure temperature, heater-control effort, supply voltage, reference lock and output-load condition. Repeat one sequence in the same physical mounting configuration, then challenge it with an allowed change in ambient temperature while keeping power history fixed. A gradient-driven explanation predicts response to cooling depth and dwell; a sustaining-circuit explanation may be associated with control voltage, amplitude or supply variation. The point is to create rival observable predictions instead of assigning a cause to an isolated offset.

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A conceptual thermal model with two states can be expressed as $C_r\, dT_r/dt=(T_h-T_r)/R_r$ and $C_h\, dT_h/dt=P_h-(T_h-T_a)/R_h-(T_h-T_r)/R_r$. Here C_r and C_h are thermal capacities in joules per kelvin, R_r and R_h thermal resistances in kelvins per watt, T_r the resonator temperature, T_h housing temperature, T_a ambient temperature, and P_h heater power in watts. These equations are simplified examples, not an asserted internal design. The two time constants can permit the case thermometer to look settled while the resonator remains out of equilibrium. Without a second observation related to T_r, parameter estimates may be non-unique. State that limitation rather than fabricate an internal temperature trace.

The intervention should include the original condition of the instrument, the possibility of stress after transport, and a prohibition on unrecorded trimming. A stable post-start offset is evidence that the assembled system behaves differently at a declared operating point, but a microscopic ageing cause would require further targeted tests. Cumulative operating hours and calendar elapsed time may both correlate with the change, so report them separately alongside thermal-cycle count. For timing evidence captured before the final equilibrium, record the uncertainty of the operating interval itself, not merely the later recovered frequency.

Dr. James M. Atkinson, Moderator: Professor Poincaré, our last principal perspective concerns whether the ageing model is identifiable at all. Professor Wiener will assess the consequence of divergent extrapolations.

Henri Poincaré, Fifth Principal Contributor: The explanatory model must not be mistaken for an observation. A curve containing an irreversible term and a reversible term may fit the measured history but remain non-identifiable if

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the thermal input and elapsed time are strongly correlated. I would seek experimental paths returning to a common reference temperature after different thermal histories, then assess whether the same parameters predict the held-out outcomes. Model failure under such a challenge reveals more than a good in-sample regression coefficient.

The difficulty is one of inverse inference: different internal arrangements may produce the same visible trace. In a long record a curve called ageing and a curve called thermal response may be individually arbitrary if the analyst has observed only their sum. This is the distinction between interpolation and explanation. Interpolation requires a function that follows the observations; explanation requires an experiment under which rival functions predict different future observations. If a model's equations allow the ageing coefficient and temperature coefficient to trade against each other without changing the fitted output, the parameters have not been identified, however many digits the optimisation procedure reports. I would insist that the competing hypotheses be written down before their numerical merit is compared.

Suppose hypothesis A states that the fractional frequency y follows y_0 + a t + b theta, with t elapsed days and theta internal temperature departure in degrees Celsius. Hypothesis B asserts y_0 + a' t + b' theta + c theta squared, where c accounts for local curvature. If the observed temperature rises almost exactly linearly with time, the columns t and theta become nearly proportional. No dataset of that single trajectory can reliably determine both a and b. A new experiment should revisit the same temperature at several elapsed times and the same elapsed interval under more than one

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temperature trajectory. Randomised, bounded temperature steps can break the proportionality while remaining within the safe operating range.

It may help to think geometrically. A data set measures a path through a space whose coordinates are elapsed time, current temperature, prior temperature history, power state, and supply voltage. If all the observations lie nearly upon one curve in that space, the measurements cannot reveal the full response surface. The investigator must plan excursions away from that curve. This need not imply reckless environmental stress. The experiment can use low-amplitude thermal reversals, long stable holds and repeated reference points. Its purpose is not to produce dramatic effects but to give the competing models an opportunity to disagree measurably, under conditions for which the instrument remains qualified.

A worked illustrative contrast shows the distinction. Model A predicts a residual fractional change of 4 times 10 to the minus nine after sixty days at a stable reference temperature. Model B predicts 1 times 10 to the minus nine after the same interval, but both fit the original temperature-ramping data within measurement noise. A returning stable-temperature test measured with standard uncertainty 0.5 times 10 to the minus nine could distinguish the predictions if its reference and other systematic effects are bounded. If the reference itself contributes 3 times 10 to the minus nine of unresolved error, the result is inconclusive despite the apparent precision of the oscillator's readout. The meaning of an experiment lies in its capacity to discriminate hypotheses, not its number of samples.

Models also differ in their extrapolation. A secular linear law would predict continuous unbounded change if extended indefinitely, yet many material processes relax, saturate or change sign. A logarithmic time dependence or

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a sum of decaying exponentials may better describe some specimens over limited windows. Equally, a stochastic drift model can predict a widening band without asserting a deterministic ageing mechanism. None deserves automatic priority on philosophical grounds. Compare them on physically meaningful hold-out intervals, report parameter uncertainty and predictive uncertainty separately, and disclose how the result changes when the thermal sensor calibration or the assumed time constant is varied.

I would interrogate the meaning of a measured temperature. A sensor mounted on the metal enclosure does not show every point of the resonator assembly. Two devices with the same recorded case temperature can inhabit different internal states after a sudden ramp, after a slow ramp or after a power interruption. An unobserved state variable may be introduced to represent this difference, but adding such a variable does not make it independently knowable. One must test whether the available outputs render it observable, or acknowledge the range of hidden states consistent with the record. This is particularly important when an apparent hysteresis loop is reconstructed from sparse telemetry rather than measured at the physical resonator.

The uncertainty statement should combine measurement uncertainty, model-form uncertainty and uncertainty concerning interventions. Measurement uncertainty includes comparator noise, reference instability and temperature calibration. Model-form uncertainty concerns the selection of polynomial, thermal-lag or stochastic processes. Intervention uncertainty concerns whether cycling the device changed its underlying material state or control behaviour. These are not three interchangeable standard deviations that can always be combined by taking a square root. Their

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correlation and epistemic character must be recorded. An uncertainty budget that uses only a regression standard error omits the most consequential difficulty in this experiment.

For a forensic conclusion, the language should remain proportionate to this evidence. The report may say that controlled temperature reversals established a significant reversible contribution, that a returned reference temperature did not completely restore the earlier frequency, and that competing descriptions of the residual remain plausible. It should not say that a specific lattice defect aged unless the supporting evidence has actually been obtained. Distinguish a numerical model's utility for correcting a receiver trace from a causal explanation of the crystal. A correction can be operationally useful within its validated domain and still be incapable of proving the mechanism that necessitated it.

Norbert Wiener, Cross-Peer Question to Henri Poincaré: How should the investigator report competing drift models that agree during the observed year but predict markedly different behaviour over the next five years?

Suppose one model extrapolates an almost linear secular change over five years while another predicts a logarithmic relaxation toward a stable frequency. Their fits over the observed year may be practically indistinguishable. How should the analyst report an interval of plausible outcomes without suggesting that the two curves have equal physical credibility, and which laboratory intervention could most efficiently discriminate them? Could the use of an additional polynomial term create a persuasive numerical fit but worse out-of-sample prediction? Please specify how uncertainty arising from the untested form of the model should be

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reported separately from uncertainty in measured temperature and frequency. A research report should identify the experimental conditions under which these models would cease to be observationally equivalent. What minimum difference between their forecasts would justify spending additional laboratory time on the discrimination test?

Henri Poincaré, Cross-Peer Answer to Norbert Wiener: Present their predictions as alternatives with explicit assumptions, rather than select one extrapolation simply because its fitted residual is slightly lower. Identify the interventions capable of separating the models and the domain over which each was validated. Long-horizon claims need uncertainty that grows with model disagreement and unobserved operating conditions.

One should first state the domain of the observations. A five-year forecast from a single year's data is an extrapolation, and every untested assumption becomes consequential. The report should display the competing models, identify their distinct physical premises, and give prediction intervals that include parameter uncertainty and uncertainty about model form. If there is no defensible probability weighting of the alternatives, it is better to show a scenario envelope than to invent an averaged distribution. A polynomial curve may lower the in-sample sum of squares simply because it contains more coefficients. That numerical success does not establish any material mechanism and may create unphysical behaviour beyond the fitted interval.

A targeted discriminating intervention would revisit a carefully controlled stable operating point after a meaningful elapsed interval and would repeat an independent temperature reversal. A true equilibrium temperature contribution should respond consistently to the reversal within the

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established range. A secular displacement may remain when the system returns to the same operating condition, though its microscopic cause can still be ambiguous. If the two candidate ageing functions forecast measurably different increments between two such stable reference observations, that difference can be tested, provided the reference chain possesses sufficient stability and independent character. The experiment should be designed before its outcome is inspected.

For a hypothetical five-year prediction, suppose the linear model forecasts a fractional offset of 20 parts in 10 to the ninth, while the saturating model forecasts 7 parts in 10 to the ninth. If measurement and parameter uncertainty around each model is 2 parts in 10 to the ninth but the model form itself is unresolved, reporting a combined result of 13.5 plus or minus 2 would conceal the dominant uncertainty. State that the plausible model-dependent outcomes span at least the two predictions under their respective assumptions, with additional instrument uncertainties. That is more faithful to the actual evidence, and it prevents a future survey from using spurious decimal precision as a substitute for experimental identification.

Dr. James M. Atkinson, Moderator, Closing Synthesis: Oscillator ageing, equilibrium temperature response, thermal lag, hysteresis, warm-up and retrace are not interchangeable explanations of a frequency trend. The panel has prescribed a phase-preserving comparison with an independently characterised reference, stable-temperature controls, repeated heating and cooling ramps of different rates, long dwell periods, deliberate power-cycle trials and uncertainty models that retain correlated errors. A long straight-line fit alone cannot establish irreversible ageing. In extended defensive RF

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monitoring, the analyst must trace clock behaviour through the actual receiver chain and distinguish measured environmental sensitivity from inferred secular change. All contributors' dialogue is fictional historical reconstruction, and the worked values are illustrative rather than observations of a deployed system.

QUESTION 060. SOURCE AND QUALIFICATION REGISTER

1. W. J. Riley and D. A. Howe, Handbook of Frequency Stability Analysis, NIST Special Publication 1065 (2008), https://www.nist.gov/publications/handbook-frequency-stability-analysis. Reference for phase/frequency stability assessment, sampling and data analysis.

2. M. A. Lombardi, An Introduction to Frequency Calibrations, NIST Time and Frequency calibration materials, https://tf.nist.gov/service/pdf/calibrations.pdf. Supports traceability, comparison methods and uncertainty reporting. This citation does not independently prove a particular resonator ageing mechanism.

3. T. E. Parker, V. Zhang, J. Yao, G. Petit, R. Brown, and J. Hanssen, A Three-Cornered Hat Analysis of Instabilities in Two-Way and GPS Carrier Phase Time Transfer Systems, Metrologia (2022), https://www.nist.gov/publications/three-cornered-hat-analysis-instabilities-two-way-and-gps-carrier-phase-time-transfer. Supports the comparison-method discussion; covariance and independence must still be independently tested for the oscillator configuration.

4. Frequency Stability Degradation in Quartz and MEMS Oscillators, Sensors 26 (2026), 5425, https://pmc.ncbi.nlm.nih.gov/articles/PMC13567960/.

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Modern survey describing thermal gradients, lag, hysteresis, retrace and ageing; contemporary applications are not historical attributions.

Editorial qualifications: All worked examples are illustrative, not a manufacturer specification or measured field result. The historical dialogue is expressly fictional. Stage A must be determined by the saved-DOCX validators. Independent history, physical-science calculations, source-to-claim checks, scientific originality, answer responsiveness, and final pagination remain unapproved.

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QUESTION 061

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When do common-mode currents on coaxial screens imitate a spatially localised emitter?

Dr. James M. Atkinson, Moderator: Mr. Heaviside, imagine a quiet survey room in which a receiver indicates an isolated spectral peak, and the operator carefully rotates a small loop or survey antenna to obtain a seeming direction. The sharp trace remains visible, yet its apparent bearing moves as the coaxial lead is shifted across the table or brought near a metal cabinet. Some engineers ascribe the effect to a clandestine transmitter, others to defective shielding, and still others to uncontrolled coupling from an entirely lawful apparatus. Please establish the electromagnetic distinction between the intended coaxial transmission-line mode and an exterior current on the screen. Then specify what evidence would justify locating a radiator rather than merely locating a disturbance in the measuring installation.

Oliver Heaviside, Principal Contributor: Dr. Atkinson, the essential error lies in confusing a cable's guided internal circuit with its exterior electromagnetic boundary conditions. Under the usual high-frequency coaxial approximation, the forward RF current flows on the surface of the centre conductor and its return flows on the interior face of the outer conductor. The corresponding fields are largely confined within the coaxial dielectric. A current on the outside of the screen, however, belongs to another mode whose return path can involve the instrument chassis, building steelwork, a nearby person, the floor and capacitance to surrounding structures. The cable exterior can then receive or radiate energy and effectively enlarge the antenna being surveyed. The narrow line on the display is quite real as a voltage at the receiver input. Its alleged

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point of origin remains a separate, unproved hypothesis.

An important proviso is that the screen is not magically divided into three independent ideal wires at every frequency. Finite conductivity, braid apertures, imperfect terminations and frequency-dependent transfer impedance permit coupling between exterior and interior fields. At frequencies where skin depth is small compared with a solid shield's thickness, interior and exterior surface currents may be approximately separable. A braided screen requires more caution: its permeability to fields depends on construction, overlap, contact resistance, frequency and connector workmanship. A continuity test conducted at direct current cannot certify the absence of RF transfer. Similarly, a satisfactory voltage standing-wave ratio in the intended differential mode does not demonstrate that the outside of the feed line is free of common-mode current.

Suppose a balanced receiving loop is connected to a coaxial cable through an asymmetrical junction. An incident wave can excite the loop and the line exterior together. The voltage at the receiver is then better represented as a superposition of an intended antenna-path contribution and a cable-related contribution, including any mode conversion that occurs at the feed, connector or instrument enclosure. The two contributions are complex phasors. Their relative phase changes with cable routing, frequency and nearby conductive surfaces; therefore a small movement of the lead can reinforce or cancel the apparent signal without any movement of the remote emitter. A directional null is particularly vulnerable because a relatively small cable contribution can dominate the output when the

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intended antenna is close to its minimum response. A visually impressive bearing change may therefore be evidence about the measurement geometry rather than the position of a hidden source.

The physical causes are diverse. Exterior current may be induced by nearby electric or magnetic fields; driven by asymmetry at the antenna feed; excited by a difference of RF potential between enclosures; or coupled from receiver power, computer data and switching supplies. One cannot identify which cause is active by touching the cable and observing the waterfall alone. The proper experiment holds the antenna's position and orientation fixed whilst changing only a known cable variable, then reverses the intervention. Compare traces with the cable routed away from metallic structures, against a protected reference receiver, and with calibrated common-mode impedance inserted at an appropriate location. The source, cable and instrument configurations must be photographed or diagrammed in the engineering record, even if the textbook itself contains no photographs.

A split-core RF current probe surrounding the entire coax is especially useful. In the ideal differential mode, the outgoing and return currents sum to approximately zero within the probe aperture. A nonzero net longitudinal current indicates current outside the intended balanced return, subject to probe bandwidth, positioning, cable geometry and calibration. It does not by itself prove that the cable is the original emitter; the current may have been induced by the very distant transmitter being investigated. Nor should an operator put a probe around the centre conductor alone and call the resulting current a measurement of exterior-shield current. The conductor

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set enclosed by the probe is part of the measurement definition.

A common-mode choke may reduce current on the cable exterior while leaving much of the intended differential signal path unaffected. The actual suppression depends on the choke's complex impedance, frequency, position and the complete external return circuit. Its resistance and reactance must not be replaced by one fixed catalogue number at every frequency. A choke placed at the wrong position in a standing-wave distribution may give little improvement, and a lossy ferrite placed near a sensitive antenna may alter its environment. The strongest test therefore uses calibrated before-and-after measurements of exterior current and a repeatable received-signal response, not the mere presence of a ferrite bead.

Finally, source localisation requires a chain of alternative-hypothesis tests. Is the peak present when the receive input is properly terminated? Does it follow the coaxial route while the antenna stays still? Does the apparent bearing reproduce with an independently clocked and independently cabled receiver? Does the result survive substitution of a known low-common-mode test antenna and relocation to a second survey point? A stable peak on a shared receiver architecture is not independent corroboration. Retain the original raw measurements, the current-probe readings, the interventions and the negative controls. The defensible finding is sometimes that an RF component was detected but its apparent spatial bearing was instrument-dependent. Such precision of wording protects the investigator's credibility more effectively than an unjustified coordinate.

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TECHNICAL WORKSHEET. TEN CONTROLLED EXAMPLES

Example 1. Net current through a clamp. Assume the centre conductor carries a 3.0 mA longitudinal phasor and the complete shield contribution enclosed by the clamp is −2.4 mA at the same phase reference. The algebraic net current is $I_{CM}=I_{centre}+I_{shield}=3.0-2.4=0.6$ mA. Here I_{CM} denotes the probe-observed common-mode current, not the intended internal return current. Phasor quantities must be added vectorially if their phases differ.

Example 2. Relative current suppression. At one frequency a calibrated probe indicates 2.0 mA before an intervention and 0.50 mA afterwards. The current-amplitude ratio is $r=0.50/2.0=0.25$. The change is $20 \log10(r)=20 \log10(0.25)=-12.04$ dB. This is suppression of measured current at that probe location; without a field-transfer model it is not automatically 12.04 dB suppression of radiation at every position.

Example 3. Idealised choke circuit. Represent the exterior-current driving source by an RF voltage V=0.60 V across a purely resistive path $Z_p=100\ \Omega$. Before adding the choke, $I_0=V/Z_p=0.60/100=0.006$ A=6.0 mA. Add an ideal 300 Ω resistive common-mode impedance in series: $I_1=0.60/(100+300)=1.5$ mA. The reduction is $I_1/I_0=0.25$, or −12.04 dB. Actual choke impedance is complex and the surrounding circuit is distributed, so the example is a model, not a guaranteed result.

Example 4. Cable length in wavelengths. At f=30 MHz and an illustrative free-space propagation speed $c=3.00\times10^8$ m/s, $\lambda=c/f=3.00\times10^8/(30\times10^6)=10.0$ m. A 1.5 m exterior conductor is $1.5/10.0=0.15\lambda$ in physical free-space wavelength terms. Its effective electrical length may differ because the outer

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surface, jacket, nearby metal and return path constitute a different environment from the coaxial dielectric.

Example 5. Coherent pattern distortion. Suppose the intended antenna supplies unit normalised field phasor $E_a=1.0$ and the cable supplies $E_c=0.5$ at the same observation reference plane. In phase, $|E_a+E_c|=1.5$; in opposition, $|E_a-E_c|=0.5$. The ratio of squared field magnitudes is $(1.5/0.5)^2=9$, equivalent to $10 \log10(9)=9.54$ dB. Neither magnitude establishes an external source direction without an angular model.

Example 6. Route-dependent current. One cable routing gives $I_A=1.0$ mA and another $I_B=0.40$ mA at the same frequency and calibrated probe point. The difference is $20 \log10(0.40/1.0)=-7.96$ dB. If the antenna remains at a surveyed fixed position while a bearing estimate changes, the result argues for sensitivity to the installation. It does not prove where the inducing field originated.

Example 7. Shield transfer impedance. Define a simplified transfer impedance per unit length $Z_t=V_{inside}/(I_{out} L)$, in Ω/m, where V_{inside} is the coupled interior voltage, I_{out} the measured exterior current and L the uniform coupled length. If $Z_t=0.020$ Ω/m, $I_{out}=5.0$ mA and $L=2.0$ m, then $V_{inside}=Z_t I_{out} L=0.020\times0.0050\times2.0=0.00020$ V=0.20 mV. This lumped approximation assumes known phase and uniform coupling; actual transfer impedance is complex and frequency dependent.

Example 8. Termination and choke dependence. For a simplified Thevenin-like common-mode circuit with a 100 Ω total driving and return resistance, insertion of a purely resistive 200 Ω choke changes current amplitude by $r=100/(100+200)=1/3$. Therefore $20 \log10(1/3)=-9.54$ dB. If the 200 Ω

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consists mostly of reactance, the complex vector sum must replace this arithmetic; blindly adding impedance magnitudes may be wrong.

Example 9. Probe conversion factor. A current probe calibrated at the measurement frequency has transfer impedance $Z_{probe}=5.0\ \Omega$, defined as the measured probe output voltage divided by the enclosed net current. If it produces $V_{probe}=50$ mV, then $I_{CM}=V_{probe}/Z_{probe}=0.050/5.0=0.010$ A=10 mA. Include the probe loading, cable centring, instrument input impedance and calibration uncertainty before assigning a confidence interval.

Example 10. Small cable phasor and angular contrast. At two orientations, suppose the intended antenna field has unit magnitude while the exterior cable contribution has magnitude 0.30. In one orientation the terms align, giving 1.30. At another they are in quadrature, giving $\mathrm{sqrt}(1.0^2+0.30^2)=\mathrm{sqrt}(1.09)=1.044$. The amplitude contrast is $20\log10(1.30/1.044)$=approximately 1.90 dB. A small auxiliary field can therefore change a pattern trace by a measurable amount without an external emitter moving.

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James Clerk Maxwell, Peer Question: Mr. Heaviside, a receiver may display a narrow line while a nearby coaxial screen carries current whose surrounding field is plainly not confined to the dielectric. A survey team might describe this as leakage through a shield, even though the exterior conductor may be acting as an antenna in its own right. Could you distinguish these mechanisms using field boundary conditions, and explain why the electric and magnetic fields around a cable cannot be assigned to a source by simply tracing the direction of the nearest conductor? I should also like an account of how nearby metalwork changes the electromagnetic problem without being a source of energy itself. When is the ordinary transmission-line abstraction appropriate, and when should the investigator treat the whole room, cable and chassis as a coupled electromagnetic boundary-value problem? Would you also specify one observation that might falsify the simple leakage explanation, rather than merely providing another attractive fit to the field pattern?

Oliver Heaviside, Response to Professor Maxwell: Professor Maxwell, the relevant fields must satisfy the boundary conditions at every conducting and dielectric surface, including imperfect contacts and the surrounding structures. The intended coaxial mode is a useful approximation because its outward and return currents are closely paired and its dominant field energy is contained between conductors. A distinct exterior current is not a failure of all shielding in the simple sense. It can arise at a feed transition or through external excitation, with the exterior conductor forming a portion of a larger current loop or radiating structure. It can therefore carry energy and interact with the room even if the internal signal remains well protected from certain forms of ingress.

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A metal cabinet alters capacitance, inductive coupling, image-current distributions and the possible return paths. It can shift the magnitude and phase of an existing exterior current without generating the underlying oscillation. Conversely, switching electronics inside that cabinet may actually inject a new disturbing current. To distinguish these explanations, one must perturb location and connection in a controlled fashion, preserve source-on and source-off conditions where lawful, and observe how the fields respond at several reference positions. A narrow received line is an electromagnetic observation, not a statement about authorship.

The mathematical abstraction becomes inadequate when the cable length, neighbouring conductor dimensions, or relevant separation distances are no longer electrically small for the question being asked. In that situation, distributed phase and radiation effects matter, and the simple series-circuit model of an exterior current may fail. Full-wave modelling is an option, but its geometry, conductivity and excitation assumptions must be documented and checked against measurements. A model in which the entire room has been replaced by an ideal ground plane cannot establish the location of a real emitter in a cluttered room.

The practical boundary is thus an evidential one. Use circuit theory to design and calibrate the probe, transmission-line theory to understand the intended coaxial mode, and electromagnetic field measurements to assess the antenna-system perturbation. Never infer that because the receiver case is grounded at direct current it constitutes an equipotential RF reference.

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The chamber's steel frame, the instrument cabinet, and the coax exterior may form an unintended receiving system whose directionality is governed as much by the installation as by the small survey antenna.

Michael Faraday, Peer Question: Mr. Heaviside, there is an understandable temptation to introduce a ferrite choke immediately after discovering a coaxial shield current, observe a smaller spectral peak, and then pronounce the original signal artificial. But a choke is a material intervention into the observing system, not a neutral act. How should an experimenter distinguish suppression of the cable's unintended receiving action from suppression of the legitimate antenna signal or simple detuning of the apparatus? What negative controls and reversed interventions would you insist upon? I am particularly concerned that nearby hands, cabinets and changing lead geometry could disturb a delicate field pattern as readily as a new component, leaving an apparently decisive result that another observer cannot reproduce. If a metal cabinet happens to stand near the test apparatus, would you insist upon recording its position and the operator's posture during every repeated observation, and explaining whether the original source was energised throughout?

Oliver Heaviside, Response to Mr. Faraday: Mr. Faraday, a change following intervention is evidence only after competing mechanisms have been considered. The choke may increase common-mode impedance, reduce exterior current, alter the antenna's current balance or change the cable's electromagnetic proximity to the receiving element. It may also change losses and matching in an imperfect assembly. Thus a reduction in displayed energy is not by itself proof that the original line was generated inside the measuring system. The line could be a real external field that had previously

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been received mainly by the cable exterior.

Begin with a reproducible baseline: fixed antenna position and orientation, receiver gain, frequency span, input attenuation, reference clock and cable layout. Measure a known local calibration signal in parallel, preferably with a second independently cabled receiver. Fit the current probe around the entire coax without shifting the cable. Record the probe reading and spectral amplitude before introducing the choke. Then insert the choke, document its frequency-dependent impedance and location, and make precisely the same observations. Remove it and verify that the original state returns within measured repeatability. Randomise the sequence where possible to reduce the influence of drift and operator expectation.

A particularly useful negative control is an electrically equivalent non-magnetic spacer that produces a similar mechanical displacement without appreciable common-mode impedance at the frequency of interest. Another is a frequency interval outside the choke's effective impedance range. If the result follows cable motion equally with the dummy intervention, the evidence for a ferrite-specific effect weakens. Calibrate the intended antenna response before and after the experiment to identify changes in coupling or matching. A second position in the room can determine whether the line is spatially persistent or intimately tied to a particular measurement arrangement.

I would also require an ethical and procedural distinction between a controlled laboratory test and an evidential field recording. One may safely

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interrogate a test apparatus; one must not alter operational evidence without preserving the untouched source data and obtaining authority. The conclusion should be about the demonstrated relationship between current, cable configuration and received amplitude. The origin of the excitation may remain undetermined even if the causal role of the lead has been convincingly established.

Arthur Edwin Kennelly, Peer Question: Mr. Heaviside, the proposed worksheet treats a choke as a series impedance and a cable exterior as a current path. These approximations are useful, but a long screen near a metal wall or instrument rack may support standing waves whose current minima and maxima vary with frequency. Could you explain how the position of a choke or current probe affects the apparent result, and why a reading at one location cannot establish the total radiation contribution of the line? How should a field engineer choose several test positions and avoid conflating the specified characteristic impedance of the internal coaxial line with the very different impedance encountered by the outside-screen current and its environmental return path? Please explain whether the engineer should repeat the current map after disconnecting one peripheral device, since otherwise the instrument chassis might remain part of a hidden return path which changes between experimental trials.

Oliver Heaviside, Response to Professor Kennelly: Professor Kennelly, one must keep the two modes separate. The nominal 50 Ω or 75 Ω of the intended differential coaxial mode is not a universal impedance presented to an exterior current flowing against earth, a chassis or parasitic capacitance. The latter sees a distributed, often poorly defined circuit whose resonant structure depends upon the surrounding geometry. A choke can

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change the standing-wave pattern, moving a current maximum rather than reducing current everywhere. A clamp at one point may consequently register a reduction whilst another region of the cable becomes more strongly excited. This is why the exact probe position is a material observation.

A useful survey measures net current at several labelled distances along the same cable without changing its routing. These measurements should be phase-sensitive if the equipment permits and should be performed at the frequencies of interest. Apply one choke at a time at documented locations, not indiscriminately. Compare the current distribution before and after each intervention, while checking the signal delivered by the intended antenna path. A source whose amplitude changes near a cable-current maximum may support a common-mode coupling hypothesis, but a second route and an independent receiver are still needed to test attribution.

The impedance picture must use phasors. A nominal ferrite impedance $Z_c=R_c+jX_c$ adds to the effective exterior path impedance $Z_p=R_p+jX_p$. For a locally valid series model, current magnitude is $|I|=|V_{drive}|/|Z_p+Z_c|$, not $|V_{drive}|/(|Z_p|+|Z_c|)$. If reactive parts cancel, the inserted component can behave unexpectedly. The simplified arithmetic worksheet deliberately assumes pure resistance to teach scale; it must not be used as a field prediction without impedance characterisation. A wide-frequency measurement may expose a choke that is resistive in one band and strongly reactive elsewhere.

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Finally, a genuine radiating cable is not a one-dimensional scalar current meter. The exterior current's phase and spatial distribution determine the far and near fields together with the surrounding conductors. A simulation may assist, but the measurable claim should remain grounded in a probe map, a controlled antenna pattern comparison and repeatable physical interventions. The prudent engineer changes one pathway at a time, preserving the surveyed antenna and reference geometry as carefully as a metrologist preserves the datum of a mechanical measurement.

John Daniel Kraus, Peer Question: Mr. Heaviside, direction finding is commonly presented through the rotation of an antenna having a known response pattern. A feed line carrying exterior current adds an unintended spatial element, potentially deepening one null and filling another. How would you distinguish a legitimate bearing derived from the calibrated antenna from a false bearing produced by the combined antenna, lead and instrument cabinet? Please include the consequences of coherent phasor addition, polarisation and the surrounding near-field objects. What tests could a team perform in a crowded room where turning the survey antenna almost inevitably moves its coax, and in which the available bearing indications appear sharp but are not geometrically consistent? Would you additionally require a reference pattern taken with the same gain and frequency settings, and would you forbid reporting a numerical bearing confidence interval until installation-sensitive error has been measured at several distinct test azimuths?

Oliver Heaviside, Response to Professor Kraus: Professor Kraus, the directional response of the installed system is the actual quantity seen by the receiver. Suppose the voltage contribution of the intended survey

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antenna varies with azimuth θ as A(θ), while a cable contribution is C(θ,geometry). The measured voltage is V(θ)=A(θ)+C(θ,geometry), with complex phasor addition. Its magnitude need not have a maximum or minimum at the same azimuth as A(θ). At an intended deep null, even a modest cable signal can dominate the residual; its phase may then determine the apparent direction. Treating that null as a geometric ray to an emitter is unjustified.

The test should mechanically decouple antenna rotation from cable movement. Support the antenna on a non-conductive fixture and route the coax along a repeatable path, with a suitable current choke placed at a characterised boundary. If the antenna geometry permits, use a low-disturbance fibre-optic transport or a receiver mounted at the antenna, recognising that either substitution creates its own calibration requirements. Rotate the antenna while photographing or diagramming the precise cable posture for each observation. Then hold the antenna absolutely still and move only the feed line. If the apparent bearing shifts under the latter condition, the original pattern contained an installation-dependent contribution.

Polarisation is particularly important. A cable running vertically may respond differently to the local electric field than a small loop intended to discriminate magnetic-field orientation. Nearby metal shelving can support induced currents and scattering, introducing apparent angular structure not present in free space. Repeat at physically distinct positions and compare bearing lines for geometrical consistency. A true single stationary far-field

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source should yield observations compatible with a common location under a defensible propagation model, although multipath and near-field conditions can make even this criterion imperfect.

The operator should report the calibrated antenna response and the installed-system response separately. A nominal manufacturer's polar plot is not a calibration of the antenna plus the particular cable, room and receiver case. Where the installed pattern is demonstrably contaminated, its maximum is evidence of sensitivity, not a proved location. This does not render the survey useless. It reveals which measurements require redesigned coupling control before localisation can be attempted responsibly.

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Heinrich Rudolf Hertz, Peer Question: Mr. Heaviside, the suspicious narrow line may arise from an external transmitted wave, from ordinary electronic apparatus in a room, or from a current driven into the measurement cable by a nearby conductor. How should a controlled experiment distinguish radiative reception from near-field inductive or capacitive coupling when the source distance is comparable to cable length or to a wavelength? Which spatial and frequency responses would you regard as suggestive, and which remain insufficient for causal attribution? Please also explain how a test transmitter of known position may be used without allowing its field to contaminate the original evidential observation or to justify a conclusion more precise than the measured propagation geometry warrants. Please distinguish a test that demonstrates local reception of a deliberately generated field from a claim that the original unidentified signal arose at that test source, and explain how those records must remain separate for forensic review.

Oliver Heaviside, Response to Professor Hertz: Professor Hertz, distance from a source must be compared with the electrical size of the radiating structure and the wavelength, not with a single simplistic boundary. In a region where reactive fields are important, a cable can be driven through inductive or capacitive coupling in ways that differ from far-field plane-wave reception. The amplitude may vary strongly with small spatial movements, and polarisation relationships can differ from those expected for a remote propagating wave. Yet such features are not exclusive signatures. Multipath, metalwork and resonant cables can also produce rapid changes in the received trace.

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An experiment begins with a lawful, low-power, characterised source and a fully documented baseline. Locate it at several known positions and orientations; alter power and modulation only within authorised limits. Measure the survey antenna and the cable exterior current simultaneously, using a reference receiver outside the suspected common-mode pathway where feasible. Compare the response when the intended antenna input is terminated, when the cable is rerouted, and when the source is replaced by a benign injected electrical calibration signal. Where possible, operate in a screened laboratory so that the test signal cannot be mistaken for an environmental emission.

Spatial variation may inform the hypotheses. A signal closely associated with one cable segment, or a current peak that changes markedly upon moving a cabinet lead, suggests a coupling pathway requiring further challenge. A stable distant emitter can nevertheless excite that same pathway, so the current map alone does not reveal whether the energy originated nearby or far away. A second independent antenna position supplies additional geometry, but its interpretation must account for scattering and the unknown effective receiving pattern. Recording a phase-coherent reference may aid analysis if clocks and cables are independently assessed.

Protect the original evidence by writing test times, frequencies, source configurations and operator actions into an acquisition ledger, with clear separators from the uncontaminated monitoring intervals. Avoid intentionally radiating into a live sensitive environment without explicit authority. The scientific aim is not to make the suspicious line vanish at any

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cost but to find a repeatable intervention that changes one causal mechanism while leaving the others as stable as the conditions permit.

Ronald Newbold Bracewell, Peer Question: Mr. Heaviside, an operator may use several measurements of amplitude or bearing to infer an emitter position, even though some observations are contaminated by the same coaxial-current pathway. If the feed cable participates in reception, the forward model of the antenna is wrong. How should an inverse-location analysis expose that lack of identifiability? Could a collection of apparently consistent angles still be misleading because all observations share one installation fault or are processed with the same incorrect antenna pattern? I ask also whether the observed change following cable movement can be assigned to a unique physical source, or whether several external and internal explanations remain mathematically compatible with the recorded voltages. If two antenna configurations yield the same best-fit source position, does that establish identifiability, or must one demonstrate that the measurements would also have distinguished at least one plausible alternative cable coupling and source geometry under controlled conditions?

Oliver Heaviside, Response to Professor Bracewell: Professor Bracewell, one must formulate the forward map before trusting its inverse. Let y_k represent a measured complex voltage or derived angular response under experimental configuration k. A simplified model is $y_k=H_{a,k}(x)s+H_{c,k}(x,geometry)s+n_k$, where x is a hypothesised emitter position, s the emitted waveform, H_a the intended antenna transfer, H_c the unintended cable-mediated transfer and n_k error. This expression is schematic. A source in the equipment itself may require an additional independent excitation term.

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If H_c is unknown and varied between readings, a family of different x values can fit the same data. A numerical optimiser producing one sharp minimum does not resolve that structural ambiguity.

The remedy is not merely more data of the same type. Introduce configurations that are informative about H_c: deliberately hold the antenna fixed while moving the cable, measure cable current at multiple points, replace the feed with a controlled alternative, and check an independent receiver with a genuinely different cable route. The candidate source hypotheses should predict distinguishable changes under these interventions. Include calibration sources at known positions to see whether the inferred bearing moves when only an installation variable changes. Uncertainty in the cable transfer should enter the localisation model instead of being set to zero.

A clean intersection of bearing rays can mislead if each ray was drawn using a contaminated pattern. When all instruments share the same erroneous calibration or source-dependent coupling, their errors are correlated. An apparently narrow confidence region calculated under independent errors will be too optimistic. Compare raw observation vectors, not only final angles; inspect residuals and conduct a sensitivity study in which plausible cable-transfer terms are varied. If candidate locations change materially, the location claim is model-dependent.

The correct outcome of an inverse problem is sometimes a statement of non-identifiability. The analyst may establish that a frequency component

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appeared at several antenna and cable configurations, while being unable to distinguish among a nearby source, field-induced exterior current and receiver-generated contamination. That is a substantive technical conclusion, not a failure of diligence. Further controlled measurements should be designed to separate the remaining hypotheses rather than force an artificially precise location from insufficient evidence.

Harold Jeffreys, Peer Question: Mr. Heaviside, I ask about the evidential weight assigned to the reduction of a suspicious line after a common-mode choke is added. The observation may favour a cable-mediated reception mechanism but need not exclude a real external signal that was coupled into the cable. How should investigators compare such hypotheses without multiplying dependent receiver confirmations or assigning arbitrary probabilities to the apparent success of a single intervention? If the calibration apparatus itself changes the antenna pattern, how should that uncertainty enter the report? I should welcome a careful distinction among evidence of a component's existence, evidence of the measurement pathway, and evidence of an intentional source at some particular location. Could the same intervention support different causal interpretations when the source spectrum changes with time, and should the expert preserve the time history of every control condition rather than selecting only the trials in which suppression appears most impressive?

Oliver Heaviside, Response to Sir Harold Jeffreys: Sir Harold, the hypotheses must be separated at the outset. H1 could assert an external emitter principally received by the intended antenna. H2 could assert a real external field principally collected by the feed-cable exterior. H3 could assert internally generated or conducted interference coupled into the receiver

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through the cable or another chassis path. These are not always mutually exclusive, and a report may require combined explanations. A reduction after choke insertion is evidence that the intervention changed the measurement chain. Its likelihood under each hypothesis depends on the unmeasured coupling paths, not on the analyst's wish that the effect point to one culprit.

Before drawing a strong inference, establish a baseline rate of comparable changes produced by mechanical movement, receiver gain drift, source fluctuation and repeated connection cycles. Conduct sham interventions and record their outcomes. Where the cable is moved by the choke installation, isolate its motion as an additional experimental variable. Independent capture chains matter because two receivers powered and referenced from the same setup can share the very fault under inquiry. Claiming three independent confirmations from three displays of one common-mode disturbance would overcount evidence.

Numerical probability statements require an empirical or defensible physical model. The investigator can instead report conditional observations: the line decreased by a measured amount when a defined choke was inserted, the exterior current changed by a measured amount, and the antenna orientation remained fixed within documented tolerances. A second experiment may show that the effect reverses on removing the choke. These facts support a causal claim about an instrument pathway, but they do not independently settle whether the energy originated in a nearby source, a distant broadcast or an internal oscillator.

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Forensic integrity demands preserving unfavourable observations as well as the successful ones. If the line persists at another frequency or receiver, retain that contradiction rather than editing it from the final presentation. If the current probe lacks calibration at the relevant frequency, state that its output is comparative rather than an absolute current measurement. The ultimate finding should have three clauses: what RF energy was observed; what coupling path the controlled tests support; and what emitter-location proposition remains established, bounded or unsupported. That division avoids dressing an inference about wiring as proof of a particular person's conduct.

Dr. James M. Atkinson, Moderator: I pass the principal token to James Clerk Maxwell for an independent account of electromagnetic boundary conditions, and invite Michael Faraday to cross-examine the resulting experimental test.

James Clerk Maxwell, Second Principal Contributor: Dr. Atkinson, a coaxial feeder is a transmission structure with distinct field and current configurations on its inner conductor and the exterior of its screening conductor. A differential circuit current inside a well-behaved coaxial path need not radiate appreciably from the cable exterior, whereas unintended common-mode surface current can couple to surrounding structures and radiate or receive. Consequently a survey antenna and its connecting cable form a possible combined receiving system. If rotation of the antenna alters the shape or strain of the coaxial route, a changing displayed signal need not represent only the antenna pattern. I would measure the net longitudinal common-mode current using a calibrated clamp that encloses

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the complete coaxial cable, then change cable route and termination while holding the antenna’s surveyed position stable. A suppression or redistribution of surface current is evidence about the unintended coupling pathway, not proof that an external source never existed. Mr Faraday may challenge the physical intervention.

The boundary conditions at the surface of a good conductor allow a more exact description than the phrase 'a cable acts as an aerial'. Let n denote the outward surface normal, E the electric field and H the magnetic field. At a conducting interface the tangential magnetic field supports surface current density K through n cross (H_out−H_in)=K, with the sign fixed by the chosen normal. The relation identifies a physical surface current; it does not assume that the coaxial exterior is perfectly isolated from its surroundings. At sufficiently high frequencies the interior return associated with the differential transmission mode is concentrated near the shield's inner surface, while an exterior common-mode current can be excited by enclosure potential, nearby fields and imperfect transitions. The distinction depends on boundary conditions and geometry, not a verbal choice of which conductor is called the return.

It would be erroneous to infer that the entirety of a screen behaves as one lumped current conductor at every frequency. The full solution of Maxwell's equations may involve skin depth, shield transfer impedance, apertures, braid contact and induced longitudinal surface currents. For a simple homogeneous conductor of conductivity sigma, permeability mu and angular frequency omega, the familiar good-conductor skin-depth approximation is delta=sqrt[2/(omega mu sigma)]. The formula has defined assumptions: homogeneous bulk material, linear response, and a geometry

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for which the local plane-conductor approximation is appropriate. A braided screen and a thin metallisation can depart materially from those conditions. Thus a calculated small delta cannot itself establish adequate shielding or negligible exterior common-mode radiation in a specific installation.

The energy pathway supplies a further check. The Poynting vector S=E cross H measures electromagnetic power flow density, expressed in watts per square metre. In the guided differential mode, the relevant fields are largely concentrated within the coaxial structure, though nonideal shields and connectors allow leakage. In a common-mode disturbance, external fields and return paths must be represented, and the surrounding surfaces form part of the electromagnetic system. It follows that a screen-current clamp placed at one position does not measure the entire power flow, just as a nearby electric probe at one point does not integrate the radiated flux through a closed surface. Such measurements are valuable local observations, not replacements for a solved or experimentally constrained field model.

An examiner should first define a set of hypothesised current paths, marking the differential inner-to-shield return separately from outside-shield current and from currents in adjacent rack frames or mains conductors. The map is then challenged by changes that affect one pathway more than another. Introducing a high common-mode impedance on the outside of the cable may reduce a particular observed peak, but an external field might also excite both the intended antenna and the cable. An impedance change modifies the receiving geometry. To distinguish these cases, preserve the original field measurement, record the choke position

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and its frequency-dependent impedance, and observe current at several positions before and after the alteration.

An especially important qualification concerns distant-field inference. A strong local magnetic indication need not imply efficient far-field radiation: it may reflect reactive energy close to a current loop. Conversely an apparently small near-field electric reading at one orientation can coexist with significant radiation from an electrically long cable. In the radiating far field of a simple propagating wave, electric and magnetic components have a defined wave-impedance relation under the appropriate medium and polarisation assumptions. Near conductive enclosures the electric-to-magnetic field ratio is generally position- and source-dependent. Accordingly, neither an E-field probe nor an H-field loop can convert a single local maximum directly to radiated power without a transfer model and calibration.

The methodology I propose is therefore comparative and reversible. Measure a controlled stimulus with a properly terminated reference receiver, document the enclosure seams and cable routing, and repeat the survey after each one-factor intervention. Track the frequency, phase, magnitude and spatial distribution, not merely the largest reading. Run a positive control in which a known exterior current is deliberately created at safe levels, and a negative control with the corresponding source suppressed. Where the test apparatus itself couples to the shield, its loading must be characterised. A conclusion that the cable formed part of the receiving system can then be supported by several mutually constraining observations, without the scientifically extravagant claim that every suspicious line in the room originated inside that cable.

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Michael Faraday, Cross-Peer Question to James Clerk Maxwell: Professor Maxwell, the operator places a ferrite on the feeder and observes the suspicious line fall. It is tempting to declare that the room had no emitter and the line was entirely self-generated. But the ferrite may simply change how a real external field couples to the cable and receiver; its impedance also depends on frequency and installation. Which measurements must accompany the intervention to distinguish a changed antenna system from a genuine disappearance of environmental RF energy? Would measuring current at a single point be sufficient to characterise the entire exterior current distribution?

Your proposed boundary model is illuminating, Professor, but I would ask you to identify what a technician should actually change first. If a finite-length braid is partly connected to an enclosure seam and partly to a receiver chassis, which observation distinguishes an exterior current induced by a nearby magnetic loop from an exterior current driven by capacitive coupling across that seam? The same clamp can register both. Would you require simultaneous measurement of the seam voltage and the current distribution, or is an orientation test with a miniature magnetic loop sufficiently discriminating? I ask because a strong current at the shield exterior need not reveal the nature of its original excitation.

James Clerk Maxwell, Cross-Peer Answer to Michael Faraday: Mr Faraday, observe at several places along the cable and retain the antenna route, orientation and reference conditions. The ferrite’s effect must be compared with controlled changes in cable length, routing and common-mode termination, and ideally against a second receiver using a different coupling path. A fall in current or displayed amplitude after installing a choke is

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evidence that the tested configuration changed sensitivity to a coupling mechanism. It is not a universal negative finding about the room. Map the current distribution and measure the received feature with independently controlled wiring where feasible. Because a common-mode cable can itself behave as an antenna, the intervention changes the measurement apparatus as well as the interference pathway. The report must disclose both effects.

The same control should be repeated with the receiving cable held in a fixed, non-conductive jig so that mechanical motion does not become a hidden experimental variable. A measured decline in one exterior-current component is a useful piece of evidence, but it must be compared with any compensating current on neighbouring conductors before one asserts that the electromagnetic coupling as a whole has weakened.

I would require more than one local magnetic indication. A current clamp describes the net current through its aperture under a specified frequency response; a high-impedance differential probe may characterise the potential across the seam but can also disturb it. Measuring both establishes separate constraints. Then alter one pathway under controlled conditions: vary the loop area or orientation of a known magnetic test source while holding the electric coupling geometry as nearly fixed as possible; in a separate trial, vary an authorised capacitive test electrode while preserving the magnetic loop. Compare the phase and frequency-dependent response of the shield current in each case. A single matched result establishes sensitivity to that test, not the absence of the other mechanism.

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The proper field statement remains conditional upon the experiment. If exterior current responds strongly to loop orientation and the predicted magnetic flux, inductive coupling becomes more plausible. If it follows a controlled change in the seam potential or nearby electric electrode, capacitive excitation becomes more plausible. In a real enclosure both can operate simultaneously. I would therefore compare complete before-and-after vector readings where practicable rather than rely on a solitary displayed magnitude. And I would avoid describing the measurement as an absolute field intensity unless the probe, spacing and receiving path have been calibrated for precisely that geometry.

Oliver Heaviside, Response to James Clerk Maxwell and Michael Faraday: Their exchange correctly shows why the feeder exterior must be treated as part of the electromagnetic boundary. Suppressing one common-mode current can remove a receiver artefact or reduce genuine field pickup. Only controlled comparisons and reference-plane measurements distinguish those explanations; a quieter display alone is not an attribution.

Dr. James M. Atkinson, Moderator: Mr. Faraday, the changing current on the coaxial exterior changes the receiving apparatus itself. May Professor Maxwell challenge your proposed intervention?

Michael Faraday, Third Principal Contributor: An intervention that changes a coaxial exterior current does not merely remove interference; it changes the electromagnetic receiving system. A ferrite sleeve can diminish current on the cable exterior while preserving the intended differential path, but the resulting RF-field sensitivity must still be remeasured. I would vary cable route, termination and measured surface current under a known benign

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source, holding antenna location fixed. A quieter spectrum after one choke is an observation, not a general denial of an emitter.

The appropriate experimental witness might comprise a calibrated current clamp on the coaxial exterior and a miniature magnetic loop whose orientation is varied in a repeatable jig. A change in the loop-probe voltage should be compared with a controlled change in current distribution and with a fixed reference antenna response. Because each probe can perturb the local field, the examiner should repeat the experiment with a second geometry and disclose whether the result remains stable across that substitution. Otherwise the apparent source attribution may depend upon the measuring probe itself.

I would begin with the distinction between a change of magnetic flux and an apparent change in a displayed amplitude. If a conductive loop encloses time-varying magnetic flux Phi_B, the induced electromotive force is -dPhi_B/dt for the stated loop orientation. Yet the loop formed by an installed receiver, its cable exterior, enclosure and surrounding return conductors may be large and geometrically ill defined. Moving a ferrite sleeve can change the current distribution and effective loop area. An observed reduction then supports a hypothesis about altered coupling but does not identify the original electromagnetic source. The counterfactual question is what the receiver would display if the same external field remained present while only one known return path were modified.

Electric coupling must be considered separately. A changing potential on a nearby conductor can drive displacement current through stray capacitance into a receiver enclosure or cable shield. The simple capacitance relation

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i_C=C dv/dt is a useful local approximation only when C is treated as adequately constant and the physical extent is electrically small. The same installed system may also carry inductively coupled current and a directly received radiated field. A probe response which decreases with distance or changes orientation is not a unique fingerprint of one coupling mechanism. Reversing probe orientation, changing loop area and changing standoff under a fixed mounting jig produce stronger evidence when the predicted signatures differ between competing models.

A practical test ought to make use of null experiments. Disconnect the intended RF input and apply a correct reference termination at the receiver's declared input plane, while preserving the relevant enclosure and cable paths. If the line persists, a direct antenna-field explanation becomes less sufficient, but conducted interference or internal oscillator artefacts remain. Reconnect a controlled antenna and route the cable along a documented alternative path without changing its characteristic impedance and end terminations. Where the change in line amplitude follows the cable exterior, a cable-mediated path becomes plausible. Repeat with a second independently clocked receiver so that the test does not mistake a common instrument spur for an electromagnetic field effect.

There is a difficulty with the apparently simplest intervention: the current clamp or loop probe is not an invisible observer. Its finite magnetic material, conductor and connecting lead can redistribute the very fields whose presence it indicates. The transfer impedance of a calibrated current probe states a relation between a defined conductor current and the measured voltage only within specified frequency and positioning conditions. A reading made at one place on a standing-wave current distribution is not

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necessarily representative of the whole feeder. Thus I would require at least three clamp locations, repeated orientation checks, an instrument-floor measurement and documentation of the probe loading before assigning a quantitative current profile.

Where the diagnostic question is whether a source is internal to an enclosure, the investigation should include a controlled perturbation of the source circuit and of the enclosure itself. Suppress or alter a permitted test oscillator, observe whether the suspected spectral line follows its frequency, and separately vary a cable route or seam configuration. A field outside the box may be excited by an internal source and radiated by the exterior cable; the presence of that external field is not evidence that the oscillator was located in the open room. This is why source, propagation pathway and detection aperture must be identified as three distinct portions of the causal account, each requiring its own test.

An editorial conclusion should therefore describe what changed and under what controlled conditions. If an added common-mode choke reduced a peak by 12 decibels, the report must identify whether the instrument measured voltage, power or calibrated field strength and use the corresponding logarithmic convention. It must not state that the radiated power fell by 12 decibels unless the calibration and propagation relationship support that statement. The intervention may have altered receiving efficiency rather than transmitter output. A reversible before-and-after result, with appropriate independent controls, is valuable experimental evidence. It is not a warrant for a categorical assertion about the location or intent of an unseen emitter.

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James Clerk Maxwell, Cross-Peer Question to Michael Faraday: If a clamp current probe reads nearly zero at one position, can the engineer conclude that the whole cable exterior is electromagnetically inactive?

Please state whether the suspected source would be identifiable from one change alone, or whether several controlled perturbations are needed to break the ambiguity between two simultaneously active coupling paths. I would also wish to know how you would record the test when probe loading itself changes the signal.

Let us then make the counterfactual more exact, Mr Faraday. An operator measures a large magnetic loop-probe voltage beside a power-converter trace and subsequently sees an RF receiver line diminish after a cable choke is moved. Which independent observation would establish whether the line was received through a near-field magnetic loop, through the cable shield as an unintended antenna, or through both paths? Please distinguish the effects expected when the antenna is terminated, when the cable is rerouted, and when the test converter's switching frequency is varied by a small authorised amount.

Michael Faraday, Cross-Peer Answer to James Clerk Maxwell: No. Current standing waves and local coupling can produce position-dependent results. Measure at multiple points and examine the return paths, cable length and frequency. The probe itself changes the local environment, so its transfer impedance and placement should be calibrated. A small local reading does not establish zero radiation or reception along the entire conductor.

One should also repeat the experiment at several frequencies because a metallic seam, a cable exterior and an enclosing chassis may exchange their

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relative importance as wavelength changes. A test source whose amplitude is held constant while its frequency is shifted in small, documented increments provides a particularly useful means of distinguishing an incidental spectral coincidence from a genuine coupling transfer function. If the receiving instrument changes its gain or filter state during that sequence, those changes must be logged and challenged. Otherwise the apparent frequency dependence may have been generated by the receiver rather than by the electromagnetic pathway.

Professor Maxwell, I would regard those interventions as the foundation of the evidence. With a safe input termination, a line persisting at the receiver indicates that the intended antenna is not necessary for that observation, although direct internal coupling and conducted interference remain possible. Rerouting the feeder while keeping the receiver and source unchanged tests whether the exterior-cable geometry contributes. Deliberately changing the authorised converter's switching rate tests whether the spectral feature follows the suspected physical source rather than a fixed receiver spur. One must record each alteration and repeat the baseline after intervention to establish reversibility.

Where two paths operate together, magnitude alone can mislead because their fields can add or cancel. Retain complex phase where feasible and measure at multiple probe locations and orientations. A local magnetic-loop maximum shows local coupling susceptibility, not the equivalent isotropically radiated power of the converter. A change in cable choke configuration can modify both the route and the receiver's effective aperture. The measured outcome should therefore be described as evidence for a particular pathway under the tested conditions, not as a

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proof that no second pathway exists. I would ask that the independent receiver remain in operation throughout as a reference for changes in the source itself.

Dr. James M. Atkinson, Moderator: Professor Kennelly, please distinguish the intended differential termination from the impedance governing common-mode exterior current. Mr. Heaviside will examine the limits of a catalogue choke specification.

Arthur Edwin Kennelly, Fourth Principal Contributor: The intended coaxial circuit and unintended exterior current can have very different impedances. A 50-ohm differential termination does not prove a corresponding well-controlled exterior current return path. Ferrite impedance is frequency dependent, can be nonlinear under large fields and interacts with the rest of the cable network. Any claimed attenuation should be stated for the measured frequency and configuration rather than as a universal suppression figure.

When the feeder is electrically long, the current distribution and apparent antenna pattern should be recorded at several frequencies. A locally successful choke test cannot be presumed to apply at a different harmonic or resonance.

The distinction between measurement and inference should extend to frequency-dependent propagation along the feeder. When an electrically long cable supports standing waves, the measured current is a function I(z,f) of longitudinal position z and frequency f; it cannot legitimately be replaced by a constant value without proof. Mapping its magnitude at a sequence of

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fixed positions supplies a more informative record than one arbitrary clamp reading.

It is useful to describe the outside-shield pathway as a distributed network whose parameters change with frequency. A short current return path may be represented by a lumped impedance, but an electrically long cable near a conducting wall supports resonant behaviour, reflections and position-dependent current. The common-mode characteristic impedance is not automatically the cable's printed differential impedance. The shield exterior, surrounding conductors and the path back to the excitation source determine the relevant modes. When a choke is inserted, the observed current change depends on the source impedance and this surrounding network; the ferrite catalogue value is neither a complete description of the installation nor a guaranteed suppression factor.

Consider an idealised local Thevenin source with voltage V_s, effective common-mode return impedance Z_s and inserted choke impedance Z_c. The current amplitude in the simplified circuit is $I=V_s/(Z_s+Z_c)$. If $Z_s=50$ ohms resistive and a nominal choke adds 450 ohms purely resistive at the tested frequency, the current drops from $V_s/50$ to $V_s/500$, a factor of ten, or 20 decibels in current amplitude. This calculation assumes a one-dimensional lumped loop, an unchanged source voltage, no alternate return path, and a choke whose operating impedance is truly resistive. It is not a prediction for a resonant cable several wavelengths long, where the current may redistribute rather than simply decrease everywhere by the same factor.

A ferrite's complex impedance $Z_c=R+jX$ changes with frequency, core material, temperature, geometry and current level. Its resistive part can

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dissipate energy; its reactive part stores and releases energy. Around a network resonance, adding a reactive element can move the frequency of maximum current, producing an improvement at one measurement frequency and a deterioration elsewhere. The practical survey must therefore examine a reasonable band rather than rely on a single peak. Repeating the test with alternative core materials or a different turn count should be a controlled engineering experiment with documented geometry, not a sequence of undocumented improvisations. The original source conditions and all negative results must be retained.

An additional vulnerability is the return route through other interconnections. A receiver connected to a laptop, power adapter and instrument control cable has several potential exterior-current paths. A ferrite on the antenna feeder can redirect common-mode current into USB, Ethernet or mains wiring, so an observed reduction in one clamp location may coexist with increased coupling elsewhere. The correct experiment measures plausible alternative returns before and after the change. Temporarily isolating an authorised test interface may be useful, but one must preserve electrical safety and never defeat a protective earth connection to obtain an attractive noise reduction. The object is to map electromagnetic coupling, not to create a dangerous floating apparatus.

The accuracy of a clamp-current comparison also requires a transfer calibration. An RF clamp gives a voltage proportional to current through a frequency-dependent transfer impedance $Z_t(f)$ under its stated conditions. The derived current is $I(f)=V_{meas}(f)/Z_t(f)$, with the understanding that magnitude-only display omits phase and that common-mode currents distributed among multiple conductors can interact. If the clamp is not

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calibrated, an amplitude ratio under a fixed arrangement may still support a relative finding, but a quoted current in microamperes would lack foundation. Record the clamp model, calibration age, conductor placement, receiver bandwidth and uncertainty of the reference signal used in the comparison.

My closing rule is to reconcile three observations: where current is measured, where the received spectral feature is measured and what controlled physical intervention changes both. Where measured current and receiver response track one another coherently across frequency and cable position, a cable-mediated pathway gains support. Where the current falls but receiver response does not, investigate an independent path. Where receiver response falls without a measurable change in exterior current, challenge the probe's sensitivity, alternative returns and instrument operating state. This procedure does not require that every unknown be solved immediately. It requires that the strength of the conclusion match the actual discrimination supplied by the experiment.

Oliver Heaviside, Cross-Peer Question to Arthur Edwin Kennelly: Can a large impedance measured for a ferrite sleeve in a catalogue guarantee an equally large reduction in the exterior current of the installed cable?

At a minimum, I would ask you to contrast the current immediately on either side of the choke with currents on other connected conductors. Without that comparison the observation might merely locate a standing-wave node, not establish the attenuation of total unwanted current.

Professor Kennelly, catalogue measurements normally specify a choke's impedance in a controlled fixture, yet a real coaxial cable may run parallel to

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a conducting wall and return through several other interfaces. If the measured current at the choke decreases by ten decibels while a nearby antenna indicates only a two-decibel change, does that falsify the common-mode hypothesis? Or can current redistribution and differing sensitivity of the measurement points explain the result? I would also ask how you would distinguish a dissipative loss introduced by the ferrite from a displacement of the current maximum along the cable.

Arthur Edwin Kennelly, Cross-Peer Answer to Oliver Heaviside: No. The reduction depends on the source and return impedances, parasitic capacitance, geometry and frequency at the actual installation. Measure current and received response before and after under controlled conditions. A simple series-impedance model can guide a test but is not a substitute for the whole electromagnetic boundary problem.

It is equally important that the experiment identify whether a numerical reduction is expressed in voltage, current or power. An attenuation of ten decibels in a current amplitude ratio corresponds to the appropriate 20-logarithm convention under consistent impedance assumptions, whereas power measurements use a 10-logarithm convention. The underlying transfer conditions matter when converting between these quantities. Where the local probe has not been calibrated, a reported change under a fixed probe placement may be defensible as a relative observation, but a claim about total power radiated into a room is not established. The report should retain the unmodified trace and give its frequency resolution and noise floor.

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Mr Heaviside, the mismatch does not automatically falsify the hypothesis, because the two instruments sample different physical quantities. A clamp measures local net current at one position; the receiving antenna responds to the field produced by a distributed set of currents and environmental reflections. Installing a choke can move the current maxima while the total field at the antenna changes less. It can also redirect current into another return path. The simplest remedy is to measure exterior current at several cable positions and at alternative returns while observing the antenna output at a fixed reference plane.

Next inspect the choke's measured complex impedance over the frequency band rather than accept its nominal catalogue figure as an installed constant. Compare a resistive-dominated core with a reactive-dominated configuration, while keeping the core geometry and supply conditions documented. A reduction of local current accompanied by thermal dissipation and a coherent decrease in the relevant far-field component supports an attenuation account. A movement of current peaks with comparatively little change in total radiation favours redistribution. Any such judgement needs a calibrated current measurement or a carefully bounded relative comparison; one attractive attenuation figure is not enough.

Dr. James M. Atkinson, Moderator: Professor Bracewell, how might a cable-supported current corrupt the apparent direction of an emitter? Sir Harold Jeffreys will assess the evidential independence of repeated bearings.

Ronald N. Bracewell, Fifth Principal Contributor: Direction finding assumes a calibrated antenna response, but a cable carrying common-mode current can alter the spatial pattern and produce false minima or bearings. When

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rotating the antenna also changes the cable route, the experiment varies more than one physical quantity. I would compare controlled stationary-cable rotations, changed cable routing with the antenna fixed, and an independent receiving antenna with different feed arrangements. The correct output is a bearing only if the installed system supports a stable directional response.

A further test should compare bearings obtained with two independent antenna/feed installations and a controlled emitter at a surveyed position. The difference between their indicated directions under deliberately altered cable routes supplies an empirical estimate of route-dependent bias. A plausible narrow intersection formed exclusively from one contaminated installation must not be treated as an independently validated location, however small its internal least-squares residual appears.

Direction finding depends on a known forward relationship between source direction and the received vector of antenna signals. If the intended antenna alone has pattern a(theta), a cable exterior carrying common-mode current contributes an additional, route-dependent pattern b(theta). A simplified complex voltage model is v(theta)=alpha a(theta)+beta b(theta)+n(theta), where alpha and beta embody the excitation and relative phase and n denotes receiver noise. A conventional angle estimator that fits only a(theta) can return a persuasive but biased direction. The bias may vary with cable bends, instrument location, amplifier gain and nearby metallic surfaces. A peak or null observed while the cable is moving is not automatically an attribute of the external wavefront.

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A null direction can be especially misleading because destructive addition of antenna and cable contributions may create a very deep minimum unrelated to the antenna's calibrated pattern. A change in the cable route can then shift the null despite no movement of the distant transmitter. To test the hypothesis, hold the antenna's position and orientation fixed while rerouting only the controlled feeder; then hold the feeder geometry fixed while rotating the antenna. If the received response follows the cable intervention, the effective receiving structure must include the feeder. If the response follows antenna rotation with stable reference controls, the intended aerial path becomes more credible. Both results must be interpreted with the receiver's gain and noise floor held within their validated range.

The localisation question also requires independent geometrical information. Several nearby bearings taken with the same contaminated feed arrangement may share a systematic bias. Their apparent intersection is not equivalent to several independently calibrated lines of position. A covariance model should incorporate shared cable geometry, common receiver reference and local propagation effects. Where multiple bearings are derived from one long recording, temporal correlation can further reduce the effective number of independent observations. It may be preferable to state a region bounded by tested configurations rather than a falsely exact coordinate. A new measurement at a materially different location with a different antenna and independent feeder arrangement provides a more valuable challenge than a tenth rotation of the same disturbed instrument.

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The differential test must also distinguish reactive near fields from propagating radiation. Close to an electrically small emitter, source impedance and relative electric and magnetic field strength can change rapidly with standoff, and simple far-field bearing assumptions may fail. Reflections from walls and metallic equipment create further spatial structure. Moving an antenna by a fraction of a wavelength can change received phase and amplitude without proving that the source moved. Accordingly a location hypothesis should be checked with measured spatial gradients, polarisation changes and a controlled reference transmitter at surveyed positions. The inversion must accommodate or explicitly exclude the operating environment in which the measurements were made.

I would also insist upon a small number of preregistered diagnostic tests. Define in advance what result would favour the cable-current hypothesis and what would favour an independent external emitter. These could include a measured exterior-current reduction associated with a change in feeder routing, the appearance of a similar spectral signature on a terminated reference channel, and the persistence of a field on a separately powered and clocked receiver. Record failed trials. Repeating interventions only until one gives an attractive bearing would introduce selection bias. The field notebook should capture the entire sequence, including unchanged configurations, to allow a later examiner to assess the weight of the evidence.

Finally, the word emitter should be used with care. The observed field may arise from normal apparatus, unintended oscillation, cable leakage or a purposeful transmitter; a receiver reading alone does not establish intent. Even after a source has been located, the legal and forensic characterisation

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of the device demands separate evidence and proper authority. The defensible scientific conclusion is narrower: the specified spectral component was observed with particular antenna and feeder configurations, altered in a documented way under controlled changes, and either remained or failed to remain under independent challenge. Such language is precise enough to support later inquiry without confusing a measurement-system artefact with an attributed hostile source.

Harold Jeffreys, Cross-Peer Question to Ronald N. Bracewell: If several nearby measurements all point toward the same corner, can their geometrical agreement establish the emitter location when each uses the same cable and receiver?

I would welcome a specific demonstration of how the estimated bearing covariance changes when the common systematic error term is admitted, so that the final report conveys not merely that the original intersection is doubtful but why its numerical confidence is overstated.

Professor Bracewell, consider five bearings whose rays meet convincingly near one instrument rack. All five were taken with the same antenna, the same coaxial feeder and the same receiver, and the cable route was changed only inadvertently as the surveyor walked between positions. What statistical evidence would you demand before treating the convergence as independent localisation? If a sixth bearing from a separately installed antenna disagrees, should it be rejected as an outlier or should it be given special evidential weight because its error pathways differ from those of the first five?

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Ronald N. Bracewell, Cross-Peer Answer to Harold Jeffreys: Their agreement may reflect a repeated instrumental bias. Independent antenna/feed paths and controlled route changes should challenge the conclusion. If the apparent bearing follows the cable rather than the antenna geometry, the location inference loses force. Report both the concordance and the shared configuration, and avoid multiplying their evidential strength as if the measurements were independent.

A numerical illustration makes the danger plain. Suppose repeated bearings have individual random uncertainty of one degree but share a previously unrecognised systematic angular shift of five degrees. Averaging more bearings can reduce the uncorrelated component, but cannot remove the common five-degree bias. The geometrical intersection may appear increasingly sharp even while its centre remains displaced. This is why a validation source at a surveyed location and a change to genuinely independent receiving hardware are necessary to challenge the error model. Without them, the apparent precision is internal to the assumed analysis and should never be represented as externally demonstrated localisation accuracy.

Sir Harold, the five bearings do not provide five independent confirmations merely because the report lists five numbers. Their error sources include a shared antenna pattern, a common cable path and one receiver's calibration. The errors may be correlated or systematically biased; taking their arithmetic mean or fitting a narrow intersection without that covariance can create spurious precision. Before treating the sixth bearing as an outlier, test whether its independent antenna and feeder path reduce precisely those shared errors. Its disagreement may be evidence that the

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original model was deficient, not evidence that the independent reading was inferior.

I would assess the measurement set using a model that distinguishes random bearing variation from known and plausible systematic terms. Repeat the survey with the original cable route deliberately fixed, then with the route changed under controlled conditions. Include a calibrated test emitter at more than one known location. If the first five rays move together as the feeder changes, they reveal a common bias, and their attractive convergence has little evidential value for locating the external source. If the independent sixth receiver remains stable under those changes, it becomes a powerful challenge. Nevertheless, I would report its own uncertainty and testing limitations, not elevate it automatically to unchallengeable authority.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The distinction central to this question is not a semantic distinction between cable and antenna. It is a physically testable difference between the confined, intended differential mode and current flowing on the coaxial exterior and its environmental return path. Exterior current may make the feed line an additional receiver, alter the installed antenna pattern, fill a directional null and change an inferred bearing when the cable moves. A calibrated full-cable current clamp, controlled routing changes, carefully characterised common-mode impedance, known-field challenges and truly independent reception offer different views of that same problem. No single one supplies unique attribution. The panel requires investigators to report the measurement reference plane, intended antenna response, installed-system response, common-mode evidence and surviving alternative hypotheses. A signal may be real whilst the claimed location is false. The eight historical

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voices in this exchange are fictional instruments of modern instruction, and every quantitative example is illustrative rather than a field measurement.

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QUESTION 061. SOURCES, TECHNICAL LIMITATIONS AND HISTORICAL NOTICE

“Understanding Common-Mode Signals,” Analog Devices, 2003, https://www.analog.com/en/resources/technical-articles/understanding-commonmode-signals.html . Supports the differential/common-mode distinction, capacitive and magnetic coupling pathways, and shield-grounding complications. Reviewed from an accessible English HTML technical article.

L. B. Cebik, “A Common-Mode Current Picture Show,” antenna2.net, https://www.antenna2.net/cebik/content/trans/cmp.html . Provides a documented discussion of exterior coaxial-screen currents, feed-line pattern effects and the placement sensitivity of common-mode chokes. It is technical-practitioner literature, not a claim of peer-reviewed experimental validation.

T. Rauch, “Common Mode Current,” W8JI technical articles, https://w8ji.com/common_mode_current.htm . Explains separation of normal interior return currents and unwanted outside-shield currents, and their effects on coupling and radiation. Practitioner source; specific numerical performance claims are not imported into this dialogue.

Keysight Technologies, “Oscilloscope Probes Selection Guide,” https://www.keysight.com/il/en/lib/resources/selection-guides/oscilloscope-probes.html . Confirms the existence and bandwidth-dependent specification of clamp-on current probing solutions, but does not certify the hypothetical probe calibration in Example 9.

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ARRL, “Common Mode Noise Reduction Kit,” https://home.arrl.org/action/Store/Product-Details/productId/2114202377 . Identifies exterior-shield current and common-mode ferrite mitigation as recognised antenna-system issues. This commercial description is used only for background terminology, not for quantified insertion loss.

EDITORIAL QUALIFICATION. The ten worked values are invented educational cases derived from explicitly stated assumptions. The simplified lumped circuit models have limited validity for electrically long structures. No particular contemporary receiver, building, ferrite, current clamp or alleged emitter has been measured. Historical dialogue is fictional. Final publication requires verification of contributor eligibility, detailed source-to-claim mapping, technical review of each example, minimum-length audit and manuscript-wide originality comparison.

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QUESTION 062

Which near-field observations distinguish electric coupling from magnetic coupling in an enclosure?

HISTORICAL RECONSTRUCTION. This moderated roundtable is a fictional instructional reconstruction. Deceased scientists did not participate in this dialogue, did not use modern digital spectrum analysers, and are not represented as having endorsed present-day surveillance procedures. Contemporary techniques, symbols and safety qualifications are editorial extrapolations.

Dr. James M. Atkinson, Moderator: Mr. Faraday, the inspector of a screened enclosure frequently observes a sharp near-field maximum next to a seam, then calls the leakage electric or magnetic on the strength of the probe label. What measurements would actually discriminate capacitive coupling through an electric field from inductive flux linkage or common-mode conduction, and how should the results be described without falsely converting local field strength into radiated power? I shall ask each principal to offer an independent method, then open his conclusion to technical challenges from the panel.

Michael Faraday, Principal Contributor: Dr. Atkinson, I would begin with the practical observation that an enclosed circuit may disturb a neighbouring detector by more than one physical route, even though a single receiver displays only one amplitude. An alternating potential on a conductor can create an electric field and displacement current through a stray capacitance, whilst an alternating current in a loop creates magnetic flux that can link another loop. These mechanisms are not separate kinds of

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electricity. They are complementary aspects of one electromagnetic field, yet distinct experiments can reveal which coupling route dominates at a given location and frequency. The cleanest comparison changes the geometry in one way at a time: rotate the detecting loop, rotate a short electric probe, vary the distance, and alter the return-current path without changing the signal source. Record the change in a calibrated quantity, not merely in a colourful spectral display.

For a small receiving loop of N turns and area A in square metres, the idealised induced electromotive force is v(t)=-N dPhi/dt, with Phi the magnetic flux through a turn in webers. If the magnetic field is approximately uniform over the loop area, Phi=mu A H cos(theta), where H has units of amperes per metre, mu the magnetic permeability in henries per metre, and theta the angle between the loop normal and the magnetic field. Under sinusoidal conditions of frequency f hertz and angular frequency omega=2 pi f, the magnitude of the open-circuit voltage is approximately N omega mu A H abs(cos(theta)), provided the loop is electrically small, sufficiently unloaded, and not itself resonant. This is an informative approximation, not a universal calibration for commercial H-field probes. A shielded loop can still suffer electric-field pickup and imbalance, particularly around its feed transition.

Imagine an illustrative single-turn loop with area 1 square centimetre, or 0.0001 square metre, placed in a uniform sinusoidal H field of 0.01 ampere per metre at 100 kilohertz. Taking free-space permeability mu_0 approximately 1.256637 times 10 to the minus sixth henry per metre, the idealised magnetic flux amplitude is about 1.256637 times 10 to the minus twelfth weber. The angular frequency is approximately 628,319 radians per

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second, so the induced open-circuit voltage amplitude is about 0.790 microvolt when the loop normal aligns with the field. At ninety degrees the ideal flux linkage vanishes. In reality finite probe balance, nearby conductors, spatial gradients and cabling prevent a perfect null, but the orientation response supplies useful discriminating evidence. This example assumes uniform H and no loading, and must not be treated as an equipment specification.

An electric pickup can be approached through displacement current. For a small parasitic coupling capacitance C_c in farads between the source and the sensing circuit, with sinusoidal source voltage amplitude V_s, the displacement-current amplitude is approximately I_c=omega C_c V_s. A coupling capacitance of 0.2 picofarad at 100 kilohertz with a 10-volt source would create an idealised current amplitude of 1.26 microamperes before the receiving impedance is considered. This cannot be compared numerically with the loop voltage until the detector impedance and circuit loading are specified. Nevertheless, it shows why a tiny gap between conductors can convey an observable interference signal even when no metallic contact is present. The investigator should look for response to changing overlap area, separation and the impedance at the receiving node.

The experimental source must be characterised. A high-voltage, high-source-impedance node often produces conspicuous capacitive pickup, whereas a low-impedance circuit carrying appreciable current can generate magnetic flux around its return path. Those are useful tendencies, not rules that allow identification from source impedance alone. A low-impedance line can possess a strong voltage relative to nearby metal; a high-impedance structure can carry displacement current and contribute to magnetic fields.

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The field configuration depends on frequency, geometry, return conductors, surrounding metal and the probe's own disturbance. Only paired measurements, with controlled variations, permit an argument about the dominant coupling path.

One test would place a driven conductor inside the closed enclosure, preserve its amplitude and frequency, and bring two electrically small, calibrated probes to the same positions outside a seam. The short electric sensor is rotated to sample different components of E; the loop's normal is independently rotated to map components of H. Map the response at several known standoffs without contacting conductive surfaces. A strong loop response with a reproducible orientation null, coupled with sensitivity to the position of the source return wire, is consistent with magnetic flux linkage. A response that increases sharply as a high-voltage conductor is approached, changes strongly with probe electric orientation and responds to a grounded electrostatic screen may instead support a capacitive pathway. Neither result, by itself, proves a pure field of one kind.

A particularly useful intervention is to alter the loop area of the *source circuit* whilst holding its current approximately constant and directly measuring that current. Widening the source-return separation changes the magnetic dipole moment and the external flux pattern. Bringing forward and return currents close together can cancel much of the distant magnetic field; the spatial distribution must still be considered near each conductor. Conversely, altering the exposed voltage-bearing area whilst preserving its drive voltage and source-return current can change capacitive coupling. Because these interventions may themselves change circuit impedance, we must log source voltage and current before and after every change, rather

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than crediting a field change to geometry without verifying the electrical drive.

The metal housing presents additional questions. A continuous conducting surface can support charges that rearrange in response to an electric field; seams, apertures and cable penetrations disturb that boundary. At sufficiently low frequency, the housing may be a poor barrier to a magnetic field, depending on thickness, conductivity and permeability. A grounded sheet inserted between source and probe may alter both field distributions, so its use does not constitute proof of exclusive electric coupling. One should compare different screens of known material, geometry and thickness, inspect the reference ground and note whether the screen changes the current path. The apparent improvement in a receiver trace must be reconciled with actual field mapping.

To preserve this as defensible evidence, photograph the test configuration, record the probe orientation and separation, preserve raw complex samples or calibrated amplitude measurements, and include a no-source baseline. At each position record instrument settings, preamplifier gain, bandwidth, cable routing and uncertainty. I would pass the token to Professor Maxwell for the mathematical reason that our electric and magnetic observations cannot be interpreted as separate, independent fluids. A near-field maximum is a local observation conditioned by geometry; it is not by itself a calibrated far-field radiation power and cannot establish the location of a concealed source without a model and appropriate control experiments.

Harry Nyquist, Peer Question: Mr. Faraday, your electrically small probes report voltages at instrument connectors, while the sought measurands are vector electric and magnetic fields at locations in space. How does the

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analyst avoid mistaking the probe's transfer function for the object's field? A receiver with a 50-ohm input may load a capacitive sensor, and a loop connected through a coaxial cable may form an unintended antenna. I ask how you would establish frequency-dependent sensitivity, orientation rejection and noise floor, and how you would choose spatial sampling increments without aliasing a narrow field maximum. Please address whether a weak, broad response can be missed when the step size is chosen solely from the mechanical dimensions of the enclosure, and distinguish a voltage in a probe cable from an electric field in volts per metre.

Please also specify the polarity conventions and whether a deliberately injected calibration tone should be measured with the probe at several stand-offs, since an incorrectly referenced voltage conversion could reverse the apparent E/H comparison. How would you document probe saturation when a strong switching transient obscures the weak narrowband emission? An instrument noise floor measured with its input terminated need not equal its noise floor with a high-impedance electric sensor attached.

Michael Faraday, Response: Mr. Nyquist, the correct response is to obtain or establish the transfer function under a known calibration field. A measured connector voltage is the result of field coupling, the probe's geometry, load impedance and its cable arrangement. For a loop, the ideal relation between uniform H and open-circuit voltage is proportional to frequency and effective area; for a short electric probe, the effective height and input impedance matter. Neither measurement becomes a field strength by dividing by an arbitrary constant carried over from another frequency. The calibration report must identify orientation, frequency range, loading and the uncertainty of cross-polarisation response.

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A practical discrimination test starts by rotating the loop through a full circle at one surveyed position and observing whether a stable response maximum and minimum occur. Repeat the procedure after rotating or rerouting the coaxial lead without moving the loop itself. If the response changes primarily with the cable, a common-mode pickup path is suspected. The same check should be applied to the nominal E probe, whose feed may act as an unintended monopole. A shielded loop should not automatically be called immune to E-field pickup; modern probe characterisation shows that differential capacitive coupling can survive shields. The field-rejection ratio is a measured property, not a name assigned by the instrument catalogue.

For spatial mapping, first perform a coarse reconnaissance to identify candidate maxima, then refine the grid around them whilst preserving the actual standoff. At a localised seam, a step of several centimetres may skip the response entirely, whereas a continuous aperture several metres long may require a wider scan to understand its pattern. The appropriate grid depends on the spatial bandwidth of the field, source geometry, probe footprint and positional uncertainty. Test repeatability by traversing the same line in the reverse direction. If the source power or frequency moves during the survey, correct or invalidate the comparison rather than interpolate a neat field map from incompatible observations.

The report should keep connector-voltage data separate from inferred E and H field strengths. Where proper calibration is absent, use defensible relative statements, such as the orientation and position that give larger response under fixed settings. Noise-floor readings taken with the source disabled should accompany each reported increase. This conservatism is especially

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important when trying to discriminate magnetic and capacitive pathways from a result only a few decibels above the receiving system's own noise.

Sir Harold Jeffreys, Peer Question: Mr. Faraday, the experimental choices appear capable of creating conflicting explanations. A loop null might arise from an actual rotation of H, from the probe's imperfect response, or from two sources cancelling at one location. An electrostatic screen could alter the source current as well as the field leakage. Would you prescribe rival causal hypotheses before the data are collected, and identify a falsifying observation for each? I should be particularly concerned by an investigator who interprets every rise in an H-probe trace as proof of magnetic leakage without testing unwanted E coupling. What should be recorded when two mechanisms remain inseparable within the measurement uncertainty?

Suppose the probe is moved after the first exciting result is seen. Would you insist on a pre-registered scan and a withheld geometry trial to prevent selective reporting? Explain how a cautious analyst should distinguish evidence that *supports* a favoured pathway from evidence that actually *excludes* its alternatives. What would be sufficient to regard the result as a mixed-mode coupling rather than as two incompatible opinions?

Michael Faraday, Response: Sir Harold, an observation acquires meaning through a contrast that rival explanations predict differently. I would write at least three hypotheses: the response is chiefly inductive through a source-return loop; chiefly capacitive through a voltage-bearing surface or aperture; or chiefly conveyed by conduction and common-mode currents on an attached cable. Each hypothesis should be associated with a controlled intervention whose likely direction can be predicted. Reducing source loop area while holding its current fixed should disproportionately reduce the

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first mechanism. Reducing source voltage while holding the relevant current fixed can challenge the second, although practical circuit coupling makes that separation difficult. Adding a properly instrumented common-mode choke or changing cable routing may test the third.

The intervention must be measured at its source. It is not enough to say that a conductor was moved. Record how its current, voltage and load changed, because the intervention can affect several mechanisms simultaneously. Repeat the observation at multiple probe orientations and standoffs. If the alleged magnetic response persists when the loop is rotated to a predicted null but follows the coaxial lead instead, the magnetic attribution should weaken. If a grounded screen changes both apparent E and H pickup, the result is not uniquely diagnostic. Where a field model is employed, compare it against withheld configurations, not only the arrangement from which its parameters were fitted.

Uncertainty should include detector noise, probe calibration, cross-field rejection, source stability, probe positioning and alternative source arrangements. The comparison is not always a simple sum of independent Gaussian errors: a cable change can alter probe loading and create a systematic bias. Rather than invent a precise probability that one explanation is correct, I would report which experiments favour which mechanism and which could not discriminate them. An apparently precise power spectrum cannot compensate for a missing causal experiment. When the evidence supports only 'near-field coupling detected outside this seam', the report should use precisely that statement.

A practical stopping rule would require two independent observational contrasts that agree on the dominant mechanism, with measured response

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differences materially larger than their combined uncertainty. If no such contrast exists, a mixed-mode explanation must remain open. The investigator may still identify a repair that reduces leakage, but should distinguish engineering mitigation from a proof of its original physical mechanism.

Dr. James M. Atkinson, Moderator: Professor Maxwell, the token now passes from Mr. Faraday to your field-theoretic analysis. Please reconcile the apparent separation of capacitive and inductive mechanisms with the coupled field equations, then invite an experimental challenge.

James Clerk Maxwell, Second Principal Contributor: Dr. Atkinson, the expression 'electric coupling versus magnetic coupling' should be understood as a comparison of the mechanisms most sensitive to a proposed intervention, not as a denial of their common electromagnetic origin. The relevant local quantities are E, electric field in volts per metre; D, electric flux density in coulombs per square metre; H, magnetic field in amperes per metre; and B, magnetic flux density in teslas. Their relations in simple linear isotropic media are D=epsilon E and B=mu H, where epsilon and mu are respectively electric permittivity and magnetic permeability. Across a surface, charges and currents influence the field boundary conditions. Once the fields change with time, Faraday induction and Maxwell displacement current make their evolution interdependent. A local sensor that favours one component cannot thereby demonstrate that the other is absent.

In differential form, a useful pair of field equations is curl E=-partial B/partial t and curl H=J+partial D/partial t, where J denotes conduction current density in amperes per square metre. The first describes the relation between time-

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varying magnetic flux and circulating electric field. The second records both conduction current and the time-varying displacement field as sources of circulation of H. These equations do not tell us whether the interference reaching a receiver is dominantly capacitive or inductive until the source geometry, frequency, material boundaries and receiver impedance are specified. A high-impedance probe close to a charged surface may respond strongly to E, while a small loop near a current return responds strongly to changing B. The fields coexist, but their ratios and spatial patterns are not generally those of a freely propagating plane wave.

This distinction is especially important in the reactive near field. The impedance relation abs(E)/abs(H)=approximately 377 ohms is a far-field plane-wave reference in free space, not a universal conversion between local E and H measurements. Near a small electric dipole, the quasistatic electric component may dominate locally; near a small current loop, the magnetic component may be more pronounced. Reactive stored energy and phase relationships complicate the interpretation. The simplistic boundary r less than wavelength divided by 2 pi can be a useful scale for an electrically small source, but finite antennas and large apertures require geometry-specific near-field boundaries. One should not apply a single spherical distance rule to an extended cable harness or large equipment enclosure.

For a free-space wavelength lambda=c/f, c is approximately 299,792,458 metres per second and f the frequency in hertz. At 10 MHz the wavelength is about 29.98 metres; lambda/(2 pi) is about 4.77 metres. A probe held 10 centimetres from a small source is therefore very near relative to that scale. But this arithmetic does not prove magnetic coupling, electric coupling, or an absence of radiation. At 1 GHz the wavelength is only about 0.300 metre,

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and a 10-centimetre stand-off may no longer satisfy the same electrically small approximation. The field of an enclosure seam can also be shaped by the enclosure dimension and resonances. All numerical classification should be attached to the actual frequency and source size.

At an ideal perfect conductor the tangential electric field at the surface is zero, the normal displacement field reflects surface charge, and the discontinuity of tangential magnetic field is associated with surface current. Real conducting walls possess finite conductivity, thickness, seams and apertures, so these ideal conditions are approximations with limitations. An enclosure surface might greatly suppress a quasistatic electric field while a low-frequency magnetic disturbance penetrates it, yet a cable opening or compromised bond can create a new path for both. The field near an aperture may not resemble a simple dipole because induced currents around its perimeter contribute to the measured response. The investigator should map the exterior field and the wall current or bonding configuration together where safe and feasible.

Power flow must not be inferred from one component measured at one point. In a time-harmonic description, the complex Poynting vector involves E cross the complex conjugate of H, with its real part related to average transported energy and its imaginary part to reactive exchange. A calibrated E magnitude alone cannot supply that vector, nor can a magnetic loop's scalar output. Even if both magnitudes are known, their vector directions and relative phase matter. A strong H probe response one centimetre above a seam may represent substantial reactive energy with modest far-field radiation. It is thus unjustified to take a near-field receiver reading, apply a

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free-space impedance conversion and announce a far-field radiated-power value without an applicable model and corroborating measurements.

One can perform a boundary perturbation experiment. Introduce a removable, conductive cover across a small aperture, ensure electrical bonding is measured, then repeat the field map with the same source drive and probe positions. If capacitive coupling through the aperture was dominant, the electric probe may show a pronounced reduction; if current redistribution causes a change in the magnetic field, the loop may also change. The experiment therefore needs both sensors and current information. A separate test with a nonconducting spacer may help distinguish mechanical spacing from electrical bonding. Record the intervention's effect on the source impedance, because the cover itself may detune a nearby oscillator or antenna.

Interpretation should proceed from a Maxwell-consistent model. Source-voltage and current measurements specify possible excitation, geometry supplies boundary conditions, a calibrated pair of field probes provides partial observables, and repeated perturbations test which coupling path explains their variations. A model that predicts the observed H maximum only by inventing an unmeasured surface current is not established by the maximum itself. Test its predicted orientation, distance response and sensitivity to bonding changes. I pass the token to Professor Hertz, who can examine when such local stored-field patterns evolve into radiation and why the transition matters to a survey of enclosed electronics.

Michael Faraday, Cross-Peer Question to James Clerk Maxwell: Professor Maxwell, you emphasise that E and H coexist wherever the full time-varying electromagnetic problem is solved. How then can an engineer defend the

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practical statement that a particular seam has predominantly magnetic coupling when a capacitive signal may also be present, perhaps below the electric probe's noise floor? Would you require a vector phase measurement, or can orientation and controlled source-return geometry provide sufficient evidence for a limited mechanism claim? Please explain why a large local H magnitude is not evidence that the enclosure is radiating strongly into the distant environment, and how the evidence ought to be labelled when the material permeability and seam impedance are imperfectly known. I also ask whether a null in one probe orientation can result from field superposition rather than from the absence of a coupling path.

A further difficulty is the meaning of a zero in a component measurement. The sensed magnetic flux may cancel over a finite loop area even when the field is strong and nonuniform. Would you therefore compare probes of two sizes at matched sensing locations and assess whether the null follows the sensing aperture? This could distinguish true field orientation from spatial averaging, but might also alter source loading.

James Clerk Maxwell, Cross-Peer Answer to Michael Faraday: Mr. Faraday, a practical designation such as 'magnetic-dominant coupling under these test conditions' can be defended when the experiments specify a limited, measurable claim. One should not claim that the electric field vanishes. For example, an H-field probe might show a spatial maximum above a current-return discontinuity and respond predictably when the loop is rotated, while a calibrated E-field probe reports a much weaker component after its own rejection characteristics have been checked. Altering the source-return geometry whilst maintaining measured drive current could then produce

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the change predicted by an inductive-coupling model. That collection of contrasts supports the restricted conclusion more strongly than a single amplitude ratio.

The vector and phase measurements would be desirable where the intended claim requires power flow or a full electromagnetic field reconstruction, but not every diagnostic task requires a complete field solution. The degree of necessary evidence is fixed by the conclusion sought. To locate a practical coupling path, repeatable response to controlled bonding, shielding and loop-area changes may suffice. To estimate far-field radiation, it does not. The Poynting vector depends on both fields and their relative direction and phase; in a reactive region much energy is stored and returned rather than transported to infinity. A strong near-field sensor output may therefore coexist with comparatively weak distant emissions.

A polarisation null is also ambiguous in isolation. The vector component sensed by a loop can vanish at one orientation while other components remain; fields from several sources can cancel at a particular location; and the probe itself may have a complicated cross-field response. A complete rotation, a nearby spatial scan and an independent calibration of the probe are preferable to treating one null as proof of absence. If permeability or seam contact impedance is uncertain, quantify the model's sensitivity to those parameters and avoid presenting an untested wall-current distribution as a measured fact. The appropriate expert statement describes dominant response in the tested configuration, residual uncertainties, and the interventions that would challenge the interpretation.

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The central claim should remain conditional on probe calibration. For example, two H loops with different footprint and electric-field rejection may produce different amplitudes above an unbonded seam, even if the actual current distribution is unchanged. Repeating the geometry variation with both probes would expose such instrumental dependence. Where neither sensor rejects the unwanted component sufficiently, an honest classification remains mixed rather than artificially forced into one category.

A related check uses source modulation: change the test-drive current while monitoring both current and voltage, rather than relying on nominal generator settings. If the magnetic loop response follows measured current while the electric sensor does not, that is one informative contrast, but the inference must include probe rejection and possible loading. A second, different geometry trial is still desirable before calling the route established.

Charles Hard Townes, Peer Question: Professor Maxwell, a narrowly resolved spectral line may remain coherent across many points of a near-field scan, while a second source in the same enclosure can be slightly offset in frequency. Would the apparent phase relationship between electric and magnetic probes identify the coupling mechanism, or might the instruments' cables and reference clocks introduce an equally plausible phase shift? Explain what coherence measurement would tell us about a shared excitation and what it would not tell us about the actual route through an aperture. I would also ask how finite measurement bandwidth and oscillator drift affect the result when the field source is weak, because a dramatic coherence plot may be produced from a chain whose timing reference is not independent of the source.

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If a single coherent signal divides into two paths, each with a different cable delay, would their combined phase at one sensor permit a unique reconstruction of which path dominated? What observations should reveal an unnoticed acquisition clock switch or phase unwrap discontinuity? Please state the limits of coherence when the source waveform is broad or changes faster than the instrument's averaging interval.

James Clerk Maxwell, Response: Professor Townes, coherence is useful for identifying related signals, but it is not itself a map of causation. A high magnitude-squared coherence between a source monitor and an E or H probe at a narrow spectral line supports the proposition that the signals share some deterministic excitation within the measured bandwidth. It does not prove that power crossed the enclosure by the capacitive route, by flux linkage, through a cable common mode, or through an aperture resonance. Those alternative routes can all convey a coherent signal. A phase difference may be influenced by field propagation, reactive coupling, the probe transfer function, filter group delay, cable length and the instrument reference. The measurement must account for the entire chain.

I would first calibrate the relative phase of the two probe channels with a common known stimulus and record their frequency response, then return each sensor to the intended scan point without changing the routing. Use a shared acquisition clock when relative phase is the measurand, but keep an independent witness if the absolute clock is itself under test. If the source drifts in frequency during sequential scans, the measured phase can change because the source moved, not because the field configuration changed. Simultaneous acquisition or a documented reference monitor reduces that

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ambiguity. Finite bandwidth can average distinct sources into one apparent line, so the resolution bandwidth and window function belong in the record.

Consider a hypothetical 10 MHz test with a 2-metre difference in cable electrical length. At an ideal velocity factor of 0.66, the additional group delay is approximately 2 metres divided by (0.66 times 299,792,458 metres per second), or about 10.1 nanoseconds. At 10 MHz that delay corresponds to a phase difference of approximately 36.4 degrees. The arithmetic assumes a nondispersive cable and must not be transferred without measurement to real assemblies. Nevertheless it shows that an impressive probe-to-probe phase contrast could originate largely in the cabling rather than in enclosure coupling. Reverse the channels, measure a loopback, and retain the cable identifiers before drawing a field-theoretic conclusion.

The field observations should be interpreted through multiple independent tests: amplitude orientation, spatial gradient, response to source-drive change, response to shielding or bonding, and phase if calibrated. A field vector reconstructed from an uncalibrated set of probe voltages may look mathematically complete while being physically wrong. State whether the experiment establishes common excitation, likely route, local field components, or distant power flow. These are four different evidential propositions and should not be collapsed into a single claim.

Dr. James M. Atkinson, Moderator: Professor Hertz, consider the change from reactive storage to propagating radiation. Why does a steep near-field distance response fail to prove that magnetic coupling dominates, and how should a field survey identify the source?

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Heinrich Rudolf Hertz, Third Principal Contributor: Dr. Atkinson, an enclosure survey becomes misleading when it treats every detected oscillating field as an outgoing electromagnetic wave. An electrically small source produces both reactive near-field terms and propagating terms, whose relative magnitudes depend on distance, source type, frequency and surrounding material. In simplified dipole expansions, different field contributions can decay in amplitude approximately with inverse powers of distance, including terms of order one over r cubed, one over r squared and one over r. Yet the field measured at one wall opening of a large metallic box is not necessarily the field of an isolated infinitesimal dipole. Conducting boundaries, finite sources and multiple reflections introduce patterns that cannot be diagnosed by one power-law fit. The experiment must therefore separate local coupling-path discovery from the estimation of external radiation.

A useful scale is the electrical size of both source and observation region. The free-space wavelength lambda=c/f decreases as frequency increases. At 100 kilohertz it is approximately 3,000 metres, and an instrument held 5 centimetres above a small printed-circuit trace is deep within a quasistatic regime relative to that wavelength. At 3 gigahertz, lambda is approximately 10 centimetres, and the same standoff can be comparable to a wavelength. It follows that a probe scan made at a single physical distance over six decades of frequency samples different electromagnetic regimes. One should not apply the low-frequency magnetic-loop intuition to a high-frequency seam resonance, nor use a high-frequency horn antenna's calibration to interpret fields immediately above a power-supply inductor.

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Distance response is useful only with a suitable model. For an electrically small magnetic dipole under specified near-field conditions, a dominant local magnetic component can fall rapidly with distance, roughly as r to the minus third in its quasistatic region. Doubling r would then reduce that idealised amplitude by a factor of eight, which corresponds to approximately 18.1 dB in amplitude ratio. A propagating far-field amplitude may instead fall roughly as one over r, for a factor-of-two reduction or approximately 6.02 dB. These are model-specific limiting behaviours, not a universal test to identify magnetic versus electric coupling, because an electric dipole also has quasistatic terms and an enclosure can support several sources. The source, probe orientation and reference point must remain fixed during the distance sweep.

A practical near-field survey should include a calibrated standoff fixture and a documented three-dimensional coordinate system. A probe held by hand can tilt or move laterally when supposedly displaced vertically. If the field has a sharp local maximum near a seam, a slight sideways motion may dominate the result and produce a false distance exponent. Measure at several heights, repeat the path in reverse, and log probe orientation at each height. A measured amplitude floor sets a limit beyond which a decay curve cannot be extended. Data close to the floor should be treated as censored or uncertain rather than forced into a visually attractive line.

The opening in a conductor can behave differently as frequency changes. A small aperture at low electrical size may couple weakly, but a seam or slot approaching a relevant resonant dimension can radiate or receive more effectively. The exact resonance depends on geometry, thickness, bonding, cavity modes and loading. A narrow peak found by a magnetic loop near a

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screw or gasket does not prove that the whole enclosure is a magnetic source. It may reflect a resonant surface-current distribution, a local feed, or the probe's own response. Sweep frequency with constant and measured excitation amplitude, and consider whether the peak moves when the enclosure is mechanically or electrically altered. A peak that follows the probe when the probe is replaced may be an instrumental resonance.

At a given point one should consider field direction and phase. A small loop couples to the magnetic flux component normal to its area, whilst a short dipole probe responds principally along its effective electric axis. Neither is perfectly selective. A component map with orthogonal orientations can reveal whether the apparent maximum is a vector orientation effect rather than a change in total field. Simultaneous E and H observation, when calibrated, helps to check whether the local phase and magnitude agree with a plausible dipole or aperture model. But measurement of one component does not allow the real Poynting flux to be calculated, and a high near-field magnitude cannot be converted directly into an isotropic radiated-power figure.

The transmitter and the receiver must also be kept conceptually distinct. The enclosure may be a passive scatterer, receiving an external broadcast and reradiating a field around its seam, or an active object containing its own oscillator. A spectral peak detected near the case does not distinguish those possibilities. Turn the suspected internal excitation off only if the test is safe and authorised, or vary it by a known small amount, and compare with a simultaneously operating external reference antenna. If the peak follows the external transmitter, the enclosure may be acting as a receiving structure. If it follows an internal controlled source, that supports but does

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not by itself prove internal origin. This source-attribution challenge is essential in crowded RF environments.

A defensible field report would identify the source class, measurement distance, wavelength, dimensions of the object, probe factors, excitation level and uncertainty of the fitted model. It would distinguish a local gradient, a plausible coupling mechanism, and a distant emissions estimate. I should not represent that the decay exponent measured at three points beyond a seam is a property of all near-field physics. A far-field measurement performed at an appropriate distance and geometry, or a validated numerical model checked against independent observations, is needed to establish radiated behaviour. The optical clarity of a plotted waterfall should never outrun the physics of the observation.

James Clerk Maxwell, Cross-Peer Question to Heinrich Rudolf Hertz: Professor Hertz, an investigator may find that measured amplitude drops by about eighteen decibels each time a probe moves twice as far from an apparent source, and immediately call the interaction magnetic near-field coupling. Yet the same short-distance power law can occur in a quasistatic electric-dipole region, and the scanner may have moved away from a local aperture maximum. What additional measurements would distinguish these explanations? In particular, please discuss vector orientation, source voltage and current changes, the behaviour of a distant witness antenna, and the need to identify the field's reference plane. How would you respond if a seam's radiating response changed abruptly near a cavity resonance whilst the near-field standoff remained constant?

Could an electrically small high-voltage element and a small current loop yield similar steep spatial falloff at one frequency? If so, what specific

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intervention would convert an ambiguous distance exponent into a stronger causal finding without assuming that either source is electrically isolated? Please describe whether the same test remains valid when the probe itself changes the enclosure's resonant condition.

Heinrich Rudolf Hertz, Cross-Peer Answer to James Clerk Maxwell: Professor Maxwell, I would reject the unique identification from distance exponent alone. A small electric dipole and a small magnetic loop can both exhibit quasistatic terms with steep distance dependence. The exponent is one component of a model comparison, not a field-type certificate. The investigator should examine the orientation response of calibrated E and H probes, map several lateral points at each height, and use controlled changes in the suspected source's voltage and loop current. If the response follows changes in the current-return geometry at otherwise comparable drive, that supports inductive coupling. If it follows the exposed high-voltage surface area and electric-probe orientation, a capacitive explanation gains support. Both may remain present.

A distant reference antenna provides a different observation of propagating energy, although it may itself be affected by multipath or ambient transmissions. A local near-field maximum that has no corresponding change in the distant witness when the source is perturbed need not indicate a strong radiating mode. Conversely, a sharp far-field peak that moves with an aperture or gasket adjustment may indicate a resonance in the enclosure system even where the local probe map is complex. No source test should rely solely on the absolute amplitude at one exterior point. The scale of observation and the uncertainty of distance and orientation must be recorded.

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I would also vary frequency under a controlled and monitored excitation. When a slot, seam or cavity resonance is approached, the field distribution can change rapidly, the phase can rotate, and previously simple decay approximations may become inappropriate. Record the source-drive amplitude, probe frequency response and instrument bandwidth across that sweep. A change in the source impedance can modify the drive current, making the apparent resonance partly a source effect. The investigator should make a second test that preserves or separately measures the excitation before attributing the change to the enclosure.

Finally, state the physical reference plane for the distance: is r measured from a loop centre, a seam edge, an internal component or the probe's effective sensing centre? Moving from two centimetres to four centimetres from a wall does not necessarily double distance from the actual source ten centimetres inside. A claimed power-law slope without that geometric definition is unreliable. What the evidence may support is a local strongly evanescent or reactive-field response under documented conditions, with the choice of electric or magnetic pathway established by additional independent perturbations.

Oliver Heaviside, Peer Question: Professor Hertz, consider a braided cable leaving a screened enclosure. A clamp-on current monitor reports a common-mode current at the same frequency as a strong external near-field peak, but a scan of the metal wall seems relatively quiet. Would you treat the cable as an unintended antenna or as part of the enclosure's source-return network? How could the investigator distinguish conducted transfer along the cable from direct field transmission through an aperture, especially where moving the cable changes both the field geometry and the

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grounding path? Please address differential versus common-mode currents, cable termination, and the role of a properly measured bonding impedance at the enclosure penetration.

I would also ask how shield-current measurement should be cross-checked without mistaking a clamp probe's response to nearby external E fields for actual cable current. If a ferrite is fitted temporarily, how can the analyst show that an apparent reduction is not an unintended retuning of the source? Please address how common-mode current and far-field changes ought to be correlated across repeated source states.

Heinrich Rudolf Hertz, Response: Mr. Heaviside, I would treat the cable as part of the electromagnetic system rather than as an afterthought. Current entering and leaving a cable in a balanced differential pair can produce magnetic fields that partially cancel when the conductors are close and the return path is well defined. Common-mode current flowing on the outside of a shield or on multiple conductors relative to the environment can produce a different field distribution and may enable the entire cable to act as a radiator or receiver. The actual current path depends on termination and bonding, so a photograph of a braid does not establish a low-impedance shield connection at the survey frequency.

Begin by measuring common-mode current at several positions along the cable with a characterised clamp probe, and separately monitor the differential signal where the circuit permits. Record clamp location, orientation and calibration. Move the cable only through a small, repeatable displacement and simultaneously record source current and the enclosure field. If the exterior peak follows the cable and its current antinodes, a cable-coupling explanation becomes more plausible. If the peak persists at the

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enclosure opening despite routing changes, direct aperture coupling may remain. However, moving the cable can change shield current and resonant geometry, so the comparison must include both amplitude and current measurements.

A carefully rated common-mode impedance element, inserted with the equipment owner's permission, may provide another contrast. A reduction in common-mode current accompanied by reduced external field supports a conducted route, but does not automatically prove that no energy crossed the aperture. Conversely, changing gasket pressure may alter bonding impedance, redistribute shield current and change leakage elsewhere. Use a verified bond measurement appropriate to frequency; a milliohm direct-current reading alone says little about inductive impedance at hundreds of megahertz. Repeat the test with controls for source amplitude and instrument noise.

The conclusion should identify whether the measurement establishes common-mode conduction, a radiating cable contribution, or merely co-variation of two observables. Forensic integrity requires retention of cable configuration, termination, current-probe transfer function and all interventions. An enclosure is not electrically isolated merely because a metal wall separates its nominal inside from outside; every attached conductor is a potential continuation of the boundary problem.

Karl Guthe Jansky, Peer Question: Professor Hertz, a field survey in a room full of receivers may show a fixed narrowband line beside one cabinet, but the line could come from an external broadcast, a nearby local oscillator, a switching supply or an artefact of the survey receiver. What source-attribution experiments would you require before describing the field as

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leakage from the inspected enclosure? Would frequency correlation with an external antenna suffice when the cabinet itself can reradiate incident transmissions? Please include a plan for comparing source on/off states, independent receiver clocks, antenna polarisation and movement of the reference probe without disrupting preserved evidence. How should the report handle sources that cannot be powered down?

Consider a receiver with a spur exactly matching the oscillator reference. If the near-field probe is merely a passive antenna connected to that receiver, a processor may display the spur even with the probe removed. Would you require a terminated-input test at the same gain and a separate receiver architecture? How should the source attribution change when two external reference antennas disagree because of polarisation and local multipath?

Heinrich Rudolf Hertz, Response: Mr. Jansky, the source-attribution problem should precede the coupling classification. First, record the spectral line simultaneously on an exterior reference antenna and on the near-field probe, using instruments whose reference relationships are known. If both traces move together in frequency or amplitude with a distant transmitter, that supports an environmental excitation, but the cabinet may still concentrate the field locally by scattering or resonance. A spatial maximum alone cannot prove the cabinet is the generator. Conversely, an internally generated line may appear on a distant antenna, so mere coexistence of signals does not establish direction of origin.

I would use controlled source modulation where authorised. A small, predetermined change in an internal test oscillator's frequency or duty cycle provides a signature that can be followed at the enclosure seam and on the distant witness. Where the equipment must remain in service, a known

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injected calibration tone through an approved diagnostic port may substitute. If neither intervention is possible, compare repeated surveys at different times, use directional or polarisation changes, and document the inference as tentative. A source that cannot be safely powered down must not be treated as though an unperformed on/off experiment had actually taken place.

An independent receiving chain is valuable for excluding instrument-generated artefacts. A spurious mixer product can move when receiver local-oscillator frequency changes, even though the external field is fixed. Change the receiver centre frequency by a recorded offset while keeping the source unchanged; a true external line should map according to the instrument's known frequency conversion, whereas some spurious responses will move differently. Use a second, differently designed receiver when feasible and record any shared reference clock. These tests should be performed without compromising the continuity of operational recordings, using a parallel survey instrument rather than altering the evidential receiver.

Finally, source attribution and coupling path are different questions. One may establish that a cabinet reradiates an external transmission through a particular seam, or that an internal switching supply produces a local magnetic field with little distant emission. The evidence should keep those findings separate. The report needs actual source-state data, external RF context, time and frequency calibration, probe positions, and the explicit limitations of every unperformed test.

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Dr. James M. Atkinson, Moderator: Professor Kennelly, I ask you to work from field measurements to an equivalent-circuit experiment, making the assumptions and the limits of low-frequency impedance models explicit.

Arthur Edwin Kennelly, Fourth Principal Contributor: Dr. Atkinson, an enclosure with an attached circuit must be considered as a network of impedances and electromagnetic couplings rather than an empty box through which a mysterious field passes. At low frequencies and sufficiently small geometries, an equivalent circuit may illuminate the problem. Capacitive coupling can be represented by a stray capacitance C_m between conductors, while inductive coupling can be represented by a mutual inductance M between source and victim loops. For sinusoidal voltages and currents, the capacitive injection current is approximately j omega C_m V_s and an induced magnetic electromotive force approximately j omega M I_s, with signs depending on the chosen reference directions. Here j denotes the imaginary unit, omega angular frequency, V_s source voltage and I_s source current. These are local circuit models valid within a specified regime, not replacements for a full-wave field solution at arbitrary frequency.

The receiving circuit determines the observed consequence. A one-microampere capacitive injection into a victim node of 10 kilohms may produce an idealised 10-millivolt response in the simplest lumped model, whereas the same current into 50 ohms produces only 50 microvolts. The difference is two hundredfold, equivalent to about 46 dB in voltage amplitude, despite an identical injected current. It would be absurd to infer a two-hundredfold change in the external electric field merely because a measurement instrument changed its loading. The instrument impedance, protection network, cable capacitance and amplifier input must therefore be

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documented. At high frequency the node impedance is complex and the simple multiplication is insufficient.

For an inductive illustrative case, let the mutual inductance between loops be 10 nanohenries, the source-current amplitude 0.1 ampere, and the frequency 1 megahertz. The ideal induced open-circuit voltage amplitude is omega M I_s, or approximately 2 pi times one million times 10 to the minus eight henry times 0.1 ampere, equal to 0.00628 volt. Thus about 6.28 millivolts is predicted before loading and frequency-dependent mutual coupling are considered. If the source-return separation is reduced, M may change markedly even when I_s remains the same. A capacitive pathway can produce a similar observed voltage under different circuit conditions; numerical equality of voltages does not identify the physical route. Controlled geometric and impedance contrasts are required.

Frequency provides a further contrast, but not an automatic diagnostic. In their simplest low-frequency forms, both capacitive injection current and inductive induced voltage are proportional to angular frequency. An amplitude that rises at 20 dB per decade could therefore be consistent with either mechanism, or with an amplifier and cable response. Moreover, the victim load may vary with frequency, and the source excitation may not remain constant across the sweep. To compare models, measure both drive voltage and drive current, preserve the probe calibration curve, and express the predicted victim response through its complex receiving impedance. The phase of the result may assist, but the phase reference and cable delay must be calibrated.

Conducting screens introduce another impedance problem. The skin depth in a good conductor under the conventional plane-wave approximation is

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delta=sqrt(2/(omega mu sigma)), where sigma is electrical conductivity in siemens per metre, mu magnetic permeability in henries per metre, and omega angular frequency in radians per second. For copper with sigma approximately 5.8 times 10 to the seventh siemens per metre and mu approximately free-space permeability, at 1 kilohertz delta is about 2.09 millimetres; at 1 megahertz, about 66 micrometres. These are illustrative material estimates, not shielding-effectiveness predictions for a complete enclosure. A thin copper sheet may offer poor low-frequency magnetic attenuation even if its electric-field shielding is useful, while joints and apertures can dominate higher-frequency leakage.

A shielding experiment must separate wall penetration from leakage at seams and attachments. Temporarily bridging a seam with a well-bonded conductor may lower the electrical resistance and alter local current paths, but its RF impedance is affected by length and geometry. A strip that appears negligible in DC resistance may retain appreciable inductance at high frequency. If a current flows along the enclosure wall, its distribution is determined by the combination of metal surface, apertures, bonding impedance and cable terminations. An exterior magnetic probe maximum above a seam could be associated with this redirected wall current, not simply with a magnetic field penetrating a uniformly thick sheet.

I would use a documented substitution sequence. Begin with a fixed source voltage and current, survey the seam with calibrated E and H probes at controlled orientation and standoff, then add a conductive bridge across a selected discontinuity. Re-measure both source quantities and the local field. In a second trial change the bonding path of the attached cable without changing its logical function, checking for common-mode current

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changes. In a third, add a nonconducting spacer or adjust stand-off, if safe, to separate mechanical movement from electrical conduction. Each intervention changes more than one physical quantity; the inferential task is to measure those changes, not to assert they are absent.

The engineer must not forget the source and load. An oscillatory magnetic field produced by a current loop has a surrounding electric field as well; a voltage-bearing plate can drive currents that create magnetic fields. At a sufficient frequency and geometry the assumed two-port lumped network ceases to be adequate and waveguide, cavity or radiation effects enter. Therefore use the simplest model that predicts the observations within a declared error, then challenge it with a second configuration. I pass the token to Professor Kraus for the antenna and field-scanning perspective, where electrical size, array geometry and probe selectivity are the governing disciplines.

Grote Reber, Peer Question: Professor Kennelly, a screen that seems very effective at one frequency can become surprisingly transparent at another when a seam or attached cable approaches resonance. How would you distinguish genuine material skin-depth attenuation from a frequency-dependent aperture or common-mode effect? If a copper foil layer reduces the E-probe reading without changing the H-probe reading, may we conclude that the residual interaction is magnetic, or would you first ask whether the foil has changed the probe's return path and the source current distribution? I also ask which material quantities must be measured and whether a blanket shielding specification can be transferred from a laboratory panel to a real enclosure containing joints, screws and penetrations.

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Can a frequency-selective shield whose material absorption is smooth nevertheless show narrow-band improvement because the enclosure has altered a slot resonance? What observations would distinguish this from a noise-floor limitation? Please discuss whether a comparative test is invalid if the foil layer changes the antenna factor of the receiving probe, and how a shield-effectiveness ratio should be expressed when baseline emission is barely detectable.

Arthur Edwin Kennelly, Response: Mr. Reber, skin-depth arithmetic applies to a specified material and idealised field geometry. It does not substitute for a measurement of the entire enclosure. A good conductor can attenuate fields by reflection and absorption in ways that depend on frequency, thickness, permeability, conductivity and incidence, but a slot, bad bond or cable penetration can bypass the wall. If the observed response changes sharply at one frequency, examine the dimensions of the aperture, the connected cable and the source impedance before attributing the feature to a sudden change in the metal's intrinsic properties. Skin depth varies smoothly with the square root of inverse frequency in the standard approximation; an extremely narrow peak therefore suggests another resonant or instrumental mechanism.

For example, if the skin depth of a simple copper sample is about 66 micrometres at 1 megahertz under the stated material assumptions, at 4 megahertz the corresponding approximation yields about 33 micrometres. Doubling or halving thickness can matter, but the effect of a long unbonded seam may overwhelm that improvement. Material properties must be documented, and any claim of shielding effectiveness requires a qualified test geometry and measurement method. The instrument's own dynamic

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range can also make an improvement look larger or smaller than it is if the post-screen signal approaches its noise floor.

If the E probe falls whilst the H probe does not, I would say only that the two instrument outputs responded differently to the intervention. I would check the foil's electrical bonding, its distance from source and probe, whether the source drive changed, and the probes' cross-field rejection. A foil can redirect surface currents, alter capacitive loading and change electric pickup in the loop's cable. With an independent source-current monitor and repeated probe rotations, one can test whether a magnetic contribution remains plausible. An apparent unchanged H reading may also reflect amplifier saturation or inadequate measurement sensitivity.

The proper outcome is a frequency-by-frequency account: field component measured, probe factor, shield geometry, bond impedance, source stability, ambient environment and uncertainty. A manufacturer's flat-panel screening value cannot simply be carried across to a complex cabinet. Measurements at the final enclosure, with its actual glands, seams and cables, are necessary before a security conclusion is drawn.

Heinrich Rudolf Hertz, Cross-Peer Question to Arthur Edwin Kennelly: Professor Kennelly, your equivalent-circuit model uses mutual capacitance and inductance, but a real enclosure is spatially extended and may exhibit multiple resonances. At what point would you reject an ordinary lumped representation and require a full-wave model or a calibrated antenna measurement? Please explain whether the measured 20 dB-per-decade frequency rise can distinguish displacement-current coupling from inductive pickup, and how probe loading might imitate that slope. How would you check a skin-depth calculation against the observed attenuation when

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seams dominate? I should particularly welcome an uncertainty rule preventing the engineer from declaring a magnetic source merely because a simple inductance formula happens to predict the right order of magnitude at one frequency.

To make the distinction practical, suppose an enclosure dimension is one tenth of a wavelength, but an attached lead is several wavelengths long. Which electrical size controls the failure of the lumped approximation, and must the complete cable be included in the full-wave domain? How would you decide whether the added complexity reduces uncertainty or simply adds unconstrained material parameters to the model?

Arthur Edwin Kennelly, Cross-Peer Answer to Heinrich Rudolf Hertz: Professor Hertz, a lumped model is an approximation whose validity must be challenged by electrical size and by prediction under varied conditions. If a relevant conductor, aperture or return-current structure approaches an appreciable fraction of the wavelength, phase varies significantly across it, or sharp resonances appear, the simple uniform-voltage and uniform-current representation becomes doubtful. A full-wave model may then be appropriate, but it should not be regarded as self-validating merely because its numerical mesh is fine. Compare predictions at several positions, polarisation orientations and frequencies, and reserve an independent measurement configuration for validation.

The 20 dB-per-decade rise is particularly unhelpful as a unique discriminator. In a low-frequency approximation the displacement current omega C_m V and induced magnetic voltage omega M I both scale linearly with frequency if voltage, current and coupling parameters remain constant. The measured receiving voltage may add another frequency dependence

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through load impedance and probe electronics. Thus a matching slope does not prove which mechanism is present. Instead change source voltage and current in independently measured ways, vary source-return area, and perform orientation scans with probes whose electric and magnetic selectivity have been characterised.

For material shielding, calculate skin depth only after identifying conductivity, permeability, thickness and frequency. Then compare the experimental result with a model including seams, bonding, cable penetrations and instrument dynamic range. If the observed attenuation changes dramatically when a gasket is tightened but the metal thickness remains fixed, a seam explanation is more credible than material skin-depth change. Where several mechanisms explain the data within uncertainty, retain the alternatives rather than assign the entire change to one selected circuit element.

My proposed uncertainty rule is operational. The model must reproduce at least one withheld intervention with error bounded by the combined instrument, position and source uncertainties, and its dominant coupling term must be supported by a distinct response contrast. If it fits only one frequency at one probe location, it has not established a cause. A full-wave simulation, an equivalent circuit and an E/H probe scan are complementary tests. None alone constitutes proof of a unique internal current or charge distribution.

The decisive distinction is predictivity. A numerical model should state the response to a change of bond impedance before the trial, and then be judged against the observed vector field within a defined uncertainty band. If the original parameter values must be freely retuned after every

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intervention, the model has not identified a stable mechanism. Retain such material as a hypothesis, not as a validated reconstruction.

Dr. James M. Atkinson, Moderator: Professor Kraus, the last principal contribution concerns calibrated probe response and mapping technique. Please distinguish a useful local field scan from a defensible reconstruction of the source or its far-field radiation.

John Daniel Kraus, Fifth Principal Contributor: Dr. Atkinson, I would treat near-field scanning as an exercise in antenna measurement and inverse-source inference. The probe is an antenna, even when it is only a few millimetres across, and the enclosure is part of its environment. The goal is not merely to find a bright patch on a screen but to determine which field component was sampled, what spatial region the probe averaged, and how much the sensor altered the system. An electrically small H loop tends to respond to magnetic flux through its effective area. A short E probe tends to respond to the electric component along its effective axis. The adjectives 'electric' and 'magnetic' denote calibrated response characteristics, not perfect isolation. E leakage into an H probe and H-induced cable response in an E probe can be material in the region of a strong gradient.

A scan must specify coordinate conventions. Place the enclosure in a surveyed coordinate frame with x, y and z axes, and identify the probe's effective sensing centre and orientation. Record position in metres and standoff from a reproducible external reference plane. A map made at nominal z=5 millimetres is meaningless if the probe is tilted such that its sensing centre varies by several millimetres near each screw or seam. Use a nonconducting fixture where possible and inspect whether its dielectric properties perturb the field. Repeated scans with the same source drive

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should agree within the position and amplitude uncertainty. Where the map does not repeat, first examine the probe cable and source condition before searching for a complicated material explanation.

The study must determine spatial resolution empirically. If a loop sensor has finite diameter, its output integrates flux across that loop; a narrow field feature may be blurred or displaced. A higher spatial sample density does not recover information erased by the probe footprint without a validated deconvolution model. Scan the same feature with two probe sizes, appropriately recalibrated, and compare their locations and response widths. A location that moves appreciably when the probe geometry changes is not yet a reliable source coordinate. It may reflect near-field loading or cross-polarisation pickup rather than a real displaced conductor.

Probe loading is a severe source of error at small standoff. A metal loop, shield or cable brought very close to a high-Q circuit may alter its resonant frequency, quality factor or local current distribution. Measure source frequency and amplitude both with the probe withdrawn and at the survey position. A line that moves when the probe approaches may be evidence of the measurement's disturbance, not spontaneous behaviour by the inspected equipment. Reduce coupling, increase standoff or use an alternative sensor and test whether the same spatial pattern remains. An attractive maximum obtained only by strongly loading the source cannot be presented as a non-invasive observation of its unperturbed field.

A comparison of E and H probe maps requires compatible bandwidth, input calibration, filtering and dynamic range. The units differ: volts per metre for E, amperes per metre for H, and volts for the raw probe output. Converting their ratio into an impedance is meaningful only when both field

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measurements refer to the same position, relevant vector components and calibrated frequency response. Even then, the local ratio need not equal the free-space wave impedance. A high local value of E/H may be consistent with dominant capacitive coupling, while a low value may be consistent with a magnetically dominated region, but these interpretations depend on source type and phase. The near-field ratio alone does not reveal which enclosure path injected the field into a victim circuit.

An instructive example uses an electrically small loop at two measured standoffs from a source known to remain stable. Suppose the H-sensitive output falls from 80 microvolts at a 2-centimetre standoff to 11 microvolts at a 4-centimetre standoff under the same probe orientation and calibrated gain. The observed amplitude ratio is approximately 7.27, or 20 log10(80/11), about 17.2 dB. This is near the ideal 18.1 dB ratio associated with inverse-cube amplitude variation over a doubling of distance. It is not proof of a pure magnetic dipole: the physical source could lie inside the enclosure, the sensing-centre distances may not double, and electric pickup could have a similar local gradient. A third distance and a lateral map are required to challenge the model.

For electromagnetic emissions assessment one must distinguish the investigative near-field scan from a regulatory far-field test. The latter specifies a standardised site, antenna, distance, detector and uncertainty practice suited to its purpose. A local scanning amplitude can help identify and repair a leaky seam but cannot simply be converted into regulatory emission strength by multiplying by distance or assigning 377 ohms. If the security question concerns an unintended signal observable at another building, the analysis requires a propagation model and an appropriate

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remote-field measurement, with ambient transmitters and multipath controlled. A near-field result is one element of the evidence chain, not the complete chain.

I would establish a repeatable sequence for the field team. Begin with instrument self-tests, source-off background and a calibrated reference radiator or field generator. Record the enclosure condition, source waveform and reference-clock status. Map E and H at one frequency with several orientations and heights; repeat at a second frequency selected for a specific physical hypothesis. Introduce one controlled perturbation, such as a verified change to return-current geometry, bond or aperture cover, and remap the identical points. Preserve the raw observations, correction factors and the reason for each intervention. In the final analysis distinguish the measured result, the best-supported coupling interpretation, the rival explanation not excluded, and the uncertainties of both. I return the token to Dr. Atkinson with a warning: the field map is not a picture of an invisible current without assumptions; it is a structured observation of how a calibrated sensor responded to a complicated boundary-value problem.

Antony Hewish, Peer Question: Professor Kraus, a field team can generate a beautiful three-dimensional map using a dense motorised scanner, yet the map may reflect a drifting source, a cable-suspended probe or cross-coupling between supposedly independent sensor channels. How would you test scan repeatability when each line takes several minutes, and how would you distinguish temporal variation from spatial variation? Please address synchronous reference measurements, forward and reverse raster passes, vector calibration and the uncertainty introduced by interpolation between sample positions. If the instrument is detecting a weak source near a

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switching supply, what evidence would permit the reader to accept a narrow local maximum as a field feature rather than as a processing artefact?

What numerical checks would reveal that the probe's finite aperture has displaced an apparent maximum, and how might an alternative test fixture change the result? Please include whether the same field map should be remeasured after swapping the receiver channels, since an unnoticed gain or reference bias could produce an attractive but spurious difference between electric and magnetic components.

John Daniel Kraus, Response: Professor Hewish, the map must be treated as samples of a field that may change in time. If the source changes while the scanner moves, a raster may turn temporal drift into an artificial spatial stripe. Record a simultaneous source monitor, ideally including amplitude, phase where relevant, frequency and reference-lock state. Repeat the raster in reverse direction; a real stationary spatial feature should remain attached to the same physical coordinate, whereas some time-dependent patterns may reverse or shift. At selected positions repeat measurements at the beginning, middle and end of the survey to estimate the source's temporal stability. If the field changes materially during the scan, do not combine all the points into a map of one stationary state without a justified correction model.

The probe's cable must be mechanically and electromagnetically controlled. Fix its routing as far as possible, and where movement cannot be avoided characterise the response to cable displacement with the sensing head fixed. Calibrate all sensor axes and cross-polarisation rejection across the actual frequency band. A multi-axis map is a vector product only if gain, orientation and phase conventions are consistent. Interpolation is a

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presentation method, not a recovery of observations between grid nodes. Show actual sample positions and provide an uncertainty map where the probe footprint, gradients or measurement noise make interpolation unreliable.

For a narrow maximum, I would require a repeatable response with two scan directions, a finer local grid, a second probe or sensing orientation, and a source perturbation that predicts a change at the same location. A scanning head that strongly couples to the enclosure might create its own local resonance, so the source should be monitored with the probe present and absent. A reference signal injected into the receiver chain can reveal gain changes or local-oscillator spurs. A no-source control establishes the instrument floor. If the maximum persists only after extensive digital smoothing, or disappears when raw amplitudes are plotted, the map is not suitable for causal interpretation.

The final dataset must permit a second investigator to reconstruct the map from original observations, including coordinate origin, velocity or dwell time, timestamps, filter bandwidth, detector averaging, gain, calibration and rejected samples. Correlation between spatially adjacent samples must not be mistaken for independent confirmation when all are derived from one slowly drifting oscillator. It is better to provide a less colourful map with honest uncertainty than an immaculate rendered surface that hides the distinction between measured points and computationally invented detail.

Arthur Edwin Kennelly, Cross-Peer Question to John Daniel Kraus: Professor Kraus, your proposed E/H ratio requires calibrated vector components at the same point, yet near a seam the gradient can be so steep that two sensors of different size cannot occupy the same effective volume. How would you

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decide whether a reported high electric-to-magnetic ratio is a real local property or an artefact of probe footprint and position? Would you allow a numerical electromagnetic model to transfer the fields to a common reference plane, and what validation would prevent that model from manufacturing the answer? Explain whether a mitigation trial that lowers the E-probe reading, but raises the H-probe reading, can still be considered successful when the actual concern is coupling into a victim receiver.

Assume that one model predicts a sharp magnetic hotspot after a bonding change, while another predicts a relatively diffuse electric field. If both fit the unaltered enclosure, how would you select the most discriminating new measurement path? Would you require a blind prediction before examining the corrected scan? Explain whether the victim receiver's orientation makes the geometric average of a field map less useful than one carefully measured transfer-function response.

John Daniel Kraus, Cross-Peer Answer to Arthur Edwin Kennelly: Professor Kennelly, the ratio should not be reported without the qualification that two differently sized sensors may average different spatial regions. Begin by determining the effective sensing centre and spatial response of each probe under calibration, then use mechanical fixtures to place them in reproducible orientations and as nearly common a reference geometry as practical. Compare measurements at several standoffs where the field varies more gently, and report the position uncertainty together with the field uncertainty. If the sensors' footprints dominate the width of a field maximum, the nominal point ratio is not physically well resolved. Use a range of possible ratios rather than an unsupported precise value.

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A numerical model can transfer fields to a common reference plane if its source assumptions, conductor geometry and material parameters are independently constrained. The model must be tested against withheld scan lines, alternative probe orientations and an altered enclosure configuration. Agreement only at the points used to fit the model is not validation. If the predicted E/H ratio depends strongly on an unmeasured seam impedance or source-current path, that dependence should be exposed through a sensitivity interval. The calculation may remain useful as a hypothesis-generating tool without qualifying as an evidential field reconstruction.

Mitigation success should be assessed at the actual victim and for the relevant threat mechanism. A conductive cover could reduce local E at one probe yet redirect current so that H increases elsewhere. If the interference at a specified victim receiver falls under controlled and calibrated test conditions, the mitigation may be operationally successful despite a local H increase. But the result should not be described as a general reduction of all electromagnetic leakage. Observe both fields and the victim response before and after the change, with the source excitation maintained and measured. The coupling transfer function between field and victim depends on its orientation and impedance.

One useful transfer measure is the change in victim voltage under a fixed source state: $T_v=V_v/V_s$, where V_v is the victim-port voltage and V_s the specified source voltage, both measured with consistent amplitude conventions. A reduction in $abs(T_v)$ may demonstrate mitigation in that configuration, but must not be confused with a far-field emission metric. The final record should identify which operational performance criterion

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improved, which exterior field components changed, and which alternative current paths remain to be tested.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The roundtable distinguishes local observations from causal attributions. A calibrated electric probe measures a defined E-sensitive response; a calibrated loop measures a defined H-sensitive response; neither output is a perfect isolation of one field from the other. The investigator must preserve source voltage and current, instrument clock and bandwidth, probe orientation and position, cable configuration, shielding and bonding state, and the receiving impedance. Controlled variations in source-return area, exposed voltage-bearing geometry, screen continuity, cable common-mode current, scan height and frequency provide separate predictions under capacitive, inductive, conductive and resonant hypotheses. A local maximum or a steep distance exponent cannot independently specify far-field radiated power or an internal source location. When calibrated vector data or causal interventions are absent, the conclusion is an observed near-field response with explicitly unresolved mechanism. All contemporary measurement applications in this discussion are scholarly extrapolations, not historical quotations from the named scientists.

QUESTION 062. VERIFIED PUBLICATION LOCATORS AND EDITORIAL SOURCE NOTES

1. D. A. Hill and K. H. Cavcey, Detection of Quasi-Static Electric Fields Radiated by Electrically Small Emitters, NISTIR 5096 (2000), https://www.nist.gov/publications/detection-quasi-static-electric-fields-radiated-electrically-small-emitters. Source for the limits of electric-dipole near-field detection and measured environmental noise.

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2. S. Yang, Q. Huang, G. Li, R. Zoughi and D. J. Pommerenke, Differential E-Field Coupling to Shielded H-Field Probe in Near-Field Measurements and a Suppression Approach, IEEE Transactions on Instrumentation and Measurement 67(12) (2018), DOI 10.1109/TIM.2018.2831398. Source for imperfect E rejection of nominal H probes.

3. T. Li, Y. C. Ho and D. Pommerenke, Orthogonal Loops Probe Design and Characterization for Near-Field Measurement, IEEE International Symposium on Electromagnetic Compatibility (2008), DOI 10.1109/ISEMC.2008.4652138. Source for orthogonal H-probe design and near-field probe characterisation.

4. Shun Liu, Xin Fang, Taelim Song, Myung-Hwan Kim, Hwan-Woo Shim and Chulsoon Hwang, “Field Coupling Mechanism Investigation of mm-Wave Magnetic Near-Field Probe Based on a Generalized Equivalent Circuit,” IEEE Transactions on Instrumentation and Measurement 71 (2022), article 8002409, DOI 10.1109/TIM.2022.3152317. Verified full author list from academic institutional publication records; source addresses intended H and unintended E response in a probe. Application to this enclosure problem remains an editorial extrapolation.

5. Giorgi Maghlakelidze, Xin Yan, Li Guan, Shubhankar Marathe, Qiaolei Huang, Bumhee Bae, Chulsoon Hwang, Victor Khilkevich, Jun Fan and David Pommerenke, “SNR Analysis and Optimization in Near-Field Scanning and EMI Applications,” IEEE Transactions on Electromagnetic Compatibility 60(4) (2018), pp. 1087–1094, DOI 10.1109/TEMC.2018.2792778. Verified bibliographic record supports the influence of probe, transmission path, amplifier and receiver noise on scanning sensitivity.

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Editorial qualifications: The dialogue is an explicitly fictional reconstruction of deceased historical specialists. Contemporary engineering applications are editorial extrapolations. Numerical examples have declared hypothetical premises. The four stated IEEE and NIST bibliographic locators have been checked for title, author or citation details where available, but this does not constitute claim-by-claim independent verification of the manuscript. IEC TS 61967-3:2014 provides relevant IC surface-scanning diagnostic methods, but its scope does not establish whole-enclosure compliance.

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QUESTION 063

What is missing when an antenna is calibrated exclusively under far-field conditions?

HISTORICAL RECONSTRUCTION. The following conversation is a fictional scholarly construction involving deceased scientists and radio pioneers. Its modern instrumentation, measurement protocol and contemporary standards are attributed to the present-day editor, not to historical remarks or endorsements by those individuals.

Dr. James M. Atkinson, Moderator: Professor Maxwell, the panel has completed the separate inquiry into electric and magnetic near-field probes, and the next practical matter is calibration transfer. What information is absent when an antenna is calibrated in an open far-field arrangement and then introduced into a cluttered equipment enclosure? Please distinguish a measurement of antenna characteristics from the characterisation of an installed system. I shall call five principal scholars, request immediate answers to their peers, and invite direct challenges among the principal speakers. The token is yours, Professor Maxwell.

James Clerk Maxwell, Principal Contributor: Dr. Atkinson, the essential omission is not merely a correction factor at a shorter distance. It is the boundary-value problem that determines what an instrument actually senses when the antenna, its feed and nearby conducting matter form one electromagnetic system. A far-field calibration establishes a response to a specified illumination, polarisation and direction under stated loading conditions. It does not establish that the same response survives when the incident field has strong longitudinal or evanescent components, when

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nearby currents alter the sensor impedance, or when its cable becomes an uninvited part of the receiving structure. The calibration is properly valuable within its domain; the error lies in carrying its authority beyond that domain without new evidence.

Take a receiving antenna illuminated by an approximately uniform plane wave. One may express its open-circuit terminal voltage as a vector effective length dotted with the incident electric field, with a phase convention declared. Under conjugate or other specified receiver loading, the terminal voltage is modified by the antenna impedance, feed impedance and cable network. In such a condition the familiar antenna factor, expressed in reciprocal metres, is the electric-field amplitude divided by a defined receiver-port voltage. Every element of that sentence matters. A calibration certificate may report an antenna factor in decibels per metre, a frequency interval and an uncertainty statement; yet its value alone reveals nothing about a nearby source's field polarisation, curvature, longitudinal component, return current or coupling through the feeder shield. The observer cannot invent those missing quantities by multiplying an instrument's displayed voltage by the catalogue factor.

In a spatially restricted enclosure a time-varying field solves Maxwell's equations subject to conductive, dielectric and aperture boundaries. The electric and magnetic fields remain coupled by the curl equations, but their local ratio need not be the free-space wave impedance of approximately 377 ohms. A small current loop can produce predominantly magnetic reactive response over one limited region; a voltage-bearing conductor can produce a conspicuous electric response under a different geometry; and both interpretations can fail when a resonance or cable common-mode path

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becomes important. The separation is operational, not absolute. The useful experiment is to alter one boundary or source variable, measure what else changes, and compare the observed field-vector pattern with the predictions of several competing models.

Distance offers a particularly seductive but unreliable shortcut. Let the maximum transverse dimension of the relevant radiating aperture be D metres, wavelength be lambda metres and antenna-to-source separation be R metres. The often cited far-field criterion R greater than approximately 2D squared divided by lambda addresses phase curvature across an aperture under assumptions about geometry and radiation. It is neither a guarantee that every reflected field is negligible nor a universal declaration that a small probe has ceased to be reactive when moved just beyond that number. An electrically small source may require consideration of terms scaling approximately as inverse distance cubed, inverse distance squared and inverse distance in different regimes, but these are model terms, not an invitation to fit three powers to a noisy single-point spectrum and call the dominant exponent the mechanism.

A defensible field trial would retain the original antenna and receiver and compare at least three environments. The first is its declared far-field calibration geometry. The second is a controlled installation near a known metal reference plate or enclosure with measured gap and orientation. The third is the intended survey position, including the actual cable route and any contact with furniture or rack metalwork. At each condition measure the impedance looking into the antenna feed, the received complex response to a known test source if possible, and the common-mode current on the outer conductor. Where the source is stable, repeat with the receiver disconnected

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and with a defined terminating load to expose cable pickup. The receiving chain is an experiment, not an immovable truth supplied by its calibration sticker.

Consider a deliberately idealised numerical example. If a far-field factor is 20 decibels per metre and the receiver observes 40 microvolts at its specified input, the conventional plane-wave estimate is 40 microvolts times ten to the power 20 over 20 per metre, or 400 microvolts per metre. This is only the inferred field under the assumed calibration configuration and loading; it is not a measured local field when the same probe stands two centimetres from a cabinet slot. Suppose the installed probe's response to the identical reference field becomes 6 decibels greater because of changed coupling. The voltage ratio is ten to the power 6 over 20, approximately 1.995. Blind use of the original antenna factor would then bias the inferred field almost twofold. The six-decibel change is hypothetical and must not be universalised as a property of all metal surfaces.

The experiment should distinguish random measurement variation from a changed measurand. Repeat displacements after a blind return to the original pose, photograph the cable path and measure the probe's electrical centre rather than merely the position of its handle. Include the source-off baseline and separate frequency-stable background signals from deliberate injected stimuli. A result that moves with the probe cable but not the sensing element demands an explanation in terms of feed currents or receiver coupling; a result that follows source polarisation may support the intended antenna-mode response. Neither result alone provides a unique source location. This is why I would require at least two independent

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perturbations whose predicted responses differ between the proposed explanations.

The final report must preserve the distinction between calibrated quantity and indicative response. It may say that the antenna detects a line under a named pose and that a known comparison signal produces a specified change when a conductive boundary is introduced. It may not turn that line into an absolute field strength, intercepted transmitter power or proof of absence elsewhere without the missing installation-specific transfer function and uncertainty. Far-field calibration remains a valuable traceability link, but it never removes the burden of proving how that link reaches the intended field geometry. I pass the token with that reservation.

Michael Faraday, Peer Question: Professor Maxwell, I ask how the investigator can tell whether a strong response obtained very close to a steel cabinet represents the originally calibrated receiving mode or a new circuit in which the cabinet and cable carry the return currents. The laboratory pattern may be known with considerable precision, but nearby conducting boundaries alter induced currents whilst the probe itself disturbs them. If the source can be controlled, which observable should be measured first, and what contrast will distinguish field redistribution from receiver-input mismatch? Please describe an experiment that does not assume one can separately measure an electric field without loading it, and specify how the physical placement of the measuring cable should be recorded. I am particularly concerned by the appeal of a single large response at a seam, which invites the observer to attribute the signal to a hidden source merely because the instrument pointer moves. How would you preserve the evidence whilst declining to overstate the mechanism?

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James Clerk Maxwell, Response: Mr. Faraday, the first distinction is between a port quantity and the spatial field that excites it. We can measure the antenna's input reflection coefficient in its far-field test configuration and again in the installed pose, using an appropriately calibrated network analyser and stable lead arrangement. A reproducible change in the port response establishes that an electrical boundary condition has changed. It does not by itself prove that the changed receiver output is caused by the mismatch, because the same cabinet may change the incident field at the sensing element. I would therefore retain a stable reference emitter and record both the source output and the receiving-chain response as complex quantities where practicable.

The second experiment changes the surroundings without moving the antenna. One may insert a removable reference plate at known distances from a safe test installation and compare the receiver amplitude, phase and impedance. In another trial, retain the plate but change the receiver cable route while measuring common-mode current. For each intervention, predict beforehand whether the direct antenna-mode response, the feed-current hypothesis and a source-drift hypothesis should be affected. If amplitude changes while the feed-current sensor and port impedance remain stable, scattering in the local illumination becomes more credible, though it is not uniquely established. If the receiver output tracks cable current, a common-mode contribution becomes a priority for further testing.

I would not claim to have measured an undisturbed field merely because the probe is small. The probe and its supports introduce materials and currents, and an adequate uncertainty statement includes their possible

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perturbations. Use at least two sensor architectures of different coupling sensitivity and preserve their calibration domains. Keep the same source monitor outside the geometry being altered, because an intervention that also changes source power invalidates a simple before-and-after comparison. Record coordinates relative to identifiable fixed marks, three-axis orientation, separation from the seam, cable photographs and the order of operations. A blind return to baseline provides a check against unnoticed movement.

The dramatic seam maximum is an observation, not yet an attribution. It may motivate closer inspection, but its evidential description should give the frequency, spectrum settings, measured port response and controlled contrasts. If the received power is diminished by a terminated-input test, note precisely what that eliminates and what it does not. A termination can reveal internal receiver artefacts, but it also removes the antenna and much of the feed network, so it cannot isolate every external coupling path. I would say that an installation-sensitive coupling route was observed, then describe the additional experiment needed to identify it. That restraint is a strength of the investigation rather than a weakness.

Heinrich Rudolf Hertz, Peer Question: Professor Maxwell, your explanation makes the region about a finite radiator rather more intricate than the familiar picture of energy streaming outward. I should like the moderator to require a numerical distinction rather than a slogan about near and far fields. An inspector has an antenna with a known aperture, a wave of declared frequency, and a measurement point a short distance from an enclosure. How should the commonly cited two-aperture-dimensions-squared-over-wavelength criterion be used, what does it fail to tell us, and

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why should the local field ratio not be set to the free-space plane-wave impedance? If a scan along a short straight line shows a sharp decay, does that prove a magnetic source? Please state the conditions under which distance exponents cease to be reliable, and how reflected waves, structural resonances and finite probe dimensions should influence a proposed test. Please distinguish a wavefront curvature test from a measurement of local reactive energy and retain the declared source size in the result.

James Clerk Maxwell, Response: Professor Hertz, let D be the largest relevant transverse dimension of an aperture in metres and lambda the free-space wavelength in metres. For a common aperture phase-error criterion, R_far is approximated by 2D squared divided by lambda. With D equal to 0.40 metre and lambda equal to 0.20 metre, R_far is 2 times 0.16 divided by 0.20, or 1.6 metres. The result is neither a safety boundary nor a comprehensive definition of field type. It tells us that a point only ten centimetres from the radiator does not meet that particular far-field phase criterion. A reflecting cabinet or another radiator of different dimension may impose additional requirements, and in a room the resultant field is not guaranteed to resemble a single outward wave even beyond 1.6 metres.

The impedance of a freely travelling plane wave is approximately the square root of permeability divided by permittivity, about 377 ohms in free space. That relation presupposes transverse propagating fields in a homogeneous medium, not every superposition near conductors. Close to an electrically small dipole, field terms decay with powers of distance and exhibit different phases; near a small loop, a different reactive term can dominate. One cannot infer from one measured voltage that the local electric and magnetic

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fields have the plane-wave ratio. A cabinet seam may support electric charge, conduction currents and a resonant slot field simultaneously.

A steep apparent decay is particularly ambiguous. A receiving probe has a finite spatial extent, so its output can integrate a nonuniform field rather than sample a point. A cable mode may change as the cable is repositioned during a scan. Reflected fields from nearby surfaces can produce interference minima whose local slope is steeper than any single source term. If a detector is logarithmic, saturating or noise-limited, the observed slope can be distorted again. I would require scans over several non-collinear paths, repeated orientation measurements, a fixed cable fixture and a separately monitored source before comparing observed slopes with theoretical predictions.

A good comparison involves both a known electric-dipole-like source and a known loop-like source under safe, controlled circumstances. Record complex response, not just the height of a spectrum peak, and compare the signatures of rotation and standoff. If the data fit several competing models within uncertainty, report non-identifiability. The equations do not authorise the investigator to choose the most picturesque model. They indicate precisely which extra field components or boundary changes must be measured before the inference becomes defensible.

Dr. James M. Atkinson, Moderator: Mr. Reber, I thank Professor Maxwell and pass you the token. Please test the theory against repeatable source-on, source-off and installation comparisons, taking account of room scattering and the field receiver itself.

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Grote Reber, Second Principal Contributor: Dr. Atkinson, I would start with a practical discomfort: a fine gain curve obtained under open-sky conditions does not tell a worker how an antenna behaves after being wedged between shelves, metal cabinets and bundled cords. In radio astronomy one learns quickly that the telescope is not the only object capable of modifying the received signal. Ground, feed, support, receiver and unwanted terrestrial transmissions create signatures that can resemble the sky. In an equipment room the same discipline must be compressed into a few metres, and the ground and structure are no longer distant nuisances. They are central parts of the coupling arrangement. What is missing from the far-field certificate is an installation experiment showing what the whole deployed receiving apparatus does.

I would insist first on a defined reference transmission that can be switched off. The reference need not mimic a covert emitter, and its purpose is not to prove that all clandestine signals would behave similarly. It supplies a controlled and repeatable comparison for the receiver chain. If possible, the radiating element should sit in several accessible positions, with its orientation and delivered power recorded, while an independent monitor establishes that the test source did not drift. The antenna under evaluation is moved through a documented set of survey poses. At every point the instrument records frequency, amplitude, detector setting, dwell interval and whether the antenna feed cable lies against metal. One ordinary receiver display cannot substitute for this record.

Now consider a dipole or broadband measurement antenna brought close to a conducting door. The induced current on the door produces a scattered field, and the combined field at the dipole is the vector sum of direct and

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scattered contributions. If the conductor also shifts the dipole's input impedance, the terminal voltage alters in two distinguishable ways: the illumination at the antenna changes, and the antenna's loading changes. Their effects can reinforce or cancel. Move the antenna a small distance and a deep minimum may vanish. A field technician who sees the minimum and declares the position quiet has confused a particular interference geometry with a negative search result. Rotate the dipole through orthogonal planes and repeat the measurement with a different antenna type before making an evidential conclusion.

The first quantitative trial should be deliberately modest. Place the controlled reference at a known frequency, collect the received voltage in three environments, and compute differences in decibels with the same matched receiver load. For example, suppose the measured levels are minus 70 dBm in the reference arrangement, minus 61 dBm beside a cabinet, and minus 77 dBm after a change of cable routing. The differences are plus 9 and minus 7 decibels relative to the first position, representing power ratios of about 7.94 and 0.20. These observations do not establish that the antenna's intrinsic gain improved or deteriorated by those amounts. They establish that the complete link changed. A separate impedance measurement and a reproducible boundary variation are required to allocate causation among antenna loading, scattering and common-mode pickup.

An antenna calibration typically describes a transfer function for a specified illumination and polarisation. Near an assembly, however, many possible fields reach the receiver by different routes. A coaxial cable may have unintended common-mode current even while its inner conductor transfers

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the desired differential signal. I would clamp a suitable current sensor around the complete cable, preserve calibration of that sensor, and compare its indication with the receiver peak while rearranging the cable through controlled, non-damaging routes. A ferrite or choke may be introduced as a diagnostic only when its own loss and impedance are independently established. If receiver output changes after that intervention, one cannot conclude that the original antenna factor was wrong. One can conclude that an omitted propagation or coupling path mattered.

I also prefer a comparison antenna of different electrical architecture, not merely a second example from the same production run. A small shielded loop and a short electric probe respond differently to field components and possess different unavoidable loading errors. Compare their patterns of change across a grid rather than demanding identical absolute values. Where they disagree, record the disagreement: it is often the most informative feature of the experiment. One probe may have insufficient cross-field rejection; another may be insensitive at the chosen frequency; both may disturb the field. The disagreement should prompt controlled orientation and standoff tests rather than dismissal of whichever detector is inconvenient.

The observer's habit of trying to draw a source location from a single maximum also deserves correction. A peak at a cabinet seam might be a local aperture current, an external signal entering the enclosure, a cable carrying common-mode energy, or a receiver artefact responsive to movement. One should first identify what moves with a source, what moves with the receiving instrument, and what survives replacement of the

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receiver input with a known termination. A good protocol randomises some repeated measurement order so that thermal drift and expectations do not masquerade as a spatial pattern. Multiple source-off and source-on trials expose intermittent background interference that a clean line drawing conceals.

Finally, I would preserve the negative findings as carefully as the dramatic peaks. A null is meaningful only within a recorded measurement threshold, an orientation, a frequency band, a dwell time and a geometry. The report should separate a calibrated far-field antenna factor from an empirically established installed-system response, and should state where neither is sufficient to infer an absolute electric-field value. A distant open-range certificate cannot describe every room. But a well-designed set of simple comparisons, repeated without theatrical interpretation, can make the local response credible enough to guide further forensic inquiry. That is the practical limit to which I would pass the token.

Arthur Edwin Kennelly, Peer Question: Mr. Reber, the use of a reference emitter is sensible, yet I question whether it demonstrates the sensitivity needed for a defensive surveillance search whose unknown emitter may couple mainly through a cable, aperture or near-field current loop. A test dipole situated a metre away can illuminate the antenna as a plane wave while the clandestine object of interest, if there be one, is centimetres from an equipment chassis. What legitimate conclusion follows when your calibration signal is detected in every corner? How would you select representative reference geometries without pretending that the set is exhaustive, and what role should an independent cable-current measurement play? I also ask how you would distinguish a reflection-

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induced pattern null from an receiver's own dead band, and whether a deliberately rotated source can correct a negative inference that was originally made with the receiving antenna fixed in one orientation. Include a falsification trial in which the reference signal remains constant while the sensing cable and receiving polarisation are changed separately.

Grote Reber, Response: Professor Kennelly, I would not regard successful detection of a single reference transmitter as validation of every plausible field coupling. It establishes that the chosen receive chain, at the chosen frequency and settings, could detect that particular known stimulus over the tested positions. The stronger and more useful result comes from a planned family of stimuli that differs in electrical size, polarisation and coupling arrangement. A low-power reference dipole, a small magnetic loop and a cable-current injection arrangement, used within authorised engineering limits, probe different susceptibilities. No finite family is exhaustive, and the report should call it a coverage experiment for specified hypotheses, not a certificate of absence for unspecified emitters.

The set of positions should follow actual access and expected survey difficulty. Include open space, near a large conductive plane, beside a slot or cable penetration, and within the cluttered interior of a rack where the instrument can safely be positioned. Keep the applied reference level under independent control and measure the receiving path's noise floor and linearity. The direct route and the cable route should be analysed separately when possible. A clamp measuring current over the complete coaxial bundle can flag unwanted common-mode energy, but its own transfer impedance and sensitivity must be known; a non-reading does not prove zero current

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below its threshold. In some cases it is more informative to reroute the cable under a fixed antenna pose than to add another source position.

A receiver dead band differs from an interference minimum in its response to movement. A fixed attenuated response over numerous source positions and polarisation trials invites investigation of front-end filters, overload and instrument settings. A spatial null that shifts when source or receive antenna geometry changes suggests vector cancellation or pattern effects, but a full source-off and terminated-input control is still needed to exclude receiver artefacts. One should also check whether automatic gain control or a tracking preselector has changed state between tests, because a reference tone can conceal a dynamic-range problem rather than reveal it.

I would use the resulting matrix to bound claims in plain language. For the tested orientations and reference classes, signals of the stated spectral occupancy and strength were detected above the chosen threshold at the documented positions. Any blind areas would be mapped with the actual antenna and cable geometry. A negative result for another class remains unproved, and no artificial percentage of comprehensive coverage should be advertised. Rotation of the source and sensor may close one particular polarisation blind spot, but it cannot establish sensitivity to all unknown structures. The distinction between a measured capability and an imagined guarantee is the central result.

Karl Guthe Jansky, Peer Question: Mr. Reber, it is possible to discover an unexpected signal by repeating observations, but repeated signals can arise from the receiving apparatus itself. Suppose an apparent narrowband source strengthens whenever the survey antenna is moved against a cabinet yet weakens when the same cabinet door is opened. The

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investigator might call this a concealed transmitter, whereas the receiver, oscillator or cable may be reacting to movement and contact. What order of isolation trials would you recommend that preserves the chain of custody and does not accidentally erase the very phenomenon under examination? Please address frequency stability, source-off observations, receiver substitution and the risk that an alternative antenna introduces new calibration errors. I am especially interested in how to record an apparently mobile spectral feature without reducing its entire history to one peak amplitude after the fact. What observation would lead you to abandon the external-source hypothesis despite the apparent correlation with the cabinet movement?

Grote Reber, Response: Mr. Jansky, the sequence should begin with documentation before intervention. Record the unaltered geometry photographically, noting the positions of doors, cable bundles, power feeds and the receiving instrument; retain time-stamped spectra or complex samples with frequency reference, span, resolution bandwidth, gain state and detector settings. If the instrument has a raw-data facility, preserve its output together with a cryptographic digest and a documented time source, whilst acknowledging any uncertainty in the clock. The source-off baseline, where safe and authorised, provides context but should not be imposed if switching power would disturb a critical system or destroy transient evidence.

Next carry out a receiver integrity trial that changes as little of the external geometry as possible. Compare the observed line with an independent receiver or instrument channel at the same nominal input connection, taking care that a splitter or switching device itself introduces loading and

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loss. A fixed input termination can reveal certain internal spurs, but it also changes cable loading and does not reproduce the original receiving boundary. Ideally retain the external antenna and cable while substituting a calibrated receiver through a defined low-reflection interface. If the line follows one receiver and not the other, the internal-instrument explanation gains weight, subject to differences in sensitivity and bandwidth. If both respond, neither the source location nor the antenna coupling mechanism is thereby proved.

Then reproduce the cabinet-door and antenna-pose interventions under monitored conditions. Randomise part of the observation order and return to the original geometry at intervals. Record frequency drift and phase behaviour independently of displayed power; a spectral line that shifts when the receiver temperature changes may reflect oscillator movement even if its amplitude also varies with nearby metal. Measure cable common-mode current during the same sequence. When a second antenna of different architecture is introduced, document its own calibration assumptions and compare relative patterns rather than assuming equal absolute antenna factor.

The conclusion is an evidence table with competing models. A real local field may be altered by the opening door; a cable mode may be altered in the same fashion; a receiver artefact may arise through mechanical stress or a shared reference clock. Separate each model's predicted response to source variation, receiver substitution, cable-routing change and polarisation reversal, then identify which observations reject or fail to reject it. Do not delete anomalous runs merely because they spoil a tidy story. A complete history of settings and geometries is often more probative than the

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apparently highest peak. The aim is a reproducible physical explanation, not merely an exciting attribution.

Dr. James M. Atkinson, Moderator: Professor Kraus, I now invite you to separate gain, effective aperture, antenna factor and impedance. Provide worked numbers and insist upon the geometric assumptions that make each equation legitimate.

John Daniel Kraus, Third Principal Contributor: Dr. Atkinson, I would distinguish three antenna descriptions that are often conflated. The first is a radiation pattern, which describes angular response under specified far-field conditions. The second is the port behaviour, including impedance, mismatch, balun performance and feed-current suppression. The third is the installed receiving transfer, which includes conductive structures, scattering, near-field polarisation and receiver coupling. A calibration of the first description does not automatically determine the second or third. The operator who multiplies a receiver voltage by a factor in decibels per metre without checking those conditions is making an inverse inference for which the data may be insufficient.

For a receiving antenna under plane-wave illumination, its available power can be related to the incident power flux density S in watts per square metre through an effective aperture A_e in square metres. Under the customary ideal assumptions P_available equals S multiplied by A_e, while effective aperture is lambda squared times gain G divided by four pi. Gain is dimensionless in this equation, lambda denotes wavelength in metres, and pi is the mathematical constant. The expression describes power available to an appropriately matched receiver from a plane wave of compatible polarisation. It must not be used as a universal formula for the power a little

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loop extracts from the reactive magnetic field of a current-carrying conductor inches away. In the latter situation the source and sensor can load one another and exchange non-propagating energy.

A worked far-field example clarifies both the use and the limitation. At a wavelength of 0.30 metre, corresponding in free space to approximately 1.0 gigahertz, suppose the antenna's linear gain is 2.0 in the direction and polarisation of interest. Then A_e equals 0.30 squared times 2 divided by 4 pi, approximately 0.0143 square metre. Under an assumed plane-wave flux density of one microwatt per square metre, the available power is about 14.3 nanowatts. If the receiver system is mismatched or the field is not a plane wave, that result is not the delivered input power. This example is a consistency check for dimensions, not an acceptance test for local enclosure measurements.

The antenna factor has a similarly precise domain. In one common definition the factor in decibels per metre is 20 log base ten of the ratio of electric field in volts per metre to receiver terminal voltage in volts, with a reciprocal-metre reference as appropriate. This logarithmic form is appropriate for an electric-field antenna under a specified test configuration. It is not a far-field conversion from every electrically sensed perturbation to a unique field vector. The relative orientation of the sensor and field enters through polarisation mismatch; the feed load enters through reflection; the test site's reflections enter through the illuminating field; and the mechanically nearby enclosure changes the boundary conditions. A certificate is evidence of how one of those arrangements was measured, not a blanket endorsement of all others.

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When the subject is physically near, the size of the test structure as well as the antenna matters. Take an aperture of characteristic dimension D equal to 0.50 metre, wavelength lambda equal to 0.10 metre, and a conventional phase-front criterion R at least 2D squared divided by lambda. This yields 5 metres. At R equal to 0.10 metre beside a rack, the usual large-aperture far-field condition clearly does not obtain. Yet the calculation does not identify the coupling as exclusively electric or magnetic, nor does it determine a universal safe or unsafe distance. It only shows that the premises for using a far-field approximation are doubtful in this illustrative geometry. Reflection, blockage and local currents still require observation.

A deployed calibration programme should record at least the reflection coefficient at the antenna port, a measured common-mode feed current, polarisation response for repeatable controlled sources, and spatial variability at anticipated standoffs. With a network analyser, measure S11 or the corresponding impedance whilst the antenna is in free space and when fixed at several distances from a conductive plate. The change in S11 does not directly equal the error in inferred field, because the incident field itself may change; nevertheless it proves that the receiving boundary has altered. Use a calibrated line and stable load when assessing gain errors, and do not conflate a cable loss correction with a near-field transfer correction.

One useful counterexample concerns the low-frequency loop. In the magnetoquasistatic regime a small loop of N turns and area A develops an ideal open-circuit emf proportional to angular frequency omega, magnetic permeability mu, effective loop area and the component of H normal to the loop. In magnitude, for a uniform sinusoidal field, V_open approximately equals N omega mu A H. At 100 kilohertz, one turn, area 1 square

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centimetre and H equal to 0.01 ampere per metre in free space, the magnitude is roughly 0.79 microvolt. This formula includes assumptions of electrically small area, uniform field and negligible loading. It is a very different calibration relation from a far-field electric antenna factor, and a screened loop with imperfect electrostatic rejection can violate the simple interpretation.

I would therefore publish two distinct outcomes. The first is the validated laboratory antenna calibration, retaining its frequency, direction, polarisation, loading and uncertainty. The second is an installation-specific evidence map of relative sensitivity, exclusion zones, cable susceptibility and measurable response to controlled field changes. An observation that survives tests with orthogonal sensors, reversed source polarisation, several standoffs and altered cable routes earns more confidence than an observation that merely agrees with the printed gain curve. Conversely, absence of a line after one orientation establishes no comprehensive absence of a signal. The correct technical report states what has been bounded and what remains unmeasured. I pass the token with a preference for dimensional consistency over impressive but unearned decibel precision.

Antony Hewish, Peer Question: Professor Kraus, your aperture calculation is rigorous under its stipulated incident plane wave, but a survey antenna is sometimes expected to recognise very short, faint or intermittent signals inside a screened room. In that setting the observer may rely on time averaging and the apparent narrowness of a spectral line to claim extraordinary sensitivity. How does an antenna factor interact with bandwidth, detector response and dwell time, and why is a threshold established for a continuous test carrier not automatically a threshold for a

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burst? Please give a numerical example in which the same available power produces a different apparent outcome under changed observation windows. I also ask whether an unknown polarisation and a changing antenna pattern in the installed environment should be represented as uncertainty, as a detection-coverage limitation, or as both when the investigator describes a negative finding. Indicate whether the observation windows were continuous or merely a sparse sequence of receiver dwells across the monitored band.

John Daniel Kraus, Response: Professor Hewish, antenna factor describes one transfer relationship between a defined field and port voltage. Detection probability is an additional receiver-and-observation problem. For a specified linear receiver the noise power in a measurement bandwidth B can be approximated by k T B multiplied by an appropriate linear receiver noise factor F, where k is Boltzmann's constant, T the reference temperature in kelvin and B the equivalent noise bandwidth in hertz. The term describes an idealised thermal-noise contribution and says nothing by itself about impulsive interference, overload, spurious tones or the spectral concentration of a particular modulation. Changing bandwidth and averaging alters the observed signal-to-noise behaviour even with identical antenna transfer.

Consider an illustrative emitter that transmits for ten milliseconds once per second, with its active-period available power otherwise fixed. If a receiver takes a ten-millisecond observation aligned with the burst, the signal may be visible. If it samples a ten-millisecond window at a random phase, the probability of any overlap between a uniformly random ten-millisecond acquisition and a ten-millisecond burst in a one-second period is about two

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percent; the chance of sufficient overlap for a reliable detection depends further on the detector and threshold. If the receiver instead averages power across a full second, the ideal duty-factor reduction in mean signal power is ten log base ten of 0.01, or minus 20 decibels relative to the active interval. No change in antenna factor is involved. The two observations can therefore disagree drastically without any contradiction in the electromagnetic calibration.

For an unknown source, polarisation loss and installed pattern nulls are not simply random scatter that may be averaged away. They may be persistent blind regions depending on source orientation and the conductive boundaries. A calibrated reference tone arriving in one polarisation can show a healthy signal margin while another polarisation is suppressed. I would map receiver response with controlled source and sensor rotations and report the response distribution over the measured set, without claiming that these finite trials determine the probability distribution of a hypothetical adversary's choices. The output can include quantitative uncertainties where the model and data support them, alongside explicitly unquantified coverage limitations.

Finally, the record must preserve time-domain information whenever the signal may be transient. Store timestamps, acquisition duty cycle, sample intervals, resolution bandwidth, detector modes and trigger rules, and check whether the instrument retunes during relevant bursts. A negative report should say that nothing above a stated criterion was recorded under those windows and poses, rather than that no emitter existed. Far-field gain and antenna factor alone cannot certify the listening schedule or the receiver's

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temporal completeness. Those are distinct layers of evidence requiring their own controls and limitations.

Dr. James M. Atkinson, Moderator: Mr. Heaviside, the token passes to you for the feeder and return-current problem. Explain why moving the cable may move the apparent radiation, and how an investigator can test the resulting alternative hypotheses without altering electrical protection.

Oliver Heaviside, Fourth Principal Contributor: Dr. Atkinson, the missing element is often the transmission system between the sensing metal and the receiver. Engineers speak of an antenna as though it ended at a connector and the cable simply transported its voltage. A current on the outer surface of a coaxial shield may carry another signal path; a bend near a cabinet may alter it; a balun may have finite impedance and frequency dependence; and a receiver's metallic case may complete a return route. In an enclosure these details can determine the whole result. The isolated far-field antenna curve says almost nothing about the magnitude of such unintended currents. An impressive factory certificate is therefore compatible with a thoroughly misleading installed measurement.

Begin with a simple source and two possible circuits. The desired circuit runs from the antenna through the intended differential feed into a properly terminated measuring instrument. The unintended circuit runs over the feed cable's external conductor, through the instrument body, capacitively or conductively to nearby metal and back through the surroundings. Both may be driven by the same ambient field, and the receiver may respond to their sum. The second is not necessarily a fault in the coaxial dielectric. It is a common-mode current path created by the complete geometry. Change the

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cable position and the effective receiving structure can become longer, shorter or resonant even when no one touches the antenna element itself.

One can make the effect measurable without pretending that it has a universally predictable magnitude. Establish a stationary reference emitter and an unaltered antenna position. Record the receiver output with the cable suspended along a reproducible reference path, then with the cable routed close to a conductive frame, then with the same cable moved away without changing the antenna position. At each trial measure the current surrounding the entire coaxial cross-section with a suitable calibrated sensor. Repeat in reverse order, because temperature drift and a changing ambient spectrum can otherwise manufacture a trend. The experiment must distinguish a physical feed-current change from mere movement of a noisy receiver connector. It should never require damaging or opening the protected installation.

A frequency-domain illustration helps. Suppose the cable outside-surface current is 2 milliamperes at one reference tone in configuration A and 0.5 milliampere in configuration B, with source output held constant. The current ratio is four, or 20 log base ten of four, about 12.04 decibels. If the receiver output simultaneously changes by ten decibels, the correlation invites examination, but it does not show that all ten decibels arise from the external current. We need phase-sensitive measurements or controlled choke experiments to separate the pathways, and we must assess whether the current probe itself loads the line. Correlation is a reason to test a mechanism, not an acceptable substitute for that test.

A simple impedance model shows why effects can be dramatic. The common-mode impedance can contain resistive, inductive and capacitive

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components, each varying with frequency and path geometry. At a chosen resonance the inductive and capacitive reactances may partly cancel, leaving a larger current for an applied excitation than in neighbouring bands. In a real enclosure the equivalent parameters depend on bonds, gaps and the placement of cables, and a lumped model can cease to describe the distributed structure. The operator should check measured phase, standing-wave response and repeatability rather than announce that every peak must be a resonance. The true source may itself be intermittent, and a receiver spur may move for reasons unrelated to antenna current.

There is also a methodological danger in adding a balun, ferrite or filter and calling the before-and-after comparison a field measurement. Such a component changes a boundary condition. It can usefully reveal an unintended coupling route but also change the desired signal transfer, noise and port match. Measure the insertion behaviour of the intervention or use an independently specified device, and report both the benefit and the new uncertainty. A ferrite placed at one cable point is not proof that no common-mode current flows elsewhere. In a system with multiple cables, common-mode currents may redistribute from one return path to another. A positive result must therefore be understood as a controlled intervention, not an absolute correction applied to all future configurations.

The electric field near a seam and the magnetic flux near a return conductor are not separate worlds. Boundary charges drive displacement currents, conduction currents create magnetic field, and the enclosure couples them through apertures and common return networks. This is why one can observe a peak with a nominal electric probe while a nominal magnetic probe also responds. An instrument may report volts at a connector; the

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inferred field quantity requires a validated response model. The 377-ohm plane-wave relation is inapplicable to an arbitrary local mixture of reactive fields. Drawing a neat diagram with a single arrow from hidden transmitter to receiving antenna may be aesthetically agreeable, but it can omit the actual route that carries the greater measured voltage.

My preferred acceptance test is a small matrix rather than a single correction constant. Change only one of antenna standoff, cable route, choke placement, reference polarisation or enclosure bond state at a time, while recording what was physically altered and what was independently monitored. Replicate the baseline after the matrix and use a second receiver chain where possible. Report which effects are stable enough to support a causal statement and which remain combined in the observed terminal voltage. The laboratory antenna factor is a reference for a defined wave; the deployed instrument is a circuit connected to its environment. Until those two descriptions are reconciled experimentally, the field estimate has no right to a spurious certainty. I pass the token to an analysis of uncertainty and measurement discipline.

Sir Edward Victor Appleton, Peer Question: Mr. Heaviside, I am concerned that the experiment may itself create or suppress the common-mode path it intends to identify. An instrument frame may be bonded to a rack, and a lead passing through a conductive aperture can acquire a different impedance after one loop is tightened or a ferrite is applied. What can a careful observer infer from a large change in the received spectrum after such an intervention? Please consider whether a clamp current probe can be trusted in the presence of nearby magnetic material, what the experiment means if several external cable paths share return current, and how phase

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information would assist. I would also value a precaution against turning an ordinary equipment-bonding test into an unsafe manipulation of protective earth, particularly where live systems or regulated installations cannot be disconnected for the convenience of the investigation. Please state precisely which power-system interventions must remain prohibited during a live survey, regardless of their apparent diagnostic convenience.

Oliver Heaviside, Response: Sir Edward, a changed spectrum after a choke, cable reroute or improved bond is evidence that the intervention has altered the receiving system. It does not, without controls, specify how much of the change arose from the targeted common-mode path. A ferrite may introduce differential loss in some arrangements, change source loading, affect nearby components or displace the cable physically. A bond can change the distribution of induced currents over several parallel metal paths. The correct conclusion is conditional: under a named change of topology, the measured terminal response changed. To assert a mechanism, we need at least one independent indication whose behaviour the model predicts.

A current sensor around the complete coaxial cable can provide such evidence, but only within its calibrated transfer impedance, frequency range and dynamic range. Its sensitivity may be affected by proximity to ferromagnetic material, its geometry and the observer's hand. Before inserting it into a tight enclosure, test the device on a controlled conductor at the relevant frequency and record the measured baseline at the actual standoff. Where several conductors return energy through separate structural paths, measuring one alone provides an incomplete current balance. Use multiple current measurements or a test circuit model that

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admits unobserved returns; it is not sensible to infer zero total common-mode current from a quiet reading on one branch.

Phase information can strengthen the causal comparison. If the received complex voltage and measured feed-current phasor change coherently when a cable route is altered, a coupled contribution is plausible. But because both may be excited by a common external field, coherent change is not sufficient proof. A second intervention that changes external cable current without materially changing the intended antenna mode would be needed, and one should estimate the uncertainty due to any probe loading or altered return path. The analysis may require a multiport model rather than a single correction in decibels.

Above all, do not remove protective earth or compromise bonding on an energised installation for a measurement demonstration. Use non-invasive variations where possible, and if a controlled bond change is scientifically indispensable, conduct it only on a safe de-energised laboratory surrogate under proper engineering authorisation. The fact that a forensic question is important does not license unsafe alteration of equipment. Preserve the original installation photographically, describe the surrogate's differences, and qualify any transfer of its result to the actual scene. That creates evidence without manufacturing a new electrical hazard.

Dr. James M. Atkinson, Moderator: Lord Rayleigh, please take the token and distinguish uncertainty in a calibrated quantity from model inadequacy after deployment, including the limits of negative evidential conclusions.

Lord Rayleigh, Fifth Principal Contributor: Dr. Atkinson, a measurement lacking a declared domain of applicability is an estimate whose uncertainty

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has not been fully named. The temptation is to preserve the uncertainty printed on the far-field calibration certificate and append nothing when an antenna enters a metal-filled room. Yet that certificate may have been obtained with excellent standards and great care, and still omit the dominating uncertainty of the new task. The calibration uncertainty concerns a particular measurand and arrangement. Installation effects, orientation, probe positioning, scattering and unknown excitation constitute other components, some of which are not well described by random variables. To claim the former certificate alone as the uncertainty of the latter observation is a category error.

I would first distinguish three kinds of uncertainty. Repeatability concerns the variation when the same operator repeats a nominally identical observation; calibration uncertainty concerns what was learned from references and their transfer; model inadequacy concerns whether the assumed relation between measured voltage and desired field is physically valid. A hundred readings at one fixed standoff may reduce the estimated random variance of their mean while leaving model inadequacy untouched. If the dominant concern is a cable-driven common-mode response, repeated observations with the same cable pose may exhibit extraordinary precision and very little accuracy for the desired electric-field quantity. The proper response is not to average more energetically. It is to change the experiment so that the omitted mechanism can be tested.

For clarity, define the measured complex receiver voltage as V, the desired field component as E, and the installed transfer as H_inst. In a locally linear representation we may write V equals H_inst multiplied by E plus an additive disturbance n. If the calibration supplies H_far, then the naive estimate

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E_hat equals V divided by H_far, whereas the physically appropriate local estimate would require H_inst and treatment of n. The fractional multiplicative error in a noiseless simplified case is H_inst divided by H_far minus one. This algebra is simple; the hard part is that H_inst may be unknown, frequency-dependent, direction-dependent and sensitive to the conducting surroundings. When multiple field components contribute, H_inst is better represented as a vector or matrix transfer rather than one scalar.

The following hypothetical example makes the distinction visible. Let a laboratory response coefficient be one millivolt per volt per metre for a specified plane wave. Let the deployed response become 0.6 millivolt per volt per metre under a nearby conducting boundary, while the actual field component is one volt per metre. Then the receiver observes 0.6 millivolt, and division by the laboratory coefficient estimates only 0.6 volt per metre. The error is minus 40 percent for this constructed case. If the perturbation is not measured, reporting a calibration uncertainty of plus or minus five percent would be misleading even if the certificate's five percent were perfectly justified under laboratory conditions. The numbers are illustrative, not a claim about typical antennas or enclosures.

A robust study needs repeated installations as well as repeated readings. Set out a grid of distances and orientations before examining the strongest peaks, and preserve a subset of locations as withheld confirmation points. Use both ascending and descending movement sequences; thermal or source drift otherwise may be confused with a spatial gradient. Observe deliberate source-off periods, and include a reference signal monitor that does not share the receiving cable under test. Mark each observation with

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its own uncertainty class. If reference power, position and angle are all measured, estimate their contributions through sensitivity coefficients where the measurement model is sufficiently reliable. If the model itself is unidentifiable, state that no combined numerical uncertainty can rescue the absolute field inference.

A common calculation combines independent standard uncertainties using the square root of the sum of squared sensitivity-weighted components. For example, in a hypothetical well-characterised local voltage model, suppose standard uncertainties expressed in decibels are 0.5 for the reference level, 0.8 for repeatable placement and 0.6 for the receiver response. If these components are independent and approximately small on the logarithmic scale, the root-sum-square is the square root of 0.25 plus 0.64 plus 0.36, approximately 1.12 decibels. That figure must not quietly absorb an unmeasured five-decibel geometry effect. Nor should a correlation between placement and cable routing be ignored merely to preserve a neat square-root expression. Correlated inputs require covariance terms or bounding studies.

The negative survey conclusion calls for even greater care. Failure to detect a particular known test source establishes information about sensitivity to that source under a finite set of environmental states. It does not establish the probability of detecting an unknown emitter unless its frequencies, powers, modulation, orientation, duty cycle and coupling pathways belong to a justified class. If those quantities are unconstrained, an unconditional claim of absence is scientifically indefensible. One can instead provide a bounded statement: the receiver reached a specified noise-limited threshold over a measured band, and controlled comparison emitters of declared

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properties were detected or missed in stated positions. The limitation is not embarrassing. It is what makes a forensic result interpretable.

I would close by requiring an explicit separation in the report between traceable values, field-dependent corrections and unquantified omissions. State the source type, reference antenna factor, loading, polarisation, geometry, bandwidth, detector, dwell time and actual cable route. Show the controlled contrasts rather than an edited map of highlights alone, and keep raw records for independent reanalysis. Where a model remains underdetermined, describe several compatible mechanisms and an experiment that could distinguish them. The scientific value of a negative finding lies in the narrowness and honesty of its stated conditions; the value of a positive finding lies in the reproducibility of its causal contrasts. I return the token to the moderator under those terms.

Sir Martin Ryle, Peer Question: Lord Rayleigh, a whole series of measurements can appear reassuringly precise while representing only one family of field geometries. Suppose an investigator calibrates a receiving antenna on an open range, repeats its factor many times, then surveys a room and reports a negative result with an uncertainty budget consisting entirely of calibration, receiver level and sample repeatability. What exact inferential error is present, and how should a publication present the uncertainty of the negative finding when the source distribution is not known? Please distinguish a conventional combined standard uncertainty from structural uncertainty about the measurement model. I also ask how a withheld validation geometry could detect overfitting to the observed strongest peaks, and what a reader should be told when a transfer-function perturbation is so large that no defensible absolute field conversion can be

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assigned. I ask that the report preserve the raw calibration certificate rather than silently replacing its stated uncertainty with a newly guessed installed value.

Lord Rayleigh, Response: Sir Martin, the inferential error is the substitution of precision under a conditional model for evidence that the model applies. A certificate may tightly constrain the antenna's response to a specified plane wave, and repeated voltage readings may precisely determine the receiver level, but neither operation constrains the unknown difference between a laboratory plane-wave response and an installed response to reactive or scattered fields. The missing term is not an obscure addition to a well-behaved variance. It may be a model-form uncertainty in which the very quantity being inferred is incompletely specified. Reporting the small laboratory uncertainty as the total uncertainty in the room would conceal that omission.

In a well-defined linear model, uncertainty propagation uses sensitivity coefficients and covariances: if y is a function of measured inputs x_i, the variance approximation includes the sum over pairs of the products of partial derivatives times input covariances. When inputs are independently measured and the linear approximation is adequate, the familiar root-sum-square expression follows. But an unobserved coupling coefficient or unknown source polarisation is not made measurable by assigning it an arbitrary Gaussian distribution. The report must distinguish quantified components from scenario bounds and from cases where no quantitative bound is available. It is better to present a family of conditional results than an invented single confidence interval.

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A withheld geometry tests whether the chosen explanatory model predicts an observation it did not help fit. One could construct an initial set of source positions, standoffs and cable routes, use those to estimate a limited installed response and then test another preselected combination without changing the model. If the resulting complex voltage or received level falls outside a predeclared prediction interval, the model needs revision. The exercise also exposes a selection bias: a model tuned to reproduce only the largest observed peak may fail systematically at quieter positions. Document the training and validation configurations, preserve negative observations and do not permit informal adjustment of the final model after seeing the withheld data without reporting that adjustment.

For a negative finding, the scientifically proper object may be an empirical detection-capability table, not a point estimate of absent radiated power. State the detected and missed reference signals by frequency, polarisation, modulation, location, dwell time and threshold, along with the denominator of trials. Without a justified population distribution for an unknown source, do not turn the proportion of laboratory trials into a probability that every possible covert device would have been seen. If installation-specific transfer has not been validated for an observed line, provide the receiver measurement and its environmental conditions without converting to absolute field strength. A reader can then assess exactly what is known, what is conditional and what has never been measured.

Dr. James M. Atkinson, Moderator: The five principal contributions have been heard and the seven ordinary interrogations answered. I now invite four cross-peer challenges, each addressed to a distinct expert other than the initiating speaker. The responses will follow each question immediately.

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The exchange must test the limits of the models rather than merely restate the same antenna-factor cautions.

Grote Reber, Cross-Peer Question to John Daniel Kraus: Professor Kraus, your aperture and gain equations properly delimit a plane-wave calculation, but an actual field survey can face an antenna whose nominal pattern changes whenever its feed passes beside a large structural member. Suppose a team concludes that a calibrated receiving antenna has retained its stated gain because S11 looks nearly unchanged after installation, although a controlled local reference field now produces a much smaller voltage. Does that observation falsify the laboratory gain measurement, or does it show that port matching is an insufficient proxy for receiving sensitivity? Please distinguish antenna impedance, embedded or installed radiation pattern, incident field strength and common-mode cable effects. I also ask what additional measurement would permit a credible quantitative correction rather than a merely qualitative warning, and whether the conventional reciprocity argument alone can guarantee that the local field is sampled as it would be in free space. The practical issue is not whether the instrument can display a number; it is whether that number retains a defensible measurand under conductive enclosure loading.

John Daniel Kraus, Cross-Peer Answer to Grote Reber: Mr. Reber, a nearly unchanged reflection coefficient establishes only that the port presents nearly the same impedance under the measurement conditions. It does not demonstrate that the antenna samples the same component of an external field or has the same spatial receiving pattern. A conductive structure can alter the distribution of fields and currents around the antenna while leaving a similar port match. Two arrangements can have comparable S11 and

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different gain, efficiency or sensitivity to a particular source direction. The observation therefore does not falsify the far-field result. It demonstrates that the premises for transporting that result to the installed setting have not been satisfied.

The appropriate language distinguishes port impedance Z_in, a far-field gain function G of frequency and direction, and the full installed voltage transfer. When the incident field consists of multiple angles or reactive components, the receiver voltage is the superposition of contributions weighted by vector effective-length response and the surrounding boundary. Common-mode cable currents may add a further pathway. Reciprocity applies to a passive linear reciprocal antenna system under specified boundary conditions; it does not assert that the system remains unchanged when placed beside metal. Nor does reciprocity turn an unknown near-field source into a known uniform plane wave. The installed system must be defined before a reciprocal transmission experiment can be compared meaningfully with reception.

For a quantitative correction, I would require a calibrated field or source geometry sufficiently representative of the intended installation, with known frequency, vector polarisation and location. Measure the receiver's complex response and the incident reference quantity, and map more than one position to test whether a single scalar correction can survive. Independently monitor source output, antenna port mismatch, cable current and receiver linearity. If the inferred correction varies strongly with source position, then an angular or spatially dependent transfer function is required. In the absence of that information, the best evidence is an installed relative-response map with conditional limits.

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The result should include explicit failure of proposed simplifications. An unchanged S11 is evidence against one explanation involving a large change in input match, but it is not evidence against scattering or a change in the antenna's embedded pattern. A different cable route may further alter the received response without changing the radiator. I would ask the investigator to report each measured contrast, preserve their phase conventions and avoid collapsing all effects into one number labelled antenna gain. A laboratory calibration need not be wrong to be inapplicable. It is the model connecting it to the field survey that needs additional validation.

John Daniel Kraus, Cross-Peer Question to Oliver Heaviside: Mr. Heaviside, suppose a cable choke lowers a suspicious narrowband peak by eight decibels but simultaneously increases the measured reflection coefficient of the sensing antenna. The investigator is tempted to announce that the eight-decibel reduction proves common-mode pickup and to subtract eight decibels from all earlier readings. Is that reasoning technically sound? Please give an alternative experimental arrangement that separates differential antenna reception from exterior feed current without violating the site's protective-bonding arrangements. I would also value your view on how a mechanical cable constraint, used to guarantee a repeatable receiving geometry, can be represented in the uncertainty budget. In a cramped rack the constraint may prevent some positions altogether; is the resulting blind area a calibration uncertainty or a geometric coverage limitation? Finally, explain why a choke specified at one test frequency may be an unreliable intervention at another frequency if cable resonance and multiple paths remain present. Does a stable port match at the receiving

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element ever suffice to validate the previously assumed vector effective length?

Oliver Heaviside, Cross-Peer Answer to John Daniel Kraus: Professor Kraus, that subtraction would be unjustified. The choke has changed an electrical network, not merely removed an unwanted voltage component of known amplitude and phase. It may suppress an exterior shield current while also changing the differential transfer or antenna match, and the eight-decibel receiver change is the sum of the resulting effects. Power levels expressed in decibels cannot generally be partitioned by simple subtraction when coherent voltage contributions interfere. The engineer must either measure the relevant complex components or construct controlled trials that isolate the pathways. A reduction after intervention is a useful clue, but it is not a calibration constant applicable to earlier unaltered observations.

A defensible alternative retains the sensor pose, source and receiver settings whilst measuring the antenna-port response and outer-conductor current independently. Use a calibrated current probe that encloses all conductors of the selected feed without breaking protective bonding, and perform the choke comparison on a laboratory surrogate first if its safety or system implications are uncertain. A second receiving path with a physically different feeder arrangement may reveal path dependence, provided its own transfer is measured. A current-suppression component can also be installed at several documented positions in a safe test chain to see whether a consistent causal pattern emerges. None of these tests presumes that an instrument case or earth conductor may be disconnected at convenience.

Repeatability fixtures deserve their own documentation. A jig may reduce random positional variation, yet it also constrains the accessible field

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geometry. Its material could perturb the field or make the cable route more stable than a normal survey. Measure its dimensions and, where material properties are relevant, test whether the jig changes the response. Uncertainty may include reproducible placement tolerance; positions the jig cannot reach are a coverage limitation rather than merely a small extra variance. The report must say plainly that those locations were not examined with that configuration.

Frequency dependence is essential. A ferrite choke's impedance has a dispersive resistive and reactive character, while a feed cable and nearby conductors exhibit distributed resonances. A component effective near one hundred megahertz may provide less suppression, or different phase effect, at a distant frequency. Parallel return routes can bypass the treated cable. Therefore the only generalisable result is a measured transfer under the stated frequency, route and termination. I would preserve the untreated baseline and all component data, and would refuse an across-the-board eight-decibel correction without a frequency- and geometry-resolved calibration model.

Oliver Heaviside, Cross-Peer Question to Lord Rayleigh: Lord Rayleigh, your warning about uncertainty is persuasive, but I suspect that an analyst can evade it by writing a large arbitrary uncertainty band around the field estimate while retaining the same unsupported antenna-factor conversion. At what point should the editor decline to print an absolute field-strength estimate rather than merely enlarge its error bars? Suppose the antenna factor certificate reports a fraction of a decibel, repeated placement trials scatter by two decibels, but controlled cable routes produce changes of twenty decibels at certain frequencies. Please separate the kinds of

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uncertainty that can be modelled statistically from the structural failure of a scalar transfer assumption, and give an operational decision rule for retaining or withdrawing the absolute conversion. I am also concerned about negative findings. How should the analyst present a thorough survey map when some coordinates cannot be reached without altering the geometry that makes the receiving system unreliable?

Lord Rayleigh, Cross-Peer Answer to Oliver Heaviside: Mr. Heaviside, an arbitrary uncertainty band is not a scientific remedy for an unvalidated relationship between observables and the claimed quantity. If a scalar antenna factor predicts a unique field value from the receiver voltage, yet the field estimate changes by twenty decibels when a physically relevant cable route changes, the model requires investigation before an absolute field can be printed. The change corresponds to a tenfold voltage ratio in a simple amplitude interpretation, far beyond the stated fraction-of-a-decibel calibration term. One cannot presume that the cable movement changes only the instrument, because the cable itself may scatter field, but the experiment demonstrates that the transfer is insufficiently stable for an unqualified scalar conversion.

Where a validated local transfer model exists and residual changes are random under specified repeatable conditions, components may be entered into an uncertainty budget. Where cable routing represents a finite set of deliberate environmental states, it may be more honest to report a range of conditional results than to assign a single normal distribution. Where the intended field component cannot be separated from common-mode or reactive coupling, the model is structurally unidentified, and numerical uncertainty in a derived absolute field has no well-established meaning. The

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value should then be withdrawn from the findings table, while the directly measured receiver voltage, frequency and settings remain available.

My operational rule has three requirements. First, a controlled source or reference field of known relevant type and orientation must establish a transfer in the intended deployment geometry. Second, the transfer must predict at least one withheld position or intervention within a predeclared tolerance compatible with the intended evidential use. Third, the dominant model components and their uncertainties must be bounded by measurements rather than assumed away. Failure of these requirements means the report may retain a qualitative or relative-response finding but should not give a confidently stated local field. This is a stricter rule than merely making error bars enormous, because it separates identifiable quantities from quantities not supported by the experiment.

For inaccessible coordinates, state the coverage explicitly. A diagram can distinguish physically surveyed points, points examined only in a modified geometry, and points not reached at all. Do not interpolate a uniform sensitivity between measured locations when the cable and enclosure effects are strongly discontinuous. A negative finding should refer only to the tested poses, sources and receiver thresholds, and should include the cases where a comparison source was missed. The most impressive map is not necessarily the most reliable; a map that visibly records its blank regions may be the stronger forensic record.

Lord Rayleigh, Cross-Peer Question to James Clerk Maxwell: Professor Maxwell, a final theoretical question concerns the widespread belief that a sufficiently careful far-field calibration must somehow contain all of the physics because the same electromagnetic equations govern the apparatus

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in every place. The governing equations are indeed general, but the boundary conditions and unknown excitations are not. How should a manuscript explain this apparent paradox without devaluing accurate standards? In particular, distinguish the equivalence of different external source configurations under limited observations from the uniqueness of a field solution when all boundary data are specified. Could a single receiver-voltage trace ever locate a near-field source uniquely, and what extra independent data would be required to sharpen the inverse problem? Please end with an explicit statement suitable for a technical surveillance countermeasures report: what exactly may be asserted after far-field antenna calibration has been transported into a steel-filled room without an installed transfer validation? I ask you also to distinguish deterministic field reconstruction from a probability distribution over unobserved candidate sources.

James Clerk Maxwell, Cross-Peer Answer to Lord Rayleigh: Lord Rayleigh, there is no paradox. Maxwell's equations govern each admissible physical arrangement, but a solution requires a specified geometry, materials, excitation and sufficient boundary or initial conditions. In a laboratory calibration the field arrangement is deliberately controlled, and the antenna's response is determined relative to that arrangement. In a metal-filled room some of the boundaries and source currents may be unknown, so the same equations admit many different configurations consistent with the observed receiver voltage. Generality of the equations is no guarantee that an investigator has supplied enough data to invert them uniquely. The weakness lies in the information available, not in electromagnetic theory or its metrological standards.

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A scalar voltage trace is a severely compressed observation of a vector field over space and time, filtered by the antenna and receiver. Different internal sources, cable currents and aperture currents can produce similar terminal spectra. Even with an exact receiver model, one measurement at one position usually cannot distinguish them, particularly when the frequencies or phases of independent sources are unknown. We must avoid an unqualified claim of mathematical impossibility for every specially constrained case: under strong prior restrictions a parameter may be identifiable from limited data. But the ordinary unknown-source enclosure survey does not supply those restrictions, and the burden belongs to anyone asserting a unique location.

To sharpen the inference, add observations that respond differently to rival models. Measurements at distinct positions and orientations with stable known probe transfer functions can provide spatial diversity; electric-sensitive and magnetic-sensitive probes can provide complementary coupling sensitivity; measurements of cable common-mode currents and antenna input impedance can expose unintended paths. Controlled source or boundary interventions supply causal diversity, while phase-resolved measurements may preserve distinctions lost in magnitude-only data. Even then the resulting inverse calculation must declare its assumed source class, boundary geometry, noise covariance and regularisation. A numerically precise point on a map can be the product of an aggressive assumption rather than a physical identification.

I would phrase the forensic conclusion as follows: the antenna possesses a documented response under its stated laboratory far-field calibration conditions, and a receiver response was observed in the installed enclosure

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under the recorded geometry. Without an independently validated local transfer model, that response does not establish a unique local electric field, magnetic field, radiated source power or emitter position. It may support further controlled testing, and its reproducibility can be reported, but the absence of a detected response does not prove an unrestricted absence of emissions. This language preserves the value of careful calibration whilst refusing to attribute to the certificate facts that were never measured.

Dr. James M. Atkinson, Moderator, Closing Synthesis: Far-field calibration supplies a traceable response under specified illumination, orientation, loading and uncertainty. It does not alone establish the spatially resolved installed receiving transfer when cabinet walls, cables, return currents, reactive source fields and instrument settings participate in the observation. The panel distinguishes plane-wave effective aperture and antenna factor from installed complex response; the opening calculation shows how an assumed 6 dB transfer change can almost double a displayed field estimate, and the later examples distinguish power ratios, geometrical phase criteria, reactive-loop emf and receiver duty-cycle limitations. The investigator should record free-space calibration separately from installed response, conduct controls with orthogonal source geometry and cable routing, verify receiver state and independently monitor known sources. Quantified uncertainty is justified only for a measurement model whose quantities are identifiable. Reproducible receiver peaks are not automatically emitters, and a negative survey remains bounded by actual bands, positions, orientations, thresholds and observation windows. No historical contributor is presented as having spoken these modern words. The next question examines how polarisation mismatch and pattern nulls qualify a negative result.

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QUESTION 063. VERIFIED BIBLIOGRAPHIC LOCATORS AND PROVENANCE LIMITATIONS

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Editorial qualifications: All named speakers are deceased historical people; their dialogic wording is a present-day fictional educational reconstruction. Contemporaneous scientific sources are supplied as bibliographic evidence and must not be treated as quotations from the named historical contributors. All numerical examples use hypothetical explicit assumptions. Stage B remains OPEN for independent historical identity checking, claim-level source review, mathematical review, semantic originality, forensic chain-of-custody review, and whole-volume layout and pagination proof.

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QUESTION 064

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How should polarisation mismatch and pattern nulls qualify a negative surveillance search?

HISTORICAL RECONSTRUCTION. The following scholarly panel is an explicitly fictional educational reconstruction featuring deceased scientists and engineers. Modern receiver controls, software-defined-radio systems, time-tagged spectrum capture and present-day measurement standards are applied by the contemporary editor; they are not claims about conversations actually held or equipment personally used by the historical contributors.

Dr. James M. Atkinson, Moderator: Professor Kraus, a technical countermeasures survey may detect no emission in an apparently clear band and nevertheless have learned very little about the presence or absence of a transmitter. Its antenna may be cross-polarised to the incident wave, turned toward a pattern null, or placed where enclosure reflections cancel the field. I ask you to specify what a negative spectral display proves, to distinguish polarisation from direction-dependent gain, and to design a defensible measurement protocol for an unknown signal whose frequency, bearing, waveform, power, and polarisation are not known beforehand.

John Daniel Kraus, Principal Contributor: Dr. Atkinson, a receiving antenna is not a neutral window through which every field arrives equally. It converts a particular component of an electromagnetic field, in a particular direction, at a particular frequency, into a terminal response. We must therefore begin with the measurand. A display reading below a selected threshold means that the specified receiver, antenna, orientation, gain state and observation period did not produce a qualifying response. It does not mean that the incident field was absent. A claim of absence is an inference over an

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assumed family of emitters and propagation conditions. The family must be declared, for otherwise the assertion cannot be tested or falsified.

For a plane wave travelling toward a calibrated antenna from direction Ω, the matched available received power may be idealised as $P_{av}=S\,A_e(\Omega,f)\,PLF$, where S is incident power flux density in watts per square metre, A_e the antenna effective aperture in square metres for the specified direction Ω and frequency f, and PLF the dimensionless polarisation-loss factor. This factor ranges from zero to one. I am suppressing mismatch, cable loss, source impedance and noise in this first expression; each re-enters the actual chain. The important point is multiplicative: a physically real source can be attenuated by polarisation mismatch and by angular response simultaneously. If either ideal factor vanishes, a perfectly operating receiver can display nothing. Instrument sensitivity does not remedy a geometrical zero.

When both the incident wave and the antenna are purely linearly polarised, and their electric-field axes differ by ψ, the ideal loss factor is $PLF=\cos^2\psi$. At ψ=0° the loss is zero decibels; at 45° the available power is halved, approximately −3.01 dB; at 60° one quarter remains, approximately −6.02 dB; and at 80° only about 0.0302 remains, or −15.2 dB. The ideal 90° result is zero, although practical cross-polar sensitivity, depolarisation, reflections and imperfect alignment often prevent an infinite real-world loss. The calculation presupposes a plane wave of known linear polarisation and the appropriate receive-polarisation definition. In a reactive near field there may be no single transverse travelling-wave polarisation to which this reduction can safely be applied.

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An antenna pattern introduces a different dependence. Let G_r(f,Ω,p) be its realised gain for an incident field state p under defined loading. A direction that is inside a main lobe may receive adequately, while an arrival from a side or rear null may receive 20 or 30 decibels less, depending on the actual instrument and environment. Pattern plots are normally measured under stated test conditions; their null depth is limited by fixtures, cable currents and nearby conducting objects. A single advertised 'omnidirectional' label cannot guarantee uniform gain in elevation, and often says little about polarisation or the pattern near a cabinet. Omnidirectional in azimuth does not mean isotropic in three dimensions, nor does an antenna factor remove geometrical blind spots.

To determine whether a negative search has evidential force, I would specify a coverage function C(f,Ω,p,r,t,s): frequency f, arrival direction Ω, polarisation state p, receiver position r, time t and receiver configuration s. It is not necessary to sample every mathematical value. It is necessary to show what range of variations was tested, how performance was established, and which regions remain unexamined. A survey may have complete frequency coverage but incomplete temporal coverage; it may have repeated temporal observations yet omit one polarisation; or it may have sensitive antennas at one position but leave spatial nulls unresolved. The matrix of coverage is the real object of assurance.

Consider an authorised test at 900 MHz in a furnished room. A reference source at a surveyed position provides a known low-level signal into a transmitter antenna whose polarisation can be rotated. Hold its output power fixed, rotate a linearly polarised receiving antenna through 0°, 30°, 45°, 60°, 75° and 90°, and record the raw power and noise floor without

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changing gain settings. Repeat at several positions and elevations. This experiment does not reproduce every unknown emission, but it measures actual sensitivity loss under deliberately varied orientations. A reference source that is thirty decibels above threshold in one pose may fall below it in another solely through changed coupling. A test that only rotates the receiving antenna without checking whether its cable and body alter the field may be deceptive; these collateral changes need recording and control.

I would add a second, differently polarised sensor, not as an automatic cure but as an independent test channel. Orthogonal linear channels can increase coverage of linear waves, but their effective phase, amplitude, noise figure and pattern must be understood; a pair with coincident angular nulls may still miss the source. A circularly polarised antenna can be comparatively insensitive to orientation of an incoming linearly polarised wave in an ideal plane-wave setting, but it sacrifices roughly three decibels of available power relative to a matched linear receiver, and it can suffer serious loss for a circular wave of opposite handedness. Thus diversity shifts the design trade-offs; it does not eliminate them.

The correct negative conclusion is bounded. One may say that no qualifying energy was detected above a stated threshold in specified frequency bands, during logged intervals, for the measured antenna configurations and verified source challenges. One cannot legitimately turn that statement into 'no transmitter is present' when polarisation, bearing, installation geometry or intermittent duty cycle remain unknown. The latter claim requires assumptions and evidence beyond an unremarkable screen. To be scientifically rigorous, a negative finding should name the experiment that could have exposed its own principal failure mechanisms, and retain the

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measurements establishing that those experiments were actually performed.

Oliver Heaviside, Peer Question: Professor Kraus, I should challenge the assumption that turning a sensor through ninety degrees alters only its response to the wave. A dipole attached to a coaxial cable is not an isolated geometrical object; the braid and perhaps the receiver enclosure can carry current that adds another receiving mode. When the technician rotates the handle, the lead commonly bends, changes its distance from nearby metal, and modifies its effective counterpoise. A striking minimum might then arise from currents on the measuring system instead of orthogonality between two freely propagating electric vectors. Can you describe an experiment that keeps the reference source and antenna electrical centre sufficiently stable to distinguish the intended linear-polarisation law from common-mode coupling, and specify what observations would invalidate a simple cos-squared interpretation? I also ask what can be claimed if the system lacks a calibrated current probe or a trustworthy complex phase record, because practical investigators frequently must work with ordinary amplitude-only instruments.

John Daniel Kraus, Response: Mr. Heaviside, your challenge is decisive because the ideal polarisation projection concerns a defined receiving mode and controlled reference plane. The coaxial shield may carry current as part of the antenna, and the instrument case can alter the return path. We should not infer the intrinsic polarisation factor merely from a hand-held amplitude trace. I would begin with a fixture that permits rotation about a repeatable axis through the sensor's electrical phase centre while holding cable strain and cable route constant as far as practical. The source must be

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independently monitored, and the receive settings frozen during each comparison. A source-off baseline at each pose is necessary because movement may change the instrument's own noise pickup.

A second set of measurements deliberately changes the suspect path. Keep the sensing element and its orientation fixed, reroute the cable through two documented positions, then introduce a suitable characterised common-mode choke or isolation arrangement under safe electrical conditions. Measure the shield current when an appropriate probe is available. If the nominal polarisation minimum shifts appreciably with cable dressing or choke configuration, the observed curve is a property of the combined antenna-cable-receiver structure, not merely a simple projection of a prescribed local field vector. Even if no current probe is available, the controlled sensitivity to cable path provides evidence that one ideal assumption is violated. The report should use that evidence rather than pretending the missing instrument existed.

A useful mathematical diagnostic is to model measured complex voltage as $V(\psi)=A\cos\psi+B(\psi)$, where $A\cos\psi$ is the ideal linearly polarised response and B is a parasitic contribution that can depend on pose. A finite amplitude at nominal orthogonality does not by itself tell us whether B represents intrinsic cross-polarisation, reflected-field coupling or cable current. In amplitude-only data, phases cannot generally be separated, and two different mechanisms can produce the same measured magnitude. Complex I/Q capture can improve identifiability if its reference and calibration are sound, but it also cannot restore a missing measurement of

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the parasitic path. At the conclusion, I would state the tested polarisation envelope under named cable arrangements, qualify the uncertainty and retain the raw spectra for independent review. A neat cos-squared fit is not a substitute for controlling the complete receiving system.

Arthur Edwin Kennelly, Peer Question: Professor Kraus, your use of effective aperture appears to make the propagation problem almost too orderly. An engineer performing a security survey near a wall, ceiling conduit or cable bundle may find neither a single plane-wave arrival direction nor a stable polarisation state. The antenna's response could be excited by multiple incoming rays whose phases change with position, or by electric and magnetic coupling that would not be characterised by the usual far-field calibration factor. Under those circumstances, what meaning can be given to the statement that the receiver 'covered the horizontal and vertical polarisations'? Would a two-channel antenna system actually observe every relevant field mode, or might both channels share a geometric null and a limitation of their reference-plane calibration? I would also ask how far the survey report ought to distinguish radiated power, a measured receiver voltage and a causal attribution to an unknown source, since those are often casually exchanged as though equivalent.

John Daniel Kraus, Response: Professor Kennelly, coverage of two declared polarisations is a statement about measured receiving modes under stipulated conditions, not a guarantee that all nearby electromagnetic coupling mechanisms have been tested. In the ideal transverse far-field model, two calibrated orthogonal linear receivers can span the transverse electric-field components in a given arrival direction. The model has no automatic authority over reactive sources or complex enclosures. There, one

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may need additional sensors, orientations and positions, and the quantities sensed by a short electric dipole and a magnetic loop may be fundamentally different. Even in the nominal far field, their angular patterns and installation losses require validation. The words 'horizontal and vertical' are incomplete unless they refer to a fixed coordinate frame and a declared range of directions and frequencies.

I would design two phases. In the first, use an independent reference antenna or calibrated field source in a known open measurement arrangement to check the polarisation response, gain variation and frequency dependence of both receiving channels. In the second, bring the arrangement into the actual installation, preserve the raw port signals, and challenge it with known polarisation and direction changes. A failure of transfer from the first domain to the second becomes an observed limitation. The objective is not to force the room response to resemble a free-space pattern, but to discover the important departures. A small movement or rotated reference source can expose a common angular blind spot even when the channels' axes differ by ninety degrees.

We should separate four propositions: energy is present in the field at a point; the receiving system produces a measurable terminal signal; the signal is assigned a frequency or waveform class; and an external source is attributed. Each implication requires additional evidence. A measured port voltage can be generated by fields arriving through the intended aperture, by common-mode currents, or by an internal receiver artefact. The numerical calculation of field strength from voltage requires an applicable

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antenna calibration and uncertainty budget. A source attribution may additionally require spatial, temporal or controlled-intervention evidence. If the chosen survey apparatus cannot distinguish those causes, it can still report its observations accurately by stating that a particular signal was or was not measured at its port. It cannot promote that statement into an omniscient assertion about every field in the enclosure.

Dr. James M. Atkinson, Moderator: Mr. Reber, Professor Kraus has separated directional sensitivity from polarisation response. Would you examine what happens when a survey antenna is carried through a cluttered room and a receiver appears to detect a source only from one posture or doorway? I am especially interested in how to recognise a true pattern null as distinct from standing-wave cancellation or disturbance created by the surveyor.

Grote Reber, Second Principal Contributor: Dr. Atkinson, a received level at one location is a compound result of source emission, intervening structure, antenna coupling and receiver state. In my judgment the practical mistake is to treat that one reading as a stable characteristic of the emitter. A surveyor who moves half a wavelength, changes the antenna tilt or alters the coaxial lead can experience a large apparent power change even when the remote transmitter remains unchanged. What matters is whether the change follows a reproducible spatial and polarisation dependence and whether the measuring apparatus itself participates in the effect. The observation must be mapped, not remembered as an impression.

At 900 MHz the free-space wavelength c/f is about 0.333 metre when c is approximated as 3.00×10^8 metres per second. A half wavelength is roughly 0.167 metre. A metal cabinet, a partition, a floor reflection and a cable rack may create fields that add or partially cancel over comparable distances. It

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follows that moving a receiving element by ten or fifteen centimetres may alter its level substantially. The exact result depends on path lengths, reflection coefficients and polarisation. One should not claim a 20 dB room fade from geometry alone without observing it; nonetheless, the wavelength establishes why a 'same room, same frequency' comparison is not necessarily a comparable electromagnetic configuration.

An ideal two-path calculation makes the issue explicit. Let a direct-wave phasor at the receiving element be E_0 and a reflected contribution be $\alpha E_0 \exp(j\varphi)$, where α is a dimensionless amplitude ratio and φ a phase difference. Then the total is $E=E_0[1+\alpha \exp(j\varphi)]$, and received power for an otherwise unchanged linear transfer is proportional to $|1+\alpha \exp(j\varphi)|^2$. If $\alpha=0.8$ and $\varphi=\pi$, the total field magnitude is only $0.2E_0$ and the corresponding power ratio is 0.04, approximately −14.0 dB relative to the direct-only reference. If $\varphi=0$, the magnitude is $1.8E_0$, giving a power ratio of 3.24, approximately +5.1 dB. These are stipulated examples, not room survey data. They show that a field minimum is not necessarily an antenna's intrinsic radiation-pattern null.

Polarisation becomes entangled with this geometry because a reflection can change the field vector and its relative phase. A vertically polarised source need not deliver a purely vertical field at every receive location after repeated interaction with furniture, ductwork, openings and oblique boundaries. If we rotate the antenna at one point, the maximum and minimum may reveal a locally dominant field orientation, not a permanent label attached to the emitter. An examiner should repeat the rotation in several spatial cells and at more than one height, taking care to preserve cable routing and the technician's position as independent variables.

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Movement that improves a response may be revealing the field geometry rather than discovering a new transmitter.

I would begin with a deliberately simple map. Mark a grid of survey points with repeatable position and height, then at each point record antenna azimuth, tilt, cable orientation, receiver attenuation, preselector and measured noise floor. Where two orthogonal receiving polarisations are available, record both at the same instant or in sufficiently adjacent intervals that source variation is controlled. A stationary test source is required to assess the map, but the source need not be intrusive: a permitted, low-power, known waveform can be injected or transmitted under site authority. Record its own output with an independent witness receiver. Without that independent witness, any level variation might merely reflect changes in the test source itself.

The operator should deliberately compare cases in which only one condition changes. First keep the receiving element fixed and rotate its polarisation, minimising any displacement of the electrical phase centre. Next keep polarisation fixed and translate the element to examine spatial fading. Next change elevation while documenting nearby reflectors. Finally modify the cable path or apply a suitable balun and look for unexpected changes; a signal that is sensitive to cable dressing may be entering on the outer conductor. If all variables are changed together, an increase in received power proves merely that the system changed. The scientific question is whether a reproducible causal explanation survives controlled interventions.

A room map requires both positive and negative observations. Store points at which the test signal was not found, the instrument's limit of detection at those points, the intervals inspected and the criteria by which a candidate

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was accepted. If a 900 MHz test signal is detectable at twenty-eight of thirty grid positions but missing at two, the correct statement is 28/30 for the tested conditions. It is not 93.3% probability of detecting every unknown transmitter, because the grid points are not necessarily random samples from all geometries, sources or waveforms. A careful map helps identify blind zones for further investigation without turning the sample fraction into an unsupported probability.

I would also vary frequency within a band using a source whose spectral output is established. The geometry of constructive and destructive interference changes with wavelength, and an antenna's own pattern changes with frequency. A probe that passes a challenge at one frequency cannot be certified by that trial for every other frequency. An operator may make a useful coarse initial sweep, but negative assurance over a band requires either a validated response model with uncertainty or sufficiently distributed challenge measurements. Similar reasoning applies to times: a continuous-carrier test does not establish capture probability for a millisecond burst within an intermittent waterfall or a switched preselector schedule.

If the reference source is seen through the room with one antenna but not another, retain the differential result and test whether the latter is truly less suitable for the unknown signal. The antenna with the stronger test response need not be the universally better survey sensor; its directivity might favour the calibration source's known bearing. Sometimes a second antenna whose pattern and polarisation differ provides a stronger diagnostic because it changes which blind spots matter. The purpose is not to collect the largest signal on one display, but to build a set of observations

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that withstand reasonable alternative explanations. The final report should therefore distinguish positional shadowing, polarisation mismatch, instrumentation limitations and the actual bounded absence of qualifying detections.

Karl Guthe Jansky, Peer Question: Mr. Reber, your room grid gives useful discipline, but I should ask how it avoids merely documenting one convenient moment. The surveyor might map several positions in a series lasting an hour, while the emission or the ambient interference changes during that hour. The first grid point would then be compared with the thirtieth under a different electromagnetic environment. Worse, a technician's body and the cable route may change as each point is visited, and the source used for calibration could drift. What sequence of measurements or fixed reference stations would allow the investigator to distinguish spatial nulls from temporal fluctuations? If a repeated grid produces a different pattern on the second pass, should one conclude that the room is unstable, the transmitter has changed, or the instrumentation is inadequate? I am concerned that a survey map may acquire an appearance of permanence which its acquisition chronology does not deserve.

Grote Reber, Response: Mr. Jansky, a room map is not an instantaneous photograph unless each measurement is genuinely simultaneous, and the distinction must be preserved. I would make at least one source monitor stationary and independent of the moving survey antenna, ideally using a receiving path whose gain and timing are stable over the observation interval. The test source should emit a known coded or otherwise distinguishable signal whose output is monitored at the source itself. Record a time tag for every grid observation and for the reference source's

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measured state. A difference between two grid points then becomes a comparison conditioned upon known changes in source output and ambient conditions. The grid is a time-indexed series, not a timeless field distribution.

I would alternate the acquisition order rather than merely walking a rectangular route once. On a second pass, visit the positions in reverse or a randomised order. Include frequent returns to an anchor point where the same receiving pose is restored. If the anchor level changes with time, temporal drift or a changed instrument condition is plausible; if the anchor remains stable while a particular position repeatedly produces a minimum, a spatial explanation becomes stronger. None of this uniquely isolates the mechanism, for even the anchor can sit in a frequency-dependent fade. A second independent source monitor and deliberate cable-path controls help narrow that uncertainty. The resulting record should display time and space as separate axes.

The observer's body deserves experimental attention. A human standing near a receiving element changes the boundary conditions and may shield, reflect or couple RF energy. Photograph or diagram the surveyor's position, use a nonconductive support where appropriate, and compare selected poses with the operator displaced. A cable suspended one way on the first pass and laid against a cabinet on the second introduces another uncontrolled change. The protocol should therefore include a repeatable fixture or at least a measured range of cable dressings. Where it cannot be controlled, note it explicitly as a limitation. A repeated spatial minimum under changed time order, source monitoring and constrained receiver

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geometry is stronger evidence than one aesthetically pleasing heat map, but it still does not guarantee that an unknown source at another frequency shares that minimum. We may claim only the reproducible response of the tested waveform under the conditions that were actually recorded.

Lord Rayleigh, Peer Question: Mr. Reber, the observations you describe may have numerous correlated uncertainties. At nearby grid points a shared reflection coefficient, antenna calibration error and receiver gain drift can influence all readings. If the examiner presents an interpolated contour map with apparently precise minima, how should that map's uncertainty be quantified? I would especially challenge the practice of measuring a sparse set of points, interpolating smoothly between them and then asserting that every location in a room was effectively searched. Is there a defensible connection between the spacing of a grid and the spatial frequency of the field variation, and can one infer such spacing from the free-space wavelength alone when the enclosure supports complicated modes? What should be done when the data indicate sharp fades that fall between measured positions, so that the strongest negative inference is driven by precisely the regions for which no observations exist?

Grote Reber, Response: Lord Rayleigh, interpolation is a hypothesis about spatial smoothness and measurement error, not an additional observation. An interpolated colour map can be useful to direct further measurements, but the values between data points are model predictions. Their credibility depends on a justified correlation length and sufficiently dense sampling, not merely on the graphic's appearance. In an ideal field comprising a limited family of propagating plane waves, wavelength gives guidance about the scale of interference. In a furnished enclosure the boundary geometry,

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reactive coupling and source positions may produce sharper changes; one cannot apply a universal half-wavelength spacing rule and declare the field fully sampled. A preliminary dense transect at representative frequencies can estimate the scale over which observed response changes, and this should inform subsequent grid design.

Uncertainty has several layers. Repeated measurements at one pose estimate short-term repeatability under that pose, but they do not include systematic errors in antenna calibration, polarisation orientation or cable interaction. A gain error common to every grid point cannot be reduced by averaging more positions. Likewise, source-power drift may induce apparent spatial trends when the positions were visited in order. A defensible analysis identifies these common and position-specific terms separately. If the final map shows a 15 dB minimum whose position moves after cable rerouting, that change is informative about the measurement system and must not be smoothed away. Report the measured values alongside any interpolated model and provide the spatial distribution of actual observation points.

An appropriate validation is to reserve a number of grid positions from the interpolation fit and then predict their response. Compare the withheld measurements with predictions and their intervals. Where prediction errors exceed the model's stated uncertainty, the map fails its own challenge and should not support a spatial coverage claim. Further measurements should be concentrated near steep gradients and unexplained minima. This procedure offers a practical distinction between describing the tested

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source's spatial response and claiming comprehensive observation of all room positions. The latter requires a specified source class and evidence that the coverage scheme is sensitive to its relevant field variations. A negative conclusion based on a few mapped sites should therefore identify the unresolved interstitial space, rather than hiding it under smooth contours and comforting colours.

Dr. James M. Atkinson, Moderator: Sir Martin Ryle, the discussion has moved from individual antenna response to a spatial sequence of observations. Could you explain how diversity and multi-position evidence affect a negative conclusion, and how the survey team should avoid mistaking a common instrument defect for independent corroboration?

Sir Martin Ryle, Third Principal Contributor: Dr. Atkinson, multiple receiving paths strengthen an inference only to the extent that they challenge different ways in which the inference could be wrong. Several identical antennas pointed in precisely the same direction, feeding receivers with a common attenuator setting, may repeat one blind spot. A second site or a second polarisation can be useful, but it does not add information by magic. The engineer should specify how the additional measurement differs, which uncertainty is reduced, and which shared dependencies remain. This is particularly necessary when the conclusion is negative, because the analyst is asking the absence of a detector response to bear the burden of a claim about an unobserved transmitter.

Let D_i be the event that receiver configuration i detects a known test waveform under a particular frequency, power, bearing, polarisation and time pattern. A crude argument might write $P(D_1 \text{ or } D_2)=1-[1-P(D_1)][1-P(D_2)]$. That expression assumes conditional independence of detection

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failures for the specified source class. It is invalid if both antennas share the same spectral null, both SDRs have the same dropped-sample interval, or the test emitter is simply off during both observations. The correct general expression is $P(D_1 \cup D_2)=P(D_1)+P(D_2)-P(D_1 \cap D_2)$. The intersection cannot be inferred from the two marginal probabilities alone without a dependence model or paired empirical observations.

In a hypothetical set of 100 controlled trials at one declared signal level, suppose a horizontal antenna detects 70, a vertical antenna detects 75, and both detect 55. The combined coverage is $70+75-55=90$ trials. These counts illustrate experimental arithmetic only. They are not an estimate for every signal in a room. The 90% combined trial success would be conditioned on the test design, imposed waveforms, positions, and reference-source variation. If the trials were all in one favourable direction, they could conceal a deep common null elsewhere. If the two channels shared the same local oscillator or host data path, their temporal failures might also be correlated. The raw paired outcomes are therefore more informative than the product of assumed independent failure probabilities.

One should separate simultaneous diversity from sequential diversity. Two co-sited antennas observed at the same instant can compare different polarisations while controlling for a transmitter's time variation. A single antenna rotated sequentially through two orientations can cover both settings over a longer period, but it cannot establish that an intermittent unknown source would have been active in both intervals. The sequential survey might systematically miss a burst whose duty cycle interacts with scan timing. It may still be useful as an initial survey, but its negative claim

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must describe the exposure window for each pose. Logging precise dwell time, switching latency and valid capture periods is essential.

Direction diversity has a corresponding difficulty. If the antenna presents a deep null toward a source at a particular azimuth and elevation, rotating only about the vertical axis may fail to expose an elevation null. A thorough examination varies both bearing and tilt while accounting for cable strain and body effects. For arrays, pattern synthesis and beamforming weights can intentionally introduce nulls; those zeros are not evidence that no external field exists. The survey should include a suitable wide-coverage channel alongside any high-gain beamformed channel, so that suppression created by spatial processing is not mistaken for absence from the physical environment. A raw-element recording can provide that independent perspective if the acquisition path is sound.

When combining evidence, retain calibration and uncertainty at the level of each channel. Let y_i denote a measured level and μ_i the expected mean under a specified source hypothesis. The joint distribution of y values depends on their covariance matrix, not solely on separate signal-to-noise ratios. Shared noise sources, frequency references, filtering or power supplies may create nonzero off-diagonal covariance. For a detection statistic formed by weighted combination, the weights must be justified by that covariance. If the underlying distribution is unknown, experimentally measured worst-case or bounded sensitivity may be more defensible than an apparently precise probability derived from an unjustified Gaussian model.

I recommend treating the survey as a set of challengeable hypotheses. One hypothesis is that a given emission class is present but polarisation-

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mismatched; another that it enters through an angular null; another that its burst escapes temporal coverage; another that the receiver is desensitised by a blocker. For each hypothesis specify an intervention expected to change the observation: orthogonal polarisation, changed spatial pose, time-continuous capture, different preselection, independent receive chain. A negative report that cannot distinguish these causes is not invalid as a record of what was not seen, but it is inadequate as assurance against the full hypothesis class.

A disciplined programme should choose a sensitivity envelope, not a heroic universal detector. For example, define a source class with frequency within a bounded band, minimum equivalent isotropically radiated power under declared geometry, duration exceeding a specified dwell, and either of two tested linear polarisations. State the frequency and spatial grid, tested instrument states, known reference limitations and environmental variability. Document the weakest detected challenge over all required conditions, and identify exclusions and blind spots. This is much more informative than claiming that every possible transmitter would have been found. Unknown signals have an effectively unbounded variety of modulation, directivity and propagation; a finite survey cannot eliminate that variety by simply multiplying the number of instruments.

The outcome should be expressed as calibrated evidence, not rhetoric. A multi-receiver absence can justify a narrower assurance statement when the combined observations have demonstrated that the tested source class would have been detected with the required probability or lower-bound margin under the tested conditions. It cannot support a categorical statement about all emitters without assumptions that make such a

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statement unfalsifiable. The aim is to make failures visible and confidence proportional to verified coverage. That remains the essential distinction between an engineering survey and a ceremonial inspection.

Sir Edward Victor Appleton, Peer Question: Sir Martin, you have proposed two receiving modes and an empirical dependence model, but atmospheric propagation and reflections can transform the polarisation of a signal between transmitter and receiver. Suppose a vertically polarised test signal is observed strongly in one channel on one day and predominantly in the other channel on another day, perhaps with an additional path delay or unexpected fading. How should the detection trial distinguish variability of the incoming field from instability of the receiving antenna, and how far can its conclusions be transferred to an unfamiliar emission whose propagation route and frequency are different? I would also ask whether a broad frequency sweep can legitimately borrow the polarisation calibration of one narrowband challenge. The direction and polarisation of arrival are often linked to frequency and propagation, so that a receiver which covers two orthogonal axes at one frequency may not have the same angular sensitivity elsewhere.

Sir Martin Ryle, Response: Sir Edward, the instrument should not be judged by pretending that the wave arriving at its site has a fixed polarisation merely because the transmitter's antenna was set to one orientation. The physical channel can rotate or mix polarisation components, whether through natural propagation or reflections near the receiver. A controlled source and a local reference receiver can help distinguish this variation from hardware drift, but only where their own response and calibration are understood. If the reference receiver shares the same local propagation

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changes, both may vary together, and that correlation must be interpreted rather than automatically attributed to transmitter power. Ideally retain complex simultaneous measurements of orthogonal field components, with a known basis, while separately recording the source state and antenna geometry.

To characterise frequency dependence, repeat the calibration at multiple frequencies and do not interpolate through an untested resonance or pattern null merely because the antenna is marketed as broadband. The frequency response of each polarisation channel includes not only the radiating element but its feed, matching network, cable and receiver filters. A device that is sufficiently sensitive at 450 MHz might be compromised at 900 MHz by a directional null or frequency-dependent cross-polar response. The survey needs a declared frequency grid informed by manufacturer data and representative on-site challenges. At frequencies where no direct tests were performed, the report should state the assumed interpolation model and retain the uncertainty caused by that assumption.

The same discipline applies to time. If a receiving channel reports a strong horizontal component at one time and a strong vertical component later, separate source variation, propagation variation, receiver state and changes of pose. A coded source monitor and fixed pilot path assist, but neither alone proves which physical mechanism caused the difference. Record orientation angles, local reflectors and atmospheric or operational conditions relevant to the chosen band. A second antenna installation some distance away can provide useful diversity, although its environmental

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channels will not be identical and its receiving mode must be independently verified. The question for a negative report is not whether the engineer can label the source 'vertical' or 'horizontal'. It is whether the actual arriving states that the survey was meant to detect fell within a measured sensitivity envelope at every material frequency and observation interval.

If the source class is unknown, that envelope may remain limited. One can strengthen it by demonstrating adequate receiver response to a deliberately diverse collection of polarisation and direction states, and by recording where the system fails. A result obtained on one frequency cannot automatically be transported to another band, nor can a laboratory calibration represent every propagation path in an office. This limitation should be an explicit finding, not an embarrassment concealed in an appendix.

Dr. James M. Atkinson, Moderator: Professor Maxwell, I invite the theoretical distinction between an idealised plane-wave polarisation factor and the field components actually found near enclosures, conductors, windows and wiring. What does your boundary-value analysis permit a surveyor to infer when an antenna orientation gives almost no received energy?

James Clerk Maxwell, Fourth Principal Contributor: Dr. Atkinson, the electromagnetic field is a vector solution of equations and boundary conditions, not a label that accompanies a transmission unchanged from its source. In a homogeneous far-field region a propagating plane wave has a transverse electric vector and associated magnetic vector, and a polarisation state can be represented by complex components with a conventional phase reference. Within a cluttered installation the field may be the superposition

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of many waves and reactive contributions, and the receiving antenna alters currents in nearby conductive boundaries. A null registered by one probe is therefore a null in that probe's transfer from the local field, not necessarily a vanishing of electromagnetic activity in the surrounding space.

In phasor notation a local receiving system can be described by a vector effective length $\ell_{eff}(f,\Omega)$ and an incident electric field $E(f,\Omega)$, producing an open-circuit voltage $V_{oc}=\ell_{eff}\cdot E$ under a specified reception convention, neglecting secondary coupling for the moment. When E is orthogonal in the relevant complex inner-product sense to the antenna's receiving mode, the dot product is zero. But the inference from terminal voltage to field magnitude requires knowledge of ℓ_{eff} and of the environment that determines the actual E. If the antenna carries unwanted outer-conductor current, or its supports couple to a cabinet, the effective receiving vector is changed by the installation. We must not infer the local field from a distant free-space pattern without checking the altered boundary conditions.

The familiar linear-linear loss $PLF=\cos^2\psi$ is a useful special case, not a full description of all polarisation behaviour. Elliptically polarised radiation requires both relative amplitude and phase of orthogonal components. An ideal circular wave projects equally onto two orthogonal linear axes, with each ideal receive channel capturing half the matched power. The handedness of circular polarisation matters when compared with a circular receiving mode, and opposite handedness can ideally cancel reception. But in an indoor environment a reflection can change polarisation state, and the antenna's axial ratio and cross-polarisation performance vary with direction and frequency. Consequently the survey should preserve complex channel

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responses where available, rather than compress every state into a single 'horizontal' or 'vertical' label.

An instructive representation is a two-component field vector $E=[E_x,E_y]^T$ in a declared transverse basis and a two-channel sensor matrix H. Then the measured complex voltages may be written $v=H E+n$, where n represents receiver noise and other error. If H has rank two and is sufficiently well conditioned under a valid propagation model, two calibrated channels may estimate two transverse components. If H has rank one, or its smallest singular value is very small, some field combinations are poorly observable or effectively invisible. A displayed absence can therefore reflect non-identifiability rather than absence of the underlying field. The example also shows why two sensors bearing different product labels are not necessarily independent modes; their actual response matrix must be measured.

For a simple idealised pair of linear sensors with equal sensitivities and relative orientation angle α, the measurement matrix can be written $H=[[1,0],[\cos \alpha,\sin \alpha]]$ after normalisation. Its determinant is $\sin \alpha$. At $\alpha=90°$, the modes are orthogonal and information is well distributed; as α tends to zero, the matrix becomes singular. In a real room the sensor responses are frequency- and pose-dependent, and their matrix may have important magnetic or common-mode contributions not captured here. Nevertheless the determinant illustrates the danger of using multiple nearly identical antenna states as if they observed different field components. More hardware can yield little new identifiability.

Boundaries complicate a supposed pattern null. A conducting enclosure can support currents that reradiate, and an aperture can couple to an internal field. The orientation of E at one point can change sharply over distances

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much less than the free-space wavelength if reactive and evanescent components are significant. In such a region one cannot straightforwardly infer an energy flux from $|E|^2/377$ ohms, since the ratio between electric and magnetic magnitudes need not equal the free-space impedance. This matters where a loop probe gives a response but an electric dipole does not, or conversely. Polarisation diversity of far-field antennas must not be confused with complete coverage of distinct near-field coupling mechanisms.

An adequate experimental method should first classify the region and probe function. Is the receiving element intended to measure an arriving radiated plane wave, an induced voltage along a conductor, or the local magnetic field near a current loop? Each has different calibrations and source hypotheses. For a far-field-oriented measurement use a calibrated reference emitter and vary controlled polarisation states; for an enclosed near-field investigation deploy validated electric and magnetic probes with known orientation and frequency behaviour. Observe whether the response follows the probe's sensing mode, the nearby cable geometry or a change in enclosing boundary. Do not call a field null a transmitter null without verifying the transfer through the relevant channel.

I would preserve both complex signal and geometric records: source polarisation when known, antenna orientation relative to an agreed coordinate frame, phase centres, relative amplitude and phase between channels, source-power monitoring, field reference planes and cable routing. If phase is not measurable, identify the resulting ambiguity. A loss of signal after rotating one sensor is compatible with several explanations: genuine polarisation orthogonality, antenna pattern loss, spatial

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interference, an altered loading condition or source intermittency. A well designed challenge changes only one of these at a time, and the subsequent inference should remain bounded to the models tested.

The most useful concluding distinction is between non-observation and non-existence. An electromagnetic field can be real yet lie in the measurement system's null space. Increasing receiver sensitivity within the same null space does not in principle restore information that the probe never couples into its terminals. Independent sensing modes, position changes and verified calibration can shrink that null space for a declared class of emissions. None of these operations establishes a universal absence over all modes, directions and times. The proper scientific report makes the sensor's limitations part of the proposition instead of treating them as inconvenient exceptions.

Herbert Kroemer, Peer Question: Professor Maxwell, your sensor-matrix model presumes that the observations represent the projected field plus some noise, but a practical receiver includes mixers, amplifiers, ADCs and digital processing that may introduce frequency-selective or amplitude-dependent response. One channel might be overloaded by a nearby strong signal even while the other remains linear; its reported 'absence' of the weak target would then be caused by front-end compression rather than polarisation. How should the investigator distinguish a physically inaccessible field component from a channel that has become temporarily incapable of representing it? Is it sufficient to calculate a matrix condition number from antenna patterns if those patterns were measured at low level and the real field includes a strong blocker? I would also ask how to preserve the logical separation between a mathematical observation null

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and the failure of a threshold detector to announce an otherwise measurable signal. Would you also require a source-off overload control, so that the asserted absence can be distinguished from a false negative produced by a desensitised analogue front end during the same interval?

James Clerk Maxwell, Response: Professor Kroemer, the linear sensor matrix is a conditional model and loses authority when the receiver ceases to operate linearly. A more faithful expression is v=F(H E+n,s), where F is the receiver transformation, potentially nonlinear or state-dependent, and s describes its attenuation, preselection, gain, ADC scaling and processing configuration. Under normal small-signal conditions F may approximate a calibrated linear operator. Under compression, clipping or desensitisation, a weak component may disappear from the reported output even if it couples well to the antenna. The system's apparent null could then be an instrument limitation rather than a property of the field geometry. The analyst should test linearity and overload independently from the polarisation experiment.

A safe laboratory method introduces the weak known signal through a calibrated coupler while varying a separate strong blocker within rated limits. For each polarisation pose, compare detected weak-signal amplitude and noise floor as the blocker changes, with attenuator and gain state retained. If the weak response improves when a calibrated attenuator is introduced upstream of a compressed stage, despite lower overall power at the receiver input, that counterintuitive outcome is evidence of overload. The test must identify the stage at which attenuation acts; adding loss downstream of an already compressed amplifier will not repair earlier intermodulation. Similarly, a display that shows no peak may be averaging a

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signal below a detector threshold even though the raw I/Q data contain a statistically recoverable component. Store raw samples where available and test the detector separately.

The singular-value argument remains useful only after its assumptions are tested. H should describe an empirically characterised linear receiving chain over a specified dynamic range, not a set of ideal antenna vectors lifted from a catalogue. A near-zero singular value indicates poor identifiability of some field combination within that model. It does not quantify missed detections created by false triggering, software decimation gaps or clipping unless those effects enter the model. If those conditions occur, declare a failed or inapplicable measurement interval rather than allowing an uncalibrated covariance matrix to hide the problem. Repeated calibration at several input amplitudes can establish a useful operating range, including its uncertainty.

For the legal and technical statement I would distinguish three forms of negative evidence: no field component coupled into the declared sensing mode above the physical detection limit; a component may have coupled but the receiver's transfer or saturation prevented faithful measurement; and a component may have been measured but failed the subsequent detection rule. These are not interchangeable. One can challenge them with controlled polarisation rotation, source-level variation, gain-state changes and alternate processing. The conclusion must report the result of each challenge, identify the intervals when the apparatus was qualified and avoid extending a negative finding through the intervals of suspected overload or

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data loss. That is how a theoretical observation model becomes an auditable measurement chain.

Dr. James M. Atkinson, Moderator: Professor Hewish, how ought the survey team convert this physics into an operational test that is reproducible by another group and capable of supporting a bounded negative finding? I ask you to address transient emission schedules, blind study design, and the difference between calibrated detection probability and an anecdotal successful challenge.

Antony Hewish, Fifth Principal Contributor: Dr. Atkinson, the practical task is to specify a signal population and measure the experiment's power to detect members of it. In astronomy we learned that a search method tuned to one temporal behaviour can miss another even when the receiving equipment performs faithfully. The same lesson applies here. An orientation sweep may detect a continuous calibration tone but miss a transmitter which emits for milliseconds at unpredictable times. A wideband capture may record the burst but suppress it in a detector that averages power over a long window. A receiver that finds one friendly test source has demonstrated one success; it has not proved comprehensive surveillance capability.

I would define a trial by its signal frequency, output power, antenna orientation, polarisation state, modulation class, duty cycle, duration, position, environmental configuration, and intended receiver threshold. Several axes may be sampled rather than explored exhaustively, but the sampling scheme should be documented before the data are examined. The observer should not be told where and when all test transmissions occur if operator expectation might change search behaviour. A separate test

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director can randomise transmission location or polarisation and retain an independent emission log. This is a controlled assurance experiment, not an attempt to simulate illicit activity or defeat legitimate surveillance.

Detection probability is conditional. If X describes the controlled source and environment and D is the event that the system issues a qualifying detection, P(D|X) may be estimated from repeated trials when the trials genuinely sample X according to a declared design. Suppose there are 95 correct detections in 100 independent, identically configured test opportunities. The point estimate is 0.95, but its uncertainty is not zero and its relevance does not extend beyond the tested source class. The same arithmetic cannot be used when all one hundred trials share a favourable orientation or one continuous waveform. Over-represented easy cases can manufacture an impressive percentage whilst leaving the difficult angular or polarisation configurations untouched.

A negative conclusion must also accommodate false positives and source variability. A low threshold might make the receiver sensitive but produce an intolerable number of unrelated detections; a high threshold may make the display clean at the cost of missed weak events. To characterise that trade-off, include source-off intervals, known-on intervals, signal strengths near the intended minimum detectable level, and genuinely independent observations of the source timing. Measure both detection probability and false-alarm occurrence under the instrument configuration actually deployed. A receiver that performs well in an empty laboratory may suffer overload or desensitisation when placed next to powerful legal transmitters. That condition should be challenged separately from polarisation and pattern loss.

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Temporal coverage should be calculated from valid acquisition intervals, not inferred from a display-refresh rate. Let T_{obs} be the nominal scheduled observation time and T_{valid} the union duration of intervals during which a particular frequency and antenna state were truly sampled with the required quality. The ratio $\eta = T_{valid}/T_{obs}$ describes duty coverage for that configuration. It is not generally the probability of detecting an unknown burst, since detection also depends on burst duration, timing distribution, threshold, receiver settling and possible repeat periodicity. For a cyclic scanning system, a source whose bursts are phase-locked to the system's blind intervals could be missed repeatedly. Randomising dwell schedules or maintaining a continuous witness channel can expose that vulnerability.

Spatial design should not merely maximise convenient coverage. Select poses at which the antenna's measured pattern suggests vulnerability, including directions near known nulls, locations near absorbing or conducting structures, and the orientation extremes of the polarisation response. Include a small number of randomly selected additional poses to challenge assumptions about room geometry. Ensure the calibration transmitter is monitored so that a weak response cannot be excused or blamed on an unknown variation of source output. Repeat a subset of trials on another day or after the receiving hardware has been disassembled and reconnected, because cable currents and accidental orientation changes can dominate what looked like a repeatable transfer function.

I would maintain a machine-readable event ledger. Each entry needs a test identifier, frequency, waveform, polarisation, antenna pointing, position, emission start and stop, receive hardware mode, filter settings, data-file pointer, source-off baseline, detector response and validation outcome.

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Failed and ambiguous trials remain visible. If the operator changes gain, retunes the receiver or substitutes an antenna, that change starts a new configuration interval. A negative result without that record can rarely support a strong inference because it is impossible to determine whether the receiver was looking at the relevant band and sensing mode when the event occurred.

At the end of testing, report a coverage table rather than a single assurance percentage. For each source class, state the lowest source level at which detection performance was assessed, the tested angular and polarisation ranges, the sample of room positions, the temporal window and the observed misses. Where plausible cases are outside the tested domain, mark them as unassessed. Where the confidence bound on detection is inadequate, say that the test did not establish the chosen assurance level; do not manufacture a larger trial count by pooling unlike conditions. The duty of the investigator is to explain what would have been detected under declared circumstances and what remains uncertain.

A carefully worded conclusion might be that no qualifying waveform was observed in the recorded intervals at a stated input-equivalent threshold, and that a calibrated set of horizontal, vertical and selected elliptical test waves was detected within defined positions and distances, subject to explicit exclusions. It would not say that the room was free of every possible transmitter. The latter language cannot be justified by a finite sample of orientations, frequencies and source geometries. The strongest negative statement is frequently the most carefully bounded one. It is informative because another engineer can reproduce and challenge it, not because it uses confident adjectives.

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William Redington Hewlett, Peer Question: Professor Hewish, I am persuaded by your detection ledger, but I should challenge whether its reported trials are genuinely independent and whether the testing operator has selected a favourable signal regime. A hundred bursts from the same antenna, injected at the same level and transmitted through the same room configuration, may reproduce one success rather than test a useful family of failures. Could you describe a practical acceptance procedure that exercises polarity, signal duration, antenna orientation, receive-gain state and sampling continuity without turning the test into an unmanageable combinatorial catalogue? How should the team decide in advance that a trial passes, particularly when the detection threshold is adjusted after seeing results? And what documentation would allow a second laboratory to reproduce failures where one antenna missed the source and the other found it only intermittently? Could the acceptance plan also document the number of valid acquisition opportunities in each polarisation stratum, including those which produced no decodable samples or whose reference signal was absent?

Antony Hewish, Response: Mr. Hewlett, the acceptance protocol should begin with predeclared performance claims and a design of experiments proportionate to the intended operating domain. The team need not enumerate every possible combination of frequency, polarisation, position, signal level and duration. It must identify the axes most likely to cause false negatives and deliberately sample their difficult boundaries. For example, a structured set of source polarisations could include horizontal, vertical, selected intermediate tilts and both circular senses where the hardware can generate them. Source duration should include values near the receiver's

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minimum qualified dwell or capture length. Position should include known angular nulls and multipath minima, not simply convenient line-of-sight points. The planned matrix should be recorded before the results arrive.

The detection rule is equally important. Define what constitutes a qualifying response: frequency agreement within a tolerance, a correlation threshold, a minimum signal-to-noise ratio, an event count or a visual classification carried out blind to the source schedule. Freeze that rule for the acceptance run. If adjustments are needed after failed trials, record those adjustments as development and repeat the acceptance set with fresh trials; otherwise the apparent success rate is biased by tuning to the observations already made. Separate detection trials from source-off controls, and retain the false alarms rather than discarding them as inconvenient. A detector whose threshold was selected to make the result look clean cannot be credited with the same measured detection probability as one tested under a predetermined decision rule.

I would stratify the trials by the major vulnerability dimensions. Within each stratum, repeat with more than one timing phase relative to the scanner, varied polarisation, and at least two source positions when geometry matters. A few full-factorial corner trials can expose interactions such as an orthogonal orientation combined with a burst that falls inside a retune transient. Randomised additional trials can challenge unseen interactions. The number of repetitions should be tied to the uncertainty acceptable for the declared assurance claim, rather than a customary round number. If misses occur, report their conditions and the extent to which they were

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reproduced. Do not pool them away under the success of easier cases.

For reproducibility, include the source and receiving hardware identification, waveform files or algorithm definitions, power calibration, antenna patterns or measured response envelope, source-position coordinates, receiver orientation, raw detection logs, timestamps and software version. Data acquisition failures should have their own state codes. A second laboratory can then reproduce the hard cases and determine whether differences arise from their environment, receiver configuration or the original test assumptions. Where results are environment-specific, that is itself a meaningful limitation. A final negative report should specify which source configurations have demonstrated sufficient detection power and which have not, not present a single success fraction that obscures the operational blind spots.

John Daniel Kraus, Cross-Peer Question to Grote Reber: Mr. Reber, your spatial mapping protocol treats antenna rotation and receiver translation as separable interventions, but I am concerned about a practical instance in which the antenna is close to a conducting door. Rotating the antenna changes both its polarisation axis and the coupling between its feed, the door and the surrounding cabling; the field it samples may also be a superposition of several differently polarised paths. How would you construct a falsifiable trial that distinguishes a true receiving-pattern null from a spatial cancellation without presuming in advance which one dominates? In particular, if the apparent minimum disappears after the antenna moves by a few centimetres, should that be interpreted as proof of multipath, or could the antenna's own current distribution have changed

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because of the nearby door? I ask you to identify the most informative record, not merely to recommend more measurements.

Grote Reber, Cross-Peer Answer to John Daniel Kraus: Professor Kraus, the disappearance of a minimum following a small displacement does not uniquely identify multipath, because moving a sensor near a boundary also changes its loading. I would therefore perform two complementary families of interventions. In the first, hold the antenna and feed geometry mechanically stable relative to one another, move the entire assembly along a measured path, and repeat the experiment with a documented source pose. In the second, keep the sensing element at the same spatial point while rotating it about a carefully controlled axis, attempting to leave nearby cable loops and conductive supports unchanged. Observe the terminal reflection coefficient or input impedance during both families, where appropriate. If the impedance changes strongly while the signal fades, the receiving structure itself is being altered and a simple free-space projection model is insufficient.

A third test exchanges the nearby environment. Insert a removable reference reflector or change the door position under a documented and authorised laboratory arrangement, keeping source and receiver settings fixed. Predict from a simplified multipath model how the phase and level might vary, then compare the observation. The reason for making a prediction before looking at the result is to avoid inventing a cause for whatever curve the instrument happens to draw. A phased observation is particularly useful: the sum of two coherent field contributions can change its complex phase across a cancellation point, while a pattern null may

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exhibit its own characteristic phase and impedance behaviour. Neither sign is individually decisive, but both constrain the competing explanations.

If the apparatus only provides power, record that limitation and undertake more repeated controlled movements. A minimum that follows antenna orientation across several widely separated locations suggests an intrinsic orientation-dependent response, while one fixed in physical space and moving with the reflecting boundary supports spatial interference. But both features can coexist, and the measurement must not be forced into one category. I would retain the original unaltered room observations, the source-output monitor, antenna pose, cable route, measured input impedance when available and every controlled intervention. Each record has a role: the source monitor excludes an emission change, pose records define the geometry, and impedance measurements challenge the assumption that the antenna's mode remained constant. The resulting negative statement would be limited to the coverage actually demonstrated, with residual coupled failure mechanisms explicitly noted.

Grote Reber, Cross-Peer Question to Sir Martin Ryle: Sir Martin, you have used paired detection trials to warn against assuming independence, but a practical survey often acquires different antenna polarisations sequentially because only one receiver and one technician are available. If a low-duty-cycle source happens to transmit during the horizontal interval but remains silent during the vertical interval, a difference in detection could be mistaken for polarisation. Yet adding a second simultaneous receiver might introduce correlated clocks, overload or shared cabling. How should one design an affordable experiment that separates temporal intermittency from

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polarisation mismatch without asserting independence that the equipment does not possess? I would welcome a precise account of what a stationary witness channel can contribute, what it cannot establish, and how repeated schedules should be organised to make systematic temporal blind spots visible. Finally, how would you prevent the calibration emitter itself from determining which antenna orientation was judged favourable, when the emitter cannot reproduce every possible bearing and polarisation of an unknown source?

Sir Martin Ryle, Cross-Peer Answer to Grote Reber: Mr. Reber, the economically constrained survey should preserve two distinctions: sequential observations cannot establish simultaneous polarisation state, and an added receiver is helpful only when its own errors are examined. A stationary reference channel can monitor source activity at a known position while the main antenna is rotated; its purpose is to establish whether a reference test emission occurred during each orientation interval. If the reference waveform is absent from the witness channel, the corresponding main-channel negative result has little evidential value for polarisation sensitivity. If it is present at a stable calibrated level, the main-channel result becomes a more meaningful measure of that orientation under the tested geometry. The witness does not, however, supply the polarisation or bearing of an unknown external emission solely through its presence.

For a laboratory test, schedule reference bursts at pseudorandom times known to an independent test director, and rotate the main antenna using an interleaved order such as horizontal, vertical, intermediate, vertical, horizontal. Repeat with the reverse order and different interval lengths.

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Record the valid observation windows, retuning and detector delays, and both hardware acquisition counters if available. A short burst falling wholly in a switching interval must remain a miss in the trial ledger. It should not be silently reassigned to an adjacent orientation. Randomising trial phase relative to any cyclic scanner helps expose a persistent blind schedule, but does not eliminate the need to demonstrate actual temporal coverage.

If only one receiver exists, one can still perform repeatable controlled trials against a fixed known source, then carefully distinguish results of separate source events. The trial may estimate conditional detection for each orientation when the source output was independently verified. It cannot claim that two orientations covered the same unknown millisecond burst unless both were observed simultaneously. That is an inherent limitation, not a software defect. For a more capable setup, add a second receiver with a characterised separate acquisition path and compare sources of common failure: power, reference frequency, preselection and data logging. Shared conditions do not make the second channel useless, but they must be included in the dependence analysis.

One should report the resulting trial table by source duration, relative phase and polarisation, not only as an average score. A system might pass 98 out of 100 long continuous-tone trials yet fail every 2 ms burst aligned with a switching interval. That failure is highly material even if its average percentage looks attractive. The proper assurance statement identifies the tested temporal and polarisation classes, demonstrates how a negative result was exposed to those challenges, and distinguishes remaining

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unobserved combinations. A constrained survey can be honest and scientifically useful without pretending it has acquired simultaneous evidence it never recorded.

Sir Martin Ryle, Cross-Peer Question to James Clerk Maxwell: Professor Maxwell, your two-component observation matrix has clarified the geometry, but I would challenge whether a condition number obtained from free-space calibration remains relevant inside a complex enclosure. The two sensor channels might have different antenna patterns in the room, and their responses to the same unknown emitter may be related by reflections and coupling. A matrix which appears full rank at one reference direction could become nearly singular at a different position or frequency. How would you determine which field states lie in the system's effective null space without measuring every impossible configuration, and where should the engineer place the boundary between a mathematically demonstrated limit and a practical empirical coverage statement? I also ask whether an unmeasured third field component or magnetic coupling can defeat claims based on two well-calibrated electric channels. Would a withheld configuration, not used to estimate the response matrix, provide a better independent challenge of the claimed coverage than further fitting of already measured source positions?

James Clerk Maxwell, Cross-Peer Answer to Sir Martin Ryle: Sir Martin, a matrix measured in one environment describes that environment or the domain in which an appropriate transfer model has been validated. It is not a universal property of the sensor. If the near-field installation introduces additional modes, we may need an augmented response H(f,r,Ω,s) whose columns represent the relevant field components and whose rows are the

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actual measured sensor channels. A two-row matrix cannot in general reconstruct more than two independent unknown components from one simultaneous observation, regardless of its numerical precision. The presence of unmeasured longitudinal electric or magnetic coupling means a negative report based only on two transverse channels must explicitly exclude those modes or demonstrate through separate tests why they are immaterial to the stated source class.

I would begin by measuring H for several controlled reference fields representing the relevant receiving modes, rather than claiming to identify every possible distribution. In an anechoic or other declared far-field calibration, vary polarisation, direction and frequency. In the intended enclosure, use safe known source arrangements and nearby electric and magnetic probes where justified. Compare predicted and observed channel responses, then construct a sensitivity envelope over the tested domain. Small singular values reveal poor identifiability within the chosen model, but they do not assign a probability to wholly unmodelled source states. It is therefore appropriate to report both the matrix's local conditioning and the empirical missed-detection cases discovered by the independent challenges.

The mathematical distinction between state reconstruction and detection must be retained. A sensor matrix may be poorly conditioned for reconstructing the exact field vector while still being capable of detecting that some nonzero field is present; conversely a noise-limited detector may fail even when the matrix is nonsingular. For a linear model with additive noise covariance R, the sensitivity of a test depends upon the signal

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projection into the noise-whitened measurement space. In principle, one can examine the smallest singular value of R^(-1/2)H for a specified field-state family. Such a calculation assumes that R is measured, stable and invertible on the retained channel space, and it cannot represent unknown receiver saturation or temporal gaps. It is a useful design diagnostic, not a guarantee of detection outside the model.

I would conclude with a two-part report. The theoretical portion identifies which field combinations are weakly observed under the calibrated response, with bounds and assumptions. The experimental portion records direct trials of source polarisation, position, orientation and duration, including misses and changes caused by the enclosure. The investigator should not invent a universal null-space proof from a few field samples, nor should the mathematics be omitted merely because empirical tests are easier to conduct. By preserving both views, one can say precisely which classes of negative result are strongly qualified and which remain unresolved because relevant field components were never tested.

James Clerk Maxwell, Cross-Peer Question to Antony Hewish: Professor Hewish, you have proposed controlled trials for detection probability, yet a statistical fraction acquired under one family of known test signals may be used politically or commercially as though it covered every form of concealed emission. Suppose the survey has repeatedly detected fixed polarisation reference bursts but the source of concern might have unknown elliptical polarisation, unknown burst duration and an antenna whose orientation cannot be predicted. What principle should determine whether the investigator may use a pooled detection percentage, rather

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than a separate lower-bound result for each vulnerability class? How should a confidence interval be interpreted when failures are clustered by position or source type, and what rule would prevent a series of successful easy trials from concealing a serious systematic blind spot in one untested polarisation and angular combination? Should the report distinguish a failure of detection due to uncertainty in the signal population from an outright failure of the instrument under a tested, independently monitored calibration stimulus?

Antony Hewish, Cross-Peer Answer to James Clerk Maxwell: Professor Maxwell, the principle is that the statistical estimand must match the claim. A detection percentage pooled across unlike source configurations estimates performance for the particular mixture actually used in the experiment. Unless that mixture has been justified as representative of the target signal population, the percentage is not an assurance against a source selected from a different mixture. For a defensive search, a worst-case or stratified sensitivity statement is often more useful than one overall mean. An examiner should define vulnerability strata by frequency, polarisation, angular pose, source level and temporal behaviour, then declare the minimum performance required for each relevant stratum. A single difficult stratum that produces systematic misses cannot be compensated scientifically by hundreds of easy observations elsewhere.

Clustering has two consequences. Trials performed at the same physical location or under the same cable arrangement may share an unmeasured cause of failure. Treating them as independent Bernoulli trials can make the confidence interval too narrow. A design with several distinct locations and

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repeated blocks across days can help expose this dependence, provided the block structure is retained in analysis. One can use conservative bounds or hierarchical modelling where the sample design supports it; one cannot conjure a universal confidence limit from a test containing no examples of a crucial source class. Zero observed misses is not proof of perfect detection, and a clean record must not be represented as an absence of risk when the trial lacks sufficient power to discover its failure modes.

An explicit pass rule helps. Before testing, declare the minimum detectable source level and a set of required configurations. Define what constitutes a valid trial and a detection; define how source-off false alarms and invalid receiver intervals are handled; and specify the number of independent challenge opportunities required to bound performance with acceptable uncertainty. If the equipment fails one critical stratum, record that as a failed acceptance condition even if the pooled mean passes. If an untested polarisation or direction could plausibly be material, mark it as outside scope and propose a specific test rather than assigning it the mean of the tested group. Such rules are especially important when the customer's expectation is 'nothing was found', because the client may otherwise confuse technical silence with demonstrated absence.

The report should also permit a reader to reconstruct the test. Preserve source coding and timestamps, survey positions, antenna angles, raw spectrum or I/Q files, decision-rule versions, and all missed or invalid trials. The original signal record must remain separate from later sensitivity analysis. If the analysis is updated, the revised results should be traceable to

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the same unchanged source data and an explicit modified model. This is not an obstacle to a useful assurance opinion; it is its foundation. One may confidently say that a declared set of emissions was detectable under the tested conditions while acknowledging that other source classes were not examined. The greatest methodological error would be a precise detection percentage whose denominator silently excludes the most consequential opportunities for failure.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel distinguishes the physical presence of electromagnetic energy from the transfer response of a particular receiving antenna, the receiver's ability to preserve that response, and the decision rule that declares a detection. The ideal linear polarisation factor $\cos^2\psi$ shows that an orientation mismatch alone can suppress measurable power; direction-dependent pattern nulls and indoor interference introduce additional blind spots. Multichannel observation can reduce, but not abolish, those vulnerabilities, particularly when channels share geometry, time gaps or instruments. A responsible negative survey must record calibrated polarisation and angular coverage, intentional orientation and position changes, appropriate electric and magnetic sensing modes, valid observation intervals, independent source challenges and the uncertainty of its detection criterion. The resulting statement is that no qualifying emission was observed within a defined and challenged detection envelope. It is never an unqualified claim that no unknown emitter could exist in the surveyed premises.

QUESTION 064. PRIMARY REFERENCES AND VERIFICATION STATUS

1. International Telecommunication Union, Handbook: Spectrum Monitoring, Supplement (2008), section 3.2, Monitoring and Measurement

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Antennas. https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-53-2008-OAS-PDF-E.pdf . The monitoring handbook discusses polarisation matching, antenna selection, directional and omnidirectional reception, and limitations of any one antenna type. Only those general claims are attributed to this publication.

2. National Telecommunications and Information Administration, Spectrum Management Technical Handbook, https://its.ntia.gov/umbraco/surface/download/publication?reportNumber=tn_89-2.pdf . Its antenna section provides a linear polarisation mismatch-power framework and explicitly states the application to received antenna power. No instrument-specific performance value has been imported from it.

3. National Institute of Standards and Technology, Josh Gordon and Benjamin Moser, “NIST’s Antenna Gain and Polarization Calibration Service Reinstatement,” Antenna Measurement Techniques Association (2023), https://www.nist.gov/publications/nists-antenna-gain-and-polarization-calibration-service-reinstatement . Supports the existence and metrological role of antenna gain and polarisation calibration; it does not certify the hypothetical equipment used in the examples.

4. NIST, Dennis G. Camell, “Uncertainty Assessment for Standard Antenna Measurements on the Open Area Test Site,” NIST Technical Note 1507 (1998), https://www.nist.gov/publications/uncertainty-assessment-standard-antenna-measurements-open-area-test-site . Supports the relevance of calibrated antenna factors, reference setups and explicit measurement uncertainty.

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5. International Telecommunication Union, Recommendation ITU-T K.60 (July 2023), https://www.itu.int/epublications/publication/itu-t-k-60-2023-07-emission-levels-and-test-methods-for-wireline-telecommunication-networks-to-minimize-electromagnetic-disturbance-of-radio-services . An application-specific emissions standard that demonstrates changing antenna direction, height and horizontal/vertical polarisation to determine a maximum. Its prescribed procedure must not be claimed as a universal requirement for every TSCM survey.

EDITORIAL QUALIFICATION: The roundtable exchanges are fictional scholarly reconstruction; all numbers, room maps, trials and signal examples are explicitly hypothetical. The numerical polarisation and interference examples are analytical derivations under stated simplifying assumptions. Every deployment-specific receiver and antenna claim must be tested against its actual installed configuration.

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QUESTION 065

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When do preselector switching transients corrupt a frequency-agile receiver?

HISTORICAL METHOD. The named contributors are deceased scholars and engineers. They are not represented as having personally used modern software-defined radios, FPGA capture systems or current spectrum-analyser models. Their documented physical and mathematical principles are applied by the present-day editor to a hypothetical lawful defensive measurement.

Dr. James M. Atkinson, Moderator: Professor Armstrong, a frequency-agile receiver changes its preselection state in order to suppress unwanted signals before conversion. A spectral burst that arrives immediately after a state change may be real, yet the switch, amplifier, local oscillator and digitiser may themselves create or obscure energy during that transition. What observable distinguishes a signal arriving from the antenna from a transient manufactured by a front end which is still changing its transfer function? Please develop a measurement model, identify where the valid sample window begins, and show why the receiver must disclose its state transitions as part of the forensic record.

Edwin Howard Armstrong, Principal Contributor: Dr. Atkinson, a receiver is a physical sequence of dependent operations, not a frequency label coupled to an immaculate mathematical transformation. The preselector is placed before a conversion or amplification stage so that unwanted energy may be rejected before it drives the apparatus into undesirable responses. This gain in selectivity comes at the cost of a switching or tuning process which itself changes the received waveform. A spectrum that appears bright or silent for

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a moment after tuning is therefore not automatically a property of the atmosphere. It may reflect a changing instrument. The proper question is what the receiver's transfer characteristics were at the precise instant represented by the acquired samples, rather than what frequency the operator had selected on a console.

For a receiver which remains in one settled state s, an approximate linear relation can be written $y_s(t)=h_s(t)*x(t)+n_s(t)$, where $x(t)$ is the input RF waveform at a declared antenna reference plane, $h_s(t)$ the equivalent linear impulse response for that fixed configuration, the asterisk denotes convolution and n_s represents the residual internal noise. This model is already conditional on amplitude, front-end linearity, coupling and frequency translation. During switching, the receiver becomes time varying. A more general relation $y(t)=\int h(t,\tau)x(t-\tau)d\tau+v_{sw}(t)+n(t)$ includes the changing impulse response and a possible control-induced component v_{sw} which can occur even with $x(t)=0$. The fact that an FFT of y contains a narrow or wide spectral component does not show which term produced it. A new filter state may reshape a real signal while generating a separate transient of its own.

Consider a three-band receiver which searches one band for eight milliseconds, changes to a second band, and returns later. A control packet may command the filter switch at time t_c, while the physical RF path reaches a reliable state only at t_c+T_g. If T_g is not measured, the first captured block can include mixed states. A burst of duration two milliseconds beginning at $t_c+0.2$ milliseconds could be completely lost if the receiver is blind for three milliseconds, or it could appear as a distorted residual if the switch passes a fraction of the burst during recovery. A

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spectrum formed from that block might show reduced amplitude, broadened modulation or a false isolated spur. None of those descriptions is an adequate account of the external signal unless the operator has separately characterised the transition.

The first experiment is a state-transition baseline with the RF input terminated at a proper impedance and with the same switching commands used during a real survey. Record raw complex samples, controller command timing, the hardware switch-select line, gain and oscillator states, any sample-overflow flags, and the analogue output if accessible without unsafe intrusion. A reproducible pulse tied to every switch event under termination is powerful evidence of an internally created component. It is not proof of the precise mechanism: feedthrough from a control line, bias recovery, an amplifier disturbance, local-oscillator settling and the digitiser's reference may all contribute. A probe inserted carelessly may alter the very circuit being examined, so the timing witness must be calibrated for its loading and latency.

The second experiment is a controlled known-signal challenge. Apply a continuous laboratory tone at a safe level in the destination passband, with its frequency and amplitude independently supervised. Repeat transitions between all relevant filter pairs. Plot amplitude and phase as functions of the elapsed time after physical switching, not merely after the software command. Where a switching artefact exists, repeat with the tone off. Next inject known short bursts at swept delays relative to the switching event. A genuine receiver should recover the specified burst parameters once its valid window has begun; a transition-limited receiver should make its blind

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interval explicit. Success for a continuous tone cannot be extrapolated to a short pulse whose energy may lie entirely inside the invalid window.

A frequency-agile receiver also includes a local oscillator which may be commanded alongside the filter. If the oscillator remains unsettled, conversion may translate the desired source to the wrong intermediate frequency or create an apparent chirp. If automatic gain control reacts to the new passband, a gain step may produce a broadband change or temporarily desensitise reception. If the digital downconverter is reset, it may change its phase origin. All these effects can coincide in the same millisecond. They must be challenged separately by holding the oscillator fixed while switching the filter, holding the filter state fixed while changing the oscillator, and replaying the same input with gain-control policies varied under documented laboratory constraints. Otherwise a repeatable burst tied to retuning remains merely a correlated event, not an attributed fault.

The validity criterion should specify a measurable error envelope rather than a vague word such as settled. If a laboratory calibration establishes that the recovered tone amplitude must lie within ±0.5 decibel of its steady-state value and phase within an application-defined tolerance, then the earliest sample index meeting those criteria for the required consecutive observation window may define a candidate valid start. Those numbers are illustrative; their adequacy depends on the target waveform and evidential use. A filter may reach amplitude tolerance before phase tolerance, or settle at one frequency and not another. The acceptance threshold must therefore be tested over relevant frequency, level, switching direction, temperature and loading. A status light indicating 'filter selected' is not the same as a measurement of the settled RF response.

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A forensic record needs three chronological layers: what the environment was capable of generating, what the receiver physically admitted, and what the processing subsequently displayed. Record state-change intervals as invalid or specially qualified, rather than silently interpolating the spectrum across them. Preserve the raw stream and explicit gaps; distinguish firmware blanking from absent acquisition; and expose the timing of every transition in the visualisation. If a narrow spike follows the filter-selection line under a terminated-input test, describe it as an instrument-related observation. If a candidate external burst persists with an independently settled receiver and changes appropriately with antenna substitution, the external hypothesis gains support. The two hypotheses may coexist, and the report should not force a false binary choice.

The broader engineering lesson is that preselection protects a receiver against one class of errors while introducing a new state variable that must be measured. The more rapidly one hops among bands, the greater the fraction of the schedule occupied by transitions unless the design has parallel, already settled paths. A sweep can be faster than the physics of its front end. This is not an argument against agility; it is an argument for a calibrated duty cycle, hardware-resolved state labels, challenge tests and conservative claims about what was observable. A receiver that records a transition honestly may provide stronger evidence than a faster receiver whose attractive waterfall quietly omits the period in which it was blind.

Grote Reber, Peer Question: Professor Armstrong, the first experiment you propose uses a terminated RF input to reveal a control-related waveform. Yet changing the antenna connection to a termination changes the impedance, removes the outer-conductor currents and may alter amplifier

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stability. A feature that disappears with termination might therefore be made by the receiver itself while depending upon the cable or a nearby antenna to complete its coupling path. How should a survey distinguish an actual exterior source from a switching artefact carried along the shield or re-entering the front end through the antenna? I ask particularly about the design of independent reference receivers, since two instruments in the same enclosure may share a power supply, control clock or ground network. What set of source-on, source-off and configuration changes would count as persuasive evidence, and how should the report describe a result which remains equivocal after these tests? The comparison should include changing shield-current paths deliberately, rather than assuming that one connector substitution has isolated the whole antenna circuit.

Edwin Howard Armstrong, Response: Mr. Reber, your objection is essential because the terminated-input experiment tests one boundary condition rather than the complete physical installation. A cable shield can carry common-mode current, and removal of that cable may stop internal energy from travelling to an unintended re-entry point. The investigator should therefore compare several distinct states: a calibrated termination at the receiver input; the operational antenna and feed line; the feed line terminated at its remote end; an electrically comparable reference lead arranged away from the suspected coupling path; and a second receiver with a genuinely independent reference and supply. Each state must be documented because a changed connector, load or physical route may alter more than one coupling mechanism.

The strongest test retains the switching command while changing the

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possible external RF source independently. Use a lawful known emitter whose on-off pattern is supervised at the source and, where practicable, observed by an independent instrument. If the suspicious transient follows the preselector command when that emitter is off, the internal hypothesis gains support. If a component follows source timing independently of the receiver's switching schedule, that is evidence of an external contribution, although receiver nonlinearities can still reshape it. Run the two schedules at deliberately different repetition periods, avoiding accidental synchronisation, and retain individual event times rather than averaging the results into an attractive composite waveform.

It is useful to put the second receiver on a different clock and a separate antenna, but one should also examine common environmental coupling. A transient associated with a power distribution fault can disturb both receivers, while one legitimate transmitter can be received by both. The purpose is not to insist upon abstract independence but to map the dependence and introduce interventions with discriminating predicted outcomes. The test can also measure current on the coaxial shield, provided the probe's bandwidth and loading are suitable; a transient current synchronous with switching helps identify a path even when the exact source within the receiver remains unresolved.

If the feature persists in some configurations and disappears in others without a unique causal account, the proper conclusion is bounded. Record that the observed energy is state dependent and that external and internal explanations have not been separated to the specified standard. It would be

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unsound to call the line evidence of a transmitter merely because an antenna was connected, or to deny any exterior possibility merely because a termination test sometimes removes it. A transparent table of conditions, time intervals, signal amplitudes and uncertainties is more scientifically valuable than a forced verdict.

Antony Hewish, Peer Question: Professor Armstrong, an intermittent emitter may transmit for only a few hundred microseconds at unpredictable times. Suppose a receiver visits ten frequency bands sequentially, and each change imposes an uncertain period during which the samples are invalid. The operator may calculate the percentage of nominal time allocated to each band and announce a probability of intercept, but the source could be synchronised, deliberately or accidentally, to the blind portion of the schedule. How should one quantify the observational coverage without assigning a convenient random arrival distribution which the evidence does not support? I am also concerned about whether a recorded FFT block after a switch can include contaminated earlier samples through overlap buffers, so that even the software's declaration of a valid block is mistaken. What exact records would be required to support a negative finding when the system hops faster than its front end can fully recover?

Edwin Howard Armstrong, Response: Dr. Hewish, begin with a deterministic map of valid acquisition, not with a probability. For each band b define V_b(t)=1 when that band is physically selected, settled under the relevant performance criteria, and captured without a known sample gap; set V_b(t)=0 when those conditions are unverified or fail. The integral of V_b over a declared period gives valid coverage time in that band. The nominal frequency-selection command alone does not define V_b. Its construction

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requires the measured transition timing, oscillator and gain states, the acquisition counter, and the processing support intervals which contribute to each derived datum.

A probability of detection requires an additional model of the source. If the emission start time were uniformly distributed relative to a periodic receiver schedule, and detection required a minimum uninterrupted overlap, one could calculate a model-specific probability from the geometry of valid intervals. But the words 'were uniformly distributed' must be prominent: deterministic or correlated emissions can evade those intervals repeatedly. For a regulated laboratory challenge, send known bursts at a grid of delays relative to switching and varied durations and powers. Plot successful detections by phase and duration, including misses and false alarms. This produces an empirical coverage surface rather than a solitary percentage claimed to apply to all unknown sources.

Processing support must be accounted for. A decimation filter uses several input samples to produce an output sample; an FFT window uses a finite span and may overlap its neighbours. An output time label can lie inside a nominally valid interval while the actual calculation includes older, invalid samples. State-dependent processing should either flush and reinitialise its memory with an explicitly documented loss interval or retain the state and compute the resulting contaminated support. The invalidity mark should propagate through the full support of every downstream operation. Otherwise a beautiful waterfall can be built partly from samples collected during a change of physical transfer function.

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A defensible negative conclusion is therefore confined to the measured class of signals and the measured valid windows. If only a fraction of a band was observed with sufficient time support, the report should not imply continuous monitoring. More importantly, when the emissions of concern may have timing correlations with the receiver schedule, the investigator should consider longer dwell, schedule randomisation under a documented protocol, overlapping receivers or continuous wideband capture. Each method has limitations and must be validated. The absence of a qualifying detection under an incomplete schedule remains an observation, not a proof that no relevant emission occurred.

Dr. James M. Atkinson, Moderator: Mr. Hewlett, Professor Armstrong has defined the transient as part of an evolving receiver transfer function. Please analyse the switching components and their bias circuits. I ask particularly how charge, relay movement, parasitic coupling and branch mismatch may put a pulse into the RF path without any external radio emission.

William Redington Hewlett, Second Principal Contributor: Dr. Atkinson, the switching element must be treated as a three-terminal or multi-terminal physical device with control energy as well as a nominal RF path. An electronic switch is not a perfect binary coefficient. Its semiconductor junctions possess capacitance, accumulated charge, voltage dependence and finite recovery. A mechanical switch contains contact movement, intermittent conduction and geometry which can change while the actuator operates. Bias networks contain inductors, resistors, capacitors and stored electrical energy. The measurement chain thus receives a controlled electrical disturbance at precisely the moment the instrument believes it is

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changing passive selection. Even where the signal input is terminated, the control circuit may inject a residual impulse into the measurement port.

One common mechanism is charge injection into a high-impedance or capacitively coupled path. If a control node changes voltage by ΔV across an effective coupling capacitance C_c, an ideal first approximation gives an injected charge $Q=C_c\Delta V$. For a hypothetical $C_c=0.5$ picofarad and $\Delta V=5$ volts, Q is 2.5 picocoulombs. If a simplified isolated capacitance of 10 picofarads were to receive that full charge, the immediate voltage increment would be 0.25 volt. The real circuit will distribute charge across impedances and cannot be evaluated from this crude two-capacitor example alone. The point is that very small capacitances can move enough charge to make a low-level measurement channel react. The actual peak and time course are governed by the driver impedance, package geometry, decoupling and the downstream transfer function.

A second mechanism is the recovery of a conducting device after its bias changes. The transition in RF insertion loss may not be synchronous with the electrical select command; on and off changes can exhibit different delays. An apparent duty cycle of ninety per cent at the logic port can correspond to less at the RF input if the relevant stage has a lengthy turn-on delay. Oscillation or ringing in bias leads may produce multiple effective changes of conduction even when the control word changes only once. The receiving operator must therefore measure at least the physical switch-control edge and the actual path response under a known RF challenge. A controller's assertion that the branch is selected establishes an intended command state, not the instantaneous RF attenuation or phase at its output.

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Mechanical switching introduces distinct risks. Contact bounce can produce a cluster of short interruptions; a time-domain display of the control coil might show one command while a properly monitored RF test tone shows several attenuation steps. Arcing under an unsuitable hot-switching condition may damage the part or generate broadband disturbance, and it is not an acceptable experiment to provoke unsafe arcs. The safer laboratory procedure follows equipment ratings, uses suitable load protection and records whether switching is specified for active RF power or requires a quiet interval. A reed or MEMS element may have excellent static loss and isolation and yet different closure, opening and residual feedthrough behaviour. These distinctions explain why static catalogue figures do not settle an acquisition-timing question.

A third mechanism is an imperfectly isolated branch. During transition, two filter paths may overlap briefly, or a break-before-make design may disconnect both. The temporary mismatch presented to a preceding low-noise amplifier can alter its gain, return loss, noise performance and stability; the following mixer may see a changing load. In a receiver containing strong ambient signals, even a brief reduction in preselection attenuation may allow a blocker to drive a nonlinear front end. The resulting recovery can outlast the switch event. A spur measured a millisecond later may thus be a nonlinear after-effect of a short overload, not a direct video feedthrough pulse. The experiment should deliberately vary the blocker level within safe limits to determine whether recovery depends on incident RF energy.

For characterisation, build a table across source and destination branch pairs rather than test only one direction. The transition from a low-

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frequency low-pass path to a high-frequency bandpass path may differ from the reverse, and a bypass state may behave differently again. Each pair should be challenged with no RF source, a low-level reference in the intended band, and a controlled off-band blocker, where the receiver ratings and laboratory authority permit. Record the output waveform, zero-input feedthrough, phase step, amplitude settling and eventual noise floor. The operational constraint is not merely 'switching time'; it is time until the full chain meets all defined measurement tolerances after every relevant state change.

A practical acceptance definition might use the earliest time T_{valid} such that an amplitude error $|A(t)-A_{ref}|$ remains below ε_A and phase error $|\varphi(t)-\varphi_{ref}|$ remains below ε_φ for a contiguous confirmation interval T_{hold}, with a separate requirement that the device reports no overload or acquisition gap. The tolerances ε_A and ε_φ, the held confirmation duration, and the calibration source's uncertainty are all stated variables. A crossing of the tolerance for one sample is insufficient if the response subsequently rings back outside it. For signals carrying digital modulation, error-vector magnitude or recovered symbol timing may matter more than steady-tone phase. For detection of weak pulses, the essential performance may be probability of capture under an explicitly specified burst timing distribution.

The design remedies have costs. Slowing the control edge may reduce high-frequency feedthrough yet lengthen the blind interval. Additional filtering can attenuate the control disturbance but introduce group delay and ringing. A parallel-path arrangement allows one branch to settle before selecting it, at the cost of more hardware, switching interfaces and possible common power disturbance. A resistor or isolator can improve matching but

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sacrifices sensitivity. The correct choice is therefore not the fastest component on paper; it is the architecture whose actual measured performance satisfies the mission's selectivity, sensitivity, noise, dynamic range and temporal coverage simultaneously.

I would require the report to state whether the artefact is observed at the input, switch output, mixer output, ADC stream or only after software processing, and how the investigators separated those stages. If the physical device was not accessible, the report must say so and restrict its attribution to the path which was genuinely tested. A small pulse seen under termination is evidence that the measuring system can generate energy during switching, not proof that every spectral feature near switching is internal. Conversely, a pulse measured only with the antenna connected is not necessarily external; cable currents and changed impedance can couple control disturbances through paths absent under a simple termination. An adequate investigation uses alternative configurations until the causal inference is supported or its uncertainty is explicit.

John Daniel Kraus, Peer Question: Mr. Hewlett, your account of switching charge and branch mismatch raises a calibration problem. A preselector's static passband may be measured with a continuous reference tone, yet an RF survey must identify short, wideband events at the edges of adjacent bands. How should the acceptance test distinguish an insertion-loss shift from phase distortion and from a transient produced by changed return loss? The same switch may be driven at very different rates, and the surrounding cable or amplifier impedance can change with installation. Would you calibrate each band independently or every possible transition between bands, and what experimental reduction is permissible when there

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are too many transitions to test exhaustively? I would also ask how the test avoids mistaking a stronger artefact for proof of greater receiver sensitivity near a marginal real signal. Please also specify how the chosen transient challenge will avoid overdriving the preselector and thereby manufacture an overload artefact which would not occur at the expected source level.

William Redington Hewlett, Response: Professor Kraus, calibrating only the final steady passband is necessary but not sufficient. The intended observable must be defined for the waveform. For a narrow continuous carrier, amplitude flatness and phase after the full settle interval may be sufficient. For a brief wideband burst, the measurement may depend upon impulse response, group delay, time-varying gain and how the detector chooses its event timestamp. A static scalar insertion-loss correction cannot account for every one of those effects. I would retain two families of test stimuli: controlled single tones spread across the passband, and a bounded wideband waveform with a well-characterised timing feature. The second family reveals distortions hidden by a single-tone calibration.

A comprehensive transition matrix can be large, but reduction must be based on physical architecture, not convenience. If several band selections share the same switching element and bias driver, their transition behaviour may belong to one experimentally justified equivalence class. Conversely, paths that employ different relays, filter resonators, bias voltages or amplifier loads should not be silently grouped. Characterise representative transitions, including the worst expected switching direction and operating temperature, and verify that omitted states conform to the proposed class. If that assumption cannot be substantiated, state that those transitions

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remain unqualified. A receiver may have a reliable forward transition and a slower reverse transition because its residual internal energy differs.

Return loss can alter more than available power. A changing source impedance can modify an amplifier's effective noise matching or lead a mixer to generate a different response under a nearby blocker. Measure reflection where practical and challenge the receiver with a tone and a controlled blocker, first at safe levels and then near the intended operating range. Separate the purely switch-induced disturbance seen under termination from the additional nonlinear or load-sensitive response when a blocker is present. Those effects may have different recovery times. If the apparent transient grows when a strong off-band signal is introduced, that observation is useful but does not itself prove a single mechanism; the causal experiment must separate overload and reflected-power changes.

A stronger transient should never be counted as improved sensitivity. Receiver sensitivity is established by a calibrated input signal and a declared detection or measurement criterion at a known false-alarm level. A switch pulse which raises the display can create the illusion that the receiver is more responsive, while increasing false alarms and masking weaker true events. The acceptance report should compare source-present and source-absent trials with the same state schedules and thresholds. It should preserve raw, time-tagged measurements rather than only an aggregate success percentage. Through such controls, each proposed transition class can be assessed against performance requirements instead of against an attractive but misleading spectrum trace.

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Lord Rayleigh, Peer Question: Mr. Hewlett, I am troubled by the temptation to turn one very rapid oscilloscope trace into a universal switching-time specification. A current pulse, a transmitted reference tone and the filtered detector output can have markedly different characteristic times, while a low-level signal may be overwhelmed by the noise of the apparatus. Which quantity should define the end of the transition, and can it be estimated as a scalar for every practical use? If an instrument's switch appears complete within microseconds, but the downstream gain recovery occupies milliseconds, does the specification of the switching device have any evidential force for the receiver as a whole? Please also explain what an uncertainty budget should do when the test signal has a fixed amplitude but the signals in the intended survey may be weaker, stronger or modulated differently. What minimum observation duration would make a declaration of settled response credible when a damped oscillation can briefly cross the tolerance band and then leave it again?

William Redington Hewlett, Response: Lord Rayleigh, the word switching-time must be tied to the measured node, transition criterion and stimulus. A switch vendor may define control-to-RF 10–90 per-cent time under a specified load. That is a legitimate component property under those conditions. It is not the time until a receiver's final sample is suitable for a forensic inference. The end of a transition at the system level can only be defined relative to all the metrics relevant to the intended measurement: amplitude error, phase error, group-delay distortion, noise and overload recovery, valid sample chronology and detector performance. Where more than one metric matters, the valid time begins no earlier than the latest of their qualifying recovery intervals under the tested configuration.

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It is sometimes possible to record a vector of time-dependent errors instead of one scalar. For example, let $E_A(t)$ be amplitude deviation, $E_\varphi(t)$ phase deviation, $E_N(t)$ noise change and $E_D(t)$ detector performance under a known challenge. A chosen application can define threshold limits for each. The measured T_{valid} is the earliest time after which the relevant limits remain satisfied for a specified confirmation interval. A different application may choose different limits and obtain a different T_{valid} from the same raw record. This is not methodological weakness; it is precision about the quantity one wishes to establish. The numerical value becomes misleading only when it is circulated without its tolerances and test conditions.

The test-signal level must be varied because some defects are nonlinear or triggered by control thresholds. A strong reference tone might dominate a brief feedthrough pulse and make recovery appear excellent, while a weak tone near the noise threshold could be masked or falsely declared present. Conversely a strong blocker might drive temporary desensitisation that a quiet test misses. Use a controlled range of input powers and source-off trials, and define the false-alarm and missed-event criteria. The sensitivity and timing estimates should be reported as functions of signal class and input level where the result materially varies, rather than averaged into a single reassuring number.

Uncertainty must include repeatability of switching, measurement timebase calibration, trigger alignment, stimulus stability, probe loading and system drift, as well as the observed spread across temperature and transition

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direction. A reproducible state-dependent bias is not automatically treated as random noise. If a device settles within one microsecond but the gain loop requires three milliseconds to restore weak-signal detection, the complete receiver cannot be declared valid at one microsecond for that purpose. Its excellent component specification remains useful engineering information, but the evidential acceptance result is the slower system-level criterion.

Dr. James M. Atkinson, Moderator: Professor Bode, we have now established candidate sources of transients. Please develop the filter-memory and dynamic-response problem mathematically. I am especially concerned with an instrument that can appear amplitude-stable while retaining a phase or group-delay response unsuitable for a short burst.

Hendrik Wade Bode, Third Principal Contributor: Dr. Atkinson, a preselector is valued for its steady-state frequency response, but the measurement problem during a state transition is fundamentally dynamical. Stored energy in inductors and capacitors does not disappear because a control command changes the desired filter response. An LC resonator, a high-Q cavity and a tracking filter all require time to establish or dissipate their electromagnetic state. Even a switch with nearly instantaneous conduction can connect a new filter whose internal state differs from the one assumed by the observer. A frequency-domain passband specification is consequently insufficient to predict the response to a short pulse following a transition.

Consider first a causal, stable, single-pole approximation whose output envelope $a(t)$ satisfies $\tau\, da/dt+a=u(t)$, where τ is a positive time constant and $u(t)$ is a step-like desired envelope. When u changes from zero to unity at $t=0$ and $a(0)=0$, the solution is $a(t)=1-\exp(-t/\tau)$. The remaining error is

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$\exp(-t/\tau)$. To reach a five-per-cent error requires $t=-\tau \ln(0.05)$, approximately 3.00τ; to reach one per cent requires about 4.61τ; and to reach one tenth of one per cent requires about 6.91τ. These are model-derived examples, not measured times for a particular filter. A high-order preselector may have multiple real or complex poles, overshoot and ringing, so no single τ may describe its settling across frequency and switching direction.

The state-space expression makes the wider problem explicit. For a settled state s, one can write $x_dot=A_s\ x+B_s\ u$ and $y=C_s\ x+D_s\ u$, where x contains the relevant internal energy-storage states. At transition time t_c, the matrices change to those of the new branch, but the physical state $x(t_c)$ may not vanish or match the new equilibrium. If the new state is initially displaced, the homogeneous term $\exp[A_new(t-t_c)]$ times that displacement survives into the output. The response can have a quiet initial interval, a peak, a damped oscillation or an apparent change in phase. This is why an early spectral line may be the relaxation of a circuit rather than an external waveform of identical frequency.

For a resonator characterised near its centre frequency f_0 by a loaded quality factor Q_L, a frequently useful approximate energy decay time is $\tau_E \approx Q_L/(2\pi f_0)$, under the stated resonant and small-signal assumptions; the envelope-amplitude decay time of the corresponding ideal lightly damped mode is approximately $\tau_A \approx Q_L/(\pi f_0)$. The distinction matters because energy is proportional to amplitude squared. At $f_0=100$ MHz and $Q_L=100$, τ_A is about 318 nanoseconds. An assumption of 10,000 for Q_L would increase that ideal envelope time to about 31.8 microseconds. A tracking electromechanical element may be much slower, and an active

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control loop may dominate both values. These figures illustrate scaling, not a blanket claim about preselector technology. Directly fitting a transient is safer than inferring exact settling from a catalogue Q value alone.

Group delay is a separate concern. If the phase transfer function is $\Phi(\omega)$, group delay is $\tau_g(\omega)=-d\Phi/d\omega$, where ω is angular frequency. The derivative is meaningful where the response is sufficiently smooth and the band of interest is defined. A receiver can pass a continuous tone at nearly correct amplitude while distorting the envelope timing of a wideband burst through unequal group delay across its spectrum. Immediately after tuning, the transient response may be time varying and the ordinary group-delay function for a stationary linear system may not apply. A single amplitude-stability threshold cannot therefore establish that the receiver can timestamp or reconstruct a short pulse accurately.

A suitable characterisation uses an input family chosen to reveal both amplitude and phase dynamics. Begin with a continuous reference tone at several frequencies across the intended passband. Then use a wideband but controlled impulse-like or coded stimulus with sufficient dynamic range and legal laboratory isolation, retaining its independent source timing. Record the received complex response after each state change and compare its envelope, phase trajectory, delay and correlation peak against a fully settled baseline. One should repeat with varied input level to discover nonlinear recovery, and at several temperatures to observe whether resonant frequency or control dynamics move. The purpose is not to create a beautiful generic impulse response, but to establish exactly when the measurement chain becomes fit for the specific waveform being sought.

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The spectral-analysis software can confound the physical dynamics. An FFT window overlapping pre- and post-switch intervals combines samples from two different system states, violating the stationary premise of a conventional narrowband spectral estimate. A windowed Fourier transform may turn a time-domain step into broadband leakage or a sequence of lobes. Averaging many such windows can preserve a reproducible spur even when no continuous carrier exists. If the implementation automatically blanks a few samples but retains an FFT segment crossing the boundary, contamination can survive the blanking. A defensible system labels raw samples by state and excludes or separately analyses any FFT windows that intersect an invalid interval, including the support of filters and overlap buffers downstream.

Dwell time is the engineering resource often overlooked by a rapid search schedule. Let T_{cycle} be the interval from one acquisition-state change to the next, T_s the measured acquisition-invalidation and settling interval, and $T_{capture}$ the subsequent valid observation interval. For a serial receiver, $T_{capture} \leq T_{cycle} - T_s$, ignoring additional transport and processing loss for simplicity. If $T_{cycle}=5$ milliseconds and $T_s=1.5$ milliseconds, at most 3.5 milliseconds remain, a valid duty fraction of 0.70. But that fraction says nothing about an event's detectability unless the event's duration, repetition pattern and phase relative to the schedule are modelled. An emission that consistently occupies the invalid 1.5 milliseconds can be missed in every cycle. One should report time-frequency coverage and acquisition validity together, not just total sweep rate.

The remedy may require a more elaborate measurement plan rather than faster retuning. A receiver can pause after switching until a hardware-

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witnessed settling criterion is satisfied; a two-path architecture can pre-tune the next filter; or a wideband parallel receiver can maintain continuous coverage across critical bands. Each approach changes noise, cost, mutual coupling and power constraints. The most defensible system is the one which records a sufficient valid sample history for each intended inference and exposes the intervals during which that was impossible. From the standpoint of control theory, time and memory are not defects to be wished away by a faster computer. They are properties of the physical apparatus which the scientific claim must respect.

Sir Edward Victor Appleton, Peer Question: Professor Bode, your state-space argument explains that filter memory can continue after the switch has changed. In an actual radio survey, however, propagation can also introduce multipath delay and frequency-selective fading. If a short burst is observed at different amplitudes or times after successive retunings, how should the examiner distinguish a transmitter and environment which genuinely change from a filter which carries residual energy from an earlier selection? Is a control experiment with one fixed laboratory tone sufficient to expose a receiver transient, or must the challenge include different bandwidths and waveforms? I am particularly concerned that an FFT window can turn a decaying time-domain response into a plausible narrowband emitter, so that an elegant frequency trace becomes more persuasive than the unedited evidence. What tests would allow the scientific claim to be narrowed without making an artificial separation between the apparatus and the propagation channel?

Hendrik Wade Bode, Response: Sir Edward, the two physical processes must be separated by interventions which affect one more strongly than the

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other. Filter memory follows the instrument's switching history; propagation effects follow the external source, antenna geometry and environment. A fixed laboratory source helps, but a single continuous tone can conceal important temporal and group-delay errors. One should challenge with several controlled signals: a continuous tone, a burst with a defined envelope and a sufficiently broadband coded stimulus with a known correlation structure. Repeat each through the selected band transitions, and retain a parallel reference of the stimulus at a declared electrical plane. The comparison should include phase and envelope chronology rather than a solitary frequency-bin magnitude.

To isolate the receiver, perform electrical input tests under known impedances and retain the full signal path through the preselector, conversion and digital analysis. The laboratory path should itself be calibrated for cable and source delays, or the test will merely transfer the unknown delay elsewhere. To examine propagation, repeat over the intended antenna path with the transmitter at controlled surveyed positions, noting that an external field and antenna may change differently with frequency and polarisation. If the anomaly remains tied to switching command delays under a stable injected stimulus, the receiver-memory hypothesis gains support. If it moves with transmitter position or a controlled obstruction while switching times are unchanged, the propagation hypothesis gains support. Both influences can be present and should be modelled jointly if the evidence demands it.

FFT support is indeed central. A transient with decaying envelope can spread

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energy across bins and create a persistent-looking line when windows are repeatedly aligned to switching. Recompute the same raw samples with several windows, hop sizes and starting offsets, carefully preserving their time supports. If a reported frequency feature depends strongly on how the FFT window crosses the transition, that is a reason to investigate nonstationarity; it is not proof that the entire feature is artificial. The appropriate event classification should refer back to the time-domain waveform and the state record, with the spectrum used as one representation of those observations.

A useful comparison is between the observed output and the convolution of a separately measured settled receiver response with the known input. Differences near a transition reveal the need for a time-varying model, but do not by themselves identify which switching device is responsible. A more refined test fits or bounds the transient state-space response under multiple independent stimuli and checks its prediction on a withheld waveform not used for fitting. Good prediction across different waveforms strengthens the receiver explanation. Poor prediction is a warning against a definitive attribution. The final finding should say which elements were measured, which were modelled and what remains underdetermined.

Dr. James M. Atkinson, Moderator: Mr. Black, Professor Bode has described energy storage and finite response. Now consider the receiver as several coupled feedback systems. How might local-oscillator locking, automatic gain control, bias regulation and software state machines produce an apparent signal which outlasts the hardware switching event?

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Harold Stephen Black, Fourth Principal Contributor: Dr. Atkinson, feedback corrects error by observing a condition and changing a control variable; it also creates dynamics which must be included in the measurement. The filter selection command is only one perturbation. It changes the amplitude and spectral composition at the mixer or detector, which may change the error presented to an automatic-gain controller. Simultaneously a local-oscillator synthesiser may be updating its phase or frequency, and a digitiser may apply a new scaling or decimation profile. The resulting system is not a collection of independent instantaneous boxes. Their transients can add, oppose or conceal one another, and the observation that one loop reports lock does not establish that every relevant measurement quantity is already accurate.

A useful decomposition writes the measured output as $y(t)=F_s\{x(t),g(t),\varphi_{LO}(t),q(t)\}+e(t)$, where F_s is the front-end transformation in selection state s, $g(t)$ a time-varying gain, $\varphi_{LO}(t)$ local-oscillator phase, $q(t)$ the digital configuration and $e(t)$ residual disturbances. This notation is deliberately schematic, not a claim of global linearity. A filter switch may change the power of an out-of-band blocker by tens of decibels, provoking gain recovery; the local oscillator may simultaneously traverse a frequency step; and digital processing may retain filter memory across the change. A brief apparent spectral feature can therefore have no single cause. To attribute it, one must temporarily control or measure the separate state variables and ask which interventions predictably alter the observation.

Consider an automatic gain loop whose detector responds to received power $P(t)$ with an equivalent time constant τ_{AGC}. If a sudden decrease of admitted blocker power causes the controller to increase gain over several

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milliseconds, a weak legitimate tone may become more visible after the filter has physically settled. Conversely a previously admitted strong blocker may hold the gain low and conceal the weak tone for a recovery interval. A receiver can therefore be electrically connected to the correct band but still exhibit degraded sensitivity. The elapsed time until an output tone reaches its desired steady amplitude is not necessarily the same as the time until the minimum detectable signal or intermodulation performance has recovered. Several acceptance metrics are needed when an instrument's purpose includes both wide dynamic range and short-burst detection.

The loop design controls the answer. A high loop gain can reduce steady-state error but may produce overshoot, noise amplification or instability if phase margin is insufficient. A sluggish loop may be stable and quiet but unacceptably slow for an agile schedule. An abrupt switch in filter insertion loss can appear to the gain controller as a change in transmitter power, even though the environment is unchanged. If the software normalises power using a calibration constant for the destination band before analogue settling, the displayed amplitude may briefly be too large or too small. An attractive reading is not a guarantee that both the analogue gain and the correction factor describe the same state.

The local oscillator presents its own requirement. A synthesiser may report a phase-locked state after its phase error falls below a chosen detector threshold, yet small frequency or phase excursions can remain. In a demodulator, a residual phase trajectory can spread spectral energy or bias coherent estimation. One cannot automatically convert a control-loop settling specification into a proven arrival-time uncertainty without measurements under the actual mode. To test independently, hold

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preselection constant while commanding the oscillator across the intended frequency plan; then hold oscillator frequency fixed while selecting filters; finally exercise combined hops. Compare the three observed transient families, taking account of the fact that their interactions may be nonlinear.

A control-state machine should record more than the name of its desired configuration. Useful states include command issued, physical selection asserted, oscillator-reference condition, gain-controller transition, downstream digital filters reset or retained, confirmation criterion satisfied, acquisition valid, and fault. The machine should prevent a sample acquired in an unqualified state from being silently labelled as valid. A hardware line may witness a physical action while another counter records ADC sample index; a timestamped log binds the two. If a state is inferred retrospectively from the data, it must be identified as an estimate rather than represented as a contemporaneous instrument assertion.

A controlled study should use three orthogonal tests. First, a quiet input and repeated state transitions expose control-induced output. Second, a steady laboratory tone at fixed power reveals gain and phase settling. Third, a low-level test signal in the presence of a safe, controllable blocker reveals desensitisation and intermodulation recovery. Sweep the relative timing of the weak event across a filter transition and calculate its detection probability or amplitude error only for the tested source family. If the result is a blind interval, qualify the search coverage accordingly. Repeated successful detections at comfortable signal levels cannot demonstrate the response near the detection threshold, where gain and noise dynamics matter most.

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Numerical specifications must also distinguish random uncertainty from an unresolved state-dependent bias. If a receiver's settled gain calibration has standard uncertainty of 0.2 decibel, this does not mean a transition-induced amplitude error of 4 decibels can be treated as a random draw from the same distribution. The transient should be measured as a separate error function of time and switching history, then excluded, corrected or bounded as appropriate. A filter transition may have a direction-dependent overshoot; averaging forward and reverse transitions into a single scalar can obscure both. Traceability depends upon the calibration being applicable to the actual state, not merely upon the source of the original laboratory reference.

The operational design must be honest about timing. Suppose a sweep controller announces a new frequency every millisecond while the combination of preselector, oscillator, AGC and digital filter requires two milliseconds to meet its acceptance criteria. The apparatus may be continuously processing numbers, but it has no settled observation in the announced bands. If the algorithm reports one detection for each nominal dwell, it manufactures apparent coverage. The logical response is either to lengthen dwell, reduce the number of visited bands, use parallel receivers or redefine the claim as a provisional transient-sensitive observation. Feedback theory cannot rescue an impossible schedule by changing its labels; the time budget must reflect physical settling.

I would end by requiring a state-specific performance certificate rather than an undifferentiated calibration statement. The receiver should record which parts of the chain were verified for each accepted measurement, what challenge stimuli established the valid window, and what limitations remain

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when two or more loops change simultaneously. Such records allow a reviewer to distinguish a changing RF environment from a changing receiver. The aim is not an instrument that never has transients, but one whose transients are measured, controlled and reported before they become false evidence.

Sir Martin Ryle, Peer Question: Mr. Black, a receiver built for high probability of intercept may be fitted with automatic gain control and a rapid synthesiser, both deliberately operated in feedback. During a frequency hop, the display can show a clean transition, yet the front end may be temporarily insensitive to weak emissions because a gain loop retains memory of a stronger signal from the previous band. How would you qualify this hidden desensitisation without assuming that the controller's commanded gain is the actual instantaneous gain? Would the result differ if the desired signal itself changes power during the retune? I would also ask for a realistic account of how the system should react when a transient is detected but the controller state is uncertain: suppress the sample, retain it with a warning, or treat it as presumptively external? I would ask whether resetting AGC before every trial might conceal exactly the state-memory problem that an operational frequency-hopping schedule creates in the field.

Harold Stephen Black, Response: Sir Martin, a gain command is only a request to a physical circuit. The correct observation is the measured response to a calibrated stimulus at the receiver input. To expose latent desensitisation, introduce a weak test signal within the intended band and measure detection probability across a controlled hopping sequence while a safe stronger signal is present in the preceding band. Change the timing

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and amplitude of the preceding blocker, keeping the subsequent weak signal fixed. If the receiver misses the weak event more often after a stronger predecessor than after a quiet predecessor, a state-memory effect is indicated. Continue the experiment until the recovery time is measured across the relevant signal levels and transition pairs.

The test should distinguish detection from amplitude accuracy. A receiver may detect the weak tone but report the wrong power because gain calibration has not caught up with the analogue state. Another may report a plausible power while the instantaneous noise figure is unacceptable. The performance criteria should include missed events, false alarms and a measured amplitude or phase envelope where appropriate. Where a legitimate incoming signal changes amplitude during the transition, an external explanation remains possible; that is why the known stimulus must be independently monitored and replayed across the same receiver schedule. A signal source and receiver sharing a control clock can produce misleading apparent agreement, so the source timing should be checked independently where this matters.

A robust controller records measured state rather than silently making a validity assumption. Samples taken during a known invalid interval should be retained when lawful and feasible, but marked invalid for any conclusion that requires settled acquisition. They should not be discarded without a record of the gap, since later inspection may reveal a useful diagnostic transient. If hardware state is uncertain, label the interval as uncertain. The software may offer a candidate classification for exploratory analysis, but

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the final forensic report must not promote that candidate to an external emission without challenge tests. The objective is to preserve evidence and prevent unwarranted claims simultaneously.

A useful state machine can require independent confirmations: oscillator phase condition, physical band-select observation, gain-controller settling criterion, and an acquisition counter free of gap or overflow. Their logical conjunction defines an eligibility flag for a particular analysis. Because some measurements are tolerant of gain error and others are not, the flag should be tied to the intended inference rather than advertised as universal. The controller may choose to suppress online alarms during the transition to reduce false positives, while retaining raw samples and event metadata for later reconstruction. This separates operational alarm policy from evidential preservation, and prevents a silent data-repair algorithm from rewriting the history of what occurred.

Dr. James M. Atkinson, Moderator: Dr. Steinmetz, the earlier contributors have concentrated on receiver architecture, switching devices, memory and feedback. Please analyse the electrical paths through which a switching command can contaminate apparently unrelated receiver channels, including grounds, power networks, inductive coupling and conducted impulses.

Charles Proteus Steinmetz, Fifth Principal Contributor: Dr. Atkinson, the physical route of a transient is not restricted to the intentional signal conductor. A control switch releases electrical energy in a wiring network which includes return paths, shared impedance, capacitance to adjacent conductors and magnetic linkage. The receiver's front end may be carefully

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filtered at its nominal RF connector yet still respond to disturbances entering through supply leads, a digital control harness or the shielding of a cable. The relevant circuit is a three-dimensional arrangement of currents and fields, not the simplified block diagram in which every ground is one zero-potential node. A transient observed at the digitiser may be created upstream, downstream or by a common disturbance reaching both.

If a branch inductance L carries current I, its stored magnetic energy is $E_L=(1/2)LI^2$. At L=100 microhenries and I=20 milliamperes, the stored energy is 20 nanojoules. That figure is modest, but a rapid interruption can develop a significant voltage across parasitic impedances because $v_L=L\,dI/dt$. If a 20-milliampere current were forced to change within 100 nanoseconds through the idealised 100-microhenry element, the magnitude of the ideal inductive voltage would be 20 volts. Such a scenario is physically self-limiting and would trigger breakdown, parasitic capacitance charging or other nonideal behaviour; it is not a prediction that a real receiver reaches that voltage. Its purpose is to show why current paths and protection networks determine the pulse, and why naive application of an ideal rate of change cannot replace measurement.

Shared ground impedance is another route. A switching control current ΔI passing through a common return impedance Z_g causes a disturbance $\Delta V_g \approx Z_g \Delta I$ in an appropriate linear frequency-domain approximation. A few milliohms can matter to low-level phase-sensitive circuitry when the disturbance has a broad spectrum and when the reference plane itself is moving relative to other nodes. The system should be examined for control-current loops, shield termination, supply-return routing and local decoupling. A high-frequency return current does not necessarily follow the

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neat direct-current ground route imagined by the wiring diagram; its impedance and associated electromagnetic fields determine the effective path. A shield which is adequate for one coupling mechanism may still allow noise through a connector aperture or common power route.

Capacitive coupling introduces charge without a metallic contact. For two conductors with mutual capacitance C_m, the displacement current from a control step may be approximated as $i=C_m\, dV/dt$, provided the lumped approximation is appropriate to the geometry and frequency range. A five-volt edge rising in ten nanoseconds through one picofarad yields an instantaneous ideal scale of 0.5 milliampere. The waveform and its actual destination depend upon return impedance, distributed geometry, switching slew and the measurement probe. It is therefore possible for a control lead carrying no intended RF information to inject a short pulse into the first amplifier or the ADC reference. A frequency-domain picture will distribute the transient according to its shape and the analysis window; a spectral peak is not thereby a continuous external carrier.

A real measurement should proceed from a controlled test hierarchy. With the input correctly terminated, switch the preselector and compare the raw output with the control edge, supply-current waveform and local reference. Change only the switching destination, then vary the slew or the supply decoupling under an authorised laboratory setup to see whether the apparent RF pulse changes predictably. Next use a separated power source or a differently routed control return, taking care not to introduce unsafe grounding conditions. If the disturbance follows a return path rather than the antenna input, the internal-coupling explanation gains support. A probe

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attached to a high-impedance node can itself create a new return path, so its effect must be measured or bounded.

The enclosure is part of the circuit. Slots, seams, connectors, ventilation openings and cable penetrations support different common-mode and differential-mode currents at different frequencies. A local current loop near the filter bank may radiate into the receiver's own antenna lead while the nominal RF input remains physically connected. A line that disappears when the external antenna cable is removed might therefore be an internal disturbance which had been using the cable shield as a radiating or receiving conductor. It does not follow that every cable-sensitive feature is an external emission. To discriminate causes, use lawful near-field scanning, cable-current probes and input substitutions in a controlled environment, while recording that each substitution changes circuit boundary conditions and may change several coupling pathways at once.

Electrical and mechanical time scales must be distinguished. A control-current spike may last microseconds, a resonant circuit may ring for tens of microseconds, and an oscillator or gain loop may recover over milliseconds. A waterfall integrating over a longer analysis window may turn these physically separate episodes into one apparently coherent burst. By measuring the time-resolved sequence, the investigator can test whether an initial conducted spike excites a later resonant response or whether an independently varying source persists after the control event. A result which agrees with the switching schedule is evidence of correlation; direct tests of source-off conditions and alternate control paths are needed for defensible causal attribution.

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For numerical example, consider a 10-millisecond dwell and a measured three-millisecond interval during which switching and coupled recovery exceed the declared acceptance tolerance. The nominal dwell is ten milliseconds, but valid observation time is seven milliseconds. If the controller revisits a band every 100 milliseconds, the valid coverage occupies only seven per cent of the overall cycle, not ten per cent, ignoring additional missing samples and overlaps. An external four-millisecond burst could be entirely outside the valid window. If the operator only records detections and not invalid states, later reviewers cannot distinguish an actual absence from a period of measurement blindness. The proper duty figure requires hardware evidence of switching times, not just software schedules.

Finally, a corrective hardware alteration should be verified as a system change, not celebrated because one spur has vanished. Added decoupling may suppress a fast pulse but extend a low-frequency recovery. A different ground arrangement may reduce one common-mode path while introducing another. Slower edges can reduce high-frequency interference but reduce scanning speed. An isolator can improve source and load separation but impose insertion loss which harms sensitivity. These are engineering trade-offs, and an improved time trace must be compared with amplitude, phase, selectivity, dynamic range and missed-event performance under the same declared conditions.

The appropriate forensic statement is therefore constrained by the full switching circuit and the actual tested reference planes. A switched preselector can produce a false spectral feature through electrical feedthrough, excite a transient through filter memory, make a genuine burst invisible through a blind interval, and leave longer recovery after an

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overload. The examiner should separate these effects experimentally. The more meticulous account of an electrical disturbance may be less dramatic than a claim of an unknown transmission, but it is precisely that measured restraint which makes a technical security report trustworthy.

Herbert Kroemer, Peer Question: Dr. Steinmetz, the electrical-coupling examples suggest that a narrow control-current pulse can be transformed into a more extended RF disturbance by resonant wiring or an amplifier's nonlinearity. How should the field engineer distinguish a direct control pulse from a later resonance or supply-recovery process when the only accessible data are complex receiver samples and a limited number of external state logs? Suppose the control edge and a weak spectral line share a reproducible delay, but the instrument's internal design is unavailable. At what point may one responsibly call the line receiver-associated rather than externally transmitted, and how could a test avoid creating the fault by attaching a probe or changing the shield termination? I would also welcome a quantitative interpretation of a timing cross-correlation when both events are periodic, because identical periods can produce apparently impressive correlations without uniquely identifying their cause. Could the same cross-correlation peak survive when the filter branch is replaced by a passive through-path, and what would that comparison say about causality?

Charles Proteus Steinmetz, Response: Professor Kroemer, begin with the observations actually available. A reproducible delay between switching commands and a received transient is evidence of temporal association. When both are periodic it is not proof of unique causation: any process synchronised to the common schedule can produce high correlation, and a local external test transmitter might even share that schedule. The

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investigation should vary the switching period, order of visited bands and relative timing independently of any known source. If the transient follows those changes and appears under a legitimate terminated-input or source-off condition, the evidence for instrument association improves. One should avoid claiming which inaccessible component caused it unless additional measurements support that attribution.

A short impulse can excite a longer response because a resonant circuit stores energy, while an amplifier or regulator can take time to recover. Time-resolved output may show an initial broadband component and a damped oscillation after it; a longer FFT window can compress both into a narrow spectral feature. Compare the observed decay time and frequency when switch direction, load and power supply condition change. If resonance changes with a known substitution of cable or termination, that points towards a coupled physical path. Yet the substitution changes boundary conditions, so alternative explanations must remain in the report until constrained by further tests. A control event entering a cable shield is still instrument-related even if removing the external cable makes it disappear.

With inaccessible hardware, the test can remain non-invasive. Use an independent reference receiver at a separate power and clock source to observe the same environment, and record its raw samples. Change the first receiver's band-switch schedule while holding the antenna and environment as stable as possible. If a feature appears in the first receiver only and follows its internal command schedule, that is strong evidence of an

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apparatus-associated artefact; if the independent receiver also observes the event on an unchanged tuning path, an external cause becomes more plausible. The comparison is not infallible because the two receivers may differ in sensitivity and coupling. The report must include detection thresholds and explain any common dependencies.

Quantitatively, a high cross-correlation coefficient is conditional on the chosen time series and their shared structure. Periodic pulses can produce regularly repeated correlation peaks, so the analyst should inspect whether the response tracks independently varied delays rather than just fixed-period coincidence. Record all tested schedules, including failed attempts and source-off periods. A safe probe may be used only when its input impedance, capacitance and return path are appropriate and demonstrably do not change the effect materially. When such evidence is unavailable, an instrument-associated classification can be qualified by the observed controls, but a specific internal fault should remain a hypothesis rather than a finding.

Hendrik Wade Bode, Cross-Peer Question to Antony Hewish: Dr. Hewish, your coverage analysis builds valid time intervals after hardware transitions, but it presumes that the method deciding a sample is valid has itself been established. A digital filter's output can depend on input samples before a switch, and the set of samples used by a time-frequency estimate may extend across several apparently valid frames. Suppose the hardware selection flag changes at one sample index, the analogue response has a decaying memory, and the decoder uses an overlapping block transform. Would it not be necessary to propagate an interval of measurement

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invalidity through the complete causal support of every estimator? I ask you to describe how one would compute such an interval without pretending that all relevant impulse responses have finite duration. What evidence permits an operationally useful tolerance-based boundary, and how should a claim of successful intermittent-signal coverage change when the relevant source may appear entirely during the excluded support?

Antony Hewish, Cross-Peer Answer to Hendrik Wade Bode: Professor Bode, the correct object is indeed the support of the measurement, not a single timestamp attached to a processed sample. For a finite-impulse-response digital filter with N nonzero taps, an output sample at index n depends upon input samples over a known range of indices, for example n−N+1 to n under a causal convention. If any of those input samples lie inside an interval where the analogue chain was unqualified, the derived output inherits that qualification unless a specific analysis demonstrates that their influence is negligible under the declared error criterion. An overlapping FFT window similarly draws upon all its contributing input samples. A software interface that labels only the window centre as valid can therefore be misleading if its support crosses a switching boundary.

An analogue response ordinarily has a theoretically decaying tail rather than a compact finite support. The practical cut-off must be based on the measurement objective. A complex impulse response can be measured with a known input family, and a bound can be placed on the residual influence after elapsed time T for the relevant amplitude, phase or event-detection criterion. This is a tolerance-based claim, not an assertion that the physics has become identically zero. The chosen bound should include the

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uncertainty of the calibration, repeatability across switching directions, input levels and environmental conditions. If the receiver changes its filtering coefficients, a new support analysis is needed. An arbitrary fixed blanking value is not equivalent to a demonstrated bound.

For an event search, coverage should be represented at the level of the source class being tested. A short burst requires enough consecutive valid input support for the detector to meet its stated sensitivity and false-alarm requirements. A longer coded signal may tolerate missing symbols or recover with uncertainty if its error-correcting or correlation structure permits, but the claim must be tested rather than assumed. Where the signal could lie wholly in an excluded interval, the system has no evidence for absence. Randomised schedules may reduce consistent alignment with periodic unknown bursts under stated assumptions, yet they do not create continuous coverage. Parallel settled paths or a sufficiently broad simultaneous receiver are stronger options when the mission demands assured observation of short events.

I would retain two representations side by side: the immutable hardware timeline with all measured selection and acquisition states, and the derived eligibility intervals for each named estimator and waveform family. A reader can then see which samples physically existed and which were trusted for a particular conclusion. If a revised model changes the settling bound, the derived eligibility can be recomputed without rewriting the raw observations. This practice prevents a signal-processing choice from silently

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manufacturing evidence of receiver coverage which the front end never supplied.

John Daniel Kraus, Cross-Peer Question to Harold Stephen Black: Mr. Black, your controller-state model is admirably comprehensive, but I question whether every channel can be assigned one unambiguous validity flag. A narrow weak signal near a filter edge may suffer substantial group-delay distortion while a stronger centre-band tone meets the amplitude criterion. A signal entering from a mismatched antenna may alter amplifier loading and AGC behaviour. If the controller reports a single 'settled' state, what does that status actually warrant across frequency, amplitude and waveform classes? How should the acceptance scheme prevent the worst-case or untested source from being averaged away by a large number of successful easy trials? I also ask whether the validity condition should be fixed before an engagement rather than adjusted in response to a later suspected signal, where retrospective tuning of acceptance criteria could undermine forensic reproducibility. Please include the special difficulty of preserving these criteria when firmware automatically changes both the gain profile and decimation factor at the band boundary, thereby changing the meaning of the processed sample.

Harold Stephen Black, Cross-Peer Answer to John Daniel Kraus: Professor Kraus, the single Boolean flag is convenient for controlling acquisition but inadequate as a universal metrological statement. It should represent at most that a defined set of prerequisites has been satisfied for a declared measurement class. More precise systems can retain an eligibility vector or a performance envelope indexed by band, signal level, waveform bandwidth and time since the last switch. A narrowband continuous tone at the centre

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of the passband may require little group-delay fidelity, whereas a burst whose onset time is material to localisation requires substantially more. A hardware condition may be necessary for all measurements without being sufficient for all. The derived eligibility must therefore carry the application identifier and its test criteria.

For validation, define critical strata before trials begin. They should include the weakest intended signals, passband edges, switching directions, representative blocker levels, temperatures and any signal durations that drive the decision. Test each stratum with a known source and retain its failures separately. A pooled success percentage is not an adequate replacement for a failed critical condition, particularly where the search seeks to support a negative finding. An untested combination should remain explicitly unqualified rather than be assigned the performance of a neighbouring, easier condition. A model may interpolate within a characterised domain, but the uncertainty of that interpolation and its validation should be recorded; extrapolation beyond the tested domain needs fresh evidence.

The validation policy should normally be fixed before the operational observation. Specify how an acceptable detector threshold, false-alarm condition and time-to-settle criterion are measured, and how they will be challenged. If subsequent evidence reveals a defect, one may revise the analytical model, but the old result and the reason for correction must remain available. The new criteria should be subjected to independent tests and documented as a new version. The original raw samples and state

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records must remain immutable. Without this separation, an analyst could shift the valid window after seeing a desired conclusion, producing an appearance of rigour without independent constraint.

The system can also report several categories instead of one pass/fail: raw sample retained, physical acquisition confirmed, receiver state settled for continuous-tone amplitude, receiver state settled for short-burst timing, and inference externally corroborated. Those categories are not all guaranteed by the same sensor. Such a design may look less tidy on an operator's screen, yet it provides stronger assurance when observations are later challenged in an engineering review or court. We should prefer explicit limitations to a universal green light whose meaning changes silently across applications.

Edwin Howard Armstrong, Cross-Peer Question to William Redington Hewlett: Mr. Hewlett, I accept that a switch can inject electrical energy directly, but an operator might use the terminated-input transient as proof that every line seen after retuning is internal. Suppose the same receiver also admits a genuine weak burst whose arrival overlaps the switching interval. How can one disentangle superposed external information from the switch pulse if the front end is changing gain and phase at the same time? Is subtraction of an averaged source-off transient a defensible correction, or does it risk concealing a real signal and producing an artificially clean record? Please examine the conditions under which such a subtraction would be identifiable, and state how a report ought to preserve the original observation when an artefact template is used in subsequent analysis. I would insist that the operator report the uncertainty of such

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compensation at the faintest accepted input level, not merely its average success with strong and easily distinguished test bursts.

William Redington Hewlett, Cross-Peer Answer to Edwin Howard Armstrong: Professor Armstrong, superposition is a powerful approximation only when the relevant system is linear, stable and in a repeatable state. In a settled linear path, one might model the observation as an external response plus an additive switching artefact. An averaged source-off template could then help characterise or perhaps estimate the unwanted component. But during transition the system is generally time varying; a strong off-band blocker may cause nonlinear gain recovery; and the artefact can depend upon load, temperature, supply state or switching history. Subtracting a single average waveform without verifying these conditions can suppress genuine signal energy or leave a misleading residual that looks new and external.

The experiment should therefore include controlled source-off trials to measure the artefact distribution, source-on trials with several known signals and levels, and trials with the input signal arriving at varied delays relative to the switch. Preserve all raw samples. Fit the proposed subtraction or compensation method on one subset of trials and verify its performance on a withheld subset. A method that works only for a single easy input or one temperature is not a general correction. A compensation algorithm must report its uncertainty and residual artefacts, and it should flag intervals where the model cannot distinguish a genuine short signal from the switching impulse.

An additional challenge is identifiability. If the external burst and the switch

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pulse occupy the same time and frequency support, and no independent observation or strong waveform prior exists, there may be multiple compatible explanations for the output. This is not a failure of ingenuity; it is an information limit of the measurement. The investigator may recover a bounded estimate or say that the event is indeterminate. The raw waveform should be retained with the switching markers, while any template-subtracted trace is presented explicitly as derived analysis, not as a newly observed physical signal. Time-domain correlation with an independent reference receiver or a known controlled emitter can strengthen the separation, but the independence assumptions must be documented.

There is a final policy distinction: online suppression of a known false alarm is an operational choice, whereas the forensic record of what the hardware captured is evidence. A receiver may choose not to alert during a measured blind interval, yet it must not erase that interval or relabel a compensated waveform as if no transient occurred. The suppression criteria should be versioned and tested against legitimate signals, especially near the detection threshold. The proper result is either demonstrated performance for a stated signal family, an honestly qualified interval, or a remaining ambiguity. It is never appropriate to infer absence merely because a numerical cleaning method makes the display quiet.

Charles Proteus Steinmetz, Cross-Peer Question to Lord Rayleigh: Lord Rayleigh, the practical testing of a preselector necessarily employs instruments and probes which have their own impulse responses. A fast switching edge may be seen as a brief peak on one oscilloscope and as a longer damped disturbance on a spectrum analyser, while a supply-current

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monitor may add impedance to the path being tested. How should the reviewer establish which timing and amplitude measurements are sufficiently trustworthy to support an inference about receiver settling? I wish particularly to challenge the assumption that the quickest observed transient is the decisive one. Could a tiny residual after a much larger pulse matter more to a weak-signal receiver, and how should uncertainty and instrument loading affect the chosen invalid window? Please also explain whether repeated measurements with one apparatus constitute independent corroboration when that apparatus shares timing and filtering artefacts with the receiver under test.

Lord Rayleigh, Cross-Peer Answer to Charles Proteus Steinmetz: Dr. Steinmetz, measurement validity must be established at the relevant scale of the claimed decision. A short large pulse and a long small residual can have different operational significance: the large pulse may create an obvious alarm that can be recognised as internal, whereas a residual near the weak-signal threshold can contaminate a more subtle measurement for longer. The appropriate settling boundary is therefore not necessarily the time at which the largest oscillation disappears. It is the time at which all the relevant residual errors have fallen below the application-specific, independently verified tolerances for the required observation duration. That statement includes noise, phase and detection performance, not merely a voltage waveform measured at one circuit node.

The timing witness requires its own calibration. An oscilloscope's front-end bandwidth and trigger placement can distort pulse amplitude and timing; a current probe can add burden or have inadequate high-frequency response;

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a spectrum analyser integrates over its chosen resolution bandwidth and sweep or FFT time support. Use instruments with sufficient bandwidth, declared rise-time characteristics and reference clocks, then check the combined measurement chain with a known calibration edge or waveform. An uncorrected probe delay can bias the relative timing between the select command and RF recovery. Where two instruments share a reference, their timing errors may be correlated; repeated records from them should not be treated as independent confirmations merely because many files were saved.

Probe loading should be challenged by comparing measurements made with and without the probe, using a second less invasive method where practical. If attaching a test lead changes the pulse, the finding is about the probed configuration unless an appropriate correction or bound is justified. Current probes and differential voltage probes can reduce some intrusion, but their placement and frequency response are still consequential. An excellent metrology report declares reference planes, calibration uncertainty, instrument loading and source-to-sensor timing. It is not acceptable to quote an apparently exact switching delay in nanoseconds when the propagation and trigger offsets between channels are unknown.

The operational threshold should be assessed at the minimum significant event level as well as under comfortable laboratory signals. A residual only one per cent of a large switch pulse may nevertheless exceed the weak-signal threshold by orders of magnitude, depending on the circuit and detection rule. Repeating the same test under different switch directions,

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levels, temperatures and load conditions can reveal whether the residual is stable or state dependent. A statistically tight spread in one unchallenged configuration is not assurance against a systematic flaw. The correct final conclusion is conditional on a calibrated measurement model and an explicitly stated operating range. Where the residual remains uncertain, extend the exclusion window or qualify the event rather than invent certainty.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel distinguishes physical switch-control energy, filter-memory relaxation, local-oscillator and gain-loop recovery, and processing artefacts produced when time-frequency windows cross an invalid transition. A preselector can improve image rejection while degrading temporal coverage; it can briefly conceal a genuine weak burst, generate a pulse under terminated-input conditions, or induce an apparent frequency shift when several loops recover together. The correct acceptance criterion is not merely that a band was selected, but that amplitude, phase, dynamic range, noise and source-specific detection performance met declared tolerances at a documented sample index. Five principal contributors, seven peer examinations and four reciprocal cross-peer challenges have addressed distinct causal hypotheses and challenge tests. The resulting dialogue is fictional educational reconstruction, not historical speech. Final scholarly acceptance requires separate verification of claims, calculations, contributor records and source-to-claim citations.

QUESTION 065. SOURCE REGISTER AND EDITORIAL LIMITATIONS

1. Keysight Technologies, Spectrum Analysis Basics, Application Note 150 (5952-0292), current publicly available PDF:

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https://www.keysight.com/content/dam/keysight/en/doc/gate/application-notes/5952-0292.pdf . Discusses preselection, preselector tuning and the effect of tuning and settling upon sweep performance. Consult the exact edition in the final bibliographic audit.

2. Keysight Technologies, Preselection Architectures in Signal Analyzers (2026): https://www.keysight.com/zz/en/cmp/2026/preselection-architectures-in-signal-analyzers.html . Provides an architecture-level discussion of YIG tracking and switched filter banks, their speed and unwanted-response trade-offs.

3. Analog Devices, ADGM1004 Data Sheet, Rev. E: https://www.analog.com/media/en/technical-documentation/data-sheets/adgm1004.pdf . Provides component-specific definitions of on/off switching times and video feedthrough. These definitions are not a general performance guarantee for a complete receiver.

4. Analog Devices, Application Note AN-98, Signal Sources, Conditioners and Power Circuitry: https://www.analog.com/en/resources/app-notes/an-98.html . Gives representative measurement techniques and switch-control feedthrough examples; instrument-specific values are not generalised.

5. Rohde & Schwarz, Measuring Frequency Settling Time, Application Note 1MA15_0E: https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_application/application_notes/1ma15/1MA15_0E_meas_of_frequency_settling_time.pdf . Provides a measurement context for frequency-settling experiments, including trigger placement and careful treatment of low-signal conditions.

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EDITORIAL QUALIFICATION. All numeric examples are hypothetical engineering illustrations, not certified measurements from deployed survey equipment. Historical dialogue is explicitly fictional. Source-to-claim review remains separate from mechanical word-count gates; no specific real equipment is certified by this discussion. The manuscript must retain a distinction between validated detection coverage and conditions in which a switch or processor made acquisition impossible.

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QUESTION 066

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How do clock feedthrough and oscillator harmonics traverse an instrument enclosure?

HISTORICAL METHOD. The moderator uses the documented fields of deceased engineers and physicists to organise a present-day technical examination. References to contemporary high-speed digitisation, digital serial interfaces or computerised spectrum recording represent editorial applications of physical principles, not claims that the named contributors designed or operated such equipment.

Dr. James M. Atkinson, Moderator: Professor Kroemer, our receiver has a shielded analogue front end and a separate digital clock distribution board. Yet narrow lines continue to emerge in the displayed spectrum at intervals related to the sample frequency. I should like the panel to follow a specific disturbance from its oscillator, through its conductors and fields, into the sensitive measurement chain. Please distinguish the electrical source from the propagation mechanism and from the later operation of sampling and Fourier analysis, so that a surveyor does not mistake an artefact of his own instrument for a transmission in the room.

Herbert Kroemer, Principal Contributor: Dr. Atkinson, the first deception is to assume that a clock, because it performs a numerical function, has merely numerical consequences. The oscillator produces an electrical waveform, and its output transistor or logic buffer conducts physical currents whose timing, amplitude, slew rate and symmetry are never ideal. An ideal sinusoid at frequency f_c has one spectral component; a practical square-like waveform possesses harmonics at integer multiples $n f_c$, with amplitudes shaped by duty cycle, finite rise time, termination, and the

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transfer function of its drivers. A clock line also changes electric potential relative to neighbouring conductors, driving displacement current through their parasitic capacitances. Neither the nominal shield nor the software's description of a clock changes those facts. The first task is to identify the complete current loop, including where its return current actually travels at each relevant harmonic frequency.

The harmonic content of an ideal fifty-per-cent-duty bipolar square wave is proportional to 1/n for odd positive n, and is zero at the even harmonics under the ideal symmetry assumption. That textbook result is not a promise about a real converter board. An offset, an asymmetric duty cycle, an uneven rising and falling edge, or nonlinear driver loading introduces additional products. A short edge also generates energy far above the nominal clock frequency. For a useful first estimate, a transition with ten-to-ninety-per-cent rise time t_r has substantial spectral content on an order-of-magnitude scale around $0.35/t_r$, although that relation depends on the assumed waveform and does not establish a universal cut-off. For t_r equal to 1 ns the corresponding bandwidth scale is 350 MHz. The harmonic frequencies are determined by periodicity; the edge speed sets an envelope, not a set of independent new clock frequencies.

Consider a sampling clock at 40 MHz with a 1 ns edge. Harmonics of the repetitive switching waveform may occur at 80, 120, 160 MHz and higher, according to symmetry and circuit response. If a sensitive receiver tuned near 120 MHz reports a stable line, it is tempting to assign that line to a source outside the enclosure. Yet if a shield seam, supply impedance or clock-to-analogue capacitance admits the third-harmonic current, the feature can originate entirely inside the measuring instrument. A shielded

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termination at the antenna socket is therefore a useful control, but it is not sufficient proof of a unique coupling path. The termination changes the port boundary while leaving common-mode paths along the chassis, power cable, Ethernet or USB leads. The component may disappear because the port condition altered an internal resonance; alternatively it may remain because the clock couples after the antenna input.

A capacitively injected current can be estimated as $i_c(t)=C_m d[v_c(t)-v_a(t)]/dt$. Here C_m is the mutual capacitance between a clock node and an analogue node, v_c is the clock-node voltage, v_a the victim-node voltage, and the derivative describes their time-varying potential difference. Suppose a controlled experiment establishes 0.2 pF of effective coupling and a 1 V edge completed in 1 ns, while victim motion is small. The illustrative peak displacement current is then approximately 0.2 mA during that edge. Its duration is brief, but when passed through a frequency-dependent impedance and repeated millions of times each second, it can establish a coherent spectral line. The calculation must not be mistaken for a measured circuit current. Effective capacitance, edge profile and return geometry require actual verification.

The semiconductor junction creates further complications. When an amplifier is driven beyond its linear range by a strong internally injected harmonic, its output may contain additional harmonics and intermodulation products not present as separate emissions at the oscillator. Let an imperfect nonlinear stage be approximated by $y=a_1 x+a_2 x^2+a_3 x^3$, where each coefficient has units consistent with the input and output. A clock leak at f_c and a genuine input at f_s can yield products near f_s plus or minus f_c and at further combinations. Merely seeing an

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apparent signal displaced from the clock does not exonerate the clock. The proper experiment adjusts one independent stimulus at a time, observing whether the new products translate according to the algebra of mixing and whether the change is reproducible under a fixed gain state.

We must distinguish an oscillator harmonic radiated into space from a harmonic that passes by conduction through the apparatus. A board may inject a disturbance into a voltage regulator through finite supply impedance, into the sample clock through a shared buffer, into the RF input by capacitive feedthrough, or into a shield by a common-mode displacement current. Those routes differ in their response to local shielding, cable movement, frequency shifts and temporary isolation. A spectrum analyser alone displays a resulting voltage or power estimate. It does not identify the topology that created the voltage. Forensic interpretation demands a directed causal experiment in which clock frequency, buffer state, supply condition and the boundary of the enclosure are independently varied wherever safe and technically feasible.

A clock perturbation experiment should use a small, specified change in f_c only if the converter and associated processing remain in an authorised operating mode. Record the actual frequency at the clock test point, the ADC configuration, the physical RF input and the displayed line before and after the change. If a spur shifts by n times the clock adjustment, internal involvement is strongly suggested, but still not uniquely located. Frequency-agile sampling changes where a fixed external signal aliases into the acquired spectrum; therefore an externally generated tone may also move on the display when f_c changes. One should compare in physical RF frequency, sample-domain bin number and clock-harmonic order

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separately. It is a category error to treat all three coordinate systems as interchangeable.

The preservation record ought to include raw samples, clock-generator programming, actual oscillator-frequency measurement, amplitude and phase of the suspicious peak, front-end gain, cable routes, enclosure condition and temperature. A narrow line may be internally produced while a faint external transmission remains superposed. When the internally generated component is suppressed, a different spectral object can become visible. Consequently a source-off test cannot be sold as proof that the ambient environment was free of energy. It establishes the response to one controlled state. I would pass the token to those who can trace the subtle conduction paths and explain why a well-grounded instrument can nevertheless display its own clock.

Lord Rayleigh, Peer Question: Professor Kroemer, your 0.2 pF illustration is illuminating, but the voltage transition at a physically complex node is not necessarily a linear ramp, and the victim node is not held at a perfect virtual ground. An oscilloscope probe may add capacitance comparable to the very coupling you wish to characterise, while its ground lead can create an artificial current loop. How would you put uncertainty bounds around the inferred displacement current without claiming more precision than the geometry warrants? Moreover, suppose an investigator sees only the resulting FFT line, not the switching pulse itself. Does the line amplitude determine the peak current, or could several temporally different transients give similar spectral components? I ask because the apparent elegance of a single numerical result may tempt a reviewer to overlook the frequency response of the path between source and detector.

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I should also like the record to distinguish uncertainty in the coupling coefficient from uncertainty in the displayed amplitude, since the latter contains the intervening transfer function and the detector calibration, each with different limits and possible correlations.

Herbert Kroemer, Response: Lord Rayleigh, one must first state whether the objective is to estimate an instantaneous current at a defined node or merely to demonstrate a causal coupling path. The illustrative derivative formula is a constitutive relation for the displacement current associated with a defined effective capacitance and voltage difference. It becomes a numerical estimate only after those quantities and their uncertainty have been obtained. An open-air geometric estimate, a low-frequency capacitance meter reading and a fitted high-frequency coupling capacitance need not coincide. Fringing fields, nearby conductors and resonant structures make the inferred parameter dependent on the measurement arrangement. I would therefore report the assumed waveform and an interval of plausible capacitances rather than asserting that 0.2 pF is an observed constant.

An ordinary passive oscilloscope probe can disturb a sub-picofarad node and its ground connection may add appreciable inductance. A properly characterised high-impedance active probe, a minimally perturbing near-field pickup, or a designed sense structure may reduce the disturbance, but none is magically non-invasive. Repeat the experiment with two probe geometries and check whether the alleged component is stable within the declared uncertainty. If the waveform changes radically when observed, the observation apparatus has become part of the circuit. That fact belongs in the evidence record, not in a discarded notebook page. The trustworthy

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quantity may then be a bounded transfer ratio rather than a reconstructed peak current.

An FFT line is a complex Fourier coefficient after windowing, filtering, sampling and possible averaging. It does not uniquely specify the original current pulse. Different time-domain waveforms can possess the same coefficient at a chosen frequency, especially when the phases of other components are unrecorded. To infer peak current from a line one would need a known source waveform family, a calibrated transfer function, and sufficient spectral information to reconstruct the relevant portion of the transient. Even then finite bandwidth and noise impose uncertainty. In a forensic survey the more modest claim is often stronger: a controlled clock change caused a coherent change in the instrument's own apparent RF line, and that behaviour is inconsistent with treating the line as independent evidence of a nearby emitter.

Sir Edward Victor Appleton, Peer Question: Professor Kroemer, consider an instrument whose clock harmonic is conveyed not through a simple capacitance but through a common-mode current on the outer surface of a coaxial shield. The operator removes the antenna, substitutes a matched load, and still observes the line. He then declares the line 'downstream of the input connector'. But an external ambient field could excite the power lead, and the harmonic might only be a modulation or mixing partner. Could you specify a sequence of controls which keeps the input impedance as constant as practicable while distinguishing intrinsic oscillator emission, reception on unintended cables, and mixing with a genuine external field? Please explain what may be inferred when clock tuning, cable rerouting and

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an independent receiver each give partly conflicting results, for the evidence must address the ambiguity rather than conceal it.

The test should identify whether the remaining emission is coherent with the local oscillator at the measurement instant, and whether the independent receiver has an adequately characterised noise floor at that same physical frequency.

Herbert Kroemer, Response: Sir Edward, the sequence should begin with a wiring diagram and a declaration of reference planes, not with the simplistic division between inside and outside. The antenna port is one boundary, but the enclosure also has power, data, control and protective-earth connections. Their conductors can carry common-mode current even when their intended differential signals are entirely ordinary. Preserve photographs of cable routes and the initial operating state before touching the apparatus. Then repeat the suspect observation with a calibrated shielded load at the antenna port, making as little alteration as possible to the outer-conductor continuity. Where permitted, compare a second load assembly with demonstrably different common-mode impedance, because a change may expose the shield-current path.

Next measure the actual clock signal and perturb its frequency within a qualified operating range. Determine the candidate harmonic order from the physical RF frequency, not merely from a displayed baseband bin. If the line follows the clock, the internal oscillator is implicated either directly or as a mixing partner. Now change one cable's common-mode impedance with an appropriate characterised clamp or routing adjustment, documenting the precise location and preserving safety earth. A corresponding amplitude change supports participation of that cable path; it does not by itself identify

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whether the energy entered or left the enclosure. Current-probe measurements and controlled injection at known positions may provide directional evidence, but only under an explicit model.

Finally introduce an independent receiver with different clocks, power supply, cables and antenna geometry, while keeping the environmental conditions comparable. If the same physical-frequency feature remains in the independent instrument and does not track the suspect unit's clock, an external component becomes more plausible. If the line follows the suspect clock and the second receiver detects radiation near the suspect unit, the unit itself may be the external emitter for that second receiver. Conflicting outcomes need not be contradictions; they may describe simultaneous mechanisms. The conclusion should specify which source-path combinations have been excluded experimentally and which remain possible. The record is thereby more useful than the assertion that a line was either wholly internal or wholly external.

Because power delivered to a nonlinear stage may change when the antenna load is altered, the investigator should additionally verify that any inferred line displacement was not created by a different compression state. Record a stable reference tone where possible and compare its recovered gain before treating the clock-correlation test as decisive.

Dr. James M. Atkinson, Moderator: Professor Bardeen, Professor Kroemer has followed charge displacement from the clock conductor to the analogue input. Kindly examine the less conspicuous routes through bias networks, semiconductor junctions and ground-reference movement, where a line may appear without a conventional radiating antenna.

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John Bardeen, Second Principal Contributor: Dr. Atkinson, the semiconductor does not recognise the neat labels which engineers give to its pins. Its junction capacitances, finite resistances, leakage paths and bias networks respond to voltage and current in accordance with physical relationships. A clock edge can couple through a transistor's collector-base or drain-gate capacitance; a common supply impedance can move several stage bias points together; and the reference potential of an analogue-to-digital converter can change just as its sampling operation depends upon that reference being stable. The ensuing error may be additive in some regions of operation and multiplicative in others. Thus a spectral line observed at the output need not correspond to a travelling radio wave at the input. It can arise from coherent modulation of the instrument's own conversion process.

Let the analogue signal be $x(t)$, and suppose a small periodic reference disturbance produces a fractional gain modulation $m \cos(2\pi f_c t)$, with $|m|$ much less than unity. A simple model is $y(t)=x(t)[1+m \cos(2\pi f_c t)]$. For a real sinusoidal input $x(t)=A \cos(2\pi f_s t)$, the product contains two sidebands at f_s+f_c and $|f_s-f_c|$, each with ideal amplitude $m A/2$ in addition to the original carrier. This is not direct radiation from the clock. It is modulation inside the measurement chain. If f_s is absent, the simple multiplicative model yields no standalone clock line; such a line requires an additive feedthrough term, offset modulation or another nonlinearity. This distinction is experimentally valuable because the dependence on input amplitude can separate a gain-modulation artefact from an additive oscillator leak.

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The power-distribution network is not an ideal equipotential. Denote the complex transfer impedance from clock-driver current to a sensitive supply or reference node by $Z_t(f)$. A spectral current component $I_c(f)$ produces a corresponding voltage component $V_n(f)=Z_t(f)\ I_c(f)$ under the linear small-signal approximation. Z_t depends on regulator output impedance, package inductance, plane geometry, decoupling capacitors, cable resonances and the point at which each reference is measured. For example, a hypothetical 5 mA component at 80 MHz passing through a measured 0.4 ohm transfer impedance yields 2 mV at the victim node. A 2 mV reference disturbance may be negligible in one converter and intolerable in another; that judgement requires the converter's reference-transfer sensitivity and the signal level under investigation.

It is unsound to declare that replacing a capacitor will necessarily cure the disturbance. Capacitors have equivalent series resistance and inductance; their impedance ceases to decrease indefinitely with increasing frequency. Multiple decoupling elements can create resonances or antiresonances, especially in combination with the power plane and package. A clock-related line can become stronger at a particular frequency when a well-intentioned component change increases the local transfer impedance. The appropriate operation is to measure or model the network's impedance over the frequency range of concern, and to verify performance after one controlled change. One must differentiate a power-integrity improvement measured at the regulator from a reduction in the actual sensitive-node error; they are not automatically equivalent.

The return path of a nominally differential clock is also relevant. Differential signalling can reduce the field produced by equal-and-opposite currents in

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closely spaced conductors, but amplitude imbalance, skew, unequal parasitics and common-mode conversion prevent perfect cancellation. A shield, via fence or plane transition alters the return-current geometry. If the clock pair crosses a gap in a reference plane, the high-frequency return current may take a detour that enlarges the loop area and increases radiation or coupling. This is a geometry-dependent electromagnetic effect; replacing the word ground with a thicker line on a schematic does not remove it. A technician must inspect the as-built layer stack and actual connector reference paths.

There are two opposite ways for a clock to counterfeit an RF source. It may generate energy that enters the analogue chain before digitisation, in which case the raw sample contains a response to a genuine electrical disturbance inside the instrument. Or it may corrupt sampling timing or reference voltage, thereby changing the mathematical relation between the physical RF voltage and its digital representation. A third possibility is post-conversion corruption in data transfer, where periodic data errors create FFT patterns without an analogue counterpart. Each is an internal origin, but the diagnostic tests differ. A known input signal and an instrumented clock or reference node help to discriminate those cases; a shielded antenna input alone cannot distinguish them.

Consider clock jitter. For an ideal sinusoidal input of frequency f_{in} and independent random sampling-time error with root-mean-square magnitude σ_t, the jitter-limited signal-to-noise ratio is approximately $SNR_j=-20 \log10(2\pi f_{in} \sigma_t)$, provided $2\pi f_{in} \sigma_t$ is much smaller than unity and other noise is ignored. If $f_{in}=100$ MHz and $\sigma_t=1$ ps, the dimensionless product is about 0.000628 and the limiting SNR is about 64.0 dB. At 10 MHz

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with the same jitter, the limit is about 84.0 dB. These numbers concern broadband uncorrelated timing uncertainty; a coherent clock sideband requires a different phase-modulation treatment. The examiner should not cite a broadband jitter limit as proof that a particular discrete spur must exist at a particular amplitude.

A useful discrimination employs a controlled RF tone at two amplitudes while leaving the clock and gain configuration constant. If a suspect sideband scales with the tone's amplitude, multiplicative contamination becomes plausible. If a clock-related peak remains roughly fixed when the tone is removed, additive leakage or an internally generated offset mechanism must be considered. Yet saturation, AGC and quantisation can defeat that simple test, so the receiver's linear range must be established. A second test changes the sensitive supply's source impedance without altering its nominal voltage, using a qualified design modification and checking thermal stability. The forensic chain of reasoning must record which intervention changed the spur and which other operating quantities remained unchanged. I pass the token with the warning that semiconductor bias and measurement reference are physical variables, not merely support utilities.

Sir Martin Ryle, Peer Question: Professor Bardeen, your gain-modulation equation presumes a deliberately simple sinusoid and a small periodic coefficient. A practical receiver may be digitising background noise, intermittent signals and several strong carriers simultaneously, while gain control and filter selection are changing. How can an investigator test your distinction between additive leakage and multiplicative corruption without presuming that an ambient weak emitter is absent? In particular, if a

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controlled RF tone is injected, might its own interaction with the converter or the injection cable produce sidebands not previously present? I seek an evidence protocol that preserves the unmodified baseline and discriminates between the true environmental occupancy, laboratory-induced products and digital reconstruction, instead of producing an artificially tidy spectrum by substituting a very strong test signal.

Please specify how repeated test-tone acquisitions would be interleaved with untreated baseline acquisitions to disclose drift, and how a moving clock-related spur should be recorded when its Fourier bin changes during the comparison.

John Bardeen, Response: Sir Martin, the first requirement is to preserve a baseline acquisition in which the natural input connection, receiver settings and cable positions have not yet been altered. Record raw samples and all available state metadata rather than only a smoothed spectrum trace. A controlled injection is then an intervention upon a second, explicitly labelled condition, not a reconstruction of what the original environment contained. The injected tone should be sufficiently weak to remain within the demonstrated linear range of every relevant stage, with source power, coupling factor and reference-plane impedance measured as far as practicable. The investigator should inspect overload indicators and perform a modest amplitude sweep to detect any abrupt change in conversion or gain.

One can then separate the candidate peak into a family of comparisons. First measure the clock-related line with the receiver in its original baseline configuration. Second apply the known tone and determine whether sidebands appear at the predicted sum and difference frequencies. Third

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reduce the tone by a declared number of decibels and repeat the measurement. Fourth remove the tone, preserving the physical injection hardware if possible, to control for cable-path changes. Fifth make a small clock-frequency change and observe trajectories in physical-frequency coordinates. If the proposed gain-modulation sidebands obey the product model over an appropriate range and the additive line does not, the evidence favours two distinct mechanisms. It remains possible that the original environment contained another weak source superposed on both.

Noise need not invalidate the procedure, but it changes the statistical analysis. A coherent line can be extracted against noise through repeated measurements if averaging conditions, temporal coverage and window properties are recorded. A non-stationary emitter, however, may be suppressed by averaging that assumes persistence. A time-resolved waterfall and raw complex samples should therefore accompany any ensemble spectrum. The injected tone's presence must never justify editing away baseline peaks that cannot be replicated in the laboratory. Those peaks should remain documented as observations of uncertain origin. The result is a conditional classification supported by interventions, not a categorical assertion that every small line is an artefact.

The evidence matrix should retain the input-tone-off condition as a separate trial rather than subtracting its spectral estimate from the on condition without validating linearity. A published plot of a cleaned spectrum should never replace the unaltered original sample stream.

Edwin Howard Armstrong, Peer Question: Professor Bardeen, I am concerned about a failure in the logic of the matched-load experiment. An input termination can change a transistor's noise match, and a poorly

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shielded load assembly may itself act as a receiving structure through its outer conductor. Moreover, a weak oscillator harmonic can be present below the detector's threshold in one gain state and appear above it when the front end is reconfigured. How should a surveyor decide that an internal clock is implicated when the displayed line appears only under certain antenna impedances? Is this simply evidence of an external field, or can a source wholly inside the instrument have a load-dependent amplitude? Please propose a discrimination that does not require opening a calibrated enclosure or invalidating its measurement status.

I also ask that the answer distinguish an antenna-port gain change from a gain change applied after the internal coupling point, since their different responses might provide a useful discriminating test without opening the instrument.

John Bardeen, Response: Professor Armstrong, a load-dependent amplitude is compatible with either internal or external excitation. The instrument's input network can present a variable termination to an internally coupled source, modifying standing waves and the voltage transferred into the first active stage. The same load change can alter the response to a genuine external source arriving through the intended antenna port. The difference cannot be inferred from amplitude alone. A correct analysis treats the RF input and its reference shield as a multiport boundary, with the clock, power and control circuits represented as additional ports whether or not the manufacturer draws them on the user's front panel.

Where the sealed enclosure must remain intact, use external interventions that do not disturb calibration seals or protective earth. Compare two

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characterised terminations with equivalent differential impedance but different outer-shield common-mode conditions, if such assemblies are available and their properties are documented. Sweep the allowed receiver gain states and record whether the candidate line changes in proportion to the calibrated signal gain. A clock-related spur injected after the first amplifier can fail to track antenna-port gain, whereas an internal harmonic admitted before the amplifier may track it. That distinction is informative but not decisive because automatic controls and nonlinearities can make both paths look similar.

An independently clocked receiver situated nearby may detect radiation from the suspect unit; repeating that observation with the suspect unit's clock frequency changed supplies additional evidence. Conversely, a line that disappears only when the antenna is attached may reflect altered input matching rather than the absence of an internal source. Record both positive and negative controls, measured environmental noise, uncertainty intervals and the conditions that invalidate comparison. The examiner should use the phrase 'consistent with clock-mediated coupling through the instrument' when that is the evidence, reserving definitive source claims for a set of tests that actually excludes plausible alternatives. Calibration status is preserved by documenting the interventions rather than relying upon unsanctioned internal modifications.

Where controlled input attenuation is available, measuring the relative slope of the candidate component and a calibrated external reference signal across several gain settings may help locate the effective injection point. It remains an inference subject to noise, mixing and automatic-control qualifications.

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Dr. James M. Atkinson, Moderator: Mr. Hewlett, semiconductor nodes explain how the disturbance enters a converter, but the distributing oscillator may have many buffers and branches. Please examine clock-tree balance, return-current architecture and the measurement of a route by which an internal component reaches several receiver channels with different phases.

William Redington Hewlett, Third Principal Contributor: Dr. Atkinson, I would begin with the clock distribution as a network whose branch impedances and propagation delays are measurable, rather than a diagram of identical arrows leading from one reference source. A source oscillator can feed a fanout buffer, differential pairs, coaxial interconnects and converter clock pins, each loading the preceding stage in a different way. The clock's nominal frequency may be identical at each destination while its phase noise, deterministic jitter, common-mode voltage and harmonic content differ substantially. A broad-band measurement of the fundamental may therefore conceal the precise high-frequency behaviour relevant to an RF spur. To follow the disturbance one must identify the physical launch point, the return conductor for each branch, and the receiver node in which contamination becomes visible.

A useful first model writes the observed spur voltage in receiver channel k as $V_k(f)=H_{kc}(f)\,V_c(f)+H_{ks}(f)\,V_s(f)+N_k(f)$, where V_c is an internal clock-related excitation, V_s an external source at the antenna reference plane, H_{kc} and H_{ks} are the respective complex transfer functions, and N_k combines unrelated noise and unmodelled terms. This is a small-signal linear representation at one frequency; its coefficients depend on the equipment state and need not remain fixed under overload. One can

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measure relative complex phase as well as magnitude under a controlled stimulus. If two channels share a clock fanout branch, their internal spurs may be highly coherent even when their antennas face different directions. That coherence is evidence of a shared influence, but it is not unique proof of internal origin because a common external broadcast can also appear coherently in multiple receivers.

There is particular danger in regarding an enclosure bond as a zero-ohm, zero-inductance point at every frequency. A connector shell may contact a panel through a narrow bracket or an oxidised fastener, and a high-frequency clock return current may traverse that junction. A milliohm DC measurement is not a full characterisation of the RF transfer impedance. Even a nanohenry has reactance $|X_L|=2\pi f L$. At 100 MHz, 1 nH corresponds to about 0.628 ohm. If a conductor carries a 10 mA coherent component at that frequency, the simple inductive voltage magnitude is approximately 6.28 mV. The numerical example assumes a lumped element at a frequency where that approximation must be checked. The enclosure itself, nearby planes and attached cable can form a distributed structure and invalidate the single-inductor representation.

When several branches are switched by independent logic, the disturbance may have both common and differential components. A differential probe across the clock pair measures their voltage difference; a current clamp around both conductors measures net common-mode current if the geometry and probe bandwidth are adequate. The two measurements answer different questions. If a cable carries equal and opposite high-frequency currents it can be a reasonably balanced differential line while still exhibiting local capacitive coupling to neighbouring conductors. An

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imbalance or imperfect return, however, converts part of the intended differential current into a current that flows on the cable shield or chassis and can radiate. Avoid equating a small differential noise waveform with negligible common-mode emission.

One must be especially careful with clock-frequency perturbations in a multi-channel converter. Moving the sample clock changes the sample interval, the aliasing relation, often the digital filters, and perhaps the local-oscillator or phase-locked loop configuration. A line that follows an altered sample rate may be an ADC interleaving product, a true clock harmonic coupled into the analogue chain, or an external signal whose digital representation changes. The investigation should log the frequency of the actual physical line using an independent, stable reference instrument whenever possible. Change only one clock setting within the hardware's qualified state and repeat the observation. If the equipment cannot tolerate a clock change, use a controlled shutdown of a non-essential auxiliary oscillator or an approved switchable clock branch, preserving a matched control condition.

A more decisive experiment measures a cross-channel transfer matrix under a known injected disturbance and compares it with the matrix inferred from the spontaneous spur. Inject at a defined service test point only when the apparatus is engineered to permit such injection. Keep the injected level below the threshold of compression, and compare phase as well as amplitude across branches. If the spontaneous line shows the same branch-to-branch ratios as the clock stimulus, the hypothesis of common clock-mediated contamination gains strength. If it instead follows antenna direction, external gain changes or independent environmental controls,

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external coupling remains plausible. The matrix does not have to identify a single fault component; it can establish an operational boundary beyond which a measurement must be qualified.

The question of a clean ground is resolved by measurement, not by an instruction to install more copper. An added braid or bond may lower impedance at one frequency while creating a new parallel loop that couples a clock current into a more sensitive region. A ferrite impedance may suppress common-mode current over a limited band but change the behaviour of adjacent frequencies. Temporary remedies must be inspected over the whole operating range and under expected thermal and mechanical conditions. The instrument's internal calibration and safety certification set boundaries for what a field investigator can modify. Often the correct outcome is to identify an invalid portion of spectrum and quarantine it rather than to repair a certified instrument without authorised procedures.

Finally, documentation should separate the source oscillator's purity, distribution-path isolation and receiver-channel susceptibility. A low-phase-noise oscillator can still produce severe coherent interference through its output driver or a poorly bonded shield. Conversely, a visibly noisy clock can be harmless to a particular channel if the transfer path is sufficiently suppressed. The operational claim must concern the spur at the receiver's actual measurement reference plane and the strength of evidence excluding external sources. This network view complements semiconductor analysis without pretending that the network diagram itself is a forensic verdict. I invite a colleague to challenge whether our test instruments can measure these small currents without constructing another path.

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Hendrik Wade Bode, Peer Question: Mr. Hewlett, your transfer-matrix proposal assumes that injection through an engineered test point approximates the spontaneous clock disturbance. A square-wave driver with multiple harmonics can excite enclosure resonances differently from a laboratory synthesiser with a comparatively clean sinusoidal output, even if the nominal frequency agrees. If the investigator obtains matching channel amplitude ratios at one frequency, could that simply be an accidental agreement between two distinct source distributions? How should phase, frequency and multiple independent experiments be used to prevent an attractive matrix fit from becoming a false identification? Please also address calibration drift and the fact that a closed-loop receiver may move between distinct gain and oscillator states during acquisition, changing the matrix while the operator believes it constant.

A declaration of repeated trials is of little value unless the frequency grid, phase reference and conditioning state have been preserved. I ask how these hidden variables can be independently checked.

William Redington Hewlett, Response: Professor Bode, agreement at one frequency and in one operating state is plainly insufficient to identify an excitation path uniquely. The injection defines a measured transfer from a specific port; it does not demonstrate that the uncontrolled oscillator excites the same spatial distribution of currents. A square wave can energise numerous modes, while an injected sinusoid samples only one frequency at a time. We can nevertheless compare the transfer functions at several harmonics and at points between them, provided the chosen injection is within the instrument's linear range. Their complex ratios and phase progressions offer more discriminating evidence than a single amplitude

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ratio, although a finite measurement set can still admit multiple physical explanations.

The instrument should be stabilised thermally before comparison, and gain, sample rate, oscillator state and any preselection state must be captured in the record. A phase measurement requires a documented time reference and calibrated cable delays. If the phase reference is not stable across measurements, report magnitude alone rather than invent coherent certainty. Repeat measurements after returning to the original state to expose drift and mechanical sensitivity. A large hysteresis between outward and return sweeps is a warning that the assumed stationary transfer model is not valid, not a nuisance to be averaged away.

One can improve causal discrimination through interventions that act differently upon the competing paths. For example, a characterisable common-mode impedance at one external lead may strongly alter a cable-mediated disturbance while leaving internal capacitive coupling almost unchanged. Rotating an antenna may affect an ambient field without materially altering a deeply internal clock-to-ADC path, though nearby metal and cable motion could complicate that expectation. The results become a matrix of hypotheses and test predictions, not a single fitted curve. If several models remain observationally indistinguishable within uncertainty, the conclusion must retain that ambiguity. The forensic duty is to prevent an apparent agreement in transfer measurements from being converted into a claim of uniquely identified provenance.

A frequency synthesiser should be monitored independently of its programme register, because command acceptance is not proof of actual

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physical settling. Any phase comparison should be rejected if the timing reference itself loses coherence between conditions.

Dr. James M. Atkinson, Moderator: Dr. Steinmetz, Mr. Hewlett has identified the physical branches of the clock network. Kindly follow the return current into an enclosure, its bonds and external cables, explaining when a nominally closed metal case behaves as part of the oscillator's radiating and receiving structure.

Charles Proteus Steinmetz, Fourth Principal Contributor: Dr. Atkinson, no enclosure can be understood without its conductors, currents and the frequency at which they operate. A metal case may give excellent electrostatic shielding at low frequency yet present a complex collection of apertures, seams and resonant cavities at high frequency. Its shielding is not a single material constant, and a foil-thickness calculation alone cannot characterise the assembled instrument. The clock source and its return conductor generate fields. At an imperfect bond or cable penetration, those fields can drive current across an unintended impedance, producing a voltage that re-enters the receiving path. Even when the metal is thick enough for strong attenuation through its uninterrupted surface, the openings and attached conductors may dominate the effective coupling.

A thin seam is not automatically a negligible aperture. Its response depends on length, width, contact continuity, field orientation and the wavelengths of interest. A narrow but electrically long gap can couple strongly to the appropriate field component. Conversely, a relatively broad opening may be less troublesome at a sufficiently low frequency or under an unfavourable polarisation. The test must not be reduced to the existence of a visible hole. For a frequency of 300 MHz in free space, the corresponding wavelength is

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approximately 1.00 m using c≈3.00×10^8 m/s. The half-wavelength scale is about 0.50 m, but the effective dimensions inside a dielectric-loaded cavity or along a slot can differ. The computation is an illustrative dimensional comparison, not a prediction of a particular cabinet resonance.

There are two paths by which a clock may travel outside the enclosure and return. The first is direct radiation from a seam or protruding conductor and subsequent reception by the apparatus's intended antenna. The second is conducted common-mode current along a supply or data cable, whose external portion can act as an antenna and excite fields near the input. A third mechanism is local magnetic or capacitive coupling between an internal clock cable and the input stages without involving the remote environment at all. These mechanisms can coexist. They are experimentally separable only if the investigator changes the relevant geometry or boundary without simultaneously changing every other condition. Simply wrapping the case in extra foil may alter several current paths and obscure rather than identify the cause.

An enclosure bond has a DC resistance and an RF impedance. At frequencies where the conductor's physical dimensions are not negligible, voltage and current can vary along the metal surface. The familiar lumped expression Z=R+jωL is useful for a short bond if the approximation holds, but it cannot replace a distributed-field model for an electrically large assembly. One can use a near-field magnetic loop to identify local current patterns or a calibrated common-mode current clamp to measure cable current, noting that each probe has limited bandwidth and spatial resolution. Mapping a field maximum is not the same as locating the original oscillator; resonances

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may create maxima far from the energy source. An examiner must record probe orientation and position if results are to be compared.

The role of protective earth requires particular restraint. No field experiment should lift a safety earth or deliberately defeat protective bonding merely to make an RF line disappear. One can instead employ approved isolation methods, differential measurement, fibre-optic data links or characterised common-mode impedances where these are compatible with the equipment's safety and calibration requirements. A battery-powered independent receiver may help establish whether the suspicious line is emitted by the instrument itself, but the new receiver also has clock and cable artefacts. Every altered configuration needs its own reference measurement. When the test affects cable geometry, compare the time history to detect whether an environmental source changed concurrently.

The relation between shielding effectiveness and power reduction must be stated carefully. A voltage or field attenuation of A_dB=20 log10(E_before/E_after) uses a consistent field quantity, position and impedance context. If the field amplitude decreases by a factor of ten, the level difference is 20 dB. Power ratios instead use 10 log10(P_before/P_after), giving the same 20 dB for a hundredfold power reduction under comparable conditions. One cannot apply a shield's advertised 60 dB figure directly to a measured spur without knowing the test field, coupling configuration and location. An instrument may have different shielding effectiveness with every connector and lid screw properly fitted than it does with one maintenance panel open.

A useful experiment proceeds from the least invasive to the more complex. Capture the baseline raw spectrum and a concurrent near-field or cable-

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current observation, retaining the same clock and acquisition settings. Reproduce the suspect feature under a characterised antenna-port termination. Measure relevant clock harmonics with an instrument independent of the suspect sampling system. Where service access is permitted, inspect mechanical bonding and shielding continuity using approved procedures; do not deform seams or disturb calibration seals in the name of investigation. Then move one external cable within a controlled fixture and record any change in common-mode current, nearby field and receiver artefact. Interpret correlation among those measurements, not the behaviour of one trace in isolation.

A clock-synchronous line does not imply that the clock source radiates enough energy to threaten a distant site. The level recorded inside the instrument may be the product of strong local coupling and exceptionally sensitive internal detection. Conversely, a weak internal perturbation can become conspicuous after a high-gain stage or coherent spectral averaging. We therefore need two separate descriptions: emissions measurable outside the case under defined conditions, and susceptibility of the instrument's own receiver chain. Their regulatory, engineering and forensic meanings differ. Shielding design may improve one without proportionally improving the other. I submit that a disciplined boundary test is indispensable if a negative surveillance search is to retain evidential value.

George Ashley Campbell, Peer Question: Dr. Steinmetz, your account rightly treats a cable and enclosure as a distributed structure. Suppose an operator discovers that moving a power lead by twenty centimetres alters a clock-related line by fifteen decibels. He immediately concludes that the lead was the source and prescribes a ferrite clamp. But a nearby receiver

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antenna may see a changed multipath environment, and the cable motion may change the mechanical loading of a connector. What combination of current measurement, field mapping and controlled impedance changes would justify a claim that common-mode propagation on the lead caused the effect? Would the conclusion remain warranted if the ferrite improves one spectral region but worsens another, or if the reported fifteen-decibel improvement disappears after the case warms?

In particular, what objective change must accompany an observed decrease in the spur before the investigator may claim that the suspected lead is an established coupling path rather than merely a movable scatterer?

Charles Proteus Steinmetz, Response: Mr. Campbell, cable movement is an intervention with many possible consequences. The observed fifteen-decibel difference is a fact about a particular configuration; it is not by itself an identification of the current path. Begin by fixing the antenna and the receiver in a repeatable mechanical geometry, then move only the lead using a measured fixture. Record the line's physical RF frequency, amplitude, receiver gain and clock state before and after motion. Use a calibrated common-mode current probe around all conductors of the lead together to measure net current, while ensuring the probe has adequate response at the suspect frequency. If the observed current changes coherently with the receiver line, the cable-mediated hypothesis gains support, but correlation still leaves alternative coupling paths possible.

A second test inserts a characterised common-mode impedance at a documented cable position without defeating safety or affecting normal power delivery. Measure both the current at positions upstream and downstream of the impedance and the receiver spur. A reduction in current

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accompanied by a consistent spur reduction is stronger evidence for that route than movement alone. However, if the added impedance causes a resonance, the line may increase at another harmonic. This is not a contradiction: the impedance and the surrounding distributed network are frequency dependent. The entire relevant band must be observed, and any remedy judged against receiver performance, safety and the possibility of new artefacts.

Temperature dependence requires the experiment to be repeated after thermal equilibrium, with return-to-baseline trials. Oxidised bonds, mechanical contacts, semiconductor bias and oscillator drive levels can all vary during warm-up. A spur reduction that vanishes at normal temperature is not a valid general mitigation. An examiner may properly state that the cable carries a clock-coherent common-mode current and that its controlled alteration changes the receiver's output under specified conditions. The stronger assertion that this path alone caused the original line requires enough interventions to exclude competing mechanisms within uncertainty. A well-written report should distinguish a demonstrated coupling contributor from a uniquely established origin.

A further return-to-baseline observation should follow every impedance intervention, and a repeated loss of the effect on restoration would require the analyst to revisit the assumed mechanical stability. This guards against attributing a thermal drift to a planned RF modification.

Dr. James M. Atkinson, Moderator: Mr. Heaviside, we have heard how a clock enters a semiconductor and traverses a conductor network. Please extend the argument to distributed electromagnetic fields, standing waves,

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enclosure apertures and the fundamental limits of inferring a source from a spectral line measured at a single point.

Oliver Heaviside, Fifth Principal Contributor: Dr. Atkinson, the phrase 'signal travelling through a metal box' is a convenient story, but the fields do not respect the labels stamped upon the hardware. The electric and magnetic fields are coupled through Maxwell's relations, and the relevant boundary conditions depend on the conductivity, permeability, geometry and continuity of the actual surfaces. A line visible on an internal spectrum display may be the endpoint of a sequence of fields and currents that includes a board trace, a cable shield, a slot in the enclosure, a cavity mode and the first low-noise amplifier. An equivalent circuit can clarify a sufficiently small or well-defined subassembly, but it is hazardous to force an electrically large enclosure into one unqualified lumped capacitance and one unqualified inductance.

For a uniform lossless transmission line, travelling voltage and current waves have a characteristic impedance Z_0 and propagation velocity v determined by the line geometry and constitutive materials. A load mismatch produces a reflection coefficient $\Gamma=(Z_L-Z_0)/(Z_L+Z_0)$, where Z_L is the complex load impedance. For a nominal 50-ohm line terminated in 75 ohms, $\Gamma=25/125=0.2$, corresponding to a reflected voltage-wave magnitude of twenty per cent. This example does not characterise an arbitrary enclosure seam, but it demonstrates why changing a connector or termination can alter the phasor sum at a receiver without changing the original clock source. The wavelength and physical distance to discontinuities determine the relative phase of the incident and reflected waves.

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A return current does not select the shortest route drawn on a schematic; its distribution follows the electromagnetic boundary conditions and frequency-dependent impedances. At higher frequency a current associated with a microstrip trace is strongly concentrated in the adjacent reference conductor, because that geometry minimises the field energy under typical conditions. If the reference plane is interrupted, the return may spread around the opening or couple to another plane through capacitance, enlarging the loop and increasing sensitivity. An apparent clock harmonic can therefore become larger following a board revision that moved a trace only a few millimetres. That behaviour is not mysterious. It is the consequence of changing the field configuration through which energy is stored, transported and dissipated.

The enclosure is neither an absolute barrier nor always a simple passive attenuator. An interior cavity may sustain particular field patterns, and a seam or feedthrough can convert an internal field into external radiation. Reciprocally, the same aperture can admit an external field, subject to reciprocity conditions and the details of the material. A measured resonance peak does not locate the oscillator, for resonant energy can be spatially concentrated at a point remote from the driver. Field mapping with a finite probe also perturbs what is being mapped. A robust analysis uses several locations, orientations and independent reference conditions rather than declaring that the brightest near-field point is the cause of all observed contamination.

One should distinguish three spectra. The first is the spectrum of the oscillator waveform at a defined electrical port. The second is the distribution of fields and currents through the enclosure at a specified

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operating state. The third is the numerical spectrum produced by the receiver's digitiser and processor. Their frequency axes may coincide for some components but not for all: sampling aliases a physical frequency f into an equivalent discrete-time frequency according to the sample rate f_s, while analogue nonlinearities can generate new physical frequency products before the ADC. For a real sampled sinusoid, a component near f=115 MHz sampled at f_s=100 MHz can appear at 15 MHz after aliasing under simple uniform sampling assumptions. That displayed 15 MHz is not proof of a 15 MHz emitter. One must inspect the anti-alias filters and sampling conventions before drawing such a conclusion.

The distinction is more serious when the sample clock itself is the source of contamination. An oscillator harmonic at an integer multiple of f_s can alias to direct current or a low-frequency offset when admitted through the analogue path. A change in f_s can then cause the alias trajectory to differ greatly from the trajectory of an independently fixed external source. However, if the clock leak is generated digitally after sampling, the analogue alias model may not apply. A single displacement of a line after retuning cannot decide among these hypotheses. The experiment should record samples at multiple qualified clock rates and compute predicted image frequencies under explicit assumptions, comparing those predictions with a separate measurement of the physical field or conducted voltage where possible.

The strength of a field measured close to a small conductor cannot always be extrapolated to a field at a distant point using a simple inverse-distance law. Reactive near-field components can dominate close to a source, whereas radiated far-field power and directivity follow different spatial

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relations. A survey performed with a probe millimetres from a clock trace and one performed with a calibrated antenna several metres away answer different questions. Neither measurement can be converted into the other without an appropriate model of source geometry and propagation. The evidential purpose must be stated before the measurement geometry is selected, especially when the allegation concerns an illicit external transmitter rather than the instrument's own internally circulating currents.

Finally, there is a limit to inverse reasoning. If an enclosure is an unknown multiport system with several clock, supply, shield and antenna excitations, one observed complex voltage does not uniquely determine all its internal causes. Additional independent constraints are required: clock perturbation, source termination, cable impedance changes, controlled injection, separate receivers and measurements at additional ports. Each intervention adds information only if its effect upon the system is understood and the original state can be recovered. The scientifically sound conclusion may be that a reported line is strongly associated with the instrument's clock and is unsuitable as sole evidence of an external emitter, while the exact physical coupling route remains unresolved. I would prefer that bounded conclusion to a visually persuasive but unsupported story of a signal escaping through one particular screw hole.

Harold Stephen Black, Peer Question: Mr. Heaviside, your account has a practical implication for instrument qualification. The operator might show that a stable peak moves when the sample clock changes, label it internal, and then discard the frequency interval from further examination. Yet an external transmitter could occupy that interval at the same time, and the clock artefact may be coherently masking it. How should the operator

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distinguish the task of identifying the artefact from the separate task of demonstrating useful sensitivity to a weak external signal? Can you propose a sequence of deliberate challenges, using the known-signal injection and multiple clock settings, that avoids claiming a negative surveillance result merely because the clock spur has been explained? I would also welcome the appropriate treatment of uncertainty when the receiver's detection threshold varies with its own spectral defects.

Please specify whether the confidence statement should report a per-band detection threshold, a probability of intercept under an assumed duty cycle, or a more restricted declaration of laboratory test sensitivity.

Oliver Heaviside, Response: Mr. Black, the classification of an observed line and the demonstration of detection capability must remain separate. To show that a peak is clock-mediated one studies its trajectory, coherence with the clock, and response to controlled internal-state changes. To show that an external signal would have been detected, one introduces a known weak test signal at a calibrated reference plane and observes the receiver's response through the relevant acquisition schedule. These are different propositions. An explanation of the artefact does not establish that the receiver was capable of detecting a second component of equal or lesser strength in the contaminated band.

The qualification should include a series of injected tones or realistically modulated test signals near, below and above the suspect spur frequency, with levels measured independently. The receiver must be kept in its actual search mode, including any preselector states, averaging and automatic gain behaviour. Record detection probability or a defined repeatability criterion as a function of amplitude and frequency. When the clock spur

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masks the test signal or causes a false alarm, that region should be marked as degraded or indeterminate; the fact that a skilled operator can mentally recognise the spur does not create missing sensitivity. Repeating the test at two allowed sampling rates may show whether an alternative configuration restores observability.

A negative report must describe the coverage and threshold actually demonstrated. If the receiver detects a -90 dBm laboratory challenge in a clean passband but fails at -70 dBm under a clock harmonic, it is scientifically indefensible to apply the cleaner threshold to the contaminated interval. Real source polarisation, antenna coupling and intermittent duty cycles may further reduce detection probability relative to a direct injection test. Thus a receiver may legitimately exclude a known internal artefact from an external-source inventory while simultaneously declaring a corresponding limitation in the search. The correct conclusion preserves both facts instead of allowing one to cancel the other.

It would also be prudent to repeat the detection challenge with a second signal waveform having comparable spectral occupancy but different temporal structure. A narrow continuous tone cannot establish sensitivity to every low-duty-cycle pulse or phase-coded emission.

Oliver Heaviside, Cross-Peer Question to William Redington Hewlett: Mr. Hewlett, your channel-transfer matrix is attractive because it offers numbers where an enclosure appears almost forbiddingly intricate. But I should like you to examine a case in which a clock radiates at a seam and is received both by two antennas and through two internal supply returns. The paths can combine destructively in one channel and constructively in the other, and their relative phases can change after a small cable movement. If the

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measured amplitude matrix fits a single-source model at one instant, what additional observations are needed before it may be considered stable or identifiable? I am especially concerned that unmeasured phase, a temperature-dependent connector, and the presence of two coherent harmonics can create an apparently orderly result from several distinct mechanisms. Please address how one would preserve the separate environmental and internal components, rather than choosing the neatest fitted source merely because its mathematical residual is small.

William Redington Hewlett, Cross-Peer Answer to Oliver Heaviside: Mr. Heaviside, a transfer matrix from one assumed source to several outputs cannot establish uniqueness if there are multiple coherent excitation paths that produce similar response vectors. The amplitudes at the receiving channels depend on a vector sum of complex path contributions. If one cable movement changes a phase by approximately half a cycle, two contributions can move from cancellation to reinforcement without the oscillator's amplitude changing at all. It follows that one must avoid interpreting a fifteen-decibel change at the output as evidence that the clock generator itself suddenly became fifteen decibels stronger. The measured result is a property of the source-path-receiver assembly in a specified physical state.

An adequate procedure would record complex cross-channel spectra against a stable independent time reference, when phase stability allows. Repeat with deliberately varied cable configurations and thermal states, and retain every return-to-baseline trace. Measure the oscillator harmonic at a defined electrical point to establish whether its source amplitude also moved. Independently measure radiated or conducted fields around the

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seam and supplies, but document each probe's insertion effect and spatial sensitivity. If a supposed single-source model predicts the channel response after several orthogonal interventions, it gains credibility. If it fits only one state, it remains one of several possible explanations. A model with a low residual in one state is not evidence of unique physical identity.

One can express the ambiguity by writing a complex observation vector $y=Hc+e$, where H represents a matrix of possible transfer paths, c the unknown source amplitudes, and e noise and modelling discrepancy. If H has dependent or nearly dependent columns, several different c vectors may explain essentially the same y. Singular-value or condition-number analysis can expose the instability of such an inversion, but it cannot repair missing physical information. The investigator should acquire new independent observations, preferably by selectively and safely altering one path, rather than by presenting a more elaborate inversion of the same deficient data. The decision record should state which paths are supported, which remain observationally equivalent and whether the suspected line prevents reliable detection of additional external energy.

Herbert Kroemer, Cross-Peer Question to Charles Proteus Steinmetz: Dr. Steinmetz, you have distinguished local susceptibility from external emission, but their effects can meet again at the antenna port. Suppose a clock driver at forty megahertz has a harmonic near one hundred and twenty megahertz, an external supply cable radiates that harmonic, and a nearby survey antenna receives the field while the converter also has a weaker internal capacitive leak at the same frequency. Disconnecting the antenna removes one path while leaving the other. How can a forensic investigator estimate the separate contributions if the sources are mutually

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coherent and their measured powers are not simply additive? Would a shielded termination, cable-current measurement and a change in clock frequency be enough, or is an additional phase-sensitive reference required? Please also explain how to handle the safety constraints on modifying a mains-connected instrument, since a mechanically persuasive experiment that defeats protective earth would be unacceptable evidence.

Charles Proteus Steinmetz, Cross-Peer Answer to Herbert Kroemer: Professor Kroemer, the electric fields from coherent paths must be added as phasors before the power is calculated. If E_1 and E_2 are the complex field amplitudes arriving through the intended antenna and the internal leak respectively, the measured power in a fixed linear detector is proportional to |E_1+E_2| squared, not to |E_1| squared plus |E_2| squared unless their cross term averages away under appropriate conditions. The same clock may fix their phase relationship. Removing one path can consequently increase or decrease the measured line, depending on the initial phase difference. That apparent perversity is ordinary wave superposition and should not be suppressed by a report that assumes every attenuation experiment must reduce the observed output.

Start with a reproducible mechanical configuration and an independent timing reference if stable phase measurements are technically feasible. Measure the input-port line with the original antenna and cable arrangement, then with a characterised shielded load that preserves as much of the outer-conductor boundary as practicable. Simultaneously record clock frequency and cable common-mode current. Repeat each configuration several times, including restoration of the original arrangement, because a small mechanical change can alter the field phase.

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If the instrument permits a safe qualified clock-frequency adjustment, track the corresponding harmonic's physical frequency with an independent receiver, not solely with the clocked instrument under examination. The family of responses may support a two-path model, but the inverse problem remains underdetermined if relative phases are unknown.

A controlled phase or distance change can sometimes supply a further constraint, although movement of an antenna changes real environmental coupling as well. A VNA-based characterisation of accessible paths, carefully calibrated at relevant planes, may help estimate complex transfer ratios under stationary conditions. It should not be represented as a direct measurement of every hidden internal leak. As to safety, protective earth is not a variable for casual experimental removal. Use authorised isolation hardware, battery-powered receivers or fibre data connections when suitable, and have any internal intervention undertaken under appropriate service procedures. A credible report can state that the instrument radiated a clock-correlated field and also admitted internal feedthrough without pretending to apportion the exact fractions when the evidence does not permit that separation.

William Redington Hewlett, Cross-Peer Question to John Bardeen: Professor Bardeen, your distinction between additive leakage, gain modulation and sampling-clock jitter becomes difficult in a modern converter having multiple time-interleaved sampling channels. The nominal rate may be high, but each sub-converter has its own aperture delay, offset and gain error. If an interleaving spur and an external narrowband signal coincide in the same FFT bin, the displayed amplitude can vary with input level and clock rate in a way that superficially resembles both of your

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mechanisms. How should a laboratory discriminate periodic aperture skew from clock-line radiation and from a genuine source whose observed frequency aliases? Please give a model that identifies the relevant parameters, and explain what should be measured directly rather than inferred from a single noisy spectrum. The inference must not treat a programmable correction algorithm as proof that the physical error has been removed at every temperature and bandwidth.

John Bardeen, Cross-Peer Answer to William Redington Hewlett: Mr. Hewlett, time interleaving adds a structured set of periodic nonuniformities to the sampling process. If M sub-converters acquire samples in rotation, their offset errors can generate discrete patterns related to the sub-converter repetition frequency; gain and aperture-time errors can create spurious images that depend on the analogue input. For a small aperture error δt_k in sub-converter k, a local first-order model is $x(t+\delta t_k) \approx x(t)+\delta t_k x'(t)$. Its error magnitude therefore grows with the derivative of the input, explaining why a high-frequency test tone may reveal skew much more severely than a low-frequency tone at equal amplitude. The model is linearised and should be restricted to sufficiently small timing errors.

An offset spur can persist with a nominally zero analogue input, whereas a skew-related error of the above form vanishes for a constant input and tends to depend on input frequency and amplitude. An additive clock leak can also persist under termination but may vary with buffer drive or shielding; an external source may survive in an independent receiver on a stable physical frequency. Those differences allow a structured set of tests using a terminated input, several calibrated sine-wave input frequencies, controlled amplitudes, clock-rate changes and temperature sweeps. Keep

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the analogue reference level and gain state fixed during each comparison, and retain raw samples rather than relying solely on a correction algorithm's output.

One should also inspect the periodic error signatures in the time domain. If samples are tagged or the interleaving phase is known, repeated phase-dependent offsets or gain variations can be estimated across the M sub-converters. A correction table may reduce a particular spur within its calibration range, but its validity at another temperature, sample rate or converter input frequency is an empirical question. The correct report records the pre-correction and post-correction spectra, the algorithm version, calibration data, and remaining uncertainty. Even if the spur is convincingly identified as an interleaving artefact, that diagnosis does not exclude a simultaneous external signal at the same displayed frequency. The relevant band may need independent receiver coverage to support a negative search conclusion.

A separate channel-by-channel analysis can expose whether the error scales with the numerical derivative of the input waveform, as a timing mechanism predicts, or instead follows a nearly constant additive offset. This is a physical discriminator rather than merely a convenient software label.

Charles Proteus Steinmetz, Cross-Peer Question to Oliver Heaviside: Mr. Heaviside, the enclosure may be an electrically small cavity at one clock harmonic and an electrically large, resonant structure at another. The surveyor is tempted to quantify a seam with a single shielding-effectiveness figure, perhaps measured at a friendly frequency and with the lid closed. Yet a connector shell, a cable clamp and an aperture can alter the internal field pattern even when no obvious external radiation is detected. What

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measurement strategy permits a reviewer to distinguish a defective shield boundary from a perfectly adequate enclosure that simply surrounds a sensitive internal conversion path? How would the experiment account for probe orientation, reference antenna position, near-field versus far-field excitation and the nonlinear dependence of a sampled spur upon its analogue input? I ask that the answer name the claims that cannot legitimately be derived from one quoted shielding number.

I would also distinguish resonant redistribution of a field from the generation of genuinely new spectral frequencies, since the two mechanisms invite different interventions and different proof.

Oliver Heaviside, Cross-Peer Answer to Charles Proteus Steinmetz: Dr. Steinmetz, shielding effectiveness has to be defined with respect to an excitation, field component, location and reference condition. A single figure may describe a controlled test geometry and nothing more. To investigate a suspected aperture, use a known test excitation outside the enclosure and measure the internal response at relevant points, or energise an internal test source and measure the external field, provided the equipment is intended for such testing. The two experiments are related through electromagnetic principles but not automatically numerically identical when their source and measurement geometries differ. Map several polarisation orientations and positions because a cavity mode may exhibit nodes and antinodes. A single field sample at a null can falsely suggest magnificent shielding while another point exhibits substantial energy.

To distinguish enclosure leakage from internal susceptibility, conduct a separate analogue-chain test with the intended antenna port terminated and the clock functioning normally. A spur that persists while external-field

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penetration is greatly reduced may arise through internal coupling or a cable penetration not represented by the external test. A controlled near-field scan of the closed enclosure can characterise emitted fields, but it must not be equated to the level at the ADC input. Complement it with common-mode cable-current measurements and, where service access is authorised, properly characterised internal test points. The aim is a convergence of observations across different boundaries and modalities, not a single dramatic scan.

The probe itself is part of the experiment. Record its orientation, calibrated frequency response, distance to conductive surfaces and whether a nearby cable or operator changes the measurement. At close range the field may be predominantly reactive and its amplitude may vary faster with distance than a radiating far field. If the shield works at one clock harmonic, that does not prove it works at another; if the near-field probe sees a strong local maximum, that does not prove an external transmitter is present. Equally, a clean external emission test does not prove the instrument's own ADC is immune to internal conductive feedthrough. The permissible claims are therefore conditional: shielding measured for stated excitations and positions, internal spur susceptibility under stated receiver states, and detection capability under separately calibrated signal challenges. Any untested generalisation should remain a qualification, not appear as a certified property of the enclosure.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has identified clock-harmonic generation at the output driver, displacement-current coupling at semiconductor and board nodes, shared-impedance modulation of converter references, differential-to-common-mode

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conversion in clock and data wiring, propagation through bonded enclosure structures and cable penetrations, and aliasing or interleaving errors during digitisation. The causal chain must be followed rather than guessed from one FFT peak. A proper negative surveillance search records tested clock states, input-reference conditions, cable geometry, raw samples, measured sensitivity and the frequencies at which internal contamination invalidates detection. Clock correlation is evidence for clock involvement, not proof of a unique physical route and not proof that a coincident external signal is absent. The discussion is a historical-fiction teaching device and remains subject to independent publication review.

QUESTION 066. SOURCE REGISTER AND EDITORIAL LIMITATIONS

1. NIST, C. L. Holloway et al., Measurement of Shielding Effectiveness of Electrically-Small Enclosures (2011). https://www.nist.gov/publications/measurement-shielding-effectiveness-electrically-small-enclosures . Documents frequency- and aperture-dependent enclosure behaviour, not the performance of the hypothetical receiver in this discussion.

2. NIST, K. D. Masterson and D. R. Novotny, Transmission Cross Sections of Optical-Fiber Feedthroughs for Suppression of Electromagnetic Interference (1998). https://www.nist.gov/publications/transmission-cross-sections-optical-fiber-feedthroughs-suppression-electromagnetic . Illustrates that real feedthrough construction alters enclosure leakage; no numerical result from the publication has been assigned to the fictional instrument.

3. Analog Devices, Staying Well Grounded. https://www.analog.com/en/resources/analog-dialogue/articles/staying-

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well-grounded.html . Supports the engineering importance of sampling-clock return paths, jitter and mixed-signal layout. Device-specific recommendations require separate review before adoption.

4. Analog Devices, Effects of Digital Crosstalk in Data Converters, Part 3: Digital Data Signal Crosstalk on the Clock. https://www.analog.com/en/resources/technical-articles/effects-of-digital-crosstalk-in-data-converters-part-3-digital-data-signal-crosstalk-on-the-clock.html . Explains how data-to-clock coupling can generate sampled-signal distortion products and sidebands.

5. Texas Instruments, Delta-Sigma ADCs: Clocking, training video (4 May 2017). https://www.ti.com/video/5422297179001 . Discusses clock jitter, clock intermodulation and layout recommendations for data converters; this citation does not certify the hypothetical test figures.

6. Texas Instruments, Synchronizing Multiple JESD204B ADCs for Emitter Position Location Reference Design. https://www.ti.com/tool/TIDA-00467 . Provides an example of clock-distribution architecture and channel phase coordination; it is not evidence that the fictional historical contributors encountered that technology.

EDITORIAL QUALIFICATION. The physical principles are discussed through fictional dialogue. All numerical values and controlled experiments are illustrative; source titles and links have been checked for existence but a full source-to-claim verification and separate expert technical, historical, mathematical, lexical and integrated-pagination reviews are not certified by this structural checkpoint. Do not use a diagnosis of internal spur

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production to assert that no external transmission exists at the same frequency.

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QUESTION 067

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What connector and cable defects cause reproducible movement of receiver spectral peaks?

SCHOLARLY RECONSTRUCTION: These deceased scientists and engineers are represented in hypothetical, modern discussions of RF test instruments. Neither the words nor the contemporary experiments constitute an authentic historical conversation. All worked numerical cases are illustrative, not evidence of a particular field installation.

Dr. James M. Atkinson, Moderator: Professor Kennelly, the operator of an authorised RF survey may observe that a weak spectral peak shifts whenever a coaxial connector is re-tightened or a cable is touched, and may conclude that the putative emitter moves. A mechanical action is indeed reproducibly associated with a changed display, but causation is less obvious. Would you distinguish the physics of passive transmission-line changes from a true frequency translation, define what quantities the instrument actually measures, and design tests that separate connector discontinuity, cable electrical length and receiver-generated spectral response? I ask the panel to preserve the distinction between amplitude movement across display bins, phase displacement, modulation sidebands, and an actual shift of a source carrier.

Arthur Edwin Kennelly, Principal Contributor: Dr. Atkinson, let us begin by identifying a seemingly modest but decisive point. A fixed, linear and time-invariant coaxial line cannot change the frequency of a sinusoidal input. It changes amplitude and phase as functions of frequency, according to its loss, characteristic impedance, electrical length and mismatches. A spectrum analyser whose peak appears to migrate after a cable is bent may

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be seeing a time-varying line during the motion, a changed interference pattern between paths, a signal near the threshold of a bin-selection algorithm, a source or receiver oscillator perturbation, or a change in the transfer response which selects a different component of a composite spectrum. The words 'peak moved' therefore do not define a physical mechanism. Record the unprocessed time or complex-frequency observations, then establish whether the carrier's instantaneous phase derivative changed, whether its amplitude merely changed, or whether a different line became dominant.

For a uniform transmission line, the propagation constant is $\gamma=\alpha+j\beta$, with attenuation α measured in nepers per metre and phase constant β in radians per metre. If a length ℓ is terminated in its characteristic impedance, the forward transfer is approximately $\exp(-\gamma\ell)$. The corresponding phase is $-\beta\ell$, and a small length or propagation-constant change has first-order phase increment $\Delta\varphi\approx-\beta\Delta\ell-\ell\Delta\beta$. For a wave with phase velocity v_p, $\beta=2\pi f/v_p$. None of these expressions translates a stable input from frequency f to $f+\Delta f$ when the geometry and dielectric remain fixed during the observation. A cable warmed and then measured in a stable new state may exhibit a new phase delay and loss but the same input frequency. The phase history during the warming process is a different question, because a varying delay $\tau(t)$ can impose a transient output phase excursion.

Take a nominal 1 GHz test tone and a cable whose effective one-way delay changes by 10 picoseconds because of bending or a changing dielectric. The phase difference is $2\pi(10^9)(10^{-11})=0.0628$ radians, about 3.6 degrees. It is not a 3.6-degree position change of a remote transmitter. If that delay change develops uniformly over 0.1 second, the induced phase-rate

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perturbation has a scale of 0.1 hertz for the selected tone, since $f_{inst} \approx f_0 - f_0 \, d\tau/dt$ in the simplified slowly varying-delay model. The result depends on the actual time course, and a sudden discontinuity will generate a more complicated transient spectrum. It is essential to record motion and the electrical event together rather than use the final static position as proof of a continuously displaced carrier.

A mismatched line is more revealing. At a connector, impedance discontinuity yields a reflection coefficient $\Gamma=(Z_L-Z_0)/(Z_L+Z_0)$ for the simple load model, where Z_L is load impedance and Z_0 is line impedance. The measured forward transmission is not necessarily a single travelling wave; it may be the vector sum of transmitted and reflected contributions, with a frequency-dependent ripple. Changing connector engagement, contact pressure or shield return can change those complex coefficients. At one analyzer frequency bin the vector sum may move upward; at a neighbouring bin it may move downward. If two nearby spectral components were already present, their relative heights may reverse, causing a peak-picking routine to report a new 'dominant frequency'. That is movement of the selected maximum, not necessarily translation of either component.

The experiment must independently observe source frequency and transfer response. A traceable generator feeds a carefully controlled branch into an independent monitor and a second branch through the suspect cable into the receiver under test. Record amplitude and phase versus time in both branches and preserve the device clock, detection settings and original sample order. Use a vector network analyzer, with calibration planes declared at the appropriate connector interfaces, to measure S11 and S21

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under a repeatable connection sequence; follow that with a time-domain reflectometry or transformed frequency-domain observation where its resolution is suitable. No result from a VNA alone proves what the live receiver did during a rapid bend; the static measurement is one element in a controlled chain.

Connection repeatability demands more than 'tighten it again'. Identify interface family, mating compatibility, connector condition, mating count, specified torque and cleaning procedure. An unknown torque setting can alter contact geometry and even damage a precision interface; excessive torque is not a cure for uncertainty. Before each test record whether the connector was disconnected, rotated, axially loaded, thermally changed or merely touched. Photographs of the external setup may assist metrological traceability, although the publication itself may omit photographs under the user's production rules. The engineer should record safe cable-bend radius and strain relief, because a test that exceeds the cable's rating can manufacture the failure it purports to diagnose.

To localise the fault, reverse a cable only if its construction and connectors make reversal appropriate, exchange the suspect assembly with a separately characterised one, and vary one mechanical element at a time. If the anomalous effect follows one cable across different receivers, a cable-related hypothesis gains support. If it remains with one receiver input after replacement, examine input connector, protective circuitry or internal reference distribution. If it follows the source and appears at an independent monitor, the source itself deserves scrutiny. A result that appears only when cable and receiver are combined may involve impedance

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interaction rather than one defective component in isolation. These distinctions make the experiment causal rather than theatrical.

Finally, a reproducible movement is meaningful only after the observer specifies its repeatability metric. How many cycles were tested? What is the distribution of phase or apparent peak frequency under unchanged conditions? Does the anomaly reverse when the cable is returned to its initial position, and is there hysteresis? Do the measurements show a change significantly greater than the instrument's amplitude, phase and frequency uncertainty? The best final statement may be that the peak-selection output is configuration-dependent within a bounded interval, and that a particular electrical discontinuity has or has not been isolated. It must not leap from cable motion to attribution of a remote RF emitter.

Dr. James M. Atkinson, Moderator: Professor Maxwell, I ask you to examine the cable not merely as a circuit component but as an electromagnetic structure. What happens when its screen ceases to act as an ideal enclosing return path, and how can the resulting field conversion masquerade as a moving emitter?

James Clerk Maxwell, Second Principal Contributor: Dr. Atkinson, an ideal coaxial line confines a transverse electromagnetic mode between inner and outer conductors, with equal and opposite longitudinal currents in the idealised simple picture. Real shields, connector transitions and enclosures admit discontinuities, finite conductivity, imperfect bonds and parasitic fields. The exterior of a coaxial screen can carry common-mode current driven by imbalance, and this current may couple into the receiver through a different route from the intended differential signal. Mechanical contact with the shield, movement against an enclosure, or a change of nearby

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conducting objects can alter the external current distribution without materially changing the desired signal at its source. A receiver may then show an amplitude, spur or apparent peak-position change as the vector sum of intended and unintended coupling changes.

Boundary conditions provide the proper language. Tangential electric field is constrained by the conductor surface, but it is not literally zero for real materials under all conditions. A gap or finite-transfer-impedance shield permits internal and external fields to influence one another. Contact resistance and inductance at the connector's outer conductor can become especially important at high frequency, where a seemingly short physical interruption has appreciable reactive impedance. One must not assume the centre pin alone constitutes the connector. A compromised outer contact can alter the return path, change the effective common-mode current and upset shielding while leaving a low-frequency continuity meter apparently satisfied. The frequency at which this happens depends on the geometry, not simply the operator's impression of tightness.

The underlying field is a solution to Maxwell's equations with boundaries established by the room, enclosure, cable and source. The measured voltage at a receiver port is consequently a projection of that field through an antenna and cable network. Move the cable a few centimetres and its effective coupling to the room may change. A very weak external signal may increase in apparent strength, a local interference line may diminish, or a spectral maximum may alternate between two nearby components. Such behaviour is not impossible; it is entirely compatible with changing coupling coefficients. Yet it identifies neither the radiating object nor the location of

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an emitter until the field structure and measurement apparatus are challenged independently.

Consider a model with intended complex voltage V_s and parasitic voltage $V_p \exp(j\theta)$ at one analysis frequency. The detected squared magnitude is $|V_s+V_p \exp(j\theta)|^2=|V_s|^2+|V_p|^2+2|V_s||V_p|\cos\theta$ when the reference phase is chosen appropriately. Even if both underlying source frequencies remain fixed, a change in the coupling phase θ can move received power through constructive and destructive interference. For equal 1 millivolt component magnitudes, the output may range ideally from zero to 2 millivolts in voltage amplitude as θ spans opposing and aligned phases. In practice finite noise, imperfect coherence and nonlinearity prevent such an ideal extremum, but the example shows how a large display change can arise without transmitter movement.

A second mechanism concerns time dependence. If intermittent contact makes the coupling coefficient vary while the field is observed, multiplication of a carrier by that varying envelope can create sidebands or broadband transient energy. If the contact opens and closes periodically at an effective mechanical or electrical rate, discrete spectral components may appear at offsets related to the modulation. If it moves irregularly, the added energy may be noise-like. Nothing in that observation alone permits one to declare a deliberate RF transmission. The investigator should record motion timing with a separately monitored safe test setup and compare the correlation between the mechanical intervention and raw electrical measurements.

The orthodox test uses an independent reference channel at the antenna or source, a correctly characterised shielded load, and a current probe whose

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own coupling and bandwidth are understood. A clamp measurement on the exterior coaxial screen may help identify common-mode current, but it cannot automatically identify the source of that current; the probe may itself load the structure. A line-current maximum may be produced by the receiving equipment, nearby electrical apparatus, or an external field. Change one return-path element, preserving RF safety and equipment ratings, and compare the current with the suspicious receiver feature. A second cable of different shield construction can be a valuable challenge if it also matches the required impedance and loss characteristics.

Near-field measurements require particular caution. Electric and magnetic components are not related by the free-space plane-wave impedance at arbitrary distances from a small structure. The cable may be capacitively coupled to one conductor and inductively coupled to a nearby return loop. A probe rotated around the suspect connector may respond differently to these components; orientation is therefore part of the measurement record. Likewise a tightly closed instrument enclosure does not guarantee immunity through every connector aperture. A cable connected through a damaged shell may supply a path whose electrical significance depends on the entire return geometry. Treat the assembly as a system rather than a list of independently perfect components.

The inference should remain modest until discriminating controls have been performed. A change on replacing a cable establishes that the observation depends upon that substitution, not that the original cable was the sole source of an alleged hidden emitter. The substituted cable may differ in length, loss, common-mode suppression, shield transfer impedance or termination. Document these differences and, where possible, normalise

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the intended signal path with calibrated insertion and return-loss measurements. The useful conclusion is a causal account of field coupling with acknowledged alternatives, not a narrative about an object moving invisibly through the room. That scientific restraint is an essential part of reliable countermeasure work.

Dr. James M. Atkinson, Moderator: Mr. Hewlett, the field explanation is illuminating. Please turn now to the practical laboratory task: how does one measure small but reproducible changes without permitting the test fixture, cable torque or calibration procedure itself to determine the conclusion?

William Redington Hewlett, Third Principal Contributor: Dr. Atkinson, an instrument comparison must be designed so that its test artefacts are smaller and better understood than the fault it seeks. The obvious temptation is to connect a network analyzer to the suspect cable, obtain an attractive S-parameter trace, bend the cable and celebrate the movement of a trace maximum. But a calibrated VNA reading describes its own stimulus, detector, calibration model and reference planes. It may not reproduce a high-level blocker, an actual receiver's input impedance, or a frequency-agile signal's timing. The VNA can establish amplitude, phase and mismatch behavior under a specified setup, but a receiver field report demands a bridge between these controlled observations and the actual acquisition chain.

The first step is to document the reference plane. A two-port calibration at the end of known test leads removes, within its model and uncertainty, many errors associated with systematic source and receiver paths. Change those leads after calibration and that model may no longer apply. The cable under test must be distinguished from the VNA's own flexible test leads.

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Sometimes a stable extension has to be used and characterised; sometimes a precision test port and fixed fixture are preferable. The test operator should prove that the measurement system remains stable by measuring a verification standard before and after the candidate cable. If the standard moves comparably, the claimed cable fault is not isolated.

For a cable assembly, record the complex forward transmission S21(f) and return measurements at relevant frequencies and incident powers. A stable frequency-dependent attenuation curve can explain why the strongest of two nearby true carriers changes when a connection varies; it cannot prove that either carrier has been frequency translated. Phase of S21 provides electrical-length information, but wrapped phase has 2π ambiguities. A coherent phase change should be compared with group delay $\tau_g=-(1/2\pi)d\varphi/df$, recognising that differentiation amplifies noise and that resonant features may make group delay vary sharply. It is a mistake to report an enormous group-delay value from one noisy phase point as a physical cable transit time.

Connector torque needs exactness rather than forcefulness. Use the connector manufacturer's approved range and a suitable calibrated torque tool for that precise interface. Do not transfer a value specified for one miniature microwave connector to a different coaxial family. A loose interface may exhibit variable contact resistance or shielding; an over-torqued interface may permanently distort the mating geometry. Cleanliness, connector pin depth, plating wear, damage and compatibility must be checked against applicable maintenance instructions. The same test should be repeated across several deliberate mate-and-unmate cycles and with the cable strain supported, while recording both the connection

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condition and the observed electrical response. Such repetitions separate a consistent mechanical sensitivity from one anomalous act of connection.

There should be an orthogonal control for each major hypothesis. To test a cable-associated phase shift, hold the source, receiver, temperature and cable termination constant while bending the cable within specified limits and measuring relative phase. To test thermal dependence, fix the cable mechanically and change temperature slowly within its safe range while monitoring its surface and connectors, not merely the ambient air. To test interface repeatability, disconnect and remate according to a documented procedure without changing the cable route. To test the source, use an independent monitored branch. To test the receiver, substitute another receiver with a separately monitored clock and record the raw spectra before peak-selection software. Each controlled comparison narrows the hypotheses without claiming a universal answer.

Uncertainty should include Type A repeatability assessed across genuinely repeated trials and Type B information from calibration standards, connector specifications, instrument drift, mismatch and environmental controls. A repeatable effect of 0.5 degree is not significant simply because the display increments by 0.01 degree. A useful budget might combine, under justified independence assumptions, a 0.3-degree standard measurement contribution and a 0.4-degree connection contribution to obtain $\mathrm{sqrt}(0.3^2+0.4^2)=0.5$ degree. A 0.6-degree observed change would then be marginal for a strong assertion, before considering correlation or unmodelled systematic effects. This is hypothetical arithmetic, not a statement of any actual instrument's performance.

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A time-domain reflectometry test adds spatial discrimination. A reflection detected after round-trip delay Δt corresponds ideally to distance $d \approx v_p \Delta t/2$ along a uniform line, where v_p is propagation velocity and the factor two accounts for the return journey. For $v_p=2.0\times10^8$ metres per second and $\Delta t=10$ nanoseconds, the inferred location is approximately one metre along the cable. But TDR resolution is bounded by excitation bandwidth and instrument response, connectors can obscure adjacent faults, and an estimated location may shift with dielectric variations. The test should be presented as evidence of a discontinuity near a calibrated electrical distance, not proof of an exact millimetre physical location.

I recommend that final findings be tabulated by intervention: initial static state, controlled flex, remate, thermal cycle, cable substitution, input termination, and independent source observation. For each, state what changed in S11, S21, time-series phase, amplitude, RF sample chronology and the peak-picking output. An investigator who can show that a perturbation follows one connector through repeated controlled exchanges has persuasive evidence of measurement-chain dependence. Yet the ultimate question is not merely why the peak moves on the display. It is which physical quantity changed, how much, under what conditions, and with what alternative explanations still credible.

Dr. James M. Atkinson, Moderator: Mr. Heaviside, I invite you to examine distributed line behaviour and the dynamic character of a moving cable, particularly where the test shows sidebands rather than a changed stationary S-parameter trace.

Oliver Heaviside, Fourth Principal Contributor: Dr. Atkinson, a cable should not be understood as a passive wire whose only property is an arbitrary

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attenuation number. Its capacitance, inductance, resistance and dielectric leakage are distributed along length; the telegrapher's equations couple voltage and current at every location. A contact fault at one point adds a boundary whose effective impedance may vary with stress, temperature or current. A shield defect changes both the return path and coupling to external fields. If these parameters change as the cable is moved, the line is not time-invariant during the experiment. Consequently its output can be modulated even though a perfectly stable signal enters it. The time-dependent boundary is a candidate source of the newly observed spectral energy.

In a simplified line with per-unit-length R, L, G and C, propagation constant $\gamma(f)=\mathrm{sqrt}[(R+j2\pi fL)(G+j2\pi fC)]$ and characteristic impedance $Z_0(f)=\mathrm{sqrt}[(R+j2\pi fL)/(G+j2\pi fC)]$. These are complex quantities in general, and their frequency dependence matters in a wideband receiver. Near a discontinuity, the launched wave and a reflected wave may combine differently as the electrical length varies. At a fixed input frequency this changes the measured amplitude and phase. If the discontinuity itself varies in time, the effective reflection coefficient becomes $\Gamma(t)$, which can multiply the incoming carrier and generate spectral components related to Γ's temporal spectrum. An operator who sees a pair of new sidebands should ask whether the instrument has measured modulation of an existing carrier rather than the arrival of two new transmitters.

Triboelectric and mechanically induced effects are not uniform properties of all coaxial cable. Some dielectric and conductor constructions produce small charge disturbances under flex; movement can also change capacitance or magnetic coupling and upset high-impedance circuits. The important

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distinction is between a voltage or current generated in the measuring assembly and modulation of an external RF signal passing through it. A low-frequency disturbance may be rejected by a well-designed receiver, may enter a gain or control path and produce modulation products, or may appear directly in a sufficiently broadband low-frequency measurement. Calling every flex-related spur 'microphonics' conceals several distinct causal pathways. Specify which one the experiments support.

For example, suppose a stable RF carrier at frequency f_0 passes through a link with small time-dependent amplitude gain $g(t)=1+m \cos(2\pi f_m t)$, with modulation index m small. The product is $g(t)A \cos(2\pi f_0 t)$, containing a carrier at f_0 and sidebands at $f_0 \pm f_m$ of voltage amplitude $mA/2$. If the cable returns to a static configuration, those sidebands may vanish even though its new static attenuation differs. This is not evidence of three independent RF emitters. A related phase modulation process can also produce sidebands, but the relative phase of their complex amplitudes distinguishes the two under suitable coherent measurement. The investigator must retain IQ data or phase-sensitive observations rather than rely solely on a magnitude spectrum.

The assumption of instantaneous uniform line changes deserves criticism. A bend propagates mechanically along a cable; contact pressure can stick and slip, and temperature diffuses through dielectric and metal at different rates. A phase change may have a hysteresis loop when the cable is flexed and returned, and a connector can intermittently switch between conducting states. Their temporal spectra may include discrete impulses, broadband shoulders or low-frequency wander. The frequency-domain display depends on window, resolution bandwidth and detector. A peak that

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looks narrow during one averaging interval may widen when a transient is captured at higher time resolution. Thus the physical motion history must be measured with as much care as the final spectrum.

A fault-locating test must distinguish a reproducible correlation from a unique explanation. Lock the cable in one geometry and gently alter the suspect connector within its safe mechanical tolerance; next lock the connector and change the cable's curvature in one section. If both affect the receiver, examine whether the test is actually moving the connector's mounting point each time. Add strain relief and observe whether the effect disappears. Use a characterised substitute line with comparable length, impedance and return loss. If the substitute suppresses the effect, identify which physical property differs; a replacement can change common-mode routing or room coupling even when its nominal specifications match the original.

We must also avoid mistaking receiver nonlinearities for purely linear line effects. A small connector reflection can change blocker amplitude at the input of a nonlinear stage and thereby alter an intermodulation product's strength or apparent prominence. The product may appear at a frequency absent from the external sources, yet its frequency is determined by the receiver's nonlinear mixing relationships. Changing cable geometry can move the display's dominant peak from a true weak carrier to that internally generated spur. Measure at reduced input power and with controlled attenuation, and examine the predicted power-law scaling of the product, while acknowledging that gain-control loops may complicate simple slopes. The mechanical correlation only identifies a condition affecting the receiver.

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A careful conclusion can be strong without being absolute: the affected assembly exhibits reproducible time-dependent transfer changes, and a measured correlation with the raw spectrum is consistent with one specified pathway. Distinguish stable S-parameter variation after remating from dynamic modulation during motion, and distinguish both from changes generated inside the receiver. Retain the full sequence of negative controls because the absence of an effect in a particular static position is not proof that the component will behave perfectly during service. The scientific achievement is not a picturesque peak that seems to walk when a cable moves; it is an identifiable, bounded electrical mechanism.

Dr. James M. Atkinson, Moderator: Professor Armstrong, would you now examine what a receiver can add to this phenomenon after energy passes the connector, particularly when an unstable peak is near the sensitivity threshold or is a mixing product?

Edwin Howard Armstrong, Fifth Principal Contributor: Dr. Atkinson, the receiver must be treated as an active participant in the observation. A cable perturbation can change the level or phase of a desired signal, an adjacent blocker, a local leak from an instrument clock or a common-mode interferer. Once those signals enter an amplifier, mixer, detector or sampler, nonlinear behavior and automatic-control dynamics may turn a small input variation into a conspicuous output change. The display may promote a different bin to 'peak' as two nearly equal components exchange strength. A coherent analyser may see a phase step caused by changing electrical delay. Neither result establishes that a remote transmitter moved. The frequency of a genuine transmitted carrier can remain perfectly fixed while its apparent location in the rendered spectrum changes.

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A receiver frequency estimate depends upon the estimator as well as on the signal. An FFT peak finder chooses the largest spectral bin after filtering, windowing and perhaps interpolation. If signal strength is near the noise floor, random noise can change which bin wins. If two lines are close to the instrument's resolution bandwidth, changing their relative amplitudes by a fraction of a decibel can shift the location of the measured maximum even if their absolute frequencies remain stationary. Long averaging may reduce random fluctuations but can conceal changes during a bend. For a rigorous test, record the complex samples and compute the frequency estimates with predeclared windows, bin widths and uncertainty measures, rather than altering analysis settings until the desired effect appears.

Consider a simple two-tone observation with components at 100.000000 MHz and 100.000400 MHz. If the first is initially 0.2 dB stronger, a peak-picking display reports the first frequency. A small cable- or mismatch-induced attenuation reversal can make the second 0.2 dB stronger, causing a reported 400 Hz 'frequency jump' though both carriers have remained unchanged. The amount of differential attenuation depends on the frequency response and interactions in the full chain; a very short well-matched line would not ordinarily develop an abrupt 0.4 kHz notch by being touched. This example isolates a peak-selector mechanism, not a universal prediction of what any connector does.

Frequency translation can occur when the effective path is time-varying, but the source must be identified. A cable undergoing changing delay can produce phase modulation; a gain-control circuit responding to contact noise can modulate a carrier; a poorly isolated oscillator may be pulled by changing input impedance in certain architectures; and a nonlinear junction

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can generate mixing products. These have different temporal signatures. Test with a source known to be stable under independent monitoring. Measure the input with a sufficiently linear reference receiver and compare the suspect receiver's oscillator or IF reference. If the apparent shift appears only downstream of one gain or conversion stage, the evidence points toward receiver-generated behavior. The test should not rest on an undocumented assumption of a perfectly linear chain.

One useful challenge is controlled input attenuation. If a candidate spur arises from third-order intermodulation between two tones, its output-power dependence may approximate a three-to-one slope relative to input power over a limited small-signal region, whereas a directly transmitted tone often has a one-to-one dependence. But the simplified slope can fail under compression, changing gain control, source contamination and asymmetric mixing. Therefore sweep levels only in safe, specified ranges, log actual settings and check whether the predicted source frequencies exist. A cable fault which changes one blocker level may create an apparent line elsewhere in the receiver spectrum. The right claim is that the signal is consistent with a nonlinear conversion product under measured conditions, not that its geographic source has been found.

An intermittent shield or connector can also change the antenna system. A coaxial feedline carrying common-mode current effectively becomes part of the receiving structure, and moving it can alter radiation coupling. A technician may be tempted to follow the largest peak by moving the cable in the room, interpreting signal maxima as bearings. That is invalid unless the antenna pattern and feedline currents are characterised. Replace the receiver input with a specified load, compare shield-current measurements,

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and use a genuinely separate antenna and receiver to evaluate the environment. A strong peak produced only when the coax hangs near a metal cabinet may reveal room coupling or an internal artefact rather than a transmitter concealed in that cabinet.

The procedure should be staged. Retain a baseline raw spectrum with cable and connectors immobilised. Observe a safe controlled flex and remate experiment while logging the exact time, thermal state and geometry. Preserve all acquisition settings, front-end overload indicators, oscillator references, FFT parameters and rejected detections. Restore the original configuration and verify whether the initial response returns. Substitute a characterised line and then, where practicable, a second receiver of different design. If signal content is legally sensitive, capture only authorised technical observables and maintain chain of custody; experimental controls should not become an excuse to acquire communications content outside authority.

In closing, distinguish three statements that are easily confused: a display peak changes position; the received signal's estimated instantaneous frequency changes; and an external source changes frequency or position. The first may be observed directly as a property of the display, the second requires a validated estimator and reference, and the third requires independent evidence excluding the measurement chain. A connector fault can contribute to the first two under particular conditions, but it does not justify the third by itself. One earns a location or attribution claim through multiple independent measurements, a calibrated receiving system, and explicit treatment of contrary explanations.

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Dr. James M. Atkinson, Moderator: Dr. Kroemer, please challenge Professor Kennelly's distinction between a passive fixed transfer function and modulation introduced by a moving connection. Where should the investigator look for a nonlinear material interface?

Herbert Kroemer, Peer Question: Professor Kennelly, a damaged connector is not necessarily a simple linear mismatch. Oxide films, dissimilar-metal contacts and intermittently conducting surfaces can possess nonlinear current-voltage behaviour, while imperfect mechanical pressure can change that behavior during vibration. Would you distinguish a static reflection arising from impedance discontinuity from a genuinely nonlinear junction that may generate harmonics or intermodulation? In the experiment proposed here, what particular combination of calibrated tones and mechanical interventions would demonstrate that spectral energy at a new frequency arises in the connector rather than in the instrument's input mixer or the signal generator itself? I would also ask how to avoid damaging a suspect contact while conducting the demonstration, since a destructive remating operation could erase the original evidence before it has been characterised. Can the experiment establish a threshold current or pressure at which the response changes discontinuously, and does the phenomenon persist when the connector is cooled or warmed without remating? Such observations might help distinguish contact films from simple mechanical impedance.

Arthur Edwin Kennelly, Response: Dr. Kroemer, the question is well taken. My linear line equations provide a baseline against which violations can be tested, not a complete model of every physical connector. A stable but mismatched connection can produce a reflected wave without generating a

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new frequency when driven by a single ideal sinusoid. A nonlinear contact, by contrast, may produce a current containing harmonics of that sinusoid, or combinations such as $2f_1 - f_2$ when two distinct tones are applied. The actual amplitudes depend on the contact law, drive level, temperature and load. An intermittent connection changes the circuit in time, so it may create broadband transients or modulation products even if its static current-voltage relation is nearly linear. These are separate hypotheses, and an RF spectrum by itself may not distinguish them. Retesting with a second predetermined set of mechanical interventions supplies evidence against a chance correlation. The analyst should maintain the same peak-selection rules during that second test, even when the revised observations contradict the initial hypothesis.

A safe two-tone test can use well-characterised low-power sources, appropriate isolation, a linear combiner and a sufficiently clean independent reference monitor. The source and combiner outputs must first be measured with the connector absent or with a verified through standard. The suspect interface is then inserted without changing the instrument's gain or overload state. Measure new combination products and repeat with a separate analyser or a calibrated attenuated measurement chain. If the products scale with applied tone level in a manner consistent with a junction model, and move with the suspect connector when it is exchanged between otherwise identical test chains, a connector-generated mechanism becomes plausible. Yet a receiver mixer also creates the same algebraic frequencies, so an isolated measurement at the connector output or a verified linear detector is essential to the attribution.

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Controlled mechanical pressure may be useful, but the permitted force, torque and motion must be specified before the experiment. I would first preserve the untouched assembly, photograph or otherwise document its state, and measure its baseline with a non-destructive fixture. Disconnecting may alter oxidation, contact asperities or shield engagement irreversibly. A laboratory surrogate with a known engineered discontinuity can be used to qualify the test without damaging the original specimen. The forensic conclusion should record whether the suspect connection was tested in situ, after removal, or after any cleaning and remating. Those conditions are not interchangeable. If the first intervention eliminates the anomaly, that outcome is itself evidence, but it limits later claims about the fault's original physical mechanism.

Dr. James M. Atkinson, Moderator: Professor Bode, please question Professor Maxwell's field-coupling model. A repeatable change may be a transfer-function change, a common-mode current shift or both.

Hendrik Wade Bode, Peer Question: Professor Maxwell, when a shield bond changes, the engineer often writes a simple equivalent impedance and assumes that the antenna, cable and enclosure remain otherwise fixed. At RF the alteration may instead change several coupled modes, the effective return current and even the port impedance seen by the receiver. How would you establish a response model without mistaking an underdetermined set of parameters for a uniquely fitted physical fault? Which measurements are independent enough to constrain shield transfer, insertion loss and common-mode sensitivity, and how would you test whether the model remains predictive after the cable is rotated or the instrument is moved to a different position? I ask because an attractive fit to

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one spectral anomaly can result from many compensating model errors. In particular, I would want one predicted change that is not used to estimate the fitted model's parameters, since successful prediction under a new configuration is stronger evidence than fitting the observation from which the model was invented. The calibration uncertainty of the added probe should be reported.

James Clerk Maxwell, Response: Professor Bode, the equivalent circuit is an approximation whose value is established by prediction under interventions, not by its visual resemblance to the physical assembly. One must distinguish terminal variables at a specified measurement plane from the distributed field solution inside and outside the shield. Measure the port reflection and transmission with a calibrated fixture, but separately observe shield-surface current or induced field at several known locations with an appropriate, calibrated sensor. A model that fits only terminal S-parameters may miss exterior common-mode coupling. Conversely a clamp probe alone does not determine the internal impedance discontinuity. Their combined responses place stronger constraints on the mechanism, provided probe loading, reference phase and the effect of moving the fixture are accounted for. The report should identify which receiving patterns were determined by actual calibration and which were assumed from ideal antenna theory. These are not equivalent when the feedline itself contributes to the spatial response.

I would formulate several candidate models: a local inner-conductor discontinuity with intact shield, a shield-transfer defect with otherwise stable inner path, a changing return connection to the enclosure, and an external field coupled along the cable. The models predict different changes when a shielded termination replaces the antenna, when the entire cable is

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immobilised, when the instrument chassis is moved while the cable is held, and when the cable is replaced by a construction with independently measured shielding effectiveness. A valid model should predict the sign, relative timing and approximate scale of changes in more than one observable, not merely reproduce the amplitude of the chosen peak after arbitrary parameter adjustment.

An apparently successful fit must be accompanied by uncertainty and sensitivity analysis. If several parameters cannot be distinguished by the available measurements, the report should say so rather than present one as uniquely discovered. Measurements in a different cable orientation or room position test whether the physical coupling model generalises. Changes in room geometry may legitimately alter exterior currents; failure to reproduce the same peak elsewhere does not necessarily falsify a local shield defect. One can at least determine whether the proposed mechanism predicts that dependence. In this work, the serious error is not using an imperfect model. It is treating an unchallenged model as a physical diagnosis and then inferring the geographic position of an emitter from it.

Dr. James M. Atkinson, Moderator: Dr. Steinmetz, would you challenge Mr. Hewlett's uncertainty budget, particularly its treatment of contact stress and temperature as though they were independent?

Charles Proteus Steinmetz, Peer Question: Mr. Hewlett, a connector can exhibit hysteresis: the electrical response during tightening differs from that during loosening, and a cable bent through one route may not return immediately to the original phase when released. Temperature, stress, contact pressure and conductor geometry are therefore correlated rather than independent experimental variables. If the engineer combines one

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standard deviation for torque variation with another for thermal variation in a simple root-sum-square calculation, what justifies that operation? How should a qualification test account for conditioning cycles, direction of approach and slow relaxation, rather than reporting a false precision from two apparently independent data columns? Further, when a series of repeated measurements follows a drift trend, how should repeatability be separated from that trend? Would you recommend comparing the full forward and reverse trajectories rather than a single before-and-after difference, and separately monitoring cable and connector temperature so that their unequal thermal time constants do not become a hidden source of bias in the fitted result?

William Redington Hewlett, Response: Dr. Steinmetz, the simple root-sum-square equation is legitimate only for components that are adequately modelled as uncorrelated and whose units and interpretations are compatible. It should never replace a physical understanding of the test process. For temperature and stress, the laboratory should construct an experimental sequence that changes one factor within fixed bands of the other, measures the actual temperatures and strains, and records the path followed through the state space. A full factorial design may be impractical for every field investigation, but even a limited up-down thermal ramp at two fixed cable geometries can reveal hysteresis that one static measurement misses. Record the time after each intervention and specify a settling criterion; otherwise a slow relaxation may masquerade as random repeatability. A practical audit should preserve the raw trajectory of each measured variable against time as well as a table of endpoint values. When

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the sequence is hysteretic, different paths to an identical final temperature or torque may legitimately produce different electrical states.

Where the data show correlation, the uncertainty of a combined result includes covariance terms. For contributions x and y with sensitivities a and b, variance is $a^2u_x^2+b^2u_y^2+2ab\ cov(x,y)$, assuming the first-order model applies. Omitting the covariance may understate or overstate the result depending on the sign of the correlation. More fundamentally, a hysteretic change may require a conditional model or bounded state range rather than one Gaussian standard deviation. If a connector follows different electrical paths on tightening and loosening, report the two paths and the difference explicitly. Do not average them into a fictional central state that the physical assembly never occupied.

A good protocol includes repeated baselines interleaved with interventions, rather than placing all baseline measurements first and all stressed measurements second. Randomising a feasible portion of the order helps reveal time drift and operator expectation; when order cannot be randomised because of irreversible conditioning, document the limitation. Use independent verification standards to monitor instrument drift. Retain rejected and failed readings, and record whether the suspect assembly was remated, cleaned or strained after the first anomaly. The final budget should distinguish repeatability within a fixed configuration, reproducibility across operators or setups, systematic corrections, and unquantified uncertainties. A numerical uncertainty is defensible only if it describes the actual path through which the measurement was made.

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Dr. James M. Atkinson, Moderator: Mr. Campbell, how would you scrutinise Mr. Heaviside's explanation of moving-cable modulation through the lens of real filter and line response?

George Ashley Campbell, Peer Question: Mr. Heaviside, the moving-boundary picture is persuasive, but a receiver often contains several frequency-selective stages following the cable. A transient produced by an imperfect connection may ring in those filters for longer than the mechanical motion, and its spectrum can be displaced or broadened by the choice of analysis window. How would a test distinguish the line's own time-dependent transfer from the receiver's impulse response? What is the minimum useful acquisition metadata for reconstructing the sequence, especially where the operator has saved only averaged spectral plots? Could a narrow peak that apparently migrates under repeated flexing be a measurement of the receiver's filter memory, rather than an instantaneous property of the defective cable itself? Is there a way to compare a transient captured directly ahead of the narrow receiver filter with the final detector output, so that the candidate fault is not blamed for ringing introduced by the measuring apparatus? The test's trigger time and filter group delay would be material.

Oliver Heaviside, Response: Mr. Campbell, the observation is necessarily the output of a cascade, and one must not assign a property of the cascade to the cable alone without isolating stages. A time-varying connector can inject an impulse or modulate a passing signal. The receiver's filters then convolve that disturbance with their impulse responses, and its gain or detector circuitry may respond dynamically. A displayed event after the cable has stopped moving may therefore be genuine in the receiver output while no

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longer corresponding to an active mechanical change. A static S21 trace cannot describe the complete transient behaviour. The investigator should retain sufficiently wideband raw samples and measure the response to an independently known test impulse or step under safe laboratory conditions. For a transient reaching the input before its recorded hardware trigger, a display cannot recreate the omitted onset by mathematical sharpening. The experimental report should declare the known pretrigger depth and the possibility of an unobserved initiating event.

There are several useful comparisons. First, record the suspect cable's output through a calibrated wideband observation path that is demonstrably less prone to the receiver's particular ringing. Second, inject a comparable, well-controlled electrical transient downstream of the cable to measure how the receiver alone responds. Third, repeat the same mechanical intervention with alternative receiver bandwidth and filter configuration, noting whether the ringing duration and apparent peak trajectory follow the receiver setting. If the transient's origin is cable-associated but its spectral appearance depends strongly on IF filtering, report both parts of the chain. The supposed defect may be in the cable while the perceived 'moving peak' is a joint artefact of cable and signal processing.

The minimum data are raw sample indices and timestamps, the actual acquisition and reference clocks, receive bandwidth, filter coefficients or documented mode, detector and averaging state, overload flags, signal level, intervention time and the exact sequence of attempted measurements. Merely retaining the final waterfall is insufficient to reconstruct a lost input phase. If only averaged plots survive, the conclusion

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must be narrower. The observer may truthfully report a reproducible display response correlated with cable movement, but cannot reconstruct an instantaneous frequency trajectory that the instrument never saved. Time-frequency mathematics is powerful only when its source record and limitations are available for independent examination.

Dr. James M. Atkinson, Moderator: Mr. Black, please question Professor Armstrong's proposed attenuation challenge, especially the risk that automatic gain control destroys the expected power-law behavior.

Harold Stephen Black, Peer Question: Professor Armstrong, the suggestion that a third-order intermodulation line will increase roughly three decibels for each decibel of input increase is useful only under a limited small-signal model. A practical receiver may contain limiting, automatic gain control, digitally selected attenuation, interstage filtering and internal clocks whose levels remain constant as the antenna input changes. If a suspected spur changes when a cable is flexed and also changes under attenuation, what sequence of measurements would identify whether it is externally delivered, generated in a nonlinear stage, or changed by a feedback-control response? Would you accept the presence or absence of a three-to-one slope as proof of any one mechanism? I would further insist upon a test in which automatic gain control is deliberately disabled, if the instrument safely permits it, and a separate run in which its gain-control trajectory is recorded. Only then might the assumed amplifier nonlinearity be distinguished from time-dependent feedback action.

Edwin Howard Armstrong, Response: Mr. Black, I would not. The power-law slope is a diagnostic under specified conditions, not an infallible classifier. First lock or record the gain-control state where the instrument allows it,

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and determine whether the input attenuator is placed before or after the likely nonlinear element. A change in a digital IF attenuation after the mixer will not reduce an RF intermodulation product generated before the mixer in the same way as an RF pad at the antenna input. Next measure the actual input powers with an independent monitor, because cable flex or mismatch can change delivered levels at a nominally constant generator setting. Sweep slowly within safe range, allowing controlled settling, and preserve the full trace rather than only one peak value.

An externally delivered single-tone component ideally changes one-to-one with input power through a linear receiving chain, while a third-order product of two input tones may show a steeper dependence before compression. But an oscillator leak generated downstream of the input attenuator can remain comparatively constant, and a reference-related spur may scale differently again. Gain control can transform these relationships into complicated curves. Repeat with a different attenuation point and compare with a known linear reference receiver. A candidate line which persists with a correctly terminated input warrants investigation of internally generated components or unexpected coupling, but the termination itself must be characterised and its shielding verified. A terminated port does not create perfect immunity to strong external fields entering through another path.

Mechanical correlation should be tested separately from level dependence. Begin with the suspect cable fixed, measure the line under controlled power steps, then restore the baseline and perform a restricted flex test without changing power. Use a suitable substitute cable to see whether the dependence follows its electrical characteristics. Preserve gain-control state

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transitions and time tags; a control loop may react after a delay and create spectral changes persisting after the actual disturbance. If the observed behaviour fits several hypotheses, the report should keep them open. The strongest finding is the one that survives controlled changes in input power, filter configuration, clocking and cable routing. A simple slope drawn from three points cannot serve as evidence of a concealed emitter.

Dr. James M. Atkinson, Moderator: Mr. Pierce, how should we interpret a peak that seems reproducible only when the analyst looks at one particular short spectral interval?

John Robinson Pierce, Peer Question: Professor Kennelly, an analyst may perform many sequential cable flexes while watching a waterfall and remember the apparent frequency changes that coincide with the most dramatic motions. A later numerical review may select the same frequency bin and ignore quiet trials, receiver reset events and the multiple frequencies searched. How should a measurement design avoid this selection bias? Would you require a preregistered metric for peak displacement, and how should the investigator distinguish a deterministic carrier shift from a random peak-selector change near the noise floor? I also ask whether a confidence interval based on independent trial assumptions is justified if the repeated measurements share a drifting clock, a common signal generator or a thermally relaxing connector. Would you also measure the false-alarm rate for the very same peak-selection algorithm under no-intervention controls, rather than borrowing a threshold from a single spectral bin? That comparison seems indispensable where many frequencies and cable configurations were examined before a striking example emerged.

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Arthur Edwin Kennelly, Response: Mr. Pierce, the test should define its estimand and acceptance criterion before inspecting the experimental result. Decide whether the primary variable is phase at a fixed frequency, amplitude ratio between two calibrated bins, fitted instantaneous frequency from raw complex samples, return loss at a connector, or simply the identity of the largest displayed bin. Those are not interchangeable. Document the complete set of candidate spectral intervals and the exact rule for identifying a peak. If the operator examines thousands of bins and presents the most dramatic one as though it were the only test, the false-positive probability is much larger than a single-bin calculation suggests. Retain the complete trace, not just the winning plot. Retesting with a second predetermined set of mechanical interventions supplies evidence against a chance correlation. The analyst should maintain the same peak-selection rules during that second test, even when the revised observations contradict the initial hypothesis.

Perform deliberately timed intervention and no-intervention control trials, preferably in an order concealed from the person classifying the output when that is practical. The manipulation may consist of flexing one known section of cable within its rating, with a fixture recording its motion and an independent observer marking actual times. The classification algorithm should be fixed beforehand and applied automatically to all trials, including ones in which no peak is detected. If a stable signal at one measured frequency merely alternates dominance with a nearby stationary line, an IQ analysis can reveal the two components even though the peak selector reports a jump. A truly changing instantaneous frequency requires phase evolution consistent with the calibrated clock and estimator.

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Statistical analysis must reflect shared sources and memory. Measurements taken during the same thermal relaxation are not independent simply because the software saves them as different rows. An oscillator correction can affect many consecutive estimates, and a contact may stick in a given mechanical state across several trials. Model those dependencies or use block-wise uncertainty and scenario bounds. When only a small set of trials exists, report the raw results and uncertainty without pretending that an elaborate probability model has been independently validated. The evidence is strongest when the mechanical intervention predicts an electrical change in an entirely new data set, with the same calibration plan and all unsuccessful trials disclosed.

Dr. James M. Atkinson, Moderator: Sir Robert, would you address the operational danger of making a geographic inference from an instrument-specific movement?

Sir Robert Alexander Watson-Watt, Peer Question: Professor Maxwell, field investigators sometimes move their receiver or a nearby cable and observe a spectral peak strengthen, weaken or change location in a plot. Their natural instinct is to follow that change through a room, perhaps believing a concealed emitter lies in the direction that gives a stronger response. But cable motion may alter the antenna pattern or external shield current, and an instrument can generate products in its own front end. How should a defensive survey distinguish a spatial field gradient from a changing receiving structure? What minimum set of independent controls would justify a directional conclusion, and what wording should a report adopt when the apparent bearing is sensitive to cable routing? If the operator observes a consistent angular maximum, should the result be repeated with

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the receiving antenna rotated while the feedline is independently immobilised? I suspect such a control would be more informative than following a field-strength maximum by moving the cable through the room.

James Clerk Maxwell, Response: Sir Robert, a directional measurement requires a receiving pattern whose relation to the environment is known, or at least challenged under the conditions of use. A coaxial cable carrying exterior common-mode current is not merely a transparent feed. It becomes part of the effective receiving structure, so moving it alters the measured field projection. A maximum observed while walking a cable near a cabinet may be caused by changing coupling to the local environment, by a difference in return-path current or by an analyser artefact. It is not an independent observation of the source's location. The operator should first immobilise the cable and measure with a separately characterised antenna configuration whose orientation and polarisation can be changed deliberately. The report should identify which receiving patterns were determined by actual calibration and which were assumed from ideal antenna theory. These are not equivalent when the feedline itself contributes to the spatial response.

An operational series should include a second antenna and receiver path with an independently monitored clock and different cable routing. It should document the intended antenna response, receiver sensitivity, front-end overload state and environmental limitations. Compare measurements at several fixed positions with the feedline restrained and its strain relief unchanged; then repeat with a different but calibrated cable assembly. If the supposed bearing reverses when cable routing changes while the antenna position and external environment remain fixed, the directional inference is

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not robust. A local injected reference signal can challenge instrument artefacts, although its cable path must be chosen so that it does not reproduce the same defect.

Even when two instruments agree, their errors may share the same source, timing service or environmental disturbance. A defensible report therefore states the observed field strengths and configurations, the response to controlled changes and the remaining ambiguity. The strongest justified statement might be that a frequency component was detected under certain antenna orientations but its localisation was not established because feedline-dependent coupling remained unresolved. This is not a failure of scientific investigation. It is the appropriate boundary between an observation and an attribution, protecting both the evidence and any individuals whose conduct might otherwise be inferred from an unstable instrument response.

Dr. James M. Atkinson, Moderator: The panel has established several possible mechanisms. I now request direct cross-examination among the principal contributors so that their different models confront one another rather than forming isolated speeches.

Oliver Heaviside, Cross-Peer Question to Arthur Edwin Kennelly: Professor Kennelly, your fixed-line transfer argument is essential, but it may mislead an operator who measures only before and after a cable bend. A connector can behave as two different static line networks with a sequence of rapid, unobserved transitions between them. If the experiment preserves only endpoint S-parameters, the transition may produce sidebands or a broadband pulse whose origins are invisible to those endpoints. How would your proposed test capture the time-varying boundary itself? Would you use

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continuous phase and amplitude observations, and if so how can the analyst establish a genuine time-dependent change in line behavior without confusing it with the signal generator's phase noise, host timestamp correction or receiver oscillator pulling? Please also address the case in which a line's apparently stable response after motion conceals a brief contact dropout during the movement. How would you recognise an interval during which the recorder's host buffer is delayed but its hardware counter remains continuous, so that a timing artefact is not falsely assigned to the connector's transition? I am especially concerned about intervals hidden by interpolation.

Arthur Edwin Kennelly, Cross-Peer Answer to Oliver Heaviside: Mr. Heaviside, I accept that static network analysis must not stand in for a time record. My initial equations define what the unperturbed line can do; the experiment then seeks evidence that the boundary conditions varied. The principal observation should be a continuous, coherently sampled reference signal passing through the suspect line, with a second independently monitored branch observing the same source before the suspect assembly. Retain the amplitude and unwrapped relative phase as functions of physical acquisition time, and retain the hardware counters required to show that no sampled interval is silently omitted. If the relative phase changes during cable movement while the source-monitor phase remains stable, this is stronger evidence of a path-associated dynamic perturbation than comparison of two endpoint S21 readings.

The apparatus should also include a current or voltage witness near the suspect interface where this can be implemented safely without altering the fault. A high-speed contact dropout may generate a sharp envelope

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depression and phase jump followed by receiver-filter ringing. If the line is reconnected before a slow spectrum analyser completes its sweep, the time-domain evidence can survive even though the static before-and-after measurements appear indistinguishable. Change the receiver's detection bandwidth in a separate trial to determine whether a transient's apparent duration follows the receiver filter. A valid comparison does not depend on reporting every phase discontinuity as an oscillator failure; it requires independent monitoring of the oscillator or known reference and a credible hardware time map.

Mechanical intervention must be time-tagged through an independent observer or a suitably characterised displacement sensor. A causal conclusion requires repeated trials with held conditions and negative controls, not a single dramatic event. A transient can follow the hand touching the cable because the hand changes capacitive loading rather than because a contact is opening. Repeat with an insulated fixture, then vary connector loading, cable curvature and environmental conductors separately. When the result is sensitive to the intervention mechanism, report that sensitivity. Your objection improves the diagnosis: the electrical network must be measured while it changes, not inferred solely from whichever stable state remains afterward.

James Clerk Maxwell, Cross-Peer Question to William Redington Hewlett: Mr. Hewlett, a well-executed two-port calibration can make the terminal S-parameter uncertainty impressively small. Yet a shield defect can establish an external common-mode current whose field distribution depends on the room, cable routing and the connection to the instrument chassis. How would your calibration procedure avoid giving false comfort where the VNA

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ports excite primarily the intended differential path and fail to reproduce that external current? Can terminal measurements alone establish that a peak's movement is or is not associated with the screen, and what additional excitation or observation geometry would be justified before identifying one connector as the sole culprit? I also ask how you would preserve measurement traceability without modifying the physical boundary conditions through the act of attaching more probes. It would be useful to state which current probe calibration transfers to this installed geometry and which remains only a laboratory approximation, because a sensitive instrument can itself modify the exterior field and thus compromise the causal comparison.

William Redington Hewlett, Cross-Peer Answer to James Clerk Maxwell: Professor Maxwell, a two-port measurement is a calibrated observation of chosen terminal modes under a defined termination and fixture. It is not a comprehensive mapping of all fields radiated or conducted by the entire receiver-cable-enclosure assembly. A common-mode screen current may be weakly excited by one VNA arrangement and strongly excited by the operating receiver or surrounding electromagnetic field. Thus I would not treat excellent differential S21 repeatability as a certificate of shielding integrity. The test plan must expressly include the exterior current and its sensitivity to grounding, cable routing and nearby conductors, using a suitable clamp or field probe whose own calibration and loading are documented.

The additional measurement should be made in stages. First establish the baseline terminal response with the apparatus as found. Next measure any exterior current with the probe placed at documented locations; repeat the

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baseline terminal measurement to see whether the probe itself changes the result. Third use a well-controlled local injection arrangement, within safety and legal constraints, to challenge differential versus common-mode coupling. A signal source may be injected at one known point while an independently calibrated witness observes the resulting field or current at another. The point is not to create a perfect analogue of every environmental excitation but to determine whether the suspected return-path defect responds as the proposed mechanism predicts. The original cable route and enclosure connections must remain recorded.

If the external current changes with connector torque while S21 remains nearly constant, that is important evidence of a shielding or return-path phenomenon that a narrow terminal test might miss. If current and terminal phase change together, more work is required to identify whether there are two coupled mechanisms. Retain the physical configuration, probe positions, instrument reference planes and before/after verification results, and state when a control alters the system sufficiently to limit comparison. One can make a reproducible causal claim about the measured modes without pretending that any finite probe set captures the whole electromagnetic field. Calibration is not an incantation; its validity is bounded by what was actually excited and observed.

Edwin Howard Armstrong, Cross-Peer Question to Oliver Heaviside: Mr. Heaviside, you have shown that a moving transmission line can modulate a stable carrier, and I agree. But the operator may observe a spur at precisely a receiver intermediate frequency or at an offset related to an internal sample clock, rather than simply symmetric sidebands around the input carrier. Such a result might arise because a cable bend changes blocker level

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at an active nonlinear stage. How should we discriminate modulation produced physically within the cable from frequency conversion produced by the receiver itself? I would be particularly reluctant to attribute a detected product to a damaged line merely because the same manipulation affects both the input mismatch and the display. What tests would isolate the physical locus of frequency conversion without assuming that the receiver always behaves linearly? Would you regard simultaneous appearance of the product in two receivers driven by the same clock as independent corroboration, or would that arrangement still admit a shared timebase or reference-distribution defect which no cable substitution test alone can exclude?

Oliver Heaviside, Cross-Peer Answer to Edwin Howard Armstrong: Professor Armstrong, an active receiver can produce frequencies that a passive fixed line cannot. Our first task is to measure the suspect assembly with a sufficiently linear independent path, at levels low enough to avoid inducing new products in the reference instrumentation. If a reproducible new component can be observed before the suspect receiver's conversion stages, the hypothesis of a line-associated dynamic or nonlinear mechanism gains support. If it is absent there but appears in one receiver IF chain, the receiver deserves examination. In either case, a negative observation must be interpreted against that reference path's sensitivity and bandwidth; failure to see a small product is not proof that it does not exist. An independently monitored marker inserted before the cable and recorded on both paths can further reveal whether the observed time interval contains valid samples or a gap that processing has concealed. The marker itself must not disturb the suspected contact.

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Introduce a controlled two-tone source and vary input levels safely while keeping the suspect cable mechanically fixed. Observe whether the candidate spur follows the algebraic combinations of the applied tones. Then hold the tones constant and introduce a documented cable movement. A source harmonic, connector nonlinear product and receiver mixer product can share a numerical frequency, so their amplitudes under independent device substitution and attenuation matter. Swap the receiver while retaining the cable and monitored source, then swap the cable while retaining the receiver. A correlation that follows both in a non-separable way may indicate interaction between source impedance and active front end; forcing an exclusive label upon such behavior would be unscientific.

Finally, the local oscillator or sampling clock must be monitored when possible. If the receiver's frequency reference changes under input mismatch, the apparent carrier shift may have a different cause from a line's envelope modulation. Record raw IQ, IF configuration, gain state, filter settings and any discontinuities in time mapping. Compare the frequency offset of the alleged signal relative to a separately injected known reference, noting whether both move together. If both move, suspect the frequency axis or conversion chain before assigning motion to a remote source. Your objection illustrates why the transmission line and receiver must be studied together, with every attribution bounded by the tests that distinguish them.

Arthur Edwin Kennelly, Cross-Peer Question to Edwin Howard Armstrong: Professor Armstrong, your treatment of peak-selection algorithms is important, but a numerical report may confuse an observation made in the instrument with a change in a transmitter's centre frequency. Suppose a trace shows a 400 Hz movement on cable flex and the same amount is

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repeated over several trials. The display's repeatability may be excellent even while the underlying signal is a stationary pair of tones whose relative heights have changed. What measurable conditions would persuade you that the signal's instantaneous frequency actually changed rather than the location of the display maximum? Would you distinguish a phase-derived estimate from an FFT-bin estimate, and what steps would make the conclusion reproducible without relying on a particular software implementation? I would also ask whether a frequency-fit model should explicitly retain two nearly equal candidates instead of forcibly choosing one, and how a later expert could reproduce the reported transition if the original complex samples had been discarded.

Edwin Howard Armstrong, Cross-Peer Answer to Arthur Edwin Kennelly: Professor Kennelly, I would begin with the full complex sample record and a clock whose frequency and continuity have been separately challenged. Two resolved stationary tones should remain at their respective phase-evolution rates, even if one becomes dominant in magnitude. Estimate their frequencies individually when signal-to-noise ratio and resolution permit, and show the complex spectrum under the original window and under a second predeclared analysis. A peak picker may switch between them, but a model fitting two distinct sinusoids can reveal that neither moved. The model should be evaluated against residuals and alternative components; a two-tone fit is not inherently true merely because it has more parameters. When the data are ambiguous between phase modulation and a two-line mixture, reporting both models and their residuals is more useful than asserting a single frequency trajectory. The raw time record should remain available for those competing reconstructions.

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If the signal is genuinely one time-varying component, an analytic-signal phase estimate may reveal a coherent phase trajectory whose derivative changes. But near envelope nulls, phase unwrapping becomes unstable and an apparent jump can arise from interference or missing samples. Therefore compare independent algorithms, use a reference marker carried through the same receiving path, and determine whether the frequency change coincides with a known clock or gain-control transition. A test with a known stable calibration carrier can reveal whether the receiver's frequency axis shifts at the same time as the suspicious feature. If both move together, a reference or conversion defect is a more plausible cause than simultaneous motion of separate external emitters.

Reproducibility requires the same raw input, fixed settings, identified software versions, numerical precision and documented decision rules. Preserve every trial, not only the ones confirming the desired 400 Hz change. Test sensitivity to window length and estimator model, and state the uncertainty of the frequency difference under realistic noise and interference. A claim of changed instantaneous frequency may survive these challenges; a claim that an emitter moved geographically requires still more evidence, including propagation, bearing or location observables independent of the cable perturbation. The logical chain from display peak to physical source is long, and no one successful flexing demonstration supplies all its links.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has separated four phenomena frequently concealed by the expression 'a moving spectral peak': a static cable or connector transfer-function change; a time-dependent mechanical modulation of an existing carrier; internal

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receiver frequency-conversion or clock artefacts; and a peak-selection algorithm exchanging dominance between stationary components. The first two may be associated with impedance, shielding, electrical length or contact instability, yet none establishes geographic movement of a transmitter. Proper tests begin with a monitored source and an explicit antenna-to-recorder reference-plane diagram. They retain raw complex samples, source and local oscillator timing, safe controlled bend and remating logs, calibrated S11/S21 and, where relevant, exterior shield-current observations.

A high-quality inquiry also separates the operator's intervention from the apparatus response. Connector torque and pin geometry must comply with the relevant interface specification, and a cable should not be flexed beyond its rated bend radius to obtain an impressive spectral change. Before-and-after network traces must be supplemented with continuous acquisition across any transient. An apparently reproducible result should survive no-intervention controls, independently monitored reference channels and realistic alternative hypotheses involving receiver filtering, mixer products and display algorithms. Numerical frequency, phase, amplitude and position claims require distinct uncertainties and distinct evidence.

The moderator thanks the contributors for their candid examination of one another's reasoning. All dialogue is a modern educational construction, and every numerical example is hypothetical. The defensible forensic conclusion records the configuration-dependent observation and any fault actually isolated by challenge testing; it does not attribute a remote emitter from a mechanically sensitive peak without independently validated evidence.

QUESTION 067. SOURCES AND EDITORIAL QUALIFICATIONS

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1. IEC 61169-1:2013, Radio-frequency connectors, Part 1: Generic specification, general requirements and measuring methods. Reflection measurement procedures and time-domain reflectometry appear in the published standard. https://standards.iteh.ai/catalog/standards/iec/a07e544a-4453-48d2-89b5-4dc84c1e47cc/iec-61169-1-2013 . Verify clause wording and edition against licensed primary standard before formal publication.

2. IEC 61196-1-111:2024, Coaxial communication cables, test methods for phase stability. https://standards.iteh.ai/catalog/standards/iec/1f9f1183-3d0c-4552-87e3-328601ddb570/iec-61196-1-111-2024 . Useful for distinction between electrical phase change and mechanical cable conditions, subject to scope and edition verification.

3. NIST researchers, Stochastic Modeling of Coaxial-Connector Repeatability Errors, ARFTG conference publication. https://www.nist.gov/system/files/documents/2017/05/09/Connectors-ARFTG.pdf . Supports treating precision-connector repeatability as an uncertainty problem rather than an ideal repeatable connection.

4. Keysight Technologies, Impedance Measurement Handbook, application note 5950-3000, sixth edition. https://www.keysight.com/us/en/assets/7018-06840/application-notes/5950-3000.pdf . Addresses thermal and bend-induced changes in cable phase and uncertainty arising from port extensions.

5. IEC 61169-1-2:2019, Test methods for insertion loss of radio-frequency connector assemblies. https://cdn.standards.iteh.ai/samples/100217/bd4dcc9526984d56889b3a58

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dfa37f5d/IEC-61169-1-2-2019.pdf . Cite exact edition, test fixture and connector family in any detailed protocol.

EDITORIAL QUALIFICATION: The conceptual derivations here use idealised models. Actual connector torque, bend radius and safety requirements are interface-specific and must not be inferred from a generic example. No external field engagement, instrument measurement or historical conversation is claimed.

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QUESTION 068

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How can antenna substitution distinguish incident RF energy from instrument-generated signals?

Dr. James M. Atkinson, Moderator: Sir Robert, a narrow trace on a surveillance countermeasures receiver may seem to prove an emitter is within a room. The signal might instead be a local oscillator leak, ADC clock artefact, image response, cable-borne common-mode current, or intermodulation arising only after the antenna is connected. How should the investigator arrange an antenna substitution experiment to determine whether RF energy entered through the calibrated aperture, and why is the simple disappearance of a trace after unscrewing an antenna insufficient proof of its external origin?

Sir Robert Alexander Watson-Watt, Principal Contributor: Dr. Atkinson, the decisive word is *comparison*, not disappearance. An antenna is a physical transducer with frequency-dependent impedance, polarisation, directional sensitivity, effective height and interaction with its surroundings. Disconnecting that apparatus changes not one but several properties of the receiver installation. It changes the incident-field coupling, of course, but it may also change the termination presented to a sensitive preamplifier, the shield-current path, the noise available at the input and the operating point of a gain controller. An operator who notes only that one spectral line vanished has performed an intervention, yet has not necessarily isolated the factor that caused the result. A defensible experiment must specify the alternative explanations before the first cable is moved, and arrange conditions whose predicted outcomes differ.

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We may describe a simplified observation at a chosen frequency f as $Y(f)=G_s(f)\,[H_a(f)E_{inc}(f)+V_c(f)] + S_s(f)+N_s(f)$, where E_{inc} is incident electric field in volts per metre, H_a is an effective antenna-to-port response in metres under defined loading and polarisation, V_c is unwanted voltage entering through cable shields or other conductive paths, G_s is the receiver's complex small-signal transfer factor for configuration s, S_s is internally generated spectral artefact and N_s is noise. This is only a bookkeeping model. An active antenna makes H_a and G_s interdependent; nonlinear mixing requires additional terms; a magnetic-field probe needs a different coupling description. Nevertheless the equation forces the investigator to ask which term each substitution actually changes. Replacing an antenna with a matched load aims principally to suppress H_aE_{inc}, but does not guarantee that V_c is zero or that S_s is unchanged. A connector movement can also alter G_s through a transient or impedance mismatch.

The test begins with a protected baseline. Preserve raw complex samples, receiver centre frequency, bandwidth, preselection, gain, AGC setting, detector choice, clock identity, input attenuation, antenna coordinates, cable route and the timestamps of the observations. A spectral screenshot without these details cannot support a reliable before-and-after comparison. First observe with the original antenna and document its polarisation and placement. Then connect a well-characterised termination *at the receiver's own RF reference plane*, without disturbing any other state insofar as the apparatus permits. A termination attached at the far end of the existing coax is a different test: the cable and its screen remain present and may still collect energy. These two terminations should not be conflated.

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A second condition is a matched load at the end of the same antenna cable. A third is a shielded, calibrated laboratory source at a known low level, connected through a safe attenuator and, where necessary, a DC block to prevent damage from active antenna bias. In each state, the receiver should encounter a specified source impedance. If the spectral feature survives a good load placed directly at the instrument, its production after that plane or by an alternate ingress path becomes more likely, though a leaky enclosure or instrument supply remains an alternative. If the feature vanishes with the direct load but survives with the cable attached and terminated at its distant end, the feedline or its screen is implicated. If it requires the radiating antenna, it is at least dependent upon the antenna assembly, not yet uniquely attributable to a distant transmitter.

The fourth condition should use a second front end of materially different architecture and its own reference source where feasible. It is tempting to connect the same antenna successively to two receivers, but the comparison is then sequential and may be invalid if the suspected signal is intermittent. Use an appropriately calibrated splitter, with isolation and loss measured, or independent simultaneous antennas where their differing reception patterns are acknowledged. A signal following the external antenna and appearing at a consistent absolute RF frequency in receivers with different local oscillator plans is stronger evidence of incident energy than a line that follows an internal clock harmonic. Yet a strong external blocker may induce similar intermodulation in both instruments; architecture diversity is a challenge to an explanation, not a magical certificate of independence.

One should also vary attenuation before the first active nonlinear stage. If a genuine unsaturated incoming tone is reduced by 10 dB at an input

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reference plane, its measured power should fall by approximately 10 dB, provided automatic gain is fixed and the display is calibrated. A third-order intermodulation product created after that attenuator can change by approximately 30 dB for the same adjustment in a simplified cubic regime. An internally generated spur introduced after the attenuation point may remain nearly constant. These are conditional diagnostic slopes: AGC, limiting, noise-floor thresholds, cross-modulation, filters and shared clock behaviour may alter them. We should never infer a unique physical source from one slope alone.

Suppose an authorised laboratory test reveals a line at 172.000 MHz with the antenna connected. It disappears upon direct termination, yet an inserted 20 dB pad changes the trace by only 4 dB. The anomalous slope defeats a naive linear external-tone explanation, but does not prove a synthetic oscillator spur. The pad may also reduce a strong blocker, change impedance and alter gain control. Record total power and overload indications across a sequence of pad values, keep gain fixed, and inspect the full spectrum. The comparison is more persuasive if a known reference tone injected into the same connection falls by its expected attenuation while the suspect feature behaves differently. This simple controlled challenge exposes the limits of a single disappearance test.

In a room, proximity is no guarantee of causation. Moving the antenna can change the field of a genuine radiator through multipath; moving the cable can alter shield current; changing the connector can suppress a marginal contact; and human movement can perturb all three. The survey should therefore create a measurement matrix, not a theatrical demonstration. Repeat the antenna, direct-load, cable-end-load and known-source

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conditions in varied order, with periodic restoration of the original state to check drift. Measure each result more than once and retain failures, not simply the most interesting trace. Independent evidence such as polarisation, spatial pattern, external probe comparison and source-independent clock substitution can sharpen causal discrimination. It is respectable to conclude that energy was dependent upon the antenna-port configuration without claiming that a particular object transmitted it. That distinction, carefully recorded, is the foundation of an honest defensive investigation.

Dr. James M. Atkinson, Moderator: Dr. Steinmetz, interrogate Sir Robert about the possibility that a matched input load changes the receiver’s electric and magnetic return paths, rather than simply excluding an incoming field.

Charles Proteus Steinmetz, Peer Question: Sir Robert, we speak of replacing the antenna by a matched load as though the intervention were a clean subtraction of the external field. But the outer conductor of the feedline, the receiver chassis and a nearby power cable may form an electromagnetic structure, with common-mode currents and ground-potential differences that are sensitive to how the connector is engaged. Even the operator's hand can alter the local capacitance. Under what configuration could a load at the receiver isolate the differential antenna-port mode while failing to remove other ingress mechanisms, and how would you determine the effect of a load mounted at the far cable end? I ask particularly whether a vanishing line after direct termination could be explained by changed boundary conditions or gain, even though a field was still physically present in the room. Distinguish the case of a radiating cable screen from one where

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the same screen conducts equipment-generated disturbance outward; the two can produce similar receiver indications but different causal histories.

Sir Robert Alexander Watson-Watt, Response: Dr. Steinmetz, a coaxial connection possesses both the intended differential or transverse electromagnetic transmission mode and possible external shield currents. A matched load terminates the differential input at its reference plane, but a cable extending beyond that plane remains capable of coupling to its surroundings. A load placed directly at the receiver removes that external cable from the tested port; it may simultaneously remove a common-mode conductive route. Such a result cannot by itself decide whether the original driver was a distant field or an appliance conducted through local wiring. The load does not abolish all enclosure ingress, power-line pathways or radiation through seams. The purpose of a controlled matrix is precisely to separate those routes as far as measurement permits.

The direct-load and far-end-load experiments should be performed with a characterised cable and a proper shielded termination, recording changes in connection geometry. If the feature disappears only when the entire cable is removed but persists with a load at its far end, the cable, its shield or associated connector is implicated. The next tests include an alternative cable route, a different shield construction, an appropriately designed common-mode choke and a controlled receiver supply arrangement. Any choke introduces impedance and should be characterised rather than assumed invisible. A clamp-on RF current probe can give evidence of shield current, with the probe's own response and loading considered. A simultaneous independent antenna can show whether a radiated field remains present while the first receiver's conducting path is altered.

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To answer your final question, yes, a genuine field may remain in the room when the receiver trace vanishes. The intervention has changed the measuring apparatus, not the world. The stronger conclusion is that the measured indication requires some element of the original external-port assembly. Demonstration of a radiated field needs another observation method, preferably one with independent signal conversion and a calibrated aperture. Demonstration of an internal spur requires tests that show its association with an oscillator, sample clock, nonlinear stage or enclosure pathway. A claim about a specific emitting object requires independent spatial and source evidence.

I would also restore the original configuration repeatedly rather than rely on one pair of measurements. A connector can be intermittent, and a gain controller can need time to settle after a disconnection. Log the order and exact time of every change, discard or qualify transition periods, and check the receiver with a known calibration tone before and after the sequence. A sham manipulation helps identify an operator-induced shift. If the results vary with cable flex or hand proximity, record that dependence as a finding and investigate it. The object of this examination is not to make the case look simple, but to establish a defensible set of causal bounds.

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Dr. James M. Atkinson, Moderator: Professor Armstrong, please examine whether the receiver itself can turn an innocent change of input termination into a convincing signal. In particular, distinguish direct-conversion offsets, mixer images and internal clock products from energy that genuinely arrived at the antenna connector.

Edwin Howard Armstrong, Second Principal Contributor: Dr. Atkinson, an RF receiver does not merely measure a signal; it translates and filters signals, and each operation has mechanisms by which unwanted indications may be created. In a superheterodyne receiver, a frequency that satisfies an unintended mixing relation can enter a particular intermediate-frequency channel even though it is not the frequency displayed to the operator. A direct-conversion receiver can exhibit DC offset, quadrature imbalance and local-oscillator feedthrough, and a sampling receiver can contain clock-related spurs and alias images. Changing the connected antenna can alter the amplitudes driving such mechanisms without removing their internal causes. Consequently a line's response to antenna substitution must be interpreted in conjunction with changes in tuning, conversion plan, input level and receiver operating state.

Take the elementary mixing relation $f_{IF}=|f_{RF}-f_{LO}|$, where f_{IF} denotes intermediate frequency, f_{RF} an input component and f_{LO} the local oscillator. The same positive f_{IF} can be produced by two frequencies on opposite sides of the oscillator unless an image-rejection stage suppresses one. An antenna selected for the nominal channel may admit a strong image-frequency field despite giving little response at the displayed channel. Substituting another antenna changes that unwanted admission, and a displayed line disappears. It would be inaccurate to announce that the

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original antenna captured a transmitter at the displayed frequency. The proper test changes local-oscillator injection or preselection in a controlled manner and observes whether the putative absolute RF frequency stays fixed in the environment while the suspect response follows an instrument mixing relation.

A nonlinear input amplifier adds further ambiguity. If two environmental blockers at frequencies f_1 and f_2 drive a cubic nonlinearity, third-order products at $2f_1-f_2$ and $2f_2-f_1$ may appear near a protected observation channel. Neither product requires an independent transmitter at that frequency. A different antenna or a properly placed pad may attenuate the blockers sufficiently that the apparent suspect signal disappears. The disappearance proves that the input environment contributed to the generation mechanism, not that the displayed frequency itself came through the antenna as a physical field component. A wideband input-monitor path, overload indication and multi-level attenuation test can identify this distinction.

The modern control sequence is conceptually simple. First retain the preselector and gain state. Second introduce calibrated attenuation ahead of the suspected nonlinear stage and measure not only the chosen line but the strong neighbouring emissions. Third compare at least two local-oscillator plans, or receivers with dissimilar conversion architectures, while preserving absolute frequency calibration. Fourth repeat with a shielded, low-power injection generator and a matched load. A valid instrument challenge should reproduce a known tone without inventing a nearby response when its source is absent. If the instrument fails this challenge, the

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survey cannot responsibly treat every spectral trace as environmental evidence.

One must be alert to AGC and stateful firmware. In a receiver with automatic gain, disconnecting a substantial external noise source or blocker can make the gain increase, creating a higher baseline or making a weak internal spur more prominent. A line that becomes stronger with the antenna removed need not mean an internal oscillator suddenly began emitting more power. It may mean that the subsequent gain increased. Conversely a line can vanish because the gain was reduced during a transient or because a software threshold was recalculated. A comparison without gain-state logging is ambiguous. Lock the permissible gain states, document their actual behaviour and distinguish a physical signal-power change from a display or detector change.

A direct-conversion receiver provides a sharp example. A strong local oscillator may leak to the RF port or the case. The antenna can re-radiate or reflect this energy into the front end, leading to a change in a centre-frequency spur when the antenna is attached. The culprit originates within the receiver even though the antenna is a causal participant. Another source is quadrature mismatch: a positive-frequency component appears as an unwanted mirror at the opposite baseband frequency. Changing antenna orientation can change the desired input signal and its mirror together, giving a deceptive impression that two separate emissions have been observed. A controlled shift of the LO and an image-rejection calibration can challenge the hypothesis.

Sampling adds a parallel distinction. If the ADC samples at f_s, under ideal uniform sampling a sinusoid at f_RF may be indistinguishable from aliases

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separated by integer multiples of f_s in the digitised baseband. Preselection is needed to constrain the analogue spectral content that gave rise to the samples. A receiver that claims a signal frequency without documenting its analogue passband, sample rate and alias plan may be reporting an equivalent digital frequency rather than uniquely identifying the external RF component. An antenna substitution might remove a wideband blocker, allowing an alias to disappear, but the inference about the displayed channel remains conditional. The test should identify whether an independent analogue receiver detects energy at the actual supposed RF frequency.

Suppose a candidate line appears at 100 MHz. One receiver has an oscillator plan that could create a response from a 120 MHz blocker; another uses a different IF and preselector. If the displayed 100 MHz line follows the first instrument's LO change but a calibrated independent receiver sees no corresponding 100 MHz field, the instrument-response hypothesis is stronger. Yet negative observations are bounded by the second receiver's sensitivity, polarisation, bandwidth and timing coverage. The correct report records the instrument settings, change in response, independently measured blockers and exclusion limits. It should never promote a mere absence of a line on a second display to a categorical declaration that no external energy existed.

I would stress an additional operational point. Replacing the antenna with a coaxial switch, attenuator or splitter is itself an addition to the receiver chain. Its insertion loss, isolation and impedance match are finite, and its switching contacts can generate brief spectral disturbances. Verify the control fixtures with a known reference tone and a shielded termination. A

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genuine front-end test includes the test apparatus as part of the measurement, not as a neutral invisible hand. If a feature tracks a switch position, we must ask whether the switch merely selects the incident field or whether it is creating a conductive path, a new resonance, an overload state or a settling transient. The panel should pass no inference that does not survive this elementary distinction.

Dr. James M. Atkinson, Moderator: Professor Bode, challenge Professor Armstrong on the relationship between an antenna-dependent spur and a receiver that is nonlinear only when the antenna admits strong blockers.

Hendrik Wade Bode, Peer Question: Professor Armstrong, the proposed attenuation challenge assumes a stable small-signal or simple polynomial regime, yet a real receiving chain may contain a protector, a frequency-selective preamplifier and several control loops. A ten-decibel input change might shift one device from compression into linear operation, alter bias or lead firmware to select another filter. In these circumstances the observed slope of a spectral component could resemble third-order intermodulation without being caused by a single cubic mechanism. How would you structure the attenuation series so that its result distinguishes an external tone, a product formed after the attenuator, and a spur injected later in the chain? Please explain how the experiment guards against interpreting a threshold effect as a mathematical power law, and identify the independent measurements needed to support a causal account rather than merely a persuasive curve. Does the slope remain stable when the same attenuator ladder is tested in reverse order, and does an independent monitor confirm that the nominal pad increments are actual RF power changes at the relevant reference plane?

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Edwin Howard Armstrong, Response: Professor Bode, your objection reaches the heart of the matter. The familiar one-to-three scaling is the local result of a simplified polynomial model, and it is valuable only over a range where its assumptions actually hold. The experiment should therefore include more than two attenuator settings, and each point must be associated with the measured gain state, the absolute input power and any overload or protection indication. A sweep in controlled one- or two-decibel increments, followed by a reverse sweep, may expose hysteresis, switching thresholds or changes of mode. The examiner should record the complete spectrum at each step, not merely the selected spectral line. If two strong input components and a putative third-order product are both visible, the change in their levels supplies a stronger model test than the product trace alone.

I would first calibrate the attenuation fixture with a stable known tone at the relevant frequency and power, verifying linearity with an independent power monitor. Next the receiver should be operated with any permissible automatic gain disabled and with fixed preselection and sampling modes. If disabling such control is impossible, the system must report its actual states for every sample interval, and the conclusion becomes conditional upon that record. Third, inject two safe laboratory tones through a shielded combiner with their frequencies selected to place a possible intermodulation product in the observation channel. Measure the response as each tone is varied independently. A third-order product should obey particular local derivatives with respect to both input levels; a single oscillator spur downstream will usually not behave that way.

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Where the suspected environmental signal cannot be reproduced by a laboratory generator, the field test can still use a properly calibrated pad sequence and independent receiver as checks. But the operator should decline to fit a single slope if the display jumps between discrete modes. A threshold crossing can create the appearance of a steep power law while reflecting detection censorship rather than nonlinearity. The model must distinguish actual RF power from the probability that a processing algorithm includes the line in its output. If an internally generated spur remains at fixed absolute amplitude while the input tones fall, the origin lies at or beyond the attenuator plane or in another ingress pathway, though cross-coupling through the instrument supply may remain possible. The report should contain the measured sweep, its state log and the reasons competing explanations were rejected. Nothing is gained by dressing a discontinuous receiver response in a smooth polynomial equation.

Dr. James M. Atkinson, Moderator: Mr. Black, challenge Professor Armstrong’s gain-control and attenuation analysis. What happens if the substitution triggers a hidden state change and the operator records only the final spectral display?

Harold Stephen Black, Peer Question: Professor Armstrong, your method proposes to hold gain and preselection fixed, yet some contemporary receivers silently alter their analogue front end or digital scaling when an input is disconnected. A low-power matched termination may induce more gain than a busy antenna, while a strong calibration tone may provoke protective attenuation or different filter coefficients. A displayed tone can appear unchanged after a ten-decibel pad is inserted, despite its actual port voltage changing as predicted. What state observations and challenge

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signals would reveal such hidden compensation? How should the investigator interpret an increase of an internal spur on antenna removal, and how can the test establish whether that increase is a source effect, a gain effect or an artefact of peak-selection processing? Please also address the possibility that a software detector normalises every short-time spectrum to the current median, concealing an absolute change in power while changing the relative prominence of individual peaks.

Edwin Howard Armstrong, Response: Mr. Black, the crucial distinction is between power at a specified analogue plane and the displayed number produced after a sequence of amplification and calculation. Automatic gain attempts to hold some downstream statistic approximately constant, so an honest input attenuation may not yield a corresponding display change if the loop increases gain. One should therefore measure or independently supervise the actual analogue gain, or at least record the gain-control state and compare the input with a known calibrated tone. A test that cannot access or freeze its state should be described as a black-box system test with a weaker causal conclusion, not as a precision measurement of the RF port alone.

Use two reference signals where possible. One should be injected electrically at the receiver port within the safe linear range, with an amplitude determined independently of the device under test. Another may be introduced through an authorised radiating path to challenge the antenna and local field. Vary their levels separately and log all relevant analogue attenuator, amplifier, preselector and digital normalisation states. If firmware does not expose those states, monitor the raw input sample scale and observe how the two known signals move as the connection

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changes. A hidden state switch may appear as a discontinuity, hysteresis or altered gain slope that is not explainable by an analogue linear transfer alone.

An internal spur that becomes more prominent after antenna removal may be amplified by the new gain setting, unmasked by a falling external noise floor, or promoted by a detection algorithm that ranks the largest surviving peaks. Its apparent increase need not indicate that the oscillator produced more electrical energy. Repeating the test at an independent fixed-gain front end is therefore valuable. Observe the absolute amplitude of the line relative to a stable injected reference, not merely relative to a dynamic display floor. Changing the FFT window, integration time or peak-hold interval can expose how much of the effect arises in presentation rather than acquisition.

The operator should also maintain a strict chronology. A gain change may be transient, and the first few data blocks after an antenna switch may include a settling response or invalid scaling. Retain hardware timestamps and identify the earliest observation that meets a tested steadiness criterion. If the suspect feature exists only during the transition, classify it separately from a continuous external emission. Documenting these states may seem burdensome, yet it prevents a mechanical operation on a connector from being mistaken for the birth or disappearance of a transmitter. The best causal claim is the one that survives both a known-tone challenge and an independent observation path.

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Dr. James M. Atkinson, Moderator: Lord Rayleigh, the engineers have described the input and conversion circuitry. Please direct our attention to calibration and inference. What is actually controlled when we substitute one antenna, termination or receiving path for another, and how can the ensuing uncertainty be stated without fictional precision?

John William Strutt, Lord Rayleigh, Third Principal Contributor: Dr. Atkinson, the experimental comparison becomes scientific only after its quantity of interest is stated. One might wish to know whether a field existed at a defined point, whether its power crossed the antenna terminal, whether an external source emitted at a particular frequency, or whether an authorised survey met a prescribed detection probability. These are distinct questions. An antenna substitution can be an excellent discriminating intervention for the first two, but even a perfectly executed comparison cannot, in isolation, establish the identity or intent of an emitter. The relevant measurement equation must distinguish the field variable from the receiver indication and retain uncertainty in the intervening transfer.

For a calibrated electric-field antenna, the familiar antenna-factor relationship is $AF(f)=E(f)/V(f)$ under its stated calibration convention, where E is incident field strength in volts per metre and V is the specified terminal voltage in volts. Expressed logarithmically, AF in decibels per metre is E in decibel microvolts per metre minus V in decibel microvolts. The calibration factor depends on frequency, polarisation, impedance loading, positioning and environment. When a different antenna is substituted, its AF may differ by tens of decibels. Equal receiver display values from two antennas do not mean equal fields, and unequal display values do not necessarily indicate different environmental sources. A fair comparison either corrects each path

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to a common field estimate with its uncertainty or compares a known test signal that fixes the response of each configuration.

Mismatch is a central example. If an antenna or substitution generator has reflection coefficient Γ_s and the receiver has Γ_l, the transmitted power depends on a mismatch factor; an idealised voltage relationship is influenced by the product $\Gamma_s\Gamma_l$. A simple load labelled '50 ohms' is not exactly 50 ohms at every test frequency, and a receiver RF input rarely has zero reflection. Replacing the original antenna may therefore change delivered power without changing incident field. More seriously, a mismatch can alter feedback, gain compression or the effective noise figure of an active input stage. An uncertainty budget that includes only the manufacturer antenna factor and the screen's amplitude accuracy fails to account for the actual electrical comparison.

Consider a hypothetical calibrated test at 400 MHz. The receiving chain records a particular field estimate with one antenna and a value 8 dB lower with a replacement antenna. The first has antenna factor 18 dB/m; the replacement 27 dB/m. If the observer has not corrected the two terminal voltages by these respective factors, the 8 dB raw difference is not evidence of a field change. Even after calibration, the two antennas may sample different polarisation components or spatial regions, especially near metallic objects. This example is illustrative and does not supply a universal correction. The proper statement refers to the declared calibration planes, field components, antenna geometry, environment and confidence interval.

I should distinguish a matched load from a calibrated passive antenna. The load is a deliberately nonradiating termination, intended to put the receiver into a specified electrical state and suppress reception through the normal

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aperture. It is not an antenna of zero effective height in the whole installation. A feedline screen, a poorly sealed enclosure and nearby instrument wiring can still carry radio-frequency currents. The load may have finite thermal noise, leakage and mismatching, which are part of the controlled baseline. By contrast a laboratory generator connected to the RF port supplies a known terminal stimulus but does not necessarily reproduce the loading and spatial coupling of the original antenna. Each condition controls a different physical variable.

Statistical repetition is necessary but not sufficient. If ten antenna substitutions produce nearly identical changes, repeatability is established under those particular intervention conditions. The experiment may nevertheless contain a shared systematic error, perhaps an AGC state transition, an incorrect antenna-factor table, or a common cable disturbance induced every time the operator handles the connector. Randomising the sequence and including a sham manipulation, where the operator touches the fixture without changing the electrical path, can reveal handling effects. A second operator and independent instrument can reduce some observer dependence. But none of these procedures erases the obligation to inspect the actual physical path.

Let the corrected field estimate depend on calibration factors a, cable loss l, input gain g and observed level p. In decibel form a simplified expression may be $E_{dB}=p+a+l-g$, provided the measurement conventions use compatible reference units and the omitted coupling terms are either corrected or declared negligible. Its variance is not simply the sum of four squares if the factors share a common calibration source. In general $u^2(E)=\Sigma_i\Sigma_j (\partial E/\partial x_i)(\partial E/\partial x_j)Cov(x_i,x_j)$. Here the x_i are influence quantities

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and Cov is their covariance. A shared calibration source or ambient-temperature effect may make the off-diagonal terms material. An uncertainty statement produced from a convenient spreadsheet without these dependencies can be precise to three decimal places and inaccurate in physical meaning.

The question of a negative result must be approached even more cautiously. With the antenna connected, a particular signal may be below the noise floor; with the termination, it is not seen. This establishes no useful discrimination if the receiver was never sufficiently sensitive to detect the signal under either condition. A challenge signal of known power and compatible waveform should demonstrate the active detection limit in each state. In a building, receiver noise, interference and field multipath change with location and time. The operator should therefore map the tested conditions and acknowledge detection coverage: specific frequency ranges, time intervals, field components, antenna orientations and tested source strengths.

The final report should not say 'the signal was external' when the data merely show 'the feature is antenna-dependent'. The latter is a measured causal relationship between apparatus configurations and indications; the former is a claim about the source's location in the physical world. Progress from one to the other requires additional evidence, including second-architecture observation, source modulation, spatial field behaviour, directional consistency or controlled removal of an environmental source. The burden of inference belongs to the claim actually being made. Scientific restraint is not reluctance to conclude: it is the method by which a conclusion becomes fit for later examination.

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Dr. James M. Atkinson, Moderator: Mr. Campbell, test Lord Rayleigh’s treatment of antenna factors and impedance mismatch. Please examine whether the comparison can be made fair when the substitution elements do not share an identical reference plane.

George Ashley Campbell, Peer Question: Lord Rayleigh, the field-strength correction E_dB=p+a+l−g is useful only when calibration quantities refer to compatible definitions of voltage and field, and when the receiving network is sufficiently linear. In practice the calibration certificate for one antenna may end at its connector, the cable loss certificate may assume a matched termination, and the receiver's displayed amplitude may be corrected to a different plane. If one antenna is active and another passive, even the noise factor and source impedance may change. What precise rules would you impose on the experiment to prevent double counting loss, omitting mismatch, or mistaking the changed system noise floor for a changed environmental signal? How should a comparison be documented where those corrections cannot be measured with the necessary certainty? Is a source-match correction defensible when the receiver input reflection coefficient changes between gain states, and should that instability instead be treated as a separate operating condition requiring its own uncertainty budget?

John William Strutt, Lord Rayleigh, Response: Mr. Campbell, the measurement equation must begin with the definition of the reported quantity and the physical plane at which it is measured. If the result is receiver-input power, specify the power available from a source of stated impedance or the power actually delivered under the observed match. If the result is field strength, require a calibrated antenna factor appropriate to

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the installed antenna and its load, and then account separately for connecting loss and receiver response according to the convention of the calibration. A certificate is not a free-standing number that can be added indiscriminately to other numbers; it is a statement about a defined calibration procedure. A cable loss already included in a whole-system antenna factor must not be added a second time.

I would require a diagram with every calibration boundary marked and a table naming each correction, its units, uncertainty, correlation and source record. The laboratory should use a standard known signal at the receiver's declared input plane to verify the amplitude display and detection threshold. It should then check each antenna assembly as actually installed, especially where active bias networks, baluns or unusual grounds are present. The reflection coefficients at important ports can be measured to bound mismatch effects. When the necessary corrections are uncertain or the active antenna has a changing gain characteristic, a calibrated relative comparison under repeated controlled conditions may be more defensible than pretending to know the absolute incident field to a fraction of a decibel.

A change in displayed noise floor is particularly treacherous. An active antenna may introduce its own amplifier noise and may present a different impedance to the first receiver stage. Replacing it with a passive antenna or load can change receiver noise figure, gain-control setting and dynamic range. An observed fall of the entire baseline is then not necessarily a reduction of environmental field. Record the gain state, equivalent bandwidth and noise statistics at each test condition. Challenge both configurations with a known tone at levels spanning the decision threshold,

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so that the probability of detection and the noise-floor response can be compared on meaningful terms.

If calibration is incomplete, the report should say so and limit its conclusion. It may be possible to demonstrate that the spectral line follows one particular antenna assembly under controlled repetition, or that it persists when the receiver input is properly terminated. Those are useful facts. It would be unsound to infer a field-strength ratio or an external source identity from them without the missing transfer information. A scientifically honest qualitative result can be stronger than a quantitatively polished but untraceable statement. We must not confuse the number of decimals in the display with the number of physical assumptions that have been verified.

Dr. James M. Atkinson, Moderator: Professor Bracewell, offer a final ordinary peer examination of Lord Rayleigh. How should the conclusion be expressed when the substitution matrix supports antenna-path dependence but the source remains only partially identified?

Ronald Newbold Bracewell, Peer Question: Lord Rayleigh, a complete matrix of antenna, direct-load, cable-end-load and independent receiver conditions might show that a spectral component appears only with one antenna and cable assembly. The result is reproducible, and the strongest line follows antenna orientation, yet the second receiving chain lacks sufficient sensitivity to register it. The investigator might reasonably suspect a true incident field, but cable-body coupling and a receiver-produced image remain possible. What hierarchy of reported findings would preserve that distinction? Can the experiment yield an upper or lower bound without a definite source attribution, and how should shared calibration uncertainties enter such bounds? Please explain how the report would avoid the opposite

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extremes of claiming a surveillance transmitter on the basis of one pattern or dismissing the entire investigation because the causal chain is not completely closed. Would the answer differ if the independent receiver used a frequency-agile scan rather than a continuous recording, leaving intervals in which the disputed burst could not have been observed with either antenna?

John William Strutt, Lord Rayleigh, Response: Professor Bracewell, the report should be organised as a sequence of propositions with their evidential support and explicit reservations. The first proposition is an observation: a defined signal-processing procedure identified a particular component at specified times and instrument settings. The second concerns system dependence: repeated changes of the antenna assembly, termination and cable path caused reproducible changes in that observation. The third concerns the electromagnetic pathway: independent tests support a particular point of ingress, perhaps the antenna aperture rather than the enclosure or supply. The fourth concerns source attribution, which requires additional observations beyond ingress. These propositions should not be collapsed into a sentence asserting a specific emitter merely because earlier tests were favourable.

Useful quantitative bounds can often be retained. If a calibrated instrument measures a terminal power above a known threshold and the field strength has been properly corrected for antenna factor and transmission loss, one may state an interval for the relevant field component under the tested geometry. If the independent receiver fails to detect the signal, its sensitivity and coverage establish only a conditional upper bound on a defined signal class and time interval. The inequality is not a universal statement about

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every source. The uncertainty of the antenna calibration, cable loss, receiver amplitude scale and noise threshold must be propagated with attention to correlation. Shared calibration standards can produce common bias and should not be counted as independent corroboration.

Where source attribution is unresolved, the report should make the competing hypotheses concrete. For example: hypothesis A, a real incident signal is captured by the antenna and displayed at the correct frequency; hypothesis B, an external blocker enters and creates an intermodulation or image product; hypothesis C, cable shielding admits conducted or radiated current that bypasses the intended aperture; hypothesis D, an internal oscillator or converter product changes with input loading. Record which experiment favours or disfavors each and which have not been tested. A qualitative causal matrix can be defensible without assigning numerical probabilities that the data do not support. If a numerical likelihood analysis is attempted, its models and parameters must be justified by calibration or independent evidence.

The opposite extremes you describe are both errors of inference. An unresolved source identity does not erase a genuine, reproducible receiver observation, nor does a reproducible observation supply the missing identity. A technical surveillance countermeasures report may properly recommend further targeted measurement, independent apparatus, or environmental control without pronouncing guilt, motive or unlawful activity. The conclusion is bounded by the tested conditions and the verified measurement chain. Such restraint allows future evidence to refine the conclusion while preserving the original data, instead of forcing a later reviewer to undo an unsupported narrative.

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Dr. James M. Atkinson, Moderator: Mr. Jansky, your research drew attention to how electrical noise can be misclassified when the investigator has not separated instrument behaviour from the environment. Would you develop a procedure for distinguishing genuine incident natural or artificial radio noise from local receiver products, and explain the evidential limits of spectral continuity, periodicity and direction?

Karl Guthe Jansky, Fourth Principal Contributor: Dr. Atkinson, an observer hearing a hiss or seeing a broad band of spectral energy ought first to remember that radio noise is not an embarrassment to be discarded but a physical observation whose origins differ. The instrument has internal thermal and semiconductor noise; the antenna admits atmospheric, cosmic and manufactured energy; nearby electrical installations may carry conducted interference; and nonlinear circuitry may produce spurious products from combinations of strong signals. An antenna substitution can change the proportion of these terms even when the system is healthy. We must resist the temptation to identify every rise of the noise floor as a covert radiator and every fall on disconnection as proof that the original signal was a discrete environmental transmission.

The appropriate first comparison is spectral shape together with a controlled, calibrated noise baseline. At room temperature, thermal noise available from a matched resistive source over bandwidth B is approximately kTB watts under classical assumptions, where k is Boltzmann's constant, T absolute temperature and B the noise-equivalent bandwidth. At T near 290 kelvin the familiar power-density scale is roughly −174 dBm per hertz. This figure is not the noise floor of an arbitrary receiver display. Its receiver noise factor, gain, filtering, preselection and

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detector must be incorporated. A hot active antenna and a cold matched load can produce different spectral floors because the source noise and transfer are different; the receiver has not necessarily developed a mysterious internal spur. A correct test measures and records the noise-equivalent bandwidth and gain state, and explains the termination temperature and impedance.

The second comparison is temporal. An internally generated oscillator harmonic may remain associated with a reference-clock frequency, while natural noise exhibits its own temporal and spatial dependence. Yet a laboratory is full of electrical equipment whose switching cycles and clocks can create regular spectral lines that enter through the antenna. Regular timing is thus neither necessary nor sufficient evidence of internal origin. A mains-related pattern, for example, may appear as harmonics and sidebands in externally received interference or as disturbance injected into the receiver power supply. One should monitor supply rails and local equipment state, but also compare with a separately powered receiver and an independently controlled antenna placed away from the suspect unit.

A field observer should examine frequency behaviour under changes of local oscillator plan and sampling rate. If a line stays at the same absolute incoming frequency across an independently calibrated conversion plan, it is more likely to correspond to a physical RF component at the input. If it shifts with the sampling clock or LO, an internal mixing or alias mechanism deserves investigation. The test is not infallible because genuine emissions may be translated into images and strong blockers can produce internally generated intermodulation; the preselector and independent analogue test

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path must provide the additional constraint. Never let an attractive waterfall trace replace the measurement of the underlying input spectrum.

Spatial comparison provides a second layer of evidence. Observe the feature with a calibrated portable reference antenna at a different receiver and distance, then repeat at multiple locations while recording orientation, polarisation, cable routing and environmental conditions. If the suspected line is linked to a real field, one may expect some spatial and directional dependence, but indoors this dependence need not follow an inverse-square law. Near-field coupling, reflections, standing waves and shielding can make a genuine emitter stronger at one point and weaker at a neighbouring point. A common reference network can cause two nearby receivers to show a correlated artefact instead. Independence has to be designed into the comparison and documented.

In the frequency domain, external noise need not appear as an isolated spectral line. A narrowband source may be intermittent, frequency-agile or concealed under wideband noise. The direct-load condition gives a receiver baseline under one electrical termination; it does not establish an upper bound on all external transmissions during the earlier antenna observation. Define the detection threshold from a measured noise distribution, specify false-alarm and missed-detection rates where data justify them, and retain raw samples for alternative analyses. An environmental feature can be real yet insufficiently detected for classification or attribution. The proper report separates detected energy, waveform classification, source location and intention as successive, independently supported propositions.

A useful controlled experiment uses three simultaneous streams. The first is the survey receiver with its normal antenna. The second is a separate

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calibrated receiver with a nearby independent reference antenna. The third is a direct input-load condition or a measured internal calibration monitor, as permitted by the hardware. Inject a known benign reference signal from a laboratory radiator at a surveyed location and vary its amplitude in a safe range. Verify how each stream responds when the emission is actually present and absent. Then repeat observations without deliberate transmission. An indication that remains in the terminated chain while vanishing from both antenna channels has a different evidential meaning from one that follows the over-the-air calibration stimulus and disappears under proper termination.

However, simultaneous streams can themselves alter the room. Splitters, additional receivers and their oscillators may radiate or change local loading. Even a laptop brought beside an antenna can contribute radiated interference. Repeat the experiment in a quiet, well-documented baseline configuration and change one element at a time. If an intervention is repeated and the result changes, first determine whether the phenomenon evolved naturally or the intervention altered the system. A signal that disappears when the antenna cable is moved may have been attenuated by a pattern null, conducted through its screen or affected by an intermittent contact. The observation is a clue, not yet a cause.

I also caution against excessive confidence drawn from a field's apparent periodicity. In the history of observation, a signal can recur with a daily schedule because of human activity, environmental cycles, propagation, or instrument operation. To interpret periodicity, the analyst must compare it with an independent clock and logged events, account for gaps in receiver coverage and verify that the periodicity survives changes in acquisition

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software. A pattern inferred from a display that updates once per second can inherit its period from the display itself. Time tagging must refer to hardware acquisition, not to redraw intervals, if the report aims to distinguish an external phenomenon from the instrumentation.

The final inference should be conditional and restrained. Antenna substitution can establish that a feature's measured amplitude depends on admitting energy through a particular receiving assembly. It may also establish that a terminated receiver presents a baseline materially different from the connected-antenna state. To identify external origin more specifically, compare frequency plan, antenna response, independent channels, temporal behaviour and controlled source removal. To identify a particular emitting object, demand yet more: spatial tests, source signatures and a carefully bounded chain of attribution. There is no indignity in a negative finding that specifies what was tested and what remains unresolved. There is much danger in a positive finding based only upon an intriguing line that obligingly vanishes when someone disconnects a cable.

Dr. James M. Atkinson, Moderator: Mr. Pierce, examine Mr. Jansky’s proposed distinction between a field entering through the antenna and a signal that only appears because the receiver display threshold changes. What can a non-detection actually establish?

John Robinson Pierce, Peer Question: Mr. Jansky, your comparison of simultaneous receiver streams is attractive because it offers independent observations, but independence cannot be assumed merely from the presence of two enclosures. Both receivers may operate in the same building, share power or see a common strong blocker whose intermodulation creates similar apparent emissions. A weak true

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transmission might also appear on only one path because the receiving apertures have different patterns or threshold settings. How would you specify the hypothesis test, estimate detection and false-alarm behaviour, and avoid calling one missing display line a disproof of an observed field? I should also like you to address the problem of choosing a threshold after seeing the data, since that would allow the investigator to create a favourable result without any alteration in the underlying RF observations. How can the operator show the decision procedure was fixed before comparing the channels?

Karl Guthe Jansky, Response: Mr. Pierce, the first answer is to treat detection as a procedure whose statistical performance must be measured under the actual receiving configuration. Let H_0 denote the hypothesis that a specified external signal of interest is absent from the declared channel and H_1 the hypothesis that it is present according to an explicit amplitude, waveform and timing model. A detection rule declares an event when a computed statistic exceeds a predetermined threshold. A false alarm occurs when the rule declares the event under H_0; a miss occurs when it fails under H_1. The two error rates are properties of the rule and its noise environment, not intrinsic labels attached to a single spectral line. A comparison must estimate them with suitable control data, accounting for temporal correlation, bandwidth and nonstationary interference.

I would predeclare the observation window, detector mode, threshold selection and treatment of multiple spectral bins before inspecting the disputed event. A long waterfall with thousands of bins and time steps offers many opportunities for a chance excursion. Reporting only the brightest peak can create an implicit multiple-comparison problem. To

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assess the false-alarm behaviour, collect independent or sufficiently decorrelated baseline intervals with a matched termination and with the field antenna, then separate their respective null hypotheses. A terminated receiver baseline cannot describe every external interferer admitted by a connected antenna. Where the hypothesis is an external signal of particular form, use laboratory injection or known legal transmissions to measure detection probability over relevant signal strengths and orientations.

Two receivers deserve a dependence analysis. They may share an oscillator reference, software detector design, mains supply or common local interference. A simultaneous indication with different antenna patterns and clock trees can strengthen evidence of external reception, but the correlation of their errors must be tested. A line seen in one receiver alone may be due to different sensitivity, spatial field structure, pattern nulls or a true intermittent source. The follow-up should vary receiver order and antenna configuration while retaining a simultaneous witness where possible. Do not multiply independent false-alarm probabilities unless the independence assumption has been established for the actual failure mechanism.

Finally, a negative report should identify the tested target class. It may say that no event meeting the predefined criterion was detected with the instrument's demonstrated coverage and sensitivity in the specified intervals. It cannot claim that no RF energy of any origin existed in a room. If a test signal inserted at a level representing the target class is detected reliably, then a non-detection of that class gains significance. If the calibration stimulus is missed, the survey's negative finding becomes correspondingly weak. A disciplined measurement is sometimes less

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dramatic than a striking spectral picture, but it is more informative because it can be reproduced and challenged.

Dr. James M. Atkinson, Moderator: Mr. Reber, the panel has discussed the source and the receiver. Would you now examine the antenna itself as an imperfect spatial sampler, especially inside rooms where metallic structures, polarisation changes and feedline coupling can make a substituted antenna appear to refute a genuine field?

Grote Reber, Fifth Principal Contributor: Dr. Atkinson, a practical antenna measures a weighted component of an electromagnetic field over a particular aperture and environment. Two antennas placed side by side do not necessarily observe the same complex voltage, and one cannot treat the antenna as a passive length of metal whose replacement merely turns the outside world on or off. Radiation pattern, polarisation, impedance, effective height, bandwidth, phase centre and mutual coupling all matter. For a physically small antenna near conductive furnishings, the local near field may be especially sensitive to orientation and position. Therefore, when an apparent emission vanishes upon substitution, the first question is whether the second antenna was capable of coupling to that field under the test conditions.

The receiving relationship can be described in a narrowband linear setting by $V_{oc}=h_{eff}\cdot E$, where V_{oc} is open-circuit terminal voltage, h_{eff} is a complex vector effective length in metres and E is the local electric-field vector in volts per metre. The dot product reminds us that the component of the field perpendicular to the effective length can be strongly rejected. Under ideal matched linear polarisation, a rotation angle ψ gives a power coupling factor $\cos^2\psi$, so a 60-degree mismatch corresponds to one-quarter

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of the aligned power, or approximately 6 dB loss. At 90 degrees ideal isolation is mathematically complete, but real cross-polar response, scattering and mismatch prevent that ideal from being a universal field prediction. A substitute antenna with the wrong polarisation can make an external source disappear without revealing any fault in the receiver.

A calibrated replacement must therefore be characterised at the actual frequency, polarisation and mounting orientation. An antenna factor measured in a standard environment may not retain the same effective response beside a metal cabinet or a window containing conductive film. The room modifies the field, and the antenna can modify the room by coupling to nearby conductors. If two antennas have different phase centres, moving their feeds into nominally equal coordinates does not make their electromagnetic sampling identical. When the scientific question is whether energy exists at the location, repeat the comparison over several orientations and points in a small spatial region. When the question is whether a specific cable or aperture admitted energy, keep the geometry fixed and perform electrical substitutions at a declared reference plane.

The feedline may be the actual antenna. A coaxial cable with inadequate common-mode isolation can carry current on the exterior of its shield, and its response depends on length, routing, grounding and nearby surfaces. Replacing a rod or loop at the end of such a cable may alter the shield-current boundary condition. A signal then appears to disappear with the antenna even though the coupling route was principally the cable. An experiment should include a direct load at the receiver, another at the far cable end, and a test with a different shielded route or known common-mode choking arrangement. The load should be appropriate to frequency

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and power. A change caused by a choke is evidence of a common-mode pathway, but it does not alone specify the external or internal origin of the current driving that pathway.

A directional antenna introduces another possible misinterpretation. In free space its beam can discriminate directions, but indoors reflections can produce apparent peaks and nulls unrelated to the straight line toward the source. A receiver operator rotating a directional antenna may find a dramatic null and assume the source has stopped. Conversely a strong reflected path may point away from the radiator. For attribution, record direction-dependent response over a grid, measure multiple polarisation states, and compare with a source intentionally placed at known locations. A source that fails to appear on one bearing is not thereby absent. A case study in which only the strongest bearing is retained risks replacing the field with the surveyor's selection bias.

Frequency diversity also matters. An antenna that is well matched at 100 MHz may be inefficient at 150 MHz; a narrowband preamplifier or balun can introduce further variation. If the suspect spectral line changes when an antenna designed for another band is substituted, the intervention has changed both field collection and input matching. For a valid comparison, use a calibrated antenna covering the disputed frequency and a characterised connection cable, or explicitly calculate the relative sensitivity at the frequencies of interest. Do not compare raw waterfall colour values as though they were field-strength readings. Use the same detector mode, reference bandwidth and receiver gain, then correct the measurements for the distinct antenna factors and line losses where physically appropriate.

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The calibrated source experiment can be conducted in stages. Begin with a shielded electrical test to verify the receiver and cable path at the port. Next use a known benign radiating source in a controlled setting to characterise the antenna's response across orientation, frequency and location. Finally return to the disputed environment and record the variation under the same well-defined measurement settings. A robust field report should preserve environmental changes, power-source status, furniture movements and nearby conductors as influence quantities. If the local field is extremely weak, the second antenna may not reach the threshold necessary to register it even when a stronger first antenna did. That does not prove the first indication was fictitious.

A useful quantitative example illustrates the importance of distinguishing powers. Suppose a calibrated antenna and receiver have a measured end-to-end sensitivity of −110 dBm for a specified waveform and bandwidth, whilst the substitution antenna incurs 12 dB additional antenna and cable loss relative to the first configuration. A field component that gave −105 dBm at the first receiver may yield approximately −117 dBm in the replacement condition under the simplified link budget. The second receiver then fails to detect it at the stated sensitivity, but the failure is predicted without invoking instrument artefacts. The calculation ignores possible pattern, impedance, polarisation and environmental changes; these must be measured or bounded, not silently set to zero. The appropriate experiment restores comparable sensitivity before interpreting different detection outcomes.

The most rigorous observation matrix includes multiple antenna assemblies, direct terminations, independent front ends, several positions and

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controlled load changes. Each row records the actual experiment, not merely a verdict of 'signal' or 'no signal'. Where a spectral line is unchanged under direct termination, investigate alternate enclosure ingress and downstream spurs. Where it follows an antenna but not a local oscillator change, establish the antenna and receiver response and investigate external-field alternatives. Where it follows a cable route, compare shield-current and cable-body mechanisms. Where it changes with polarisation or position, record that response before inferring direction. These steps are not cumbersome ornaments: they separate physical facts from assumptions.

My concluding position is that antenna substitution is powerful only when one understands what has been substituted. An antenna assembly includes its radiating element, feedline, balun, preamplifier, mount, ground reference and near-field environment. A calibrated change of one element can localise a coupling route; an uncontrolled change of the entire assembly can only establish that the complete configuration matters. The aim is not to force the observations into the binary story that an emitter is either inside or outside the receiver. The aim is to reduce the space of viable causes with discriminating, reproducible measurements, while preserving the uncertainty of every inference beyond those observations.

Dr. James M. Atkinson, Moderator: Mr. Blackman, assess Mr. Reber’s concern that substitution changes the antenna pattern and threshold. Can comparative measurements be made without assuming that the same field is sampled at both apertures?

Ralph Beebe Blackman, Peer Question: Mr. Reber, imagine a weak burst whose amplitude fluctuates rapidly across the room. We replace one

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receiving antenna with another while holding the receiver in the same nominal position, but the phase centre, polarisation and connection cable differ. The second antenna records no burst, and an operator argues that the first receiver generated its own signal. Can one infer anything reliable from that sequential comparison? What arrangement would allow both antenna systems to be challenged by a common known field without requiring their raw voltages to be numerically equal? Please address how windowing, detection thresholds and the statistical treatment of burst duration interact with the unequal transfer functions. I am particularly concerned about a test that repeats many substitutions and reports only the clearest disappearance rather than the full distribution of results, which seems calculated to produce an impressive conclusion regardless of the underlying cause.

Grote Reber, Response: Mr. Blackman, a sequential comparison of two different apertures in a fluctuating field is not a direct test of instrument origin. It shows only that the combined antenna-receiver responses differed at two times. The instrument states must be stable, the source must be sufficiently repeatable, and the aperture responses must be known before an absence can be interpreted. If the field changes during the swap, the comparison is confounded by time. If a phase centre shifts even slightly relative to standing waves, the local amplitude can change substantially. A true external burst may therefore be visible on one antenna and not the other. A defensible report would retain the result but call it inconclusive until an additional control reduces the alternatives.

A controlled field or calibrated source gives the first useful comparison. Illuminate each assembly with a specified signal at the disputed frequency,

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polarisation and duration in a documented environment. Determine its response, insertion path and detection threshold separately; do not force its uncorrected voltage to match that of another antenna. Then, where practical, observe a real source simultaneously through two independent receiving chains, with their relative gains and patterns calibrated. The simultaneous method removes some temporal ambiguity, although it may introduce mutual coupling or shared reference dependence. A non-detection is informative only if the second chain would have detected the tested signal class with sufficient probability under the actual geometry.

Windowing and burst duration must also be controlled. A brief event may occur entirely between the analysis windows or below an averaged detection threshold. If the two receivers have different sample rates or FFT hop lengths, they do not necessarily inspect the same instantaneous interval despite nominally matching clock times. Retain raw sample indices and hardware timing, repeat analysis under a common explicitly defined detection procedure, and test the procedure with known-duration pulses. Any interpolation or smoothing should be retained as a derived product rather than silently replacing the raw trace. The question is whether the physical observation was made, not whether an aesthetically similar spectrogram was produced.

Repeatability should be examined across all substitutions, including unsuccessful and ambiguous trials. Randomise or counterbalance the order and restore the original antenna periodically to reveal drift. A proper table includes observed level, noise floor, configuration, environmental notes and evidence of overload. An operator selecting one dramatic disappearance from twenty trials has changed the statistical question by selecting the

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outcome. Preserve the complete register and compare it with the predicted distributions under plausible hypotheses. A careful investigator may ultimately conclude only that the first antenna assembly provided greater sensitivity to a particular field component. That is valuable knowledge and should not be inflated into attribution of an internal spur.

Dr. James M. Atkinson, Moderator: I now ask the principal contributors to examine one another directly. The purpose is to test unresolved causal alternatives, not to repeat the seven ordinary interrogations. Sir Robert, please address Mr. Reber.

Sir Robert Alexander Watson-Watt, Cross-Peer Question to Grote Reber: Mr. Reber, your distinction between a radiating aperture and a feedline acting as an unintended antenna is compelling, but an investigator may not have access to the inside of an installed receiver or permission to modify its wiring. How would you design a non-destructive and legally authorised test of shield-current coupling that preserves both the original evidence and the installation's safety? Suppose a line vanishes when a choke is added to a cable; the choke may have altered differential insertion loss, common-mode impedance, nearby field geometry or the preamplifier's operating point. What additional comparisons would prevent a premature claim that common-mode current has been proved to be the sole mechanism? Please address cases where the source remains in the near field, so that the traditional separation of cable and antenna becomes physically blurred. Include a practical control for the possibility that the current probe itself modifies the cable balance or unintentionally couples a nearby field into the very conductor whose current is being measured.

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Grote Reber, Cross-Peer Answer to Sir Robert Alexander Watson-Watt: Sir Robert, I would start by observing rather than modifying. A calibrated clamp-on current probe, used within its frequency and amplitude limitations, can examine current on the exterior of the feedline or associated return conductor without opening the receiver. Such a measurement requires care: the probe can load the circuit and may respond to nearby fields, so its calibration and positional repeatability must be established. A simultaneous independent antenna can monitor the ambient field while the cable is examined. These observations may show temporal and spectral correlation between shield current and the suspicious line, but correlation does not yet establish which current drove which indication.

Next use a controlled laboratory duplicate or a removable external test lead, provided the original installation must not be disturbed. Measure the candidate feature with the original cable routing, with an alternative characterised path, and with a properly selected common-mode suppression device. The device should be measured for both common-mode impedance and differential insertion loss near the disputed frequency. A known calibrated tone applied through the ordinary differential input checks whether the device unintentionally attenuates the intended receiving path. If the suspect signal changes while the reference tone remains stable and a measured common-mode current changes consistently, the shield-route hypothesis gains force. A second suppressor with different design but similar common-mode effect supplies another challenge to a fixture-specific artefact.

In a near-field environment the test becomes less absolute. The antenna element, feedline and nearby metal can form a coupled structure, so the

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boundary between intentional aperture and unintended conductor is a matter of the chosen measurement model and reference plane. A choke may perturb the entire coupling pattern. Therefore, I would not write that the choke 'proved' the sole cause. I would write that the observation is sensitive to a measured change in common-mode impedance, that the independent differential reference tone did not show a comparable change within its uncertainty, and that alternative physical explanations remain possible. A controlled source at known positions can help map the coupled system, but its findings belong to those test geometries.

For a lawful defensive survey, preservation is part of the science. Retain original instrument data before the intervention, photograph or describe the unaltered connection, and record time, cable position and each test fixture. Avoid leaving a modified system in operation when the change has not been authorised or safety assessed. If the original environment cannot be perturbed safely, the correct outcome is a limited causal conclusion and a proposal for a controlled bench comparison. Uncertainty does not justify invasive testing, and a non-destructive result is useful when its limitations are reported accurately.

Dr. James M. Atkinson, Moderator: Lord Rayleigh, examine Professor Armstrong directly on the numerical evidence that can be extracted from a receiver with imperfectly characterised automatic gain and attenuation.

John William Strutt, Lord Rayleigh, Cross-Peer Question to Edwin Howard Armstrong: Professor Armstrong, attenuation slopes may distinguish a linear signal from intermodulation, but they are usually plotted in logarithmic units while the gain and noise statistics change with frequency and instrument state. What uncertainty should attach to a slope estimated

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from only a handful of attenuator settings, especially if their calibration errors are correlated? Could a two-tone result under controlled laboratory conditions fail to predict a multi-signal field environment in which the antenna pattern and source impedances differ? I ask also whether one ought to privilege a direct independent receiver measurement over a beautiful cubic fit where both instruments share the same antenna splitter and oscillator reference. Please explain what would constitute adequate model validation rather than a merely plausible regression. Should the predictive test be performed at two independent carrier frequencies so that a mechanism tied to a single receiver image or calibration accident is less easily mistaken for a general law?

Edwin Howard Armstrong, Cross-Peer Answer to John William Strutt, Lord Rayleigh: Lord Rayleigh, I would never promote the nominal slope of an intermodulation product into an isolated fact about the field without examining the statistical and physical conditions under which it was measured. If P_out in logarithmic power units is plotted against P_in, the derivative dP_out/dP_in has an interpretation only where gain, frequency selection and the set of interacting signals remain constant. A regression from three points spanning an AGC threshold is not an estimate of the local cubic response. Measurement uncertainty attaches both to input attenuation and output level, and the same pad calibration can introduce correlated errors in several points. A fit that assumes independent error in its horizontal variable will understate uncertainty if the attenuation scale itself is poorly known.

One sensible experiment samples a larger set of safe power levels in both increasing and decreasing order, retains repeated measurements and state

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logs, and checks for stable residuals under the proposed model. The instrument can be challenged with controlled single-tone and two-tone inputs that vary independently, using an external power monitor to verify levels. The predicted third-order products should appear at the appropriate calculated frequencies and change under independent adjustments in the manner expected for the model's valid region. Where they do not, I would not rescue the hypothesis with an arbitrary curve; I would investigate clipping, gain switching, receiver protection and the possibility of more than two interacting signals.

The field case may differ sharply from the laboratory because its blocker powers, phases and source impedances are unknown. A two-tone test demonstrates an instrument capability and a possible mechanism, but does not prove that the mechanism actually produced a particular line during the survey. A wideband capture, controlled preselection and another receiver architecture should therefore be used to identify candidate driving components. If a splitter is shared, the receivers may share both the same incoming disturbances and a feedline-generated artefact. Independent receiving apertures and clocks add value when their response limits are characterised. Any comparison should document that independence as a physical property rather than an administrative label.

I would count model validation as agreement across predictions not used to fit the model. Suppose the initial data suggest a third-order mechanism. The operator may predict how the candidate product will move when one input tone is changed by a known frequency increment, how its amplitude will respond to a small independent power change and how the signal will behave under a different preselector state. If those predictions are

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confirmed by blinded or predeclared tests, the explanation gains credibility. If only the selected line fits while the expected partner products or blocker relations do not, the model remains weak. The final statement should include the tested power range, uncertainties, control states and alternative explanations that survive. Elegant logarithmic arithmetic cannot replace a discriminating experiment.

Dr. James M. Atkinson, Moderator: Professor Armstrong, please put a reciprocal challenge to Mr. Jansky. The distinction between environmental noise and receiver-state artefact has major consequences for defensive survey claims.

Edwin Howard Armstrong, Cross-Peer Question to Karl Guthe Jansky: Mr. Jansky, you properly insist that externally admitted noise may be genuine without belonging to any discrete transmitter. But a survey receiver can generate an elevated noise floor from gain compression, reciprocal mixing under a strong blocker, digital clipping or internal clock phase noise. Disconnecting the antenna can improve the floor dramatically. How do you prevent the observer from describing that improvement as the physical disappearance of external noise, when the original noise floor partly arose from receiver-created effects triggered by strong input energy? What controlled tests separate actual incident noise power, source-dependent desensitisation and reference-clock-related spectral spreading? I would also ask how one could preserve a useful negative finding when the receiver is demonstrably unable to detect a weak test signal in the presence of the environmental blocker. What control would reveal a reference-oscillator spur appearing within the same analysis bandwidth when the blocker is

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removed, thereby preventing the operator from misinterpreting a changing noise-floor estimate as a newly transmitted field?

Karl Guthe Jansky, Cross-Peer Answer to Edwin Howard Armstrong: Professor Armstrong, the correct interpretation starts with the distinction between available noise power at the receiver port and noise-equivalent response at the receiver output. A large external blocker may raise the apparent noise floor through reciprocal mixing against local-oscillator phase noise, while a preamplifier in compression may lose sensitivity to a weak desired signal. The broad spectral elevation then depends upon incident energy and instrument defects together. Disconnecting the antenna removes the blocker, but the fall of the displayed floor cannot be assigned wholly to a reduction in physical environmental noise. The report should state that the coupled system showed a reduced output-noise indication under the new input condition, then test the mechanism.

A suitable experiment adds a calibrated weak probe tone at a fixed safe level while independently varying a stronger blocker. Measure the weak tone's recovered signal-to-noise ratio, the displayed broadband floor and any overload or gain-state indicators as blocker level changes. Perform the series with a high-quality external source, a characterised input pad and at least two preselector states. If the weak probe becomes less detectable as the blocker grows, the system displays desensitisation. If the floor rises in an offset pattern that depends on oscillator phase-noise characteristics and blocker frequency, reciprocal mixing deserves examination. A receiver with a different LO or reference plan offers a stronger challenge than another copy of the same architecture.

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To distinguish incident noise from instrument noise, compare a calibrated matched termination, a known noise source and the receiving antenna under consistent bandwidth and gain conditions. A noise-figure or Y-factor procedure can inform receiver contributions in a suitable laboratory configuration, but an antenna-dependent active front end and variable environment complicate transfer of that calibration. Record the noise-equivalent bandwidth, input impedance, preamplifier state, thermal conditions and uncertainty. A source with high external noise may mask an internally generated spur; a quiet load may unmask it. Neither appearance proves that the spur was newly created by the act of substitution.

Your last question concerns the integrity of a negative search. If a calibrated test tone representing the minimum target signal is not reliably detected in the presence of the blocker, the system has not demonstrated the sensitivity needed to support a negative finding for that condition. The correct action is to change the measurement method within lawful and safe limits, perhaps using preselection, attenuation and an independent front end, and then repeat the challenge. If those measures do not restore detection capability, disclose the untested interval or frequency as a coverage limitation. The duty is to describe the instrument's effective observation space, not to declare a room free of emissions merely because an overloaded receiver remained silent.

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Dr. James M. Atkinson, Moderator: Mr. Jansky, close the reciprocal examination by testing Sir Robert’s causal inference. Please ask whether a line that follows the antenna assembly is sufficient to establish an external transmitter.

Karl Guthe Jansky, Cross-Peer Question to Sir Robert Alexander Watson-Watt: Sir Robert, the four-state substitution matrix is valuable, yet it may produce a strong-looking result: a narrow line is present with the antenna, absent under direct termination, present again when the original antenna is restored, and visible on a second receiver whose sensitivity is similar. The investigators may be satisfied and begin a search for a nearby concealed transmitter. But both receivers could be responding to a legal external broadcaster by an image or intermodulation route, or to common-mode current from a building cable, while an apparent spatial maximum could be caused by standing waves. What further evidence is necessary before the team can move from 'antenna dependent' to 'incident field at the displayed frequency', and thence to a particular source? How should the language of a forensic report distinguish these stages without becoming so vague that the technical findings are unusable?

Sir Robert Alexander Watson-Watt, Cross-Peer Answer to Karl Guthe Jansky: Mr. Jansky, I would begin by treating the four-state matrix as a successful experiment establishing an association with a defined reception configuration. It is an important finding precisely because it is reproducible, but it is not yet a complete account of energy origin. To show incident field at the displayed frequency, the investigator should use an independent receiving chain with a different conversion architecture, a calibrated antenna that can respond at that frequency, and appropriate preselection to

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reject possible images and strong blockers. A swept analogue monitor or a second SDR with a different oscillator plan may provide useful independence if its sensitivity and calibration have been demonstrated. The team should record the absolute RF frequency and confirm that it does not follow the first receiver's local oscillator or ADC clock.

To exclude common-mode cable routes, test direct and far-end terminations, controlled cable routing, shield-current observations and a change of receiving aperture with its own known feed. The aim is not to prove that every conductor in the room is irrelevant, which may be impossible, but to demonstrate a pathway consistent with the claimed field observation and inconsistent with the most plausible instrument alternatives. If the feature follows a local test generator at a known frequency, the instrument's frequency assignment is strengthened; if it follows a strong off-channel blocker, the image or intermodulation hypothesis becomes stronger. Controlled source removal where lawful can provide especially persuasive causation, but it must not be attempted by disrupting unrelated communications or equipment.

The step to identifying a particular emitter demands still more evidence. Directional response, distance trends, modulation characteristics, timestamps, known equipment activity and independent inspection may contribute. Indoor multipath and near-field coupling make a single bearing or apparent field maximum inadequate. Measurements should be taken over multiple positions and polarisation states, with environmental controls and uncertainty bounds. A source can be genuine without being malicious, intentional or even within the premises. A legal and evidential conclusion must not outrun the technical record.

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The report could therefore say: 'A repeatable spectral feature at the reported frequency was observed with the specified antenna assembly; the feature was not observed under the direct-load control; independent testing with a differently configured receiver corroborated an incident component within stated sensitivity and uncertainty. Several receiver-image and cable-coupling alternatives were challenged as described. The emitting equipment has not been established.' If later evidence identifies a source, the earlier record remains useful. If it does not, the report has not accused an object or person without grounds. Technical precision and professional restraint are compatible; in this discipline they are inseparable.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel distinguishes four evidential propositions. First, a spectral indication exists under recorded settings. Secondly, its amplitude or detection depends on a specified antenna or input configuration. Thirdly, calibrated and independent measurements support incident RF energy at a declared antenna reference plane and frequency, rather than an image, overload product, clock spur, cable-body current or display artefact. Fourthly, further spatial and source-specific evidence may identify the emitting apparatus. These propositions do not automatically follow from one another. Antenna substitution is a discriminating experiment only when loading, gain, noise, cable routing, timing and sensitivity are controlled, the alternative explanations are stated in advance, and the complete result register is preserved. Disappearance after disconnecting an antenna is evidence of configuration dependence; attribution requires more. All the dialogue here is fictional educational reconstruction, and all numerical illustrations are hypothetical.

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QUESTION 068. SOURCE REGISTER AND PUBLICATION QUALIFICATIONS

1. International Telecommunication Union, Recommendation ITU-R SM.378-7, Field-strength measurements at monitoring stations (2007), official record https://www.itu.int/rec/R-REC-SM.378/en . Addresses calibrated monitoring antennas, installation, field-strength measurements and environmental effects.

2. International Telecommunication Union, Recommendation ITU-R SM.329-13, Unwanted emissions in the spurious domain (2024), official contents https://www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.329-13-202409-I!!TOC-HTM-E.htm . Annex 2 identifies selective receiver characteristics, antenna measurements, terminal loads and substitution approaches. It is a transmitter-emission measurement recommendation; its substitution procedures are not automatically equivalent to the receiver-ingress experiment discussed here.

3. International Telecommunication Union, Recommendation ITU-T K.136, Electromagnetic compatibility requirements for radio telecommunication equipment (2022), https://www.itu.int/epublications/en/publication/itu-t-k-136-2022-11-electromagnetic-compatibility-requirements-for-radio-telecommunication-equipment . Describes calibrated receiver-input stimuli and cautions about common-mode currents on shielded cables.

4. National Institute of Standards and Technology, Measurement Uncertainty of Radiated Emissions, NBS Technical Note 1389, https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1389.pdf . Discusses reference-antenna substitution and antenna/receiver mismatch

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uncertainty; exact textual applicability is to be verified page by page before final publication.

EDITORIAL QUALIFICATION: This discussion is a fictional scholarly reconstruction, not a transcript or historical quotation. Mathematical examples use idealised models and hypothetical values and do not represent field measurements. Mechanical length checks, peer pairing and document integrity are Stage A controls only; full source-to-claim, historical, mathematical, semantic-duplication and publication-pagination reviews remain outstanding.

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QUESTION 069

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When do resolution and video bandwidth settings cause a swept analyser to miss brief pulses?

Dr. James M. Atkinson, Moderator: Professor Blackman, consider a surveillance receiver showing a clean baseline throughout a broad swept span while a laboratory pulse source is known to be active. The operator has narrowed the resolution bandwidth to distinguish small adjacent tones and lowered the video bandwidth until the displayed noise looks quiet. Under what circumstances do those sensible-looking adjustments make the measurement blind to short RF bursts? Please distinguish the act of acquiring energy from the later business of depicting it on a screen, and explain what a negative trace actually establishes.

Ralph Beebe Blackman, Principal Contributor: Dr. Atkinson, a spectrum analyser is a chain of causal operations rather than a transparent window onto electromagnetic events. We must distinguish the signal present at its input connector, the output of its tuned intermediate-frequency or digital resolution filter, the detector statistic, the subsequent video smoothing and the representation of those values as finite trace points. A short pulse may reach the input during the observation yet fail to create a discernible output because the analyser is tuned elsewhere. Alternatively, the instrument may be tuned correctly but present a heavily attenuated response because the intermediate-frequency filter has insufficient time to rise. A third case occurs when the filter responds but the detector or video processing conceals the excursion. These are different mechanisms. They demand different corrective experiments, and cannot be inferred merely from an empty display.

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Let the transmitted waveform be $x(t)=A\,p(t)\cos(2\pi f_c t+\varphi)$, where A is the radio-frequency carrier amplitude, f_c the carrier frequency, φ a constant phase, and $p(t)$ an envelope that equals unity during the pulse and zero otherwise. The pulse duration is τ seconds. In a conventional swept receiver the centre frequency of the resolution filter is $f_s(t)$, itself a function of time. A pulse is favourably observed only when $f_s(t)$ is sufficiently close to f_c for the passband response to be appreciable, and when that overlap lasts long enough for filter settling and data formation. Both a time condition and a frequency condition must hold. A spectral peak is not the pulse itself, but a statistic extracted from this doubly conditioned process.

A useful idealisation of the filter is a first-order linear response with characteristic time T_R; for a step in input envelope its output grows as $y(t)=A[1-\exp(-t/T_R)]$. This is a teaching model, not a manufacturer's calibration law for a particular resolution filter. If $T_R=20$ microseconds and the pulse lasts $\tau=5$ microseconds, the output at the end of the pulse reaches only $1-\exp(-0.25)=0.221$ of its eventual amplitude. Expressed as a voltage ratio this is $20\log10(0.221)=-13.1$ dB. A narrow bandwidth can thus convert an otherwise strong burst into a smaller transient. Different analogue filter poles, digital FFT acquisition windows, detector definitions and centre-frequency motion modify this result, so the investigator must validate it with a known source rather than apply one universal correction factor.

Do not mistake the familiar inverse relation between bandwidth and response time for a precise universal equality. One may write $T_R\approx\kappa/B_R$, where B_R is effective resolution bandwidth in hertz and κ is a dimensionless coefficient tied to the filter impulse response and the selected settling criterion. The value of κ differs for Gaussian-like filters, synchronously tuned

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filters and FFT-derived bins. A tenfold reduction in B_R increases a representative settling time approximately tenfold if the architecture remains comparable. It may also change noise power in the filter, which complicates attempts to interpret an apparent rise in sensitivity. A reduced noise floor does not necessarily imply an improved probability of detecting brief signals.

There is a further sampling problem. Suppose a 100 MHz span is swept in one second, with a nominal 10 kHz frequency-resolution region of interest. An elementary linear-frequency model gives an overlap duration of approximately 1 s×(10 kHz/100 MHz)=100 microseconds for a fixed carrier, before allowing for filter shape and instrument-specific step acquisition. If a random 2 microsecond pulse occurs once every 100 milliseconds, only a minority of independent pulse opportunities will coincide with that region. It would be technically indefensible to turn this rough time-frequency coverage into an exact instrument probability without measuring blanking, IF dwell, retrace, firmware behaviour and correlations. The rough calculation does, however, expose why several apparently excellent sweeps may provide little assurance.

The detector introduces a distinct question about what statistic is retained. An appropriately implemented positive-peak detector is well suited to maintaining the largest response actually captured within its observation bucket, but it cannot recover a pulse absent from the underlying sample sequence. An RMS detector reports an energy-related quantity over its integration interval; a sample detector can miss extrema; a negative-peak detector is inappropriate for finding rare maxima. Trace maximum-hold may record the strongest observed peaks across many revisits, but does not

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repair radio-frequency blind time. A max-hold trace which remains quiet after five minutes supports only a finding about the events and frequency-time conditions actually visited during those minutes.

Finally consider video bandwidth B_V. In many traditional analysers a video low-pass filter acts on the detected envelope after frequency selection. Excessively narrow B_V suppresses short excursions and makes the display attractively placid. With a first-order example $T_V=1/(2\pi B_V)$, a B_V of 1 kHz corresponds to approximately 159 microseconds. A 5 microsecond positive excursion yields an output fraction of roughly $1-\exp(-5/159)=0.0309$, or about −30.2 dB in amplitude before other loss mechanisms. This is not an assertion that all analyzers perform identical exponential smoothing, nor that all digital trace averaging uses this transfer function. It demonstrates the hazard of applying long time averaging to short signals.

My concluding procedure is therefore a matrix rather than a single setting: vary resolution bandwidth, video bandwidth, sweep duration, detector type and acquisition mode independently while injecting controlled pulses of measured duration, amplitude and repetition. Keep input attenuation, preamplification, frequency span and reference level fixed when isolating each effect, and capture the original trace metadata. Compare the complete detector outputs, not only the final screenshot. An empty trace is a conditional observation about the chosen instrument. It is not proof of a silent room, and certainly not evidence that an emitter could never have radiated there.

Dr. James M. Atkinson, Moderator: Dr. Harold Black, scrutinise the distinction between noise visibility and pulse capture. A very narrow resolution filter may make a weak continuous signal visible while making

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brief emissions substantially less visible. What exactly would be measured to separate those two effects?

Harold Stephen Black, Peer Question: Professor Blackman, I accept the mathematical distinction but challenge the practical inference that broadening the resolution bandwidth is a simple cure. Increasing the bandwidth necessarily admits more receiver noise power, and a modest pulse in a dense field of adjacent transmissions may become less distinguishable even though its filter envelope rises more promptly. If the input preamplifier is nonlinear, a wider filter and altered preselection can also admit products which were previously outside the analysis window. How do you construct a controlled test where the same incoming physical pulse is represented on equal terms by narrow- and wide-bandwidth configurations? Would you measure maximum voltage, integrated energy, or probability of declaring an event at a specified false-alarm rate? I should also like a rule for documenting a pulse whose centre frequency falls between nominal trace bins, particularly when the synthesised sweep changes the effective dwell at each bin. Without such discipline the investigator can declare success by selecting whichever display appears most dramatic.

Ralph Beebe Blackman, Response: Dr. Black, your objection is well founded because bandwidth is not a free improvement in sensitivity. For a receiver whose input noise has approximately flat one-sided power spectral density N_0 over the relevant passband, the noise power is proportional to its equivalent noise bandwidth B_e, so $P_n \approx N_0 B_e$. A tenfold increase in B_e therefore increases integrated white-noise power by ten decibels, all else equal. A continuous narrow tone may become less conspicuous against that

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background even while a five-microsecond pulse attains a more faithful temporal response. We must not compare the visibility of two differently processed pictures without preserving the detection criterion.

I would use a calibrated pulse generator and record three outcomes for each configuration: recovered peak at a specified detector and reference plane, integrated response over a documented observation interval, and empirical detection probability at an independently chosen false-alarm constraint. Define an event decision threshold before running the final trial. Estimate a noise-only distribution using a source-matched termination, but do not suppose that a cable termination reproduces real environmental noise or common-mode currents. Repeat the experiment with genuine antenna-connected background. If the question is whether a short burst can be detected at all, empirical recovery and false alarm should dominate a visually appealing peak measurement.

The instrument must disclose actual sweep points, filter equivalent noise bandwidth where known, detector bucket statistics, any digital resampling and the frequency step between adjacent observations. If the pulse carrier is deliberately offset by half a nominal bin, the test can expose passband scalloping or under-sampling of the filter shape. A second offset near the edge of the filter's defined passband tests a different ambiguity. The operator should vary pulse onset against sweep phase through controlled delay rather than accepting naturally favourable coincidences.

An elevated noise floor may conceal a weak pulse even when the input energy reaches the filter, so the report should explicitly distinguish failure of acquisition, attenuation by finite response, and failure of statistical declaration. A defensible result might say that a 2 microsecond, −70 dBm

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laboratory burst was recovered in 87 of 100 trials with one configuration and 28 of 100 with another at their respective precommitted thresholds. Such numbers would be empirical results if actually observed, not the hypothetical figures in this explanation. The essential point is that the comparison retains both miss rate and false-alarm rate, rather than placing judgement on a single colourful spectral picture.

Dr. James M. Atkinson, Moderator: Dr. Pierce, the same trace often contains a thousand frequency buckets but few details about what happened between them. Please press the point about the mathematical difference between a frequency bin and a genuine opportunity to observe a rare event.

John Robinson Pierce, Peer Question: Professor Blackman, when we say that a display contains 1,001 bins we may unconsciously treat them as 1,001 simultaneously observed channels. A swept heterodyne receiver does not ordinarily provide that parallel coverage. Its local oscillator visits places in sequence, perhaps pausing, retracing or changing filter states, while digital firmware later composes a line that resembles one instantaneous spectrum. In a field survey the operator may leave the instrument sweeping for many minutes and falsely believe that every displayed frequency has enjoyed the same temporal protection. How would you represent the coverage as an exposure function of both time and frequency? If pulse arrivals are periodic, does repeating the same sweep schedule guarantee an increasing probability of observation, or can coherent synchronisation create permanent blind spots? I also ask whether shortening the sweep can merely substitute inadequate filter settling for inadequate temporal overlap, which might leave the probability of a correct detection unchanged even when the number of displayed sweeps rises.

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Ralph Beebe Blackman, Response: Dr. Pierce, it is better to model the receiver as a time-dependent measurement kernel K(f,t) than as a permanently open collection of frequency bins. A simple binary coverage map C(f,t) may equal one when the receiver provides a validated sensitivity at frequency f and time t, and zero during tuning, blanking, retrace, inaccessible filter states or other known blind intervals. A more informative map records the measured recovered response to a standard pulse as a function of its onset, duration and carrier offset. It includes the imperfect shoulder of the resolution filter rather than asserting that the band is either entirely open or entirely shut.

The probability of detecting a randomly timed event is then associated with the proportion of event-onset positions for which the pulse and the receiver's observation kernel produce a sufficient statistic. The naive independent approximation P(at least one recovery)=1−(1−p)^n is appropriate only when the n observation opportunities really have independent capture probabilities p. A periodic transmitter and a repetitive sweep can be locked into the same unfavourable relative phase. Then n can increase without supplying new, independent information. The correct response is to randomise or deliberately dither the sweep start, introduce independent continuous observation at the frequency of concern, or prove that phase coverage has genuinely varied.

Your second point is equally important. A very fast sweep can traverse the frequency of interest before the resolution filter settles; the transient's peak is then attenuated or displaced. Manufacturers may compensate some sweep-induced amplitude errors in calibrated modes, but this must be demonstrated for the instrument, filter, amplitude and signal class being

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tested. A larger sweep counter does not transform defective measurements into valid ones. Accordingly the coverage record should log valid dwell, filter-settling qualification, detector integration and effective retrace time. Merely recording elapsed wall-clock time is inadequate.

For an audit, I would present a two-dimensional heat map of verified pulse recovery over onset phase and carrier frequency, with uncertainty limits from repeated injections. A sparse region becomes visibly distinguishable from a truly negative measurement. Where an external transmitter cannot be controlled, characterise the instrument with an authorised local source, then state the assumptions under which that characterisation bears on the disputed event. The most honest report may identify a lower bound on useful surveillance coverage rather than invent a universal probability of having seen all possible bursts.

Dr. James M. Atkinson, Moderator: Professor Gabor, take the issue beyond the sweep mechanism. Explain how duration and frequency concentration constrain the very meaning of a pulse spectrum, and why a highly resolved display can be a misleading representation of an ephemeral emission.

Dennis Gabor, Second Principal Contributor: Dr. Atkinson, the relevant difficulty is not simply that an analyser is sometimes looking in the wrong place. It is that the analyst may demand a sharp answer in frequency while refusing the observation time required to justify it. A brief electromagnetic pulse has temporal localisation. Its spectrum necessarily spreads across frequencies according to its envelope; a rectangular carrier burst is accompanied by a sinc-shaped spectral envelope, not a solitary infinitely thin line. A spectrum analyser that resolves narrow continuous-wave carriers admirably can be a poor instrument for estimating the time and amplitude

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of a very brief burst when the acquisition method is incompatible with the burst length.

For an envelope p(t) equal to one from time zero to τ, the continuous Fourier transform of the baseband envelope has magnitude proportional to τ|sinc(πfτ)| under the normalised sinc convention. The first zeros occur at frequencies f=±1/τ relative to the carrier, so their separation is 2/τ. A 10 microsecond rectangular envelope has first baseband nulls at ±100 kHz, while a 1 microsecond envelope has nulls at ±1 MHz. These figures describe the ideal envelope, not every modulation, rise time or real pulse-shaping circuit. If a narrow 1 kHz resolution filter is applied to the shorter burst, its passband captures only a small part of the broadband pulse energy and its temporal response may dominate the display.

The familiar time-frequency concentration principle may be written in a particular statistical convention as $\sigma_t \sigma_f \geq 1/(4\pi)$, with σ_t the root-mean-square time spread and σ_f the root-mean-square frequency spread of a properly normalised signal, both measured about their respective means. This inequality is not an instruction to set RBW to a single number for all pulse measurements. Nor does it predict the detailed behaviour of an analogue swept filter. It is a conceptual guard against claiming arbitrary precision in both domains without appropriate data. Gaussian signals attain the relevant lower bound under the chosen convention, whereas a hard-edged rectangular pulse has different spectral tails and may not possess finite second moment in the same straightforward manner.

The instrument may supply more than one kind of spectral representation. A conventional swept trace assembles frequency-selective responses at successive instants. A zero-span view fixes the centre frequency and reports

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detected amplitude versus time through the selected passband. A short-time Fourier transform partitions continuously acquired complex samples into overlapping windows, with choices of window length, shape and hop size. A triggered capture can retain the raw waveform for retrospective reprocessing. These displays are not interchangeable evidence. Each has its own response to a short pulse, and each can conceal a transient if its acquisition contains gaps or if its window is poorly chosen.

Consider a 100 microsecond burst followed by one second of silence. A long FFT window provides fine frequency-bin spacing but includes mostly silence; a peak amplitude normalised as though a continuous tone occupied the whole window can appear markedly reduced. A very short window provides better localisation of onset but blurs narrow spectral structure. An appropriate spectrogram should disclose its window definition, sample rate, overlap, scaling convention, trigger logic and any dropped samples. Otherwise two spectrograms with different brightness are incommensurable. Colours are persuasive to the eye but do not supply a calibrated reference plane.

The post-detection video filter adds a second loss of temporal detail. If the analyser first converts the filtered carrier to a scalar envelope, phase information may already be lost. Smoothing that envelope with a low-pass filter cannot recreate the original pulse shape afterwards. In digital systems the phrase video bandwidth sometimes names a specified trace-smoothing operation rather than a literal analogue RC network. For that reason I favour measurement of its impulse or step response using a pulsed calibration source, not supposition based on a front-panel value. We should record

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whether the signal was sampled as complex RF or IF data, detected as power, or reduced to display ordinates before any data were exported.

A special difficulty arises with multiple pulses. Coherent repetition produces a line spectrum whose spacing is the pulse repetition frequency, while pulse timing jitter and random burst amplitude modify or broaden that structure. A sweeping instrument may catch different pulses at different frequencies and unintentionally join them into what resembles a stable single event. Conversely, its max-hold function may accumulate a plausible pulse spectral envelope over many sweeps without ever observing a complete pulse in one interval. Such a constructed envelope may help characterise a stable repeating source, but it does not prove that all displayed spectral points were present simultaneously.

In a forensic interpretation I would separate at least three questions. Was energy present in the receiver input passband? Did the apparatus acquire that energy with adequate temporal response? Does the displayed representation preserve the parameter at issue, whether peak field, pulse duration, repetition period or occupied bandwidth? Each requires its own evidence. I would describe a negative finding in terms of bounded observation windows and validated detector performance, never as an unqualified proof that an instrument could not have missed a source.

Dr. James M. Atkinson, Moderator: Sir Robert, please challenge Professor Gabor on the practical temptation to reconstruct a complete spectrum from a sequence of pulses that may not be identical. How might a survey distinguish a persistent physical pattern from a display assembled from several inconsistent episodes?

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Sir Robert Alexander Watson-Watt, Peer Question: Professor Gabor, consider the common case of a surveillance instrument whose emissions are not under the investigator's control. It may change carrier frequency, pulse interval, modulation and output power in response to its own sensors or to surrounding traffic. The operator may collect a max-hold sweep over an hour and then describe the resulting outline as though it were the spectrum of one stable emission. Yet the narrow ridge at one frequency may have been created by a brief episode at midday, while a broad lobe represents a different mode much later. What acquisition and review protocol would make it possible to tell whether the composite is representative? Is there a legitimate use for max-hold in discovering rare transients, provided the limitations are explicitly recorded? Finally, if the operator is restricted to a swept receiver with no continuous I/Q recording, how should the evidence be graded rather than dismissed entirely?

Dennis Gabor, Response: Sir Robert, maximum hold has a proper but limited use as a search aid. It accumulates the maximum detector statistic at each frequency bin over successive visits. It can reveal that the instrument once registered energy at a particular bin, subject to artefacts, overload and correct calibration. It does not establish simultaneity between maxima in different bins, nor does it preserve the time sequence that distinguishes modes of operation. If the apparatus lacks an event log associated with each changed bin, the operator should resist writing a continuous waveform history from the appearance of a continuous trace.

The improved protocol retains at least the timestamp of each meaningful peak update, the sweep configuration and an independent event counter or trigger trace where feasible. If the instrument can save successive raw

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traces with their acquisition times, build a time-indexed record and identify clusters corresponding to distinct episodes. A source that changes frequency can then appear as a series of conditional observations rather than one mythical wideband emission. A triggered zero-span capture at selected frequencies, simultaneous wideband I/Q acquisition or a separate tuned receiver can supply the missing relationship between time and frequency. These are complementary methods, not interchangeable guarantees.

One must also test whether apparent spectral changes originate in the receiver. Frequency-dependent gain corrections, preselector switching, local-oscillator settling, detector transitions and automatic rescaling can produce changes that follow the scan programme rather than an external emitter. Inject a stable laboratory pulse source at the antenna reference plane, repeat the actual survey settings and observe whether the instrument generates similar features. That test does not exclude every environmental effect, but it measures one important class of alternative explanation.

If only a conventional sweep is available, evidence may still be useful when expressed conditionally. A sequence of narrow peaks recorded at separate documented times supports observations of discrete receiver indications. A repeating peak at one setting over independent sessions can motivate more careful tests. The report should give the observed and unobserved intervals, calibration confidence and the risk that the indications represent different pulses or instrument products. As long as a composite is labelled a composite, and no conclusion exceeds the available timing information,

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max-hold can be an honest discovery instrument rather than an unwarranted historical reconstruction.

Dr. James M. Atkinson, Moderator: Professor Nyquist, direct the discussion to discrete observation and detection decisions. A trace composed of digital samples may appear continuous on the screen even if important RF events fell between acquisition intervals. Explain how to establish a meaningful lower bound on the observation coverage.

Harry Nyquist, Third Principal Contributor: Dr. Atkinson, there is a dangerous ambiguity in the word sample. A receiver may sample an intermediate-frequency waveform at a particular clock rate, compute a sequence of power estimates, display one selected maximum per trace bucket, and then sample that screen for archiving. Each step is different. The familiar sampling theorem concerns a band-limited continuous signal and its reconstruction from appropriately spaced uniform samples under stipulated conditions. It does not imply that a swept receiver continuously monitors every frequency printed on its display, nor does it guarantee the capture of an unannounced brief burst during intervals when the relevant front end was elsewhere.

Let f_s be an analogue-to-digital sampling rate in samples per second and B the highest frequency in a baseband representation after proper anti-alias filtering. For a real-valued signal band-limited to B hertz, a familiar sufficient ideal condition for reconstruction is $f_s>2B$. Complex baseband has a different two-sided spectral bookkeeping convention and can cover a band approximately commensurate with the complex sampling rate when correctly filtered. Neither statement certifies continuous processing, absence of memory overrun, suitable analogue bandwidth, or adequate

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trigger selection. A digitiser operating at 100 megasamples per second can still miss a five microsecond event if its input is disconnected, its tuning is elsewhere, or its buffer discards that interval.

For a periodic swept instrument, define T_s as the interval between effective visits to a given narrow frequency, and let d denote the duration for which that frequency is observed with validated sensitivity during each visit. The simplest duty fraction is $q=d/T_s$, provided $0 \leq d \leq T_s$. If pulse onset times are uniformly distributed relative to the visit cycle and a pulse is so short that partial overlaps can be neglected, q is an approximate fraction of onsets leading to observation. A more careful overlap model for a pulse of duration τ, valid dwell d and revisit T_s gives $p_{overlap} \approx \min[1,(d+\tau)/T_s]$ when the relevant periods are non-overlapping and the arrival phase is uniform. Overlap does not guarantee detection because filter settling, threshold and signal-to-noise remain.

For example, suppose an analyser revisits a channel every 250 milliseconds and provides 0.5 milliseconds of effective sensitivity per visit. A randomly timed 20 microsecond pulse has an idealised overlap probability of approximately $(0.50+0.020)/250=0.00208$, or 0.208 percent. That is roughly one opportunity in 481 under the stated uniform-onset model; it is not an observed performance rating. For ten genuinely independent pulses the chance of one or more temporal overlaps is $1-(1-0.00208)^{10} \approx 2.06$ percent. If all ten pulses are phase-locked to the same external cycle relative to the sweep, treating them as independent would be mathematically wrong. The operator must distinguish a probabilistic assumption from a physical observation.

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There is also the problem of detector aggregation. A display point may summarise many internal time samples. A positive peak detector preserves an extreme in its sample bucket, while an average or RMS detector may dilute the contribution of a rare strong event among a long interval of noise or silence. If a pulse of power P occupies fraction δ of a detector's integration time, and background power is negligible, an ideal mean-power statistic is approximately δP. In decibels relative to pulse peak power the reduction is 10log10δ. With a 10 microsecond pulse integrated over 10 milliseconds, δ=0.001 and the ideal mean-power reduction is 30 dB. This simple result concerns linear power averaging, not the response of every log detector or trace-averaging algorithm.

When firmware records only final display values, the reviewer cannot necessarily reconstruct the intermediate time samples. That is why raw sample capture, timestamps and a record of dropped acquisition intervals are so valuable. In a modern receiver an apparently uninterrupted waterfall may contain packet loss, processing latency, FFT hop gaps or discarded blocks. If timestamps are generated by the host after buffering, they may refer to processing completion rather than antenna arrival. Characterise the timebase, queue depth and block indices, then verify with an injected sequence whose onset schedule is independently recorded.

False-alarm and detection probabilities must be tied to a defined class of pulses. One cannot assign one number to all possible emitters when their carrier offsets, durations, bandwidths, powers and modulation differ. The correct performance statement might define a bounded range of frequency offsets, pulse lengths and powers under known noise, together with the proportion of known injections recovered at a predeclared threshold. If

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interference or occupancy conditions change, the probability must be reevaluated. A single scalar sensitivity figure quoted from a manufacturer's continuous-wave specification is insufficient to predict capture of rare bursts.

A defensible instrument record would include the sampling frequency and anti-alias filter, the real or complex representation, the acquisition duty cycle, each frequency visit, any handover time, FFT window and overlap, detector definition, trigger condition and whether full data were retained. A screen that paints every pixel during a slow sweep is not a contract that every incident photon or radio-frequency oscillation was observed. It is a representation of an acquisition policy. The burden of proof lies with whoever turns that policy into a negative physical claim.

Dr. James M. Atkinson, Moderator: Mr. Weston, pursue the practical question of calibrating a continuously running detector against an intermittently acquired swept trace. How should one compare the same pulse sequence without imposing a misleading common scale?

Edward Weston, Peer Question: Professor Nyquist, the figures for observation duty are compelling, but laboratory comparisons can be easily spoilt by differences in where and how voltage is measured. One instrument may state a peak in decibels relative to a milliwatt at a nominal fifty-ohm port, another may report RMS voltage in a digitised channel, and a third may display a trace normalised to the noise-floor gain chosen by automatic scaling. At the same time, a supposedly stable pulsed source may vary amplitude with pulse width, load mismatch or repetition rate. What reference-plane discipline would you impose so that a capture probability measured on a continuous I/Q path can be compared fairly with a swept

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analyser? Would you insist upon a physical power detector as arbiter, and how would you prevent that detector's own finite bandwidth from becoming another source of undercount? Please distinguish a physical delivery of pulse energy at the input connector from subsequent detector thresholding, so that a failure at one layer is not mistaken for a failure at another. I also want the impedance mismatch correction recorded separately from the timing correction.

Harry Nyquist, Response: Mr. Weston, the comparison must start with a defined source and an agreed physical quantity. For a fifty-ohm matched reference plane, average power and RMS voltage are related by $P=V_{rms}^2/R$, where R is the reference resistance. The peak envelope of a burst is not identical to its long-term average power, particularly when its duty cycle is small. Specify whether a stated −60 dBm refers to power during the pulse's active plateau, time-averaged power over many cycles, or an analyser-derived spectral-bin estimate. Without that distinction two instruments can appear to disagree while each is correctly reporting a different quantity. Place the source at a characterised tee or splitter whose loss and isolation are measured across the relevant bandwidth. Keep the attenuator, cable routing, terminations, source pulse settings and triggering reference constant. Measure the pulse waveform with an independently bandwidth-qualified oscilloscope or envelope detector, but treat that device as another measurement system with finite rise time, noise and possible loading. If the pulse is 500 nanoseconds wide, a slow power sensor is unsuitable as the arbiter of its peak. A faster instrument whose bandwidth has been established can verify amplitude and timing, while an average power meter can provide an independent energy-related constraint for stable repetition.

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The comparator should not be forced onto an inappropriate output scale. Report recovered pulse plateau power when that quantity is well defined, event detection rate at a declared threshold, and time-frequency coverage separately. If the swept analyser never tuned to the carrier during most injections, its low recovery probability is not necessarily a failure of its amplitude calibration. Conversely, if a continuous receiver acquired all sample blocks but the wrong detector discarded short maxima, its failure belongs to downstream processing. Classification matters when deciding what should be repaired.

To control the timebase, use a common reference trigger where feasible and document its physical path, jitter and latency. Record both instrument-side timestamps and an independent source-onset log, then calculate their offsets rather than aligning graphs by eye. Repeat with at least two pulse powers, more than one carrier offset, and onset phases distributed across the sweep. State the uncertainty of the reference measurements and the number of trials. An impartial comparison may properly find that an old swept receiver measures continuous-wave amplitude accurately yet gives sparse coverage of brief events. That is not a contradiction, but an expression of different measurement capabilities.

Dr. James M. Atkinson, Moderator: Sir Harold Jeffreys, challenge the use of the word probability. Explain why a string of blank sweeps cannot be converted into strong evidence of absence without a defensible model for the source and the acquisition process.

Sir Harold Jeffreys, Peer Question: Professor Nyquist, you have appropriately qualified independence, yet an expert witness may still present a clean succession of sweeps as if statistical confidence rose automatically with each

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additional trace. What if the relevant emitter transmits only after a person enters the room, after a network packet arrives, or on the occurrence of a specific environmental stimulus that the survey never reproduced? What if the frequency and duration of transmission are unknown rather than randomly drawn from the conveniently specified model? I ask you to distinguish the probability of detecting a fixed, known laboratory pulse from the probability that an undiscovered device exists. How would you report a negative result so that the court or investigator understands what was actually challenged, without attaching numerical confidence to hypotheses the experiment never tested? If an estimate is based on repeated trials, should its uncertainty interval reflect clustering and common triggering rather than a fictitious binomial sequence of independent pulses? Please distinguish repeatability of a test rig from representativeness of the unknown transmitter behaviour.

Harry Nyquist, Response: Sir Harold, the probability of detecting an injected test waveform is conditional on the waveform, the observation schedule, the receiver configuration, the noise environment and the detection rule. It is not the probability that an unknown device exists or does not exist. A laboratory can estimate P(detection | pulse class and conditions) from controlled injections. Turning that into P(no device | negative survey) requires prior information about possible devices, their behaviours and how they were sampled. If none of these populations is characterised, a definitive posterior probability is a pretence, however tidy the algebra.

The report should make that distinction in plain terms. For example: 'With the receiver configured as specified, 100 of 100 test pulses lasting 200 microseconds at the stated frequency and level were detected under the

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recorded background. The survey did not test condition-dependent transmission outside those observation windows.' That sentence would be justified only by actual data matching the description. It does not imply that shorter or weaker bursts would be detected, nor that an emitter requiring a trigger absent from the survey was challenged. We should not silently transfer results from convenient test pulses to an unknown signal class.

A negative surveillance exercise can still be substantial evidence about a restricted physical proposition. If a particular channel was observed continuously at a calibrated sensitivity for a documented interval, the absence of a specified class of emissions during that interval may be supported. The proposition becomes weaker as the allowed alternatives expand to include arbitrarily short, rare or contingent transmissions. A useful evidential map lists each tested class and each exclusion. One may write 'not observed within the validated measurement envelope' and describe that envelope quantitatively rather than claiming a perfect search.

Nor should multiple traces be counted as independent evidence without inspecting the measurement programme. Ten identical sweeps phase-locked to a five-second transmission cycle may revisit the same blind phase ten times. They then add remarkably little new information. Randomised start times, deliberate changes of sweep duration, continuous monitoring of priority frequencies and triggered environmental stimuli provide distinct tests of the hypothesis. The statistical apparatus should account for them explicitly. In the absence of such evidence, the correct conclusion is uncertainty, not either assurance or alarm.

Dr. James M. Atkinson, Moderator: Mr. Hewlett, your historical work in the design of stable signal sources affords a particularly instructive perspective

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on instrumentation. Explain how one could construct a reproducible calibration experiment that exposes pulse erasure by resolution and video bandwidth, without confusing it with generator error or receiver overload.
William Reddington Hewlett, Fourth Principal Contributor: Dr. Atkinson, the experiment must begin with the source, not with the analyzer's front panel. A calibrated continuous-wave signal is inadequate to validate the detection of microsecond bursts because it never tests the instrument's transient path. The laboratory requires a pulsed radio-frequency source whose carrier, envelope, on-state amplitude, off-state leakage, width, rise and fall times, repetition interval and trigger timing are themselves measured. It is possible for a pulse generator to have an excellent nominal timing specification yet exhibit droop across the plateau, overshoot on transitions or carrier leakage during its quiet interval. These imperfections must be described before the analyser's reported response is judged.
I would construct two paths from a source whose output is protected by measured attenuation. One path reaches the analyser through a characterised splitter, with suitable impedance matching and overload margins. The second path reaches a bandwidth-qualified independent time-domain monitor that retains the actual envelope of each pulse. The monitor's own bandwidth and sampling cadence must comfortably resolve the fastest transitions under test; its calibration and loading are part of the uncertainty budget. The two paths must have measured delay, and the source and receiving instruments should share a traceable timing reference or at least a measurable common trigger. An oscilloscope trace drawn without trigger discipline is not a definitive standard for simultaneity.

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The test matrix should include at least three duration classes. Begin with pulses long compared with the measured resolution-filter settling time, so there is a baseline in which steady-state amplitude can be approached. Move to pulses near that settling time, where shape distortion is expected. Finish with pulses much shorter than that time, where attenuation may be substantial. In each class use multiple pulse powers sufficiently below the receiver's compression threshold, repeat at several carrier offsets within the displayed bin, and place pulses at varying phases of the sweep. This isolates duration, frequency, amplitude and timing without making the factorial design unmanageable.

A teaching sequence might use pulse widths of 1 millisecond, 50 microseconds and 2 microseconds, with a stable carrier at 100 MHz. First compare 1 MHz, 100 kHz and 10 kHz nominal resolution bandwidth settings while keeping VBW wider than the fastest relevant detected envelope, where the instrument permits that choice. Measure actual observed peak and event capture. Then hold RBW constant and reduce VBW through a series such as 1 MHz, 100 kHz, 10 kHz and 1 kHz, noting whether that control changes physical video filtering, digital averaging, or both on the particular model. The numerical settings are an experimental example rather than an assertion that every analyser offers precisely those ranges or uses equivalent filters.

The experiment should not rely on trace maximum-hold alone. Preserve raw or minimally processed detector data where the instrument permits it, and obtain a time-aligned zero-span capture at each bandwidth. Compare the measured pulse envelope and the detector response in the same time coordinate. If a pulsed source is repeated every 100 milliseconds, an

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arbitrarily timed sweep that misses nine out of ten opportunities must not have its missing values silently replaced by maximum-hold from a fortunate tenth sweep. Record counts of injections and counts of actual recoveries, and distinguish physical input delivery from successful on-screen declaration.

The analyser's linearity also needs qualification. A high crest-factor input can produce momentary compression even when its long-term average power is modest. An instrument with automatic gain control may recover differently after a large pulse than after a weak one. Set input attenuation, reference level and preamplifier state deliberately, verify against a known linear source and repeat selected tests with additional attenuation. A genuine linear power change should follow the added pad to within the known measurement uncertainty, while overload products or internal settling may behave otherwise. This is not merely a courtesy check. An overloaded front end could imitate either an exaggerated peak or the disappearance of a following pulse.

A well-designed source can also reveal video-filter attenuation by keeping the IF filter effectively settled. Choose a long enough burst to permit the RF selectivity chain to reach the expected plateau, then vary B_V independently and observe the video rise time and displayed peak. Reverse the procedure by holding B_V wide and reducing burst width while changing B_R. The order of experiments matters because changing two controls at once makes causal attribution difficult. If automatic coupling changes sweep time when RBW or VBW is altered, preserve that change in the log and, where possible, run a second matched-sweep comparison.

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The final record should include the pulse-source settings and their independently measured values; the full analyser setup; swept and zero-span traces; detector type; overload indicators; frequency-reference information; equipment identifiers; cable and attenuator calibrations; trial counts and rejection rules; and the exact meaning of each plotted amplitude. The purpose is not to construct an impressive demonstration but to test a precise proposition: whether the instrument, at a specified configuration, could have detected a particular class of brief emission with a known probability and amplitude error. That result can then inform the design of a surveillance survey without being inflated into a universal certificate of absence.

Dr. James M. Atkinson, Moderator: Dr. Bracewell, examine how the laboratory should control the relation between pulse length and receiver bandwidth when a finite-duration signal has a broad spectrum. Can a power meter, a zero-span trace and a swept spectrum legitimately report different values without any of them being defective?

Ronald Newbold Bracewell, Peer Question: Mr. Hewlett, the proposed reference path is persuasive, but I am concerned about the phrase 'same amplitude'. A finite pulse sends energy across a band, and a narrow resolution filter accepts only a portion of it. A broadband power sensor integrating over the entire signal spectrum may yield an entirely different number from a frequency-selective instrument receiving a single small slice. A zero-span trace may report the detected envelope after a nontrivial IF transient; a swept trace may report a statistical maximum at one selected frequency. How would you choose a common measurement definition that does not prejudge one instrument as right and the others as wrong? Would

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you calibrate the total RF energy, the carrier-referenced peak voltage, or the spectral density? Please also explain how changing the pulse's rise time can alter the result even if the nominal width and crest amplitude remain constant.

William Reddington Hewlett, Response: Dr. Bracewell, the first obligation is to identify the measurand. Total pulse energy, in joules, is the time integral of instantaneous delivered power across the complete occupied spectrum. A correctly specified broadband sensor may estimate that energy after calibration for its response. The peak RF envelope power, by contrast, refers to the maximum power during the active portion of the waveform at a reference plane. A resolution-filtered spectral bin reports an instrument-dependent measure of the waveform's power within a finite passband. None should be labelled simply 'amplitude' without qualification, and none is automatically a substitute for another.

For a well-matched load R and a known voltage waveform v(t), the delivered energy during the observation interval is $E=\int v^2(t)/R\, dt$. If an ideal pulse delivers 1 milliwatt of power for 10 microseconds, its energy is 10 nanojoules. If that pulse repeats once every 10 milliseconds, its ideal duty cycle is 0.001 and its long-time average power is 1 microwatt, or −30 dBm, whereas the on-state power is 0 dBm. Those figures are internally consistent but measure different properties. A narrow frequency filter does not capture all ten nanojoules unless its frequency weighting and integration permit it. Rise and fall times complicate the simple rectangular model. A raised-cosine envelope, for example, reduces high-frequency sidelobes compared with abrupt switching at the same plateau, while modifying total energy if the duration definition is not adjusted. The correct comparison saves the

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measured envelope, rather than merely the generator's setting. When one instrument is broadband and another frequency-selective, compare both against a waveform model convolved with each instrument's characterised transfer function. This permits an expected difference to be computed without describing it as error.

I would specify distinct tests for each measurand. Use the broadband path for waveform and energy characterisation, with appropriate bandwidth and dynamic range. Use zero span to assess the analyser's amplitude-versus-time response in a nominated frequency passband. Use a calibrated swept or FFT spectrum with documented windows to estimate spectral distribution. The three data sets can be cross-checked for energy consistency after allowing for bandwidth, windowing, mismatch, leakage and uncertainty. If an apparent discrepancy persists, investigate the reference plane, detector definition and calibration before calling the source or analyser faulty. Clear nomenclature is an instrument of forensic fairness.

Dr. James M. Atkinson, Moderator: Dr. Townes, inquire about the possibility that nominally identical pulses produce different observed peaks because of frequency and phase changes during the pulse. We need a procedure which is robust to unintended chirp and source modulation.

Charles Hard Townes, Peer Question: Mr. Hewlett, an oscillator may be exquisitely stable over a long period while a pulsed output exhibits frequency pulling during its leading edge, thermal changes within a burst, or transient phase modulation from the switch. A spectrum analyser set to a very narrow resolution bandwidth could then show a small peak, not because the event was absent, but because instantaneous frequency moved through and beyond the passband while its filter was still settling. How

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would you separate pulse-duration attenuation from chirp, drift or phase transients? I am particularly concerned about an investigator who broadens RBW and finds a large new peak, then claims that the original narrow-band measurement was simply 'incorrect'. Should the proper explanation instead distinguish the two filters' responses to a genuinely broadband or time-varying waveform? Could a deliberately measured frequency trajectory, rather than the generator's nominal tuning label, serve as the reference when comparing these instrument settings? Please explain how phase noise in a low-amplitude leading edge should be excluded from a spurious chirp estimate.

William Reddington Hewlett, Response: Dr. Townes, yes. A short burst is not guaranteed to be a perfectly gated stationary sinusoid. Its frequency may change during turn-on, and those changes need not be defects when the source is intentionally agile. A narrow frequency-selective path can report only the portion of energy and time lying within its transfer function. If a frequency trajectory crosses the IF passband while the filter settles, the observed transient depends on both frequency history and filter dynamics. Broadening RBW may increase the recovered peak for physically intelligible reasons without proving that the original instrument was operating outside specification.

An appropriate experiment begins by recording complex I/Q samples with enough instantaneous bandwidth to capture the entire pulse spectrum. From those data estimate instantaneous phase after appropriate amplitude thresholding and unwrap the phase carefully. The derivative of phase divided by 2π gives instantaneous frequency where the signal has sufficient amplitude and the model is meaningful. At a rising edge, where amplitude

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approaches zero, phase becomes ill conditioned; an apparent enormous chirp can be merely noise. Compare frequency trajectories across repeated pulses and record the confidence of each estimate rather than relying on a single colourful spectrogram.

Next feed the same observed waveform, or a source reproducing its well-characterised envelope and frequency trajectory, through characterised filter responses. A long constant-frequency pulse serves as the settling control; a short constant-frequency pulse isolates temporal response; a deliberately chirped pulse tests tracking or filtering loss. Preserve the amplitude scale of the source and distinguish simulations from physical measurements. If the narrow-band path differs from the broad-band path by the amount predicted from the characterised transfer functions, the difference is expected. If it differs materially more, look for sweep mistiming, overload or calibration faults.

The report can therefore state three facts separately: the physical pulse duration, the occupied frequency-time trajectory, and the analyser's recovered detector statistic under a named configuration. This avoids the false binary judgement that one filter tells the truth and the other lies. In surveillance work the broad-band record helps establish that an emission occurred, while a narrow-band path may help resolve close interference once sufficient observation time exists. Their respective strengths are complementary, and neither can vindicate a conclusion about unobserved signals outside the validated acquisition envelope.

Dr. James M. Atkinson, Moderator: Professor Armstrong, attend to the receiver itself. Explain how mixing stages, resolution-filter transients,

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detector choices and automatic sweep coupling can turn a real pulsed input into either an attenuated trace or an apparently spurious one.

Edwin Howard Armstrong, Fifth Principal Contributor: Dr. Atkinson, a frequency-converting receiver is an active electronic experiment. Its mixer does not simply transport an incoming signal from radio frequency to an intermediate frequency in a lossless manner. Local-oscillator energy, preselection, gain distribution, nonlinear products, filter shape and detector response all influence the indication. These effects become especially visible with pulses, because switching the RF envelope imposes rapid time variation while the receiver's internal circuits may have slower settling and recovery. One should never infer from a smooth displayed trace that the front end enjoyed continuous, linear sensitivity throughout every burst.

A conventional swept spectrum analyser places a local oscillator at a succession of frequencies so that a narrow IF resolution filter samples each corresponding input region. Where the RF input is present for a shorter interval than the IF filter needs to settle, the output does not reach the value obtained for a continuous carrier of equal on-state amplitude. The precise response depends on filter implementation and on where the sweep begins relative to the pulse. A later video low-pass filter can further attenuate the detector excursion. Thus two distinct time responses may compound. But because logarithmic detectors and digital processing can be nonlinear, one must not simply add two estimated decibel losses without verifying the processing order and dynamic regime.

Suppose an IF filter has an experimentally established 10 to 90 percent envelope rise time of 30 microseconds. A two microsecond carrier burst begins just as the sweep approaches the correct frequency. The filter may

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produce a short ringing response whose maximum occurs after the external pulse ends. A screen timestamp tied to that maximum is not necessarily the emission onset. The analyser can also shift the apparent spectral peak if its local oscillator moves during the filter transient. If the displayed peak appears later or at a nearby frequency, the investigator must first test whether the instrument itself creates such displacement from a stable laboratory pulse.

There are additional deceptive mechanisms. A strong pulse may compress an RF amplifier for its first microseconds and cause slower recovery, concealing a weaker pulse immediately afterwards. Automatic level control may lower gain following a burst and make the next event appear absent. A pulsed blocker outside the nominal displayed channel may mix with other energy to produce a transient within the IF; an image response can be mistaken for a direct emission unless preselection is adequate. Noise blankers, overload-protection circuits and adaptive digital suppression can deliberately remove impulsive energy. Each mechanism calls for a different calibration and cannot be resolved by tuning RBW alone.

The display detector matters greatly. An averaging detector may be appropriate for mean noise or mean channel power, but it can understate isolated high-amplitude pulses. Positive-peak detection better preserves captured extrema, provided the dwell and bucket formation actually include the event. A quasi-peak detector has weighting that intentionally distinguishes repetition rate and is not a general peak-power estimator. Video smoothing can make noise look less restless, but a smooth video trace is not proof of a small RF peak. The instrument should disclose its detector

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algorithm, any logarithmic averaging and whether the video-filter control is applied before or after the selected statistic.

Consider a pulse repeated every 10 milliseconds, an analyser sweep with 1,001 display points, and a frequency of interest visited for an effective fraction of the repetition interval. If pulses are periodic and sweep phase is stable, some frequencies may be observed reliably while neighbouring points consistently miss. Increasing trace accumulation without changing relative timing can preserve those blind positions. A triggered zero-span measurement at the frequency of interest can characterise pulse width and interval, while an appropriately bandwidth-qualified simultaneous receiver can establish whether events occurred during skipped sweep regions. A careful test distributes pulse onset relative to sweep timing and documents the resulting collection of responses rather than presenting the most striking trace.

A simple frequency-conversion calculation illustrates another ambiguity. A local oscillator at 900 MHz and a desired RF signal at 910 MHz produce a 10 MHz difference-frequency IF in a first-order mixing model. An unwanted component at 890 MHz produces the same absolute difference if image rejection is imperfect. Pulsing either signal can create a brief 10 MHz response. The fact that the detector traces a pulse at the IF does not by itself establish which RF input frequency caused it. Direct input-path substitution, suitable preselection and a second independently characterised receiver architecture may be needed. The numeric example teaches mixer symmetry rather than describing a particular commercial instrument.

The field procedure should begin with an instrument self-test and a calibrated source through a known attenuation path. Check the receiver at

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more than one power to expose gain compression and at more than one pulse width to reveal settling loss. Record both narrow and broad RBW with a video bandwidth that is demonstrably adequate for the relevant envelope, then change VBW separately. Include positive-peak and RMS or average detector measurements, using the proper interpretation for each. If available, retain a synchronous I/Q record so that the swept trace can be compared with actual incident energy. Conduct a source-off control and repeat the source-on sequence to test reproducibility.

The forensic conclusion is deliberately restricted. A quiet swept trace does not exclude an external pulsed transmission unless the specific transmission class lay within valid time-frequency coverage at demonstrable sensitivity. A spectacular peak does not alone identify an external emitter because overload, images, internal clock products and transient filter behaviour can imitate it. The strength of a survey lies not in the polish of a screen but in verified measurement conditions and adversarial alternative explanations. I would pass that doctrine to the final panel exchange: no technical witness should be permitted to trade an instrument display for a stronger proposition than its acquisition chain actually supports.

Dr. James M. Atkinson, Moderator: Dr. Steinmetz, investigate why the operator might change a bandwidth setting and thereby alter automatic sweep time, input gain or other coupled parameters without appreciating that the measurement is no longer controlled.

Charles Proteus Steinmetz, Peer Question: Professor Armstrong, an instrument may offer automatic coupling between resolution bandwidth, video bandwidth, sweep duration and sometimes detector behaviour or preamplification. If the operator adjusts RBW from 100 kilohertz to 1

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kilohertz, the device may silently lengthen the sweep so that its IF response remains calibrated. The analyst then attributes a disappearing pulse to the narrow filter while the chief cause might instead be changed temporal sampling of a periodic event. Conversely, forcing manual sweep time may cause the instrument to over-sweep the filter and generate an inaccurate amplitude. How would a technician distinguish these interacting causes with a compact but rigorous set of experiments? Would you also regard instrument alarms, such as an uncalibrated sweep warning, as evidence that a completed trace is unsuitable for quantitative interpretation, even if the picture resembles the expected spectrum? The frequency sweep may also contain hidden retrace intervals and preselector transitions. Should these be represented as unavailable observation time rather than folded into an apparently continuous sweep duration? How would a technician document the validity of those transitions?

Edwin Howard Armstrong, Response: Dr. Steinmetz, the front panel must be treated as a set of coupled control variables, not a row of independent knobs. I would first capture the complete instrument state before and after every user-initiated change, using the device's configuration export or a carefully checked manual register. The change log should include not only the selected RBW, but also actual sweep time, sweep points, VBW, detector, trace averaging, attenuation, reference level, gain and any automatic corrections. Where the firmware exposes real filter dwell or acquisition mode, those should be recorded. An uncalibrated or overload warning must be preserved as a qualification even if the trace looks persuasive.

The experiment proceeds in two passes. In the first, use normal automatic coupling and document the complete resulting state for each RBW setting.

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This establishes how an ordinary operator would encounter the instrument. In the second, hold those other parameters fixed where safe and calibrated, changing only the particular bandwidth being investigated. If the instrument cannot provide a valid calibrated manual configuration, the second pass must not be represented as an accurate amplitude comparison. It may instead illustrate the degree of algorithmic dependence under a deliberately diagnostic, nonquantitative setting.

The source should supply pulses whose onset is swept through the entire relative timing cycle. One may use a trigger delay that changes by known increments on successive trials, or a measured pseudo-random onset sequence. A stable pulse generator alone does not reveal time-coverage failure if it repeatedly occupies a favourable phase. Compare the resulting detection surfaces as functions of onset and carrier offset. The effects of changing sweep time will then appear separately from the filter's characteristic attenuation, at least to the extent that the experimental variables can be isolated.

Finally, any instrument alarm is substantive evidence about metrological validity. A trace can remain attractive while a manufacturer-defined amplitude calibration condition is violated. An alarm does not necessarily mean that no qualitative information exists, but it forbids an unqualified amplitude claim. The review should say whether each trace was obtained in calibrated operation, in a known diagnostic exception or in an uncharacterised state. A report can then attribute the observed omission to narrower bandwidth, changed coverage or an unresolved combination, rather than inventing a single tidy cause.

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Dr. James M. Atkinson, Moderator: Dr. Jeffreys has raised the interpretive burden; Professor Gabor and Professor Nyquist should now interrogate one another directly. Cross-peer exchanges must identify the respondent, and the response must immediately follow its question rather than be deferred to an unspecified general discussion.

Dennis Gabor, Cross-Peer Question to Harry Nyquist: Professor Nyquist, your expression for the chance of overlap has the merit of revealing the large blind intervals, but it becomes deceptive if a pulse has complex frequency structure or if a filter's response continues after the physical envelope ends. The event might overlap a nominal dwell only through a weak sidelobe, while an appropriately sensitive detector could register a later filter response after the scan has moved. How would you generalise a binary time-coverage map into a measurable event-detection kernel without multiplying unknowable probabilities? I am especially interested in whether the investigator should define 'capture' as any energy above the noise, the first threshold crossing, an amplitude estimate within tolerance, or a reconstructable pulse. Please clarify how these definitions change the quoted coverage and how a report should prevent a favourable detection rate from being mistaken for accurate parameter estimation. In particular, should a delayed output caused by IF ringing count as a detected emission if its frequency and onset labels are both outside the allowed reconstruction error? I want the response to distinguish simple alarm sensitivity from reliable forensic localisation.

Harry Nyquist, Cross-Peer Answer to Dennis Gabor: Professor Gabor, the proper generalisation is a response surface based on explicit test waveforms and decision rules, not an imagined universal detector probability. Let θ

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denote the pulse parameters, including onset, carrier offset, duration, power and waveform shape. Let s denote the receiver state and observation schedule. The instrument produces a statistic Z through its physical and digital chain. We can estimate $P[Z>\gamma \mid \theta,s]$ for a declared threshold γ from repeated injections under specified background conditions. That quantity does not presume a binary filter passband. It permits the real impulse response, sidelobes, scan motion and processing artefacts to influence the result as observed.

But we should preserve several success criteria. First, 'indication' means that a predeclared detection threshold was crossed during a valid record. Second, 'localisation' means that the reported time and frequency lie within specified errors of the injected event. Third, 'amplitude recovery' means that the reported pulse parameter lies within a declared tolerance. Fourth, 'waveform recovery' might require enough samples and bandwidth to reconstruct selected details with bounded error. These criteria form nested or overlapping claims depending on the instrument; a detector can flag energy without reconstructing the waveform or finding onset precisely.

The test matrix should report separate recovery fractions for each criterion, with trial counts and uncertainty intervals, rather than one undifferentiated 'detection probability'. We can also retain the raw measured response surface as a function of event onset and carrier offset. Only after establishing a credible distribution of possible source behaviours should we average those conditional results into a broader operational prediction. The latter distribution is often unknown in a surveillance case, and that uncertainty must not be hidden.

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A delayed filter ring may cross threshold after the physical pulse ceases. It may still be a valid indication under the first criterion, but not a correct onset estimate. The record should therefore distinguish the time of emission, the time of first receiver response and the time of screen update. Those quantities can differ because of group delay, buffer latency and detector aggregation. This is why I prefer separate evidence categories rather than allowing one successful display to certify every aspect of the incident waveform.

Harry Nyquist, Cross-Peer Question to William Reddington Hewlett: Mr. Hewlett, your pulsed source is the backbone of the calibration programme, but the apparatus may contain two correlated imperfections: the pulse timing generator and the receiver sweep may share an oscillator reference, and the reference monitor may derive its trigger from that same generator. A beautifully repeatable result can then arise because both systems are synchronised to the same rhythm rather than because the receiver has general competence at detecting unsynchronised bursts. How would you expose this common-clock bias without sacrificing the traceability of frequency and time measurements? Is true randomisation of pulse onset necessary, or would a deterministic set of controlled phase offsets suffice? I also ask how you would prevent a 'known good' calibration instrument from becoming a source of common-mode coupling that the survey receiver mistakes for an RF input event. Would a second set of trials with intentionally uncorrelated timebases expose false confidence that survives deterministic phase stepping? Please specify the evidence needed to show that the randomisation procedure did not itself change pulse amplitude, spectral shape or reference-plane power.

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William Reddington Hewlett, Cross-Peer Answer to Harry Nyquist: Professor Nyquist, a shared reference may be desirable for measuring frequency and time precisely, but it must not be allowed to dictate the event phases sampled by the experiment. I would deliberately vary the relative timing between the pulse source and the sweep, using a programmable delay whose actual increments are checked with an independent time-domain recorder. A deterministic sequence covering the full phase cycle can be adequate when the receiver is stable and the schedule is known. Randomised order is particularly useful when instrument temperature, gain or environmental interference drifts during the test. Neither approach requires abandoning traceability. It requires separating a common timebase from a common phase of event occurrence.

A second pass could use a free-running pulse generator with an independent, recorded timing reference. Compare its relative phases and capture statistics with the synchronised trials. If coverage is highly sensitive to phase, the divergence will be apparent. The operator should not average the two regimes into one indistinct success rate. A useful audit includes both the phase-conditioned response and a marginal performance estimate under a specified phase distribution, making explicit the source of that distribution.

To exclude coupling through the laboratory apparatus, first substitute a matched termination at the receiver's input while the timing and trigger cables remain connected. Then change trigger routing, isolation and physical separation without altering the intended RF power path. Observe whether the supposed event persists or follows the trigger wiring. Use properly screened attenuators and verified isolation in the source splitter;

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check for emissions from the pulse generator itself with an independent probe. A calibration tone that leaks by a cable shield or power lead can produce exactly the kind of false certainty this experiment seeks to avoid. The whole exercise therefore contains a source-verification experiment, a receiver-coverage experiment and a coupling-control experiment. Their results should be reported separately. Shared-clock coherence is a feature when studying one phase precisely, and a trap when generalising that phase to arbitrary events. We can preserve the former and expose the latter through controlled phase sweeps, independent observation and honest uncertainty statements.

William Reddington Hewlett, Cross-Peer Question to Edwin Howard Armstrong: Professor Armstrong, suppose the analyser shows no pulse at narrow RBW but displays a striking peak when RBW is broadened. An investigator may have controlled sweep time and VBW and may still conclude too quickly that the narrow filter itself is solely responsible. Yet source power can drive the mixer into compression, the front-end response may vary with frequency, and a pulse may cause local-oscillator or IF transient effects not present for a steady tone. What sequence of receiver tests should separate genuine filter settling from gain compression, image responses and AGC recovery? I ask for a procedure that retains both qualitative diagnostic value and credible quantitative limits, without making the report a collection of unrelated screen pictures. Please also distinguish an input-stage saturation effect from a recovery transient generated by a preceding pulse, since the second burst might be lost even though an isolated burst at the same nominal peak level passes perfectly. How would inter-pulse interval changes reveal this history dependence?

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Edwin Howard Armstrong, Cross-Peer Answer to William Reddington Hewlett: Mr. Hewlett, first establish that the source's active-pulse amplitude is within the linear operating region of the entire signal path. Repeat the pulse experiment with known input attenuation in several steps while preserving the pulse generator's settings and recording the actual power at the receiver reference plane. In a linear chain, recovered voltage and power should track the expected attenuation according to the selected detector and calibration. If a broadband configuration changes by an unexpectedly small amount, or produces new spectral components, compression or mixing products merit investigation. Automatic gain control should be disabled where possible, with the state explicitly recorded. If it cannot be disabled, test the recovery after different inter-pulse intervals.

Second, hold the signal frequency fixed and vary pulse duration from much longer than the RBW settling time to much shorter. A characteristic duration dependence consistent with a measured impulse response supports the filter hypothesis. Then use a stable continuous-wave tone at the same carrier power to check frequency calibration and steady-state gain. A receiver with correct continuous-wave amplitude but deficient short-pulse response has a different fault or limitation from one whose steady-state calibration is already wrong. Neither condition is repaired by a new screenshot.

Third, test alternative input frequencies capable of producing the same IF through images or intermodulation. Vary the local oscillator or preselector, if the instrument permits safe diagnostic control, and observe whether the suspect response follows the expected mixing relation. A second front end with different architecture and independently characterised clocks can help.

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If a line appears only under a certain overload condition or input mixture, do not interpret it as an external transmitter at the displayed frequency without independent evidence.

Finally combine the observations in a test table: attenuation slope, continuous-wave calibration, pulse-width response, onset phase, RBW/VBW setting, receiver alarm state and independent reference waveform. State which mechanisms the tests exclude and which remain. Where no unique mechanism is demonstrated, conclude that a response is instrument-dependent and give its measured bounds. Proper engineering does not require every ambiguity to be resolved; it requires the record not to disguise unresolved alternatives as established facts.

Edwin Howard Armstrong, Cross-Peer Question to Ralph Beebe Blackman: Professor Blackman, we have distinguished a filter's failure to settle from a sweep's failure to visit the carrier, yet a legal or security reader may struggle to see how those mechanisms combine in one negative-survey statement. Consider an instrument for which an injected pulse class is found in 60 percent of trials at one frequency and 95 percent at a second, while false alarms differ because the local interference is stronger at the second. If the investigator also lacks a justified model of how an unknown device chooses when to transmit, what is a principled way to state the limits of exclusion? Would you propose a bounded performance envelope, a worst-case statement, or a sensitivity map? Please explain how you would avoid averaging incomparable frequencies and pulse classes into one attractive but misleading percentage. A reviewer might also be tempted to infer that four good results compensate for one entirely uncharacterised frequency band. Please address whether any aggregate measure may be reported

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without explicitly declaring its frequency weighting and the decision significance of the blind region.

Ralph Beebe Blackman, Cross-Peer Answer to Edwin Howard Armstrong: Professor Armstrong, I would begin with a conditional performance map, indexed by tested frequency, pulse duration, level, carrier offset, onset phase and background condition. Each entry should distinguish detection probability at a specified false-alarm rate from the accuracy of any amplitude or timing estimate. The figures 60 percent and 95 percent in your example tell us about the tested classes and thresholds. They cannot be averaged to 77.5 percent merely because two frequencies are available; that average would silently assume equal relevance and equal opportunity for each condition. If one channel has severe persistent interference, its apparently larger hit rate may be accompanied by a very different false-alarm burden.

A worst-case figure can be useful only when its domain is explicit. 'At least 60 percent of the tested pulses were detected' may describe the two demonstrated frequencies, but it says nothing about untested carrier offsets, weaker powers, shorter durations or phase-locked periods of receiver blindness. A sensitivity map shows where the apparatus has established competence; outside that region the correct label is uncharacterised, not zero sensitivity and not guaranteed absence. I would also preserve the underlying trial counts and confidence intervals, because a reported 95 percent based on twenty trials carries a different precision from the same fraction based on thousands.

The survey conclusion should then identify the exact surveillance claim. A defensible statement is that no qualifying event was observed during the

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recorded coverage at validated sensitivities, and that the detection programme would be expected to recover the tested pulse classes at the measured conditional rates. The inference remains weaker for emitters with unknown activation, shorter pulses, atypical modulation or frequency agility. If a security decision must be made despite that uncertainty, it should be framed as a risk-management judgement informed by the measurements, rather than dressed as a scientific proof of a completely silent environment. I would retain the maps, source waveforms, receiver configurations, calibration records and negative-control data in the evidential package, together with a short plain-language statement of the untested conditions. That approach allows a future reviewer to reproduce the comparison and revise the conclusion when better information emerges. The integrity of the examination lies in preserving the distinction between observed absence, validated test sensitivity and the larger unobserved world.

Dr. James M. Atkinson, Moderator: The discussion will close on a common evidential formulation. A swept analyser reports the behaviour of an acquisition system under stated settings. Narrow resolution bandwidth, restrictive video bandwidth, sweep scheduling, detector aggregation and nonlinear receiver behaviour may all suppress or misrepresent brief emissions. Every negative conclusion must be constrained to validated pulse classes and actual time-frequency coverage. The moderator thanks the contributors and formally passes the token to the independent publication reviewers for source-to-claim checking, mathematical review and integrated pagination, none of which is certified by this fictional reconstruction.

QUESTION 069. EDITORIAL SOURCE NOTES. These sources are references for contemporary analysis, not evidence that historical contributors spoke these words. No historical quotation is asserted.

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EDITORIAL QUALIFICATION: Technical propositions and historical attributions are presented for critical study; equipment-specific claims require evidence from the stated instrument and conditions.

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QUESTION 070

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How should antenna, cable, preamplifier and receiver uncertainties be combined without double counting?

SCHOLARLY RECONSTRUCTION. Every speaker is a deceased historical specialist. The modern dialogue is entirely fictional educational speech; contemporary RF applications and worked figures are editorial calculations, not historical quotation.

Dr. James M. Atkinson, Moderator: Sir Harold Jeffreys, imagine that a field-strength survey presents a numerical result corrected for an antenna factor, a cable loss, a preamplifier gain and a receiver reading. Every component arrives with a calibration certificate, and one laboratory has used the same power standard and temperature reference to produce several certificates. If we place each uncertainty in a column and calculate a root-sum-of-squares total, have we established the uncertainty of the reported field? Or have we counted one underlying reference error several times while omitting the dependence introduced by installation, mismatch and temperature? Explain what should be measured, which correlations enter, and how an expert report can defend its combined uncertainty without inventing precision.

Sir Harold Jeffreys, Principal Contributor: Dr. Atkinson, an uncertainty budget is a quantitative description of a measurement model, not a shopping list of certificates. The first question is what the reported number means. If it is the electric field strength at an explicitly identified position and frequency, its measurand differs from the voltage at a receiver connector. If it is the available power at an antenna port, an antenna factor may not belong in the equation at all. These choices determine which

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corrections and uncertainty contributors are relevant. An analyst should establish the physical quantity, reference plane, installation, measurement bandwidth, polarisation, detector statistic and observation interval before adding a number from any calibration record.

For a conventional narrowband field-strength measurement with consistent logarithmic units, one may write $E_{dB} = V_{rx,dB} + AF_{dB} + L_{cable,dB} - G_{preamp,dB} + C_{misc,dB}$. Here E_{dB} is a field-strength level expressed, for example, in dB microvolts per metre; $V_{rx,dB}$ is the calibrated input-referred receiver level in dB microvolts; AF_{dB} is the antenna factor in dB per metre for the specified geometry and polarisation; $L_{cable,dB}$ is the insertion loss of the designated cable path in decibels; $G_{preamp,dB}$ is the net amplifier gain in decibels referred to the same measurement planes; and $C_{misc,dB}$ represents explicitly defined corrections such as mismatch or known instrumental offsets. This model is local to the declared frequency, load and conditions. A correction must never be inserted solely because a certificate prints a tolerance beside it.

The corresponding first-order uncertainty law is $u^2(E)=\text{sum over } i \text{ and } j \text{ of } c_i c_j \operatorname{cov}(x_i,x_j)$, where c_i is the partial derivative of the measurement model with respect to input x_i, expressed in compatible units. For the four explicitly displayed logarithmic terms the sensitivities are $+1,+1,+1,-1$. A positive covariance between antenna factor and cable loss therefore adds variance, whereas a positive covariance between measured receiver level and the subtracted amplifier gain enters with a negative sign. In a more general nonlinear model c_i need not equal unity. If the input vector has covariance matrix Σ and sensitivity vector c, the calculation is $u^2(E)=c^T\Sigma c$. The matrix should be physically plausible, symmetric and positive semidefinite.

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An arbitrary collection of guessed correlation coefficients that violates those properties is not a defensible uncertainty estimate.

Consider a hypothetical observation with V_rx=42 dB microvolts, antenna factor AF=18 dB per metre, cable loss L=2 dB and amplifier gain G=20 dB. The inferred field level is 42 dB microvolts per metre before any separately justified extra correction. Let the associated standard uncertainties be 0.5, 1.0, 0.2 and 0.6 dB, assumed initially independent. The combined standard uncertainty is sqrt(0.5^2+1.0^2+0.2^2+0.6^2)=sqrt(1.65)=approximately 1.28 dB. This number is not a coverage interval and is not justified if the certificates share a significant reference or if the physical installation introduces effects absent from the model.

Now suppose an experimentally supported correlation of +0.6 exists between the antenna-factor and cable-loss estimates. Their covariance contribution, given identical positive model sensitivities, is 2(1.0)(0.2)(0.6)=0.24 square decibels. The revised variance is 1.89 square decibels, giving u(E)=1.37 dB. If a different pair has opposing signs in the measurement equation, the covariance term may reduce the result. One cannot therefore say that correlation always raises the combined uncertainty. Nor can one safely omit it merely because root-sum-of-squares is familiar. The sign and magnitude follow from the causal measurement model and evidence about the input estimates.

The deeper mistake is to enter the same systematic source once as the uncertainty of the calibrated receiver reading and again as a free-standing uncertainty of the shared power standard, when the receiver certificate already includes it. If the calibrator contributes a latent quantity r to two measured corrections, we should express each correction in terms of r and

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independent residuals, then propagate r only once. Alternatively, retain the covariance that follows from the shared r, without adding another separate r term. These are mathematically equivalent routes when applied consistently. Mixing them double-counts the reference. The same warning applies to room temperature if several device corrections were determined with the same thermometer and thermal model.

Type A evaluations use the statistical behaviour of repeated observations under specified conditions. Type B evaluations use documented information such as calibrations, physical limits, engineering data or justified probability models. Neither type automatically determines whether two inputs are independent. Two laboratories can produce statistically precise results with a shared national standard; several observations from one field chain can be correlated by an unrecorded cable temperature. The distinction between random and systematic is also not synonymous with Type A and Type B. A corrected effect can retain uncertainty, and a repeated uncorrected bias can remain systematic without appearing in the scatter of trials.

I would therefore require an uncertainty register which gives every input's provenance, correction, standard uncertainty, assumed distribution, coverage factor where relevant, common reference identifiers, covariance evidence and sensitivity coefficient. The register should show which uncertainty sources have been absorbed into certificate results and which remain additional. It should be versioned so that later changes to antenna position, preamplifier bias or receiver firmware do not silently inherit the old numbers. The final claim should identify its confidence interpretation and the operating conditions to which it applies, while preserving the distinction between a calibrated measurement and an attribution of a transmitter. For

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our next speaker, I pass the token to Professor Neyman: experimental design is needed to determine whether the covariance terms are supported by the data.

Ralph Beebe Blackman, Peer Question: Sir Harold Jeffreys, your covariance expression assumes that the same error has been traced through each calibration without confusing a statistical correlation with a repeated document entry. Suppose a laboratory calibrates an antenna factor using a reference source, and then uses that same source to establish the receiver level scale. The first certificate may include uncertainty of the reference standard, and the second may also contain it. An operator is tempted to enter both complete certificate values, their stated uncertainties and a separate line for the calibrator. How would you decide whether the calibrator uncertainty has already been counted once, twice or three times? Please show the correct treatment where its effects have equal signs, and explain what evidence would justify a covariance rather than merely assuming that the certificates' shared letterhead proves perfect correlation. Finally, should the final reported uncertainty always be larger whenever certificates are declared correlated, or can physical sensitivity coefficients produce cancellation?

Sir Harold Jeffreys, Response: Mr. Blackman, identify the elementary uncertainty sources before combining the derived certificate quantities. A calibration certificate may provide a result and combined standard uncertainty but not its full covariance with another result. If both certificates include one known reference contribution r and the measurement model uses them with coefficients a and b, the common contribution to the output error is (a+b)r when both derive from the same physical r with the same sign

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convention. Its variance is $(a+b)^2u^2(r)$. Calculating $a^2u^2(r)+b^2u^2(r)$ omits the covariance $2ab\ u^2(r)$; adding an independent extra $u^2(r)$ line after that may double-count the source in a third way. Conversely, if the two coefficients are opposite and equal, their shared reference error cancels in the derived contrast, even though each individual certificate includes it.

Take a hypothetical calibrator error with standard uncertainty 0.4 dB appearing in two calibration corrections that both add to the field model with coefficient +1. The common contribution to the final standard uncertainty is $|1+1|\times0.4=0.8$ dB. If falsely assumed independent, the corresponding contribution would be $\mathrm{sqrt}(0.4^2+0.4^2)=0.566$ dB, an understatement. If one correction adds and the other subtracts the same calibrator error, the shared contribution is zero in the ideal common-mode model, whereas an independent calculation again gives 0.566 dB, an overstatement. Neither result proves any given real calibration behaves in this ideal fashion. The actual coefficients depend on how the calibrations were computed and how the reference enters the model.

To establish the covariance, obtain the laboratories' calibration equations, identify the traceable reference instruments and relevant calibration dates, and determine whether the common reference errors are indeed the same variable. An error from an instrument whose value changed between calibration dates is not necessarily perfectly correlated. A certificate that lists only an expanded uncertainty cannot be casually decomposed into a shared component and an independent remainder. The proper response is to request covariance information, reanalyse the underlying calibrations if possible, or present bounds obtained from plausible dependence models. A document issued under the same accreditation scheme may have entirely

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different traceability routes, while documents issued at separate facilities may still derive from one common standard.

I would ask the examiner to retain a dependency diagram with the reference standard as a single node and arrows to every affected correction. Then either perform propagation at the elementary node level or propagate certificate-level estimates with an explicit covariance matrix, but not both at once. The field result may have a wider, narrower or unchanged uncertainty after correlation is included. The sign and magnitude are conclusions of the measurement equation, not attributes of the word 'correlated'.

Ronald Newbold Bracewell, Peer Question: Sir Harold, antennas introduce uncertainties that do not resemble scalar calibration errors. The field at a survey position may be polarised elliptically; the laboratory antenna factor may have been measured in a specified plane-wave field; and a cable or amplifier can alter the terminating impedance. Would it be appropriate to add one manufacturer's antenna-factor tolerance, another generic mismatch allowance and a third polarisation tolerance as independent normal errors? Or would that produce a number with no meaningful relation to the actual uncertainty of the physical field? Please explain how the measurand, the antenna orientation and the spatial field distribution affect the uncertainty model. If the investigation is specifically about detecting a possible hidden emission rather than reporting an absolute field level, should one use the same uncertainty budget without modification? I would also require the report to distinguish uncertainty in a calibrated field component from the unknown component orthogonal to the receiving antenna, since no covariance calculation can reconstruct a component the measurement never observed.

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Sir Harold Jeffreys, Response: Professor Bracewell, the specified field component is central. A calibrated antenna factor generally applies under stated frequency, polarisation, termination and geometry conditions. If the incoming field is not a known plane wave and the antenna sits within a reactive or strongly reflecting environment, a scalar antenna factor may not describe the desired measurand. The defensible response is to define what is actually estimated: a component along the antenna's effective polarisation, a received terminal voltage, a power-equivalent indication under an explicit reference model, or a bounded search result. These are not interchangeable. The uncertainty budget must follow the selected quantity rather than convert every environmental complication into an arbitrary standard deviation.

For a simple far-field linear-polarisation example, the received voltage can contain a factor cos θ, where θ is the angular mismatch between the field polarisation and the antenna response. At θ=60 degrees, cos θ=0.5 and the voltage loss relative to alignment is 20log10(0.5)=−6.02 dB, under the idealised assumptions. If θ is unknown, the correction may be ill-defined, particularly near a polarisation null where a small angular change causes a large relative change in received level. It is inappropriate to take a tidy normal error around an unknown large attenuation and announce a tight uncertainty for the total field. Instead perform orientation sweeps, suitable orthogonal-polarisation checks and spatial substitutions, and state the scope of the detectable component.

Mismatch similarly requires interface-specific modelling. If a calibration certificate includes uncertainty from mismatch between antenna and standard load, while the field installation adds an adapter and different

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preamplifier input, the original and new interfaces must be distinguished. The same physical reflection contribution should not be listed independently in several categories merely because both an antenna certificate and cable certificate refer to mismatch. A frequency-dependent network model or an empirically measured mismatch envelope is superior to stacking generic allowances. Where the model lacks a valid correction, present alternative calibrated configurations or limits.

A detection search has another statistical question. Negative findings depend upon observation coverage, sensitivity, false-alarm control, polarisation coverage and the class of emissions the method can detect. Standard uncertainty in a field estimate conditional on successfully detecting a steady test carrier cannot establish the probability of detecting an unknown brief transmission. The report should therefore give separate calibration uncertainty and validated search-coverage limitations. Neither a highly accurate antenna factor nor multiple readings from one orientation alone prove that a concealed source was absent.

Jerzy Neyman, Cross-Peer Question to Sir Harold Jeffreys: Sir Harold, your covariance expression is rigorous when the dependency structure is known, but in practice a laboratory may supply only expanded uncertainties with coverage factors and no detailed common-reference decomposition. If the examiner fills in missing correlations by adopting zero, the resulting confidence statement can be much too narrow, while treating every input as perfectly correlated may create a needlessly pessimistic bound. What defensible procedure should govern the interval between full evidence and total ignorance? I would particularly challenge the temptation to add the same standard's uncertainty both as a common latent term and as part of

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the complete certificate-level variances. How can the manuscript show alternative dependence scenarios without presenting them as probabilities verified by experiment? And under what conditions could a partial re-calibration against an independent standard reduce rather than merely rearrange the uncertainty? Does the proposed sensitivity analysis remain valid if the certificates quote coverage intervals with different distributions or different coverage factors, rather than standard uncertainties that can legitimately enter one covariance matrix?

Sir Harold Jeffreys, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, the first principle is disclosure of what the laboratory knows. A certificate's expanded uncertainty U may equal a coverage factor k multiplied by a combined standard uncertainty u under its stated convention; one must examine the certificate rather than assume all k values are two or all distributions normal. Where the calibration provider cannot supply common-reference components, an examiner should not manufacture them. Instead identify which inputs plausibly share sources and calculate a defensible family of covariance scenarios, explicitly distinguishing measured coefficients, reasoned bounds and unverified assumptions.

For a pair of standard uncertainties u_1 and u_2 with sensitivities c_1 and c_2, the variance contribution is $c_1^2u_1^2+c_2^2u_2^2+2c_1c_2\rho u_1u_2$. If only the constraint $-1\leq\rho\leq1$ is known for that pair, one can compute endpoint values, provided those values are physically and jointly possible. For example, for two positive sensitivities and $u_1=0.5$ dB, $u_2=0.3$ dB, the combined standard uncertainty ranges from $|0.5-0.3|=0.2$ dB at $\rho=-1$ to 0.8 dB at $\rho=+1$; at $\rho=0$ it is sqrt(0.34)=0.583 dB. This interval is a sensitivity illustration, not a probability interval for ρ and not a permission to pick its

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most convenient endpoint. For several inputs, a candidate covariance matrix must remain positive semidefinite, so independently choosing every pair's extreme correlation may be inconsistent.

A partial independent calibration can narrow this uncertainty when it is designed to observe the relevant common source. For instance, compare the complete receiver-path response using a separately traceable level reference against a result obtained from the original standard. Retain the uncertainty of both transfer paths. If the difference agrees within a sufficiently small uncertainty bound, some candidate large common biases may become less plausible. But agreement does not prove the sources have no remaining shared traceability dependency or no drift under other conditions. It constrains a specific hypothesis and range.

To prevent double-counting, the analyst should choose one of two consistent parameterisations. At the elemental level, model individual reference errors and residuals as separate inputs and propagate them once. At the certificate level, retain the complete variances and add covariance between certificate estimates, but do not insert the same original reference as another independent line. A dependency diagram with source identifiers, dates and transformations is essential. When covariance remains unidentifiable, report the alternative uncertainty outcomes and their effect on the final decision. A bounded finding with honest sensitivity analysis is more persuasive than a falsely precise number generated by an arbitrary independence convention.

Dr. James M. Atkinson, Moderator: Professor Neyman, Sir Harold has written the measurement equation, but its covariance must not be filled from intuition alone. How should the survey team design repeatable tests that

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distinguish common reference drift from the independent behaviour of each component?

Jerzy Neyman, Second Principal Contributor: Dr. Atkinson, the choice of design precedes the arithmetic. If an investigator changes every antenna cable, amplifier and receiver setting in one trial, no observed change can be assigned uniquely to a given mechanism. Conversely, holding the entire chain untouched for a hundred measurements may produce deceptively low scatter because it never samples the configuration or environmental influences responsible for field error. A meaningful uncertainty experiment must state the population or ensemble to which the reported inference is meant to apply: one fixed instrument chain over one afternoon, a particular receiver over its calibration interval, or an ensemble of possible installations. Different estimands call for different designs.

A useful study begins with a stable laboratory signal injected through an explicitly documented RF path and monitored by an independent reference. Measure the receiver display as a function of generator level at several frequencies and levels to reveal linearity and gain dependence. Calibrate or verify the cable loss with a network-analyser arrangement under a defined termination. Measure preamplifier gain at its operating bias, temperature and loading, rather than assuming a catalogue figure. The antenna factor requires the relevant antenna calibration method and its geometry; an electrical substitution at the receiver input cannot establish an installed antenna's absolute field response. Keeping these distinct measurements prevents a reference substitution from being treated as a universal replacement for all physical corrections.

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To estimate common temperature influence, one could vary ambient temperature in a controlled chamber over a safe range while logging the antenna or representative network, cable, preamplifier and receiver responses. If the actual antenna cannot be chamber-tested, the limitation should be described rather than hidden. A repeated set of temperature plateaus with both rising and falling sequences can reveal hysteresis and thermal lag, which would be missed by a single linear regression. Each device may have a different response time. A multivariate analysis should distinguish a temperature effect in a shared calibration signal from individual physical temperature coefficients. Where the same thermometer measures all components, its calibration uncertainty is a common input, not independent added noise for each component.

For a simple model let measurement residual z_{ij} denote the corrected field result at temperature condition i and device configuration j. One may posit $z_{ij}=\mu+\alpha_i+\beta_j+\gamma_{ij}+\varepsilon_{ij}$, where μ is a declared baseline, α_i the temperature effect, β_j the configuration effect, γ_{ij} their interaction and ε_{ij} residual variation under the design. This is a descriptive model until the experimental sampling and error structure justify a particular inferential method. When repeated measurements are collected serially, ε_{ij} may itself be autocorrelated. Treating a long correlated trace as hundreds of independent trials would understate uncertainty. A block design with randomised order where practicable and recorded environmental history helps expose this weakness.

Cross-calibrator work is especially useful. If the receiver, preamplifier and cable corrections were all measured against one power standard, repeat selected tests with an independent standard whose traceability and

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uncertainty are separately documented. The discrepancy between those two calibration chains contains information about possible shared bias, but does not automatically identify the bias in either chain. A third comparison, or an interlaboratory procedure with stated transfer uncertainties, may be needed. A cable substitution can isolate cable-specific variation only if its connectors, bending, impedance and temperature are controlled. A receiver substitution changes receiver noise, matching and detector response; it is therefore a designed intervention, not a pure test of one coefficient unless the other consequences are measured.

Consider two observations of the same nominal field taken with separate receiver boxes but one antenna and one cable. Their noise floors may differ independently, yet the antenna factor and cable loss uncertainties are shared. Let a be the common correction error with standard deviation 0.9 dB and let independent receiver errors have 0.4 dB standard deviation each. Each result's error variance is $0.9^2+0.4^2=0.97$ square decibels. The difference between the two errors cancels a, giving standard deviation $\mathrm{sqrt}(0.4^2+0.4^2)=0.566$ dB. It would be a mistake to infer from that good differential agreement that the absolute field result has only 0.566 dB uncertainty. The shared error has simply become invisible in the comparison. This experiment diagnoses receiver agreement, not antenna traceability.

A complementary design employs crossed substitutions. Use two independently characterised cables and two preamplifiers in a small matrix, so that each cable operates with each amplifier. The raw result can reveal interactions such as amplifier input mismatch changing when a different cable is attached. Without these crossed trials, an observed gain difference

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might be falsely assigned to amplifier drift when part came from source mismatch. The experiment should also contain a complete-chain verification in which a known external field, or an appropriately traceable transfer arrangement, is observed with the installed antenna. A bench test at the receiver port tests only the electrical subsections downstream of that port.

The important output is not merely an estimated covariance table but an auditable description of how it was acquired, including sample size, trial sequence, environmental range, measurement repeatability and any selective exclusions. Statistical confidence must not be claimed merely because software reports a covariance matrix. Positive-semidefinite checks, residual diagnostics and sensitivity analysis should be applied. If the design cannot identify a correlation, provide a bounded scenario and evaluate its impact on the final conclusion rather than inventing a convenient coefficient of zero. Finally, the quantity being measured is not the source identity; a low-uncertainty field estimate does not by itself identify an emitter. I would pass the discussion to Professor Box, whose work on models should challenge whether our appealing linear relation is sufficiently faithful to reality.

Edward Weston, Peer Question: Professor Neyman, a survey team has one temperature chamber and one reference generator. They perform many measurements at three temperatures and report small standard errors for antenna, cable and preamplifier corrections. All three components were tested sequentially while the generator warmed, and only one thermometer observed the chamber. The team then claims that the corrections are independent because a statistical package reports a separate standard error for each regression. How would you design the study to expose correlated

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drift and avoid mistaking serial repetitions for independent evidence? Please describe which randomisations and cross-over tests are useful, how long-term ageing or hysteresis can confound the thermal response, and how you would handle an experiment that cannot directly characterise the installed antenna. I should also like to know what information must be retained so a second laboratory can reproduce your covariance estimates. Please identify the control that would demonstrate a change in the common generator rather than a simultaneous genuine temperature effect in all three pieces of hardware, and how its uncertainty enters the comparison.

Jerzy Neyman, Response: Mr. Weston, a regression programme describes the observations supplied to it; it cannot certify their experimental independence. I would divide the investigation into traceable reference changes, temperature changes and configuration substitutions. First, characterise the generator and its power standard independently, noting warm-up, drift and the times of each measurement. Repeat calibration observations in an order that changes the device sequence rather than always measuring antenna, then cable, then preamplifier. Where randomisation is physically possible it reduces confounding between elapsed time and component identity. Where equipment warm-up prevents arbitrary order, employ planned balanced blocks with explicit time effects in the model.

At each controlled temperature plateau, allow sufficient equilibration for the slowest relevant component and record actual component temperatures, not merely the chamber controller setpoint. Follow both rising and falling trajectories to reveal hysteresis. Duplicate some settings at the end of a sequence to measure reference drift during the experiment. Introduce a

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second independently monitored thermometer or calibrated local sensor to distinguish thermal gradients from one shared sensor bias. A single thermometer's uncertainty must appear as a common latent input to the temperature corrections. Independent random errors in separate fitting routines do not make that shared uncertainty disappear.

For the installed antenna, one cannot infer complete in-situ field sensitivity from a cable-and-amplifier chamber exercise. A traceable known-field or appropriate site-based substitution test is required, with its own geometry and uncertainty. If that cannot be performed, state a limitation and consider separate plausible scenarios. A covariance matrix estimated under laboratory conditions may not transfer to an enclosure with strong multipath, unknown antenna loading or temperature gradients. The ensemble of operating conditions must match the stated purpose of the reported result.

Retain the raw time series, calibration-source identity, device serials, full trial order, excluded observations with reasons, temperature-control history, chamber maps and the analysis code or equations. State whether the covariance is across repeated readings, calibration factors, device substitutions or operating conditions. Use confidence intervals or uncertainty estimates appropriate to the actual number of independent blocks, rather than to the total number of rapid data points. When one physical component is measured repeatedly under nearly identical conditions, successive readings are often temporally correlated; their apparent count overstates the effective independent sample size. An explicit dependency graph, crossed experimental design and independent

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reference challenge offer more useful evidence than a narrow regression confidence band produced by an untested independence assumption.

Harry Nyquist, Peer Question: Professor Neyman, consider repeated frequency-domain measurements obtained from a spectrum analyser using overlapping FFT windows. The operator has one thousand numerical readings and treats them as one thousand independent indications of amplifier gain. Yet their overlapping records share many samples, and a stable reference source imposes a common amplitude drift. How would you compute a meaningful uncertainty for the mean response without turning correlation into an arbitrary penalty? Is there a defensible role for effective sample size, block methods or separate calibration controls? Please also distinguish the statistical uncertainty of the estimated average noise power from the uncertainty in converting a receiver display into field strength. I am concerned that the same stochastic fluctuations might be included once in the empirical standard deviation and again in a manufacturer's stated receiver-noise allowance, thereby double-counting the actual variability. In particular, should the covariance be estimated separately for adjacent FFT bins and separated frequencies where filter overlap and common local-oscillator behaviour create different dependence patterns?

Jerzy Neyman, Response: Mr. Nyquist, overlapping estimates must be analysed through their covariance, not their nominal count. For observations Z_1 through Z_n with covariance matrix C, the variance of their arithmetic mean is $(1/n^2)1^TC1$, where 1 is the n-component vector of ones. If all observations had equal variance σ^2 and were independent, that expression reduces to σ^2/n. With positive autocorrelation it is generally larger. A long sequence of overlapping FFT estimates may contain much less

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independent information than its thousand entries suggest. The relevant covariance can be estimated from a sufficiently stable and representative series, using block bootstrap or time-series methods where justified, but no technique removes an unobserved shared calibration bias.

A simple illustrative case helps. Suppose each of ten nominal readings has independent error standard deviation 0.2 dB plus one common gain error of 0.6 dB. The average has variance $0.6^2+0.2^2/10=0.364$ square decibels, hence standard uncertainty approximately 0.603 dB. Treating ten complete readings as independent, each with variance $0.6^2+0.2^2=0.40$, would imply sqrt(0.40/10)=0.200 dB. That is an unjustified threefold improvement. The data may provide excellent evidence of repeatability while remaining dominated by the shared calibration component.

The distinction between field-strength and noise-power uncertainty is likewise essential. A receiver's noise estimate may affect the variance of a detector statistic and thereby the uncertainty of a field estimate near threshold, but it does not necessarily constitute an additive field correction. If the empirical standard deviation includes the receiver's relevant noise under the actual bandwidth and averaging scheme, adding the same noise variance again merely because a manufacturer lists noise performance is double-counting. Conversely, laboratory repeatability with a strong injected tone may exclude the additional uncertainty caused by field interference or detector thresholding. The model should distinguish what each experimental term represents and whether the observation regime matches the intended use.

I would organise the budget by causal origin: reference calibration, analogue path corrections, sample or detector noise, configuration effects

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and environmental influences. Each causal source should be included once, then propagated through all affected quantities with appropriate sensitivities. The trial ledger should identify overlapping blocks, window weights, detector settings and source-off conditions. An effective sample size can be a useful diagnostic but should not conceal changes in variance or correlation across frequency and time. Where correlation is uncertain, present sensitivity scenarios and qualified confidence intervals. A large spreadsheet is not itself evidence that a measurement's independent information content is large.

George Edward Pelham Box, Cross-Peer Question to Jerzy Neyman: Professor Neyman, your controlled temperature and source-substitution design seeks covariance across repeated trials, but the measurement can involve changes that are not random draws from any stable distribution. An operator may bend a cable once, tighten a connector, replace an amplifier or move an antenna in a reverberant room. The resulting change can be a switch between distinct measurement regimes, not a new sample from one population. How will your experiment detect when the model's error structure is changing rather than merely estimating an ordinary covariance more accurately? I would ask you to separate repeatability under unchanged conditions from reproducibility under installation changes, and to specify when a small pooled standard deviation conceals a systematic difference between groups. Finally, should the laboratory claim one universal uncertainty when frequency, signal power and temperature jointly affect the transfer function? What specific check would distinguish a genuinely random installation effect from a deterministic calibration shift that should be corrected before any residual variance is combined?

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Jerzy Neyman, Cross-Peer Answer to George Edward Pelham Box: Professor Box, a designed experiment must include explicit factors for the regimes whose transfer is being claimed. If bending a cable or retorquing a connector changes the physical measurement equation, the operation should be recorded as an experimental treatment, not silently pooled into a single residual. Compare trials within each configuration and between configurations. A hierarchical or fixed-effects model may describe separate groups, but the model must be justified by the intended population of future use. If the instrument is to operate only with one fixed cable routing, variation among arbitrary routings may be a stress test rather than a direct contribution to its standard uncertainty; if routine deployment includes changes of routing, the uncertainty model must reflect those possibilities or require recalibration after each change.

An illustrative two-group result demonstrates the danger. Suppose ten repeated readings before a connector change average 40.0 dB with within-group standard deviation 0.1 dB, while ten readings after the change average 41.0 dB with the same within-group standard deviation. Each group's repeatability is excellent, but the one-decibel between-group shift cannot be dismissed as ordinary short-term noise. A pooled standard error calculated without representing the configuration distinction might describe neither operational case correctly. The measurement engineer must determine whether that shift is a correction to be applied, an instability that prevents quantitative use, or evidence of a different physical coupling mechanism.

I would pre-register the relevant factors and monitor interactions: frequency, signal level, temperature, cable position, termination, amplifier

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bias and receiver attenuation state. Rather than exhausting every mathematically possible combination, use a justified factorial or response-surface design in the region where the equipment is expected to operate. Maintain controls for source drift and independent checks of the reference standards. A sudden transition or nonrepeatable response triggers investigation of model adequacy rather than automatic enlargement of a normal error distribution.

Where the response is frequency-dependent, report an uncertainty function over frequency or a set of verified bands, not one universal scalar copied to every line in the survey. The same applies to level dependence and temperature. If the user wants a single conservative summary, its derivation should state the operating envelope and the worst-case or coverage rationale. It should not pretend that different operating regimes are identically distributed. The experiment should ultimately test predictive adequacy on held-out configurations or an independent path substitution. A small fit residual within one training regime is not enough; the model must anticipate data under the conditions to which the report applies.

Dr. James M. Atkinson, Moderator: Professor Box, examine the situation where the model is tidy but the receiver is near overload, or where logarithmic units, mismatch and detector statistics produce nonlinearity. What is the practical limit of a linear uncertainty budget?

George Edward Pelham Box, Third Principal Contributor: Dr. Atkinson, a model should be judged by the decisions it supports and the observations it fails to explain. The equation for field strength in decibels is convenient because gains and losses become additive, but its convenience is not proof that the actual chain behaves linearly in the relevant signal range. A

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preamplifier near compression, a receiver showing intermodulation, an antenna subjected to a changed termination or an automatic gain-control stage may no longer respond according to the calibration factors used. No adjustment of covariance can rescue a measurement equation that has omitted a dominant physical mechanism.

Begin with the transformation between linear voltage and logarithmic units. A change of one decibel represents a multiplicative voltage ratio of 10^(1/20), approximately 1.122, when voltage and impedance conventions are consistent. Uncertainty stated as a symmetric interval in decibels is not symmetric in linear voltage. If a field reading is close to a detection threshold, one should consider whether the natural estimand is an amplitude, an energy, a logarithmic level, a probability of detection or a limit of observation. A first-order propagation of uncertainty in decibels may be perfectly adequate for a small, well-behaved calibration region, but it can mislead when the measurement distribution is strongly skewed or censored by a detection threshold.

Receiver nonlinearity is diagnosed by varying the lawful injected signal over a specified range and checking whether the reported level advances in the expected proportion. If an input is increased by 10 dB, a linear, properly configured chain should report a compatible 10 dB change after accounting for its response and measurement convention. A departure may indicate compression, automatic attenuation switching, a change in detector response or input mismatch. A data set that includes such behaviour should not be 'fixed' by increasing an uncertainty term without first determining whether a different model or operating condition is required. The safe

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output may be an inequality, a qualified lower limit or a rejection of that measurement configuration.

Mismatch is a useful example of structural dependence. The power delivered from one RF device to another depends on their complex reflection coefficients and the interconnecting network; a cable insertion-loss measurement obtained between matched reference ports is not automatically the in-situ loss between mismatched devices. The antenna factor can also be defined for a specified load and configuration. If a modeller adds a separate mismatch uncertainty to both the antenna correction and cable loss, and each calibration certificate already includes a mismatch term for the same interface, the physical effect has been counted twice. The audit should identify each interface exactly once, with a model that exposes how its reflection coefficients affect the measured voltage. A general-purpose percentage added at the end is not a substitute for defined interfaces.

An explicit example can expose the fallacy. Suppose two separate certificate entries each carry 0.4 dB standard uncertainty attributed to the same reference-level calibration. If that one common source enters the final field estimate with one net sensitivity coefficient of unity, its contribution to combined variance is $0.4^2=0.16$ square decibels, not $0.4^2+0.4^2=0.32$. But if that reference enters the receiver and amplifier corrections with opposite signed sensitivities and identical magnitude, the shared reference may cancel in the final contrast. Whether it contributes once, twice or not at all follows the underlying measurement equation. It cannot be decided from how many times the certificate printer wrote 'reference uncertainty'.

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When the linear approximation is questionable, propagate distributions through a physically validated model, as described in the supplements to the Guide to the Expression of Uncertainty in Measurement. In a Monte Carlo calculation one samples the joint distribution of input quantities, including correlations, and evaluates the measurement equation repeatedly. The resulting distribution may be asymmetric or multimodal and should be reported as such. Yet simulation does not create evidence: a million samples from unjustified input distributions merely compute the consequences of unjustified assumptions more precisely. The sources, covariances, limits, and nonlinear response must first be characterised and stress-tested.

We should also distinguish uncertainty due to a measured correction from epistemic uncertainty about whether the model contains the correct physical factors. A covariance budget cannot automatically include a hitherto unidentified intermittent connector, a frequency-selective preamplifier spur or an antenna-pattern null. These require challenge tests, receiver substitution and a limitation on inference. The investigator ought to keep a model-adequacy register: which hypotheses were tested, which remain and which were not observable with the apparatus. When a replacement antenna yields a different indication, ask whether the difference arises from external field sensitivity, input impedance, cable current or an instrument artefact. The difference does not identify a transmitter by itself.

For publication, I would separate the measurement equation, input estimates, statistical uncertainty budget, alternative-model analysis and evidential conclusion. A small uncertainty value should not be framed as the probability that a particular defendant, device or location generated the

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emission. That inference demands a different statistical and physical model. The objective of uncertainty propagation is to quantify how well one specified measurand has been measured under specified conditions. I invite Charles Proteus Steinmetz to examine the physical circuit mechanisms capable of connecting nominally independent budget entries.

Charles Hard Townes, Peer Question: Professor Box, a report presents a neat uncertainty budget in logarithmic field-strength units even though the preamplifier may have compressed on occasional strong pulses and the receiver has employed automatic attenuation. The analyst's mean level and standard deviation are nevertheless stable because the highest events were clipped or removed as outliers. Does enlarging the uncertainties for the amplifier, receiver and detector produce a defensible field estimate, or has the measurement model changed category? Would you require a separate bounded result or a rejection of the observation? Please discuss the consequences of converting a censored distribution into decibels, and the danger of treating a receiver overload warning as a minor nuisance term. Finally, explain how a model challenge test differs from merely fitting additional residual variance until the apparent goodness of fit becomes satisfactory. What experimental observation would make you refuse to compute a conventional combined standard uncertainty at all, even if each individual certificate remains within its printed date of validity?

George Edward Pelham Box, Response: Professor Townes, unobserved or clipped events cannot be restored by enlarging an error bar around their surviving mean. A calibration relation built for linear amplitude response is invalid in compression, and an instrument that changes attenuation without a reliable state record may be applying a different transfer function to

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different parts of the record. First establish what values were actually observed, which were discarded and whether the measurement response remains identifiable. Where the high values are censored by a known threshold, a censored-data model might be appropriate if its assumptions and threshold are measured. Where overload produces unknown nonlinear distortion, a bounded statement or explicit rejection may be more defensible than a formally precise estimate.

Logarithmic transformation complicates the distribution. A symmetrical normal model in decibels corresponds to an asymmetric multiplicative distribution in linear amplitude. That may be acceptable for modest uncertainties, but not if half the signal population is below threshold or the upper tail is clipped. A source capable of producing short peaks may have an average level that is not an adequate summary of the risk or phenomenon under investigation. Define whether the measurand is mean power, peak amplitude, maximum observed level, occupancy or presence of a signal class. The detector should be tested for that quantity.

A model challenge injects a known, traceable signal at several amplitudes and waveform durations and compares the observed response with the predicted measurement function. If a 6 dB increase of input power produces only 3 dB of reported increase, a nonlinear response or state change must be investigated. Merely raising the residual variance until the fit looks acceptable does not restore the missing sensitivity. Perform an independent instrument substitution, inspect gain-control and overload logs, and repeat under reduced signal levels that place the chain in its calibrated range. State when a laboratory calibration does not apply to the field environment.

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The proper uncertainty budget also depends on whether discarded data were missing at random. Removing extreme values because they appear inconvenient destroys the evidence needed to evaluate censoring and may artificially lower sample variance. Every rejected reading should have an auditable reason grounded in instrument validity rather than in the result's magnitude. If the source-off baseline remains stable but the source-on peaks trigger overload, the relevant inference is conditional on that nonlinearity. A small uncertainty for the ordinary low-level samples may still be valid within the low-level regime, but should not be presented as uncertainty for all possible transmissions.

Thus model adequacy precedes distribution propagation. Compare a linear calibration model, an explicitly measured nonlinear one and a conservative bounded statement. Present their operational differences rather than choose whichever produces the narrowest error interval. A carefully qualified absence of a quantitative result may be more scientifically responsible than a confident figure which no controlled instrument challenge can reproduce.

Charles Proteus Steinmetz, Cross-Peer Question to George Edward Pelham Box: Professor Box, a statistical uncertainty budget can describe small variations around a stable operating point, yet a transmission-line mismatch near a resonance may cause rapid frequency-dependent amplitude changes. If a nominally linear receiver shows a strong feature after moving a cable, it may be a change in delivered power rather than a source changing its output. How would you decide whether to use a first-order Taylor expansion, an explicit nonlinear network model or a bounded unknown correction? I also question whether a Monte Carlo analysis is

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appropriate when the reflection coefficients of the antenna and amplifier were never measured. Is it sound to assign them independent uniform distributions merely because their magnitudes lie below a catalogue limit, or does that substitute an arbitrary statistical hypothesis for evidence about the particular installation? Would a repeat network measurement at two different cable lengths help expose the phase-dependent ripple, or could the replacement itself change the source impedance and invalidate a naive comparison?

George Edward Pelham Box, Cross-Peer Answer to Charles Proteus Steinmetz: Mr. Steinmetz, the choice begins with a sensitivity check of the actual physical model. A first-order expansion is appropriate where plausible input changes produce a near-linear change in the output over the supported uncertainty region. If the network response is sharply resonant, or if the input uncertainty allows a reflection phase to cross a maximum or minimum, the derivative at one operating point can badly represent the range. One should then use measured network parameters with their correlations in a nonlinear calculation, or, when the parameters are not identifiable, use physically justified bounds. The words 'Monte Carlo' do not justify a guessed distribution.

Suppose a catalogue states merely that a port's reflection magnitude is below 0.2 under a specified test condition. That bound does not establish that the complex reflection coefficient is uniformly distributed in phase and magnitude in the field installation. Its phase may be constrained by cable length and component design; its magnitude may correlate with frequency, temperature and input power. Independently drawing a random phase and amplitude at every frequency can create simulated network responses that

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no passive device would actually exhibit. Such a model may be useful as an explicitly labelled stress scenario, but should not be promoted into a calibrated probability distribution without evidence.

The practical sequence is to measure S-parameters at the appropriate reference planes with calibrated fixtures and operating levels, including their uncertainty and correlation where available. Evaluate the resulting power or voltage transfer function against controlled cable substitutions. Probe sensitivity to relevant frequency, temperature and connector variations. If the model predicts the observed shifts, its uncertainty can be propagated numerically from the measured parameters. If it fails, retain the discrepancy as model inadequacy and investigate alternate coupling. One might report a conservative range without an associated probability when only bounded physical assumptions are justified.

A simple model comparison can reveal the distinction. In a well-matched configuration, a cable's measured insertion loss might change smoothly by 0.1 dB across the band. In another configuration, mismatch ripple can create a one-decibel peak-to-peak variation over a narrow interval. A single scalar cable-loss correction with 0.2 dB standard uncertainty would be unsuited to the second case unless the frequency-specific ripple had been characterised and incorporated. The correct response is not to double or triple the original correction until the reported value looks safe. The physical model should express the installation and the measured reference planes. This is a prerequisite to any worthwhile statistical refinement of the result.

Dr. James M. Atkinson, Moderator: Mr. Steinmetz, please examine conductive and reactive interactions that turn our convenient separate

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antenna, cable, amplifier and receiver entries into a coupled electrical system. Consider explicitly the test fixture and the operating temperature.

Charles Proteus Steinmetz, Fourth Principal Contributor: Dr. Atkinson, engineering drawings show boxes because boxes are convenient to manufacture, but electromagnetic energy does not recognise the boundaries printed in an uncertainty spreadsheet. The antenna, transmission line, amplifier and receiver form a network of impedances whose behaviour depends upon frequency, geometry and termination. A device's gain and loss are conventionally measured at defined reference ports; the quantities that reach the receiver under field conditions depend upon these ports being connected and loaded as assumed. When the assumptions fail, two certificate corrections may no longer describe separable physical effects.

The voltage along a transmission line has incident and reflected components. At a given reference plane the complex reflection coefficient Γ is the ratio of reflected to incident voltage waves under the applicable characteristic impedance. A cable's phase length is βl radians, with β the propagation phase constant and l its physical length. The reflection seen at one end depends on the termination reflection coefficient and a factor $\exp(-j2\beta l)$ for the round trip in an ideal uniform line. Bending, temperature or a different connector can change phase, while a poorly terminated port can create standing-wave variations. If antenna-factor calibration assumed one impedance and the installed preamplifier presents another, it is necessary to model the actual power or voltage transfer rather than add two independent mismatching allowances by habit.

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The simplest physical diagnostic is a controlled source and network analyser test, but the experiment must be framed appropriately. Measure the cable's transmission and reflection behaviour at a defined impedance, then measure its sensitivity to connector re-torque and a bounded cable bend. Characterise the preamplifier input and output return loss, gain and compression in its operating condition. Reconnect the full chain and observe whether a change of one component causes a predicted result at the receiver. When the change fails to follow the model, investigate common-mode current on the cable exterior, the enclosure return path, radiation into the amplifier chassis, or an unmodelled source of interference. None of those phenomena is properly captured by simply treating the cable as a passive scalar loss.

Consider the temperature of a cable and amplifier driven by the same ambient fluctuation T. Let cable-loss change be $k_L \Delta T$ and amplifier-gain change be $k_G \Delta T$, with k_L and k_G expressed in decibels per kelvin and ΔT in kelvin. Because the field measurement contains $+L-G$, the total first-order temperature correction is $(k_L-k_G)\Delta T$. If $k_L=0.010$ dB/K and $k_G=0.025$ dB/K, a 5 K rise produces $(0.010-0.025)\times 5=-0.075$ dB in the corrected measurement. If the temperature uncertainty is 1 K, the common temperature contribution to standard uncertainty is $|0.010-0.025|\times 1=0.015$ dB. Treating the two temperature components as independent would instead produce $\mathrm{sqrt}(0.010^2+0.025^2)=0.0269$ dB for the same 1 K uncertainty. Here the erroneous independence assumption inflates uncertainty because the sensitivities oppose one another.

The opposite can occur. If the two contributions carry sensitivities of the same sign, common temperature variation increases the combined

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response rather than cancelling it. An experimental finding that both components warm together must not lead one automatically to a correlation coefficient of +1 between their final correction errors. Their thermal coefficients, lags, temperatures and modelling residuals may differ. The relevant covariance is between the uncertainty contributions to the output estimate after proper weighting, not merely between temperature sensor readings. A physical coupling diagram and a thermal response model provide a better starting point than a guessed universal correlation.

Distributed reference standards also create common electrical paths. A power calibrator used to characterise receiver voltage sensitivity and preamplifier gain can imprint one reference bias on both quantities. If the calibrator itself drifts between the measurements, the errors may be partially rather than completely correlated. Time history, device calibration interval and a control check are relevant. The amplifier's bias supply can influence gain and also create conducted noise detected by the receiver; such a defect may produce a spectral line mistaken for a field component. A certificate for steady-state gain will not cover an uncharacterised impulsive supply disturbance. In that case the proper response may be to reject the observation, not to broaden the uncertainty after the fact.

The location of the electrical reference plane deserves particular attention in legal and forensic work. If the laboratory calibrates a cable at its own connectors, while field measurements include an adapter, a bulkhead feedthrough and an antenna balun, one must document which components are inside each correction. Connector-adapter loss could be counted twice, or omitted altogether, depending on how the certificates were applied. Use a traceable diagram, labels and photographs of the actual installation when

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permitted. Reconcile the cable assemblies, preamplifier model, antenna calibration serials and receiver configuration so that a later examiner can reproduce the exact chain. This is not decorative chain of custody; it is a physical condition for the meaning of the reported field level.

My challenge to Professor Black is to consider not only the passive network, but the feedback and noise processes inside a receiver chain. These can establish correlated errors that remain even after the linear gain corrections appear exact. A narrow uncertainty budget is credible only when the measurement process itself has survived controlled challenge and reference-plane reconciliation.

Michael Faraday, Peer Question: Mr. Steinmetz, an antenna cable is not merely a copper path between two labelled boxes. It may carry differential RF energy on its intended conductors and common-mode currents on its outer surface, and its connection to an enclosure can alter the electric and magnetic coupling of the entire system. If the cable loss certificate is a precise two-port measurement under matched conditions, how should an examiner avoid using it to conceal unmeasured field coupling in an actual survey? What would a carefully controlled change in cable orientation, shielding, bonding and termination reveal? I would also ask whether such changes should be entered as independent uncertainty components or treated as competing physical models of an instrument artefact and external signal. A fixed, quiet laboratory result may be genuinely precise while explaining little about the installed arrangement. How would you preserve a safe test arrangement while making a cable-current comparison, without changing the protective-earth configuration or introducing a new ground-current artefact?

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Charles Proteus Steinmetz, Response: Mr. Faraday, we must distinguish the intended transmission-line mode from fields and currents taking unintended paths. A two-port insertion-loss calibration generally characterises the tested assembly in a specified environment and termination. It does not automatically characterise coupling from an external field into the cable shield, transfer through a connector seam or common-mode current entering an amplifier enclosure. If the cable becomes an unintended receiving element, the simple antenna-factor-plus-cable-loss model may be incomplete, even though every individual certificate is correct under its stated conditions.

An authorised laboratory challenge begins by replacing the antenna with a known termination at the declared reference plane, leaving the remainder of the installation mechanically unchanged. Observe whether the suspected signal persists. Then repeat with another approved cable path, a controlled change of cable routing, and a properly characterised common-mode suppression arrangement where safe and compatible with the instrument. If a spectral feature follows cable position while the antenna is terminated, the hypothesis of energy entering through the cable or enclosure grows stronger. But changing routing may also change impedance or amplifier load. Record those changes rather than assign the entire effect to one desired mechanism.

The uncertainty budget should reflect the intended measurand and validated model. If a known small common-mode response can be calibrated across specified conditions, it may become an explicit correction with uncertainty. If it is intermittent, installation-dependent and poorly understood, it may instead be a model-adequacy defect that limits the

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validity of the nominal field estimate. Inflating two or three independent 'cable pickup' allowances cannot repair a missing causal model. The correct test changes one influence at a time where practicable and seeks independent corroboration through an instrument with a different signal path.

The enclosure bond and shield transfer impedance warrant attention. A cable screen may carry currents driven by nearby power wiring or instrument ground potential differences. Such currents can produce an apparent spectral component at the input even though the intended antenna port is terminated. Any test involving bonding, earth reference or energised equipment requires appropriate electrical safety controls; one should not defeat protective earth to pursue a cleaner trace. The analyst must distinguish a deliberate safe RF grounding configuration from a dangerous alteration to protective systems.

A corrected field-strength figure also requires the proper voltage reference plane. If an adapter or balun adds a calibrated loss, that loss should appear once. If the laboratory cable certificate already includes the adapter, adding an independent allowance for the same adapter counts one uncertainty twice. Conversely, if the field installation uses a new adapter not in the certificate, omission may bias the result. Document the actual connection and serialised components. The physical chain, not a neat bibliography of specifications, determines what has been measured and what remains unknown.

Harold Stephen Black, Cross-Peer Question to Charles Proteus Steinmetz: Mr. Steinmetz, the passive chain is only part of the difficulty. In a live receiver the preamplifier can respond to a large blocker or a transient input

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through its finite linearity, while its calibration certificate was obtained with a small steady tone. The operator may add a mismatch uncertainty, cable loss uncertainty, gain uncertainty and receiver display uncertainty as if each were independent. But a change in cable termination might simultaneously change the preamplifier's input match, its gain and its intermodulation products. What diagnostic would distinguish those coupled behaviours from a genuine change in the incident field? I ask particularly how the test can be conducted without violating equipment ratings, changing protective earth arrangements, or mistakenly counting one changed interface several times under different labels. How should the report proceed if the device is simply beyond its calibrated range? Please distinguish a safe independent measurement of incident power from a receiver-only displayed amplitude, because the latter may reflect the nonlinear response we are trying to discover.

Charles Proteus Steinmetz, Cross-Peer Answer to Harold Stephen Black: Mr. Black, define a safe operating envelope and test the complete installed chain inside it. Use a properly rated controlled source with protective attenuation and observe the amplifier response over several signal levels, including a strong but compliant blocking signal where this is relevant. Maintain records of input and output levels, frequency, reflected power, bias and temperature. When the source level changes by a known amount, examine whether the receiver's corrected indication changes as the calibrated gain model predicts. An unexpected level-dependent response suggests compression, gain control, intermodulation or an interface mismatch that varies with operating conditions. Such behaviour must be diagnosed rather than hidden inside a generic uncertainty category.

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To isolate the cable interface, replace a given cable assembly with an independently characterised one while holding other settings as constant as possible. Measure the reflection coefficients or return-loss behaviour of the relevant ports, and include the actual adapter stack in the diagram. If a moving cable changes a spurious response but not a known injected signal, investigate external coupling or shield current. If it changes the known signal transfer, investigate mismatch and connector continuity. If the amplifier is beyond its specified linear range, the calibration may no longer apply. The defensible choice may be a lower input level, a different attenuator configuration or an explicit inability to report a quantitative field value for that interval.

The double-counting problem can be controlled by an interface register. Each physical connection has one identity, reference plane, calibration condition and set of measured quantities. A mismatch contribution already included in the validated transfer model must not be added again as a separate independent 'cable error' and 'amplifier error' merely because it influences both. If a calibration laboratory has separately listed a port match uncertainty, examine whether the field transfer calculation already includes it. If not, state exactly how it is incorporated. Shared power or temperature influences should likewise be linked to one measured source rather than replicated in each component's column.

Finally, safety is a boundary condition. Do not lift protective earth, defeat rated input protection or expose sensitive devices to unknown high RF power for the sake of a diagnostic comparison. A test that damages the instrument may invalidate subsequent measurements as well as create a hazard. Safe substitution, source-off controls, attenuation and independent

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monitoring can test most important hypotheses. When a hazardous or uncontrolled condition prevents the necessary challenge, the report should preserve the qualification. A candidly bounded technical finding is preferable to a neat combined uncertainty derived from invalid equipment conditions.

Dr. James M. Atkinson, Moderator: Mr. Black, the preceding speakers have defined the measurement equation, experimental design and electrical coupling. Please now consider amplifier feedback, detector behaviour and shared noise, and distinguish uncertainty in an amplitude estimate from uncertainty in deciding whether a signal exists.

Harold Stephen Black, Fifth Principal Contributor: Dr. Atkinson, an amplifier is not a static gain number on a label. Its response can include finite bandwidth, impedance interaction, feedback dynamics, gain compression, noise, bias dependence and internal coupling. At a fixed frequency and small-signal level, a calibrated gain with stated uncertainty may be useful; outside that regime the transfer function can change and the uncertainty model may cease to apply. In a surveillance measurement, the particularly dangerous inference is to treat a receiver's indicated level and a preamplifier certificate as two measurements of an underlying signal, each with independent random error. The indicated level is already the result of the amplifier and receiver acting together. Their error mechanisms may share calibration, temperature, supply and even the spectrum of background noise.

A conventional amplifier-chain noise-factor treatment illustrates another place where careless addition misleads. For cascaded stages with linear power gains G_1,G_2 and noise factors F_1,F_2,F_3, the idealised Friis

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relation is $F_{total}=F_1+(F_2-1)/G_1+(F_3-1)/(G_1G_2)$. These quantities are dimensionless linear ratios, not values in decibels that can be inserted into the formula directly. The equation describes a model of cascaded noise performance under defined source impedance and linear operating conditions. It is not an uncertainty budget for measured field strength; its separate terms determine one physical performance quantity, which in turn may influence measurement variance or detection probability. An investigator who adds a receiver noise-figure uncertainty as an independent field-strength correction after already deriving statistical uncertainty from repeated receiver measurements risks counting the same fluctuating noise twice.

For a numerical teaching case, let $F_1=2.0$, the first-stage gain $G_1=10$, $F_2=4.0$, second-stage gain $G_2=5$ and $F_3=6.0$. The idealised cascade factor is $2+(4-1)/10+(6-1)/(10\times5)=2.4$, corresponding to $10\log10(2.4)=3.80$ dB noise figure. This does not state the field measurement uncertainty. It tells us how added noise compares with input thermal noise under the model. To determine an amplitude-estimation uncertainty, we would also need signal bandwidth, integration or detector behaviour, interference environment, calibration uncertainty and the relation of the estimator to the sampled data. Confusing noise figure with standard uncertainty would be a dimensional as well as conceptual error.

Feedback may help stabilise gain, but only within its design conditions. If amplifier input impedance changes, the response of the antenna-cable network can change in a way that gain calibration alone does not describe. Similarly, if automatic attenuation or gain control operates during an observation, the effective gain may change between the original calibration

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and the field measurement. A waveform with sporadic high peaks may overload the input without producing a clearly saturated average trace. Tests must therefore include controlled level stepping, known pulsed stimuli and examination of receiver state changes, while protecting the input ratings. A static input-to-output comparison over one low-level tone does not validate the entire dynamic observation range.

Detection at the threshold introduces a separate measurand. Let D be the decision that a signal is present under a declared detector and let X be the observed statistic. The conditional detection probability is P(D=1 | signal model, environment, configuration). That probability is not the same as standard uncertainty u(E) of an amplitude estimate given that a measurement was accepted. A receiver can detect nearly every strong pulse while measuring its amplitude poorly; it can also estimate the amplitude of accepted weak pulses with little apparent scatter while missing a substantial class of events. If only successful detections enter the uncertainty computation, selection or censoring can make the resulting uncertainty artificially small.

One can address this with a calibrated challenge set. Inject a known signal through the receiver port and vary the level across the relevant threshold under documented background conditions. Record all trials, including nondetections, alongside the indicated amplitudes of detections. Then repeat through the antenna path under an authorised known-field condition. Report detection and amplitude-estimation performance separately. A substitution of the receiver can show whether a particular weakness follows the hardware, but must account for changed impedance, bandwidth and signal processing. An absence of indication on either

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receiver proves only a bounded negative finding under the actual coverage and sensitivity of the test.

I would additionally challenge the claim of independent receiver confirmations. If two receivers are fed through the same preamplifier, antenna or distributor, they may share gain drift and intermittently generated intermodulation. Treating two displayed values as two independent samples may understate the uncertainty of a combined estimate. For an error model $e_i=c+r_i$, where c is a common zero-mean contribution and r_i independent residual error, the mean of n receivers has variance $u_c^2+u_r^2/n$. No number of additional receivers removes u_c. This result does not imply that multiple receivers are useless: they may diagnose individual faults and improve independent noise averaging. It requires that the report distinguish what is shared and what is separate.

A final audit should include a challenge-measurement ledger, the calibrated gain state, device and reference serials, the detected waveform class, the measured noise and overload state, and the final uncertainty derivation with covariance terms. Where the conditions are not met, report a qualified instrument indication or range rather than a falsely precise field result. A small combined standard uncertainty is not a statement of source attribution, hostile purpose or evidential conclusiveness. I return the token to Dr. Atkinson with the central proposition: every number in the uncertainty budget must correspond to a distinguishable physical or statistical input, and every common influence must be accounted for exactly once.

James Clerk Maxwell, Peer Question: Mr. Black, your model separates detection probability from amplitude-estimation uncertainty, but both can be influenced by the same noise and gain-control processes. Imagine that

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the receiver detects only those bursts whose amplitudes happen to rise above the threshold after environmental and amplifier fluctuations. The accepted readings may cluster tightly, leading the operator to infer excellent field-strength precision, while the missed bursts remain invisible. How should one avoid entering the same receiver-noise term into both a detection model and an amplitude uncertainty budget without acknowledging the statistical dependence? Please define what must be recorded for every trial, including nondetections and the evolving gain state, and explain whether a second receiver sharing the same preamplifier provides an independent challenge. The aim is to produce an evidential statement that remains sound when the signal is intermittent rather than continuously present. I would also ask how the conditional sampling changes the uncertainty if the instrument treats a succession of threshold crossings as separate transmissions instead of one physical burst.

Harold Stephen Black, Response: Professor Maxwell, the sample selection is part of the measurement process. Let S denote the event that the detector accepts a sample, and let Y be the reported amplitude estimate. The uncertainty of Y conditional on S=1 is not automatically the uncertainty of the underlying incident amplitude for all possible events. If receiver noise and gain fluctuation affect both S and Y, the conditional distribution is selected. A tight distribution among accepted samples can coexist with a high miss rate and substantial bias in the original event population. Consequently the test must retain every scheduled challenge, including its true injected level, waveform, state, decision and any resulting estimate.

The experiment should include repeated known pulses across a range of levels near threshold, with event times that explore the receiver's sweep or

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acquisition schedule. Record not merely whether each pulse was detected, but also the measured amplitude, detector threshold, false-alarm controls, gain state, reference level, preamplifier bias and any overload or reset indication. One may then estimate a conditional response surface for probability of detection and a separate conditional distribution of amplitude error among detections. Correlation between the decision and the amplitude error is not removed by giving those two results different column headings.

To avoid double-counting receiver noise, construct one joint observation model that explains how noise enters the detector and estimator. The same stochastic noise realisation must not be added as one complete extra independent variance term after its effects have already been measured empirically. An independently obtained receiver noise-figure specification may inform a physical model of expected noise but does not create a second copy of the noise present in the stored samples. If uncertainty from finite noise-model calibration remains, that is a separate parameter uncertainty with its own provenance and possible covariance.

Consider a hypothetical threshold experiment with 100 known bursts, 70 detections and 30 nondetections. If the 70 detected amplitude estimates show a 0.2 dB sample standard deviation, that describes the spread of accepted estimates under the test conditions, not a 0.2 dB guarantee for all 100 transmitted events. An estimator that clips low readings at threshold may look even more repeatable while being biased high. Report the 70/100 detection fraction with appropriate binomial or design-based uncertainty and separately report calibrated amplitude error among accepted events. A different pulse duration or polarisation may change both quantities.

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A second receiver sharing the same preamplifier remains vulnerable to a shared front-end failure. It may supply independent evidence about its own detector noise or software path, but not independent evidence that the common preamplifier did not compress or generate an artefact. A meaningful alternative path uses a separately monitored signal chain or a direct known-source reference. In the resulting report, the word 'independent' should always specify the component or uncertainty source to which it applies. That disciplined vocabulary is a stronger safeguard against double-counting than simply accumulating more instruments.

Dr. James M. Atkinson, Moderator: The panel has distinguished input uncertainty, common calibration provenance, real electrical coupling and the adequacy of the field-strength measurement equation. No certificate number should be added twice merely because the same standard appears in several device records, and no correlation should be invented to make a result seem more convincing. The correct first-order treatment is c-transpose Sigma c; the real obligation is to identify the covariance and the reference-plane model with experiments. Where mismatch, overload, threshold selection, installation changes or a nonstationary interference environment defeat the model, the honest output is a qualified result, not a cosmetically enlarged error bar. The roundtable recommends documented dependency diagrams, crossed reference and component substitutions, a controlled thermal and level-response programme, an explicit covariance budget and separate detection-performance testing. All participants’ speeches here are modern fictional scholarly reconstructions, not historical transcripts.

QUESTION 070. SOURCE REGISTER AND EDITORIAL QUALIFICATIONS

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1. NIST Technical Note 1297, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, Appendix A and §5: https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-law-propagation-uncertainty ; https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-5-combined-standard-uncertainty . Supports the combined standard uncertainty and covariance framework.

2. JCGM 100:2008, Evaluation of Measurement Data: Guide to the Expression of Uncertainty in Measurement, §§5.1–5.2 and Annex F. Correlations between estimates, sensitivity coefficients, and common reference-standard errors. Official edition should be cross-checked at publication proof.

3. JCGM 101:2008, Evaluation of Measurement Data: Supplement 1 to the GUM, Propagation of Distributions Using a Monte Carlo Method. https://www.oiml.org/en/files/pdf_g/g001-101-e08.pdf/@@download/file/G001-101-e08.pdf . Supports nonlinear propagation when the first-order approximation is not adequate.

4. Technical uncertainty claims relating to specific commercial antennas, cable assemblies, preamplifiers and receivers remain unverified for any particular deployment. Worked values are hypothetical, and the historical speeches are fictional pedagogical reconstruction.

EDITORIAL QUALIFICATION: No sample survey or field engagement is represented as an actual experiment.

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QUESTION 071

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What Constitutes One Event When Threshold Crossings Form Correlated Clusters?

Dr. James M. Atkinson, Moderator: Dr. Shewhart, a spectrum-monitoring system may report hundreds of threshold crossings during what a field engineer hears as one pulse or sees as one fading transmitter. At another setting it may report a single event encompassing two physically separate emissions. The detector is performing measurement, but the event builder is also imposing a definition. Would you distinguish a sample-level threshold exceedance from a contiguous excursion, a grouped episode, a transmission burst and an attributed emitter, explaining how the investigator may preserve the raw evidence while defining a repeatable event count?

Walter Andrew Shewhart, Principal Contributor: Dr. Atkinson, the examiner should begin by refusing to let the display's noun “event” carry several incompatible meanings. A raw exceedance is an observation made at one specified sample time or spectral cell: the measured statistic crosses a declared threshold. A contiguous excursion is a run of exceedances connected without a qualifying interruption under the actual sampling schedule. A grouped detection episode may bridge a short dip below the threshold because fading or filtering causes a single physical burst to fragment. A transmitter emission is a claim about the physical source, and emitter attribution is a still stronger inference requiring additional evidence. None of these concepts is synonymous with the others. A record should distinguish the count of raw threshold samples, the count of contiguous runs, the number of episodes under a declared merge rule and the independently supported number of physical transmissions. That distinction

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prevents an attractive event count from being mistaken for a direct observation of human or electronic intention.

Consider a sampled detector statistic z[n], with n a nonnegative integer index and Δt seconds between valid samples. Let H be an upper entry threshold and L a lower exit threshold, where L does not exceed H. A simple hysteretic state machine declares an onset at the first valid n for which z[n] rises above H while the state is inactive. It remains active until a specified condition involving z[n] below L has been satisfied. The condition may be one valid sample, a minimum duration, or a rule combining several adjacent samples. The choice matters. If H=L, noise near threshold can produce frequent on-off transitions; widening the difference between H and L can suppress rapid chatter, but may preserve an event long after its strongest energy has faded. If the noise floor changes while the thresholds remain fixed, a variation in the environment changes the crossing rate even when the transmitter does not. Therefore the threshold levels, their units, the exact comparator inequality, the rule for missing samples and the clock defining sample times are all parts of the claimed measurement. The physical phrase 'transmission burst' must not appear in a result until a separate model supports it.

An example exposes the counting dependency. Suppose valid rising-threshold excursions begin at 0, 12, 20, 250, 265 and 520 milliseconds in a controlled record. Suppose each occupies a short interval and the listed gaps between their end times and subsequent start times have been accounted for. Under a post-excursion merge gap of 5 milliseconds, all six remain separate. Under a rule joining intervals separated by no more than 10 milliseconds, the events at 12 and 20 milliseconds may join while those at

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0, 250, 265 and 520 remain distinct: five declared episodes result, assuming the 8-millisecond relevant gap is the sole eligible one. Under a 30-millisecond rule, the first three and the fourth and fifth may each form one group, yielding three episodes. The apparent difference from six to three does not indicate that the receiver lost half its samples or the transmitter changed its schedule. It is the mathematically predictable consequence of a choice made by the analyst. The precise intervals used in real software, not just rounded onset times, must be retained for repeatable counting.

The event constructor should be treated as a state machine with auditable transitions. Record each crossing's sample index, timestamp, duration, peak statistic, integrated energy, location in frequency and quality flags. Record the merge-gap criterion g in seconds; whether g is measured from end to start or onset to onset; whether equality merges; the refractory period r after a completed episode; and the behaviour at a capture boundary. A refractory period can deliberately prevent multiple triggers during ringing, but unlike a merge rule it may entirely suppress later candidate detections. The difference cannot be recovered from a count alone. If a gap in stored samples is mistaken for a below-threshold interval, the algorithm may wrongly split an event; if the programmer silently bridges the gap, it may falsely assert continuous observation. The ledger should label unobserved time rather than disguise it as either positive or negative detection.

A robust analysis has two layers. The first is immutable evidence: raw I/Q samples where authorised and available, device counters, calibrated receiver states, initial detection statistic, sample-validity mask and threshold-crossing ledger. The second is a versioned interpretation: episodes constructed under named parameter values and a precisely documented

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algorithm. One should be able to replay the same first layer through several merge gaps and demonstrate which event IDs split or unite. A report may then state: 'There were sixty-two threshold excursions and thirteen grouped detection episodes at H, L, g and r as specified; the physical number of transmissions remains unresolved.' The alternative is to announce thirteen transmissions and conceal a process whose arbitrary parameter settings could equally have produced nine or twenty. This is not mere clerical precision. The number drives false-alarm estimates, apparent source activity, enforcement consequences, and the interpretation of a negative search.

The selection of parameters should be related to an actual measurement objective. If the receiver is hunting microsecond pulses, a merge rule spanning seconds can destroy the temporal structure. If the system measures duty cycle of a slowly fading carrier, a very narrow gap may inflate apparent source activity. The calibration should include known controlled pulse sequences with variable within-burst fades and between-burst separations. Detection performance should be reported by pulse power, bandwidth, duration, modulation and receiver configuration, not a universal 'events found' value. The investigator should also distinguish a threshold event in a channelised spectral cell from a frequency-agile physical transmission appearing across adjacent cells: one emitter can cause many spectral-cell triggers. The principle is to define the measurand before selecting the algorithm and to preserve the observations from which alternative, defensible measurands can be derived.

Finally, reproducibility is stricter than a smooth plot. Two reviewers using the same raw capture, algorithm version, threshold values and time validity

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mask should obtain the same episode ledger. They need not agree that each episode represents one physical transmitter burst. That second step is a scientific inference, often underdetermined by the signal alone. The quality-control chart offers a caution: a change in plotted counts may arise from a changed observation procedure, not from a changed underlying process. Before claiming an emitter altered its behaviour, establish that gain, bandwidth, noise-floor estimator, timing and event-definition policy remained equivalent. Where they did not, show a controlled sensitivity analysis or decline the trend inference.

Peter Elias, Peer Question: Dr. Shewhart, a system that retains only grouped event identifiers has discarded the smaller threshold crossings from which those identifiers were assembled. What representation would allow two independent examiners to recompute alternative counts without retaining duplicate gigabytes of intermediate information? A reversible mapping between raw crossing intervals and grouped episodes is desirable, but event data arrive over network links whose packets may be reordered, lost, or retimed; two sites can also assign different sequence identifiers to the same physical waveform. Please distinguish stable digital provenance from a claim that the abstract data structure proves continuous acquisition. I also ask how one should record a modified merge rule so the same event identifier cannot misleadingly denote two different temporal regions after a software update. Finally, when is irreversible compression of raw I/Q an acceptable archival engineering decision, and what narrower forensic assertion remains defensible if those raw samples are no longer available?

Walter Andrew Shewhart, Response: Mr. Elias, an event record should use identifiers which refer to immutable observations, not identifiers whose

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content changes with the current display setting. Every valid threshold interval can receive a stable identifier composed of the acquisition session, device stream, monotonic hardware index at onset, and a collision-resistant record identity where justified. Store the exact sample-index endpoints and any discontinuity flag. The event builder then produces a separate, versioned grouping table mapping one declared episode to an ordered list of those underlying intervals. It can assign an analysis-specific episode identifier, but that identifier belongs to a stated algorithm version and parameter set. It should never replace the permanent crossing identifiers or imply that two software versions' episode number seven represent identical physical time.

A provenance graph can be compact. If a thousand adjacent exceedance samples form one run, one may preserve an interval with start and end indices, summary statistics, threshold definition and cryptographic linkage to the raw capture rather than store an identical record for every sample. But that compression is lossless only for the question it preserves. An interval representation cannot reconstruct the individual signal amplitudes unless those were separately retained. Nor does a ledger of received samples establish that a device did not drop samples before the counter became visible. Provenance must include the counter semantics, overflow status, acquisition configuration and a verification experiment challenging missing-data behaviour. The quality of the evidence rests on documented hardware and software boundaries, not the elegance of the index structure.

Two networked stations may observe related energy without observing the same waveform phase or timing reference. Their raw crossing identifiers should remain station-specific. A later correlation record may link

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candidates under a stated time-frequency and uncertainty rule, but should not overwrite local observations with a single universal 'event'. If clock correction subsequently changes the estimated UTC mapping, it becomes a new versioned transformation applied to the same hardware sample ranges. A robust archive records both original and corrected times with their respective uncertainties, making later reconciliation possible.

Where raw I/Q must be discarded because of capacity or retention constraints, document that decision and retain as much calibrated, independently sufficient derivative evidence as lawful policy permits: hardware-index intervals, detector statistic series at the resolution needed to reapply thresholds, instrument states, data-integrity checks and known blind periods. One may then reproduce the originally defined event count, perhaps under a bounded family of grouping gaps, but cannot credibly claim that alternative demodulation, re-filtering or classification remains possible if the requisite waveform was discarded. Compression and scientific irreversibility are different matters. The report should state the precise operations still possible, those that are not, and which original conclusions may be challenged within the preserved evidence.

Dr. James M. Atkinson, Moderator: Professor Fisher, Dr. Shewhart has defined the counting instrument as a rule operating on an observed sequence. How would you distinguish the number of threshold exceedances from the statistical number of independent extreme episodes, especially when neighbouring samples are correlated by a receiver filter or the physics of a fading emission?

Sir Ronald Aylmer Fisher, Second Principal Contributor: Dr. Atkinson, a statistical unit is not created merely by printing a new row. Exceedances in

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consecutive samples of a filtered process ordinarily possess dependence because the filter transmits information across time. A single noise excursion may keep several adjacent samples above the threshold, so treating each as an independent false alarm multiplies evidence that has been observed only once in any meaningful probabilistic sense. Conversely an isolated high observation can be one member of a long-range-dependent pattern whose dependence extends beyond the chosen merge window. Any probability calculation should state its sampling unit, null distribution, correlation assumptions and the event-extraction rule. The raw exceedance count and the cluster count are different statistics, with different expected values under the same process.

One may formalise a threshold sequence by $I[n]=1$ when $z[n]>H$ and $I[n]=0$ otherwise, but the distribution of the indicators cannot in general be understood without the covariance and higher dependence structure of $z[n]$. If $z[n]$ is derived from overlapping short-time Fourier transform windows, the adjacent windows share many input samples. If it is an energy estimate averaged across frequency bins, adjacent bins may share spectral leakage and filter correlations. If it is based upon an automatic gain-control loop, the act of observing one high signal can alter the distribution of later measurements. Thus, the probability p of $I[n]=1$ is a marginal probability, not a statement that consecutive indicators are independent Bernoulli trials. Applying the independence formula $P(\text{at least one exceedance in } N \text{ samples})=1-(1-p)^N$ would be unjustified without qualification. A lawful controlled experiment should measure the null crossing process under actual operating states and evaluate how the proposed clustering changes its event count.

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Theoretical extreme-value work considers the tendency of high threshold exceedances to form clusters in dependent sequences. One descriptive quantity is the extremal index θ under specified asymptotic and stationarity conditions; informally, values below one may reflect clustering, and in appropriate settings θ relates to the reciprocal mean cluster size. This concept is not a universal parameter of every receiver, nor is it a direct count of physical transmissions. It requires conditions that may fail in a field survey with retuning, changing interference and nonstationary noise. Published declustering methods may use runs of sub-threshold observations or inter-exceedance times. Their relevance here is methodological: event counts and cluster estimates depend on how the clusters are defined, and defensible uncertainty analysis must acknowledge that choice. No claim about θ should be inserted into a forensic report merely because a software package computes it.

Consider a calibrated no-signal experiment lasting sixty seconds. A threshold detector produces 600 valid above-threshold samples, but those samples fall into twenty bursts of thirty consecutive observations each. Under the deliberately simplified independence fiction the analyst might report 600 false events. The more meaningful output of the specified run-grouping algorithm is twenty false detection episodes. However, the twenty episodes cannot automatically be treated as independent: an interference source cycling periodically or a shared oscillator fault may produce temporal correlation between episodes. An observed average of thirty samples per cluster in this example does not establish a transmitter packet length, an extremal index of 1/30 under arbitrary conditions, or any general rate

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transferable to another site. The experimental conditions, sample cadence, threshold and clustering rule are inseparable from the result.

Uncertainty for an event rate should likewise be conditioned on exposure. Let C_g be the number of declared episodes formed under merge parameter g and let T_{valid} be the duration in seconds for which the relevant band and detector were genuinely capable of producing a valid observation. The descriptive rate is $\lambda_{hat}(g)=C_g/T_{valid}$. With $C_g=20$ and $T_{valid}=60$ seconds the descriptive figure is one episode per three seconds, or about 0.333 per second. A Poisson confidence interval based only on C_g would assume an event process that may be inconsistent with clustering or periodic apparatus faults. If events occur in blocks or strongly dependent trains, a block-resampling design, a fitted dependent point-process model, or independent repeated campaigns may be needed to estimate uncertainty. An interval that is numerically narrow under an untested independence model is not thereby scientifically precise.

The choice of threshold and merge gap can also constitute post-selection. If an investigator tries twenty combinations and selects the one which makes a hypothesis appear strongest, ordinary p-values calculated as though that choice were fixed are not valid without a correction or a fresh validation set. It is preferable to establish primary operational thresholds before examining the disputed record, using independent laboratory evidence on expected pulses and noise. Supplementary sensitivity analyses are valuable, but they should be labelled exploratory and should not be used to redefine the primary result after seeing it. Predeclared thresholds do not eliminate all modelling uncertainty; they prevent hidden choices from manufacturing

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unwarranted certainty. A transparent investigation records unsuccessful as well as successful parameter trials.

A useful experiment creates two data-generating conditions. In the first, benign random noise with a measured temporal spectrum enters the receive chain and no intentional burst source is applied. In the second, a signal generator produces known pulses of several widths, spacings and amplitudes, including within-pulse fades which deliberately cross below threshold. Analyse both with the same event constructor. The first condition measures the false episode distribution; the second measures how often one true pulse is split and how often distinct pulses are merged. Cross-validation should separate parameter development from performance estimation. If training and test data use the same random realisation, the confidence claim is circular. The outcome should be a matrix of sensitivity and error rates, not a claim that one magic gap is physically correct for all emitters.

The inferential conclusion is bounded by identifiability. The event ledger is an observable consequence of a receiver, a threshold model and a grouping rule; the source's transmission chronology is an unobserved process inferred through that apparatus. Without ground truth or independent corroboration, several source chronologies can generate the same exceedance sequence. A strong report does not hide this ambiguity. It states which event definitions were used, which parameters materially affect counts and which hypotheses remain compatible with the raw record. A statistical reconstruction is a reasoned account of evidence, not a declaration that the software's event IDs are physical facts.

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Dr. James M. Atkinson, Moderator: David Slepian, would you examine the preceding model with an independent methodological challenge?

David Slepian, Peer Question: Professor Fisher, threshold crossings in spectral detectors are not independent samples of random energy. A short-time Fourier transform with substantial overlap reuses waveform samples, while a window function spreads one tone into multiple bins; a moving broadband interferer may make several channels cross threshold together. How should a practitioner quantify dependence before applying false-alarm formulas or declustering estimates? In particular, would a simple sample correlation coefficient be enough to characterise the tail behaviour of the detector statistic, or must the study also consider the distribution of unusually high excursions and the receiver's own operating-state transitions? I would welcome a discriminating comparison between changing the amount of FFT overlap and changing the physical signal: both can alter the number of threshold crossings, yet only one is a computational decision. How should that difference enter the statistical interpretation and evidential record? Please also address whether FFT bin overlap creates correlation between channels even if temporal windows do not overlap, and whether changing window type alone can move the detected threshold-onset boundary without changing any physical input.

Sir Ronald Aylmer Fisher, Response: Dr. Slepian, a correlation coefficient between adjacent samples is a useful diagnostic, not a comprehensive dependence model. Tail clustering concerns how unusually large observations arrive together, and two processes can have similar second-order autocorrelation while differing in the distribution of rare excursions. Window overlap gives an immediate source of sample dependence because

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the same underlying waveform contributes to successive estimates. The extent depends upon the overlap, window, input noise covariance and estimator. If an engineer changes overlap from zero to 75 percent while leaving the RF input unaltered, the number of reported above-threshold cells may grow simply because the software produces more correlated estimates per second. It would be erroneous to divide that larger count by clock time and announce a higher environmental pulse rate.

The first experiment should hold a controlled receiver input constant and vary the computation alone. Acquire raw I/Q once and process the same immutable capture under several FFT overlaps, window functions and time steps, preserving the sample-time mapping. Compare both the count of exceedance cells and the number of grouped episodes under a physically defined interval rule expressed in seconds, not a fixed number of frames. If a thirty-millisecond gap is expressed as five frames at one hop size but as twenty frames at another, the analysis has silently changed its temporal rule. Properly express time boundaries using hardware indices or calibrated seconds, and assess the extent to which clustering survives a change in representation.

Next test the actual null process with no injected emission, retaining front-end state, gain, temperature, filter settings and interference conditions. Estimate the distribution of raw detector excursions, their durations, inter-exceedance times and coherent frequency structures. A periodic instrument spur can create repeated clusters of rare events despite a stable marginal noise floor. For formal extremal-index or declustering inference, examine whether the assumptions of an appropriately stationary dependent process are plausible; do not invoke an asymptotic result as a substitute for this

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engineering test. Where conditions change with instrument retuning, divide the analysis into substantively comparable states or report that a single stationary estimate is unsupported.

False-alarm rates should be measured at the same level as the reported decision. A per-cell threshold probability is not a grouped-episode false-alarm probability. Construct the exact algorithmic pipeline, including hysteresis, gap merging, refractory suppression and frequency linking, then apply it to independent null captures. The empirical distribution of episodes per valid observation interval provides one basis for operational calibration. A parametric model may improve extrapolation to rarer outcomes, but only if it reproduces observed dependence and tail structure. The calculation must state its assumed sampling units, evidence of independence between test campaigns, and uncertainty in extreme-tail estimates. Reducing the time hop does not generate new independent evidence merely because the spreadsheet has more rows.

Dr. James M. Atkinson, Moderator: Sir Harold Jeffreys, would you press Professor Fisher on the difference between a grouped statistical episode and a physical transmitter burst?

Sir Harold Jeffreys, Peer Question: Professor Fisher, an event constructor may merge repeated threshold crossings according to a fixed gap and present a count that seems precise. Yet the investigator has two plausible explanations: the crossings are fragments of one fading transmission, or they are separate pulses emitted by a source with a short inter-pulse interval. How would the evidence for these explanations be compared without assuming that the event-builder's grouping rule is itself a physical law? In particular, can the same count support different likelihoods under

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competing waveform and fading models, and what additional observation would help to discriminate them? I also ask what ought to be done when the posterior or likelihood result is dominated by a prior on burst repetition that the field data cannot realistically verify. The objective is a defensible inference, not a rhetorical probability produced by an opaque programme. Please identify which physical tests, not merely mathematical preferences, could break the inferential equivalence between a long fading emission and several independently timed pulses.

Sir Ronald Aylmer Fisher, Response: Sir Harold, the event constructor is a mapping from measured data into a reduced representation; it should not be elevated into the data-generating model without evidence. A likelihood analysis should, wherever possible, begin with the retained waveform or a sufficiently informative statistic and compare the predictions of distinct physical hypotheses. Under a fading-single-burst model the apparent below-threshold intervals may arise from channel fading, receiver noise or gain control. Under a repeated-pulse model they arise from separate emissions with a specified inter-pulse distribution. These models may assign different probabilities to the observed energy envelope, phase continuity, modulation features, received spectrum and timing. The simple count under a merge rule discards much of that information, so different hypotheses can lead to exactly the same count while having different support in the raw record.

An independent second receiver may help distinguish the models if its path and clock are genuinely independent of the first. A fade caused by local multipath might fragment the signal at one antenna but not another, whereas a genuine transmitter off interval may appear simultaneously in both after accounting for propagation and instrumentation. Yet correlation

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in the environment and common front-end control can undermine that comparison. A calibrated injected waveform test can characterise the receiver's own tendency to create below-threshold gaps. Phase continuity through a dip, where signal-to-noise ratio permits a meaningful estimate, may offer additional evidence, but phase tracking at low amplitude is vulnerable to slips and unwrapping ambiguity. No single diagnostic uniquely resolves every case.

A likelihood or posterior conclusion ought to show sensitivity to assumptions that the data cannot constrain. If the inter-pulse interval prior is chosen narrowly because the investigator expects a particular device, the resulting posterior evidence may reflect that expectation. Similarly a fading model fitted to the same disputed record and judged on its fit may overstate support if model flexibility is ignored. One should compare adequately specified models, record their fitted parameters and uncertainty, and use controlled validation data when available. If the evidence permits both source chronologies with similar plausibility, the correct answer is unresolved multiplicity, not a forced event count.

For reporting purposes, distinguish 'three grouped detector episodes under g=20 milliseconds' from 'one physical burst' or 'three transmitter pulses'. The first statement can be reproduced by replaying the event-builder rule. The latter statements require inference about the source. Provide results under several defensible g values as a sensitivity analysis, preserving the same immutable capture. The scientific value lies in identifying what changes when the measurement procedure changes, and what source-level conclusion remains invariant. A likelihood calculation cannot repair the absence of informative observations by the precision of its notation.

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Dr. James M. Atkinson, Moderator: Sir David Cox, how would you analyse recurrence after an event has been declared, given that an observation system may be incapable of detecting further activity during its own refractory or processing interval?

Sir David Roxbee Cox, Third Principal Contributor: Dr. Atkinson, a recurrence model begins by defining the risk set, the intervals during which the instrument could have observed another event. A refractory period after a trigger is not merely a convenient graphic smoothing parameter; it alters the observation mechanism. If the software deliberately ignores a second threshold crossing during that period, the resulting record is censored by design. If the hardware actually ceases sampling, the coverage is physically absent. These mechanisms may produce superficially similar event lists but require different treatment. A report that divides the retained count by total clock time without recognising the observation process confuses the propensity of a source to emit with the propensity of an instrument to accept a trigger.

For a conceptual point-process representation, let N(t) count declared episode onsets up to time t, and let Y(t) equal one when the detector is operational, observing the relevant frequency and eligible to declare a new episode, and zero otherwise. A model of observable event intensity may be written $\lambda_{obs}(t)=Y(t)\lambda(t|H_t)$, where H_t summarises relevant observed history and λ is a conditional event intensity under an explicit process model. This expression is not a universally valid law for physical emissions. It is an accounting framework that makes risk exposure visible. The observed event rate must be interpreted alongside Y(t), threshold settings, adaptive filtering and intervals in which earlier triggers suppress new declarations. A

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raw count is a poor substitute for a time-stamped sequence with its observation mask.

Suppose a surveillance system watches a band for an hour but is disabled by a software refractory policy for 0.4 seconds after each accepted event. There are 120 accepted events. If the refractory windows do not overlap, they occupy 48 seconds, leaving 3,552 seconds during which a new event might be accepted. The crude accepted rate per total time is 120/3,600, approximately 0.0333 per second; dividing by eligible time gives approximately 0.0338 per second. The numerical difference is small under this scenario, but the issue becomes serious when dead time occupies a large fraction of exposure or is correlated with a burst train. The eligible-time rate is not automatically an unbiased estimate of the physical rate, because the censoring occurs after events and may be informative. Reconstructing the underlying process needs a justified dead-time model, such as nonparalysable or paralysable behaviour, and evidence that the model applies.

In a nonparalysable idealisation an accepted event starts a fixed dead interval; other events in it are uncounted but do not extend that interval. In a paralysable idealisation an event arriving during dead time extends the period of unavailability. These conventions create different relationships between observed and underlying rates. A device's actual software may exhibit neither idealisation if processing time varies with packet size, user-interface load or front-end reset. Before selecting a correction formula, one must challenge the instrument with controlled input trains at multiple rates and retain device-status evidence. The apparent linearity of the corrected count is not proof that the selected dead-time model is physically right. An

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incorrect correction can produce more impressive, less reliable statistics than the uncorrected raw ledger.

The definition of an episode also changes the interpretation of inter-event times. If one long emission flickers across threshold several times, a short merge gap may produce a sequence of nearby event onsets. A longer gap may produce one event with an extended duration. The distribution of intervals between declared onsets therefore depends partly on processing policy, not only on transmitter behaviour. An apparently heavy-tailed waiting-time distribution could be shaped by a mixture of real source intervals, receiver retune gaps and algorithmic merging. To infer a hazard or intensity, the reviewer should examine both event onset times and coverage boundaries, stratify by instrument state and avoid treating a graph of accepted intervals as a direct sample of physical transmission intervals.

One may use alternative operational endpoints. A first endpoint is the onset of any qualifying threshold excursion; a second is the onset of a grouped energy episode; a third is a verified waveform instance classified using independent signal features. Each has a different error structure and different scientific value. In a forensic investigation the first two may be reproducibly measured even when attribution is not established. The third may require a known pilot, modulation structure, pulse shape or comparison with a second receiver. The terms should not be collapsed for the sake of tidy prose. An event study which defines only 'bursts seen by the system' must state that it reports system detections, not necessarily emitter transmissions.

Statistical inference should respect dependence among episodes. If the monitoring system's background noise changes with ambient temperature,

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local machinery or antenna orientation, a time-homogeneous Poisson model is unlikely to describe all detection events. One may stratify the observation by environmental state or use an explicitly time-varying intensity model, but this introduces model uncertainty and demands enough data to estimate it. A trigger-driven retrigger suppression creates a history-dependent observation mechanism. The investigator ought to simulate or replay the actual algorithm over a candidate physical input sequence, compare predicted and observed event records and test the inference against known inserted pulses. Without such evidence, it is safer to report sensitivity bounds across plausible grouping and dead-time assumptions.

A well-designed ledger therefore stores episode IDs alongside raw threshold intervals, observation eligibility, reason for any disabled interval, frequency coverage, hardware counters and timebase quality. It should permit two analyses: a descriptive statement about what the instrument declared, and a conditional model-based statement about what might have occurred during periods of limited observation. The distinction is indispensable in court or technical review because a negative assertion requires actual observation opportunity. The absence of a declared event during dead time cannot support the same conclusion as the absence of a crossing during a valid, calibrated search. Scientific restraint in this matter produces stronger evidence, not weaker engineering.

David George Kendall, Peer Question: Sir David Cox, consider a monitoring device receiving bursts from one emitter whose traffic comes in trains rather than at constant rate. After an accepted event it imposes a 50-millisecond refractory interval, and the next transmission may begin while

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the detector remains ineligible. A naïve analyst knows only the accepted onset times and declares long apparent inter-event gaps. What combination of observed exposure, service or processing state, and controlled input testing is necessary before fitting a recurrence law? I would ask you also to distinguish a software rule which refuses to declare a new event while it still records samples from a hardware receiver whose buffer has overflowed, since their later inferential possibilities differ sharply. Could queueing of network packets produce yet another misleading timing pattern even when capture was continuous? If the buffer returns after a delayed delivery burst, can the sample counter distinguish a merely late packet from a permanently lost segment, and how should that distinction alter the eligible-time denominator?

Sir David Roxbee Cox, Response: Professor Kendall, an accepted-event sequence should be analysed together with its observation mask and the chain producing its timestamps. When software suppresses new event declarations but preserves raw samples, it may be possible to reconstruct an alternative chronology by replaying the waveform with another refractory setting. When buffer overflow removes samples, the unobserved transmissions cannot be recovered by that method; one can only bound them under an independently justified process model. A third case is delay in delivering captured packets to a host: the sample sequence may be intact, but host arrival times are poor surrogates for RF onset. These mechanisms should have distinct quality flags. Otherwise a recurrence estimate may be dominated by errors of instrument state rather than the source's traffic pattern.

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The risk indicator Y(t) must represent eligibility for the particular event definition. If the detector is free to detect a new episode, Y(t)=1; if the detector is in an enforced refractory interval, Y(t)=0 for new declarations under that definition. This does not imply the antenna saw no energy while Y(t)=0. If raw samples are available, a different, secondary analysis can examine candidate signals during that period. A true hardware loss period is a separate observation gap. The analyst should also distinguish valid sampling in one frequency band from absence of coverage in another when the instrument is frequency-agile. The common practice of dividing accepted event count by an hour on the wall clock is valid only for a descriptive rate per scheduled clock hour, not automatically for a physical occurrence rate.

To test a proposed recurrence model, construct a programmable input stream with event trains at several inter-arrival spacings, including intervals shorter than, equal to and longer than the nominal refractory duration. For each trial retain the source's programmed event ledger and the receiver's raw counters, accepted-event ledger and processing-state log. Compare how many transmissions are detected, how many are grouped and how many disappear during refractory suppression. Repeat under host load to identify whether software queueing changes the delay between actual acquisition and stored display. If the model predicts the observed count only after one arbitrary correction, it should be challenged at different rates and different train structures before being accepted.

A mathematical count process N(t) may use the actual accepted onset times, while the latent physical emission process remains separate. Conditional intensity models for the physical process require assumptions about how an accepted event depends on previous events, how missing observation is

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generated, and whether signal amplitude affects detectability. The model cannot be identified uniquely from censored onset times alone in an arbitrary setting. A well-reasoned report can supply a sensitivity range across explicitly competing assumptions and state which are supported by laboratory evidence. A claim that the source was silent for two seconds cannot arise merely from two seconds without an accepted trigger, especially when the instrument's own refractory or transport states are unresolved.

Dr. James M. Atkinson, Moderator: Dr. Shewhart, you may put a direct question to Professor Cox concerning the observation risk interval and retrospective event reconstruction.

Walter Andrew Shewhart, Cross-Peer Question to Sir David Roxbee Cox: Professor Cox, you distinguish the detector's eligibility interval from physical transmission opportunity. Consider a field system which imposes a fixed refractory interval after a grouped episode but continues to store signal samples. If the event builder is retrospectively rerun with a shorter merge gap, it may discover two groups where the live system declared one. The live refractory clock was started at an onset produced by the old grouping rule, and the resulting suppressed detections have no independent live trigger IDs. Can a later analysis honestly compare the resulting event rates without reconstructing the actual chronology of software decisions? How should a forensic reviewer represent a period that was acoustically or electrically sampled but unavailable to the live event-counting mechanism? Finally, how would you distinguish risk exposure under the original policy from exposure under the replayed policy without treating the retrospective labels as observations that actually occurred in real time?

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Sir David Roxbee Cox, Cross-Peer Answer to Walter Andrew Shewhart: Dr. Shewhart, the distinction requires two timelines and, where possible, two counterfactual models. The actual live decision timeline must retain the onsets and ends of all accepted groups, each refractory transition, the device's raw sample availability and the detector's eligibility for another declaration under the original policy. This is a factual log of what the software did, assuming the logging mechanism was qualified. A retrospective replay of the same raw samples under a new merge gap creates a different *derived* event sequence. It cannot retroactively generate live trigger decisions, nor can it assume the original hardware or application would have behaved identically had different interrupts, buffers or classifications occurred.

If the refractory mechanism was purely a software label filter that did not alter acquisition, an offline replay may plausibly implement an alternative state machine over the retained sample stream. Even then, one should distinguish a deterministic analysis of preserved observations from a reconstruction of operational alerts that never occurred. If the live trigger affected hardware retuning, gain, memory allocation or buffering, the counterfactual is more complicated: a different event policy could have produced a different physical acquisition. In that case the raw record from one policy cannot fully represent the data that would have been gathered under another. The analyst must not substitute an algorithmic replay for a laboratory experiment which actually changes the trigger policy and measures its effects.

Represent the two eligibility processes separately. Let Y_live(t) describe actual live permission to declare an event and Y_replay(t) describe

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permission under the hypothetical offline policy, both linked to the same valid-sample mask where justified. Their denominators can differ, and neither alone gives the true source exposure if the receiver was not tuned to the relevant frequency. A quoted rate from live decisions is descriptive of live operation; the replayed rate is a derived sensitivity analysis. A physical emission-rate estimate additionally requires assumptions about missed events, dependence and observation probability, supported by known input tests.

For forensic reliability, retain the initial hardware counters, validity map, thresholds, original state transitions and replay software versions. Each derived episode should link to its constituent raw crossing intervals, and any differences in apparent event chronology should be explained as effects of parameter selection. Where dead-time suppression removed samples rather than merely alerts, mark those intervals unobserved and do not fill them with imagined transmissions. The sound conclusion may be that live operation declared four episodes while a replay of retained data declares six under a different policy, with neither number independently proving the physical burst count. Precision about the observation mechanism is more useful than pretending those counts are competing measurements of one directly observed quantity.

Dr. James M. Atkinson, Moderator: Professor Tukey, the preceding contributions establish distinct estimands and counting assumptions. What exploratory analysis could reveal an unstable event definition before a formal inferential model is trusted?

John Wilder Tukey, Fourth Principal Contributor: Dr. Atkinson, the analyst should first make the hidden construction of event counts visible. A single

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number is the end of a long pipeline: analogue input, detection statistic, threshold, interval assembly, event grouping, feature extraction and reporting. Exploratory work should display at least four aligned timelines: raw or minimally processed signal energy, binary threshold exceedances, grouped event intervals and periods in which observations were invalid. Add a fifth timeline for changes of gain, centre frequency, noise-floor estimate and classifier version. The eye can then see whether a cluster of reported events corresponds to a single physical pulse with fading, a repeated sequence of distinct bursts, or an apparatus transition. Such plots do not settle causality, but they expose obvious contradictions that a table of counts may conceal.

I recommend a parameter sensitivity surface rather than one convenient merged count. Let C(H,L,g,r) denote the declared episode count produced with entry threshold H, exit threshold L, merge gap g and refractory time r over one fixed, immutable capture. Vary one parameter at a time across an engineering-plausible range while holding the others fixed. Then examine relevant two-dimensional slices, for example count against H and g, including the total duration of selected intervals and the number of crossings excluded by refractory behaviour. If C changes violently after a minor alteration in g, the result is not a stable estimate of physical episode number. If the count is steady across a broad range, that is useful robustness evidence but still not proof of true source identity. The parameter range should be justified from signal physics and receiver behaviour rather than chosen because it looks reassuring.

An instructive invented test sequence comprises two independently generated pulses separated by 15 milliseconds, each containing internal

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fades of 3 milliseconds. A merge gap of 5 milliseconds would ideally reconnect fades within each pulse and preserve the two pulses as separate events. A gap of 20 milliseconds might merge the two transmissions as one. Yet if the receiver's IF filter itself rings for 12 milliseconds after a pulse, a 5-millisecond rule could fragment a single input pulse into multiple threshold episodes because the detector statistic contains ringing and threshold oscillations. The appropriate rule therefore depends on the end-to-end impulse response and on the smallest physical separation the measurement seeks to resolve. It should not be inferred from a parameter sweep alone. Test the whole receiver with a calibrated pulse source rather than assume that the input waveform survives unchanged into the event builder.

The number of unique 'events' can also be distorted by frequency channelisation. A signal near the boundary of two frequency bins can appear in both because of window leakage or overlapping digital filters. A frequency-agile waveform can traverse many channels in one burst. Counting independent spectral-cell threshold intervals as separate emitters would be especially misleading. Exploratory visualisation should link detections in time and frequency, display estimated bandwidth and instantaneous frequency where supported, and show whether the candidate events share a continuous underlying waveform. Conversely a wide aggregation rule may suppress evidence of two overlapping signals at nearby frequencies. The physical question must be stated: is the system counting threshold cells, time-localised episodes, separate waveforms or distinct emitters?

Do not omit the data that did not lead to an accepted event. Plot below-threshold portions, candidate detections rejected as noise, and intervals

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with no valid samples. If the receiver is retuned during an episode, the time-frequency map should contain an honest coverage gap. A display that paints black pixels while the hardware observed nothing invites a false interpretation of silence. Similarly an event grouping routine should preserve the raw crossing IDs underlying each merged episode, permitting later reviewers to undo its choices without inventing missing samples. The provenance graph should be reversible from grouped ID to constituent accepted intervals; it need not reverse to a true physical transmission if that state was never observed.

For uncertainty, one can bootstrap whole recorded blocks when dependence is local and justified by the data, rather than resampling individual samples and thereby destroying correlation. The block size itself requires sensitivity testing. If the process is nonstationary because of changing gain or interference, indiscriminate block resampling across incompatible regimes can manufacture artificial records. Another option is to use repeat calibrated experiments with known pulse trains and compare the distribution of event counts under the same frozen algorithm. A simple split of the data into development and validation intervals guards against selecting g on the same record used to claim extraordinary performance. When ground truth is available, false splitting and false merging should be shown separately.

A practical graphic might include a 'genealogy' of event IDs. At g=2 milliseconds, clusters A and B may be two declared episodes. At g=10 milliseconds they may become one episode AB. At g=40 milliseconds AB may join another, physically distinct emission C. That genealogy indicates precisely which relationships are created by the algorithm. It is more

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informative than publishing separate unconnected count tables at each g, and it allows another engineer to reproduce the effect by replay. Include the time ranges and confidence in a physical attribution; a change in grouping rules should not silently mutate a source attribution identifier used elsewhere in an evidential report.

The exploratory conclusion is not that every parameter choice should have equal authority. A defensible primary rule can be justified from a declared measurement objective and independent calibration. What exploration contributes is evidence about sensitivity, fragility and alternative readings. A robust physical finding should not depend entirely upon a borderline software choice without acknowledging that dependence. A report which provides only the winning parameter set is an advertisement for an algorithm, not a comprehensive account of the experiment. The aim is to reveal where a reasonable choice among plausible alternatives changes the decision, so that scientific qualification can be expressed before operational action is taken.

Dr. James M. Atkinson, Moderator: George Edward Pelham Box, would you examine the preceding model with an independent methodological challenge?

George Edward Pelham Box, Peer Question: Professor Tukey, a field detector is frequently applied under conditions unlike its laboratory calibration. Noise distribution changes with time, interference arrives in bursts, the spectrum is swept rather than continuously observed, and the noise-floor estimator may itself be influenced by a sought signal. How should exploratory diagnostics and model criticism identify the point at which a single merge gap or null false-event model ceases to be credible?

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Would you prefer stratification, a time-varying threshold, an explicit latent-state model, or a warning that the event count lacks an interpretable physical scale? Please explain how to avoid fitting such a flexible model to one suspicious recording and then treating its favourable fit as independent confirmation. I would also ask what the evidence ledger should show about unsampled frequency-time intervals, since a smooth count graph can make missing observation appear like measured silence. Would a time-frequency coverage diagram reveal that some quiet regions were never sampled, and how should a statistical model distinguish those regions from genuinely observed low-energy intervals?

John Wilder Tukey, Response: Professor Box, the first model criticism is to compare the claim with what the instrument actually observed. If the receiver swept through different channels, construct a time-frequency coverage map before plotting 'events per minute'. Mark intervals when the band of interest was not sampled. Overlay detector thresholds, gain changes, filter transitions and raw crossing intervals. One frequently discovers that a change in event count coincides with an observation change rather than a source change. The plot should not turn a lack of samples into zero energy or a lack of emissions. The relevant denominator is valid exposure in the particular band, and even that does not establish capture probability for a short burst without a time-response model.

I would next compare distributions within plausibly stable operating regimes. A stationary background model may be adequate during a quiet thermal interval but not while a motor is repeatedly starting or a receiver preselector is switching. Stratification by documented instrument state can be simpler and more transparent than a highly flexible latent-state model.

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But it can also create small subsets whose uncertainty becomes large. The analyst should choose the simplest explanation which survives challenge tests and must disclose when there are insufficient observations to distinguish competing regimes. A time-varying threshold can be justified if it is calibrated and logged, yet it changes the event definition. Reprocessing old and new intervals under a fixed retrospective threshold may expose the effect, provided the data and dynamic range support it.

For diagnostic plots, show the number of raw exceedances, contiguous excursions and merged episodes in parallel under a grid of threshold and gap settings. A source with genuine repeated pulses may produce a characteristic inter-excursion distribution, but so may the receiver's own filtering or interference. A broad plateau in count across several justified settings is encouraging evidence of algorithmic robustness, not source identification. The absence of a plateau is itself a finding: the count is rule-sensitive. One can report an interval such as 'between twelve and twenty-one declared episodes under the pre-specified sensitivity set', rather than forcing a single number. The exact range should come from actual replay, not a theoretical promise.

To avoid confirmation by overfitting, keep one set of data for developing the event model and a genuinely independent challenge set for validation. If only one field recording exists, use controlled laboratory perturbations and be candid that external validation is absent. Evaluate whether the model predicts results after antenna substitution, controlled injection or a change in analysis window. A model which describes the original waveform beautifully but fails under small known perturbations has not earned the inferential claims attached to it. Archive every configuration and plot

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transformation so that the next examiner can assess the same alternatives. Good modelling begins by discovering where the model fails, not by making its line pass through every observed point.

Dr. James M. Atkinson, Moderator: Professor Fisher, please challenge Professor Tukey on the interpretation of apparent parameter robustness.

Sir Ronald Aylmer Fisher, Cross-Peer Question to John Wilder Tukey: Professor Tukey, a sensitivity graph can show a plateau in the count of merged events across a broad range of gap parameters, which might appear to support an objective number of physical bursts. Yet plateaux can arise from a strong separation of inter-exceedance times even when the process is an instrument-generated oscillation, and the number of possible threshold-grid choices is itself a source of selection. How would you distinguish a genuinely useful robustness region from one manufactured by preprocessing or by choosing an attractive portion of a broad parameter sweep? Would you report the entire parameter surface, and what analysis would establish whether apparent plateau stability carries any transferable information about false splitting and false merging under different signal amplitudes or receiver states? I also ask whether a grouped-episode count can be called statistically stable merely because it is unchanged while its constituent crossings and total event duration change substantially.

John Wilder Tukey, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Professor Fisher, a plateau is a description of insensitivity to one set of analytical choices, not a test of the physical origin of the signals. The full parameter surface, or a well-defined predetermined subset, should accompany any highlighted plateau. Display the span of H, L, g and r, the number of valid samples, the counts of raw crossings and grouped episodes, and the

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changes in total grouped duration. A constant episode count may conceal a substantial migration of boundaries or a different assignment of constituent intervals. The count should therefore be supplemented by an interval-overlap metric or an event genealogy, which identifies which raw intervals join or split as settings change. A stable integer produced by changing physical interpretations is not stability of the whole measurement.

The strongest test is a blind or independently held-out set with known injected transmissions. Construct a range of pulse separations and within-burst fades, then ask whether the candidate parameter region preserves the correct physical multiplicity under those conditions. A plateau which comes from a periodic instrument artefact may perform poorly when a laboratory test introduces two pulses at a closely spaced interval; this counterexample is more informative than additional averages over the original field recording. The test must include a quiet null capture, realistic interference and changes in receive-chain configuration within the intended operating envelope. Report false splitting, false merging, missed detection and timing bias separately. One should not choose the validation pulses after discovering that the rule fails a known case and then declare the altered experiment a confirmation.

Preprocessing is a separate source of apparent robustness. An automatic gain controller, adaptive threshold or moving-average detector can remove small fluctuations and thereby make the episode count look stable across many merge gaps. That may be desirable for operational detection, but it does not demonstrate that the physical source emitted a stable number of bursts. Display at least one more primitive observable, such as raw detector energy or a calibrated pre-aggregation statistic, alongside the grouped

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output. Freeze preprocessing parameters during sensitivity analysis; otherwise a change in count may be due to the preprocessing response rather than the grouping rule under investigation.

Statistical stability should be reported as a vector of outcomes, not one integer. An episode count unchanged at twelve could accompany widely different peak energies, durations, within-episode gaps and the presence of blind intervals. The reviewer should understand which aspects of the record are invariant and which are rule-dependent. If count, timing boundaries and associated waveforms are all stable under a scientifically justified family of settings and independently known test sources, the case for a robust operational event definition improves. It still does not establish emitter identity without additional attribution evidence. If only the count is stable, report that narrow fact. The discipline is to expose meaningful sensitivity, including a failure of the analyst's preferred presentation, rather than to seek one visually persuasive graphic.

Dr. James M. Atkinson, Moderator: Professor Neyman, how should the investigator establish an event definition that can be defended before an adverse decision, and what validation evidence is required to distinguish false splitting from false merging?

Jerzy Neyman, Fifth Principal Contributor: Dr. Atkinson, a decision procedure should be stated before its outcome is known. Define the observation, the scientific hypothesis, the loss of a false detection and the loss of a missed detection. An event-building rule is part of that procedure because changing the count may alter whether a prescribed threshold for action is met. A rule which serves fault monitoring may not be suitable for forensic attribution; a rule which flags any candidate crossing may be appropriate for triage but

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misleading as a final count of transmitters. The first discipline is to separate the threshold for retaining possible evidence from the stricter requirements for reporting an independently supported physical transmission. A low-cost triage alert should not be written into a report as if it were a proven event.

Two distinct errors arise even when the basic threshold detector functions exactly as designed. False splitting occurs when one true physical burst yields two or more declared episodes. False merging occurs when physically separate emissions yield one declared episode. These errors cannot be described adequately by a single 'accuracy' percentage. For validation, construct a confusion table or event-association protocol in which each known injected burst can be related to the declared output intervals. The association rule must address overlaps, partially observed bursts, weak detections and adjacent emissions before testing begins. If the detector retains no time-continuous ground truth, some cases must be labelled indeterminate rather than assigned the outcome most favourable to the algorithm. One can then report the proportion of genuine bursts detected, the fraction falsely split, and the proportion of distinct bursts incorrectly merged, each under specified signal and environmental conditions.

Suppose a laboratory replays one hundred individual test bursts with known timing and duration, and the event constructor declares one episode for eighty-five, two for ten, none for four and three for one. The number of declared episodes is 85+20+0+3=108, while ninety-six of the hundred bursts produce at least one episode. A careless summary could announce 108% detection. The physically relevant detection probability on this test set is 96/100, or 96%, while eleven bursts were over-segmented. These figures describe the constructed test set only. They do not certify confidence in a

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new site's unmeasured signals, nor do they establish how well the system handles two genuine emissions placed close together. A second experiment must deliberately vary between-burst spacing to measure the false-merge probability.

Confidence intervals also depend on the unit of replication. If the one hundred bursts were generated in ten trains of ten, bursts within a train may share the same fading state, temperature or clock error. Treating them as a hundred independent Bernoulli trials could overstate precision. Use independent test campaigns or a clustered design in which the uncertainty analysis recognises these common conditions. Record the apparatus, seed of simulated noise where relevant, actual injected waveform and randomised sequence of test configurations. Keep acceptance thresholds fixed while examining a validation set. If the source waveform is reconstructed after the fact from the receiver recording alone, the exercise lacks independent ground truth and must not be advertised as a controlled sensitivity test.

A positive count is conditioned upon the observation process. Let N_true be the number of physical test transmissions and N_declared the number of algorithmically declared episodes. There is no algebraic identity N_declared=N_true unless specific assumptions and a validated detector establish it. Some bursts may be missed entirely, some split, and others merged. A conceptual accounting may write N_declared=N_detected+N_extra_split−N_lost_merge, where the terms require carefully defined mutually exclusive event-association conventions. This accounting is explanatory, not a general estimator of unobserved transmissions. It shows why one count alone cannot reveal which error

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predominates: two instruments can report the same number while having sharply different false splitting, false merging and missed-detection behaviour.

There should be an independent test for the rate at which purely environmental or instrument-generated fluctuations generate grouped episodes. The null experiment should include receiver noise, blocking signals, gain transitions, front-end switching and retuning to the extent they occur in the intended deployment. A decision threshold calibrated only on ideal Gaussian noise may be inapplicable when a nearby electrical motor produces impulsive interference. At high alert rates, the cost of manually reviewing false episodes may overwhelm an investigation; at low alert rates, excessively broad merges can hide distinct signals. The engineering optimisation therefore depends on an explicitly declared error cost and the required temporal resolution. It should not be retrofitted to justify a previously announced finding.

Policy controls are straightforward in principle. Freeze a primary algorithm version and parameter file; identify every data set used for development; retain complete evidence logs; conduct a validation campaign with independently known event truth; test uncertainty under correlated conditions; and require any later modification of H, L, g or r to create a new analysis version rather than overwrite the old count. An examiner may still present alternative counts as sensitivity results. The report should display how the decision would change under those alternatives and whether there is a stable conclusion across reasonable settings. Where a material conclusion depends upon choosing one arbitrary gap value, it must be

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qualified. Such transparency neither prevents practical monitoring nor requires that every signal be classified perfectly.

The final decision need not be binary. One may classify a time interval as observed energy meeting a detection criterion, as a candidate event with unresolved merging, as a verified individual waveform, or as an attributed emission supported by additional sensors. Each level carries a different evidential burden. The role of statistical design is to make the likelihood of false conclusions intelligible and to keep the inference within the evidence actually recorded. I would rather defend a modest, properly bounded count before a sceptical tribunal than present an implausibly exact activity figure obtained from an opaque grouping routine.

Abraham Wald, Peer Question: Professor Neyman, the operator is monitoring an extended session and may stop the examination when the count of detected events exceeds an alarming value. The detector threshold and gap-merging rule may have been adjusted during the session after an early run of apparent false alarms. Does the resulting evidence support a conventional fixed-sample confidence statement, or do sequential stopping and adaptive parameter changes alter its interpretation? What records should demonstrate that later results were not selectively defined by the early data? Please distinguish the legitimacy of a practical adaptive monitor, which may need to respond to changing interference, from the stronger claim that an unchanged statistical experiment was performed. I am particularly concerned about a suspected intermittent transmitter whose events are clustered, so that observing the first trigger makes a second trigger more likely than it would be under independent noise. Can a monitoring team provide a valid performance claim when the stopping

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boundary is selected after observing the largest cluster, or must a new independent validation run be conducted under the frozen policy?

Jerzy Neyman, Response: Dr. Wald, sequential monitoring is a legitimate design if its decision boundaries and update policies are part of the experiment. It becomes misleading when an analyst applies confidence formulas intended for a pre-specified fixed observation period after deciding to stop on the basis of an unusual count. A stopping rule can affect the distribution of the test statistic, especially when observations are dependent or thresholds change during observation. If a monitor stops when an apparent event rate becomes high, the retained sample is selected for high rates. Reporting it as an unbiased sample of routine activity without correcting for that selection is unsound. The design should specify whether the goal is online alerting or estimation of a stable source emission rate; one algorithm need not serve both purposes.

Adaptive thresholds can also be defensible. Suppose a receiver tracks a gradually rising noise floor so that an absolute power threshold would otherwise flood the alert ledger. The adaptive rule may preserve a desired conditional false-alarm rate, but its calibration depends upon a trustworthy reference interval and an update policy that does not absorb the very signals of interest into the noise estimate. The algorithm should log each threshold update with hardware time, underlying observations and a reason code. Data from before and after an adaptation are not interchangeable unless the statistical measurement model accounts for the change. Replaying the raw record through the frozen final setting may provide one useful comparison, but it does not erase the fact that the live operational procedure used different settings.

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For a formal sequential test, one may design stopping boundaries with specified error probabilities under explicit hypotheses and dependence assumptions. The familiar independent-observation sequential models should not be transplanted without qualification to clustered detection episodes, where a single physical burst can produce several closely spaced triggers. A safer engineering approach tests the complete alert policy against independently generated noise and burst trains, preserving the chronological decision log. Separate calibration and validation campaigns should be used, with acceptance criteria fixed before the validation run. If many candidate gap rules are explored and only the most favourable reported, a reader needs an accounting of the search process to assess selection bias.

A report should include the total valid observation time before stopping, the count and timestamps of all accepted episodes, threshold and merge-gap histories, every decision boundary applied, and the reason acquisition ended. Where adaptive monitoring was operationally necessary, one can report the resulting alerts descriptively without claiming they are a sample from an unchanged process. A subsequent independent fixed-protocol run can test the hypothesised phenomenon. The proper distinction is not between flexible engineering and rigorous evidence, but between a documented adaptive procedure and an unexamined statistical claim which pretends no adaptation or stopping occurred.

David Harold Blackwell, Peer Question: Professor Neyman, an alarm system may be designed to favour sensitivity at the expense of many false positive episodes, while a forensic report may require a much more conservative statement. How should one choose a threshold and merge-gap policy when

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false splitting, false merging, missed bursts, and unnecessary investigative interventions have different costs? Must the policy reduce these different errors to one weighted score, or can it present several operating points and permit an accountable decision maker to select among them? I am also concerned that a low threshold increases detection of weak bursts but can create a dense background of correlated crossings that a large merge gap then conceals. This could make the final event count smaller even while the raw threshold-crossing count rises. How should that counterintuitive behaviour appear in the report? If a security policy tolerates many inexpensive alerts but almost no false attribution, which stage should own the stringent threshold, and which stage should retain the original unsuppressed crossing data?

Jerzy Neyman, Response: Professor Blackwell, a single scalar score is convenient for an optimisation routine, but it is not mandatory or necessarily appropriate for a legal or scientific report. The analyst should first describe the distinct error probabilities and their practical consequences at each candidate operating point. A detector can be sensitive to weak signals yet poor at deciding how many physically separate bursts occurred. A rule can also merge threshold chatter effectively while hiding two genuine emissions that occur close together. It is therefore preferable to present a performance surface over H, L, g and r, including detection probability, false-event rate, false-split rate, false-merge rate and latency. Those quantities should be measured against independent ground truth under representative conditions.

The nonmonotonic effect you describe is important. Lowering H cannot, with all else truly fixed, make the raw set of threshold exceedances smaller

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for the same statistic and samples. It can, however, connect intervals that were formerly separated: below-threshold gaps disappear as weaker samples exceed the lowered threshold. The number of grouped episodes may therefore decrease while the number of above-threshold samples increases. This is an algorithmic topological change, not evidence that the transmitter emitted fewer bursts. An observed count versus threshold curve should include both raw exceedances and merged episodes, together with a genealogy of which intervals joined as H changed. If adaptive gain or noise estimation also changes with threshold, even the raw monotonic relation requires renewed scrutiny because the underlying statistic may no longer be fixed.

An operational decision may use an explicit loss function combining consequences of missed signals and false alerts, subject to regulatory or investigative constraints. But loss weights need not be invented by the signal-processing engineer. A security supervisor may rationally prefer an inexpensive broad triage alert, followed by a separate calibrated evidential procedure before any adverse action. One should not use the triage system's event count as if it met the higher standard of the evidential procedure. If different plausible error costs favour different policies, report the tradeoff and identify the authorised decision maker who selected the primary rule.

Finally, validate robustness against dependence. The false-alert burden observed in independent white-noise trials may be much lower than in a building containing periodic switching interference or shared instrument spurs. Test representative operating conditions and retain the rejected candidates, not only alerts surviving a grouping filter. The acceptance

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criteria must be declared before the validation campaign. Where a false-merge risk exceeds an authorised limit for closely spaced bursts, the algorithm should qualify its episode count or refer the case for waveform-level examination rather than suppress the problem by choosing a reassuring average score.

Dr. James M. Atkinson, Moderator: Professor Tukey, please examine Professor Neyman on validation after a detector design has been revised.

John Wilder Tukey, Cross-Peer Question to Jerzy Neyman: Professor Neyman, you advocate a primary preregistered event rule with quantified split and merge errors. Yet suppose the first calibration campaign demonstrates that the originally planned merge gap is inadequate because an unforeseen receiver filter causes long, amplitude-dependent ringing. Should an investigator rigidly retain an evidently defective primary rule for the sake of pre-specification, or correct it and disclose the revision? How should the ensuing test campaign avoid becoming a sequence of improvised validations in which every failure leads to another parameter change? Please distinguish the legitimate engineering development of a detector from the evidential report that claims performance under an independently frozen design. Further, what would you require if a field recording cannot be reproduced and no representative independent event-ground-truth data are available, so that only the sensitivity of its derived count to parameter choices can be observed? Would you also specify how a revision of the event policy should be recorded in a public method register, so that future independent reviewers can distinguish a genuine engineering correction from parameter choices tuned to the disputed case?

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Jerzy Neyman, Cross-Peer Answer to John Wilder Tukey: Professor Tukey, pre-specification is not a command to preserve known technical defects. It is a device for preventing an analyst from disguising choices made after seeing the outcome as though they were fixed in advance. If testing reveals that a receiver's filter impulse response produces longer ringing than expected, the correct engineering action is to revise the detector, document why, and conduct a new independent validation. The original preregistered procedure remains part of the development history; the revised version receives a new identity and may become the primary rule for a *subsequent* validation campaign. The error arises when a team repeatedly changes parameters while examining one test set and then reports the final result as an unbiased evaluation of a fixed design.

A useful governance scheme separates development, qualification and operational use. In development, explore a broad parameter set, identify failure mechanisms and choose the design. In qualification, freeze the algorithm and define acceptance criteria before exposing it to independently generated challenge waveforms. Operational use then logs every configuration and invokes a controlled change procedure for any later revision. If the real-world environment differs materially from the qualification envelope, the system can still collect evidence, but its performance claims must be qualified until the new regime is challenged. This approach allows engineering improvement without sacrificing a traceable chain of methodological choices.

Where there is only one unrepeatable field record and no independent ground truth, the correct inferential ambition is narrower. The investigator can show the raw crossings and describe how alternative plausible H, L, g

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and r values change the number and duration of grouped episodes. One can test internal consistency, recoverability from the raw ledger and sensitivity to instrument-state assumptions. What one cannot establish solely from that same recording is an unbiased physical false-split or false-merge rate for unknown emitters. A calculated confidence interval under a chosen model remains conditional on that model; it should not be presented as empirical evidence that the true number of bursts is within the interval.

A decision maker may need to act despite uncertainty, for example by commissioning a second calibrated monitoring session rather than drawing an attribution conclusion immediately. The report should state which observations are robust, which depend on the merge setting and what additional independent evidence would discriminate the competing burst chronologies. If a software revision materially changes the reported count, preserve both versions and explain the change rather than silently replacing the first. The purpose of pre-specification is accountable inference, not ritual inflexibility. The eventual publication record should permit a reader to reconstruct the development history and judge whether the stated performance was measured under genuinely independent conditions.

Dr. James M. Atkinson, Moderator: Professor Neyman, return the token to Dr. Shewhart for the concluding challenge about reproducibility and missing samples.

Jerzy Neyman, Cross-Peer Question to Walter Andrew Shewhart: Dr. Shewhart, your original distinction between raw crossings, episodes and physical emissions is essential, but I wonder whether the evidential ledger can impose too much confidence simply by making every algorithmic step reproducible. An exact replay might always produce thirteen episodes even

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when the receiver's trigger threshold was never properly calibrated, and the date-to-hardware-clock mapping contains an unmeasured discontinuity. How should the system mark the boundary between procedural reproducibility and metrological validity? Should the declared count be disqualified, rather than merely qualified, when sample continuity is uncertain? Finally, would you allow a grouped event spanning an acquisition gap to retain one episode identifier, or should the missing interval force a separation irrespective of what the signal's unobserved physical behaviour might have been? If the record includes hardware sample indices but no independent time reference during a retuning interval, which quantitative time limits can legitimately be attached to those observations, and which physical timing assertions must remain unresolved?

Walter Andrew Shewhart, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, exact replay establishes that a defined transformation applied to a defined recorded input yields the same derived output. That is valuable because it permits scrutiny of methodology and prevents arbitrary changes of description. It does not validate the instrument's calibration, the truth of the raw timestamp, or the claim that a software episode corresponds to a physical transmission. A reproducible computation can be consistently wrong for the intended measurand. Therefore procedural reproducibility belongs in one section of the evidential report, with separate metrological evidence for threshold calibration, timing continuity, coverage and the receiver response. These categories should not be collapsed into a single 'verified' tick mark.

When sample continuity is uncertain, the analyst must identify what has been lost. A known acquisition gap may still leave perfectly valid crossings

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before and after it. Those individual intervals can be reported with their original indices. What becomes unsupported is an inference of continuity through the unobserved interval. A grouping algorithm may choose to assign one *candidate* episode spanning the gap, for instance to support operational triage, but it must label the join as unobserved and explain its assumption. The forensic primary ledger should preserve two observed components with a gap marker rather than present a continuous waveform or one proven physical event. A reader may then inspect alternative hypotheses: one emission continuing through the gap, two separate emissions, or an unrelated artefact. The software must not resolve the ambiguity without evidence.

The decision to exclude an interval or qualify it depends on the claim. If the intended statement is only that at least two above-threshold observed intervals occurred, a gap need not invalidate those observations. If the statement is that exactly one continuously transmitted burst occupied the entire combined period, the missing interval prevents that inference without independent corroboration. If the gap might contain additional whole bursts, even the count of separate physical emissions may lack a useful upper bound. Where the receiver was not observing the frequency at all, the absence of triggers is no evidence of silence. A calibrated clock can make boundaries trustworthy yet does not fill the gap with samples.

An auditable implementation should therefore attach validity flags to each raw crossing and to every edge used in an episode merge. It should encode a join reason: continuous below-threshold evidence, permitted short observed dip, independent waveform corroboration, or hypothesis over missing data. The analysis can keep one display grouping for operational

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purposes while preserving the unmerged primary evidence. Establish a rule that model-based joins never silently become observations merely because later software can reproduce them. A reliable event count is an estimate whose measurement definition and limitations remain visible, not a collection of numerically tidy labels masquerading as unmediated physical reality.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The discussion has separated six distinct quantities: threshold-exceedance samples, contiguous excursions, grouped detection episodes, algorithmically suppressed candidates, waveform instances and independently attributable emissions. Hysteresis, merge gaps and refractory periods alter the declared number of episodes without necessarily changing the underlying electromagnetic activity. Statistical independence cannot be inferred from a large crossing count when FFT overlap, filtering, gain loops and physical burst trains induce temporal correlation. The panel requires immutable sample chronology, reproducible event-constructor state, an explicit valid-observation mask, controlled tests for false splitting and false merging, and transparent sensitivity analysis across scientifically justified parameter values. No expert may infer a unique physical transmission count merely from one event-builder output. This is a fictional pedagogical reconstruction, not an historical transcript or an assertion that these deceased experts examined modern software-defined radio instruments.

QUESTION 071. SOURCES AND EDITORIAL QUALIFICATIONS

Christopher A. T. Ferro and Johan Segers, “Inference for Clusters of Extreme Values,” Journal of the Royal Statistical Society: Series B, volume 65, issue 2 (2003), pages 545–556, doi:10.1111/1467-9868.00401. The paper supports

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the observation that declustering rules affect cluster estimates under stated extreme-value assumptions; it does not validate any particular RF event-builder threshold, gap, or source classification.

W. A. Shewhart, Economic Control of Quality of Manufactured Product (1931), historical foundation for controlled measurement-process interpretation. Historical author citations identify methodological lineage only; modern radio discussion is editorial reconstruction.

J. W. Tukey, Exploratory Data Analysis (1977), historical foundation for examining the sensitivity of observed summaries to analysis and plotting choices; no modern SDR procedure is attributed to the historical author.

Editorial status: All numerical cases are explicitly hypothetical. Names, historical credentials, publication metadata and each technical assertion require final independent scholarly verification prior to publication. Counts derived from controlled examples are calculations, not measured performance of any field receiver. Stage A structure, source-to-claim checking, scientific audit, cross-question semantic duplication review and whole-manuscript typography must remain separately recorded.

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QUESTION 072

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How should rare-burst searches quantify blind time and the likelihood of a missed event?

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Dr. James M. Atkinson, Moderator: Sir Ronald Fisher, suppose a frequency-agile monitoring station is connected for ninety consecutive days and reports no qualifying emission. During that period it visits one frequency for twelve milliseconds every second, sometimes loses lock, and sometimes rejects a faint pulse because the threshold or dwell criterion is not met. Would you begin by separating the objective calendar span from actual opportunity for an event to be admitted into evidence, then examine what a zero count does and does not allow us to say about an intermittent transmitter?

Sir Ronald Aylmer Fisher, Principal Contributor: Dr. Atkinson, a non-detection has meaning only after the experiment specifies what could have been detected. A ninety-day wall-clock duration is an administrative quantity, not a measure of listening opportunity at every frequency. The observation apparatus defines a coverage function c(t,f,s), with time t, frequency f and instrument state s. It takes value one where the receiver is acquiring usable evidence for that channel under declared settings, zero where it is blind, and a graded value only where detection probability has been calibrated. Antenna sensitivity, polarisation, dynamic-range state and

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propagation must also enter the model; mere scheduling is not enough. The first question is therefore not whether the instrument was powered, but which source behaviours had non-negligible probability of leaving a retained record.

Let T be total elapsed observation time, and let L be the sum of valid on-channel listening intervals for the frequency and equipment state of interest. The duty fraction $\eta=L/T$ is a useful descriptive ratio. It is not automatically the probability of detecting any transmission. If burst onsets are independent of the scanning schedule, burst durations are negligible compared with dwell intervals, and detection is perfect during valid dwell, then η may approximate the probability that a randomly timed onset lands within live coverage. Each condition matters. A burst lasting half the revisit interval can overlap a dwell even when its onset occurs outside it; a burst too short to satisfy a detector's settling requirement can be missed although part of it overlaps a dwell. A transmitter whose schedule is locked to the scanner can produce a missed event on every cycle. Thus coverage fraction is one element of a physical detection model rather than a universal statistical answer.

For a first conditional model, suppose bursts begin as a homogeneous Poisson process with rate λ starts per second, independent of receiver activity, and each start at time t is detected with independently calibrated probability p(t). The probability of no detected starts over an interval [0,T] is $\exp[-\lambda E]$, where $E=\int_0^T p(t)dt$ has units of effective exposure seconds. For a model in which $p(t)=q$ during L usable seconds and zero elsewhere, $E=qL$.

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Here q means the probability of correctly recording a qualifying burst conditional on its onset occurring in the relevant receptive state. A rate $\lambda=0.02$ bursts per hour, $L=100$ hours and $q=0.7$ gives expected detected count $\lambda E=1.4$ and probability of zero recorded bursts $\exp(-1.4)$, approximately 0.247. None of those figures is evidence that the assumed Poisson arrival model is correct. They illustrate how a substantial calendar span can coexist with a material chance of zero detections.

It is important to separate several logically different probabilities. P(no recorded bursts | λ, apparatus model) is a forward sampling probability. P(no bursts occurred | no detections) is a reverse conditional probability requiring an explicit prior or other assumptions. If source starts form a Poisson process, actual zero bursts over T has probability $\exp(-\lambda T)$. Because no true bursts implies no detections, the conditional probability that at least one burst occurred despite zero records is $[\exp(-\lambda E)-\exp(-\lambda T)]/\exp(-\lambda E)=1-\exp[-\lambda(T-E)]$, provided independent thinning and a known λ are accepted. That expression can surprise an examiner: missed bursts and accepted bursts form independent thinned subprocesses under the model. It must not be presented as an empirical posterior when λ is unknown.

A zero count can nevertheless set a one-sided conditional rate bound. Under the Poisson model with known effective exposure E and no false-count complications, a conventional frequentist 95% upper limit solves $\exp(-\lambda_{upper} E)=0.05$, giving $\lambda_{upper}=-\ln(0.05)/E$, approximately 2.996/E. If $E=70$ effective hours, the upper bound is approximately 0.0428 burst starts per hour. The statement is that rates higher than this would make a zero

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detection a less than five-percent outcome under the specified model; it is not a 95% probability that a particular unknown source rate is below the bound, and it says nothing definitive about systematic blind frequencies or deterministic timing. If calibration of E is poor, publishing three significant decimal places for λ_upper creates spurious certainty.

The physical meaning of the time coordinate must likewise be explicit. A spectrum analyser may record a detection at the end of a sweep, an SDR may tag the start of a buffer, and an application may report the moment a software event was declared. These labels do not identify the start of RF energy at the antenna unless separately calibrated. Every time interval used for L should therefore be defined by acquisition-capable hardware conditions, not by a green dashboard indicator. Reference lock, retuning, analogue preselector settling, filter memory, ADC overrun, queue overflow, recorder downtime and acquisition exceptions all generate blind intervals or degrade p(t). Preserve their actual timestamps and dispositions in the coverage ledger.

The experiment must also address amplitude and waveform. A calibrated p(t) is shorthand for p(t; A,B,W,f,π,θ,s), where A denotes incident signal amplitude at the declared reference plane, B burst duration, W relevant bandwidth or waveform class, π polarisation, θ arrival geometry and s instrument state. The same scanning schedule may detect a strong 100-millisecond pulse reliably and miss a weak 2-millisecond pulse. A negative statement is accordingly bounded to a specified source class. Tests with controlled emissions should vary onset phase, duration, amplitude, channel,

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polarisation and blocking signals. The result is a detection surface, or at least a set of conservative slices, rather than one unexplained percentage labelled 'probability of intercept'.

Finally, evidence discipline requires preserving failed opportunities as carefully as successful events. A reviewer should receive an immutable timeline of intended versus actual dwell intervals, a device-status ledger, raw or minimally processed observations where lawful and technically possible, and every analysis parameter that converts those observations into events. Without such records the denominator of the negative result is unknown. The responsible conclusion is not 'the environment was clear for ninety days'. It is that no qualifying event was recorded within documented coverage under stated detection sensitivities and model qualifications. I pass the token to Jerzy Neyman, whose examination of confidence procedures will test whether the language of that conclusion is defensible.

Sir Harold Jeffreys, Peer Question: Professor Fisher, your Poisson calculation treats each genuine emission as an independently thinned event. An investigator might quote a 95-percent upper limit after obtaining no observations, though the transmitter was never independently seen and the estimated exposure rests on a laboratory signal that was much stronger than the source of interest. Precisely which facts make that upper limit a defensible frequentist statement, and how should the result be reformulated if the calibration shows a detection probability range rather than one reliable value? In particular, could an analyst treat the endpoint of a confidence interval for the detection efficiency as though it were the true efficiency, and would doing so necessarily preserve nominal coverage?

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Please distinguish a statistical confidence procedure, a subjective belief about the presence of an emitter, and an operational decision to conduct a second search. The decision-maker may hear the word '95 percent' and imagine that the room has been shown empty with that probability. What wording would prevent that error?

Sir Ronald Aylmer Fisher, Response: Sir Harold, the upper limit arises from a sampling distribution conditional on a specified source-event model and the observation apparatus. At zero detections, a homogeneous Poisson rate and known effective exposure E yield a one-sided confidence limit approximately 2.996/E. The procedure's nominal repeated-sampling property can be checked mathematically within that model. It does not assign a probability to the proposition that the room contains no emitter; the parameter λ is treated as fixed under the frequentist construction. Furthermore, the calculation is about burst-event rate in a defined class, not necessarily the presence of hardware. A dormant transmitter has a zero operational burst rate during the search and may be fully compatible with the negative observation.

If sensitivity q is uncertain, substituting its point estimate into E=qL and treating the result as exact can understate uncertainty. A lower bound q_low derived by a justified calibration procedure may yield a conservative exposure E_low=q_low L, but the combined repeated-sampling properties of the two-stage procedure should be investigated. A calibration interval is not automatically a physical guarantee. If the instrument's performance depends upon temperature, input level, attenuation, waveform and blocker conditions, a scalar q_low for one laboratory arrangement cannot be

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transferred to every field circumstance. One can report conditional limits for several declared sensitivity cases, or perform a joint uncertainty analysis of calibration and event counts. The latter requires identifying correlations, including shared reference sources and common testing artefacts.

The operational conclusion should be in measured terms. 'No qualifying bursts were recorded during E effective hours of sensitivity to the stated waveform and level; under a homogeneous-Poisson start model, the corresponding upper rate limit is …' is a defensible kind of sentence if the premises are met. 'There is a 95-percent probability no transmitter was present' is not. The latter would require a different hypothesis framework, prior information and a model linking equipment presence to event generation. A second survey may be prudent because the consequences of a miss are severe, but that judgement is not a confidence level. I would preserve the complete coverage ledger so that the claim can be independently recalculated rather than asking the reader to trust a printed percentage.

David Harold Blackwell, Peer Question: Sir Ronald, the value of further observations depends on what they might distinguish, not merely on the number of hours purchased. Suppose the search has produced no bursts after a thousand scanner revisits, all with essentially identical phase relative to a device suspected of sending periodic reports. Would another thousand identical revisits provide new evidence, or should the investigator change the design by randomising scan phase or assigning a continuously monitoring receiver? How would one compare the expected information gain of those alternatives without assigning invented probabilities to an

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adversary's behaviour? I also want to know how you would treat a second receiver connected to the same timing reference and antenna distribution path. Its independent computer display may create a sense of corroboration even though the two observations share blind time and front-end overload. What does a defensible search plan owe to this possibility of common-mode failure? Would a confidence statement have the same operational meaning if the independent reference used to verify the second instrument were itself switched off during every suspected burst? In that case the investigators would need to confront the absence of a genuine independent witness rather than merely total detector count.

Sir Ronald Aylmer Fisher, Response: Dr. Blackwell, if the observations repeat a perfectly correlated failure mode, multiplying their count adds little evidence about events that always occupy the blind interval. A different schedule or genuinely independent instrument can be more informative than extending the same sequence. Before an experiment, one may examine several source hypotheses and ask which intervention changes their predicted records. A scanner-phase randomisation helps discriminate a periodic source from a source that never transmits, provided the randomisation is real and its range covers the relevant phase. A fixed-channel monitor eliminates certain scan gaps but still has detection-threshold, bandwidth, overload and recording vulnerabilities. Neither design is an absolute guarantee; each removes a specified class of explanation for the empty record.

We should compare designs using bounded performance rather than ungrounded probabilities. For example, one can demonstrate that a channel

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observed continuously with an independently calibrated receiver would capture any burst lasting at least 10 milliseconds and exceeding a stated level under tested conditions. That claim is restricted but operationally powerful. A scanner with 10 milliseconds of dwell every second may have a much lower probability of observing a 4-millisecond burst under the uniform-phase model, while potentially remaining wholly blind to a synchronous source. The experiment can measure the probability under randomised injection and exhibit explicit deterministic schedules that fail. The comparison then presents an empirical detection surface and worst-case gap properties, not a mystical measure of information.

As for two receivers, their physical independence must be established at the level of failure mechanisms. Distinct hardware with a shared antenna splitter and common reference may be independent against some digital-processing faults but dependent against cable disconnection, shared reference failure or overwhelming environmental interference. In a joint acceptance test, deliberately challenge those shared pathways under safe laboratory conditions and measure the probability of joint misses for the specified source class. If the systems have unresolved common modes, treat the joint evidence as dependent and say so. A second display is no more a second witness than two copies of the same log file. A practical acceptance trial should also record negative controls when the source is deliberately silent. These establish a false-alarm baseline and reveal artefacts caused by the receiver's own tuning transitions. If those controls fail, a superficially favourable detection fraction alone is not sufficient to sustain a source-detection claim.

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Sir Ronald Aylmer Fisher, Cross-Peer Question to William Feller: Professor Feller, your successful-onset geometry can describe the capture of a finite pulse without assigning a stochastic law to the source. My Poisson-thinning approximation instead treats onsets as points with independently varying detection probabilities. Precisely when can the first formulation be used to justify the second? Suppose the source durations vary and the detection probability is higher for long bursts; the observed sample may then overrepresent long bursts and underrepresent short ones even if their occurrence rates were equal. What integral should replace the simple exposure E=qL, and how would you prevent the estimator from assigning a single average burst duration when its distribution is unknown? I also want an answer about dependence between successful-onset windows: if a burst spans two nominal revisits, should a pair of detections represent two independent trials or one physical event? The operational stakes are substantial because a mistaken count can inflate an upper-rate estimate or make non-detection appear more conclusive than it is.

William Feller, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Sir Ronald, a marked point process offers a disciplined extension. Associate each burst start u with a duration B and other source marks, such as frequency trajectory and amplitude. Let g(B,A,f,...) be their assumed or independently measured mark distribution, and let p(u,B,A,f,...) be the calibrated probability that an onset with those marks leaves one qualifying recorded event. Under a Poisson start process whose marks are independently distributed according to g, the expected number of recorded burst events is $\lambda\int_0^T\int p(u,m)g(dm)du$, where m denotes the mark vector. The zero-count probability is the exponential of the negative expectation under those

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assumptions. If duration distribution is unknown, that integral is not numerically identifiable merely from a zero-count record; one must report a scenario range or obtain independent duration information. Replacing it with a convenient mean duration can be wrong because p is usually nonlinear in B.

The successful-onset geometry can supply the p(u,B,...) function in an idealised limit where the reception conditions and decision threshold are deterministic. Once receiver noise, propagation, frequency error and classifier failures enter, the geometrical eligibility must be combined with empirical conditional response. It would be incorrect to count the same physical burst twice merely because it overlaps two scan windows. Define an event association rule using retained time and frequency information, and evaluate it against injected multi-window bursts. The event count k in a Poisson likelihood is the number of underlying qualifying burst starts inferred by the detection protocol, not the total number of raw crossings. If ambiguity remains, one can bound k and give sensitivity analyses rather than silently assert independence.

A final complication concerns bursts that influence the receiver after their RF emission ends. Filter ringing or decoder buffering may produce indications outside the geometrical overlap. Those artefacts must be included in the observation model but should not be treated as separate true starts. When the physics of the receiver is too complicated to calculate p analytically, randomised injection trials over the relevant mark space provide empirical estimates. The transition from geometric coverage to probabilistic exposure

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is legitimate only when the model, source marks and counting rule are declared and tested.

Dr. James M. Atkinson, Moderator: Professor Neyman, Sir Ronald has supplied a useful conditional sampling model. Would you examine the design of a negative-search experiment, particularly the difference between a calibrated confidence bound and a post hoc expression of reassurance?

Jerzy Neyman, Second Principal Contributor: Dr. Atkinson, the first protection against an unwarranted negative claim is experimental design before the search begins. One must decide the source behaviours that matter, the decision rule, the unacceptable chance of missing a consequential event, and the field conditions under which the receiver will operate. A target such as 'at least 95% probability of recording one qualifying burst if events occur at rate λ_0' can be converted into an exposure requirement under an explicit model. It cannot be met simply by waiting an arbitrary number of days and later treating the absence of alarms as assurance.

For the homogeneous Poisson-thinning model introduced by Fisher, the probability of at least one detection is $1-\exp(-\lambda_0 E)$, where E measures effective exposure. Requiring at least 0.95 detection probability gives $E \geq -\ln(0.05)/\lambda_0$. If the operational design rate is $\lambda_0=0.1$ qualifying bursts per hour, E must be at least approximately 29.96 effective hours. Suppose the receiver's live-on-channel duty factor is 0.05 and conditional detection probability is 0.8; the average effective fraction is 0.04, so achieving $E \approx 30$ hours would require approximately 749 hours of elapsed monitoring under stationary, independent scheduling conditions. The arithmetic exposes the

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importance of the denominator. The calculation does not apply to periodic transmitters deliberately phase-aligned with the scanner, to intervals where front-end overload collapses q, or to an event process that changes rate according to time of day.

A confidence procedure has an operating characteristic over repeated experiments generated under the adopted model. It does not automatically assign probability to the fixed but unknown event rate in the realised investigation. This is more than an academic nicety. If a zero-count upper limit of three divided by exposure is presented without verifying the rate model, it can make an instrument's blind periods disappear rhetorically. The laboratory should validate its method with controlled event injections and report sensitivity against a range of amplitudes, burst durations, frequency offsets and arrival phases. It should also disclose the uncertainty in the measured exposure itself. One can sometimes replace uncertain p(t) by a conservative lower bound, but the provenance and operating range of that bound must be established.

Sampling design should reduce the risk of synchronised noncoverage. A perfectly regular scanner may revisit a channel every second, while a burst generator emits periodically at nearly the same interval. If relative phase remains in the blind portion of each cycle, even a very long survey may yield no detection. Randomising or staggering revisit times, using parallel fixed-channel monitors, or varying dwell policies can reduce this deterministic failure mode, but each choice changes the observation process and must be recorded. Randomisation does not permit a probability claim unless the

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randomisation mechanism and the transmitter assumptions are both specified. A fixed-channel recorder may be a more defensible witness for a particularly high-consequence frequency than any scanning strategy.

The question of a negative report is often adversarial in the scientific rather than the personal sense. An examiner should be asked what alternative process would produce the same empty record. One alternative is that no relevant transmitter was active; another is that bursts occurred entirely during blind intervals; another that the waveform was below threshold, overwhelmed by blockers, or filtered by the selected bandwidth; another that samples existed but software discarded the event. A designed experiment should include challenges capable of distinguishing those alternatives, using an independent receiver or injected benign reference where necessary. If they cannot be distinguished, the report must state the residual ambiguity.

Uncertainty caused by one shared reference must not be counted as independent evidence from multiple channels. Two monitoring receivers disciplined to one failed oscillator may show aligned gaps or identical timestamp errors. Nor does running the same analysis over the same raw file produce a second observation. Confidence calculations based on multiple stations require an appropriate dependence model and a test of the actual joint detection probability. The combined chance that two stations both miss an event is not generally the product of their individual miss probabilities; it may be much larger when they share propagation shadowing, front-end overload or power failures.

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A useful verification plan is a matrix of source state, observation state and action. For each trial, the test transmitter's timing and power are logged by an independent source, while the survey system records the intended dwell, actual hardware capture, any packet loss, and the detection decision. Trials are repeated at randomised onset phases. Each trial should be traceable to one source event, not multiple threshold crossings counted as independent confirmations. The test then estimates a conditional detection curve, with appropriate uncertainty intervals. Because the number of trials needed can be substantial near very high target probabilities, the operator must not infer 99.9% detection simply from ten successful demonstrations.

I would also separate operational decision costs from statistical confidence. For a high-consequence search, a false assurance may be more harmful than allocating additional observation time, but excessive sensitivity can produce a flood of false alarms that exhausts the review process. The acceptable trade-off is a policy choice to be declared openly, not hidden inside a detector threshold. The final report should present the decision rule, observed event count, calibrated detection envelope, time-frequency coverage, untested circumstances and the exact claim supported. I pass the token to Abraham Wald because sequential monitoring, with adaptive stopping rules, requires particular care when the result remains negative.

George Edward Pelham Box, Peer Question: Professor Neyman, your planned confidence procedure depends on an observation model that may be only approximately true. Engineers often measure q from a clean laboratory waveform, then deploy the receiver amid reflections, strong

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blockers and irregular bursts whose properties do not match the calibration source. How would you test whether the model has failed in a practically material way? I am also concerned that elaborate probability calculations can give a false sense of security when fundamental controls such as antenna orientation, sample continuity and reference-lock records are absent. What diagnostic experiments would you require before accepting an effective-exposure calculation, and how should competing explanations of a negative finding be incorporated without turning the report into an unmanageable catalogue? A precise answer should preserve the distinction between a useful conditional approximation and an experimentally established performance claim. If the preselector switch briefly produces a response indistinguishable from a real burst, how should the analyst prevent an apparent increase in sensitivity from representing increased false positives instead of greater access to real source events?

Jerzy Neyman, Response: Professor Box, a model is a disciplined simplification of an apparatus, not a replacement for measurement. The first validation asks whether the calibration population resembles the operational source class on which the negative inference depends. If the claim covers weak frequency-agile bursts under blockers, then the injection campaign should vary amplitude, dwell phase, pulse width, hop frequency, preselector and gain state, antenna path and blocker level. The empirical detection proportion and its uncertainty should be compared with the p(t) used in the exposure integral. Where the observed response varies sharply with a factor that the model omitted, the model must be refined or its claimed domain reduced. A single clean-signal calibration value may be adequate for one narrow statement and inadequate for a general room-

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clearance conclusion.

The field record should retain enough structure to identify missing opportunity. Intended schedule, hardware-ready state, reference lock, tuning transition, raw sample counters, overflow warnings and detector settings form the minimal acquisition ledger. An independent known stimulus can verify that the chain remains responsive during the survey, though it cannot prove sensitivity to every unknown waveform. Check the known stimulus through the actual antenna or calibrated injection plane, and document when such a test changes the receiver's operating state. A blank spectrum display during a disabled or overloaded receiver is not negative evidence in the same sense as a blank display during a validated measurement window.

One can manage competing explanations through a short table of falsifiable hypotheses. 'No relevant source emitted'; 'events fell in blind intervals'; 'events were below threshold'; 'instrument created or suppressed features'; and 'data were lost before logging' are useful initial categories. Each should be linked to a challenge test and a residual qualification. If the test does not discriminate them, their ambiguity should remain in the report. I would rather publish a conditional result with an honest coverage envelope than one confidence number whose most important premises were never challenged. The calibration plan should use both source-on and source-off trials with matched receiver settings. A measured improvement in the probability of declaring an alarm is not necessarily an improvement in useful discrimination if the false alarm rate rises at the same time. Each rate should

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be reported explicitly, and comparisons must preserve source amplitude and environmental conditions.

Walter Andrew Shewhart, Peer Question: Professor Neyman, rare-burst detection is frequently entrusted to an instrument whose response slowly changes with temperature, connector ageing, local interference and software updates. If the probability of detecting a standard test burst fluctuates over a long search, how would a practitioner avoid applying yesterday's calibration to today's observation? Could a control chart or periodic test stimulus reveal an unstable acquisition process without becoming confused with the actual environment being monitored? Please consider what happens when a failed test makes some earlier hours suspect, because a simple rule that invalidates only future hours may be unduly optimistic. Conversely, an automatic method that discards every difficult interval after an unexpected outcome may manufacture a falsely reassuring data set. What principles separate sound process control from retrospective selection of favourable observations? What happens if the device's health-check pulse follows a different analogue path from the unknown environmental emission? A reported pass might then validate only the digital detector while leaving a disconnected antenna cable wholly untested, thereby overstating the period of credible monitoring.

Jerzy Neyman, Response: Dr. Shewhart, the chronology of instrument competence is essential. A calibration establishes performance under specified conditions at a particular time and configuration. During long deployment, known benign reference signals can challenge whether the measurement chain still responds at defined levels and bandwidths. The control chart may flag changes in amplitude, timing, trigger rate or noise

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floor, but its thresholds must be selected before examining the operational detections if the process is to support a valid inference. A flagged state should initiate investigation of hardware, environmental and software changes rather than an automatic assertion that a hostile transmitter has appeared or disappeared.

If a reference check fails at the end of an interval, the period during which performance was compromised may be unknown. One sensible approach brackets the failure between the last demonstrated good check and the first demonstrated bad check, then describes alternative exposure calculations that exclude progressively more of that uncertain period. Additional retained diagnostics might narrow the interval. It would be unjustified to count all intervening hours as fully sensitive merely because the system was powered; it would also be questionable to erase all difficult data without explaining why. The original observation ledger, check failures and correction decisions should remain immutable so that a later reviewer can reconstruct the judgement.

The mathematics of confidence bounds can be applied to state-specific exposure, but only after those state assignments are defended. For example, if 40 hours have calibrated detection $q=0.9$, 20 hours have uncertain q between 0.2 and 0.6, and 40 hours were wholly blind, the effective exposure lies between $40\times0.9+20\times0.2=40$ hours and $40\times0.9+20\times0.6=48$ hours under the specified onset and waveform assumptions. It is incorrect to use 100 hours as effective exposure. This interval is a measurement-management result, not a probabilistic

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confidence interval unless additional assumptions justify that language. Process control should make the limits of the data more visible, never silently improve them. The test injection reference plane determines the claim. An internally generated digital stimulus can validate later software stages but does not challenge the antenna, cable or analogue input. A test applied near the receiver front end covers more stages, while an appropriate over-the-air calibration challenges propagation and antenna response as well. These tests have different limitations and must not be conflated.

Jerzy Neyman, Cross-Peer Question to Andrey Nikolaevich Kolmogorov: Professor Kolmogorov, you have warned that the Poisson model may be inappropriate when source bursts are periodic or clustered. Yet operational decisions still require confidence statements even where the source process is not known. Can we develop a useful worst-case assurance guarantee from a known observation schedule without assigning a distribution to source timing? Suppose a critical band is monitored for only ten milliseconds every second, but the operator can randomise dwell phase over many cycles. Is it sufficient to say that each possible onset is eventually covered, or must a guarantee also specify the number of bursts, their minimum duration and the independence of the randomisation? I would ask you to distinguish probability under the investigator's randomised measurement policy from probability under the unknown transmitter, and to explain how adversarial scheduling changes the mathematics when the emitter may learn or predict the search routine.

Andrey Nikolaevich Kolmogorov, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, there is an important difference between a deterministic

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guarantee of coverage and a probability statement generated by the investigator's own randomisation. A periodic scanner with a fixed blind interval cannot guarantee detection of even an infinite sequence of perfectly synchronised short bursts. If the monitor independently randomises its observation phase according to a known distribution, then for a fixed sequence of source onsets that does not adapt to the randomisation, each event may enjoy a bounded probability of falling within a successful-onset set. If the randomisations across trials are genuinely independent, a product bound on the probability of all misses can follow. But that reasoning depends on source timing being fixed independently of the realised scan choices.

For example, suppose the policy guarantees that for every permitted burst of duration B at the specified amplitude, the probability of a qualifying measurement under one random scan phase is at least p_{min}. For n bursts with fresh independent randomisation and a source schedule fixed in advance, the probability that all are missed is at most $(1-p_{min})^n$. This is a probability over the measurement randomisation, not a declaration that the unknown transmitter itself is stochastic. If the transmitter can observe the scanner's current state and adapt its emission timing, the conditioning changes and the guarantee may collapse. An adversarial emitter can wait until the receiver is blind unless the system has continuous coverage or some other unpredictability and independence property that the source cannot defeat.

The word 'eventually' also needs qualification. A probability-one statement

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about infinitely many trials does not give a finite-time operational assurance, and independent randomisation may fail in implementation because of a shared timer, repeating seed, or deterministic control loop. Validate the randomisation stream and record its real dwell outcomes. If there is a guaranteed minimum burst duration longer than every blind gap, deterministic temporal coverage may be possible without randomisation, subject to receiver sensitivity and settling. Absent such source restrictions, the scientific report should describe conditional probabilistic coverage and the set of physically unexcluded source behaviours. Model-robustness is achieved by reporting the exact assumptions under which a bound survives, not by pretending that model uncertainty has disappeared.

Dr. James M. Atkinson, Moderator: Dr. Wald, what changes when the investigator keeps extending or terminating a search according to the alarms, reference checks and changing conditions observed during the run?

Abraham Wald, Third Principal Contributor: Dr. Atkinson, a planned observation interval and an adaptively terminated one are different experiments. If a survey stops the moment an alarm appears but continues whenever it does not, its exposure and censoring depend on the data. This may be entirely appropriate operationally, yet the analysis must follow the actual sequential rule. Treating the elapsed time as if it were fixed in advance and applying an unrelated fixed-sample confidence formula may misstate false-alarm or missed-event properties. The remedy is not to ban adaptation but to define the monitoring policy and the associated operating characteristics before interpreting the realised result.

Consider a sequential search in which the receiver records accepted bursts

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and updates an exposure ledger each hour. Under a homogeneous rate λ and known p(t), the number of detections over accumulated effective exposure E follows a Poisson process with mean λE. For a predetermined target rate λ_1 and null rate λ_0, an idealised log likelihood ratio after observing k detections and exposure E is $k \ln(\lambda_1/\lambda_0) - (\lambda_1-\lambda_0)E$. Every symbol matters: λ values are hypotheses for rates of true event starts, k is a count of valid detections after the agreed event-clustering rule, and E is opportunity weighted by detection probability. If $\lambda_0=0$, the ratio requires special treatment; one cannot simply divide by zero. Where arrivals are clustered or p(t) estimated with large error, this likelihood expression ceases to be an adequate description.

A negative result increases evidence against a higher-rate hypothesis only during valid exposure. If the scanner is blind for two hours, the likelihood should remain unchanged during those hours, regardless of the operator's sense that 'monitoring has continued'. Conversely, a sudden increase in conditional detection probability because the receiver is moved to a better antenna location adds more effective exposure per minute, if the change has been calibrated. A defensible sequential dashboard would therefore show real time, valid dwell time and effective exposure as separate quantities. It should never combine them into one unqualified uptime percentage.

Stopping rules must also account for recalibration, outages and equipment replacements. Suppose a receiver initially uses q=0.4 for faint two-millisecond bursts, and after a preselector modification it achieves q=0.8.

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Accumulating hours as if q had remained constant is incorrect. The exposure is a sum of state-specific contributions, $E=\Sigma q_j L_j$, or an integral if the states vary continuously. If the calibration runs only at high signal amplitudes, applying q_j to low-amplitude unknown events is an extrapolation, not a measurement. A revised detection algorithm may also alter the definition of one event, changing k; versioned records and replay against an untouched capture are required to preserve comparability.

The strongest sequential strategies include explicit action thresholds and protections against nuisance alarms. A sudden spectral line might be a receiver artefact, overload spur or external signal. If every suspicious crossing terminates a search as a 'detection', the statistical model effectively counts false positives. If an investigator retrospectively excludes difficult alarms without a defined validation rule, the apparent negative record becomes selected evidence. A two-stage process may first register a candidate event with raw data and then subject it to controlled challenge tests; the first-stage event count and the later confirmed-event count should both be retained. Otherwise it is impossible to reconstruct how one set of observations became the zero count on which a confidence statement relies.

The independence assumption deserves special scrutiny when a search reacts to its own observed environment. If the controller spends longer on channels where activity was previously seen, the observation schedule becomes correlated with the event process. An exposure integral can still describe where the system listened, but a simple Poisson thinning calculation that assumes exogenous p(t) may no longer hold without

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modelling the adaptive policy. Some events may be more likely during times when the receiver happens to be attentive, and others less likely, making a naïve rate estimate biased. A logged decision history allows simulation of the policy against known synthetic event sequences to assess the bias.

A practical stress test should include a burst generator whose schedule is unknown to the analyst performing the search and whose onset phases are deliberately varied. The receiver is operated under the proposed real acquisition policy, including any automatic retuning, alarm-driven dwell extension and buffer handling. An independent log records every true burst and compares it with detected candidates. False discoveries, misses, detection delays, and intervals in which the receiver failed to observe the relevant channel are reported separately. That test can demonstrate how a policy behaves without relying on a selective list of successful detections. It is especially valuable where operations resemble a long-running watch rather than a bounded laboratory trial.

My conclusion is that sequential observation can be rigorous if its adaptive rules are transparent and its likelihood model is appropriate. But a statement such as 'no suspicious signal in ninety days' conceals precisely the information needed to judge the result. It should be replaced by a structured account of effective exposure under specified event classes, controlled false-alarm handling, and the stopping or continuation rule. I pass the token to William Feller, who will challenge the use of smooth average exposure in a world of periodic bursts and finite observation windows.

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W. Edwards Deming, Peer Question: Dr. Wald, many monitoring programmes measure success by operational uptime or by the number of spectrum sweeps completed. The incentive can reward uninterrupted dashboards rather than defensible evidence. Suppose a station silently increases its detection threshold during noisy periods to reduce false alarms, while its report continues to show 99.9-percent system availability. How should the investigation distinguish equipment availability, valid time-frequency coverage, and detection effectiveness? Would you require a formal change-control mechanism that links software settings to an exposure budget, and how should a report treat a midnight update that altered the meaning of an event without changing the file schema? I am particularly interested in preventing a management indicator from masquerading as a scientific finding. Suppose the transmitter itself changes its coding and emits shorter packets after a firmware update. Should an operational detector that was calibrated only for longer packets still count that period as fully exposed, even if its internal settings and nominal gain have not changed?

Abraham Wald, Response: Dr. Deming, the quantities must be defined at separate layers. Equipment uptime indicates electrical and software operation; valid on-channel dwell indicates physical acquisition opportunity for a particular channel; conditional detection effectiveness indicates whether a specified burst would have survived filtering and thresholding; and evidential validity addresses the traceability of the resulting record. High performance at one layer does not establish another. A receiver can remain powered while its input is disconnected, scan efficiently while a required frequency is never visited, or acquire continuously while a changed

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threshold suppresses weak events. Each counter should bear a description of what is actually measured.

Change control is part of scientific reproducibility. A midnight threshold change divides the search into distinct detection states even if the output file retains the same columns. The exposure ledger should record exact change time, old and new configuration, software version, calibration evidence and any possible transient gap. If the event definition changed, the investigator must not merge counts across versions without a reconciled rule, ideally applied by replay to preserved raw samples. When replay is impossible, state the incompatibility rather than fabricate a unified series. A cautious analysis can report separate counts and conditional bounds for each state, with sensitivity to uncertain periods.

The practical control system should discourage retrospective success selection. An immutable record of intended configuration, observed configuration, alarms, failed checks, calibration changes and operator decisions allows review of the entire decision process. A metric such as 99.9-percent uptime can remain useful for maintenance, but it must never become the denominator of a rare-burst detection bound unless it coincides with tested valid exposure. Performance measures should be chosen to encourage accurate reporting of errors. A system that acknowledges a 40-percent sensitivity loss is scientifically healthier than one that conceals it to preserve an attractive status graph. The legitimate negative result is bounded by what the apparatus was physically able and documented to observe. The source class matters as much as the detector state. A changed

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burst duration or coding structure alters its admission probability. If a credible alternative waveform lies outside the validated envelope, the conclusion must be restricted accordingly. Firmware changes by a suspected emitter are not observable from silence alone; this is another reason to report conditional assurance rather than absence as fact.

Abraham Wald, Cross-Peer Question to Jerzy Neyman: Professor Neyman, I wish to challenge your use of a prespecified 95-percent detection target for a sequential search in which the observation policy adapts after each accepted candidate. Suppose an engineer doubles the dwell on a suspect channel following a weak crossing and then reduces it after a period of quiet. The resulting effective exposure is influenced by an event that may subsequently be rejected as an instrument artefact. Can an ordinary zero-count upper limit still be calculated from the final exposure, or does that data-dependent policy require accounting for the selection mechanism? What safeguards would you use so that a plausible stopping rule remains testable rather than being replaced after the fact? Please discuss the difference between a well-defined predictable acquisition policy, post hoc removal of failed intervals, and a deliberate repeated search designed to exploit favourable random fluctuations. I ask also whether the corrected confidence rule remains valid if some acquisition windows are retrospectively labelled unreliable solely because they contain an awkward candidate event.

Jerzy Neyman, Cross-Peer Answer to Abraham Wald: Dr. Wald, an adaptive schedule need not invalidate every analysis, but it changes what must be justified. If the observation probability at time t is determined by past recorded information and the model properly conditions on that history,

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there are settings in which likelihood-based counting-process analysis remains possible. The intensity of detected events can be expressed conditionally, and exposure can be accumulated according to the actual predictable acquisition state. However, it is not correct simply to take a fixed-sample confidence interval formula, substitute a random end-of-study exposure, and assume its coverage remains unchanged for every arbitrary stopping policy. The validity depends on the exact process, adapted controls and inferential method.

A defensible protocol therefore states in advance how a candidate crossing changes dwell, how long the change persists, and when a candidate is confirmed or rejected. The recorder must retain the raw candidate, change decision, full detector state and source-independent calibration data. If an apparently false candidate causes the system to monitor one channel more intensely, that increased exposure is real, but its occurrence is selected by the observations. Subsequent source-rate inference should account for that conditioning. If a failed health check makes previous exposure suspect, the criteria used to exclude it must be documented without editing history to favour a particular conclusion.

In practice one can examine the policy through simulation using the exact control algorithm and synthetic source sequences, followed by independent hardware-in-the-loop validation. Report the nominal and realised operating characteristics, not only a theorem under a simplified policy. For a high-consequence defensive search, it may be preferable to maintain a fixed baseline monitor while an adaptive channel conducts supplemental

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interrogation. The baseline preserves a stable exposure denominator and can challenge an adaptive method whose selection is difficult to model. If such a design is impossible, qualify the statistical conclusion rather than treating adaptation as harmless. Rigorous sequential inference derives from the whole rule, not from the attractiveness of its final number. A report should therefore include a sensitivity case that retains all originally scheduled windows, a second case excluding only independently documented failures, and a record of why any difference is consequential. This comparison exposes an otherwise invisible selection decision.

Dr. James M. Atkinson, Moderator: Professor Feller, would you address the geometrical problem of whether a burst of finite duration actually overlaps a scanner dwell, including periodic and phase-locked regimes?

William Feller, Fourth Principal Contributor: Dr. Atkinson, the apparent simplicity of a listening fraction hides a geometrical condition. Let the receiver's valid on-channel windows be a set W in time and a burst occupy [u,u+B], where u is its onset and B its duration. The event can overlap a valid listening window if and only if u belongs to W expanded backwards by B. For ideal detection on any positive overlap, this expanded set determines the onset phases that could be recorded. But a real detector typically requires a minimum overlap duration h for filter settling, integration, or enough accepted samples. Then its successful-onset set is smaller and must be derived from the exact decision criterion. This is a coverage problem before it is a probability problem.

For one isolated dwell [a,a+d], with burst duration B and an overlap requirement h satisfying $0<h\leq\min(B,d)$, the set of successful burst onsets is

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[a+h-B, a+d-h]. Its length is d+B-2h, provided the interval is nonempty. This derivation assumes the interval boundaries are ideal, that both burst and dwell are contiguous and that no additional waveform effects prevent detection. When a burst is very short, h may approach B, so the beneficial extension before the dwell largely disappears. In a periodic scan with revisit period R, the onset-coverage fraction for a uniformly random phase is the measure of the successful-onset intervals modulo R divided by R. Overlapping such intervals must be unioned rather than summed to avoid double counting.

For example, take a channel visited for d=10 milliseconds every R=1 second, a B=4 millisecond burst, and a minimum usable overlap h=2 milliseconds. The successful-onset interval associated with each isolated dwell is 10+4-4=10 milliseconds long; under a uniform random phase and absent other losses, the probability of a qualifying overlap is about 0.01. If the detector instead accepts any infinitesimal overlap, the interval length approaches d+B=14 milliseconds, giving about 0.014, but that physical assumption is often unreasonable for a weak, bandwidth-limited receiver. Neither number should be described as a universal interception probability without amplitude and threshold calibration. In this example the difference between models is forty percent relative to the smaller probability, despite identical hardware uptime.

Now suppose the bursts recur with exact period R and an unknown but fixed phase. Either the phase places each burst into a successful-onset interval or it does not. In the latter case, repeated scanning does not create new

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independent opportunities; a thousand negative scan cycles may leave the same uncertainty about the transmitter as one cycle. If burst and scanner periods differ slightly, the relative phase can walk around the cycle, but its rate depends upon the difference between the periods and any oscillator drift or jitter. A claim of improved coverage must demonstrate that the relative phase actually explored the relevant range rather than merely assume that many repetitions were independent.

Randomising revisit phase can make this vulnerability less severe. If each revisit phase is independently randomised and each burst has a stable chance p of qualifying, then under that stylised model the miss probability for n bursts is (1-p)^n. For p=0.01 and n=100, this is approximately 0.366. But a single random phase selected at the beginning and held fixed across all bursts produces a miss probability of 0.99, not 0.366. The distinction is enormous, and it flows from dependence across trials rather than from any arithmetic error. A scanner that introduces only minor timing jitter may be closer to the fixed-phase case than to independent randomisation. The randomness must be tested, not inferred from an irregular-looking plot.

A second complication is the geometry of frequency hopping. Time overlap is insufficient when the signal moves across frequency or the receiver's passband does not contain the emission. Represent valid coverage as W(t,f), and a burst as a region in time-frequency space. A qualifying observation requires overlap after accounting for the instrument's finite passband, selectivity and retuning transient. If the frequency plan has holes, a burst may be invisible whatever its onset time. A tuned channel's nominal width is

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not the same as its usable sensitivity interval, because passband roll-off and interference can change detection probability near an edge. The credible observation set is therefore a calibrated region, not a binary catalogue of frequency labels.

There are also bursts whose starts are clustered rather than isolated. A packet train may be admitted as one event under a merge rule, and some packets may be detected while others fall in blind intervals. Counting detected threshold crossings as independent burst starts inflates the evidence available for estimating a Poisson rate. The event definition should follow the source process and the actual observable, and its consequences should be checked with injected multi-pulse test waveforms. A receiver can produce a hundred alarms from one extended oscillator transient. That is not a hundred independent opportunities to infer the prevalence of rare emitters.

The honest search statement specifies the successful-onset set for each source class or, where its derivation is too complex, reports empirical detection curves obtained by randomised onset injection. It also records which periodic schedules could evade observation indefinitely, what randomisation actually occurred and what timing uncertainty remains. The calculation is not merely mathematics dressed around an RF instrument; it is the geometry of the evidence the instrument was physically capable of collecting. I pass the token to Andrey Kolmogorov, who will consider the dependence assumptions embedded in every probability claim.

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John Wilder Tukey, Peer Question: Professor Feller, the scanner's successful-onset windows can be calculated for ideal rectangular bursts, yet real events have uncertain onsets, variable envelopes and amplitude-dependent triggers. How should an exploratory analyst use the observed records to discover that the assumed overlap geometry is wrong without treating every alternative window choice as an independent statistical discovery? Would graphical examination of detected versus injected burst start phase be a better diagnostic than relying upon one percentage? I also ask whether changing the merge gap between candidate detections alters the event count and the resulting estimate of arrival rate, particularly where one long transmission causes repeated threshold crossings. Please distinguish a genuine rate correction from analysis choices made after seeing an unexpectedly reassuring or alarming result. If an analyst tries many merge thresholds and retains only the one yielding the most stable estimated event rate, has the search acquired information about the source or merely fitted an algorithm to its own observations? How should that exploration be disclosed?

William Feller, Response: Professor Tukey, a useful experiment plots the known injected burst onset phase against capture outcome, and stratifies by amplitude, duration, receiver state and frequency offset. Instead of a single detection proportion, that display can reveal hard blind zones, gradual transitions near the edges of dwell windows and unexpected periodic structure. A phase-response curve with confidence intervals is often more diagnostic than a headline percentage. The analyst should retain failed trials and the complete injection schedule. A plot from successful trials alone can make a detector appear uniformly reliable even though all failures occupy a

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narrow recurrent phase interval.

Real waveforms require a measured effective acceptance function rather than an ideal rectangular rule. A threshold detector may need several samples after filter settling, and weak bursts may enter the window earlier than their recorded threshold crossing suggests. Characterise those latencies with a calibrated source and independent acquisition timestamp. Then compare the measured phase-response curve with the theoretical geometry; disagreements reveal missing parts of the model, such as AGC recovery, preselector switching or software buffering. A disagreement is evidence to investigate, not an inconvenience to smooth away.

Event clustering is a separate decision that affects the count numerator. If one burst creates ten threshold excursions and the algorithm records ten events, the empirical arrival rate is inflated. Conversely, an excessively long merge gap can conceal two distinct transmissions. Define the event identity rule by source behaviour and test it with injected multi-burst sequences at varied separations. Report how the inferred event rate changes with reasonable cluster thresholds rather than choosing one after observing the results. Because the number of candidate events and the effective exposure are different quantities, neither can silently compensate for defects in the other. The inferential target must be specified before the counting procedure is chosen. Exploratory comparisons can be scientifically useful if every tested threshold, resulting count and reason for eventual selection are retained. A threshold chosen after looking at the data should not be presented as if it were prespecified for confirmatory inference. Independent

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validation data or a clearly stated sensitivity analysis can prevent that selection from masquerading as external proof.

Dr. James M. Atkinson, Moderator: Professor Kolmogorov, the previous contributions have used Poisson arrivals, random phases and deterministic schedules. How should the investigator handle uncertainty when none of those models is fully established by the observations?

Andrey Nikolaevich Kolmogorov, Fifth Principal Contributor: Dr. Atkinson, a probability statement must be attached to a defined random experiment. When the source process is unknown and the observer is intermittently blind, repeated absence of alarms does not by itself identify the process. The observed record is compatible with an inactive source, a rare random source, a periodic emitter synchronised to blind windows, or a stronger source that was undetectable under the prevailing antenna and receiver conditions. A model may organise this uncertainty, but it does not remove it. The observer should enumerate plausible families of source behaviour, identify which are constrained by the coverage schedule, and distinguish measured parameters from assumptions introduced for mathematical convenience.

A homogeneous Poisson process is characterised by independent increments and a constant rate. It is a defensible sensitivity analysis for certain unstructured arrivals, but many engineered transmitters are driven by clocks, buffers, application events and power-management schedules. Their bursts may have heavy-tailed waiting times, periodic patterns, clustering or dependence on environmental conditions. The number of calendar hours observed cannot be converted to a useful miss probability

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without a statement about those mechanisms. One can calculate several conditional probabilities under alternative models and present their spread as model uncertainty; one should not select the most reassuring model after seeing an empty record.

Consider a thought experiment with 100 equal-duration monitoring intervals and total live fraction 0.1. Under an ideal independent model with 100 burst onsets independently uniformly distributed across those intervals, the chance all fall outside live coverage is 0.9^100, approximately 0.0000266. Under a single fixed but uniformly distributed phase determining all 100 onsets relative to the scanner, the chance all fall outside is 0.9. Both calculations can use the same marginal coverage fraction, and both are arithmetically correct. Their radically different answers arise from dependence. Thus '100 missed opportunities' has no statistical meaning until the experiment says whether those opportunities were independent, identical and genuinely able to produce records.

Multiple receivers complicate the dependence further. Suppose station A and station B each have marginal miss probability 0.2 for a specified burst class. If their conditional failures are independent, the probability that both miss the same burst is 0.04. If both use a shared reference, antenna shadow or synchronous retuning policy, the joint miss probability can approach 0.2 in a strongly correlated regime. The data of the individual miss probabilities do not determine the joint probability. An independent challenge generator and separate observations of the receivers' states are needed to measure or bound their dependence. An assertion that 'two receivers mean twice the

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assurance' is therefore not justified by receiver count.

An uncertainty ledger should separate at least four levels. First are known geometric blind intervals, which can be reconstructed from hardware counters and scan state. Second are conditional response probabilities, derived by controlled calibration under amplitude, waveform and environment ranges. Third is uncertainty about the temporal and spectral process that generates the bursts. Fourth is uncertainty in the legal and operational significance of a detected event, which is not a detector-performance variable. Combining all four into one unexplained probability of intercept invites misinterpretation. Some uncertainties can be quantified statistically; others must remain explicit alternative hypotheses or bounded cases.

Simulation can test the consequence of assumptions, but its output is not experimental verification. A useful simulation uses the actual recorded scanner coverage timeline and overlays source sequences drawn from several declared models: Poisson, periodic with random initial phase, periodic with fixed phase, clustered, and state-dependent. It then applies empirical detection curves and the real event-clustering algorithm. The results can map how miss probability changes with event duration, period, signal level and scan strategy. A second analyst should be able to reproduce the simulation from retained code, seeds, data and versions. Where simulated confidence is high only under one fragile model, the report should disclose that dependency.

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What should an operator do when the source model is genuinely unknown? Increase physical coverage, vary scan phase, deploy a suitably independent continuous recorder for key frequencies, challenge the installation with injected lawful stimuli, and report a negative finding only for classes of events shown to be observable. A model-free guarantee for arbitrary finite bursts is impossible when the receiver has blind intervals and the source could place every burst within them. That limitation is not a defect of statistical technique; it follows from the existence of unobserved possibilities. It is better to state this sharply than to conceal it under a small but unearned numerical probability.

Finally, no detection claim should be used as an attribution claim. Even successful capture of a short signal does not establish source identity, purpose or legal significance without further evidence. Conversely, failure to capture a signal cannot eliminate the possibility of a transmitter whose timing, frequency or power lies outside the validated search envelope. The appropriate product of a rigorous rare-burst investigation is a coverage-and-uncertainty account that can be independently interrogated. I return the token to Dr. Atkinson for peer examination of these competing models, particularly where sequential decisions and physical receiver constraints interact.

Sir David Cox, Peer Question: Professor Kolmogorov, the most consequential uncertainty may be the choice of arrival model rather than any measurable clock error. A zero-detection record is compatible with a Poisson emitter of low rate, a periodic source always in blind windows and a cluster process producing many related bursts during rare activation

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periods. What model checking can the analyst undertake if no true events have been recorded, and how should the report communicate the fact that the data themselves cannot discriminate these explanations? Can an investigator claim a model-robust confidence interval by examining several models and taking the narrowest limit, or would such a procedure reverse the logic of a conservative analysis? Please consider the useful role of sensitivity bounds without making the manuscript's mathematics appear to prove facts beyond observation. Would it help to distinguish the event onset time from the time at which the detector completes its decision? A receiver may present only the latter, making a burst appear to occur when the system happens to be observing rather than when the RF energy actually began.

Andrey Nikolaevich Kolmogorov, Response: Sir David, an empty event record offers little direct information about temporal dependence. It can constrain particular models through known coverage, but it generally cannot identify whether a source process is Poisson, periodic or clustered. Model checking must therefore rely on independent information: controlled trial emissions, prior measurements of the same class of equipment when lawfully available, documented behaviour of the application driving the transmitter, or bounded physical restrictions on burst timing and duration. When such information does not exist, the report should present the divergence of predictions as an explicit limit of inference. Choosing the narrowest interval from several models would reward an optimistic assumption and has no automatic coverage justification.

One can construct a set of scenarios with common physical input: the same

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actual scan schedule and calibrated detection surface. Under each declared source-arrival law, compute the probability of a zero count or the upper bound appropriate to that law. The output is a sensitivity table, not a probability distribution over the laws unless a defensible model-weighting scheme has been established. Worst-case analysis can establish that a deterministic emitter synchronised to blind intervals remains entirely unexcluded; random-phase and Poisson scenarios may offer more informative conditional bounds. These claims are not contradictory because they answer different questions.

It is valuable also to distinguish uncertainties capable of experimental reduction from those requiring changed apparatus. More independent onset-phase trials can narrow estimates of conditional detection probability. Better instrumentation may reduce lost-sample uncertainty. But no number of repetitions of one unaltered periodic scan can exclude a transmitter that always emits during its gaps. Resolving that ambiguity requires altering observation coverage, not merely refining a model. A continuous receiver on the key frequency, staggered scanning, or an independently timed challenge test can convert an unobservable behaviour into an observable one. The final report should separate model-derived confidence, experimental coverage, and physically unexcluded scenarios with clear terminology. Yes. Preserve the hardware acquisition timestamp and the algorithmic decision timestamp separately. A filter or integration detector may declare the event later than the physical onset, with latency dependent on signal strength. An externally measured timing marker can calibrate that

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delay for a specified source class. Such calibration should never be silently applied as though it were an unedited raw measurement.

Andrey Nikolaevich Kolmogorov, Cross-Peer Question to David Harold Blackwell: Dr. Blackwell, you have argued that altering the scanning policy may yield more information than collecting another long sequence of identical missed opportunities. How should an investigator compare the value of a continuous receiver on one critical channel with a randomised scanner that covers many frequencies, when the source's frequency distribution is unknown? A continuous monitor eliminates temporal gaps for one band but leaves all other bands unobserved. A scanner distributes attention while leaving every channel blind for much of the time. The decision also has a resource constraint: independent timebases, antenna systems, storage and human review are not unlimited. What criterion could select an arrangement without inventing a probability distribution over malicious source choices, and how would you preserve the distinction between optimising a coverage policy and proving the absence of a transmitter? The resource allocation ought to disclose whether its worst-case performance assumes a stationary source, since deployment may change the very field conditions that made the earlier site calibration favourable.

David Harold Blackwell, Cross-Peer Answer to Andrey Nikolaevich Kolmogorov: Professor Kolmogorov, without a defensible probability model for source choices, a single numerical optimum can be artificial. One may begin with an explicit loss function or a hierarchy of operational priorities: some channels are essential to monitor continuously because their missed transmissions have exceptional consequences, while others can be sampled

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to discover broader occupancy. A minimax approach might optimise the worst guaranteed coverage over a declared class of signals, but if the class includes arbitrarily short bursts at arbitrary frequencies, no finite number of narrowband receivers can guarantee observation of every event. The constraints must therefore be real and visible, including minimum burst duration, frequency range, signal strength and permissible equipment capacity.

For a constrained comparison, enumerate receiver resources and their validated observation sets. A fixed channel monitor may provide nearly continuous temporal opportunity for a source whose frequency lies in its band, while a scanner may provide short but repeated opportunity over many bands. Calculate each method's successful-onset coverage for source classes of interest, then examine worst-case gaps and empirical detection surfaces. If frequency distribution is unknown, present a coverage frontier: increasing breadth reduces continuous attention per channel, unless additional hardware is provided. Neither method dominates all possible sources. A mixed architecture can preserve continuous attention to high-consequence bands whilst scanning the rest, with independently logged capture states and shared-resource dependencies made explicit.

The evidential language must remain conditional on this design. Choosing a policy to improve coverage does not establish that no transmitter existed. It only makes some failures less plausible or removes specific blind regimes. A transparent protocol says why particular bands received priority, what remained unmonitored and what alternative source behaviours were not

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excluded. Those statements may be less rhetorically satisfying than a uniform percentage labelled 'assurance', but they can be tested. Decisions under uncertainty benefit from recognising that unobserved frequency-time regions are genuine limitations, not zeros in a statistical table. A professionally sound report lets its reader inspect the trade-off rather than disguising it. In addition, changes to receiver gain, environmental noise or cable geometry should trigger requalification of the claimed observation set. The original allocation decision remains a resource policy, but its evidential performance is conditional on the acquisition chain remaining comparable to that tested.

Dr. James M. Atkinson, Moderator: The panel has established that the number of monitored days cannot substitute for the time-frequency intervals during which specific emissions were physically observable. The remaining inference depends on the assumed source process, the detector acceptance rule, the independence of repeated opportunities and whether the observation policy adapts to its own findings. The strongest negative report therefore gives a reproducible ledger of valid acquisition windows, response curves by burst class, known blind intervals, event-clustering rules, and a clearly qualified statistical model. No mathematical bound is a direct observation of a transmitter that was not detected. The fictional expert dialogue is an instructional reconstruction, not historical testimony.

QUESTION 072. TECHNICAL SOURCE REGISTER AND REVIEW QUALIFICATIONS

1. International Telecommunication Union, Handbook on Spectrum Monitoring, 2026 Edition, https://www.itu.int/pub/R-HDB-23. Describes monitoring tasks, pulse measurements, occupancy, sampling design and

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statistical confidence. Its relevance is methodological; no instrument-specific claim above is attributed to an ITU field test.

2. International Telecommunication Union, Handbook on Spectrum Monitoring, Supplement (2008), https://www.itu.int/dms_pub/itu-r/opb/hdb/R-HDB-53-2008-OAS-PDF-E.pdf. Discusses scanning speed and its dependency on measurement purpose, including the faster requirements for single-event bursts.

3. Russell Lyons, Stochastic Processes (lecture notes), https://rdlyons.pages.iu.edu/pdf/StochProc.pdf. Poisson thinning and independent retained/missed event processes support the conditional mathematical examples. Source author, edition and page should be checked again during final citation proof.

4. Adriaan M. Dokter, E. Emiel van Loon, Wimke Fokkema, Thomas K. Lameris, Bart A. Nolet and Henk P. van der Jeugd, Analyzing time-ordered event data with missed observations, Ecology and Evolution (2017), https://pmc.ncbi.nlm.nih.gov/articles/PMC5606873/. General non-RF analysis of observation bias in event sequences; cited as a conceptual analogy, not evidence of particular RF receiver performance. Bibliographic metadata verified against the publisher-indexed PMC record, 2017, 7(18):7362–7369, doi:10.1002/ece3.3281.

EDITORIAL QUALIFICATION: All source schedules, Poisson rates, waveform examples, receive probabilities and numerical calculations are hypothetical teaching examples. The historical dialogue is fictional; mathematical results depend on explicitly stated stochastic assumptions. Stage A compliance

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alone does not certify source-to-claim verification, interpretation of legal obligations, whole-manuscript originality, or publication acceptance.

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QUESTION 073

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When Do Harmonic and Sideband Relationships Support a Common-Oscillator Hypothesis?

SCHOLARLY RECONSTRUCTION. Every historical specialist named below is deceased. Their attributed conversation was composed as modern pedagogical dialogue; it is not a quotation, transcript, or evidence that the named persons discussed current receivers, technical surveillance countermeasures, or digital instruments.

Dr. James M. Atkinson, Moderator: Professor Nyquist, imagine that an authorised defensive survey finds a carrier at one frequency, a second at twice that frequency, and pairs of narrow sidebands whose separation remains almost constant as equipment warms. Several receivers display similar timing and phase movement. What may the investigator infer, and what could be a coincidence? I ask you to distinguish algebraic relationships that can arise in one oscillator, modulation shared by separate oscillators, nonlinear mixing inside a receiver, and a common external reference feeding otherwise independent instruments. The decisive question is whether a physically identifiable causal pathway has been demonstrated, not whether a frequency plot looks persuasive.

Harry Nyquist, Principal Contributor: Dr. Atkinson, a proportional frequency relationship is a useful hypothesis generator, never a complete attribution. One may observe two components whose estimated frequencies satisfy $f_b(t)$ approximately equal to $n\ f_a(t)$, where n is a positive integer. That is compatible with harmonic generation from a single nonlinear waveform, yet the same relationship may be produced by independent synthesizers disciplined to a common reference, separate transmissions obeying a

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frequency plan, a spurious response inside the measuring receiver, or a coincidence within finite frequency resolution. The observation must be indexed by its time interval, frequency reference, and uncertainty. The words 'approximately equal' conceal assumptions unless the analyst states how close a ratio must remain and which error sources can make two independently generated estimates co-vary.

Begin with a periodic source whose phase is $\varphi(t)$ radians. Its instantaneous frequency is $f_a(t)=(1/2\pi)d\varphi/dt$ hertz when a meaningful unwrapped phase derivative exists. A physically generated nth harmonic of that source can have phase $n\varphi(t)+\psi_n$, where ψ_n represents a fixed phase shift associated with a particular stable path. Its instantaneous frequency is $n f_a(t)$ if ψ_n is constant. During a small common drift Δf_a, the harmonic drifts by $n\Delta f_a$. Thus an observed 10 Hz drift of a 12 MHz component, accompanied by roughly 20 Hz drift of a 24 MHz component, fits a doubling mechanism. But an unrelated 24 MHz source disciplined to a reference that itself drifts can display the same numerical relationship, perhaps with a different path-dependent phase transient. A frequency-ratio fit is therefore necessary under a simple harmonic model, not sufficient to identify an emitter or oscillator enclosure.

The stronger test uses simultaneous phase records. If $z_a(t)$ and $z_b(t)$ are properly demodulated analytic signals at the two carrier bands, form the phase residual $r_n(t)=\mathrm{unwrap}[\arg z_b(t)]-n\,\mathrm{unwrap}[\arg z_a(t)]$ after compensating known propagation and measurement delays. A constant or slowly varying r_n supports a phase relationship. Yet this is a relative

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relationship, and the measured residual can be distorted by a shared digitizer clock, frequency-converter noise, phase unwrapping across missing samples, or a reference distribution fault. It is possible for physically independent sources to remain phase-coherent because they are synchronized to the same external standard. The experiment must therefore determine whether the relevant shared cause is a single free-running oscillator, a common reference, a shared power supply, or merely a processing artifact.

In a practical survey, first acquire raw samples in two sufficiently linear, independently monitored receive paths. Document antennas, filters, calibration planes, downconverter settings, local oscillator states, gain, and sample timing. Then test the effect of a known incremental change in the suspected source, performed only with authorisation and within the apparatus' safe operating limits. If a laboratory source's fundamental is shifted by +8 Hz and its alleged second harmonic moves by +16 Hz, the response is consistent with the model; a coherent phase perturbation should also be transferred with the predicted multiplication where the mechanism is truly harmonic. If both observed channels shift by +8 Hz instead, a shared frequency-translation term or reference error deserves investigation. In the field one may have no lawful control over an unidentified transmitter, in which case a counterfactual substitution with an authorised test oscillator is an instrument challenge rather than proof of the external source.

Antenna response and environment complicate these comparisons. The

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fundamental and harmonic may have different radiation patterns because an antenna and its feed structure behave differently at different wavelengths. A cable can serve as an unintended radiator at one frequency but not the other. Standing waves can impose frequency-dependent amplitude and phase changes. A component strong in one survey position and weak in another need not have changed its generating oscillator. Conversely two independent emitters may share a power-distribution disturbance and thereby display simultaneous amplitude sidebands. The investigator must separate 'same observed modulation' from 'same physical oscillator' and must not infer origin from correlated display motion alone.

Time resolution is equally important. If a receiver averages ten seconds of frequency data, a short phase step may disappear inside an apparently smooth trace; if it samples too sparsely, sideband relationships can be aliased into spurious correspondences. Preserve the measurement intervals and their spectral windows, and evaluate a phase-residual time series in addition to a graph of fitted frequency ratios. For a brief burst, a finite Fourier window limits the precision with which a narrow sideband offset can be distinguished from spectral leakage. The width and amplitude of spectral features are products of the waveform and measurement operator, not intrinsically immutable labels.

Finally, report competing explanations in a form an independent examiner can test. A defensible finding might read: 'The components are consistent with second-harmonic generation and show phase co-movement within the stated interval; the evidence does not distinguish a shared oscillator from

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two sources locked to a common reference without additional controlled comparisons.' That is more useful than an attractive but overconfident assertion of common origin. A scientific claim grows stronger by exposing the ways it could fail, recording those tests and retaining all observations, including those that contradicted the initial hypothesis.

Sir Harold Jeffreys, Peer Question: Professor Nyquist, an analyst could translate the ratio and coherence measurements into a likelihood ratio supporting a common-source explanation, but only if the competing hypotheses are defined properly. Would you specify the distinction between one oscillator with harmonic production, two oscillators coupled to one frequency standard, and an image or spur generated within the receiver? How does the hypothesis space change when the investigator selects only the most convincing pair from thousands of measured spectral features? Does a very small frequency-ratio residual, by itself, justify a large evidential weight when a common clock can generate correlation under more than one hypothesis? I would also ask what experimental evidence should be required before a report uses the phrase 'same emitter' rather than 'compatible with a shared reference or generating mechanism'. The legal and technical consequences of that choice are considerable, especially if the apparent correlation is then used to support a location or attribution conclusion.

Harry Nyquist, Response: Sir Harold, define the models before using likelihood language. Under H1, a particular nonlinear source produces both the fundamental and the harmonic; under H2, separate sources are phase-related through a common reference; under H3, the analyser or receiver produces the second line from an external fundamental; and under H4, the

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observed relationship is a chance selection from an ensemble of candidates. Each model predicts distinct responses to controlled changes in the input power, local-oscillator plan, reference connection, or candidate source frequency. A small residual may be probable under several of those models, so it is not logically equivalent to evidence uniquely favouring H1.

Selection among thousands of spectral pairs adds a multiple-comparison problem. Suppose the analyst searches every candidate integer multiple among a thousand lines and retains the closest match. Even with independent frequency estimates the best residual is expected to be smaller than the residual of a prespecified pair. Real spectral observations are not independent, and the effective comparison count must itself be justified. One should preserve the entire candidate register, selection threshold, frequency resolutions, rejection reasons, and any subsequent targeted measurements. An empirical null distribution produced using the full search procedure may be more defensible than an abstract probability assigned to the single chosen pair.

The strongest discriminatory evidence comes from intervention and independent measurement. If an external reference is safely disconnected from a laboratory candidate and both components free-run together, that narrows the common-reference explanation. If the suspected second harmonic changes with the analyser input attenuation according to receiver distortion rather than external input, H3 gains support. If independent clocks reproduce the phase relation, one instrument-specific common-clock explanation weakens. An answer of 'same emitter' requires an identified

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source path or a suitably bounded convergent set of tests. Without those, describe the observed relationships and their uncertainty, not a degree of confidence manufactured from unvalidated likelihoods. A valuable auxiliary result is the change in the estimated residual as the candidate-matching tolerance is varied. If the claimed association disappears under an entirely reasonable uncertainty interval, the decision is not robust. That sensitivity should be preserved alongside the main likelihood argument.

David Harold Blackwell, Peer Question: Professor Nyquist, imagine that a field team can undertake only three further measurements before leaving a secured premises. It has two suspected spectral components, one stable broadband test source, a receiver with selectable input attenuation, and a second independently clocked receiver. Which experiment should come first if the practical aim is to distinguish source harmonics from receiver-generated spurs? How should the team assess the value of an intervention that changes more than one variable, such as substituting a low-pass filter that also changes impedance and gain? In addition, a null result may arise because the test loses sensitivity at the harmonic frequency. What record should be kept so that a later reviewer does not mistake disappearance of a line for causal exclusion of a hypothesis? Please address the ordering problem in terms of information and experimental economy rather than assuming that unlimited laboratory conditions are available.

Harry Nyquist, Response: Dr. Blackwell, the highest-value test is the one expected to discriminate current hypotheses while preserving enough sensitivity to interpret a negative outcome. I would generally begin with a measured input-attenuation challenge because it is quick, often reversible, and can distinguish external input power scaling from distortion created

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within the receiver. Keep the source and receiver frequency plan fixed, and record the fundamental and suspected harmonic before and after a known attenuation change. A genuinely external harmonic entering the same linear path should decrease approximately by the inserted attenuation in dB; a harmonic created after attenuation may decrease faster, with its precise behaviour determined by the nonlinearity and gain stages. A reading that changes by twice the attenuation is suggestive, not a universal diagnostic, because compression and internal gain adjustments can change the scaling.

The second test would compare an independently clocked receiver with a different front-end architecture, provided its detection floor and calibration at the suspected harmonic are established. If the line appears consistently in two independent signal paths, a single-analyser artifact becomes less likely. This does not eliminate a shared external interference mechanism or a common antenna-cable coupling path. The third test could insert a verified low-pass or notch network whose loss and impedance effects are separately measured. Such a filter can suppress a known fundamental before a nonlinear stage, but it may also alter matching; therefore compare a through-path control and calibrate the filter response at both frequencies.

The team should record anticipated test outcomes before the changes: which hypothesis predicts which frequency, phase and level response, and how large an effect would be observable above the noise and uncertainty floor. An unchanged signal in a test too insensitive to reveal the predicted effect does not update the conclusion meaningfully. Equally, a vanished signal should be reported with the new detection threshold and bandwidth.

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The efficient sequence is not simply three switches on a console; it is three controlled contrasts whose alternative predictions are written down and whose scope of inference remains explicit. The first experiment should also include a repeat baseline at the end. If the receiver gain, termination or internal reference changed during the challenges, the final control shows whether the original state was recovered or whether the tests must be treated as a sequence of different configurations.

Harry Nyquist, Cross-Peer Question to John Robinson Pierce: Dr. Pierce, your analysis of nonlinear harmonic generation may supply a physically concrete mechanism for a ratio that I have treated as an inferential clue. Can you identify the condition under which amplitude scaling and phase multiplication would be strong evidence for generation within one device, yet still allow a second receiver stage to manufacture the apparent harmonic? I ask specifically whether a measured n-fold phase relation distinguishes harmonic radiation from receiver mixing when the receiving path has nonlinear components. Could a strong fundamental, admitted through a supposedly benign preamplifier, produce the same relationship even when no harmonic energy exists at the antenna input? What minimal two-reference-plane experiment would discriminate the two locations of generation without altering the antenna's exposure or the original signal history? If the external oscillator and a nonlinear receiver share the same phase timebase, their phase relationship may remain indistinguishable under mere observation. Would you specify which calibration intervention reveals the generating stage before a forensic report names the source?

John Robinson Pierce, Cross-Peer Answer to Harry Nyquist: Professor Nyquist, the phase law follows from nonlinearity wherever that nonlinearity

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resides, so it is not a geographical certificate. Write the voltage entering a nonlinear element as $v=A \cos \varphi(t)$. A quadratic term a_2v^2 produces a component proportional to $(a_2A^2/2)\cos[2\varphi(t)]$ as well as a DC term. That same expansion applies to a power amplifier in the transmitter and to an overloaded preamplifier or mixer in the receiver. In either case the doubled carrier inherits $2\varphi(t)$, apart from added device phase and conversion noise. A perfect n-fold phase relation therefore tells us about the transformation, but not its location.

I would measure at two declared reference planes. At the receiver antenna connector, use an independently calibrated, sufficiently linear sampling path or a proper high-isolation directional arrangement to determine whether the harmonic is already present at the specified level. Then measure after the suspected nonlinear receiving stage under the same excitation. A change from 'below the input detection limit' to a substantial line at the output, combined with power-dependence testing, supports internal generation, although the input detection limit must be reported honestly. If a controlled, low-loss attenuation placed before the stage reduces the harmonic with second-order scaling while the fundamental falls linearly, the model becomes more persuasive. Repeat with an alternate high-linearity front end to challenge the result.

One cannot simply unplug the antenna during an evidential observation and interpret the absence of the line as a final field result. Disconnecting changes impedance, common-mode paths and often automatic gain. Record a contemporaneous unaltered baseline and repeat the intervention as a

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labelled instrument challenge. The original observations and the test data must remain distinct. A common-oscillator inference grows credible only after the nonlinear transformation is located in the external source path, not merely after its algebra has been identified. When the suspected generating stage cannot be physically accessed, the conclusion must be correspondingly limited. Independent observation of the RF input, verified injection standards and attenuation response may favour a mechanism, but should not be described as direct observation of an inaccessible transmitter circuit. These qualifications must survive into the final claim.

Dr. James M. Atkinson, Moderator: Dr. Pierce, Professor Nyquist has shown why a numerical relationship is insufficient. Please take the token and develop the actual circuits capable of generating related carriers and sidebands. Distinguish true external emissions from products produced by the receiver itself, and explain which controlled changes would reveal the location of the nonlinear stage.

John Robinson Pierce, Second Principal Contributor: Dr. Atkinson, the frequency spectrum of a radio system contains the signature not only of its intended oscillator but of every significant nonlinearity and modulation process. An oscillator may generate a nominally sinusoidal fundamental. Yet if its output passes through a nonlinear power stage, a diode junction, a frequency multiplier or an inadequately isolated mixer, the output may contain integer harmonics, sums, differences and modulation sidebands. The precise relationship depends on the physical transfer law. For a memoryless weak nonlinearity, one may write an illustrative truncated model $y(t)=a_1x(t)+a_2[x(t)]^2+a_3[x(t)]^3$, with coefficients a_1, a_2 and a_3 appropriate to the input amplitude units and output response. This is an approximation

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within a limited operating region, not a universal representation of a receiver mixer or a saturating power amplifier.

Suppose $x(t)=A\cos(\omega_0 t+\beta\sin \omega_mt)$, where A is signal amplitude, $\omega_0=2\pi f_0$ is the angular carrier frequency, $\omega_m=2\pi f_m$ is the angular frequency of a small imposed phase modulation, and β is the dimensionless phase-modulation index in radians. The square term produces a second-harmonic component proportional to $\cos(2\omega_0 t+2\beta\sin \omega_mt)$. The harmonic's phase modulation index is thus twice the fundamental index under this simple law. For small β, the first-order phase-modulation sideband power relative to its corresponding carrier is approximately $(\beta/2)^2$ at the fundamental and approximately $(2\beta/2)^2$ at the second harmonic. At β=0.005 radians these expressions predict roughly −52.0 dBc and −46.0 dBc per first-order sideband respectively, a 6 dB difference, assuming the relevant carriers are separately measured and the underlying approximation is satisfied. The calculation is a model expectation, not a statement about measured equipment.

That relationship is a useful challenge signature. If a known oscillator is modulated at 120 Hz and an observed doubled carrier develops sidebands spaced by ±120 Hz, with a modulation-index change consistent with phase multiplication, the pair is compatible with common harmonic generation. Yet one cannot infer that an unverified 24 MHz field feature came from a 12 MHz emitter merely because the ratio, offsets and relative sideband levels fit this model. A receiving amplifier can generate the same second harmonic from a strong admitted 12 MHz signal. A phase-coherent synthesizer locked

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to the same reference can reproduce related phase excursions at two different carrier frequencies. An RF distribution system may leak one channel into another. The intervention must be designed to discriminate among these arrangements.

Power scaling adds valuable information but also introduces traps. Within the weak quadratic regime, the second-harmonic voltage is proportional to A^2. If the fundamental's voltage rises by a factor of two, the quadratic harmonic voltage ideally rises by a factor of four. In decibel terms, a 6.02 dB fundamental voltage increase can yield approximately a 12.04 dB second-harmonic voltage increase, when measured at consistent impedances. An external harmonic received through the same linear path may instead scale according to the external transmitter and path, not the receiver's square law. But real nonlinear devices leave the weak regime, change operating bias, generate intermodulation and compress. A logarithmic slope close to two is compatible with one model; it does not prove the complete circuit topology.

Distinguish harmonics from mixing products. With two sinusoidal inputs f_1 and f_2, a square-law term includes components at f_1+f_2 and $|f_1-f_2|$, whereas a cubic term can generate $2f_1-f_2$ and $2f_2-f_1$. If the analyst observes a family of lines, a frequency plan can explain several of them without a single external emitter at each displayed frequency. Conversely unrelated transmitters can occupy frequencies coincidentally compatible with a polynomial combination. The correct test varies one known input while holding the other fixed, monitors the expected slopes and tracks the

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product through successive reference planes. If f_1 is shifted by 100 Hz while f_2 is fixed, a proposed $2f_1-f_2$ product should move by 200 Hz under the ideal expression. Such an experiment is meaningful only when the input change is authorised and the relevant circuit has not changed modes.

An additional diagnostic is the receiving front end's attenuation. In a controlled receiver-side nonlinearity experiment, increase attenuation before the suspected nonlinear stage by a known amount, disable automatic gain control if safely and technically appropriate, and record signal power at the mixer input. If the apparent harmonic recedes more rapidly than a line already present at the antenna port, that supports internal generation. But not every attenuator is physically located ahead of the problematic device. An input attenuator following a low-noise preamplifier cannot challenge distortion generated upstream of it. A software 'attenuation' control may alter digital gain after conversion, leaving the original overload untouched. A proper chain diagram is therefore indispensable.

Isolation measures matter because electromagnetic energy can bypass the nominal connector path. Clock leads, USB shields, power supplies, structural seams and coaxial outer conductors can deliver common-mode currents into a receiver. A component may remain after terminating a nominal RF input because it couples directly into a later circuit, not because it is a legitimate independent emission. Similarly a preselector may reject an apparent harmonic while leaving mixer images and reference spurs unaffected. Challenge the enclosure, cable geometry and reference

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distribution separately. Retain both the baseline and the changed configuration, with measured frequency responses and noise floors.

The strongest scientifically phrased conclusion separates what has been observed from what has been established about its cause. Frequency ratios, modulation-index multiplication, phase relationship and power scaling can jointly favour harmonic generation. Only an experiment that localises the generating nonlinearity can then support a particular transmitting circuit or enclosure as the origin. If one cannot perform that intervention, the report should identify several physically tenable mechanisms and the evidence that each would require for exclusion. The role of receiver engineering is not to decorate a hypothesis with more decimal places; it is to construct measurements capable of making competing hypotheses behave differently.

Walter Andrew Shewhart, Peer Question: Dr. Pierce, your ideal square-law argument offers a neat power-slope test, but how can the engineer know that the receiving chain remains in the weakly nonlinear regime throughout the attenuation sequence? A transistor amplifier can warm, bias can shift, an AGC loop can compensate, and a limiter may impose a discontinuous transfer curve. Please develop a controlled acceptance test that distinguishes actual harmonic scaling from a software display that has merely changed its level calibration. I should also like you to consider whether a single successful power sweep is enough evidence for an external emission claim, or whether the operator must monitor stability, repeat in opposite directions and retain observations rejected as anomalous. The concern is that a measurement designed to test nonlinearity may itself bring

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about a new operating state and thereby invalidate the baseline against which its results are judged. If a stable reading appears only after the input chain has reached thermal equilibrium, should the acceptance protocol distinguish a warm-up criterion from a power-slope conclusion? Would periodic reference checks reveal whether an attractive fit merely reflects slow drift in the measuring apparatus?

John Robinson Pierce, Response: Dr. Shewhart, a power-slope experiment is valid only over a range in which the measured transfer function behaves approximately as the assumed model. Choose several small, documented attenuation increments and keep the receiver configuration fixed. Record the input reference level, output fundamental, candidate harmonic, amplifier bias indicators where accessible, ambient temperature, gain state and frequency plan. Make the scan in both ascending and descending power to expose thermal lag, hysteresis and mode changes. If software reconfigures gain or sample scaling, retain a hardware reference measurement independent of the displayed spectrum so that the calculated slope is not just an artefact of a hidden correction.

For each step compute the local logarithmic slope $m=\Delta P_h/\Delta P_f$, where P_h and P_f are powers expressed in dB referenced to consistent impedances and planes. In an ideal weak square-law regime the harmonic power change may be approximately twice the fundamental power change, giving m near two. But this power-ratio observation requires careful interpretation: when the input itself is attenuated, the external harmonic, if already generated by the transmitter, may enter the receiving path with a distinct level, and a filter may change the relative scaling. One should model the precise location

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of the attenuator, not merely fit a line. The slope is meaningful only where the fundamental remains detectable, the harmonic is above the verified floor, and compression and AGC effects are excluded or explicitly modelled.

I would also recommend injecting a calibrated fundamental into a matched termination or controlled port, using an independent low-distortion source whose own harmonics have been suppressed and measured. This creates a known test of the receiver's internal harmonic generation. The baseline spectrum should be preserved before changing the apparatus; the test is a separate experimental condition. Repeat the sweep on different days or temperatures where those factors may matter and record the full sequence, including failures. A single elegant slope plot is not enough to establish source identity. What matters is reproducibility of the causal distinction under conditions in which the instrument's own response has been challenged and the original evidential observations have remained intact. In addition, an engineer should account for the measurement bandwidth used in estimating fundamental and harmonic power. A narrow filter can attenuate a drifting component differently from a stationary one, making an apparent slope change that is unrelated to the underlying circuit nonlinearity. That check should include a controlled reversal to baseline.

W. Edwards Deming, Peer Question: Dr. Pierce, suppose two laboratories examine the same receiver and disagree over the presence of a second harmonic. One measures at the antenna connector, another after a preamplifier whose gain varies with temperature; both cite a calibrated spectrum analyser. How should the measurement procedure specify the quantity being compared and the allowable differences in conditions? I ask

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especially about the meaning of an exact numerical sideband ratio when one laboratory uses peak detection and the other averages a windowed spectrum. Would your method establish a reproducible result across operators, not merely across repeated acquisitions by one operator with one setting? Finally, what would count as a finding that contradicts the proposed common-oscillator explanation, rather than being dismissed as an equipment quirk? In such a comparison, how should the laboratories establish comparable sensitivity limits for non-detections, and what evidence would show that a difference arose from calibration planes rather than independent oscillators? Please make the error treatment part of the test design, not an amendment drafted after the result.

John Robinson Pierce, Response: Dr. Deming, the comparison first needs a declared measurand: for example, the carrier-relative power of the upper first-order sideband at an explicitly identified output reference plane, under a specified input level, bandwidth, and operating temperature. A measurement at an antenna connector and one following a preamplifier are different measurands until the gain, noise, mismatch and nonlinear response of the intervening path are evaluated. Likewise peak detection and windowed averaging may produce different values for an intermittent or frequency-agile line. Neither difference proves negligence; it demonstrates that the measurement processes were not equivalent.

A reproducible protocol would distribute a waveform file or controlled hardware stimulus whose properties are independently characterised. Specify calibrated source power and source harmonic suppression, test port impedance, cable and attenuator configuration, instrument bandwidth,

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detector, window, averaging count, input attenuation, gain state, and the exact algorithm for extracting carrier and sideband power. Each laboratory should preserve raw spectra and time-domain observations where available, with an audit trail of adjustments. The results should be compared against an uncertainty budget embracing both random repeatability and systematic differences, not against a tolerance chosen after the readings are known.

Crucially, define falsifiers in advance. If an alleged external harmonic disappears in a properly calibrated second receiver while the fundamental remains strong and the first receiver exhibits the same line during a known linear-source injection, the common external-source interpretation is seriously weakened. If phase multiplication fails during a controlled oscillator perturbation that was large enough to be resolved, the simple harmonic hypothesis loses support. If frequency co-movement persists only when both receivers share the same reference, shared instrumentation may be the cause. Not every contrary result is conclusive, but each must be retained and weighed. A genuine scientific protocol names the observations that would require changing the conclusion, not merely those likely to affirm it. To separate these possibilities, an interlaboratory study should include blinded specimens with known external harmonic content and specimens whose only second harmonic is generated by a controlled nonlinear receiving stage. Correct differentiation under both conditions would give the procedure a stronger empirical foundation. The final acceptance record should separately preserve a laboratory comparison of measurement floors, because agreement over detected harmonics alone cannot establish comparable competence to report their absence.

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John Robinson Pierce, Cross-Peer Question to Hendrik Wade Bode: Professor Bode, I can produce $2f_0$ through a square-law device, yet two separate synthesizers disciplined to one oscillator can also exhibit exact integer relations and coherent modulation sidebands. Which features of their phase-transfer dynamics would distinguish those arrangements? I am particularly interested in the transient following a small reference phase step. Does a nonlinear multiplier reproduce that step immediately according to the harmonic order, while two phase-locked loops reproduce it with their separate bandwidths and possible overshoot? If the measured traces appear identical at low time resolution, what additional experiment and acquisition bandwidth would expose the different control mechanisms without over-interpreting small residual noise? An equal frequency-ratio response to a static perturbation does not necessarily distinguish these devices; would you require a sweep of several modulation offsets to expose the transfer dynamics? How should uncertain path delays enter that comparison? Which observation best separates their response models?

Hendrik Wade Bode, Cross-Peer Answer to John Robinson Pierce: Dr. Pierce, the contrast lies in the dynamics as well as the static ratio. An ideal memoryless multiplier maps its input phase into n times that phase apart from fixed device delay and any added noise. A disciplined synthesizer instead contains a control loop whose response depends on its reference and internal oscillator paths. If the reference receives a small phase step, each synthesizer follows through its own closed-loop transfer function, possibly with different settling, overshoot, ringing or holdover behaviour. The observed output phase is a filtered response, not simply an instantaneous integer multiplication of every reference disturbance.

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Let H_i(s) represent the small-signal transfer function from reference phase to output phase for synthesizer i, after incorporating its frequency multiplication factor. Two outputs can share a static integer relationship while H_1(s) and H_2(s) differ materially at transient frequencies. Introduce a safe, small, calibrated phase modulation at several modulation frequencies rather than relying on one abrupt step alone. Compare amplitude and phase of the observed modulation transfer, and capture continuously with sufficient sample rate and dynamic range to observe the relevant loop bandwidth. If each output follows its own filter characteristic, separate disciplined oscillators become plausible; if a simple harmonic responds with the expected nearly immediate phase multiplication over the test band, the local multiplier model gains support.

The inference must still account for cable delay, filters and instruments. A nonlinear multiplier can include resonators, and a synthesizer can be configured to mimic a similar response. One experiment may not identify topology uniquely. But a measured frequency-dependent transfer function offers far more discriminatory evidence than a static harmonic ratio. Retain the imposed stimulus, source-reference record and receiver response so that a later reviewer can calculate the same transfer functions independently. Any inferred response difference should be compared with an injected calibration signal passed through the same receiving paths. Without that control, a phase-lag difference might belong to the test instruments, rather than to the oscillator architectures under examination. Repeat each stimulus at an amplitude small enough to preserve linear

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response, and compare the phase delay across offsets before drawing conclusions about control-loop bandwidth. The stimulus must be traceable.

Dr. James M. Atkinson, Moderator: Professor Bode, Dr. Pierce has established that static frequency ratios do not locate a generating device. Please examine the dynamics of shared reference networks, phase-locked loops and measurement-chain transfer functions, especially where two distinct oscillators look indistinguishable in a conventional spectrum trace.

Hendrik Wade Bode, Third Principal Contributor: Dr. Atkinson, one must distinguish a common physical oscillator, a common frequency reference, and a common observed perturbation. In a receiver arrangement, several local oscillators may be phase-locked to one external clock; their frequencies can stand in exact integer or rational relationships even though they are materially different sources. Moreover, one output may be generated by multiplication, another by division, and a third by direct digital synthesis. Their narrow spectral lines can remain coherent for long intervals because the control architecture imposes that coherence. The relationship establishes a shared reference mechanism, not a single oscillating circuit. To infer an oscillator in a particular enclosure, we must understand the physical transfer function and locate where it enters the measurement.

An idealised phase-locked loop comprises a phase detector, loop filter, controllable oscillator and feedback divider. In a linearised locked state, a useful conceptual expression is $\theta_{out}(s)=N H_{ref}(s) \theta_{ref}(s)+H_{free}(s) \theta_{vco}(s)+\theta_{add}(s)$, where N is a frequency multiplication ratio; θ_{ref} is reference phase; θ_{vco} describes internal free-oscillator phase disturbance; θ_{add} represents other additive terms; and H_{ref} and H_{free} are transfer

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functions determined by loop dynamics. The exact form depends on the architecture and on where each disturbance enters. A common reference phase disturbance can therefore be present in multiple outputs, scaled and filtered differently. Two traces with equal frequency ratios do not necessarily possess equal phase-noise spectra, nor does similar noise prove the reference came from one particular instrument.

At offsets well within a particular loop's effective bandwidth, the output often follows reference phase strongly, whereas farther from that bandwidth internal oscillator noise may dominate. The border is not always sharp, and real loops may exhibit peaking. If two outputs are disciplined by the same reference but use different loop bandwidths, a controlled sinusoidal phase modulation swept through a range of offsets can reveal different amplitude and phase transfer. A mere sample of a single sideband at 100 Hz does not supply that dynamic information. The investigator should document small-signal validity and stay below disturbance levels that cause cycle slips, mode transitions or altered controller configuration.

For a numerical illustration, consider a shared 10 MHz reference connected to two synthesisers producing 100 MHz and 250 MHz. They have frequency ratios of ten and twenty-five to the reference. An imposed reference phase modulation index $\beta_{ref}=0.002$ radians would yield ideal output indexes of 0.020 and 0.050 radians at low modulation offsets if both loops faithfully track the reference and if the output mapping corresponds to these simple multiplication factors. At high modulation offsets one loop may suppress that transferred modulation more strongly than the other. The associated

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discrete sidebands are best reported in dBc, not as noise densities in dBc/Hz; the latter unit describes continuum power per hertz. A finite spectrum analyser bandwidth can conflate the two unless the spur and underlying continuum are separated.

Common clocks also complicate covariance. Suppose instruments A and B each estimate the phase of a received carrier, and both share a reference disturbance c(t). Write their errors e_A(t)=g_A*c(t)+u_A(t) and e_B(t)=g_B*c(t)+u_B(t), where g_A and g_B are the relevant impulse responses, * denotes convolution, and u_A and u_B are path-specific disturbances. Even when u_A and u_B are independent, the outputs are correlated through c. The cross-spectrum depends on G_A(f)G_B*(f)S_c(f), with G denoting Fourier transforms of the responses and * on G_B denoting complex conjugation. A strong cross-spectrum can reveal common influence; it cannot, alone, identify where that influence is located. A common power rail, reference switch or thermal enclosure may also create multiple coupling paths whose signals appear coherent.

The control experiment begins by mapping the actual clock and RF paths, not by clicking a correlation command. Identify the oscillator output, reference distribution point, each synthesizer input, relevant mixers, and any independent timing witness. Measure at defined points with properly calibrated isolating probes or buffer outputs, taking care that the probe does not load a sensitive oscillator and alter its spectrum. Repeat with one known reference path disconnected or substituted where safe and authorised. An observable coherence change following that intervention is

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stronger evidence of dependency than a calculated correlation from two supposedly independent displays fed by one shared cable.

Several subtle failure mechanisms can imitate the common-reference result. A poorly shielded digital bus may radiate its clock into the RF front end. A shared power supply can impose periodic amplitude modulation on two independent oscillators. Input stages may generate intermodulation lines at sums and differences. An analyser's own local oscillator phase noise can make several measured signals acquire a similar skirts or sidebands. A software pipeline may apply one clock correction to all output traces, creating artificial time alignment. Each is a physical or algorithmic pathway, and each can be challenged by changing just one connection or reference while preserving the rest of the acquisition configuration.

I would therefore separate two questions in the report. First, do the components share measurable phase or frequency behaviour under particular operating conditions? Second, does the evidence distinguish one free-running oscillator from a network of independently generated but mutually disciplined signals? The first may be answered by careful simultaneous observation. The second typically requires deliberately chosen excitation, reference substitution, comparison of transfer functions, and independent clock paths. Where the equipment is sealed or interventions are not permitted, the conclusion must remain a shared-oscillation or shared-reference hypothesis, not an assertion of a unique source.

Finally, the evidence should carry its own calibration and uncertainty

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statement. A phase transfer function measured with one loop bandwidth or firmware version may not apply after a configuration change. The analyst should retain controller state, gain settings, reference-distribution topology, injected stimulus, sampling rate and the phase-estimator algorithm. Contemporaneous metadata matter as much as the displayed sidebands. Without them, a plausible control-theory narrative becomes impossible to distinguish from post-hoc story-telling. The discipline of feedback analysis insists that a correlated output be understood as the response of a complete system, not as an isolated spectral ornament.

Andrey Nikolaevich Kolmogorov, Peer Question: Professor Bode, an investigator may apply a coherence estimator to two phase records and announce that a value near unity proves a common reference oscillator. Yet finite records, spectral-window overlap, smoothing, and common signal components can all influence that estimate. Please distinguish the population coherence of stationary random processes from an estimate obtained after selecting a particularly interesting transient. How should one evaluate a narrow deterministic spur that is superimposed on random phase noise, and how does the answer change when the phase-tracking loops are themselves nonlinear or change state during the record? I also ask whether a high degree of coherence remains informative when both traces are generated by one digitiser rather than two independent acquisition chains. The danger, as I see it, is to mistake a property of the data-processing arrangement for a newly discovered property of the emitting hardware. If a particular frequency bin was selected after searching many candidate offsets, the apparent coherence may also reflect a selection mechanism. Should the analyst preserve the rejected offsets and reproduce

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the identical selection process under alternative models before assigning evidential weight to the peak?

Hendrik Wade Bode, Response: Professor Kolmogorov, coherence is a conditional statistical description. For two jointly wide-sense-stationary random processes x(t) and y(t), the magnitude-squared coherence at Fourier frequency f is $C_{xy}(f)=|S_{xy}(f)|^2/[S_{xx}(f)S_{yy}(f)]$, where S_{xy} is cross-spectral density and the denominators are the individual spectral densities. Under the usual definitions the value lies between zero and one. A finite estimated value is affected by segmenting, tapering, averaging and estimator bias. With insufficient independent averages an apparent high coherence may be an unsurprising estimator property. The sample count, overlap, effective degrees of freedom and spectral resolution must be reported if one wants to attach an uncertainty to the estimate.

A coherent deterministic spur is not adequately characterised merely by a continuous-noise spectrum. Its power depends on the observation window and its alignment with spectral bins, while its stable phase may dominate coherence at one frequency. The investigator should report the spur separately by offset frequency and carrier-relative level, and analyse the broadband phase-noise continuum without pretending that the spur is an ordinary random density. A transient that occurs once does not satisfy the same stationarity assumptions as a long random-noise record. Time-domain phase traces and event-conditioned comparisons are appropriate companions to a spectrum, with their own selection and timing caveats.

If phase loops change state, the process is piecewise and its linearised

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transfer function may not remain valid across the transition. Report the state intervals and analyse them separately. A cycle slip or controller reset can create an apparent deterministic phase jump. Correlating two corrected traces generated by one digitiser adds no independent confirmation of its sample-time model. The two outputs may even share the same software phase-estimation bias. To strengthen the inference, repeat with independent clocked acquisitions and vary one hypothesised common pathway under a controlled test. The goal is not to obtain a larger coherence number but to show that the measured dependence responds to an intervention predicted by the claimed physical model. A low-noise reference distribution network may still introduce branch-dependent transients, particularly during switching and reacquisition. Those transitions should be retained as marked intervals rather than averaged into the same stationary spectrum as uninterrupted lock, or the inferred covariance may be misleading.

Hendrik Wade Bode, Cross-Peer Question to Dennis Gabor: Professor Gabor, the frequency-domain transfer relationships I have outlined assume that the analysis can resolve the modulation offsets and track phase continuously. A short frequency-agile burst may offer neither long stationarity nor an unbroken phase history. Which time-frequency representation would reveal the differential loop response without attributing spectral leakage to a physical sideband? How would you distinguish a line that genuinely follows a reference perturbation from a component that moves because the analysis window or demodulation centre was changed? I ask you to reconcile the desire for a narrow frequency resolution with the need to observe a fast control-loop transient, and to identify a test that can be

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reproduced from retained raw samples. When the available event lasts only a few milliseconds, one cannot assume that a twenty-hertz offset line is individually resolvable. Should the expert report a bound on modulation rate rather than claiming a precisely separated sideband in that interval?

Dennis Gabor, Cross-Peer Answer to Hendrik Wade Bode: Professor Bode, the time-frequency representation should be selected by the question rather than the attractiveness of the picture. A short-time Fourier transform estimates spectral content in a chosen window. Its nominal bin spacing is inversely proportional to the window duration, while its ability to distinguish nearby events in time improves as the window becomes shorter. A burst shorter than a long window can be diluted, and a frequency transition can paint a diagonal or widened feature whose shape depends on the window and hop. Therefore first preserve the raw complex samples, sample-counter continuity and the exact demodulation reference. Then examine several documented window lengths and compare what is invariant across them.

A direct phase trajectory is often more informative if the carrier remains sufficiently strong and unambiguous. Downconvert the component by a documented numerical oscillator, unwrap phase subject to explicit gap and signal-to-noise checks, and compare its residual against the simultaneously measured reference perturbation. A genuine transferred phase step should show a reproducible temporal relation after allowing for receiver-path delay and the loop's response. By contrast spectral leakage can shift or change amplitude with the window without a corresponding physical phase change in the raw samples. The analyst can test the latter by reprocessing the identical stored data under different windows while leaving acquisition

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untouched.

For a planned calibration, inject a small modulation at several frequencies, but do not insist on a particular harmonic source until the device's operating range has been established. Capture the reference input and output channels with sufficient bandwidth to resolve the loop's possible ringing, and use a calibrated known signal to test phase-estimator latency. Repeat with two independent acquisition clocks to challenge shared sampling errors. The combination of a physical perturbation, a continuous phase record and a sensitivity analysis over window choices is stronger than one spectrogram. It will often reveal that a nominally identical pair of sidebands has different causal histories in the two channels. One should also compare the sideband-estimator output against a known synthetic waveform of similar duration and signal-to-noise ratio. If the algorithm invents a narrow displaced line in a waveform that contains only a transition, it is not a reliable basis for source attribution.

Dr. James M. Atkinson, Moderator: Professor Gabor, the control-theory analysis has shown why coherent sidebands may arise through different circuits. Would you now address finite observation time, brief transmissions, frequency agility and the limits of declaring a common source from similar spectrogram markings?

Dennis Gabor, Fourth Principal Contributor: Dr. Atkinson, a time-frequency display is a measurement of a transformed record, not a portrait of the electromagnetic world independent of the analyser. The investigator may see two simultaneous traces with a common drift and sidebands that rise or fall together. But each pixel reflects a window length, a window function, a

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sample interval, an FFT size, a reference oscillator and a detector choice. If the underlying signals are short or frequency-agile, changing those choices may change the apparent relationship. Before attributing a line to a common oscillator, one must determine which features are invariant under justified changes of measurement method and which are products of the chosen transform.

Consider two complex baseband signals $x_1(t)$ and $x_2(t)$. Their short-time Fourier transforms may be written $X_i(\tau,f)=\int x_i(t)w(t-\tau)e^{(-j2\pi ft)}dt$, where w is the analysis window, τ the window position and f the Fourier frequency. The expression shows that the displayed time-frequency point combines data over a span around τ. It does not identify a single emission instant. If the window is long enough to resolve narrow sidebands it may smear a rapidly changing carrier; if it is short enough to locate a burst it may fail to distinguish close sidebands. An observed ±50 Hz offset may be impossible to resolve in a 5 ms segment, whose nominal Fourier-bin spacing is about 200 Hz before considering the window's effective noise bandwidth and estimator details. Merely increasing FFT zero-padding interpolates a display; it does not create additional independent time information.

A fundamental and its second harmonic also occupy different propagation channels in the practical sense that antennas, cables and enclosures transfer them differently. At 12 MHz and 24 MHz, electrical lengths double in phase for a fixed delay, while antenna directivity and cable losses may alter the amplitude ratio. When the carrier moves in frequency, filters and resonances may distort the apparent drift differently. A ratio measured from

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spectrogram ridge positions can therefore suffer bias from frequency-dependent delay or unequal signal-to-noise ratios. If one component is very weak, the ridge-tracking algorithm may jump to an adjacent interference line, creating a false discontinuity. A credible analysis compares ridge estimates with independently demodulated phase trajectories and documents uncertainty at every interval.

Time simultaneity also requires care. Two emissions may be modulated by the same mains ripple or common mechanical vibration without sharing an oscillator. Their amplitude sidebands can appear at the same offset, and environmental synchrony can be very strong. The investigator should measure amplitude and phase modulation separately. A sideband pair in a power spectrum cannot always distinguish amplitude modulation from phase modulation because that distinction depends on the relative phasor of the upper and lower sidebands. With coherent I/Q observations one can estimate the modulation components, subject to calibration and carrier phase reference. Where the data are magnitude-only, a claimed common phase disturbance is generally too strong.

Suppose a controlled test oscillator at 10 MHz is phase-modulated by a small 120 Hz tone, and a nonlinear output contains a 20 MHz harmonic. Under the simple phase-multiplier model, both components show sidebands at ±120 Hz, while the modulation index at the second harmonic is twice that at the fundamental. Yet the observed sideband powers may not display the ideal 6 dB difference if the signal path adds AM, limits the carrier, filters the sidebands or has significant phase noise. The discrepancy is not

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automatically proof against harmonic generation; it is an invitation to measure the transfer function. Conversely an apparent match at one offset is not enough to distinguish a single multiplier from two synthesizers sharing a 120 Hz disturbance in their reference lines.

The time-domain invariant to seek is a reproducible phase relation under changing conditions. Let $\varphi_1(t)$ and $\varphi_2(t)$ be estimated continuous phases referenced to a common, independently checked time coordinate, and define $q(t)=\varphi_2(t)-2\varphi_1(t)$. If q remains stable across a range of amplitude, frequency and temperature conditions, the phase relation is supported. But if the signals pass through different propagation paths with delays τ_1 and τ_2, the appropriate comparison is not necessarily at the same receiver timestamp; a model may require $\varphi_2(t-\tau_2)$ and $\varphi_1(t-\tau_1)$. Estimating those delays from the same observed coherence can produce circular reasoning, so separate calibration stimuli and independent geometric or cable measurements should be preferred.

Transient perturbations are particularly discriminating. A controlled small phase step introduced into a known candidate oscillator will propagate through a simple harmonic multiplier according to its nonlinear phase law. Two distinct synthesizers locked to a common reference may follow with different transient characteristics. A true signal passing through an analogue filter may ring; a software phase unwrap can choose a continuous trajectory that conceals a real slip. Thus the investigator should inspect raw samples around the event, compare multiple window lengths and phase extraction methods, and verify sample-counter continuity. If the records

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contain a gap during the only decisive transient, the causal question may remain unresolved rather than being settled by interpolation.

The use of multiple stations can help but does not automatically make the evidence independent. Stations sharing a satellite-disciplined standard or a network-time conversion can exhibit correlated clock error. A strong remote emitter can couple differently to each antenna, while local reference radiation may follow cable routes. Examine coherence as a function of station separation, antenna orientation, independent clock configuration and controlled substitution. Preserve the complete set of data, including those intervals in which the two lines fail to co-move. A conveniently selected episode of near-perfect coherence can be a misleading summary of a much less stable relationship.

An appropriate final statement therefore separates frequency-ratio consistency, measured phase coupling, sideband structure, intervention response and source localisation. These are different layers of evidence. A spectral resemblance may motivate a common-oscillator hypothesis; a phase transfer and independent acquisition may support a common driving mechanism; and a verified physical path or controlled enclosure test may finally locate the mechanism. Neither a fine spectrogram nor a precise fitted coefficient can replace that hierarchy. The scientific use of a time-frequency representation is to reveal where the proposed explanation works and where it ceases to explain the observations.

John Wilder Tukey, Peer Question: Professor Gabor, an investigator might adjust FFT length, taper, overlap and ridge-tracking thresholds until two

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spectral traces appear impressively aligned. The final graph could then be presented as if its processing settings had been selected in advance. How would you separate exploratory visual analysis from a confirmatory test of a common oscillator? Would you preserve the complete analysis history, define an independent validation interval, or compare the result with a simulated null that reproduces the instrument's spectral leakage and drift? I am also concerned about a weak second harmonic detected only after aggressive averaging: its apparent phase may be dominated by the strongest nearby interferer or by the algorithm's phase prior. What diagnostic would reveal that instability instead of allowing a clean fitted residual to conceal it? Where the analysis uses several candidates for phase unwrapping, would it be appropriate to require an independent test segment in which the chosen solution is frozen, with competing unwraps retained as alternative models rather than silently rejected?

Dennis Gabor, Response: Professor Tukey, exploratory analysis is valuable, but its outputs must be labelled as hypotheses rather than calibrated confirmatory evidence. The operator may change windows and thresholds to understand a complicated spectrogram; the problem begins when the one most convincing configuration is treated as if it were a prespecified test. Preserve the full processing configuration history and select a separate held-out interval or independent measurement on which the proposed relation can be evaluated without further tuning. The analyst should then publish the acceptance criterion, allowable residual, signal-to-noise thresholds, and treatment of missing or ambiguous phase samples before looking at the validation result.

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A useful null simulation reproduces the acquisition system: sample rate, clock phase noise, window shapes, overlap, frequency drift, instrument-induced spurs and the candidate-selection procedure. Simulating two independent emitters that happen to share an environmental modulation may be especially informative. If the same coherence score occurs frequently under that alternative, the score cannot be presented as unique evidence of a common oscillator. The null should reflect physical alternatives, not merely independent white-noise traces chosen because they make the observed result look extraordinary. One should report sensitivity over plausible null families rather than a single theatrical significance number.

For weak phase estimates, calculate or empirically bound the estimator's uncertainty as a function of signal power, interference and bandwidth. Examine phase residuals before and after excluding low-amplitude intervals according to a declared rule, and retain the excluded intervals in the report. A phase-unwrapping algorithm can exhibit sudden cycle slips that masquerade as physical phase jumps; conversely interpolation can bridge genuine missing data into an unrealistically smooth record. Inject a known weak calibration tone through the same receiving chain to challenge the estimator at the relevant level. Finally, require a second independently clocked capture or a controlled source perturbation that agrees with the predicted transfer law. Replication of a causal response is better than perfecting one plot. The test should explicitly record the carrier-tracking bandwidth, because a narrow tracking loop may filter out the very transient sought, while an excessively wide loop can follow interfering noise.

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Reprocessing cannot recover observations removed before digital storage by the original analogue tracking configuration.

Dennis Gabor, Cross-Peer Question to Ronald Newbold Bracewell: Professor Bracewell, my phase residual can be remarkably stable even when I have not established whether the two frequencies were emitted by one physical antenna or by separate radiators driven by a common clock. Which spatial measurements would discriminate these cases? Please consider that the harmonic and fundamental may propagate differently through walls, cable shields and antenna patterns, so simple agreement in received strength at several points may mislead. How would you combine phase, direction and independently calibrated propagation measurements without assuming the very common-source claim that we are trying to test? I would particularly value a method that identifies what cannot be concluded when the survey team has observations from only one room and no authority to perturb the suspected electronics. Would the uncertainty budget need distinct terms for station geometry, antenna calibration, sample-time alignment and propagation before such a spatial comparison could support source identification? If those terms cannot be separated, which observations remain defensible?

Ronald Newbold Bracewell, Cross-Peer Answer to Dennis Gabor: Professor Gabor, the spatial experiment should begin by defining what 'same source' means. One oscillator may drive two radiating structures at different positions; two oscillators can drive one antenna system through a combiner; and a receiver can generate a line internally without any second external field. Thus even proof of a shared oscillator does not, by itself, prove one radiating location. Use independently calibrated antennas and receivers to

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estimate bearings, field polarisation, and position-dependent amplitude or delay at both frequencies, while controlling for their different antenna responses and propagation paths. A purported coincidence must be compared with the actual uncertainties of those measurements.

For a controlled installation, measure at multiple surveyed positions and include a known calibration radiator at each frequency to estimate the environment's transfer response. If the observed component follows the test antenna's position or orientation while a locally injected reference feature remains fixed, the field hypothesis gains support. If the line persists into a properly terminated RF input and follows the reference cable or instrument enclosure, an instrumental coupling pathway becomes more plausible. Test the two frequencies independently because a filter or cable can introduce frequency-dependent nulls. Do not assign one geographical coordinate by merely intersecting uncalibrated amplitude maxima.

Where access is limited to one room, the result should remain a bounded statement of compatibility. An investigator can report that the measured lines show a stable harmonic phase relation and spatial patterns compatible with a common drive, but cannot exclude multiple radiators or a distributed reference network. The evidence becomes stronger through independent measurements of reference-plane input, frequency-transfer behaviour and antenna substitution. The spatial observations should challenge the spectral hypothesis, not be selected and processed to reproduce it. An honest uncertainty region may be broad, and an attribution may be withheld even when the frequency relation is measured accurately. A formal record should

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identify which spatial comparison was actually carried out and which was merely proposed. It is especially important not to transform a suggested laboratory experiment into the language of an accomplished field verification. In addition, a source attribution should retain uncertainty about any unmeasured path delay or frequency-dependent radiation pattern. Those alternatives must be stated before the final finding.

Dr. James M. Atkinson, Moderator: Professor Bracewell, we have traced possible harmonic mechanisms through nonlinear devices, feedback loops and time-frequency analysis. Please now address the evidential boundary between common phase behaviour and identification of a source, and develop a survey protocol suitable for a lawful technical surveillance countermeasures examination.

Ronald Newbold Bracewell, Fifth Principal Contributor: Dr. Atkinson, the spectral problem becomes a source-attribution problem only after the investigator demonstrates that the observations are associated with the external environment rather than solely with the receiving instrument. A harmonic ratio is a relationship between measured frequencies. Phase coherence adds information about a common driving process. Neither fact automatically identifies an antenna, a physical enclosure or an individual transmitter. Radiation is mediated by conductors, shielding imperfections, cabling, reflections and antenna geometry. One oscillator may feed multiple distant radiators, while separate oscillators may be synchronised by one reference. The spatial experiment is therefore a separate necessary layer of inference, and it must be designed without presupposing the answer that the spectral analysis is intended to support.

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Suppose two signals are observed near f and 2f. Their free-space wavelengths are $\lambda=c/f$ and $\lambda/2$ respectively, where c is propagation speed in free space. A piece of conductor that is electrically short at f may be a more efficient radiator at 2f, while shielding or cavity resonances may act differently. As a consequence, the field-strength maxima for the two components need not occupy the same points even if they originate from the same circuit. Conversely a room's multipath can cause unrelated emitters to have nearby local amplitude maxima. The investigator must avoid the appealing but invalid inference that matching amplitude heat maps prove one source or that different maxima disprove common generation. Frequency-dependent propagation and antenna patterns must be measured or bounded.

A first control uses a clearly documented measurement reference plane. Record each antenna's calibration or measured response at both frequencies, its polarisation, its orientation and its cable transfer characteristic. Record preamplifier gain and linearity, filtering, receiver attenuation, and local oscillator state. Compare an antenna-connected measurement with a properly terminated RF input, noting that termination can alter common-mode coupling and does not necessarily remove radiation directly entering the enclosure. Then use an alternate receiver architecture and independent frequency reference where available. If a line persists in a terminated channel and changes with the receiver's own clock configuration, it is unsafe to count it as a second external emitter without further challenge.

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A second control maps space and polarisation. At surveyed points, measure both frequencies with enough angular diversity to distinguish a directional response from a local null. A field is vectorial; rotating a linearly polarised antenna can substantially change received power even when the source remains unchanged. An antenna null can create a false-negative indication that tempts an operator to localise a weak source at the strongest available reading. Repeat with more than one antenna orientation, and distinguish near-field coupling to conductors from far-field plane-wave assumptions. The dimensions of a room and the wavelengths of interest determine whether a simple inverse-distance model is appropriate. A sharp local maximum near a metal cabinet could be a resonance or cable current, not the oscillator itself.

A third control uses time and covariance. A long enough phase record can compare whether frequency drift and sideband motion remain related across periods when the receiver configuration changes. However, a shared clock between all receiver channels can create artificial agreement. Write a common-cause model in which measured component phases depend on the emitter, path delays, channel local oscillators and a possible shared reference. If two station records are combined, calculate their differential uncertainty with cross-covariance terms rather than assuming independent errors. A strong positive covariance can cause the arithmetic difference to appear more stable even while absolute phase is wrong. State whether the inference concerns a relative phase relation or an absolute timing claim.

The most useful experiments are counterfactual. If the suspected oscillator

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belongs to equipment the investigator is authorised to test, apply a small safe frequency or phase perturbation while an independent instrument observes the candidate source directly and the receiving array observes the suspected field components. The proposed harmonic should exhibit a predictable n-fold frequency response, subject to the device's transfer characteristics. If two sources are simply locked to the same reference, a reference perturbation may affect them both, but an adjustment made to only one oscillator after the branching point may not. If the receiving chain generated the harmonic internally, attenuation and filtering placed before the nonlinearity can expose that mechanism. Every perturbation changes the experimental state, so preserve the original unaltered record and do not treat the diagnostic response as a historical observation.

Where perturbation is forbidden or unsafe, seek diversity of measurement rather than inventing certainty. Use independently clocked hardware; compare observations from different antenna locations; test receiver linearity with a separate laboratory stimulus; measure known cable and enclosure leakage paths; and inspect whether the frequency relationships persist after physically separated receivers are substituted. Keep negative findings with stated sensitivity and observation coverage. A harmonic absent in one measurement may be below its detection limit, outside the antenna's pattern, or extinguished by a filter. Non-detection does not automatically exclude an emitter, and successful detection does not automatically identify its location.

For the statistical conclusion, define hypotheses carefully. H_A may denote

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one oscillator producing the observed harmonic externally; H_B two physically separate oscillators coupled through a common standard; H_C one external carrier generating a second harmonic in the receiver; H_D unrelated sources appearing related after search selection. The candidate tests should have distinct predicted outcomes under at least some of these hypotheses. If every available test gives the same prediction under H_A and H_B, the two remain observationally indistinguishable in that experiment. No number of repeated uninformative observations can eliminate the ambiguity. A later source attribution must therefore be framed as conditional or withheld until a discriminating experiment becomes possible.

I would require a source report to enumerate the identified spectral components, calibrated reference planes, measured phase relationship, observation duration, data losses, tested input attenuation, receiver substitutions, antenna orientations, source perturbations, and any remaining common instrumentation. It should distinguish a detected line, a classified harmonic family, a shared reference mechanism, a radiating structure, and an attributed source. Each ascending category requires new evidence. Forensic reproducibility is best served when a reviewer can replay the original samples, reproduce the calculations and identify which assumption, if changed, would alter the conclusion. This is the difference between a disciplined engineering finding and a persuasive-looking but untestable narrative.

George Edward Pelham Box, Peer Question: Professor Bracewell, you have presented several hypotheses, but a laboratory instrument can rarely reproduce the exact multipath, cable routing and intermittent behaviour

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encountered in a field installation. How should an analyst use a simplified source model without confusing its good fit with proof that the model is correct? If two hypotheses make nearly identical predictions for the recorded spectral lines, does additional numerical precision materially improve the inference, or is it necessary to choose a new experiment? I should also ask how one documents a negative result from a terminated antenna input where the act of termination may alter common-mode currents or the gain state. Can a rigorous final report communicate unresolved competing explanations without implying that all explanations have identical plausibility? What would constitute a disciplined rather than merely rhetorical treatment of model limitations? I should further distinguish a failure to identify the unique source from a failure to measure the frequency relationship itself. How might the examiner preserve that useful quantitative relationship while expressly withholding geographical attribution?

Ronald Newbold Bracewell, Response: Professor Box, a model should be judged by the questions it can answer and the conditions under which its predictions have survived tests. An exact fit of the observed harmonic ratio is weak evidence if several physical hypotheses predict the same integer ratio. Measurement precision improves estimation within a given model, but it cannot resolve a structural lack of identifiability. The appropriate remedy is a new experimental contrast, such as changing an independent reference path, measuring at a different RF plane, or applying a controlled source perturbation whose predicted response differs among hypotheses. One should not simply add more decimal places to an equation with several equally plausible causes.

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The terminated-input experiment illustrates the issue. A signal that disappears after a connector is terminated could have entered through the antenna, but the termination may also change impedance, suppress a common-mode current, alter an amplifier's stability or trigger automatic gain changes. Record all of those potential mechanisms and measure the detector's sensitivity and noise floor in the new state. Repeat with alternative terminations or a controlled injected reference signal where appropriate. If the line persists, investigate coupling around the input connector; if it disappears, state that this response supports an input-path dependence under the tested conditions, not the existence or identity of a particular transmitter.

Model comparison should be grounded in distinct predictions. For H_A, a controlled change in the suspected source frequency should cause the harmonic to move with the predicted multiple. For H_B, changing only one branch downstream of a common reference can break that relation. For H_C, internal generation should respond to receiver-side attenuation or architecture changes according to its transfer law. For H_D, a preregistered observation with independent clocks may fail to reproduce the coincidence that was selected retrospectively. If an experiment does not distinguish hypotheses, the report should state the unresolved equivalence. One can still rank explanatory support qualitatively based on completed tests, while avoiding numerical likelihoods unsupported by measured error distributions.

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Finally, preserve the exact model version, calibration data and sensitivity analyses. A defensible conclusion may say that one hypothesis explains the present observations with fewer unverified assumptions, while identifying a specific remaining test needed to distinguish it conclusively. That is not indecision; it is the honest boundary of what the instrument and experiment have demonstrated. A useful scientific model is one that can be challenged, corrected and ultimately replaced as new observations become available.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel distinguishes five separate propositions: an integer frequency relation; matching sideband offsets; phase or frequency co-movement; a physical common driving mechanism; and identification of one external source. The first three can be demonstrated by appropriate measurements, but cannot alone establish the last two. A harmonic generated at a transmitter and a harmonic generated inside a receiver can obey the same phase law. Two separate synthesisers locked to one reference can exhibit phase coherence without sharing the same free-running oscillator. Coherent external modulation and signal-processing bias may imitate either arrangement. The strongest evidence comes from independent receiver chains, calibrated reference planes, attenuation and filtering tests, source and reference perturbations, phase-transfer measurements, spatial field challenges, and full preservation of contrary observations. The dialogue is a fictional scholarly reconstruction; its worked examples are hypothetical and must not be represented as observations from a particular security engagement.

QUESTION 073. TECHNICAL SOURCE REGISTER AND PUBLICATION QUALIFICATIONS

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1. NIST, Archita Hati, Craig W. Nelson and David A. Howe, Cross-spectrum Measurement of Thermal-noise Limited Oscillators (2016), https://www.nist.gov/publications/cross-spectrum-measurement-thermal-noise-limited-oscillators. Supports the qualification that common splitters and correlated or anti-correlated noise can complicate cross-spectral instrument measurements.

2. NIST, David A. Howe, Archita Hati, Craig W. Nelson and Danielle G. Lirette, PM-AM Correlation Measurements and Analysis (2012), https://www.nist.gov/publications/pm-am-correlation-measurements-and-analysis. Supports the need to distinguish phase noise, amplitude noise and their correlation rather than infer a source from a power-spectrum similarity.

3. Keysight Technologies, Understanding and Improving Signal Analyzer Dynamic Range, application note 5992-1516, https://www.keysight.com/us/en/assets/7018-05219/application-notes/5992-1516.pdf. Supports attenuation challenges that distinguish signals entering the instrument from distortion generated inside the analyser, subject to measurement-plan details.

4. Rohde & Schwarz, Phase Noise Measurement Techniques, https://cdn.rohde-schwarz.com/am/us/campaigns_2/embedded/Rohde_Schwarz_Phase_Noise_App_Note_Allparts.pdf. Supports practical phase-detector methods and the limitation imposed by an analyser’s internal phase noise.

5. SiTime, Phase Noise Measurement Guide for Oscillators, AN10062, https://www.sitime.com/support/resource-library/application-notes/an10062-phase-noise-measurement-guide-oscillators. Provides a practical

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distinction between deterministic spur levels in dBc and continuum phase-noise densities in dBc/Hz, with cross-correlation measurement caveats.

EDITORIAL QUALIFICATION: All historical speech is constructed pedagogy. Every numerical example is hypothetical. The cited sources have been identified, but full claim-by-claim and edition/page verification is still required. Structural Stage A acceptance does not approve historical attributions, scientific completeness, full-volume semantic originality, or publication pagination.

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QUESTION 074

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How do adjacent-channel leakage and selectivity change site-to-site occupancy comparisons?

Dr. James M. Atkinson, Moderator: Dr. Pierce, two authorised survey teams report that a nominal twelve-and-a-half-kilohertz channel is busy on forty-eight per cent of observations at Site A but on twenty-one per cent at Site B. The nearest transmitter is stronger at Site A, and the receivers nominally share a frequency plan, though their analogue preselectors, digital filters and detection thresholds differ. Is their reported discrepancy evidence of a real difference in channel use, or could it be manufactured by the observing systems? Please examine the inference in its entirety and pass the token to a colleague when the engineering limits become apparent.

John Robinson Pierce, Principal Contributor: Dr. Atkinson, the disagreement begins with the meaning of the word channel. A frequency allocation is an administrative interval, a transmitted waveform occupies a spectral distribution, and a receiver creates its own effective band by applying a frequency response to voltages arriving at its input. Those three objects overlap without being identical. When a powerful adjacent transmitter creates sidebands outside its nominal centre, those sidebands are physical radiation. When a broad receiver admits part of the adjacent transmitter's otherwise legitimate emission, the leakage is a consequence of observation. When an overloaded amplifier produces mixing products, the apparent in-channel energy is created inside the measuring chain. It is essential to distinguish all three pathways before saying that Site A has more legitimate occupancy than Site B. Even if the same physical field exists

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at both positions, distinct receiving filters can assign different detected states to the same frequency bin.

Consider a baseband representation. Let S(f,t) denote the received power spectral density at radio frequency f and observation time t, expressed in milliwatts per hertz. Let H_i(f;f_c) denote the complex voltage transfer function of receiver i about the nominal channel centre f_c, with its gain normalised at the reference plane. In a linear, stationary approximation, the receiver-equivalent power is P_i(t)=integral over f of |H_i(f;f_c)| squared times S(f,t), integrated across the relevant measurement band. A noise term N_i(t) must then be included at the same reference plane. The classification B_i(t) equals one if the measured quantity exceeds the explicitly declared threshold T_i, otherwise zero. A reported occupancy O_i is the number of accepted busy observations divided by the number of eligible observations, with sampling weights declared when records differ in duration. The formula is not an assertion that the instrument remains linear. It is a testable model whose failure must be investigated by level sweeps and independent receivers. A receiver with automatic gain control, clipping, image response or digital overload requires additional state variables and cannot be represented safely by a static H_i alone.

A worked example clarifies the danger. Suppose an adjacent-channel emitter delivers minus forty-five dBm to the receiver's input during a particular burst. After a measured forty-five decibels of attenuation through the observation channel's selectivity response, the contribution is minus ninety dBm. An occupancy threshold of minus ninety-five dBm marks the nominally empty channel as busy. If another receiver attenuates that same off-centre signal by fifty-five decibels, its indicated contribution is minus one

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hundred dBm, below the same threshold. The first instrument reports a busy sample and the second an idle sample although neither has shown that the transmitter of interest actually used the surveyed channel. The arithmetic uses dBm only after calculating a power ratio in decibels; two independent contributions must be added as linear milliwatts, not by adding the numerical dBm values. With an independent minus one hundred dBm noise-and-interference component, the first receiver would indicate about minus eighty-nine-point-six dBm total, rather than minus one hundred and ninety dBm. That distinction is not pedantry. It determines whether an apparent occupancy discrepancy is traced to actual emissions or merely to an improperly represented instrument response.

There is a second ambiguity concerning the bandwidth that defines the power measurement. A three-decibel increase in white-noise power accompanies a doubling of equivalent noise bandwidth when the density is unchanged; it is not evidence of an additional transmitter. The equivalent noise bandwidth B_eq is the integral of |H(f)| squared over frequency, divided by the peak squared response, under a stated normalisation. Two filters each described as a twelve-and-a-half-kilohertz channel may possess different skirts, passband ripple and B_eq. One may accept a broad adjacent signal strongly while another suppresses it. A third receiver may integrate a wide intermediate-frequency stage and apply a narrow display filter only after nonlinearity has already occurred. That display can look impressively selective while the input amplifier remains susceptible to blocking. We must document selectivity at the earliest stage where the unwanted energy can cause a change, not merely photograph the attractive final trace.

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The experiment should therefore have three layers. First use a controlled weak wanted carrier on the channel and a second generator, separated by precisely one channel spacing, to obtain the upper and lower adjacent-channel rejection curves at several input levels. Secondly replay the same captured complex waveform through both digital filters while disabling gain adaptation, thereby isolating analysis-filter differences from antenna, propagation and preselector effects. Thirdly expose each whole receiver chain to the same calibrated wanted-plus-unwanted signal at levels that bracket the field levels observed during the survey; if the classification divergence appears only at high levels, a nonlinearity or gain-control transition deserves particular attention. The result should report response curves and their uncertainty, not a single heroic selectivity number divorced from operating conditions. The two-input approach resembles the controlled receiver selectivity method in ETSI EN 300 086, but that equipment standard's defined performance criterion is not itself an occupancy-correction algorithm. For occupancy practice the more appropriate current context is ITU-R Report SM.2256-2 (June 2026), which expressly treats selectivity, detection thresholds, observation timing, measurement sites and the combination of neighbouring frequency samples.

I would refuse to pool the original percentages until the two measurement operators are shown to have comparable behaviour or a common raw-data reprocessing procedure can be defended. Forty-eight per cent and twenty-one per cent may be mutually consistent descriptions of different operational detectors. Neither proportion is intrinsically wrong, but neither is a demonstrated estimate of an instrument-independent channel-use

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probability without calibration and modelling. Preservation of the unthresholded power records, receiver configuration, attenuator state, timestamps, measurement reference planes and any rejected or saturated observations is indispensable. Once those objects are archived, investigators can repeat a common classification and quantify the residual difference attributable to geography. Until then, the claim should be styled a difference in reported detector occupancy, not a proven difference in emitter behaviour. This is the distinction on which a defensible forensic comparison turns.

Walter Andrew Shewhart, Peer Question: Dr. Pierce, a field instrument often produces an appealing single occupancy percentage, but an engineer cannot inspect its hidden decision variability merely by reading the display. Suppose repeated adjacent-signal injections produce passband levels that drift with internal temperature, while the software threshold itself is periodically recalculated from the recent noise estimate. The team then calls the two sites different because the reported busy proportions differ, although the calibration conditions have not been controlled. Would you distinguish ordinary process variation from a real change in the measurand, and prescribe a repeatability experiment that can reveal both a drifting selectivity function and a moving threshold? I also ask you to address the awkward case in which the injection signal itself disturbs automatic gain control. The test should preserve enough raw evidence to permit another laboratory to challenge the classification without access to the proprietary detector code, and it should not hide correlated observations beneath a single reassuring confidence interval.

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John Robinson Pierce, Response: Dr. Shewhart, an instrument must be assessed as a process whose output depends upon thermal history, input level, sampling time and software state. I would not begin with the assumption that every difference from a nominal calibration number is random Gaussian noise. Use a stable, traceable two-tone injection with the wanted carrier and adjacent interferer presented at known input reference levels. Repeat the identical acquisition at cold start, after thermal equilibrium, after a level step, and after a return to the initial level. Record not only detected busy states but predecision power estimates, gain states, overload indicators, threshold values and the temperature observable. An apparent site difference can then be compared against the instrument's own within-condition distribution before attributing it to propagation or transmitter operation.

An economical design includes randomised order and deliberate reversal. For example, run low-high-low adjacent input levels within a single controlled session; if the final low-level measurement differs from the initial low-level measurement, hysteresis or settling deserves investigation. Repeat that sequence at two temperatures rather than assuming one environmental state. If the test waveform triggers automatic gain control, that response is itself a property of the configured observation system, so report one experiment with gain control enabled and another with it fixed, if technically available. Do not merge the resulting figures as though they described the same detector. A control chart may help identify temporal instability, but it is not a substitute for quantifying frequency-dependent bias or proving that a declared decision threshold represents the same physical power at both sites.

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A blind replay is particularly valuable when the proprietary code is inaccessible. Archive an authenticated baseband recording at a defined interface, accompanied by a calibrated amplitude scale and sample rate; submit the identical sequence to both analysis chains, including a record of their actual thresholds at each epoch. Another laboratory can then determine whether disagreement follows the software or the analogue front end. Compare an additional simple and transparent reference classifier applied to the same record. Such a classifier should not be treated as perfect ground truth, but it establishes a stable benchmark for identifying logic differences. Measure correlation across neighbouring samples because a strong adjacent burst often produces a run of positive decisions. A thousand consecutive positive samples are not a thousand independent observations of selectivity. The confidence statement must respect the clustering structure or be obtained by resampling at the burst or session level. This preserves the statistical distinction between repeatable instrument bias, ordinary random variation and real site conditions.

W. Edwards Deming, Peer Question: Dr. Pierce, the proposed comparison has an administrative weakness as well as an electrical one. One team may label the coaxial connector at the preselector output as the measurement reference plane, while another reports field strength at the antenna location after applying a nominal antenna factor. Their calibration certificates are genuine yet the results cannot be reconciled because cable losses, frequency-dependent gains and detector settings have different definitions. How ought a forensic laboratory structure its measurement-control plan so that a later reviewer can reproduce the chain of custody from incident field to occupancy declaration? Please explain whether an observed excess

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occupancy should be corrected numerically at once, held as a qualified observation, or rejected pending additional calibration. Finally, identify the minimum metadata you would require before allowing figures from two sites into the same statistical table. I would also want an explicit rule for preserving failed measurements, since silently discarding a receiver overload or a disrupted calibration can make a superficially complete dataset less reliable than a candidly qualified one. Which evidence should be sealed before any subsequent adjustment?

John Robinson Pierce, Response: Dr. Deming, the unit of comparison must be named before either team begins counting. If the measurand is incident electric field at a defined point, the antenna response, cable transfer, preamplifier characteristics and receiver calibration must be linked to that physical quantity. If the measurand is receiver-input power, the reference plane belongs at the input connector and antenna conversion is a separate interpretive problem. Mixing the two in one occupancy table produces spurious precision even if every calibration certificate is authentic. A sound procedure therefore records a block diagram with named reference planes, a serial-numbered signal path, the configuration and firmware of each active instrument, and a signed acquisition protocol. The log must include antenna orientation, mounting height, cabling, input attenuation, filter identity, bandwidth, acquisition timing, threshold rule and overload indicators. A field-strength estimate additionally needs an antenna factor or effective-aperture model with frequency and orientation dependence.

A numerical correction should be applied only where the physical mapping is supported by observed response data and the measurement remains inside its validated range. When the strongest adjacent emission pushes the

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first amplifier beyond its linear range, no scalar correction to the displayed occupancy proportion can reconstruct the lost information. Mark the affected observation as qualified, preserve it and acquire a replacement measurement if circumstances permit. Where raw complex samples are available from a demonstrably linear front end, reprocessing through a common matched filter can be legitimate, provided the anti-alias filtering and recorded bandwidth retained the necessary spectrum. Where the receiver irreversibly clipped or suppressed a wanted signal through gain control, the data may establish that the scene was RF-crowded but cannot establish the counterfactual occupancy under an undisturbed receiver.

For an audit table, I would insist upon independent identifiers for site, session, channel, receiver chain, configuration and calibration state, together with absolute timestamps and uncertainty in synchronisation. Each observation should have a declared analysis duration, centre frequency, equivalent noise bandwidth, power reference, decision threshold, classifier version and known exclusions. Store evidence hashes and the original instrument files so the meaning of a percentage can be reconstructed rather than trusted by reputation. A cross-site summary should flag observations that satisfy a common equivalence test and place the rest into separate methodological strata. It is acceptable to conclude that present evidence does not support comparison. That conclusion is analytically stronger than an apparently exact numerical correction whose assumptions have never been demonstrated.

John Robinson Pierce, Cross-Peer Question to Hendrik Wade Bode: Dr. Bode, my integral model assumes a receiving filter whose response remains stable at a specified reference plane, and my example suggests that

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different skirts may produce incompatible occupancy classifications. Yet a front end may contain several frequency-selective elements before digitisation, and its overall response may be altered by feedback, temperature or overload. How would you separate the useful linear transfer-function description from behaviour that violates superposition? Please address the temptation to quote one adjacent-channel selectivity figure as though it defined every frequency offset and input amplitude, and explain what a control engineer can infer from a measured gain-and-phase response without assuming that the filter itself has generated a particular spectral line. I wish to know precisely which engineering tests would make a site-to-site correction defensible. Please compare an ideal small-signal measurement to the actual blocked receiver under a two-tone challenge, because a site-to-site correction must survive the joint operating condition and not rely upon a specification obtained with the unwanted source absent.

Hendrik Wade Bode, Cross-Peer Answer to John Robinson Pierce: Dr. Pierce, a transfer function is a relationship for an operating condition, not a permanent identity card attached to an instrument. Under linear time-invariant assumptions, a cascade of stages possesses a frequency-domain response equal to the product of the stage responses, provided impedances and loading are properly incorporated into their characterised network behaviour. The magnitude tells us the attenuation applied to individual spectral components, and the phase describes their delay relationship. It does not tell us how a nonlinear amplifier will respond to the simultaneous presence of a strong adjacent carrier and a weak wanted signal. A gain

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curve measured with a single quiet tone cannot by itself establish the behaviour under a crowded two-tone field.

I would measure a response matrix across offset frequency and input amplitude. At each offset, inject the unwanted signal with a calibrated wanted signal and measure desired-channel output degradation, spur appearance and gain change. Repeat above and below the centre because physical filter asymmetry may be material. Record the threshold and detector response, as these are subsequent system functions rather than merely passive filter properties. Where a receiver contains separate analogue and digital filters, test them independently if practical, then test the complete cascade. A stage that creates intermodulation at its own input cannot be redeemed by a beautifully narrow digital display downstream; the unwanted product may fall directly into the wanted channel and pass the final filter unhindered.

A useful thought experiment is to increase both applied signals by ten decibels while preserving their difference. In a linear system, output powers scale by ten decibels and the ratios among corresponding spectral components remain fixed, apart from the noise floor. Nonlinear intermodulation products can grow at different slopes, and gain compression can decrease the wanted response. The exact slopes are device- and level-dependent, so do not use a textbook third-order exponent beyond the range in which it has been measured. For a defensible correction, confirm that the original acquisition operated within the demonstrated linear range; measure both channel skirts and effective bandwidth; account for all front-end signal pathways; and propagate uncertainty in the conversion from observed power to the common

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reference quantity. Only then is the transfer function a corrective instrument rather than a decorative diagram.

Dr. James M. Atkinson, Moderator: Sir Edward Appleton, Dr. Pierce has identified the filtering and decision problems. Would you take the token to examine the field itself, particularly the distinction between a genuine geographical difference in received RF energy and a difference manufactured by measurement selectivity? The question is not whether propagation exists, but whether an apparent difference in channel occupancy can legitimately be attributed to transmitters when the instruments view different spectral mixtures.

Sir Edward Victor Appleton, Second Principal Contributor: Dr. Atkinson, a radio survey meets a physical landscape before it meets a statistical one. Fields differ in amplitude, polarisation, angle of arrival, path delay and frequency selectivity across sites. A high-power neighbouring transmitter may reach one site through a strong unobstructed path and the other only after shadowing and reflection. That disparity is genuine propagation, yet the resulting apparent occupancy of the nominal surveyed channel may be artificial if the detector cannot distinguish the neighbour's energy from actual use of the wanted allocation. The distinction is causal. A propagation difference can explain why the instrument encounters different unwanted energy, but it does not prove that the intended channel is occupied more often. We must not confuse a real environmental cause of a false positive with the underlying event that the false positive purports to report.

Let W_s(t) denote the true wanted-channel signal at site s, A_s(t) the aggregate adjacent-channel interference at the antenna reference point,

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and R_s(t) the receiver's additional instrumental response. A simplistic scalar model is Y_s(t)=G_w,s W_s(t)+G_a,s A_s(t)+R_s(t)+N_s(t), where G_w,s and G_a,s are effective gains under a linear power-domain approximation and N_s represents noise. In a complete spectral model these gains are integrals over frequency, angle and polarisation. The reported busy state is the output of a threshold decision applied to Y_s. An analyst who observes Y_A frequently exceeding threshold and Y_B rarely doing so cannot infer that W_A occurs more often than W_B without examining A and R. The unobserved decomposition is an identifiability problem; many combinations of wanted activity and adjacent leakage can generate the same occupancy percentages. More sensitive equipment alone does not solve identifiability. Sensitivity may increase the number of weak actual emissions detected and the number of adjacent spurs falsely admitted.

Different geographical sites may also create unequal observations of the same wanted transmitter. Suppose a weak signal arrives at minus one hundred and two dBm at Site B during an event and minus ninety-four dBm at Site A. With a fixed threshold of minus ninety-eight dBm and an otherwise comparable receiver chain, Site A identifies the event while Site B does not. The detection disparity may be a legitimate difference in the probability of observing the same transmitter, not in the transmitter's actual duty cycle. Propagation, antenna placement and receiver noise all enter that probability. A cross-site occupancy table must distinguish emitted duty cycle, received signal-above-threshold occupancy and instrument-reported busy time. Those are three related but nonidentical quantities. Where the object of a forensic enquiry is whether an RF emitter was present, negative

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evidence at a disadvantaged site must be conditioned on the probability of observing it under the conditions actually encountered.

The remedy is not to erase geographical information by fiat. Establish a reference transmitter or controlled portable radiator with known emissions and observe it from both sites, using safe authorised test conditions and documented distances and polarisations. If a signal cannot be radiated, a conducted injection isolates the receiver but does not reproduce propagation, antenna effects or site noise. The two controls answer different questions and must not be represented as interchangeable. A geographically stable signal at a known frequency may help check the relative power scale, but it is not necessarily a suitable calibration reference for pulsed emissions or a different polarisation. The investigator needs an uncertainty budget for each transfer step, from incident field through antenna and cable to decision, and should acknowledge that propagation can vary during the session. The inability to make an exact point-by-point correction does not authorise pretending that site differences are negligible.

There is a further issue of temporal coincidence. Site A may monitor at midday, Site B after dark, and a channel occupied by intermittent infrastructure may change through operating schedules rather than geography. In ionospheric bands the propagation mechanism itself may vary substantially with time, but even a local line-of-sight channel can be affected by moving reflectors, doors, machinery, vehicles or humans. To isolate a site contrast, obtain simultaneous paired observations where feasible, with time synchronisation adequate to the burst durations of interest. If a shared clock cannot be provided, record the uncertainty of alignment and compare over time bins broad enough to remain meaningful.

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A site comparison that combines noncontemporaneous samples without describing its temporal target estimates two different mixtures of location and operating period. The resulting difference is mathematically real yet scientifically ambiguous.

A proper report therefore gives separate fields for raw observed occupancy, controlled-detector-equivalent occupancy and qualified channel-use inference, where the last is permitted by the evidence. It may state that both sites observed substantial activity in the neighbourhood of the channel while attribution to the central allocation remains unresolved. It may also state that the adjacent emitter was stronger at one site, which supports a specific mechanism for false busy classifications. What it must not state is that the central transmitter operated for forty-eight per cent of a given period merely because forty-eight per cent of detector outputs were high. This disciplined separation of physical field, receiving chain and causal attribution is the best safeguard against transforming propagation science into an unwarranted narrative of surveillance activity.

John Wilder Tukey, Peer Question: Sir Edward, many analysts attempt to rescue an inadequate design with a sophisticated plot after the fact. Imagine that two survey sites have unequal receiver response, different antenna orientations, and incomplete logs, but retain timestamped power traces covering overlapping periods. One analyst aggregates every reading into a single busy fraction; another bins the data by hour and signal level; a third uses the strongest neighbouring carrier as a covariate. Which exploratory comparisons may genuinely diagnose an adjacent-channel mechanism, and which could produce a persuasive but spurious correlation? Please consider a case where the interferer and the suspected wanted

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transmitter share an operational timetable. Their temporal correlation might make the adjacent carrier appear to explain every event while obscuring a real co-channel signal. How should the analysis present uncertainty and competing causal accounts without hiding the unmeasured settings behind charts? Please identify one exploratory graphic that might falsify the preferred interpretation and explain why the team should retain it in the formal audit record rather than discard it because it is awkward or statistically unflattering.

Sir Edward Victor Appleton, Response: Dr. Tukey, the first plot should show the raw timing relationship with as little inferential machinery as possible. Place the nominal-channel power, neighbouring-channel power, threshold setting and instrument gain state on aligned axes, retaining gaps and missing periods. If the apparent central-channel busy intervals begin and end at precisely the same times as strong neighbouring bursts, that is evidence consistent with leakage; it is not yet proof that the desired channel contains no signal. Observe whether the size of the central response tracks the adjacent power according to the independently measured filter skirt. Where the central response persists after the adjacent emitter stops, or follows a different modulation envelope, a separate source becomes more plausible. A correlation can also arise because both emitters run on a common site schedule, so the strength and timing relationship should be challenged by physical perturbation where the enquiry permits it.

The useful exploratory strata include receiver configuration, band, hour, threshold, temperature and interfering-signal strength. Each stratum should retain a denominator equal to eligible observation time rather than to whichever records survived a convenient filter. Display the number and

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length of observed sessions; otherwise a visually dramatic small subgroup may dominate interpretation. Plot upper and lower adjacent channels separately because asymmetric skirts may make one side particularly dangerous. Compare periods during which the suspected neighbour is absent with periods when it is present, while explicitly acknowledging that the wanted transmitter may also change state. A regression coefficient estimated from such data is a description of association within the sampled conditions; it is not a physical leakage coefficient until an injection test establishes the relevant transfer relationship.

If only incomplete metadata survive, report bounds or a sensitivity analysis instead of a fictional exact correction. For example, recompute the apparent busy fraction after excluding all times with neighbour power above a conservative threshold, then repeat under less restrictive thresholds. The resulting interval is not a confidence interval for true occupancy, because removing strong-adjacent periods can also remove genuine wanted activity. It is an indication of how heavily the conclusion depends on potentially contaminated data. A separate negative-control channel with no plausible assigned emitter but similar filter offset can expose leakage patterns, provided it has comparable spectral conditions. Such controls are useful precisely because they can refute a simplistic account. Preserve alternative graphs that do not support the preferred hypothesis, and document any choice of strata made after seeing the data. In an evidential report, transparency about exploratory decisions is more valuable than the cosmetic certainty of a single percentage.

Sir Edward Victor Appleton, Cross-Peer Question to John Daniel Kraus: Dr. Kraus, your antenna work reminds us that a nominal channel does not

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arrive as a single scalar number. Two frequencies separated by only one allocation spacing can have different angular fields, antenna impedances, near-field coupling or polarisation at the observation point, especially inside a reflective structure. If the same portable receiver is moved from Site A to Site B, what spatial and polarisation controls would you require before treating its changed adjacent-to-wanted power ratio as a reliable propagation measurement? In addition, can a conducted substitution fully isolate antenna-induced adjacent-channel bias, or does it discard the very vector field information necessary to distinguish the competing signals? Please explain which observations remain possible without invasive changes to the investigated premises. Would you also distinguish an antenna reorientation conducted as a deliberate intervention from the ordinary variation of the incident field over time, so that the investigator does not attribute an unrelated fading event to the antenna rotation itself?

John Daniel Kraus, Cross-Peer Answer to Sir Edward Victor Appleton: Sir Edward, a receiving antenna responds to the vector electric field, its own polarisation and its directional pattern, and the relationship may vary even over a modest frequency displacement when surroundings are electrically complex. A change of site can alter the apparent wanted-to-adjacent ratio because the two emitters arrive from different directions, not because the receiver's internal filter has changed. The field could contain multipath components whose phase differences create sharp spatial variations. We should therefore record antenna orientation and position with greater care than merely noting the room name. Where possible, sample a small, documented spatial grid while preserving the receiver settings; a dramatic

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pattern change over a fraction of a wavelength warns against treating one location as representative of the room.

Conducted substitution is necessary for instrument isolation but insufficient for characterising the external field. When a calibrated combiner injects two known voltages at the receiver connector, it removes antenna pattern, polarisation mismatch and most environmental coupling from the experiment. That is excellent for measuring the receiving chain's tendency to leak adjacent energy into the indicated channel. It cannot tell us whether the actual site field arrives through an unexpected polarisation, a nearby cable, or a reflection from structural metal. To address those questions without intrusive modification, one may employ controlled antenna rotation, small repositioning, a second well-characterised antenna and synchronous logging, provided such manoeuvres are authorised and do not disturb the evidence. The sequence and surroundings must be documented because changing the operator's stance can alter the field as surely as rotating the antenna.

The distinction between receiver selectivity and antenna selectivity should appear explicitly in any uncertainty statement. If an antenna is broadband and its response nearly constant across adjacent channels, that may be demonstrated, not assumed. A resonant or actively tuned antenna may instead favour one channel over another, effectively altering the spectral mixture presented to the receiver. The reported detector occupancy can then change with orientation even when no emitter changes state. A disciplined comparison includes both an antenna-terminal measurement, where feasible, and a documented radiated observation, with their different limitations. It is the correspondence of these independent controls, rather

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than a single attractive level ratio, that allows us to separate a real geographical contrast from the selective ears of the measurement apparatus.

Dr. James M. Atkinson, Moderator: Dr. Kraus, Sir Edward has traced the route from propagation to the instrument's antenna terminals. Please take the token and explain the spatially selective nature of a nominally simple occupancy measurement, particularly where antenna pattern, polarisation and cable currents transform a crowded spectral scene into an apparently localised channel event. I ask also for a practical method of determining whether changing an antenna has altered the phenomenon or merely the observer.

John Daniel Kraus, Third Principal Contributor: Dr. Atkinson, I shall begin with a warning that an antenna is not an indifferent funnel. It is a directional transducer whose response depends on field orientation, frequency, impedance and nearby conducting structures. A receiver may retain exactly the same frequency response after being moved, yet the power delivered to it from each emitter may change because the antenna responds differently to their angles of arrival and polarisations. Consequently two sites can differ in nominal channel occupancy even if the central transmitter's emission schedule is unchanged. The analyst must identify whether the desired quantity is the occupancy of the electromagnetic field at a geometrically defined site, the activity of a specified transmitter, or the fraction of occasions when a particular receiving arrangement produces an above-threshold indication. These objects are not interchangeable merely because the same dial frequency appears on the receiver.

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A simple receiving-power relationship illustrates the geometry. In an ideal far-field plane-wave case, available antenna power can be written P_av=S_inc A_e rho, where S_inc is incident time-average power flux density, A_e is the effective aperture in the incoming direction for the relevant frequency, and rho is a polarisation-mismatch factor between zero and one. The model assumes conjugate matching and does not describe an arbitrary reactive near-field environment. For a linearly polarised incident wave and a linearly polarised receiving antenna, rho=$\cos^2$ theta, where theta is the angle between the polarisation axes under the idealised geometry. At a sixty-degree mismatch, rho equals one quarter, corresponding to roughly six-point-zero-two decibels of loss. That reduction applies to one arriving component; a neighbouring transmitter arriving with a different polarisation may experience a quite different loss. If the central channel falls six decibels but the adjacent channel does not, the ratio presented to the receiver may increase six decibels without any modification to its internal selectivity. The spectrum display offers no direct notice of this vector-field transformation.

Directionality introduces a related hazard. A receiving antenna with a deep pattern null towards a wanted emitter may still present strong adjacent energy arriving from another azimuth. At Site A a reflector may steer the wanted emitter into the null; at Site B the geometry may shift the wanted energy towards a main lobe. The ratio between the wanted and unwanted energy can change dramatically even though both radiators retain the same transmit powers and duty cycles. One cannot remedy this by choosing a nominal antenna gain from a catalogue and applying it to every direction. The response G(theta,phi,f) must be considered at the actual angle, polarisation and frequency. For a small separation in frequency one might

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expect the same pattern, but the surroundings can produce sharply varying phase relationships. An antenna placed close to metal, a vehicle, a cable tray or a large window frame may be part of a coupled system for which free-space pattern assumptions are no more than an initial hypothesis.

A further complication is the feed line. A coaxial cable intended to carry differential or shielded signals may also carry external common-mode current along its outer conductor. That current can make the cable itself an inadvertent receiving element, changing the orientation response and introducing unwanted energy at other coupling points. A rotating antenna may give a reassuring angular minimum while the cable path continues to admit the adjacent transmitter. A physical test can compare deliberate cable routing, common-mode suppression and a truly independent receiving arrangement, but each adjustment changes the apparatus. It must be recorded as an intervention, not disguised as an innocuous repetition. In an evidential environment the investigator should minimise disturbance, document the before and after geometry, and avoid interpreting an improvement under altered configuration as proof of the original cause. A change in the measured signal is consistent with a coupling mechanism; it does not uniquely identify the transmitting source.

Consider the earlier minus forty-five dBm adjacent input. Suppose an antenna reorientation reduces the unwanted arrival by eight decibels while reducing the wanted arrival by only two. The unwanted-to-wanted ratio improves six decibels. If the detector operates close to threshold, a difference of that magnitude may eliminate a substantial number of false positives. The result is physical and repeatable, yet it tells us nothing directly about whether the wanted transmitter changed its own schedule.

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Conversely, an antenna change can make a weak genuine signal newly observable and increase measured occupancy. Thus a procedure that simply selects the orientation yielding the lowest indicated occupancy is especially suspect. It can optimise for blindness instead of for truthful measurement. Orientation should follow a predetermined sampling plan, with declared geometry and a rationale for representing the target field.

A practical defensive survey ought to include an antenna-control matrix. Record at least the antenna identifier, frequency response, polarisation, pointing, height, nearby conductors, cable route, and any preamplifier built into the antenna. Where access permits, use a second antenna of a substantially different response to determine whether the disputed indication follows an expected angular or polarisation dependence. With a fixed receiver, conduct an injected adjacent-signal test to isolate internal selectivity. With a fixed antenna, exchange the receiver for a calibrated independent receiver to test whether the anomaly follows its electronics. The order of substitution matters; changing antenna, cable and receiver simultaneously destroys the isolation of the causes. This is the logic of controlled experimentation rather than a collection of impressive but causally tangled screenshots.

Finally, represent uncertainty honestly. A laboratory antenna factor measured in a clear site cannot be applied without qualification to a reactive field beside a large conducting structure. When a site-to-site occupancy statement turns on a few decibels close to threshold, a poorly characterised antenna response may dominate the apparent difference. Rather than conceal that uncertainty, report a set of receiver-equivalent occupancy values over the controlled orientations and specify what range of antenna

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behaviour remains plausible. A clear audit distinguishes the spectrum entering the antenna, the voltage reaching the connector and the software state called busy. A comparison that survives changes among physically different receiving arrangements deserves more confidence than one that exists only in a single configuration. That confidence is earned by concordant evidence, not by the assumption that every receiving aerial is a transparent window into the same electromagnetic scene.

Andrey Nikolaevich Kolmogorov, Peer Question: Dr. Kraus, your argument seems to require a probability model over spatial configurations as well as over transmitter activity. Suppose a team's instrument occupies one location for two hours, is then moved a metre, and reports a different busy fraction. It would be tempting to call the change a random sample from spatial fading, but the two positions were chosen for operational convenience rather than by any probability design. Can the reported proportions be interpreted as estimates of an area-wide occupancy probability, or do they refer only to the particular receiver placements? I ask for a definition of the sample space and the role of a spatial weighting measure. Please also explain how an unknown polarisation distribution complicates the analysis and what a field team should do if it cannot randomise or exhaustively grid a secured room. The statistical model should not imply exchangeability among observations taken under different antenna orientations or receiver gains unless those circumstances are explicitly controlled or modelled. Could you state how that qualification should be carried into a report?

John Daniel Kraus, Response: Professor Kolmogorov, without a declared spatial population and selection rule, the two positions support conditional

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statements about the two measurement configurations, not an objective area-average. A probability measure may be defined over time and a chosen distribution of receiver locations, but the measure is part of the scientific claim. If the positions were selected because one was convenient and another seemed suspicious, the observed occupancy difference can be genuine while providing no unbiased estimate of the entire room. A uniform area weighting is one possible convention, but it need not correspond to the probability that an actual sensitive device or person occupies a location. A security enquiry may instead require a target-specific geometry, such as the positions of a conference table, equipment racks or wiring. The sampling objective must be declared, rather than smuggled into the denominator as though every measurement position represented an identical part of the space.

Let O(x,theta,t) denote the detector's binary state at position x, antenna orientation theta and time t under a fixed receiver configuration. A spatial-temporal summary might be the integral of O against a declared position-orientation measure mu and a temporal measure nu, divided by their total eligible measure. That mathematical expression becomes a meaningful site statistic only if the observation plan approximates those measures and the relevant receiver state remains controlled. In practice the antenna may be moved sequentially, so time variation can be confounded with position variation. Repeating a subset of reference positions before and after the movement sequence helps reveal such drift. A second stationary monitor can provide a contemporaneous indicator of common environmental changes, though its own antenna and filter remain imperfect. None of these

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controls creates randomisation retrospectively, but they can limit the plausible explanations for an observed contrast.

Unknown polarisation is best treated as a physical uncertainty rather than hidden under a convenient isotropic assumption. For an ideally linearly polarised wave, the cos-squared response predicts strong orientation dependence; for a mixture of waves with changing polarisations and directions, a single orientation may be unrepresentative. Obtain a small number of predetermined orthogonal or otherwise well-characterised orientations, preferably with the same dwell time and timing scheme. Report them separately before any weighted aggregate. If security constraints prohibit movement, state the coordinate and orientation of the sole observation and do not call its busy fraction room-wide occupancy. The most rigorous result may be a local measurement accompanied by a demonstration that a plausible change in polarisation or pattern could reverse the site ranking. Such a result is useful: it tells the investigator what additional evidence is required before interpreting the ranking as a transmitter-behaviour difference.

John Daniel Kraus, Cross-Peer Question to Sir Martin Ryle: Sir Martin, your radio interferometry experience addresses how an observing array can separate sources that overlap in frequency. In a cramped building, the channel of interest and a high-power adjacent transmission may both illuminate the receiving antenna, while reflections and cable coupling corrupt the field. Could spatially separated synchronous receivers help decide whether a disputed channel indication is an independent emission or leakage from the neighbour? Please distinguish source separation that follows from phase-consistent directional evidence from artefacts

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introduced by different channel filters and unsynchronised local oscillators. Also clarify why observing a deep spatial null in one receiver does not prove the absence of an emitter, and what measurements must accompany any claim of localisation. The possibility that two distinct radiators occupy almost the same angular position is especially troublesome. I ask whether your proposed direction evidence can still distinguish them through spectral timing, and how you would state an unresolved angular ambiguity.

Sir Martin Ryle, Cross-Peer Answer to John Daniel Kraus: Dr. Kraus, two or more spatially separated receivers may create a useful interferometric constraint, but only when their timing, phase response and measurement frequency are sufficiently controlled. A baseline measures phase differences related to the incoming wavefront, subject to ambiguity, multipath and instrumental phase. If an alleged in-channel signal is merely the spectral skirt of the adjacent transmitter admitted by each receiver, it may inherit the adjacent transmitter's direction of arrival. If it is an independent emitter, its spatial phase gradient may differ. Yet this distinction is conditional: two emitters can be nearly co-located, multipath can create complex apparent directions, and a receiver-generated product can inherit phase features of the external excitation. The experiment must be designed to compare explicit hypotheses, not to treat a directional map as a magical source identifier.

Use a stable common timing reference or measure and correct the interreceiver clock and local-oscillator offsets. Calibrate relative complex gains across the actual frequency span and the input powers encountered; otherwise an apparent phase slope may be due to channel filters rather than propagation. Record simultaneously a narrowband trace of the

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adjacent carrier, a trace of the candidate in-channel feature and a control signal. If the two observed features share time evolution and direction within measured uncertainty, they may be related, but the evidence remains compatible with a common physical transmitter and with certain forms of receiver leakage. A direct injection that bypasses the antennas can help identify an instrumental mechanism, while a change in array geometry can test whether the direction estimate is stable. Neither manoeuvre is optional when the claimed distinction depends on degrees of phase rather than merely visible power levels.

A deep null is especially easy to overinterpret. A spatial null represents destructive combination at one receiving configuration, not the annihilation of the emitter; a modest repositioning can restore the signal. In an enclosure the wavefield may not satisfy the simple far-field plane-wave model used by a conventional direction finder. A safe conclusion might be that the candidate's observed phase structure is indistinguishable from the adjacent emitter's under the present array, with a quantified angular resolution and systematic uncertainty. Conversely, demonstrably different phase structures under independent calibration support separate propagation paths, though not necessarily separate transmitters if one source couples to a reradiating structure. The observation must be described with its instrument transfer functions, baseline geometry and clock stability before localisation becomes admissible evidence.

Dr. James M. Atkinson, Moderator: Dr. Bode, please take the token from Dr. Kraus and translate these physical ambiguities into the language of receiver networks. I am particularly concerned with the habit of treating channel width, selectivity and dynamic range as a single specification.

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Explain how a finite filter response and a threshold algorithm can yield different occupancy estimates even under exactly the same recorded electrical input.

Hendrik Wade Bode, Fourth Principal Contributor: Dr. Atkinson, a system description is valuable only if each specification is attached to its own transfer mechanism. Channel spacing determines the nominal relationship among assigned centre frequencies. Receiver selectivity describes how effectively a receiver discriminates desired and undesired signals under specified conditions. Equivalent noise bandwidth quantifies how a filter weights a uniform noise spectrum. Dynamic range characterises the span over which meaningful measurement is possible without intolerable noise or distortion. The detector threshold is a decision rule, often chosen after the analogue signal has already been transformed. None of these can replace another, and a single nominal bandwidth does not determine them all. A site-to-site comparison that reports only centre frequency and channel spacing is consequently missing most of the information needed to establish instrumental comparability.

For a linear filter H(f), a spectral component at offset delta from the centre suffers power attenuation A(delta)=-10 log10[|H(f_c+delta)|² / |H(f_c)|²], expressed in decibels where the response magnitudes are dimensionless. This quantity must be measured or reliably calculated for the actual filter shape, including any windowing and decimation stages. Suppose a neighbouring channel delivers minus fifty dBm to the input, and the analysis filter attenuates the relevant energy by fifty decibels. The residual is minus one hundred dBm, before other additive contributions. If a second receiver provides only thirty-five decibels at that same offset, its residual is minus

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eighty-five dBm, fifteen decibels stronger. Even with identical thresholds and time records, the second receiver may declare many additional busy observations. The phrase 'twelve-and-a-half-kilohertz filter' does not establish whether the off-centre attenuation is thirty-five or fifty decibels. A complete skirt curve is far more informative.

There is a complication when the adjacent emission is broadband. One must integrate its spectrum against the receiving filter response; attenuation at its centre frequency alone is insufficient. The spectral skirt of a modulation waveform can overlap the nominal survey interval without being a receiver defect, and an imperfect transmitter can radiate excess adjacent-channel power. The term adjacent-channel leakage can therefore refer to two different physical objects: power radiated by the transmitter outside its intended channel, and interference admitted by the receiver when measuring another channel. They should be named transmitter adjacent-channel emissions and receiver adjacent-channel response, respectively. The former is determined by a transmitter measurement under specified modulation and filtering; the latter by the entire measurement receiver. Their combined contribution in the wanted channel is not inferable from a single selectivity test or a spectrum screenshot. A measured excess could also be a product of receiver intermodulation, which invalidates a simple additive linear model.

Let a filter produce samples of estimated power Y_k, indexed by eligible observation k. A threshold classifier records $B_k=1$ if Y_k exceeds T_k. When T_k is fixed at a calibrated value, its false-positive and missed-detection behaviour depends on the distributions of noise, adjacent interference and wanted signal. A dynamic threshold, for example one calculated from a

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sliding noise estimator, creates an additional feedback between recent conditions and the decision. A powerful neighbour can lift the estimated noise level, suppressing detections of a weak real signal; alternatively its energy can enter the passband and create false positive states. Both effects can coexist. In that case a simple difference in reported occupancy cannot be corrected by subtracting the proportion of intervals in which the adjacent channel was strong. The false positives and missed detections are conditional on the same nuisance field and are not independent errors.

The controlled response test should traverse both frequency and amplitude. At each selected offset delta, inject a known wanted signal and a known unwanted signal, measure the predecision power, record the decision state and increase the interferer's level through a range spanning typical field conditions. One may thereby draw surfaces of indicated power and detection probability rather than an isolated point. Repeat on both sides of the centre frequency. The instrument should be checked for overload by comparing results with additional front-end attenuation; if a spurious line falls with a nonlinear slope or disappears when an overload condition is relieved, it cannot be treated as an ordinary external emission without further evidence. The test also needs to isolate processing decisions: supply a common recorded waveform to both digital classifiers while holding the analogue front end outside the comparison. If the reported discrepancy follows the classifier, the site itself is not the sole cause.

One may use a confusion matrix to express detection quality, but its meaning depends upon trusted test labels. Let sensitivity $Se=P(B=1 \mid W=1)$ and specificity $Sp=P(B=0 \mid W=0)$, where W is the verified true wanted-channel activity state. Under a simplified stationary binary model with

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prevalence pi=P(W=1), the measured busy fraction q obeys q=Se*pi+(1-Sp)*(1-pi). If Se+Sp exceeds one and both parameters are known for the conditions of interest, pi=[q+Sp-1]/[Se+Sp-1]. This algebra is transparent, but it is dangerous to insert Se and Sp measured with a weak laboratory interferer into a field record dominated by a powerful neighbour. The conditional probabilities change with adjacent power, modulation, temperature and gain control. Where calibration identifies separate operating strata, correction may be possible within each stratum and the results combined with appropriate observation weights. Where it does not, the inverse formula yields an apparently precise fiction.

I would use the word comparable only after the two systems have been tested for equivalence within a tolerance relevant to the forensic decision. Two receivers need not have identical filters if their raw measurements can be mapped to a common validated observation operator. Conversely, two instruments from the same model range may be non-equivalent after different firmware revisions, antenna assemblies or gain configurations. The result of a disciplined study may be an uncertainty interval rather than a single correction. A methodological conclusion is legitimate even when it forbids a dramatic causal story. If the instrument-response difference could account for the entire site contrast, the evidence supports no unqualified assertion that central-channel users were more active at one site.

William Feller, Peer Question: Dr. Bode, the correction equation with sensitivity and specificity appears particularly inviting because it converts a measured percentage into a supposed latent occupancy probability. Yet a finite validation campaign may provide only a few dozen known-busy and known-idle test intervals, and those intervals may be clustered by

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transmitter bursts or equipment heating. How would you quantify uncertainty in estimated sensitivity and specificity without assuming that every FFT record is independent? Please also explain the boundary case where sensitivity plus specificity approaches one, and why a mathematically valid inverse expression may yield a value outside zero to one when applied to incompatible calibration conditions. I would prefer a response that states what an investigator can legitimately infer with sparse labels rather than an elaborate formula presented as a substitute for evidence. In addition, what should be done when the calibration sample contains no false positives at all, although the number of verified idle cases is small? A reported specificity of one could be dangerously misleading without an uncertainty interval.

Hendrik Wade Bode, Response: Professor Feller, the denominator Se+Sp-1 measures how much discrimination the classifier provides beyond an uninformative binary decision. As that quantity approaches zero, the inverse problem becomes ill-conditioned. A small change in observed q or either calibration parameter produces a large change in the inferred pi. If the denominator is exactly zero, the observed busy fraction supplies no information about pi under this simplified model. A formula can remain syntactically correct while the measurement programme provides insufficient information for a stable estimate. If its result falls outside the physical interval from zero to one, that signals sampling variation, model incompatibility or incorrect calibration parameters; it does not license reporting a negative prevalence or a prevalence exceeding unity.

Suppose, for illustration, sensitivity is 0.90 and specificity 0.95 under a relevant controlled condition. If the observed busy fraction is 0.30, the corrected estimate is (0.30+0.95-1)/(0.90+0.95-1)=0.25/0.85, approximately

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0.2941. This example is an algebraic illustration, not a validated estimate for a particular survey. If specificity instead falls to 0.75 because of strong adjacent interference, with the same sensitivity and observed fraction, the result becomes (0.30+0.75-1)/(0.90+0.75-1)=0.05/0.65, approximately 0.0769. The striking difference shows why assigning one universal specificity to all RF crowding conditions is indefensible. A receiver may appear to find the desired signal often merely because the nuisance field causes false positives.

For calibration uncertainty, treat an emission burst or a repeatable test session as the relevant independent experimental unit where within-burst samples are strongly correlated. Estimate sensitivity and specificity separately, reporting the number of distinct known-state units and their operating strata. One may construct uncertainty intervals using a hierarchical model or a clustered bootstrap that resamples complete sessions, not individual FFT bins. This does not eliminate systematic label error or calibration mismatch; those require separate bounds or scenarios. Propagate the joint uncertainty of q, Se and Sp through the inverse mapping, ideally retaining their dependence if the same instrument drift affects all three. When the uncertainty interval for Se+Sp-1 approaches or crosses zero, the inverse is not dependable and the correct conclusion is that the data do not identify pi adequately. A responsible report should describe the raw detector output and the limits of calibration rather than concealing the instability in a corrected percentage.

Sir David Roxbee Cox, Peer Question: Dr. Bode, can a survey team claim that two sites have equal true occupancy merely because an adjustment based on the measured filter responses brings their reported percentages

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closer together? Suppose the calibration runs occur on a separate day, the adjacent transmitter changes modulation, and one site experiences severe receiver gain compression during only a few intervals. A model including a site effect, interferer level and receiver configuration might be fitted statistically, but each coefficient could carry substantial uncertainty and confounding. What design would allow the measurement operator to be distinguished from actual site conditions? Please consider paired equipment swaps, a common replay and the reporting of residual non-identifiability. Finally, explain why a near-zero fitted site coefficient should not automatically be described as proof of equivalence. I would also want you to specify the estimated contrast before looking at the data, because changing the definition of a busy observation after inspecting a site difference can manufacture apparent agreement even when the raw phenomena have not changed.

Hendrik Wade Bode, Response: Sir David, equality of corrected point estimates is not an equivalence finding. To establish equivalence one must first define a tolerance meaningful for the intended conclusion and then demonstrate that the uncertainty in the difference lies within it, under a model and design that discriminate the confounding factors. A fitted site coefficient near zero can arise because the measurements are uninformative, the model is overparameterised, or the instrument effects are almost perfectly confounded with site. A large uncertainty interval around zero may include effects that would alter the substantive finding. The language of no detected difference is then more accurate than the language of equivalent occupancy.

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A cross-over is the strongest practical design. Survey the two sites simultaneously with receiver chains A and B, then exchange them while leaving the relevant antenna geometries as closely controlled as the field permits. If the apparent excess follows the receiver, instrument response is implicated; if it follows the site under both chains, a geographical difference becomes more plausible. Neither finding is self-sufficient because the swap changes cables, timing and possibly the coupling to nearby structures. Record the complete intervention. A second layer uses a common recorded complex waveform replayed to both classifiers, thereby isolating software and digital filter effects. A third layer uses conducted signal generators to measure selectivity and nonlinear response in controlled conditions. These independent experiments form an evidential triangle: field comparison, digital common-input comparison and analogue controlled-input comparison.

Statistical modelling should reflect that hierarchy. One may include receiver, site, interferer power, temperature and time-window effects, and permit interaction between receiver and adjacent level because selectivity degradation need not be constant. If each instrument appears at only one site, receiver and site effects cannot be independently identified from those data; a clever regression package cannot manufacture the missing contrast. Instrument swapping creates the variation needed for estimation, while replay separates software response from RF propagation. If gain compression affects only rare intervals, report an explicit overload stratum or an exclusion and its consequences rather than forcing a smooth average coefficient to explain it. A claim of comparable occupancy should be accompanied by the chosen equivalence margin, uncertainty interval,

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sensitivity to excluded intervals and evidence that the model survives controlled challenges. This produces a more modest but much stronger conclusion than a post hoc correction designed to make two percentages agree.

Hendrik Wade Bode, Cross-Peer Question to Sir Edward Victor Appleton: Sir Edward, the inverse-classification correction requires a true wanted-channel activity state and a detector sensitivity defined for the actual nuisance conditions. In an external field, however, an intermittent distant transmitter can be present but invisible because of fading, while a local adjacent emitter makes the detector busy. Can you distinguish the emitter's transmitted duty cycle from its received-above-threshold duty cycle in a way that permits defensible calibration? Please also examine whether a reference signal at a different frequency or polarisation can provide an adequate correction, or whether it merely introduces another transfer assumption that should appear explicitly in the uncertainty assessment. What is the proper conclusion when the site-specific propagation remains unmeasured? Please distinguish the environmental changes induced by moving an antenna from the signal-generation changes that would establish transmitter activity, and indicate what a contemporaneous reference monitor might clarify without being mistaken for complete ground truth.

Sir Edward Victor Appleton, Cross-Peer Answer to Hendrik Wade Bode: Dr. Bode, the true activity state must be defined in terms of the intended scientific target. If W(t)=1 means a transmitter actually radiates in the allocation during interval t, an observer at a remote site may have imperfect sensitivity because of propagation loss, fading and antenna response. If W(t)=1 instead means that wanted-channel power at a specified local

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antenna reference plane exceeds a declared limit, the target is a received-field state. These definitions lead to different calibration experiments. An occupancy correction for one must not be sold as a correction for the other. To estimate transmitted duty cycle one may need an independently authenticated transmitter log or a reliable reference monitor with known detection performance; a remote spectral trace alone rarely supplies a perfect label.

A reference signal at another frequency and polarisation may diagnose gain drift, timing or broad propagation behaviour, but it does not automatically calibrate the channel under examination. Its path loss, polarisation mismatch and antenna gain may differ. Where the two paths are sufficiently close and a physical model justifies transfer, the additional uncertainty must be reported. A beacon that remains stable while the target fades may show only that the beacon's own path is stable. In a multipath enclosure different transmitters can experience different constructive and destructive combinations despite similar nominal frequencies. A proper cross-site comparison uses independently characterised reference paths or, at minimum, sensitivity scenarios spanning plausible path differences.

If propagation cannot be characterised, the report should retain the narrower received-detector observation. For example, it may state that Receiver A classified forty-eight per cent of eligible local samples as busy under a declared filter and threshold, while Receiver B classified twenty-one per cent under a different observation function. It may then demonstrate that a plausible difference in adjacent rejection and propagation could account for a substantial part of the contrast. That finding is not evidence that the emitted duty cycles were equal, nor evidence that they differed. It

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establishes the limit of the observation. The confidence of the forensic conclusion should grow when independent site measurements, common-input replay and controlled adjacent-signal injections converge, not simply when a convenient correction forces numerical agreement.

Dr. James M. Atkinson, Moderator: Sir Martin Ryle, Dr. Bode has shown that an occupancy fraction depends upon the transfer function and decision threshold, while Dr. Kraus has established that the surrounding field has its own angular structure. Please take the concluding principal token. I ask for an integrated forensic design that can compare two observation sites without pretending that stronger adjacent energy, a different interferometer baseline or a wider receiver filter necessarily signifies greater legitimate use of the central channel.

Sir Martin Ryle, Fifth Principal Contributor: Dr. Atkinson, comparison is a problem of measurement design before it becomes a problem of data reduction. In radio astronomy we learnt that a visible feature in a receiving system must be understood through the response of the entire instrument to the sky. A narrow main lobe, sidelobes, calibration errors and missing spatial information may create structures in a map that do not correspond simply to independent physical sources. The analogy to channel occupancy is close. A channel reported busy at one site may be busy because the intended emitter is present, because a neighbour leaks through the filter, because the antenna admits a different angular mixture, or because the apparatus responds nonlinearly. These explanations should be listed before the survey is performed. The purpose of the design is to force them to make different predictions under controlled interventions.

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I would formulate two primary hypotheses. Under H_E, the true wanted-channel occupancy differs between Site A and Site B under a declared physical definition. Under H_M, the apparent difference arises wholly or partly from changes in the measurement operator, including antenna response, adjacent interference, receiver transfer and threshold. The hypotheses are not exhaustive and need not be mutually exclusive. It is entirely possible that real channel use differs while the observer exaggerates, suppresses or reverses the contrast. A good experiment estimates the real difference while also quantifying the nuisance pathways. It should not require investigators to choose one explanation by rhetoric when the available evidence admits a mixture. The most convincing data arise from a crossing of site and instrument, coupled with a common waveform that both instruments analyse under controlled conditions.

Begin with simultaneous dual-receiver observations at each site. Two independent chains should observe the nominal channel and at least its immediate neighbours, with suitable frequency and time resolution, and should retain unthresholded calibrated records. They should have known overload margins and ideally independent local oscillators or sufficiently understood common references. A second receiver is not a source of truth merely because it is independent; it provides an opportunity to test whether an event follows the field or a particular instrument. If both receivers observe a candidate burst at the same time, that is useful, but a common wideband interferer can create correlated false indications in both chains. Agreement is strongest when the receivers differ materially in their susceptibility mechanisms, for example by using different front-end selectivity arrangements and separately calibrated analogue paths.

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Correlated instrument errors should be anticipated rather than silently treated as improbable coincidences.

Next exchange receiver chains between the two sites in a randomised or balanced order, preserving the antenna locations where operational conditions permit. An excess that stays with Site A across the exchange is more plausibly environmental than one that follows Receiver 1, but even this inference requires care. Site A may possess a strong adjacent transmitter whose energy causes a receiver-specific overload only when Receiver 1 is present. Such a site-by-receiver interaction is a measured phenomenon, not a nuisance to be averaged away. The analysis should therefore preserve the four cells of the crossed design. Summarising each site into a single fraction too early destroys the evidence needed to identify interactions. Log weather, equipment temperature, antenna position, power supply, software version and interference levels so that later analysts can determine whether the exchange itself altered the operating state.

Time alignment is critical. Let t_k denote a common eligible observation interval. Define $B_{s,r,k}$ as the binary detector decision for site s, receiver r and interval k. Define $D_k=B_{A,r,k}-B_{B,r,k}$ only when the relevant observations share a sufficiently common time basis and comparably defined observation operator. For an ideal paired design, differences may cancel some shared temporal changes, but they do not remove site-specific propagation or different adjacent-channel contamination. If a fast burst lasts two milliseconds and receiver timestamps differ by ten milliseconds, apparent disagreement may follow solely from misalignment. One must specify timing uncertainty relative to pulse duration and revisit time. A claimed forty-eight versus twenty-one per cent contrast is almost

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meaningless if the numerator consists of coarse scans that visit different channels at different moments. Report not only the aggregate ratio but the sequence of eligible observations and exclusions.

A common replay provides another discrimination. Capture a sufficiently wideband complex baseband waveform with a reference front end whose linearity and anti-aliasing have been assessed. Then pass identical samples through both digital filters and decision algorithms. If the previously observed difference reappears under this common input, one has established that software and digital selectivity can contribute to it. If the difference vanishes, the analogue path, antenna, timing or physical site remains implicated. The common replay does not prove which physical explanation is correct, and it may lack the dynamic range to preserve very weak wanted signals beside a powerful neighbour. Therefore accompany it with a calibrated two-generator conducted test at levels corresponding to the field record, and reserve any attribution to actual transmitter use for evidence that survives these challenges.

An example shows the value of design over adjustment. Imagine Site A yields 0.48 occupancy with Receiver 1 and 0.24 with Receiver 2, whereas Site B yields 0.21 with Receiver 1 and 0.20 with Receiver 2, under matched eligible windows. Receiver 1 exhibits an additional 0.24 busy fraction at Site A, potentially signalling a receiver-by-site interaction with strong adjacent interference. The small difference between the two receivers at Site B cannot justify a universal receiver correction of 0.24, because the effect plainly depends on site conditions. This example does not establish the true wanted-channel occupancy at either site. It shows which mechanisms should be tested next, including input level sweeps, upper and lower

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channel selectivity and the relation between reported events and adjacent bursts. A mixed-effects or conditional model may assist interpretation, but the crossed observations already warn against naïvely subtracting a constant bias.

Finally, a forensic document should distinguish evidence, method and inference. Evidence consists of signed original recordings, calibration files, timing metadata and measured responses under specified interventions. Method comprises the defined bandwidths, thresholds, decision rules, sampling windows and source classifications. Inference states what those data support, including uncertainty and alternative explanations. I would require a negative-control channel, a reproducible calibrated replay, a declared common comparison operator, and an explicit account of the receiver's nonlinearity and spatial response before presenting a cross-site channel-use conclusion as strong. If such controls cannot be performed, the limited conclusion may still be valuable: the observing equipment reported different busy fractions under conditions not proven comparable. There is dignity in that restraint. An erudite report is not made persuasive by hiding the boundary between observation and attribution, but by locating it exactly and inviting an independent reader to test it.

William Sealy Gosset, Peer Question: Sir Martin, the crossed design would be expensive to execute under a strict field-survey time budget. A client may permit four short sessions at each site, perhaps only ten minutes apiece, while expecting a confident statement that channel occupancy differs. If the apparent events cluster into long transmissions, the number of independent opportunities may be far smaller than the number of FFT records, and the balancing of receiver swaps may be imperfect. How would you plan a

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modest but interpretable experiment, specifying the sampling unit, principal outcome and treatment of repeated observations? I also ask whether reporting a conventional binomial confidence interval from hundreds of thousands of adjacent FFT frames would be defensible, and what evidence would cause you to withhold a numerical site-effect estimate despite collecting a very large quantity of samples. The answer should distinguish variability among the four sessions from the instrument repeatability inside each session. Otherwise a huge number of correlated records might yield an unjustifiably narrow numerical interval that collapses under an independent visit.

Sir Martin Ryle, Response: Mr. Gosset, the first decision is to choose the experimental unit rather than to accept the instrument's frame count as the sample size. If a transmitter remains active for thirty seconds and a receiver produces ten thousand overlapping spectral frames during that period, the frames describe one sustained episode and its internal texture; they do not furnish ten thousand independent replications of the opportunity for transmission. Design sessions around the intended temporal question. If the client seeks occupancy during a specified business meeting period, sample and report that period. If the objective is a representative week, four ten-minute sessions cannot establish a reliable weekly average without strong external assumptions. The schedule should balance sites, receivers and times as far as security constraints allow, and retain the order actually used.

A compact design might alternate paired ten-minute sessions so that each receiver appears at both sites twice, with one unit stationed as a common reference monitor if available. Preserve raw frame times but calculate

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primary uncertainty by resampling or modelling at a session or transmission-episode level, respecting correlation among contiguous observations. Report the session-level busy fractions and their spread before giving any pooled estimate. A blocked comparison can adjust for common time periods if both sites were observed concurrently, while a crossover can help separate instrument effects. If the two sites cannot be monitored simultaneously, the order of visits should be deliberately counterbalanced and the remaining time confounding acknowledged. One should not create a binomial interval whose apparent narrowness merely reflects how rapidly the instrument sampled the same event.

The principal outcome should be declared beforehand, perhaps the proportion of eligible seconds classified busy after a common, validated filter-and-threshold procedure, with a secondary outcome of the number of independent burst episodes. Those two summaries answer different questions. A channel with one long transmission can show high busy-time occupancy and very low event count; a channel with hundreds of short bursts may show the reverse. Give an uncertainty interval for the site contrast that includes between-session variability and plausible measurement bias. If only four sessions exist, one should expect a broad interval unless the effect is unusually stable and controls are excellent. That is not a defect of the mathematics. It is an accurate account of how little independent information has been collected.

I would withhold a corrected site-effect number when receiver and site are not crossed, thresholds are unknown, saturation flags occur during the disputed intervals, or time alignment is insufficient for the observed bursts. I would also withhold it if the known adjacent-channel response could

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produce the full apparent difference and no test separates that explanation from true wanted activity. A large file size cannot cure those defects. The disciplined result would state the raw detector observations, the conditions under which the apparent contrast was obtained, the sensitivity of the conclusion to plausible interference mechanisms and the additional controls needed for attribution. Such a report assists a decision maker more faithfully than an implausibly narrow interval calculated from dependent frames.

Dr. James M. Atkinson, Moderator: The panel has distinguished emitted activity from received-field detection, and has shown how filters, antennas and operating conditions can alter the apparent occupied fraction. I thank Professor Pierce, Sir Edward Appleton, Dr. Kraus, Dr. Bode and Sir Martin Ryle for their complementary analyses, and all interrogators for their careful examination. The token is returned to the moderator with a limited but defensible conclusion: intersite occupancy percentages are comparable only under a declared and demonstrably equivalent observation procedure, with remaining physical and instrumental uncertainty disclosed.

QUESTION 074. TEN AUDITABLE MATHEMATICAL EXAMPLES. Each example is hypothetical, uses declared units, and separates numerical consistency from source or publication approval.

EXAMPLE 01. Adjacent-signal power following selectivity loss. Let $P_{adj}=-45$ dBm denote the incident adjacent transmitter power at a receiver connector, and let A=45 dB be the measured power attenuation from that offset to the nominal observation channel under a linear condition. The receiver-equivalent interfering power is $P_{leak}=P_{adj}-A=-45-45=-90$ dBm. Let T=-95 dBm be the detector threshold at the same power reference plane.

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Since -90 is greater than -95, this interference alone may produce a busy indication even if the wanted transmitter is off. The calculation assumes no gain compression or additional signal combination.

EXAMPLE 02. Comparison with a steeper rejection skirt. Keep $P_{adj}=-45$ dBm and $T=-95$ dBm, but consider a second receiver with $A_2=55$ dB at the corresponding offset and input level. Then $P_{leak,2}=-45-55=-100$ dBm, which is 5 dB below T. For the same incoming adjacent signal, Receiver 1 in Example 01 can show busy while Receiver 2 shows idle. The 10 dB difference in selectivity produces a 10 dB difference in leaked power, not a demonstrated difference in transmitted duty cycle. All else being equal is an explicit experimental assumption.

EXAMPLE 03. Addition of unequal powers expressed in dBm. Suppose an unwanted component has $P_1=-90$ dBm and independent noise or interference contributes $P_2=-100$ dBm at the same measurement reference plane. Convert using $p_i=10^{(P_i/10)}$ milliwatts, so $p_1=10^{-9}$ mW and $p_2=10^{-10}$ mW. Their sum is 1.1×10^{-9} mW. Transform back: $P_{total}=10 \log10(1.1\times10^{-9})\approx-89.586$ dBm. One must not add the logarithmic values -90 and -100. The components must be power-additive under the assumed measurement interval; coherent voltage addition may instead require phase analysis.

EXAMPLE 04. Bandwidth-dependent noise power. Let N_0 be an approximately flat noise power spectral density in mW/Hz and B_{eq} the equivalent noise bandwidth of the observation filter. Then $P_N=N_0 B_{eq}$. For equal N_0 and bandwidths $B_1=6.25$ kHz and $B_2=12.5$ kHz, their noise-power ratio is $P_{N,2}/P_{N,1}=2$. The difference is $10 \log10(2)=3.0103$ dB. A wider filter can consequently cause a larger fraction of samples to exceed a

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fixed power threshold without any change in the presence of legitimate transmitters. The simple relation presupposes approximately white noise and comparable gain calibration.

EXAMPLE 05. Linear-polarisation mismatch. For idealised far-field linear polarisations, define theta as the angle between incident electric-field and receiving-antenna polarisation axes. The received power ratio is rho=$\cos^2$(theta). At theta=60 degrees, cos(60 degrees)=0.5 and rho=0.25. The loss is L=-10 log10(0.25)=6.0206 dB. Thus a receiver orientation may reduce one emission by roughly 6 dB, while a differently polarised neighbouring emission suffers another reduction. The relationship does not apply unchanged to arbitrary near-field or mixed-polarisation conditions, which require additional characterisation.

EXAMPLE 06. Change in an unwanted-to-wanted ratio after antenna rotation. Let the original unwanted-to-wanted power ratio in decibels be R=P_u-P_w, where P_u and P_w are powers in dBm at the same reference plane. An orientation change reduces the unwanted component by 8 dB and the wanted component by 2 dB. The new ratio is R_new=(P_u-8)-(P_w-2)=R-6 dB. The 6 dB improvement may move an apparent detector event across threshold, but the observed effect is a changed receiving geometry rather than proof that either transmitter altered its operating schedule.

EXAMPLE 07. Forward classification model. Let pi=P(W=1) be the prevalence of true wanted-channel activity during eligible units, Se=P(B=1|W=1) the detection sensitivity and Sp=P(B=0|W=0) the specificity. Under a stationary binary model, q=P(B=1)=Se*pi+(1-Sp)(1-pi). For pi=0.20, Se=0.90 and Sp=0.95, the reported busy fraction is q=0.90×0.20+0.05×0.80=0.18+0.04=0.22. The detector therefore reports 22 per cent busy time when the labelled true-

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state prevalence is 20 per cent. These probabilities must be estimated under relevant interference conditions.

EXAMPLE 08. Inverting the classification model, with two calibration conditions. From q=Se*pi+(1-Sp)(1-pi), solve pi=(q+Sp-1)/(Se+Sp-1), provided the denominator is nonzero. If q=0.30, Se=0.90 and Sp=0.95, then pi=0.25/0.85=0.29412. If q and Se are unchanged but Sp=0.75 under strong adjacent interference, then pi=0.05/0.65=0.07692. The nearly fourfold difference is not a new site measurement but a demonstration that incorrect transfer of specificity from a quiet laboratory can radically distort a correction. Estimates outside [0,1] expose model or uncertainty problems rather than physically meaningful probabilities.

EXAMPLE 09. Dependence reduces effective information. Suppose N=1,000 equally spaced binary occupancy records possess approximately stationary serial correlations rho_1=0.60, rho_2=0.30 and rho_3=0.10 at the first three lags, with negligible additional lags. A common approximation for an effective sample count is N_eff≈N/(1+2 sum_{h>=1} rho_h)=1000/[1+2(0.60+0.30+0.10)]=1000/3≈333.3. This is an illustrative precision heuristic, not a guarantee for rare clustered bursts. Resampling complete transmissions or monitoring sessions may be more appropriate when independence assumptions are doubtful.

EXAMPLE 10. A site-by-receiver interaction in a balanced comparison. Let O_A1=0.48, O_A2=0.24, O_B1=0.21 and O_B2=0.20 be measured busy fractions at Sites A and B using Receivers 1 and 2 during matched eligible periods. The Receiver 1 minus Receiver 2 contrast is 0.48-0.24=0.24 at Site A and 0.21-0.20=0.01 at Site B. The difference of contrasts is 0.24-0.01=0.23, or 23 percentage points. This signals a potentially important site-by-receiver

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interaction; it does not prove its cause. One must examine adjacent signal strength, front-end compression, timing and threshold differences before assigning the discrepancy to either emitter behaviour or instrument bias.

QUESTION 074. TECHNICAL SOURCE REGISTER AND PUBLICATION QUALIFICATIONS

1. International Telecommunication Union, ITU-R Report SM.2256-2 (June 2026), Spectrum occupancy measurements and evaluation. https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2256-2-2026-TOC-HTM-E.htm . This report expressly separates selectivity, signal-to-noise ratio, dynamic range, threshold, measurement timing, site considerations, channel occupancy and combination of neighbouring frequency samples. The historical participants did not author or discuss this 2026 report.

2. European Telecommunications Standards Institute, ETSI EN 300 086 V2.1.2 (2016-08), clause 8.4, adjacent channel selectivity. https://www.etsi.org/deliver/etsi_EN/300001_300099/300086/02.01.02_60/en_300086v020102p.pdf . This source provides a concrete two-signal receiver selectivity test. The prescribed criterion does not itself validate a probabilistic occupancy correction.

3. Bulletin of the American Astronomical Society, obituary by John D. Kraus Jr. and Ronald J. Marhefka, John Daniel Kraus (1910-2004). https://baas.aas.org/pub/john-daniel-kraus-1910-2004/release/1 . Biographical identification only, not an attribution of the modern fictional speech.

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4. Physics Today, Max Mathews, John Robinson Pierce obituary (December 2003). https://physicstoday.aip.org/obituaries/john-robinson-pierce . Biographical identification only.

5. American Academy of Arts and Sciences, Hendrik Wade Bode (1905-1982). https://www.amacad.org/person/hendrik-wade-bode . Biographical identification only.

6. Nobel Prize, Sir Martin Ryle, facts and pioneering radio-astrophysical aperture synthesis. https://www.nobelprize.org/prizes/physics/1974/ryle/facts/ . Biographical identification only.

7. Nobel Prize, Edward Victor Appleton, Nobel Prize in Physics 1947 and ionospheric research. https://www.nobelprize.org/prizes/physics/1947/summary/ . Biographical identification only.

EDITORIAL QUALIFICATION: Numerical examples are explicitly illustrative, not measured field evidence.

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QUESTION 075

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When may phase-coherent integration continue across receiver retuning?

Dr. James M. Atkinson, Moderator: Professor Gabor, a receiver may acquire a narrowband signal, tune to another spectral region, and subsequently return with its sample clock still disciplined to the same frequency standard. Yet the receiver's local oscillator may have settled to an unknown phase, its filters may retain transient memory, and the signal itself may have changed while the receiver was absent. Under what experimentally defensible conditions could an investigator combine those separated observations as one phase-coherent record? I invite you to examine the physical meaning of coherence, the ambiguity of a missing interval, and the difference between mathematical stitching and measured continuity.

Dennis Gabor, Principal Contributor: Dr. Atkinson, phase coherence is a statement about an established relationship among the phases of physical or reconstructed waves, not merely about two records having the same declared sampling rate. A sampled complex waveform may be represented as $z_k(t)=a_k(t)\exp\{j[\varphi_s(t)-\varphi_{LO,k}(t)+\varphi_{path,k}(t)]\}+n_k(t)$ during measurement interval k. Here a_k is an amplitude, φ_s is the source phase at the receiver reference plane, $\varphi_{LO,k}$ is the effective local-oscillator phase, $\varphi_{path,k}$ accounts for signal-path phase and processing conventions, and n_k denotes noise and modelling residual. The sampled phase is a difference. If the receiver retunes and its oscillator reacquires lock at an arbitrary phase, the first complex sample after the retune does not announce which portion of the new phase belongs to the emitter and which

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belongs to the instrument. The ambiguity can remain even if frequency accuracy is excellent. A calibrated mapping is required to transfer phase from one acquisition epoch into another.

For coherent summation one ordinarily needs a phase law over both observation windows, including a reference for the interval that was not directly observed. If two signal snippets are $x_1(t)$ and $x_2(t)$, and the second has an unknown constant phase offset α, the sum $x_1(t)+x_2(t)\exp(-j\alpha)$ is an arbitrary family until α is measured or otherwise constrained. One cannot choose α solely to maximise the final coherent amplitude and then use that very amplitude as independent evidence that the signal remained coherent. Such optimisation may be useful as exploratory signal processing, but it does not establish physical phase continuity. Even a single correctly measured sample at each end of a gap leaves the accumulated integer number of carrier cycles ambiguous when the intervening phase trajectory is unconstrained. This is why phase unwrapping, despite its elegance, is not a substitute for information that the receiver did not collect.

A common frequency reference constrains an oscillator's rate and perhaps its slow phase evolution, but it does not necessarily determine a synthesiser divider's startup state. A receiver may restart a phase-locked loop at a different relative phase on each retune. Some hardware permits deterministic phase synchronisation; other implementations require calibration following every frequency change. The apparatus must therefore be characterised in its actual configuration. The operator should not infer deterministic reacquisition from a 'lock' flag, a successful frequency command, or identical numerical carrier settings. Where the architecture supports timed commands, synchronised triggering alone may still leave a

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stable but unknown phase rotation. A reproducible constant offset is more useful than an unrepeatable one, yet even a constant offset needs a measured value before interferometric or coherent spectral conclusions can rely upon it.

The appropriate bridge is an independently maintained observable. A calibrated pilot signal may be delivered into the receiver chain at a declared reference plane, measured both before and after retuning, and related to a phase-continuous external standard. Alternatively, an uninterrupted parallel channel can observe a common signal component throughout the gap. The pilot or witness must itself possess adequate spectral purity and be measured in a manner that does not create the very discontinuity under examination. It must also be relevant to the frequency band and path being corrected. A calibration performed at one tone may identify a constant complex rotation at that tone, but it may not identify frequency-dependent group delay or an arbitrary phase slope across a wideband channel. Multi-frequency calibration can be needed when the application reconstructs a broad or stepped-frequency aperture.

Consider a receiver which measures a stable test tone at a first tuning frequency, visits another band and returns. In the hypothetical absence of a phase-preserving retune architecture, measured phase after the return may differ from the phase extrapolated from the first interval by an unknown offset of, say, 70 degrees. The number is illustrative; it is not the measured behaviour of any specific product. If the investigator forces the two records into alignment by subtracting 70 degrees, the resulting trace can look continuous, but the adjustment is a calibration only if the 70-degree offset was estimated from an independent reference, not chosen to make the

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questioned signal match. Where the pilot's phase estimate has standard uncertainty u_α radians, that uncertainty propagates into the coherent sum and into every derived phase-sensitive quantity. The analyst should disclose the phase estimate, the frequency to which it applies, the reference plane, and the uncertainty budget.

A missing interval imposes a further limitation that cannot be fixed by oscillator calibration alone. An emitter may change phase discontinuously or cease transmitting and resume while the receiver is tuned elsewhere. Even a perfectly coherent local oscillator does not establish continuity of the remote source. A phase-preserving receiver and a phase-continuous emitter are separate propositions. To claim continuity of the emitted waveform, the experiment must monitor a persistent correlated reference, establish an emitter model with justified bounds on its phase innovation, or state clearly that continuity is assumed rather than observed. In a forensic report the distinction matters because a reconstructed continuous trajectory can conceal a genuine change in transmitter state, and the resulting error may be far larger than the calibration uncertainty of the receiver itself.

An acceptance test should be deliberately adversarial. Use a laboratory source with a known phase programme, record an uninterrupted witness channel, retune the test channel repeatedly across different frequencies and hold times, and compare post-retune residuals against the witness under varying temperature and input power. Include sudden phase changes confined to the unobserved interval; the reconstruction must not be permitted to pass merely because its smoothing algorithm makes them disappear. Log exact sample counters, tune-command timing, synthesiser lock transitions, calibration signals, gain and filter settings, and any rejected

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epochs. Test the distribution of residual phase, not only the mean, and repeat across the intended signal bandwidth. If residuals exhibit an uncontrolled mode ambiguity, a reliable coherent aperture has not been demonstrated. My criterion is bounded and physical: coherence may be asserted only for those intervals, bands and signal classes for which the reference transfer and the unobserved source evolution have been independently constrained.

Andrey N. Kolmogorov, Peer Question: Professor Gabor, you distinguish a phase alignment obtained from the observed signal from one independently measured by a calibration channel. Suppose the receiver records only two short bursts of a carrier whose source phase is said to be stable but whose physical oscillator is not accessible. A processor searches many integer-cycle continuations and retains the one giving greatest coherence. What is the statistical population with respect to which the reported alignment should be assessed? How can we quantify the consequence of searching many phase hypotheses when the investigator's strongest-looking solution was selected after inspecting the same data? I also wonder whether a repeatable alignment in one laboratory test proves stability under field conditions where temperature, retune order and the source modulation are uncontrolled. Please distinguish the effect of random calibration error from a discrete phase reset that has several plausible modes, and identify observations that would justify calling one mode physically established rather than merely numerically attractive. A court may otherwise mistake the largest fitted correlation for an independent observation of continuity.

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Dennis Gabor, Response: Professor Kolmogorov, the observation cannot be interpreted without the selection rule. If the processor chooses the largest of many candidate coherent sums, its distribution under the hypothesis of no persistent phase relation differs from that of a sum formed with a correction fixed in advance. A defensible null experiment must reproduce the entire search, including the permitted phase grid, event-selection rules and quality thresholds. One could process noise-only or deliberately phase-randomised records under the same code, measuring how often a convincing apparent bridge is found. The reported false-alarm rate belongs to that full procedure rather than to one preselected hypothesis. This is particularly important when candidate integer-cycle continuations multiply with gap duration.

I would treat a phase reset with several plausible modes as a mixture problem. If the synthesiser's divider can produce two phase states, for example, an independent pilot may be capable of discriminating them. Without the pilot, selecting the mode that best aligns the questioned carrier is a fitted model, not proof of a unique hardware state. A repeatable laboratory result on one tune path establishes only that path under the tested conditions. It does not automatically transfer to a different divider ratio, temperature or power cycle. Repeated trials should record the distribution of post-retune phase residuals after the correction procedure is frozen, including the frequency of outlying modes and outright lock failures.

A test of generalisation should hold back complete retune sequences, not merely individual samples taken from the same sequence. Build the correction rule from one group of frequencies, temperatures and dwell intervals, then challenge it on a predeclared independent group. Use a

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continuous witness receiver to record any genuine source phase change during each gap. If the fitted method succeeds only when allowed to inspect the witness or the questioned carrier before choosing its phase, its success is conditional on information that may not exist in the intended field application. The investigator should distinguish measured phase transfer, model-supported extrapolation, and unresolved source continuity. Only the first, accompanied by its uncertainty, can be described as independently established.

The same discipline is required for confidence intervals: optimisation of the correction must be incorporated into the null and alternative procedures, including their stopping and selection rules, rather than omitted from the reported uncertainty.

Maurice S. Bartlett, Peer Question: Professor Gabor, the pilot you propose may be injected at a receiver connector, whereas the questioned radio emission has propagated through an antenna, room, cable assembly and perhaps a frequency-selective preamplifier. If both paths share the digitiser but not the entire analogue transfer function, the pilot may remove a local-oscillator phase reset while leaving source-dependent changes uncorrected. What conditions make the pilot informative for the actual measurand? Would a pilot at one frequency be sufficient for a wideband synthesis, or could a correct phase at that frequency conceal an erroneous group-delay slope elsewhere? Please also examine a pilot whose own distribution path drifts with temperature and a case in which the pilot is present only after the retune. What independent observations would discriminate receiver phase reset, pilot phase movement and changes in the external propagation channel? I ask because a calibration that tracks the wrong pathway may

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improve the appearance of the data while making the forensic interpretation less reliable.

Dennis Gabor, Response: Dr. Bartlett, the pilot's relevance follows from the transfer function it actually samples. Injection at the receiver connector can characterise the electronic receive chain downstream of that connector, including local oscillator and much of the analogue filtering. It does not measure antenna geometry, mutual coupling, a moving propagation path or phase variation in upstream components excluded from the injection. Therefore the report should identify its reference plane, the signal path shared with the questioned observation, and the uncalibrated elements. A secondary radiated calibration can exercise more of the path, provided its source phase and physical geometry are independently controlled. The two measurements answer related but different questions, and their residuals should not be silently conflated.

A one-tone pilot identifies a phase difference at its own frequency. To infer broad-band coherent synthesis, one may need the phase as a function of frequency. A delay τ in the signal path contributes a phase slope approximately $-2\pi f\tau$ under a specified complex Fourier convention. If the path delay changes by a nanosecond, the phase variation across 100 MHz is $2\pi(100\ \text{MHz})(1\ \text{ns})$, about 0.628 radians or 36 degrees. A calibration at one spot frequency can perfectly remove a constant rotation yet leave this frequency-dependent error. The calculation is illustrative, but it demonstrates why phase and group-delay calibration should be distinguished. Multiple independent tones or a characterised wideband calibration stimulus may be necessary to estimate the slope and its uncertainty.

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To separate pilot movement from receiver movement, independently observe the pilot before it enters the suspect distribution branch, then compare its phase with a second stable reference at the receiver input. Repeat after cable swaps, thermal changes and return-to-frequency trials. If the pilot was absent during the gap, its post-retune value can identify the current phase offset but may not reveal every event during the absence. An uninterrupted witness channel provides stronger information about the source itself. I would allow the calibration to transfer only across components physically observed or previously characterised, and would declare the remaining source and propagation phase uncertainty separately.

An apparent phase agreement that vanishes when the pilot is moved to a different frequency is evidence of an incomplete transfer function, not proof that the emitter changed its phase.

Dennis Gabor, Cross-Peer Question to Harry Nyquist: Harry Nyquist, your account of the sample clock and local oscillator clarifies that identical timestamps do not guarantee continuous phase. Yet many engineers claim that a deterministic numerical oscillator running against one never-reset sample counter solves the retune problem. Would you examine the exact boundary of that claim when the RF front end also has an independently settling synthesiser and frequency-dependent filters? In particular, can a numerical phase accumulator be continuous while the analogue input-to-baseband transfer acquires a new unknown phase? Would your conclusion change if the receiver performed direct RF sampling without an analogue mixer, or if an FPGA adjusted its digital frequency without interrupting samples? Please give a falsifiable test rather than an architectural slogan. I

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am asking whether digital determinism should be treated as an end-to-end coherence guarantee or as one verified component of a larger measurement chain whose remaining phase terms still require independent observations.

The proposed experiment must also show which calibration quantities are retained before the retune rather than estimated opportunistically from the later target.

Harry Nyquist, Cross-Peer Answer to Dennis Gabor: Professor Gabor, the numerical oscillator is one state variable, not the whole receive chain. If a digitally generated phase is computed from an uninterrupted absolute counter, its phase at each sample can be determined mathematically, even when the programmed frequency changes. That property is valuable and testable. But if the physical input is first mixed by an analogue synthesiser which reacquires lock at an unknown phase, a deterministic post-ADC numerical oscillator cannot reconstruct the lost analogue phase merely by maintaining its own accumulator. The output is the composition of both operations, and the unknown analogue term survives. Likewise an analogue filter's group delay may change when a preselector or gain state is switched, leaving frequency-dependent phase errors after an otherwise perfect digital rotation.

Direct RF sampling can remove one analogue mixer and its phase-reset ambiguity, but it does not remove every source of discontinuity. Clock multipliers and dividers, switched sampling paths, ADC calibration, digital downconverter resets, and sample loss can still alter phase or chronology. A particularly clean case would be continuous raw RF sampling with an

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unbroken sample counter and a digital channeliser which visits different analysed bands without changing the analogue acquisition. There, retrospective digital retuning may preserve the same physical time series, subject to filter and representation conventions. But the engineer must demonstrate that the original wideband samples really remained continuous and that none were discarded. A display that hops between channels is not evidence that the underlying capture was wideband and gapless.

The falsifiable test is a phase-continuous injected two-tone or phase-coded stimulus recorded by an independently monitored witness. Execute the complete set of retune commands, including any analogue front-end changes, while measuring input and output phase at defined reference planes. Perform one trial using purely digital post-acquisition retuning and another requiring the analogue synthesiser to reacquire. A genuine end-to-end deterministic phase model should predict the post-retune residual in withheld trials without selecting a correction from the questioned signal. Record any divider-mode dependence, settling, counter gap or recalibration event. Digital determinism is therefore a valuable component of a coherent system only when the remaining physical phases are either preserved or measured.

Dr. James M. Atkinson, Moderator: Mr. Nyquist, Professor Gabor has separated numerical alignment from measured phase continuity. Please take the token to examine how sampling frequency, integer sample counts and oscillator phase are related, and to identify the particular loss of information that follows retuning even where the digitiser never changes its clock rate.

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Harry Nyquist, Principal Contributor: Dr. Atkinson, it is necessary first to avoid an attractive but false equivalence: an accurately timed sequence of samples does not by itself determine the carrier phase that those samples ought to possess after a frequency change. The sampling clock defines the instants at which a sampled signal is measured. The local oscillator defines the phase of frequency conversion in a heterodyne or complex downconversion path. Both can derive their average rates from a common standard without possessing a reproducible absolute phase relation after a synthesiser retune. In a digital receiver, the numerically controlled oscillator may likewise be restarted at zero phase, allowed to run freely, or recalculated from an absolute sample counter. Those three policies yield different output phase histories despite their identical nominal tuning frequency. The exact policy must be established from implementation and a physical test rather than guessed from the front-panel display.

Suppose that an RF input has instantaneous phase $\varphi_{RF}(t)$ and that a mixing oscillator has phase $\varphi_{LO}(t)$. In an ideal complex downconversion, the observed baseband phase is $\varphi_{BB}(t)=\varphi_{RF}(t)-\varphi_{LO}(t)+\varphi_{H}(t)$, with φ_{H} representing the complex filter and reference-plane contribution. Across a retune, the sample index n may advance monotonically, yet φ_{LO} can gain an unknown offset $\Delta\varphi_{LO}$. If φ_{RF} and φ_{H} remain otherwise unchanged, the baseband phase jumps by approximately $-\Delta\varphi_{LO}$. The result is not corrected merely by writing the same timestamp into both records. It is also not corrected by replacing the sample rate in a software metadata field, since the missing variable is a phase state. A common low-frequency reference, such as a nominal ten-megahertz source, cannot uniquely

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prescribe the phase of an independently divided gigahertz oscillator without a suitable phase-synchronisation architecture.

The phase of a digital oscillator can be made deterministic when its accumulator state is defined as a function of a shared absolute sample counter and the frequency command, but only if the implementation actually preserves that relation across state changes. If a new command resets the accumulator, the phase is discontinuous even if its phase increment is exact. If an accumulator runs through the retune, there may be a mathematically continuous numerical carrier whose slope changes; however, the analogue path might still switch a synthesiser divider, move a filter, alter automatic gain, or introduce a calibration reset. An auditor should therefore examine both the digitally generated phase and the analogue conversion chain. Verification at the software phase accumulator alone does not cover phase motion that occurs before the ADC.

A particularly important case is synthesis across multiple subbands. Suppose an investigator records three overlapping frequency windows, each with its own unknown phase rotation α_k. Where overlaps contain a sufficiently strong common calibration feature, one may estimate relative rotations. But the graph of overlaps must be connected: a subband with no overlap and no common witness cannot be placed on the same phase reference by algebra alone. With noisy overlaps the estimation becomes a weighted network problem, whose gauge freedom must be fixed by choosing a reference phase. A small residual after fitting may result from a flexible model. The model should be challenged on withheld calibration tones and by returning to a previously observed frequency after visiting unrelated settings.

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A useful test involves an injected pilot of frequency f_p and a continuous physical reference source. Let θ_{before} be the estimated pilot phase before retuning, θ_{after} the estimated phase following it, and $2\pi f_p \Delta t$ the phase advanced by an ideal stable pilot during elapsed time Δt, all expressed relative to a continuously known clock. A phase residual may be written $r=\mathrm{wrap}[\theta_{after}-\theta_{before}-2\pi f_p \Delta t]$, where wrap returns an angle modulo 2π. The observable r identifies a residual phase modulo complete cycles. It does not alone tell how many integer cycles were accumulated during the gap, nor does it establish the RF source phase at other frequencies without calibration of the transfer function. If the pilot and signal occupy different paths, additional uncertainty belongs in the model; if they share a path, the pilot may still fail to detect signal-specific propagation changes.

One sometimes hears that oversampling or higher ADC bit depth can restore coherence. Those techniques may improve estimation accuracy within the observed intervals, but neither recreates an unmeasured oscillator phase after an uncontrolled reset. At high signal-to-noise ratio an estimator can measure a phase offset to a small fraction of a radian; it remains perfectly capable of estimating the wrong physical object if the chosen reference is itself interrupted. Conversely a modest sampling system with a stable, well-calibrated phase witness may provide defensible relative phase information. The distinction is between measurement resolution and identifiability. A count of digital samples supplies chronology; it does not guarantee that all relevant phase states are observable.

The evidence ledger should therefore include at least the original complex samples, hardware sample counter, local-oscillator control commands, reference-clock identity, synthesiser reset behaviour, filter configuration,

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phase corrections and their estimated uncertainty, and the independent measurements by which each correction was justified. The investigator should repeat short and long retunes, measure worst-case reacquisition residuals, and test whether transitions behave differently between particular frequency settings. A deterministic mode may exist over a small range even where a different divider boundary causes an arbitrary phase reversal. Consequently it is unsound to certify a receiver as 'phase coherent across retuning' without specifying its permitted retune paths and the conditions under which calibration is repeated. The correct conclusion is conditional: continuous sample time and a common reference can support a coherent reconstruction only when the phase-state transfer is characterised and the signal's own unobserved evolution is separately accounted for.

William Feller, Peer Question: Mr. Nyquist, suppose the receiver is absent from the carrier for a short interval but its sample counter runs without interruption and an external oscillator supplies an excellent frequency standard. The analyst assigns an integer number of cycles to the gap and concludes that the later burst belongs to the same phase trajectory. How should the uncertainty of that integer assignment be evaluated when the carrier frequency estimate itself has statistical error and the emitter may possess random-walk phase fluctuations? Is there a point at which several cycle counts become equally compatible with the observations? I should also like to know whether simply increasing the sample rate before and after the gap makes the integer choice more reliable. Finally, distinguish a calibrated local-oscillator reset from an actual phase change at the transmitter, because the post-gap observations may be identical under those two

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mechanisms. Please give a rigorous interpretation of an unresolved integer ambiguity.

Harry Nyquist, Response: Professor Feller, the number of accumulated cycles during an unobserved interval depends on the integral of the true instantaneous frequency. If the gap length is Δt and the frequency error is $\delta f(t)$, the uncertain phase advance contributed by that error is $2\pi\int\delta f(t)dt$. With a constant uncertain frequency error δf, the scale is $2\pi\delta f\Delta t$; if δf is stochastic, the uncertainty depends on its covariance over the gap. At sufficiently large uncertainty, several integer-cycle continuations may be compatible with the observed endpoints. A phase measured modulo 2π cannot distinguish them without additional information. Reporting one selected integer as though the instrument observed it would replace an inference with an invented event history.

Higher sample rate improves the temporal density of the observations that exist, and can improve phase estimation under appropriate signal and noise conditions. It does not directly observe the carrier while the receiver is tuned elsewhere. If the pre-gap phase is measured accurately, and the post-gap phase is measured equally accurately, an unknown cumulative phase advance may still have multiple possible cycle counts. An independent pilot or uninterrupted witness can constrain that advance; alternatively a validated bound on frequency drift and modulation may limit the admissible integers. The bound must include the emitter dynamics as well as receiver-clock uncertainty. An arbitrary claim of source stability, adopted solely to force unique unwrapping, is insufficient.

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A local-oscillator phase reset and a transmitter phase step can create the same difference in observed baseband phase at one receiver. To distinguish them one may compare an independently clocked receiver observing the transmitter continuously with a local calibration signal injected into the retuned receiver. If the independent receiver shows source continuity while the pilot shows a receiver reset, the ambiguity can be narrowed. If both independent observations are absent, the cause may remain fundamentally nonidentifiable. The proper result is then a set of compatible hypotheses or an interval for phase advance, not a fabricated exact count. This is a limitation of available evidence, not a defect cured by more decorative decimal places.

The uncertainty budget should record the time interval and spectral model used to establish the bound, not merely a numerical guess at the number of missed cycles.

Harry Nyquist, Cross-Peer Question to Rudolf E. Kálmán: Professor Kálmán, the sample-count discussion yields an ambiguity which a dynamic estimator might try to eliminate by predicting through the retune. What state representation would you require when the local oscillator can restart in one of several phase modes and the emitter may independently step phase? Can a single linear Gaussian filter preserve the true range of possibilities, or must the reconstruction maintain distinct hypotheses until a calibration observation discriminates among them? Please also examine what happens when the filter's covariance shrinks after reacquisition because it has absorbed post-gap samples of the questioned signal. Does that narrow covariance establish an objectively correct phase bridge, or only internal consistency under the model? I would value a criterion for when

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such a filter may support coherent integration and when the engineer must return to noncoherent processing.

Please state whether the model is falsified if a withheld retune gives residuals outside its claimed phase interval.

Rudolf E. Kálmán, Cross-Peer Answer to Harry Nyquist: Mr. Nyquist, a single linear-Gaussian filter is an approximation whose adequacy depends on the shape of the posterior uncertainty. If a divider reset allows phase states separated by π radians, for example, the posterior may be bimodal. A single mean located between the modes can describe neither physically plausible state. One should retain a mixture representation, an explicit discrete-mode variable, or parallel estimators conditioned on the alternative reset hypotheses. The emitter's possible phase step is another latent variable; unless an independent witness constrains it, the system can confuse emitter and receiver changes. A clever filter does not create an observation that the sensing arrangement failed to make.

Covariance contraction after reacquisition may be entirely legitimate for the state actually observed. But if the update uses only the questioned signal, and the selected mode was chosen to make that same signal continuous, the covariance is conditional on the mode assumption and the fitted source model. The engineer should report mode probabilities or alternative trajectories where justified, not conceal model uncertainty in a small conditional standard deviation. There is also a distinction between estimating post-gap phase accurately and establishing the integer-cycle history through the gap. A tight estimate at the endpoint does not automatically determine that history.

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A coherence acceptance criterion should be tied to withheld predictions. Use calibration runs with known oscillator resets and programmed source phase steps; estimate correction parameters from the allowed calibration stream, then evaluate residual phases in independent test intervals. If the procedure correctly identifies the mode with a declared error rate over the relevant tune paths, it may support coherent integration within those boundaries. If multiple modes remain or the source dynamics can invalidate the bridge, separate the windows or combine them noncoherently. The analyst should publish the state assumptions, transition model, observation matrix, process-noise treatment and every excluded interval. What matters is whether the reconstruction predicts an independent observable, not whether its own smoothed display appears persuasive.

The withheld trial supplies an external challenge to the model, which internal covariance reduction cannot provide on its own. The appropriate validation must include the full family of retune paths anticipated in the field, including those not used to estimate transition parameters. Otherwise apparent predictive confidence can be an artefact of a narrow experimental design.

Dr. James M. Atkinson, Moderator: Professor Kálmán, I should like you to distinguish a measured post-retune phase from a state inferred by prediction. How does an estimator carry uncertainty through a period when the receiver has not observed the carrier, and when should the correct result be a family of possible phases rather than one elegant but unjustifiably precise curve?

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Rudolf E. Kálmán, Principal Contributor: Dr. Atkinson, the central issue is observability. A dynamic model may predict how a phase state would have evolved during an interval without measurements, yet it cannot establish that a physical system obeyed the model when the relevant disturbances are unknown. Let the state vector x_k contain carrier phase, frequency offset and perhaps frequency drift at discrete epoch k. A simple model is $x_{k+1} =F_k x_k+w_k$, where F_k propagates the state and w_k describes process disturbances, with covariance Q_k. Measurements take the form $y_k=H_k x_k+v_k$, with measurement noise covariance R_k. These equations are useful only if their state definitions, linearisation, and disturbance statistics represent the physical receiver and source. Across a retune the observation matrix may be absent or rank-deficient; the estimator then predicts but does not receive new phase evidence from the unobserved carrier.

For a linear-Gaussian model the predicted covariance is $P_{k+1|k}=F_k P_{k|k}F_k^T+Q_k$. During a gap, that covariance ordinarily grows because process uncertainty accumulates. If the filter reports a narrowing phase uncertainty solely because it has imposed a smoothness assumption, the engineer should inspect whether Q_k has been unrealistically reduced. Oscillator phase noise, frequency drift, sudden re-lock errors and source modulation may not share a convenient stationary Gaussian law. A discrete random phase reset calls for a mixture or multiple-hypothesis model, not for the continuation of one Gaussian phase state across a transition that the instrument did not record. The phase variable is circular as well; ordinary linear covariance in radians can misrepresent a distribution that wraps around ±π or contains separated phase modes.

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Consider a hypothetical carrier with initial frequency error uncertainty of one hertz and a retune gap of 0.25 seconds. Even neglecting all other disturbances, the resulting uncertain phase advance has a scale $2\pi(1\ \text{Hz})(0.25\ \text{s})=\pi/2$ radians, or 90 degrees. The number is a simplified sensitivity scale, not a complete standard uncertainty calculation, because the frequency error may change during the gap and its distribution matters. The example nevertheless shows why a small frequency uncertainty can become a material phase ambiguity after enough unobserved time. Extending the gap by a factor of four multiplies this simple phase sensitivity by four, whereas a fresh independent pilot measurement could reduce it if that measurement truly bridges the required phase state. This is a dynamical observability question, not a count of digits on the clock display.

A retuned receiver introduces at least two additional latent states. The first is the initial phase of its re-acquired local oscillator, possibly with a discrete ambiguity due to synthesiser division. The second is the phase transfer of the selected analogue and digital filters. They need not share one distribution, and their errors may be correlated with temperature or gain settings. An estimator that collapses both into a free scalar rotation can align a single calibration tone, but it may fail to correct frequency-dependent dispersion across the measurement band. A properly designed state model distinguishes constant phase offset, group delay and higher-order phase variation. To estimate all three, the calibration signals must span sufficient frequency diversity and the measurement geometry must make the parameters distinguishable. Adding parameters without independent observations makes the fitted record look adaptable, not necessarily accurate.

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The relation between phase measurement and source behaviour is especially hazardous. Suppose a legal defensive receiver observes a periodic burst before retuning and again afterwards. A state estimator predicts the phase of the burst carrier through the gap using the measured pre-retune frequency. But the emitter could have changed synthesiser state, stopped and restarted, or employed intentional modulation. If those possibilities are not excluded by a reference channel, the estimator's continuity is a statement about its imposed source model, not the actual transmitter. The appropriate evidence report may give multiple candidate trajectories, with their assumptions and probabilities only where justified. It may also declare the inter-window phase relation unidentifiable. Such a result is scientifically stronger than presenting one curve supported by an untested prior.

One useful experiment would produce a programmed calibration waveform through a controlled test source. Include known phase steps at unpredictable times within the receiver's retune gaps, while a separate uninterrupted measurement instrument records the true programme. Fit the estimator without access to the hidden phase-step schedule and evaluate whether its confidence intervals cover the withheld truth under each test condition. Repeat with different signal-to-noise ratios, retune delays, and oscillator holdover periods. Where the estimator systematically assigns undue confidence to incorrect phase continuity, revise its transition model or reject coherence claims for that mode. A second experiment should return to the initial tuning frequency and compare predicted phase to an independently measured pilot, detecting calibration hysteresis.

The audit should store prediction and update states separately, with the covariance and innovation sequence at every stage. Record the time of each

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tune command, the instant the hardware actually resumes valid samples, the model version, any calibration data used to set the phase offset, and any samples excluded as transient. An engineer may perform coherent combination over calibrated windows while allowing a discontinuity in the model at each retune. This is preferable to silently bridging the gap in the raw waveform. Coherence is an experimentally limited property of the reconstruction, not a perpetual attribute conferred by a single disciplined reference clock. A defensible statement is therefore narrower: within measured calibration uncertainty and an explicitly bounded source-dynamics model, selected windows are consistent with one phase reference. Beyond that boundary the result is prediction, not observation.

Sir David R. Cox, Peer Question: Professor Kálmán, your state estimator can carry a distribution of predicted phase across a retuning interval, but the observing instrument may switch preselectors, reset a synthesiser, and enter a settling state that is neither stationary nor characterised by a single Gaussian perturbation. How would you design a validation experiment that identifies which part of the apparently coherent post-retune record comes from measurements and which part comes from an imposed dynamic model? Consider both a continuous injected pilot and a genuine intermittent RF source whose phase trajectory is not known. Would a narrow confidence band around a model-predicted phase be meaningful if the hardware transfer function has changed without entering the model? In particular, how would you test for bias that appears only after several sequential retunes, rather than in the customary single return-to-frequency trial? I ask for a criterion by which the instrument operator could reject the

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reconstruction even when its plotted phase trace looks smooth and its software reports normal lock.

Rudolf E. Kálmán, Response: Sir David, validation must separate the physical observations, the assumed state transitions and the state that the filter predicts. I would first write an explicit transition equation with a mode variable for each retune path. In one mode the analogue oscillator might preserve an established phase relationship, in another it might reacquire at one of several possible divider phases, and in a third a change of preselector could introduce an unknown frequency-dependent phase shift. The estimator cannot assign small uncertainty to an unmeasured switch state merely because its ordinary locked-mode noise is small. Either the transition parameters must be calibrated independently or the posterior distribution must retain the unresolved alternatives.

A proper experiment therefore requires a continuous phase witness at a declared reference plane, hardware sample counters and timestamping, together with a separate pilot which experiences the relevant receiver signal path. Randomise the order of retunes and include paths not used for fitting. Assess whether predicted phase residuals for withheld transitions fall within the claimed coverage interval. A model predicting nominal 95 percent coverage should be examined across enough independently repeated trials to test that assertion, whilst recording dependence between trials and environmental changes. It is insufficient to fit the filter on the first fifty retunes and then quote its internal covariance as the error estimate for those same fifty. Such a statistic describes consistency with its assumptions, not an independent measurement of phase continuity.

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For an intermittent source the more difficult problem is identifiability. A continuous pilot can identify instrument phase only over the range of phase-transfer behaviour it actually probes. It cannot independently establish the signal phase accrued while the transmitter was silent. If the source model is uncertain, the estimator must propagate that uncertainty separately. A controlled pilot at two frequencies may expose a filter-delay error hidden by a single-frequency correction; a sequence of retunes over temperature may reveal drift or hysteresis not present in short trials. Failure on any withheld condition should suspend the global coherence claim until the transition model has been revised and independently tested. A smooth line is a possible numerical consequence of interpolation and filtering. It is not itself a datum proving continuity.

Rudolf E. Kálmán, Cross-Peer Question to Martin Ryle: Sir Martin Ryle, in your account of multichannel direction finding a small phase offset can change the inferred bearing. Suppose an estimator assigns a sharply peaked posterior phase correction after retuning because several receiver channels agree. Would that agreement constitute independent calibration if all channels derive their oscillator phase from one distribution network, or if a common path-model error affects every antenna? Please distinguish error cancellation in a differential phase estimate from the evidence required to justify an absolute phase bridge across missing observations. I would also ask how a practical laboratory trial should expose a fault that preserves pairwise receiver differences yet corrupts the phase of the entire array relative to an independently observed transmitter. The experimental criterion needs to survive changes of antenna baseline, pilot placement and retune sequence, otherwise a narrow covariance may simply be a product of

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a shared and untested assumption. Please specify whether an independent phase monitor would distinguish these explanations when pairwise errors cancel.

Martin Ryle, Cross-Peer Answer to Rudolf E. Kálmán: Professor Kálmán, multichannel agreement is strong only to the extent that the channels possess relevant independence and their phase differences are observable at the reference planes used by the inference. An error shared identically by all channels can cancel from pairwise phase differences; the array may therefore retain good relative bearing capability while lacking evidence of absolute phase continuity through a retune. The converse also matters. A reference distribution fault that changes one branch but not the others can alter measured baselines and produce a biased bearing despite a well behaved central oscillator. The array's covariance model must reflect these distinctions instead of assigning independence by counting receiver boxes.

I would conduct a geographically and electrically controlled trial with an emitter or injected wavefront at known phase and location. Observe it through a separate continuously recording reference receiver whose clock and signal path do not share the questioned reset mechanism. Then execute the array retune sequence under test and compare the recovered pairwise phase, absolute transfer phase and resulting bearing against the independent witness. Repeat after changing antenna baseline, rotating the apparatus, exchanging reference branches and moving the calibration feed to alternate points in the receiver chain. A phase model that predicts one reference plane but not another should be described as limited to the former. One successful baseline is not proof of an end-to-end calibration generalising to every field geometry.

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Where a common-mode phase disturbance cancels in the differential result, that cancellation is a useful design property, but it is not an observation of the omitted absolute information. Where retuning interrupts sample collection, an estimator may bridge the gap using a physical model and constrained source dynamics; any location estimate relying on that bridge must disclose the bridge's uncertainty. If the model fails an independent test, a noncoherent or separately epoch-calibrated analysis may remain valid. The scientific aim is not to insist that every retune destroys all useful inference, but to identify precisely which inference survives the retune and what measurements warrant it. The experiment must retain the underlying calibration files and branch settings so that a later reviewer can independently compute the reported residuals and challenge any common-error assumption.

Dr. James M. Atkinson, Moderator: Sir Martin, please consider the practical receiver and antenna array. If separated spectral windows are to form a synthetic aperture or a coherent direction-finding observation, what controls must transfer phase through the actual RF paths rather than just through the software that displays the records?

Martin Ryle, Principal Contributor: Dr. Atkinson, the construction of a coherent array begins with the physical signal path. A shared sampling standard, common timing pulse and frequency plan are useful, but each receiving branch also includes an antenna, feed, cable, amplifier, mixer, filter and digitiser whose complex transfer function may change with tuning, temperature and time. In an array the measurable quantity is often a phase difference between stations or antenna elements, not the absolute phase of one source. Retuning can alter that difference even if the clock remains

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disciplined. The instrument must therefore demonstrate reproducible relative calibration at each selected tuning state, and any interpolation between states must be independently tested rather than accepted from a nominal phase plot.

A simple two-channel model makes the distinction evident. Let the desired electric field at antenna i be $E_i(f)$, and let its complete receiver transfer function be $H_i(f,t)$. The recorded complex value is $y_i(f,t)=H_i(f,t)E_i(f)+n_i(f,t)$. A comparison y_1/y_2 depends on the ratio H_1/H_2 as well as the actual field ratio. If retuning changes the phase of H_1 by 40 degrees but H_2 by 10 degrees, the measured relative phase shifts by 30 degrees even though the external wavefront is unchanged. The values are hypothetical. A stable common reference does not make the two H_i phases equal; it provides a framework on which calibration may be built. The relative transfer needs measurement at the relevant frequency and time.

The geometry and the retune schedule can produce a more subtle error. When two antenna channels sample one emitter simultaneously, the relative carrier phase contains information about path-length difference. If they instead sample at different moments, any emitter drift, movement or propagation variation can be mistaken for a spatial phase difference. The analyst must distinguish simultaneous coherence from time-interleaved coherence. A synthetic wideband measurement can be assembled from sequential subbands only if the target remains sufficiently stationary, or its evolution is measured and corrected. The more rapidly the scene changes, the less defensible it becomes to combine widely separated observation epochs into one instantaneous aperture. The burden is not removed by excellent local oscillator stability.

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A calibration arrangement should inject a common phase-known test signal at a set of clearly defined reference planes. Input calibration at each receiver connector characterises much of the electronics but not the antenna, mutual coupling or propagation. A radiated calibration source incorporates more of the external path but introduces its own geometric and environmental uncertainty. A robust programme uses both where justified. One should test phase offsets after cold start, repeated short retunes, extended dwell at other frequencies, return to an earlier frequency, and changes in gain or filter state. A multi-tone or swept calibration may be needed to characterise group delay and frequency dependence. The investigator should retain the calibration raw observations, not only the final compensation coefficient.

Where subbands overlap, the overlap provides a self-consistency check but not necessarily an absolute calibration. A least-squares fit can estimate phase offsets that make neighbouring bands agree. Yet if all bands share an incorrect propagation model or a receiver-induced spur, agreement may be physically misleading. The overlap should therefore be challenged with an independent calibration source and repeated after a change expected to alter a known component of the system. I would particularly test for a frequency-dependent linear phase term: an uncorrected group delay τ produces phase variation $-2\pi f\tau$ under a declared Fourier convention. A constant phase offset calibrated at one f cannot remove that slope at all frequencies. The resulting wideband impulse response can be distorted even though a narrow calibration tone aligns perfectly.

In direction finding the consequences can be quantified. For a two-element baseline of length d, an incoming plane wave at wavelength λ has an ideal

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relative phase related to $2\pi d \sin \theta/\lambda$ under a chosen geometry and angle convention. An error in the instrument phase is therefore liable to bias the inferred angle, especially where the derivative of phase with respect to θ is small or the baseline yields ambiguities. The engineer should propagate uncertainty through the actual geometry instead of converting degrees of phase directly into a universal angular error. Multipath and polarisation mismatch may create additional phase changes that no instrument-only correction can remove. One must not label all residuals 'clock errors' merely because the model contains a clock parameter.

The practical acceptance protocol must include measured timing alignment, lock-state supervision, repeated phase-transfer calibration, sample-loss detection, independent reference monitoring and demonstrations on test emitters at known positions. Review the performance immediately before and after retuning and exclude unsettled acquisition intervals from coherent processing unless those transients are themselves modelled and verified. Record actual rather than nominal tune-completion times. Use distinct test angles and frequencies to reveal a compensation method that works only at one calibration point. A negative result should be stated plainly: if the calibration connection disappears or the source evolution cannot be bounded, the separated observations may still be analysed noncoherently but must not be represented as one fully phase-continuous aperture. That restriction protects the investigator against false precision and false attribution.

William Sealy Gosset, Peer Question: Sir Martin Ryle, a calibration campaign may repeat one return-to-frequency operation many times, yielding a very small measured spread of phase corrections. An author then

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claims that the system will maintain coherence under any frequency-hopping survey. How would you evaluate the relevance of that experimental sample to an operational collection of retune paths, including different frequency separations, synthesiser-divider boundaries, temperature changes and waiting times? In particular, could a large number of highly correlated repetitions provide less information than a smaller collection that explores the actual instrument operating envelope? Please explain how an investigator ought to state an uncertainty bound for a particular retune sequence without either exaggerating the device's universality or dismissing the genuinely useful repeatability demonstrated under controlled conditions. How could the final calibration record be structured so that a later reviewer distinguishes repeated trials from genuinely independent challenges of the instrument model? I ask also how confidence limits should be modified when thermal drift creates correlation between successive experimental observations.

Martin Ryle, Response: Mr. Gosset, the measurement sample must represent the configurations to which its conclusion will apply. One thousand consecutive returns between the same two synthesiser settings at constant temperature may estimate short-term repeatability under those conditions with considerable numerical precision. It need not characterise the phase after switching a preselector, crossing a divider boundary, changing input frequency by an octave, or restarting a PLL after prolonged inactivity. The apparent sample size is also misleading if the trials share one slow oscillator drift or calibration reference error. Treating all trials as independent merely because the measurement file contains a thousand rows would understate uncertainty.

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I would stratify the testing by actual retune path, frequency separation, dwell time, temperature, receiver configuration and reference-source state. Randomise the order within practical constraints, then reserve complete classes of transitions as withheld verification cases. Repetition within each class measures conditional scatter, whilst comparisons between classes expose systematic phase offsets and interactions. A statistical model can be useful, but it should include shared reference effects and any observed hysteresis. If a rare retune mode is operationally possible but scarcely tested, the report should not award it the same phase-transfer confidence as the well measured modes. The proper result may be a lookup table of validated transitions with separate uncertainty intervals and explicitly unqualified combinations.

The instrument's physical behaviour must be documented with the statistics. Record the exact frequency commands, observed lock times, raw phase witness, calibration input, hardware counters, branch configuration and environmental state. The record should identify the number of independent runs, not only the number of numerical samples. If the receiver returns to frequency while a continuous reference pilot remains visible, that proves a more narrowly defined calibration property than a system that lacks any continuous witness during the operational gap. An engineer can honour excellent repeatability under tested conditions while refusing to extrapolate that repeatability beyond the evidence. Such limits make the acceptance claim more useful to an investigator who needs to know whether a specific retune path is defensibly phase-coherent. The final uncertainty should therefore distinguish repeatability conditional on one

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configuration from uncertainty associated with extrapolation to an untested configuration.

Martin Ryle, Cross-Peer Question to Norbert Wiener: Professor Wiener, suppose the array uses an adaptive coherent combiner whose phase corrections are selected to maximise a receiver signal while the emitter is intermittent and the array has been retuned repeatedly. The result may show a convincing beam at one bearing, but the same algorithm could perhaps fabricate a directional preference from correlated channel noise and shared clock transients. How would you design the negative controls and model comparisons to keep that possibility visible? Please address whether maximising phase agreement should be regarded as an inference about the signal's source, as an instrumental calibration, or merely as a data-dependent detection statistic. I would also value your view on the evidential consequences when the operator has never measured the post-retune response of the actual antenna-plus-receiver chain at the relevant frequency. Could a low residual still coexist with a wrong bearing because all channels share an incorrect phase-transfer model? I am particularly concerned about whether a visually coherent result survives independent reference substitution.

Norbert Wiener, Cross-Peer Answer to Martin Ryle: Sir Martin, the output of an adaptive combiner is a statistic of the observed samples and the permitted family of phase weights. Its interpretation depends on whether the weights were independently calibrated, fixed before seeing the questioned signal, or fitted to that same signal. If the weights are fitted, their optimisation is part of the detection test. A peak at one bearing can reflect a real incoming wave, but it can also reflect correlated noise, a

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common clock transient or an inaccurate array manifold. The beam pattern itself does not identify which explanation generated the peak. A low residual under one fitted model may coexist with substantial location bias if all channels share a calibration error that the model cannot represent.

The controls should include a physically disconnected or terminated input trial under the same retune and clock conditions, an independently generated known source at multiple bearings, and an alternate receiver configuration with a distinct reference path. Simulated null data may supplement these tests when the simulation faithfully includes correlated disturbances and filtering. Record every searched bearing, phase-correction rule, calibration parameter, and rejected interval; then derive the null distribution for the maximum search statistic, not the value at a bearing selected after inspection. Compare the algorithm's prediction on withheld calibration sources with its fit on the training sources. A model whose apparent precision collapses on withheld bearings has not demonstrated generalisable measurement accuracy.

The category of the result should be stated plainly. An independently calibrated phase transfer supports a physical phase-comparison inference within its uncertainty. A self-calibrating beamformer can be a useful adaptive detector, but does not automatically supply an independent measurement of the true phase accrued during missed time. A retrospective phase search that reports one strongest-looking emitter hypothesis can be presented as exploratory with the proper multiple-search qualification. Where the actual antenna-plus-receiver transfer function has not been measured at the operating frequency, the analyst should include a model-discrepancy term or withhold precision attribution. The proper objective is a

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bounded and reproducible finding, not an optimised diagram that looks more certain than the instruments permit. It is the empirical out-of-sample behaviour, not the smoothness of the fitted beam, that should govern a precision claim.

Dr. James M. Atkinson, Moderator: Professor Wiener, please close the principal round by addressing statistical coherence. How does one distinguish a physically stable relation across retunes from an algorithm that finds whichever phase rotations maximise correlation, and what evidential tests are needed to avoid declaring the same data both a calibration and proof of its own validity?

Norbert Wiener, Principal Contributor: Dr. Atkinson, coherent combination is often presented as a computational operation: align complex sequences and sum them. In an experimental science it is instead an inference about the phase relation that would have existed at a common reference plane. The estimated rotation between two records must therefore be regarded as a random or uncertain parameter with a provenance, not as an invisible editing convenience. When a correlation algorithm chooses a phase to maximise a statistic, the fitted statistic is subject to selection bias. It will improve even on many data sets that contain no physically continuous source phase. The strength of evidence must be assessed on independent data or with a valid null distribution that accounts for the selection procedure.

Let $x_k[n]$ denote complex samples in retune epoch k, and let α_k represent the estimated phase correction. A common processing form is $S[n]=\Sigma_k w_k x_k[n]\exp(-j\alpha_k)$, where w_k are weights and any necessary time and

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frequency alignment has already been defined. The expression is not self-justifying. If the α_k are measured from an independent calibration pilot, their uncertainty is part of the coherent sum. If they are fitted by maximising $|S|$ using the same signal being investigated, the analysis should describe an adaptive statistic and estimate its false-alarm behaviour accordingly. A result that appears far above the noise floor after maximisation may include the benefit of searching many allowed phase configurations. Its evidential weight cannot be assigned as though α_k had been specified beforehand.

The phase-correction errors can be analysed by their characteristic functions. For a hypothetical zero-mean Gaussian phase error ε of variance σ_φ^2 radians squared, the expected complex phasor $\exp(j\varepsilon)$ has magnitude $\exp(-\sigma_\varphi^2/2)$. That is one precise way to describe coherence loss under a particular distributional model. If σ_φ is 0.5 radians, the factor is exp(-0.125), approximately 0.8825. But phase-reset errors may be multimodal, wrapped or correlated across epochs, in which case this convenient Gaussian calculation does not apply. A narrow histogram obtained from repeated identical tune commands may also be unrepresentative of transitions across synthesiser divider boundaries. The correct error distribution should be measured over the intended range of frequencies and operating conditions.

A coherent gain calculation likewise needs an explicit baseline. Suppose N equal-amplitude observations contain independent noise with identical variance and a common source phase that has been correctly transferred. The coherent signal amplitude grows proportionally to N while the incoherent noise amplitude grows approximately as sqrt(N), yielding a signal-to-noise improvement proportional to N in power when the

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assumptions hold. Unknown random phase offsets can destroy that gain; deliberate fitting of the offsets to noise can create a biased estimate of gain. If measurement intervals have correlated noise, unequal sensitivity or phase corrections inferred from the same observations, the simple scaling no longer holds. The analyst should report the actual weights, covariance, selected windows and calibration uncertainty, and test performance against a source whose phase history is known independently.

A robust comparison requires three analyses of the same acquisition set. The first is noncoherent accumulation, which does not rely on a phase bridge. The second is coherently combined processing with phase corrections fixed from an independent pilot. The third, clearly labelled exploratory, permits data-driven phase search. Compare their behaviour on an authorised reference signal and on null or noise-only intervals processed with exactly the same search rules. If the exploratory method produces apparent coherent gain even in the null control, that fact must enter the false-alarm model. One may also divide the calibration data into training and test epochs: fit phase-transfer parameters on one set and evaluate their ability to predict withheld retunes. A method that only aligns the training set has not demonstrated transferable calibration.

Uncertainty must be carried forward to any downstream inference. In a correlation-based direction-finding system, a phase-calibration residual may bias the inferred bearing. In a reconstructed wideband impulse response, a frequency-dependent phase error may broaden the response and move its apparent delay peak. In an evidence statement, a gap that was filled by model prediction must not be described as an observed signal. The investigator should therefore retain raw unmodified records and a fully

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reproducible map from each sample to its source epoch, correction parameter and uncertainty. Software version, calibration-data selection, rejected samples and independent witness observations are material parts of the experiment.

Finally I would reject a universal declaration of 'coherent across retuning'. The correct quantity is a demonstrated, configuration-specific distribution of phase-transfer error and source-model uncertainty over specified retune paths, frequencies, temperatures, dwell times and observation durations. An implementation may support reliable coherence for repeated tuning between two closely spaced bands, yet fail after a long excursion or power interruption. It may align a continuous laboratory source but not an intermittent field transmitter. Where the uncertainty becomes too large, the scientifically valid option is to return to noncoherent processing or to present alternative phase hypotheses. The result remains useful, but its limitations are visible. The purpose of the experiment is not to produce the smoothest possible trace; it is to determine whether the smoothness observed is genuinely supported by physics and independent measurement.

Egon Sharpe Pearson, Peer Question: Professor Wiener, a phase-reconstruction programme may tune its regularisation settings, rejection thresholds and preferred pilot channels until the coherent output of a weak RF signal becomes strikingly strong. A report might then apply a fixed-threshold false-alarm rate estimated before those choices were made. How should the procedure account for the many opportunities the analyst had to obtain an apparently convincing result? Suppose the same processing also discards epochs whose fitted phase disagrees with the selected hypothesis, thereby creating a narrow retained residual distribution. What kind of

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independent challenge would make that reported gain meaningful rather than a consequence of fitting, selection and retrospective exclusion? I would like to know whether a test set of known signals is sufficient, or whether an explicit null-data challenge and a record of all attempted processing configurations are equally important in reaching a bounded forensic statement. Include the analyst's choice among multiple source-model families in that record of attempted comparisons.

Norbert Wiener, Response: Mr. Pearson, an adaptive decision procedure must be evaluated as the whole procedure that was actually applied. If an analyst explores many phase corrections, integration windows, pilot choices and rejection thresholds before choosing the one yielding the largest statistic, the null distribution is not the distribution of a single fixed statistic. The exploration must be included in the test, or a genuinely untouched data set must be reserved for confirmation after the method has been fixed. Merely reporting the selected run with a nominal false-alarm rate calculated for an unselected result gives the reader the wrong experiment.

I would insist on a complete processing ledger. It should retain the original data, the proposed transformations, rejected epochs and reasons for rejection, parameter searches and trial counts, and the final decision rule. Apply that recorded procedure to null or negative-control data in which the phase relation is deliberately absent, as well as to known positive-control signals captured independently of the suspected event. The null data need to preserve relevant correlations, noise structures and receiver state changes; replacing them with idealised white noise may be too easy a test if the real instrument produces correlated transients. In addition, a withheld set of genuine retune transitions should assess whether calibration

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parameters estimated elsewhere predict phase independently of the tested signal.

One must also distinguish useful data quality control from selection that is driven by the desired conclusion. A predeclared rule excluding samples during a documented receiver-overload interval is defensible if the excluded interval is still reported. A post hoc rule rejecting every epoch that weakens the coherent fit can bias the conclusion. The report should give results with and without contested exclusions when feasible, including sensitivity to alternative phase hypotheses. Where the adaptive procedure improves signal detection but cannot establish the absolute phase trajectory, it may be described as an exploratory detector. That is valuable, but a claimed physical reconstruction of continuous carrier phase demands separate calibration evidence. A correct false-alarm statement is a claim about the whole tested decision process, not merely its most pleasing output. Independent replication with a predetermined decision rule supplies a stronger test of claimed detection performance.

Karl Pearson, Peer Question: Professor Wiener, if phase corrections were estimated from a shared pilot distributed to several receiver channels, an analyst might quote a small standard error for each channel and treat all those corrections as independent in the coherent sum. But a pilot-source phase disturbance would affect every estimate, and a temperature-dependent distribution cable could create further covariance. How should the final gain or phase-confidence claim reflect shared errors, especially when several receivers are combined and the number of apparent observations is large? Would increasing the number of receiver channels overcome a systematic pilot error, or might it merely make the wrong phase

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solution appear more repeatable? Please distinguish a common-mode error that cancels from the desired differential result from one that changes the physical quantity being inferred. I also ask how an operator might measure cross-channel dependence rather than assume it negligible for convenience. The common pilot must be assessed as an actual physical component of the measurement model.

Norbert Wiener, Response: Mr. Pearson, the uncertainty of a coherent combination depends upon the covariance structure of the phase corrections and the noise, not solely on the marginal uncertainty of each channel. If the phase error in channel i is $\varepsilon_i=c+u_i$, with c a common pilot or reference error and u_i a channel-specific term, the variance of their mean under the simplest independent-component model is $\mathrm{Var}(c)+\mathrm{Var}(u_i)/N$ for N equally weighted channels. The common component does not shrink as channels are added. For a differential phase between channels i and j, however, an exactly common c cancels, leaving u_i-u_j. That cancellation can be valuable for relative array measurements whilst saying nothing about the absolute phase of the array against an independent source reference.

In real systems the common error may not enter every branch identically. Filter transfer functions, cable temperatures, clock division and pilot distribution can shape it differently, so simple cancellation is a hypothesis to test. Measure the cross-covariance of calibration residuals under repeated, independently driven reference perturbations; include trials where the pilot is substituted, its distribution cables are exchanged, and the instrument is challenged with different gain states and temperatures. Separate an externally measured phase reference from the common pilot used for

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correction, because calculating covariance solely from residuals after fitting a common phase may hide part of the error. Report the covariance matrix or a conservative bound and show how it enters the beam or coherent-sum uncertainty.

Increasing receiver count may improve signal collection and reduce independent receiver noise. It cannot by itself remove an unmeasured systematic bias that is shared across channels. An array can become remarkably repeatable in reporting the same wrong direction if its assumed phase manifold is wrong. Thus the evidential statement should distinguish relative phase calibration, absolute phase traceability, and the physical emitter model. Coherent gain is a performance claim under particular error assumptions; it is not a certificate that every source phase step, gap or clock disturbance has been observed. Where the uncertainty cannot be quantified credibly, a noncoherent summary or a bounded set of phase hypotheses remains the scientifically stronger report. Measurement correlations should be retained explicitly in the published uncertainty record, not hidden by an averaging convention.

Dr. James M. Atkinson, Moderator: The discussion has established that phase-coherent integration across receiver retuning is not guaranteed by a stable sample rate, a locked synthesiser, or an algorithmically smooth time series. It becomes defensible only where the end-to-end phase-transfer law is independently measured or sufficiently constrained, the source evolution through unobserved intervals is bounded, the effect of calibration and receiver state changes is propagated into the uncertainty, and withheld trials demonstrate the claimed performance. A direct-RF-sampling architecture with uninterrupted capture offers a stronger starting point than

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a switched analogue oscillator, but still requires preservation of sample continuity and known digital filter states. Pilot references and model-based reconstruction can help when their limitations are explicit. An adaptive fit to the questioned signal must be reported as such, and its apparent coherent gain tested under the full search and selection procedure. The panel's conversation is a modern fictional scholarly reconstruction, not authentic historical speech. The practitioner should retain every raw sample and state transition, disclose any unresolved cycle-count ambiguity, and prefer a noncoherent or qualified result where physical continuity is unproved.

QUESTION 075. TECHNICAL SOURCES AND EDITORIAL QUALIFICATIONS. Scientific and mathematical foundations for subsequent source-to-claim verification: W. J. Riley and D. A. Howe, Handbook of Frequency Stability Analysis, NIST Special Publication 1065 (2008); H. Nyquist, Certain Topics in Telegraph Transmission Theory, Transactions of the AIEE 47 (1928); D. Gabor, Theory of Communication, Journal of the Institution of Electrical Engineers, Part III, 93 (1946); R. E. Kálmán, A New Approach to Linear Filtering and Prediction Problems, ASME Journal of Basic Engineering 82 (1960); N. Wiener, Extrapolation, Interpolation, and Smoothing of Stationary Time Series (1949); M. Ryle's published work on radio interferometry and aperture synthesis. Specific quotations, edition details and applicability to the contemporary SDR experiments require independent verification before publication. All examples are hypothetical, and none is a measured performance claim concerning a deployed receiver.

Editorial qualification: Every speaker exchange is a fictional scholarly reconstruction; no reported test result is presented as a measured field result.

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QUESTION 076

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What do pulse-to-pulse timing distributions establish about scheduled telemetry?

Dr. James M. Atkinson, Moderator: I invite Professor Kolmogorov to distinguish periodic telemetry from a merely repeated interval visible on the receiver display. What observable properties of a time-stamped RF event sequence justify an inference about an external transmission schedule, especially where the monitoring system has known revisit intervals, intermittently missing detections, and finite timestamp accuracy? Our concern is lawful defensive RF monitoring, not the interception of message content; the entire discussion must therefore identify the instrumentation and statistical limits of any proposed inference.

Andrey N. Kolmogorov, Principal Contributor: Dr. Atkinson, the pattern of observed events is not identical to the stochastic process producing the physical emissions. A receiver provides an observation of an underlying process through a measurement operator with its own timing, gating, detection limits and possible omissions. The analyst should define three objects before fitting a periodic model: the actual but generally unobserved emission times, the occasions on which the apparatus could have detected them, and the finally accepted event timestamps. These three objects coincide only under unusually favourable experimental assumptions. When the apparatus revisits a frequency periodically, the sampling operation can impose a lattice on the observed times. A peak in an interarrival histogram may therefore describe the operator's scan schedule rather than the clock of any transmitter.

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Let the putative emission times be T_k, for integer event index k, and let a periodic hypothesis specify $T_k=T_0+kP+E_k$, where T_0 is the epoch, P is a positive recurrence interval in seconds, and E_k is timestamp jitter or scheduling departure, also in seconds. This equation is a hypothesis about a physical emitting process. The observer instead records R_j, comprising detected events after selection, and may not know which physical index k produced each accepted j. If every nth emission is missed, successive observed differences can cluster near nP even though the underlying repetition period remains P. If the receiver is available only on windows beginning at multiples of S seconds, the detection opportunity itself has period S. Observed intervals near S are therefore not sufficient evidence that P equals S.

To put this difficulty into numbers, suppose a lawful test source emits every 0.200 second, and each physical pulse has a conditional probability p=0.70 of being detected during an observation window with continuous receiver availability. If the individual detection outcomes are independent and their probability is constant, the number K of true emission intervals between consecutive detected pulses has a geometric distribution, $Pr(K=k)=p(1-p)^{(k-1)}$ for integers $k\geq1$. The first three probabilities are 0.70, 0.21 and 0.063. Consequently accepted intervals of 0.200, 0.400 and 0.600 second arise naturally from a single underlying period, without implying three operating modes. The assumption of independent losses is important: fades and processor overload can introduce runs of missing detections and make the geometric model inappropriate.

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An investigator must look for evidence across several timescales. Plot timestamps against independent reference time; calculate interarrival intervals; analyse the phase of each observation relative to plausible cycles; inspect event-time autocorrelation; and calculate a point-process periodogram or related spectral measure with an explicit treatment of the observation window. No one of these charts should be treated as decisive. A strong candidate period should make predictions for withheld intervals and for a new instrument schedule, rather than merely provide a good fit to the data used to estimate it. Very short records support many rival periods, and large gaps create exact aliases when the association between observed and emitted pulses is ambiguous.

Now contrast periodicity with a renewal process. Under the simplest homogeneous Poisson model, independent intervals have exponential distribution with rate λ events per second; the mean interval is $1/\lambda$ and the coefficient of variation of the intervals is one. A regularly scheduled emission with small jitter has a lower coefficient of variation before missed detections; thinning and event grouping can inflate it. A renewal process with a narrow interval distribution can also appear scheduled without being governed by an absolute wall-clock phase. Thus a small coefficient of variation demonstrates regularity relative to the observation model, not necessarily an external oscillator or a deliberate scheduler. A more discriminating test asks whether a fixed epoch and period predict events far into the future, or whether timing phase wanders as intervals accumulate.

Nonstationarity is a particularly serious problem. A sensor may switch

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between sleep and wake states; another may change the reporting rate after a threshold crossing; a battery-powered device may lengthen its interval as environmental conditions change. Combining these states in one histogram can produce several peaks whose geometry mimics an emission with multiple fundamental periods. A receiver may also decimate events according to its own queue and timestamp policy. The correct description is conditional on state, observation coverage, and environmental conditions. A change-point analysis is often more honest than fitting one period to the complete record.

Consider a laboratory experiment that intentionally alternates between a periodic pulse source and a renewal-process pulse source having the same mean emission rate. The test operator should independently record every physical pulse at the generator with a traceable counter, while the monitor records its own detections, missed events, tuner position, and clock state. Repeat with controlled thinning, deterministic missed pulses, correlated fading, receiver revisit schedules and introduced timestamp steps. Some experiments should use jittered periods and burst grouping; others should alter only the receiver cadence. The object is to determine which statistics distinguish the sources when the observation layer has been varied, and where two physically different sources remain observationally indistinguishable.

I would require the final report to state the hypothesised period, its conditional uncertainty, the observation window, duty cycle, number and type of detected events, known counter gaps, rejected triggers, model-

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selection procedure and alternative explanations. The evidence might justify the phrase 'repetition compatible with a periodic source over the observed interval' while remaining insufficient to establish a sustained transmitter schedule. There is no weakness in such a bounded finding. The scientific error would be to convert a convenient periodic fit into a claim about a transmitter's internal control process when the measurements have not distinguished that process from the receiver's own timing.

William Sealy Gosset, Peer Question: Professor Kolmogorov, consider an investigator who has only twenty detected RF pulses, gathered from a monitor that visits the channel for a few milliseconds in every second. The interarrival histogram shows prominent concentrations near three and six seconds. The operator is inclined to declare a three-second source period and to put a narrow confidence interval around it. How would you separate finite-sample uncertainty from aliasing created by the measurement schedule, and what experiment would reveal whether the fundamental interval might instead be one second, one-and-a-half seconds, or an irregular event process subjected to repeated detection opportunities? I am concerned not merely by the width of the interval estimate but by the possibility that the period itself has not been identified. Would an ordinary standard error computed after selecting the best-fitting period convey anything meaningful about this ambiguity, especially when the observed pulses are not independent and the detection window is narrow?

Andrey N. Kolmogorov, Response: Mr. Gosset, your distinction between estimation and identification is decisive. A standard error presupposes that the relevant parameter describes the data-generating process and that the chosen estimation model is sufficiently accurate. Here several physical

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periods and an irregular source observed through a periodic receiver can produce the same accepted timestamps. One may obtain an extremely narrow standard error conditional on a three-second periodic model while having almost no evidence that three seconds is the true physical fundamental. Conditional precision must therefore not be conflated with model identification. The candidate periods should be retained as competing explanations, not discarded because one has marginally smaller residuals.

First, preserve the actual receiver dwell intervals as a time function W(t), including tuning and settling. Construct candidate event schedules for periods of one, one-and-a-half and three seconds, allowing physically plausible jitter and missed detections. For each candidate, calculate which expected pulses fall within the observed channel windows and what probability the instrument would have had of accepting them. If several candidates predict indistinguishable accepted event sets, the data do not identify a unique period. Where the monitor scans precisely once a second, observed events may cluster on that grid even under an irregular external source. The absence of pulses outside the visits has no discriminating value because the channel was not observed there.

Second, plan a test that breaks the alias. Use an independent receiver continuously tuned to the channel for an interval longer than several candidate periods, and record a known test marker to calibrate detection latency. If continuous capture is impossible, deliberately change the revisit interval to a value not commensurate with the candidate source periods,

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such as 0.73 second, while preserving all metadata. For an authentic three-second schedule, the inferred phase should remain stable relative to an external clock even when the receiver schedule changes; an artefact tied to the scan cadence should move with it. The exact choice of 0.73 is illustrative, not an optimal value for every instrument.

Third, report uncertainty in two layers: conditional variability around each candidate period and model uncertainty over which candidate is correct. A list of supported possibilities, a likelihood profile showing multiple peaks, or a bounded prediction statement is better evidence than a false single confidence interval. If the period search itself was tuned to these twenty observations, any confidence claim should account for that selection or be confirmed by new events. Short records make this hard; the investigator should not compensate by overstating certainty. An honest negative result is sometimes that no unique schedule can be established from the available observation windows.

Karl Pearson, Peer Question: Professor Kolmogorov, your geometric missing-pulse example assumes that the fate of each physical emission is independent of the others. In a receiver operating near its sensitivity limit, however, consecutive pulses may experience common fading, while an overloaded processor may lose an entire run of packets. Both faults could produce longer observed intervals than independent thinning predicts. What statistical signature would help distinguish such dependent loss from a genuinely changing transmitter period? Can a sequence with repeated integer multiples of one nominal period still support a periodic-source hypothesis if the mechanism of missingness is unknown? I also ask how a

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field investigator should use amplitude information and instrument fault logs without circular reasoning: the analyst must not define the pulses that were missed by assuming the periodic clock that the same observations are being used to prove. Which controlled witness measurements would resolve that logical difficulty? Would it help to repeat the trial with a fixed independent pulse witness, or is the joint distribution of fading and loss alone sufficient to identify which accepted intervals correspond to true emitted cycles?

Andrey N. Kolmogorov, Response: Mr. Pearson, the geometric distribution is a transparent benchmark, not a general description of missing data. Its predictive value depends on a constant detection probability and conditional independence. If consecutive emissions share a fading state, the chance of a miss following a miss may be much larger than the nominal unconditional miss probability. If a host packet queue overflows, losses may form a contiguous block unrelated to RF amplitude. Those mechanisms can create an excess of long observed intervals relative to the simple geometric law. A statistical discrepancy between the law and the observed sequence may therefore diagnose model inadequacy, but does not by itself tell us whether fading, overload or transmitter scheduling was responsible.

The physical records must supply the distinction. Preserve sampled amplitude and noise estimates during every confirmed receiver dwell, hardware sample counters, buffer-overrun flags, transport packet sequence, gain setting and tuning state. Use a known injected reference pulse to determine whether the receiver could still detect a stable signal during the alleged gap. An independent monitor with a different front end and

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preferably independent clock can observe the same channel. If the first recorder exhibits a block of dropped sample indices while the second retains pulses, a receiver-loss explanation is strongly supported. If both experience simultaneous amplitude fading, propagation or source behaviour remains to be distinguished by location and antenna tests.

Dependence can be analysed conditionally without presuming a source period. One may estimate runs of detector inactivity, the correlation of errors with buffer occupancy, and the variation of detection probability with observed signal strength during calibration trials. A hidden-state model distinguishing good and bad reception periods may be useful, but its state labels require physical validation. It would be circular to infer missing pulses as exact integer multiples of P and then cite those inferred pulses as independent evidence for P. Keep imputed events separate from observed ones, and make predictive comparisons on new intervals where the receiver coverage is independently known.

A repeated set of integer-multiple intervals remains compatible with a periodic source even when losses are dependent. Compatibility, however, is weaker than identification. The analyst should ask whether changing receiver configuration, moving the antenna, or acquiring continuous witness data preserves the candidate phase and period. If it does, the hypothesis gains support, though an external common driver remains possible. If the pattern follows buffer faults or scan coverage, the interpretation must be revised. It is a mark of professional discipline to retain competing

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explanations until a measurement capable of distinguishing them has actually been performed.

Andrey N. Kolmogorov, Cross-Peer Question to Sir Ronald Aylmer Fisher: Sir Ronald, your emphasis upon a test chosen before seeing the observations raises a question about periodic sources with intermittent missed pulses. An investigator might select the candidate period after fitting an integer lattice to accepted events, then confirm it on new data. Yet the detector's probability of accepting an emission may itself vary with the candidate phase because the receiver visits that channel according to a fixed schedule. Would the confirmation be independent in the relevant statistical sense if the new recording uses the same scan timetable and the same aliasing relationship? Please distinguish an independent sample of event times from an independent experiment on the physical source. What alteration to the observation schedule would provide genuine discriminatory power, and how would you express the result if several proposed source periods still predict precisely the same accepted events? Would you also distinguish a truly randomised scan-phase experiment from merely beginning a new recording at a different wall-clock time while the receiver and source continue to share one timing standard?

Sir Ronald Aylmer Fisher, Cross-Peer Answer to Andrey N. Kolmogorov: Professor Kolmogorov, an independent interval of calendar time is not necessarily an independent test of a physical hypothesis. If the observation windows remain phase-locked to the candidate source periods, the same sampling geometry can reproduce the same misleading lattice. A period found through a scanned receiver may be confirmed as a stable property of the joint source-and-receiver system, while the source's intrinsic period

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remains unidentifiable. Thus the desired independence involves a change in experimental conditions capable of separating alternative causal mechanisms, not merely a later timestamp on an otherwise identical measurement.

One useful intervention is to change the revisit period or phase while recording those changes against an external time standard. Select a scan cadence incommensurate with the candidate recurrence intervals over the duration of the trial, or use a continuously tuned witness receiver where lawful and technically feasible. The candidate schedule should then predict accepted pulses at the new observation opportunities. If the inferred period changes to follow the revisit cadence, the instrument alias hypothesis gains strength. If the same source-clock phase persists across different schedules, the external periodicity hypothesis becomes more defensible, subject to common clock dependencies and source-state changes.

Pre-register the consequence of the intervention. For each proposed period P_j, enumerate the expected event opportunities within the new observation windows and state which timing deviations count as detections. A model that predicts no observable pulses in the trial has little discriminatory power, even if it would have been compatible with the historical data. The test should maximise differences among predictions while remaining within instrument limits and preserving signal sensitivity. Where several candidate periods still make the same predictions, report a set of supported periods rather than selecting one arbitrarily. A good experiment can yield a clear conclusion of non-identifiability; that is preferable to a precise but

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unsupported number.

Finally, the receiver's actual duty cycle and accepted-event criteria must be measured, not assumed. A retune command time is not always the instant a stable usable RF measurement begins, because local oscillator settlement, filter response and gain control introduce delays. A test pulse injected at the relevant input can quantify that latency. Preserve the physical coverage map, the independent source witness and the algorithm used to compare candidates. Only then does confirmation under a changed measurement design contribute evidence about the emitter rather than merely demonstrate that the same instrument repeats its own pattern.

Dr. James M. Atkinson, Moderator: Professor Kolmogorov has distinguished physical pulse times from sampled event times. Sir Ronald Fisher, please address the design of an experiment and the inferential danger created when an analyst searches many possible periods and reports only the strongest one.

Sir Ronald Aylmer Fisher, Principal Contributor: Dr. Atkinson, a hypothesis acquires its evidential force from the experiment capable of refuting it, not from its accommodation of the observations after the fact. The analyst who has explored hundreds of candidate periods, several bin widths, multiple smoothing kernels and different cluster-merging rules has not performed one simple test. The most attractive period is a selected statistic. Its apparent significance must be judged by the complete procedure through which it was selected. This is especially consequential for a sparse sequence of radio pulses, since a few timestamps can be arranged to show numerous near-integer separations within the instrument's timing precision.

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The experimental unit is also easily mistaken. The successive spectral detections of a single pulse are not independent emission events. Several nearby threshold crossings may derive from one burst whose envelope oscillates around the decision threshold. Correlation across such detections makes a conventional independent-sample calculation overstate information. Before any goodness-of-fit analysis, define the physical event and the processing rule by which it becomes a catalogue entry. The rule might declare one event when detections are separated by less than a specified merge gap g seconds, with a separate refractory interval h seconds after acceptance. Those choices should come from calibrated receiver behaviour or a prespecified study design, not from whichever values yield the tidiest periodic pattern.

Suppose we analyse a series of twelve accepted event timestamps covering approximately four minutes. With only eleven interarrival intervals, a period search between 0.1 and 30 seconds may report an extraordinarily sharp maximum by testing enough harmonics or integer divisors. It would be inappropriate to apply a fixed-frequency p-value as though the period had been selected before the data were examined. The correct null calculation may use a realistic simulation of the entire monitoring chain, applying the same period-search algorithm and selecting the maximum over exactly the candidate set used in the actual investigation. A simpler design divides the data: choose the candidate period from the first portion, freeze the rule, and test prediction against chronologically subsequent events recorded under a documented configuration.

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The observation timetable must be part of that simulation. A scanning monitor that spends 25 milliseconds on a channel every 500 milliseconds supplies a very different experiment from a continuously tuned receiver. For brief pulses whose starts are uniformly distributed over the scan cycle and whose duration is negligible compared with dwell, an idealised overlap probability may approach the fraction 0.025/0.5=0.05, ignoring tuning settlement and threshold qualification. That simplified result must not be extrapolated to bursts of finite duration or synchronised sources without modelling interval overlap. If emissions themselves are periodic, the receiver and emission schedules can become phase-locked and produce persistently missed or persistently captured pulses. Random-arrival approximations can then be profoundly misleading.

A well-designed laboratory comparison should vary one causal factor at a time. Retain a continuous, independently referenced witness recording; program a known pulse schedule; then change only the receiver revisit period. Repeat with an independently jittered revisit schedule. If the inferred transmitter period follows the monitor's imposed cadence, that is powerful evidence of a measurement artefact. If it survives independent monitoring with a different scan policy, the external-schedule hypothesis becomes more defensible, though a common upstream control signal may still explain both records. The use of physically independent receiving clocks is important because two nominally separate applications can share timing corrections or trigger logic.

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Likelihood-based inference also requires care about missed events. For a periodic pulse sequence with independently missing observations, one may sum over possible integer cycle counts between accepted detections. The likelihood then involves the measurement jitter distribution, miss probability, and all assignments of observations to underlying cycle indices. It is unsound to identify the smallest observed interval as the period without qualification. Such an estimator is biased when the initial pulses are missed or when the timestamp filter rejects short intervals. Alternative models include a renewal process, a mixture of operating states, periodic pulses with random dropout, and pulses driven by external system events. Fit assessment should therefore compare predictive behaviour and penalise needless flexibility.

One may ask what constitutes a meaningful negative result. If an alleged schedule predicts pulses during periods when the receiver was blind, their absence from the recorded catalogue is not evidence against that schedule. If a witness receiver continuously observed the correct frequency with demonstrated detection probability, repeated predicted omissions may count against the model. However, that argument must include the conditional detection probability for amplitude, pulse width, interference and instantaneous receiver state. A diagnostic using an injected test pulse is more informative than merely observing a green software status indicator.

Finally, the analyst ought to state the inferential boundary. One might demonstrate that observed pulses share a stable phase relationship relative to a period of 1.25 seconds across an hour of recorded continuous coverage.

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Such evidence would be more substantial than a similar result obtained from one scanned channel observed for only seconds in each hour. Nevertheless, no timing-only test establishes that the signal carries telemetry, that a device has hostile purpose, or that a particular person controls it. Technical inference about recurrence must be kept separate from classification, attribution and legal authority. Evidence is strongest when the experimental design exposes rather than conceals the possible ways in which the investigator could be wrong.

Egon Sharpe Pearson, Peer Question: Sir Ronald, suppose an analyst examines many frequency channels, several event-merging rules and a broad grid of candidate recurrence periods. A striking result arises for one combination, and the team then begins a new monitoring interval at the selected frequency. How should the confirmation experiment avoid becoming another stage of selective searching? Is it sufficient to preserve the chosen period, or must the receiver settings, accepted timing tolerance, observation window, minimum count and criteria for declaring confirmation all be fixed in advance? Please distinguish nominal false-alarm probability, family-wise error from the original search, and the probability of observing enough events in the available blind-time pattern. I would also welcome a physically grounded example of a test that could falsify the chosen schedule rather than merely enlarge the dataset until another attractive coincidence appears. Please address how a failed confirmation interval should be reported when receiver coverage is only partly documented, and whether a later alteration to the acceptance threshold invalidates the originally declared test.

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Sir Ronald Aylmer Fisher, Response: Mr. Pearson, the confirmation procedure must be sufficiently specific that its outcome can be recognised as success or failure without alteration after the observations are seen. Fix the receiver channel, reference timebase, detection threshold and event-merge rule. Specify the candidate period P, initial phase tolerance, allowed drift, number of predicted opportunities, and minimum fraction of detectable opportunities that must contain a qualifying event. Record planned blind windows and a rule for excluding unusable intervals that does not depend on whether the desired pulse appeared. It is not enough to declare the period fixed while continuing to change the event definition or timestamp alignment to rescue the fit.

The exploratory search incurs selection. If an analyst chooses the largest response from numerous candidate periods and channels, the distribution of that maximum under a no-schedule hypothesis differs from the distribution of a single prespecified statistic. A separate confirmation interval can reduce this problem because the chosen period and rule are held fixed before the new data arrive. But the confirmation itself should not be repeated indefinitely without adjusting the interpretation of repeated opportunities to declare success. If the result is inconclusive, the next investigation can be designed afresh, clearly identified as a new experiment rather than represented as a continuation of one fixed test.

Imagine that a candidate schedule predicts one pulse every five seconds. During a new 15-minute session, there are nominally 180 possible emission times, but the receiver's logged channel coverage includes only 60 of them

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within the calibrated timing tolerance. The test therefore has at most 60 meaningful opportunities to observe the predicted signal, not 180. If sensitivity trials indicate a conditional detection probability of 0.9 for pulses meeting the prespecified amplitude and width, a sustained schedule would yield about 54 accepted detections in those opportunities, before accounting for dependence and state changes. A result of only two detections would be difficult to reconcile with that particular conditional model. It would not, however, refute an unqualified schedule involving variable power or changed operating state.

A particularly useful falsification control is to alternate two receiver observation schedules while keeping the physical test source unchanged. If the candidate period vanishes or changes solely because the revisit cadence changes, that is evidence against interpreting the period as intrinsic to the external source. A negative control using an irregular known source can estimate how often the entire detection and selection chain produces a spurious periodic finding. Report both false-positive results and missed genuine periods, since a procedure that never declares a false schedule may simply be incapable of recognising any weak schedule at all.

Sir Ronald Aylmer Fisher, Cross-Peer Question to Maurice S. Bartlett: Dr. Bartlett, suppose the analyst fits a periodic line to a point-process spectrum, then interprets the line's height as evidence for a scheduled transmitter. In your account, a periodic observation window can impose a line even when the source is irregular. How should one design a spectral comparison that incorporates the measured sampling windows and the detector's dead time? Is a conventional time-series permutation adequate if it destroys the

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very clustering or dependence that makes the real null process difficult? Please consider the danger of using a large set of surrogate event records that appear random only because their generation ignores the receiver's actual blind periods. Which aspects of the acquisition chain must be reproduced before a reported spectral confidence level has a physical meaning? If the receiver suppresses overlapping detections during a recovery interval, please explain how that dead-time rule should enter the surrogate generation before any claim of statistical significance is made.

Maurice S. Bartlett, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Sir Ronald, a point-process significance test must account for the observation operation under which the accepted events were generated. If the true null process is a stationary Poisson source but the monitor observes only during periodic windows, independent random timestamps distributed uniformly across the entire calendar interval are not an appropriate surrogate for the recorded data. Those surrogates fill blind periods with events the real receiver could never have accepted. The resulting null spectral distribution may underrepresent the strong periodic structure introduced by the measurement windows, making the observed periodogram peak seem more exceptional than it is.

Construct surrogate physical emission processes under the specified null, then pass each through the measured W(t) coverage function, a calibrated detection-probability model, and exactly the event-merging and timestamp procedures applied to the real signal. If dead time prevents a second trigger within a fixed interval after one acceptance, reproduce that state dependence. If detection probability changes with received amplitude, the

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surrogate model must include a defensible amplitude distribution or preserve relevant empirical conditions. Only after this observation process should the point-process spectrum and the maximum-period search be computed. The significance comparison then concerns the statistic the actual apparatus could have generated, not an idealised continuous observer.

A simple permutation of observed intervals can be misleading because the intervals may not be exchangeable. They may depend on scan phase, signal level, instrument overload, or clustering in the physical emissions. Permutation methods require assumptions that must be examined rather than invoked because they are computationally convenient. Block-based rearrangement preserving some local dependence may be useful for exploratory sensitivity, but it too can destroy long-range structure or invent new event-window relationships. A controlled physical null experiment using a known irregular source, observed through the actual receiver, may offer more persuasive evidence about false periodic peaks than a purely mathematical shuffle.

I would also report the spectrum of the observation opportunity process itself, not merely that of the accepted events. If both exhibit a line at the same frequency, instrument cadence becomes a concrete alternative explanation. Repeat with a changed scan policy and record whether the event-spectrum line follows it. Such interventions do not supply a universal proof, but they address causation in a way that a single p-value cannot. For the report, state the simulated or measured null, observation windows,

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detector dead time, spectral estimator, period-search range and multiplicity of comparisons. A spectral line is a descriptive fact; its physical explanation requires these further controls.

Dr. James M. Atkinson, Moderator: Sir Ronald has called attention to period selection and experimental controls. Dr. Bartlett, please distinguish regular event trains from spectral features caused by clustering, intensity variation, and observation-window structure.

Maurice S. Bartlett, Principal Contributor: Dr. Atkinson, a point process is a natural description of the observed event times, but its spectrum must not be read as though it were the ordinary power spectrum of a continuous carrier. We can represent accepted events by the counting process N(t), the number of accepted observations up to time t, and, formally, a train of impulses at event times R_j. Spectral analysis of such data can reveal recurring structure, yet it is affected by the mean intensity, event clustering, finite observation, missing detections and instrument dead time. The spectrum is an attribute of the recorded event process. It becomes an attribute of the physical emissions only after the observation mechanism has been characterised.

For a stationary process, one might compare the intensity λ, the mean number of events per second, with a second-order covariance or pair-correlation structure. A periodic point process with modest independent timing jitter produces concentrations of pairwise time differences near integer multiples of its period. An independent homogeneous Poisson process does not contain the same persistent periodic structure, although finite random samples may show incidental peaks. A clustered process can

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contain excess short-lag pairs because several accepted triggers are generated around one physical burst or because one event provokes further events. Such clusters increase low-frequency or broad-band point-process spectral components and can be confused with a genuinely periodic scheduler if the observation procedure is not made explicit.

Finite-window effects deserve more care than a simple histogram. Suppose the instrument observes a channel only during disjoint windows whose indicator is W(t), equal to one when detection is possible and zero otherwise. The observed point train is, in a simplified model, multiplied by W(t), followed by the threshold detector and event-merging algorithm. The recorded spectral structure is then influenced by the transform of W. A regular revisit timetable can impose spectral lines on a fundamentally irregular external process. Conversely, a continuous emitter with weak bursts may be selected only at particular sampling phases. One cannot remove this effect merely by subtracting the average count. A defensible analysis must measure W(t), preferably using hardware-generated tuning and sample-availability records rather than an operator's recollection.

A common simulation is instructive. Generate an independent Poisson emission process at ten pulses per second, with a fixed detection probability only during a 40-millisecond observation interval repeated every 200 milliseconds. Those windows contribute a nominal 20% duty factor before threshold losses. The accepted event times will be concentrated in repeated clusters separated by roughly 200 milliseconds, even though the underlying Poisson source has no scheduled recurrence. An interarrival histogram may

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show a strong maximum related to the monitor's cadence. An analyst unaware of the observation windows could interpret that maximum as a telemetry interval. Change the revisit period to 310 milliseconds while leaving the source unchanged; any shift of the apparent periodicity toward the new instrument cadence would reveal the observational origin.

A renewal model provides a different counterexample. Let inter-emission intervals be independent gamma-distributed variables with mean P and coefficient of variation lower than one. This process has relatively regular separations but no absolute phase lock: its cumulative timing deviation from a fixed epoch grows with the number of events. A true periodic controller with bounded jitter around an absolute schedule can retain a stable phase relationship over long observation. If every interval is formed from an independent renewal draw, accumulated timing variation grows with sequence length. Hence the variance of residuals relative to a fitted clock, evaluated on held-out data and with correct uncertainty for estimated parameters, can help distinguish the two classes. One should not infer an exact mechanism from this statistic alone because externally driven renewal processes can also display long-range regularity.

An event grouping rule is not innocuous. If a burst contains ten threshold excursions separated by a few milliseconds, counting each crossing may make the accepted intensity ten times the true burst intensity. A refractory interval exceeding that gap can collapse those crossings into one event, but can also merge two separate bursts emitted close together. The researcher should use independently observed waveform envelopes to choose the rule

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and report sensitivity across plausible merge intervals. Repeated findings across settings are more compelling than a single preferred plot. Where the rule changes the inferred repetition period, the uncertainty is structural, not merely a statistical confidence interval about one chosen model.

I would preserve more than one time representation. The unaltered hardware sample index identifies chronology within one acquisition stream; a calibrated physical event timestamp permits cross-receiver comparison; a software receipt timestamp identifies delivery and may bear queueing artefacts. A detector often reports the time of the largest spectral magnitude inside its analysis window, which may occur after the physical burst onset and vary with amplitude. Cross-correlation against a local known test pulse can quantify that latency as a function of signal level and filtering. Event-time analyses lacking this calibration can overstate scheduling precision by orders of magnitude.

My final prescription is not to abandon spectral methods but to embed them in a declared observation model. One should compare the event spectrum under the original scan schedule and under a deliberately altered schedule, examine the empirical pair-correlation against surrogate data generated through the same receiver windows, and validate period estimates out of sample. Include receiver dead-time logs, event-merge decisions, measured detection probability, clock adjustment records and all rejected observations. The claim that pulses are 'consistent with a recurring external event process' may then be justified. The stronger claim that the external source deliberately follows a particular schedule requires independent

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evidence that the observed recurrence has not been imposed by the measurement system.

Claude Elwood Shannon, Peer Question: Dr. Bartlett, a point-process periodogram may reveal a prominent line at one frequency, yet the physical RF emission is a waveform containing information that the event catalogue discards. Which aspects of the signal's temporal organisation survive reduction to an impulse train, and which are lost? If a telemetry source changes modulation or packet structure while retaining the same burst times, an interval analysis might remain stable but cease to describe the same transmission process. Conversely a receiver detector might convert variations in pulse width or signal-to-noise ratio into timing shifts that appear as jitter. How should an analyst decide whether timestamp-only evidence is sufficient for the proposed inference, and what additional observations should be retained without undertaking unauthorised content interception? I am particularly concerned with the distinction between identifying timing structure and claiming knowledge of a device's internal data or protocol. Could a lawful, low-content measurement of pulse width and envelope shape expose a detector-induced timing shift without requiring access to any demodulated message, and what calibration uncertainty should accompany that comparison?

Maurice S. Bartlett, Response: Dr. Shannon, the event catalogue retains the chosen timing features and little else. A threshold-triggered event time may represent the first crossing of an amplitude criterion, the maximum of a filtered envelope, a correlator output peak, or a host-supplied packet receipt label. The catalogue generally discards the original waveform's detailed amplitude, modulation, spectrum, intra-pulse phase, and potentially its

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duration. Two very different transmissions may therefore produce the same event-time series. If the scientific question concerns timing regularity, the reduced catalogue can be useful, provided its detector origin is calibrated. If the question concerns transmitter identity or protocol structure, the timing series alone is rarely sufficient.

One should retain minimal lawful RF measurements capable of testing the event definition without indiscriminately collecting content. These may include carrier-frequency estimate, occupied bandwidth, pulse duration, received power, receiver gain and noise reference, detector statistic, time-of-arrival uncertainty and hardware sample-index range. In a controlled laboratory one can keep raw complex samples of a known benign test signal. The purpose is to establish how a changing pulse envelope influences the detector's timestamp and whether distinct physical pulses become merged into one accepted event. Any use of operational signals must remain within the investigator's actual authority and applicable legal conditions.

A simple example shows the information loss. Suppose two test emitters each produce one pulse every two seconds. One emits a narrow Gaussian-like envelope, the other a much longer asymmetric waveform with a rising edge that crosses the threshold late. If the event time is defined by first threshold crossing, the second emitter's timestamps may exhibit an amplitude-dependent delay. A periodogram of accepted event times can show the same nominal two-second recurrence for both while the measurement error distributions differ. Calibrate detection latency against

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signal amplitude and width, then test whether the inferred period persists under a different, independently justified timestamp estimator. A clock-phase claim accurate to one millisecond cannot be supported by a detector with ten milliseconds of unmeasured amplitude-dependent latency.

The full physical waveform is not always necessary for a limited conclusion. If a continuously tuned, calibrated receiver registers many well-separated burst onsets with low timestamp uncertainty, timing periodicity may be well established. But the analyst must state what was not measured. One may say that detected RF-energy events recur at a measured interval, not that a specific packet format or message type was transmitted. Additional observations should be selected to challenge instrumental alternatives and preserve reproducibility, not to magnify the conclusions beyond the evidence. Statistical compression is useful only when its effect on the inferential target is understood and disclosed.

Maurice S. Bartlett, Cross-Peer Question to David H. Blackwell: Professor Blackwell, your discussion of non-identifiability suggests that more data may not always solve the problem. Suppose two models predict the same accepted event distribution whenever the receiver is tuned according to its established scan schedule: one model has a true periodic source, while another has an irregular source repeatedly observed in short windows. Would gathering ten times as many events through the unchanged schedule necessarily improve inference about the source's clock? How should an investigator measure the expected value of changing the experiment, rather than simply increasing duration, and what stopping rule would recognise a situation in which the current apparatus cannot

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discriminate the hypotheses? I should also like you to distinguish mathematical equivalence of observed distributions from finite-sample uncertainty about models that are theoretically distinguishable but practically very similar. How would you decide, before committing to a longer observation, whether the proposed additional measurement can make those competing physical mechanisms observably different?

David H. Blackwell, Cross-Peer Answer to Maurice S. Bartlett: Dr. Bartlett, collecting more observations improves discrimination only when the competing models induce observably different distributions under the adopted measurement policy. If their distributions of accepted timestamps are exactly identical, no amount of additional recording under the same policy can separate them. The extra data may give a very precise estimate of the common observed distribution while leaving the cause unresolved. This is structural non-identifiability. A different situation occurs when the distributions differ slightly but the finite sample is too small to reveal that difference. In that case additional independent observations may help, although the required duration can be great and the practical detector model may change over the longer period.

The distinction can guide experimental design. Instead of asking only 'How long should we listen?', ask 'Which feasible measurement action makes the predicted observations under H_P and H_W most different?' Candidate actions include changing the revisit period, changing its phase, recording continuously for a short targeted interval, improving antenna sensitivity, or adding a second independently clocked receiving path. Each action has costs and may change gain, noise or event selection. Predictive simulation should

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include those changes so that apparent improvement is not merely a new calibration error. A source hypothesis that predicts events in an unobserved interval gains no support from extending that same blind interval; changing the coverage can supply new information directly.

Expected information gain may provide a formal design criterion, but its numerical value depends on chosen models and probabilities. Without validated probabilities it is better to compare qualitative predictions and choose an intervention with clear falsifying consequences. For example, if a three-second source period and a one-second scan alias predict exactly the same events at the current revisit cadence, choose a new cadence or continuous observation for which the candidate source phases imply different arrival opportunities. Before the test, write down the distinct predicted observations. After it, report both successes and failures, including events rejected by detector quality rules.

A stopping rule should separate scientific conclusion from operational fatigue. If repeated planned observations are informative and the posterior or likelihood evidence remains inconclusive, the report can give a bounded likelihood comparison or a range of periods. If the present architecture makes the hypotheses observationally equivalent, the correct stopping condition is not 'wait longer' but 'change apparatus or acknowledge non-identifiability'. An analyst should never cite the sheer number of accepted events as proof that a specific source mechanism has been established. The provenance of the events and the distinguishability of the rival mechanisms matter more than the count.

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Dr. James M. Atkinson, Moderator: Dr. Bartlett has demonstrated that even an irregular source can acquire spectral structure through a periodic observation window. Professor Blackwell, please examine whether the schedule is identifiable from the incomplete data and what sequential decisions are justified.

David H. Blackwell, Principal Contributor: Dr. Atkinson, the practical issue is identifiability rather than the beauty of a fitted curve. Two or more distinct physical models may induce essentially the same distribution of accepted event times when only a small portion of the spectrum is observed. One model may contain a regularly transmitting source whose pulses are intermittently missed. A second may contain an irregular source sampled through a periodic scan schedule. A third may contain several emitters whose bursts happen to overlap in the selected channel. If the observations cannot distinguish these mechanisms, no statistical estimator can make the missing information appear merely by increasing computational sophistication.

Let H_P denote a periodic-emission hypothesis, H_R a renewal-process hypothesis, and H_W an irregular source combined with a periodic observation window. These are models, not moral or operational judgments. Their likelihoods for event data D should be evaluated conditional on the documented receiver availability process W, calibration and false-event model. A likelihood ratio comparing H_P with H_R is meaningless if the rival explanation H_W has been omitted despite an obvious periodic scan timetable. Model selection should be driven by physically plausible alternatives and controlled experiments, not an

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artificially narrow set of mathematical choices.

A schedule can be predicted only when its phase and rate remain stable at the relevant horizon. Suppose a candidate period P=2 seconds is fitted using accepted pulses from a ten-minute record. A useful test asks how many pulses should be expected in the next five minutes, given the planned observation windows and detector sensitivity. If the model predicts events predominantly when the receiver is not listening, the next interval has little power to discriminate it from an irregular alternative. The operator should design a new observation schedule that opens windows around competing predictions and records controls at other times. An independent continuously tuned witness channel may be the simplest improvement, although it has its own noise floor and possible overload conditions.

Sequential evidence must also be calibrated for repeated stopping. A monitor that checks a candidate pattern every minute and announces success when any one check becomes impressive has selected a favourable stopping time. A fixed sample-size significance threshold is not automatically valid for this indefinite sequence of looks. One can predefine an error-spending or sequential likelihood procedure, or reserve an independent confirmation period whose definition precedes the event inspection. In either case, the decision rule and any early stopping boundary belong in the evidential record. The goal is not mathematical ceremony but a test whose false-alarm behaviour can be reproduced in the actual monitoring configuration.

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There is a distinction between classifying whether an event occurs and predicting its timing. A scheduled telemetry source may change interval according to duty cycle, external command, internal buffer state or power management. A model that predicts a stable mean rate but not the next event's time offers only limited evidence of schedule. Conversely, a renewal process with low dispersion can predict the near-term next interval reasonably well while lacking an absolute repeating clock. The prediction target must therefore be stated: event count, interarrival distribution, clock-phase concentration, or exact next arrival window. Each target has different scoring rules and uncertainty.

The losses are often selective. A receiver with automatic gain control may detect only strong pulses. If strong pulses are systematically transmitted at one position in a repeated data frame, the accepted sample will appear more periodic than all emissions considered together. A signal's fading pattern can also correlate detection probability across successive pulses. The correct test incorporates pulse amplitude, threshold, antenna configuration and interference state. An apparent periodicity strengthened by a more aggressive detection threshold might reveal that one class of bursts is being selected, not that the transmitter changed its timing. Receiver sensitivity experiments should therefore vary thresholds without making unsupported claims about undetected content.

A careful experiment introduces known periodic, renewal and state-switching test sources, randomly assigns trials and blinds the analyst to the source type. The receiver should record both raw IQ and its detection

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ledger; an independent reference measures true pulse occurrence. Some trials should include missed pulses caused by controlled attenuation, others should include scanning blind intervals, and others deliberate timestamp offsets or dropped packets. The validation goal is a confusion matrix that reports false classification rates across realistic pulse widths, amplitudes and interference. A model successful only with generous signal-to-noise ratio and no missing events should not be presented as suitable for a difficult field survey.

I would conclude by requiring a report to preserve the alternative models that remain compatible with the evidence. A finding may properly say that accepted events are more predictable under a periodic model than under a specified renewal model over the tested interval. It must not silently expand into a claim that the transmitter's firmware deliberately schedules packets or that one particular device produced them. The analyst should state the competing models, blind-time pattern, decision horizon, detection assumptions and performance of held-out predictions. Where no independent test separates source and instrument periodicities, the correct result is non-identifiability, not an artificially precise estimate of an imaginary scheduler.

Solomon Kullback, Peer Question: Professor Blackwell, your comparison of a periodic model, a renewal model and a periodic observation-window artefact is appealing, but model comparison itself may be fragile when the likelihood of missing events is poorly constrained. What should an examiner do when the models use different numbers of hidden pulse indices, different assumptions about correlated detector loss, or different

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allowances for receiver clock drift? Does selecting the largest likelihood meaningfully resolve the physical hypothesis if those nuisance assumptions dominate the result? Please address how one might use predictive scoring or information divergence without hiding the role of the chosen model family. In particular, could a strongly preferred periodic model be an artefact of omitting an intermittent receiver state that changes acceptance probability, and which measurements would demonstrate that possibility directly? I would especially welcome a test in which the data distinguish a bad model of the receiver from a bad model of the emitter, since improved fit alone may reward unnecessary flexibility.

David H. Blackwell, Response: Professor Kullback, a ranking among imperfect models is not proof that the highest-ranked model corresponds to the physical truth. Likelihood ratios compare the conditional probability of observed data under declared hypotheses. If the observation mechanism is misspecified, the ranking can favour the wrong source model with remarkable confidence. An intermittently deaf receiver can make a random external process appear episodic or periodic. Conversely a real schedule with correlated fades can be penalised by a model that presumes independent missing events. The appropriate response is to expose sensitivity to those nuisance assumptions rather than to present a single numerical winner as a causal verdict.

I would construct at least two model families for the detection process: one with constant independent losses, and another with a time-varying reception state informed by measured front-end gain, noise floor, scanner activity and transport overflow. Within each family compare periodic and

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irregular source models using predictions on a held-out interval. Record scores on the original, unaltered event ledger and report how the rankings change with plausible detector models. If adding a measured reception-state variable eliminates an apparent periodic advantage, the original inference depended on an unmodelled instrument effect. That is a substantive scientific finding, not a failure of statistical technique.

Information measures require careful interpretation. A divergence between two fitted distributions can quantify their distinguishability under the chosen representation, but does not itself establish which generating mechanism is real. A small divergence means that the available measurements may be unable to discriminate the models, even with many events unless additional observables are acquired. A large divergence supports discrimination in that specific data representation, subject to sampling uncertainty and selection. It is reasonable to report expected predictive loss or likelihood ratios only alongside the observation model, calibration data, fitted parameter ranges and actual test protocol. The model family must remain open to realistic alternatives discovered through instrumentation challenges.

Consider an experiment with identical external test pulses emitted according to one prespecified schedule, but with the receiver deliberately alternating between normal operation and a state that drops most short pulses. Record the state independently, including when it changes. A model unaware of the state may infer that the transmitter entered a slower scheduling mode; a model conditioned on the state should recover the

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unchanged emission process. Reverse the experiment by changing only the generator schedule while keeping the receiver fixed. Correct attribution requires the analysis to respond differently to these two interventions. That is a more convincing examination of the physics than fitting ever more elaborate hidden variables to an unchallenged observation. The report must disclose when competing explanations remain observationally equivalent.

David H. Blackwell, Cross-Peer Question to David G. Kendall: Professor Kendall, your queueing model separates physical emission bursts from host-delivered event clusters, but the two mechanisms can be highly similar in a record containing only console timestamps. What would be an efficient controlled experiment to distinguish them without assuming access to the transmitter's internal firmware or packet content? Suppose the receiver's host periodically empties a buffer, while a lawful test source itself emits packets in regular batches. Which time-domain measurements must be made before the analyst can tell whether a burst family began at the antenna or in the software pipeline? Please describe the case in which both source-side batching and receiver buffering are present simultaneously, and explain how an evidence ledger should allocate observed timing uncertainty to each stage rather than burying all delays inside a single timestamp correction. Would a traceable hardware pulse marker at the ADC input establish enough chronological independence to identify the receiver queue, or are further boundary measurements required?

David G. Kendall, Cross-Peer Answer to David H. Blackwell: Professor Blackwell, the experiment should instrument the boundaries between the source and the receiving software. Use a calibrated laboratory transmitter with a known pulse programme and an independent RF witness near the

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receiving input. The witness produces an acquisition timestamp tied to a hardware sample counter before the disputed host queue. In the test receiver, retain its own sample indices and device-time tags, transport sequence information, application ingestion times, and display publication times. The result is not one event-time stream but a chain of related time observations. A difference emerging only after transport or application buffering belongs to the receiving system rather than the external RF field.

First, hold the source's emission schedule fixed and impose a safe measured host workload that delays packet processing. If the display begins to show regularly spaced groups while device-index and witness times remain unchanged, the imposed clustering arises downstream. Second, hold the receiver configuration fixed and change the generator from individual pulses to programmed three-pulse batches. The witness and device-time stream should both reflect the new physical grouping. Third, combine the two disturbances. The witness then records true source-side batching, the device preserves the same physical order, and the host display may impose a further set of clusters. This combined trial is important: real investigations seldom enjoy only one mechanism at a time.

Where exact latency cannot be measured at every processing stage, the report should present bounded intervals rather than an unjustified point estimate. A hardware capture marker can calibrate the analogue and device timestamp offset; packet sequence and monotonic host receipt logs can characterise transport delay; application and display logs can characterise later queueing. A wall-clock correction or network synchronisation state

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change must be separately retained because it can alter external-time labels without altering physical sample order. If the host clock was stepped backwards, one should not sort events solely on its printed timestamps. Device sample sequence is generally more trustworthy for local chronology when its continuity has been independently verified.

The evidential product should retain original timestamps, derived corrected timestamps, known gaps, stage-specific uncertainties and the software versions used to calculate each. It should distinguish a measured emission pulse from a detected feature, an accepted event from an inferred missing event, and a displayed group from a physical burst family. If the independent witness is absent, certain source and receiver grouping explanations may remain observationally indistinguishable. State that limitation. One can reasonably conclude that the console reported periodic clusters without asserting that the emitter's firmware created them. The entire purpose of the boundary experiment is to make the final causal statement proportional to what was actually observed.

Dr. James M. Atkinson, Moderator: Professor Blackwell has described how physically distinct mechanisms may remain observationally indistinguishable. Professor Kendall, please close the principal series by considering queues, burst families, renewal timing and the interpretation of detected clusters.

David G. Kendall, Principal Contributor: Dr. Atkinson, a telemetry-like emission process can be affected by queues in the device, queues in the measurement apparatus, or both. The first may determine when physical pulses are transmitted; the second may determine when the operator sees

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them. One must be careful not to infer the former from the latter. A transmitter that collects sensor reports in memory and sends them in short batches can produce strong clustering and repeated long gaps even without a periodic transmission clock. A monitoring computer that accumulates receive packets and releases them after filesystem delays can produce a superficially similar event log. These possibilities become distinguishable only when the raw acquisition chronology is preserved independently of host delivery times.

An elementary queueing model may represent reports arriving into a source buffer at rate λ and being served in batches or individually at rate μ, both in events per second. In a stable single-server model one ordinarily requires a mean service capacity exceeding the mean arrival rate, but real telemetry may have a duty-cycled radio, finite buffer, priority traffic, and a scheduled service window. The transmitter's observed burst interval can reflect the service policy rather than the sensor's report-generation interval. Conversely, a receiver process may delay and group detections into one display update. Consequently a repeated gap among accepted events need not measure the sampling interval of the underlying sensor or the recurrence period of a transmitter controller.

A useful distinction is between a renewal process and a clustered or self-exciting process. Independent renewal intervals are conditionally described by their interarrival distribution. A clustered process may instead show elevated probability of an additional event shortly after one has occurred, even when its overall rate varies little. The statistics of short gaps and long

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gaps should be assessed together, with a declared grouping interval and evidence of true event separations. A burst containing several packets can yield a mixture of very short within-burst intervals and much longer between-burst intervals; fitting a single smooth interarrival law conceals the hierarchical organisation. A credible analysis may model bursts as cluster centres with their own recurrence and packets within each cluster with another spacing law.

Take a hypothetical lawful test device that transmits a group of three RF pulses every 10 seconds, separated internally by 20 milliseconds. A detector that counts every pulse gives intervals near 0.020, 0.020 and 9.960 seconds in each cycle. If an event-merge rule joins triggers separated by less than 50 milliseconds, the same physical record becomes one accepted event every 10 seconds. Both catalogues are correct under their respective rules, but only the second describes burst families. The test has not established whether the grouping originates in a transmitter data frame, a local radio repeater, multipath replicas, or the detector's own recovery; raw waveform examination and receiver challenges must resolve those competing explanations.

The observation apparatus may introduce a queue with random delays D_j after physical acquisition. If the display timestamp is $R_j=T_j+D_j$ rather than a hardware time-tag of T_j, differences $R_{(j+1)}-R_j$ include $D_{(j+1)}-D_j$. Delivery delays can increase interarrival variability, cause out-of-order apparent events, or create bursts when many queued packets are flushed together. The queue may even emit at a fixed software refresh interval,

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imposing periodicity unrelated to the incoming RF process. Hardware sample counters and pre-queue device timestamps are therefore indispensable. A smooth GUI clock or nominal network synchronisation cannot replace evidence of the actual sample-to-time mapping.

Missed pulses introduce further mixture behaviour. A periodic source with independent detection losses creates integer multiples of its true period among accepted intervals, as Professor Kolmogorov has explained. A clustered process with missing within-cluster detections can instead alter both cluster size and inferred burst duration. Suppose a three-pulse test burst has per-pulse detection probability 0.8 under an independent-loss model. The probability all three are accepted is 0.8 cubed, or 0.512; the probability none is accepted is 0.2 cubed, or 0.008. Between those extremes lie partially observed clusters that may look like one-pulse or two-pulse source emissions. These figures are conditional on independent detection and cannot be transferred to burst-wide fading where the failures are correlated.

The experiment should compare an independently recorded source-event ledger with the receiver's raw samples, packet counters and displayed event file. Vary the transmitter's batch schedule while holding the measurement configuration fixed; then vary only the receiver buffering and event-merge settings. Include deliberately introduced host backlog, known scan blind intervals and controlled amplitude fades. Estimate within-cluster and between-cluster distributions separately and test whether conclusions remain stable across reasonable changes in the event definition. An

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apparent source period that shifts with the GUI refresh interval has been attributed to the wrong system. Likewise, a burst grouping that disappears when the detector threshold is altered deserves qualification before it is described as a source protocol.

A report should distinguish physical emission pulses, received waveform features, accepted detector triggers, reconstructed burst families and displayed event summaries. It should disclose counts and timing for each layer, including any data that were deliberately rejected. The purpose of this separation is not pedantry. Each layer answers a different question, and each may be required to explain the observed timing. A warranted conclusion might identify statistically repeatable burst families in the measured RF energy while leaving their internal scheduler and source identity unresolved. The analyst's obligation is to retain the timing evidence and its uncertainties in a form that a later examiner can challenge, not to assign an exact transmitter mechanism because one interval histogram appears pleasingly regular.

Norbert Wiener, Peer Question: Professor Kendall, an analyst may see several apparently independent RF events arrive at the console simultaneously, although the actual acquisition occurred at different times. Suppose the device and host form a layered queue: an RF detector produces hardware time tags, USB transfers packets, a background application writes records, and a graphical display refreshes at a fixed rate. Which portions of that chain could impose periodic arrival patterns or artificial clustering, and how could the operator reconstruct the original chronological order? I also ask how one should distinguish the actual transmitter's queueing behaviour

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from a receiver's packet backlog without relying on unobserved assumptions about the source's internal design. Would a correlation between display update times and burst detections ever be enough to infer a source schedule? If the hardware time tags remain monotonic while software receipt times reverse order, is the inversion itself evidence of delivery reordering, or must one first exclude a clock adjustment or timestamp conversion defect?

David G. Kendall, Response: Professor Wiener, the ordinary display-time record is downstream of several stochastic and deterministic stages. The RF source may generate a physical pulse at T_k. The device records a hardware timestamp H_k, ideally related to T_k by a calibrated constant and small error. The packet enters a transport queue, accumulates a variable delay Q_k, reaches the application, and is finally published at a display refresh D_j. If the software assigns the event time at D_j, several distinct physical arrivals may appear simultaneous at each refresh. A histogram constructed from those display times can show an impressive period equal to the GUI refresh cadence even when the RF source is irregular. Such regularity is evidence about the graphical interface until its relation to hardware acquisition has been demonstrated.

Reconstruction should begin with immutable sample counters or device timestamps, not with host wall-clock ordering. Preserve packet sequence identifiers, counter resets, overrun and dropped-sample flags, transport receipt times, queue depths and the conversion that maps hardware time to externally referenced time. Sort on the physically meaningful acquisition index where possible, noting any ambiguity introduced by missing packets

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or counter wraparound. A time estimate reconstructed from a new calibration is a derived result, not an original observation; retain both. If the acquisition hardware did not record its own chronology, some reorderings may be impossible to determine after the fact, and that limitation cannot be repaired by a confident spreadsheet sort.

To distinguish source queueing from receiver backlog, employ an independent continuous witness receiver that records the waveform before the disputed host transport path. If the witness shows physical pulses separated by milliseconds but the console reports them together every second, the receiver system has imposed the visible grouping. If both independent acquisition streams show actual over-the-air bursts with the same physical clustering, that supports a source-side phenomenon, although common external triggers or relays may still explain it. The experiment should also challenge the receiver transport deliberately: impose controlled processing load or adjust the display refresh without altering the test generator. A pattern that follows this manipulation originates at least partly in the measurement chain.

Correlation between display updates and reported detections cannot by itself establish a transmitter schedule. The application may process and publish events only when the display refreshes, ensuring correlation by design. A useful log identifies the physical sample time, event-detector decision time, application ingestion time and display time as separate columns with uncertainties. Event counts should be reported by acquisition interval, not by display frame, unless the latter is the explicit estimand. A

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disciplined investigator distinguishes a source emitting clusters from a host delivering clusters; both can be described by queueing mathematics, but the forensic conclusion depends upon measurements showing which queue is being observed.

Richard W. Hamming, Peer Question: Professor Kendall, consider a software engineer who has correctly recorded the beginning and ending hardware sample counters for each block but uses a convenience function to fill missing event timestamps by interpolation. If a short block was actually dropped during an RF burst, the resulting catalogue may show a smooth succession of evenly spaced pulses. What software tests would reveal this synthetic regularity, and which provenance fields should make it impossible for a later reviewer to mistake interpolated events for measured ones? I am also concerned about overflow recovery. An SDR driver may reconnect a stream after losing samples, while the application reinitialises its counter and continues writing a valid file. What invariant should the capture software enforce to prevent that discontinuity from being concealed behind an apparently continuous timeline? How would you design an automated acceptance test that fails the build when missing-sample intervals are hidden, even if the recovered event timeline looks periodic and every output file can be opened?

David G. Kendall, Response: Professor Hamming, the distinction is between samples observed and events predicted. A missing acquisition block cannot be reconstructed by interpolation as if the physical waveform had been measured. An analysis programme may produce estimated pulse times under a periodic model, but those estimates must be recorded in a separate layer with their assumptions and uncertainty. The raw ledger should

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preserve hardware counter ranges, whether each range was actually captured, and any device error flags. It should never insert an inferred event into the same category as an observed threshold crossing without a conspicuous provenance field. A later investigator must be able to discard every inferred event and reproduce the original catalogue unchanged.

A suitable acquisition invariant is that each accepted data block has a unique device identity and epoch, an explicit first and last sample index, and a documented relationship to the preceding block. If a counter resets during reconnection, the software must create a new epoch rather than silently continuing the old numbering. Missing ranges are identified as gaps; overlaps and duplicates are flagged; and the mapping from device ticks to calibrated time is versioned separately. Where a device cannot provide trustworthy counters, the programme should document that limitation and use an independent known marker to test continuity. A monotonic host clock alone does not prove that RF acquisition remained continuous during the interruption.

Fault-injection testing should make every failure mode observable. Under controlled laboratory conditions, block packet delivery, force a buffer overrun, restart the driver, step the host wall clock, and introduce a known pause in the generator while an independent recorder preserves the physical source timeline. The resulting audit file must distinguish each cause: transport delay without loss, dropped samples, clock discontinuity and actual silence. Run the event detector on the raw samples and compare its output with a catalogue reconstructed from the recorded device

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counters. If an interpolation stage creates apparent equal intervals across a gap, the audit should identify the generated entries automatically and the publication statistics should exclude them from evidence of observed periodicity.

The final recording should include a checksum of the raw acquisition, the detector software version and settings, a list of every transformation and its inputs, the error log, and a stable link from each accepted event to its underlying sample range. These controls do not prevent all scientific mistakes, but they prevent a particularly serious one: replacing missing physical measurements with a convenient model and then citing the model's regularity as evidence that the transmitter behaved regularly. Quality assurance should test not only whether the software continues running after an error, but whether it tells the truth about what was lost.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel distinguishes physical emission times from receiver observation windows, detector triggers, buffer-delivered events and software-displayed clusters. A prominent interarrival peak can arise from an external scheduled source, a narrow renewal interval distribution, state-dependent burst grouping, missed periodic emissions or the receiver's own revisit cadence. A defensible inference begins with hardware event provenance, calibrated receiver availability, a declared model-selection rule, and independent attempts to break the possible alias through altered scan timing or continuous witness observation. Integer-multiple intervals and a clean point-process spectrum are evidential clues rather than proof of an emitter's internal scheduler. Where multiple physical models explain the accepted timestamps equally

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well, the conclusion is non-identifiability. No inference about message contents, purpose or source ownership follows from timing statistics alone. The exchange is a fictional pedagogical reconstruction, and all example figures are hypothetical.

QUESTION 076. TECHNICAL SOURCES AND EDITORIAL QUALIFICATIONS

1. M. S. Bartlett, “The Spectral Analysis of Point Processes,” Journal of the Royal Statistical Society, Series B, vol. 25, no. 2 (1963), pp. 264–281, DOI: 10.1111/j.2517-6161.1963.tb00508.x. Publisher catalogue confirms the work and its focus on renewal and clustered point processes. https://academic.oup.com/jrsssb/article/25/2/264/7035255

2. International Telecommunication Union, Handbook on Spectrum Monitoring, 2026 edition, https://www.itu.int/pub/R-HDB-23. This handbook supplies the general spectrum-monitoring context; specific equations in this question are editorial derivations and are not attributed to an unspecified page of the handbook.

3. ITU-R Report SM.2256-2 (06/2026), Spectrum occupancy measurements and evaluation. The published contents distinguish duration of monitoring, sample time, observation time, revisit time, transmission length and thresholds. https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-SM.2256-2-2026-TOC-HTM-E.htm

4. Additional historical bibliography, contributor expertise and individual mathematical assumptions require independent source-to-claim verification. The statistical examples are hypothetical; their assumptions, including independence and stationarity, are explicitly limited within the discussion.

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EDITORIAL QUALIFICATION: Stage A requires minimum individual word counts, five distinct principals, seven ordinary peers and four cross-peer examinations with directly matched answers. Publication approval remains withheld pending independent historical, mathematical, technical, legal and whole-volume semantic originality review.

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QUESTION 077

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When can inter-arrival statistics identify a class of intermittent control links?

Dr. James M. Atkinson, Moderator: Professor Feller, our question concerns what inter-arrival statistics might establish about a class of intermittent control links. Please separate renewal behaviour from scheduled signalling, and distinguish the transmitted waveform, the receiver's observations and the analyst's inference. The floor is yours.

William Feller, Principal Contributor: The first necessity, Dr. Atkinson, is to prevent three clocks from being mistaken for one another. There is the physical transmitter's clock, if a physical clock governs its emissions; there is the measurement clock that assigns timestamps to acquired events; and there is the statistical clock defined by the waiting time from one observed occurrence to the next. The third does not disclose the first merely because its intervals have an attractive numerical shape. A simple renewal process is one in which the successive waiting times, X_1, X_2 and so forth, are independent and identically distributed with a common distribution function $F(x)=P(X<=x)$, where x is elapsed time. Its survival function $S(x)=1-F(x)$ is the probability that an interval has not yet ended at elapsed age x. Where F admits a density f, the hazard $h(x)=f(x)/S(x)$ measures an instantaneous conditional propensity to observe the next event given that it has not already occurred. These are properties of the selected event process. They do not, by themselves, identify whether the source is a remote-control transmitter, a thermostat, a laboratory oscillator or a detector reporting the same pulse twice. A claim about device class must bring additional observations and a defensible reference population into evidence.

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For an exponential waiting law with mean m seconds, F(x)=1-exp(-x/m), h(x)=1/m, and the event intensity is constant. Such a model is memoryless in event age, although it need not imply that an engineer built a memoryless signalling device. For a nearly regular renewal law, the interval variance may be small compared with the squared mean; yet a source scheduled every ten seconds whose every second transmission is intermittently missed may exhibit a multiple-spaced distribution unlike the nearly regular physical emissions. Conversely, a truly irregular source watched through a receiver that revisits a frequency at regular times can appear more periodic than it is. In the field notebook I should require a record of antenna position, dwell window, threshold rule, timestamp origin and event-merging convention. The statistical sequence without that observation description resembles an instrument panel photographed after its legends have been stripped away. It can still be measured, but its causes are ambiguous.

Consider a first hypothetical experiment. A receiver observes 121 intervals, their summed duration being 605 seconds. The naive sample mean is 605/121=5.00 seconds. Under an independently observed exponential renewal model the maximum-likelihood rate is lambda_hat=n/T=121/605=0.200 events per second, and its reciprocal is five seconds. That numerical calculation is sound within the model, but it does not classify the link. The same count can be generated by scheduled events with missed detections, a superposition of two controlled sources, or a nonstationary intensity chosen to have the same total integral. The sampling uncertainty is also conditional on the specified observation scheme. One must not import the usual independent-exponential standard error when interval values have been rounded, when the receiver falls blind after

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detections, or when the recording interval is deliberately terminated following an unusually long silence.

A second experiment demonstrates the danger of confusing a physical period with a detected interval. Suppose an authorised training transmitter emits a beacon every 2.0 seconds, and an independently calibrated detector records each beacon with probability p=0.60, independently across emission opportunities. Let K be the number of physical periods between successive detections. Then P(K=k)=p(1-p)^(k-1), for integer k>=1. The probabilities at 2, 4 and 6 seconds are 0.60, 0.24 and 0.096. The mean observed separation is 2/p=3.333 seconds; an investigator who describes a roughly 3.3-second clock from the sample average has invented a timing mechanism that does not exist. The characteristic lattice of two-second multiples may nevertheless survive in the interval histogram, but only if timestamp resolution and oscillator stability are good enough to resolve it. For practical classification, we should ask whether the hypothesised renewal law predicts the entire observed gap distribution rather than interpreting its mean alone.

The question of class is thus a question of distinguishability under interventions. A receiver using one gain level can confuse a low-duty intermittent source with a weak continuous source that crosses the threshold sporadically. Repeating the measurement at a controlled second sensitivity, with identical live-time accounting, may reveal whether supposed events multiply in a manner attributable to the instrument. A second simultaneously tuned independent receiver can discover acquisition gaps that a single scanner conceals. A deliberately transmitted, known reference sequence can test whether the timestamp pipeline preserves a sequence of one-second and ten-second gaps without merging, deletion or re-ordering.

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All these controls convert an otherwise decorative fit into a testable model of observation.

We should also say what independence means. An interval process may be stationary in its marginal histogram while retaining correlation between adjacent gaps. If a transmitter emits three short packets in a burst, then waits before the next burst, the pooled histogram may display two characteristic lengths. There may be no single interval distribution under which successive gaps are independent. A renewal diagnostic can compare conditional gap distributions after a short versus a long preceding gap, or evaluate the lag-one correlation with uncertainty adjusted for finite samples. If the next interval changes with the previous one, simple independent renewal modelling is falsified, but that finding does not automatically prove intelligent command traffic. Thermal state, battery voltage, channel contention, an overloaded recorder and intentional retransmission protocols may all generate dependence. We require a candidate mechanism and a control able to make it fail.

Nor may an analyst identify a particular apparatus from the apparent rarity of a pattern. A device family might be described by a prespecified set of timing characteristics validated on known exemplars, such as burst length, recovery-time distribution, diurnal exposure and probability of simultaneous activation with environmental stimuli. A finding that an unknown trace falls within that distribution may rationally support a cautious family-level comparison, perhaps as a likelihood ratio under two explicitly described reference populations. It does not give licence to turn that ratio into a probability of guilt or identity without prior odds, selection procedures and competing explanations. I would record the class hypothesis separately

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from the event detector, document every change to classification thresholds and retain the raw timestamps along with the intervals. In the quiet of an electronics laboratory, the temptation is to hear an orderly mechanism whenever a display blinks rhythmically; sound discipline consists in testing the order before naming its source.

Jerzy Neyman, Peer Question: Professor Feller, I am concerned by the way a classifier might be judged after an analyst has chosen which spectral channel and which apparent interval deserves attention. Suppose the instrument records 120 candidate frequencies during an evening survey, each frequency offering perhaps several event thresholds, and the analyst ultimately reports the most regular inter-arrival sequence. The apparent event rate, coefficient of variation and lattice spacing are then not products of an experiment fixed in advance but of a selection procedure driven by the same data under examination. Even a correct likelihood for an isolated renewal sequence would fail to reflect the probability of having found that sequence among all the alternatives. Would you define a test that includes the search procedure itself, and would you separate statistical confidence about a class from a mere decision to inspect a frequency more carefully? I also ask how you would handle a class whose genuine exemplars range from battery-powered short bursts to mains-driven periodic control frames, because a convenient single distribution might be too narrow to represent its true diversity.

William Feller, Response: Dr. Neyman, the correct experimental unit is the complete selection procedure, not the single attractive channel recovered at its end. If a laboratory wishes to estimate how frequently an intermittent control-like pattern arises in benign background activity, it must repeat the

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complete search over disjoint, prospectively defined periods and count how often its final selection rule declares a candidate. The null distribution therefore includes antenna selection, frequency scanning, threshold adaptation, the number of interval tests and the rule for stopping. One can use resampling or simulation only if the surrogate observations preserve the real temporal dependencies and the receiver's missing-data structure. Randomly shuffling all timestamps would destroy clustering and could create a dishonest reference distribution.

The distinction between discovery and confirmation is indispensable. The initial survey can be labelled exploratory and used to formulate a specific, falsifiable observation protocol. The confirmation period then freezes channel definitions, minimum event energy, timebase calibration, burst-merging rules and the decision boundary before data are collected. A class label should not be issued unless the predictor is calibrated on independent known examples and known counterexamples. The richer the class, the greater the danger of treating its definition as elastic. A collection of carefully stratified reference distributions, with prespecified weights for the relevant environments, may be more faithful than a single nominal curve. The result should state its coverage: for example, measurements obtained with a particular receiver family, signal-to-noise range and lawful test-site protocol. Anything outside that range remains extrapolation. The final decision may reasonably be to gather further evidence rather than to pretend that a weak inference has become strong merely because the statistic carries several decimal places.

For a numerical illustration, suppose that a frozen detector was exercised against 200 independent negative test recordings, including its complete

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multi-channel search, and generated 12 alerts. Its observed false-alert fraction is 12/200=0.06, not the nominal single-channel p-value that happened to motivate the detector. The precision of 0.06 is itself limited by the number and heterogeneity of test records; an interval estimate should accompany it. A classifier trained on the very same 200 records would give an optimistic figure because it has used the labels for parameter selection. This is not an obscure philosophical concern. It determines whether an investigator gives a magistrate a defensible statement about a method's performance or merely a retrospective account of a conspicuous flashing indicator. I should require the test archive, its frozen software version, its receiver configurations and the full set of negative outcomes, including those in which nothing of interest appeared.

Claude Shannon, Peer Question: Professor Feller, your renewal law compresses a continuous radio waveform into one timestamp per accepted event. In a communications channel the physically consequential distinction might lie in pulse width, modulation alphabet, packet coding or occupancy, none of which necessarily survives an onset detector. Two dissimilar transmitters can produce the same set of onset times while carrying utterly different information, and a matched filter tuned to one waveform may systematically discard another at identical radiated power. What mathematical criterion would tell a field investigator when the timestamp catalogue is sufficient for the particular hypothesis and when a second feature stream is indispensable? I ask especially about purported control-link classification. The word control implies a relationship between a command and a response, whereas a temporal sequence may arise from telemetry, synchronisation, channel contention or the scanning instrument

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itself. How should an analyst refrain from putting semantic information into the model that no measurement channel actually acquired?

William Feller, Response: Dr. Shannon, a statistic is sufficient only relative to a specified family of probability models and the parameter whose information we seek to retain. A list of onset times may be adequate to estimate an event-rate parameter under a correctly specified point-process model, yet wholly insufficient to establish that one emission addressed a receiver, encoded an instruction or caused an actuator to change state. That distinction should appear in the title of the recorded inference. We may write 'timing compatible with a recurrent burst process' where the evidence permits, but not 'command link identified' merely because an intervalogram shows concentration near a preferred lag.

A forensic acquisition system should preserve the original spectral or complex-baseband record when lawfully and practicably obtainable, and should store the detection decisions as derived annotations rather than as the sole surviving evidence. Additional independent features may include bandwidth, pulse energy, waveform similarity across bursts, frequency agility, synchronised response in a permitted test apparatus, and changes under controlled attenuation. They must be linked to their acquisition conditions. If a waveform's duty factor determines whether a swept analyser captures it at all, then a refined interval classifier cannot recover missing signal semantics from timestamps alone. One must also distinguish uncertainty in observed pulse onset from uncertainty in internal timebase state, since those errors enter different parts of the likelihood.

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A careful investigator might adopt nested hypotheses: H0 describes background detections under the known sensor, H1 describes a nonstationary stochastic emission process, and H2 describes a particular family of lawful reference devices. Showing that H0 predicts poorly is not sufficient to establish H2. The likelihood of the actual data under H2 must be compared with the best substantive alternatives and tested out of sample. If all competing device classes predict the same onset distribution, then the timing channel has zero discriminatory power between them, whatever the beauty of its display. This is an instance of information absent from the observation, not of a clever algorithm waiting to be found. I would pass that limitation with the token rather than conceal it beneath a dramatic label. The absence of a waveform record is an information loss, not a merely inconvenient processing choice; it must be documented as such in the evidentiary limitations.

William Feller, Cross-Peer Question to Sir David R. Cox: Sir David, I should like you to distinguish two cases that a renewal histogram cannot separate. A source might possess a rate that changes deterministically as the laboratory ventilation fan starts and stops; alternatively, the rate itself might vary randomly because of an unobserved state of the equipment. Over a short observation the two could produce similar clustering and identical pooled waiting-time distributions. I ask whether a conditional-intensity formulation can identify which covariates are genuinely informative, and whether such covariates may be included when the analyst notices them only after the events have been plotted. How would you define exposure time when the receiver is blind during retuning, and how would you use a prospective holdout interval to distinguish a model of the emission process

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from a model of the instrument's attendance at the channel? Kindly also consider whether improved fit is any evidence of purpose, as opposed merely to a reduction in predictive error.

Sir David R. Cox, Cross-Peer Answer to William Feller: Professor Feller, the essential separation is between the mechanism creating physical events and the observation mechanism by which some of those events enter our catalogue. A conditional intensity lambda(t|H_t,z_t) is a local event rate at time t, conditional upon the recorded history H_t and relevant covariates z_t. It does not imply that time has become a cause. A deterministic intensity might depend on a logged environmental state, such as temperature or fan operating status; a stochastic-intensity model allows unrecorded variation in that underlying rate. In either case we must explicitly account for an exposure indicator e(t), which is one when the receiver is eligible to record the nominated source and zero when it cannot. The effective observable intensity is not simply lambda(t), but is modified by e(t), detection efficiency and any dead-time or pulse-merging process. Their effects should be estimated in separate calibration experiments wherever possible.

A prospective test must commit to its covariates before confirmation. If a fan event is discovered only after an interesting pattern appears, we should treat the correspondence as a hypothesis and schedule a new experiment in which fan state is varied deliberately and recorded synchronously with receiver live time. The model can then ask whether an increase in conditional intensity replicates under preassigned conditions. A random-intensity model may capture clustering that remains after known covariates have been accounted for, but its extra flexibility must be penalised and evaluated by predictive scoring on independent segments. One does not

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obtain a causal interpretation merely by naming a fitted latent process 'control'.

Suppose a 600-second experiment contains 300 seconds in which the receiver is truly available, with 30 accepted events in that live interval. The uncorrected rate of 30/600=0.05 events per second is the rate per elapsed calendar time, whereas the exposure-normalised observed rate is 30/300=0.10 events per live second. Neither is necessarily the physical transmission rate unless detection efficiency and the censoring model are known. If availability depends on the event history, a naïve division by live time can be biased. The output should carry a live-time ledger, and predictions should be evaluated conditional upon the same observation schedule. I thank you for drawing attention to the problem, and return the floor to the moderator for the distinction between rate modelling and physical attribution.

Dr. James M. Atkinson, Moderator: Sir David, Professor Feller has established the necessity of distinguishing physical generation from the receiver's sampling. Please explain conditional intensity, covariate-dependent clustering and the danger of treating a suitable statistical model as a diagnosis of an apparatus.

Sir David R. Cox, Principal Contributor: Dr. Atkinson, the decisive move is to replace the seductive label 'intermittent control link' with an explicit set of competing mechanisms. Consider first an intensity that is constant within a test interval. If event counts N(t) follow a homogeneous Poisson model with rate lambda events per second, counts in disjoint intervals are independent, and the number of events in an interval of length T has mean and variance

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lambda T. A second model permits lambda to be a known function of time, perhaps conditioned on the recorded state of laboratory machinery. A third, a doubly stochastic Poisson model, allows that intensity to be itself random. The observable counts in this third arrangement can exhibit greater variance than the mean because periods of high latent intensity gather events into clusters. The same visual impression might also be produced by a transmitter emitting deterministic bursts while a receiver randomly omits some bursts. Statistical form must be attached to the actual observation operation or it has no secure engineering interpretation.

My first practical requirement would be a timeline with distinct fields. The physical event times are latent unless an independently monitored reference transmitter supplies the ground truth. The receiver has a sample clock; the scheduler has dwell and revisit intervals; the detection algorithm declares a pulse onset when a defined decision variable crosses a defined threshold; finally, the software may merge nearby declarations into a single event. Each transformation can change the observed interval process. A digital recorder whose buffering occasionally delays or batches timestamps may produce the appearance of a scheduled transmission even while receiving an unstructured sequence of test pulses. Its clock drift can lead an analyst to mistake apparent rate modulation for behaviour in the source. We should therefore archive a continuous timebase calibration record, any packet or frame counter exposed by the instrument, the distribution of processing latency, and the explicit live-time mask. In a sensitive inquiry, every unmeasured transformation is an alternative explanation, not a footnote.

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A conditional-intensity model can express these issues without pretending to know the hidden hardware. Let H_t denote the accepted event history strictly before time t; let z(t) be a vector of logged environmental covariates; and let e(t) be a live-time indicator. An illustrative model is $\lambda_{obs}(t|H_t,z)=e(t)\,q(t)\exp(\beta_0+\beta_1 z_1(t)+\beta_2 z_2(t))$, where q(t) is a calibrated probability of acceptance under the relevant signal conditions, β_0 is the baseline log-intensity, and the beta coefficients represent specified covariate associations. This equation is a simplified thinning model. It does not apply without qualification when the detector has history-dependent dead time or merges close events. A candidate conditional intensity may fit beautifully yet be an artefact of a covariate sampled with the same periodicity as the receiver's revisit schedule. We should repeat the experiment with an independent sampling schedule before we attribute a coefficient to the source.

A worked calculation will show how a seemingly large association may be nothing of the sort. Suppose a lawful test records 12 events during 240 seconds of live time while an air-handling relay is off, and 36 events during another 240 seconds of live time while it is on. The observed rates are 12/240=0.05 and 36/240=0.15 per second; the raw rate ratio is 3.0. But the relay may alter broadband background amplitude, which changes q(t), or the receiver's scanning sequence may be synchronised to the relay. If acceptance probability is independently measured to be 0.5 in the first condition and 0.9 in the second, a simple corrected comparison under independent thinning gives estimated source event rates 0.05/0.5=0.10 and 0.15/0.9 approximately 0.1667 per second. The corrected ratio is about 1.667, not three. Such correction remains model-dependent; it is not a

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causal finding. The decision to randomise relay status, within safe laboratory constraints, is more important than the apparent confidence conveyed by the decimal.

One should prefer a prediction test where the physical hypothesis and the alternative models disagree. A renewal process with independent waiting times might predict that the next interval depends only on the elapsed age of the current gap. A self-exciting event model might predict a temporary increase in the likelihood of another event immediately after the last one. A varying environment may predict fluctuations that track a measured external covariate. A scheduled controller may predict a response to an authorised stimulus within a reproducible latency window. If the models give almost indistinguishable timing predictions, no classifier can recover certainty by extending the numerical precision of its coefficients. Data of another kind are required, and those data should be obtained with a lawful, non-invasive observation protocol or a controlled exemplar, not by inferring sensitive semantics from opaque RF bursts.

The event history can be tested through the time-rescaling principle. Under a correct, continuous conditional-intensity model, successive integrated intensity increments Delta_i = integral from t_(i-1) to t_i of lambda(s|H_s,z_s) ds should behave as independent unit-mean exponential variables, subject to regularity conditions and the correct handling of censoring. A departure suggests model inadequacy; apparent agreement is not proof of a unique causal mechanism. If live-time gaps cut across intervals, the integral must follow observable exposure rather than pretend every calendar second could contain an accepted event. Likewise, a hardware timestamp wrap or repeated processing delay may create a sharply peaked feature that a

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flexible intensity model can accommodate while the field engineer should instead repair the clock. The mathematical residual diagnostic and the engineering configuration log belong together.

A classification report ought therefore to state what was held fixed, what was allowed to vary and what claim would have been rejected by the opposite result. 'The observed burst timing resembles that of our laboratory's intermittent-controller exemplar under this receiver and environment' can be meaningful if the exemplars, selection rule and error rates are documented. 'The unknown emitter is an intermittent controller' ordinarily asserts more than a timestamp-only test can establish. One cannot summon the missing evidence from the posterior by selecting an obliging prior, nor from a conventional significance threshold by ignoring untested alternatives. The point of model building is to clarify the sources of uncertainty so that a decision-maker knows what can and cannot be established, not to conceal ambiguity beneath a polished likelihood plot. I pass the matter to colleagues who can challenge the choice of observation window and the conditional assumptions.

Maurice S. Bartlett, Peer Question: Sir David, your conditional-intensity proposal is attractive, but a scanner's sampling schedule may introduce a periodic zero pattern into the opportunity for any event to be detected. In the simplest presentation one multiplies the source intensity by an exposure indicator, yet a real analyser contains filter settling, video averaging, asynchronous buffering, overload recovery and trigger hold-off. It can report nothing during one interval, a delayed trigger during the next and several merged pulses after that, so the observation error itself may be temporally correlated. If an analyst measures environmental covariates only

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every minute, while physical bursts have millisecond durations, the apparent relationship to those covariates may also result from time aggregation. What residual test would reveal a mis-specified observation mechanism rather than a mis-specified emitter model? Would you insist upon an independent clocked reference channel to establish live time and timestamp stability, even where doing so reduces available receiver channels for surveillance?

Sir David R. Cox, Response: Dr. Bartlett, an exposure indicator is a beginning, not the completion of the observation model. It accurately describes an ideal receiver that is either eligible or ineligible to detect an event and whose probability of acceptance is otherwise independent of past events. A real receiver may have a response kernel, a delay distribution, frequency-dependent gain and a dead-time rule. The inferential target must then be a joint model of latent event generation and the observation transformation. For high-integrity field work, I would recommend a separate laboratory calibration trace made with known pulses that vary systematically in spacing and amplitude, followed by a small number of independent reference injections during the actual survey where permitted. The aim is not to interfere with unknown devices but to characterise the instrument with an authorised signal path.

The residual analysis should be diagnostic at several levels. First compare the accepted-event timestamps with the receiver's actual active-tune mask rather than its nominal programme. Then examine the distribution of timestamp offsets relative to dwell boundaries, processor batches and reference clock edges. If the measured event rate spikes immediately after each retune or dips after each trigger, there is evidence that the

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instrument's state affects acceptance. Next fit a physical candidate model while incorporating the empirically measured observation kernel. If the time-rescaled residuals still show correlation concentrated at revisit harmonics, that suggests the observation description is inadequate or that a process synchronised with the scan remains unmodelled. It does not unambiguously distinguish the two. An independent receiver with a deliberately different revisit schedule can help because genuine source times should not be tied to both schedules in the same way.

The aggregation issue is equally serious. A minute-sampled temperature may act as a crude proxy for a relay's short-cycle operation; a fitted temperature coefficient might actually represent an unobserved intermittent load. One can analyse its sensitivity by shifting or coarsening the covariate series, by introducing independent logging or by explicitly acknowledging that there is insufficient temporal resolution for a mechanistic inference. If a 30-minute data set contains only six episodes of equipment state change, treating its thousands of individual pulse detections as thousands of independent demonstrations of a state association produces severely underestimated uncertainty. Episodes or independently assigned state changes, not the raw event count, may form the appropriate unit for a causal experiment.

The expense of an independent reference channel is justified when the intended conclusion is consequential and the timebase is not otherwise demonstrated. If resource constraints prevent it, the conclusion should remain qualified. An engineering report can retain a plausible classification hypothesis while clearly marking timebase validation and live-time metrology as incomplete. This is preferable to granting the instrument an

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accuracy which was never measured. The result should be reproducible in principle by another investigator given the same raw trace, calibration records and software rules, and not depend upon an analyst's memory of what the waterfall happened to resemble during an event.

Sir David R. Cox, Cross-Peer Question to George E. P. Box: Professor Box, a maximally flexible Cox-process description may follow every cluster in a training record, especially when the analyst can introduce arbitrary smooth functions of time and environmental covariates. I should be grateful for an account of how an experimentalist should distinguish that sort of statistical accommodation from a genuinely predictive classification. What diagnostic would you require before the words 'intermittent control-like behaviour' entered a forensic report? Consider specifically that the investigator may have chosen the event detector by viewing the same records, and that an apparently successful model can simply reproduce the receiver's revisit schedule. How would you design a separate confirmation campaign, and which aspects of the modelling exercise ought to be deliberately frozen? Please address the practical trade-off between a rigid but wrong model and an excessively adaptive model that explains away every contradiction. In particular, would you specify a preassigned negative-control experiment whose result would invalidate the class interpretation even if its initial training likelihood remained exceptionally high?

George E. P. Box, Cross-Peer Answer to Sir David R. Cox: Sir David, modelling becomes an evasion when nothing can happen that would cause the model to be rejected. A useful statistical design begins with a clearly described engineering question, a hierarchy of predictions and a list of measurements capable of exposing model failure. For the proposed

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classification I would require a training set drawn from known lawful exemplars and a separate collection of negative controls, including background sources that are not controllers but create superficially similar bursts. The analyst must freeze event detection, channel selection, interval censoring, the vector of features, model complexity, the numerical decision rule and the form of uncertainty report before opening the prospective confirmation data. Any post hoc alteration is a new experiment and needs another holdout.

I would not insist that the simplest possible model be true. A renewal model can be an informative baseline even when the real source has clustered, covariate-dependent emission. The relevant question is whether complexity improves held-out prediction under a scoring method chosen in advance. With a point process, the likelihood of withheld event times and the integrated intensity over exposed time provide one such scoring method, but both can be subverted if live-time and dead-time behaviour are inaccurately described. Calibration plots for predicted probability of one or more events in prespecified windows, together with residual analysis against receiver state, are often more informative to the reviewer than a single classification percentage.

An experimentalist must also randomise what can be randomised. If the purported source changes when a fan relay changes, vary relay state independently of the receiver scan if permitted. If the source-like pattern follows scan timing, alter dwell and revisit schedules while monitoring the same controlled environment. If the model predicts a class-specific latency after an authorised control stimulus, specify a latency band before the experiment and record how often unrelated background devices produce an

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indistinguishable response. A classifier that survives several orthogonal perturbations is more credible than one which gives a vivid account of a single night's trace. Even then, discrimination among classes is not identification of a particular device.

Suppose a complex model gives an average negative log-predictive score of 1.18 per held-out observation and a simpler model 1.22 under a specified proper scoring rule. The difference is 0.04 per observation, but its uncertainty must account for dependence between adjacent events and repeated conditions. If there are only five independent recording sessions, five thousand pulse timestamps do not magically create five thousand independent experimental replicates. State the practical size of the improvement and an interval derived from independent sessions or defensible block resampling. I should prefer the simpler model if the complex one gains little under independent test, and I should seek better measurements if both models fail. The proper output is a tested inference with explicit conditions, not an ornamented description of an ambiguous spectral line.

Dr. James M. Atkinson, Moderator: Professor Box, Sir David has passed you the question of statistical accommodation versus genuine predictive discrimination. Please consider the workshop practice of dividing records into development and confirmation sets, and explain how to prevent the instrument and the analyst from manufacturing a purported control-link signature.

George E. P. Box, Principal Contributor: Dr. Atkinson, a detector can be a wonderfully efficient manufacturer of facts which are true only of its own

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settings. There is nothing dishonest about acquiring a timestamp when an amplitude crosses a threshold, provided that the analyst remembers that it is a threshold-crossing timestamp. The mistake arises when an event created by the analysis procedure is treated as an independently existing packet with a known purpose. In an industrial experiment I should begin with a process map: the lawful test source, the antenna and propagation path, the analogue filter, any amplification, the sampled data, the detection statistic, the threshold, the event-merging software and the final classification. Every node introduces variation or selection. The map should identify variables controlled by the investigator, variables observed but not controlled, and variables that were never recorded. Without such a map it is easy to mistake the variability of the measurement process for variability of the object measured.

There is a profound distinction between explaining the existing data and predicting another observation. Imagine a development record in which an intermittent background source appears to produce a burst every 24 to 28 seconds, except when the laboratory ventilation fan is running. An analyst can fit an elegant mixture distribution, introduce a term for the fan and add a latent state for the occasional missing burst. The curve may track the historical data almost perfectly. But perhaps the receiver visited the channel every 26 seconds, lingered for 200 milliseconds and happened to do so at a different processor load when the fan-controller network was active. Another receiver, continuously tuned, could reveal that the source generated many events during the supposed silences. Unless the observation schedule is recorded and tested, the analyst has estimated characteristics of a combined system rather than of the emitter alone. I

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would therefore insist on comparing at least a continuous-monitor reference with the time-sliced survey where authorised, before the record acquired any class label.

Model choice should be guided by the technical purpose of the decision. If the purpose is to nominate a few frequencies for further lawful observation, a relatively permissive detector with an explicitly measured false-alert rate may be sensible. If the purpose is to state that a particular class of command apparatus was present, the same method is inadequate without calibration on real devices, controls representing alternative source classes and proof that the claimed features survive changes of instrument. Sensitivity and specificity are conditional on the population of tests; neither is a timeless property of a mathematical formula. The composition of the negative set matters greatly. If all negatives are benign laboratory noise while all positives are strong, neatly timed reference beacons, a classifier can learn signal strength and acquisition time rather than any signature of control traffic. The experimental record must disclose that problem.

Here is a worked classification example. Let the positive reference set contain 80 independent controlled sessions, of which a frozen detector correctly flags 68, and let the negative set contain 120 independent sessions, of which it incorrectly flags 18. On these test populations the observed sensitivity is 68/80=0.85, and observed specificity is (120-18)/120=0.85. Equal numerical values do not imply that a positive detection has an 85 percent probability of being a control link. With a hypothetical prevalence pi=0.02 in the intended survey population, Bayes' rule gives P(class|alert)=[0.85*0.02]/[0.85*0.02+0.15*0.98], approximately 0.104. That 10.4 percent is not a measured field prevalence; it illustrates why

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the proportion of positives among all candidate events matters. Replace the prior 2 percent with a different defensible value and the posterior changes. Where prevalence is unknown, report the likelihood ratio and its uncertainty rather than silently assuming an attractive prior.

The same attention must be given to serial correlation and sample splitting. An engineer could record a thousand pulses from the same five devices and then randomly assign individual pulses to training and test files. Such a division creates severe leakage. The test file contains the timing quirks of the very devices already used for training. A more credible design assigns whole recording sessions, days, device exemplars or sites to separate partitions. If the model is to generalise to a new type of instrument, withhold entire instrument types during validation. If it is intended only for repeated surveys with the same instrument, test it on new operating conditions with independently checked calibration. The relevant independence unit depends upon the intended claim. An impressive accuracy produced by resampling correlated pulses is not an estimate of generalisable field accuracy.

Our descriptive calculations should also distinguish static and dynamic features. A histogram of gap lengths is static in the sense that it discards their order. It may still be useful as a first account of what happened. But a control-like signal may exhibit a recurring cycle of several short events followed by a long interval, and a histogram of those same durations cannot show whether the long gap always follows three short ones or occurs at random positions. An ordered transition table, a renewal-age diagnostic or a conditional model might reveal the dependence. In designing a confirmation experiment, I would specify at least one feature sensitive to

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order and one deliberately insensitive feature, and compare their out-of-sample predictive value. Failure of the order-sensitive model can be valuable: it says that the attractive cyclic story did not survive the next recording.

There is an engineering reason to prefer several simpler experiments rather than one encyclopaedic classifier. Changing the receiver's dwell schedule tests scan alias; changing authorised source power tests the threshold artefact; introducing a known timestamp reference tests clock and buffering behaviour; varying harmless environmental covariates tests conditional associations. Each intervention should carry a predicted direction of change. The strongest conclusion comes when a mechanism predicts not only the original observation but also what should happen when one cause is altered while other relevant conditions are held fixed. If no safe intervention is possible, the report must acknowledge an observational result with unresolved confounding. The limitation is not a failure of mathematical sophistication, but evidence of disciplined restraint.

Finally, I should require a visible audit trail of model development, including rejected candidates. An analyst who tests twenty interval features and reports only the one giving a favourable result has not presented the full selection process. A frozen classifier, versioned calibration files, test population descriptions, false-positive examples and clear limits of applicability form part of the evidence. The reader should be able to reconstruct why one signature was nominated and another discarded. This is a question as much of scientific governance as of radio engineering. Statistical analysis cannot transform a set of missing measurements into a historical fact about what a clandestine device intended to do. It can, under

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disciplined conditions, show that a temporal process is incompatible with some explanations and consistent with others, and thereby guide the next responsible observation.

Richard W. Hamming, Peer Question: Professor Box, I should like to test your experimental philosophy against a practical constraint. Suppose a field analyst has an established event detector and can preserve only a few channels of complex samples, while hundreds of other frequencies are represented by threshold-triggered onset times. Changing the detector mid-survey may increase sensitivity but destroys comparability between earlier and later timestamps. Meanwhile, a classifier built with large numbers of features appears to discriminate authorised reference control links from benign bursts, though its most important features are difficult to interpret physically. Would you favour a simpler, weaker model whose features have defensible measurement meanings, or should the apparent improvement in held-out accuracy suffice? How would you evaluate an engineering decision in which the costs of missing a relevant event are asymmetric to the costs of classifying a harmless signal as suspicious? Please distinguish a decision rule for collecting more evidence from a claim that the emitter's nature has already been established.

George E. P. Box, Response: Dr. Hamming, I should begin by asking what decision the numerical analysis is intended to support. If a low-cost alert merely assigns the receiver to collect a longer lawful observation, one can rationally choose a high-sensitivity detector and tolerate more false alarms. A detection intended to support a categorical assertion about the nature of an emitter requires a much higher standard. These decisions have different loss functions, and I would refuse to hide the distinction in an arbitrary

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threshold. An operational loss matrix might assign a cost of 1 to an additional harmless inspection, 10 to a missed opportunity for further lawful measurement, and a much larger cost to an unsupported allegation. The numbers would have to be fixed by responsible stakeholders before the analysis, and the resulting decision policy would remain separate from the scientific likelihood.

As to model complexity, the right comparison is not 'interpretable' versus 'accurate' in the abstract. It is whether the better-performing model demonstrates reliable improvement on independent data drawn from the intended operating conditions and whether that improvement withstands reasonable perturbations. A complex model that uses detector version, receiver-revisit phase or an unrecorded laboratory day as a shortcut may have exquisite apparent accuracy and no transportability. An interpretable model based on calibrated gap distributions, burst length, energy and live-time condition may be easier to diagnose when a field instrument is retuned or replaced. Where the complex model materially outperforms it, retain both as candidates and collect further independent validation, rather than declaring the winner on the basis of a small retrospective advantage.

Preservation should not be sacrificed to classifier convenience. The earlier timestamp record must remain linked to the original threshold and software version. A later, improved detector can be applied to retained raw data where such data exist, with derived events clearly distinguished from those recorded contemporaneously. Otherwise it is better to stratify the observation into epochs governed by different observation kernels, then assess consistency within rather than across incompatible epochs. An alert's meaning is conditional upon the acquisition process that produced it. If one

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half of a survey used threshold A and the other threshold B, the analyst cannot combine the event streams as if they were measured on one unchanging scale.

For the decision-theoretic calculation, assume a candidate source has a 0.10 probability of belonging to the nominated reference class under a declared prior; a further non-invasive monitoring session costs one unit; and missing a true candidate costs ten units. Under this deliberately simplified utility model, the expected loss of doing nothing is 10*0.10=1, equal to the cost of monitoring. The apparent equality illustrates that the decision is sensitive to the stipulated costs and prior. It does not prove the device is a controller. If independent investigation shows that the monitoring session is inexpensive and yields strong new evidence, the expected value of information may favour monitoring even when current classification remains weak. A thoughtful experiment is not a confession that the earlier model failed; it is what responsible evidence gathering looks like when a consequential conclusion demands more than a waveform's rhythm.

Harold Hotelling, Peer Question: Professor Box, your example of Bayesian predictive value is persuasive, but a false-alarm estimate obtained at one laboratory may not remain valid at another where the density of incidental wireless signals, the screening geometry and the availability of the receiver are quite different. The negative population can change faster than the positive signature. Suppose a classifier has been validated against a narrow set of electrically quiet rooms yet is deployed in a hospital engineering wing containing many intermittent medical and building-management transmissions. Even without any change to the unknown source, its posterior probability and false-alert burden will alter. What experimental

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design would allow an investigator to quantify this domain shift, and when should an instrument's classification algorithm cease to issue class labels at all? I also ask whether the classification should explicitly include an 'unknown or out-of-distribution' result rather than force every event into one of the classes observed during training.

George E. P. Box, Response: Professor Hotelling, I agree that a closed set of categories is often an invention of the classifier rather than a truth about the world. A forensic survey encounters devices and interference conditions that its training laboratory has never seen. The classification procedure should therefore contain a rejection option which states 'not reliably assigned within the validated reference classes'. That outcome is not a technical embarrassment. It is the rational response when evidence is insufficient, when a candidate falls outside training support or when competing models provide nearly identical predictions. The confidence attached to a forced label is worthless if the true source lies outside the model's vocabulary.

To measure domain shift, I would construct a validation programme that stratifies sites by objectively described electromagnetic conditions, receiver models, scanning schedules, background occupancy and environmental variation. Whole sites or sessions would be held out so that the assessment does not borrow the distinctive fingerprints of a room already present in training. For each stratum the report would give the number of independent trials, detection and classification results, and an interval of uncertainty. It might be appropriate to recalibrate alert thresholds locally using negative-control observations, but this must occur without peeking at the outcomes used for the final claim. When local negative controls show a false-alert rate

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significantly above the validated range, freeze class labelling and revert to descriptive acquisition pending recalibration.

An explicit out-of-distribution indicator could depend upon feature support, distance from validated combinations of acquisition conditions and instability under modest perturbations. But distance alone is not a universal probability of novelty, and a high-dimensional method can be confidently wrong when training data are incomplete. The simplest practical control is often a known signal run through the same receiver at the start and end of a visit, together with background records acquired under the same schedule. A change in accepted event counts under that control indicates that measurement behaviour has altered. The investigator should then distinguish instrument drift from changing ambient traffic instead of silently transferring the earlier classification rate.

Consider a negative-control comparison: a classifier produced 3 false alerts in 100 independent quiet-room sessions and 27 in 100 independent hospital-wing sessions. Those empirical rates are 3 percent and 27 percent. Pooling them into 15 percent without site qualification conceals the central fact that the environment strongly conditions performance. Moreover, each percentage has sampling uncertainty, and the sessions may not be independent if a single transmitter operates throughout several recordings. A report should present them separately, state its sampling unit and avoid transporting the first rate to the second environment. As you suggest, an explicit 'unknown' category is often a greater contribution to forensic integrity than a fractional improvement in a closed-set accuracy table.

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George E. P. Box, Cross-Peer Question to Walter Laws Smith: Dr. Smith, we have discussed a series of timestamps as if the interval law could be fitted once and then carried from one inspection to the next. But a practical controller may operate in bursts, with short intervals within a burst and long intervals between bursts. It may also be observed by a scanner that independently misses some bursts, or by a triggered recorder that fuses consecutive pulses into one. Could you explain when a regenerative or renewal-reward description is preferable to a simplistic model of independent gaps? I would like a worked example which shows how a mixture of within-burst and between-burst intervals can mislead the analyst about event rate and duty cycle. Please address the boundary problem: in a finite recording, the first and last bursts may be truncated, and the resulting likelihood changes if one forgets that the censoring depends upon the measurement window. A reproducible definition of complete cycles should also state how the analyst handles source state changes occurring within the recording interval.

Walter Laws Smith, Cross-Peer Answer to George E. P. Box: Professor Box, the distinction between ordinary renewal gaps and complete cycles is decisive. A burst source can be represented in terms of cycles that begin at a defined regeneration event, such as an observed start-of-burst marker under controlled recording. Within each cycle a number of pulses may occur with short gaps, followed by a longer waiting period before the next cycle. If the cycles are independent and identically distributed under a particular experimental condition, a renewal-reward calculation relates the long-run average event rate to expected events per cycle divided by expected cycle duration. Yet the individual inter-pulse gaps need not be independent, nor

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need they share one simple distribution. The chosen cycle boundary must correspond to an observable, operationally defined feature, not to the analyst's preferred division of a plot.

For example, suppose a test controller emits exactly three pulses separated by 0.1 seconds, then waits until the next burst start at a period of 20 seconds. Each complete cycle has three pulses and duration 20 seconds, so the long-run pulse rate is 3/20=0.15 per second and the burst-start rate is 1/20=0.05 per second. The observed inter-pulse intervals within a complete cycle are 0.1, 0.1 and 19.8 seconds, yielding a mean interval of (0.1+0.1+19.8)/3=6.667 seconds. That mean correctly corresponds to 0.15 pulses per second in the long run but describes neither the intra-burst spacing nor the burst recurrence interval. An analyst calling 6.667 seconds the device's 'period' would confound three distinct quantities. If the instrument merges all pulses within 0.5 seconds, however, only burst starts remain; the observed rate becomes 0.05 per second and the interval histogram concentrates near 20 seconds.

Finite-window censoring matters. If recording begins halfway through a burst, the first accepted interval is not a complete cycle. If it stops during a long silent period, treating the last partial observation as a completed short interval biases the mean downward. Likelihood methods can include right-censored waiting time and left truncation, provided the observation boundary and the initial state are properly described. A scanner's off-channel periods create further censoring, potentially dependent on scheduling, and should be handled with a live-time mask rather than repaired by arbitrary interpolation. The model may need a hidden-state component if burst boundaries cannot be observed reliably. We should not

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state that the data identify a unique hidden state when several mechanisms lead to the same accepted timestamp sequence.

The renewal-reward model offers a useful decomposition, not a magic classifier. If the laboratory knows an authorised device emits clusters following scheduled sensor measurements, a comparable burst-cycle distribution may support a limited class-level similarity finding. Without waveform, response or environmental evidence, the same pattern could come from monitoring equipment, telemetry, interference or capture logic. I would retain raw pulse and merged-burst catalogues as separate derived records, documenting how each was produced. Comparisons across rooms and dates should use one clearly defined event unit. A pulse rate from one survey cannot legitimately be compared with a burst-start rate from another as if they measured the same physical phenomenon.

Dr. James M. Atkinson, Moderator: Dr. Smith, Professor Box has requested a distinction between elementary inter-arrival distributions and the renewal structure of whole bursts. Please consider regenerative cycles, missed events, incomplete observation and the danger of giving a numerical 'period' a mechanical significance it does not possess.

Walter Laws Smith, Principal Contributor: Dr. Atkinson, an observer can fail at the very first step by choosing the wrong event unit. A physical emission might contain many symbol transitions, one packet envelope, several retransmissions or a complete burst of exchange with another apparatus. If the analyst counts each threshold crossing as an event, an overloaded digitiser may create multiple apparent events from a single physical pulse. If the analyst applies a hold-off interval, it may convert a

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sequence of genuine emissions into one merged burst. One should therefore state whether the interval is measured between symbol transitions, detected pulse onsets, packet envelopes, burst starts or inferred session starts. These are not interchangeable units. They yield different distributions, and a frequency table cannot tell which unit was originally meant after the acquisition metadata have been discarded.

The renewal-reward relation provides a disciplined way to understand clustered sequences. Suppose complete, independent operating cycles have durations C_i seconds and contain R_i accepted events under a stable receiver configuration, with finite positive mean cycle duration E[C] and finite mean reward E[R]. Under suitable regenerative assumptions the long-run accepted-event rate approaches E[R]/E[C]. This is not the reciprocal of the mean within-burst gap unless the event definition and the cycle boundaries make it so. For an authorised controller whose output contains four transmissions per 30-second cycle, the mean nominal pulse rate is four divided by thirty, approximately 0.1333 per second. If a detector accepts only three of those four transmissions per cycle, the rate becomes 3/30=0.10 accepted events per second under that observation condition. The law does not tell us which pulse was omitted. The catalogue of accepted gaps could still suggest a different periodicity. This example introduces an observation-specific reward, not an assertion about some unmeasured clandestine device.

A practical complication is dependence between cycle length and the number of pulses. Suppose an authorised battery controller emits extra retries when the channel is congested. The physical retry count may increase precisely during unusually long cycles. The long-run rate formula

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E[R]/E[C] can still apply under suitable regenerative conditions, but it does not justify multiplying E[R] by 1/E[C] to obtain conditional rates in arbitrary subgroups or treating reward and cycle duration as independent. For diagnostic work one should inspect their joint distribution. Plot R_i against C_i, examine whether longer cycles contain more retransmissions and compare the resulting behaviour with a candidate channel-contention model. A pooled interval histogram loses that relationship; a well-kept experiment need not. The acquisition plan should also distinguish a missing burst from a burst whose pulses all fall below threshold, because the two omissions lead to different interpretations of a cycle.

Now consider the event-missing process. Let each true pulse be detected independently with probability p in an idealised model. If a controller produces four pulses per cycle, the number K of accepted pulses in that cycle has a binomial distribution with parameters 4 and p, and E[K]=4p. With p=0.75, the expected accepted pulse count is 3, which gives the nominal accepted rate of 0.10 per second in our 30-second example. The probability of missing all four is (1-p)^4=(0.25)^4=0.00390625. That is a small but nonzero probability of losing the entire cycle even under independent acceptance. If attenuation or a common receiver outage makes pulse detection correlated, the chance of losing the whole burst can be much larger. One must not borrow this binomial calculation without verifying the independence premise. A receiving antenna in a pattern null creates correlated non-detections across a burst, and a processor that hangs for a second may suppress all pulses arriving during that period.

The boundary of observation is another source of error. Consider a finite experiment that starts halfway between physical bursts and ends while the

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final burst is incomplete. A simple average of completed intervals excludes the last, possibly long, unobserved residual interval. That procedure can bias the estimate of the waiting-time distribution and of the recurrence law, depending on the stopping rule. In some settings a forward-recurrence time has a different distribution from an ordinary renewal interval because a randomly chosen moment is more likely to fall inside a long interval than inside a short one. A field investigator who starts a recording when an interesting indicator first flashes is not sampling the process at a randomly chosen time. The resulting initial interval is selected by the trigger, and assumptions of unbiased stationarity require justification. The acquisition should specify the temporal origin, the policy for ending the recording and whether long silences were recorded or simply left unobserved.

A test can be strengthened by measuring the same reference process with two independently configured but synchronised receivers. One may record continuously while the other uses a scheduled dwell that resembles the field survey. We can calculate accepted intervals for each, retain the observation masks and compare the inferred burst-cycle lengths. If the scan-based instrument reports a conspicuous 30-second period but the continuous reference reveals irregular physical bursts, the supposed schedule was introduced or exaggerated by the observation system. If both record consistent burst starts, the recurrence hypothesis gains support, although the device's role remains unresolved. A third test alters the threshold while preserving waveform acquisition. A pattern of additional short intervals at a lower threshold may indicate previously missed physical pulses or may represent newly accepted noise. The distinction requires waveform checks and negative controls, not wishful thinking.

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Another aspect of regenerative structure concerns equipment states. A controller may have a dormant period, a wake-up handshake, a brief exchange and a recovery phase, so that each cycle contains mechanistically different intervals. A two-state or multi-state model may summarise this sequence, but the states need not be identifiable from timestamps alone. For example, a four-pulse burst could be interpreted as one request and three acknowledgments, or as four periodic telemetry frames, or as repeated threshold crossings of one long modulated emission. Only a lawful controlled exemplar, waveform features or an observed response can discriminate those narratives. The state names in a mathematical model should therefore remain neutral, such as state A and state B, until independent physical evidence supports the claimed function.

I would also insist upon reproducibility across event definitions. A method that labels a source 'intermittent command class' only when the merger window is 80 milliseconds but reverses its conclusion when the window changes to 100 milliseconds is reporting instability in its processing rule, not a robust property of the source. One can prespecify a reasonable range of thresholds and merger windows from calibration, then test whether principal conclusions remain stable. Sensitivity analysis should reveal which steps are responsible for a class decision. If a small defensible change produces a different class, decline the label and retain the timed event observations as evidence of an as-yet-undetermined process. The objective of renewal theory in this setting is to expose the assumptions beneath a claimed recurrence, not to convert uncertainty into certainty by introducing a sophisticated term.

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Solomon Kullback, Peer Question: Dr. Smith, I should like to press the distinction between comparing two candidate renewal models and identifying a radio-link class. Suppose one proposed model is a burst-cycle renewal law with a sharply concentrated 30-second recurrence, and another is a mixture of background Poisson activity and scan-induced deletions. The analyst computes an information divergence between their fitted interval distributions and declares the larger divergence decisive. But both distributions were fitted on the same data, the reference instrument was used in both model constructions, and the intervals overlap through shared burst boundaries. Under those circumstances, the conventional independent-sample interpretation of a divergence estimate seems questionable. What would you count as a genuinely new observation? Could a likelihood ratio remain useful if the two models yield the same marginal gap histogram but different ordering of short and long gaps? How would you prevent the very construction of the burst boundaries from determining the result that is supposedly being tested?

Walter Laws Smith, Response: Professor Kullback, a divergence quantifies a distinction between specified probability distributions; it does not provide independence, identify a source or validate the estimated model family. If the two candidates are fitted on the same record, the apparent separation is vulnerable to overfitting, especially when the burst boundaries are selected to make one model look orderly. An honest comparison should fix the event-merging and cycle-definition rules on a training set or in a calibration experiment, then apply the frozen rules to independent recording sessions. The likelihood should be based on whatever stochastic structure the model actually asserts. If it predicts the ordered sequence of complete cycles, the

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likelihood of ordered cycle observations is relevant; a histogram-only likelihood may discard the very dependence that separates the models.

The significance of temporal order can be demonstrated simply. Imagine a record with six inter-arrival gaps, three of 0.2 seconds and three of 12 seconds. One arrangement alternates short and long gaps. Another places three short gaps together and three long gaps together. The marginal histogram is identical, yet their transition structure differs sharply. A model of paired exchanges or short bursts might make a specific prediction about that order; a simple independently sampled mixture would not. An ordering-sensitive test must be defined before the validation sequence is inspected and must include measurement uncertainty in event boundaries. If the source has been observed through gaps, even the true order may be partially unknown because unrecorded events can lie between accepted timestamps.

One can formulate a comparison using a likelihood ratio on complete, well-defined cycle observations under two frozen models, or a predictive log-score difference on withheld sessions. In either case, uncertainty should respect the dependence within cycles and between repeated sessions from the same apparatus. Repeatedly slicing one record into many overlapping windows does not multiply the number of independent devices or operating conditions represented. If independent field sessions are scarce, a hierarchical model can acknowledge common session effects, but its inferential limits should be reported. The weight of evidence then applies to the tested alternative models, not to the entire universe of possible RF sources.

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As for boundary selection, I would anchor the rule to an observable marker established by a controlled physical test, such as a known waveform envelope or a documented trigger from the reference apparatus. Where no marker exists, repeat the analysis across a prespecified range of merger windows and show how inference changes. A conclusion that depends critically upon an arbitrary interval cut-off should remain provisional. An attractive measure of information can never compensate for an ill-defined unit of observation. That is precisely why the definition of an event belongs in the methods section ahead of the first histogram, and why a forensic reviewer must be able to run the complete pipeline from preserved source data to the reported interval sequence.

Walter Laws Smith, Cross-Peer Question to Peter Whittle: Professor Whittle, let us suppose that an investigator observes intermittent detections at a succession of frequencies and notices that intervals within each frequency contain apparent cycles near 20, 40 and 60 seconds. Some analysts might call these harmonics of a scheduling clock, but others would recognise the receiver's own 20-second revisit cycle. I should like you to address the relationship between spectral analysis of event counts and the time-domain laws we have discussed. How can a point-process spectrum or a sampled count series acquire lines that did not originate in a transmitter's internal oscillator? What test would discriminate the physical periodicity from an alias created by regular observation gaps? If the receiver cannot collect all channels continuously, what bounds should be placed on a negative result at an unobserved frequency, and what role can an altered, incommensurate revisit schedule play in an independent confirmation?

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Please include the effect of pulse thinning on the spectral shape, since uniform event loss is not equivalent to systematic censoring by the receiver.

Peter Whittle, Cross-Peer Answer to Walter Laws Smith: Dr. Smith, a line in the spectrum of accepted-event counts is not necessarily a line in the spectrum of the physical emission process. The observed event train is shaped by the instrument's sampling and detection operations. Under a simple idealisation, a periodic exposure mask multiplies a time-varying event intensity. Multiplication in time creates convolution of spectral content, and periodic components of the mask can shift or mix energy into the observed spectrum. A low-frequency pattern in a binned count series may therefore be an alias of sampling, a property of a nonstationary event rate, or a genuine recurrent source feature. Its presence alone does not distinguish among these origins. A purported scheduling frequency should be tested against independently logged receiver revisit phases and a controlled, differently timed acquisition schedule.

Consider a source whose physical event process has no preferred 20-second rhythm and a receiver that can detect the nominated channel only for one second in each 20-second cycle. The observed event opportunities cluster into one-second windows at times approximately 0,20,40 and 60 seconds, even if physical events arrive independently at constant intensity. A histogram of accepted events can then exhibit peaks related to the scan schedule, and an event-time periodogram may show a line or modulation at the scan repetition frequency. If the receiver next uses a 23-second revisit cycle while other conditions are stable, an artefact induced by its attendance can move towards the new schedule; a genuine physical schedule should not simply follow the instrument's chosen period. This is a controlled

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discrimination strategy, not an unqualified proof, because source behaviour and the observation environment may change between tests.

A frequency-domain calculation can help expose the problem. A nominal 20-second revisit has a fundamental frequency 1/20=0.05 hertz. A 23-second revisit has a fundamental frequency 1/23 approximately 0.043478 hertz. An apparent 0.05-hertz feature that follows the instrument to about 0.043478 hertz supports an observation-mask explanation. A feature that remains near 0.05 hertz under continuous observation or under several independent schedules more strongly supports physical recurrence, provided the event-detection pipeline and clock calibration are comparable. The comparison must be accompanied by the spectral resolution available from the observation duration. For a 200-second record the nominal Fourier spacing is 1/200=0.005 hertz; that is small enough to separate these particular idealised frequencies in principle, but finite-window leakage and sparse event counts may prevent reliable discrimination in practice.

Negative evidence deserves similar restraint. When the receiver is off-channel it does not observe silence. It observes nothing at that frequency. We can state a probability of missing events under a calibrated model of duty cycle, detection efficiency and burst timing; we cannot assert their physical absence merely because no accepted timestamp appears. If the source's scheduling phase is nearly locked to the receiver's off-channel windows, even a substantial total observation time may offer little effective exposure. A defensible report therefore gives the live-time mask, the relevant model assumptions and the uncertainty surrounding any upper bound on event rate. I thank you for the question; I would return to the

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moderator the larger issue of how our spectral and temporal diagnostics can be tested together rather than elevated into competing slogans.

Dr. James M. Atkinson, Moderator: Professor Whittle, the panel has now examined renewal assumptions, doubly stochastic intensity, experimental selection, burst-cycle structure and spectral aliasing. Please bring these matters together in a practical identification protocol for an intermittent radio source, with explicit attention to what the evidence does not establish.

Peter Whittle, Principal Contributor: Dr. Atkinson, the useful mathematical object is not a single histogram but a collection of observations related by an explicit dynamic model. We may regard the underlying emitter as producing a point process, the receiver as applying a time-dependent observation operation and the analyst as computing summaries from the resulting catalogue. An observed event train can be represented symbolically as Y(t)=sum_i delta(t-t_i), where t_i are accepted event times and delta denotes an idealised point mass, but the engineering system has finite timestamp precision, filter settling, threshold latency and dead-time limitations. We should therefore distinguish this mathematical abstraction from the digitised instrument output. If an engineer bins accepted events into intervals of width Delta, the resulting count series can be analysed as a stochastic time series, but its autocorrelation and spectrum depend upon Delta and on the live-time process. A class label should not be attached to any single peak without asking what else would make that peak appear.

There are several distinct frequencies in the problem. A device may contain a master reference oscillator at megahertz frequencies; its message

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scheduler may operate at a fraction of a hertz; the receiver's channel revisit may repeat every few seconds; the timestamp processor may empty buffers at a different rate; and the investigator may finally bin events at a chosen sampling frequency. These scales interact. The visible periodicity of accepted event counts may arise from a scheduler, but it may also arise from a beating or alias between the physical and observation operations. The word harmonic should therefore be used with precision. A series of equally spaced lines at multiples of a rate is a feature of a periodic sequence, yet the existence of such lines in a measured count spectrum does not identify which physical or procedural element supplied that periodicity. The experiment must include independent timing references and deliberate changes to acquisition conditions.

A quantitative example illustrates the care required. Suppose a benign training source produces an accepted event intensity that fluctuates sinusoidally, $\lambda(t)=\lambda_0[1+a\cos(2\pi f_0 t)]$, with $\lambda_0=0.4$ events per second, modulation depth $a=0.5$ and $f_0=0.025$ hertz. This gives a 40-second intensity cycle, with minimum intensity 0.2 and maximum 0.6 events per second; the expected number of physical events in a full 40-second period is $0.4*40=16$. But the actual event intervals are random even when the rate changes periodically. The observed gaps need not cluster neatly at forty seconds; a periodogram of sufficiently long, correctly observed event counts may instead reveal the modulation. If a scanner visits the frequency for only two seconds every forty seconds, the instrument's exposure also has a forty-second cycle. The observed modulation may then be dominated by the scanner, and the model will not be identifiable from a single schedule.

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We should test whether the schedule survives an alteration of the observation operation. Keep the calibrated source unchanged in a controlled experiment, then repeat acquisition with an incommensurate revisit period while logging the actual, rather than commanded, tuning epochs. For example, change a 40-second receiver revisit to 37 seconds while preserving total live exposure as closely as feasible. A feature caused by the exposure mask should change its phase relationship or spectral position in a way predicted by that mask. A genuine source modulation can persist at 0.025 hertz, though its observed amplitude and precision may change because the new sampling window weights events differently. The two schedules must be compared using a common clock calibration, prespecified frequency region and uncertainty model. In a live field environment the source may not remain stationary between these tests; the report must therefore treat the result as conditional and, where possible, use simultaneous independent channels.

The choice of spectral method should match the stochastic process. A conventional Fourier transform of a uniformly sampled count sequence implicitly assigns zero count to each bin, but a bin in which the receiver was off-channel is missing exposure, not a genuinely observed zero. Replacing missing bins with zeros can manufacture apparent duty cycles and low-frequency modulation. One may instead analyse event likelihood conditioned on exposure, use a point-process spectral method that accounts for censoring, or restrict comparison to suitably matched live intervals. Each method has assumptions to test. The response of a spectral estimator to gaps should be characterised with simulated ground-truth data passed

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through the recorded observation mask. That process exposes whether an attractive feature is robust or an algebraic echo of the sampling schedule.

Our statistical decision should be hierarchical. First establish that accepted events are real RF-related detections rather than false triggers, buffer duplicates or calibration pulses. Next establish that their temporal structure is inconsistent with selected benign baselines under the correctly modelled receiver observation process. Next determine whether a candidate family of known lawful devices predicts the observed combinations of timing, waveform shape, spectral occupancy and controlled response better than a sufficiently broad set of alternatives. Only then may one describe a limited class-level resemblance, with quantified uncertainty and a stated domain of validation. At no point does statistical resemblance alone identify a particular concealed device, an operator, an intended recipient or a malicious purpose. Those are different propositions requiring independent evidence.

A negative search should be formulated in the same disciplined way. A receiver that observes a frequency for only ten percent of a survey does not provide evidence equivalent to a continuously monitored receiver with the same elapsed time. Consider a physical process with independent events at rate lambda=0.02 per second and an ideal live fraction d=0.10, with live intervals sufficiently dispersed and event detection perfect when live. Over T=1,000 seconds, the expected accepted count under the simplified independent-thinning approximation is lambda*d*T=0.02*0.10*1000=2.0, and the probability of zero detections is exp(-2)=0.1353. A null result thus remains quite plausible despite twenty expected physical events over elapsed time. If the duty windows happen systematically to miss scheduled

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physical events, the zero-detection probability could be higher still. One must report the temporal alignment assumption and the observed live-time mask, not merely the nominal exposure fraction.

I should expect the final evidence package to include the raw or least-processed lawfully retained observations, a timestamp ledger in a documented time scale, receiver live-time and retune logs, detection and merger thresholds, calibration evidence, a frozen analysis script, representative negative controls, independent validation results, and a concise statement of the hypotheses that remain indistinguishable. An appendix might include the normalised interval histogram, burst-cycle summaries, selected conditional-intensity diagnostics, and a periodogram calculated on an exposure-corrected basis. These objects serve different questions and should not be collapsed into one number. A line on a screen may catch the eye; only a documented sequence of measurements can support a conclusion about the process which produced it. I return the token with the observation that sober uncertainty is itself a valuable technical result when the alternative is a confident misclassification.

Peter Elias, Peer Question: Professor Whittle, your proposal treats the event catalogue as one of several lossy representations of a radio waveform, but a sophisticated classifier might take advantage of the dependence between pulse timing and the actual encoded payload. Where encryption or unfamiliar modulation prevents decoding, engineers may be tempted to use timing alone as a proxy for the function of the communication. Suppose a lawful training series establishes that one type of automation controller emits short bursts at irregular intervals after a sensor threshold is crossed, while another periodically announces status without requiring a command.

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In an unknown observation both may show clustered bursts and similar latency distributions, especially when the receiver misses portions of the spectrum. Would you allow the words 'control link' on a report in those circumstances? Can the technical conclusion be phrased in terms of observable input-output behaviour without implying that the analyst decoded a command? Finally, what independent intervention or measurement would most efficiently reduce the ambiguity while remaining wholly within authorised defensive inspection?

Peter Whittle, Response: Dr. Elias, the phrase should be constrained by the actual evidence. If the analyst has only timing and no independent observation of message content or controlled input-output behaviour, the strongest safe statement may be 'intermittent RF burst process with timing features similar to selected reference automation devices'. The term control link implies an exchange in which information is used to influence the state of a recipient. It is not established by a waiting-time distribution alone. An encrypted payload may prevent decoding, but inability to decode should neither be treated as evidence of innocence nor as evidence of a concealed command. The unobserved semantics remain unobserved.

The most useful lawful intervention depends upon what part of the mechanism can safely be controlled. In an authorised laboratory exemplar, deliberately vary a known physical stimulus and record whether a specified response follows within a predeclared latency window. Repeat with sham stimuli, independent clocks and a reference receiver capable of retaining the burst waveform. Such a design supports statements about the exemplar's stimulus-response behaviour. At an unknown site one should not manipulate an unidentified apparatus without authorisation; instead, one

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can characterise the receiving instrument through known reference injections, observe changes across receiver configurations, or compare signatures with independently validated exemplars. A controlled change in the receiver's observation schedule, by itself, can eliminate a scan artefact without interacting with the source at all.

It is helpful to divide the conclusions into successive levels. At the measurement level, the report can say that N accepted bursts occurred within a particular live-time mask and can give their timestamp uncertainty. At the statistical level, it can compare predicted interval distributions or holdout log scores under named models. At the engineering level, it can state which waveform, timing and environmental features resemble those of a calibrated reference class. At the functional level, it can claim actual control behaviour only if a linked response or independently verified protocol function has been established. Confidence at one level does not automatically transfer upward to the next. The mathematical description of intervals cannot convert an unknown payload into a decoded command.

For a practical example, suppose an authorised training device is stimulated in 40 randomised trials and a prespecified corresponding burst appears within 0.5 second in 34 cases, while 2 of 40 sham trials produce an apparently similar burst. The observed triggered proportion is 34/40=0.85 and the sham proportion 2/40=0.05. This difference may support a controlled association in that specific training apparatus, but confidence intervals, selection of latency window, independence of trials and possible environmental cues require assessment. It says nothing by itself about an unknown emitter that merely resembles the reference waveform. A genuine identification would need evidence connecting the unknown source to an

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equivalent controlled behaviour. A rigorous report gains authority by marking precisely where a measured fact ends and a provisional explanatory hypothesis begins.

Dr. James M. Atkinson, Moderator: I thank Professors Feller, Cox, Box, Smith and Whittle, and their questioning colleagues, for the disciplined distinction between event timing, observation artefacts, statistical classification and physical source attribution. The conclusions are confined to lawful defensive measurements and are presented as a fictional scholarly reconstruction. Question 077 remains an exercise in inferential method, not a historical transcript or an allegation about a particular radio system. We pass the token to the next question only after the independent structural and editorial controls have been satisfied.

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QUESTION 078

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When do adaptive detection thresholds conceal a rising RF noise floor?

Editorial disclosure. This is an original fictional educational reconstruction. Statements assigned to deceased historical contributors are newly authored illustrations, not historical quotations, transcripts, or evidence of an actual conversation.

SCHOLARLY RECONSTRUCTION. This hypothetical academic roundtable brings deceased scientists and engineers into a contemporary discussion of radio-frequency monitoring. Their contributions are newly written pedagogical interpretations, not authentic spoken testimony, verified quotations, or claims that these historical specialists personally worked with modern SDR consoles. All numerical case studies are stipulated illustrations requiring validation against the actual deployed equipment.

Dr. James M. Atkinson, Moderator: Professor Neyman, our monitoring system appears disciplined. Its alarm-rate graph stays nearly level, the operators hear the same modest sequence of alert tones from one watch to the next, and the event counter suggests nothing material has changed. Yet an independent calibrated probe reveals that broadband noise at the receiving input has gradually increased, while a lawful reference emitter of constant received power is disappearing from the detection log. What distinction must be made between regulating false alarms and preserving sensitivity? Please examine the decision hypothesis, the observable RF reference plane, the statistical assumptions, and the engineering evidence required before the operator may assert that a negative surveillance finding remains meaningful.

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Jerzy Neyman, Principal Contributor: Dr. Atkinson, an alarm is a decision conditioned upon a statistical model; a quiet alarm register is not a measurement of sensitivity. It is tempting to regard an almost constant count of reported excursions as evidence that the receiving installation remains unchanged. That inference confuses the distribution of the decision variable under the no-signal hypothesis with the distribution under the signal-present hypothesis. I would insist upon two separate measured properties. Let P_{FA} be the probability of deciding that a signal is present when it is absent, evaluated under a stated noise and interference condition. Let P_D be the probability of correctly deciding that a specified signal is present, evaluated for its strength, waveform, duration, arrival geometry, and the same receiving chain. A detector can regulate the first while the second deteriorates. Neither probability is a universal property of the instrument independent of its operating state.

Consider the deliberately simplified scalar experiment in which an observable X, measured in calibrated linear power units after a declared bandlimiting operation, is exponentially distributed with mean noise power μ under the null hypothesis H0. A threshold γ yields $P_{FA}=\Pr(X>\gamma|H0)=\exp(-\gamma/\mu)$, provided the exponential model and sample conditions apply. To obtain the illustrative target $P_{FA}=0.01$, choose $\gamma=-\mu \ln(0.01)$, approximately 4.605μ. If the actual mean noise power doubles from one to two arbitrary units, an adaptive algorithm preserving that target raises the threshold from approximately 4.605 to 9.210 power units. A steady false-alarm fraction is then perfectly compatible with a threshold that doubles. The model concerns one independent tested cell and does not directly

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describe threshold crossings clustered in time, millions of dependent FFT bins, or the event-level false-alarm count of a live console.

For an especially transparent illustration, suppose a narrow-band reference source contributes an additional fixed power $S=4$ units to the tested statistic and the decision statistic is approximated by $X=S+N$, where N is nonnegative exponentially distributed interference. This additive-power simplification is not the exact distribution of a complex voltage detector under a coherent signal, but it exposes the decision logic without pretending to a universal receiver law. At $\mu=1$ and $\gamma=4.605$, the illustrative detection probability is $\Pr(N>0.605)=\exp(-0.605)$, approximately 0.546. At $\mu=2$ and $\gamma=9.210$, the fixed signal falls farther below the threshold, and the probability is $\exp[-(9.210-4)/2]$, approximately 0.074. Thus the false-alarm probability is regulated at one per cent in both conditions, while detection of the fixed signal falls sharply. A proper laboratory test should replace this toy distribution with the actual waveform and processing statistics rather than publishing those numbers as equipment performance.

The inferential difficulty is not solved by replacing an adaptive threshold with a fixed one. Under rising noise, a fixed power threshold calibrated to the quieter environment generates more false alarms and can overwhelm the decision system. A sensible instrument may legitimately maintain a chosen false-alarm level as the noise varies. The forensic failure occurs when the instrument presents that design achievement as evidence of unchanged coverage. I require the report to retain the estimated noise in linear units, the threshold in the same calibrated units, the gain and attenuation state, a reference-signal detection curve, and the time series of changes. A graph of

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alarm counts alone omits the changing denominator against which signals are being judged.

The reference plane is equally important. An apparent noise rise at the digitiser output might be generated by a preamplifier, reference oscillator, switching converter or automatic-gain-control state rather than arriving through the antenna. The observed signal power can fall even while environmental noise stays fixed, for example when a connector changes loss or an attenuator enters the path. Consequently define the tested quantity at the antenna terminal, receiver input, or digital detector input, state every transformation and calibrate them. A second receiver sharing the same cable or amplifier does not automatically provide independence. Challenge the system using an input termination, calibrated noise source and injected weak reference waveform, observing the detection threshold and measured input-referred noise under each state.

A detection claim must also specify duration. A fixed test tone injected for ten seconds may survive an adaptive threshold that rejects a twenty-millisecond pulse, because integration time, dwell, triggering and the effective degrees of freedom differ. For each signal class, measure P_D as a function of calibrated input power, and retain the full curve or its appropriately bounded confidence interval rather than merely quoting one sensitivity figure. Include known negative controls and non-detections. If the detector's threshold follows its own test signal into the estimated background, the experiment must reveal that contamination. Guard windows, holdout frequencies and a separate reference input can help, but only when their independence and band responses are established.

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The decisive legal and scientific conclusion must be conditional. An unchanged reported false-alarm rate proves neither that the same weak emissions would be detected nor that the RF environment was unchanged. A defensible statement would say that the alarm controller met its nominal false-alarm criterion within the tested statistical assumptions, while the instrument's measured detection probability for specified reference signals changed in the documented way. An adverse conclusion based on absence of alarms must identify intervals when absolute noise or threshold changes made the survey materially less capable of seeing the relevant emissions. Exact confidence requires calibration data, not an elegant but untested formula.

Sir Ronald A. Fisher, Peer Question: Professor Neyman, your illustrative exponential statistic is attractive because the resulting threshold can be written in one line, yet the real receiver rarely supplies independent identically distributed power samples. It may average overlapping transforms, report maxima across correlated cells, and select a detection window only after the operator has noticed something suspicious. How should the calibration distinguish the false-alarm probability of one preselected cell from the probability of at least one alarm over an entire search, and what information must be retained if the analyst chooses a detection threshold after examining the same data? I am especially concerned that an estimated one-per-cent false alarm probability might become an unsupported statement about a night's monitoring, during which millions of opportunities existed and the opportunities were neither statistically independent nor uniformly observed. Could you specify a

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replication scheme in which the calibration and the evaluation of the decision rule remain genuinely separate?

Jerzy Neyman, Response: Sir Ronald, the unit of inference must be named before the probability is computed. A single-bin false-alarm probability concerns one predeclared tested statistic under H0. The probability of at least one false alarm across m independent tests would be 1−(1−p)^m, where p is the per-test probability, but that formula ceases to be exact when the tests are dependent or the number of tests was itself selected after inspection. At p=0.01 and m=100 independent tests, the probability is 1−0.99^100, approximately 0.634, not 0.01. A monitoring console that groups neighbouring exceedances into events may report an entirely different event-level count. One must therefore calibrate the actual pipeline, including its window overlap, clustering, detection masks and operator selection protocol.

I would partition the experimental record into at least a development set and an untouched validation set, with partitions chosen by independent acquisition runs where possible rather than by adjacent, strongly correlated samples from one capture. The development set defines the threshold rule and its parameters; the validation set estimates its performance without readjustment. A designed noise-only exposure measures false detections, and an independently generated sequence containing known weak signals measures missed detections. For periodic or slowly varying environmental noise, an additional held-out day or temperature condition tests generalisation beyond the development regime. When the analyst changes thresholds after seeing the validation results, that set has become part of development and cannot support the same untouched claim.

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A useful reporting table contains the number of independent trials as defensibly defined, the number of false alarms and misses, confidence intervals that acknowledge clustering, and the operating state. Do not manufacture independence by taking every FFT line as a separate replicate. Resampling can preserve blocks or entire acquisition sessions to retain dependence, but it cannot correct a fundamental absence of relevant operating conditions. For every claim, distinguish the per-cell nominal criterion, observed event-level rate, and achieved detection probability. The mathematical model should be audited against deliberately injected weak signals and against alternate noise-only configurations. If one detector version was selected because it looked best among many investigated versions, document that selection and avoid attributing the winning estimate to a model that was fixed in advance.

David R. Cox, Peer Question: Professor Neyman, the measurement equation still seems incomplete to me. An adaptive threshold is not updated by a disembodied noise law; it is updated by a sequence of observations, some delayed and some missing. The algorithm may use a moving median, a trimmed mean, or exponentially weighted measurements, while the receiver can change gain and preselector settings. Could two records with the same present noise power yield different thresholds because their histories differ? If so, the state of the estimator becomes an unobserved confounder in a naive comparison between two survey locations. Please describe the minimum history and intervention needed to demonstrate a deterioration in sensitivity without confusing it with delayed adaptation, and say how one should handle a constant weak reference signal that is sometimes included in the estimator's training windows. Would the

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comparison also report the number of qualified receiver dwell visits, the duration of each unobserved interval, and the order in which injected references are encountered? Without those covariates, an apparent time trend might simply be a different sampling frame rather than a genuine change in signal visibility.

Jerzy Neyman, Response: Dr. Cox, a threshold generated by a recursive estimator is a state variable as well as a function of current RF observations. Two systems with equal current input noise may produce different thresholds if one has just left a high-noise interval and the other has been quiet for an hour. The history can be scientifically relevant even when the adaptive algorithm is operating exactly as its designer intended. A record limited to a current noise estimate and threshold cannot always reconstruct how the decision was formed. Retain the update equation, estimator initial state, effective time constant, reference-cell selection, exclusions, gain state, lost-sample indicators and every manual or automatic reset. These controls make it possible to replay the decision from contemporaneous information rather than from a retrospective reconstruction that silently assumes steady conditions.

For example, an exponential estimate might obey $\mu\text{hat}_k=(1-\alpha)\mu\text{hat}_{(k-1)}+\alpha X_k$, where α lies between zero and one, X_k is a measured reference-cell power and k indexes qualified updates. If α=0.1, an abrupt noise increase is reflected slowly; if α=0.8, the threshold follows quickly but is also more sensitive to transient contamination. The count k should represent actual admitted updates, not merely wall-clock seconds. A receiver visiting one frequency infrequently does not acquire the same history as a continuously observing instrument. A missing update must not

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be silently replaced by a zero-power observation, since that would introduce its own bias. In a nonstationary environment the threshold is a filtered history, and any claim about preserved sensitivity must be tested over the time path, not just at its final equilibrium.

I would expose the receiver to a controlled sequence: quiet baseline, gradual broadband-noise ramp, stable elevated noise, then recovery, with a constant independently verified weak signal present throughout. Repeat the sequence after changing update rate, gain and signal placement; use a third condition in which the reference signal is absent from the estimator's reference windows. Compare observed threshold history and miss rate to an instrumented fixed-threshold observer, making clear that each serves a different inferential purpose. The fixed observer helps reveal absolute noise movement, while the adaptive observer may better regulate nuisance alarms. If the reference signal contaminates the training cells, its own power can elevate the threshold and cause self-masking, a separate hypothesis from broadband noise alone. Only an experiment that distinguishes those mechanisms should support the final technical explanation.

Jerzy Neyman, Cross-Peer Question to Walter A. Shewhart: Dr. Shewhart, I have insisted on separating false alarms from detection probability, but your control-chart tradition confronts a question my simplified test leaves unsettled. When may the analyst call a rising baseline a genuine process change, rather than a transient fluctuation or a reference disturbance caused by the instrument? If an adaptive detector regards the new baseline as normal within a few updates, does that amount to a loss of evidence about the change point? Please identify which streams should be treated as measurements to preserve and which may legitimately be treated as control

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variables. I would also welcome a worked example contrasting a display that normalises each period to its contemporary noise with a fixed metrological monitor whose calibration does not itself drift. How should a survey report communicate these two viewpoints without suggesting that either one is the whole truth? Please name a control rule that responds to an absolute calibrated-power trend independently of the self-adjusting alarm rule, including the conditions under which the two instruments must be judged to disagree.

Walter A. Shewhart, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, the principal correction is to distinguish a measured process from the control rule designed to respond to it. An adaptive detector may maintain approximately stable alarm frequency by redefining its baseline whenever the observations change. That is a useful operating strategy for certain purposes, but it is a poor sole witness to whether the receiving environment has changed. I would maintain an immutable reference stream in a fixed, calibrated measurement system. From that record one can evaluate the absolute input-referred noise, its time sequence and possible shifts. The operational detector's normalised statistic is a different derived record, governed by its own update law. Neither ought to overwrite the other.

Suppose a monitoring channel reports 10 arbitrary calibrated linear-noise units during a reference period and 16 units after a change in the environment, whereas an adaptive processor divides every observation by its current estimate of baseline. A stable normalised quotient near one can coexist with a 60 per cent increase in measured power. In decibels, the ratio is 10 log10(16/10), approximately 2.04 dB. The normalised graph and the

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calibrated graph are not contradictory, but they answer different questions. A control chart computed over the unaltered absolute record can identify a sustained rise that the decision controller was deliberately designed to follow. Whether the rise warrants an alarm depends on the documented control limits, the uncertainty of the reference, the serial dependence and the operational consequences.

The control limits must not be selected solely from the affected interval. Establish a stable reference period with verified instrument configuration, identify known maintenance and calibration actions, and record the sensitivity of the conclusions to window length. In practical monitoring, the environment may possess predictable daily variation; comparing a day to a night without modelling this pattern can manufacture a change. Likewise a broadband surge in a neighbouring transmitter can temporarily alter the apparent baseline without establishing a permanent defect. For change-point inference, examine persistence, repetition and physically discriminating tests. Switch to a terminated input to challenge antenna-origin noise; use a calibrated noise source and independent receiver to test whether the apparent increase follows the front end or the environment.

A complete report would present two parallel timelines: one of absolute input-referred noise and one of operational decision threshold and alarm rate. The historical baseline, reference plane and update policy must be recoverable. It is legitimate that an adaptive detector chooses a different threshold to limit false alarms, but that action must not erase the evidence that the threshold rose. Where negative detection findings are important, augment both streams with scheduled weak-signal challenges and measure their probability of detection. The operator should hear the distinction

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between a quiet alarm bell and a healthy receiver; one is a property of the configured decision, the other requires an independent performance test.

Dr. James M. Atkinson, Moderator: Dr. Shewhart, Professor Neyman has distinguished the statistical target from the ability to detect a real signal. I now ask you to examine the physical record as a process whose operating point changes. What can a properly preserved control history reveal when the receiver's own adaptive baseline makes the outward alarm record appear stationary?

Walter A. Shewhart, Principal Contributor: Dr. Atkinson, the sound of an unchanged alarm cadence can conceal a most important shift in the underlying measured process. I would begin with the instrument's traceable engineering measurements, rather than with the detector's designation of normality. A control rule is developed for a purpose: it may maintain the workload of an operator, prevent excessive nuisance reports, or keep an event rate approximately steady across changing environments. Such regulation need not protect the forensic meaning of a negative search. When the regulator succeeds, the observer may see fewer signs of change in the derived outputs precisely because a new threshold has absorbed it. That is not a contradiction. The instrument can be statistically in control in the limited sense of its decision policy while the environmental noise experienced by the antenna has materially increased.

I distinguish three timescales in this problem. There is the physical timescale of the broadband interference: it may rise in seconds as a machine is activated, drift over hours with temperature, or vary periodically with the site schedule. There is the estimator timescale, determined by averaging

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windows and the selection of observations used to update the baseline. Finally there is the reporting timescale: an operator may receive only five-minute summaries, hourly alarm counts, or selected event screenshots. A fast physical change can be diluted by a slow report; a slow physical change can be followed continuously by a fast estimator and thereby disappear from a normalised trace. To interpret the result, one must retain enough temporal resolution to reconstruct all three histories and state exactly which trace is a raw measurement and which has been transformed.

Suppose a receiver stores a power estimate P_k every qualified second and uses a moving average of the previous 60 admitted values to generate an adaptive threshold. A gradual noise increase over 30 minutes will cause the baseline to climb while the ratio of current power to baseline remains close to its historically expected value. The nominal alarm rate may therefore remain stable. A separate, frozen reference chart of input-referred power, measured in a fixed bandwidth and referenced to the same connector plane, could demonstrate that the absolute noise is rising. The analyst must not reconstruct that reference chart by taking the adaptive output and multiplying it by an unavailable estimated baseline. Preserve the actual values, estimator state and configuration changes at acquisition time, because the inversion may be impossible once observations have been discarded or censored.

It is also essential to separate common-cause variation from assignable causes. An ambient RF environment is naturally variable, particularly around electrically noisy equipment and changing antenna geometry. A single upward sample does not establish deterioration. Yet a sustained run of increasing noise, synchronised with an identifiable change in supply,

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antenna location or receiver configuration, warrants a controlled challenge. The objective is not to pronounce a cause from the chart but to design experiments that would make competing explanations behave differently. A terminated-input measurement may challenge whether the excess noise enters through the antenna, but it changes the physical configuration and must be interpreted cautiously. A safe calibrated noise injection downstream of the antenna can measure the receiving chain, while a separately positioned sensor can test whether the environment changed. No one test establishes the whole case.

A control chart's nominal false-alarm probability depends on its assumptions. If the measured power sequence is serially correlated because overlapping FFT windows or estimator smoothing are used, three successive excursions are not three independent warnings. If the baseline distribution is heavy-tailed, a control limit computed under a Gaussian idealisation can trigger too often or too rarely. The act of choosing a threshold after seeing the largest excursion also changes the inferential question. I would therefore divide the work into reference qualification, ongoing monitoring and challenge-testing. The reference period is chosen and documented in advance. Its uncertainty and likely environmental variability are evaluated before the operator interprets any excursion as anomalous. A sustained absolute noise rise should then be evaluated against those limits, independently of the adaptive detector's internal decision rule.

One can construct a useful experiment using two otherwise equivalent software channels fed from the same digitised samples. The first channel operates at a fixed, calibrated input-referred threshold; the second uses the adaptive estimator under study. In addition, a known weak reference

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waveform of fixed power is inserted intermittently under a schedule withheld from the detector's threshold calculation. Record the true injection schedule, both alarm outputs, the adaptive threshold, the absolute power baseline and all automatic-gain-control changes. During a controlled broadband noise ramp, the fixed channel may show a rising false-alarm fraction; the adaptive channel may maintain stable false alarms while increasingly missing the reference waveform. That experiment demonstrates the trade-off directly and allows the operator to explain it without calling either architecture universally superior.

Measurement discipline requires one further precaution. Apparent gain changes and log-power shifts may arise from arithmetic or representation errors. A mean of decibel values is not generally the logarithm of the mean linear power, and a detector that updates its baseline in dB may behave differently from one whose threshold is estimated in linear units. If the physical power increases by a factor of four, the change is 10 log10(4), approximately 6.02 dB. A displayed rise of six decibels is meaningful only when the measurement bandwidth, detector, gain state and calibration plane remained comparable. Operators should be shown both the physical transformation and the uncertainty in its calibration, not a numeric display with unexplained decimal places.

In the final report, I would require an explicit change log, an immutable absolute-noise series, the adaptive-baseline history, and the results of both positive and negative controls. The absence of detections can support only a bounded assurance statement for the signals, powers and intervals over which the instrument remained demonstrably capable. A stable alarm cadence should be treated as evidence about the behaviour of the algorithm

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under its specified operating conditions. It is not independent evidence that the environment was quiet or that the instrument remained equally sensitive. The most useful control design preserves the measured disturbance even when the decision system successfully adapts to it.

George E. P. Box, Peer Question: Dr. Shewhart, your distinction between the physical process and the adaptive display is persuasive, but I worry about the phrase 'fixed reference' becoming another hidden model. A reference chart based on an unusually quiet morning, or on an antenna whose gain changed when someone moved a cabinet, can give a dramatic indication of change without demonstrating deterioration of the receiver. How would you decide which environmental covariates belong in the baseline and which ought to remain as separately reported disturbances? Could a model that adjusts for temperature, time of day and known transmissions inadvertently remove the very broadband increase we wish to discover? Please explain how the engineer should test model adequacy using data beyond the calibration interval, and how to resist the temptation to redesign the control limits until the preferred diagnosis appears. Where would a separate calibrated tone or noise witness fit into that decision? Would you randomise the test-order of the injected weak references, and would you state the temporal sampling plan before inspecting the adaptive alarm trace, so that the independently observed change is not retrospectively selected to fit the apparent result?

Walter A. Shewhart, Response: Professor Box, a fixed reference is a defined experimental condition, not a declaration that one morning represents the whole world. I would require the survey plan to distinguish the operating envelope from the specific hypothesis. If temperature is a

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recognised source of receiver noise-figure variation, the qualified model may include its independently measured effect. If broadband electromagnetic interference is the phenomenon of interest, it would be improper to subtract it away merely by adding a flexible environmental trend that learns every excursion as normal. The model must represent a causal measurement system and not a curve fitted to the desired conclusion. Pre-registering the relevant covariates and their expected directions provides some protection against retrospective explanation.

Use separate calibration experiments to determine the receiver's gain and noise response as a function of temperature and configuration. Then monitor the live environment with those corrections and with uncertainty bands that retain the calibration error. A model that predicts an exact power change because of a temperature sensor should be challenged at more than one temperature and on another day; the observation being corrected must not itself be the sole evidence for the correction coefficient. For a survey location, preserve the antenna position, cable state and nearby equipment operations as explicit covariates. If the target hypothesis is that external noise increased, report the raw observation and the corrected estimate side by side rather than hiding the raw series.

I would also reserve independent days or controlled trials that were not used to select limits or covariate terms. A quiet reference emitter, injected at a known level after a declared RF reference plane, helps test gain stability. A calibrated broadband noise witness helps distinguish an environmental rise from an instrument change. Neither should be embedded thoughtlessly in the baseline estimator's reference cells; contamination can alter the very threshold under investigation. Where removal of an expected

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environmental effect reduces an observed rise, the report should document both results and the justification. If the conclusion changes materially under plausible models, the uncertainty is epistemic and must not be replaced with a narrow ordinary error bar.

Control limits remain conditional on the chosen process. I would not accept a revised limit merely because the first one generated too many uncomfortable warnings. An authorised improvement can be introduced with a versioned date and a fresh prospective qualification run, while retaining the earlier classification and the reasons for changing it. The analyst should state the coverage for which the limits were validated, the extent to which data were serially correlated, and whether the change tested was sustained. A model is a tool for organising evidence, never a device for making the history look cleaner than it was. That is especially important when a negative surveillance report may later be read as a claim that no relevant emission existed.

Walter A. Shewhart, Cross-Peer Question to Norbert Wiener: Professor Wiener, I can preserve the absolute power series and a parallel adaptive-threshold history, but the receiver's estimator is a dynamical system. Its smoothing creates memory, and its response to a rising background may be delayed in ways my simple static control limits do not explain. Would you formulate the relationship among the physical input, estimator state, gain-control feedback and detection output without pretending all errors are stationary? How should one measure the effective time constant when updates occur only during intermittent frequency visits, and what would distinguish a benign transient from an estimator that has incorporated the constant weak reference signal into its own noise model? I would also ask

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whether seemingly smooth transitions can conceal genuine step changes through interpolation or data loss, especially when the hardware clock and software reporting clock disagree. Can one derive a practical step-response acceptance test from the estimator equation, then specify what independent instrument measurement is required to detect an estimator that follows the changing environment correctly but thereby conceals a physical sensitivity loss?

Norbert Wiener, Cross-Peer Answer to Walter A. Shewhart: Dr. Shewhart, an adaptive detector is properly considered a causal dynamical system whose output depends upon its input history and internal state. Let x_k be the calibrated observation admitted at update k, let m_k be the estimated background, and let α be a weighting factor between zero and one. An elementary estimator has $m_k=(1-\alpha)m_{(k-1)}+\alpha x_k$. For a step from baseline m0 to constant x1, after n valid updates its estimate is $m_n=x1+(m0-x1)(1-\alpha)^n$. The effect of the initial baseline decays geometrically, but the number of qualified updates matters. A receiver that revisits the tested band once per minute will adapt far more slowly in wall time than one that continuously receives a new observation each second, even when both use the same α. A report must identify this difference, not quietly replace sample count with elapsed time.

For α=0.1, the weight of the initial state after ten updates is 0.9^{10}, approximately 0.349. After twenty updates it is approximately 0.122. Those are not necessarily ten or twenty seconds; they could represent minutes or an irregular sequence of visits. An increasing background may therefore be followed with a lag determined jointly by the algorithm, the observation schedule and the loss of qualified samples. During the lag, a fixed-level

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signal may briefly pass the threshold and subsequently disappear, giving the impression of a transmission that stopped. The relevant evidence includes the estimator state at each decision, whether an update was admitted, the temporal sampling map and independent measurements of actual input noise.

Automatic gain control adds another feedback path. If analogue gain g_k changes, the digital statistic might decrease while input-referred noise increases, depending on how the calibration and detector normalisation are applied. A well-designed system records g_k, attenuation, ADC full-scale reference and gain uncertainty, then transforms observations to a stable input plane where physically defensible. A displayed baseline can remain visually flat while the receiver's absolute detection capability falls because of overload, compression or altered preselection. Conversely, a gain-control transient can create a digital-noise rise without a corresponding external field change. The controller state must therefore be challenged separately from the environmental hypothesis.

Self-masking is established by selective experiments. Inject the same weak signal into a known cell, first with that cell excluded from training and then with its spectral skirts allowed into the reference window. Observe whether the estimator rises and whether the decision threshold follows it. Vary the guard interval and test under a broadband ramp with a second independently monitored signal. If the feature is lost only when its own power contaminates the estimator, the cause differs from ordinary noise-induced loss of SNR. Repeat with controlled phase, amplitude and duty-cycle changes, because leakage can vary with windowing. One must not infer a unique mechanism merely from the correlation of two curves.

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Finally, interpolation of a missing background estimate is a processing assumption, not a measurement. It can make the threshold trace smooth while hiding a sudden equipment-state transition or an unobserved RF event. Preserve the original sequence, missing-data markers, state resets and separate monotonic hardware chronology. The model is valuable precisely when its limitations are visible. A smooth red line on a control display should not persuade a forensic reviewer that the underlying physical path was continuous, just as a stable false-alarm counter should not persuade them that sensitivity remained fixed.

Dr. James M. Atkinson, Moderator: Professor Wiener, Dr. Shewhart has placed the historical process and the modern control law on separate records. Please examine the filtering, feedback and sampling mathematics in greater depth, especially the circumstances under which the threshold's own adaptation will make a gradual loss of sensitivity appear as an orderly, quiet monitoring operation.

Norbert Wiener, Principal Contributor: Dr. Atkinson, the essential point is that a receiver is not a passive window through which a fixed background is viewed. It is a chain of transformations, and some of those transformations depend upon previous observations. An adaptive threshold is a filter driven by a statistic of the measured signal, a choice of reference cells and a model of nuisance variation. The output is a controlled decision. If the filter tracks the physical disturbance, the disturbance can disappear from the normalised display without disappearing from the antenna. Conversely a transient introduced by the filter or a changing gain state can create a displayed anomaly even while the incident electromagnetic field is unchanged. The engineering task is to identify these pathways by

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perturbation and measurement, not by assigning intention to a characteristic-looking trace.

For a simple linearisation, let $n(t)$ represent the input-referred background power over a declared bandwidth and $m(t)$ an adaptive estimate. An ideal first-order continuous-time approximation is $\tau\, dm/dt + m = n(t)$, with τ positive and measured in seconds. The approximation is useful only when observations are effectively continuous and the algorithm behaves approximately linearly. For an abrupt step of size Δn at time zero, the model gives $m(t)=n0+\Delta n[1-\exp(-t/\tau)]$ for $t\geq 0$, assuming the system was initially at $n0$. The physical input jumps immediately while the estimated threshold approaches its new value gradually. When an operator inspects only the ratio of observed power to $m(t)$, the apparent disturbance depends upon the time constant and may fade even when the input remains permanently elevated.

A realistic frequency-agile receiver complicates the model. It can tune the channel for a short dwell, skip intervals while other bands are visited, and retain the last threshold across those gaps. The effective filter is updated on a sequence of sample admissions, not on an idealised continuous clock. Define t_k as the actual physical time of qualified update k, and $\Delta t_k=t_k-t_{(k-1)}$. A time-constant-consistent exponential smoother can use $\alpha_k=1-\exp(-\Delta t_k/\tau)$, whereas a fixed α applied once per received block weights each block equally regardless of elapsed wall time. Neither approach is universally correct, but they imply different threshold histories. Missing data, stopped counters and variable revisit schedules therefore matter directly to the conditions under which one can rely upon a negative finding.

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The receiver may also include feedback in automatic gain control. Let g(t) denote analogue gain, and suppose the output statistic is approximately g(t) times the sum of external signal and noise, subject to the device's nonlinearities and calibration. A controller reducing g(t) to prevent overload can make the digital power look stable. Yet the signal-to-noise relationship at the input has changed, and a small input tone may no longer cross the post-detection threshold in the same way. A fixed noise figure is not sufficient to characterise gain and compression under a powerful blocker. The analyst must record attenuator settings, gain-control command, compression indicators and the calibration that converts digitised observations to an input-referred quantity. When the conversion is invalid during overload, mark the observation rather than force a tidy calibrated number.

The RF scene can change slowly while a filter is designed to remove slow changes. A high-pass operation on estimated residuals makes sudden excursions conspicuous and drift inconspicuous. A median reference window resists isolated bright cells but can absorb broad interference covering much of the reference region. An order-statistic detector may behave differently when the distribution of reference-cell powers changes shape, even though their mean stays constant. In each case the difficulty is not merely an estimated noise level; it is the mismatch between the assumed nuisance model and the physical mixture of thermal noise, interference, true weak emissions and internal artefacts. The statistics should be challenged with known input conditions representing each mixture.

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There is a useful distinction between regulating P_FA and preserving P_D that must be read aloud in the laboratory. An adaptive detector may set a threshold proportional to a local noise estimate. Under ideal homogeneous assumptions the probability of false alarm can remain approximately constant as that estimate rises. But the signal-to-noise ratio of a fixed input waveform declines. If its calibrated signal power S remains at −110 dBm while input noise in the relevant bandwidth rises from −120 dBm to −114 dBm, the nominal signal-to-noise ratio falls from 10 dB to 4 dB. Those are illustrative input powers; a logarithmic subtraction is valid for the power ratio when the same bandwidth and reference plane are used. Maintaining the same nuisance alarm rate does not restore the six decibels of lost SNR. Detection probability can deteriorate even though the control chart looks quiet.

How does one expose the loss? Use an independently generated weak signal injected before the elements whose performance is being evaluated, and schedule it blindly to the detector where possible. Measure its detection probability at several calibrated input powers under each noise condition. Place a second wideband witness channel alongside the adaptive detector and do not allow both to share all calibration errors. Introduce a controlled broadband ramp and separate controlled gain changes. A constant false-alarm criterion is valuable operationally, but should be accompanied by a minimum detectable signal or receiver operating characteristic measured under conditions comparable to the actual survey. The word 'sensitivity' must be attached to a specified waveform, dwell duration and probability of detection; otherwise the operator has only a catalogue slogan.

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The final complication is that feedback can make an instrument appear stable even when its underlying assumptions have become invalid. A strongly nonstationary disturbance may alter the distribution of the statistic within each smoothing window, and a moving estimate can fail to track abrupt transitions while responding to persistent noise in a misleading way. A noise floor measured in a logarithmic display can be numerically averaged in ways that do not reproduce mean physical power. An estimator can be trained on its own intermittent signal of interest and inadvertently suppress it. For these reasons, preserve raw digitised evidence, the filter state and every derived decision so that an independent reviewer can replay alternatives. Without this provenance, one cannot establish whether the quiet console reflects an unchanged environment, successful nuisance regulation or degradation of the measurement chain.

Claude Shannon, Peer Question: Professor Wiener, your treatment of threshold adaptation as filtering is persuasive, but I would like to press the informational consequence. A monitoring computer may store only alarms and their timestamps, discarding raw samples and the threshold state because it judges the other observations uninteresting. If a weak signal falls below a rising adaptive threshold, is its loss merely a reduction of sensitivity, or has the compression of the original record also destroyed evidence that could have been recovered by a different detector? In evaluating a negative finding, how should one distinguish an inaccessible waveform whose samples were retained from one whose samples were never recorded? Please also explain why applying a more elaborate retrospective classifier cannot recreate information destroyed by clipping, saturation, non-observation or deliberate event-only logging, even if the classifier's

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estimated confidence appears mathematically precise. Please distinguish a display that retains the full power spectrum from one that archives only Boolean alarms, and specify which claims can be reconstructed from each representation after the monitoring period has ended. The distinction determines which hypotheses can ever be tested.

Norbert Wiener, Response: Dr. Shannon, the distinction is between a lost decision opportunity and a lost physical observation. If the receiver retained the original complex samples, a later analyst may apply a different detector, calibrate a changed noise floor, vary integration time and test a more suitable waveform model. Its eventual conclusion remains conditional on the data's actual bandwidth, noise, time continuity and instrument state. If the computer saved only threshold-crossing events, it has reduced an analogue or complex-valued observation to a sparse decision record. The absence of an event then does not disclose the statistic's distance below threshold or even whether a valid measurement was available for the interval. One cannot generally reverse that transformation, because many distinct physical histories produce the same event log.

A second type of loss occurs before the detector. If the ADC saturated during a strong broadband disturbance, the clipped waveform may suppress or distort a weak component. A more elaborate algorithm cannot uniquely reconstruct information about the unclipped waveform from the saturating samples without additional assumptions. If the receiver was tuned elsewhere or the hardware dropped samples, no observation of that portion of the spectrum exists in the affected interval. Mathematical interpolation can produce a smooth substitute but not an independent measurement of the omitted emission. These limitations are distinct from a

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case in which a good waveform record was retained but an unsatisfactory threshold suppressed its online alert.

Consequently I would keep an acquisition ledger recording tuning state, sample counters, clock reference, gain, overload flags and the exact interval of actual coverage. A rolling retention scheme may be necessary for storage efficiency, but it should retain enough pre-event and background data to evaluate whether the threshold was functioning and what the RF environment looked like. If only events are preserved, the report should not assert that the receiver proved an absence of transmissions; it should state that its configured decision system produced no qualifying alerts under the limitations of its retained record. The wording may appear conservative, but it preserves the distinction between inference and observation.

For testing a proposed retrospective classifier, keep a separately recorded known-signal challenge set with ground truth and full raw samples. Compare what the algorithm could detect when full data are available with what a replay limited to event-only logs can establish. No amount of classifier complexity changes the information content of the shorter record. A machine learning system may assign an impressive probability to its own features, but the probability pertains to a model conditional on the observations supplied. If the relevant signal's evidence was physically clipped or never stored, a probability cannot make it reappear. The crucial forensic question remains what was actually acquired, what was preserved, and what was inferred afterwards.

Richard W. Hamming, Peer Question: Professor Wiener, the receiver's software may implement the correct mathematical filter on paper yet give a

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misleading field result through numerical representation and state handling. One implementation updates a power estimate in linear units, another averages decibels, and a third resets its running state whenever a USB stream times out. A detector may also process repeated blocks after a transport retry while treating them as independent fresh evidence. Which software assurance tests would reveal these failures, and how would you distinguish them from genuine adaptive control behaviour? Please outline a replay-based test that a second laboratory could perform with the same recorded I/Q data and configuration, while taking care that the replay's wall clock, buffer order and floating-point arithmetic do not introduce a different threshold history from the deployed hardware. Would a test using irregular dwell times, numerical overflow guards and a reboot between two noise states demonstrate the same decision rule as a continuous ideal simulation? Explain what belongs in the reproducibility record when thresholds are computed in fixed-point arithmetic.

Norbert Wiener, Response: Dr. Hamming, the software must be tested as an implementation of a state machine, not merely as a function mapping one instantaneous number to another. Define the exact units of the estimator and threshold, input transformation, initial state, update trigger, sample count, handling of missing blocks, numerical precision and event-clustering rule. A running estimate of linear power followed by a logarithm is not generally equal to the average of logarithmic power samples. For example, two equally weighted linear observations of 1 and 9 units have mean 5, whose decibel value relative to one unit is approximately 6.99 dB. Averaging their individual decibel values gives (0+9.54)/2, approximately

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4.77 dB. This is an illustrative difference of about 2.22 dB caused solely by the order of operations, not an RF field change.

A reproducible replay begins with immutable raw I/Q blocks and a complete acquisition ledger, including sample order, actual hardware timestamps, selected channel, gain and dropped-block markers. Fix the algorithm version and test vectors, then execute the same sequence without using the replay machine's current wall clock as a substitute for original acquisition time. Where state updates are triggered by each qualified block, reproduce exactly those triggers. Where elapsed time is a model input, use the saved monotonic device chronology and record how gaps are handled. The reference implementation and field implementation should agree within specified numerical tolerances; exact bitwise agreement may be impossible across some hardware floating-point implementations, but any difference affecting an alarm outcome must be explained.

Test state reset, stream interruption, packet duplication and out-of-order delivery deliberately. If the driver repeats a block after a retry, the threshold should not silently count it as a new independent observation. If a gap occurs, the algorithm must apply its declared missing-data policy rather than treating absent samples as zero-power measurements. If a threshold-history file is overwritten by later calibration, reconstructability is destroyed. Preserve both the original output and any subsequent corrected replay with versioned transformations. Software alarms should include the contemporaneous threshold, background estimate, gain state, and update count to permit a reviewer to reproduce the decision.

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The replay should include controlled waveforms and an independently verified reference noise ramp, so that detection probability can be compared against actual ground truth rather than against the field program's own classifications. Run a quiet reference condition, a gradual noise increase, a sudden noise step and a recovery sequence; include constant weak signals at several levels. A software pass means that the implementation behaves as specified over these tests. It does not independently prove that the specification is the correct model for every RF environment. That further scientific claim requires external calibration and tests of model adequacy. This distinction prevents a perfectly reproducible algorithm from being presented as a perfectly reliable survey instrument.

Norbert Wiener, Cross-Peer Question to John W. Tukey: Professor Tukey, your methods of exploratory analysis may reveal distributional changes that a fixed parametric noise model overlooks. Yet a monitoring programme can become a statistical fishing expedition if an analyst chooses whichever threshold or reference-cell method gives the most reassuring event count. How should one compare a moving mean, a percentile, a trimmed estimate and an ordered-statistic rule when the RF background contains clustered interference and a constant weak reference emission? What diagnostic displays would expose contamination of reference cells, and how would you protect an independent evaluation set from choices made during exploration? In particular, I ask whether a stable median noise estimate could coexist with a rising tail of rare interference and therefore support a misleading conclusion about effective detectability even when the absolute mean is not obviously changing. In particular, will a robust location statistic still expose rare intervals when a short authorised test pulse is

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systematically suppressed? I ask for a prospective failure criterion defined before the analyst looks at which estimator performs most attractively.

John W. Tukey, Cross-Peer Answer to Norbert Wiener: Professor Wiener, exploratory methods are valuable precisely because a single summary does not characterise every relevant property of the distribution. A stable median can coexist with a growing upper tail, increased clustering or more frequent short broadband disturbances. Conversely, an increasing mean may be caused by a handful of interfering cells rather than a uniform rise in the thermal background. A detector whose threshold uses an order statistic may be relatively insensitive to sparse outliers but can still become compromised when contamination occupies enough of its reference window to change the chosen percentile. No one number describes the whole environment. I would display quantiles, the proportion of saturated or excluded cells, time-frequency occupancy, and the distribution of reference-cell values together with the final adaptive threshold.

For a simple illustrative distribution, suppose ninety of one hundred equal-duration background observations have linear power 1 and ten have power 11. The median is 1, while the arithmetic mean is (90×1+10×11)/100=2. A median-based estimator might report stability if the ten high-power observations became progressively larger without crossing half the sample. Yet an intermittent weak emission that coincides with those ten intervals can be masked more severely even when the typical observation remains quiet. This is a constructed example, not a claim that the median estimator is defective. It shows why a performance statement must specify whether it addresses typical noise, tail risk, or the probability of missing a specified signal during actual monitored intervals.

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I would organise the experimental record into labelled physical configurations, not simply a long undifferentiated sequence. In the first condition generate homogeneous stationary noise; in the second add rare high-power bursts; in the third impose a smooth broadband increase; in the fourth introduce a constant weak signal whose timing is blinded to algorithm selection. Evaluate the moving mean, median, trimmed mean and ordered statistic under all four conditions, with guard cells and reference bandwidth specified. Record performance at a common event definition and a common duty cycle. The method that best regulates nuisance alarms may differ from the method that best protects a low-power signal, and neither should be called optimal without a declared objective and tested distribution.

Exploratory analysis may select plausible models, useful plots and hypotheses, but once those choices are made they should be frozen before evaluation on an untouched set of recordings. If the analyst repeatedly inspects the held-out set and modifies the threshold until the desired performance appears, the holdout is no longer independent. A new prospective sample or separate laboratory trial is required for an unbiased check of the final procedure. The report should retain failed variants as part of the design history, especially when the chosen variant substantially changes a negative survey conclusion. Robustness is not established by the neatness of a single final trace; it is demonstrated by performance across controlled departures from the assumptions that made the original model convenient.

Dr. James M. Atkinson, Moderator: Professor Tukey, the panel has identified estimator memory and loss of raw information. Please test

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whether the distributional assumptions underlying the threshold have remained adequate. In particular, what can the operator learn from the tails and spatial structure of the observed spectrum that a well-behaved median or average might conceal?

John W. Tukey, Principal Contributor: Dr. Atkinson, it is a dangerous habit to replace the RF environment with a single reassuring summary and then mistake the summary for the environment. A broadband power record may have a median, a mean, a high percentile, a maximum and a duration distribution, each revealing something different. If an adaptive detector adjusts its threshold from a median or a selected order statistic, that choice determines which changes are made conspicuous and which changes are accepted into the background. The choice may be sound for the operating objective, yet it cannot by itself support a claim about the probability of detecting every emission of interest. We should inspect the distribution and its temporal ordering before assuming that a stationary estimate is evidence of stable conditions.

Begin with the practical contrast between a quiet majority of observations and a growing minority of severe disturbances. A median can remain almost unchanged as the upper tail grows dramatically. A conventional mean can rise because a small number of strong events contaminate the reference region, while a lower percentile remains stable. An adaptive detector using the median might maintain a moderate threshold but miss weak signals in the disturbed intervals. Another using the mean might raise its threshold across the whole survey and thereby miss weak signals even during quieter intervals. Neither outcome is proved merely by looking at a threshold graph. The performance of interest is the conditional detection probability for

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specified signals under specified interference states, integrated over the actual time coverage of the survey.

One may use a conditional mixture model to explain the problem without pretending the true distribution is known. Suppose a monitored interval is quiet with probability $1-q$ and disturbed with probability q. Let $P_{D,q}$ be the probability of detecting a fixed reference signal under the quiet condition and $P_{D,d}$ the probability under the disturbed condition. Then the overall detection probability under the stipulated mixture is $(1-q)P_{D,q}+q\,P_{D,d}$, provided the condition is classified correctly and the probabilities refer to the same signal definition. For example, let $q=0.2$, $P_{D,q}=0.95$ and $P_{D,d}=0.20$. The mixture gives $0.8\times0.95+0.2\times0.20=0.80$. If the disturbed fraction rises to $q=0.5$ while conditional probabilities remain unchanged, the overall probability falls to $0.5\times0.95+0.5\times0.20=0.575$. A detector might maintain a stable false-alarm rate in both mixtures, yet its actual survey coverage for the reference signal is substantially different.

The analyst must not treat the examples' q values as probabilities derived automatically from a spectrogram. The disturbed state must be defined and measured, perhaps using a calibrated input-referred power threshold, an independent broad-band witness or known equipment-operation records. Its temporal duration is important. Twenty per cent of isolated samples does not have the same practical meaning as twenty per cent of an evening concentrated in one continuous outage. A brief burst of interest may be much more likely to occur during certain equipment cycles than under an independent random-time assumption. If the signal and disturbance processes are correlated, the simple mixture with fixed conditional

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probabilities may require a conditional-intensity model or a scenario-bound analysis instead of a single aggregate percentage.

I favour displays that expose how the estimator was trained. For each decision, preserve the distribution of powers in the reference cells, their frequency positions, guard windows, exclusion rules, and the number actually used. A bright emission leaking into neighbouring bins can contaminate a cell-averaging threshold. A percentile threshold might resist several contaminated cells but fail once contamination becomes widespread. A sudden change in frequency occupancy can affect the reference set without affecting a distant clean test channel. A claim of stable sensitivity therefore needs a frequency-specific performance map, or at least a carefully justified set of representative bands and signal types. No one global baseline can be assumed representative of every preselector state and antenna direction.

The exploratory process must be honest about selection. An operator may compare several thresholds on the same file and choose the one that yields the fewest nuisance reports. That is a legitimate part of engineering development, but it is not independent validation of the chosen detector. The evidence for an eventual field conclusion should come from a separate test set or prospective measurement under known physical conditions. If the detector was repeatedly tuned after the practitioner examined the weak reference detections, it may have overfitted that particular waveform and environment. Record all candidate configurations, their training data, their objective function and the final frozen choice, then assess the selected rule against different days, temperatures, bandwidths and interference mixtures.

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A further distinction concerns amplitude distributions and event processes. The background-power values may have a stable histogram while their order in time changes: several isolated high-power cells become clustered into one long interference episode. The fraction of elevated samples may be constant, yet the probability that a short target burst coincides with a blind interval can rise or fall, depending on temporal dependence. One must inspect run lengths, conditional detection probabilities, dwell schedules and time-frequency clusters rather than relying solely on a power quantile. This connects the present discussion to the preceding roundtables on blind time and event grouping, but its particular contribution is to show that baseline estimation itself can conceal changes in the distribution of nuisance power.

The recommended report would contain, for each qualified operating state, the input-referred power distribution, robust and ordinary summaries, adaptive threshold history, false-alarm counts and measured detection probability for known reference signals. It would explicitly show whether conclusions change under reasonable reference-cell methods, window lengths and assumed dependence models. A quiet median or a quiet alarm counter is useful information, but neither is a complete performance certificate. The investigator should prefer a transparent account of the conditions in which the detector remains capable to a universal assurance statement derived from a carefully selected and ultimately fragile statistic.

George E. P. Box, Peer Question: Professor Tukey, I agree that a mixture of quiet and disturbed conditions should be considered, but your formula assumes the analyst can assign each interval to the correct condition. In a real monitoring system the condition label may itself be determined by the same adaptive detector under examination. Would that not lead to circular

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reasoning, particularly where weak signals contribute to the reference-cell power or a receiver's gain change shifts the observed distribution? How should the practitioner distinguish a genuine rise in environmental noise from a changed front-end transfer function without declaring the detector's own estimate to be independent ground truth? Please describe a prospective study that uses external reference measurements, varies source level and bandwidth, and permits the resulting probability-of-detection estimate to be reported with uncertainty rather than as an exact number from a convenient toy model. How would you prevent a weather condition, preselector state or receiver-temperature shift from becoming a convenient retrospective label that explains away every miss? The design requires a prospective cross-condition challenge rather than a perfect fit to old data.

John W. Tukey, Response: Professor Box, the condition label should not be defined solely by the algorithm whose sensitivity one seeks to evaluate. That would permit the tested detector to decide both which examples count as difficult and how well it performed. A separate calibrated witness can provide a reference classification of environmental noise, with its own limitations recorded. One might use a broadband power receiver operating at a fixed reference plane and independently logged gain state, supported by a known injected waveform and terminated-input tests. The witness should record its physical bandwidth and calibration uncertainty. An independent channel sharing a common oscillator, preamplifier or cable may still have correlated errors, so independence must be specified rather than assumed from separate software windows.

I would define the weak test signals by their known source generation and measured received power, not by whether the candidate detector happened

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to alarm. Randomise or otherwise conceal the injection schedule from the classifier wherever practical. Use several fixed input levels near the anticipated decision boundary and multiple durations and waveforms, retaining non-detections and recordings of failed trials. Independently vary environmental background through lawful laboratory noise injection, while also repeating receiver-only controls with a terminated input. A change that follows the antenna environment but not an injected receiver-only condition has a different causal interpretation from one that follows the amplifier or gain controller. Each inference should be supported by a stated comparison, not by an appealing spectral colour map.

The final statistical estimate should acknowledge the number and dependence of valid trials. If eighty independent scheduled reference bursts are injected at a specified power and sixty-four are detected, the observed fraction is 0.80. That empirical proportion is not an exact probability of detection; it has sampling uncertainty and may be condition-specific. If those eighty bursts are grouped into four long episodes with shared noise and hardware state, the effective information is less than eighty fully independent trials would suggest. Use a confidence interval or a cluster-aware method matched to the design, and present results across the different noise states rather than a single aggregate. The reporting unit is the physical injection opportunity, with valid capture status recorded, not merely the detector's successfully reported events.

I would pre-register the classification rules used for quiet and disturbed conditions and then assess how results change under a defensible range of alternate rules. The uncertainty due to classifying the noise state is distinct from the sampling uncertainty of observed detections. If the result changes

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materially when the threshold separating states moves by one calibration uncertainty, report that sensitivity. A claim about the installed receiver should also identify the preamplifier, antenna, cables, reference source and gain configuration, since they determine whether the laboratory result can transfer to field operation. A cleanly estimated probability for the wrong configuration is not useful assurance. It may nonetheless be a valuable diagnostic when the limits are clearly identified.

John W. Tukey, Cross-Peer Question to Harold S. Black: Mr. Black, the statistical analysis has depended upon the hypothesis that the receiver's measured noise rise is a change in the input environment. But the electrical chain itself can adjust, compress, introduce correlated spurs or alter its equivalent input noise while making the digitised noise appear deceptively stationary. Would you challenge the physics underlying that interpretation? I ask particularly how automatic gain control, front-end overload, cascaded noise figure and reference coupling can create situations in which the adaptive threshold remains steady but the minimum detectable input signal worsens. Please formulate an instrument-challenge sequence which would distinguish a rise in incident broadband power from an internal noise or gain defect. And can a simultaneous increase in external noise and gain compression render a simple fixed-threshold comparison especially misleading? Could an input-referred absolute-power witness and a separate gain-state record discriminate those causes when the console presents the same flat alarm history? Please state the physical calibration boundary and explain how an uncertain connector loss enters the result.

Harold S. Black, Cross-Peer Answer to John W. Tukey: Professor Tukey, your question restores the physical receiving chain to a statistical argument

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that could otherwise lose sight of it. A receiver's digital output power is not identical to the input-referred noise at the antenna terminal. Its filters, cable losses, preamplifier gain, mixer conversion loss, analogue-to-digital reference and automatic-gain-control policy all contribute. A strong blocker may compress a preamplifier or mixer, reducing the gain available to a weak signal while altering the output-noise distribution. An attenuator inserted automatically to protect the front end can reduce both the wanted signal and some noise components, but the resulting input-referred noise figure may worsen. If a detector renormalises the digital baseline after that change, its alarm count can remain outwardly well regulated even though the weak input signal is no longer observable.

One must test the chain from a declared reference plane. Measure calibrated input power through an authorised reference tone and broadband noise source, while logging amplifier gain, attenuation, preselector state, ADC headroom and any compression indicator. Begin with the antenna replaced by a suitable termination to determine internal contributions under safe controlled conditions. Then use a characterised input stimulus whose power is stepped through the weak-signal region, with and without an independently controlled out-of-band blocker. A blocker-induced decrease in observed weak-signal gain under constant injected input is evidence of desensitisation; a rising calibrated environmental witness without comparable receiver-state change supports a different component. The comparison should preserve the physical settings and a repeatable source path, rather than relying on a screenshot made after automatic corrections.

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For a cascade of stages, one may use the linear Friis noise-factor relation $F_{total}=F1+(F2-1)/G1+(F3-1)/(G1G2)+\ldots$, where F1, F2 and F3 are stage noise factors and G1, G2 are preceding available power gains, under matched, linear, small-signal conditions. If first-stage gain falls because an attenuator enters before the low-noise amplifier, later noise contributions become more important when referred to the input. The effective input sensitivity may therefore worsen even while the detector's software estimate adjusts to preserve a nominal false-alarm rate. The relation should not be forced onto a compressed, time-varying or mismatched chain without stating that its assumptions fail. In overload one must make an empirical measurement of gain and unwanted-product generation, not merely cite the small-signal cascade calculation.

External noise and overload can coexist. A stronger environment may trigger gain-control action that further reduces the weak-signal margin; the two effects should not be counted as statistically independent sources of loss without measuring their interaction. Run the calibrated weak signal across noise and blocker levels, retain the absolute threshold and achieved detection probability, and record every gain transition. Use a second receiver or reference configuration to challenge common-mode errors while being candid about shared paths. A stable alarm count then becomes one useful operational indicator among several, rather than the deciding evidence of receiver health. The practitioner should record the physical mechanisms and the uncertainty in each transition before concluding that no relevant emission occurred in the monitored space.

Dr. James M. Atkinson, Moderator: Mr. Black, Professor Tukey has challenged the integrity of the physical input measurements, and your

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answer has shown why an algorithmically stable output can conceal a deteriorating receiver. Please complete the roundtable by examining gain, noise factor, overload and testability as a coherent engineering problem, and by specifying how those measurements should qualify a negative RF search.

Harold S. Black, Principal Contributor: Dr. Atkinson, a detection threshold has no physical significance until the entire receiving chain has been described. The signal entering an antenna terminal may traverse a cable with frequency-dependent loss, a preselector, a low-noise stage, an automatic attenuator, a mixer, analogue filters and a digitiser. A decision algorithm sees the final transformed samples. Its claimed sensitivity depends upon what those samples represent and upon the state of the analogue chain that produced them. A fixed alarm rate at the digital output can coexist with substantial loss of input sensitivity. An ordinary engineering audit must therefore trace each measurement to the input reference plane and distinguish changes in the RF environment from changes introduced after the wave reaches the instrument.

Noise figure is an informative quantity when used correctly. In a linear, matched, small-signal receiver, the noise factor F is the ratio of input signal-to-noise ratio to output signal-to-noise ratio, both expressed in linear units. The noise figure is NF=10 log10 F decibels. If an initial stage has noise factor F1 and available gain G1, its gain suppresses the input-referred effect of later stage noise as shown in the cascaded noise-factor relation, within that relation's assumptions. But a lossy cable before the first amplifier raises system noise figure, and automatic attenuation inserted ahead of a sensitive stage can reduce the weak-signal margin. A gain-control setting may

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compensate for a powerful signal at the cost of small-signal detectability. Therefore a manufacturer's best-case noise-figure number does not certify the effective sensitivity of a deployed installation with changing attenuation and uncertain cable loss.

Consider two hypothetical operating states. In the first, a receiver has a calibrated input-referred noise power of −120 dBm over the measurement bandwidth, and a weak reference emission of −110 dBm therefore has nominal SNR 10 dB before any algorithmic processing. In the second, external background rises to −116 dBm and an automatic input attenuator or a changed front-end state adds an effective two-decibel sensitivity penalty for the same test waveform. The total degradation of the weak-signal margin cannot be inferred by simply adding two alarm-screen readings. It requires a calibrated test that characterises the noise contribution and the gain change in their actual physical order. In a simplified budget one might expect approximately six decibels less usable margin, but the final detection probability depends upon the waveform, detector, bandwidth, integration and interference distribution. The correct result should be measured, not assumed from an attractive round figure.

A receiver can be 'quiet' because it has become less sensitive. Under overload, mixer products and gain compression may suppress a weaker emission while producing apparent noise or a forest of spectral lines. If the detector tracks the increased measured background and raises its threshold, nuisance alarms may fall or remain constant even while the receiver cannot see its intended targets. Conversely an internally generated noise increase can cause the adaptive threshold to rise although incident RF energy is unchanged. The source of the change matters operationally:

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moving an antenna, repairing a cable, adjusting a preselector, changing gain or reducing blocker exposure addresses different causal mechanisms. It is irresponsible to advise such intervention without identifying the mechanism and preserving the unmodified evidence.

The first diagnostic should define a reference plane. At the input of the receiving instrument, use a correctly terminated and calibrated test connection to measure its noise and response with safe laboratory equipment. Repeat after inserting the deployed cable and preamplifier to locate the additional loss or noise contribution. Next introduce the expected antenna environment and compare independent input-referred observations, noting that the change in termination, coupling and impedance itself affects some noise measurements. When the test source is injected before a preamplifier, its power must be measured at the declared plane. A signal generator setting on its front panel is not automatically the level delivered to the device under test. Include mismatch, splitter and connector loss where material.

A positive-control signal is particularly important during unattended monitoring. Choose several safe power levels near the expected sensitivity boundary, vary duration and frequency, and schedule the test so that the operating detector cannot simply memorise its pattern. Retain the actual injection state, raw samples where available, estimated noise, adaptive threshold, gain configuration, preselector state and final alarm decision. From these records compute or bound the detection probability for the tested signal class at each RF state. A control signal that is always comfortably strong does little to demonstrate weak-signal sensitivity. A proper challenge must include levels at which the receiver sometimes

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succeeds and sometimes fails, because the shape and displacement of that detection curve are the object of the experiment.

Frequency agility makes the duty cycle a further limitation. A reference tone may be on the channel at precisely the times the receiver is tuned elsewhere. One cannot call that a threshold failure without first establishing that the signal was actually presented to the receiver's decision chain. Record channel dwell, revisit, preselector settling and sample continuity. Repeat the test with the waveform injected at known times both inside and outside qualified observation windows. This separates blind-time losses from threshold-induced missed detections. A stable false-alarm rate averaged over an hour may conceal both effects. The percentage of time under observation and the probability of detection conditional on observation belong in different columns of the report.

The essential assurance framework contains three independent lines of evidence. First, a traceable physical measurement establishes the absolute input-referred noise and gain state over time. Secondly, the decision algorithm's threshold, learning state and measured false-alarm properties are preserved as derived quantities. Thirdly, controlled weak-signal challenges establish actual probability of detection under a declared range of environmental and instrument conditions. Agreement among these lines justifies a bounded claim that an instrument would probably have detected a specified signal during the covered intervals. Disagreement is a diagnosis requiring further tests, not an invitation to select whichever chart looks most reassuring. Without all three, 'no alarms' remains a statement about software output, not evidence that the RF scene was empty.

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I would finally insist that uncertainty be honest about shared influences. Several receivers using one antenna distribution and clock can share the same sensitivity impairment. Three simultaneous quiet displays are then not three independent demonstrations of absence. A second input path and an independently calibrated receiver can challenge this dependence, but only if their actual shared components and signal conditions are disclosed. Where power uncertainty, gain transitions or overload defeat a defensible probability estimate, the negative finding must be qualified. The aim of engineering is to create a measurement chain that admits correction and challenge; the aim of the report is to preserve the truth of what was measured. A quiet, adaptive dashboard can be useful, but it cannot replace measured sensitivity.

Charles Proteus Steinmetz, Peer Question: Mr. Black, your laboratory sequence separates cable loss, preamplifier behaviour and receiver gain in a manner I appreciate, but I am concerned that a simple injected test tone can itself be a poor representative of the emissions for which the surveillance system was designed. An impulsive, phase-modulated or frequency-agile waveform interacts differently with filters, detectors, switching transients and clipping. How would you qualify a family of test signals without turning the acceptance programme into an endless list of arbitrary waveforms? Please also distinguish the case of external broadband electrical noise arriving through an antenna from conducted noise travelling along common-mode cable paths or the instrument supply. Both may raise a displayed spectrum while requiring different corrective action, and both can be correlated across several receivers. What minimum practical controls would establish which impairment has damaged the weak-signal sensitivity

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that the operator claims to maintain? For the blocking-signal condition, please also specify how a strong adjacent emission could change the receiver operating point while leaving the weak reference at exactly the same antenna-terminal power. The repeatability requirement must include frequency placement and instrument settling time.

Harold S. Black, Response: Mr. Steinmetz, the calibration signals should be selected from a declared class of relevant threats or measurements, not from a desire to demonstrate the highest possible detection score. Describe the class using physical properties: occupied bandwidth, duration, duty cycle, modulation, polarisation, input amplitude and known uncertainty. Choose representative signals covering the expected extremes of detector response, including a narrow carrier, a brief burst, and an appropriately bandlimited modulated waveform where those are relevant. The aim is a defensible coverage envelope rather than a universal promise. A single unmodulated tone is useful for measuring gain and frequency response, but it cannot by itself demonstrate correct detection of a short or frequency-agile signal after a preselector switch.

The reference path must be challenged. To test conducted coupling, compare measurements with an appropriately terminated antenna port and then with the deployed antenna and cable, maintaining equipment safety and a known reference plane. A conducted noise current on a coaxial screen may couple into the receiver in ways not eliminated by terminating the central conductor alone. Use an appropriate common-mode current probe or controlled isolation arrangement, with calibration and safety qualifications, to investigate that hypothesis. Separately record supply ripple and instrument state; do not automatically classify a spectral line at a

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convenient mains-related offset as evidence that the supply is its cause. A different antenna position or cable route that changes the indication supplies useful evidence but can also alter the legitimate incoming field, so the experiment requires controls and repeated conditions.

For an actual sensitivity test, inject a known weak waveform at a documented point after any component deliberately excluded from the test, then repeat upstream to include the additional cable, filter and preamplifier. If detection is good downstream and poor upstream, the differential result directs attention toward components in between; if both degrade under a blocker, the receiver or its current configuration may be responsible. Challenge the automatic-gain-control state by recording its commands and measuring the incremental response to the weak signal at each state. Where the frontend is nonlinear, the small-signal relation must be verified rather than assumed. An isolated quiet-noise plot cannot reveal desensitisation that occurs only when the environment is strong.

The validation matrix should cross signal type with noise state, gain setting and observation interval, but avoid treating highly correlated trials as independent evidence. Document each physical injection opportunity and separately record whether the instrument was tuned, whether it acquired valid samples, whether the detector saw the signal, and whether it reported an alarm. A weak signal missed during genuine blind time is not identical to one rejected by an adaptive threshold, and a clipped waveform is not equivalent to a clean low-SNR waveform. This classification makes the testing finite and informative rather than an uncontrolled catalogue. It also permits a later investigator to express a carefully bounded assurance statement for the specific combinations actually tested.

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Ultimately the repair decision follows the causal evidence. A rising environmental noise witness may justify changes to antenna placement, shielding or operating conditions; a measured gain defect may require recalibration or service; a contaminated reference window may justify detector redesign. Every intervention should be followed by a fresh prospective challenge rather than a retrospective improvement to the appearance of old traces. The original samples and decision history should remain intact. That preservation makes it possible to distinguish a real improvement in detection probability from a mere reduction in audible alarms, the central distinction of this discussion.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has established that a constant false-alarm rate and constant receiver sensitivity are not equivalent requirements. Professor Neyman separated error under the null hypothesis from detection of a specified signal; Dr. Shewhart preserved an absolute control history; Professor Wiener showed how estimator memory and gain feedback can obscure change; Professor Tukey demonstrated the importance of distribution tails and contaminated reference windows; and Mr. Black restored the physical measurement chain, including noise factor, overload and input-referred calibration. The proper evidential record contains raw observations or their defined retention limits, the absolute noise and threshold histories, receiver state, timed coverage and independently scheduled weak-signal challenges. A negative survey conclusion must be bounded by the measured detection probability under the relevant conditions. No constructed historical dialogue here should be mistaken for testimony by its named participants.

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SELECTED TECHNICAL SOURCES AND LIMITATIONS. 1. NIST Interagency Report 8195, Requirements for Spectrum Monitoring in Industrial Environments (2017), https://nvlpubs.nist.gov/nistpubs/ir/2017/NIST.IR.8195.pdf. Source establishes that noise figure, spurious-free dynamic range and receiver specifications are relevant to qualified monitoring. 2. MathWorks, Constant False-Alarm Rate (CFAR) Detectors, R2026b documentation, https://www.mathworks.com/help/phased/ug/constant-false-alarm-rate-cfar-detectors.html. Supports the general statistical relationship among noise variation, adaptive thresholds and false-alarm regulation. 3. Adaptive frequency-domain CFAR for robust spectrum sensing under jamming and administrator-controlled counter-access, Scientific Reports (2026), https://doi.org/10.1038/s41598-026-48876-7. Discusses fixed and adaptive thresholds for changing wideband interference. Its numerical simulations are not source measurements for the hypothetical receiver used in this discussion. 4. NIST Engineering Metrology, established uncertainty and instrument-calibration principles, including input reference planes and uncertainty budgets; identify precise relevant documents and clauses during Stage B verification. EDITORIAL QUALIFICATION. All numerical data and signal trials in this dialogue are hypothetical. Claims about a specific deployed instrument require traceable calibration and direct measurement. Citation-to-claim review, comprehensive historical contributor verification, mathematical audit, semantic duplication audit, whole-volume pagination and publication approval remain pending.

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QUESTION 079

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How should false-alarm probability be controlled across millions of spectral comparisons?

Dr. James M. Atkinson, Moderator: Professor Neyman, a defensive technical-surveillance team may examine millions of frequency-time-receiver cells while searching for rare, weak emissions. A test threshold described as having one false alarm in a million trials sounds stringent, yet a search with many opportunities may produce numerous apparent discoveries even under noise alone. Would you define the appropriate unit of inference and describe how an examiner should allocate error probability across the entire monitoring protocol rather than merely print a persuasive per-cell figure? I ask our colleagues to challenge both the independence assumption and the tendency to confuse a statistical discovery with attribution of an emitter.

Jerzy Neyman, Principal Contributor: Dr. Atkinson, statistical error must be associated with a decision rule, a specified population of possible observations, and a declared repeatable procedure. Calling a spectral cell unusual is not the same decision as alleging that a coherent transmitting system exists. Nor is either equivalent to identifying an individual device or purpose. A defensible protocol should articulate separate hypotheses: background compatible with the calibrated receiver-noise model, energy inconsistent with that model, a structured emitter, and finally an attribution hypothesis requiring evidence beyond spectral significance. A false alarm means rejecting a specific null hypothesis when it is true. The term has no stable numerical meaning if the hypothesis or decision rule changes after the data are inspected.

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Suppose there are M tests, each with a nominal null false-rejection probability p. Under independence and a common p, the probability of no false rejections is (1-p)^M, so the family-wise probability of at least one is 1-(1-p)^M. For M equal to one million and p equal to one in a million, the limiting Poisson approximation gives 1-exp(-1), approximately 0.6321. Thus a threshold that sounds extraordinary for a single test would yield at least one nominal false discovery in about sixty-three percent of such complete null searches. This is a calculation under an explicit model, not a measured rate for any particular receiver. If p is reduced to 0.05/M, the union bound guarantees that the chance of at least one false rejection cannot exceed 0.05, provided the individual marginal error bounds are valid. The union bound itself does not require independence.

The family must be defined before the inspection begins. Is it one receiver for one hour, the complete survey across sixteen antennas, all retries after operator intervention, or the combined survey repeated each morning? If analysts quietly choose the most impressive display among twenty configurations, the number of effective selection opportunities extends beyond the cells initially advertised. A threshold calibrated for one window or antenna cannot be used without adjustment when multiple alternative windows, FFT sizes, preselectors, and detection algorithms are also searched. The family can be structured hierarchically, with a global test for evidence of any anomaly followed by narrower location or frequency questions under controlled procedures. That structure is preferable to pretending that every pixel is a free-standing scientific experiment.

The relevant null is seldom ideal white Gaussian noise. Real instruments exhibit correlated spectral estimators, window-overlap dependence, local

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oscillator phase noise, interference and drift. One may begin with a tractable mathematical model but must test it using receiver data under states known to be free of the target signal. Calibrated noise-only captures should be processed through precisely the same bandpass filters, FFT windows, threshold adaptation, event clustering and reporting pipeline as operational captures. This produces an empirical distribution of the maximum statistic across the family, rather than merely a histogram of marginal cell values. If the intended family-wise probability is five percent, the threshold is the ninety-fifth percentile of that maximum distribution, with appropriate sampling uncertainty and out-of-sample validation.

The experiment must preserve genuine dependencies rather than erase them by randomising individual cells independently. For example, resampling entire nonoverlapping background records preserves within-record correlations and synchronised receiver artefacts; resampling each FFT bin independently destroys precisely the dependence whose consequences must be assessed. Conversely, if records share a clock or power supply, treating entire receivers as independent bootstrap units is also suspect. The sampling unit ought to coincide with the physical independence unit, perhaps a day, installation, clock state or environmental episode, depending on what can be justified. Uncertainty from the limited number of calibration records must accompany the advertised false-alarm level.

Power matters alongside error control. A threshold stringent enough to make the family-wise probability tiny may miss a low-power signal of interest. Let Pd denote detection probability under a defined signal model, and let Pfa denote probability of a false detection under a defined null. The

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entire Pd-versus-Pfa curve should be evaluated across signal power, occupancy, bandwidth and receiver states. No investigator should hide a loss of power by displaying only the attractive false-alarm rate. The finding should say, for example, that under stipulated calibrated states the complete search procedure met an empirical global alarm criterion, while detection probability for a weak burst of specified duration was separately measured. That is more informative than announcing an unexplained significance threshold.

Finally, statistical significance is not a licence to infer malicious intent. A rejected noise-only null may arise from ordinary communication, an instrument defect, a laboratory stimulus or unanticipated environmental coupling. The correct sequence is detection, challenge, classification and evidential interpretation, each with its own uncertainties. Under formal inquiry the raw acquisition, calibrated null records, threshold policy, software versions and all rejected candidates must survive, not merely the most alarming waterfall frame. I pass the question to the other panel members with the warning that a numerical guarantee applies only to the procedure and hypotheses for which it was established.

Peter Elias, Peer Question: Professor Neyman, your proposed calibration uses the maximum statistic of a whole search, but the word 'whole' becomes slippery when an operator can change the observation interval, receiver bandwidth and analysis window after seeing a suspicious feature. Suppose a short pulse is discovered with one spectrogram window and appears less impressive with two others. If the investigator reports only the most favourable result, does the original family-wise calibration retain its interpretation? I would also question the data reduction chain. Spectral

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estimates may overlap in time and frequency, and interpolation may create many displayed pixels from a much smaller number of independent measurements. How should a team register exploratory choices, handle reruns on the same captured data, and distinguish the number of rendered pixels from the number of distinct statistical selection opportunities? Can the answer be more practical than simply forbidding post-event analysis, which is often necessary for forensic interpretation?

Please distinguish the initial exploratory selection from the later physical challenge, since otherwise the same waveform can be used twice to support a claim of independent confirmation.

Jerzy Neyman, Response: Mr. Elias, exploratory analysis need not be prohibited, but the status of its claims must be made explicit. An exploration can reveal a useful feature, a plausible bandwidth or a new instrument fault. It cannot then turn around and treat the same selection as a fresh prespecified test with its old nominal p-value. The investigator may separate discovery and confirmation records, use a reserved independent acquisition, or calibrate the entire adaptive procedure against background records in which the same sequence of algorithm choices is repeated. If the latter is automated, one can record the maximum detection score across every permitted window, overlap and parameter setting and derive its empirical null distribution. That calibrates the search protocol, not just an arbitrary pixel.

A practical register should include the fixed menu of candidate bandwidths, FFT lengths, thresholds, antennas and revisit policies; the order in which human or automated decisions may change them; a permanent log of all candidates, not just selected detections; and the versioned code

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implementing the final statistic. Reprocessing one stored data set ten times does not create ten independent corroborations. It creates one set of observations with ten correlated analyses. Independence must be established by physical or statistical argument and cannot be obtained from file names or screen captures. Where human judgement cannot be reproduced, describe the result as exploratory and require a separate blinded challenge before claiming a calibrated alarm probability.

The number of display pixels is likewise not automatically M. Window overlap and interpolation make neighbouring pixels dependent, but choosing an 'effective number' by eye is unsafe because the dependence can be strong, nonstationary and non-Gaussian. A rigorous family-wise upper bound can still use the full count with valid marginal bounds, though often conservatively. Better power may be obtained by empirical maxima of the exact decision pipeline. If the independent noise-only calibration record is scarce, disclose uncertainty in the estimated tail rather than report six significant decimal places. The proper contrast is not between forensic flexibility and statistical discipline; it is between an auditable procedure whose adaptations are included in calibration and an undocumented search through alternatives whose reported significance cannot be reconstructed.

David Slepian, Peer Question: Professor Neyman, in communications theory the exact geometry of signals and noise in a finite observation interval matters, and a receiver's filtering can create correlations between nominally separate spectral cells. A procedure that counts one million cells may represent fewer independent degrees of freedom, but a correlated field can also generate extended excursions that persist across many cells. If the detection unit is changed from a cell to an event cluster, will the nominal

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false-alarm guarantee remain valid? I am concerned about whether a cluster is identified after the threshold is applied and whether threshold selection, clustering radius and event merging are all calibrated together. What would you require before treating a hundred adjacent above-threshold pixels as one false alarm, and could the opposite mistake occur when a single receiver transient is broken into several supposedly independent events?

I would welcome an explicit distinction between counting spatially contiguous bins and detecting a physically coherent temporal event, because each definition has different reproducibility requirements.

Jerzy Neyman, Response: Dr. Slepian, the choice of decision unit changes the statistical proposition. A cluster-count alarm means that a prescribed rule maps a spectral field to connected components or other events. The null distribution of that output cannot be inferred merely from the marginal p-value of each pixel. Define the connectivity in time, frequency and receiver space, the threshold, minimum duration or area, exclusions around known receiver artefacts, and merge conditions before evaluating error rate. The full procedure then maps a known noise-only record to a number of candidate events, a maximum cluster score or another clearly defined statistic. Its distribution is what must be calibrated.

Suppose a receiver's phase-noise transient produces thirty adjacent bright bins during a reference switch. Calling them thirty independent 'signals' overstates the event evidence; merging them into one labelled reference-associated cluster may be justified if the same logic is applied in background and operational analysis. But merging cannot be an ad hoc response to an embarrassing false-alarm count. Likewise one external burst could excite several separated filter outputs or create multiple detections during

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scanning. A documented, validated merging rule can prevent counting that burst repeatedly. The rule must be challenged with injected single bursts and deliberately separated pairs to measure false splitting and false merging. No universal cluster radius suits all instrument configurations.

If the question is simply whether any suspicious event occurred within the complete survey, a maximum cluster score can provide a family-wise decision after empirical calibration. If the question concerns the expected fraction of false reported event clusters among all reported clusters, a different multiplicity concept is required. These definitions do not become interchangeable because both are printed as percentages. Finally, records must retain the raw pixels, the list of cluster memberships and the software transformations, allowing a subsequent examiner to challenge whether a rejected or combined event concealed independent evidence. It is the operational reproducibility of the family definition, not the convenience of the event count, that preserves the meaning of the error guarantee.

For an operational decision, the number of identified clusters is itself a random variable, and its uncertainty should be reported across multiple controlled background runs. An investigator must not infer cluster independence from visual separation alone; one power-supply transient can generate several separated spectral products. Keep the event ledger and all associated instrument-state records for that reason.

Jerzy Neyman, Cross-Peer Question to Ronald Aylmer Fisher: Professor Fisher, I invite a challenge to the relation between individual evidential strength and a long search. You have historically emphasised the interpretation of experimental evidence rather than a purely mechanical accept-or-reject ritual. Suppose a receiver yields one narrow line with a local

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tail probability of 10^-8 after two million spectral comparisons, and an analyst has also tried several alternative filters that were not recorded. How would you express the weight of the observation without pretending that a local p-value establishes an external emitter? Could the likelihood of a persistent narrowband component, evaluated on a fresh observation, be separated from the process that originally selected the frequency? Please identify where an apparently spectacular result can be an artefact of selecting the greatest departure among many opportunities.

Would you also separate the magnitude of the selected spectral feature from the reliability of its physical origin, particularly when a receiver-side spur can remain stable through many repetitions? A numerical result may be strong evidence against simple thermal noise and yet weak evidence for the specific emitter alleged by a report.

Ronald Aylmer Fisher, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, I would first describe the reported number as conditional on a precisely specified test statistic and null distribution. Selecting the most extreme component from a large field changes the reference distribution for that selected component. The probability that a single prespecified cell is as extreme as observed is not the probability that at least one of a million cells is equally extreme. If the analyst inspected unspecified alternative filters, the actual selection history is part of the evidence and cannot be tidily dismissed. One might calculate a corrected global tail probability with a known, predetermined family, but an unrecorded search makes a confident correction implausible.

Evidence is strengthened by a new experiment whose purpose and analysis are registered beforehand. Prespecify the observed candidate frequency,

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reasonable tolerance for drift, antenna and preselection conditions, reference-source checks and a statistic chosen to distinguish an incoming signal from receiver-generated products. Then collect a genuinely new receiver record with a different temporal opportunity, or where practicable a different measurement chain. Under the new test the candidate is no longer chosen as the maximum among the original millions of cells. Its local behaviour has a new evidential meaning, provided the follow-up protocol does not itself expand into an uncontrolled hunt.

The alternative must also be physically meaningful. A stable carrier can persist because a local oscillator spur persists; repeated detection in the same instrument does not establish external origin. A calibrated termination, antenna substitution, controlled attenuation, independent clock or different frequency-conversion plan can supply the needed physical discrimination. A well-defined null should include ordinary interference and instrument responses where those mechanisms are relevant. Significance against an oversimplified white-noise null merely tells us that reality differs from that null, not which explanation is true. A disciplined report could say that an exploratory wideband search selected a candidate, and that a prespecified second-stage measurement found an external-input-dependent feature within specified uncertainty. That is persuasive without claiming certainty or inventing a tail probability for the total human search.

The examiner should retain the complete set of alternative receiver configurations attempted in the follow-up, including those in which the feature disappears. Disappearance is not automatically proof of an artefact, because changing a preselector can reduce sensitivity, but the predicted

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pattern of change should be specified before interpreting it. This controls both statistical selection bias and physical misattribution.

Dr. James M. Atkinson, Moderator: Professor Fisher, please now examine what a strikingly small local significance level contributes to a scientific inference, whilst acknowledging the large number of opportunities offered by a modern RF waterfall.

Ronald Aylmer Fisher, Second Principal Contributor: Dr. Atkinson, the instrumental display tempts an observer to treat every bright point as an isolated experiment, but the origin of a discovery matters. A cell chosen in advance and a cell chosen because it is the most extreme among many cells have different statistical distributions. I begin with the distinction between a tail-area calculation and a physical hypothesis. A p-value is a probability, under an assumed null and test rule, of a statistic at least as extreme as the observed value. It is not a posterior probability that the null is true, nor the probability that a displayed feature is a real transmitter. The analyst should state the null, the score, the selection process and the conditions under which the mathematical probability was calibrated. These declarations are part of the substantive scientific claim.

A useful example is a detector with a nonnegative, exponentially distributed noise-power statistic X, normalised to mean one. Under a valid noise-only null, P(X greater than x)=exp(-x) for x at least zero. For a single prespecified cell a threshold x=ln(10^6), approximately 13.8155, gives nominal p=10^-6. Across one million independent cells, however, the probability that the maximum exceeds that threshold is 1-(1-10^-6)^1000000, approximately 0.6321. If the entire search is to have a five-percent probability of any false alarm, the threshold must be raised to the solution of 1-(1-exp(-

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x))^1000000=0.05, which is approximately x=ln(1000000/[-ln(0.95)]) or 16.7856 using the rare-tail approximation. These numbers describe an idealised model, not a measurement of a deployed receiver. Correlated cells require re-evaluation.

A single extreme finding invites an over-optimistic estimate of effect size. The selected maximum has been selected partly for favourable random fluctuation, so its displayed power is subject to selection bias. An independent second measurement can correct the evidential impression, even when it shows a weaker but repeatable component. If an investigator averages many new samples only at the previously selected frequency, that follow-up addresses a different question from the original search. The follow-up should preserve its own prespecified frequency tolerance, analysis window and signal classification criteria, rather than adapting them until a desired confirmation appears. The difference between discovery and confirmation is essential in the presence of high-dimensional opportunity.

I would also distinguish the physical units of the scan. A frequency-time tile from an FFT has noise power dependent upon window normalisation, equivalent noise bandwidth, detector and gain setting. The null distribution for one tile is not transferable to another simply because both tiles are coloured green. If the receiver changes its preselector, reference clock, FFT size or gain, standardisation is necessary before pooling tail probabilities. The mere presence of a value called 'p' in a software record does not ensure comparable calibration. Some estimators are based on adjacent bins presumed to contain noise; those reference cells can be contaminated by a broad signal or by leakage from a powerful adjacent transmission, turning the derived significance into an instrument-dependent quantity.

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We must be equally cautious with repeated visual scrutiny. A human may notice a pattern, enlarge the plot, adjust gain and decide the feature is extraordinary; these choices produce valuable hypotheses but not an automatic independent test. In a defensible scientific report label the first result exploratory, record the search provenance, then test the finding in a blinded or reserved record. Calibration may include an automated search policy if it is sufficiently reproducible. Where judgement dominates, the evidence should be narrative and physically corroborated rather than dressed as a probability from a nonexistent selection model. A good descriptive figure is not automatically a calibrated significance test.

The analyst should consider alternatives to the noise-only model: a common power-supply spur, a receiver intermodulation product, an antenna resonance, a false clock lock and electromagnetic leakage from nearby equipment. An extremely small noise-only tail probability may be correct while the source attribution remains incorrect because the null omitted these mechanisms. Comparing hypotheses requires experiment. For instance, if an apparent carrier remains under a properly terminated input, grows with front-end gain in an unexpected manner and changes with local oscillator retuning, the instrument-artifact explanation deserves attention. If it tracks antenna geometry and survives independent receiver changes, an external signal explanation strengthens. Neither observation alone identifies intent.

A final distinction concerns scientific importance. A tiny p-value can accompany a minuscule spectral difference of no operational concern when enormous data volumes confer detection power. Conversely, a weak, short signal of high defensive interest may fail a harsh family-wise threshold. The

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report ought to state effect size in physical units, uncertainty, probability of detection over a defined signal class and the false-alarm criterion, not one impressive p-value. The value of a measurement lies in its reproducible bearing on a properly stated question. When the receiver has inspected millions of alternatives, the question must include that fact before any conclusion is pronounced.

I therefore pass the token to colleagues who will ask whether a family of thousands of correlated tests ought to be evaluated through false-discovery proportions, global maxima or some other criterion. The answer depends on the decision's consequences. One false attribution in a high-stakes forensic finding is not equivalent to a handful of false exploratory candidates sent for inexpensive technical challenge. Different loss functions justify different error budgets, and the words 'statistically significant' should never conceal the policy choice.

David G. Kendall, Peer Question: Professor Fisher, I should like you to consider the tendency to treat an event count as if it were a sequence of independent trials. Suppose the same intermittent external transmission appears in seven adjacent FFT bins, across ten overlapping time windows, and on two simultaneously clocked receivers. A software dashboard may report a hundred and forty significant cells, but the physical evidence may comprise one emission. Conversely a local oscillator perturbation can produce the same multiplicity without any external transmission. If the operator first selects the maximum cell, then forms clusters, and finally chooses one striking cluster for verification, how should the degrees of selection be represented? Must we calculate a fresh multiplicity correction for every stage, or can a single, prespecified global statistic represent the

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entire detection chain? Please explain how the answer changes when clustering was chosen only after inspecting the event.

I would also wish to know whether the cluster definition remains identical for the null calibration and actual survey, including any operator-controlled review or manual merge decisions.

Ronald Aylmer Fisher, Response: Dr. Kendall, the physical event and the statistical selection unit should be distinguished at the outset. A hundred and forty displayed cells may derive from one waveform, but the investigator has still encountered a collection of opportunities for a high score. A prespecified processing chain can use a global statistic such as the highest cluster-integrated energy, maximum likelihood-ratio estimate, or number of qualified events. The null distribution of that statistic should be calibrated by running the complete chain on representative background acquisitions. Then there is one global decision rule, and the internal clusters are intermediate computations rather than unaccounted second-stage experiments. This avoids the false necessity of multiplying separately calculated corrections when a joint calibration is feasible.

If clustering was chosen after the striking observation, however, one may not treat the choice as if it had been independent of the data. The correct path is either to reconstruct and calibrate the broader search over plausible clustering rules, or to regard the selected rule as exploratory and confirm its predictions on reserved observations. The latter may be more realistic for a forensic investigator who must understand unexpected receiver behaviour. A history of candidate merge gaps, frequency tolerances and chosen filters reveals how much discretion shaped the reported event. The acquisition

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data should remain intact so that a reviewer can test whether a different documented clustering policy would reverse the inference.

The number of correlated cells should not be replaced by an intuitive effective-trial count without validation. A simulation that preserves window overlap, frequency leakage, common clock disturbances, noise adaptation and actual event clustering offers a more direct check. Ideally the simulation's generating assumptions should themselves be challenged by recorded noise-only surveys from differing installation states. Any failure to reproduce the extreme tails should be stated as a model limitation. If clustering algorithms include nonstationary thresholds or learned classifiers, their training and tuning records must be excluded from the held-out calibration set or accounted for explicitly.

Your example also shows why one must keep separate layers of the scientific claim. The dashboard may present one cluster, and the formal global test may detect an anomaly. To say that this anomaly arose at the antenna requires challenge tests against receiver-generated products. To say that it belongs to a particular transmitter requires further waveform, temporal, spatial and lawful contextual evidence. Statistical multiplicity correction addresses the calibrated detection question; it does not eliminate the need for physical attribution tests. This separation preserves the usefulness of numerical statistics without allowing them to overwhelm the engineering interpretation.

Ronald Aylmer Fisher, Cross-Peer Question to Solomon Kullback: Dr. Kullback, may I ask you to distinguish information in a waveform from the multiplicity of tests applied to it? A very large number of frequency-time cells may each offer a small increment of evidence, and the investigator may

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maximise a likelihood-ratio statistic over unknown bandwidth, onset time and modulation. How should a practitioner interpret the resulting score when the parameters were selected from the same data? Would it be reasonable to treat the maximum as if the best-fitting alternative had been specified in advance? I also invite you to examine the distinction between a likelihood ratio comparing two explicit generative models and a posterior statement about an identified device, which would require additional assumptions not contained in the spectral measurement. Please include the possibility that a technically attractive signal model is misspecified because it omits correlated receiver artefacts.

If the alternative has been optimised against a finite catalogue of templates, should an apparently precise estimated source strength be interpreted with a selection correction as well as a detection correction?

Solomon Kullback, Cross-Peer Answer to Ronald Aylmer Fisher: Professor Fisher, a likelihood ratio measures relative support for specified probability models at the observed data; it does not free the investigator from declaring how those models were chosen. If bandwidth, onset, carrier offset and modulation are fitted by maximising over a large parameter family, the maximum likelihood ratio has a null distribution different from the ratio for a fixed, prespecified template. A threshold derived from the latter can be badly anti-conservative when applied to the former. The appropriate calibration must reproduce the maximisation itself, including the parameter grid, estimator constraints and stopping rules. If the statistic is adjusted after looking at the detected line, that adaptation must be represented or the result must be treated as exploratory.

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Information-theoretic quantities may help describe how distinguishable the signal and noise models are, but they do not replace an error criterion. A divergence between two stipulated distributions can be large even when neither distribution realistically describes a receiver affected by gain changes, oscillator phase noise or intermittent interference. A physical challenge should therefore compare predicted changes under attenuation, reference substitution, preselector state and noise-floor variation, not merely search for the model with the most favourable numerical score. The trained and tested parameter spaces must be separated so that model complexity does not masquerade as external evidence.

For a mathematical example, let X be a vector of complex spectral observations, with null covariance matrix $\Sigma 0$ and alternative mean vector μ. Under a complex Gaussian approximation the quadratic evidence for μ depends upon $\mu^* \Sigma 0^{-1} X$ and $\mu^* \Sigma 0^{-1} \mu$, where * denotes conjugate transpose. If $\Sigma 0$ contains nonzero off-diagonal terms from window overlap and common receiver states, replacing it with a diagonal matrix changes both the score and its calibration. If μ is estimated by trying thousands of templates, the distribution of their maximum is the relevant null. A small score from a marginal cell cannot simply be promoted to the value of a jointly optimised detector.

Finally, likelihood evidence alone does not assert that a particular physical device is present. The alternative model may describe an internally generated spur just as well as an external emitter if both produce the assumed spectral shape. To claim a device identity, one must connect model parameters to independently observed properties and challenge competing explanations. A posterior probability also requires prior model weights and

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properly specified alternatives; a p-value or likelihood ratio does not silently provide those priors. The engineer's duty is to preserve the calibrated inference and the bounds of the physical model as separate statements.

Dr. James M. Atkinson, Moderator: Dr. Kullback, would you now examine the decision to report many candidate signals, some of which are expected to be false, rather than impose a requirement that the entire survey almost never produces a single false indication?

Solomon Kullback, Third Principal Contributor: Dr. Atkinson, an instrument that produces an extensive candidate catalogue may serve an operational function different from one that issues a formal evidential accusation. The first stage may legitimately tolerate some false leads if each candidate is inexpensive to challenge. The second stage, particularly where reputation, privacy or legal consequence is involved, requires much stronger evidence. The statistical question should therefore be framed by a decision loss, not by an arbitrary fashion for a particular percentage. Family-wise error rate concerns the probability of making at least one false rejection in a family. False discovery rate concerns the expected proportion of false rejections among all rejections, ordinarily defined with that proportion set to zero when nothing is rejected. These are not interchangeable guarantees.

Let V be the number of false discoveries and R the number of all reported discoveries in a defined family. The false discovery proportion is V/max(R,1), and false discovery rate, FDR, is its expectation. A method controlling FDR at level q=.05 does not guarantee that each reported individual signal has a five-percent chance of being false, nor that no more than five percent of the reports in every particular survey will be wrong. It is an expectation over repetitions under the stated model. If the result set is later filtered by an

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undocumented human selection, the achieved false discovery proportion in the selected subset need not retain the same formal guarantee. The meaning of the chosen family and the downstream reporting rule must be preserved in the record.

The modern Benjamini–Hochberg step-up procedure, an editorial development subsequent to the lives of some historical panel members, illustrates this distinction. Given m valid p-values $p_{(1)} <= \ldots <= p_{(m)}$ and a target q, find the largest index k for which $p_{(k)} <= k\, q/m$ and reject the hypotheses corresponding to the first k sorted p-values. Under independence of true-null p-values, the original proof controls FDR, with suitable extensions under specified positive dependency. The procedure is not justified by merely sorting arbitrary detector scores labelled p. Each p-value must be calibrated under its null, and the full dependencies and reporting process must satisfy the procedure's conditions. For arbitrary dependence, the Benjamini–Yekutieli correction uses the harmonic factor $H_m=\sum_{j=1}^{m} 1/j$ in a conservative threshold; the price can be substantial lost power.

Consider a hypothetical calibrated catalogue with m=100,000 candidate cells, q=.05 and a sixth-smallest valid p-value of 2×10^{-6}. The sixth Benjamini–Hochberg boundary is (6x.05)/100000, or 3×10^{-6}, so that p-value passes the rank-six inequality. But the algorithm must identify the largest qualifying k over all ranks, not simply stop on one favourable comparison. Other p-values may or may not pass, and dependence assumptions matter. These numbers are teaching values. They should not be converted into a statement that any selected candidate has a posterior error probability exactly equal to q.

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A major difficulty in RF surveys is that the nulls can be composite and spatially heterogeneous. One frequency region may contain quiet receiver noise, another licensed ambient traffic, another a strong carrier whose spectral leakage contaminates neighbouring bins. If 'no signal of interest' is the null, the distribution of a test statistic depends upon which ordinary emissions and receiver states are deemed allowable under that null. Miscalibrated p-values can overwhelm the multiple-testing correction. If a receiver estimates the null from the same candidate-contaminated region, its threshold may respond to signal density and invert what was intended as evidence. Null calibration must therefore be tied to known input conditions, realistic occupancy and the actual front-end measurement chain.

Filtering hypotheses before testing is legitimate only under appropriate conditions. A prefilter based on independent technical information, such as an authorised frequency allocation or a known receiver mask, can reduce unnecessary tests. A filter chosen because a candidate looks impressive is another selection step and must be included in calibration. Likewise a hierarchical scheme might first test broad bands globally, then analyse narrow subbands whose parent test passes. The error accounting depends on the hierarchy and testing policy. An investigator should log this structure before the survey, maintain a separate record of exploratory branches and avoid treating omitted tests as if they had never occurred.

Dependence may help or harm. Many spectral cells are correlated because they share an analogue filter, FFT overlap, a digitiser or common noise modulation. Some positive dependence structures permit certain FDR procedures; arbitrary dependence does not. It is not sound to claim that fewer effective independent bins automatically permits the ordinary

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Benjamini–Hochberg result. A practical approach is to calibrate event-level p-values against complete noise-only traces and then test dependence assumptions or use conservative procedures. Where the number of hypotheses is enormous and valid null simulations are limited, report the uncertainty of the tail calibration and treat estimated false-discovery rates as conditional on the model.

A further issue is the relation between discovery and identification. FDR control may be useful for deciding which candidate events receive additional lawful investigation. A candidate is not a device, and an event cluster is not an emitter identity. Several reported candidates may originate from one instrument failure or one transmitter, so a list of 100 rejections may not be a list of 100 distinct physical objects. A responsible report states its unit: spectral tests, event clusters or putative source classes. The testing procedure should be challenged against independent signals and receiver artefacts, so that the meaning of 'false discovery' is stable and understandable to another examiner.

In conclusion, choose the error criterion based on the decision. A broad, reversible screening list may use a calibrated expected-false-proportion rule, accompanied by individual physical challenge tests. A high-stakes attribution claim should not rely solely on the catalogue's FDR. It should demand independent corroboration, explicit uncertainty and careful legal interpretation. Control of error is an instrument of honest inquiry, not a substitute for professional judgement about the measured world.

Sir Harold Jeffreys, Peer Question: Dr. Kullback, you have distinguished family-wise error and false-discovery-rate control, yet I remain concerned about what either quantity tells us about a named candidate. The

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investigator may tell a tribunal that the survey's false discovery rate was five percent and infer that there is a ninety-five-percent probability that this particular suspicious carrier is real. Such a statement resembles a posterior probability but seems to arise from an expectation over many possible repetitions, not from a probability model for the specific signal. What evidential expression would avoid this confusion? How should we deal with a candidate detected during highly unusual receiver conditions that were rarely represented in calibration data? I should also like you to distinguish a result that merely rejects a noise model from one that discriminates an external signal against internally generated radio-frequency products, especially when those competing physical explanations are not exhaustively modelled.

Please address how the burden of demonstrating an external physical origin differs from the mathematical burden of rejecting one narrow null hypothesis.

Solomon Kullback, Response: Sir Harold, your objection is decisive. A five-percent FDR refers to the expected proportion of false rejected hypotheses under a specified repeated-testing model and selection policy. It is not a direct posterior probability for the particular carrier under consideration. Individual posterior beliefs would require a model for the relative prevalence of genuine and spurious candidates and the likelihood of the actual observed evidence under the relevant alternative explanations. Neither the FDR calculation nor a small p-value supplies those priors or an exhaustive list of causes. To convert the result into an individual probability by verbal sleight of hand would be a serious misrepresentation.

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The correct statement is bounded. The survey applied an algorithm calibrated to control an expected catalogue-level false-rejection proportion under its reference background population. The particular candidate crossed the stated threshold. Its amplitude, duration, frequency stability and response to controlled input changes are measured separately. The examiner should disclose the calibrated family, model limitations and candidate-specific evidence. An unusual operating state that scarcely appears in the calibration records weakens the applicability of the nominal error guarantee; such an event may deserve targeted challenge, but its formal score should be labelled out-of-distribution or otherwise qualified.

A useful practical test is to subject the candidate to source-path interventions designed to distinguish an external signal from an internal product. Retain the raw samples, then change the antenna or terminate the receiver input under proper conditions, substitute an independently calibrated receiver, vary attenuation and check whether the feature responds as the proposed physical model predicts. None of these interventions should be treated as a magic test in isolation, because changing the circuit can alter gain, intermodulation and sensitivity. The strength arises from coherent predictions across several interventions with separate failure modes. A source that changes with an antenna does not automatically belong to an intrusive device; ordinary lawful emissions remain possible.

If the survey used several receivers sharing the same clock or computer, coincidence among their alarms may reflect a common error source. A conditional posterior model or likelihood calculation must include that dependence. If the relevant physical alternative is absent from the model,

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apparent numerical confidence can be greatly overstated. A forensic report should therefore provide clear findings at different levels: a calibrated anomaly detection, a receiver-chain-origin challenge, a signal classification if supported, and an attribution conclusion only if independently justified. The numerical FDR is relevant to the first level, not a universal substitute for the rest.

David H. Blackwell, Peer Question: Dr. Kullback, I would press the decision-theoretic consequences. Suppose the operator can afford to inspect one hundred candidate bursts a day, but the instrument can produce many more low-significance indications. A strict family-wise threshold might generate too few leads and miss rare signals, whereas a liberal false-discovery criterion might overload the investigators and create unnecessary privacy intrusions. How should a team choose its loss function and allocate review resources without pretending that cost ratios or event prevalences are known precisely? I am also concerned that a rule tuned to the first week's environment may be used for months, even though the background occupancy and instrument noise state drift substantially. Can one preserve a formal error guarantee under such adaptation, or must the investigator characterise every operating epoch separately?

If the decision rule is altered after a series of false leads, must subsequent measurements be regarded as a separate calibration epoch rather than pooled under the originally advertised error guarantee? I ask especially about the treatment of candidate queues with fixed maximum capacity, since truncation changes which false leads reach an examiner and can make an apparently improved false-discovery rate merely the result of selective retention.

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Solomon Kullback, Response: Dr. Blackwell, a decision rule is an agreement about consequences under uncertainty. Start by distinguishing reversible internal triage from intrusive or consequential external action. A false lead retained in a private engineering queue may cost only analysis time; an unjustified allegation or interception can have substantial legal and ethical cost. It follows that the same numerical threshold need not govern every stage. A high-recall screening detector may feed a slower, independent verification stage, while final attribution requires much stronger physical evidence. The performance metrics should be stated separately, and the operator should not publish a screening hit as though it were a final finding.

Resource limits can be represented through a prioritisation function involving estimated detection value, expected inspection cost and an uncertainty penalty, but the quantities must not be invented to create spurious optimisation precision. Sensitivity analysis over plausible cost and prevalence ranges is more defensible than one unexplained utility number. A capacity-limited catalogue can also introduce selection bias: if only the hundred highest-scoring candidates are stored, the saved record has been truncated. Retain at least aggregate counts and calibrated score distributions for rejected events, together with the selection algorithm, so that reviewers can understand how opportunities were discarded.

Background drift requires explicit monitoring. Establish operating epochs tied to instrument gain, antenna configuration, preselector state, calibration, environmental occupancy and reference-clock status. Evaluate whether held-out noise-only controls and known test signals remain compatible with the original null calibration. If not, suspend the old formal error statement and recalibrate. An adaptive procedure can retain

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guarantees under specialised sequential testing frameworks, but one cannot simply apply a fixed-sample theorem to an evolving, retrospectively tuned threshold. When conditions change without an independent calibration record, label the significance as conditional and uncertain.

A robust two-stage protocol would periodically introduce an authorised synthetic weak reference signal to measure detection power while separately recording background maxima to assess false alarms. It would also challenge high-ranking candidates with different receiving apparatus. The operator can then report how many candidates were triaged, how many passed physical challenge, and how often controls revealed degradation. In that structure resource allocation is transparent without smuggling an unverified posterior probability into the software display. The true objective is to make better, lawful decisions with calibrated limitations, not to force every uncertainty into a single attractive percentage.

Solomon Kullback, Cross-Peer Question to David R. Cox: Sir David, the reference tests are not isolated observations. Neighbouring FFT windows overlap, frequency bins leak into one another, and multiple receivers may share clocks or environmental interference. The original independent-test false-discovery-rate result does not automatically extend to every such dependence structure. How would you design a statistically honest calibration when we know correlations exist but do not possess a complete joint distribution? In particular, should the operator estimate an 'effective number of independent trials', use blockwise null records, or evaluate the maximum and the complete reporting procedure empirically? I invite you to distinguish the difficult finite-sample tails, where very small probabilities are demanded, from the central part of the noise distribution that is easy to

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measure. What consequence follows if the null model is wrong only during rare high-power blocker events?

Could a configuration-specific maximum statistic be preferable even when it is conservative, because the assumptions are observable and the consequences of a false external-emitter allegation outweigh the loss of a few weak exploratory candidates?

David R. Cox, Cross-Peer Answer to Solomon Kullback: Dr. Kullback, the dependence must be treated as a property of the measurement process, not an inconvenience that can be removed with a convenient scalar correction. An effective number of trials may be a useful descriptive approximation for a restricted stationary model, but it is not a universal multiplier valid across thresholds or operating states. Extreme-value behaviour depends upon clustering, tail dependence and the statistic being maximised. If the purpose is to calibrate the complete monitoring system, I would prefer to obtain representative noise-only records containing the true window overlap, receiver configuration, common-clock effects and intermittent interference, then process those records through the exact operational pipeline. The resulting empirical distribution of a whole-search maximum is a direct observable, though still subject to sampling uncertainty and representativeness.

One should not pretend that a thousand calibration records can directly establish a one-in-a-million tail with exquisite precision. Without an extrapolation model, zero exceedances merely bounds the probability rather than proving it zero. For an independent Bernoulli event observed zero times in n trials, a rough one-sided ninety-five-percent upper bound is about 3/n, with an exact binomial expression available. If complete searches

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are dependent across calibration days, even that approximation requires reconsideration. Tail modelling may improve efficiency but demands diagnostics and sensitivity analysis. The claim must disclose its extrapolative character.

A second problem is the changing null. A clean receiver under quiet conditions may produce an orderly correlation structure; a high-power adjacent blocker can create nonlinear mixing and nonstationary threshold behaviour. It is unsafe to pool these states and assume the resulting marginal p-values are uniform under each one. Stratify calibration by relevant operating state, or define a conservative null encompassing all supported conditions. When a rare blocker produces an unmodelled burst, the guarantee for the normal state does not extend to that episode. Store the blocker level, gain and filter states and treat the observation as potentially outside the calibration domain.

For false-discovery-rate methods the dependence theorem and selection policy must be checked, not asserted. A procedure proven under particular positive-dependence conditions cannot be justified for arbitrary shared receiver interference merely because the correlations seem positive on one histogram. An explicitly conservative method may be necessary for publication claims. Alternatively, the team might retain a less formal exploratory catalogue and use an independently calibrated second-stage hypothesis test for each consequential finding. That arrangement often aligns better with forensic practice than insisting that an enormous adaptive discovery pipeline deserves one precise tail probability. The measurement record should allow another analyst to repeat the calibration and identify

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where the evidence ceased to be supported by the assumed stochastic model.

Dr. James M. Atkinson, Moderator: Sir David Cox, please extend the inquiry to experimental design, dependence and post-selection inference, particularly where the receiver changes its own detection rule as the electromagnetic environment evolves.

David R. Cox, Fourth Principal Contributor: Dr. Atkinson, practical inference from a large RF monitoring system requires the statistical procedure to be described as an experiment, not merely as a calculation applied to a final spreadsheet. We must know when frequencies were observed, how candidate scores were formed, which measurements share components, and whether the selection rule evolved during the search. Millions of tests do not constitute millions of independent experiments; they may represent repeated views of a small number of physical noise states. The selection mechanism, observation geometry and nuisance variables should therefore be components of the model. A report that starts with the final p-values while omitting these foundations may be numerically elaborate and scientifically underdefined.

The most direct way to address dependence is to define a global statistic at the level of the operational decision. If one alarm anywhere in the surveillance interval would trigger a consequential action, calibrate the maximum alarm score over the full frequency-time-receiver field. If the decision instead concerns the number of candidate event clusters sent for verification, calibrate the event-generation process, including cluster formation and thresholding. If individual device attribution is intended, spectral tests alone are insufficient; the physical challenge stage must be

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part of the evidential model. This separation prevents a correct calculation at the pixel level from being used to justify a different decision at the device level.

An idealised example begins with m independent null p-values uniformly distributed on [0,1]. Then $P(\min p_i <= t)=1-(1-t)^m$. But real spectral p-values often share correlation through filtering, overlap and receiver state, and their marginal distributions may depend upon gain or local interference. A simple estimate of m_{eff} obtained from covariance eigenvalues might give a rough impression of effective dimensionality, but it generally does not guarantee the far-tail distribution of the minimum or maximum. Two fields can have similar covariance and dissimilar extreme clustering. The engineer should compare candidate approximations against full-chain background records and avoid representing a guessed m_{eff} as a verified correction factor.

Sampling the null is an experimental undertaking. Reserve contiguous intervals known to lack the target signal, but do not assume that an interval is representative merely because the investigator did not hear a transmission. Include multiple antenna orientations, temperature regimes, interference levels, clock states and preselection conditions. Preserve entire multichannel time blocks when resampling so that cross-channel dependence remains. Exclude records used for detector training from final performance evaluation. If null calibration was chosen or revised in light of an observed suspicious feature, the same evidence cannot also be used as an untouched validation set. Partitioning by calendar day or physical test campaign may be more robust than randomly splitting neighbouring FFT windows, which are strongly dependent.

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Extreme tails present their own measurement problem. A survey advertised as having global false-alarm probability 10^-4 should not be calibrated solely from two hundred simulated backgrounds; the estimated tail would be dominated by extrapolation. One may use a justified parametric model, importance sampling or conservative statistical bounds, but each introduces assumptions and needs diagnostics. An exact zero false-alarm count in a limited validation does not establish an absolute zero risk. In a publication report show the number of independent validation units, their provenance, the observed exceedance count, the uncertainty interval and any model-based extrapolation. This prevents an alluring threshold figure from concealing a weak evidence base.

Post-selection inference must also be recognised. A detector may scan several threshold policies, choose the one with the lowest observed false-alarm count on a particular calibration data set, and then report that count as if it were independent confirmation. The optimisation has fitted noise fluctuations in the calibration set. A reserved holdout or nested validation experiment is needed to estimate performance after tuning. Similarly, choosing the most prominent carrier from a live scan and reporting its local significance as if the carrier had been specified beforehand is a form of selection. The remedy is not to ban exploration, but to distinguish exploratory formation of a hypothesis from prospective evaluation of its predictions.

Operating states can drift. A quiet installation on Monday may differ from a crowded radio environment on Friday; a receiver may silently switch attenuation, reference lock or FFT policy. The null distribution should be monitored using known test inputs and background statistics, with clear

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criteria for when an established calibration ceases to apply. Adaptive control has virtues, but retrospective use of fixed-sample p-values after an indefinite sequence of threshold adjustments is not automatically valid. Sequential testing requires its own error accounting, including stopping times and repeated looks. The software should retain the adjustment ledger so a later reviewer knows which policy produced each signal claim.

No statistical procedure identifies a hostile emitter from a spectral fluctuation alone. A rejected noise-only null is only the beginning of physical investigation. The team should attempt antenna and termination challenges, change receiver architecture where feasible, inspect common oscillator and power paths, and seek reproducible signal properties in a fresh acquisition. It should also report negative control results and failures of the detector during injected-signal validation. A statistical guarantee is then accompanied by a measured account of engineering sensitivity and alternative explanations, which is necessary for defensible forensic interpretation.

Finally, the analyst should consider the cost of errors explicitly. A broad search that generates a queue for technical inspection can tolerate a higher candidate false-discovery proportion than a report making a consequential claim about a particular person or place. The error budget and confirmation policy should be agreed before data collection rather than improvised once a dramatic feature appears. A responsible conclusion states the family and target risk, how they were calibrated, how many opportunities and alternatives were actually considered, and where the interpretation extends beyond statistical detection into physical inference. That is a scientifically auditable architecture for a very large spectral search.

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George E. P. Box, Peer Question: Sir David, your discussion assumes we can represent the background of the receiver with a reasonable family of statistical models. But spectrum occupancy, instrument gain and interference all change over time, and the same input conditions may recur in predictable operational cycles. If an engineer selects a Gaussian null because it is mathematically convenient, should the anomaly alarm be judged against its estimated tail even after the residuals reveal heteroscedasticity and outliers? How ought model criticism be built into the formal acceptance test, rather than performed only after an attractive result has been announced? I am also interested in the distinction between robustness to a small number of outlying calibration records and a model that wrongly treats an entire physical regime, such as strong adjacent-channel interference, as merely rare random noise. What diagnostic failures should cause the instrument to suspend its numerical false-alarm guarantee?

Would you specify whether a failed null-model diagnostic should block the detector from generating an attributed finding while still permitting raw acquisition to continue?

David R. Cox, Response: Professor Box, a probability model is an instrument of inquiry and ought to be assessed by its observable predictions. If the null assumes stationary exponential or Gaussian statistics, verify the residual distribution after conditioning on gain, frequency, bandwidth and instrument state. Examine tail quantiles, spatial correlation, time clustering and the frequency of events during known reference-clock transitions. An impressive fit in the middle of the distribution is inadequate when the operational threshold resides far in the tail. The validity of a nominal false-

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alarm rate at that threshold depends especially upon the model's behaviour in the rarely observed region. One cannot rescue a poor model by calling every disagreement a nuisance outlier.

A practical diagnostic programme should include withheld background records from multiple installations or dates, controlled changes of preselector and attenuator state, and known benign test sources that stress nonlinear response. Compare observed maximum statistics with their predicted quantiles and test whether the frequency of false alerts exceeds predefined acceptance bounds. A distribution that repeatedly underpredicts large scores during a strong blocker indicates that the null is missing a physically distinct regime. It may be appropriate to stratify, enlarge the null to include the blocker, or mark such conditions as outside calibrated operation. Merely increasing a scalar variance estimate cannot necessarily represent new spectral lines caused by intermodulation.

Robust methods are useful when a few contaminated records would distort parameter estimation, but robustness does not relieve the team from investigating why those observations occurred. A trim-and-average policy can hide systematic faults if it discards all the very episodes relevant to forensic risk. Preserve excluded observations, document exclusion criteria, and check performance both with and without them. The correct question is whether the intended decision rule still meets its declared error control under every state in which it will be used. If not, it should fail closed: continue capturing raw data if safe and authorised, but suppress numerical confidence claims until the state has been diagnosed and recalibrated.

The consequences are especially important when a candidate is selected on the basis of the model's failure. If the unexpected line appears only in a

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regime absent from training, its extremeness under the training model is not meaningful as a calibrated p-value. It remains an interesting technical observation, properly labelled as such. A separate physical challenge may reveal an instrument spur, a new environmental signal or an unmodelled disturbance. The evidential record should contain the failed diagnostics and the engineer's reasoning, not only the later corrected curve. In this way model criticism becomes a safeguard against false certainty rather than a decorative paragraph at the end of a report.

David R. Cox, Cross-Peer Question to Abraham Wald: Dr. Wald, I should like you to examine a monitoring system that never has a predetermined stopping time. It scans continually and reports when any statistic exceeds a threshold. The operator may celebrate a nominal five-percent significance threshold calculated for one hour, but the same test is repeated during thousands of hours, under shifting nuisance conditions, and the survey may stop precisely when an alarming candidate appears. How ought repeated looks and optional stopping be incorporated into the error statement? Could a sequential design express a valid risk of a false alarm over the monitored horizon without simply applying a one-hour p-value afresh at every update? Please distinguish a finite planned monitoring campaign from indefinite surveillance and explain what must be recorded when instrument configuration changes during the decision process.

I would welcome a distinction between a scheduled test that consumes a preassigned risk allowance and an opportunistic extra look prompted by a borderline feature, because those opportunities must not be silently omitted from the accounting.

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Abraham Wald, Cross-Peer Answer to David R. Cox: Sir David, the stopping rule is part of the experiment. A fixed-sample tail probability calculated for one predetermined analysis is not automatically a guarantee after repeatedly inspecting the accumulating data and stopping on a favourable fluctuation. A sequential probability ratio test, for example, compares the evolving likelihood ratio of observations under two fully specified hypotheses against boundaries chosen to control error probabilities under a valid observation model. The relevant statistic and boundaries depend on the joint distribution of the increments; independence or other model assumptions may be essential. The method does not confer a universal guarantee when the receiver silently changes filters, null calibration or the hypotheses under consideration.

For a finite campaign one may allocate a total false-alarm budget across scheduled looks using a prespecified plan. A simple conservative method assigns marginal budgets α_t whose sum does not exceed α_{total}, so the union bound ensures that the probability of any false alarm does not exceed α_{total} if each constituent test has a valid bound. This may lose power, but it makes the risk accounting transparent even without independence. More efficient sequential methods are possible when the mathematical conditions can be defended. For indefinite monitoring, a fixed positive per-look false-alarm probability applied forever will eventually make a false alert exceedingly likely in many ordinary models; indefinite operation requires a specified long-run rate, time-varying risk allocation, or an always-valid sequential construction.

The instrument's operational policy should therefore record each eligible look, its threshold, its test statistic and calibration regime, the accumulated

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error budget, and the decision whether to continue or declare an event. Changing an FFT window or reference-clock source may change the distribution of subsequent evidence; the procedure must either update its model in a planned way or mark the old guarantee as inapplicable. It is not legitimate to erase the previous tests from the ledger when a filter change makes the current result more attractive. A reviewer needs the complete path by which the decision was reached.

Sequential error control also cannot turn poor physical discrimination into good evidence. Repeated observations of one internal oscillator spur may generate a very large likelihood ratio against a white-noise null, yet the external-transmitter hypothesis would remain unsupported if the alternative model ignored internal artefacts. The sequential design must be coupled to instrument challenge tests and responsible source attribution. A formal bound on a specified false rejection does not identify why the null was false, and every consequential conclusion should make that distinction audible in its language and visible in its raw evidence.

Dr. James M. Atkinson, Moderator: Dr. Wald, may we now consider how an uninterrupted monitoring programme can retain an intelligible error budget when no particular burst time, frequency or final observation count is known in advance?

Abraham Wald, Fifth Principal Contributor: Dr. Atkinson, long-duration surveillance differs from a finite experiment because its termination and opportunities for finding a surprising feature depend upon the data itself. A survey that claims 'one false alarm in a million' must state whether that probability applies to one sample, one FFT cell, one hourly scan or the entire operational period. Without a defined family or temporal horizon, the

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number conveys little about the chance that an operator will eventually encounter an ordinary noise excursion. I would begin with a design that treats time as an essential part of the decision policy, rather than an afterthought added when the first intriguing waterfall line appears.

Let E_t denote an alarm event at scheduled look t, with valid marginal probability no greater than α_t under the stated global null. The union bound gives $P(\text{at least one } E_t \text{ over all scheduled looks}) <= \Sigma_t \alpha_t$, regardless of dependence between looks, provided the per-look bounds genuinely hold for the operational procedure. A predetermined summable allocation such as $\alpha_t=\alpha_{total}/[t(t+1)]$ for t=1,2,… has $\Sigma_t \alpha_t=\alpha_{total}$. This is deliberately conservative and can give extremely small thresholds at late times, but it makes an indefinite horizon mathematically meaningful. In real RF monitoring the unit of a look must be defined, and adaptive choices require their own calibration; the formula is not a free pass for uncontrolled changes in how tests are generated.

Sequential likelihood methods offer another route when models are specified. Let L_t be a likelihood ratio of accumulated observations under an alternative H1 against a null H0. In an idealised independent-increment setting, log L_t is a sum of log likelihood ratios. One may stop when L_t reaches a specified upper boundary, continue between boundaries, or accept a different decision at a lower boundary. Error guarantees arise from the actual likelihood model and boundary choice; arbitrary products of detector scores do not have the required interpretation. A receiver affected by correlated time windows, repeated observations of one transmitter or an unknown oscillating interference source may violate the increment assumptions if they are simply ignored.

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Consider the distinction between running a fresh test on an hour of data and accumulating evidence about a persistent narrowband source. The first approach creates many opportunities for at least one extreme noise value. The second must address whether the source model predicts continuity, how retuning or missing data alters the evidence, and whether the observations are independent conditional on the physical source. A stable internal spur can persist just as a genuine transmitter can. The sequential likelihood should therefore include relevant instrument-state alternatives or require a separate challenge before identification. A high likelihood ratio against a simplified stationary-noise model does not prove that the observed energy came from the antenna.

A practical budget can be divided between exploration, candidate verification and formal reporting. Exploratory alarms may trigger nonintrusive checks, with their counts and thresholds retained but without claims of final attribution. Confirmatory tests use prespecified features of a candidate in newly collected data, ideally through a different clock or receiver path. A final evidential declaration invokes validated physical controls. The stages need not share one undifferentiated p-value, but the transition between them must be documented so that repeated exploratory looks are not quietly relabelled as confirmatory replications. The burden of proof and the cost of a false assertion should influence the stage at which a strong guarantee is required.

An important alternative is to monitor the rate of false alarms rather than the probability of any false alarm over an indefinite horizon. Suppose the validated system reports an average of λ false candidate clusters per hour under a clearly defined stable null. For a hypothetical Poisson model, the

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count over T hours has expected value λT and P(at least one)=1-exp(-λT). If λ equals 0.01 per hour, a hundred-hour record has expected count one and probability about 0.632 of one or more; the figures are modelling illustrations. A false-alarm rate can be a sensible operational measure for a continuously monitored installation, but it is not the same as family-wise error probability and must not be reported under that name. If alerts cluster strongly, the Poisson assumption should be challenged experimentally.

Nuisance states demand attention because long-run operation will expose rare conditions absent from short laboratory tests. Oscillator reacquisition, power-line disturbances, temperature excursions, antenna movement and high-power nearby transmitters can create temporally correlated false events. The validation set must include such conditions or the report should restrict the formal guarantee to operating states that were actually supported. A system can fail gracefully by recording an 'uncalibrated state' rather than producing a numerical false-alarm probability drawn from the wrong regime. This is a scientific improvement, even if a dashboard designer regards an explicit uncertainty warning as unattractive.

The monitoring record should retain timestamps for each eligible testing opportunity, not merely for successes. Store the null-calibration version, reference input, gain and filter state, the number of frequency cells considered, all adaptive threshold changes and the reason for any stop or reset. Without that ledger, a later investigator cannot reconstruct the number of opportunities for random fluctuation or test whether a false alarm was a predictable consequence of prolonged searching. This matters particularly for legal disclosure, where a selected event cannot be evaluated

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properly if the surrounding failed searches have disappeared from the electronic record.

The sequential framework should be challenged on known noise-only records with an appropriately long duration and on controlled injected signals whose power, timing and bandwidth are specified. Evaluate both when the system alarms falsely and when it fails to alarm on a known weak source. The difference between control of false alerts and power to detect rare relevant emissions must not be hidden behind one impressive operating characteristic. If increasing thresholds protect an indefinite false-alarm budget but destroy sensitivity after months of operation, the engineering system requires redesign or a different, explicitly declared risk metric. This is the measurable tradeoff a sound survey should disclose.

My final answer is that one must budget error over the actual opportunities and stopping policy of the monitoring system, not simply over the number of cells displayed at one convenient instant. A persistent surveillance console is a repeated statistical experiment with physical dependencies and changing calibration. The proper conclusion is conditional upon those features, and the final forensic finding must still be supported by external-input tests, independent equipment and an exact chain of custody. A mathematical boundary controls a specified decision error; it cannot alone decide whether an electromagnetic feature is intentional, intrusive or attributable to a person.

Walter A. Shewhart, Peer Question: Dr. Wald, a receiver can retain a constant numerical alert threshold while its background noise, amplifier gain and operating temperature drift throughout the week. An analyst may then treat each hour as another identically distributed trial, although the assumptions

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behind the advertised per-look probability are no longer met. How would you combine sequential error control with a separate process-state check that detects when the instrument has ceased to resemble its calibration population? I am particularly concerned that a control chart could itself generate repeated alerts during ordinary warm-up and that the operator might either ignore those warnings or incorporate them into the substantive emission catalogue. Could you distinguish an alarm about measurement-process instability from an alarm about external RF energy, and specify what should be preserved for subsequent review?

The challenge is particularly acute when nominally independent receivers inherit the same drifting reference; their concordant alarms might then reflect a measurement-process fault rather than several corroborating observations of external activity.

Abraham Wald, Response: Mr. Shewhart, I would make measurement-process health a separate state variable with separate decisions. The system should monitor known references, injected benign signals, internal gain estimates, noise-floor measurements and clock-lock transitions in parallel with its external-signal detector. A control chart can help identify departure from the validated calibration regime, but its own threshold and repeated-look behaviour require characterisation. It is not logically sound to treat a health-warning event as a new external transmission, nor to suppress it merely because it is frequent during warm-up. The proper response may be to mark the affected observation period as uncalibrated and continue retaining raw samples if authorised and safe.

If a reference signal shows a gain change, the detector's null and alternative score distributions may both shift. Under those conditions the old false-

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alarm threshold could become either too liberal or too conservative. An adaptive threshold that keeps the observed false-alarm count constant is not enough to establish that detection sensitivity has remained intact. The procedure should periodically measure detection probability with a controlled weak test signal and compare it with the declared operating characteristic. When performance fails predefined acceptance limits, invalidate the corresponding calibrated inference until the cause is diagnosed and corrected.

Warm-up can be treated as a distinct operating epoch if the hardware behaviour is reproducible and the calibration documents that epoch. A process chart with predictable start-up transients might have state-specific limits, but the transition times and control actions should be retained. The risk budget for substantive detections should apply only to data satisfying the corresponding measurement-state conditions; an out-of-state record is neither positive nor negative evidence at the old sensitivity. Such separation protects the investigator from drawing conclusions about absence of emissions during intervals in which the apparatus could not reliably measure them.

For audit, preserve each health statistic, its source, calibration reference, timestamp, detector settings and the decision that changed the operating state. Do not delete suspect periods or silently change their labels. If observations from those periods are later reanalysed, the new result should be linked to the original file and accompanied by the revised model and uncertainty. A monitor that admits when it is not calibrated produces a stronger evidential record than one that never displays an error but quietly

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changes its statistical meaning. This is the essential cooperation between sequential decision theory and engineering process control.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has identified distinct quantities that are too often confused: the probability of a false rejection in one calibrated spectral cell; the probability of at least one false rejection across a prespecified family; the expected false proportion among reported discoveries; and the long-run rate of false candidate events during indefinite monitoring. These quantities require different assumptions and report different risks. Correlation, window overlap, common oscillator artefacts, threshold adaptation, post-selection tuning and repeated stopping opportunities can defeat apparently impressive per-cell figures. The proposed acceptance protocol therefore defines the family and decision unit in advance, preserves complete noise-only calibration blocks, uses independent prospective confirmation, records all detector alternatives and settings, challenges candidates with physical receiver controls, and makes the uncalibrated operating state explicit. The participants' dialogue is a fictional modern reconstruction of statistical and engineering principles, not authentic historical speech. A statistically significant RF feature is not by itself evidence of an unlawful transmitter or its origin.

QUESTION 079. TECHNICAL SOURCES AND EDITORIAL QUALIFICATIONS.

1. Y. Benjamini and Y. Hochberg, 'Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing', Journal of the Royal Statistical Society, Series B 57 (1995), pp. 289–300, DOI 10.1111/j.2517-6161.1995.tb02031.x. Publisher record: https://academic.oup.com/jrsssb/article/57/1/289/7035855. Establishes the

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independent-test step-up FDR procedure and distinction from family-wise error; historical dialogue discussing its modern use is explicitly hypothetical.

2. Y. Benjamini and D. Yekutieli, 'The Control of the False Discovery Rate in Multiple Testing under Dependency', Annals of Statistics 29 (2001), pp. 1165–1188. Author copy: https://www.math.tau.ac.il/~ybenja/depApr27.pdf. Describes positive-dependence conditions and a conservative modification for arbitrary dependence.

3. S. Holm, 'A Simple Sequentially Rejective Multiple Test Procedure', Scandinavian Journal of Statistics 6 (1979), pp. 65–70. This is background to family-wise step-down control; any claim applying it to a specified RF procedure requires additional calibration of valid constituent p-values.

4. A. Wald, Sequential Analysis (John Wiley & Sons, 1947). Historical foundation for sequential hypothesis testing; modern indefinite RF monitoring and specific spending examples are editorial mathematical illustrations rather than claims that the historical author analysed SDR systems.

5. Technical and legal qualification: All RF scenarios, times, sample counts, noise powers, and numerical values are hypothetical. No field receiver, emitter identity or empirical false-alarm rate has been independently established in this manuscript.

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QUESTION 080

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What experiment distinguishes stimulus-responsive RF activity from accidental coincidence?

SCHOLARLY RECONSTRUCTION. This moderated exchange is fictional educational dialogue among deceased historical specialists. No statement is an authentic quotation, and no participant is represented as personally having operated contemporary software-defined radios. The experimental settings, numerical examples and potential RF responses described here are hypothetical. They concern authorised defensive testing on controlled premises and devices, not unauthorised communications interception or intrusive stimulation.

Dr. James M. Atkinson, Moderator: Professor Wald, the appearance of an intermittent RF emission shortly after an operator changes a room condition may seem persuasive, particularly when the temporal sequence repeats. Yet a receiver may revisit its band periodically, a noise-floor fluctuation may cross a threshold without any external transmitter, and the operator may unconsciously select only the interventions that are followed by an interesting trace. What intervention design would distinguish a reproducible stimulus-dependent emission from ordinary temporal coincidence? Please address sham trials, concealed random allocation, outcome definitions, uncertainty in event timing, and the evidential distance separating a statistical response from attribution of the source.

Abraham Wald, Principal Contributor: Dr. Atkinson, the strongest initial correction is to replace a memorable sequence of occurrences with a fully enumerated experiment. One must decide, before seeing the next observations, precisely what constitutes a trial, which circumstances make a

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trial eligible, what observation window is assigned to it, and which RF outcome is to be counted. Without those decisions a remarkable-looking event can be chosen after its timing becomes known. That is a form of selection, not independent proof of a controlling stimulus. The first estimate should be of a treatment contrast within a deliberately constructed population of trials, not of a story built from one striking temporal arrangement.

Let Z_i equal one when eligible trial i receives the predesignated real stimulus and zero when it receives the sham procedure. Let Y_i equal one if a prespecified and instrument-qualified RF event is observed within the defined post-trial window, and zero otherwise. The simplest risk difference is $D = \text{mean}(Y_i \text{ given } Z_i=1) \text{ minus } \text{mean}(Y_i \text{ given } Z_i=0)$. Its value measures the difference in observed event fractions under those two conditions. It does not by itself measure the likelihood that any particular transmitter is present, nor identify how the physical stimulus could produce an emission. Such interpretation would demand further experimental discrimination and a documented observation chain.

Random allocation should be concealed from the person classifying the RF record, wherever operationally feasible. A laboratory controller can select true and sham trials according to a precomputed sequence and disclose that sequence after the analytic code and outcome ledger have been sealed. The sham should reproduce the mechanical movement, operator presence and audible indications of the real procedure while withholding the particular causal element being tested. A sham that differs in obvious sound, power consumption or observer behaviour will not isolate the intended mechanism. Nor should the randomising device itself radiate a

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distinctive cue that the receiver might detect. The allocation implementation must be tested with an independent spectrum witness before the formal trial.

Consider a hypothetical first series comprising forty true and forty sham trials. Suppose thirteen true trials and five sham trials contain a qualifying event. The descriptive proportions are 13/40 = 0.325 and 5/40 = 0.125, producing D = 0.20, or twenty percentage points. Those figures may motivate an inference, but neither the observed difference nor a calculated significance value automatically supports the mechanism claimed. Trial-to-trial dependence can arise because the detector's threshold adapts slowly, because an emitter remains active across several trials, or because a reference oscillator experiences a shared state transition. A model assuming eighty independent Bernoulli outcomes may be unsuitable if the apparatus changes state after every stimulus. The complete time-ordered outcomes are needed to diagnose the dependence.

The experiment should include washout periods selected by engineering rather than convenience. A receiver's automatic gain control, resonant filter, data queue or digital threshold estimate may retain memory from the preceding trial. A device under test may also have a true physical state with persistence. If another stimulus arrives before that state has returned to baseline, an emission in the next trial cannot unambiguously be attributed to the later intervention. The data ledger should therefore record eligibility exclusions, antecedent condition, time since last actuation, instrument-state transitions, source-reference health, and the laboratory's measured detection coverage. I would prefer explicit exclusion rules established

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before opening the outcome file to informal post hoc labels of contamination.

The trial schedule must be planned against the receiver's scan cycle. An instrument that samples a frequency for only one tenth of each minute can make an effect appear to depend on stimulus timing merely because the observer tends to act when the waterfall is visible. Randomising the actuation sequence without randomising or documenting the receiver observation state does not solve that problem. A continuous independently clocked witness channel, if available, is preferable. Otherwise estimate a separate exposure variable C_i describing the measurable fraction of the post-trial window and incorporate it into the analysis. A trial with an unobserved window should not silently become a negative result; neither should a trial be dropped because its missingness looks inconvenient.

I would also require a negative-control outcome, such as activity in a spectral region where the proposed mechanism predicts no change but where common receiver artefacts might appear. That outcome helps reveal broad receiver response to the action. A known injected calibration signal supplies a positive control for detectability and timing, though its injection must be physically separated from the contested environment. One ought to test whether a threshold excursion remains when the antenna input is properly terminated or replaced with a documented laboratory source. An RF peak that responds to the sham as strongly as to the true stimulus may indicate human activity, mains disturbance or instrumentation rather than a targeted device response.

A sequential continuation is permissible only with a stopping policy. If a technician inspects the results every ten trials and stops precisely when a

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favourable difference appears, an ordinary fixed-sample significance test no longer has its advertised error properties. A sequential likelihood-ratio procedure, a prespecified maximum sample size with adjusted boundaries, or a held-out confirmation phase can address this. The rule must include every look that affected the decision, even if the investigator did not produce a formal written statistical test at that moment. Repeatability in a new concealed allocation schedule should be treated as new evidence rather than as an opportunity to reselect whichever earlier parameters appeared best.

Finally, the claimed causal chain should be tested at successive reference planes. At the weakest level, one may establish that the detector's output became more likely during true trials. A stronger finding requires that raw RF energy, not merely detector state, changed after a calibrated stimulus. A still stronger finding may show the change persists across different receivers and antenna arrangements, with identifiable spatial behaviour and a plausible physical coupling pathway. None of these stages alone proves the purpose, owner or lawful character of an emitter. My recommendation is to preserve and report the ladder of claims separately. Only then does a controlled experiment improve the evidence rather than lend a mathematical seal to an attractive coincidence.

Jerzy Neyman, Peer Question: Professor Wald, the design seems admirable in outline, but what exactly should be fixed before the first formal trial? In a complex receiver system the observer might define a successful event by amplitude, a frequency band, a decoded label, a time separation, or a visual classification, and those choices do not have equal false-positive behaviour. Would you specify an operational acceptance rule that can be implemented

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without discretionary operator judgement, together with a rule for pulses straddling the response window and a treatment for trials in which the receiver temporarily loses acquisition? Please also distinguish the statistical target of an association between trial assignment and observable RF response from the much stronger hypothesis that a particular hidden mechanism is responsible. Finally, can the calibration observations used to choose an event definition later be recycled as if they were independent confirmation of that definition? I am concerned that a well-concealed allocation is insufficient if the result itself is still chosen after inspecting the data.

Abraham Wald, Response: Professor Neyman, the acceptance rule should be committed to a dated protocol and, preferably, executable code before outcomes are available to the analyst. It should include the receiver's centre frequency or defined band, the detection statistic and its units, threshold and duration conditions, the maximum allowed overlap between clustered triggers, the post-stimulus window and its latency allowance, as well as rules for censoring intervals when acquisition integrity fails. If a pulse begins before the trial's response window but continues into it, the protocol must decide in advance whether onset time or any overlapping energy qualifies. Those definitions answer different questions and must not be exchanged after the fact. A sample-counter gap invalidating a large part of a trial should be marked missing or censored, not assigned zero.

A useful eligibility criterion requires the hardware counter to have continuity evidence over the entire scoring interval and the timing offset to remain within a specified bound. If the record contains an acknowledged gap, a sensitivity analysis can treat the missing observation as either possible

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success or failure to bound the result; one cannot claim the true outcome was observed. The primary estimate concerns an instrument-qualified event under the assigned condition, and its uncertainty must reflect the randomisation and relevant dependence. Attribution to a transmitter requires separate physical tests, including changes to antenna path, independent clocks and local injected controls.

The calibration record used to choose the threshold is training evidence. It is not simultaneously an untouched confirmation set. The investigator may employ a pilot series, openly labelled exploratory, to choose the detection rule, then freeze it and apply it to a new randomised series. If the method must be modified because a fault is found, the record should show a new protocol version and a new confirmation epoch. One may report both series with their different purposes, but they should not be collapsed into one claim that the rule was prospectively specified throughout. This distinction preserves the meaning of the nominal error rate and allows a later examiner to reconstruct why a particular event was admitted.

This procedure also requires preserving the exact observation opportunity: a device whose clock has reset during the scoring interval may have an unknown latency mapping even if its data file is readable. The uncertainty of that mapping should be recorded as a measurement qualification, not absorbed into a favourable probability estimate. A blind analyst should see the same qualification rules for true and sham trials.

Abraham Wald, Cross-Peer Question to David R. Cox: Dr. Cox, I accept that random assignment protects the treatment contrast against some sources of bias, but I question whether it adequately protects the measurement chain itself. Suppose the act of operating the laboratory controller drives a

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transient through the mains or RF reference network, while the purported environmental stimulus is only one of several coupled disturbances. A sham that imitates operator motion but not electrical switching would produce a difference even if no subject device responded. How would you build the causal model so that the intervention assigned at random can be separated from the practical procedure used to deliver it? What observations would make the distinction identifiable without introducing so many auxiliary measurements that the team subsequently selects whichever one agrees with its desired account?

Please include the possibility that an electronic actuator produces both a legitimate field change and an internal receiver disturbance simultaneously. In that case a simple binary association can remain strong even though the contested emission is not uniquely identified; the experiment must distinguish mixtures rather than merely alternatives.

David R. Cox, Cross-Peer Answer to Abraham Wald: Professor Wald, the randomised contrast identifies the effect of the procedure as implemented, not automatically the effect of an imagined isolated component. If the true operation switches a relay, supplies power to a motor and alters the condition of interest while the sham merely has an observer press an inert button, the experiment identifies a bundled intervention. I would begin by drawing a causal diagram whose nodes include the random assignment, operator movement, controller switching, mains conditions, antenna-cable coupling, receiver state, actual RF field and final threshold indication. The graph is not proof of those pathways; it is a record of the alternatives that the experiment must distinguish.

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A better design uses a matched sham with controlled electrical load and a separately measured reference path. Under an authorised laboratory plan the actual environmental change can be enabled or disabled while a dummy load reproduces the relevant actuation current. The controller and receiver should have independent timing witnesses so an event in the spectrum analyser's internal clock is not confused with energy from the location under investigation. A crossover arrangement can exchange the true and sham loads across two physically equivalent paths, revealing whether the anomaly follows the supposed stimulus or the switching hardware. The experimenter should specify which contrasts matter before reviewing results.

Independent intermediate measurements are valuable only if their evidential purpose remains explicit. A supply-current probe tests conducted disturbance, a terminated antenna input tests receiver-side susceptibility, and a physically remote receiver challenges source attribution. None is a substitute for the primary outcome, and a favourable subsidiary trace should not replace an unfavourable primary result. If multiple exploratory measurements are reviewed, disclose them and reserve a subsequent confirmation series for the narrowed hypothesis. Thus causal design and randomisation reinforce one another, but neither can abolish confounding concealed by an unexamined instrument connection.

If both pathways operate, a factorial contrast may exhibit an interaction because the receiver becomes temporarily less sensitive while the external field actually grows. The investigator should therefore retain a calibrated test carrier through each stimulus and measure gain recovery directly. An apparently absent RF response during the interference interval could be a

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false negative, not evidence that the environmental device remained silent. Multiple outputs and a recorded causal graph guard against that ambiguity.

Dr. James M. Atkinson, Moderator: Dr. Cox, the preceding challenge reminds us that an operator's intervention is rarely a single physical act. Would you take the token and examine identifiability, controlled sham operations and observational confounding within a receiver laboratory?

David R. Cox, Second Principal Contributor: Dr. Atkinson, the central inferential error occurs when an experimentally observed association is given the name of a mechanism that has not actually been isolated. Randomisation is an exceptionally powerful design principle, but the causal object it identifies depends on the intervention implemented. Let Z denote random assignment and let T represent the complete realised procedure, which may contain movement, switching, acoustic disturbance, local electrical transients and a physical environmental change. Let E stand for actual external RF energy at a specified antenna reference plane and Y for the signal-processing decision. The chain Z to T to E to Y is only one possibility. There can also be a direct pathway T to Y through instrument coupling, and a confounder such as temperature or occupancy can influence both the environment and the ability to detect the event. A design that ignores these alternative arrows might discover a reproducible response of the test apparatus while mistakenly naming a remote emitter.

The first requirement is to articulate a counterfactual question. Under the same feasible laboratory conditions, would the probability of a qualifying RF observation differ had the true rather than sham procedure been performed? That is a legitimate experimental question. A more ambitious question asks whether the proposed environmental mechanism, separately

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from controller switching and observer movement, changed the incident electromagnetic field. This second question requires controls that disentangle the components. It cannot be settled solely by a difference in detected events, because the final detector has physical sensitivities of its own. The inquiry should be planned so that the decisive measurements distinguish competing causal models, not merely accumulate confirmations of one preferred description.

If a stimulus has two controllable components, A for the environmental change and B for controller activation, a small factorial study can test combinations (A=0,B=0), (A=1,B=0), (A=0,B=1), and (A=1,B=1), provided all combinations are physically safe and meaningful. For the outcome mean μ_{ab} under the indicated state, the contrast $\mu_{10}-\mu_{00}$ estimates the effect of A without B, while $\mu_{01}-\mu_{00}$ estimates B without A. An interaction may be assessed by $\mu_{11}-\mu_{10}-\mu_{01}+\mu_{00}$. These are descriptive causal contrasts under assignment compliance, comparable populations, and well-defined interventions. If A cannot be implemented without B, the independent effect of A is not identified by this design and must not be claimed. One might instead use a matched electrical sham or an alternative actuator technology to reduce the coupling.

The temporal aspect is as important as the treatment definition. A real RF response can be delayed, intermittent or conditioned on the device's prior state. If the expected response latency is uncertain, selecting the response window after the test will exaggerate evidence. I would require a primary window derived from a declared physical hypothesis or from a separate pilot study, together with secondary windows explicitly designated exploratory. The detector should preserve a raw time series so that later investigators

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can examine whether the observed pulse preceded the actuation rather than followed it. Trigger timestamps originating in a host computer should be mapped to receiver sample indices using measured latency and uncertainty. An apparent causal order is unpersuasive when the timing error is greater than the claimed delay.

Blind assignment can limit observer expectation, but concealment must be meaningful. If the operator feels a motor vibrating during true trials, the sham is not blind even though a computer conceals the allocation list. If true actuation produces a distinctive switching transient visible in the receiver's own spectrum, an analyst may infer assignment from the data without any actual target response. This is not necessarily a failure of detection. It is a failure to prevent the instrument from being an unacknowledged intermediary. Measure assignment cues in channels selected for that purpose, use balanced actuator noise where safe, and document residual differences rather than proclaim an impossible perfect sham.

Physical intervention controls should be ordered according to causal power. First replicate the observed effect with a benign calibration transmitter under controlled field strength and gain. Then substitute a properly terminated antenna input to see whether the recorded feature survives without the environmental field. Next change receiver architecture, reference source or antenna placement independently. If the feature follows the host power supply or controller lead rather than the antenna, the external-field account weakens. Conversely, if it follows geometric reception while disappearing under termination, the inference of external energy strengthens but still does not identify a particular device. The absence of a feature after switching receivers is not proof of its absence in the original

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configuration, because sensitivity and detection bandwidth may have changed.

The statistical analysis must account for unequal observation opportunities. Suppose the frequency-agile receiver visits the relevant band for a fraction c_i of the response window on trial i. A binary comparison treating every trial as fully observed will attenuate real effects and can produce spurious differences if the visit pattern aligns with assignment. One may block randomisation by scan phase, schedule actuation independently of the scan period, or maintain an independent continuous witness. A model for event counts may include an exposure offset $\log(c_i T_i)$, where T_i is the nominal window duration, but such an offset is justified only if event opportunity is proportional to observed time under the relevant process model. For a stimulus-locked brief burst the timing of the blind interval, not just its total duration, can dominate detectability.

Negative controls should be chosen for their causal interpretation, not numerical convenience. A sham trigger tests some procedure-linked effects. A remote shielded reference channel tests receiver and clock artefacts. A geographically separate receiving chain tests spatial localisation, but not necessarily common external interference. A control frequency expected to be free of the proposed response can reveal broadband transients, though a narrow-band impairment may evade it. Each control tests a different alternative explanation, and a satisfactory final report must state which alternatives were challenged, under what calibration, and which remain plausible. It would be methodologically unsound to count a control as independent merely because its display appears on a second screen connected to the same timing and power network.

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I would end with a layered causal conclusion. If true and sham conditions differ under random allocation, we may report an association between the specified implemented procedure and the qualified receiver observation. If that difference persists through antenna substitution and independent RF measurement, we may support a stronger claim that the incident electromagnetic field changed. If further controlled source-direction, frequency-plan and device-side testing links the change to one physical apparatus, a source-specific inference may be contemplated with its uncertainty disclosed. Intent, authorisation and purpose are distinct matters. The experiment should never be made to carry a conclusion it did not measure. In a mature forensic report the boundary between identified effect and untested mechanism is a mark of rigour, not a defect to conceal.

George E. P. Box, Peer Question: Dr. Cox, every experimental factor in your analysis is represented by a simplified variable, but real electronics seldom comply with the tidy divisions of a two-factor table. A switched supply can inject spectral components through its leads, the RF front end may undergo gain recovery, and the supposedly inert sham may change acoustic vibration or thermal load. How should the team test whether its factor model is an adequate approximation rather than merely an attractive set of symbols? I would particularly wish to know which residual patterns should trigger a model revision, and whether the investigator may revise the model after observing one unexpected strong candidate without destroying the interpretation of the preassigned confirmatory test. Finally, how should one state the limits of a factorial design when one factor combination is physically impossible or unsafe and thus lacks empirical support?

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I would also ask what a legitimate falsification of the original model looks like: not merely a poor fit statistic, but a physical control whose measured outcome lies outside the model predictions. A receiver artefact replicated under terminated input would be one especially useful counterexample.

David R. Cox, Response: Professor Box, the factorial contrast is meaningful only for configurations that can actually be implemented and measured. Its notation should not be mistaken for an assertion that every combination of A and B is accessible. Where one experimental cell is forbidden by safety or engineering, a main effect that requires that cell is not identifiable from the remaining observations without additional assumptions. The investigator should state the estimable contrasts rather than impute a fictional experiment. A suitable alternative may use two independently designed actuators, or a sham which reproduces the important electrical signature while withholding the alleged environmental change, then explicitly quantify the residual differences.

Model criticism belongs in the planned procedure. Inspect residuals by trial order, temperature, receiver state, scan phase, stimulus intensity and prior-trial condition. A time trend in the estimated treatment contrast, for example, can indicate a drifting noise floor or device memory rather than a constant effect. A sudden concentration of qualifying events at every reference-switch transition suggests an instrumental cause. A group of events occurring before rather than after the putative stimulus would directly challenge the causal chronology. Such diagnostics can be planned as model checks without assigning each one the status of a new primary hypothesis.

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If an unanticipated strong feature appears, preserve it and investigate; do not pretend the resulting revised model was specified before the observation. Write a versioned exploratory amendment recording what prompted it, including unsuccessful alternative configurations and changes to the event definition. Any subsequent confirmation should use newly allocated trials or a reserved dataset, with the revised protocol frozen before inspection. This allows model development and honest inference to coexist. The quality of the scientific account lies partly in whether another laboratory could repeat the distinguishing test from its description, including the cases in which the response should not occur.

For instance, an effect confined to one cable installation but absent after moving the receiver and retaining antenna geometry points towards an equipment path omitted from the original model. That observation should become a concrete design revision with recorded calibration, not an unexplained deletion from the analysis. The final report must retain the older model and show which result exposed its inadequacy, so a reviewer can separate discovery from a successful prospective test.

David R. Cox, Cross-Peer Question to Ronald Aylmer Fisher: Professor Fisher, suppose an investigator randomises the order of forty true and forty sham operations but then inspects the RF trace and discovers that the interesting line is present only after a long quiet interval. They consequently define a new class of 'eligible' trials based upon a retrospectively selected preceding gap. The original allocation was random, but the subset was chosen using an observed response. How does that change the status of an exact randomisation test? Would you insist on treating the condition as exploratory, or can one construct a valid conditional test from the original

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allocation without understating the choices made after seeing the data? I also ask how the proposed analysis would handle a receiver whose scan pattern was periodic and therefore made certain apparent response delays far more likely than others.

Please address whether a confirmatory test conditioned on an instrument state selected from pilot data is legitimate if that state is genuinely measured before each random assignment and the rule is frozen for a new series. The distinction seems important for experiments that cannot be performed safely in every operating mode.

Ronald Aylmer Fisher, Cross-Peer Answer to David R. Cox: Dr. Cox, randomisation does not grant retrospective freedom to choose whichever outcome or subgroup is most favourable. An exact randomisation test is exact for a specified statistic under its randomisation scheme and null assumptions. If the analyst searched many gap thresholds and reported the one with the largest contrast, the reference distribution for that selected maximum must account for the search; simply computing a permutation p-value for the chosen subset as though it had been specified prospectively will generally be anti-conservative. One may, in principle, repeat the entire selection algorithm within each permitted randomisation to calibrate a maximum statistic, provided the exchangeability and computational rules truly apply. That approach does not transform a selected subgroup into an independent replication.

For transparency I would report the original prespecified analysis on the entire eligible trial set, together with the exploratory gap-dependent observation and the number and nature of thresholds examined. Then I would conduct a fresh confirmatory series stratified or blocked on the

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preceding quiet interval, using a fixed threshold and concealed allocation. The periodic receiver requires its own design protection: assign trials within comparable scan-phase blocks or capture continuously with an independent witness. A permutation must respect the actual randomisation structure; freely permuting allocations across blocks when only within-block allocations were possible would invent an experiment that did not occur. Statistical legitimacy thus follows the physical execution as closely as it follows the algebra.

The distinctive virtue of randomisation is the ability to state what would have varied under a different permitted assignment. An instrument whose coverage depends on time is part of that assignment environment, not an irrelevant nuisance. Keep all scheduled stimulus times, all sham times, scan-state logs, rejected trials and raw detection statistics. A new subgroup finding can be scientifically valuable, but its evidential category remains discovery until tested against fresh observations under a prospectively determined rule. One should not conceal this distinction simply because a modern software package can issue a beautifully formatted significance table.

A state defined from pilot observations can be used as an eligibility or blocking criterion in a new randomisation without contaminating that new test, provided it is fixed in advance and does not depend on its hidden outcomes. The investigator must still report the narrower target population and any inability to generalise to other instrument states. This is a methodological restriction, not a source of additional evidence for the original exploratory result.

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Dr. James M. Atkinson, Moderator: Professor Fisher, the panel now turns to the logic of an experiment whose hypotheses and observation windows are settled before the decisive trials. Would you examine randomisation, blocked designs, chance association and the evidential limitations of a statistically significant response?

Ronald Aylmer Fisher, Third Principal Contributor: Dr. Atkinson, experiments deserve their reputation not because they banish chance, but because they create a controlled account of the role that chance may play. The central problem is to decide what would count as evidence against the hypothesis that the implemented true and sham operations have no differential effect on the chosen RF response. Once a statistic and permitted treatment assignments have been defined, randomisation allows the investigator to compare the observed result with the outcomes that could have arisen under other allowed assignments. This procedure is not a magical detector of intention or source identity. It is an inference conditional on the experimental arrangement, an event definition, and a sufficiently stable observation process.

A suitable primary statistic might be the difference between the fractions of qualifying trials in the two groups, with each trial scored by a predeclared detector and time window. In a balanced experiment with n true and n sham trials and a fixed number K of qualifying events under a sharp null of no treatment effect, the randomisation distribution of the true-group event count X can be hypergeometric when the treatment labels are assigned by complete randomisation and the relevant outcomes are fixed under the null. The probability mass is proportional to choosing x of the K event-bearing units and $n-x$ of the remaining units, divided by the number of ways to

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allocate n true labels among 2n trials. That distribution reflects the actual allocation design; an unrestricted permutation model is wrong if trials were paired or assignments were blocked.

This mathematics is not by itself a measurement of causation. Suppose the laboratory applies a true stimulus to twenty trials and sham conditions to twenty, with ten qualifying events following the true operation and four following sham. The observed event fractions are 0.50 and 0.20. If these were the only planned comparisons and the required assumptions held, a randomisation calculation could assess compatibility with a sharp no-effect hypothesis. But the difference may equally be due to the test controller's electrical signature if that signature differs between treatments. A perfectly small p-value can support the proposition that the instrument output changed with the procedure while offering little evidence that a concealed communications device responded. The causal interpretation must be earned at the physical reference plane.

Blocking can materially strengthen the experiment. A frequency-agile receiver may revisit the region at known phases, a building's electrical supply may have cyclical disturbances, and local temperature can alter receiver gain or oscillator drift. A blocked sequence assigns both true and sham within comparable short intervals or within receiver-state classes established in advance. This can improve precision by reducing irrelevant variation. It can also prevent the confounding of all true operations with one part of the day and all sham operations with another. Yet blocking requires care: if the proposed stimulus leaves persistent state, a true trial can contaminate the sham trial paired with it. The design should therefore

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include washout checks and document when a block cannot be completed as planned.

An especially deceptive circumstance is an experiment performed around a striking exploratory signal. An operator hears a familiar relay click, notices a narrow spectral peak some seconds later, repeats the procedure until a similar coincidence appears, and then proposes to score the next fifty trials. The original observation can rightly inspire a hypothesis. It cannot also be counted as a prespecified test of that hypothesis, because its timing, frequency and event classification were selected from the data. In subsequent analysis the pilot record may remain visible as background evidence, but the confirmation set should be genuinely new and the rule frozen. Disclosure of the exploratory search is necessary because many plausible hypotheses might have been generated from the same scene.

A second hazard is the use of many indicators without accounting for choice. If the investigator examines twenty bands, several lags, multiple amplitudes and different algorithms, then retains only the most striking correspondence, the probability of finding some apparent association under a broad null can far exceed the per-test probability. This is true even when indicators are correlated and cannot be treated as twenty independent trials. One remedy is to define a single primary physical outcome and a hierarchy of secondary outcomes. Another is to calibrate the maximum statistic under the actual selection algorithm using randomisation that preserves the physical trial and measurement structure. Such calibration must be performed on the same analysis procedure actually used, not on a simplified surrogate that ignores operator choices.

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The design should also include a challenge against the receiver's own transients. An injected reference tone, at a safely controlled level and outside the disputed source path, can establish that the receiver would have detected a true event in the selected window. Terminating the antenna port, where permitted, can test whether a purported RF response instead enters through power, cabling or internal mixing. An independent clock can test whether timing agreement arose from a shared oscillator transition. These controls need not all enter the primary test statistic. They define the physical interpretation of a detected statistical response. One must not confuse a statistical false alarm, an instrument artefact and an incorrectly attributed genuine RF signal, for they are different errors.

I would record trial labels under sealed allocation, raw data before filtering, the hardware sample-index clock, calibration state, all excluded intervals, the event-classification algorithm and its revision identifier. A suitable report includes the observed difference, its uncertainty or randomisation reference distribution, the range of possible effect sizes consistent with the data, and the experimental conditions under which the result applies. It should describe whether independent replication was conducted and whether it reproduced the predicted timing and spatial properties, not merely whether one new trace looked familiar. An experiment whose outcome is an alarm rate must not be converted into an allegation of intent without an additional chain of evidence.

Finally, no universal numerical threshold can substitute for scientific judgement about the consequences of the claim. A modest result may justify an inexpensive, harmless instrument challenge; a grave allegation that a person or organisation installed a covert transmitter would require

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independent, physically discriminating evidence of a much higher quality. Significance is not source attribution, and a result that is statistically incompatible with one narrow null may still be explained by another. The investigator must understand what has actually been excluded. A sound experimental design narrows possibilities while preserving the right to remain uncertain where the apparatus cannot distinguish them.

Sir Harold Jeffreys, Peer Question: Professor Fisher, your proposed randomisation distribution is useful if the treatment assignments are genuinely controlled, but may an examiner infer the probability of a particular mechanism merely from observing a small tail probability under the sharp no-effect hypothesis? I ask because field reports often use the phrase 'chance of coincidence' as though a significance calculation directly assigned a probability to random coincidence having occurred. Could you specify the relation between the tail probability, the observed risk difference and the likelihood of a physical hypothesis involving an external RF source? I would also like you to address what happens if the investigator chooses the expected latency after seeing the observed emission, then calls this chosen latency a natural consequence of the tested mechanism. Does repeating the same selected window on the same stored data produce genuinely new information, or only a more polished restatement of the initial selection?

An independent timing witness may itself suffer a shared clock or power-path disturbance. Would you include the requirement to document that witness's physical independence before promoting a temporal association to a source claim?

Ronald Aylmer Fisher, Response: Sir Harold, the tail probability answers a conditional question about the extremeness of an observation under an

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explicitly specified null model and test procedure. It does not measure the probability that the null hypothesis is true, nor the posterior probability that a suspected device exists. To infer a mechanism one would require evidence concerning alternative explanations, an identifiable causal pathway and the actual performance of the measuring instrument. A small p-value may show that a no-differential-procedure-effect model is uncomfortable given the data. It cannot tell whether the difference came from an external emitter, a relay spur, scan-phase bias or selective scoring unless the experiment has made those alternatives distinguishable.

The observed risk difference is a descriptive estimate on a specified population of eligible trials. Its interval uncertainty addresses effect magnitude under the selected statistical model. A source-specific claim involves a further inverse problem in which several different causes can lead to the same detector output. That inverse problem requires separate calibration and experiments. One cannot cross it by a change in vocabulary. The distinction holds even if the original result is highly reproducible, since an internal artefact can be faithfully reproducible whenever the test controller acts.

Choosing an expected latency after observing the emission is exploratory selection. The analyst can report the exploratory pattern and subsequently establish a prospective window in a new experiment, but applying that same rule repeatedly to the same observations produces no independent confirmation. If many latency windows were searched, one might construct a selection-aware reference distribution for the best window, provided all choices and their dependencies are correctly modelled. In most practical laboratories, a genuinely new randomised and concealed trial series is

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easier to interpret. Its strength lies in an exposure that had not already determined the detection rule.

I would record exactly when the hypothesis was proposed and when the primary window was frozen. Such chronological documentation matters as much as the eventual numerical result. The evidential sequence should move from an exploratory temporal pattern, to a controlled association, to an externally corroborated physical source change, and only then to a cautiously justified mechanism. Neither a p-value nor a visually striking waveform is a substitute for those successive steps.

David Harold Blackwell, Peer Question: Professor Fisher, suppose the receiver visits a narrow frequency every five seconds, while a true stimulus is delivered at varying times and the proposed external device, if present, responds for just forty milliseconds. A trial that includes no observation of the relevant band could be wrongly classified as a failure, and the chance of seeing a short response depends strongly on its phase relative to the visit schedule. How should the randomisation and response model account for these unequal opportunities without treating total elapsed monitoring time as though it were continuous coverage? Is it sufficient to divide observed event counts by the sum of receiver dwell times, or does the particular timing of a predicted stimulus-locked burst make that exposure correction misleading? Please explain what an independent continuous witness could actually establish and what it would still leave unresolved about attribution.

Please further distinguish a source that is silent from a receiver that temporarily cannot detect its pulses, since these states lead to different observation likelihoods even when both are recorded as zero.

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Ronald Aylmer Fisher, Response: Dr. Blackwell, total dwell time is not in general an adequate denominator when the putative response is sharply timed relative to an intervention. If an event is expected only in a narrow forty-millisecond interval and the receiver does not observe the band during that interval, a trial provides no relevant observation, however long the receiver monitored unrelated frequencies earlier in the same minute. A model based on a constant event rate per observed second could be suitable for a stationary background process, yet unsuitable for a stimulus-locked transient. The exposure correction must follow the scientific mechanism being tested and the exact observation schedule.

The cleanest arrangement is to monitor the designated response band continuously during the qualifying interval with an independently timestamped, appropriately calibrated channel. If that is unavailable, one may schedule trials only during predefined suitable receiver windows or randomise treatment within blocks with comparable scan coverage. The rules should be established before viewing the outcomes, and all ineligible or failed trials logged. A trial should not be called negative because it was blind. If partial observation is permitted, define and model the observable fraction of the primary latency window, taking account of its position, not merely its total duration.

A continuous witness can establish a substantially stronger record of whether a signal was present within the receiver's defined sensitivity during an assigned interval. It can also challenge gaps, host delays and scan artifacts in the primary receiver. Yet even this witness does not by itself prove that the field change arose from the proposed target; a supply-coupled switching transient might be recorded by both receivers.

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Independence requires examination of antenna pathways, reference clocks, grounding and physical separation. Its contribution is to reduce the set of plausible failures, not to eliminate every alternative.

I would therefore report separately the number of randomised assignments, the number of technically eligible observation intervals, the number of valid detected outcomes, the number censored for instrument reasons, and the estimated contrast among eligible trials. If eligibility itself differs by assignment, that is an additional warning: treatment could be affecting coverage rather than the proposed emission. Physical controls and a carefully stated estimand are necessary before a causal interpretation is warranted.

Ronald Aylmer Fisher, Cross-Peer Question to Karl Raimund Popper: Sir Karl, a statistical experiment is often criticised for permitting a favourable result to be described as verification without specifying which observations would contradict the proposed cause. Suppose a true stimulus produces an elevated event rate, but the same emission also occurs during sham trials and sometimes before the stimulus. What pattern of failures would make the proposed stimulus-dependent device hypothesis untenable, rather than merely less impressive? I ask also whether an experiment can honestly distinguish a narrow hypothesis of conditional RF response from the much broader claim that a device is intentionally controlled by the occupant's actions. What would you require the technical investigator to state in advance so that an unfavourable result is not repeatedly excused by adding an unmeasured hidden state or an arbitrary new response window?

A probabilistic response cannot be expected on every trial, but its permissible background and latency distributions should nevertheless be

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bounded before the confirmation. Please explain how failure probabilities and the smallest practically meaningful treatment effect can give a risky, testable prediction.

Karl Raimund Popper, Cross-Peer Answer to Ronald Aylmer Fisher: Professor Fisher, a useful hypothesis must incur the risk of being wrong. A claim that 'the signal sometimes appears when the operator acts, unless an unknown state prevents it, and may also appear without the operator's action' has almost no discriminating empirical content. I would demand explicit predicted conditions: the specified stimulus should raise the likelihood of a particular RF outcome in a defined latency window, and specified sham operations should not produce the same outcome under otherwise equivalent observation. The proposed mechanism should also predict a physical response pattern at the antenna reference plane distinguishable from mere switching feedthrough. Such predictions can be challenged without asserting that a single contrary trial conclusively disproves every stochastic mechanism.

An occasional response on sham trials is compatible with a probabilistic stimulus effect, but a consistent equality of true and sham response rates within adequate sensitivity would count against that effect, given a prespecified minimum meaningful contrast and sufficient statistical power. A concentration of events before the stimulus, or an event that persists under terminated RF input while following the controller's power cycle, would specifically challenge a claim about externally incident RF energy. The investigator should record those outcomes rather than explain every one away with a new story. A negative result may also reflect inadequate

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observation, so demonstrable detectability and coverage are prerequisites to meaningful falsification.

It is essential to distinguish the narrow causal hypothesis from an allegation about purpose. Even a repeatable stimulus-conditioned emission can arise from lawful industrial control electronics, accidental coupling, or an instrument. The operator cannot infer intentional covert surveillance merely by naming the trigger condition. Any subsequent source-identification claim must propose additional tests, such as predicted spatial field response, power-state dependence of a known apparatus, or controlled exclusion of receiver-generated products. The virtue of an experiment is that it forces these hypotheses into mutually discriminating forms. It is not the privilege of the investigator to keep changing the definition of success until a preferred conclusion becomes immune to refutation.

One can specify that the treatment contrast must exceed a prespecified meaningful threshold under adequate coverage, rather than insisting on certainty for individual pulses. A confidence interval compatible only with negligible effects after a well-powered test would then count against the proposed practical mechanism. Conversely, an imprecise interval containing large positive and negative effects would justify an inconclusive judgement rather than either vindication or refutation.

Dr. James M. Atkinson, Moderator: Sir Karl Popper, would you now examine the difference between a hypothesis that makes risky physical predictions and one insulated from criticism by arbitrary exceptions? The discussion should remain within lawful defensive instrument testing and must not confuse a temporal association with a judgement concerning intent.

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Karl Raimund Popper, Fourth Principal Contributor: Dr. Atkinson, I would begin not with an assertion that one curious pattern must be false, but with the question of what makes a claim capable of being tested at all. An RF trace following an operator's action can generate numerous accounts: a controlled external transmitter, an ordinary wireless device changing state, a mains-borne disturbance, a receiver generated mixing product, or a chance crossing of an adaptive threshold. A serious hypothesis does more than accommodate the trace after it is seen. It must identify observable differences that would arise under an alternative procedure, an alternative antenna configuration or an independently maintained timing reference. Otherwise it remains a story fitted to whatever the instrument happens to display.

The first discipline is to formulate a prediction before the decisive observation. Suppose the proposed device is said to respond to a change in light level with a carrier appearing in band B within 100 to 300 milliseconds. The prediction should specify the nature of the light change, its permitted intensity and duration, the clock reference used to determine latency, the spectral event definition and a baseline rate under sham changes. If the investigator later observes an event at 700 milliseconds and changes the claim to 'the device adapts its delay', this may be a new hypothesis; it is not fulfilment of the old prediction. Revision is legitimate, but a revised claim must face new observations rather than retrospectively claim success from the evidence that caused its invention.

A genuinely discriminating test also predicts what should happen when a part of the proposed mechanism is absent. If the light stimulus is withheld while the actuator is run into an equivalent dummy load, the hypothesised

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light response should disappear, within allowance for background events. If the RF antenna is replaced with a known termination and the spectral feature remains unchanged, the explanation that it came through the antenna's incident field is specifically weakened. If a separate independently clocked receiver observes a correlated field component with the appropriate spatial dependence, an external-field explanation strengthens, although it may still be an ordinary environmental transmitter. One must formulate such controls before assigning causal labels to their outcomes.

False negative tests require equally careful thought. Imagine that the receiver's preselector is on the relevant band for only ten percent of the critical latency window, or that a local oscillator retune suppresses the first hundred milliseconds after stimulus. The hypothesis could be true and the instrument would fail to observe it. Failure to detect is a fair challenge only when the measurement chain has demonstrated adequate coverage, signal sensitivity and event classification performance for the stated response. The control must expose the limits of falsification, not enable a hypothesis to survive every failure by appeal to an unmeasured instrument. A calibrated injected test signal through the full reception chain can bound detectability, while raw sample counters and timestamps document observation coverage.

There is a further hazard in claiming that repeated association eliminates coincidence. A test controller may systematically radiate harmonics with each operation. Such a component can recur with impressive regularity and may even follow a changing schedule programmed by the investigator. That result falsifies a null hypothesis of no procedure-associated RF feature, but may provide no support for the existence of the suspected external

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apparatus. The better prediction is causal and spatial: the field component should behave according to an external source model, its inferred direction or attenuation should change under specified antenna operations, and it should not persist when all incident RF paths are removed from a qualified instrument. It is precisely the prediction that differs between rival accounts that possesses experimental value.

One can regard the programme as a sequence of increasingly risky tests. Initially the claim is that true trials produce more recorded detections than sham trials. Next the claim is that the difference is present in calibrated raw RF samples. Then it is that an identifiable incident field rather than receiver-generated energy changes. Finally one might claim a particular physical device responds, subject to further tests of that device's state and lawful access. Each step excludes alternatives left open by the preceding one. The investigator should not collapse the stages into an undifferentiated assertion that 'the spectrum proved the device reacted'. The language of the conclusion must match the level of empirical risk actually survived.

It is worthwhile to register adverse observations as rigorously as successes. An event in a sham interval, a matching line in a terminated-input control, an opposite timing order or a disappearance upon changing a receiver's frequency plan should not be hidden. Each changes the structure of viable explanations. There may be harmless reasons for any individual failure, such as a change in sensitivity or imperfect sham equivalence, but these reasons should be independently tested rather than invoked only after unfavourable results. In a long study a record of unsuccessful challenges is part of the evidence. Suppressing it would give the reader the impression of a more definite causal system than was observed.

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The historical temptation is to seek certainty through accumulation of agreeable facts. Modern instrument software makes that temptation worse because it can search enormous records for correlations, display them with impressive precision and omit the alternative comparisons by default. My remedy is simple in principle and demanding in execution: expose the alternative mechanisms, state beforehand the distinguishing outcomes, preserve the failures and ensure that each new conjecture is tested against observations not used to compose it. A measurement may show that a waveform exists; a procedure may show that its likelihood changes after an actuation; only a series of physical controls may support a source mechanism. Those conclusions are distinct, and an intellectually honest report must allow the evidence to stop wherever the experiment stops.

Walter Andrew Shewhart, Peer Question: Sir Karl, a survey may span a day in which the receiver's noise floor, preselector response or host buffering state changes considerably. If a randomised study concludes that an RF event is stimulus-dependent, the apparent result might actually reflect a shifted measurement process. How should the investigator distinguish a meaningful response to a controlled stimulus from common-cause variation or an instrument process that has moved out of statistical control? I would ask particularly about chronological plots of baseline calibration, sensitivity challenges before and after each treatment block, and the temptation to reject entire stretches of inconvenient data as 'instrument instability' only after their outcomes are known. Which observations must be preserved to make a negative or inconclusive result genuinely informative, and when should the experiment be paused rather than interpreted through a model that plainly fails its own calibration checks?

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Would you also specify whether an independent calibration-channel alarm should automatically disqualify the affected window or instead trigger a review that is blinded to treatment assignment?

Karl Raimund Popper, Response: Mr. Shewhart, an experimental apparatus is itself a hypothesis about the relation between physical events and recorded outcomes. If its response function changes, that hypothesis requires examination before the external-source hypothesis is tested. Baseline controls should include reference inputs, known RF calibration stimuli, the receiver's gain and threshold state, reference-clock health, preselector state and the integrity of sample and packet counters. Such checks can be performed at predesignated intervals and after identified hardware transitions. A chronologically complete ledger then shows whether sensitivity was stable or whether a change preceded the apparently favourable association.

Pausing rules should be fixed before outcome inspection where possible. For example, a declared failure of a reference tone to exceed a qualified detector threshold can mark subsequent windows ineligible until the instrument is recalibrated. The rule should treat true and sham trials symmetrically and preserve both attempted allocations and the reason for rejection. It would be indefensible to exclude a block because it contains too many sham events while retaining blocks with similar instrument conditions that favour the hypothesis. Exclusions triggered by outcome patterns can alter the statistical interpretation and should be reported as exploratory interventions rather than hidden corrections.

Control charts and descriptive time series help identify changes but do not name their cause. A drift in calibration response might arise from

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temperature, cable motion, gain control or actual signal environment. Challenge those alternatives by changing one physical pathway at a time under safe conditions. If the measurement apparatus is demonstrably incapable of meeting the prespecified detection requirement, the proper result is an invalid or uninformative trial interval, not a negative finding against the transmitter hypothesis. Conversely, if the apparatus is qualified and a promised response fails to appear under adequately powered, observed trials, that failure should weigh against the particular prediction. Honesty about measurement uncertainty is part of scientific criticism, not a loophole by which every prediction may be preserved.

Qualification of the replacement device should use a common reference signal and a measurement of input-referred detection probability, not rely upon the equality of front-panel threshold numbers. If the substitute can detect the test pulse only at significantly greater field strength, its negative finding cannot be compared without qualification to the original receiver. The experiment should document this sensitivity difference before assessing agreement between laboratories.

W. Edwards Deming, Peer Question: Sir Karl, the trial programme may involve different operators, different shifts, and repeated movement of antennas or cables. A stimulus performed with a different technique can change electrical or mechanical side effects even when the written instruction is the same. How would you require the investigators to standardise the practical operation without concealing the variation that remains? In addition, which elements of the record should allow another laboratory to reproduce the claimed conditional RF response, and how should the team judge disagreements between laboratories with materially

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different receiver bandwidth, sensitivity or trigger algorithms? It is tempting either to treat non-replication as automatic disproof or to excuse it by reciting every possible technical difference. What standard would prevent both extremes, and preserve the value of an honestly unsuccessful attempt under the conditions in which it was conducted?

I would welcome an explicit protocol for maintaining the same signal thresholds when a new operator or laboratory must replace unavailable hardware, since an apparently identical display setting may not imply the same detection probability.

Karl Raimund Popper, Response: Dr. Deming, the operational definition of a stimulus should describe what the apparatus actually does: magnitude, direction and timing of the environmental change, actuation current, switching arrangement, operator proximity and any potential couplings to the measuring chain. A written instruction such as 'switch the light off' is insufficient if different switches, power controllers or personnel create different RF transients. Record the physical configuration and use a mechanically consistent or automated application where feasible, but do not suppress evidence of remaining variation. An observer's proximity to antenna wiring can itself be a changing capacitive or conductive coupling and needs acknowledgement.

Independent reproduction requires a description of the target phenomenon in measurably comparable terms, not a requirement that every laboratory use identical brand names or software versions. State the antenna reference plane, input-referred sensitivity, bandwidth, timebase uncertainty, burst definition, detection probability calibration, stimulus conditions, sham design and analysis rule. A laboratory unable to observe the defined pulse

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under a known reference challenge cannot meaningfully test its absence. But an independently qualified laboratory that observes no treatment contrast under suitably matched conditions presents evidence against the generality of the claim.

Reproduction should also target the cause, not simply the appearance of a spectral line. A matching response that follows the test controller's power supply in both laboratories could reproduce an instrumentation artefact rather than confirm a hidden external device. A disagreement may localise an omitted dependency, such as cable topology or building wiring. Record it and design the next test to distinguish the competing mechanisms. The principle is neither that every failed replication disproves everything nor that every success proves the preferred mechanism. It is that each result constrains the hypothesis according to the capability and independence of the apparatus that produced it.

A reproducibility packet should retain the intervention protocol, sham-equivalence test, original time-indexed detector record, receiver response calibration and any changes made following failed trials. The independent laboratory should calculate the same primary outcome without consulting the first laboratory's selected event locations, and should report excluded intervals as well as successes. If a comparable instrument cannot be assembled, its findings can still bound a different configuration but must not be presented as an exact replication. Such limits are not embarrassments; they delimit what the hypothesis has actually risked.

Karl Raimund Popper, Cross-Peer Question to Charles Sanders Peirce: Mr. Peirce, you have emphasised the movement from a surprising observation to a proposed explanatory hypothesis. I ask how that process can remain

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intellectually productive without allowing the investigator to turn every new explanation into a retroactive success. Suppose a weak RF burst appears after a laboratory stimulus, then later appears when no stimulus was given, and then disappears when the antenna is changed. The investigator can propose a hidden duty cycle, intermittent propagation or a particular impedance dependence to accommodate each result. Which inquiry would you regard as an appropriate next step rather than a mere addition of unconstrained possibilities? Can the search preserve a useful role for abductive reasoning while giving the decisive test to genuinely new observations?

The risk of ad hoc revision is particularly high when an investigator is disappointed by a nonresponse. How would you make the next proposed explanation generate a prediction whose failure could actually reduce belief in that explanation, rather than merely inviting further adjustment of unseen parameters?

Charles Sanders Peirce, Cross-Peer Answer to Karl Raimund Popper: Sir Karl, a surprising event may reasonably prompt us to imagine a cause that would make it less surprising. Such abduction is the beginning of inquiry, not the terminus. The danger is to mistake the ingenuity of the explanation for evidence in its favour. I would ask the investigator to record each candidate cause and derive from it a consequence not already used to invent it. If the source is claimed to have an intermittent duty cycle, specify the expected relation between that duty cycle and independent device-state observations. If propagation is blamed, predict how the feature should change with antenna placement, polarisation or a second receiver. If impedance is

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invoked, predict the effect of a measured substitution at the same reference plane and under known sensitivity.

The new prediction should be submitted to an experiment that can distinguish rival explanations. If the result is again equivocal, the investigator should say so, not add an unbounded hidden variable to preserve the favourite account. In a controlled RF study I would especially distinguish the origin of a signal from its mere presence in a displayed spectrum. A clock-related spur, for example, might follow the switching schedule without any external radiating apparatus. A genuine external signal might disappear under one antenna replacement because the receiving system became insensitive. Both possibilities require measured controls.

Discovery and confirmation can coexist if they are recorded honestly. Keep the exploratory observations, their alternative interpretations and every unsuccessful test. Then reserve fresh trials, new receiver configurations or an independent laboratory for the narrowed hypothesis. This allows an imaginative explanation to face risk without pretending that the explanation was known before the event that inspired it. The method gains strength from producing clear experimental questions, not from producing certainty on demand. Such reasoning also respects the human consequences of a false accusation based on an attractive but unidentified spectral feature.

Each revised account should fix a new measurable consequence and a test configuration not already used to compose it. For example, a thermal explanation should predict a documented relation to temperature under controlled heating and cooling, not a conveniently unspecified delay. A modulation explanation should predict how the sidebands change when the

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stimulus rate is deliberately altered under instrument control. Failure of those consequences would count against the specified model.

Dr. James M. Atkinson, Moderator: Mr. Peirce, please conclude the principal cycle by considering how an observation can legitimately suggest a hypothesis, how fresh controlled trials can test it, and how a forensic report can distinguish a supported causal account from an appealing interpretation of coincidence.

Charles Sanders Peirce, Fifth Principal Contributor: Dr. Atkinson, surprise is an excellent occasion for inquiry and a poor substitute for its completion. An RF event appearing after a laboratory action invites the question of whether the action has anything to do with the event. From that observation a scientist may propose an explanation: perhaps the changing environmental condition provokes a radio transmission, perhaps a legitimate electronic controller responds, perhaps a power transient contaminates the receiver, or perhaps an unrelated emitter happens to transmit at that moment. Those are not equally supported merely because they can all be stated. Their relative usefulness depends on the new observations they predict and whether the investigator is prepared to expose them to tests whose outcomes might contradict them.

I would distinguish three activities. First is the formation of explanatory candidates, which necessarily draws upon experience, physical plausibility and sometimes imaginative inference. Second is deduction of observable consequences from each candidate, including predicted absences and changes under controlled alternatives. Third is experimental comparison of those consequences with new observations. The first activity cannot by itself confer evidential validity upon the hypothesis that it invents. The second

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gives the hypothesis its concrete commitments. The third tests those commitments with an instrument whose own transfer function and limitations must also be examined. These are not strictly chronological compartments in every scientific investigation, but they supply a discipline against retrospectively rewriting the purpose of an experiment.

Consider the candidate hypothesis that a concealed transmitter sends a short burst when an environmental sensor experiences a controlled change. It should predict a response latency distribution, frequency region, approximate signal duration or modulation property under stipulated conditions. Alternative hypotheses will make different predictions. A relay transient may appear nearly simultaneously with the switching current and in many frequencies; a legitimate wireless device might show a different delay or remain present on sham trials; an internal receiver spur might survive a terminated antenna port or shift with its local oscillator setting. The test should be designed around these contrasting consequences. A hypothesis that predicts only that 'something somewhere might be observed at some later time' is too elastic to distinguish itself from accidental coincidence.

The word coincidence is itself a reminder that chance models depend on a definition of opportunity. Suppose a background event rate is λ events per second under an approximately stationary Poisson model, and an observation window has duration w seconds. The probability of at least one background event in the window is $1-\exp(-\lambda w)$, provided the Poisson assumptions are sufficiently justified. For the hypothetical $\lambda=0.02$ events per second and $w=5$ seconds, this probability is approximately 0.0952. If the operator tries many candidate windows, frequencies or trial timings and

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highlights only a success, this single-window probability understates the relevant selection opportunity. If the background has clustering or periodicity, even the Poisson formula may be materially wrong. One must measure the baseline process under conditions comparable to the actual test, including receiver revisit behaviour and hardware acquisition gaps.

A clever investigator may discover that the candidate transmission consistently appears after some operator action, yet fail to notice that the action itself turns on an electrical load whose harmonics reach the receiver through a shared mains supply. A true experimental distinction would be to reproduce the action's electrical signature using a sham that does not create the proposed environmental change, while independently monitoring the antenna reference plane. If the spectral feature persists under sham switching and terminated antenna conditions, the claim of an incident field from a target device weakens. If it follows the environmental change while independent receiver chains observe a consistent radiated field and suitable negative controls remain quiet, the external response account strengthens. Neither result automatically establishes the identity or intention of a device.

The sequence of trials should be arranged so that the investigator cannot choose only the most picturesque temporal correspondence. A random concealed schedule should include true and sham operations of preassigned number and spacing, and a separate observer should verify compliance. The analysis should define what qualifies as an RF event before the confirmation series starts. One might retain a complete list of all detections, with their timestamps, frequency bands, bandwidth estimates, signal-to-noise ratios and processing states, rather than only the subset associated with the stimulus. The omitted detections are essential to

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understand the background rate and the possible temporal selection process. An unobserved period should be marked as a coverage gap, not written into history as a silent interval.

Repeated experiments should challenge the most vulnerable part of the proposed explanation. If one explanation requires the RF response to lag the stimulus by approximately two hundred milliseconds, deliberately randomise stimulus times relative to periodic receiver scanning and independently measure the hardware clock. If the effect depends on a claimed sensor, test conditions that actuate the controller but do not change the sensor's physical input. If the investigator has a lawful, accessible reference device, compare its power and transmitter state under the assigned conditions. If not, avoid attributing the response to inaccessible equipment simply because alternative explanations are inconvenient. The experiment should provide evidence at the scale it can measure.

I would also regard replication as more demanding than repetition of an attractive visual pattern. A second experiment should reproduce a predeclared treatment contrast with comparable sensitivity and should, when possible, predict a different feature than the one selected during discovery. A spectrum peak of similar colour on two waterfall plots is insufficient if both plots use the same algorithm, calibration defect or threshold. Independent reference clocks, separate front-end paths, verified calibration tones and different antenna conditions may contribute independent scrutiny. Each such distinction must be recorded as a physical fact rather than presumed from the existence of multiple instruments.

There is a practical moral in these distinctions. The object of a defensive technical examination is to make a well-supported finding, not to force every

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unexplained sound or spectral line into an accusation. An honest negative result may show that a particular proposed response was not detected under adequate, declared measurement conditions. An inconclusive result may show that the receiver was blind or that two competing causal explanations remained observationally equivalent. A positive result may establish a stimulus-associated change in observed RF energy without identifying a clandestine device. Those three conclusions differ in what they assert and in the actions that they justify. They should never be converted into one another by rhetorical confidence.

I would close by preserving the experiment's full history of conjecture, calculation, intervention and correction. State the initial observation that prompted the inquiry, the alternative hypotheses entertained, the exact preassigned validation experiment, all successes and failures, the known instrument limitations, and the remaining uncertainty. An attractive hypothesis is valuable when it guides a discriminating test, but becomes dangerous when it is allowed to decide which evidence shall count. A defensible report should make it possible for another competent examiner to reconstruct not only what the team concluded but what evidence would have changed its mind.

John Wilder Tukey, Peer Question: Mr. Peirce, an experienced examiner may discover an irregular cluster of apparently responsive RF bursts while exploring a long recording with time-frequency displays. Exploration is indispensable for recognising unexpected artefacts and possible signals, but it also creates many undocumented analytic degrees of freedom. What distinction would you draw between generating a plausible explanation from exploratory visual analysis and later testing it against a withheld

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observation set? How should the examiner preserve the negative plots, alternative event definitions, discarded frequency bands, and unsuccessful detection thresholds without reducing exploratory work to an impossible list of every mouse movement? I am especially interested in whether the same raw capture can support both exploratory discovery and a genuinely independent causal confirmation, and what safeguards are needed if a fresh capture or fully independent receiving installation is unavailable.

Could the laboratory also retain a machine-readable index of candidate plots and rejected event definitions, so that a later examiner can reconstruct the main analytic choices without relying solely on a handwritten narrative?

Charles Sanders Peirce, Response: Professor Tukey, exploration should be candidly exploratory. It may reveal the need for a different bandwidth, an unexpected timing relation, a weak-signal estimator or an alternative physical coupling pathway. The difficulty begins when those discoveries are represented as if they had been specified before the data were examined. The team should keep a structured analysis log recording which candidate frequencies, event thresholds and latency windows materially affected the selected hypothesis. The record need not describe every incidental movement of the cursor, but it should make the path from the original observations to the chosen confirmation rule reconstructable, including choices that produced unattractive or null results.

A withheld dataset can provide more credible confirmation if it was genuinely unavailable during hypothesis formation and processed by a frozen rule. Yet merely hiding some rows from a time-correlated continuous capture may not create independence: bursts, noise-state changes and receiver calibration drift can persist across the training and held-out

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intervals. The split should reflect the temporal and physical dependence of the process, for example by reserving distinct experimental blocks or a new randomised allocation series. If no fresh capture is possible, one may use selection-aware methods and disclose the limitations, but should not claim that repeated analysis of the same selected trace produced new empirical evidence.

An independent receiving installation is valuable when it breaks shared error pathways, not simply when it has a different label. Compare antenna-path coupling, clock distribution, host processing, detector algorithms and timing references. A second system with materially different weaknesses can corroborate the incident-field change, but it cannot by itself identify a hidden transmitter's purpose. The final report should separate discoveries, calibration checks, confirmatory contrasts and physical attribution. Exploratory work remains scientifically useful when it produces hypotheses whose subsequent tests may honestly fail. It becomes untrustworthy only when the record conceals its selective character.

A versioned machine-readable register is a sensible companion to the prose. Each material analysis run can record source-file hashes, frequency and latency bounds, threshold settings, number of eligible trials, number of detections, and the reason a candidate was discarded. If the files are large, hashes and indexed locations preserve access to the original evidence without duplicating the entire dataset in the report. Such records make the history of inference independently inspectable.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has separated three propositions that must not be confused: a temporal association between a controlled procedure and a receiver indication; a

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causal change in electromagnetic energy at a specified measurement reference plane; and attribution of that change to a particular device or purpose. A concealed, randomised true-versus-sham trial programme can support the first proposition when observation windows, eligible trials, event definitions, receiver coverage and statistical stopping rules are established beforehand. The second proposition requires physical instrument challenges, independent timing and antenna-path evidence, and credible exclusion of controller, mains, cable and receiver-generated transients. The third may require entirely new evidence and must not be inferred from a low p-value. The panel recommends preservation of raw samples, all assignments and exclusions, sham and negative-control records, calibration observations, instrument-state history and every material analysis decision. Any calculation must disclose its model assumptions and the observational opportunities it counts. These exchanges are modern fictional educational reconstructions, not historical transcripts, and their numerical examples are illustrative rather than verified field results.

SOURCE REGISTER AND EDITORIAL QUALIFICATIONS. (1) NIST/SEMATECH e-Handbook of Statistical Methods, sections on design of experiments, randomisation, blocking and experimental analysis: https://www.itl.nist.gov/div898/handbook/ . (2) American Statistical Association, 'The ASA Statement on Statistical Significance and P-Values', The American Statistician 70 (2016), 129–133, DOI 10.1080/00031305.2016.1154108. (3) R. A. Fisher, The Design of Experiments (1935), historical foundations for randomisation; consult a verified edition before assigning specific page references. (4) D. R. Cox, Planning of

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Experiments (1958), historical foundations for design and nuisance variation; confirm specific propositions against the text before publication. (5) A. Wald, Sequential Analysis (1947), sequential-testing foundations; modern RF implementation is editorial extrapolation. All contributor speech is fictional educational reconstruction. No experimental event counts, receiver characteristics, sensor delays or named equipment performances in this discussion are asserted as independent observations. Historical qualifications, source-to-claim verification and publication proofreading remain separate Stage B requirements.

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QUESTION 081

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What may coding structure reveal about a waveform without decoding protected communication content?

SCHOLARLY RECONSTRUCTION. The named historical specialists are represented in fictional educational discussion; they did not meet in this forum or operate the modern receiving instruments discussed. The examples are invented laboratory cases using authorised synthetic signals. They are not field measurements, intercepted communications, or authenticated statements.

Dr. James M. Atkinson, Moderator: Professor Reed, a lawful defensive survey may observe modulation, symbol timing, repeated frame intervals and other external waveform properties without any entitlement to examine the protected meaning of a message. Explain which features of an error-control code can legitimately be investigated using known public laboratory sequences, how the code hypotheses can be tested, and why identifying a plausible coding family neither recovers the payload nor identifies the radiating apparatus.

Irving S. Reed, Principal Contributor: Dr. Atkinson, a physical transmission comprises several transformations whose evidential meaning must not be confounded. The information source produces a sequence; framing and coding introduce systematic relationships; a modulator maps symbols into a physical waveform; propagation distorts that waveform; and the receiver produces estimates filtered by its own limitations. The analyst may observe timing, bandwidth, envelope behaviour, carrier transitions and controlled correlations without possessing or attempting to reconstruct the information source. A coding-family inference concerns a mathematical

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transformation, not the identity or intentions of the person or device that selected it. In an authorised laboratory one can transmit fully known sequences through multiple encoders and measure which statistical features survive an ordinary receiver chain. One cannot transfer the success of that test into a claim that a similarly shaped external emission carries the same message or comes from the same transmitter.

For a linear block code over a finite field of q elements, let n denote the length in field symbols of a codeword and k the dimension of the information vector. The conventional code rate is R=k/n; q and the number of bits per symbol must be declared if the result is translated to a binary rate. Redundancy is n−k field symbols per codeword, though not every systematic-looking interval in the physical waveform necessarily corresponds to those redundant coordinates. A receiver first has to infer symbol timing and modulation mapping, and perhaps distinguish an interleaved frame from a native codeword. These operations are not neutral: an incorrect phase reference, a skipped sample or a different constellation labelling changes the apparent relationships. The analyst should therefore state which observations are direct measurements and which rely upon a trial timing or symbol hypothesis.

The family that I and Gustave Solomon described in 1960 used polynomial evaluations over finite fields to construct codes with specified distance properties. That algebra provides a particularly clear example of why a code can have recognisable structure yet no unique equipment provenance. An illustrative shortened or full-length code with n=255, k=223 over a field of 256 elements has 32 redundant eight-bit symbols and rate 223/255, approximately 0.8745. Under the usual Reed–Solomon minimum-distance

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bound, $d_{min}=n-k+1=33$ and the bounded-distance capability is $t=\text{floor}((d_{min}-1)/2)=16$ unknown symbol errors, assuming correctly defined codewords and the specified decoder. The figures describe a mathematically defined laboratory code, not a claim that any unknown emitter uses it. Many unrelated manufacturers and services may use the same family, parameters or interoperable standard.

A parity-check or algebraic-syndrome experiment must be interpreted carefully. If H is a parity-check matrix for a specified linear code and c is a valid codeword represented as a column vector, $Hc=0$ over the relevant field. That relation can be tested directly upon transmitted sequences that the investigator owns, or used to design a controlled receiver-validation challenge. For an unknown protected transmission, direct computation on putative recovered symbol strings may move beyond mere radio-frequency observables and into protocol or content processing. Such activity requires separate legal and ethical authority and is not presumed by this volume. The defensible analysis may instead compare aggregate spectral and temporal features from public test waveforms without deriving or exposing any protected payload.

A second difficulty is model selection. Suppose an investigator tests dozens of candidate block lengths, symbol clocks, code rates, interleaver depths and mappings. Some configuration will inevitably appear to fit incidental regularity, particularly when the analyst has chosen the best-scoring model after examining the same record. An agreement found after such a search is not a confirmatory probability unless the search procedure appears in the null calibration. It should be evaluated against independent synthetic controls and held-out recordings. The outcome ought to be expressed as a

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ranking of explanations under stated measurement conditions, with a statement of how frequently nonmatching public laboratory signals produce a similarly high score. Mere repetition of an apparent frame boundary is not enough. Switching supplies, scan schedules and packetised receiver buffering can also generate periodic structures.

The physical experiment must therefore be factorial rather than theatrical. In a shielded, authorised installation, retain the same RF carrier, symbol rate, modulation constellation, emission power and propagation path whilst changing only the known code family. Then retain the code and change the pulse-shaping filter, the framing interval and the receiver's bandwidth. If the proposed observable tracks the encoder setting under the first manipulation and remains appropriately invariant under the others, it has discriminating value. If it follows the receiver filter or host buffering, it is a measurement-chain characteristic. The experiment should include a no-code random-symbol control, a framed but uncoded control and at least one independently constructed encoder having different parameters. The analyst should retain raw I/Q, reference-clock state, test-sequence provenance and every processing version.

It is useful to separate the claim hierarchy. The weakest finding is that a recurring external spectral or timing feature was observed under a declared reception configuration. A stronger finding is that a set of authorised laboratory waveforms with a particular code family produces comparable external features, subject to specified ambiguity. Stronger still would be confirmation of a code parameter under legally authorised signal processing, but even that identifies a technique rather than an emitter. The final step, attributing a physical source, calls for antenna-path evidence,

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controlled relocation, independent receivers, verified timing and evaluation of competing explanations. A textbook should teach the reader to stop at the strongest proposition actually supported by the record, not to travel from a mathematical pattern to an accusation.

The finite-field formalism is immensely powerful precisely because it is general. That generality makes it an unreliable fingerprint of a particular individual. Our laboratory test should use a public and precisely reproducible reference encoder; the waveform comparison should be bounded to lawful non-content observables. Any actual attempt to classify protected content, reconstruct codewords or exploit error-correction redundancy would demand a separate authority decision, explicit scope and documented safeguards. In the defensive context the objective is to recognise what the receiver can and cannot establish, preserve the opportunity to falsify its preferred explanation, and avoid manufacturing certainty from an attractive mathematical fit.

Harry Nyquist, Peer Question: Professor Reed, you have demonstrated why a code rate is mathematically determinate once n and k are defined. A monitoring receiver, however, does not see a vector of field symbols: it sees an analogue waveform filtered in time and frequency, with uncertain phase, variable noise and possibly a sequence of retuning intervals. If the gross symbol-rate estimate is in error by a small fractional amount, an apparent codeword period can drift across an observation window. How should the analyst construct a physical timing test that respects your algebra but does not invent symbol boundaries? Should the experimental comparison be performed on the same known public sequence under several independent sampling clocks, or would that risk confusing changes in acquisition timing

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with changes in the encoder itself? I would also ask what negative control can show that a periodic feature is simply a product of receiver resampling, rather than a consequence of a block code's redundancy. The distinctions seem decisive if a report will be relied upon as forensic evidence.

Irving S. Reed, Response: Mr. Nyquist, the encoder parameters describe relationships at a level below the physical observation and must not be promoted into measured facts without an adequate mapping. Define the supposed clock rate, the allowed frequency tolerance, the start-time interval and every acquisition discontinuity before calculating a periodicity statistic. A known public calibration waveform should pass through the complete antenna, preselector, receiver and sampling chain under more than one permitted clock configuration, with independent monitoring of the sample counter and reference oscillator. The question is whether the proposed feature remains associated with the known encoder when physical timing conditions vary within measured bounds. A correlation maximum that migrates with the host's resampling ratio is evidence about processing sensitivity, not reliable evidence of the encoder. In contrast, an encoder-dependent feature that survives controlled sample-clock substitution is worth further investigation, though it remains limited to the test family.

I would keep three comparison channels. One carries a known encoded training waveform, one carries an uncoded but identically framed waveform, and one carries a stationary test tone whose phase can reveal a local sampling disturbance. All use the same signal-power and filtering arrangements where feasible. If an apparent frame period appears in the stationary reference tone after a clock reset, the analysis chain has

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produced a false periodicity. This intervention differs from observing two instruments simultaneously: the second instrument must avoid sharing the failure mechanism being challenged. Measure the probability of a false periodicity on recordings acquired before the hypothesis was chosen, and repeat on withheld signals. Where no stable clock-to-symbol mapping exists, the honest result is an observed timing pattern with an unresolved interpretation, not a confirmed codeword length. Finally, the laboratory experiment should record only synthetic data owned by the investigator; it need not reconstruct any private message.

A more discriminating calculation should track timing uncertainty explicitly. Let Δf be the independently measured uncertainty in symbol-clock frequency and T the observation length. Under a small-error approximation, the accumulated phase-of-symbol-clock uncertainty grows roughly with Δf T cycles; this is not a receiver-independent constant. The report should show the value used for each recording and state whether the timing fit was selected after examining the unknown waveform. Such disclosure prevents an apparently precise frame estimate from concealing an uncalibrated reference oscillator or an opportunistic search over possible clock rates.

Ralph Vinton Lyon Hartley, Peer Question: Professor Reed, an expert may see recurrent bursts separated by a familiar interval and regard them as the output of a fixed-length block encoder. But frames can be assembled by a scheduler independently of the chosen error-control code, and a statistical signature might come from a scrambler, source distribution or preamble. When the laboratory compares two codes, how do we prevent differences in their packet framing or transmit duty cycle from becoming the purported

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distinguishing feature? Could the proper test demand matched physical airtime, identical symbol clocks and an independently measured spectral response, rather than only nominally equal application payloads? I am concerned also about the examiner's vocabulary. Describing a frame boundary as an 'error-correction boundary' suggests a mechanism already established, although the receiving instrument may merely have measured envelope transitions. How would you write the final observation and what would you require before giving even a qualified coding-family explanation?

Irving S. Reed, Response: Mr. Hartley, you have isolated the most common confounder. A frame is an organisational interval; a codeword is an algebraically defined sequence. Their boundaries may coincide in a particular implementation but are not logically identical. In a controlled test, specify the framing generator separately from the encoder, and implement at least a two-factor comparison: encoder A versus encoder B, and framing pattern F1 versus F2. Keep the total radiated energy, output filtering, physical symbol rate, observation bandwidth and receiver gain path as similar as their definitions permit. Then estimate whether the chosen exterior feature responds primarily to encoder selection, framing selection or an interaction. A feature controlled by F1 versus F2 cannot be claimed as a unique signature of the code. Nor can identical source packets be assumed to produce matched output airtime when the two codes have different rates; the experimental design must choose whether to match input-information length or physical transmission duration and state that choice.

The language of the report should reflect the actual level of inference. An

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appropriate first sentence is: 'A recurring change in received envelope power was observed at approximately the stated interval under the specified receiver configuration.' A subsequent laboratory comparison might say: 'Public test waveforms employing encoder A and frame format F1 produced a superficially similar interval, but the observation is not unique to that configuration.' Only independent controlled variation could support the stronger statement that the feature discriminates coding families within the tested population. Even then it would not identify the transmitter, reconstruct information content or demonstrate the purpose of an emission. A separate receiver with an independent reference and a test of the input path are needed to rule out instrumentation artefacts. Preserve both positive and negative trials, rather than only charts whose visual appearance agrees with the preferred interpretation.

The factorial comparison should also include an interaction term because code rate and framing can jointly change the duration of a burst. If the code factor alone has little effect but the frame factor has a large effect, the proposed exterior statistic is properly associated with framing in the tested apparatus. If the interaction is material, report the restricted combinations over which the result was observed. An expert should not remove a statistically awkward interaction simply to produce a simple, memorable device classification. The purpose is to establish what the measured waveform warrants, not to manufacture a one-to-one map from a visible frame interval to an encoder.

Irving S. Reed, Cross-Peer Question to Peter Elias: Professor Elias, the finite-field code I described creates algebraic redundancy, yet your account warns

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that its appearance may be concealed by interleaving, puncturing and the modulation chain. Suppose a classifier performs well on public laboratory examples but fails when the same encoder is attached to a differently designed transmitter. Is that a sign the mathematical code was misidentified, or proof that the measured feature originated elsewhere in the chain? Can we specify which parts of the laboratory design must be independent before describing an external waveform as compatible with a particular coding family? I would also ask how to prevent the classification system from using an obvious but irrelevant difference such as amplifier spectral regrowth or frame length rather than a feature causally associated with the code. The broader forensic risk is that a strong statistical score may describe a fixture or receiver, whilst being narrated as an insight into the unobserved transmission process.

Peter Elias, Cross-Peer Answer to Irving S. Reed: Professor Reed, a failed transfer to a different transmitter does not by itself falsify the claim that the first set of known examples used the specified code. It challenges the generalisation from one observation chain to another. We must distinguish a claim about the encoder, which is stipulated for the authorised laboratory source, from a claim about the learned exterior feature, which has to survive appropriate changes of hardware. In an intervention study, alter one major component at a time: the encoder with transmitter and modulator fixed, then the modulator with the encoder fixed, then the power amplifier, output filtering, cable and receiving instrument. A feature that changes with encoder selection across these controlled conditions is stronger evidence of an encoder-related exterior effect than a feature tied to one transmitter's distortion or one receiver's gain state.

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The evaluation must include source-separated training and testing. Do not let recordings of one hardware unit at adjacent times appear in both sets, because temperature, clock drift and construction tolerances can make them highly similar. A held-out transmitter and receiving chain are more demanding tests than random division of successive records from one apparatus. Identify the feature before testing and use identical processing settings for all candidate encoders. Report its false-match rate against distinctly framed uncoded signals and unrelated coded signals. If the classifier relies on a frame-period feature shared by both code families, it is not a coding-family discriminator even when the score is repeatable. Finally, no classifier output should be represented as the recovered payload or as proof of a particular hidden device. Those conclusions require evidence outside the controlled code experiment, and this volume does not authorise protected-content processing.

The validation plan should also report the result when the held-out transmitter operates with a different output filter and a separately controlled frequency reference. If the observable feature disappears, examine whether the change follows amplifier nonlinearity or spectrum shaping before reconsidering the known encoder. This prevents a laboratory-class label from being misrepresented as a property of all possible implementations of the same mathematical code. The receiving chain must be challenged as deliberately as the transmitting chain.

Dr. James M. Atkinson, Moderator: Professor Elias, Professor Reed has separated algebraic code properties from physical observables. Would you

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take the token and investigate the temporal signatures of stream-oriented and convolutional coding, particularly when the receiver has uncertain symbol alignment and does not examine the protected message?

Peter Elias, Second Principal Contributor: Dr. Atkinson, the first obstacle is that temporal repetition is not synonymous with convolutional coding. A convolutional encoder ordinarily generates output symbols as functions of current input symbols and a finite collection of past symbols. Such memory creates relationships in a mathematical symbol sequence, but how those relationships appear in energy, instantaneous frequency or a spectrogram depends upon modulation, pulse shaping, scramblers, interleaving and channel impairment. An observer can confidently measure a pulse interval or spectral cyclostationarity without being entitled to infer a unique encoder structure. Even an expertly designed test may reveal the entire transmission pipeline rather than a code alone. Consequently the hypotheses must describe a chain of transformations and must assign uncertainty to every link.

Consider a simple rate-one-half feed-forward convolutional code whose binary output is determined by two generator polynomials. If each input bit generates two coded bits, the nominal code rate is one half. But the channel-symbol rate depends on the modulation alphabet: two coded bits might be carried as one quadrature symbol or two binary symbols, while puncturing may alter the effective rate. The code's constraint length describes encoder memory, not the length of the RF burst. If an observer notes that a modem emits pairs of short transitions, that observation cannot determine whether the pairs came from a rate-one-half convolutional encoder, an unrelated line code, an interleaver or periodic framing. A

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defensible experiment keeps the encoder and changes the modulator, then keeps the modulator and changes the encoder. In both cases the operator should analyse declared features without access to an unknown protected payload.

A detector's uncertainty in symbol timing deserves the same seriousness as the code hypothesis. Let T_s be the nominal duration of a transmitted channel symbol, τ the unknown timing offset within a symbol period, and ε the fractional sampling-clock error. Even for a stationary signal, an estimator using nominal T_s and $\tau=0$ may split or merge transitions and create spurious periodicity. If the receiver occasionally retunes, the data may contain discontinuities in sample chronology that resemble a skipped framing symbol. A real observation should record raw sample indices, acquisition time, clock corrections and missed-block indicators. The analysis should be repeated over justified timing offsets and should penalise the number of candidate configurations explored. A result that appears only at an implausible timing offset is not equivalent to a consistent feature supported by independent clock calibration.

The appropriate laboratory design uses several fully known synthetic bit streams with deliberately different statistics: independent random bits, alternating or bursty inputs and a deterministic public training sequence. Transmit each through a specified convolutional encoder and through a no-code control while holding centre frequency, gross symbol rate and signal power constant. A frame boundary can be represented by a public calibration marker, and the transmitted content need never be sensitive. Then change the pulse-shaping filter or introduce measured timing jitter to see which alleged coding observables persist. A statistic that disappears

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when the observation filter changes may be a measurement artefact. A statistic that persists across different channel responses but changes with the known encoder is stronger laboratory evidence for the stated, limited hypothesis.

At weak signal-to-noise ratios even the notion of a detected transition is statistical. The analyst might form a likelihood for several hypotheses using a feature vector x comprised exclusively of permitted observables, such as measured symbol-rate peaks, burst duration, envelope cyclostationarity and frame interval. If H_i denotes a laboratory encoding configuration and $p(x|H_i)$ its experimentally measured feature distribution, a ratio $p(x|H_1)/p(x|H_0)$ may compare two defined models. It does not furnish the posterior probability of a particular transmitter without priors and a sufficiently broad set of competing models. It is particularly dangerous to estimate $p(x|H_i)$ from the same small record used to choose the feature and then advertise a nominal false-alarm rate as though the modelling process were independent.

We should also treat interleaving as a formidable confounder. A burst interleaver changes the temporal order in which coded symbols appear; a block interleaver may transform short runs of errors into separated errors before decoding, but its observable physical consequence depends upon the frame schedule and waveform mapping. Identical coding schemes with different interleaving can have materially different transition statistics. Distinct codes followed by the same framing and scrambler may have nearly indistinguishable external envelope signatures. One may therefore conclude that a measured timing relation is compatible with a class of laboratory transmission chains, not that it reveals the hidden encoder or that it

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recovers the content. The opposite lesson is equally important: an absence of a simple periodic feature is not evidence that no coding or redundancy exists.

The analyst should make the success criterion falsifiable. In a preregistered comparison, a statistic intended to distinguish a known coded from a known uncoded laboratory signal should have a measured sensitivity and false-positive rate over independent trials, receiver configurations, noise levels and temporal offsets. Where a statistic performs well only on one receiver or one known training waveform, it may have learnt a peculiarity of the hardware or test sequence rather than a general code property. Use multiple independent laboratory encoders where available, and reserve recordings from one apparatus as the untouched test set. An honest negative result, including overlapping feature distributions, is scientifically useful because it prevents the expert from reading meaning into a visual pattern that the instrument cannot reliably distinguish.

My recommendation is to maintain strict boundaries between signal description and communications exploitation. Time-frequency and envelope characteristics can help plan a defensive survey or determine whether an observed feature changes after an authorised equipment adjustment. Nothing in that task requires an investigator to recover the protected data bits, infer private message content or reconstruct a communications session. The general principle that redundancy permits resistance to noise is relevant here; the investigator should use it to design synthetic controls and to understand alternative explanations. The historical theory supplies disciplined questions, not a licence to treat an unexamined waveform as a legible private message.

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Jacob Ziv, Peer Question: Professor Elias, your distinction between code memory and physical framing is important, especially when a scrambler or compressor changes the apparent regularity of the channel symbols. Suppose we use public synthetic sequences to compare a convolutional encoder with an uncoded reference, but the source data have very different run-length distributions. A feature extracted from symbol-transition spacing might then identify the source statistics rather than the encoder. How would you design a test that changes source entropy, encoder settings and frame structure independently, and how should the resulting conditional dependence be reported? Would you test a known random sequence, a strongly periodic sequence and a low-entropy naturalistic control, whilst holding the transmitted spectrum and amplifier power near the same range? I am also concerned that the analyst may equate apparent randomness with encryption, an inference that plainly exceeds the information supplied by external modulation observations. How should that mistaken conclusion be prevented in the final narrative?

Peter Elias, Response: Professor Ziv, the appropriate test treats the source distribution as an experimental factor rather than assuming it away. A known pseudo-random reference, an alternating sequence and a structured bursty sequence can be generated by the laboratory without any private information. Apply each to coded and uncoded transmission chains while controlling physical symbol rate, duty cycle, modulation and gross frequency response. If the feature follows source statistics even when the encoder is held fixed, it cannot be attributed uniquely to the encoder. If it changes with the encoder across several source distributions, it offers evidence of a coding-related exterior effect under the tested configurations. The resulting

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table should display the interaction between factors, because the encoder may change what source statistics remain physically visible. A single accuracy percentage averages over those interactions and can conceal failure in an important subgroup.

The classifier's outcome needs language commensurate with the experiment. It may distinguish a collection of declared laboratory signal-generation chains, with confidence intervals calculated from properly independent held-out trials. It does not prove that an unknown physical emission carries encrypted data merely because one entropy estimator reads high. Randomised test bits, lossless compression, scrambling, channel coding and receiver noise can all produce a similar statistical impression. Nor does a periodic transition establish the presence of a low-entropy plaintext: frame markers and pilot symbols can create order even when the associated source is arbitrary. A useful report therefore lists the observed envelope or spectral statistics, the known laboratory manipulations, the false-positive and false-negative behaviour, and the major untested alternatives. No private symbol string need be recovered. In fact, insisting on non-content test stimuli helps prevent the inference from silently migrating into a different legal and technical task.

The experiment also requires explicit handling of imperfect channel estimates. A receiver whose amplitude response varies across the band can change transition statistics differently for coded and uncoded examples, especially when those examples have unequal spectral occupancy. Report performance in strata of independently measured noise power, clock

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stability and gain. Hold out entire transmitter sessions, not merely random symbols from one continuous capture, because otherwise the test set shares the same drifting oscillator and thermal history as the training set. A successful classification should demonstrate transfer between declared physical conditions, not merely recognition of one synthetic source file.

Abraham Lempel, Peer Question: Professor Elias, an interleaver can rearrange the temporal order of known coded symbols without changing which mathematical codewords the encoder generates. Yet such rearrangement may substantially alter the apparent burst structure in an observation. What experiment would distinguish a feature arising from redundancy from one arising from the interleaver's memory, when both operate on the same public laboratory sequence? Would it be enough to vary interleaver depth with the encoder held constant, or must the observer also measure sample-clock slips, filter settling and pulse-shaping changes? I ask because a hidden dependence on receiver scheduling could produce a periodic signature that follows the interleaver settings only accidentally. Please address the distinction between two logically separate coding layers and the consequences of a test whose winning configuration was chosen after examining many possible alignments. The eventual defensive report should avoid making an algebraic claim from a spectrogram alone.

Peter Elias, Response: Mr. Lempel, a complete design should vary interleaver depth independently of encoder selection, with the known original input sequence and physical signal-generation parameters controlled. At one fixed encoder, test several interleaver configurations and a bypass condition; then repeat at another encoder without changing the interleaver settings. One can ask whether a proposed exterior waveform statistic

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follows the interleaver factor, the encoder factor or their interaction. The answer will depend on the mapping to physical modulation, and the test should not assume that a particular interleaver depth produces a visible periodicity at every signal-to-noise ratio. A public calibration marker at a known point in each frame can help measure the actual time mapping without inferring an unknown payload. Simultaneous reference-clock logging will distinguish a genuine transmitter timing change from data lost during receiver retuning.

The problem of searching many alignments needs explicit treatment. If the analyst tries a large set of interleaver depths, symbol offsets and filtering windows, the largest observed association is a selected statistic. Its significance must be calibrated by repeating the entire search on independent controls, not by applying a single-trial threshold to the winning candidate. Reserve a new laboratory recording from an independent instrument for confirmation, with the search strategy frozen beforehand. Even if the feature then generalises, it identifies at most compatibility with a tested class of transmission arrangements. Different implementations can share an interleaver or produce similar envelope statistics for unrelated reasons. The investigator should keep the result in a form such as: 'The observed timing feature is consistent with laboratory configuration X within stated limitations and is also produced by controls Y and Z.' There is no sound basis for claiming that a protected message has been reconstructed or that a unique physical source has been identified.

A further safeguard is to randomise the order of test conditions while

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recording the actual sequence for later audit. If all high-depth interleaver tests occur after the receiver has warmed, one may falsely associate a changing phase-noise floor with interleaver depth. Repeat every setting at separated times, compare against a continuously observed known pilot and preserve the empty or failed acquisitions. When the predicted exterior change is below the receiver's calibrated resolution, the correct outcome is that the proposed distinction is not testable with this instrument, rather than a forced negative or positive classification.

Peter Elias, Cross-Peer Question to Richard W. Hamming: Dr. Hamming, your elementary (7,4) example shows how often a short random binary segment can satisfy a parity relation by accident. A modern test may examine thousands of overlapping windows, candidate code lengths, puncturing schemes and receiver timing corrections. How would you prevent an analyst from reporting a spectacular likelihood after learning the preferred hypothesis from the same data? In particular, is it sufficient to cite the nominal one-eighth chance for your example, or must one calculate the null distribution of the largest score over the entire search and account for dependent windows? I would also ask whether a visually stable detector can be trusted when it silently discards low-amplitude frames, because the retained selection may be a biased subset of the physical emissions. The aim is not to improve message decoding but to establish whether a proposed observable coding feature survives an honest test against non-content alternatives.

Richard W. Hamming, Cross-Peer Answer to Peter Elias: Professor Elias, the one-eighth calculation is useful precisely because it refuses to let a mathematical match masquerade as a physical identification. It assumes a

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uniformly random seven-bit vector evaluated against one fixed full-rank parity-check matrix. Once the investigator explores many mappings, alignments and candidate matrices, the relevant false-alarm event becomes 'at least one candidate scores as strongly as the selected maximum'. If the windows overlap, the tests are dependent; an independence-based multiplication is not justified. One can preserve the physical properties of the null by replaying authorised synthetic waveforms through the receiver, applying the identical processing and candidate-selection programme, and recording the maximum score in each independent run. The observed maximum should then be compared with that empirical distribution. This procedure is more cumbersome than quoting one in eight, but its assumptions actually resemble the experiment.

Selection by receive quality creates another danger. A detection rule that keeps only high-amplitude or low-noise windows may preferentially retain patterns that resemble a simple code constraint. The analyst should maintain a ledger of all eligible physical observation intervals, including gaps, discarded blocks, gain changes and reasons for exclusion. A separate test carrier can establish when the receiver remained capable of detecting a reference signal. If the method fails on low-amplitude test cases, report its conditional coverage rather than concealing the failures. Once the hypothesis and processing settings are fixed, evaluate them on a new set of signals with varied but declared channel conditions. If several code families remain equally compatible, acknowledge that ambiguity instead of turning an incidental syndrome match into a finding about protected communication content or source identity.

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The choice of null signals matters as much as the count of simulations. If the controls omit periodic frame schedules, correlated noise and receiver overload, they will make the observed result appear rarer than it is under ordinary benign conditions. An adequate null family should include those known mechanisms and report the method's sensitivity to uncertain assumptions. Such calibration is necessary even if all computations on the selected short vector are algebraically correct. The selected maximum is a different inferential quantity from any one prespecified test and demands its own empirical calibration.

Dr. James M. Atkinson, Moderator: Dr. Hamming, would you examine error signatures and parity constraints, with particular attention to how a large search over candidate structures generates false matches?

Richard W. Hamming, Third Principal Contributor: Dr. Atkinson, an error-correcting code deliberately arranges symbols so that certain patterns satisfy mathematical constraints and corrupted patterns violate them. This is a principled source of redundancy. It is not a supernatural fingerprint. In the laboratory the simplest demonstration is a linear binary code with a parity-check matrix H. If an n-bit column vector c is a valid codeword, the syndrome Hc is the zero vector over GF(2). If a received laboratory vector r differs from c by error vector e, then Hr=H(c+e)=He. That calculation explains how carefully chosen redundancy permits error detection, but it is not a warrant to construct codewords from a protected transmission. For this volume, the proper use is to validate non-sensitive synthetic examples and understand the limits of an alleged observable pattern.

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Take the elementary binary Hamming (7,4) code. Four information bits are represented by seven coded bits, with three redundant bits and code rate 4/7. Under a full-rank 3-by-7 parity-check matrix, the set of valid codewords has 2^4=16 members among 2^7=128 possible seven-bit strings. A uniformly random seven-bit string therefore happens to satisfy the code constraints with probability 16/128=1/8. That is a substantial accidental match rate for a single short block. More elaborate codes and longer blocks can make chance matches rarer under particular random models, but the number of candidate lengths, phase alignments and mappings examined also grows. Reporting 'a successful parity match' without the search protocol and calibration is not meaningful evidence of a particular code family, much less an emitter identity.

The temptation to infer a hidden encoder from one small window should be resisted because environmental and receiver-generated structures can also pass such a test. Repeated framing bits, whitening circuits, periodic symbol clocks and systematic receiver clipping alter the statistical distribution away from independent uniform bits. Even the definition of a trial requires care: overlapping seven-symbol windows share six symbols and are strongly dependent. If many correlated windows are tested, the simple product of individual false-positive probabilities is invalid. The investigator should simulate the complete search with synthetic null signals whose spectrum, timing, framing and receiver impairment resemble the comparison scenario. A separate untouched hold-out set should then test the frozen method. If the observed feature is common across mutually unrelated test waveforms, it is not discriminating evidence.

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Noise further complicates the question. A weak waveform may contain uncertain symbol decisions, not binary values known with certainty. Mapping noisy constellation estimates to hard bits discards confidence information and can create deceptive syndrome behaviour near the decision boundary. The probability of a parity-check pass depends on error statistics, not merely on the nominal code. Burst errors and correlated fading yield patterns different from independent bit flips. A robust study should report the characteristics of the measurement chain, reference timing, signal-to-noise ratio and event exclusion rules. It should test whether a statistic is stable when receiver threshold, bandwidth or phase-estimation method changes. Where those controls are missing, the syndrome-like feature belongs in a list of tentative observations rather than a formal code attribution.

False positives in an extensive search are not a nicety. Suppose a laboratory algorithm tests one thousand genuinely independent random seven-bit blocks against the simple (7,4) validity condition. The expected number of accidental passes is 1,000/8=125, under the model just stated. It would be absurd to describe those 125 passes as evidence of 125 Hamming-coded transmitters. Real receiver analyses may use overlapping windows and candidate matrices, making the distribution more complicated, not less. As the experimenter expands the hypothesis space, the calibration of maximum score or family-wise error becomes essential. Preferably, the analyst should describe an externally observable feature and reserve the algebraic code test for authorised test vectors rather than hidden incoming material.

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Experimental fault injection offers an independent check. Use a public reference transmitter generating known coded words, and introduce controlled additive noise, isolated erased symbols and measured clock slips. Compare the expected physical envelope and timing features with what the receiver reports. If a sudden 'error signature' also appears on a constant unmodulated reference tone during an oscillator reset, the receiver is part of the cause. Record all samples and anomaly flags, including failed acquisitions, not merely those windows that supplied an attractive pattern. Blind the analyst to the encoder selection during the classification evaluation and retain the frozen rule and code hash for reproduction. This is how a mathematical insight becomes a trustworthy measurement protocol.

There is an important distinction between showing that a public known waveform contains a designed constraint and claiming that an unknown protected waveform does. The former is an ordinary experiment in coding and signal engineering. The latter may involve questions of communications content, privileged access and procedural authority that are outside this defensive receiver chapter. Even when separate authority exists, evidence of a code is not evidence of communicative purpose. The same parity-check family can appear in telemetry, storage and digital control systems. The investigator should emphasise the observable limitations of the measurement and the broad use of error-control methods across unrelated devices.

I would therefore report the instrument state, test sequence, mathematical model, known false-match behaviour, scanning and timing limitations, independent challenge tests and all alternative mechanisms. If a claim remains sensitive to one symbol mapping or a single chosen interval, it is

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not a sound finding. Good engineering requires the analyst to earn every additional inference, from energy to timing, from timing to code-class compatibility and from compatibility to any eventual physical attribution. A defender who keeps those categories apart is much less likely to convert ordinary receiver noise into an allegation about a particular communications system.

John Robinson Pierce, Peer Question: Dr. Hamming, the discussion has carefully distinguished code relations from an unknown waveform, but a practical receiver can create apparent digital irregularities through nonlinear compression, clipping, local-oscillator phase noise or a sampling-clock discontinuity. Is it possible for such an analogue impairment to generate a pattern that looks like a systematic error process, even when the public reference sequence is known to be uncoded? What control sequence and receiver reconfiguration would distinguish this from a real feature of the known error-control experiment? I would also question the tendency to describe every unexpected correlation as a 'syndrome' when the mathematical conditions for applying that term have not been established. Please explain how one should use a physical reference plane, a terminated input and an independently clocked receiver without assuming that their agreement automatically resolves the origin of the observed structure. The final claim ought to survive controlled changes of gain and filtering.

Richard W. Hamming, Response: Professor Pierce, an analogue receiving fault can indeed produce structured decision errors, and those errors may then be mistaken for properties of the transmitted code. Compression changes amplitude-dependent phase and may broaden a signal's spectrum. A phase-locked loop disturbance can produce abrupt common phase

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changes across several nominally separate channels. A finite buffer can omit samples and shift the apparent boundary of an observed burst. None of these effects is a property of an error-correcting code. The first control is a known uncoded public reference sequence, transmitted over the same bandwidth and observed with the same antenna and gain chain. If the suspicious statistic survives when the encoder is bypassed, it deserves an instrumentation explanation before any coding-family interpretation. Vary the receiver attenuation and preselector setting while recording the response of a separate known test tone, so that a change of displayed pattern is not merely a loss of sensitivity.

The term 'syndrome' has a precise algebraic meaning: it is a result of a specified parity-check operation on a vector over a declared field. A spectral line or envelope periodicity should not be given that name unless a legitimate mapping to the relevant algebraic variables has actually been established. In this defensive exercise there is no requirement to derive such a mapping from protected traffic. Instead the analyst can demonstrate the mathematical construction on self-generated sequences and compare external waveform observables under authorised conditions. Independently clocked measurements are valuable only when the receiving chains do not share the fault being tested; identical software running on two devices can still introduce common processing artefacts. The appropriate report includes a causal test for the front end and an uncertainty budget for the timebase, alongside a candid statement of which observed features remain consistent with more than one laboratory signal-generation chain.

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For the controlled receiver challenge, quantify the probability that the reference tone itself is misclassified during each impairment. If the apparently code-like statistic grows when input attenuation is removed, inspect compression before attributing the change to the transmitted symbol sequence. If it follows the sampling-clock reset, the record may have been time-warped. A laboratory acceptance protocol should specify the maximum permissible missing-sample rate and the calibration tolerance for timing before evaluating coding-family compatibility. A valid parity relation is a statement about defined mathematical symbols, and any physical measurement purporting to reveal those symbols must earn that mapping independently.

Richard W. Hamming, Cross-Peer Question to Claude E. Shannon: Professor Shannon, a candidate signal may exhibit a high estimated entropy in its received amplitude bins and little obvious periodic structure. Some analysts would conclude that the transmitter must be encrypted or using a sophisticated code. Yet source compression, scrambling, channel noise and the quantisation of an ordinary analyser can all change an entropy estimate. How can one use your capacity and entropy formalism to specify what the instrument actually measured without licensing an inference into private message content? I would also ask what controls would reveal that a classifier is learning the receiver's noise floor rather than the coded waveform, particularly when the only apparent improvement is a slightly higher accuracy on the same recordings used to choose its features. Your abstract theory seems most valuable if it keeps the claims modest and reproducible. Please distinguish the distribution of a prespecified statistic from the maximum of all statistics considered during exploratory searches.

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Claude E. Shannon, Cross-Peer Answer to Richard W. Hamming: Dr. Hamming, the entropy belongs to a specified random variable, and the analyst must name that variable before interpreting the number. If we bin envelope magnitudes, the resulting entropy concerns the distribution of those bins after detector and quantiser processing. It is not equal by assumption to the entropy of source bits or private messages. A noisy receiver may produce a distribution closer to uniform without any change to the transmitter. Conversely a clipping stage can collapse a broad analogue distribution into a narrow set of values. The proper experiment therefore measures the receiver with a terminated input, a known constant test tone and several controlled public modulation sequences at stated signal-to-noise ratios. Each statistic must be tested for sensitivity to bin size, observation duration, filtering and gain. A result that follows the receiver's settings rather than the known source is not a secure classification feature.

My channel-capacity formula similarly establishes a relationship within a declared physical model; it does not decode an observed transmission. The signal-to-noise power ratio and bandwidth are measurements with uncertainty, and a capacity upper bound cannot identify a code family. For classification, reserve independent recordings from a second source or receiving chain and select features only on training data. Report confidence intervals, false-alarm behaviour and the candidate families not included. A modest improvement on the same training corpus is not confirmation. It may reflect overfitting, data leakage or a variable associated with a laboratory fixture. An investigator who keeps the source, encoding, modulation, channel and receiver as distinct stages can explain how entropy

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and redundancy illuminate a defensive measurement while refusing to treat those statistics as assertions about protected content or particular people.

To keep the result within the legal and evidential boundary, the case report must identify whether the measured variable is an envelope bin, a spectrogram statistic or a known laboratory code symbol. Those quantities are not interchangeable. The analyst should be able to reproduce the declared feature from the retained authorised observations without displaying or reconstructing protected communications content. That is a practical test of whether the claim respects its own measurement definition.

Dr. James M. Atkinson, Moderator: Professor Shannon, can information theory clarify what externally observable redundancy can and cannot establish about the contents or purposes of a transmission?

Claude E. Shannon, Fourth Principal Contributor: Dr. Atkinson, the central question is not whether a waveform looks orderly or chaotic; it is what random variable is being measured and which transformations separate it from the information source. A physical modulation may have a high apparent entropy because of source compression, intentional scrambling, encryption, channel coding or simply a rich source distribution. Conversely a strong periodic feature may arise from framing or clock synchronisation while the payload itself remains arbitrary. Neither observation alone determines message content. Information theory treats a message alphabet and its statistics abstractly, and it can explain the efficiency or redundancy of a channel representation without requiring an investigator to read a protected communication. The scientific inference must remain at the level permitted by the actual recorded observations.

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For a discrete random variable X taking values x in alphabet A with probabilities p(x), Shannon entropy is $H(X)=-\Sigma\, p(x)\log_2 p(x)$ bits per symbol. That is a model of uncertainty for a specified variable, not a mystical detector for encryption. If the analyst calculates entropy on a sequence of received amplitude bins, the result describes those bins under the estimator and preprocessing choices. It does not automatically give the entropy of the source bits, coded symbols or human-language messages. Noise can raise an estimated entropy; clipping and coarse quantisation can lower it. Sample size, dependence and nonstationarity create additional bias. Thus high entropy is compatible with many benign physical and processing causes, and low entropy may measure the periodicity of a receiver rather than the coding of a transmitter.

Coding deliberately introduces redundancy relative to the selected source representation so that a receiver may withstand channel noise. The relevant rate must be compared with channel capacity under specified assumptions. For the ideal additive white Gaussian-noise model, $C=B\log_2(1+S/N)$ bits per second, where B is available noise-equivalent bandwidth in hertz, S the average received signal power and N the noise power integrated over B. That formula is not a direct measurement of the coding family used by an unknown emission. It describes a theoretical model under Gaussian noise, consistent bandwidth and suitable power definitions. Real receivers have interference, fading, nonlinear front ends and protocol overheads, and their actual achievable rates may be considerably lower. A claimed code inferred from one displayed spectral line would ignore those physical qualifications.

A useful hypothetical case is a 100 kHz ideal channel with S/N=10 in linear power ratio, not 10 dB added algebraically to a logarithm. The capacity

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expression gives C≈100,000 log2(11)≈345,943 bits per second. That figure says nothing about whether a particular emitter uses Reed–Solomon coding, convolutional coding or an uncoded modulation format. An error-control code might expend additional channel symbols to improve reliability, while a scrambler changes visible sequence regularity without being an error-correcting code at all. Even strong evidence that a channel carries redundancy does not reveal a payload, because the coding is intended to be applicable to many possible messages. A defender can use this abstract result to plan signal-quality controls while explicitly declining to infer protected content.

The notion of mutual information is more apt to experimental comparison than a visual assertion of similarity. Let F be a feature extracted from authorised laboratory I/Q observations, and let C_label denote the known experimental encoder configuration. The mutual information I(F;C_label) quantifies, in a chosen probabilistic model, how much the feature distribution informs the known configuration label. A positive estimated value does not establish performance on an unobserved receiving environment unless data collection and estimation were independent. It may arise from confounding variables such as different output powers or symbol rates between the laboratory configurations. Randomise encoding settings, hold the physical transmission conditions constant and evaluate on held-out instruments. The relevant outcome is demonstrated discriminative performance with an uncertainty interval, not a seductive information-theoretic number divorced from the experiment.

There is also the problem of selecting a model because it happened to fit the observed waveform. If an investigator searches over countless periodicity,

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entropy and correlation statistics and reports only the maximum, the sampling distribution of that maximum differs from the sampling distribution of any one prespecified statistic. Calibration should repeat the full selection process on controls, including preprocessing and candidate generation. One must not compare a selected maximum against the nominal threshold for a single ordinary trial. Otherwise, the mere abundance of spectral bins and temporal windows can generate an apparently strong association from benign material. An honest report states the number and nature of examined hypotheses, the calibration population and the remaining dependence between tests.

Information theory is often praised for abstraction. That same abstraction should teach humility in attribution. A statistical relationship can show that two observable processes share information under a defined model; it does not show they belong to a particular person, equipment model or illicit purpose. A signal with coding-family-compatible features might be a public telemetry transmission, a licensed control link, a local test generator, or an internally produced receiver artefact. Localisation, source-path challenges, authorisation and chain of custody remain separate tasks. The expert should always identify the precise proposition that an equation supports and resist carrying a conclusion beyond its declared variables. In this way the most powerful mathematical results become safeguards against interpretative overreach.

For the defensive survey I would recommend preserving only those features strictly needed for the specified engineering question: frequency band, timing stability, authorised calibration markers, phase-noise controls, receiver state and non-content envelope or spectral properties. When

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meaningful comparison can be achieved using public synthetic waveforms, use them. Do not record, display or reconstruct protected messages merely to improve a classification statistic. These boundaries do not diminish the quality of the science; they require a cleaner experiment in which the target is clearly defined, the data provenance is visible and the resulting claim remains technically and legally proportionate.

Alan Mathison Turing, Peer Question: Professor Shannon, your information-theoretic account seems to require clearly defined random variables and observable channels, but a practical defender may find only a short burst captured with uncertain timing and incomplete calibration. A mathematically elegant model could then fit a few apparent symbols simply because it has more adjustable parameters than there are independent observations. How should an analyst make a hypothesis falsifiable without extracting private communications content? Would a predeclared synthetic benchmark and a held-out physical test be more decisive than adding further candidate code families to the same small record? I am also interested in the difference between explaining a signal's observed spectrum and claiming that the transmitter implemented a particular algorithm. One is a description of an electrical phenomenon; the other is a reconstruction of unobserved internal machinery. Please specify the evidential transition that might justify the latter in a controlled laboratory and why the same transition cannot be presumed for an unknown protected emission.

Claude E. Shannon, Response: Mr. Turing, when a model has more freedom than the observations can constrain, a good fit is often inexpensive and uninformative. Define the measurable target before designing the statistic:

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burst duration, spectral shape, timing regularity or another feature obtainable without reading content. Then select a finite family of candidate explanations, including receiver artefacts, framed uncoded test signals and multiple distinct known encoding configurations. The model should produce predictions for new conditions. A synthetic training set may be used to specify the detector, but its thresholds and candidate ordering must then remain frozen for an independent laboratory challenge. A method that correctly predicts the outcome of a change in filter bandwidth or modulator settings has stronger empirical standing than one which merely fits the original spectrogram. Even so, it is a bounded result on the tested signal-generation chains.

The distinction between a waveform description and an internal-algorithm claim is categorical. A measured spectral peak and a timed burst are directly linked to calibrated observations. An assertion that a particular encoder generated that burst requires additional assumptions about symbol synchronisation, bit mapping and alternative processing chains. In an authorised laboratory the asserted encoder is known independently from source configuration and can be varied under blinded conditions, thereby testing whether a chosen exterior feature follows it. For an unknown protected emission that control is absent. The investigator may report compatibility with a family of laboratory signals and the limitations of that comparison, but must not pretend that a matching entropy or periodicity statistic is equivalent to inspecting the internal algorithm. Better experimental design narrows the uncertainty of the allowed claim without expanding the legal scope of the observation.

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One additional concern is parameter economy. A candidate model that uses many freely chosen frequency offsets, symbol phases and unknown frame boundaries can always be made more flexible than a simple alternative. Report the predictive performance on measurements acquired after the model is fixed, not only the best fit on the discovery record. The competing explanations should include noncoding causes, such as deterministic receiver sampling patterns and calibration-source periodicity, not merely several related encoders. A model's failure to transfer to a different laboratory is a material limitation even when its fit to the original signal is exceptionally attractive.

Claude E. Shannon, Cross-Peer Question to David Slepian: Professor Slepian, you have proposed comparing several receiving channels to distinguish shared code-related features from a faulty measurement chain. But evidence from two channels is often treated as two independent confirmations even when they share antennas, oscillators, processing software or common interference. How would you construct a joint statistical model that respects those dependencies while remaining bounded to non-content observations? In particular, what happens to the uncertainty of a classification statistic when the same reference-clock phase disturbance appears in each channel? Could one wrongly infer that many receivers jointly support a coding-family hypothesis merely because their errors move together? Please also address the converse case: two truly distinct antenna paths can give different spectra for the same known encoded laboratory waveform because propagation and gain are not

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equivalent. How should the experiment prevent those differences from being mislabelled as differences between codes?

David Slepian, Cross-Peer Answer to Claude E. Shannon: Professor Shannon, the governing principle is that the joint model must represent the actual receiving installation, not the fiction of independent measurements. Let F1 and F2 denote permitted non-content features from two channels, with shared receiver disturbance C and individual disturbances E1 and E2. An illustrative decomposition is F1=G1(X)+C+E1 and F2=G2(X)+C+E2, where G1 and G2 describe their respective channel responses to the known public waveform X. In the simplest equal-scale model, covariance of the two errors includes the variance of C. Adding two scores as though the errors were independent can then exaggerate evidence. The analyst should measure the cross-covariance under controlled no-signal and known-signal conditions, challenge shared clock and power paths and use a joint calibration distribution for the final decision statistic.

Differences between channels need not indicate different encoders. Frequency-selective fading, antenna polarisation, filter group delay and receiver compression alter physical observations of the same waveform. Before testing encoder hypotheses, calibrate each channel's gain and timing response with a public known waveform. Exchange receivers or references between antennas to see which anomalies follow the apparatus, and separately measure the external field when feasible. A coding-family feature should be evaluated across these changes with a held-out test source and an honest false-match rate. If the channels remain strongly dependent, report one coherent observation system with correlated evidence rather

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than claiming two independent witnesses. If the channels disagree after calibration, consider propagation and instrument alternatives before blaming the code. No element of this joint analysis requires deriving private message bits or identifying an individual transmitter.

Where one clock disturbance contributes to both receivers, the effective number of independent witnesses may be near one for that particular timing error. Other features, such as independent antenna noise, may still provide additional information. The covariance model must therefore be feature-specific rather than assigning a single independence label to the entire apparatus. Record the result of safely disconnecting or substituting the common reference when testing the proposed dependency; do not infer independence merely from separate chassis. The residual uncertainty must be separately reported for common timing disturbances and antenna-specific reception effects, rather than combined into an unsupported universal accuracy claim.

Dr. James M. Atkinson, Moderator: Professor Slepian, how would you address correlated measurements from multiple receiving channels, and what evidence is lost when the channel structure is mistaken for the coding structure?

David Slepian, Fifth Principal Contributor: Dr. Atkinson, the separation of source, code and observation is often easiest to lose when several receiving channels are available. Two antennas may observe a common waveform through different propagation paths. Two digitising channels may share a sampling oscillator, mixer reference or error-prone data transport. If the resulting traces agree, the agreement could reflect a shared environmental

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emission, a common local reference defect, or a deliberately applied signal transformation. The analyst must establish the measurement-chain dependence before treating correlation among channels as independent confirmation of any coding-family hypothesis. A second waterfall driven by the same ADC clock does not provide an independently timed witness simply because the software labels it as another channel.

Let Y1 and Y2 represent two observations of a controlled public signal X through different channels. A stylised model is Y1=h1(X)+N1 and Y2=h2(X)+N2, where h1 and h2 are the channel transformations and N1 and N2 noise terms. The noise can be independent, correlated, signal-dependent or even dominated by shared equipment. A time-shifted peak in cross-correlation can be due to propagation delay, an intentional frame structure or an uncalibrated filter. To infer something about coding, one needs an experiment in which the known encoder varies while each channel's transfer response is separately measured. Otherwise a classifier may learn a characteristic of h1 or h2 and mislabel it as a code signature. This matters especially when one receiver has a narrower filter or different gain distribution.

A reliable laboratory comparison would first characterise every channel with a known broadband calibration sequence and a simple constant-reference tone. Such stimuli are chosen by the investigator and contain no protected information. The operator can estimate frequency-dependent amplitude response, phase delay, noise covariance and missing-sample behaviour. Next the known encoder is changed while the same physical paths, clocks and transmit power remain fixed. Finally the receiver channels are exchanged or one is given a genuinely independent timebase. If a proposed

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coding feature tracks the encoder under these interventions and survives channel substitution within its uncertainty bounds, the limited coding-family compatibility hypothesis becomes stronger. If it follows a cable, amplifier or clock port, the evidence points to the receiving installation.

The presence of shared side information illustrates why information observations are not always independently additive. If two noisy versions of one public test waveform are recorded, their joint description can be more economical than describing them separately, depending on their dependence. This mathematical insight should not be misread as a licence to combine two protected messages. Here it helps design a measurement audit. If each receiver's apparent 'coding signature' arises from the same shared error, adding their likelihood scores as if independent can exaggerate evidential weight. When likelihoods are combined, the joint null distribution must include common clocks, correlated interference, environmental drift and the actual selection rule. A false sense of confidence may otherwise grow as additional identically compromised channels are attached.

The communication channel can also obscure a genuine laboratory code signature. Frequency-selective fading and intersymbol interference change the distribution of received transition intervals, and a nonlinear front end may create products that resemble intentional periodic structure. An analyst who ignores channel equalisation may conclude that a known code is absent when the receiver simply cannot preserve the selected observable. Conversely a processing algorithm that estimates channel coefficients from the same record and optimises the best-fitting code hypothesis risks data reuse. The proper experimental design freezes the model on a calibration

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population and tests the result on a separate challenge population, preferably from an independent measuring apparatus. Report failure rates across the range of channel states, not only a favourable nominal case.

To separate observables from payload recovery, the exercise should classify only declared characteristics of controlled public waveforms. For example, one may ask whether a gross frame interval persists across two receiver channels or whether a pulse-width distribution changes after a known calibration filter is inserted. These questions do not require examining a private bit stream. A posterior distribution over candidate laboratory encoders, if calculated, is conditional on the candidate set and prior model; it is not a probability that a particular unknown emitter has been identified. In a defensible technical report the candidate space, the omitted alternatives, the sensor limitations and the lawful scope must be recorded with equal prominence.

The strongest evidence for a physical source still comes from an independent causal test of the receiving chain: separate antenna paths, known calibration signals, controlled relocation, and reproducible changes in the external field rather than in software processing. The code hypothesis may guide which benign synthetic control waveforms to inject, but the eventual claim about the monitored environment must rely on observations collected with authority and measured uncertainty. When the feature remains ambiguous among several coding families or channel artefacts, the correct conclusion is ambiguity. A knowledgeable observer should regard that as an outcome of the experiment, not as a failure of professional confidence.

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The panel's shared obligation is to preserve identifiability. A mathematical code relation may be strong while the mapping from those code symbols to external radio-frequency observations is weak. Two competing transmission chains may therefore be observationally equivalent at the chosen resolution. The experimenter must either devise a lawful intervention capable of distinguishing them, or limit the conclusion to a broader class. That is the practical significance of information theory and error-control coding for a defensive survey: it supplies controlled ways to challenge an inference without requiring the examiner to expose or exploit anyone's private communication content.

John von Neumann, Peer Question: Professor Slepian, the research team may implement all of these comparisons in software, with a database that stores raw I/Q, calibration metadata and the many candidate statistics computed during exploration. As additional experiments accumulate, the temptation is to overwrite raw timestamps with improved estimates and discard negative or inconvenient classifier runs. What minimum software architecture and evidential ledger would make the coding-family compatibility claim independently reproducible without storing protected message content? Can the same design also reveal when data loss or receiver resampling has changed the feature distribution, especially where the acquisition hardware and the host operating system use different clocks? I would also ask how the system should handle model updates: a new algorithm may fit old recordings better, yet that does not turn an exploratory result into a successful preregistered test. An explicit separation between immutable observations and versioned derived analysis seems necessary to prevent the manuscript from concealing its own errors.

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David Slepian, Response: Professor von Neumann, the principal design rule is to preserve immutable source observations and to treat each subsequent numerical result as a derived object with an explicit lineage. A capture ledger should identify the authorised test transmitter, experimental code configuration, signal-path reference planes, receiver model and firmware, calibration status, hardware counter sequence, host timing conversion, data gaps and error events. For each processed result, retain the input file hashes, algorithm version, parameter file, permitted feature definitions, candidate-model list and the precise trial exclusions. The system may store envelope and spectral features without retaining any unknown protected payload content; if other communications were inadvertently present, segregate them under the governing legal and retention rules rather than analyse them for this exercise. A successful software run does not establish a valid physical measurement if the sampling chronology has a gap.

An improved analysis should be saved as a new derivative, not a replacement for the original timestamp or the older report. Distinguish exploratory development from confirmatory evaluation in the record. If a classifier was revised after examining the test result, it requires a fresh withheld test set before its reported accuracy can count as confirmation. Device counters, queue occupancy and overflow indicators allow a later reviewer to distinguish delayed delivery from physically missing samples. A verified clock-mapping transformation should be recorded rather than silently inserted into the raw data. Finally, publish the full distribution of validation results across code configurations, receiving channels and noise levels, including failures. This disclosure helps the reader determine

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whether the observed feature is stable, whether the method was tuned opportunistically and what the scientific evidence actually supports. Nothing here requires or authorises recovery of protected message content.

The integrity ledger must also distinguish a software-generated gap marker from a hardware-confirmed loss. A receiver may deliver all acquired samples late, while another may silently discard samples before assigning packet numbers. Those conditions have different consequences for symbol timing and any alleged coding feature. Require the acquisition system to record device-side and host-side counters separately, and include controlled overload tests in the qualification evidence. When the hardware exposes no trustworthy continuity marker, describe the resulting waveform statistics as conditional on an unverified acquisition assumption. That limitation should accompany every subsequent classification derived from the record.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The panel has separated directly measurable waveform properties from proposed coding structures, from protected data recovery and from physical-source attribution. A block-code parity relation or convolutional-code memory can be demonstrated upon authorised synthetic sequences, yet an unknown transmitter cannot be identified from such algebra or from a spectral rhythm alone. All classifications require calibration of symbol timing, receiver linearity, sampling continuity, model search and correlated errors. The panel has examined direct peer objections and reciprocal challenges among the five principal contributors. Structural completion does not, however, confer scholarly or publication approval; independent source-to-claim, mathematical and historical verification remain required.

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SOURCE REGISTER. C. E. Shannon, “A Mathematical Theory of Communication,” Bell System Technical Journal 27 (1948), 379–423 and 623–656. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x ; R. W. Hamming, “Error Detecting and Error Correcting Codes,” Bell System Technical Journal 29 (1950), 147–160. https://doi.org/10.1002/j.1538-7305.1950.tb00463.x ; I. S. Reed and G. Solomon, “Polynomial Codes Over Certain Finite Fields,” Journal of the Society for Industrial and Applied Mathematics 8 (1960), 300–304. https://doi.org/10.1137/0108018 ; Peter Elias, National Academy of Sciences biographical memoir and selected bibliography, https://www.nasonline.org/wp-content/uploads/2024/06/elias-peter.pdf .

EDITORIAL QUALIFICATION. Sources establish the historical mathematics, not the fictional dialogue. All numerical examples are hypothetical. Stage A strict structural gates were applied; separate source-to-claim, historical, scientific, full-manuscript semantic duplication and final pagination proof remain pending. No protected communications payload has been inspected or reconstructed.

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QUESTION 082

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When Does Payload Compression Defeat Entropy-Based Sender Attribution?

SCHOLARLY RECONSTRUCTION. This is a fictional instructional exchange among historically real, deceased scientists. It is neither a transcript nor a quotation from any participant. Contemporary receiver tests, synthetic bit streams and numerical examples are editorial hypotheticals, not records of interception or field measurements.

Dr. James M. Atkinson, Moderator: Professor Ziv, an authorised RF investigation may encounter a waveform whose measured symbol transitions appear statistically irregular, and an analyst may describe that appearance as the fingerprint of a particular communications device. Yet lossless compression, encryption, interleaving, symbol mapping and receiver errors can all produce superficially similar observations. Would you establish what your work on universal compression permits us to infer from a compressed sequence, where statistical identifiability fails, and why a compression-related feature cannot safely be promoted into the identity of a sender?

Jacob Ziv, Principal Contributor: Dr. Atkinson, the central error is to convert a statement about representation into a statement about agency. A compressor transforms one finite sequence into another under a specified reversible rule. A receiver subsequently measures a noisy electrical waveform after that transformed sequence has been framed, coded, mapped to symbols and filtered through a physical channel. Consequently, the visible absence of repeated strings does not establish which transform occurred, much less which person or instrument caused it. Compression

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addresses the description length of a source in a particular coding framework; sender attribution requires an independent association between a measurable property and a genuinely distinct, reproducible physical source. The inferential bridge between these subjects is not supplied by the adjective 'random'.

Consider a finite sequence X_1 through X_n drawn from an alphabet A, where n is the source length and $|A|$ its alphabet size. A lossless encoder C maps the sequence to a finite code representation $C(X_1^n)$. Its realised compression ratio may be written $r=|C(X_1^n)|/|X_1^n|$, provided numerator and denominator are expressed in the same units and the comparison includes a precisely declared convention for framing, dictionaries and termination. A ratio less than one means a saving for that file under that convention. It does not measure a universal entropy of the source by itself. Header overhead can make short files longer; the same source process may compress differently under different dictionaries or block sizes; and a particular incompressible file does not demonstrate encryption. The modern observer must separate sequence length from the physical bandwidth or elapsed transmission time needed to carry it.

Our 1977 work with Abraham Lempel concerned a universal algorithm for sequential compression. Its merit arose from exploiting repeated substrings without requiring the encoder to begin with a complete probabilistic model of the source. But the universality claim is an asymptotic performance result within a stated source model, not a promise that arbitrary short captures will expose an encoder's internal history. Indeed, a short fragment may contain an isolated codeword from a stream whose earlier dictionary is unavailable. The observer cannot recover a unique prior parsing state

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simply from that fragment. Different input sequences, encoder implementations or reset schedules can yield similar local proportions of zeros and ones. Other transformations after compression may erase the distinctions that mattered within the compressor.

The familiar binary plug-in entropy estimate H_hat= -p_hat log2(p_hat) -(1-p_hat)log2(1-p_hat) bits per observed binary symbol is a useful descriptive statistic, with the usual interpretation 0 log2 0 =0. Here p_hat is the fraction of ones in an explicitly defined binary observation alphabet. It measures marginal balance, not temporal independence or compressor identity. A deterministic alternating sequence has p_hat=0.5 and H_hat=1 bit, even though its next bit is perfectly predictable given the previous bit. Conversely a useful source with a strongly unequal symbol distribution can have low marginal entropy while having no readily discernible sender-specific feature. A responsible analyst examines dependence across lags and conditions, not only a histogram.

A more discriminating experiment uses synthetic laboratory sources for which the uncompressed records are owned and retained. Generate repeated text-like tokens, a memoryless binary source, and a correlated Markov source, then pass each through several publicly specified lossless compressors with fixed initial states. Hold the RF symbol rate, forward-error-control code, carrier power and propagation arrangement constant. Apply independently documented symbol mappings and capture with two receivers of differing architectures. Compare only lawful, non-content features such as occupied bandwidth, burst duration, frame periodicity, marker timing, decoder-independent spectral envelopes and bit-like test sequences available from the laboratory generator. Alter compression

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independently of the physical transmitter so a classifier that follows the compressor rather than the hardware is revealed as a transform classifier, not a sender classifier.

A negative result should also be informative. Suppose two programmes compress the same source and then each uses distinct framing. If the purported fingerprint changes with framing while the compressor is fixed, it cannot be attributed uniquely to the compressor. Suppose the same programme runs on different instruments and produces the same synthetic output. Matching irregularity tells us about the common computation, not which chassis emitted it. If a difference survives only when the receiver's automatic gain control is active, we must challenge the measurement path. In each case the causal object under test is the feature-generating mechanism, not an unobserved owner.

Machine-learning classification intensifies rather than abolishes these concerns. A model trained on overlapping fragments of the same recording can memorise recording conditions and appear accurate even when unable to classify an independently acquired source. Randomly partitioning adjacent windows across training and testing leaks temporal dependence; instead split by complete recording session, source generator and receiver setup, and reserve data that were not used to select features or thresholds. Evaluate confusion matrices across both benign source variability and deliberate transform changes. A high test accuracy under one narrow source collection is a conditional result, not a universal claim about all future transmitters.

I therefore distinguish three propositions. First, a given measured sequence exhibits specified statistical patterns under a declared observation model.

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Secondly, controlled examples demonstrate that particular encoder, framing or coding configurations can produce comparable patterns. Thirdly, a particular external sender produced the measured signal. The first may be an observation, the second a bounded model comparison, and the third is an attribution requiring separate, independently validated evidence. Compression can remove the redundancy that once differentiated source files, but it cannot manufacture the physical provenance that entropy alone never measured. A formal defensive report should state that distinction even where the compressed trace looks deceptively unique.

Irving S. Reed, Peer Question: Professor Ziv, redundancy can arise from the information source, from framing, and from channel coding introduced after compression. An investigator might notice repeated blocks or parity-like relationships and assert that the compressor failed to remove structure, when in reality an error-control encoder or periodic synchronisation marker created those repetitions downstream. How should a laboratory differentiate these layers without attempting to read the protected payload? Would you specify what must remain constant when an investigator changes the compressor, the framing convention, and the forward-error-control code in turn? I am particularly concerned about the selection of a convenient test length after examining the data, since an observed periodicity may be a coincidence of two framing intervals rather than a distinguishing property of any compressor. What counterexample should be included before this kind of claim is made to a court or a technical reviewer? Please identify how many negative configurations are needed to distinguish a framing-origin repetition from a coincident spectral marker, and how that number should be decided before the trial begins.

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Jacob Ziv, Response: Professor Reed, a useful design treats source, compressor, frame builder and channel encoder as distinct interventions, each controlled at a declared electrical reference plane. Begin with known generated source sequences and record their full lengths, seeds, alphabet definitions and pre-existing dependence. Encode those same sequences with a declared compressor while leaving framing and the RF chain unchanged; then hold the compressor constant and change only the framing. Finally change the channel code while retaining the earlier values. The observer can compare external waveform summaries without examining unauthorised payloads because every experimental payload is supplied by the laboratory itself. All changes and resets should be logged, and the raw acquisition retained.

The appropriate counterexample is easy to construct. Imagine a compressor producing a well-balanced binary stream, but the frame builder inserts a fixed marker every 1,024 transmitted bits. A periodogram of a corresponding permitted test sequence may exhibit a periodic contribution at the marker cadence. If the marker is deleted while the compressor remains identical, the spectral contribution disappears. The correct inference is that the framing decision produced the feature. Similarly, a linear error-control code may introduce parity constraints whose manifestations depend upon mapping and interleaving. Repeated structures do not necessarily survive pulse shaping or realistic channel errors; their visibility is a receiver-dependent matter as well.

Trial length should be chosen in advance because searching over many

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candidate periods increases the probability of finding an apparently impressive accidental match. Define the period grid, window sizes and scoring rule from an independent engineering rationale, and estimate the family-wise false-alarm behaviour using known negatives. Preserve all failed candidate periods rather than showing only the most favourable one. If two independent source processes with different compressors produce the same reported signature under common framing, the claimed signature is not uniquely identifying. The report may still describe a framing-compatible hypothesis, but that is a different proposition from sender attribution.

The physical chain also needs independent challenges. Vary antenna or receiver, monitor the reference clock, and inject known non-content test tones to exclude a spur or gain-control artefact. Reproduce the finding on a second instrument with different frequency conversion. Document uncertainty associated with timing and observed power. The best experiment seeks to refute an attractive origin story by constructing a different process that yields the same observation. Success in that test does not erase the feature; it changes the degree of specificity the feature can support.

Ronald Newbold Bracewell, Peer Question: Professor Ziv, a blind classifier may be fed short windows selected because they contain an unusually clear spectral or timing feature. Yet the process of selection changes the sample population, and the receiver's own filter may create a degree of regularity not present at the antenna. Can you explain how to evaluate an information-theoretic feature when the first and last samples of a burst are censored by a detection threshold? I would also ask how one can tell whether apparently

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distinct training and test records are independent when they arise from adjacent windows of the same RF event. A system may report excellent discrimination at a particular receiver gain setting, yet the advertised distinction might vanish under another front end. Which negative controls are indispensable before the evidence is used beyond engineering diagnosis? Would a receiver with a different channeliser but the same upstream antenna count as independent corroboration, or must the investigator also examine reference distribution and common-mode cabling to establish real independence?

Jacob Ziv, Response: Professor Bracewell, the acquisition selection rule belongs in the statistical model. If the recorder begins only after a threshold crossing, the captured sequence is conditional upon an event that has already met a selection criterion; it is not an unconditional sample of the transmitted process. A short retained block can be biased towards higher-amplitude portions of a burst and towards particular phases of a pulse-shaping filter. In that setting a claim about source entropy drawn from the retained samples is not merely imprecise; it refers to the wrong population. The calibration must reproduce the trigger, pretrigger buffer, filter settings and any missing edge samples.

An independent laboratory stimulus can disclose this bias without analysing a protected message. Present a known synthetic waveform, first in full continuous acquisition and then through the normal event-triggered process. Calculate the exact same feature on each version, with all windows and preprocessing declared. Move the threshold through a documented range while keeping the waveform fixed. The resulting feature sensitivity is

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an instrument characteristic, not evidence that the source changed. If a classifier responds primarily to threshold, filter or gain changes, separate that dependence in the report.

For genuine out-of-sample testing, reserve whole acquisition sessions, transmitters and clock configurations. Two overlapping slices of one event share the same noise realisation, fading channel and transient filter response; placing one in training and one in testing is a form of data leakage. The correct hierarchical partition may be by source, location, day and receiver configuration, depending upon what sort of generalisation is claimed. A model intended to distinguish encoder families requires held-out encoder configurations or carefully described restrictions; a model intended to distinguish devices requires independent devices and repeated acquisitions under controlled transformations.

Include null examples with fixed transmitter hardware but altered compression; examples with fixed compressed input but changed transmitter chain; and measurements through a terminated or known injected input to identify internally generated features. Evaluate detection failures as well as selected positive events. Report confusion rates with uncertainty intervals and retain the test-set membership and selection protocol. If the result deteriorates under a benign front-end substitution, it is unjustified to treat the original result as a stable external fingerprint. An attractive plot is not a substitute for controlled identifiability.

Jacob Ziv, Cross-Peer Question to Abraham Lempel: Professor Lempel, our universal compression work deals with transformations that exploit source

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constraints, but practical implementation requires finite buffers, dictionary resets, framing decisions and a rule for representing phrase references. An analyst who sees a locally irregular sequence may assume that all encoders of the same broad family behave identically. Would you explain how implementation state can produce apparent markers that are not source properties, and why a compressor reset at a burst boundary can imitate a device-specific scheduling signature? I ask especially whether the same external waveform feature might be reproduced by unrelated hardware that happens to share a software library, or by one transmitter using two different compression parameter sets. What falsification experiment should be required before the feature is described as belonging to one physical sender? Include how the laboratory can prevent the changing dictionary from becoming perfectly correlated with elapsed equipment warm-up time, which might otherwise create a false physical-origin signature.

Abraham Lempel, Cross-Peer Answer to Jacob Ziv: Professor Ziv, an implementation is a procedure with state, not a mathematical label floating free of machinery. A phrase dictionary may be initialised at the start of a file, may persist across blocks, or may be reset by a protocol boundary; the chosen convention affects local output length and the position of some state-dependent transitions. A dictionary can evolve differently for two inputs that have the same simple symbol histogram. That does not contradict the theory of universal compression. It reminds us that an asymptotic performance statement cannot determine the local coding record of an undisclosed finite state machine.

Consider two authorised synthetic streams formed from the same sequence

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repeated many times. Compressor A resets after every block and Compressor B retains its dictionary across blocks. Their output sizes and local phrase-reference structure can differ despite identical source content and identical RF hardware. An observer recording only burst lengths may see a reset-related length pattern and mistakenly attribute it to a transmitter's clock. If A and B are exchanged between two physical RF generators, the pattern may follow the software, not the chassis. If the receiver independently resamples the bursts, even that apparent correspondence may change with the observation method.

A proper challenge therefore varies implementation and hardware as orthogonal factors. Operate the same compressor binaries on multiple machines, and multiple compressors on one calibrated transmitter chain. Control all symbol clocks, carrier levels, pulse shapes and frame intervals. Record whether the proposed feature follows compression parameters, burst segmentation, receiver scheduling or actual hardware. Repeat after the dictionary is deliberately reset and after it is allowed to persist. Where the feature appears only under one segmentation rule, describe a segmentation-conditioned result, not a universal source fingerprint.

The inquiry must also distinguish what is externally observable from an internal code phrase. Without explicit authority to access a payload, the researcher should not claim to have reconstructed private dictionary states. A legal and reproducible demonstration can use synthetic known sequences and compare non-content spectral, duration and event-time features. A surviving association may support a restricted engineering diagnostic.

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Sender identity would still require independent physical or documentary corroboration. The essential safeguard is to design the experiment so that a shared implementation on different hardware constitutes a genuine competitor to the claimed inference.

Dr. James M. Atkinson, Moderator: Professor Lempel, the opening exchange has separated an encoder family from its finite implementation. Would you now examine the controls needed to determine whether an apparent output-length or statistical pattern was caused by the compressor, the source selection, or the equipment that carried the resulting symbols? Please make the experimental design capable of contradicting an incorrect attribution, rather than simply illustrating the proposal that inspired it.

Abraham Lempel, Second Principal Contributor: Dr. Atkinson, a well-designed study begins by specifying the quantities that are actually manipulated and observed. The treatment may be the presence or absence of lossless compression, the choice between two known algorithms, or an explicit dictionary-reset policy. The response cannot simply be labelled 'entropy' without an observation alphabet, a finite-sample estimator and a measurement reference plane. A spectrum analyser measures electrical energy in specified time-frequency bins. It does not directly measure the informational entropy of a private file. An event-timing recorder measures onset and duration under a declared trigger. It does not directly discover an encoder's phrase table. The permitted scientific task is to determine whether changes in a known data-processing condition cause reproducible changes in those measured external features.

To separate competing causes, use a balanced, randomised factorial design. Let S identify the synthetic source family, C the compression method, F the

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framing scheme, R the RF transmitter chain, and M the measurement receiver. An illustrative response Y might be a predeclared burst-duration statistic. A suitable model is $Y=\mu+\alpha_S+\beta_C+\gamma_F+\delta_R+\eta_M+$selected interaction terms$+\varepsilon$, where μ is a grand mean, the Greek coefficients represent effects under the declared factor coding, and ε describes the residual variation. The model is descriptive until checked for adequacy. Compression may interact with source family; a fixed-length frame can conceal a change in encoded data length; and receiver thresholding can interact with pulse shape. It would be intellectually careless to interpret β_C without considering these dependencies.

Randomisation is not a magical property of an experiment; it controls particular threats. Vary the compression treatment in a concealed order while retaining source input and frame length controls. If a thermal transient in the RF amplifier evolves monotonically during the test, random order reduces the chance that the drift is mislabelled a compression effect. Replicate under different oscillator states, receiver gain settings and antenna configurations. Use a prewritten schedule of permissible input sequences and negative controls rather than selecting the clearest subset after the fact. Keep the full acquisition ledger, including failed or missing events, since those failures may depend on the treatment.

One may construct an elementary numerical example from public synthetic strings. Suppose each of 100 known blocks contains 8,000 source bits. On 50 authorised trials a compressor emits 2,500 payload bits; on the other 50 it emits 7,800, depending on deliberately changed source regularity. At a fixed gross coded bit rate of 100,000 bits per second and ignoring a separately documented constant frame overhead, the payload-carrying durations are

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25 milliseconds and 78 milliseconds. This example shows how source compressibility can change burst duration without changing transmitter hardware. It does not establish that field measurements of 25 or 78 milliseconds arose from these sources. A fixed 100-millisecond frame might erase the duration difference entirely. Conversely if the transmitter adapts its symbol rate to the output length, the same waveform duration can represent different payload sizes.

An important confounder is measurement of the wrong layer. Adding a scrambler after compression can whiten simple second-order statistics without changing the fundamental fact that the source was compressible. Forward error correction adds redundancy back into the channel code, and mapping to a modulation constellation transforms symbol sequences into amplitudes and phases. An error-prone channel can produce bit errors that mask the encoder's structure even for the investigator's own known test signals. Thus the observation model must propagate transformations through the entire chain. The analyst should not compare an input-source entropy estimate directly with a spectral flatness statistic as if their physical units and semantic meanings were interchangeable.

To preserve causal interpretation, an engineering team should perform purposeful substitutions. Hold a single transmitter and receiver fixed whilst changing C; hold C fixed whilst changing the permitted source S; hold both fixed whilst changing F; and then reproduce the experiment with a second transmitter and receiver. Measure amplitude, timing, frequency response and packet continuity at each step. If a proposed signature follows a particular software configuration across different hardware, it is evidence about the configuration. If it persists only with one instrument even when C,

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S and F change, investigate device artefacts before claiming a transmitter signature. A truly instrument-specific property requires stability under benign environmental changes and distinctness relative to a suitably diverse negative population.

One should also distinguish predictive accuracy from causal identification. A classifier may consistently separate two labelled laboratory source groups when those groups differ simultaneously in compressor, carrier frequency, RF gain, location and date. That performance is useless for deciding which factor caused the separation. Remove shortcuts by matching or randomising nuisance conditions and evaluating held-out configurations. When a prospective test includes a new compressor version or dictionary policy, the model should be allowed to abstain rather than assign the new observation to the nearest familiar class with unwarranted confidence. In a forensic setting, the cost of a confident false attribution can be greater than the cost of an inconclusive measurement.

The final claim hierarchy should be written before collecting data. A frame-duration response to known compression is a replicable demonstration within the experiment. A similarity between an unknown observed duration and a laboratory duration is an unresolved comparison. Inferring software, device or sender identity from that similarity would require additional independent evidence and appropriately characterised alternative causes. Compression does not create a stable personal signature. It is a transformation whose measurable effects depend on inputs, encoder state, framing and transmission decisions. The strongest scientific conclusion may be that a tempting attribution was successfully falsified.

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David Slepian, Peer Question: Professor Lempel, two test sources may be individually balanced in their zero-and-one counts but differ substantially in memory and correlation, so a compressor's realised performance could appear to be associated with the operator's chosen equipment when it is really responding to source dependence. How would your experimental design keep the source population from becoming a concealed surrogate for the claimed sender? Should one randomise source sequences within device, use matched examples across all compressors, and retain entire sessions when separating training from testing? I would also ask how an investigator might report uncertain or interval-censored event lengths when a detector fails to capture the beginning of a short burst. The observed response may then be a lower bound on duration rather than a precise outcome, and an apparently strong compression effect might rest on a biased selection of complete bursts. Please specify whether a statistically significant source-by-compressor interaction should be interpreted as a limitation on transportability and whether its uncertainty should be estimated across independent source sessions.

Abraham Lempel, Response: Professor Slepian, the simplest defence is a crossed design in which every synthetic source sequence appears under every authorised compressor and transmitter configuration, subject to an explicit and randomised execution order. The source sequences must include independent symbols, short-range Markov dependence, long repeated phrases and a structured adversarial negative case constructed to defeat one simplistic feature. This allows differences attributed to compressors to be estimated within matched source inputs. Replicate complete source-generation runs under new random seeds and retain those

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seeds in a protected laboratory register. If source families are wholly confounded with transmitters, there is no experimental basis for separating their effects.

Analysis should preserve the hierarchy of repeated measures. Multiple windows cut from one transmitted burst are not multiple independent emitters or multiple independent test trials. A mixed-effects or cluster-robust analysis may be appropriate when the same source sequence is transmitted repeatedly, but the particular statistical treatment must reflect the actual randomisation unit. For a predictive model, group the train/test split by complete session, not by random fragments within a session. Reserve novel source sequences and new receiver configurations for final testing, because familiar noise patterns can yield deceptive validation accuracy.

An event whose beginning is missing because of threshold activation must be labelled as censored. If the receiver sees an ending at t_end but first acquires at t_start after the true onset, the observed duration t_end−t_start may understate the actual duration. The bias may depend on signal amplitude and receiver gain. One can use an independent continuously recording laboratory witness to determine the true duration for permitted test waveforms and estimate the conditional error distribution of the operational trigger. Where that witness is absent in a field record, numerical treatment must respect the coverage gap; the analyst cannot restore the unseen onset merely by fitting a convenient regression model.

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I would require the report to show distributions of accepted and rejected trials, by treatment and source family, and to provide a sensitivity analysis under plausible unobserved intervals. A classifier trained exclusively on complete bursts could fail systematically on weak or truncated bursts. The appropriate result is a conditional demonstration of what the known experiment measures, with explicit limits on generalisation. That is much more valuable than a high percentage reported from a biased sample whose selection history has been discarded.

Alan Mathison Turing, Peer Question: Professor Lempel, in many engineering demonstrations the researcher experiments with numerous candidate features, partitions, model classes and hyperparameters, then presents the one that best separates known examples. If a claim is subsequently tested upon the same observations used to select the feature, the apparent evidence has already been consumed in constructing the hypothesis. How would you require the investigator to separate exploratory model building from genuinely independent corroboration? In particular, what record of failed features, intermediate models and cross-validation splits should survive, and how should a classification system respond when it encounters a source family or compression format outside its original training set? An 'unknown' answer may be less impressive to an audience than a confident identity, yet scientifically more defensible. Should an independent examiner be able to reproduce all discarded model candidates, and what objective criterion would distinguish a genuinely novel source from an unusually noisy member of an existing class?

Abraham Lempel, Response: Mr. Turing, the first obligation is to state which data were used to discover the purported pattern. Exploratory work can

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examine many representations, but the resulting performance estimate is optimistic unless the search procedure itself is included in validation. Reserve a sealed test set before the analyst selects the feature set, encoder hypotheses or classification model. Better still, collect a prospective replication with fresh synthetic source inputs, altered RF equipment and independently measured nuisance conditions. A genuinely external evaluation should occur after the analytic decision rules are frozen, with no informal retuning in response to the outcome.

A complete audit trail should contain the candidate feature definitions, unsuccessful fits, cross-validation membership, random seeds, training labels, preprocessing steps and code versions. A nested validation scheme can be appropriate when model selection is intensive: the inner data choose settings, while the outer held-out groups estimate the performance of that selection process. Yet even a carefully nested procedure over a narrow laboratory sample cannot establish performance for transmitters or compression implementations that are absent from the sample population. The external validity claim must be correspondingly narrow.

An 'unknown' or 'insufficient evidence' category is not a defect. One can calibrate a decision threshold on known classes and quantify how often novel negative families are mistakenly forced into familiar labels. Use diverse open-set negative controls. A model that assigns every high-entropy looking record to one known sender cannot distinguish absence of a matching hypothesis from strong evidence of membership. If a new implementation shares a public library with one old source, the correct

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output may be ambiguity, not identity. Feature attribution should identify which controlled variable drives the response and whether that variable was even observable on the unknown physical chain.

Reproducibility further requires an independent research team to reimplement the analysis from the fixed protocol and original acquisition data. If their result changes materially when the order of random seeds is altered, or when a single receiver is exchanged, that instability belongs in the report. A court or standards committee may prefer a crisp answer, but engineering inference cannot grant certainty that the experiment did not earn. The scientific objective is to quantify how many alternatives remain consistent with the observation and how those alternatives were challenged.

Abraham Lempel, Cross-Peer Question to Claude Shannon: Professor Shannon, the finite experiment shows that a compressed output can have little obvious redundancy, but the wording 'high entropy' is itself ambiguous when inferred from a short, error-prone, framed physical waveform. Would you explain what source entropy, conditional entropy and mutual information measure under explicitly specified random variables? I am particularly concerned that an analyst may treat a near-one-bit empirical marginal entropy as a demonstration of unpredictability, then convert that apparent unpredictability into a claim of cryptographic processing or sender identification. How could two distinct source and encoder systems be indistinguishable under the chosen statistics while retaining completely different internal meanings and histories? What physical measurement would distinguish the information-theoretic proposition from an assumption about hidden equipment? In your answer, separate finite-sample estimator

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error from the deeper identifiability problem where several distinct models generate exactly the same observed statistics. Also define the distinction between a genuinely unobserved source variable and a variable measured with finite precision, since those two uncertainties cannot legitimately be conflated in any claimed attribution.

Claude Shannon, Cross-Peer Answer to Abraham Lempel: Professor Lempel, the distinction begins with the definition of a probability model. For discrete random variable X with outcomes x and probabilities p(x), Shannon entropy is $H(X)=-\Sigma_x p(x)\log_2 p(x)$, expressed in bits per draw when the alphabet is discrete. That is a property of a stated source distribution, not an adjective one may attach to an unknown voltmeter trace. Conditional entropy $H(X|Y)$ describes residual uncertainty about X when Y is known, while mutual information $I(X;Y)=H(X)-H(X|Y)$ measures dependence under the joint model. All three quantities can be estimated poorly from a short, selected sample. Their values alone contain no physical sender identifier.

If X is a sequence of source bits and Y is a quantised observation of receiver output, the mapping between them includes coding, modulation, channel and quantisation. An entropy estimated from Y need not equal the entropy of X, and equal estimates do not imply equal causes. Different internal processes can induce the same one-symbol distribution for Y. A deterministic alternation and a memoryless fair coin both have balanced marginal symbols but differ in conditional uncertainty. A compressed known source and a deliberately randomised uncoded test source can yield similar summaries, even though their mechanisms and physical origins are distinct.

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To test the information-theoretic claim, specify the observation alphabet, transformation, record length and stationarity assumptions, then challenge the estimator with synthetic models of known dependence. Distinguish marginal frequency counts from block entropy estimates and predictive performance on held-out sequences. Ensure that any alleged difference survives an independently calibrated receiver and signal mapping. Where missing samples or unequal noise alter the observed sequence, propagate those uncertainties rather than declaring a property of an inaccessible payload.

Identifying an external sender is a separate causal hypothesis. A common source distribution does not establish a common chassis; a common compressor may be installed across unrelated devices; and a single transmitter may vary its encoder over time. Physical attribution requires independent evidence such as calibrated location measurements, timing records, equipment-specific characteristics that survive controlled substitutions, and lawful records linking observations to a source. Information theory can clarify the limits of what the data contain. It cannot replace the physical or legal evidence necessary to connect a sequence to an origin.

Dr. James M. Atkinson, Moderator: Professor Shannon, would you take the floor to examine the distinction between the entropy of an actual information source, the entropy estimated from finite observed symbols, and the physical behaviour of a modulated receiver output? I would welcome an explicit account of the assumptions under which a statistical

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quantity can be interpreted as a rate or capacity, and the boundaries beyond which it is no more than a descriptive measurement.

Claude Shannon, Third Principal Contributor: Dr. Atkinson, the scientist must begin by naming the random experiment. It is not enough to say that a received waveform is 'entropic' because a spectral trace looks irregular. Electrical waveforms possess power spectra, correlation functions, bandwidth, amplitude distributions and phase trajectories. Information-theoretic entropy refers to a probability distribution over specified symbols, conditional histories or continuous random quantities, and those definitions are not interchangeable. One can construct an analogue waveform with a visually flat spectrum but deterministic content, and one can transmit an unpredictable source through a narrow, structured carrier. The appearance of the receiver display is a transformation of the process under study, not the process itself.

Let $X_1, X_2,\ldots$ denote a discrete source. For independent and identically distributed draws, its per-symbol entropy is $H(X)=-\Sigma\, p(x)\log_2 p(x)$, provided the probabilities are well defined and the source model is applicable. For a dependent stationary process, the entropy rate is $h=\lim_{n\to\infty} H(X_1,\ldots,X_n)/n$ under suitable existence conditions. A source whose first-order histogram is balanced need not have $h=1$ bit per symbol. A deterministic alternating binary process has a balanced marginal but approximately zero asymptotic entropy rate once its phase is known. Conversely, a binary memoryless source with $p(1)=0.5$ has one bit per symbol under that model. An observer who estimates only the balance of zeros and ones cannot distinguish them. The difference appears in

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dependencies and predictability, not in an unqualified declaration of 'random appearance'.

Compression uses the statistical or combinatorial structure of the source to obtain a shorter description. A well-designed lossless compressor can reduce a redundant file; its compressed output may present fewer obvious repetitions, because those repetitions have been represented more economically. But a file's finite compressed length and its theoretical source entropy are related only under precise coding conventions, asymptotic conditions and knowledge of the source family. A short file may expand because the encoder includes headers or a dictionary. A file with no observed compression saving under a given programme may simply be an inconvenient match to that programme. There is no theorem that a visually irregular received burst was encrypted, compressed, sent by one manufacturer, or produced with adversarial intention.

The channel adds a separate layer. A memoryless channel with input X and output Y has mutual information $I(X;Y)=H(X)-H(X|Y)$ under its declared law, and the channel capacity is the supremum of $I(X;Y)$ over admissible input distributions for the stated channel model. This abstraction cannot be transferred unchanged to a receiver whose analogue gain control, quantisation, fading and filter states are unknown. In particular, the spectrum analyser's displayed bandwidth multiplied by an observation time is not itself an observed payload entropy. A wideband noise-like signal can carry highly structured or even no useful message content; the transformation from source symbols to recorded voltages determines what the external measurement can justify.

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One can inspect a permitted synthetic laboratory data set to illustrate finite-sample bias. Suppose a fair binary source produces ten symbols. The plug-in estimate may be exactly one bit if five ones appear, but it can also be lower when the realised balance is unequal, despite the true source entropy being one bit. For larger alphabets, rarely observed categories and structural dependencies produce additional bias. A researcher selecting only captures with favourable sample entropy compounds the problem. Appropriate confidence and bias assessments require a declared stochastic model, resampling assumptions or independent simulated records. A precise-looking number printed with six decimals is not thereby a precise estimate of the underlying information process.

A practical defensive investigation should therefore separate three observation levels. At the analogue level, document RF power, occupied bandwidth, carrier frequency, pulse duration and instrument uncertainty. At the digital-symbol level, where lawful and possible using known test content, document how the demodulator defines a symbol and handles errors, erasures and synchronisation. At the source level, describe the synthetic or otherwise authorised input distribution and the actual compression rule. These levels can be linked experimentally when the investigator controls the whole chain. They cannot be linked by imagination when some intermediate transformation is unknown or inaccessible.

A carefully designed experiment includes both compressible and incompressible known inputs, multiple distinct source families, several compressor algorithms, independent framing schemes and at least two receiver architectures. Hold the RF power and symbol clock fixed while changing the compressor; then hold the compressor fixed while changing

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the forward-error-control code. Record whether the measured external feature changes at all. If an entropy-based classifier claims to identify a sender, exchange compressor binaries between independent transmitter assemblies. If the predicted class changes with the binary, the observed feature cannot identify the physical assembly. If it does not change, test the remaining shared hardware conditions and environmental confounders rather than pronounce identity.

A final ambiguity is the choice of features used after looking at the capture. Investigators may search many symbol mappings, window sizes, entropy estimators and candidate lags. An apparently exceptional match may be expected under that multiple-search process. Hold out a new acquisition as a confirmatory test and retain all unsuccessful alternatives in the research record. A result produced by optimising a model on the very event under investigation is exploratory. In a forensic report, its strongest defensible role may be to suggest further controlled tests, not to certify the sender or the legal character of any communication. The ultimate task of theory is to prevent an inference from outrunning the quantities the experiment has actually measured.

John Robinson Pierce, Peer Question: Professor Shannon, a receiving chain may contain nonlinear mixers, logarithmic detectors and gain-control circuits that change a measured amplitude distribution without changing the source programme at all. An apparently featureless spectral response may also be the product of filter bandwidth or averaging. Could you distinguish the entropy of a discretised sample sequence from the spectral flatness or occupied bandwidth measured by a conventional spectrum analyser? Which electrical measurements would establish whether an

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entropy-related feature was generated before the antenna, in the receiver, or during subsequent numerical processing? I am also concerned about a common mistake: treating the absence of a visible spectral line as proof that the incoming source symbols are independent. A wideband laboratory generator can be entirely deterministic while looking noise-like to an under-resolved analyser. What controls would you require before discussing an information-theoretic hypothesis? Would checking the same feature against raw I/Q samples, detected powers and separately calibrated analogue measurements help locate the stage at which apparent randomness first enters the record?

Claude Shannon, Response: Mr. Pierce, spectral flatness is generally a functional of a power spectral density or its estimate, not an entropy of a source alphabet. A common spectral-flatness statistic is the geometric mean of estimated nonnegative spectral powers divided by their arithmetic mean over chosen bins, when these means are meaningful. Its value depends upon the analysis bandwidth, window, data length and treatment of near-zero bins. The Shannon entropy of a quantised sequence requires a distribution over explicitly defined symbols. The two statistics can respond differently to the same signal, and neither independently establishes the underlying sender. A carefully constructed deterministic pseudo-random sequence can have broad spectral appearance while being completely reproducible from its generation rule.

To locate the mechanism, perform a reference-plane experiment. Observe a permitted waveform directly at the controlled generator output, after the RF transmitter, at the receiver input and after each relevant demodulation or

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quantisation stage. Use a known, independently calibrated reference signal alongside the synthetic source to monitor receiver changes. Repeat with a second architecture that differs in frequency conversion and detector implementation. A feature that appears only after a logarithmic detector may be a detector characteristic; one that changes with automatic gain-control settings deserves a gain-state explanation before a source explanation.

Avoid interpreting a spectral hole or line as a property of the encoder before considering pulse shaping, subcarrier allocation and time-frequency resolution. A rectangular pulse, for example, has a characteristic transform whose sidelobes depend on its duration; changing the window or filter can reshape the displayed spectrum. Similarly, a digital frame marker inserted after compression can create a cadence even if the compressed payload is balanced. The investigator should estimate the covariance of measurements across frequency and time rather than treating all bins as independent information sources.

If the laboratory controls synthetic data, compare source-level statistics directly with receiver-level statistics under known transformations. Record the point at which a particular feature emerges, disappears or becomes unmeasurable. With unknown protected content, that comparison is unavailable; the report must say which links in the causal chain remain unobserved. A finding of 'no distinguishing feature detected within this receiver's tested sensitivity' is far more defensible than the categorical

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proposition that the source has no structure. This distinction is metrological, statistical and legal all at once.

Claude Shannon, Cross-Peer Question to Ralph Vinton Lyon Hartley: Mr. Hartley, an analyst sometimes selects a binary alphabet solely because the receiver produces two-level decisions, and then interprets the resulting entropy estimate as if it were an intrinsic property of the transmitter. Yet a different threshold, constellation partition or observation interval would define a different alphabet. Could you explain how the act of counting distinguishable alternatives depends on the physical signalling convention and the available time-bandwidth product? What would follow if one transmitter sends the same known message through different symbol mappings, or if two unrelated transmitters use the same modulation and framing convention? I would also ask you to challenge the assumption that a high apparent symbol diversity identifies a unique source when the observer has not established that the compared alphabets are equivalent. Please explain whether a quantiser changed after observing the waveform invalidates a nominal significance estimate unless that choice is accounted for in the testing procedure.

Ralph Vinton Lyon Hartley, Cross-Peer Answer to Claude Shannon: Professor Shannon, the counting convention is not merely a mathematical convenience: it encodes a decision about what the receiving system can distinguish. For N equally possible and discriminable alternatives, a simple information measure is log2 N bits per selection. But the adjective 'discriminable' demands an electrical model of signalling, noise, timing and the observer's resolution. A receiver mapping a continuous complex waveform into two symbols by a threshold discards information, and

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another threshold can produce different symbol frequencies from the same analogue samples. The resulting alphabet belongs partly to the instrument and analyst, not only to the source.

In my 1928 treatment, physical considerations connect the number of signal distinctions with bandwidth and available signalling time. Such reasoning does not justify estimating a sender's identity by counting how many quantised values occur in a finite recording. Two unrelated transmitters using one public framing convention can present the same symbol alphabet. Conversely one physical transmitter can change modulation order or mapping and thereby alter the visible alphabet while its identity remains constant. The decision rule and observation window must be the same, or rigorously calibrated, before comparing their statistics.

A useful demonstration uses a known transmitter sending the same synthetic sequence under two lawful modulation mappings. Record continuously with a calibrated complex-sample receiver, then compute the same entropy estimator after several predeclared quantisers. If the apparent signature changes with the quantiser while the sender and source are unchanged, the signature cannot be invariant to observation method. Next hold the quantiser fixed but change the transmit modulation. If the statistic follows modulation rather than the physical transmitter, report it as a modulation-associated feature. These are straightforward interventions, but they prevent a common intellectual error.

The analyst must also distinguish a count of symbols from a count of

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physically independent trials. Adjacent samples filtered by the same analogue pulse and taken faster than the system's independent degrees of freedom are correlated, even if the record contains millions of numbers. Treating them as millions of independent observations can make uncertainty intervals absurdly narrow. A time-bandwidth assessment can motivate a bound on measurement degrees of freedom, but exact effective sample size depends upon the signal and filter. I would therefore insist on a declared reference plane, threshold rule, sample cadence, filter bandwidth and uncertainty model before a numerical information measurement is used as evidence of origin.

Dr. James M. Atkinson, Moderator: Mr. Hartley, please develop this question from the perspective of physically available distinctions and observation conventions. In particular, how could a receiver's finite time-frequency resolution, a modem's framing choice, or the analyst's quantisation produce an apparent statistical signature that disappears when a measurement is repeated using another valid observation alphabet?

Ralph Vinton Lyon Hartley, Fourth Principal Contributor: Dr. Atkinson, the first task is to keep distinct the thing transmitted, the thing physically observed and the thing classified. In a communication system there must be a convention by which the receiver distinguishes one possible signal from another within a limited time and bandwidth. An analyst who divides an RF trace into symbols has imposed an observation rule. That rule can be excellent for the intended engineering purpose while being wholly unsuitable for identifying the transmitter. The physical apparatus may observe only a narrow band, integrate energy for a relatively long interval, or discard phases and amplitudes that the source actually used. It is

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therefore a mistake to infer an intrinsic information source from an undeclared digital summary.

My 1928 account of the transmission of information emphasised physical signalling and the relation between distinguishable alternatives and available resources. For N equally likely alternatives, one writes $H_H=\log_2 N$ bits per selection. This elementary count presumes that all N alternatives have been specified and can be resolved under the observation model; it does not certify that they are equiprobable in an unknown source, nor that their choice identifies any particular sender. To compare two records, one must define what constitutes a selection, where the physical sampling interval begins and ends, and whether both instruments implement the same distinctions. Otherwise the symbol count is a measure of apparatus and convention, not simply of the incoming field.

Consider an authorised laboratory waveform represented by complex baseband samples $z_n=I_n+jQ_n$, where I_n and Q_n are the in-phase and quadrature components for sample index n. An analyst may assign binary labels using the sign of I_n. Another analyst may use the sign of Q_n, and a third may partition the complex plane into four quadrants. These rules generate different symbol alphabets from identical analogue data. Their empirical symbol frequencies may differ because of carrier phase, offset, gain, quadrature imbalance and receiver noise. No physical transmitter change is required. If the apparent sender fingerprint changes when the symbol definition changes, the fingerprint has failed even a basic invariance test.

Pulse shaping makes the problem subtler. Adjacent samples may be correlated by the transmitter's filter and by the receiver's own anti-aliasing

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and channelisation. Counting one million oversampled values as one million independent symbol observations is invalid. A finite time-bandwidth resource restricts the distinguishable degrees of freedom under the assumed noise and signal model, although it does not supply a universal formula for every real receiver's effective sample size. The investigator should inspect autocorrelation and filter memory, account for scan gaps, and calibrate timing against a stable reference. The covariance structure matters more than the impressive length of the stored sample file.

A compression step occurs upstream of these physical choices. The compressed known source may have approximately balanced output bits; the frame builder may insert a fixed preamble; the forward-error-control coder may introduce parity relations; a scrambler may further alter local correlations. A subsequent modulator and pulse shaper convert the result to voltages. If an investigator sees a repeatable envelope or cadence, that feature may be due to the frame boundary rather than to the compression rule. If changing the compressor changes transmitted duration only when framing is variable length, the observation is conditional on the framing policy. The words 'payload entropy' should never be used to elide these alternatives.

An instructive experiment compares four known conditions. In condition A a fixed synthetic file is transmitted without compression under a fixed symbol clock. In B the file is compressed but the frame size is fixed by padding. In C the compression remains but padding is removed so occupied burst duration may change. In D the source and compressor remain fixed while the modulation mapping changes. Monitor the antenna input with a calibrated complex-sample receiver and an independent timing witness. If

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the proposed signature appears only in C, it concerns duration and padding, not a universal property of compression. If it changes in D, it concerns mapping or measurement. This trial need not decode a protected message because every transmitted test string is the researcher's own.

All numerical estimates need uncertainty. Suppose a binary-quantised record contains 600 ones among 1,000 samples, giving p_hat=0.6. Its plug-in entropy is approximately 0.971 bits per sample. If carrier phase rotates and the same receive samples are reassigned under a different threshold, p_hat may change, and the resulting number changes with it. The value 0.971 is neither an estimate of device ownership nor proof that the encoder compressed data. Its sampling uncertainty cannot be computed from a binomial model unless the samples are appropriately independent; pulse-shaping correlation will reduce effective information. One should state the estimator and its assumptions rather than present an isolated decimal as a sender characteristic.

The final implication for forensic reasoning is modest but valuable. A reported feature can support the proposition that an observed signal is compatible with a particular modulation, framing or coding arrangement under controlled tests. It cannot by itself bind an invisible source file, compressor, chassis or human operator to that signal. A proper report identifies the observation convention, tests alternative quantisers and receiver architectures, documents the experimental coverage, and refuses to treat incompatible statistical scales as interchangeable. Physical measurement should narrow a hypothesis only to the degree that controlled alternatives have actually been excluded.

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John von Neumann, Peer Question: Mr. Hartley, an experimental group may preserve the analysed sample sequence but not the software configuration by which the spectrum, quantised symbols or classifier inputs were produced. Such a record can look objective whilst depending on a chain of discretionary choices, including window overlap, filter length, threshold, resampling ratio and omitted bursts. What minimal computational provenance would permit a later reviewer to reproduce the claimed entropy statistic from the original measured voltages? How should one treat a software update that changes rounding, detector normalisation or event boundaries without changing the RF emitter? I would also ask whether an apparently precise uncertainty estimate can survive if the number of effective independent observations was never measured and correlated samples were silently counted as independent evidence. In a controlled replication, should changes in software dependencies and arithmetic libraries themselves be treated as experimental factors when the target effect is only a few hundredths of a bit per symbol?

Ralph Vinton Lyon Hartley, Response: Professor von Neumann, the primary record must preserve the original complex samples or other minimally processed electrical measurements, their sample indices and clock mapping, and a complete configuration snapshot of the receiver. A later feature calculation should be a reproducible transformation with a declared software version, processing code hash, filter coefficients, window and overlap, quantisation rule, detection threshold, missing-sample treatment and output units. A table of derived entropy values without those particulars is a summary of an unknown experiment. It cannot serve as a secure foundation for comparison when the feature itself is sensitive to the

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unrecorded steps.

One should also establish the physical observation boundary. Was the recorded value a voltage at a calibrated receiver output, a detected magnitude, a logarithmic power, or a post-decoded symbol estimate from a known laboratory signal? The distinctions matter because nonlinear transformations can alter statistical distributions. A software update that changes a threshold could change the measured fraction of ones and the resulting plug-in entropy while the transmitter is untouched. The investigator must compare pre- and post-update results on immutable raw test captures and document any revised algorithm as a new derived representation, not overwrite prior evidence.

For uncertainty, the count of stored samples is not necessarily the count of independent observations. A long finite-impulse-response filter, oversampling or a slowly changing receiver gain may produce substantial correlation. An independence-based standard error may then be overconfident. Use controlled resampling or appropriate dependence-aware methods, specifying which time scales and stationary assumptions are justified. Where the sample sequence includes censored intervals, a correction must account for the selection rule or report bounded conclusions instead of pretending missing observations were present.

I would require at least one independent replay on an instrument with a different receiving and analysis chain. Preserve negative controls that test whether a feature arises with a terminated antenna port, a known injected

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test waveform or a changed gain state. A statistic reproducible only within one software version and one receiver setting is an instrument-specific diagnostic at best. Neither its numerical stability nor its attractive presentation establishes sender identity. The intellectual principle is elementary: the record must permit another examiner to see which observable was measured and which decisions created the final number.

Ralph Vinton Lyon Hartley, Cross-Peer Question to Peter Elias: Professor Elias, even when the source has been compressed, communication systems frequently add deliberate redundancy through error-control coding, synchronisation and interleaving before physical transmission. An investigator may find a pattern of near-regular errors or repeated frame lengths and mistakenly infer a particular compressor or sender. Would you examine the direction in which information and redundancy travel through the chain, and the conditions under which a channel-code effect could resemble a compression fingerprint? What should be learned from a controlled experiment where the compressor remains fixed but code rate, interleaver depth and permitted error probability are varied? I also ask how the investigator should distinguish a known laboratory codeword property from an unsupported inference about an unknown protected payload. Could the same nominal code rate create different bursts under puncturing, padding or a variable modulation order, and how should those confounders appear in the measurement ledger? Please identify whether a receiver that records only burst-level energy could even resolve the changes in code rate, and specify the laboratory reference measurement needed to establish those differences.

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Peter Elias, Cross-Peer Answer to Ralph Vinton Lyon Hartley: Mr. Hartley, the source and channel stages serve different purposes. A lossless compressor attempts to reduce a description of source redundancy under a chosen code, while an error-control encoder introduces structured redundancy to make reliable reception possible under specified channel impairments. There is no contradiction in a communications system first reducing one form of redundancy and then adding another. A recorder observing only the final waveform may not know where one process ended and the other began. The evidence must therefore be framed as a comparison against explicit candidate chains, not a single inferred compressor.

Let k denote the number of input information symbols and n the number of coded channel symbols for one block under a defined code alphabet. The rate $R_c=k/n$ is a channel-code rate under that convention. A lower R_c can increase the number of transmitted symbols for the same compressed input, but the change in burst duration depends also on physical symbol rate, modulation bits per symbol, framing and padding. The simple expression is not a direct measure of original source entropy. A rate-one uncoded laboratory condition can be compared with several public error-control codes while all other factors are held constant. If a purported compressor signature changes with R_c, its causal description must acknowledge the channel code.

Interleaving further complicates local patterns. Permuting a sequence's positions can disrupt short-range correlation and distribute burst errors without changing the multiset of transmitted symbols. Thus a first-order

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histogram may remain the same while a lag-correlation statistic changes substantially. Noise, fading and detector errors then add further variation. An investigator who sees high apparent unpredictability in a short capture cannot determine whether the pattern arose from compression, interleaving, scrambling, encryption, measurement noise or a mixture of these mechanisms merely from that appearance.

A controlled study should transmit only owned, synthetic test messages, record the code and interleaver configurations, and challenge its waveform feature across code rates, burst lengths, signal levels and independent receivers. Retain both error-free and deliberately impaired test conditions. Evaluate whether a classifier's decisions follow coding settings rather than the transmitter identity. An unknown protected payload cannot be converted into a known codeword by assertion. If the necessary message or decoder states are inaccessible, the researcher must limit the claim to externally observable compatibility and uncertainty, not pretend to have proved an internal encoding history.

Dr. James M. Atkinson, Moderator: Professor Elias, would you now develop the complete account of channel redundancy, error patterns and receiver uncertainty, including what can be established with an authorised synthetic challenge, and what remains unavailable when the semantic contents of an external communication are not accessible?

Peter Elias, Fifth Principal Contributor: Dr. Atkinson, a communications chain may be understood as a sequence of distinct maps whose effects are not identifiable from a single coarse observation. A source produces data, a compressor may remove predictable description length, a channel encoder

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adds structured redundancy, a modulator and pulse shaper produce a continuous waveform, and the channel and receiver introduce impairments. A statistic measured at the end is a property of that composition under the instrument's configuration. If the analyst proposes to label it a sender fingerprint, every intermediate map and nuisance mechanism becomes a potential competing explanation. Our first obligation is to ask what experimental manipulations can separate them without examining protected content.

Error-control coding has an elementary mathematical representation. A binary linear block code may map k information bits into n transmitted code bits, with nominal code rate $R_c=k/n$. The number $n-k$ represents added code bits per block under that model, although precise redundancy must consider framing and shortened or punctured codes. If a known source output is B bits, and B is divisible into k-bit input blocks for a simple idealised calculation, then the channel encoder produces nB/k coded bits before any interleaver, preamble or physical framing. At gross symbol rate f_s symbols per second and m transmitted coded bits per modulation symbol under a declared mapping, nominal useful transmission time is approximately $(nB/k)/(m f_s)$. This equation assumes no packet overhead or gaps and is an illustrative calculation, not an instrument specification.

Suppose B=4,000 compressed bits, k=100, n=200, m=2 and f_s=100,000 symbols per second. The idealised coded output is 8,000 bits and the payload-carrying duration is 0.04 seconds. If the code changes to n=125 at the same k, the duration becomes 0.025 seconds, with all other terms unchanged. That 15-millisecond difference would be visible to a sufficiently well calibrated acquisition system, but it would identify a change in channel-

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code configuration, not a different sender. A fixed-length burst with padding could hide the difference, and an adaptive symbol clock could also compensate. Any event-duration inference must therefore report framing and timing controls as well as compression status.

The observed errors can be equally misleading. A channel with independent bit error probability p is one model, but real RF channels may exhibit fades and clustered errors. An interleaver can redistribute the order of coded symbols so that local error bursts are spread across codewords, while a decoder's subsequent success or failure depends on its code and operating assumptions. A frequency-domain receiver that never decodes any protected content may still observe broad changes in burst power or duration, but it cannot claim knowledge of internal error syndromes unless those are obtained from its own authorised laboratory sequences. The existence of a successful laboratory decoder is not evidence that an unknown field transmission used the same coding rule.

In the historical and contemporary literature, variable-length and convolutional coding methods may be compared using their mathematical structures, but an observation of apparent redundancy is not a unique signature for either. Framing markers, parity relationships, interleavers and synchronisation procedures can introduce periodicity after compression. Conversely channel noise can destroy a periodic feature even when it is genuinely present at the transmitter output. When the instrument has only an energy detector, one must not insinuate that it can resolve bit-level code structure. Measurement capability determines the scope of the claim; the sophistication of the theory does not increase the evidence available from an inadequate instrument.

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A strong synthetic experiment therefore crosses compressor family, error-control rate, interleaver depth and modulation map while preserving independent replicates at each condition. Use two physically separate transmitter chains and at least two receiver architectures; monitor system state, oscillator reference, power and timing continuously. Collect negative tests with no emitted signal, with a known constant reference tone, and with a code configuration intentionally outside the classifier's training population. Predeclare the primary statistic, trial boundaries, missing-data rules and error metric. If a classification depends upon one coding parameter, the report should say it detects an effect compatible with that parameter under controlled conditions, not that the parameter determines the sender.

There are important inferential boundaries around entropy. An error-control encoder can increase the length of a compressed description while leaving its source information content unchanged in the ideal lossless model; nevertheless the emitted waveform may have different spectral and timing properties. A receiver with poor sensitivity may convert noise into apparently random symbol decisions, increasing a simple empirical entropy estimate while destroying information about the transmitted symbols. If a detector omits low-amplitude portions, it can bias the retained record toward a different distribution. Thus higher estimated symbol entropy at the receiver can correspond to worse measurement quality. It is not evidence of a more secure or a more hostile transmitter.

A publication-quality analysis must present the alternatives that the experiment could not discriminate. It should state which RF observables were measured directly, which code properties were demonstrated only on

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authorised synthetic sequences, how errors and uncertain event boundaries were handled, and which mappings remain unknown. Source-to-claim citations should support the exact theorem or engineering mechanism being invoked rather than the mere existence of a famous author in the bibliography. The historical specialists in this constructed roundtable contribute principles; they are not witnesses to a present-day investigation. In the absence of independently traceable physical origin evidence, the correct conclusion is that a particular statistical appearance is compatible with multiple transforms and multiple senders. That conclusion can be technically valuable even when it is deliberately inconclusive.

Antony Hewish, Peer Question: Professor Elias, radio astronomy teaches the danger of attributing a striking observed pattern before the measurement chain and the observing schedule have been challenged. An intermittent signal can be distorted by receiver gain changes, channel filters and gaps in observation, and a coherent periodic feature can have an entirely mundane instrumental origin. What independent antenna or receiver substitutions would you prescribe before treating a change in waveform entropy or burst cadence as evidence of any transmitter-side coding decision? I am particularly interested in the difference between losing a weak part of a burst and actually observing a more random source. If the first condition selectively removes predictable low-amplitude intervals, the empirical statistics could look impressive for exactly the wrong reason. How should a negative search result then be worded? I would additionally ask whether the analysis should report results separately for weak and strong signals, because survivorship of high-amplitude bursts could lead to markedly different conclusions from continuous acquisition.

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Peter Elias, Response: Professor Hewish, first identify the observation chain that creates the statistic. Record the receiving antenna, polarisation, cable loss, preselection, gain, local oscillator, filter response, detection threshold and data retention rule. Challenge the putative feature using a known synthetic reference waveform injected at a documented reference plane. Repeat with a second receiver architecture and an independently monitored clock. If the feature changes with gain, filter or threshold while the source remains fixed, its attribution belongs at least partly to the measurement process. The test should be conducted over a range of signal-to-noise ratios, including cases where the receiver sometimes fails to trigger.

For missing low-amplitude intervals, preserve a coverage ledger rather than treating retained windows as the entire waveform. Suppose a burst contains a predictable low-power preamble and an irregular higher-power segment. A detector that begins recording only after the preamble will return a fragment with a different symbol distribution from the full burst. Its increased apparent entropy is a consequence of censored acquisition. An independent continuous laboratory witness can measure how often this happens under controlled conditions, but a field record without that witness cannot reconstruct the missing content as an observation. An analysis should report the selection boundary and the resulting uncertainty.

A terminated-input measurement can expose internally generated spurs and signal-like artefacts, subject to the expected termination noise and receiver state. Changing antenna position or polarisation can challenge a true external field hypothesis, although such changes also affect sensitivity

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and multipath. An independently clocked receiver offers a useful timebase check. However, disappearance under a new configuration does not prove the original signal was fictitious, because the measurement transfer function and detection probability have changed. Proper attribution requires predictions of how the competing mechanisms should respond to each intervention, not an unreasoned appeal to a second display.

The negative conclusion should be bounded to the tested sensitivity, settings, frequency-time coverage and event-definition rules. It might say that no qualifying signal compatible with the declared laboratory feature was detected in the monitored intervals under the stated apparatus configuration. It must not say that a particular compression algorithm, channel code or sender was absent from the entire environment unless the experiment actually supports that broader claim. The evidence hierarchy remains explicit: measured external behaviour, proposed compatibility with a transform, and physical sender identity are different propositions.

Dr. James M. Atkinson, Moderator, Closing Synthesis: The discussion has established that payload compression can erase useful source redundancy while introducing no unique evidence of sender identity. Universal compression performance, information-theoretic entropy, symbol-alphabet selection, channel coding, framing, receiver noise and incomplete acquisition all affect the observed statistics in different ways. A lawful forensic investigation may compare known synthetic chains under controlled changes, but must not infer encryption, private message content, malicious purpose or physical origin solely from high apparent entropy. The panel's reciprocal questions show why the most credible experiment

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deliberately changes software while holding hardware fixed and then changes hardware while holding software fixed. All conclusions require declared measurement reference planes, independent held-out tests, explicit uncertainties and alternative hypotheses. The historical conversations are fictional educational reconstruction, not authentic proceedings.

SOURCE REGISTER. Jacob Ziv and Abraham Lempel, “A Universal Algorithm for Sequential Data Compression,” IEEE Transactions on Information Theory 23(3) (1977), 337–343, DOI 10.1109/TIT.1977.1055714; Claude E. Shannon, “A Mathematical Theory of Communication,” Bell System Technical Journal 27 (1948), 379–423 and 623–656, DOI 10.1002/j.1538-7305.1948.tb01338.x and 10.1002/j.1538-7305.1948.tb00917.x; Ralph V. L. Hartley, “Transmission of Information,” Bell System Technical Journal 7(3) (1928), 535–563, DOI 10.1002/j.1538-7305.1928.tb01236.x. These source records establish historical primary works, not any statement in the fictional dialogue. Peter Elias contributions are treated as original educational extrapolation, pending specific source-to-claim review. Peter Elias, “Coding for Noisy Channels,” IRE Convention Record 3(4) (1955), 37–46, confirmed in the Massachusetts Institute of Technology 1955 institutional publication register and National Academy of Sciences bibliography; and “Universal Codeword Sets and Representations of the Integers,” IEEE Transactions on Information Theory 21(2) (1975), 194–203, DOI 10.1109/TIT.1975.1055349. Historical records establish those works, not the fictional participant speeches.

EDITORIAL QUALIFICATION. Numerical examples use expressly stipulated synthetic parameters; no protected communications content has been accessed and no field transmitter identified.

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QUESTION 083

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How should frequency-hopping bursts be surveyed when scanner dwell is incomplete?

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Dr. James M. Atkinson, Moderator: Mr. Hartley, kindly establish the observational problem. An intermittently tuned receiver sees only a changing subset of frequency and time. What exactly is measured, and what ought a cautious investigator refuse to infer from an incomplete spectral record? The token is yours.

Ralph Vinton Lyon Hartley, Principal Contributor: The first duty is to define the observation universe before counting anything within it. A frequency-hopping emission does not leave an equal mark on every tuneable receiver, and an empty spectral cell cannot be treated as proof that the transmitter avoided that channel. Consider a test system commanded to use K discrete centre frequencies, with K a positive integer. Let the transmitter select one frequency for each hop of duration H seconds; let the receiver visit one of those frequencies with a nominal dwell D seconds, a settling time S seconds and an additional blanked or record-ineligible duration B seconds. The useful receiver aperture on each visit is A = max(0,D-S-B). It is A, not D, which belongs in the simplest intersection calculation. If D is 12 milliseconds, the retuning and calibration interval is 3 milliseconds, and the recorder blanking

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interval is 1 millisecond, only eight milliseconds of each nominal visit can contribute actual defensible observations. A report using twelve milliseconds silently overstates its exposure by one half relative to the eight-millisecond effective interval. That error may propagate into every subsequent claim about how frequently a channel was occupied. The geometry is temporal as well as spectral. On a time-frequency sheet, the sender's hop is a horizontal strip with width H along the time coordinate and a location defined by frequency and occupied bandwidth. Each receiver aperture is another strip, possibly on another frequency, with width A. A detection requires a nonempty overlap of the two strips and a sufficient signal-to-noise ratio during that overlap. To obtain a complete feature estimate rather than a fragment, require overlap of at least a specified T_min seconds, not merely an instantaneous intersection. The receiver may also capture an adjacent channel when its intermediate-frequency response has finite skirts; that event must not be represented as an exact centre-frequency match without a resolution and selectivity assessment. The mathematical abstraction should preserve the physical receiver's actual passband rather than imposing an ideal frequency bin after the fact. Here is a first numerical case under deliberately restrictive assumptions. A known laboratory emitter chooses uniformly among forty nominally separated channels, each hop lasts ten milliseconds, and an independently scheduled receiver aperture lasts eight milliseconds. If the relative starts are uniform over a twenty-millisecond comparison period, the intervals overlap at all whenever the start offset lies in a measure of eighteen milliseconds, so an unrestricted temporal intersection would have probability 0.9. Yet the scanner listens to only one of forty channels, and the event of exact channel

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agreement has probability 1/40. Independence would then give 0.0225, or 2.25%, for one synthetic opportunity, before the added requirement of enough dwell for classification. The arithmetic is illustrative: its premises are not justified for an actual deterministic hop and scan schedule merely because the numbers are convenient. Nor may the temporal window be replaced by the hop period indiscriminately if a receiver visits last longer than the hop or crosses repeated hop boundaries. Under a different uniform-phase model, direct interval geometry must be recomputed. The distinction between scheduling knowledge and observation knowledge is decisive. If the sender cycles through a known list of forty frequencies while the scanner does the same in a fixed order, their relative phase may lock into an unproductive pattern. Ten thousand visits do not become ten thousand independent trials. In the extreme, the receiver can continue arriving only after each transmitter burst has ended, producing an impressive archive of absences from an actively transmitting laboratory source. The correct response is not to declare the transmitter absent but to change the scan order or introduce a deliberate phase offset, preserve the timebase and compare the resulting capture rates. An observation design must attempt to break aliasing, not congratulate itself on the volume of its own repeated mistakes. An interval-censored encounter should be recorded as an event whose frequency, start and end times are bounded by the instrument's limitations. An event beginning before the receiver opened its gate is left-censored; one persisting after the gate closed is right-censored. An event visible for four milliseconds might be an intrinsically four-millisecond emission or merely the middle of a much longer hop. Duration histograms derived from such fragments tend to acquire false short tails

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unless the censoring mechanism is represented. It follows that the observed distribution of interarrival times, hop durations and channel use cannot be made equal to the underlying source distribution without modelling the inclusion probability. If a recorder suppresses events beneath a threshold, censoring is additionally amplitude-dependent and may correlate with frequency-dependent cable loss. For a defensible field record, I would require a machine-readable log containing commanded tune frequency, actual lock or calibration readiness, effective aperture start and end timestamps, receiver passband, detection threshold, raw power statistic, trigger status, clock uncertainty and reason for each deliberate recording gap. Every retained burst should carry a field separating direct measurement from inferred full-hop duration. A monitoring period with no captures must still contain the same exposure log. The negative result then reads: no event satisfying the stated detector rule was observed within the documented frequency-time apertures. It does not read: no hopping transmitter was present, and it certainly does not identify a sender by the gaps in a record. The resulting discipline is almost elementary, but that is precisely why it matters. Frequency and time are two independent axes of opportunity, while signal strength, filter shape and recording eligibility add further conditions. A probability assigned without naming the sampling space is a number without an honest referent. In forensic scholarship, a smaller carefully bounded conclusion is worth much more than an elegant but imaginary complete view of an unseen hopping pattern.

Abraham Lempel, Peer Question: Mr. Hartley, your frequency-time strips clarify what the receiver was capable of seeing, but I worry about the way event files are compressed, deduplicated and summarised before the

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analyst receives them. A logger may retain only the strongest pulse per dwell, merge multiple peaks into one event or discard a burst as redundant because its spectral shape resembles an earlier burst. Some products report the total number of detections without recording the number of opportunities or the excluded events. Would you insist that the survey preserve all detector decisions, including rejected candidate events, rather than saving only final positive records? Please distinguish the loss produced by receiver exposure from the loss introduced by post-processing, propose a lawful seeded experiment that can measure both kinds of loss separately, and explain how a supposed hopping period might be manufactured by a recorder that groups events at regular reporting intervals. In particular, please state how a software change-log and a sample-level reference recording would reveal an event merger that reverses the observed sequence order, and what versioned metadata would permit an independent examiner to reproduce that transformation.

Ralph Vinton Lyon Hartley, Response: Mr. Lempel, the two losses must never be multiplied together as if they had a common cause. Exposure loss arises before a signal could be evaluated: the receiver was on a different channel, not locked, or otherwise outside an admissible detection interval. Processing loss occurs after the receiver has obtained a candidate measurement but before the investigator's retained event table is created. Let N_truth denote seeded transmitted bursts, N_exposed those whose frequency-time and passband intersection satisfies a declared physical criterion, N_triggered those for which the detector asserts a positive event, and N_retained those preserved after aggregation. The ratios N_exposed/N_truth, N_triggered/N_exposed and N_retained/N_triggered estimate different

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stages of a synthetic test, provided all denominators are nonzero and the test truth is independently logged. Their product is N_retained/N_truth, but the separate terms reveal which stage creates a discrepancy. It is important not to call this product a field detection probability unless the test conditions represent the intended field exposure distribution. A proper calibration must split the paths before lossy aggregation. One recording branch keeps raw complex samples or minimally processed detector statistics for a manageable bounded trial; a second branch performs the proposed event collapsing. Give the emitter an independently authenticated timestamp log and a deliberately varied set of frequencies, burst lengths and amplitude levels. The comparison should include overlapping emissions so that a deduplication rule has something difficult to decide, and it should include negative control intervals during which nothing is transmitted. If the displayed event rate follows the software's reporting tick rather than the seeded transmitter timing, change the reporting tick without modifying the emitter and look for a corresponding shift in the supposed period. Such a displacement is direct evidence of a measurement artefact, not evidence of a special radiating schedule. The case is still subtler if false triggers are merged into genuine ones. A retained record can represent one emission, many emissions, or a collision of an emission with a noise excursion; the mathematical denominator then requires matching rules, not simple file-row counts. Store the association uncertainty and event lineage, including every automated transformation and the versions of software responsible. I would not require unlimited raw storage in a practical survey, but a bounded audit sample, an immutable decision trace and versioned configuration can permit independent reproduction of the inclusion

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mechanism. When those controls are missing, the examiner ought to report an unquantified selection limitation rather than reconstruct lost opportunities by imagination. A false impression of meticulous precision is often more dangerous than an explicitly incomplete log.

David Slepian, Peer Question: Mr. Hartley, you have described an equal-probability channel model, but many real and synthetic frequency-agile sequences deliberately suppress channels, employ uneven channel weights or alter their available set after interference assessment. Their temporal behaviour may also be correlated with channel choice, especially when a source holds one frequency longer during a packet exchange. How should the observer construct an exposure model when the hop list is not known, and how would you separate an apparent channel preference from the very different explanation that the scanner visits some frequencies for longer, or has more gain on them? I should like a concrete example with measured exposure time per channel and a statement of what cannot be estimated from events alone. In particular, when might the observed proportion on a channel be an estimator with unavoidable selection bias rather than a legitimate measure of transmitter use? Would you distinguish a conditional channel capture rate from a source channel-use probability even when the analyst has selected a seemingly representative monitoring hour, and how would complete non-exposure of one channel appear in the final uncertainty statement?

Ralph Vinton Lyon Hartley, Response: Professor Slepian, the missing denominator is the central danger. Suppose there are five candidate frequency regions and an archive contains forty bursts in the first region, twenty in the second and ten in each of the remaining three. The raw

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proportions suggest that the first region is favoured. But if receiver exposure, after lock and recording exclusions, comprises forty seconds in the first region, ten in the second and five seconds in each of the others, the event rates are respectively 1, 2, 2, 2 and 2 captures per exposed second. That result no longer supports the first region as most active, though the rates themselves still mix the emitter's use, detection sensitivity and pulse duration. We have not inferred transmitter occupancy simply by dividing file counts by exposure, because some frequency regions may admit signals more readily and because a single long hop can contribute more apparent event opportunities than a short one. Construct an exposure matrix $E_{c,t}$, where c indexes frequency channel and t indexes discrete time cells. Mark each cell with effective receiver eligibility, gain, threshold, known interference, and a measurement-quality flag. Construct a detection matrix $Y_{c,t}$ from actual eligible observations, retaining missing entries as missing, not as zeros. When an external seeded source is available, estimate a conditional detection probability $d_{c,t}(a,h)$ for amplitude a and hop length h, then use it to describe how a hypothesised source would be sampled. A simple inverse-weighted estimator may be examined when eligibility probabilities are strictly positive and adequately known; it becomes unstable or impossible when a channel has zero or unknown inclusion probability. The mathematical limitation is structural, not a problem that a larger pile of detections can cure. A source which uses channel three only during times when the receiver visits channel one cannot be distinguished from a source which never uses channel three if all observations are confined to those times. The survey design can help by changing channel order, randomising start phases, deploying a second

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asynchronous sensor or capturing a calibrated wideband segment. These interventions are preferable to assuming independence after the data have been collected. If the hop sequence may adapt to interference, compare tests with and without controlled changes to the artificial interference field in a screened environment; a survey in the field cannot lawfully or credibly create interfering emissions merely to provoke an unknown transmitter. The proper conclusion is conditional on the exposure model and on the lawful measurement controls actually used. An unobserved channel remains unobserved, regardless of how tempting it is to paint the missing cell as empty.

Dr. James M. Atkinson, Moderator: Mr. Hartley, thank you. You have distinguished an opportunity to observe from the appearance of a retained event. Professor Nyquist, I pass the token to you to examine receiver timing, settling and the ways that successive samples can imitate a schedule.

Harry Nyquist, Second Principal Contributor: A scanner's dwell is not a block of perfect attention. It is a series of physical and computational operations whose readiness must be demonstrated. A tuning command changes a synthesiser's desired state; it does not instantly certify the local oscillator's frequency error, phase noise, amplitude settling, intermediate-frequency filter state, or the automatic gain loop's response. Accordingly, the time at which the control programme believes a dwell has started and the time at which measurements meet a specified validity tolerance can differ. Let T_cmd denote the commanded retune time, T_lock the observed time when the oscillator first enters a defined frequency tolerance, T_filter the time when a relevant filter's transient response has decayed into tolerance, and T_agc the time when gain has stabilised within its required amplitude limits.

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In a conservative test, the first valid measurement time is at least max(T_lock,T_filter,T_agc), and may be later if digital buffers, blanking or synchronisation have independent constraints. A manufacturer's nominal lock indicator cannot replace a measured passband and amplitude response at the actual acquisition reference plane. For clarity, distinguish electrical lock from metrological readiness. A synthesiser might attain a frequency error below ten parts per million in a few tens of microseconds yet retain transient sidebands which make a weak signal undetectable. An IF filter might be stable at its centre frequency but slow to recover from the high-amplitude response to a prior channel. Software may mark samples with their arrival timestamp even though they were acquired earlier and delayed by internal buffers. A scanner with a nominal dwell of five milliseconds and a settling budget of two milliseconds has a usable aperture no greater than three milliseconds, before further blanking. Yet a transmitter's hop may last one millisecond and may begin and end entirely within the excluded interval. The receiver's frequency list can appear exhaustive while its temporal coverage remains very poor. I would not claim a general sampling theorem that makes a hopping waveform reconstructible from undersampled scanner visits. The usual bandlimited continuous-signal sampling argument depends on assumptions radically different from observing a discrete and possibly unknown frequency-hopping state through gaps. What matters here is timebase aliasing and phase relationships. Suppose a synthetic emitter changes frequency every ten milliseconds and the scanner revisits a particular channel every forty milliseconds. A stable relative phase can cause every return to observe the same fraction of the emitter's cycle, making a sparse observation look

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periodic. If the scanner's revisit interval is instead forty-one milliseconds, the phase changes by one millisecond per revisit relative to the ten-millisecond hop grid; over ten returns it walks through the nominal hop interval, subject to clock error, changing source sequence and measurement gating. This controlled detuning of visit cadence is a diagnostic method, not a guarantee that every event will be seen. Time stamps require an uncertainty budget. If the source reference clock and receiver reference clock have fractional frequency errors epsilon_s and epsilon_r, their relative first-order drift over elapsed time T is approximately T times (epsilon_r minus epsilon_s), assuming small constant errors over the interval. If those errors are respectively plus two and minus three parts per million, the relative magnitude is five parts per million; over one hundred seconds the inferred phase can move by half a millisecond. This is not negligible when a proposed burst period is a few milliseconds. Clock discipline may reduce but not eliminate uncertainty arising from trigger thresholds, sample indexing, timestamp quantisation and processing latency. These components cannot always be combined as independent Gaussian standard deviations; bounded systematic errors must remain separately visible. A useful test reverses the apparent cause. First hold a seeded emitter's hopping schedule fixed and vary only the receiver revisit interval. Second hold the receiver fixed and vary the seeded emitter's start phase by known offsets. Third insert a deliberate and recorded receiver gain-settling perturbation while preserving the transmitted waveform. Record the time-frequency event table and the independent stimulus schedule. If an alleged hop period moves when only the scanner schedule changes, its observed structure is at least partly conditioned by the scanner. If detections disappear when gain

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settles slowly, a changing threshold is a more plausible explanation than a change in the source. If the feature survives these tests, its evidential force improves, but the source still has not been identified. The experiment should include a channel where no intentional source is present. A retuning transient may itself make a narrow spectral peak through oscillator leakage, IF ringing, synthesiser spurious emission or digital leakage. Because the same tuning commands repeat, the artefact will exhibit a repeatable cadence. It can resemble a burst from an external device, particularly when the instrument records only selected peaks. Conducting the test with a properly terminated receiver input, with a shielded reference source and with a second receiver architecture is a useful discriminant. However, a termination test may change the impedance and common-mode coupling of the instrument; document the altered physical state rather than claiming that all environmental RF paths have disappeared. I therefore insist that the survey log not merely announce the frequency and dwell duration. It must establish the time relationship between the command, actual settled measurement aperture, recorded sample and external reference. A receiver is a clocked physical apparatus, not an omniscient observer. Where its own timing controls are not independently characterised, the strongest statement is that a particular pattern occurred in the receiver's retained observations under a particular schedule. The claim that a transmitter obeyed that same schedule remains a hypothesis awaiting tests capable of separating the two.

John Robinson Pierce, Peer Question: Professor Nyquist, your definition of metrological readiness properly includes synthesiser lock, but a receiver with several local oscillators, a scanning preselector and an automatic

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calibration path may exhibit multiple recovery intervals, not all visible through the lock indicator. It may also apply a frequency-dependent gain correction while the source is already transmitting. Could a controlled response test reveal that a reported hopping burst is actually an instrument-generated transient, particularly when the transient appears at different absolute frequencies as the receiver retunes? Please explain how to distinguish fixed intermediate-frequency products from a real signal traversing different front-end paths, and how to document the ambiguity when one branch of the receiver cannot be disabled. I also ask whether a real-time wideband capture truly eliminates this problem or simply substitutes another set of sampling, buffering and dynamic-range limits. For example, what outcomes should one expect if the same seeded burst is placed just before lock, just after lock and midway through the stable dwell, while the signal strength and absolute carrier frequency remain unchanged?

Harry Nyquist, Response: Mr. Pierce, a single lock flag is plainly insufficient. Begin with a matrix of physical states: commanded frequency, preselector range, attenuation, preamplifier path, oscillator selection, gain-control mode, calibration status and sample-buffer index. Drive the receiver with a lawful screened reference source whose frequency and amplitude are independently monitored, and take a second dataset with the RF input terminated through a documented impedance. For each tuning transition record not only the time at which a peak appears but its displacement in absolute RF frequency, indicated IF frequency and digital frequency-bin position. An internally produced IF spur may remain at a nearly constant baseband offset when the RF tuned frequency changes, whereas a fixed external carrier moves through the receiver's displayed relative offset. The

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inference is conditional: image responses, aliasing and mixing products can defeat simplistic versions of that rule, so multiple LO settings and independently measured bandpass responses are necessary. If a peak is produced with no applied reference source and tracks a command transition, treat that as an instrument-origin candidate. If the peak remains after replacing the whole receiver with a second instrument of independent design, the external hypothesis becomes more plausible but is not automatically proved. Shared power, grounding, computer interfaces and nearby radiators can couple into both instruments. A disciplined series changes one reference-plane variable at a time, records the outcome and retains uncertainties. The test should establish the detection threshold before looking at the result, not adjust it afterwards to make a suspected pattern appear. A wideband recorder avoids sequential tuning gaps only within the band it continuously and correctly captures. It still has finite instantaneous bandwidth, ADC quantisation, overload behaviour, anti-alias filtering, dropped buffers, timebase error, dynamic-range competition and software-trigger policies. An extremely strong in-band signal can mask a weak hop even though all samples are nominally present. Short-time Fourier transforms are themselves observation windows: a rapid transition can straddle adjacent windows and create apparent simultaneous occupancy. A fair comparison therefore uses the same seeded source and reports an inclusion region in frequency, time and amplitude for each architecture. No instrument earns a presumption of complete coverage simply because its label contains the words real time. Its measured readiness and its documented data gaps decide what it can establish.

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Alan Mathison Turing, Peer Question: Professor Nyquist, a fixed scanner schedule and a fixed hopping schedule can generate deterministic aliasing, but investigators sometimes attempt to estimate the unseen hopping sequence by searching many period candidates and choosing the most regular apparent reconstruction. That procedure may find an impressive pattern even in a sparse random event list. How would you design a falsifiable test which prevents the analyst from using the same data both to select the period and to assert that the selected period is significant? Please address exploratory versus confirmatory samples, clock offsets, the number of periods examined and a null model that includes the known scanner timetable. I should also like to know how much an apparently excellent fit means when the receiver was insensitive for ninety per cent of the interval, and why one should not call an inferred schedule an authenticated transmission schedule. Would a blind third set of observations obtained with a deliberately changed dwell order offer a stronger refutation test than another random split of the same continuous event log, and why?

Harry Nyquist, Response: Mr. Turing, divide the evidence by function before performing the search. Let one independently delimited acquisition segment be exploratory, with its permitted period interval, phase grid, event inclusion rule and test statistic recorded. Lock those choices, including how many models were considered, before analysing a later segment whose scanner schedule is deliberately changed. Use a null model that generates candidate events under the measured scanner exposure and false-trigger process, not an unrealistic model of uniformly available time-frequency space. If there are M period candidates with roughly independent false-positive probability alpha each, the chance of at least one spurious positive

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under that simplified assumption is 1-(1-alpha)^M. With alpha equal to 0.01 and M equal to 100, that number is about 0.634. Correlation between candidates changes the calculation, but it does not justify ignoring multiplicity. An observed best fit selected from a large search cannot be tested as though it had been the only proposed model. The proposed confirmatory segment should contain interventions. Change the scanner's visit phase, scan-order random seed and revisit cadence while holding the laboratory emitter fixed. Then change the emitter seed while holding the scanner configuration fixed. If a period estimate persists across materially different observation schedules and follows known changes in the emitter, that strengthens a source-side explanation. If it follows the scanner, the inference fails. These are different experiments, and their results should remain distinguishable in the report. A blind evaluation, in which the person scoring the receiver does not know which synthetic sequence was used for each run, guards against improvised thresholds and unconscious selection of favourable passages. When ninety per cent of candidate intervals are not exposed, even an apparently exact sequence may have many unobserved alternatives. The inference should report that multiplicity explicitly. One can construct distinct hidden hop histories which all agree on the retained events but differ arbitrarily in the unseen gaps. If the observation operator maps these histories to the same retained record, no algorithm acting solely on that record can identify which is correct. That is a question of identifiability, not merely of how clever a search programme becomes. Only additional observations, such as an asynchronous sensor or a lawful reference schedule, can separate those alternatives. Until then I would call

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the pattern a schedule-compatible hypothesis, not an authenticated transmission history.

Ralph Vinton Lyon Hartley, Cross-Peer Question to Harry Nyquist: Professor Nyquist, I accept your timing analysis but wish to challenge the reporting practice it may encourage. Suppose a survey programme logs eight milliseconds of useable aperture on one channel per forty-millisecond revisit, and an independent clock trace establishes that the transmitter changed frequencies every ten milliseconds. The programme may regard the eight-millisecond aperture as eighty per cent of a hop, even though channel agreement remains unknown. Moreover, if the four scanner visits per 160 milliseconds are phase-locked to the source, the detection events are dependent. Would you require two distinct exposure denominators, one for time and another for the actual channel opportunities, before any empirical capture rate is discussed? Please show how your clock uncertainty and lock-time measurements should enter the denominator without manufacturing fractional observations in time-frequency cells that were never sampled. Finally, can an analyst derive a nontrivial upper bound on undetected activity from this design alone, or must the report state that the unseen transmissions are unconstrained by the record?

Harry Nyquist, Cross-Peer Answer to Ralph Vinton Lyon Hartley: Mr. Hartley, two denominators are useful, although a joint eligibility indicator is ultimately more faithful than multiplying unrelated rates. Let X_c(t) be one when the receiver is demonstrably valid on channel c at time t and zero otherwise; let Z_c(t) indicate that the synthetic emitter is active on that channel. The physically observable overlap duration is the integral over time of X_c(t)Z_c(t), summed across relevant channels, with an additional event-

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specific minimum-duration and sensitivity rule. X is measurable from receiver telemetry when the measurement chain is adequately instrumented. Z is known in a seeded reference experiment but precisely the unknown quantity in an uncooperative field survey. The investigator may report the integral of X alone, which describes where the receiver was capable of observing; the overlap with Z cannot be calculated in the field without additional assumptions. Multiplying temporal coverage by an imagined uniform channel probability hides that distinction. For timing uncertainty, give each aperture start and end a bounded or probabilistic interval. In a conservative exposure calculation, exclude edge portions for which validity cannot be guaranteed. With an eight-millisecond nominal effective aperture and start uncertainty of 0.2 millisecond plus end uncertainty of 0.2 millisecond, the guaranteed common interior may be only 7.6 milliseconds, if these are bounded outward uncertainties and the original figure was not already conservative. That does not create an extra 0.4 millisecond of evidence; it reduces a claimed ability to observe. For a statistical calculation one may instead propagate a justified timing-error distribution, but do not combine that with the conservative result as though both were simultaneous independent allowances. A nontrivial bound on missed events requires a finite possible event population or a model restricting source duty cycle, amplitudes or allowed channels. If an emitter may transmit arbitrarily many brief hops only during the receiver's gaps, the observed data impose no finite upper bound on that unseen count. With a known laboratory emitter and a stipulated random independent phase model, one can calculate a probability interval for the number of misses. Such an interval is a conditional model result, not an unconditional forensic

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fact. My conclusion agrees with yours: the evidence certifies eligible observation intervals and actual detections, while its silences must be left silent unless independent information restricts what might have occurred there.

Dr. James M. Atkinson, Moderator: Professor Nyquist, thank you for separating oscillator lock from metrologically admissible measurements. Professor Shannon, kindly take the token and address inference from incomplete and non-random observations, including what repeated negative visits may establish.

Claude Elwood Shannon, Third Principal Contributor: The central inferential question is not whether a hopping transmission can be imagined, but whether the distribution of retained observations distinguishes one hypothesis from another after conditioning on the receiver's selection mechanism. Let H_0 denote the hypothesis that events arise from a specified background and instrument process, and H_1 denote the hypothesis that a synthetic frequency-hopping source contributes to them. An analyst may calculate a likelihood ratio $L = P(Y|H_1,E) / P(Y|H_0,E)$, where Y is the retained event table and E describes the frequency-time eligibility of the scanner, its detection threshold and its stated error process. This notation is only meaningful if both conditional models are specified. A raw ratio constructed without E is liable to favour a source hypothesis solely because the scanner's schedule has produced a striking pattern of selective observation. It is particularly dangerous to treat the absence of observations in unvisited channels as an absence expected under H_0 but not under H_1. The difference between missing at random and missing in a structured way matters. If the scanner visits channel one more frequently when its control

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programme predicts a particular periodic event, the inclusion probability may depend on the very hypothesis under test. If the receiver's gain is lowered after an overload, later weak bursts may be missed preferentially after strong ones, creating apparent inhibition or alternation in the sequence. If the source adapts to interference and the scanner's own configuration changes the interference environment, an apparent relation between observation time and source activity may be causal in either direction. These mechanisms cannot be exchanged for the convenient assumption of independent Bernoulli detections without evidence. They require a model of how Y came to be retained. For an intentionally simplified laboratory example, suppose a known source sends N = 1000 independently timed candidate bursts, each having a known encounter-and-detection probability p = 0.02 under a randomised receiver schedule. The expected number of detections is Np = 20, with variance Np(1-p) = 19.6 and standard deviation approximately 4.427. A normal approximation would therefore suggest fluctuations of several detections even when the source and receiver remain perfectly stationary. But it would be wrong to take this binomial calculation into a deterministic scanner-source phase-lock scenario, where a single random phase may determine outcomes for many repeated cycles. A sequence of related failures does not create the thousand independent pieces of information assumed by the variance formula. An effective-sample calculation or an explicit schedule simulation is then required. One should distinguish probability of at least one detection from probability of reconstructing a hop list. Under N independent opportunities with common detection probability p, the former is 1-(1-p)^N. At p = 0.02 and N = 100, this is approximately 0.8674. Yet a high chance of seeing at

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least one burst provides very little evidence about the unseen ninety-nine opportunities, and may be nearly useless for estimating the number of channels or the periodicity of a hidden sequence. A receiver can be likely to detect something while remaining incapable of determining the source's full operation. If p varies by opportunity, the probability of at least one is 1 minus the product of (1-p_i) over the indexed opportunities, assuming conditional independence; without that independence, the product is not justified. There is also a distinction between entropy of the observed channel labels and entropy of the true hopping sequence. Suppose the source uses ten channels uniformly but the receiver spends half its eligible time on one channel, with equally effective sensitivity elsewhere. The retained label distribution will be biased towards the frequently visited channel even if the transmitter is perfectly uniform. Computing Shannon entropy on that selected list measures a feature of the combined source and observation operator. It neither authenticates the source nor quantifies the intrinsic unpredictability of a hidden hopping algorithm. The correction would require exposure information and a validated model of detection probabilities on each channel. If a channel has zero probability of being observed, its contribution is not statistically recoverable without external restrictions. To evaluate a claimed schedule, construct independent blinded trials with seeded hopping sequences. Some trials should use genuinely random channel order; others deterministic cycles; others intentionally phase-locked and intentionally phase-shifted scanners. The analysis protocol should specify before release of the seeds how hypotheses will be compared and what statistic counts as a success. False-positive rates should be assessed by repeating the entire period-search procedure on null trials, not

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by calculating a nominal single-period significance threshold after the best period is already selected. Report not only successful detections but the full confusion matrix of schedule hypotheses, including missed source events, instrument transients misclassified as hops and indeterminate results. This is a lawful defensive measurement problem, not a licence to reconstruct message content, access protected communications or identify an individual sender from an RF pattern. The experimental source should transmit arbitrary known test sequences in a screened or otherwise authorised setting. The interesting inference concerns properties of the measurement and its failure modes. A conditional statement, such as 'the observations favour a time-varying signal under these exposure and noise assumptions', can be scientifically valuable while remaining intentionally silent about the unknown emitter's identity, purpose and payload. My closing warning is mathematical rather than rhetorical. Every claim about what a sparse scan proves must carry its sampling condition with it. Information lost through an observation operator cannot be restored merely by applying a clever estimator to the operator's output. A carefully stated distribution over possible unobserved histories is sometimes possible; a unique historical record of those hidden events is not, unless independent constraints make the inverse problem identifiable.

John von Neumann, Peer Question: Professor Shannon, your proposal of a likelihood ratio conditional on the sampling schedule is attractive, but a practical investigator seldom knows either the noise model or the dependence structure of events. A nearby unintentional emitter may produce bursts with clustered arrival times, while a scanner's own retuning artefacts produce regular peaks. Both could create a large ratio in favour of

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some poorly chosen frequency-hopping model. How should one prevent the analyst from fitting the model so flexibly that it explains every observation, and how should the model treat the entire timetable of blank periods? I ask you to propose an operational null experiment using a terminated input, a laboratory dummy source and deliberately varied scanner schedules. Please include a way of evaluating the uncertainty introduced by estimating model parameters from the same sparse dataset subsequently used for inference. Please also address what happens when a model can explain a false peak by inventing one extra hidden hop: how may one quantify the cost of that flexibility without silently suppressing alternative instrument explanations?

Claude Elwood Shannon, Response: Professor von Neumann, the danger of a flexible model is precisely why model complexity and prospective testing must enter the design. Begin with a null collection recorded using the same receiver states, scan timetable, gain settings and processing pipeline but with the authorised test source disabled. Include deliberately varied nearby benign stimuli where lawful and practical, because a terminated input alone will not reproduce all field interference or every common-mode coupling path. Use these observations to characterise frequency-dependent false-trigger rates and correlations with retuning. Next construct a separate source-present library with known synthetic burst times and channels. Hold out whole acquisition sessions, rather than randomly splitting adjacent events, since neighbouring events share a clock, a scan phase and potentially an AGC state. The evaluation should compare models on sessions whose emitter seeds and receiver start phases were not used to tune the inference procedure. A likelihood ratio must be scored against a specified candidate set. If the alternative contains all schedules whatsoever, it can

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generally fit the retained sample too well. Specify a finite family of physically plausible synthetic schedules, use penalties or predictive scoring selected before testing, and report the number and type of alternatives searched. It is useful to include an 'unmodelled or indeterminate' outcome rather than force every record into one of two attractive labels. Calibration curves should show whether observations assigned a probability of 0.8 truly exhibit the event in approximately eight of ten comparable blinded trials, not merely whether the classifier chooses the correct label on a favourable subset. For parameter uncertainty, use a nested procedure. Fit nuisance quantities such as per-channel false-trigger rates and exposure-related detection probabilities on the training data, then evaluate on independent held-out trials. Within training, a bootstrap may resample complete acquisition sessions or seeded cycles rather than individual detections, preserving much of the dependence structure. Sensitivity analysis should repeat the inference over plausible ranges of clock error, unmeasured dead time and gain recovery. If conclusions reverse under modest changes to these parameters, the report must not conceal that fragility. The blank periods enter the model as explicit unobserved intervals, never as events with zero source power. A terminated input result can discredit a proposed external cause of a particular peak if the same peak remains under an adequately controlled termination test, but its absence under termination alone is not proof of an external radiating source in the original field arrangement.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Professor Shannon, let us examine a concrete problem with confounding between sampling and signal schedule. In one seeded trial the transmitter changes

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channel every ten milliseconds, while a scanner cycles every forty milliseconds; in a second trial the scanner cycle is altered to forty-one milliseconds without changing the emitter. The second produces a much richer set of observed channel labels and more apparent periodic structure, although the transmitter is identical. Can your likelihood method avoid declaring the second trial a stronger source solely because its design provides more opportunity? I ask how you would normalise or condition on frequency-time exposure, what should be done when the detector probability is unknown at some channels, and whether two conflicting data sets can both support the same underlying source hypothesis without forcing their observed event histograms to agree. Please specify a falsification criterion rather than relying on a flexible post hoc explanation. Should the confirmation criterion therefore be stated in terms of prediction under a new scan-phase distribution, rather than a desirable minimum number of logged bursts alone?

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Professor Nyquist, the legitimate comparison conditions on each trial's exposure operator. Label the two records Y_40 and Y_41 and their recorded eligibility schedules E_40 and E_41. Fit a common hypothesised synthetic source process S, but calculate separate observation likelihoods P(Y_40|S,E_40) and P(Y_41|S,E_41), including known detector properties. More detections in the forty-one-millisecond trial need not favour the existence of S over a comparable null if the exposure schedule itself predicts more detections. A useful normalised discrepancy is the observed count minus its model-conditional expected count, accompanied by a variance or predictive interval that reflects cycle dependence. It would be misleading to compare raw

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counts without conditioning on those unequal expected opportunities. When detector probability is unknown on some channels, do not replace it with the average from measured channels merely for convenience. Report a range of predicted outcomes under a justified sensitivity envelope, or designate the likelihood contribution of those channels unidentified. If an alternative model predicts zero expected probability for an event that is clearly present in a demonstrably valid aperture, it may be falsified, subject to false-positive controls. More generally, predefine a predictive scoring rule and a rejection threshold using independently simulated or seeded null trials. A source hypothesis that consistently predicts detections in eligible apertures where none appear, despite independently measured high detection probability, may be rejected. Conversely, it cannot be rejected simply because unvisited channels did not yield records. The two observations can support the same source because their measurement operators are different. This is the most important result: a physical source has one latent state history but each instrument projects that history through a different function. The observed histograms are not required to match. What is required is that a common S, combined with each documented E and independently measured measurement errors, predicts the relevant features of each record without continually inventing new unobserved corrections. An explicit third blinded trial with a new scanner timing law provides a meaningful test. If the model fails that prospective trial, the investigator must revise or reject it rather than rescue it with a newly assumed hidden channel list. The scientific test is prediction under changed observation, not retrospective narrative coherence.

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Dr. James M. Atkinson, Moderator: Professor Shannon, your distinction between source history and the observation operator is accepted for the purposes of this hypothetical exercise. Professor Hamming, please take the token and address missed-hop populations, evidential error handling and the danger of interpreting an imperfect event log as a complete discrete sequence.

Richard Wesley Hamming, Fourth Principal Contributor: A sparse event sequence invites the analyst to tidy it into a complete one, and that tidying is often where the most consequential error occurs. In coding theory we may speak of an alphabet and a sequence of symbols, but the receiver's event list is not necessarily a faithful list of transmitted channel symbols. Some hops were never in the receiver's passband. Some were inside the passband yet fell below the threshold. Others produced detector events which were mislabelled by finite filter selectivity or missed because the receiver was not ready. Still others may have been merged by software into adjacent events. These are different error mechanisms: deletion, substitution, insertion and timing displacement. A sequence-analysis programme that handles them as one homogeneous random noise term forfeits the very distinctions needed for forensic reliability. Let the true synthetic hop sequence have length N and let the retained event sequence have length M. Unless the test source provides ground truth, N may be unknown and an event cannot safely be assigned to a unique transmitted hop. A useful alignment may therefore contain unobserved positions rather than fabricated channel labels. Let d_i be the probability that true hop i is deleted by the observation process under a stated model, s_i the conditional probability that its channel label is wrong when retained, and f_i a false event insertion parameter over a

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defined eligibility interval. These quantities are not universally constant. Detection deletion can depend on channel, amplitude, burst length, antenna polarisation and scanner state. Receiver transients may make false insertions more likely immediately after a retune, and adjacent-channel leakage can make substitutions systematically biased rather than symmetric. Consider a twenty-hop seeded laboratory source. Suppose only six source hops encounter eligible receiver apertures; of these, four yield valid detector events; one event is assigned the neighbouring channel by an incorrectly characterised filter and the logger adds one false transient peak. The final file contains five event rows, not twenty. Counting the five rows cannot recover the source's sixteen unreported hop positions, and the one false row is not simply another source hop. A ground-truth comparison should therefore produce a provenance table showing twenty transmitted positions, six eligible intersections, four triggered source bursts (three correctly channel-labelled and one mislabelled), and one additional false event, with clear matching rules and uncertainty. The exact numbers in this example are stipulated, not empirical claims. Their value is to expose how many distinct explanations are obscured by a neat-looking output table. Error correction is not an instrument of historical divination. A decoder corrects errors only because a known code constrains admissible transmitted sequences and because an error model supplies some basis for choosing among possibilities. If neither the hopping code nor the initial state nor the observation channel is established, a regular-looking completion may be one of many. The familiar minimum-distance argument cannot be invoked as proof that an unknown transmitter used a particular schedule. Nor should an analyst try to recover protected payload content

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under the pretence of validating channel hops. A defensible test can use a synthetic seed known to the test authority and compare the receiver's ability to reconstruct that public test sequence without ever accessing a private communication message. Time alignment itself should be challenged. If the scanner measures a burst after oscillator lock and software processing delay, that recorded timestamp may fall in the next nominal hop period. A sequence matcher may label it a channel substitution when it was in fact a correct channel event with a shifted time. Conversely, a false peak following each retuning command may appear as a perfectly consistent hopping schedule if the programme correlates event order rather than absolute time. Preserve independent hardware timestamps, reference clock histories and trigger delays where available. The scoring rule should allow an indeterminate association instead of forcing every event into a nearest-neighbour match. For each seeded experiment, report precision and recall as separate metrics. Precision is the number of correctly matched retained positives divided by all retained positives, after rules for ambiguous matches have been settled. Recall is the number of true source events correctly detected divided by the independently known true source events within the stated opportunity population. One can also report recall conditional on receiver exposure, which answers a different diagnostic question: how often did the system detect an event it could in principle observe? This conditional recall can be excellent while overall source capture remains dismal. Reporting only it would let a narrow but exquisitely sensitive scanner appear equivalent to a receiver that covers the entire relevant band continuously. Failure-mode testing should be adversarial in an editorial sense, not in a communications-intrusion sense. Seed bursts exactly at dwell boundaries,

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deliberately vary amplitude near the detector threshold, schedule a hop during the source's own transition, and use benign adjacent-channel reference signals to measure mislabelling. Record how error rates change with each controlled variable, and leave untested field conditions outside the claimed performance envelope. The purpose is to show the reader how the evidence breaks, not to pretend that every missing sample has a recoverable label. The final evidential object is therefore a partial sequence with typed missingness and typed uncertainty. Its legitimate product may be a family of schedule-compatible hypotheses and a quantified observation limitation. Such an account is not a failure to solve the problem. It is a correct statement of the information that survives the receiver's narrow and intermittent contact with the source.

Ronald Newbold Bracewell, Peer Question: Professor Hamming, suppose an investigator collects two imperfect event lists using two independent receiving antennas at different positions. Their geometries, polarisation responses, multipath and front-end overload behaviour differ. It is tempting to merge their detections into one supposedly complete hopping sequence and treat matching timestamps as confirmation. Yet shared clock errors or a common interfering signal may correlate both lists, while different propagation fades may cause genuine events to appear in only one. How would you establish an association rule and guard against double counting when an emission is detected at both stations? Could a second receiver also create a misleading impression of extra hop channels through its own images or local oscillators? Please describe a validation design that separates diversity gain from correlated instrumental failures, and how uncertain event associations should be recorded rather than retrospectively

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forced into a single answer. What separate reference measurements should document timestamp correlation through a shared clock distribution, and would those tests have to be repeated after changing antenna cables or front-end gain configurations?

Richard Wesley Hamming, Response: Professor Bracewell, a second receiving system provides new information only to the extent that its observation errors are separately characterised. First synchronise the clocks against an independent reference or document the transformation and uncertainty between them. Then set a predeclared association window which includes timestamp uncertainty, possible propagation delay differences, filter latency and known processing delays. The association should consider occupied frequency and bandwidth within calibrated tolerance, not just near-simultaneous event times. Give each candidate detection an immutable local identifier and preserve a many-to-many association table, because a source burst can generate more than one detector event and an ambiguous peak can match several possible source events. Do not simply concatenate the two event lists and call the result the number of transmitted hops. Use a screened reference emitter with a known hop schedule and move one antenna through documented orientations and positions. Introduce a controlled fading or attenuation condition in one receive path while leaving the other stable. Separately test each receiver with terminated RF input, fixed known tones and input levels near overload to identify its own image and intermodulation signatures. A signal which appears at a stable internal IF offset in only one receiver as its tuning changes is suspect, while a signal appearing in both through physically independent paths with consistent frequency, time and direction

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may strengthen the external-signal hypothesis. The conclusion still depends on excluding common pickup through shared cables, network timing systems or power supplies. For scoring, separate source-level recall from station-specific recall and from the fraction of source events detected by at least one station. A simple union probability p_A+p_B-p_Ap_B presumes conditional independence of station detections given the source event. Multipath fading or shared front-end interference may violate that assumption. Estimate joint detection outcomes on seeded trials or report bounds rather than assert the product formula for the field. Where association is uncertain, assign a status such as possible duplicate, possible independent event or unresolved. A report that preserves these distinctions remains auditable when a later calibration reveals a timing offset or a previously unknown image response. Confidence arises from measured error behaviour, not from making two instruments agree by editorial force.

Claude Elwood Shannon, Cross-Peer Question to Richard Wesley Hamming: Professor Hamming, your partial-sequence model invites a difficult inference question. In a controlled trial the true source sequence is known, so deletion, insertion and substitution may be estimated against it. But in the field we possess only the censored output of the receiver, and an unknown source might emit additional hops on frequencies never sampled. Can a scoring algorithm distinguish the possibility of a short hopping sequence with few misses from that of a much longer sequence with frequent misses? Please identify which parameters are jointly unidentifiable and explain whether a prior distribution can make the reconstruction uniquely true rather than merely conditionally probable. I also request an explicit account of how source-generated burst silence differs from receiver-

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imposed observation gaps, since these are often conflated by event-list programmes that write zeros where the instrument recorded nothing. Could you specify how an analyst should record incompatible hypothetical completions of a partial sequence without turning their relative model scores into an asserted history of actual emissions?

Richard Wesley Hamming, Cross-Peer Answer to Claude Elwood Shannon: Professor Shannon, the two histories can indeed be observationally equivalent. Suppose the output contains five correctly labelled events at five distinct times. One latent model has five actual source events and detects all of them; another has fifty source events and detects one in ten, with the other forty-five occurring in unobserved intervals or below the sensitivity threshold. Without independent restrictions on transmission rate, allowed channels, hop duration or receiver capture probability, both models may fit the same event list. A prior can rank the models if its assumptions are accepted, but it cannot convert conditional plausibility into an authenticated historical fact. The posterior distribution speaks of uncertainty under that prior and observation model. It is not a recovered record of events which no instrument saw. The missingness distinction can be represented with three states rather than one binary variable. Mark a cell 'observed occupied' when an eligible measurement satisfies the detector rule, 'observed not detected' when a valid eligible measurement does not satisfy it, and 'not observed' when the receiver was elsewhere or invalid. Even observed not detected does not imply the transmitter was silent; it means the measurement did not cross the selected threshold. If the source reference is independently known in a seeded trial, an additional ground-truth state distinguishes actual emitter silence from actual source activity. It must not be invented in

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a field record. An alignment algorithm should therefore retain an explicit null association for both absent source evidence and unexplained detector events, with the appropriate type. It may calculate a likelihood for proposed latent sequences if the receiver model has been calibrated, but it must display alternative sequences with comparable scores and disclose dependence on assumed channel weights or dwell times. An honest minimum-error reconstruction can be useful for testing instrument configurations against synthetic truth. It is not a warrant to fill unknown field intervals with fictional hops. I would require the report to give a lower bound on directly observed distinct events and to avoid an upper bound on true unobserved events unless source rate and duration constraints make such a bound defensible. The distinction between zero and missing is the foundation of the entire enterprise.

Dr. James M. Atkinson, Moderator: Professor Hamming, thank you for identifying insertions, deletions and uncertain associations without inventing missing observations. Mr. Armstrong, I now pass the token to you for a physical receiver-chain analysis and practical defensive survey protocol.

Edwin Howard Armstrong, Fifth Principal Contributor: The state of the receiver must be as thoroughly investigated as the state of the air. A scanning radio can be an excellent instrument for locating an unexpected carrier and still be an inadequate instrument for reconstructing a brief frequency-hopping schedule. The same front-end that provides selectivity also imposes a finite response to changes in frequency. Its preselector may switch a tuned circuit or filter bank; its mixer may encounter strong signals on adjacent channels; its amplifier may saturate and recover over a period not represented by the nominal dwell; and its intermediate-frequency chain

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may respond to a recent channel after the software reports that the receiver has moved to the next. A spectral peak is a result of the entire receiving chain, not a sealed envelope delivered by the transmitter. I would start with a physical block diagram for each survey configuration. Record antenna polarisation and orientation, cable and connector condition, limiter and attenuator settings, filter response, low-noise amplifier linearity, mixer conversion, oscillator spur spectrum, digital sampling rate, anti-alias filtering, detector bandwidth and display persistence. The operator should know where any preamplifier sits relative to a preselector, since a powerful out-of-band signal may overload a wideband preamplifier even when a downstream filter rejects it. If the instrument retunes across a region containing strong nearby services, the apparent dwell-to-dwell variation in weak-signal sensitivity may follow gain compression or recovery, not an agile source. The survey cannot honestly claim a uniform detection threshold across all channels without measuring the relevant reference-plane sensitivity in those states. Consider a synthetic source which emits a one-millisecond burst on each of sixteen known channels, with a twenty-millisecond nominal interval between starts. A receiver which visits each channel for five milliseconds but requires two milliseconds for lock and another one millisecond before its filter response and gain are within tolerance has at most two milliseconds of effective exposure per visit. Its per-channel revisit period is eighty milliseconds, excluding overhead beyond the stated five-millisecond allocation. If the emitter and scanner share an unfortunate relative phase, a given channel's burst can systematically fall outside those two-millisecond windows. Increasing the nominal dwell to six milliseconds increases the effective exposure to three milliseconds under

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unchanged transition conditions, but it also makes the complete sixteen-channel sweep ninety-six milliseconds. Whether capture probability improves depends on phase, channel distribution and source behaviour. More dwell is not unconditionally better, because an additional millisecond of attention to one frequency is an additional millisecond away from another. The operator should therefore compare surveillance architectures rather than revere one setting. A sequential narrowband scanner offers useful selectivity and dynamic range but poor simultaneous coverage. A parallel bank of several narrowband channels can remove some tune gaps at the cost of calibration complexity, cable splitting loss, interchannel mismatch and common reference coupling. A wideband receiver can observe many channels continuously within its instantaneous bandwidth, but front-end linearity and quantisation must be checked against the strongest signals present. A swept analyser can give a convincing broad picture while missing short events between sweep positions. A real-time spectrum display may improve temporal visibility yet still aggregate data through finite windows and be unable to show a below-threshold event. The engineering decision should be expressed as a trade-off between instantaneous frequency span, sensitivity, dynamic range, temporal completeness and auditable event retention. Controlled substitution is the most persuasive diagnostic. Inject a known synthetic hop sequence at a documented input reference plane and verify its power and timing with an independent measurement instrument. Repeat across channel frequencies and amplitudes, especially near the claimed detection threshold. Repeat with the source replaced by a termination, with the antenna relocated or reoriented and with an alternative preamplifier path. Where practical,

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substitute another receiver with a different oscillator or IF arrangement. Observe whether an alleged hop persists at the same absolute external frequency and time or follows an internal tuning operation. A genuine external signal may disappear with antenna orientation or propagation fade, so loss under one substitution does not automatically mean the earlier signal was false; interpretation requires an explicit hypothesis for what the intervention was intended to test. A useful uncertainty table includes amplitude calibration uncertainty, noise-floor variance, gain drift, trigger-level error, frequency error and timestamp error. These are different physical quantities and must not be combined casually into a single mysterious percentage. For example, if a known test burst is nominally 6 dB above the stated detection threshold and the receiver's measured amplitude uncertainty is 2 dB under the test conditions, it is not valid to call the event guaranteed simply because six is greater than two. The threshold decision also depends on noise fluctuations, filter integration and the signal's effective overlap duration. Specify whether the quoted 2 dB is a standard uncertainty, a worst-case bound or a manufacturer's tolerance. The probability of successful detection must be established from an appropriate ensemble of trials or from a defensible probabilistic model. Lawful defensive collection can be designed to avoid intrusive content acquisition. Use aggregate power statistics, frequency-time occupancy, instrument state and synthetic test sequences; if complex RF samples are needed for bounded calibration, control their storage and exclude protected communications decoding. A survey of premises should maintain a chain of custody for instrument configuration and output files, including firmware revisions, host clock settings, calibration certificates and the checksums of retained

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records. A temperature change during the survey may alter oscillator performance or cable attenuation, so environmental conditions and their temporal relationship to the observations belong in the technical record. Finally, the physical path may make events appear on channels where no transmitter hopped. Mixer images, reciprocal mixing from strong adjacent carriers, oscillator leakage and intermodulation can create peaks which follow receiver tuning and bear a false resemblance to a frequency-agile pattern. In a forensic setting this is no small technicality: a regular succession of receiver-generated peaks may look more purposeful than genuine traffic obscured by fading. The survey succeeds when it reveals the limits of its own sight as clearly as it reveals any emission. The scientific conclusion should state what was directly captured, what was verified under a reference stimulus, and what remains indeterminate because the receiver was not in a position to observe it.

Antony Hewish, Peer Question: Mr. Armstrong, a radio telescope and a premises survey receiver differ greatly in scale, yet both are vulnerable to internal signals that masquerade as celestial or external emissions. In a frequency-agile survey, a repeated local-oscillator spur, clock leakage or switching pulse may recur precisely when the scanner visits particular settings, while a genuine emitter can also produce intermittent events through fading and directional antenna response. How would you design a measurement programme that separates those explanations without relying on one attractive waterfall display? I am especially concerned about the interaction between antenna substitution, cable routing, shielding, input termination and common-mode currents. Please explain why a disappearing peak is not always sufficient to locate its cause, and how observations from

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multiple antennas or sites should be reconciled when their sensitivity and time exposure differ substantially. I would also ask how an investigator should handle a weak signal that survives an antenna substitution but changes its apparent duration because the two receiving chains possess different filters and trigger rules.

Edwin Howard Armstrong, Response: Professor Hewish, I would design a sequence of interventions with their predicted effects written down before observing the result. In the first configuration, retain the ordinary antenna and cable path and log the instrument's exact tune sequence, front-end states and detector traces. In the second, apply a matched termination at the receiver input, keeping power, computer connections and the local clock arrangement as similar as possible. In the third, substitute an independently calibrated source at the same reference plane and reproduce an authorised set of burst frequencies and amplitudes. In the fourth, alter antenna polarisation, location and cable routing one variable at a time, monitoring changes in common-mode cable currents where suitable measurement equipment is available. Finally, repeat the suspect frequency region with an independent receiver design and a documented reference timebase. Each step has a causal target and a limitation. A peak persisting with the input terminated may support an internal-origin hypothesis, but it can also reflect radiation entering the instrument elsewhere, including through its power or digital cables. A peak disappearing under termination could be due to an external emitter, antenna-coupled instrument leakage or the different loading of an imperfect input circuit. Similarly, relocating an antenna can change the response to a genuine external signal through multipath interference without relocating the source. The report should express which

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hypotheses were made less plausible by each intervention and which remained open. A directional inference from amplitude differences requires a characterised antenna pattern, polarisation information and propagation conditions, not merely a louder trace at one position. For multiple sites, preserve separate exposure maps and sensitivity calibrations before combining detections. A second site may see a burst that the first could not observe because it was tuned elsewhere, and the lack of agreement is not itself contradiction. If both record the same event, use bounded clock uncertainty and frequency agreement to establish a possible association, then record that association as one candidate source event rather than two definite independent transmissions. If the first site used a high-gain antenna and the second a short test lead, raw occupancy counts are not comparable. A joint report should show site-specific eligible time, detector settings, antenna factor and missed-signal behaviour under a common synthetic stimulus. Only after those are known can repeated observations strengthen a common-source hypothesis. The strongest evidence is generated by a procedure that can fail its favoured interpretation. If the alleged pattern follows receiver tune commands when the synthetic source is disabled, it is not evidence for a hopping external transmitter. If the pattern survives independent clock, receiver and antenna substitutions and corresponds to a controlled source's known events, it supports the competence of the survey method. In an unknown field case, even that competence does not prove the identity or intent of the radiating source. The appropriate endpoint is a bounded observation, a reproducible test record and an explicit account of remaining alternative causes.

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Richard Wesley Hamming, Cross-Peer Question to Edwin Howard Armstrong: Mr. Armstrong, your substitution tests should reveal instrument-generated events, but I wish to press a statistical objection. Suppose an operator changes from a scanning receiver to a wideband recorder and sees three times as many bursts. One might conclude that the scanner missed two thirds of the source activity. Yet the wideband recorder may be triggering multiple times on each emission, include noise peaks or respond to different bandwidth and threshold settings. Conversely, its analog-to-digital converter may be overloaded by a strong signal, hiding genuine weaker hops. How would you define common event truth and comparable detection rules before judging the two receiver architectures? I ask for an explicit reconciliation of detection count, event duration, frequency resolution and false-trigger rate, including what should be done when the source is unavailable for controlled repetition. Moreover, would you insist upon testing both receivers with common synthetic strong adjacent signals, so that apparent sensitivity improvement is not confused with overload or a changing event-splitting rule?

Edwin Howard Armstrong, Cross-Peer Answer to Richard Wesley Hamming: Professor Hamming, the raw ratio of three to one is not a missed-event fraction. First define a source event in the synthetic reference experiment as a transmitted burst with a specified start, end, nominal centre frequency, occupied bandwidth and permitted timing tolerance. Next create a common matching rule. A receiver event is a correct detection only if its frequency-time region overlaps a known source event by a prespecified criterion and its measured attributes satisfy documented error tolerances. Multiple triggers matched to one source burst count as one source detection and

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additional retained detector events; they should not inflate the event-level recall. Triggers that match no source burst count towards false detections, subject to the known independent source log and chosen association rules. The two instruments must then be tested against a common source across amplitudes, channel frequencies, burst durations and deliberately introduced strong interferers. Compare sensitivity at a common physical input reference plane, with receiver bandwidth and gain corrections recorded. If one detector integrates energy over a long window while the other uses a shorter threshold crossing, their observed event durations may differ even for the same source burst. Measure that difference rather than declare either instrument's duration the transmitted truth. Calibrate frequency discrimination with two nearby known tones and record the circumstances under which the wideband architecture merges them or the scanner misclassifies one through a filter skirt. Compute at least three separate rates: source-event recall, false retained events per eligible observation time, and duplicate triggers per correctly matched source event. Report those rates by frequency and amplitude. A wideband recorder may achieve higher recall in a sparse, brief-burst experiment while suffering a higher false-event rate at a more permissive threshold. It may also become less reliable under overload. The distinction is quantitative and experimentally testable; the adjective wideband settles none of it. Without an available source for repeatable calibration, one may compare coincident observations with care, but the real source's true event count remains unknown. Use a common artificial reference transmitter or signal injector as a calibration surrogate, clearly stating the conditions it represents. Preserve the raw observations and unmatched associations, and call the result a

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receiver-comparison study rather than a measurement of a particular unknown emitter's total missed hops. A test which cannot establish ground truth cannot compute absolute recall. It can identify relative differences under its own controlled conditions, which is a respectable conclusion if described without exaggeration.

Dr. James M. Atkinson, Moderator: Closing Synthesis: The panel has distinguished scanner dwell from valid measurement exposure, channel agreement from mere temporal overlap, and a retained event list from a transmitted hop history. It has shown why fixed scan phases can alias a synthetic schedule, why timebase and receiver settling errors can create apparent periods, why non-detection in an unvisited channel is not evidence of transmitter silence, and why multiple instruments should be compared against common seeded truth rather than their raw file-row counts. The appropriate defensive protocol is to log every eligible frequency-time aperture and instrument state, characterise receiver detection and false-trigger behaviour, run blind seeded reference tests with changed scanner phases, and retain uncertainty and alternative hypotheses in a reproducible evidence record. No participant has recovered protected message content or authenticated an unknown transmitter, and the historical dialogue is an original fictional reconstruction, not a record of actual speech.

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EDITORIAL QUALIFICATION. All numerical scenarios are invented reference experiments with declared assumptions. Source-to-claim verification of each technical proposition, independent mathematical review, historically precise contributor biographies, semantic redundancy assessment and full-volume production proof remain outstanding. No hidden transmitter was identified, no protected content was decoded, and structural validation alone cannot constitute publication acceptance.

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QUESTION 084

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When does cyclic-prefix correlation indicate multicarrier structure rather than periodic interference?

SCHOLARLY RECONSTRUCTION. This is a fictional posthumous scholarly dialogue for educational purposes. The deceased contributors did not meet to debate the named modern waveform, and no passage purports to reproduce their historical speech. Illustrations use authorised synthetic signals and calibrated test receivers; the discussion does not decode protected communications or establish transmitter identity.

Dr. James M. Atkinson, Moderator: Dr. Shannon, I should be grateful if you would begin with the exact observation rather than the alluring name of the waveform. Our hypothetical laboratory receiver has detected an elevated lag-correlation peak in complex baseband samples. Explain what repetition in time actually demonstrates, what a cyclic prefix predicts, and which alternative physical mechanisms remain compatible with the same numerical result. You have the token.

Claude Elwood Shannon, Principal Contributor: The word correlation names a relationship among observations, not a manufacturer, protocol or source of intent. When a receiver reports a large sample correlation at some lag, it has demonstrated that two portions of the collected sequence resemble one another under a particular definition of resemblance. The resemblance can arise through an intentional redundant interval, through a periodic interferer, through multipath, through a digital resampling mechanism, or through repeated structure manufactured within the measurement instrument. None of those causal claims follows from the magnitude of a single estimated correlation coefficient alone. The proper task begins by

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defining a contest among hypotheses rather than attaching the label of a favoured modulation immediately after seeing a peak. Let x[n] be a complex baseband sample at integer sample index n and let L be a positive sample lag. For an eligible window of length W samples, a lag product may be written R(L,n0)=sum from k=0 to W-1 of x[n0+k] times the complex conjugate of x[n0+k+L]. The associated normalised squared coherence may be defined as C(L,n0)=|R|^2 divided by the product of the two corresponding sample-energy sums. C is between zero and one when the denominator is positive. It does not possess an evidential interpretation without specifying n0, W, the candidate lags, the receiver's filtering and the noise model. A small denominator in a near-silent window demands special exclusion or a stabilised calculation, because normalisation does not create valid information from instrument noise or a numerical underflow. In a conventional cyclic-prefix multicarrier example, let N denote the useful discrete Fourier transform length and G denote the number of copied guard samples. A transmitter forms N useful samples and prefixes the last G of them to the front of a symbol, yielding a nominal total length of N+G samples. Within that construction, samples in the prefix correspond, before channel impairment, to a segment N indices later. A correlation statistic at lag N, calculated over approximately G eligible prefix positions, therefore has a structural reason to rise. The cyclic prefix is a design device for maintaining circular-convolution behaviour across a dispersive channel when its duration and other receiver conditions are adequate. The copied samples are not a cryptographic signature, and their appearance does not reveal the messages carried by the underlying symbol. To see the difficulty, consider a single sinusoidal test interferer x[n]=A exp(j omega n+j phi),

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where A is a nonzero complex amplitude, omega is angular phase advance per sample and phi is a starting phase. For every lag L, x[n+L] is a constant complex rotation of x[n]. The normalised magnitude coherence is consequently one, regardless of whether the waveform possesses a cyclic prefix. If an engineer searches many lags and retains only the largest result, a pure tone may look even more impressive than a noisy genuine multicarrier capture. The phase of the lag product is also not unique evidence, because a constant-frequency tone contributes a perfectly stable phase proportional to L. This is not a marginal exception. Narrowband ingress, oscillators and local clock leakage are common enough alternatives to demand direct challenge. The strongest discriminating evidence therefore concerns the pattern of correlation in time, frequency and lag jointly. A hypothesised prefix mechanism predicts high correlation for a restricted set of positions within successive nominal symbols, not uniform high coherence at nearly every position or lag. Its characteristic support should move coherently when the observation clock is offset from the symbol clock, and the pattern should repeat at a symbol interval compatible with the proposed pair N and G. A tone, by contrast, tends to remain coherent outside those prefix intervals, subject to fading and noise. A periodic switched interferer might yield isolated windows resembling prefixes, but its underlying spectral concentration, transition timing and tolerance of changed synthetic controls will differ. Such distinctions are probabilistic observations, not immutable class boundaries. For a deliberately synthetic test, take N=1024 useful samples and G=128 copied samples with a sample rate F_s=1,024,000 samples per second. The useful symbol lasts N/F_s=0.001 second; the prefix lasts G/F_s=0.000125 second;

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and the whole symbol lasts 0.001125 second before channel or receiver offsets. The subcarrier spacing of that hypothetical transform is F_s/N=1000 hertz. None of these figures establishes that a captured waveform uses those values. They simply define a candidate against which a reserved observation window can be tested. If the analyst first chooses N and G to fit the most agreeable fluctuation, the quoted false-alarm probability must account for the search across competing values. Information theory supplies an interpretive discipline. A statistic summarises chosen dimensions of a signal; it cannot be asked to bear an infinity of unmeasured distinctions. In particular, redundancy and predictability may be introduced by framing, coding, synchronisation, compression metadata, a source's own periodic rhythm or the receiving apparatus. A signal may show strong repetitive evidence while conveying no recovered message content to the investigator. Equally, a real prefix can be difficult to detect when fading, interference, receiver clipping or insufficient samples prevent reliable estimation. The lack of a peak is not a proof that multicarrier operation is absent. I would reserve the language of identification until several independent predictions have survived trials not used to select the model. One set of data may select candidate lags and window lengths; a second, separately collected or legitimately held-out set must test the expected periodic support, broadband energy distribution and behaviour under changed receiver states. The experiment should log how many cells and parameter combinations were examined, how many were deemed technically eligible, and how correlation was normalised. The scientific finding then becomes an auditable statement about compatibility with a hypothesised signal construction. It is not a message recovered, a sender

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authenticated or a device convicted. That narrow conclusion preserves the distinction between seeing patterned light on the instrument's display and hearing a physical explanation supported by the rest of the measurement chain.

David Slepian, Peer Question: Dr. Shannon, your coherence equation is attractive, but it appears to treat the sampled window as if its borders merely delimit a benign counting interval. In a field recording the front-end filter colours the noise, the acquisition gate may begin in the middle of a transient and the sample groups at neighbouring trial lags may overlap heavily. Those conditions mean that the statistic's distribution is not the simple independent-sample distribution printed in elementary treatments. Could you explain how an investigator should select window length and normalisation without making the selection itself part of a hidden search for an impressive result? I ask particularly whether the absence of a known preamble or symbol boundary should force a larger uncertainty statement, and how a short valid observation can produce a high coherence by chance when only a few degrees of freedom remain. Please identify which assumptions may be checked experimentally and which should remain explicit qualifications.

Claude Elwood Shannon, Response: Dr. Slepian, the finite window is an active part of the measurement and cannot be concealed behind a symbol. The ordinary normalised coefficient is dimensionless, but its sampling distribution depends on the number of independent pieces of information, not simply the number of stored samples. When the noise is coloured, neighbouring samples share energy and phase structure; when the windows overlap, the numerator and denominators inherit further

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dependence. A one-hundred-and-twenty-eight-sample window in a sharply filtered receiver may carry substantially fewer independent degrees of freedom than an ideal white-noise calculation assumes. Stating a theoretical false-alarm probability derived from white and independent complex Gaussian vectors would be unjustified without an appropriate noise calibration. I would distinguish three uses of data. In exploratory data, one may search lags, start positions and guard widths freely, provided the exercise is described as exploratory. In calibration data, one characterises the actual receiver under known no-signal and controlled interference conditions, while freezing the acquisition settings that matter to the operational statistic. In reserved evaluation data, one tests the prespecified statistic and decision rule without looking ahead to revise them. If only a short archive exists, methods that correct for the whole search may be used, but the narrower evidence should not be disguised as if it had arisen from an independent confirmation campaign. Whether one chooses a held-out interval or a new acquisition, time and environmental dependence must be considered when deciding whether the separation is genuine. A practical normalisation uses measured sample energies from exactly the two lagged vectors, an explicit rule for excluding zero-energy or saturated windows, and stable numerical accumulation. Compare the observed distribution of C with a null made from realistic terminated-input recordings, independent noise-source injections and lawful tone interference, all recorded through the same analogue filters and digital pipeline. Such a null may require resampling or simulation that preserves the relevant correlation, acquisition gaps and threshold adaptations. Randomly shuffling individual samples often destroys those properties and makes the apparent significance much

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too generous. A conservative block-resampling scheme can preserve longer dependence, but its block length is a further engineering decision whose sensitivity should be reported. The window length should reflect a proposed physical mechanism and an uncertainty interval, rather than the length that maximises a previously seen peak. If W is too small, the normalised value can be high through accidental vector alignment; if W is much larger than the repeated region, unrelated samples dilute the prefix feature. The strongest case examines a limited, predeclared family of plausible W and L values, then evaluates the whole family jointly. When a symbol boundary is unknown, a sliding test must disclose the count of start positions and their overlap rather than calling each position a separate independent experiment. It may be legitimate to estimate timing on one part of a record and validate on another. My recommendation is that the evidential summary present the raw correlation versus time and lag, the normalisation denominator, effective independent exposure, null-calibration conditions, and sensitivity of the result to reasonable perturbations. An analyst should be particularly suspicious when a claimed detection rests on one short, isolated and exceptionally bright window whose neighbours do not obey the predicted symbol rhythm. One attractive coefficient is an observation. A tested pattern supported by several independent controls is a significantly stronger inference.

Richard Wesley Hamming, Peer Question: Dr. Shannon, an apparently lawful and tidy detection report can still hide a severe data-association defect. Suppose the receiver writes each burst to disk with a timestamp supplied by a host process, while the complex samples themselves carry hardware counters. If the software stitches buffers with one absent block, the

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apparent lag N may connect samples that were not adjacent in the physical stream. Alternatively, a zero-filled gap can create a repeated margin, or an automatic normalisation routine can inflate a weak residual. What minimum acquisition-integrity checks would you require before treating a lag peak as a property of the source rather than an artefact of reconstruction? I should also like you to distinguish a checksum proving that the recorded file remains unchanged from a measurement proving that the sequence was captured correctly in the first place. This distinction is vital when a technical report is later used as evidence.

Claude Elwood Shannon, Response: Dr. Hamming, acquisition provenance is logically prior to signal interpretation. The analyst must know whether x[n] actually denotes uniformly timed consecutive complex samples at the asserted sample rate. A file can be perfectly intact and still embody skipped hardware counts, repeated DMA blocks, substituted zeros, reordered segments or resampling performed without adequate documentation. A cryptographic digest protects the sequence after the digest was created; it does not tell us whether the receiver captured the right analogue signal or whether the mapping between timestamps and sample indices was valid. The two forms of integrity should therefore be documented and tested separately. A suitable record carries hardware sample counters, clock source and lock state, buffer sequence numbers, sample rate and decimation configuration, any overrun or underrun flags, and a log of changes in gain, filters, tuning and frequency correction. A sample block should not be silently concatenated across a gap. Instead, the analysis masks invalid intervals and records their boundaries, because a lag comparison that crosses a gap is not evaluating the stated model. If a gap is filled for display

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continuity, the synthetic samples must remain marked and ineligible for evidence statistics. The code that applies those eligibility masks should be versioned and independently tested with deliberate gaps of known length. Begin with an authorised laboratory source engineered to provide a precisely known repeated sequence. Inject it at a defined receiver input, capture hardware counter and decoded sample records independently, and vary host computational load while keeping the analogue source unchanged. If the correlation peak changes when disk scheduling rather than the source changes, investigate the recording path. Repeat the test with a terminated or matched-load input and with the local oscillator operating, because a computer-controlled receiver may produce internally synchronous interference even without an external signal. An additional receiver with independent hardware and clocking provides helpful corroboration only when its failure modes are not shared. The evidence statement should identify every excluded sample range and the reason for exclusion. It must also preserve the original raw data and the reproducible analysis script, including the units in which lags and frequencies are expressed. If the analysis has been repaired after an error, preserve both the earlier and corrected version together with the rationale, rather than overwriting the provenance trail. This discipline cannot make an inaccurate capture accurate, but it can prevent the system from translating a known data-quality failure into a confident claim of multicarrier structure. The audible confidence of a polished report must not exceed the quality of the recorded evidence on which it rests.

Claude Elwood Shannon, Cross-Peer Question to David Slepian: Dr. Slepian, the hypothetical example fixes a useful transform interval of 1 millisecond

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and a copied prefix of one eighth of that duration. Yet a carefully chosen periodic interferer can create high correlation for an entirely different physical reason. Would you design a discriminating experiment in which the estimator is obliged to predict an interval of high correlation, not merely a lag at which correlation is high? Please show how window concentration, spectral colour, sample-clock perturbation and a held-out record can be combined without turning the design into an endless search whose favourable results alone are published. I am particularly concerned about false confidence when the null recordings are taken through a different receiver filter or gain state from the questioned capture, for then the calibration and the observed coefficient are scarcely comparable. Which observations would cause you to reject the prefix interpretation rather than simply modify the proposed guard length until it fits?

David Slepian, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, I would first freeze a finite menu of plausible useful-symbol lags, guard intervals and sliding-window positions, and record the number of tested combinations. For each candidate pair N and G, the test predicts that a time-localised correlation plateau or elevated segment recurs at intervals of N+G samples, after allowance for plausible clock drift. It is not enough to identify a bright pixel somewhere in the lag-time plane. A periodic tone creates high normalised correlation over many positions and many lags, and a narrowband spectral test can expose that competing explanation. The joint shape of the evidence matters more than the largest number in its table. The experiment should collect an authorised synthetic multicarrier source with its known N and G, a synthetic tone, a periodic switched waveform and terminated-input noise through the same receiving hardware. Repeat across

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declared filter settings and representative gain states, and calibrate each condition separately if their covariance structures differ materially. For a disputed field sample, evaluate the frozen statistic against a null derived from comparable instrument states rather than transporting a p-value from an ideal laboratory white-noise model. When the original noise environment is no longer reproducible, widen the interpretation and state the mismatch. A block-bootstrap or spectral simulation can be informative only if its dependence assumptions are exposed and checked against the actual receiver output. Reserve a second observation interval for a genuinely predictive test. The model fitted to the first interval should forecast both the lag and where the prefix-like correlation will recur, within a bounded timing tolerance. Measure the width and spacing of each candidate ridge, compare energy and spectral concentration, and test whether the pattern persists in a second receiver whose acquisition errors are different. A candidate that succeeds only after guard length, lag, start position and detector threshold are revised repeatedly upon viewing the reserved interval has failed the prospective exercise. Its observation may remain a useful exploratory clue, but not a confirmed waveform classification. Rejection criteria should include a tone-like coherence pattern extending through non-prefix windows, disappearance when a receiver's local oscillator reference is changed, collapse under a second independently calibrated capture of the same synthetic emitter, or a nominal prefix duration inconsistent with the repeat spacing. Conversely, a physically plausible prefix plateau supported by multiple reserved symbols and controls strengthens a multicarrier hypothesis without uniquely identifying its coding, standard or transmitter. A disciplined analyst must be prepared to let the attractive hypothesis fail.

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Dr. James M. Atkinson, Moderator: Dr. Shannon, thank you for distinguishing statistical repetition from physical attribution. Dr. Slepian, I pass you the token. Please examine finite records, the spectral concentration of interference and the way overlapping correlation windows alter the uncertainty of this experiment.

David Slepian, Second Principal Contributor: A finite observation does not merely shorten an otherwise infinite process. It changes the questions that the data can answer, because time limitation and frequency concentration interact. A narrowband oscillation observed for one short window can possess an apparently broad spectrum simply because the window interrupts it, while a genuine broadband waveform passed through a selective receiver can acquire correlations whose origin lies in the filter's impulse response. In both cases, the analyst sees the signal through a measurement operator. The operator includes antenna response, front-end gain, filters, sample clocks, quantisation, blanking and the mathematical window applied after acquisition. A correlation peak belongs initially to the output of that operator, not automatically to a source radiating beyond it. The common expression R(L)=sum x[n]conjugate(x[n+L]) hides the central importance of window choice. A rectangular window declares every included sample equally informative, then assigns zero weight immediately outside its boundary. The sharp discontinuity generates spectral leakage when Fourier analysis is applied and influences the effective correlation distribution even before explicit Fourier processing. A tapered window reduces certain sidelobes while broadening the main response and decreasing the concentration of information available for a copied-prefix test. Neither choice is universally superior. If the hypothesised repeated

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interval comprises G samples, the window should be selected to test that region while considering the channel transition and filter settling, rather than borrowed uncritically from a general-purpose spectrum display. The time-bandwidth product supplies a useful conceptual scale. If an observation lasts T seconds and its effectively occupied or measured bandwidth is B hertz, the nominal product BT describes the scale of independent degrees of freedom that can be supported under idealised conditions, up to factors depending on real versus complex representation and the exact concentration definition. It is not an automatic integer sample count. In practice the receiving filter, spectral colour and gaps can reduce the dimension of independent observations. An apparently stable correlation estimated from many heavily overlapping windows may have a small effective sample size. The statistical uncertainty must reflect this dependence; counting every new one-sample shift as an independent replication is an elementary but consequential error. Consider a lawful synthetic comparison. A multicarrier generator produces N=1024 useful samples and G=128 prefix samples at 1.024 million samples per second, while a second generator produces a continuous sinusoid of similar received power. The analyst computes a normalised correlation at lag N in W=128-sample sliding windows. The multicarrier source should produce a repeated elevated region at particular positions in each 1152-sample symbol, subject to channel conditions. The sinusoid may produce a value near unity throughout the recording, which defeats the simplistic 'largest peak wins' decision. Adding broadband noise can lower both coefficients but will not repair the logical inadequacy of the decision rule. A classifier must compare the temporal support and nuisance-dependent distributions of the statistics

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rather than their isolated maxima. A second counterexample is a narrowband periodic pulse source whose interval matches the expected symbol period. Its gating can generate spectral sidelobes and periodic amplitude patterns; after filtering, those may form short correlation ridges resembling a prefix schedule. A third is a dispersive echo of a pulse train, in which repeated delayed energy appears at fixed lags as a property of the propagation path. A fourth is a strong nearby carrier leaking into the sample clock or analogue-to-digital converter reference, which can couple instrument synchrony into the record. These alternatives can sometimes be distinguished by measuring spectral rank, comparing controls, changing lawful laboratory input conditions, and checking whether the inferred period persists in a receiver with independent timing architecture. Null simulation has to preserve the dependence that matters. Generating independent circular Gaussian noise and computing C offers a convenient theoretical baseline, but it is insufficient when the actual receiver noise is band-limited or coloured. If the null vector consists of two independent, isotropically distributed complex Gaussian vectors of length G, the expected squared normalised inner-product magnitude is 1/G. With G=128 this expectation is 0.0078125. That is a conditional mathematical illustration, not a universal false-alarm threshold. Filtering, overlapping windows, common interference, non-stationarity or different vector energies invalidate its direct use as the observed field null. The prudent analyst estimates the relevant distribution empirically under matched instrument conditions and accounts for the search over many candidate lags and positions. The same caution applies to independent confirmation. Two software detectors run on the same I/Q samples are not two independent receivers. Two antennas feeding the same

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downconverter may share local-oscillator defects, clock instabilities and gain-control dynamics. A second architecture may provide useful evidence, particularly if its signal path and timing system differ, but independence must be argued rather than celebrated. The strongest controls include terminated-input tests, calibrated injected waveforms, deliberate changes in receiver filter bandwidth, changes in sample-clock configuration where technically feasible, and paired observations during no-source and known-source trials. I would also insist upon a full map of eligible observation intervals, not merely those in which the detector found the desired feature. A high correlation can occur when signal power is so low that the denominator is unstable, or when a clipped amplifier imposes repeated digital values. Exclusion criteria for low energy, saturation, buffer gaps and transients must therefore be written before testing and applied symmetrically to successful and unsuccessful windows. If the criteria are adjusted after seeing the strongest peak, the final uncertainty statement is optimistic. In controlled experiments, preserve every rejected interval and its reason, for the rejection mechanism may itself be correlated with the class of signal under test. My conclusion is deliberately limited. A cyclic-prefix hypothesis proposes a patterned relation between lag, position, symbol spacing and spectral occupancy. Its evidential strength comes from satisfying those joint predictions under comparable measurement conditions, not from the decorative precision of an isolated coefficient. When the time-frequency concentration or coloured-noise structure makes a null model uncertain, the correct scientific response is to enlarge the interval of doubt. The quiet page of a properly qualified report is more

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informative than the bright waterfall of an instrument whose confidence has outrun its sampling model.

Dennis Gabor, Peer Question: Dr. Slepian, you describe the test in terms of windows and effective degrees of freedom, yet a field examiner often begins with a spectrogram rather than a carefully selected correlation plane. The spectrogram's apparent shape changes when the window length or taper is altered. Could you explain whether a supposed multicarrier feature should persist across more than one sensible time-frequency resolution, and what kind of change would signal that the feature was created by a window rather than by the received waveform? I should like the answer to consider a periodically keyed tone with spectral leakage, an actual cyclic prefix whose duration is short compared with the display window, and an automatic receiver filter whose impulse response continues ringing after the input has ceased. How can these be compared without allowing the analyst to change the display settings indefinitely until a preferred appearance emerges? I also ask whether the same peak survives a test in which window lengths are fixed before the reference signal is switched on, rather than tuned retrospectively.

David Slepian, Response: Mr. Gabor, changing the analysis window should be viewed as a controlled perturbation of the measurement rather than an artistic adjustment of the display. A true physical periodicity need not look identical at every resolution, but its predicted lag and symbol recurrence should transform in a mathematically interpretable fashion. The spectrogram alone is insufficient because it intentionally trades time resolution against frequency resolution. A long window may integrate over the brief copied interval and conceal its temporal boundaries, whereas a

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short window may show the beginning of a burst distinctly but spread narrowband energy across many displayed frequencies. The underlying digitised data remain unchanged, and the analysis must say exactly which function was applied to them. For the periodically keyed tone, apply at least two predeclared window lengths and compare both spectral concentration and the distribution of lag coherence across eligible time positions. If most energy remains in a narrow spectral ridge whose sidelobes vary predictably with the taper, that observation favours a tone or keyed-carrier explanation over a broadband multicarrier source. It does not prove the absence of every multicarrier component, since a mixed source is possible. A synthetic reference tone with matched amplitude and gating schedule should be measured through the same receiver. The comparison is far stronger than simply noticing a broad-looking cloud on the waterfall screen. For a true prefix example, compute the lag statistic directly on calibrated complex samples, retaining the absolute time indices, rather than inferring it from pixel intensities. Use an independently generated known multicarrier test source to measure how the receiver's filter smears the expected interval. Short windows may resolve the local correlation plateau; longer windows may reduce variance while diluting it. If the two measurements exhibit the predicted trade-off for the controlled source but not for the unknown, the discrepancy must be examined. Conversely, agreement across two resolutions lends support only if the test thresholds were set in advance and the windows were not chosen retrospectively. Filter ringing can be exposed by applying a single, authorised input pulse and measuring the instrument output after the pulse ends. That response defines a finite memory of the measurement chain, which may overlap subsequent detector windows. A

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lag peak tracking the filter's measured impulse response rather than the laboratory source's symbol schedule is an instrumental explanation. Repeat at different front-end filter bandwidths and with a terminated input, controlling gain and receiver state. Report how the feature moves or changes under those controlled interventions. Most importantly, freeze the primary test before inspecting the reserved data; treat all subsequent alternative windows as exploratory diagnostics rather than retroactive confirmation of the original claim.

David Slepian, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, a null model may have elegant analytical assumptions and still be defeated by the unglamorous machinery that makes the file. In an instrument with a long buffering path, a receiver can silently repeat a block after an overrun, splice together samples with different frequency corrections, or fill a missing block with constant zeros. Those interventions may manufacture correlation at a precise lag that happens to resemble the proposed useful-symbol length. Would you construct an acquisition-integrity test that can separate such digital repetition from a real cyclic prefix? Please specify what the raw record must retain, how a test should deliberately introduce known faults, how pairwise lag comparisons should be masked when an interval is missing, and which claims must be withheld if the hardware clock and host timestamps cannot be reconciled. I ask because a beautiful statistical fit is worthless if its sample indices are fictitious. Please include the possibility that a checksum verifies stored bits but cannot verify the receiver actually captured the intended analogue interval.

Richard Wesley Hamming, Cross-Peer Answer to David Slepian: Dr. Slepian, the instrument needs a ledger that binds every sample to an acquisition

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state and a monotonically advancing hardware count. The log should contain counter values, sample-rate configuration, clock lock, receiver tuning, gain, filter changes, buffer identifiers, overflow and underflow flags, and any correction made after capture. A host arrival timestamp is useful for file-management history but does not substitute for the sample clock. If two adjacent blocks contain repeated counter ranges, or the second begins with a jump inconsistent with its declared length, the data are not an unbroken time sequence. No amount of downstream signal processing can restore the absent physical observation. Create an authorised known-source capture, then deliberately impose controlled faults in separate trials. Introduce dropped blocks of known sample counts, repeated DMA buffers, incorrect decimation metadata, short zero-padding intervals and a timebase adjustment at a known boundary. Verify that the integrity checker flags each fault and that the detection code never treats an invalid cross-gap comparison as eligible. For a lag L, every pair x[n] and x[n+L] must fall in valid intervals with compatible acquisition states. When either endpoint crosses an excluded interval, the pair is removed from the statistic. The numerator and both energy denominators must use the same set of valid pairs, otherwise the normalisation ceases to represent a coherent vector comparison. Test a synthetic prefix source first with all faults disabled, then apply each fault while preserving the independent truth log. The resulting change in detector decisions measures susceptibility to acquisition artefacts rather than an unexplained property of the source. Run an additional no-source recording with the receiver tuned and gain active. If the test algorithm reports the anticipated prefix rhythm after a deliberate repeated buffer, the fault injection has exposed a concrete false-positive mechanism.

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Preserve that failed test in the evidence file; it is a finding about the instrument, not a shameful anomaly to remove from the published statistics. Where the hardware clock and host record disagree, the analyst should state that absolute event timing is uncertain by at least the unresolved discrepancy, and should not align the suspect feature to another instrument's event within a narrower tolerance. A relative lag confined entirely to an intact block may remain measurable, but cross-record correlation or claimed symbol synchrony can be unsupported. If acquisition provenance cannot be repaired or independently verified, the proper classification is 'instrumentally ambiguous'. A checksum may confirm subsequent file integrity, but it cannot confer original measurement validity. That distinction is fundamental to the evidential chain and protects the investigator from mistaking a repeated computer memory block for a radiated waveform.

Dr. James M. Atkinson, Moderator: Dr. Slepian, thank you. Dr. Hamming, take the token to examine data integrity, repeated patterns and the forensic requirements for an independently reproducible correlation result.

Richard Wesley Hamming, Third Principal Contributor: A remarkable numerical pattern is not a certificate of its own provenance. The investigator's first question must be whether the samples in the alleged pattern were actually measured at the times assigned to them. In digital systems, an error can be repeated perfectly and can even survive every subsequent checksum. When a buffer is duplicated, two regions of a file become identical; when an interpolation algorithm fills a gap with a stored waveform, it may create a periodic relation that never existed at the antenna. These are not hypothetical inconveniences introduced to diminish

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good statistical work. They are examples of why an inference about a physical emission must be supported by an auditable acquisition chain. The statement that x[n] and x[n+N] are copies in a hypothesised cyclic-prefix region depends upon a trusted sample-index mapping. If n is merely the row number assigned after the recording software has reconstructed a sequence, the lag N may measure a difference in file address rather than a physical time interval. A hardware sample counter that increments monotonically at the actual converter rate is preferable to an operating-system timestamp assigned after buffering. Yet even a hardware counter requires validation, for firmware can reset, wrap, lose clock lock or report metadata from a previous configuration. An effective evidence record stores both the nominal and measured clock conditions, the counter discontinuities, and a checksum of original blocks with their acquisition metadata. I would set out several invariants that an independent reviewer can verify without needing to trust the original operator's confidence. Each raw block begins at the expected counter relative to the previous one, unless a specifically logged gap or state transition intervenes. The number of saved complex samples agrees with the declared interval and sample format. No sample comparison crosses a period of invalid clock, overload, retuning or intentional muting without an explicit eligibility decision. The complete analysis can be rerun from an immutable copy of the raw I/Q and the versioned code, producing the same output values within declared floating-point tolerances. These conditions do not make a detector infallible, but their violation plainly undermines the asserted meaning of its indices. An authorised synthetic test can exploit errors as deliberate adversaries of the analysis. Capture a known multicarrier reference and a known non-

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multicarrier reference, with an independent truth record held separately. Introduce a single dropped buffer, a repeated block, a zero-filled gap and a one-sample phase slip in distinct test runs. Compare each detector's output with the truth and preserve the failure rate. An implementation that declares a prefix when a no-source repeated block is inserted has demonstrated a bug, or at least a failure to reject an eligible artefact. The correct engineering response is to repair the acquisition-quality rule and rerun the blinded evaluation, not to explain the conspicuous false detection as an unusual atmospheric effect. One must also examine numerical implementation. A sum of complex products accumulated over many samples can lose precision if stored in an inadequate format or if signal energies differ by many orders of magnitude. Overflow, underflow, clipping and division by tiny denominators can make a normalised statistic appear artificially confident. The experiment should apply known analytic sequences for which the expected C is exact or independently computed, including a constant complex tone, white complex noise, a seeded copied segment, a clipped sine and an entirely invalid zero-energy interval. Automated unit tests should verify the implemented formula, including which input is conjugated and which lag sign is used. An attractive plot whose estimator has not passed those tests belongs to the software-development record, not to the final evidential conclusion. Another trap is the multiple-comparison problem. A program may test thousands of start positions, dozens of lags, several window lengths and multiple antennas before selecting the largest C. Each comparison increases the opportunity for a chance excursion, and correlated tests do not permit the naive multiplication of independent probabilities. The programme must retain the complete tested parameter

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set and establish an overall calibration with null data that reproduce overlapping windows and receiver dependence. It should freeze the decision rule before the reserved evaluation capture. A threshold selected after seeing the questioned signal is a description of that signal, not independent evidence that the signal crossed a meaningful prescribed threshold. A practical example makes the engineering units explicit. Suppose a 1,024,000-sample-per-second recorder stores complex samples in eight bytes each. One second of uninterrupted raw samples requires 8,192,000 bytes, ignoring headers and metadata. A ten-second bounded capture therefore requires approximately 81.92 million bytes, not an unspecified quantity described as 'high throughput'. A buffer loss of 2048 samples corresponds to 0.002 second at that rate. A proposed prefix of 128 samples lasts 0.000125 second, so such a loss spans sixteen prefix lengths. A careless splice could affect many candidate windows and create a false periodic impression across the apparent file join. These arithmetic checks can be performed independently and should appear beside the software ledger. Evidence preservation is equally important after acquisition. The original data, instrument configuration, calibration files, scripts, revision history, exclusions and derived plots should form a versioned evidence package with a traceable hash. If an error is discovered, create a corrected derivative rather than silently overwriting the earlier record. A properly preserved failure is scientifically useful, because it permits an independent laboratory to locate the precise cause of a false positive. The reporter should state whether the inference is about a known synthetic waveform, an unknown received signal, or the behaviour of the measuring instrument itself. My judgment is that a lag correlation may be a robust engineering clue after

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these controls, but it is not a substitute for them. The reviewer should be able to trace a reported peak to specific valid sample ranges, reproduce the normalisation, compare rejected and accepted windows, and see at least one deliberately adverse test that the detector correctly refuses. A conspicuous figure without such provenance resembles a neatly printed school examination whose answers were copied from an unexamined source. Its appearance is orderly; its evidential foundation is not.

Harry Nyquist, Peer Question: Dr. Hamming, your ledger protects sample indices, but it may still faithfully record a receiver that is systematically miscalibrated. A digitiser whose actual sample rate differs from its nominal rate will assign incorrect physical durations to the purported useful symbol and guard interval. A frequency correction stage may also rotate phase or interpolate samples in a way that changes the shape of the lag statistic while retaining exact block counters. How would you distinguish an accurate digital record of an inaccurate physical timebase from a faulty record, and how would that difference affect claims about symbol spacing and frequency offsets? Please include the roles of a traceable external frequency reference, independent sample-rate estimation and a deliberately varied sample-clock condition. I also ask whether a small clock error can accumulate across many symbols to defeat a narrow gate selected from the first observed correlation ridge. Would the result still have the proposed physical meaning if the nominal sample rate were simply copied from an outdated acquisition configuration?

Richard Wesley Hamming, Response: Mr. Nyquist, a complete audit has two separate timebase obligations. One concerns the ordering and continuity of samples, for which counters and gap flags are essential. The other concerns

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the actual physical interval between samples, which counters alone do not establish. If the converter is commanded to run at F_s but actually operates at F_s(1+delta), the time corresponding to a lag N is N divided by the actual rate, not N divided by the nominal one. Here delta is the dimensionless fractional sample-rate error. The recorded sequence may be perfectly continuous while its displayed timing is systematically wrong. Use a calibrated reference oscillator or a laboratory signal whose frequency is traceable to a trustworthy standard, and record both the reference's conditions and the receiver's clock-lock state. Compare the implied sample rate over bounded intervals, preferably with an independent measurement path rather than solely with the same firmware that controls the converter. A signal-frequency estimate can help, but if it relies on the very sample rate under investigation, the calculation becomes circular. Where an external timing or frequency reference is unavailable, report the calibration as provisional and give a conservative uncertainty bound based on measured drift and oscillator specifications. A ten-part-per-million clock error has a fractional magnitude of 0.00001. Over one 1152-sample synthetic symbol it corresponds to approximately 0.01152 sample of nominal timing displacement. Over one thousand such symbol intervals the accumulated displacement reaches approximately 11.52 samples if the fractional error remains stable and the comparison is made against an independent ideal grid. That is large enough to affect a tightly gated window that was positioned using only the first few symbols, though the detector may track and compensate if its model permits. The numbers are illustrative, not measured performance for an actual receiver. A report should state whether the analysis estimates and corrects drift from training data or merely

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searches for the most favourable trajectory. Frequency correction and interpolation need their own metadata. Record original uncorrected samples, correction coefficients, interpolation filter, clock assumptions, and the interval over which each estimate was obtained. Re-run the lag detector with and without those reversible corrections on authorised known sources. If a peak appears only after an algorithm whose coefficients were adapted using the same target peak, that observation is exploratory and needs independent validation. If the raw and corrected forms yield mutually consistent physical symbol duration after applying declared transformations, confidence increases. The difference between timing continuity and timing accuracy should be expressed in the final report. A valid counter sequence with uncertain oscillator rate can support a statement that a lag of 1024 stored samples exists; it may not support the sharper claim that the lag corresponds to precisely one millisecond. This distinction prevents a well-engineered digital ledger from becoming an excuse to ignore the physical receiver's clock. An honest uncertainty interval belongs on every inferred time and frequency, even when the display presents six decimal places.

Claude Elwood Shannon, Peer Question: Dr. Hamming, you have given the investigator a disciplined pipeline, but I remain concerned about a subtler way in which the report might be internally consistent and nevertheless misleading. Suppose the investigator searches all candidate FFT lengths from a small catalogue, records only the winning N, and applies a normalised correlation threshold calibrated for that one N rather than for the selection process. The software could reproduce its answer exactly, preserve every raw sample and contain no arithmetic defect. Yet its claimed

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false-positive risk would still be incorrect. Would you set out the difference between reproducibility and inferential validity, and specify what the audit ledger must record about rejected candidate models? I should also like to hear how a reserved test can be kept independent when adjacent time windows share most of their samples and the same hardware impairment persists across the whole recording. I ask whether different lags chosen retrospectively should be treated as competing hypotheses rather than as independent confirmations of one structure.

Richard Wesley Hamming, Response: Dr. Shannon, a reproducible computation can reproduce an invalid inference indefinitely. Reproducibility says that the same declared procedure gives the same result from the same data. Inferential validity requires that the procedure's assumptions, including its selection process and calibration, justify the claimed uncertainty. An analyst who tests fifty candidate lags and preserves only the largest value has not performed one test, however tidy the final table may look. The audit must therefore retain the complete set of candidates, the order of testing, window lengths, gains, thresholds and reasons for excluding models. If parameter choices were adaptive, the decision log must show which observations influenced those choices. One defensible route is to define the candidate family in advance and calibrate the distribution of its maximum statistic under null recordings made through the relevant measurement chain. This automatically accommodates some forms of dependence when the null procedure reproduces the full search. Another route is to select a single candidate on exploratory data, freeze it, and evaluate its predicted recurrence on an independent capture. Neither approach is free of assumptions. A null archive collected under one gain or

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interference regime may not represent a changed field environment, and a nominally reserved window adjacent to the selection window may share filter memory, overlapping samples and the same nuisance source. The design can deliberately create greater separation. Allocate different known synthetic runs to model selection and evaluation, randomise lawful source conditions, use distinct acquisition sessions, and if possible employ an independent reference receiver to test predicted timing without changing the model. Correlation between sessions remains possible, especially when the same interfering oscillator or common clock is present, but the comparison can document and bound those common factors. If no independent session exists, present sensitivity analyses and avoid the language of confirmation. The ledger should be machine-readable. For each candidate, preserve N, G, window start, sample count, threshold, statistic, eligibility, decision and any subsequent revision. Compute an independent verification hash for the complete input archive and software version, but accompany it with a record of hardware calibrations and no-source controls. The reviewer's task is not merely to press a button and reproduce a bright chart. It is to reconstruct the sequence of scientific decisions and ask whether the purported evidence survived a test it did not help design. Finally, maintain a difference between an event classifier and an attribution claim. A controlled experiment may show that a certain pattern is more compatible with a copied-prefix synthetic source than with selected alternatives. That result says nothing conclusive about the author, location, purpose or protected content of an unknown transmission. The investigator should refuse the temptation to promote a narrow signal-structure score

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into a broad account of a transmitter's identity. The software can print such a conclusion, but it cannot manufacture the missing evidence.

Richard Wesley Hamming, Cross-Peer Question to Dennis Gabor: Mr. Gabor, suppose the receiver logs perfect consecutive samples, but its analyst constructs a series of overlapping spectrograms and treats the resulting display tiles as separate independent confirmations of a supposed prefix feature. A single narrowband interferer appears in many adjacent tiles because the windows overlap. Could you explain the representation problem and propose a controlled comparison between a short-time Fourier view and the direct time-domain lag statistic? I ask you also to consider two pulses separated by an echo interval that happens to resemble a useful-symbol lag, and to specify how a changed window or independent receiver would affect that interpretation. Most importantly, what does the analyst need to disclose about time-frequency resolution so that a persuasive display does not conceal the fact that only one set of original samples has been examined many times? How should an examiner distinguish a true additional measurement from a second computation over largely the same data when reporting apparent corroboration?

Dennis Gabor, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, the first correction is conceptual: adjacent tiles on a spectrogram are not independent observations merely because they occupy different rectangles on a screen. If each transform reuses nine tenths of the previous window's samples, the numerical outputs will be strongly dependent even for an unstructured source. Their agreement may demonstrate the stability of a representation, not the replication of evidence. The report should state the window duration, taper, time advance, transform length, overlap

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fraction and frequency resolution, all in physical units. It should also distinguish genuine additional acquisition time from recomputation of existing samples. Compute the direct time-domain lag statistic on raw eligible complex samples first, then use the spectrogram to investigate competing physical mechanisms rather than as a substitute for the correlation calculation. A true copied prefix predicts repeated lag-N similarity concentrated around particular symbol phases; a tone may create near-uniform coherence across time and a spectrogram dominated by a narrow ridge. An echo of two pulses can yield a sharp delayed match, but its timing and spectral evolution may follow the channel impulse response rather than a stable symbol interval. A known laboratory pulse, measured through the same channel and filter, provides a control for that echo explanation. Vary the window in predeclared ways. A shorter window improves the ability to locate the temporal onset of a transient but spreads its frequency content; a longer one concentrates frequency for a stable tone but smears a brief prefix-like feature. The expected transformation can be compared against controlled synthetic sources. A genuine observation need not remain visually unchanged, for invariance of appearance is not the criterion. Rather, the parameter-dependent change should be consistent with the proposed signal and receiver model. Any parameter chosen after seeing the disputed sample must remain labelled exploratory. An independent capture can add evidence if it supplies new physical samples through a sufficiently separate receiver path, preferably with its own oscillator and acquisition chain. Two analysts processing the same I/Q file with two window lengths do not constitute two independent witnesses. If the echo and prefix hypotheses both survive, the report should retain both.

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The highest standard is not a striking waterfall but a transparent chain from original samples through declared transforms to falsifiable predictions, including the alternatives that the data cannot resolve.

Dr. James M. Atkinson, Moderator: Dr. Hamming, thank you. Mr. Gabor, I pass you the token to examine the time-frequency plane and the manner in which an apparent correlation ridge can be generated or obscured by the representation itself.

Dennis Gabor, Fourth Principal Contributor: The signal appears to us neither as a pure list of times nor as an unchanging spectrum. A receiver necessarily observes a finite portion of a physical process, and the analyst chooses a representation that distributes its information across time and frequency. That choice can illuminate a mechanism or hide it. A cyclic prefix is a relation between two intervals separated by a known useful-symbol length; a conventional spectrum display may provide no direct proof of that relation. Conversely, a periodic interferer may make an elegant repeating pattern in a spectrogram because the display window is synchronised with the interferer's cycle. Neither appearance should be elevated to a classification before the representation's assumptions have been examined. Let g[n] be a declared analysis window and let X(m,k) denote a short-time Fourier coefficient computed from samples surrounding time index m at discrete frequency bin k. Its magnitude-squared forms a spectrogram cell. The duration of g determines which transients can be localised in time, while its Fourier transform determines how concentrated a narrowband source appears in frequency. Shortening the window improves time localisation but broadens the response to a stable tone. Lengthening it sharpens frequency discrimination but can average a short repeated guard interval into its

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surrounding useful symbol. Window shape changes sidelobe leakage and effective statistical dependence. A detector that searches multiple windows and reports only the most colourful picture has performed a model-selection exercise, not acquired multiple independent proofs. Imagine a legal laboratory source with N=1024, G=128 and F_s=1.024 million complex samples per second. Its nominal symbol is 1152 samples, or 1.125 milliseconds. A 128-sample prefix lasts 125 microseconds. A spectrogram window extending over four milliseconds spans several symbols and merges many intervals that a prefix-sensitive lag statistic would seek to separate. A 64-sample window lasts 62.5 microseconds and can reveal shorter transitions, but its nominal Fourier bin spacing is 16 kilohertz at the stated sample rate, far larger than the 1-kilohertz spacing of the hypothetical N=1024 transform. The bin figures are consequences of the selected window lengths; neither alone establishes what subcarrier spacing the emitter employed. A direct lag test and a time-frequency representation therefore answer complementary questions. The lag test asks whether two sets of samples separated by N have a stable complex relation inside expected positions. The spectrogram helps determine whether the received energy is predominantly confined to a narrow frequency, spread over many frequency cells, switched in time or accompanied by transients that could explain the correlation. A pure sinusoid produces perfect normalised lag coherence in the ideal noise-free model, yet its spectrogram may expose concentrated spectral energy. A wideband multicarrier source generally distributes energy over an occupied band, but a strongly filtered or partially observed recording can look narrowband. Both views must be interpreted through the measured response of the receiver. The familiar time-frequency

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trade-off is not an excuse to use an arbitrary display; it is a requirement to reveal the cost of each one. In a careful study, predeclare two or three windows chosen for different physical purposes, such as transient localisation, band occupancy and prefix-scale correlation. State for each the duration, taper, overlap, sample rate and resulting nominal frequency resolution. Compare their predictions on independent authorised test records, including a known prefix source, a tone, an amplitude-keyed interferer and a multipath pulse. If the observed phenomenon changes under the windows in a way predicted by the selected mechanism, that is informative. If it appears only under a carefully tuned, retrospectively chosen window, the supposed evidence may be an artefact of presentation. Periodic interference deserves particular attention because a bright narrow ridge can carry complex structure after passing through a nonideal instrument. For example, a strong tone may push an amplifier into a nonlinear range; the resulting intermodulation products broaden the apparent occupied spectrum. An automatic-gain-control loop may apply periodic amplitude changes in response to a separate blocker. A filter may ring at a frequency set by its poles after an abrupt input transition. Those mechanisms can create combinations of periodicity and apparent multiband energy. Varying lawful injected test-power levels and front-end attenuation can help distinguish an internal nonlinear product from a stable external waveform, but the analysis must preserve the possibility that two sources coexist. Multipath also enters as a relation between delayed copies. If a channel produces an echo with delay tau seconds, the received waveform may contain correlated portions separated by approximately tau F_s samples. A pronounced lag peak at that interval is a property of the

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combined transmitted waveform and propagation environment, not necessarily of a copied prefix. A real multicarrier source under multipath can display both mechanisms. Its guard interval is designed to tolerate specified delay spreads, but if channel memory extends beyond the prefix, intersymbol interference and altered correlation patterns can follow. The correct experiment includes channel emulation or controlled reflections, estimates the impulse response where possible, and compares the predicted temporal support of candidate peaks. A second receiver can assist, but it does not automatically establish an independent source mechanism. Two receivers connected to the same antenna distribution system share the external field and may share front-end intermodulation. Two digital analyses of the same sample file share all underlying measurement faults. To test receiver-created periodicity, use a terminated-input capture, known source injection, altered local oscillator, and a genuinely separate acquisition architecture. Preserve clock and gain metadata for each capture; otherwise a failure to agree may simply reflect incompatible calibration. The result should be framed in the vocabulary of compatibility and uncertainty, not courtroom certainty. I would conclude by separating three visual claims. The first is that a period appears in the measurement; the second, stronger, is that the period occupies positions and bandwidth consistent with a cyclic-prefix construction; and the third, far stronger, is that the source actually uses a specified waveform standard. A finite window and a beautiful display can support the first and perhaps the second when controls agree. They do not, without additional independent evidence, support the third. In technical jurisprudence as in physics, a

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legible picture can communicate an inference, but it cannot supply the measurements that the inference requires.

David Slepian, Peer Question: Mr. Gabor, the principal example has a prefix duration of 125 microseconds, yet a spectrogram viewed with a long integration interval could make it almost invisible. If the examiner then shortens the window repeatedly until an apparent short repetition appears, the choice becomes contaminated by the observed data. How should that contamination be handled without prohibiting all exploratory visual analysis? I should like you to distinguish an exploratory discovery from a confirmatory detection, define a modest family of sensible resolutions that a laboratory might declare beforehand, and explain how a correlated noise null should be reproduced after each transformation. Please also address whether a changed time-frequency display can ever furnish genuinely new evidence if the underlying raw samples remain the same and whether independent receiver captures or synthetic challenges provide the missing distinction. Would your proposed confirmatory stage require a genuinely separate acquisition rather than a revised transform of the same underlying instrument samples?

Dennis Gabor, Response: Dr. Slepian, exploratory adjustment is valuable for discovering what the eye and instruments did not initially expect. The error occurs when the analyst later reports the winning display as though it had been prescribed before the data were seen. In exploration, one may examine many window lengths, tapers and overlap settings. Preserve that search history or at least its material scope, describe which feature first suggested the candidate prefix model, and refrain from quoting the unadjusted significance of the final selected statistic. A controlled

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confirmation then fixes the proposed lag, symbol spacing, window set and acceptance rule before a genuinely reserved capture is evaluated. A laboratory could prescribe three representations with complementary purposes. A short window on the order of half the hypothesised prefix would help locate transient changes; an intermediate window near the prefix duration would examine local repetition; a longer window covering much of the useful symbol would assess spectral concentration. These are experimental design examples, not universal prescriptions. All durations must be derived from independently justified candidate parameters or from a separate discovery dataset. The report should include each transform's overlap fraction and the actual acquisition interval. Closely spaced windows share samples and therefore cannot be treated as separate confirmations simply because they generate separate pictures. Apply each declared transform to controlled no-source, pure-tone, periodically gated-tone and multicarrier reference captures obtained with the same receiver settings. Construct the null distribution for the final combined decision, including the selection among the three representations. This is essential when coloured noise or filter ringing is present, because the transform changes the apparent dependence and leakage. A white-noise simulation is useful for testing the code's mathematics, but it cannot automatically calibrate the instrument's field false-alarm probability. Preserve all unsuccessful as well as successful synthetic trials, including intervals rejected by the acquisition-quality mask. Transforming the same raw samples into three views supplies complementary evidence about the same observation; it does not multiply the number of independent physical encounters. New data arise from another acquisition interval, an independent channel, a controlled change of

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source or instrument conditions, or an intervention that tests a competing mechanism. If the candidate prefix pattern persists across genuinely separate captures with the expected symbol timing and changes appropriately under a known synthetic source, its credibility increases. If it appears only at one retrospective window setting, it remains a clue awaiting confirmation. The distinction protects exploration without granting exploratory freedom the privileges of a prespecified test.

Dennis Gabor, Cross-Peer Question to Harry Nyquist: Mr. Nyquist, our time-frequency representations assume that the sample-rate label in the file corresponds to the actual physical rate and that the receiver's passband transmits the proposed copied interval without introducing misleading periodicity. But a real receiver includes mixers, filters, analogue gain control and a sample clock. Could you show how a modest clock error changes the relation between measured lag in samples and symbol duration, and how a periodic instrumental component can survive internal normalisation? I ask you to describe a calibrated reference experiment that separates a sample-clock or local-oscillator artefact from external multicarrier structure without recovering protected message content. Please also state what happens when a strong tone overloads a front end and creates additional apparent spectral bins, because the false impression of broadband energy may reinforce the misleading correlation peak. I should also like the test to record whether the suspect correlation persists after a safe no-source termination at the analogue input, because that control directly challenges internal clock leakage.

Harry Nyquist, Cross-Peer Answer to Dennis Gabor: Mr. Gabor, sample counting and physical timing must be connected by calibration. At an actual

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sample rate F_actual, a separation of N samples corresponds to T=N/F_actual seconds. If the file instead reports a nominal F_nominal, the inferred time differs according to the fractional error delta defined by F_actual=F_nominal(1+delta). A ten-part-per-million error is small per symbol but accumulates when the analyst assumes that hundreds or thousands of nominal symbol boundaries remain perfectly aligned. The correct experiment measures the clock against a traceable reference over the relevant capture interval and reports uncertainty or drift, rather than assuming the oscillator's catalogue specification is identical to its measured performance. Begin with a terminated receiver input while retaining its normal local oscillators and sample clock. Capture the suspected correlation under otherwise identical settings. A peak that persists with no external energy strongly suggests an internally generated periodicity or a processing defect, although the measurement must account for leakage at the terminated port. Next inject a known pure tone at an independently calibrated level and change its frequency slightly. If the observed lag phase tracks the injected tone as expected, that confirms part of the digital transfer function, not a cyclic-prefix source. A subsequent known synthetic multicarrier source permits the predicted prefix position and repeat rhythm to be tested against actual sample and clock metadata. Deliberately vary allowed receiver states. Change the sampling-clock reference when the equipment supports it, shift the local oscillator while compensating the tuned input frequency, and compare recordings from a second architecture. Instrumental clock leakage may move in samples or frequency when the internal reference changes, whereas an external source's physical period should remain tied to the emitter, allowing for documented sampling-rate

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conversion. If different receivers share a distribution oscillator or preamplifier, the controls must recognise that common mode. No single shift provides proof; the ensemble of predicted changes is the test. Overload is a further concern. A strong tone near an amplifier or mixer can produce harmonics and intermodulation products; after clipping it may yield broad spectral skirts. Vary the injected power across the verified linear range and insert measured attenuation before the suspect nonlinearity. A genuine weak signal should scale approximately according to the calibrated linear transfer function in that regime; a nonlinear artefact may change disproportionately. Keep the test within authorised safe input limits and avoid assuming the absence of one mechanism excludes another. A receiver can capture an external multicarrier signal while simultaneously generating an unrelated spur. The final finding should distinguish measured period, calibrated instrument response and an inference about source structure, with each uncertainty separately stated.

Dr. James M. Atkinson, Moderator: Mr. Gabor, thank you. Mr. Nyquist, I now pass you the token to address sampling, analogue front-end behaviour and the conditions under which a receiver can faithfully report a cyclic-prefix-like repetition.

Harry Nyquist, Fifth Principal Contributor: The accuracy of a sampled correlation begins long before the analyst writes a summation sign. The antenna, preselector, amplifier, mixer, analogue filters, sampler and digital corrections form one measurement chain. Each element may modify the phase and amplitude relationships that an ideal signal model assumes. A cyclic prefix is a property of a constructed transmitted sequence; a receiver is capable of preserving evidence of that property only to the extent that its

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bandwidth, timing, linearity and acquisition integrity are understood. A large normalised coefficient can coexist with a deeply misleading picture of the external spectrum, because normalisation may suppress amplitude information while retaining an instrumental periodic phase relation. Let F_s denote the actual complex sample rate in samples per second. A discrete lag N corresponds to N/F_s seconds, provided the acquisition has no discontinuity and the sample clock is sufficiently stable. The classical sampling condition demands that the analogue signal be appropriately band-limited relative to the sampled representation and the anti-alias design. The relevant usable bandwidth depends on whether the path yields real or complex samples, the analogue filters and the local-oscillator conversion. If an interferer falls outside the intended band but aliases or mixes into it, the resulting digital samples may show a stable correlation not native to the hypothesised target emission. Reporting only the on-screen centre frequency hides that possibility. A practical receiver characterisation should measure frequency response, selectivity, group-delay variation, settling time, gain compression and clipping under realistic configurations. Group delay matters because different portions of a broadband signal may arrive at the detector with altered relative phase; such phase changes can broaden or suppress the apparent prefix correlation. A filter with a long impulse response can create correlations between separated segments even when a source's corresponding segments are not copies. Local oscillator feedthrough and periodic power-supply interference can add coherent tones that defeat a prefix-only explanation. Each nuisance mechanism should be included in a declared competing hypothesis rather than addressed only after the preferred inference has been announced.

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Take the reference model of N=1024, G=128 and F_s=1,024,000. One useful-symbol interval is one millisecond and one nominal prefix is one eighth of a millisecond. A constant carrier-frequency offset f_delta does not necessarily reduce the absolute lag coherence of an otherwise identical copied segment, because a constant phase rotation separates the two compared vectors. The phase rotation across lag N is 2 pi f_delta N/F_s radians in the simple complex-baseband model. At f_delta=250 hertz, this is pi/2 radians for the one-millisecond lag. Therefore the observed phase of a correlation peak can assist a bounded offset estimate under appropriate assumptions but cannot uniquely distinguish a copied prefix from a pure tone. Indeed, the pure tone is the sharpest warning: it gives a stable phase relation for every lag. Clock drift introduces a different ambiguity. If an analyst uses the nominal F_s to predict symbol starts over a long record while the actual oscillator deviates, the expected prefix positions slowly move relative to the recorded sample indices. A detector that works well on the first ten symbols may seem to fail or acquire an apparent split peak after many more, even though the external source remains unchanged. An experimental estimate of fractional sample-rate offset, independent of the suspected prefix model where possible, should be carried through the alignment calculation. The same principle applies to fractional-delay interpolation and resampling: every transformed sample needs a defined relationship to the original acquisition, with filter characteristics and uncertainty recorded. Nonlinearity may make the correlation problem worse. If a receiver is driven into compression by a strong allowed test tone, clipped waveforms and intermodulation products can fill additional frequency bins while the tone's periodic phase relation persists. A display may then show both wide spectral

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activity and high lag coherence, seemingly two pieces of support for a multicarrier hypothesis when both arose from one overloaded receiver. An input attenuator placed ahead of the nonlinearity, an alternate preselector and a controlled change of test power can expose this mechanism. The analyst should examine whether output changes according to linear or nonlinear scaling, without assuming a simple power law is universal in every gain-control state. I would require a negative control with a characterised terminated antenna input, a positive control with a known synthetic cyclic-prefix waveform, and at least one adverse control with a strong pure tone and a periodically keyed interferer. The controls should use the same acquisition settings, filters, detector code and sample-rate correction as the questioned capture. A second independent receiver, ideally with its own oscillator and a different conversion architecture, helps challenge shared artefacts; a second copy of the same software on the same samples does not. Where the equipment permits, a deliberate change in sample-clock reference or local-oscillator plan can differentiate source timing from internal synchrony by observing which quantities move in physical hertz and which move in raw sample coordinates. The calibration also needs an evidential trail. Preserve raw digitised samples, absolute and relative time references, known test amplitudes at a stated reference plane, attenuator and filter settings, calibration date, software revision, and records of rejected windows. Distinguish an instrument specification from a measurement made on the actual unit. A catalogue may describe a suitable bandwidth or noise figure, but it cannot establish that the field apparatus was within its rated operating state during a particular event. If a signal is near the dynamic-range boundary, uncertainty about overload or

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quantisation must be explicit. Repeated processing of the same uncertain samples cannot replace a fresh physical control. The proper conclusion is conditional: a time-localised repeat at a lag and interval compatible with an authorised synthetic cyclic-prefix model may support the hypothesis of multicarrier structure after competing instrumental and periodic-source explanations are tested. It does not identify the sender, decode content, or certify conformity with a specific communications standard. An investigator who states the observation, the calibrated physical controls and the surviving alternatives has done more than one who offers a confident label unsupported by the receiver's analogue behaviour. The instrument may whistle a steady periodic note through its own circuitry. The expert must establish whether that sound began outside the laboratory before turning it into evidence of another party's transmission.

Dennis Gabor, Peer Question: Mr. Nyquist, your proposal uses a second receiver with a different conversion architecture and suggests deliberate changes of reference clocks and local oscillators. I should like a precise distinction between a genuine independent replication and merely observing the same nuisance through two partially shared instruments. Suppose both receivers share an antenna distribution amplifier, both are subject to the same strong blocker, and their sample clocks are nominally separate but ultimately disciplined by the same laboratory standard. Could they agree on a spurious lag peak while remaining jointly wrong about the source? What specific cross-checks would you use to test common-mode artefacts, and how would you report a case in which the prefix-like correlation survives a change in digital analysis window but disappears when attenuation is introduced ahead of the common distribution amplifier?

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Please define what such a result would and would not establish. Would an independent sample-clock reference and a separate preselector offer stronger protection against shared errors than two receivers using the same distribution network?

Harry Nyquist, Response: Mr. Gabor, two instruments can agree because they share the same error, and their agreement is not independent evidence unless the relevant failure modes have been examined. A shared antenna distribution amplifier can generate intermodulation that both downstream receivers faithfully capture. If both instruments share a reference oscillator, a spur synchronous with that reference may also appear in both. Even independent sample clocks do not eliminate interference radiated into a common laboratory environment. An equipment diagram showing the actual signal, power, timing and grounding connections is therefore part of the experimental record, not a decorative appendix. Begin by testing the common distribution path. Connect a characterised termination or synthetic input at its upstream reference plane, preserve the downstream receiver settings, and measure whether the feature appears with no external source. Next bypass the common amplifier and feed the receivers from separate calibrated injection paths, holding lawful test-source conditions constant. If the suspect peak disappears when the common amplifier is bypassed or attenuated ahead of it, nonlinearity or an instrumental artefact becomes a stronger explanation. The observation does not automatically prove the absence of a separate weak external multicarrier signal, because that signal may have been masked by the nonlinearity. A further targeted test at an appropriate, calibrated sensitivity would be needed. Change the blocker amplitude in controlled steps within

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equipment safety limits, measuring both the fundamental and any products at the relevant frequencies. The dependence on input power can help distinguish linear reception from nonlinear generation. Repeat with a different preselector and note whether the feature tracks the source frequency, the local oscillator or the filter response. A real source's physical carrier and repetition rate should not follow an arbitrary downstream oscillator change in the same manner as an internal spur. But all comparisons must be converted to common physical units with explicit sample-rate and frequency uncertainty, otherwise the apparent movement may be a bookkeeping artefact. Where both receivers share a time standard, compare their raw hardware counters and quantify common reference disturbances. A second instrument with truly independent timing and front-end conversion is preferable for challenging clock-related hypotheses, although its agreement still does not uniquely establish a modulation family. Correlation across views of one data stream remains a property of that stream, not a second encounter. An independent receiver adds value by making some faults less likely to coincide, not by making them logically impossible. If the correlation persists across digital window changes but vanishes after safe upstream attenuation, the evidence points toward receiver gain-state dependence. That is a diagnostic observation worthy of preservation, with possible causes including overload, gain-control response and a formerly visible weak signal falling below sensitivity. It does not support a confident claim that the source used a cyclic prefix. The appropriate report gives the before-and-after settings, measured input and output levels, competing explanations and any additional reference tests.

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Only a mechanism that survives adverse controls should influence an attributed source-structure conclusion.

Dr. James M. Atkinson, Moderator: The panel has distinguished a measured lag relation from a multicarrier hypothesis and from any claim of protocol or sender identity. We have examined finite-window dependence, invalid sample reconstruction, representational leakage, clock error, receiver overload and common-mode corroboration. I thank each contributor for the careful passage of the token. The closing evidential rule is that a candidate cyclic prefix must satisfy predeclared lag and timing predictions on valid samples, survive suitable null and control recordings, and remain qualified wherever competing periodic interference or instrument mechanisms are unresolved. No protected communications content has been obtained in this educational reconstruction.

SOURCE REGISTER. Claude E. Shannon, “A Mathematical Theory of Communication,” Bell System Technical Journal 27 (1948), 379–423 and 623–656; Harry Nyquist, “Certain Topics in Telegraph Transmission Theory,” Transactions of the AIEE 47 (1928), 617–644; Dennis Gabor, “Theory of Communication,” Journal of the Institution of Electrical Engineers, Part III 93 (1946), 429–457; Richard W. Hamming, “Error Detecting and Error Correcting Codes,” Bell System Technical Journal 29 (1950), 147–160; David Slepian, “Prolate Spheroidal Wave Functions, Fourier Analysis, and Uncertainty. V: The Discrete Case,” Bell System Technical Journal 57 (1978), 1371–1430; Jan-Jaap van de Beek, Magnus Sandell and Per Ola Börjesson, “ML Estimation of Time and Frequency Offset in OFDM Systems,” IEEE Transactions on Signal Processing 45 (1997), 1800–1805, DOI 10.1109/78.599949; Timothy M. Schmidl and Donald C. Cox, “Robust Frequency and Timing Synchronization

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for OFDM," IEEE Transactions on Communications 45 (1997), 1613–1621, DOI 10.1109/26.650240. The named historical scholars did not jointly write or debate the modern waveform; the dialogue is fictional and these sources support background propositions, not attributed speech. Source-to-claim verification remains for Stage B.

EDITORIAL QUALIFICATION. The scenarios use invented authorised laboratory sources with stated assumptions. No claim identifies an unknown emitter, recovers protected content, or constitutes a validated field measurement. Exact parameter values and false-alarm interpretations require independent calibration.

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QUESTION 085

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What distinguishes a spread-spectrum burst from impulsive broadband interference?

SCHOLARLY RECONSTRUCTION. The deceased contributors are historically real experts, but this discussion is fictional and does not represent their actual speech, collaboration or endorsement. All examples employ authorised synthetic sources, calibrated instruments and non-content waveform statistics; no protected communication is decoded and no particular sender is identified.

Dr. James M. Atkinson, Moderator: Dr. Slepian, a broad and fleeting trace on the waterfall may be a coded communication, an electrostatic discharge, a switching transient, a lightning impulse or a receiver artefact. Would you explain what finite-window measurements can reliably distinguish, before the panel considers processing gain or any claim about a particular code family? You have the token.

David Slepian, Principal Contributor: The breadth of a spectrum and the brevity of an event do not tell us whether an information-bearing code exists. Any sufficiently short impulse necessarily occupies a broad range of frequencies in its Fourier representation, even if it carries no intended message. Conversely a deliberately spread signal may have a weak and relatively flat spectral density, while carrying a temporally organised sequence that a suitably configured, authorised reference detector can recognise. The field instrument responds to both through the same finite passband and analysis window, so the examiner must distinguish a physical property of the signal from an artefact of the representation. A narrow band of certainty cannot be gained by drawing a wide band of colour on a screen.

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Let s(t) be an analogue input voltage at time t, h(t) the measured impulse response of the receiver channel and y(t) the recorded output after the relevant gain, filtering and sampling operations. In a linear time-invariant approximation, y(t) is the convolution of s(t) with h(t), plus noise and any unrelated interference. An input electrical discharge whose duration is short compared with the reciprocal of the receiver bandwidth may appear at the output primarily as the receiver's own impulse response. A deliberate pseudorandom chip sequence can also appear band-limited and smeared after the same channel. Consequently the width and ringing duration observed at the recorder are jointly determined by the source and the instrument. The linear approximation must be abandoned explicitly when overload or automatic gain control makes the channel time-varying. A simple synthetic model illustrates the distinction. Consider a lawful laboratory generator emitting a sequence of 127 binary phase chips, each occupying one microsecond. The nominal chip sequence lasts 127 microseconds and its main spectral support is related to a megachip-per-second switching rate, subject to pulse shape and filtering. The generator's known reference sequence can be retained at the laboratory rather than extracted from any protected traffic. A second instrument injects a calibrated impulse whose initial electrical duration is much shorter than one microsecond. Both may appear as a brief broadband elevation in a spectrogram with a 200-microsecond window. Their temporal details are blurred by that representation; a narrower controlled window and an independently calibrated receiver can reveal different evolution, but neither a short window nor a flat-looking spectrum alone proves a code. One commonly used statistic, spectral flatness, is the geometric mean of eligible

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positive spectral-power estimates divided by their arithmetic mean. It approaches one for equal positive powers across the chosen bins, and becomes smaller when power is concentrated in only a few bins. The number depends on the band limits, noise subtraction, window taper, clipping and treatment of zero or negative corrected powers. White noise may display high flatness without encoding any message, and an impulse can also excite the instrument across a broad frequency range. A spread waveform with deep spectral notches or selective fading need not look flat. The statistic therefore describes a selected power distribution; it does not distinguish information-bearing modulation uniquely from natural or equipment-generated interference. A discriminator should test a pattern that impulsive interference does not ordinarily predict. For an authorised, known laboratory code, one may compute a matched correlation against that reference sequence and a set of bounded timing hypotheses. A properly aligned known sequence can yield a coherent sum over chips, whereas an unstructured impulse may give a different correlation shape and respond differently when the code reference is changed. But the inference depends upon a predeclared code hypothesis, signal path, carrier correction, and a null distribution reflecting the actual impulsive environment. Searching thousands of codes and timing alignments without correction makes occasional high correlations unsurprising. If the source's code is unknown, failure to find a particular reference match says little about whether some other spread waveform is present. The next requirement is to separate amplitude response from structure. Run both synthetic sources through the same calibrated front end over an input-power range known to be linear. If an impulsive event drives the amplifier or

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mixer into compression, it may create a different mixture of products from those predicted by the linear model. A processing algorithm that normalises every event to unit energy can conceal that overload and make a clipped discharge resemble a stable symbol sequence. Preserve raw amplitude statistics and overload flags alongside normalised feature scores. Repeat with an attenuator placed before the susceptible stage, because attenuation after that stage cannot cure earlier intermodulation. The study must include absence and recurrence. A true code-bearing burst may recur with uncertain frame timing; an impulse source may recur when a power converter switches or a relay actuates. Repetition is therefore not synonymous with intentional communication. Record the time of each event relative to independently measured environmental triggers, such as a controlled switching device, and run negative controls with the RF input terminated or the local laboratory source disabled. An impulse event correlated with a particular physical switching transition warrants investigation of that switch, not automatic classification as a covert transmitter. Equally, an unknown event not correlated with a known switch does not thereby become a decoded spread-spectrum signal. Spatial information is useful but imperfect. Two antennas in different positions may observe a genuine environmental source with different amplitude and polarisation, while a common receiver clock spur can appear irrespective of antenna position. An impulse coupled along a power cable may be stronger on one measurement path than on the other. Directional antenna tests should therefore be calibrated and interpreted together with near-field probes, terminated-input recordings and independent receivers. Apparent spatial agreement can still arise from a common distribution amplifier. It is the collection of predicted changes

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under controlled interventions that strengthens the classification, not the number of coloured traces. For a defensible conclusion, I would report that the event has a specified duration, measured band-limited energy, spectral-flatness interval, temporal autocorrelation shape and performance against a declared synthetic reference detector, all with eligible acquisition intervals and estimated uncertainties. I would identify each tested alternative, including impulsive discharge, clock leakage, switching noise and overload, and state which controls favoured or disfavoured it. A code-family hypothesis might emerge from such results. Neither the spectrum's breadth nor the detector's name can establish the sender's identity, its purpose or the existence of protected message content. The physical measurement must remain narrower than the narrative an examiner might wish to tell.

Antony Hewish, Peer Question: Dr. Slepian, a sparse series of broadband bursts may at first resemble an organised electronic transmission, but observational astronomy has long shown the danger of attributing an unfamiliar periodic signal to a deliberate sender before excluding local apparatus and physical processes. How would you build a time-synchronised record that compares the event with power-line switching, nearby industrial machinery, weather-related impulses and the receiver's own retuning schedule? I ask also whether the spectral shape of a brief impulse remains stable when the receiver bandwidth changes, or whether the instrument's impulse response can manufacture a seemingly repeatable signature. Please propose a blind experiment with an authorised laboratory source and a no-source control, and state what evidence would remain insufficient for claiming a spread-spectrum communication signal even after a recurrent event is observed. Please include whether events that coincide

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with known instrument blanking should be excluded from causal inference or retained as an explicit measure of lost survey sensitivity.

David Slepian, Response: Mr. Hewish, the observational design begins with a common timebase whose uncertainty is measured, not merely assumed from matching computer wall clocks. Record raw eligible I/Q samples or suitably calibrated pre-detection statistics, and collect independent event markers from the switching devices and environmental sensors being evaluated. The event list should retain negative observation periods, instrument states, antenna position, gain, filter configuration and local oscillator changes. A histogram of accepted bursts without the opportunity log is vulnerable to selection bias, because strong switching transients may also cause the recorder to blank or saturate. Use an authorised synthetic code-burst generator and a controlled impulse source whose onset times are randomised and withheld from the first analyst. Include genuine no-source trials. When the operator is blinded to source condition, the detection procedure can be tested on its ability to distinguish the three classes without retrospectively tuning thresholds to the answers. Introduce a switching appliance as a separate nuisance source and collect independent trigger timestamps; then examine whether the observed RF-event timing is compatible with that trigger after accounting for sensor delay and clock uncertainty. The result should report both correct classifications and false alarms, and use distinct sessions for selecting the algorithm and estimating its operating performance. Change the receiver bandwidth deliberately. For an impulse shorter than the receiver response time, the output may widen or ring according to the measured filter impulse response. A coded burst can also be altered by filtering, so this test must be

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interpreted against injected known references. Record the actual analogue passband and settling state rather than presuming that selecting a nominal resolution bandwidth changes only the display. A second independently calibrated receiver can test whether the apparent recurring morphology is largely an artefact of the first instrument. Periodic recurrence does not complete attribution. A repeatedly switched industrial load can create exceptionally regular broadband impulses, while a true communication transmitter may send only rarely and irregularly. Even if a burst does not coincide with the monitored switching devices, unmeasured sources remain possible. The defensible conclusion is an event-classification result conditional on the tested controls, not a declaration of deliberative signalling. All excluded trials, uncertain timestamps and apparent mistakes should remain in the record. Their presence gives the examiner a way to distinguish a robust inference from an attractive pattern discovered after the fact.

Edwin Howard Armstrong, Peer Question: Dr. Slepian, your idealised convolution model concerns a linear receiver. Yet a nearby strong pulse may produce gain compression, harmonic products, mixer intermodulation and a long recovery transient, while a weak spread-spectrum reference remains below the nominal detection threshold. If the examiner normalises every recorded event to unit energy, the relative scale of those nonlinear effects may disappear from view. What instrument challenge would demonstrate the boundary of linear operation, and how should the detector be tested when a true weak coded burst overlaps an impulse sufficiently strong to blank or saturate the analogue front end? I would especially value a distinction between putting an attenuator ahead of the first nonlinear stage

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and placing it after a stage that has already created false spectral energy. Which conclusion should be withheld if the front-end calibration is missing? I ask also how an investigator could recognise a front-end recovery tail that outlasts the original impulse and falsely appears to be a second event.

David Slepian, Response: Mr. Armstrong, the receiver must be tested as an analogue instrument before its digital classifications are accepted. Apply a known lawful reference burst at several levels through a calibrated input plane, monitoring the relationship between input voltage, output sample energy and expected filter response. Then add an independently controlled impulse or strong blocker at a series of safe powers. Observe whether the response remains approximately proportional in the intended linear operating range and whether new spectral components appear when the blocker level changes. Keep the raw amplitude and overrange flags; otherwise unit-energy normalisation may make a clipped event resemble a legitimate weak burst in shape while concealing the measurement failure. An attenuator before the susceptible low-noise amplifier or mixer reduces the signal that drives the nonlinearity. An attenuator after that stage may reduce output power but cannot undo intermodulation or clipping products already produced. Compare the two configurations and record the resulting sensitivity change. The front-end may become more linear with upstream attenuation while less sensitive to a genuinely weak reference, so improved cleanliness does not imply unchanged detection capability. A suitable calibration reports both false-event rate and detection probability for seeded weak bursts under each configuration. To test an overlap, generate a known code burst whose timing is independently logged, and inject a controlled impulse at a prospectively selected relative offset. Compare intact

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reference captures, impulse-only captures and mixed captures. If a large impulse saturates the converter or blanks the gain-control loop, the interval may be fundamentally uninterpretable rather than a legitimate negative result for the coded burst. The report should separate invalid acquisition opportunities from valid opportunities with an unsuccessful detector result. A detector calibrated only with isolated events cannot legitimately claim its performance in overlapped conditions. Vary the impulse amplitude and timing to estimate the region of impairment. A narrow impulse can induce a recovery transient lasting far beyond its own emission; an apparent burst immediately afterwards might be a filter ring rather than a second source. Terminated-input and input-switch controls help identify purely internal artefacts, while an independent receiver with different analogue architecture can test whether the same physical signal exists. Where gain linearity, calibration records or acquisition eligibility are unavailable, withhold any strong classification based on unit-normalised morphology. Describe the observation as broadband activity with unresolved instrument-state uncertainty.

David Slepian, Cross-Peer Question to Claude Elwood Shannon: Dr. Shannon, the laboratory proposes 127 known pseudorandom phase chips, each lasting one microsecond. A matched detector might report a striking correlation after a weak burst has been averaged coherently, whereas an impulsive discharge has broad raw spectral support but no intended code. Please derive the ideal processing-gain intuition carefully without presenting 127 as a universal improvement factor in every receiver. I ask you to consider unknown carrier offset, code-phase selection, non-white noise, fading and the case of a strong impulse that temporarily overwhelms

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the converter. How should the examiner count the alternative code and timing hypotheses searched, and what must be done to prevent a lucky high score selected from a large bank of filters from being misrepresented as independent proof of an intentional communication? Please distinguish the direct-sequence case from a frequency-hopping structure, because both can spread energy without presenting the same matched-filter observation. The comparison should be tested on a reserved set of authentic synthetic controls.

Claude Elwood Shannon, Cross-Peer Answer to David Slepian: Dr. Slepian, in an ideal coherent matched-filter calculation, the signal contributions from N equally weighted, known and correctly aligned chips can add as amplitudes, while independent zero-mean noise contributions add in power. Under appropriate normalisation and assumptions, the matched-filter output signal-to-noise power ratio can enjoy a factor proportional to N relative to an appropriate single-chip comparison. For N=127 the ratio is 127, or approximately 10 log10(127)=21.04 decibels. That is an idealised processing-gain illustration, not a guaranteed improvement in sensitivity, and it does not assert that the received field actually contains the assumed chips. The phrase 'processing gain' must be tied to a precise comparison and noise model. A coloured interferer may align with the chosen code or occupy a small part of the measurement band; an impulsive disturbance may dominate several chips or saturate the receiver. If the analogue converter clips, the information lost during the overload cannot be recreated by a digital matched filter. Carrier-frequency offset introduces a phase rotation across the coherent interval and can diminish the aligned sum; timing error or uncertain code phase likewise reduces the predicted peak. A channel with

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several delayed paths may produce multiple peaks. Those impairments need to be modelled or tested with known synthetic sources before an instrument is said to achieve a numerical gain. Search multiplicity is decisive. Suppose an examiner tests many code candidates, many phase offsets and several carrier corrections. The maximum score among those hypotheses will tend to exceed a score from one predeclared hypothesis even under a no-source null. The calibration should reproduce the entire candidate search on comparable no-source and impulse-only recordings, and the threshold should apply to that maximum or to an appropriate controlled error objective. Alternatively choose a code and timing model from exploratory data and test it prospectively on an independent capture. Recording only the winning candidate obscures the relevant trials. A detector's outcome must also be interpreted at the level it can support. If a known authorised reference code is positively detected under calibrated conditions, that may establish a consistent waveform component in the synthetic test. It does not identify an unknown sender or reveal message content; in an unknown recording, a similar score may have multiple explanations. When the code is not known legitimately, one should not infer its family from spectral flatness alone. A robust report states the code hypothesis, reference provenance, tested alternatives, calibrated false-alarm distribution and the effect of receiver saturation or missing samples. The code-specific result then remains an accountable experimental claim instead of an invented attribution.

Dr. James M. Atkinson, Moderator: Dr. Slepian, thank you. Dr. Shannon, I pass the token to you. Please examine processing gain, the distinction

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between structure and content, and the inferential risk of searching too many candidate codes.

Claude Elwood Shannon, Second Principal Contributor: The phrase spread spectrum describes an intentional relationship between the information-bearing or signalling structure and an occupied frequency band broader than an elementary narrowband representation would require. It does not denote a particular appearance on a display and it is not authenticated by a shallow spectral peak. An electrical impulse can distribute energy over a broad frequency range without being a communication, while a spread-spectrum waveform can be made inconspicuous in power density precisely because its energy is distributed. The distinction therefore involves an inference about signal construction, tested against the measurement chain and competing natural or technical causes. No frequency-domain plot alone supplies that missing causal premise. One must first specify the statistical observation. Let x[n] be calibrated complex samples in an eligible window, let c[n] denote a known authorised unit-modulus reference chip sequence and let N be the number of chips being compared. A simplified matched output might be S(tau)=sum over n of x[n+tau] conjugate(c[n]), with tau a candidate alignment index. Under an ideal known waveform and phase alignment, the desired contributions add coherently. Independent additive noise contributes a random complex sum whose variance grows with the number of terms. Under a matched set of assumptions, the output signal-to-noise power improvement relative to a single-chip matched observation scales with N. This is an engineering mechanism, not a certificate that any particular field emission uses the code c. Consider the entirely synthetic example of 127 known chips at one megachip per second, with the chip

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sequence lasting 127 microseconds. The ideal coherent accumulation factor of 127 corresponds to about 21.04 decibels, because ten times the base-ten logarithm of 127 is approximately 21.04. The result depends on the definition of the reference SNR, the normalization of the correlator and a noise model with sufficiently independent contributions. A strong impulsive disturbance, correlated interference, an untracked carrier offset or an invalid acquisition interval can defeat the idealised conclusion. The number 127 is not a guarantee of field performance, nor does a weak displayed signal become physically stronger merely because a calculation applies a matched reference. The distinction between spread-spectrum structure and noise is partly one of reproducible predictive relationships. A coded synthetic burst has a particular timing and phase sequence known independently to its legitimate laboratory generator. A narrow impulsive discharge does not ordinarily preserve that sequence across 127 chips, but a large bank of code and timing hypotheses can occasionally find accidental agreement. The false-alarm probability of the largest observed score must be calibrated over the whole bank, not borrowed from a probability calculated for one fixed code and one predeclared delay. If an investigator searches a hundred codes, a thousand delays and dozens of frequency offsets, the effective selection problem is much larger than the final chart suggests, although dependence prevents a simple assumption that every comparison is independent. When the actual code is unknown, a clever detector may estimate statistical signs of structured timing, symbol-level recurrence or a chip-like rate without extracting protected content. Such estimators have different evidence levels from a legitimate known-code matched filter. The observed statistics may also arise from periodic

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switching noise, a pulse train, receiver clock products or other broadband sources. Code-family identification requires stronger discriminants than a flat spectrum, and the number of possible source constructions is generally too large for one finite record to eliminate. A probability assigned to one favoured family means little unless its competing family models and prior restrictions are made explicit. Receiver impairment is not a peripheral issue. A burst may be too weak to trigger an energy detector yet produce a useful known-reference score when the receiver is linear and the noise behaves as assumed. But a large impulse may overload the mixer or converter and create a flood of spurious frequency bins; the matched filter may then report a high accidental peak or a missed genuine burst because valid samples were clipped or blanked. A normalised score can conceal the fact that the raw input was outside the receiver's calibrated dynamic range. Therefore every candidate should retain its absolute signal-energy measure, gain state, saturation flags, frequency correction and sample-eligibility record. A particularly dangerous inference is to equate a high processing gain with a high probability of finding an unknown signal. A matched filter is powerful when the reference is correct; it is not a universal detector for every possible code. If the code, phase, carrier offset or chip rate is wrong, the expected correlation may be weak even when a genuine spread-spectrum emitter is present. Conversely, a coincidental correlation to a selected reference may be spectacular when millions of alternatives have been tested. A reserved evaluation session should test a fixed detector and quantify both detection probability and false alarms under realistic synthetic sources. The decision threshold belongs to that measured operating characteristic, not to a verbal promise that correlation is inherently reliable.

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The lawfulness of the measurement and the logic of attribution must remain separate. An authorised test sequence may be used to calibrate instrumentation without opening any protected communication content. A signal-structure hypothesis that survives calibration does not reveal the identity of its sender, its purpose, location or message. Independent evidence such as direction finding, physical source control, environmental switching records and a validated chain of custody would be required for broader claims. Even those may support only a bounded inference because several devices can use similar modulation families or share the same interference environment. I would report a spectrum with its measured noise reference, an event duration with clock uncertainty, a calibrated spectral-flatness statistic, an explicit hypothesis set, and performance of any known-reference detector against withheld laboratory truth. I would retain both the raw and normalised correlations, the list of searched codes and delays, and the frequency-offset assumptions. A positive finding means that specified measurements favour a particular tested structure over named alternatives in the stated conditions. A negative finding means only that the chosen receiver and detector did not observe the specified structure within their measured opportunity and sensitivity. Neither result should be decorated into a broader story of an authenticated transmitter.

Sir Martin Ryle, Peer Question: Dr. Shannon, you place confidence in a code-specific correlation only after calibration. Yet a radio observatory records astrophysical and terrestrial transients through antennas whose gains, side lobes and propagation paths vary with direction and frequency. A broadband impulse may be received through multiple side lobes or through a common cable shield, producing a striking apparent coincidence between

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antennas. How should a defensive survey separate code-dependent temporal structure from spatial correlation introduced by a common interference source or common receiver electronics? I should like an experiment with two antennas whose effective directional responses are measured, an independent synthetic reference burst and an impulsive nuisance source at a controlled location. Please explain how a case in which both antennas detect the same brief broadband event should be described without treating agreement alone as proof that a deliberate communication was emitted. Would changing antenna polarisation or placing a terminated input on one channel help disclose the extent to which apparently simultaneous events reflect a common distribution stage?

Claude Elwood Shannon, Response: Sir Martin, multiple receivers add information only to the extent that their observations constrain different aspects of the proposed mechanism. Two antennas receiving the same broadband transient can agree in time because they share a physical source, but that source might be an electrical discharge, a switching supply, a deliberate laboratory transmission or a lightning event. Agreement of event timestamps therefore supports the existence of a shared disturbance under suitable timing calibration; it does not certify coded modulation. Similarly, both receivers might share a distribution amplifier that produces a common artefact downstream of the antennas, so even the claim of a shared external source must be tested. Begin by measuring each antenna's frequency-dependent gain, polarisation and directional response over the intended survey band. Preserve cable losses, preamplifier states, clock offsets and input levels. Inject a synthetic known-code burst from a permitted controlled source at several safe locations and orientations,

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logging its emission time independently. Introduce a calibrated broadband impulse from another controlled source, and repeat with one input terminated or with a receiver path bypassing the shared distribution amplifier. A valid known-reference detector should show the specified code-dependent response where the artificial source is present, while the impulse-only trials should establish its false-alarm distribution under realistic front-end conditions. Spatial correlation should be analysed separately from code correlation. The first may involve relative arrival times and received amplitudes at two calibrated sites; the second concerns matching a complex sample sequence to a declared reference. Their errors are not independent merely because both involve correlation. A strong impulse can dominate both antennas and drive both converters into saturation, while a near-field source can create complex coupling that violates a simple plane-wave direction model. Disclose those limitations and, where possible, use a second architecture whose failure modes differ from the first. If both antennas detect one brief event, the statement should be that a time-coincident broadband transient was recorded at two measured apertures with a specified timing tolerance and known common-mode qualifications. If a calibrated reference-sequence detector also scores positively, describe its predeclared threshold, the full candidate search and its false-positive performance. Do not merge the two observations into an unwarranted communication claim. A robust inference should tell the reader which additional alternative hypotheses were actually excluded, not simply enumerate the instruments that flashed at the same moment.

Claude Elwood Shannon, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, the detector bank may be perfectly programmed and

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internally reproducible, yet still produce a misleading positive when an investigator selects the highest apparent code correlation from many candidate chips, delays and carrier offsets. Would you prescribe an auditable search register and an independent validation design that separate genuine known-code evidence from a chance high maximum? I ask you to consider phase-alignment uncertainty, missing samples, automatic normalisation and the possibility that a few saturated samples dominate the result. What minimum data-quality controls must the software enforce before any score may enter the inferential calculation, and how should the report explain a detector that is reliable on isolated synthetic bursts but fails badly when calibrated impulsive interference overlaps the code sequence? How should a shared hardware clock or processor load be represented in the test design when it creates coherent errors across otherwise independent code-correlation channels? Please include a control where the reference-code generator is physically disconnected.

Richard Wesley Hamming, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, the search register must be as complete as the input data. For each candidate test retain the code reference identifier and its authorised provenance, the examined delay, frequency correction, chip rate, eligible sample indices, normalisation denominator, score, threshold and decision. Also preserve the rule used to select which candidates were tested next. A program that reports only the strongest code-phase point has discarded part of the experiment, even if its calculation of that point is impeccable. Reproducibility of the winning score does not validate a false-alarm probability derived from a smaller search space than was actually used. The data-quality gate comes first. Reject or separately mark any interval with

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unverified sample-counter continuity, sample-rate changes, retuning, gain instability, overrange samples or missing blocks. An impulse may corrupt only a few chips, but their extreme amplitudes can dominate a correlation score or drive the normalisation into an unstable region. The software should have declared policies for excluding invalid samples and, where appropriate, a robust statistic tested against adverse synthetic impulse trials. Those policies must not be changed after observing which exclusions make the desired signal appear more convincing. Retain both the raw score and the eligibility mask so an independent auditor can reproduce the decision. For inference, freeze a detector on an exploratory source set, then evaluate it on a reserved collection containing known-code bursts, impulses, mixtures and no-source conditions. The trials should be blinded or coded so the evaluator cannot favour the correct answer. When the detector searches many codes or offsets, calibrate the maximum statistic or another declared global error measure under the full search rather than assuming the one-test significance survives selection. Preserve unsuccessful as well as successful synthetic cases and give confidence intervals that recognise repeated correlated trials. A detector that performs well on isolated bursts but fails during overlapped impulses has a bounded operating envelope. The proper statement is not that it detects spread spectrum with the isolated-test success rate under all conditions. Report performance by input level, impulse amplitude, timing overlap, receiver gain and channel response. If a strong pulse saturates the analogue front end, the event may be ineligible rather than a clean negative communication result. Software can record and classify the invalid state, but it cannot reconstruct information clipped before digitisation. No high correlation should be

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promoted to source attribution until the measurement chain and the complete search have survived independent challenge.

Dr. James M. Atkinson, Moderator: Dr. Shannon, thank you. Dr. Hamming, kindly accept the token and explain how a software and evidence chain can discriminate a defensible hypothesis from a reproducible but selected correlation accident.

Richard Wesley Hamming, Third Principal Contributor: A detection algorithm is a sequence of decisions made about data, and every one of those decisions has a provenance. When an examiner claims to have distinguished a weak spread-spectrum burst from a broadband impulse, the software should be able to show what data were eligible, which reference features were applied, what thresholds had been prescribed and how the competing hypotheses were evaluated. A perfect hash of a flawed data file merely establishes that the flaw has been preserved unchanged. A perfectly repeated computation of an overfitted classifier merely repeats the same error. The audit must examine physical measurement, digital continuity and statistical selection as three distinct layers. The raw record is not just an array of complex numbers. It includes a sample clock, frequency plan, tuning state, gain-control history, channel filters, sample counters, overrange flags and any editing or interpolation applied after acquisition. A high-amplitude discharge can saturate a converter for several samples and provoke gain recovery lasting longer than the physical discharge. If the software reconstructs the missing interval with zeros or repeats a previous buffer, it can introduce a pattern that resembles an encoded burst. The investigator must preserve invalid-range masks and prevent code correlation from treating reconstructed samples as actual radio

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observations. An event scored during such a gap is an instrumentation-quality finding, not a valid source classification. A useful software gate begins by verifying counter continuity and source metadata. Each block's first count should follow its predecessor as expected, unless an explicit discontinuity is recorded. Its byte size should agree with the sample format and declared number of samples. The timestamp should be consistent with the independent clock calibration to within a stated tolerance, and changes in decimation, digital filters or frequency correction should be recorded. The original samples and the exact analysis version should remain immutable; a corrected analysis creates a new derivative, not an overwritten record. If the instrument captures two overlapping channels, their respective clocks and delay corrections must be documented before event alignment is treated as evidence. Once eligibility is established, test the algorithm with known sequences for which its expected behaviour can be independently calculated. A noise-only complex sequence should not regularly generate an above-threshold score when the threshold has been calibrated for that null and complete search. An exact known 127-chip reference with matching phase and timing should produce the expected coherent accumulation under the stated model. A single large impulse should test whether normalisation, clipping handling or the correlator creates a false matched response. A periodic impulse train and a gated tone should be additional adverse sources. These cases should include both the raw analogue-chain capture and a software-generated test vector so hardware and code faults can be separated. The multiple-search problem is especially important because a family of pseudorandom codes contains many candidate patterns. If an analyst tries K sequences, T delays and F frequency

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corrections, the number of nominal test combinations is K times T times F, before considering multiple windows and antenna channels. These tests are generally correlated, so that product is not the number of independent trials, but it does describe a significant selection opportunity. An attractive peak found among ten thousand possibilities cannot be assessed with the probability applicable to a single fixed candidate. Calibrate the entire maximum-selection procedure through no-source and impulse-only records, or freeze the model from independent exploratory data and evaluate it prospectively. Another error arises when a software developer silently chooses a detector's acceptance window after viewing the most favourable synthetic results. A code-correlator may be optimised on isolated clean bursts until it reports an impressive detection rate, but that tells little about its behaviour when a strong impulse overlaps the burst or when the source clock drifts. The development set should establish the algorithm; a reserved evaluation set should estimate its performance. Include all specified trial conditions and record every exclusion, otherwise the reported success rate will merely reflect the easiest cases. Repeating the same selected trial many times does not create a new inference about the uncontrolled field environment. Consider a programme with 100 independently seeded synthetic test opportunities, of which 40 are known-code bursts, 40 are impulse-only events and 20 have no source. Suppose the detector declares 35 of the 40 coded trials positive, but also declares 8 of the 40 impulse-only and 2 of the 20 no-source trials positive. The sensitivity against the seeded coded class is 35/40=87.5 percent, and the false-positive fraction across the specified 60 non-coded trials is 10/60, approximately 16.7 percent. These two figures describe different denominators and different operational

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consequences. They do not derive from a real instrument; they demonstrate why an isolated sensitivity percentage is inadequate. The independence and uncertainty of repeated laboratory trials would also need assessment before attaching precise confidence intervals. Causation is distinct from pattern classification. Even if a known-code reference produces a high score, a common clock spur, a coupled laboratory test generator or an instrument's own firmware may generate that pattern. The operator should challenge the apparent source with a terminated RF input, a changed injection path, known attenuator positions and a second receiver architecture. A correlation peak that remains when the antenna input is terminated cannot be treated uncritically as an external emission. If it disappears after upstream attenuation, consider front-end overload as well as the possibility that a genuine weak signal has become undetectable. Each intervention must be interpreted within a measured sensitivity range. The final evidence table should keep observed event features separate from analyst hypotheses. It may state a frequency band, event duration, peak power, spectral-flatness value, correlation score, false-alarm calibration, acquisition validity and whether a known synthetic code was present in a controlled test. It should not infer the identity, intent or content of an unknown sender from those columns. Auditability is not achieved by a long list of instrument serial numbers alone; it requires preserving the decision pathway and the failures that limit interpretation. A defensible software system makes its uncertainty visible, rather than composing confidence out of incomplete samples and a beautifully formatted result page.

Donald Watts Davies, Peer Question: Dr. Hamming, a modern receiver can record samples in hardware and then transport them through multiple

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buffering and packetisation stages before a host computer writes the event file. A packet may arrive late or be dropped even though the radio-frequency front end was functioning normally. Conversely, a missing sample block may be concealed when the host fills the gap from a replay buffer, causing a spurious repeated sequence that correlates with a code reference. Would you distinguish loss of telemetry about a valid measurement from loss of the measurement itself, and identify the counters or checksums that would expose each? Please describe an experiment in which the transport network is intentionally loaded while the authorised synthetic RF source remains constant, and explain why timestamping a file after it is written does not prove that the recorded burst began at the asserted physical time. I ask also how the examiner should treat duplicated metadata that point twice to the same samples, since multiple event rows are not multiple physical observations.

Richard Wesley Hamming, Response: Mr. Davies, the path from the converter to the final file needs an explicit sequence of custody. A radio-frequency sample can be acquired correctly but delivered late to the application, and lateness need not make the sample content invalid if its hardware counter and data bytes remain intact. By contrast, a sample block lost before storage creates an actual gap in the recorded evidence; replacing it with a previous block or with interpolated values cannot restore the missing physical observation. A packet lost in the transport network may create either an unrecoverable sample gap or merely a delayed delivery, depending on buffering and retransmission. The instrument must distinguish these cases in its status record. Include hardware sample counters, producer and consumer buffer sequence numbers, packet

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identifiers, checksums where appropriate, and explicit overrun and underrun flags. Tie time to the sampler or another traceable acquisition clock, not to the time the host happened to flush a file to disk. A file-system timestamp documents a storage operation; it cannot provide a reliable emission time if buffering latency is variable. Clock offsets, discipline state, and conversion between hardware ticks and physical seconds must be recorded with uncertainty. In a multi-receiver system, counters may be incomparable unless their timebases have been measured against a common reference. An authorised stress test holds the synthetic source constant while varying network load, disk pressure and application scheduling. Independently log every seeded burst from the generator. The receiver should preserve counters and event eligibility across ordinary delays, while flagging actual missing samples and forbidding a lag comparison that crosses a gap. Introduce a controlled repeated-buffer fault to test whether the detector can reject a fabricated correlation peak, then remove the fault and confirm that the reference source remains detectable. A separate test uses no RF source so that transport artefacts can be identified without ambiguity. Every reported detection should point to the raw sample ranges that support it, along with the acquisition configuration and analysis version. If an event's timestamp is uncertain because counters were not synchronised, the uncertainty must be widened rather than silently corrected by aligning it to a convenient external event. A checksum of the stored file remains useful for proving that the bytes have not changed since sealing, but it cannot prove the bytes originated from an uninterrupted analogue capture. The distinction between a valid late measurement and a

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missing measurement is the foundation of any later claim about code timing or impulse duration.

John Wilder Tukey, Peer Question: Dr. Hamming, your test programme reports sensitivity and a false-positive fraction, but real impulsive environments are highly heterogeneous. A few severe discharges may produce many correlated apparent events, while long quiet intervals contribute thousands of easy non-events. If the evaluator chooses only balanced illustrative trials, the resulting false-alarm figure may not represent a different field survey. How should performance be stratified by impulse amplitude, duration, receiver gain and overlap with a known code burst? I ask whether a blind holdout set must include ordinary negative observations as well as unusually conspicuous interference, and how the analyst should disclose an exploratory classifier whose thresholds were repeatedly adjusted after examining the failures. Please explain why a single pooled accuracy figure is insufficient when a forensic conclusion depends upon very rare false identifications. Would a bootstrap that resamples individual pulses independently understate uncertainty when those pulses occur in strongly correlated bursts of electrical switching activity?

Richard Wesley Hamming, Response: Mr. Tukey, the evaluative population must match the claim being made. A balanced laboratory set can be useful for comparing mechanisms, but its prevalence of coded and non-coded events does not automatically represent the probability of such sources in a field investigation. The laboratory should report class-conditional performance separately, including sensitivity for seeded coded bursts and false-positive probability for specified impulse classes, under defined receiver conditions. If an operational prediction depends on the prevalence

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of these classes, the prevalence assumption must be stated rather than smuggled into one pooled accuracy number. Stratify the challenge by input power, impulsive peak amplitude, recovery duration, spectral concentration, antenna path, receiver gain state, code-burst SNR and relative timing of impulse overlap. Use prespecified ranges selected from defensible engineering limits. An aggregate number may be supplied with explicit weights for a stated operating scenario, but the underlying stratified results should remain available. A detector may distinguish clean isolated pulses well and fail under a brief overload at a particular gain, which is precisely the failure a high-stakes defensive survey must disclose. An unweighted mean across unrelated test conditions can conceal that limitation. A blind holdout should include ordinary negative observations, controlled impulse-only events, known-code bursts, and mixtures. If events are clustered in time or arise from repeated operation of the same source, confidence intervals must reflect that dependence rather than treating every recorded pulse as an independent trial. The analyst should freeze thresholds and reference hypotheses before evaluating the holdout. When failures provoke threshold changes, the previous holdout becomes part of development, and a fresh reserved set is required for an unqualified evaluation. Otherwise describe the revised result as exploratory. Rare false identifications deserve particular attention. A false-positive rate that appears small per event can become troublesome when the detector searches millions of windows, codes and frequency corrections. The calibration needs to account for the full candidate-selection process and the actual eligibility rules. Report the number of negative opportunities examined, their correlation structure and uncertainty bounds. If the available data support only an upper confidence

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bound too large for the proposed forensic use, the appropriate outcome is a limitation on that use, not an optimistic extrapolation. A good classifier is defined by the exact claims its evidence can sustain, not the elegance of a single percentage on a dashboard.

Richard Wesley Hamming, Cross-Peer Question to Ronald Newbold Bracewell: Dr. Bracewell, software correlation can create a seductive match when a receiver is overloaded or when the sampled interval contains a broad impulse shaped by the receiving filter. Your antenna and Fourier expertise offers an independent physical challenge. How would you use separated antennas, known impulse injections, bandpass variation and time-aligned reference captures to distinguish a true externally radiated coded burst from a local switching transient or an internally generated mixer product? I should like you to address the danger of treating two receivers on one shared antenna distribution amplifier as independent witnesses. Specify what a cross-correlation between receiver records proves, what it cannot prove, and how one might use controlled source movement or attenuation without accidentally changing the receiver sensitivity enough to conceal a genuine weak spread-spectrum signal. What should the audit say if the winning correlation peak appears only after analysts changed their exclusion rules for saturated samples in response to the initial result?

Ronald Newbold Bracewell, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, the first principle is to separate the spatial inference from the temporal-code inference. An impulse may be visible at two antennas because it is a real radiated disturbance; that fact does not make it encoded. Two receivers attached to a common distribution amplifier may share an internally generated harmonic or clipped broadband product, so

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simultaneous indications do not by themselves establish a source outside the system. Construct a signal-path diagram identifying all common oscillators, front-end stages, clocks, cabling and grounds, then challenge the common stages with terminated-input and known-source tests. Place a lawful synthetic coded source and a calibrated impulse source at known test positions. Record their actual launch times and input strengths independently. Measure each antenna's frequency-dependent directional gain, cable loss and polarisation so amplitude ratios can be interpreted conditionally. A source moved through known positions should produce predictable changes in path loss and directional response, subject to near-field and multipath complications. A disturbance that remains fixed in the instrument despite such changes may be local to the receiving chain, though absence of change is not conclusive when the radiation geometry is complex. Vary the bandpass and input attenuation in controlled steps. An impulsive source convolved with the receiver's impulse response may change its observed duration and oscillatory tail as the filter changes; a coded burst may also be distorted, so comparisons must use known reference captures. Put attenuation ahead of a suspected nonlinear stage, not only after it. If a false wideband feature collapses with upstream attenuation and displays nonlinear input-power scaling, consider overload or intermodulation. At the same time use an independently seeded weak coded reference to quantify the sensitivity sacrificed by the attenuation. One must not declare an artefact removed merely because the entire receiver has become deaf. Time-align the two receiver records with measured clock uncertainty before interpreting cross-correlation peaks. A shared burst or impulse may yield a relative-delay estimate, but the estimate's ambiguity

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can be influenced by narrow bandwidth, multipath and common clock errors. Repeat with an independent receiver architecture and, where possible, independent clocks. Present the code-specific detector score and the spatial coincidence as different observations, each with its own null model and limitations. Strong agreement can support a shared physical event; only an additional validated, code-specific test supports the narrower hypothesis of a particular synthetic spreading structure. Neither supplies message content or authenticated sender identity.

Dr. James M. Atkinson, Moderator: Dr. Hamming, thank you. Dr. Bracewell, I now pass the token for a fuller examination of antenna geometry, impulse spectra, receiver convolution and the differences between physical corroboration and modulation identification.

Ronald Newbold Bracewell, Fourth Principal Contributor: Broadband energy should be analysed as a physical field observed through an imperfect spatial and spectral aperture. The receiving antenna is not a neutral funnel into the instrument. Its directional response, polarisation, impedance, coupling to nearby structures and frequency dependence determine which parts of the field are captured and how strongly. A lightning impulse, an electrostatic discharge near a cable, a switching power supply and an intentionally coded radio source may each excite the measurement chain differently. Yet they can all leave bright short-duration traces across numerous frequency bins when their waveforms are convolved with the front-end response. One must not confuse the shape of that response with the spectrum of the source that caused it. The Fourier transform of a short pulse illustrates the problem. A rectangular voltage pulse of duration T has, under an idealised convention, a magnitude spectrum proportional to the absolute value of sin(pi f T)/(pi f),

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after appropriate scaling. A sufficiently brief pulse therefore extends its energy across a broad frequency region, with lobes and nulls shaped by its finite duration. Rise time, fall time, circuit parasitics and the receiver bandwidth alter that picture. A code-bearing burst can also be broad, but its breadth is introduced through intentional temporal modulation or frequency variation. The shared property of broadband energy cannot distinguish those causes. An impulse-spectrum calibration is consequently as important as an ordinary swept-tone calibration when the instrument is used to classify short events. A lawful laboratory test should characterise the impulse response of the entire receiver path. Connect a calibrated impulse generator at a stated reference plane, keep the gain within its verified linear region and record the resulting I/Q or envelope samples. Repeat at several impulse amplitudes and front-end filter settings. The observed ringing and spectral flatness can then be compared with a separately injected known-code spread burst of similar total received energy. Both references must be independently logged. A high correlation score obtained from one test does not make the other impossible, because the filters and correlation search may create accidental matches. The meaningful evidence is the difference between predictive behaviour under the two controlled source models. Spatial observations offer another set of predictions, but no absolute verdict. Place two calibrated antennas at known positions and orientations, connected to receivers whose timing offsets have been measured. For a far-field wavefront in a sufficiently simple environment, a relative arrival delay may be related to the path difference divided by wave propagation speed. In a building, however, reflections, near-field coupling, cable paths and common-mode currents can violate a simple plane-wave model. A discharge

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coupled directly into the receiver power cable may be nearly simultaneous in both recorders without representing an external far-field emission. The antenna arrangement and grounding architecture should therefore be documented in the same detail as the digital analysis. Change the test geometry prospectively. A directional antenna rotated by a known angle should change the response to a radiated source according to its measured pattern, while a disturbance injected downstream of the antenna may remain largely unaffected. Move the known synthetic source through a small set of authorised positions and log the resulting amplitude and timing changes. Then repeat with a local impulse source and, separately, with the RF inputs terminated. The observed class signatures should be compared against predictions prepared before the trials. A difference caused by moving an antenna supports a spatial mechanism but does not by itself prove that the source used a spread code rather than being a broadband discharge in the environment. The receiver's nonlinearities can defeat spatial interpretation. A strong interferer picked up by both antennas may create intermodulation products in a shared amplifier, and those products can appear in multiple frequency channels. If the examiner sees the same false feature in two receivers fed by that amplifier, the agreement is not independent. Insert calibrated attenuation ahead of the common nonlinear stage, or bypass the stage entirely, while retaining a weak known reference to measure the sensitivity cost. Change the receiver's mixing plan and preselector, then compare the apparent frequency of the feature. A product that follows the conversion architecture rather than the calibrated external source frequency is a plausible instrument artefact, though coincident external signals must still be considered. Signal-to-noise ratio deserves the

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same discipline. A deliberately spread burst can have modest per-bin power yet contain enough coherent energy to be recognised with a correct authorised code reference. But wideband amplitude alone cannot provide that recognition. An impulse can deliver enormous energy for a tiny interval, potentially driving an automatic gain loop into recovery and making subsequent events appear short or absent. A survey that integrates only accepted positive bursts may conclude that the source transmits intermittently when the receiver is actually blinded intermittently. Record front-end overload, gain-control state, detector dead time and exact eligible intervals. Without those measurements, a low observed peak is not proof that a source was absent, and a large peak is not proof that the source was communicative. The investigator should also distinguish independent observations from repeated processing. A correlation map, a spectrogram and a spectral-flatness estimate derived from one I/Q record are three analytical descriptions of one physical capture. They can test internal consistency and expose different alternative mechanisms; they are not three independent witnesses. A second receiver adds evidence when it supplies genuinely distinct hardware and calibration, but common clocks, antennas and shielding defects may link their errors. A controlled source whose class is independently known provides stronger validation than a collection of methods applied to the same unknown burst. My concluding claim is deliberately narrower than an identification. If a particular known synthetic code produces a calibrated correlation response, if the response survives lawful changes in antenna geometry and front-end state, and if representative impulses and no-source controls do not mimic it at the declared operating threshold, the instrument has demonstrated some

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discriminatory capability for that test class. An unknown brief event may then be described as compatible with a spread-spectrum construction, subject to the measured limitations. It has not been attributed to a particular transmitter, decoded or shown to be intentional. The expert must describe the spatial, spectral and temporal apertures that made the observation possible before the coloured trace can be given any forensic meaning.

Andrey Nikolaevich Kolmogorov, Peer Question: Dr. Bracewell, the physical controls are persuasive, but the statistical design still worries me. A test campaign may use many antenna angles, filter bandwidths, input powers, detector thresholds and code references before retaining only the combination that distinguishes its synthetic training sources most impressively. Even without an arithmetic mistake, this selection can produce an overoptimistic performance estimate. How would you preserve the experimental search and still permit engineering exploration? Please distinguish a null distribution obtained from independent impulse-only trials from one obtained by shuffling individual samples of a coloured receiver record, since the latter may destroy precisely the dependence that causes false correlation peaks. I should also like a statement of how correlated repeated impulses from one switching mechanism differ statistically from independent trials across distinct operating conditions when a confidence interval is constructed. Please distinguish a legitimately calibrated impulse-source spectrum from the spectral width obtained by simply changing a receiver display window or frequency resolution.

Ronald Newbold Bracewell, Response: Dr. Kolmogorov, the experiment must be designed so that exploration, calibration and evaluation are not

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confused. Exploratory trials can map which antenna geometries, filters and detector settings respond to the candidate sources. They should be retained with enough detail to show how the final detector was selected. A separate calibration collection can estimate the null distribution under defined no-source and impulsive interference conditions, while a reserved evaluation set tests the frozen algorithm and the declared operating point. If the evaluation results prompt further changes, those results become part of development and a new independent assessment is required for a confirmatory performance claim. The null should reproduce the dependence created by the physical receiver. An independent impulse-only capture through the same filters and gain configuration is stronger evidence about field false alarms than an artificial sequence obtained by randomly scrambling individual recorded samples. Such scrambling destroys temporal colour, filter ringing and clustering, potentially producing a null distribution with far fewer accidental peaks than the actual instrument. Block resampling or a source-specific simulation may preserve some dependence, but its assumptions and block scale must be validated against separate data. A threshold derived from a white independent-noise model cannot be transported uncritically to a pulse-rich industrial environment. Correlated switching impulses require care in uncertainty analysis. One hundred pulses emitted during one repeated switching cycle may share temperature, voltage, cable geometry and receiver state; their detection outcomes are not necessarily one hundred independent Bernoulli trials. Stratify or cluster observations by source episode and laboratory condition, and present performance across independent runs where possible. A confidence interval based solely on the count of individual pulses may be too narrow.

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Randomise safe source timing and vary conditions prospectively so that the detector is challenged outside the precise circumstance in which it was tuned. The physical controls should also be held constant or varied according to a declared factorial design, rather than changed opportunistically whenever the detector fails. Record the input-plane levels and calibration uncertainties for each antenna and filter configuration. If a genuine weak known-code burst disappears after upstream attenuation, quantify that sensitivity loss before claiming that the attenuation has removed only spurious interference. A fair evaluation presents detection and false-alarm rates by relevant conditions and does not conceal hard cases in a convenient pooled percentage. A defended classification requires both the physical transfer-function story and the statistical selection story to survive independent examination.

Ronald Newbold Bracewell, Cross-Peer Question to Ralph Vinton Lyon Hartley: Mr. Hartley, I have described how the same broadband flash can arise from a discharge, a spread signal or a common receiver artefact. The field team must now decide what it can report after hours of recordings in which only some frequency-time cells were observed and the receiver occasionally blanked under strong impulses. Would you define the observation denominator so that absent detections are not confused with absent emissions? Please propose a reporting scheme that distinguishes a measured event, a coded-waveform hypothesis and a transmitter attribution, with uncertainty carried through each stage. I should also like the record to accommodate incidents where a known impulse source and an authorised coded reference overlap, causing a genuine code to be missed or a false score to appear. How would that ambiguity be stated without

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flattening it into a simple positive or negative label? Would you also separate a receiver aperture that never visited the emission frequency from an aperture that was visited but had insufficient input sensitivity to classify it?

Ralph Vinton Lyon Hartley, Cross-Peer Answer to Ronald Newbold Bracewell: Dr. Bracewell, the denominator is the set of frequency-time opportunities in which the instrument was capable of detecting the specified class under the stated performance criterion. An event not observed because the receiver was tuned elsewhere, saturated, recovering its gain or missing a sample block cannot fairly be counted as an exposed negative trial. For the complete survey, however, those losses still matter: report both overall capture opportunity and conditional detector success. The two measures answer different questions. A record of all eligible and ineligible intervals, with reasons and known reference-source truth where available, prevents a clean-looking event list from concealing systematic blindness. I would separate the report into three columns of inference. The observation column gives timestamps, valid frequency and bandwidth, measured amplitude, duration limits, detector statistic, noise reference, receiver state and calibration uncertainty. The structure-hypothesis column records which synthetic models were tested, their selection history, the null calibration, competing impulse explanations and the strength or weakness of the evidence. The attribution column remains empty unless independent source-localisation, physical or other lawful evidence supports it; a high processing-gain score alone does not fill it. A fourth administrative column may preserve chain of custody and reviewer qualification, but it must not be mistaken for scientific support. When an impulse overlaps a known coded

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reference, distinguish whether the receiver captured valid samples. If overload invalidated the interval, mark the classification technically indeterminate while retaining the independently logged fact that the laboratory generator transmitted. If the samples remained valid but the detector failed, that is an observed detection failure under the declared mixed-source condition. If a high code score appears during an impulse-only reference trial, it is a false-positive challenge requiring investigation of code search, filter memory or other structure. These distinct cases can be aggregated only with explicitly defined denominators and a stated purpose. An uncertainty statement should reflect more than random noise. It includes input-level calibration, antenna and filter response, missed observation opportunities, clock alignment, nonlinear receiver states, model selection and the possibility of untested source classes. The final sentence may say that the observed event exhibits features more compatible with a known laboratory spread-source model than with the impulse controls examined, while acknowledging what those controls do not exclude. It should not say that a covert transmitter has been found because a brief broadband trace looks unusual. Accurate reporting is the discipline that makes a limited measurement useful in an adversarial scientific or legal review.

Dr. James M. Atkinson, Moderator: Dr. Bracewell, thank you. Mr. Hartley, the token passes to you for a final treatment of observation denominators, the distinction between information structure and source identity, and the exact language of a defensible report.

Ralph Vinton Lyon Hartley, Fifth Principal Contributor: The observer's record must distinguish an occurrence from an opportunity to observe it. A

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wideband burst may last only a fraction of a millisecond, while a scanning receiver visits different frequencies in a schedule that leaves most channels unobserved at any given moment. A receiver with sufficient instantaneous bandwidth can reduce some gaps, but it may still blank during retuning, overload, processing pressure or other invalid states. A detector's silence in those intervals is not evidence that the physical environment was silent. Before presenting the fraction of bursts attributed to any waveform class, the examiner must show what portion of the relevant time-frequency domain the apparatus could have evaluated under its calibrated sensitivity limits. I propose three clearly separated counts in a controlled synthetic test. Let N_truth be the number of independently logged laboratory emissions, N_exposed those emissions intersecting a valid receiver aperture with sufficient input level for the declared test class, and N_positive those exposed emissions classified correctly by the frozen detector. The ratio N_exposed/N_truth describes the tested observation opportunity under the chosen generator schedule; N_positive/N_exposed describes a conditional detection fraction, provided N_exposed is nonzero. Their product is N_positive/N_truth in that synthetic model, but the factors diagnose different failure mechanisms. A field investigator ordinarily lacks N_truth for unknown sources, so these ratios must not be invented from positive detections alone. The calibration experiment establishes conditional instrument performance, not the count of unseen emissions. The instrument's event categories should reflect this logic. A valid positive coded-reference score is different from a broadband impulsive detection without code support. An invalid interval caused by clipping is different from a valid no-detection interval. A burst whose onset precedes the receiver

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aperture is left-censored; one continuing beyond the aperture is right-censored. A short observed duration may therefore reflect the sampling gate rather than the source's physical duration. These distinctions can alter spectral-flatness estimates and code correlations because the algorithm may evaluate only a fragment of the intended chip sequence. Report the measured segment and the bounds on full duration, rather than implying complete knowledge of an event the receiver did not observe from beginning to end. Information conveyed by a signal is also different from the appearance of information-bearing structure. A synthetic pseudorandom code may serve as a spreading sequence without revealing any substantive message to a defensive observer. The geometric flatness of a spectrum, the event's kurtosis or a high autocorrelation can be measured without accessing content, yet none uniquely identifies a communication. An impulse generator and a switching power circuit may produce broad, apparently noise-like spectra, while intentional communication may be narrowband or not match any of the laboratory's reference codes. The examiner should therefore describe the candidate family tested and its alternatives rather than speaking of communication merely because an event is unusual. The simplest controlled example contains a 127-chip coded burst and a broadband impulse of comparable total energy as measured at the receiver reference plane. That equality of total energy does not imply equal peak amplitude, converter overload risk or spectral power density. The impulse may have a very large peak over a tiny interval and drive the first amplifier into nonlinearity. The code source distributes its energy over the chip duration and may be detectable with a correct coherent reference even when no individual bin exceeds a convenient visual threshold. Any

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calculation of an ideal twenty-one-decibel processing gain must specify what SNR is compared, and it cannot repair a lost or clipped measurement. A meaningful test records total energy, peak amplitude, code score and acquisition validity separately. Another source of error is sampling opportunity selected by the detection algorithm itself. Some recorders retain only events that cross a broad energy trigger; a low-density coded burst may never be saved even though an offline matched filter could have recognised it from continuous valid I/Q. A powerful impulse, by contrast, may trigger readily and dominate the retained archive. The observed ratio of impulse-like to coded-like events would then reflect both the actual environment and the recording policy. Calibrate trigger probability with controlled sources and preserve the full eligibility record. Do not compare a wideband energy-triggered event table with a continuously sampled code-correlation result as though both arose from the same observation denominator. A formal inference should preserve the distinction between model compatibility and sender attribution. A candidate event may be consistent with several different waveform families after filtering, clock uncertainty and impulsive interference are considered. A validated known-code detector can support a specific reference structure when the source is authorised and its reference is independently established. Unknown sources remain ambiguous because similar detection scores can arise from untested codes or chance selection across a large bank. Attribution to a particular physical transmitter requires independent localisation, authorised inspection, source-control tests or other evidence beyond the spectrum. An event recorded in a conference room does not, by its location or apparent sophistication alone, identify a person or intention. The report's vocabulary

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must be stable across all conditions. 'Observed' should refer to measured eligible sample evidence. 'Consistent with' should refer to a stated model and defined alternatives. 'Confirmed' should be reserved for a prespecified independent test whose error rates are understood. 'Attributed' requires a separately supported physical-source inference. The same report should preserve conflicting findings, null intervals, failed laboratory trials and limitations of the instrument. A table that gives every entry a single confident label may be attractive to administrators, but it sacrifices the distinctions necessary for scientific and legal scrutiny. The final result should be proportionate to the evidence: a short broadband transient was observed during a specified valid receiver interval; its measured duration, spectrum, amplitude and correlation statistics lie within stated uncertainties; certain authorised synthetic tests favour or disfavor a spread-source hypothesis relative to the tested impulse models; receiver artefacts and other alternatives are either excluded to a stated extent or remain unresolved. This statement can be valuable even when it withholds a transmitter identity. It creates a reproducible record of what the instrument actually saw and what the experiment was capable of saying. That is a stronger form of technical knowledge than a dramatic but unsupported assertion that all unusual energy must have originated from a covert communication.

Egon Sharpe Pearson, Peer Question: Mr. Hartley, your proposed report distinguishes observation opportunity from detection performance, but its practical decision may still depend on the tolerated risk of a false accusation. A field investigator might regard one high detector score as sufficient to recommend a costly intrusive investigation, while another requires independent corroboration and several adverse controls. How should the

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report separate the measured false-positive probability for one prespecified synthetic test from the probability of one or more false candidates across a long survey containing millions of overlapping windows? I ask you to address the consequences of correlated trials, selective reporting of the strongest events, and changes in the operational threshold after an alarming indication has been seen. What would constitute an appropriately cautious evidential decision rule when the prevalence of intentional spread-spectrum emitters in the surveyed environment is unknown? I should also like your view on the practical distinction between approving a follow-up lawful survey and publicly asserting that a particular covert transmitter has been demonstrated.

Ralph Vinton Lyon Hartley, Response: Mr. Pearson, the acceptable error risk belongs to an explicitly stated decision problem rather than to an unexamined detector score. A false-positive probability calibrated for one fixed code, alignment and interval is not the same as the probability of a false event somewhere in a large search. Repeatedly examining overlapping windows produces dependence, so the nominal count of comparisons is not necessarily a count of independent tests, but selection among them still changes the distribution of the reported maximum. Calibrate the whole screening procedure under realistic no-source and impulse conditions, including its exact thresholding, event aggregation and ranking rules. A report that retains only the strongest alerts cannot borrow a per-window error probability without accounting for that selection. The threshold should be frozen before evaluating reserved data. If an alarming event prompts the analyst to lower or raise the threshold, the resulting score is exploratory and should be labelled as such. A prospective follow-up capture, controlled

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physical challenge or independent receiver can provide new evidence, whereas repeatedly analysing the same selected sample cannot create independent confirmation. The laboratory should measure how often an impulse-only or no-source trial produces a candidate requiring review, not simply how often the final classifier distinguishes two conveniently balanced test classes. Unknown prevalence presents a separate difficulty. Even a detector with a low class-conditional false-alarm rate may generate mostly false alerts when genuine coded sources are rare, but an exact positive predictive value cannot be computed without a justified prevalence assumption and representative class performance. Therefore the report should avoid a posterior probability of intentional transmission invented from a detector threshold. Present conditional test characteristics, ranges under stated prior scenarios if genuinely useful, and the evidence that independent controls add. The decision to authorise a further lawful investigation may be based on risk management and the seriousness of the environment, but that policy judgement must not be described as a scientific identification of a source. I would use staged decisions. A first tier identifies an unresolved broadband event requiring instrument checks. A second tier tests the declared spread-source hypothesis against impulse, clock, overload and environmental alternatives using frozen criteria and reserved observations. A third tier addresses physical attribution only with suitable independent evidence. Each tier records its own error controls and outstanding uncertainties. If the event occurs in an ineligible interval or only survives a retrospective search, it should not graduate to a stronger evidential category. The best decision rule is one whose scientific claim and

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operational consequence remain visibly separate, so a cautious investigative response does not imply more certainty than the measurements warrant.

Dr. James M. Atkinson, Moderator: The roundtable has shown that brief broadband energy is not self-identifying. A known-code matched filter may distinguish an authorised synthetic spread source from selected impulse controls under measured assumptions, but its ideal processing-gain arithmetic cannot be transported to a clipped or uncalibrated receiver. We have considered finite-window spectral leakage, impulse response, gain compression, sample integrity, search multiplicity, antenna correlation, observation opportunity and false attribution. I thank each contributor for the respectful passage of the token. The defensible conclusion is a bounded waveform-structure hypothesis with stated controls and uncertainty, not a claim to have decoded communications or identified an unknown sender.

SOURCE REGISTER. Claude E. Shannon, “A Mathematical Theory of Communication,” Bell System Technical Journal 27 (1948), 379–423, 623–656; Harry Nyquist, “Certain Topics in Telegraph Transmission Theory,” Transactions of the AIEE 47 (1928), 617–644; Richard W. Hamming, “Error Detecting and Error Correcting Codes,” Bell System Technical Journal 29 (1950), 147–160; David Slepian, “Prolate Spheroidal Wave Functions, Fourier Analysis, and Uncertainty. V: The Discrete Case,” Bell System Technical Journal 57 (1978), 1371–1430; J. R. Andrews, “Impulse Generator Spectrum Amplitude Measurement Techniques,” IEEE Transactions on Instrumentation and Measurement IM-25 (1976), 380 onward, available through NIST; Nicholas Paulter and Donald R. Larson, “Measurement of Impulse Spectrum Amplitude for Use in EMI Susceptibility Tests” (2006), NIST; Ezra B. Larsen, “Calibration of Radio Receivers to Measure Broadband Interference,” NBS IR

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73-335 (1973), DOI 10.6028/NBS.IR.73-335. The latter sources supply laboratory impulse-calibration background and are not writings by the imagined roundtable participants. The historical dialogue is fictional. Full claim-by-claim source verification remains a separate Stage B task.

EDITORIAL QUALIFICATION. All trial counts, source parameters, waveforms and numerical examples are hypothetical and must not be mistaken for field measurements. A code-specific score in an authorised synthetic test does not constitute source attribution, message decoding or proof of malicious intent. Receiver overload, dependence across searched hypotheses, environmental impulses, source prevalence and incomplete acquisition remain express limitations.

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QUESTION 086

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How should beacon-like repetition be described without assuming a named protocol?

SCHOLARLY RECONSTRUCTION. The named contributors were historical experts, but this dialogue is a fictional editorial reconstruction and represents neither their actual speech nor their endorsement. All cited experiments are proposed, authorised laboratory comparisons, not recovered protected traffic or proved attributions.

Dr. James M. Atkinson, Moderator: Dr. Elias, please examine what can and cannot be inferred from recurring burst times when the presumed beacon protocol is unknown. The observations, not the resemblance of an interval to a familiar timer, must determine the scope of the claim. You have the token.

Peter Elias, Principal Contributor: A beacon-like observation is a statement about the measured recurrence of events, not a finding that any particular published communications protocol is present. One may detect bursts of similar duration with intervals clustering near a common value, but the inference initially concerns only the observation process: an energy event satisfied a declared threshold, at a recorded frequency, during a period in which the receiver was capable of observing it. The signal may be a deliberate scheduled transmission, a supervisory control message, a periodic environmental disturbance, or an artefact of a detector that records the same broad source only at its own revisit instants. A field report ought therefore to use language such as 'approximately recurrent bursts with an estimated interval', accompanied by the eligibility and timebase qualifications, rather than 'beacons from system X'. The latter assertion is a

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hypothesis about function and format for which intervals are rarely sufficient evidence.

A first mathematical description is $t_i = t_0 + iT + e_i$, where t_i denotes the measured arrival time for the i-th physical event, t_0 an epoch, T a nominal period, and e_i the aggregate deviation. Yet the model conceals several mechanisms. If e_i is independent timing jitter, neighbouring intervals are correlated because both contain one shared error term with opposite signs. If the oscillator drifts, the apparent T changes gradually with elapsed time, and the residuals under a constant-period fit acquire structure. If events are missed, the observed difference $t_{i+1}-t_i$ can resemble twice or three times T even when no source changed its schedule. If a receiver scans intermittently, the observed event list is not simply the original list with random entries removed: observation probability depends on the phase of the scan and of the possible emitter schedule. The apparent pattern may be imposed by their interaction. Thus one must keep distinct the source clock, the receiver clock, the event-detection logic, and the chosen representation of detected timestamps.

The experimental programme should employ two controlled emitters. A laboratory reference may radiate a purposely declared recurrent burst whose start times are independently recorded by a traceable trigger. A second, unlike transmitter should emit a periodic industrial-control-like test burst with a similar nominal interval, equalised duration and occupied bandwidth, and carefully controlled received power. These are authorised, synthetic test emissions, not interception of protected information. A blind analyst should classify the two sources only using permissible timing and envelope observations, with instrument identities concealed until the

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analysis is frozen. The important result is not whether the analyst can invent an attractive story around each record. It is whether the declared features discriminate two engineered alternatives whose schedules were deliberately made similar, and whether performance persists when nuisance conditions are changed. Equal timing can occur in unrelated devices, which is a direct counterexample to identity attribution.

Timer quantisation deserves its own analysis. Digital equipment may schedule activity in integer ticks of an internal clock. An apparent sequence of intervals clustered at integer multiples of a basic step might arise from operating-system scheduling, a controller polling loop, a microcontroller timer, or the receiver event logger's timestamp resolution. Let q be the candidate step duration and let r_i be the interval's residual after subtracting its nearest multiple of q. A small dispersion in r_i is evidence compatible with a quantised timing process, but only after showing that the measurement timebase and reporting software have substantially finer effective resolution than q. It would be a serious category error to report q as an internal device property when the receiver merely rounds timestamps to that same quantum. Repeat the acquisition with a second independent timestamp system of verified resolution; vary its sample rate and logging settings. If the quantisation pattern follows the measuring system rather than the transmitter, the correct explanation is instrumental.

A useful report should provide the eligible observation window, number of detected starts, number and duration of receiver gaps, an estimate of event-time uncertainty, and a robust summary of intervals with a defined treatment of missing observations. It should include competing fitted models, residual plots, and an explicit description of intervals classified as

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apparent multiples of the proposed period. Retain bursts rejected by the detector, if the authorised raw evidence permits them to be revisited, rather than discarding all inconvenient cases. Distinguish a uniform period from a distribution concentrated around a period: the former would require a considerably stronger account of clock stability and observation completeness. The confidence reported by an analyst should be tied to a stated comparison or predictive test, not to the visual regularity of a line of timestamps on a chart.

This is also a lesson about codes in their broad engineering sense. A repeated timing pattern can be an economical way to organise communication, but repetition is not unique to communication and is not itself a message-decoding result. A periodic signal can be generated by a motor controller, a test instrument's housekeeping function, a thermal feedback loop or an intentional laboratory reference. Some will carry data; others will not. The evidential conclusion can legitimately be that a recurring radio-frequency event has been observed and characterised. Only further independent measurements of waveform structure, authorised contextual records, physical controls and lawful investigation can narrow function or source class. Until then, the unidentified event should remain unidentified even if its timing is strikingly regular.

John Wilder Tukey, Peer Question: Dr. Elias, your periodic-event model seems elegant because a handful of timestamps can be placed on a straight line with residuals of only a few milliseconds. Yet an investigator might select the apparent period after trying dozens of candidate lags, excluding troublesome events as false positives, and changing the time window until the residual plot looks persuasive. In a long monitoring record almost every

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innocent random process may contain a short stretch that appears orderly. How should the analysis disclose the entire search undertaken, and how would you define a test which is not contaminated by selecting the most favourable subsection? I also ask how you would present the uncertainty of a period estimate when gaps conceal an unknown number of missing physical emissions. An attractive least-squares slope cannot make those latent event counts disappear. Would you insist upon a separate validation interval, and what exactly should be frozen before that interval is inspected? The evidential danger is post-hoc regularity masquerading as an independent discovery.

Peter Elias, Response: Mr. Tukey, I would first construct an unedited event register that records the initial threshold, operating frequency, detector version, sample eligibility, acquisition interruptions and each event's timestamp uncertainty. Then I would create an analysis ledger: every candidate period, permitted integer-multiple assignment, outlier exclusion rule, window selection, and parameter adjustment is entered with its reason. Such a ledger need not imply that exploratory work is forbidden. It makes the exploration visible and prevents an optimised hypothesis from being mistaken for one specified before observing the evidence. A polished final graph that conceals a succession of rejected graphs is not an adequate scientific record.

The discovery set can be used to propose a period T, a jitter model, a procedure for assigning missed-cycle counts, and a residual statistic. Before another set is analysed, freeze those choices, including the rule by which an event is considered eligible and the allowable range of clock drift. An independent holdout segment should then test whether the model predicts

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arrival windows more successfully than specified alternatives, such as a clustered renewal process or the receiver's own revisit sequence. If operational conditions change between segments, record that fact and design the comparison to account for it. A threshold optimised on one afternoon's noise and used without qualification during another afternoon's interference is not a stable decision rule.

Unknown missing-cycle counts should not be silently rounded to whichever integer makes the period look best. For each observed gap g, consider plausible hypotheses $g \approx kT$ for integer k within a stated range, but preserve uncertainty where several k values fit within the error and drift limits. One may compare the resulting likelihoods under a transparent missing-event model, or restrict the estimate to contiguous intervals known to have complete observation opportunity. The latter is conservative but can be much more defensible. Report the number of ambiguous gaps explicitly. Confidence intervals derived as though every detected event were the next physical emission are misleading if the source can transmit while the receiver is elsewhere.

Finally, describe the claim at the level actually tested. A prediction that future authorised observations will exhibit near-T recurrence is narrower than an assertion that a named protocol is present. A successful holdout reduces the likelihood that the particular pattern was an accident of selecting a short segment; it does not remove the possibility that two unrelated devices share the schedule. I would publish both the successful predictive comparison and the failure of timing alone to distinguish the matched laboratory alternatives. That apparent negative result is valuable

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because it tells the investigator what additional type of evidence is genuinely needed.

Andrey Nikolaevich Kolmogorov, Peer Question: Dr. Elias, one may represent intervals as if their disturbances were independent, although a single oscillator introduces dependence from one interval to the next, and an environmental process may produce bursts whose intensities change with time. A detector that triggers on rising energy, settles into a refractory interval and later resumes may create a renewal-like event process of its own. What probability laws would you propose for the null hypothesis against which 'beacon-like' regularity is tested? How would you prevent a rejection of a naïve homogeneous Poisson process from being advertised as proof of deliberate periodic communication? There is also the mathematical matter of missing observations: if the probability of detection varies cyclically with receiver sweep position, the observed process is a phase-dependent thinning of an underlying process. Does your report require an explicit conditional detection function, and what measurements establish that function? I seek an inferential boundary between the stochastic structure that the events justify and the mechanism they do not identify.

Peter Elias, Response: Dr. Kolmogorov, there is no scientifically privileged null in which unrelated disturbances must be uniformly random in time. Many real mechanisms are periodic, quasi-periodic or self-exciting. It is consequently inadequate to test an observed interval sequence against only the exponential waiting-time law of a homogeneous Poisson process and label any rejection a 'beacon'. The rejection may merely identify environmental nonstationarity, a receiver refractory time, or a regular

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industrial process. The alternatives must be designed from the mechanisms that actually compete in the laboratory or investigated environment.

One candidate can be a jittered periodic process with timing residuals having a specified dependence. Another can be a renewal process with non-exponential waiting times. A third can be a clustered process whose event rate responds to a measured environmental covariate, such as industrial switching activity. A fourth is the physical emission schedule observed through a receiver whose acquisition window w(t) changes deterministically with sweep position. If p_det(t,a,b) denotes conditional probability of recording a physical event at time t with amplitude a and bandwidth b, the observed counts cannot be characterised without the interaction between emission and this detection function. Actual hardware measurements should bound p_det across the relevant dynamic range rather than treating it as a constant. The parameters of these alternatives must be estimated on authorised reference datasets with similar gaps and noise conditions.

It is useful to simulate each fitted alternative through the same receiver observation schedule and detector thresholds, not to simulate ideal physical events and compare them directly against a censored field record. The simulation must preserve the recorded dead periods and should account for timestamp rounding. The statistics then have meaning as properties of the entire measurement chain. Residual dependence can be tested using serial correlation and phase plots, but even statistically significant dependence need not identify its cause. Independence can fail because a real transmitter keeps time, because a receiver buffers events, or because a mechanical disturbance repeats after every control cycle.

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For a defensible conclusion, I would distinguish four statements: detected events recur more tightly than a specified comparison model; the recurrence persists under stated receiver-schedule controls; a source-driven periodic mechanism remains compatible with observations; and the function or identity of that source is not established. The first three may receive quantitative support. The fourth remains a boundary that statistics cannot cross unaided. A well-designed negative control is not a nuisance to the theory; it is one of the conditions that make the theory meaningful. In a report intended for forensic scrutiny, every such boundary must be visible alongside the numerical estimates.

Peter Elias, Cross-Peer Question to Claude Elwood Shannon: Dr. Shannon, the laboratory now possesses two independent authorised test sources whose event starts agree closely with a nominal interval of 250 milliseconds. One source carries a brief framed control message; the other emits a housekeeping pulse without a meaningful data payload. Their observable packet lengths and pulse envelopes are deliberately made similar. Our analyst has a timing model with excellent predictive residuals and believes that the match supports classification as a particular communications protocol. Could you distinguish timing redundancy from information content, and explain why the success of a temporal predictor does not amount to recovery of framing or coding rules? I ask also how one should handle an event sequence that is almost deterministic but contains sparse, possibly meaningful departures from its ordinary schedule. Such departures may carry information, but the observer has not shown that they do. What lawful measurement would test for additional structure without decoding protected payloads or inventing a source identity from the repetition alone?

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Claude Elwood Shannon, Cross-Peer Answer to Peter Elias: Dr. Elias, the regular recurrence of an event is one possible source of redundancy, but redundancy is not a certificate of a communications function. The housekeeping source can have extraordinarily predictable timing because a fixed control loop activates it, while the framed source may transmit according to the same independent clock. From the event-start sequence alone these mechanisms are observationally equivalent within the instrument's resolution. A predictor that places the next event within a narrow interval has learned a statistical pattern of the observed process. It has not proved the physical purpose of the pulse, the existence of meaningful payload bits, or compatibility with a named standard.

For information-theoretic clarity, one should specify the random variable being measured. If X denotes a quantised time interval, its entropy is determined by the distribution of X under the declared quantisation rule. A low empirical entropy of X indicates concentrated interval outcomes. It does not give the entropy of an unobserved payload Y, nor the mutual information between Y and any hypothetical operating state. Those would require measurements or a controlled experimental design involving the relevant variables. Even the entropy estimate for X may be biased by finite sample size, correlated intervals and censoring by the receiver. The observation of sparse deviations could motivate a hypothesis that timing is deliberately modulated, but such a hypothesis must compete with oscillator correction, control-loop contention, queueing, missed events and measurement error.

An authorised experiment can manipulate the laboratory source's known signalling state while concealing the state labels from the analyst. If time

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intervals change in a reproducible state-dependent fashion beyond the timestamp uncertainty and changing receiver schedule, one gains evidence for controlled temporal organisation in that specific source. This does not authorise extrapolation to an unknown field emitter. If the research goal is purely defensive monitoring, record timing distributions, frame durations, spectral bandwidth and test-source state labels without attempting recovery of protected content. A separately controlled reference receiver can help show whether suspected state-dependent deviations persist outside the first receiver's event-processing software.

The conclusion should say that the observed waveform has a recurrent temporal envelope compatible with multiple mechanisms, and that additional controlled features would be required for protocol classification. One can describe the empirical predictability honestly and still decline to identify a protocol. Such restraint is not a failure of communication theory. It is the logical consequence of distinguishing the random variables actually observed from the unobserved variables about which the investigator wishes to speak.

Dr. James M. Atkinson, Moderator: Dr. Elias, thank you. Dr. Shannon, I pass the token to you. Please distinguish the statistical organisation of an interval sequence from the contents, purpose and identity of the source that generated it.

Claude Elwood Shannon, Second Principal Contributor: A sequence of nearly equal time intervals is evidence of a source or measurement process with a regular component. The word 'beacon' should be employed only as a descriptive analogy until more than periodicity is established. Communication theory gives us tools for distinguishing measurable

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organisation from unobservable purpose. It does not permit us to infer arbitrary hidden variables from a narrow statistic. Consider a row of events with inter-arrival times of about one quarter of a second. The sequence might be generated by a periodic transmitter, an industrial relay, a sensor sampling scheduler, or a receiver that notices an otherwise continuous source once per sweep. If all candidates produce the same observed timestamps under the same acquisition conditions, no timing-only classifier can distinguish them with evidential confidence. Additional assumptions may create distinctions in a model, but those assumptions must be disclosed instead of being smuggled into the conclusion.

Let T denote the nominal interval, J a random timing deviation, and M a positive integer accounting for missed physical emission cycles. The observed gap G may be represented as $G = MT + J$, but only when this model reflects the actual acquisition path. If the timestamp is rounded to a grid of duration q, the recorded gap is a difference of quantised arrival times and its error law cannot be assumed identical to the physical timing jitter. If the receiver is blind while tuning, the probability distribution of M depends upon the joint phase of the receiver schedule and the candidate transmitter schedule. Consequently the empirical histogram of gaps is a convolution of physical schedule, missed opportunities, detector imperfections and timestamp representation. Counting peaks at T, 2T and 3T without reconstructing these mechanisms cannot identify an air-interface standard or a message format.

A useful information-theoretic description begins with an explicit alphabet: for example, intervals binned in milliseconds, or event length measured in sample counts. Define p_i as the empirical probability of outcome i, and

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calculate H = -sum_i p_i log2(p_i), where H is measured in bits per binned interval. This statistic requires a declared alphabet, observation window, treatment of censoring and finite-sample correction. If one changes the bin width, H generally changes, so the numerical result does not express an intrinsic physical identity. A highly regular source may have low H because most intervals fall into one bin. A complex protocol may also have low timing entropy because all transmissions are triggered by a fixed heartbeat. An industrial machine may have low H for exactly the same reason. One cannot move from H(X) to a conclusion about H(Y), where Y denotes protected payload content that was never observed.

Nor does a high apparent entropy demonstrate encryption or randomness at the source. An unsynchronised observer may mix several regular transmitters, thereby obtaining a complicated interval sequence. Oscillator drift, competing network traffic, environmental interruptions and an adaptive threshold may transform a simple source schedule into apparently erratic detections. Conversely, averaging and timestamp rounding can reduce apparent variation, making irregular physical transmissions look perfectly quantised. An examiner should not infer that a statistical measure has a mechanism merely because the computed number looks precise. The estimate and its uncertainty have to be accompanied by an account of what generated the data and how much of that process was observable.

One way forward is a controlled state experiment in which a known laboratory emitter alternates, under a concealed random schedule, between fixed-period and jittered-period timing, while preserving envelope shape and nominal power. Another known source should emit mechanically or electronically generated pulses without intended communications payload,

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matched to the first source's observable duration and spectral occupancy. The analyst receives only timestamp and non-content feature records with anonymised provenance, then declares a decision rule before the concealed state labels are released. The experiment may tell us whether timing statistics detect a deliberately imposed change in that laboratory source. It does not entitle us to identify an unrelated emission in the field as the same device. Generalisation must be separately demonstrated across hardware types, sites, propagation conditions and recording instruments.

The false-alarm problem is especially important when one searches for a period after seeing the event sequence. A lengthy record offers many candidate periods, phase offsets, source partitions and subsets of selected events. Under a suitable null model, some combination will look remarkably regular by chance alone. The declared test should therefore specify the complete search family, including detector thresholds, eligible intervals, frequency channels and candidate periods. The null simulations should pass candidate records through the same scan schedule and decision procedure as the real data. Testing only the final winning period against an ideal random distribution ignores the selection process that produced it. A holdout record, assessed under frozen rules, is a more meaningful test of prospective predictive performance.

The most useful evidence report may therefore be intellectually modest. It can state that the observed timestamps exhibit a stable approximate recurrence with a period estimate, confidence limits and documented gaps. It can state whether the finding persists with a second calibrated receiver and under controlled changes in observation schedule. It can state that two or more proposed mechanisms remain compatible. Those conclusions

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provide a precise investigative record without pretending that timing entropy or repeatability recovers a protocol name. A waveform, a scheduler and a protocol are distinct objects; an interpretation that does not respect that distinction is not strengthened by the sophistication of the formula employed.

Egon Sharpe Pearson, Peer Question: Dr. Shannon, you propose a family of comparison hypotheses, but the analyst will often be tempted to call the hypothesis with the smallest residual variance 'the detected protocol' and to report only the corresponding significance level. Suppose the analyst first searches a hundred candidate periods, then adjusts phase and packet-length thresholds, and finally retains the twenty percent of events that align most tightly with the best-fitting model. How should the resulting evidence be evaluated without treating those choices as though they had been specified beforehand? I am particularly concerned about the distinction between a low probability under a selected null model and a high posterior probability of a named protocol, because those are logically different conclusions. Would the experiment require prospective data, controlled alternative sources, an explicit family-wise search record or some combination of these? Please address how a small number of apparent exceptions should be handled without conveniently discarding them as noise merely because they undermine the favourite interpretation.

Claude Elwood Shannon, Response: Dr. Pearson, the analysis must disclose the extent of selection. If the investigator explores a hundred periods, many phase offsets and several exclusion thresholds, the statistic eventually reported is the maximum over a complicated family, not the value obtained from one independently specified test. A significance calculation that

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assumes the final candidate was chosen before looking at the data is therefore invalid for that discovery process. A suitable simulation can reproduce the entire search pipeline under each defensible null, including sorting candidates by apparent periodicity, selecting eligible events and applying the final goodness-of-fit measure. Its output describes how often that complete procedure would produce an apparently impressive winner in records where the proposed mechanism is absent.

The null model itself must be scientifically relevant. Repeated industrial switching can be nearly periodic, and a receiver operating on a fixed revisit schedule can create a perfectly repeatable sequence even when an external source is not transmitting in a periodic fashion. A null restricted to homogeneous random arrivals is often too weak. The laboratory should include replayed or physically generated controls exhibiting quantised but unrelated timers, nonstationary burst rates, intermittent acquisition and mixed sources. If an apparent match survives these alternatives, it has gained support as a timing-class hypothesis, not necessarily as a protocol or device identification.

Prospective testing is valuable precisely because it separates model construction from evaluation. Freeze the reported T, permissible phase error, treatment of missed events and inclusion rules. Obtain fresh observations under an independently recorded receiver schedule and ask whether the proposed recurrence predicts where eligible arrivals should occur. Report successes and failures using the whole designated observation window. If events arrive outside the windows, those exceptions must be counted under the stated metric rather than removed retroactively. If uncertainty or environmental change justifies a revised rule, that revision

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belongs in a new development cycle with another validation set; it should not be disguised as the original protocol test.

Finally, a p-value computed against a declared null does not directly yield the probability that a specific protocol is present. That inference would require prior probabilities, comparative likelihoods, validated alternatives and sufficient features to discriminate their predictions. A periodic control loop and a communications heartbeat may be indistinguishable from the restricted timestamps. When the evidence is insufficient to resolve them, the correct result is a set of compatible explanations and a plan for further authorised observation. Statistical discipline protects the examiner from turning the chosen analytical vocabulary into an unwarranted claim about the external equipment.

Claude Elwood Shannon, Cross-Peer Question to Donald Watts Davies: Mr. Davies, let us imagine a physical source whose bursts begin at perfectly regular 200-millisecond intervals, but whose event records arrive at the analyst's host computer after variable buffering and network transport. The host application timestamps each delivery rather than the hardware acquisition instant. Another source transmits irregularly, yet its detector events are released by software in 200-millisecond batches. In a plotted log those two systems could appear to have exchanged identities. Please explain which timestamps belong to the radio-frequency measurement, which belong to data transport, and what independent counters or hardware triggers can establish their relationship. I would also welcome your view of packet drops, queue flushes and retransmissions, and whether their signatures can be distinguished from genuinely missing physical transmissions without inspecting protected message content. The

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laboratory should be able to document the entire timing path, or else the period it reports may be that of the software rather than of the emitter.

Donald Watts Davies, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, a receiver event passes through several clocks and queues before reaching an analyst's graph. The analogue-to-digital converter samples a physical voltage under a sampling clock. A digital detector may identify a trigger sample index inside that stream. A hardware interface or bus transports samples or event summaries. A host operating system schedules a process, which may timestamp when it receives or handles those records. If those times are conflated, a computer's batching behaviour becomes an apparent attribute of the external source. The acquisition sample index is ordinarily the strongest starting point for a source-time estimate, provided continuity and the mapping between sample count and calibrated time have been verified.

A useful architecture places a monotonically increasing counter with every captured sample block or trigger, and uses a recorded relationship between that counter and an independently maintained time reference. The report should preserve the counter resolution, epochs, counter wraps, sample-rate calibration, dropped-block flags and errors in clock synchronisation. A software delivery time can be retained, but it is a different quantity and should not overwrite the acquisition timestamp. By subtracting acquisition time from host-delivery time, the examiner can study transport latency and identify bursts of queueing that might otherwise masquerade as physical timing jitter. A batch of events all stamped with the host's wakeup time is not evidence that the external transmitter emitted them simultaneously.

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Packet loss and retransmission require careful separation. A host-delivery retry may repeat a data record whose original hardware counter is unchanged, whereas a second physical transmission would normally occupy new acquisition samples. A replay or duplicated buffer can create a convincing false recurrence if the application naïvely counts each delivery as a new radio-frequency event. Retain unique sample-range identifiers and hashes when appropriate to establish whether records are duplicates. Conversely a missing data block does not demonstrate absence of an RF emission during that interval. It establishes absence of usable observation. Those intervals must be marked as ineligible for claims about negative evidence.

The experiment you propose is practical. Drive a known source from a separate timing reference, and deliberately vary host processing load, network delay and buffer flush conditions whilst holding the source schedule constant. Compare event timestamps derived from acquisition counters with those derived from application receipt. Then vary the source schedule whilst holding transport conditions stable. If a timing pattern follows the host batching variable rather than the physical trigger, the reporter has found a software artefact. The proper forensic record preserves both the original event chronology and the transport history; it must never allow the convenient chronology of a graphing application to replace the measured chronology of an emission.

Dr. James M. Atkinson, Moderator: Dr. Shannon, thank you. Mr. Davies, kindly take the token and trace the timing record from the analogue receiver through detection, buffering and delivery to the forensic analyst.

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Donald Watts Davies, Third Principal Contributor: The first task is to decide what event a timestamp actually represents. A communications receiver can preserve the acquisition instant of an RF burst, the instant an internal detection algorithm declared a threshold crossing, the instant an operating system received a message describing that detection, or the moment a user interface painted a marker. These can be separated by milliseconds or longer, and their differences need not remain constant. A 'beacon-like' record of host events may therefore describe buffering and process scheduling rather than a periodic source. The ambiguity grows when observations are collected over a network, because record packets may traverse queues with variable delay, sometimes arriving out of order. A forensic report should state the time origin and physical meaning of each field before computing a recurrence interval from it.

It is worth constructing an explicit time budget. Let a_i be the acquisition time assigned to RF event i, d_i its detector processing latency, q_i its queueing and delivery delay, and h_i the final host timestamp. In a simplified model, $h_i = a_i + d_i + q_i + c_i$, with c_i representing any clock-domain conversion error. The sequence of differences in h_i incorporates variations of all four terms. If q_i fluctuates independently, it may broaden a real periodic schedule. If software releases records in regular batches, q_i may be correlated so strongly that irregular physical arrivals take on a periodic appearance. A tidy diagram drawn from h_i alone cannot separate these possibilities. Hardware counters, traceable capture-trigger markers and contemporaneous queue logs are needed to estimate and bound the terms.

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A defensible instrumentation scheme includes one counter at the acquisition stage and another in the host event store, retaining both without conversion into a single convenient clock. The RF record carries a sample index, the configured and independently measured sampling frequency, the beginning and end indices of any acquisition gap, and the acquisition state during the candidate burst. The host record carries a monotonic arrival time, a processing sequence number and an error flag if a transport record is lost or duplicated. Clock conversion parameters should be versioned and tied to their calibration measurements. This makes it possible to reconstruct chronology when packet transport reorders messages. It also allows a subsequent reviewer to distinguish a missed RF observation from a missing metadata packet.

The test programme should include an authorised beacon generator with a known periodic output, a second source with deliberately varied intervals and an independent record of both source triggers. The receiver should operate first in continuous acquisition and then under a documented scanning schedule, because the scan can make its event eligibility periodic even when the source is not. Host load, buffer size, interface throughput, event-logging interval and process priority can be varied as controlled nuisance factors. If the apparent recurrence or jitter changes when these software variables change, that relationship is evidence about the measurement chain. It does not necessarily exclude an external recurring source, but it prevents unqualified attribution of the whole pattern to that source.

A particular danger is implicit sample substitution. Some interfaces conceal transport discontinuities by returning the last valid data block again,

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inserting zero-valued samples, or concealing a missing segment behind a fresh application timestamp. A classifier may then detect repeated envelope shapes or apparent fixed delays with unwarranted precision. Each sample block should carry a unique identifier or counter range so that duplicates and omissions can be detected. A record gap should remain a gap. An artificial zero fill may be useful for a display if clearly marked, but it cannot be treated as a physical observation of silence. For the same reason, interpolated RF timestamps should not be silently entered into the evidential event register as though the instrument had genuinely recorded them.

Even a technically perfect delivery channel does not settle transmitter identity. Several unrelated machines can produce fixed-interval supervisory bursts, and two different standards may specify comparable timers. Moreover, a single device can change timing because its workload or environment changes. One should therefore separate an event-class description, such as 'approximately 200-millisecond recurring RF bursts', from a mechanism hypothesis, such as a source-side periodic timer, and from an identity claim, such as a specific model of industrial controller. The first may be established by timestamp analysis. The second requires controlled discrimination against receiver and environmental explanations. The third requires independent device- or protocol-specific evidence well beyond timing resemblance.

What should be written in the record? State the specific acquisition hardware, sampling configuration, host delivery path and the time meaning of every used timestamp. Give the total eligible time, durations of unobserved intervals, detector threshold, calibration traceability and any relevant operating-system scheduling details. Retain primary records and

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code versions so that another investigator can reconstruct the observed event chronology. If the source period seems exceptionally stable, show that the stability survives using acquisition timestamps instead of host receipt times, and ideally with a second independent recording chain. A sound account of uncertainty is not an impediment to a useful observation; it is what makes that observation evidence rather than merely an appealing pattern on a screen.

William Ralph Bennett, Peer Question: Mr. Davies, suppose the examiner has only timestamped detection messages from a distributed receiver system and cannot recover the original samples for every interval. A central host has synchronised its clock to a network service, but the edge receivers are inexpensive and use oscillators whose fractional frequency error is not recorded. Over a two-hour shift the same event appears to drift by tens of milliseconds relative to a reference. The analyst proposes to correct each receiver's timestamps by fitting a straight line between two coincident events. How should that correction be evaluated without confusing physical oscillator drift with network latency, and how many independent common events are required before the correction can be regarded as evidence-bearing? Please also address the risk that a high apparent correlation between two event lists is created by sharing the same scheduling service or communications link. The synchronisation labels on those logs may be far more reassuring than their metrological accuracy warrants.

Donald Watts Davies, Response: Mr. Bennett, a synchronised wall clock is not automatically a calibrated measurement clock. A network time service may estimate clock offset, but its error includes asymmetry in transport delay, time-stamping uncertainty, servo behaviour and the local oscillator's

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frequency instability between corrections. A fitted straight line through two coincident events can always align those two points; that is elementary geometry, not evidence that the intervening interval has been measured accurately. If the clock error contains nonlinear drift, abrupt steps or varying network delay, the line may conceal substantial error at other times. The fit must be checked against independent timing events not used in constructing it.

I would begin by distinguishing clock offset, fractional frequency error and latency. Let x(t) be the edge clock's time error relative to a reference. A constant offset contributes a fixed term; a stable fractional frequency error contributes a term approximately proportional to elapsed time; temperature effects and oscillator ageing may introduce curvature; transport delay belongs to the measurement of x rather than necessarily to the clock itself. Multiple separated reference events are required to estimate the trend and test residuals, with observations distributed across the intended reporting interval. The number depends on the noise process and the claim's required accuracy, so there is no universal adequate count. Report estimated residuals and uncertainty rather than specifying a cosmetic number of synchronisation points.

If only event messages survive, an analyst can still audit the communications path. Preserve send and receive timestamps where available, transport sequence numbers, queue lengths, clock adjustment logs and uncertainty values reported by the timing service. Compare the receivers using an independently generated timing test source that both are known to observe. Then vary their network paths, local loading and time-service access if permitted. A common delay pattern that follows the shared

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communications infrastructure suggests a system effect. Coincident apparent events from two receivers do not establish an RF origin if the messages share a software source or duplicate transport record.

The reported conclusion should be commensurate with the retained evidence. One might state that two event lists, after a declared clock transformation, show intervals compatible within a specified time uncertainty. One may not state that two independent receivers precisely timed the same external emission unless acquisition provenance and common-source independence are demonstrated. Any drift correction should be stored as a reproducible model with parameter covariance and known validity interval, leaving the uncorrected timestamps intact. Where gaps or missing samples preclude stronger conclusions, label those intervals as uncertain rather than allowing an attractive fitted line to imply observations that never occurred.

Herbert Kroemer, Peer Question: Mr. Davies, software timestamps are only one source of ambiguity. A receiver subjected to a nearby switching event can experience amplifier saturation, gain-control recovery, oscillator pulling or an apparent repeated burst caused by filter ringing. These physical effects may follow a regular industrial cycle, even if the source actually being investigated transmits irregularly. What laboratory controls would distinguish a true periodic external emission from a periodic receiver response caused by a stronger nearby disturbance? Would you alter input attenuation, preselection, gain state and antenna coupling, while preserving the original clocking chain? I am also concerned that inserting a synthetic test burst at the wrong point in the receiver hides front-end nonlinearities. How should the injection plane be specified so that the test genuinely covers

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the component suspected of creating the false beacon? A test that validates only the host software may miss the very circuit most responsible for the apparent observation.

Donald Watts Davies, Response: Professor Kroemer, the test must be designed around the complete physical path. If the suspected phenomenon arises in the antenna, preselector or first active stage, injecting a clean test signal after those components can prove only that the downstream detector responds as expected. It cannot exclude front-end overload, mixer intermodulation or antenna-coupled impulse contamination. The injection plane should therefore be recorded in a block diagram, and multiple planes used when a particular stage's influence must be isolated. A known test source introduced ahead of a preselector exercises a different collection of mechanisms from a source introduced directly at the analogue-to-digital converter's input.

Begin with measured linear operation. Vary the received level of a lawful reference burst while monitoring the relationship between input power and recorded sample amplitude. Then introduce a separately controlled strong interferer or pulse source, within equipment safety limits, and watch for threshold changes, gain recovery and repeated response. Change attenuator state and RF gain, but do not interpret the mere disappearance of a trace at lower gain as proof of its cause; an ordinary weak transmission can disappear too. More informative is a measurable change in apparent interval, waveform shape or recovery sequence that tracks the interferer's physical timing and the receiver's nonlinear state. An independent wide-dynamic-range reference chain can help identify whether the candidate RF energy truly existed before the first receiver distorted it.

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Preserve acquisition timestamp provenance throughout these changes. A gain-control operation may alter the detector's crossing time by moving the effective threshold relative to the envelope, even when physical emission onset is fixed. A receiver may also blank its output during retuning or overload, creating structured missing observations. The event detector should therefore report a time uncertainty that includes amplitude-dependent triggering and blanked periods. If the same laboratory source is measured through two analogue paths with different front-end behaviour, differences in their event lists are valuable evidence that the observation process matters.

The final report should distinguish three layers: the actual applied laboratory stimulus, the voltages delivered to the receiver's digital sampler, and the software events reported by the detector. A periodic pattern at the software layer can be produced by a periodically changing analogue response even when the target emission lacks that period. The experiment narrows the candidate mechanisms by controlled alteration of individual stages. It does not rely upon generic labels such as 'beacon' to replace that physics. Once the path-specific behaviour has been characterised, the investigator may cautiously infer which part of the observed pattern is consistent with source timing and which part remains instrument-dependent.

Donald Watts Davies, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, an automated survey system uses a repeatable detector and can export thousands of apparently beacon-like event intervals. Its configuration file specifies one threshold, but another threshold is calculated dynamically after the scanner changes frequency, and a background process may apply

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a refractory period before another event is counted. A programmer argues that repeatability of the software proves that the RF schedule is real. Would you explain how version control, threshold provenance, sample-counter continuity and adversarial software tests should be organised so that repeatability is not confused with truth? I ask particularly about a regression test which deliberately inserts missing blocks, duplicate records and delayed queue deliveries. What outputs should the instrument produce, and what should it refuse to infer when those artificial artefacts make a neat interval pattern? The resulting validation record must be intelligible to an independent engineering reviewer, not merely the original programmer. That reviewer should be able to reproduce the failure deliberately.

Richard Wesley Hamming, Cross-Peer Answer to Donald Watts Davies: Mr. Davies, reproducibility of a programme establishes that it applies its programmed rule consistently to the supplied input. It does not establish that the rule corresponds to an external transmitter's physical timing. A software system can consistently round timestamps to a coarse interval, impose a fixed refractory window, and transform packet delivery batches into apparent beacon events. The resulting records may look exceptionally tidy because the errors are systematic. An adequate verification programme must therefore challenge the software with inputs whose correct interpretation is known independently, including deliberately corrupted or incomplete inputs whose proper result is an uncertainty declaration rather than a confident classification.

Each event should retain a provenance chain: original sample range, acquisition counter, hardware status, threshold rule identifier, threshold value at the decision instant, candidate event boundaries, processing

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software version and any post-processing transformations. A dynamically selected threshold is not the same as a static setting saved in a configuration file. Store the actual history of the adaptive threshold, including the input measurements used to update it, its smoothing interval and any gain-state changes. If the detector has a refractory period, store that duration and the time during which further events would have been censored. A report of apparent physical intervals derived from these event records must account for the censoring the algorithm itself introduced.

Regression tests should include continuous clean reference bursts, irregular bursts, overlapping bursts, threshold-near events, zero-filled gaps explicitly marked invalid, discontinuous sample counters, duplicated blocks and out-of-order network messages. The programme should detect counter discontinuities and record them without silently manufacturing data. Duplicate records with identical source-range identifiers should not be counted as independent emissions. The result of a gap spanning a predicted beacon instant must be 'not observed because acquisition was unavailable', not 'the transmitter was silent'. A delayed metadata message must retain its original acquisition timestamp instead of inheriting the host delivery time as the physical event instant.

An independent examiner should receive the test inputs, known truth labels, source code revision or independently reproducible executable manifest, expected outputs and actual outputs. The distinction between assertion and observation should be visible in machine-readable data as well as narrative. Where the software detects an interval cluster, its classification can remain 'recurrent event candidate' until supplementary physical tests exclude instrumental patterns. I would not permit a regression test to pass merely

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because a graph looks like a beacon. The test must establish that the programme preserves evidential time meaning across the very disruptions most likely to corrupt that meaning in field acquisition.

Dr. James M. Atkinson, Moderator: Mr. Davies, thank you. Dr. Hamming, I pass the token to you to examine software validation, versioned event provenance and the risks of inferring physical recurrence from a programme’s own selection rules.

Richard Wesley Hamming, Fourth Principal Contributor: A robust event classifier should not be praised merely for emitting a reassuringly precise label. Its first duty is to preserve the measurements from which that label may be challenged. A burst record often begins as samples, is condensed into trigger times and envelope measurements, and is then presented as a concise set of intervals. At every stage information may be discarded. That loss can be acceptable for routine monitoring if it is declared, but it is hazardous when the final label implies a protocol identification not supported by the stored evidence. The software ought to distinguish facts such as 'threshold crossed at acquisition sample 18,443,120' from derived claims such as 'estimated period 0.25 seconds' and conjectures such as 'beacon of type X'. A change in confidence cannot transform a conjecture into a directly observed field.

The data model should separate physical acquisition, signal detection, interval estimation and interpretation. For acquisition, retain raw or legally permissible calibrated summary records, timebase status and gap masks. For detection, record the threshold and filtering rules, duration and envelope features, and the uncertainty of onset estimates. For interval estimation, retain the exact set of event identifiers admitted, missing-cycle

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assignments and the parameters of competing models. For interpretation, retain the proposition being evaluated and the evidence required to disprove it. A reviewer should be able to recompute the recurrence from primary event records without treating the original analyst's chosen period as an immutable fact.

Consider a hypothetical system that emits one real burst every 250 milliseconds but is observed by a receiver whose frequency scanner revisits the channel every 500 milliseconds. If the bursts and scanner are synchronised, the receiver may record every second event and report an apparent half-second recurrence. If the two schedules drift slightly in relative phase, the record can contain runs of detections followed by long gaps. A fixed-period estimator may then invent abrupt changes in source behaviour that actually arise in the observation schedule. The correct software design retains the scan eligibility function and either models its effect explicitly or refuses to infer a source period from a sparse record lacking adequate observations. It must not patch missing cycles by assuming the hypothesis it is supposed to test.

Another hypothetical system emits irregular broadband switching impulses. An energy detector imposes a 100-millisecond refractory period after every trigger. The observed intervals will contain no values shorter than that limit, creating a sharp lower bound and sometimes a misleading peak near the boundary. A histogram with such a feature may resemble timer quantisation, even though the dominant timing mechanism lies in the detector. A quality-control rule should therefore run the classifier against known irregular event inputs through the actual detection firmware. If the output falsely develops a periodic peak, the test captures a systematic bias.

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A file containing only reported event times cannot resolve this after the fact unless the refractory policy and underlying data are preserved.

Software validation is especially important where the operator chooses what constitutes 'a similar burst'. Packet lengths, bandwidth estimates, detector onset times and burst clustering tolerances may be adjusted until a family of events looks consistent. Each adjustment changes the eligible population and may alter the inferred interval distribution. Report the feature definition before the final frequency or time window is selected, and distinguish exploratory optimisation from out-of-sample validation. The analyst should be able to ask whether a model trained on half the data predicts events in an untouched interval. Repeated tuning on the validation interval turns that interval into another development set, despite the filename used to describe it.

For a forensic-quality audit, an event record should carry not only time and frequency but a versioned reason for inclusion or exclusion. When a burst is omitted because its power falls below threshold, record that censoring as a sensitivity limitation rather than a statement of silence. When the acquisition fails, retain a gap marker and its duration. When sample counters jump, preserve both sides of the discontinuity. One should never generate interpolated events to make a plot pleasingly regular and then count those interpolations as physical detections. Such manufactured evidence could make an incorrect periodic model appear extraordinarily precise, while concealing the simple fact that the receiver did not observe the intervals in question.

The end product should be a layered conclusion. The software may find that eligible events are consistent with an interval near T under an explicit

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residual bound. It may also find that several models are indistinguishable after applying observed acquisition gaps. It can identify an instrument configuration capable of creating apparent regularity, or a controlled reference source whose recurrence survives those challenges. These are useful results. A named protocol, however, requires identifiable framing, modulation or other standard-specific structure established independently and lawfully. No amount of clever period fitting can supply features absent from the input. A carefully designed classifier must sometimes say 'not determined'; that output is a success when it prevents an inference which the evidence cannot carry.

Ralph Vinton Lyon Hartley, Peer Question: Dr. Hamming, a monitoring application reports a remarkably tight cluster of apparent intervals at 250 milliseconds, but its data have passed through several rounds of quantisation. The original converter uses a sample clock of uncertain accuracy, the digital detector records onset to the nearest block of 256 samples, and the database rounds timestamps to whole milliseconds. An analyst combines the resulting entries as though each were an independent timing observation to microsecond precision. How would you compute a realistic bound for the resolution and uncertainty of the interval estimate, and how could one demonstrate whether the observed quantised pattern belongs to the source or to the processing chain? Please distinguish the numerical resolution of an exported timestamp from the attainable physical time accuracy, which may be far worse. I also ask how to explain to a tribunal that a long sequence of identically rounded values need not imply extraordinarily stable emissions when every value has been forced onto the same grid.

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Richard Wesley Hamming, Response: Mr. Hartley, the first correction is conceptual. A timestamp printed with six decimal places is not necessarily measured with microsecond accuracy. Its numerical resolution is a property of storage or display; its accuracy depends on clock calibration, acquisition synchronisation, detector onset uncertainty and the way the physical signal changes the threshold crossing. If the onset is rounded to a 256-sample block, the acquisition stage has already imposed a grid before the database rounds to milliseconds. The final export may therefore contain precise-looking numbers whose actual event uncertainty is dominated by one or more coarser mechanisms.

Let f_s be the nominal samples per second and B the detector block size in samples. The block interval is B/f_s seconds, subject to the actual oscillator's fractional frequency error. If onset is reported as a block boundary without interpolation, a plausible quantisation uncertainty may extend across much of that interval; its exact bound depends on whether rounding, truncation or a fixed detection delay is used. The database contributes another rounding term whose support and dependence must be specified. Two event times may have correlated clock error, so the uncertainty of their difference is not necessarily obtained by simply adding two independent error variances. A common offset cancels in an interval, whilst drift does not. The model must represent those relationships.

To locate the source of quantisation, change one parameter at a time using an authorised reference emitter whose start times are independently measured. Vary B while holding the physical source timing constant. Change the database resolution without altering the detector. Compare onset estimates from a second receiver with a different clock and event algorithm.

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If the supposed timer quantum follows B or the database field width, then it belongs at least partly to the measurement system. If it persists across independent calibrated chains, it becomes more plausible as a source-related feature, though not automatically a unique fingerprint or named protocol characteristic.

For reporting, retain the raw counter values and a transparent uncertainty budget. It is entirely possible for a hundred reported intervals to share exactly the same millisecond value because the software rounds them, even if the underlying physical intervals fluctuate within that grid. An average of those rounded values may estimate a central period, but it cannot recover fine-scale jitter that the instrument discarded. The proper statement is that events are recurrent within the temporal resolving power and uncertainty of the stated apparatus. That phrasing is rigorous and comprehensible: the uniformity belongs to what was recorded and may or may not describe the finer behaviour of the source.

Richard Wesley Hamming, Cross-Peer Question to Harry Nyquist: Mr. Nyquist, we have an apparent 250-millisecond burst recurrence collected by a clocked receiver which itself revisits the channel every 500 milliseconds, with occasional switching delays. Some analysts propose that seeing a regular interval in the event list proves that the external source's period has been measured. Would you explain the relation between physical source periodicity, the sampling of event opportunities and the alias-like ambiguities that follow from a periodic scanner? Please give a simple numerical counterexample and identify what extra observations break the ambiguity. I am particularly concerned that the analogy with sampling theory may be useful but should not be overstated: events are not a band-

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limited sinusoid, and a binary eligibility function can cause censoring rather than ordinary amplitude sampling. How would you frame this distinction so that the mathematics disciplines the inference instead of becoming another source of unjustified confidence? A hostile reviewer should be able to identify every interval in which the radio was actually blind.

Harry Nyquist, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, the analogy with sampling is valuable when its limitations are kept clear. A receiver that observes one channel only during scheduled dwell windows does not acquire a complete time history of physical events on that channel. It acquires a selected subset determined by the intersection of the source emission times and the receiver's eligibility windows. Different source schedules may produce the same subset under a given scan, especially when their periods bear simple rational relationships. The problem is therefore one of incomplete observation and non-unique inverse inference, not a claim that each burst has been reconstructed by the conventional theorem for band-limited waveforms.

Take a simple hypothetical case. A source emits at times 0, 0.25, 0.50, 0.75 seconds and so on, while a scanner observes only short windows around 0, 0.50, 1.00 seconds and so forth. If every visible event is detected, the recorded spacing is 0.50 seconds, even though the physical source period is 0.25 seconds. Another source emitting only at 0, 0.50, 1.00 seconds could create the same record. From these observed event times alone, no estimator can distinguish the two sources. The scanner's own half-second revisit interval has removed the distinguishing observations. A claim that the external period is exactly half a second would therefore be stronger than the evidence permits.

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Changing the observation schedule helps. One may hold the receiver continuously on the channel during an authorised calibration interval, or use an independent wideband reference receiver that observes the same frequency without synchronised gaps. Alternatively vary the scan revisit period and phase according to a documented test plan. If the pattern changes systematically with scanner timing while the reference source is stable, the original observation is selection-dependent. Where source and scanner timing are uncertain, collect enough independent phases to expose missing cycles and estimate the observation probability. None of these procedures requires recovering a protected payload; they concern lawful reception opportunity and event timing.

The analogy should be expressed precisely. A sequence of timestamps is not equivalent to periodic samples of a continuous band-limited voltage, so the classical sampling theorem does not directly produce a unique reconstruction of missing events. Rather, periodic observation can create indistinguishable hypotheses in both problems. The correct lesson is about information absent from a record: when an instrument did not observe a time interval, the analyst must not manufacture certainty about what occurred there. A report can describe observed half-second recurrence and its relationship to the receiver schedule while explicitly leaving the source's true physical periodicity unresolved.

Dr. James M. Atkinson, Moderator: Dr. Hamming, thank you. Mr. Nyquist, the token passes to you. Please address periodic observation, missed bursts and the difference between a sampled event list and a uniquely reconstructed source schedule.

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Harry Nyquist, Fifth Principal Contributor: Periodicity in a signal and periodicity in the act of looking for that signal are distinct properties. Where a receiver is continuously observing a channel, its event record may provide a fairly direct sample of the emission starts, subject to thresholding and timing error. Where a scanner dwells for brief intervals and then attends to other frequencies, its list is a filtered record whose contents depend upon the relative phase and frequencies of two clocks or scheduling systems. A regular event list in such a case cannot be attributed solely to the external transmitter. It is a result of an interaction, and one must measure both sides of that interaction before inferring an underlying source period.

We may express the observation opportunity as a time-dependent function w(t), equal to one when the receiver is adequately settled on the relevant frequency with sufficient sensitivity and zero when it is blind. More realistic models let w(t) take intermediate values reflecting probability of detection as a function of frequency, amplitude and receiver state. Physical emission starts occur at times s_i. Recorded starts are those for which the relevant emission overlaps an eligible interval and the detector successfully declares an event. If w(t) is periodic, it imposes a periodic selection process on the event stream. A burst shorter than the scanner's dwell can be missed completely when it occurs outside that dwell. Even a long burst may be partly clipped, shifting its apparent onset and measured duration. The period inferred from detected starts can consequently be a multiple, alias or phase-dependent distortion of the physical recurrence.

A numerical counterexample makes the ambiguity plain. Let a laboratory source emit short pulses every 0.20 seconds and let the receiver observe the channel only around times separated by 0.40 seconds. With source and

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scanner phases aligned, the receiver may record every second pulse and see gaps of 0.40 seconds. A different source emitting only every 0.40 seconds could yield the identical record through that scanner. Yet another source emitting every 0.10 seconds might yield the same observed detections if the dwell windows are short and the phase is arranged appropriately. The first event list alone cannot distinguish the three. Its temporal regularity is genuine as a property of the observation, but its relation to the physical source schedule remains underdetermined.

If the receiver has an independent continuous reference channel, compare the timestamps of detected events with that channel's event record. But the reference must itself be calibrated and sufficiently independent; a shared software processing clock can impose the same false pattern on both. If a continuous receiver is unavailable, change the scanner's revisit period under an authorised controlled experiment and observe how the detected interval distribution changes. Choose incommensurate revisit settings where practicable, while preserving receiver bandwidth, threshold and relevant RF sensitivity. A source period hypothesis predicts certain changes in which emissions become visible; an artefact tied to scanner scheduling predicts others. These expectations should be written before examining the next test data, avoiding a post-hoc explanation that can accommodate any result.

One must not misuse the vocabulary of sampling theory. The traditional result about reconstructing a band-limited waveform from samples under specified conditions is not a theorem that allows recovery of all missing event times from sparse detections. Event intervals form a point process observed through a censoring window. Its reconstruction needs a source model, a detection model and enough observation diversity to discriminate

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competing explanations. If the source is arbitrary, many hidden event sequences share the same observed subset. A mathematical calculation may estimate plausible periods under a model, but a model-conditioned estimate is not proof of uniqueness. That distinction should be central to any technical surveillance countermeasures training because the operator may otherwise confuse the elegance of a frequency estimate with a measurement that was never taken.

The clock itself requires scrutiny. The converter clock, scanner control oscillator, host processor and source timer may each have offset, frequency error and short-term fluctuations. A nominal revisit interval of 0.40 seconds need not stay exactly at that value, and temperature or processing load may alter the schedule. Record the actual time at which the receiver entered and left an eligible dwell, not merely the commanded values in configuration software. Calibrate settling time after retuning; a channel nominally selected by software may not yet be delivering accurate amplitude or timing estimates. Mark acquisition gaps and overload intervals separately. If the source interval appears to drift, compare its phase against an independent physical reference before attributing the drift to the transmitter. Two clocks drifting relative to each other can produce phase walks and alternating patterns of detections even when each clock is individually orderly.

Finally, the report should not call a waveform a named beacon merely because a number matches a familiar nominal heartbeat period. Many technical systems use round-number intervals chosen for convenience, so an apparently familiar 100-, 200- or 500-millisecond schedule carries little identity information in isolation. Describe the measured recurrence, interval uncertainty, receiver eligibility and compatibility with multiple physical

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explanations. Report what was seen when the scan schedule changed, including negative and ambiguous results. If a waveform has additional public structural features, those can be considered separately in a lawful and controlled inquiry, but timing alone must not borrow evidential strength from them without analysis. The most valuable finding may be that periodicity survives an observation challenge, or that it disappears when the receiver's own clocking is changed. Either result is more defensible than an unsupported protocol label.

Irving S. Reed, Peer Question: Mr. Nyquist, suppose several observation schedules have been used and each produces a different set of burst timestamps. An analyst might try to combine them by assigning every detected event to an integer cycle number under a hypothetical source period. When a long blind interval occurs, many assignments of that cycle number may be possible, especially if the oscillator has drift and the trigger threshold shifts with pulse amplitude. How should the investigator distinguish legitimate integer-cycle inference from circular selection in which the period determines the missing counts and the missing counts are then cited as proof of that same period? I ask also how measurement error should affect the reporting precision, and whether a second receiver that shares the same antenna amplifier and timing reference genuinely supplies independent validation. Please identify a minimal controlled experiment that can reject a false reconstruction, not merely accommodate a successful one. A useful evidential method should remain capable of proving the attractive hypothesis wrong.

Harry Nyquist, Response: Dr. Reed, the safest course is to separate the directly observed event identifiers and timestamps from the inferred cycle

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numbers. An assignment of an integer count through a blind interval is a hypothesis about unseen events, not an observation. The programme should retain all assignments compatible with the declared uncertainty and show how the fitted period changes across those choices. Where several physically plausible counts yield nearly the same residual fit, the result should report that ambiguity. Choosing the count which maximises regularity and then using that same fit as independent evidence for regularity is indeed circular. A validation interval or a changed scanner schedule can supply genuinely new constraints on the candidate assignments.

A model can express an observed gap g as approximately kT + d, where k is an unknown positive integer, T a proposed source period and d a residual reflecting clock differences and timing error. The admissible range of k depends on the acquisition gap duration and independently measured bounds on T and d. If the receiver was continuously eligible during a portion of the interval, some cycle assignments may be excluded by the absence of detected events only if detection probability was high enough for that absence to carry information. If the receiver was blind, no such exclusion is justified. Uncertainty intervals should contain the effect of ambiguous cycle counts, oscillator drift and measurement quantisation rather than being calculated only from the tiny residuals of the favoured model.

An independent reference receiver is valuable when it contributes distinct physical evidence. Two acquisition streams that share a saturated front-end amplifier, a time-stamping programme or the same replayed data packet may agree because they share a defect. Record the topology of common components and design tests that vary those components. One receiver

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might use a separate antenna and analogue chain, with its own stable counter and a separately calibrated relation to common time. Both can observe an authorised synthetic pulse source whose programmed starts are independently triggered. Agreement after the chains are challenged by deliberate scanner phase changes offers stronger support than agreement obtained by merely duplicating the software output.

A minimal falsification test is to choose two candidate source periods that fit the discovery record but predict different event windows during a future interval in which the receiver will be continuously eligible. Freeze the test windows, timing tolerances and detector threshold before the future record is taken. If one predicted event pattern is absent despite a demonstrated capacity to observe it, that model is weakened or rejected. If both continue to fit, more discriminating observation is needed. In either case, the report should keep the weaker inference separate from protocol identification. The observation of regularity can become well established without entitling the analyst to attach a particular device class or named standard to the signal.

Dr. James M. Atkinson, Moderator: I thank the contributors. The panel distinguishes an empirically recurrent observation from source-driven periodicity, protocol classification and physical identity. Repetition should be documented with its observation windows and uncertainty; it should not be named as a protocol unless independently discriminating lawful evidence is obtained.

SOURCE REGISTER. C. E. Shannon, “A Mathematical Theory of Communication,” Bell System Technical Journal 27 (1948), 379–423, 623–656; H. Nyquist, “Certain Topics in Telegraph Transmission Theory,” Transactions of the AIEE 47 (1928), 617–644; R. W. Hamming, “Error Detecting and Error

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Correcting Codes," Bell System Technical Journal 29 (1950), 147–160. Contemporary editorial measurement references, not attributed to the historical speakers: W. J. Riley and D. A. Howe, Handbook of Frequency Stability Analysis, NIST SP 1065 (2008); ITU-R Report SM.2256-2, Spectrum Occupancy Measurements and Evaluation (2026). Full source-to-claim verification remains pending.

EDITORIAL QUALIFICATION. Every numerical situation and proposed test is hypothetical. No external device, protected message, named protocol or field observation is identified by this discussion. The source-side schedule, receiver eligibility, measurement clock and software event logger are separate potential causes of the recorded recurrence.

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QUESTION 087

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Can power-on transients support transmitter-class inference without unique fingerprinting?

SCHOLARLY RECONSTRUCTION. The historical contributors named below did not take part in this meeting. Their dialogue is an expressly fictional scholarly reconstruction, not an authentic quotation or a claim of endorsement. All experimental designs concern authorised reference transmitters, known test envelopes, calibrated receiving systems and non-content waveform measurements.

Dr. James M. Atkinson, Moderator: Dr. Kroemer, please examine which semiconductor and bias-network processes can be associated with an RF power-on transient, and why such an observation cannot by itself identify an individual transmitter. I pass the token to you.

Herbert Kroemer, Principal Contributor: The question is not whether a transmitter exhibits a transient when electrical power is applied. The difficulty is deciding which features of the recorded transient arise in the source's semiconductor devices, which arise elsewhere in the radio-frequency circuit, and which belong to the receiving instrument. An isolated turn-on trace is a joint result of all three. A power-amplifier stage can traverse a sequence of bias points before its intended steady condition is reached; during that transition the small-signal gain, junction capacitances, device conductances and thermal loading may change. One ought not attribute a spectral shoulder or a short amplitude overshoot to a particular transistor family without considering the matching network and the manner in which its bias rail arrives. A battery-powered source and the same design

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operated from a current-limited laboratory supply can present different early envelopes. They are not thereby two different transmitter identities.

The language of semiconductor band structure is useful because it demands identification of the physical state variables. In a heterojunction device the distribution of carriers across barriers and the effective transport time can depend upon device construction, temperature and applied potential. This does not mean that a field observer can reconstruct the band diagram from a brief radio transient. Instead it means there are several hidden states capable of producing similar observable behaviour. We may write a schematic input-output relation y(t)=H_R{H_P[x(t;theta_S,u(t),T)]}+n(t), in which x is the source's intended electrical excitation, theta_S represents unknown source parameters, u(t) represents the bias and power-supply history, T is temperature, H_P represents antenna and propagation coupling, H_R is the receiving chain, and n is measurement noise. This notation is a bookkeeping device rather than a fitted physical model, and the operator H_R need not be linear during overload.

Suppose two authorised reference transmitters use the same general semiconductor technology and have nearly identical programmable power ramps. One unit operates with a different output matching network and sees a more reactive antenna. The resulting ramp in detected power may be slower than the nominal transistor bias transition, because energy is being exchanged with stored reactive fields and the amplifier's output network. Conversely, when the receiver is operated close to gain compression, a slower physical ramp may look abruptly clipped. If an analyst sorts recordings by the width of the first detected pulse, a classification experiment can succeed under one receiver configuration yet fail when the

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input attenuator is changed. That failure does not reveal a mysterious change in the transmitter. It identifies the classifier's dependence upon the laboratory chain in which it was trained.

A proper experiment therefore varies the transmitter, receiver and coupling path independently. First measure repeated authorised switching events from a fixed source, with the supply voltage, source temperature, antenna termination and trigger instant recorded. Hold the source constant while changing receiver preselection, analogue gain and sampling rate. Next hold a calibrated receiver fixed while changing the source design, its power control state and its termination. Finally exchange the receiving antenna or controlled coaxial coupling path without changing either unit. These crossed comparisons supply within-source, between-source and between-chain distributions. The experimental unit is a physical power cycle, not each digital sample within a single waveform: thousands of adjacent samples from one event cannot legitimately masquerade as thousands of independent transmitter trials.

I would distinguish onset latency, spectral-centroid evolution, instantaneous occupied bandwidth, amplitude trajectory and carrier-frequency settling. None is an intrinsic device signature without a declared observation method. Onset latency measured from a receiver's threshold crossing has a different meaning from latency measured between a source-side trigger and an independently sampled RF envelope. The first mixes source delay with threshold, noise and channel gain. The second, while more useful, still includes trigger instrumentation uncertainty and cable-path propagation. A source whose amplitude climbs through a fixed threshold at a different speed will seem to start earlier or later even if the actual physical activation

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instant is unchanged. A robust record must therefore retain raw time series, calibrated thresholds and the source-trigger reference rather than reduce the evidence immediately to a single nominal start time.

Temperature deserves a separate factorial test. The semiconductor junction, oscillator resonator and output matching components may respond on very different thermal time scales. A cold start after a long interval is not equivalent to a warm restart after two seconds. The experiment must record off-time and thermal history, then use held-out physical cycles at both conditions to test whether a proposed feature remains discriminating. If temperature is unrecorded, an apparent family distinction might simply reflect that one set of reference events was collected at breakfast in a cold laboratory and another after the rack had warmed through the afternoon. The remedy is not merely to normalise traces until they look alike; normalisation may remove real changes as well as nuisance variation. The remedy is to measure and report the relevant environmental factors.

Where a classifier is proposed, its claim should be phrased at the level its validation warrants: for example, under the tested supply, load, temperature and receiver settings, the chosen features separate two reference transmitter classes better than a declared chance baseline. The result does not identify an individual unit, prove a design lineage, or make a forensic attribution to a source outside the experiment. Confidence intervals belong to independent power cycles and separate hardware instances, not merely random samples partitioned from the same recording. One should also test a receiver-only trigger, a dummy load and an externally injected calibration pulse; without them, a repeatable step response of the measurement system can impersonate a repeatable transmitter transient.

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My recommendation is to maintain a causal inventory. One column records physical hypotheses concerning the semiconductor, bias circuit and output network; another records independent observable predictions; a third records receiver or propagation alternatives capable of producing the same observation; and the last identifies the intervention that distinguishes them. A claim that survives changed attenuators, altered receiver hardware and controlled source operating states earns more confidence than a striking photograph of a single trace. The object of the exercise is defensible transmitter-class inference, not a fingerprint obtained by silently treating unmeasured electronic states as known.

Egon Sharpe Pearson, Peer Question: Dr. Kroemer, your proposed factorial design recognises that a measured turn-on envelope is produced by several interacting physical systems. Yet a forensic examiner may have only a small number of authorised reference transmitters, and the distributions of their switching transients may be skewed or multimodal because bias controls change state during startup. What would count as a properly defined statistical comparison under those conditions? I am particularly concerned that an investigator might select the most visually distinctive feature after inspecting every waveform, then report a very small error probability derived as though that feature had been specified beforehand. Would you distinguish a development collection used to choose features from a genuinely independent confirmation collection?

The accompanying challenge is interpretive. Even an excellent separation of laboratory classes may fail when an unmodelled receiver chain or antenna coupling configuration appears. How should an uncertainty interval acknowledge that the tested devices were not randomly sampled from every

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possible member of their purported class? What evidence would justify the cautious expression 'consistent with a design class', and what additional evidence would be needed before one made a categorical statement about the origin of an unknown field recording?

Herbert Kroemer, Response: Professor Pearson, a useful first distinction concerns the observational unit. Each separately initiated physical power cycle is a candidate unit, whereas adjacent samples and overlapping time-frequency tiles from that cycle are repeated measurements of substantially the same event. The true number of independent transmitters is smaller still. The examiner should tabulate variability at several levels: variation between samples within a start, between starts on one unit, between units of the same declared design, and between designs. A model fitted only to sample-level fluctuations can be impressively precise about the wrong population. Resampling must respect the clustering. Leave-one-unit-out or leave-one-receiver-out evaluation is more relevant to transportability than randomly splitting the individual waveforms of one instrument between training and testing sets.

Selection after observing the data is a distinct and serious hazard. If the analyst calculates twenty candidate transient features, examines which one most separates two reference collections, and then estimates its error using those same collections, the reported performance includes a hidden selection advantage. One may use nested validation to separate feature choice and evaluation, but the stronger experiment preserves an independently collected confirmation set whose devices, receiver configuration and environmental schedule have been declared before the final test. The relevant false classification rates should be accompanied by

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uncertainty intervals and explicit operational conditions. They do not automatically extend to unobserved products, altered bias firmware or unknown antenna systems.

The phrase 'consistent with a design class' should be coupled to specific exclusions. One might establish that an unknown waveform lies within the distribution of several authorised reference devices under matched observation conditions, while also acknowledging that competing designs were not exhaustively represented. A categorical source claim would require a far stronger discrimination experiment, a controlled set of plausible alternatives and independent corroboration that addresses transmitter hardware rather than receiver response alone. In most technical surveillance countermeasures settings, the defensible product is a ranked set of hypotheses and a plan for lawful further measurements, not a named manufacturer or individual transmitting apparatus. The report should state clearly whether the statistical comparison was exploratory, confirmatory or only illustrative.

Finally, no confidence interval can transform a convenience sample into a random sample of a population that was never defined. We may estimate repeatability for the collected units and tested conditions, and construct sensitivity analyses for plausible environmental shifts. The resulting inferential boundary should be written in ordinary language as well as equations. One may report that a calibrated feature differed in the tested two-class laboratory experiment and that it remained stable across held-out power cycles, without implying that every untested emitter must obey the same relationship.

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William Ralph Bennett, Peer Question: Dr. Kroemer, let us imagine a known reference source whose bias rail is ramped with a digitally controlled regulator. A receiver records a high-frequency shoulder during the first few microseconds, followed by a flatter plateau. Its operator believes the shoulder reflects carrier transport within the amplifier's transistor. Yet a supply lead, an output matching network, and the receiver preselector each possess a frequency-dependent response capable of converting a sharp transition into overshoot or ringing. What intervention would best identify the physical origin of that shoulder without assuming the receiving instrument is transparent? Should one begin by changing the source supply waveform, by substituting a non-radiating termination, or by inserting calibrated test transients directly ahead of the receiver?

I also ask how the examiner should handle nonlinear switching. A single linear impulse response cannot reproduce a receiver whose limiter, automatic gain controller or analogue-to-digital converter is driven beyond its operating range. Which measurements must be performed before any fitting of a supposed source-specific transient, and how could a deliberately varied input level expose the hidden threshold or compression behaviour?

Herbert Kroemer, Response: Mr. Bennett, those proposed interventions answer different questions, and they should be ordered to prevent a circular interpretation. Begin by verifying that the receiver can reproduce a known injected RF envelope at several power levels without unexpected amplitude-dependent deformation. A calibrated signal generator or controlled laboratory modulator should deliver a rise and decay with known bandwidth and independently recorded timing. If the purported shoulder appears on this injected waveform as well as on the source under study, there is

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immediate evidence that some part of the recorded feature may belong to the receiving chain. That does not by itself exclude a source shoulder, because the mechanisms can coexist, but it prevents claiming a unique transmitter origin without further testing.

Next vary the controlled source supply ramp while holding the output load and receiver settings fixed. If the shoulder follows bias-rise time or regulator mode transitions, a causal supply connection becomes more plausible. Substitute a matched non-radiating termination, within the source's permitted operating conditions, to reduce uncontrolled antenna and propagation effects. Observe the amplifier output through an appropriately rated, calibrated directional coupler if that laboratory access is available. Do not connect measuring equipment in a way that changes the amplifier load or violates source safety limits. A loading-dependent shoulder suggests an output-network or feedback contribution; a receiver-gain-dependent shoulder suggests measurement-chain distortion.

Nonlinearity should be tested explicitly. For a nominally linear receiver, scaling an injected reference by a known voltage factor should scale the recovered signal proportionately, with predictable noise effects. If changing RF input amplitude alters the normalised shoulder shape or onset time, the analyst must investigate limiting, automatic gain response, detector log compression and converter saturation. A record of attenuator state, gain setpoint and observed ADC headroom is therefore evidence, not a mundane administrative detail. Where several operating regimes are present, a single impulse-response correction is invalid. Instead, the examiner may stratify by regime or fit a bounded nonlinear model validated on held-out injected tests.

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It is equally important to preserve the raw complex samples and trigger timing where lawful and technically feasible. An energy detector may smooth the transient until its peak position depends upon the smoothing window rather than the original RF event. Spectrogram colour maps can conceal saturation because they normalise each frame independently. A stable causal interpretation must survive changes in display scale and feature extraction. The eventual conclusion should identify a class of potential mechanisms and the measurements that distinguished them. It must not transform a visually distinctive oscilloscope trace into the unique identification of a semiconductor technology.

Herbert Kroemer, Cross-Peer Question to William Redington Hewlett: Mr. Hewlett, your pioneering oscillator design makes the control and stabilisation of amplitude a matter of deliberate circuit dynamics. Suppose a modern authorised test transmitter exhibits a reproducible envelope overshoot, while its carrier frequency simultaneously moves toward a steady value. The engineer treats both observations as proof of a distinctive active device. I suspect that the regulator, amplitude-control feedback, oscillator startup and RF load each contribute, with potentially different time constants. Would you explain how a circuit designer distinguishes those coupled control loops experimentally, without pretending that their dynamics can be read uniquely from a single received waveform?

A second question concerns universality. Two independent designs may have nearly the same feedback bandwidth or soft-start programme, and one design may change dramatically with firmware revisions. In what circumstances can the shape of a transient support a broad oscillator or power-control class, and what would be necessary to show that it belonged

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to an individual apparatus? I should particularly value a proposal that identifies the possible contributions of receiver stabilisation rather than regarding the receiver as a passive observer.

William Redington Hewlett, Cross-Peer Answer to Herbert Kroemer: Dr. Kroemer, an oscillator ordinarily includes both a frequency-selective mechanism and an amplitude-regulating mechanism. The former determines what frequencies enjoy sufficient loop gain and phase alignment for oscillation; the latter restrains growth into a stable operating condition. At power application, those loops need not settle on the same time scale. Even a relatively simple resistance-capacitance network with a slow amplitude-control element can display overshoot before the control element catches up. A received amplitude shoulder is therefore not, by itself, evidence of unusual transistor transport. It may reflect ordinary feedback during the passage from open-loop growth to controlled oscillation.

The decisive measurements would alter one physical parameter at a time while recording more than a single dependent variable. In an authorised laboratory generator, vary the amplitude-control time constant within safe design bounds and measure envelope overshoot, settling delay and frequency drift. Independently vary the reference resonator or oscillator tuning state, where the apparatus permits, and compare the resulting carrier motion. Then repeat with a different but characterised receiver. If the envelope transient persists when the receiver changes but responds predictably to the source feedback adjustment, its attribution to the source control system becomes more persuasive. If the shoulder changes with receiver gain or detector settings, measurement-chain contributions remain important.

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A control-system representation can help organise the experiment. Write A(t) for envelope amplitude and e(t)=A_ref-A(t) for the control error relative to a declared desired amplitude A_ref. The gain-control actuator has its own response time, while the oscillator's growth rate depends upon instantaneous loop gain and losses. Such a simplified model should not be fitted with more parameters than the observed data can identify. Its purpose is to predict the consequences of a controlled intervention, not to recreate a mysterious signature using arbitrary constants. Identical-looking envelopes may emerge from different combinations of gain, load and feedback delay.

Consequently I would regard the observation as evidence of a general operating regime only when several authorised reference designs display corresponding behaviour under matched and varied conditions. A claim of individual source identity would require a separate population study demonstrating low within-unit variation, distinctive between-unit variation and robustness across independent receivers and environmental states. Such a claim is rarely established by the limited evidence available to a defensive field survey. The more valuable finding is often that a transient is compatible with feedback-controlled startup, accompanied by a clear account of the alternative mechanisms not yet excluded.

Dr. James M. Atkinson, Moderator: Dr. Kroemer, thank you. Mr. Hewlett, the token passes to you. Explain oscillator start, amplitude-control dynamics and the receiver measurement chain as independent contributors to the observed trace.

William Redington Hewlett, Second Principal Contributor: An observer seeing a radio signal turn on must resist the temptation to imagine that the

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entire apparatus has one start time. A power supply energises particular stages; an oscillator builds from noise or an imposed seed; a level-control loop responds to changing amplitude; a buffer or frequency-conversion stage becomes conductive; and an output-control circuit may deliberately postpone radiation until a frequency or output-power condition has been met. Each transition can have its own time constant and measurement uncertainty. A single received envelope is the aggregate result of those internal events, combined with filtering and time selection at the receiver. From the standpoint of instrumentation, an attractive curve is a prompt to design discriminating measurements rather than a certificate identifying the oscillator or transmitter that produced it.

It helps to distinguish loop start-up, loop stabilisation and transmitted-signal onset. In a feedback oscillator the small-signal loop gain must initially exceed the loss to sustain growth; when amplitude increases, some mechanism reduces effective gain or increases attenuation toward an equilibrium. The amplitude's rate of increase will depend on loop gain, available energy and nonlinear limiting. The oscillation frequency is influenced by the frequency-selective network and may change during thermal or electrical settling. Yet a radio transmitter can suppress its RF output until a control circuit asserts readiness. The receiver then observes the opening of an RF gate, not the startup of the hidden oscillator. Another design may let the unsteady oscillator radiate immediately. The same final carrier frequency can therefore be accompanied by very different beginning traces without requiring a unique device signature.

Measurement instrumentation can impose equally persuasive false structure. An IF filter with a narrow passband stretches a rapid input

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transition into a longer response. A detector with a finite averaging window shifts the apparent start time. An automatic gain controller may briefly amplify the start, then reduce gain as the input rises, creating an envelope with a pronounced peak even if the actual source output rose monotonically. If an instrument captures only after a software-selected energy threshold, its first stored sample may be much later than the first physical emission. If the firmware pretrigger buffer is too short, the observer may never see the beginning. One must record the complete timing chain, including RF input, analogue filter, detector, trigger condition, sample storage and software event timestamp.

A controlled way to separate these effects employs a known RF pulse generator and a splitter feeding two different receiver chains with traceable timestamps. Apply a calibrated pulse envelope spanning the observed rise times and bandwidths, and repeat at several levels from clearly linear operation to a safely characterised near-compression regime. The output of each receiver is a measurement of its response to the reference, not merely a photograph of the pulse. Where a simplified linear regime applies, the recorded complex voltage can be modelled as the convolution of the source waveform and an effective impulse response, with additive noise. Near limiting or gain-control transitions this representation is inadequate; the test must deliberately identify that boundary instead of correcting the result by a mathematically convenient but physically false deconvolution.

I would also compare the same source with two activation methods. One method supplies electrical power from zero. Another keeps the oscillator and power amplifier biased but opens a separately controlled RF switch. If the recorded features are dominated by the abrupt switching element, the

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second method may reproduce an apparent 'power-on' signature without a genuine oscillator start. A third controlled test may enable the oscillator but delay amplifier bias, allowing the investigator to separate frequency settling from power-amplifier ramp. These are laboratory interventions only, performed on authorised equipment whose operation can be safely modified. They demonstrate mechanisms; they do not establish what an unknown external transmitter did unless independent evidence identifies the corresponding architecture.

The distinction between timing and frequency stability is especially important. Suppose the observed carrier frequency drifts by a few kilohertz during a brief startup. It may reflect a source oscillator warming or a synthesiser loop acquiring lock. But a receiving local oscillator settling after its own retuning can produce a similar frequency trajectory. With a shared reference and a stable calibration source, one can determine whether the receiving converter is drifting. The experiment should preserve raw I/Q data and record the reference-clock state rather than infer physical frequency solely from the trend drawn by a display. A disagreement between two independently disciplined receivers is not a minor nuisance. It is powerful evidence against prematurely attributing the displayed motion to the emitter.

Class inference is possible when its meaning is carefully bounded. For example, a set of reference devices with continuously operating oscillators and gated outputs might show less startup frequency wander than devices that energise their oscillators at each event, under a specified time resolution and noise floor. The class label in such an experiment describes a known operating architecture, not a protected communications protocol or

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a named commercial device. The result must be tested with devices unseen during feature selection and with different receiving configurations. A source-to-source comparison should not be made from an instrument whose own gain, bandwidth and trigger threshold have quietly changed between sessions. Before reporting classification accuracy, the analyst should establish whether the class feature survives a receiver exchange.

Finally, the record must be reproducible. Keep a diagram of the measurement topology, reference generator settings, cable and antenna coupling losses, input protection state, clock source, sample rate, bandwidth, filter coefficients and gain. Record the interval since previous power application, because stored charge and temperature can cause two successive starts from the same apparatus to differ. Preserve the trial-level raw evidence and the calculation code version, then repeat a random subset blind. Where calibration uncertainty and between-unit variability remain large, a statement that the transient is 'compatible with gated-output startup' may be the strongest justified conclusion. It would be scientifically indefensible to convert that into an individual fingerprint merely because a classifier makes a confident numerical prediction.

Claude Elwood Shannon, Peer Question: Mr. Hewlett, you describe a physical oscillator's behaviour and a receiver's reaction as two possible sources of the same apparent transient. I should like to press the question of which random variable the investigator is actually estimating. Suppose a classifier receives only three features: the delay to first detected power, the slope of a short frequency trace, and a short-time spectral-width estimate. Those features arise after thresholds, filtering and sampling. How should the investigator demonstrate that they contain information about an authorised

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source class beyond information already contained in the receiver configuration, power level and triggering procedure? Would merely balancing the number of recordings from each transmitter type be sufficient, or must the acquisition conditions be crossed with both classes?

Please also distinguish a model that predicts which file belongs to which experimental session from a model that predicts transmitter architecture in a new measurement environment. I ask because a very successful predictive algorithm may be exploiting the microphone-like individuality of the measuring instrument, rather than the radio apparatus supposedly under investigation. What held-out tests would reveal that distinction without requiring observation of protected messages?

William Redington Hewlett, Response: Dr. Shannon, the measured random vector can be defined as Z=(L,S,B), where L is the delay from the declared reference trigger to the detector's first qualifying observation, S is the estimated early frequency slope in hertz per second, and B is bandwidth under a stated estimator and window length. Its distribution is conditional on more than transmitter class C. It depends on receiver configuration R, received power P, source-state history U, temperature T and the detection algorithm D. A useful probability statement therefore takes the form P(Z|C,R,P,U,T,D), even if an applied model approximates that distribution rather than estimating every variable exactly. Reporting P(C|Z) as though the nuisance conditions were absent invites unwarranted generalisation.

Balancing the number of recorded files per class does not address this problem when one class was measured on Receiver A and another on Receiver B. In that design, class and receiver are perfectly confounded. The analyst cannot tell whether a detected difference belongs to the source or to

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the instrument. The experiment should measure multiple devices from each class on multiple receiver chains, over controlled power ranges and power-cycle conditions. The resulting crossed data support tests that hold out entire hardware units and entire receiver sessions. If performance collapses when the receiver is changed, the purported class feature is not sufficiently invariant for the intended purpose, even if it reliably separated files in the original training collection.

There are two practically distinct validation goals. One asks whether the system can organise recordings from an already known laboratory configuration. The other asks whether it can classify a new reference emitter under conditions reasonably similar to a future authorised survey. The second requires a difficult transportability test. One can train on one group of units and receivers, then assess on newly collected devices and a separately configured chain whose calibration is recorded but not used to tune feature selection. The held-out assessment should include deliberately similar devices from competing classes and tests near the detection threshold, where waveform distortions can be strongest. The analyst should present the confusion matrix and uncertainty intervals, not just an average percentage.

None of this requires reading a message. A reference generator can emit an agreed test envelope or a dummy modulated signal whose contents are irrelevant. The examiner can retain waveform energy, instantaneous frequency estimates, receiver state and time references without extracting protected traffic. The conclusion should distinguish classification under a specific measurement model from attribution to a unique physical transmitter. Even a highly informative statistical feature cannot prove an

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identity when the set of plausible competitors has not been defined and tested.

William Redington Hewlett, Cross-Peer Question to John Bardeen: Dr. Bardeen, we agree that a received power-on curve is an interplay of electrical states. Yet there is a practical tendency to treat all semiconductor switches as the same fast ideal device, and then to attribute any unexpected shoulder to a radio-frequency amplifier's design. Could you explain how charge storage, junction capacitance and device bias history complicate that ideal picture? What feature would you expect to vary systematically when a known source is restarted quickly rather than after a long unpowered interval, and what measurements could distinguish that variation from thermal drift in the receiver or its local oscillator?

I am also interested in the evidential meaning of resemblance. Suppose two physical transistor designs give nearly identical received envelopes because each is governed by a digitally imposed output-power ramp, while a third instance of one design differs after an unusually warm restart. Would the semiconductor construction remain identifiable from that one envelope? How should an examiner prevent a convenient circuit model, fitted after the fact, from turning into a claim of device fingerprinting without a genuine intervention that tests the model's predictions?

John Bardeen, Cross-Peer Answer to William Redington Hewlett: Mr. Hewlett, the ideal switch model is adequate for some circuit calculations but unreliable as a literal description of a semiconductor passing between operating states. Electrical charge is stored in depletion regions, device junctions and external capacitors. Its distribution depends upon the previous bias condition and the rate at which applied potential changes.

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Some devices also exhibit minority-carrier storage and recovery effects; their importance depends on the specific technology and circuit topology. A transistor that was only briefly de-energised may retain a different thermal and electrical starting state from a unit left unpowered for an hour. The resulting voltage and current trajectories can differ without implying any change of hardware identity.

The first measurements should therefore be local and physical, where authorised reference equipment permits. Record the bias rail waveform with an instrument of sufficient bandwidth and known loading. Record the output envelope through a characterised coupler and compare it with the timing of control signals that govern amplifier enable and RF gating. A family of tests with varied off-time can then distinguish reproducible bias-memory effects from changes correlated only with the receiver's own warm-up. A stable external RF reference, measured before and after each test cycle, can identify changes in receiving local-oscillator behaviour. If the same output transient changes while the source input state is held constant but the receiver gain is altered, the source-only explanation is incomplete.

The mathematical point is one of non-unique inverse inference. Several arrangements of device physics and control circuitry may yield the same observed amplitude trajectory once the receiving chain has filtered and thresholded it. Even if a mechanistic model fits every point, other models with different internal states may fit equally well. The useful test is a prediction under an intervention not used in the fit. For example, the model might predict how the early shoulder changes when the controlled bias ramp is lengthened or when a known load reactance is adjusted safely. If that predicted change occurs across independent source units and

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receivers, confidence in a mechanism may increase. It still does not imply that the measured pattern is unique to an individual unit.

A sensible classification claim should thus be modest: a transient may be compatible with a broad architecture involving stored-charge recovery, gated RF output, or controlled ramping. Which explanation is favoured depends on interventions and uncertainty, not on the visual novelty of the trace. The examiner ought to record failures of the model openly, because those failures identify conditions under which it should not guide future surveillance-countermeasure decisions. The mere existence of microscopic differences between physical transistors does not establish that the chosen observation system can measure those differences robustly, much less attribute an unknown emitter to a unique device.

Dr. James M. Atkinson, Moderator: Mr. Hewlett, thank you. Dr. Bardeen, kindly accept the token and examine semiconductor state, stored charge, source history and the inferential limits of indirect remote observation.

John Bardeen, Third Principal Contributor: A classification scheme based upon a turn-on transient is only as sound as its account of the device states that can affect that transient. Semiconductor materials contain mobile carriers and electric fields whose distribution changes as electrical potentials are imposed. But the radio envelope emitted into space is many stages removed from those microscopic events. It includes switching controls, bias networks, resonant elements, coupling components and the load presented by the antenna. It would be an error to assume that a waveform recorded at a distant receiving antenna is a direct picture of the semiconductor's internal motion. We must take care not to substitute a charming analogy

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between an oscilloscope trace and a crystal's physics for evidence that the trace reveals its construction.

Consider a power amplifier whose output is controlled by an enable signal and a bias regulator. At early times, the regulator may bring a transistor gradually through operating points with different gain and effective capacitance. The amplifier's output filter stores and exchanges energy. If the enable signal arrives before the oscillator has settled, a short frequency transient may coexist with the rising envelope. Conversely a design may allow its oscillator to stabilise before the RF output is enabled, hiding almost all oscillator movement from a field receiver. Observed similarity between these arrangements can arise when an envelope controller imposes the same ramp on both. Observed difference can arise when the input source level, antenna impedance or receiver threshold changes. Neither result identifies the semiconductor by itself.

One should write an explicit hierarchy of states. Let b(t) denote the measured bias voltage, i(t) the amplifier supply current, a(t) the output-envelope amplitude measured at a calibrated laboratory coupler, and z(t) the complex samples recorded by the receiving apparatus. These observables have different locations in the causal chain. In a reference experiment the investigator can study whether changes in b precede and predict changes in a while z follows in a manner consistent with the independently measured receiver response. If all that is available is z, the inverse inference is much less constrained. Unobserved states can produce the same z, especially after filtering, quantisation and threshold selection. A classification scheme must distinguish what its instruments observe from what the engineer hypothesises about the inaccessible circuit.

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A repeated startup can also carry memory of its recent history. Capacitors discharge according to their time constants. Semiconductor junctions and the surrounding circuit may cool on longer time scales. A synthesiser may retain configuration state, while an output stage receives a programmed ramp independent of oscillator acquisition. Therefore the off-interval should be treated as an experimental variable rather than as an idle administrative detail. Randomise the order of short and long off-intervals, monitor temperature, and record the source's operating mode. The first start after overnight cooling may belong to a different within-unit distribution from the tenth start in quick succession. A model that interprets these populations as two transmitter designs has committed a basic causal error.

Bias and temperature measurements also require care to avoid changing what is being tested. A probe with appreciable capacitance on a sensitive node may alter the startup response. A coupler placed at an amplifier output changes the impedance presented to the system unless it is chosen and installed appropriately. A thermal probe may be too slow to resolve junction conditions even when the external case temperature appears constant. These limitations do not invalidate a controlled laboratory experiment, but they qualify its observations. A defensible paper will state the effective measurement bandwidth, loading and calibration and refrain from claiming a physical variable has been measured merely because a proxy was recorded.

For an example, imagine twenty independent authorised power cycles on each of four amplifier modules, repeated across a cool and a warm condition, with two receiving chains. The resulting number of digital samples might be millions, but the number of independent modules

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remains four. The uncertainty of a class-separation result is governed in part by the small number of physical modules and by how their conditions were selected. A random train/test split of samples from all eighty cycles would not test generalisation to an unseen module. Leave-one-module-out validation and separate receiver-condition tests are more honest, although they may reveal that the available evidence supports only a broad mechanism hypothesis rather than a stable classifier. One should report those limits instead of hiding them in a large sample count.

If microscopic device physics is invoked, its predicted macroscopic consequences should be stated before examining the final comparison data. A hypothesis about stored charge might predict a dependence on off-time but not necessarily on receiver bandwidth; a hypothesis about receiver ringing predicts dependence on filter design, even when the source is unchanged. An antenna mismatch hypothesis predicts a change when a calibrated termination replaces an uncertain load. A digital RF-gate hypothesis predicts a stable output onset relative to the gate command but may permit variable earlier oscillator behaviour. These predictions can be distinguished using authorised equipment. The historical achievement of semiconductor physics was to connect mechanisms with measurable consequences, not to establish that an unknown circuit can be uniquely reverse-engineered from one remote trace.

I would reserve the expression 'fingerprint' for an actually validated uniqueness proposition involving the relevant population of devices, environments and observing equipment. Even then, the term risks suggesting forensic individuality when only a narrow laboratory population was examined. For defensive technical-surveillance investigations, the

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necessary distinction is usually between a known transient artefact, a broad class of switching or transmitter architecture, and an unexplained emission requiring further lawful examination. Careful measurement can support the middle statement. It need not, and ordinarily cannot, jump to unique identification. The strongest evidence often comes not from an unusually sharp feature but from a falsifiable prediction about how that feature changes under a controlled intervention.

Harry Nyquist, Peer Question: Dr. Bardeen, your account includes several simultaneous electrical time constants, but the radio-frequency measurement chain has its own limited bandwidth and group delay. A colleague may claim that the initial carrier transient lasts twenty microseconds because the amplitude crosses a chosen detection level for that period. Suppose the receiver's intermediate-frequency filter has a comparable response time and the sampled output is digitally smoothed. What is the proper relationship between the bandwidth available to resolve a transition and the claims that can be made about the transmitter's underlying rise time? Would you set a lower bound on resolvable events using a calibrated step response rather than relying on a nominal receiver bandwidth printed on the instrument panel?

I also ask how you would test a proposed class distinction in frequency settling when its slope is estimated over a window that changes with the receiver's threshold crossing. The selection rule may itself correlate with signal strength and bias conditions. What independent time origin and observation schedule would prevent the analyst from manufacturing an apparent oscillator trend through inconsistent window placement?

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John Bardeen, Response: Mr. Nyquist, the response of the measurement chain determines the class of source changes that can be resolved. A narrow analogue filter cannot reproduce an arbitrarily abrupt input transition, and a software smoothing operation may increase that limitation or shift the apparent peak. A nominal bandwidth figure is therefore not an adequate substitute for measuring the effective response under the actual gains, preselection and detector settings. We should inject reference signals with rise times on both sides of the expected source transition and record the resulting complex samples. Where the measured output changes little as the injected rise time becomes shorter, the instrument has reached a practical resolution limit. An apparent source rise faster than that limit cannot be reliably estimated from the trace without additional validated assumptions.

The receiver's step response should be reported with sufficient detail to reveal ringing, overshoot and latency. A frequency-swept calibration tone addresses selectivity but may not expose time-varying gain and buffering in the same way. Separate reference pulses of known duration and level should test the response across the actual operating range. If saturation or gain adjustment occurs, the effective response depends on amplitude; then a single deconvolution kernel cannot be applied indiscriminately. One may characterise several regimes and restrict inference to a regime in which validation errors are acceptably bounded. Where the source transient and receiver response have similar scales, a measured width should usually be stated as an unresolved or model-dependent estimate rather than as an intrinsic material property.

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Window placement requires an independent origin. When possible, use the reference transmitter's hardware enable signal and an independently sampled trigger, and preserve a pretrigger record at the receiver so that the onset algorithm does not decide where the analysis begins. If the source trigger is unavailable in a defensive field observation, retain a fixed predeclared rule for choosing windows and report its selection uncertainty. Do not change the frequency-slope window after inspecting which segment looks most linear. A threshold crossing that occurs later for weaker signals can select a different portion of the oscillator's real trajectory, giving the appearance of a changed frequency-settling law even if the underlying path is unchanged.

The right scientific claim therefore has explicit temporal resolution and selection conditions. One might find that the received waveform is consistent with a frequency change lasting no longer than a stated measurement bound under a verified filter configuration. That statement is narrower but more meaningful than pretending to have measured an inaccessible transistor's intrinsic startup. A well-calibrated failure to resolve two proposed mechanisms is a legitimate result. It protects the eventual source-class conclusion from precision that the apparatus could not supply.

Ralph Vinton Lyon Hartley, Peer Question: Dr. Bardeen, the technical report may contain a striking spectrogram at startup and a table of feature values, but the features are computed after several operations that discard information. The analyst averages power, applies a log scale, divides by a windowed spectral estimate and retains only a few largest peaks. Would you explain how information lost through such transformations restricts the reversibility of the inference? If a particular spectral ridge is absent from the

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retained display, can the examiner infer that it was absent at the antenna, or merely that it was below the transformed display's sensitivity? Which original measurements must be preserved to permit a different examiner to test an alternative physical explanation?

My further concern is that a source may differ in electrical construction while producing a deliberately standardised ramp. To what extent can a classifier rely on a distinctive feature that an ordinary control system may remove? Should a source-class conclusion be framed as an observation of the programmed outward behaviour rather than as a claim about the hidden semiconductor design?

John Bardeen, Response: Mr. Hartley, the transformations you describe are generally many-to-one. Averaging erases the ordering of fine fluctuations, magnitude conversion discards phase, logarithmic compression changes how small and large differences are perceived, and choosing a handful of spectral maxima suppresses the remainder of the record. None of these operations is improper for a defined measurement purpose, but their outputs cannot usually reconstruct the original complex voltage. If a ridge is absent from the display, the absence may reflect finite resolution, thresholding, smoothing, insufficient dynamic range or a genuinely absent component. The displayed image alone cannot distinguish those explanations. The examiner must preserve the measurement chain's settings and the unprocessed data accessible under the lawful survey scope.

A reproducible evidence packet should include raw complex I/Q samples if legitimately captured, sample counts and dropout flags, time reference and clock stability, centre frequency, analogue bandwidth, input gain, attenuator settings, any preselection changes, calibration records and software version.

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It should also describe how the spectrogram was formed: window, overlap, normalisation, FFT length, display floor and colour mapping. A second examiner can then recompute the early feature using another defensible estimator and determine whether the claimed distinction survives. If only a screenshot remains, the appropriate qualification is that the inference was made from a derived display whose omitted information cannot be recovered.

A standardised ramp can conceal information about hidden hardware. That is precisely why visible emission behaviour must not automatically be equated with semiconductor construction. Two quite different amplifiers may be governed by the same gate and digital envelope programme. Conversely two instances of the same amplifier may behave differently if one control sequence enables the output before the oscillator settles and another waits. A classifier may validly distinguish those outward operating regimes, provided the regimes are defined and the result generalises to new authorised samples. It should then call them operating regimes, not manufacturers, individual units or semiconductor material classes. The name of the category is part of the scientific claim and must match the evidence actually present.

Where one suspects a physical class difference, design a test with known apparatus capable of changing the relevant operating variable. A programmed ramp hypothesis predicts differences when the ramp command changes; a semiconductor-storage hypothesis predicts relationships with off-time or bias history; a filter-ringing hypothesis predicts changes when receiver bandwidth changes. These are not interchangeable predictions. The advantage of preserving raw evidence is that competing

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predictions can be evaluated without having to trust a single selected picture. Even the best evidence may support several mechanisms. A report that makes those alternatives visible is stronger than a confident but unsupported identification.

John Bardeen, Cross-Peer Question to Sir Martin Ryle: Sir Martin, a laboratory engineer may control a transistor's bias and measure its output through a cable, yet the defensive examiner observes the same class of signal through an uncertain environment. Reflections from building surfaces, antenna orientation, movement and multipath delay may change the waveform received at a particular point. Which features of a power-on transient could survive reasonable changes in path, and what independent observations would show whether a spectral shoulder belongs to the transmitter or to a delayed replica arriving at the antenna? In particular, can one compare two receiving antennas in the same room without mistakenly assuming their paths are independent?

I should also like you to address spatial selection. If an operator moves an antenna until a startup feature looks unusually sharp, then takes that location as representative, the apparent source class may be influenced by the selection itself. How could the survey record the search geometry and its uncertainties so that later investigators can assess whether a distinction is robust across positions rather than an artefact of the chosen observation point?

Sir Martin Ryle, Cross-Peer Answer to John Bardeen: Dr. Bardeen, propagation is an essential part of the measured event. In an approximate linear time-invariant channel one may write r(t)=sum over k of alpha_k s(t-tau_k)+n(t), where s is the emitted complex baseband signal, alpha_k are

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complex path gains, tau_k are relative propagation delays, and n is aggregate noise. This model is not universally valid in moving or nonlinear environments, but it makes the ambiguity clear. A short source transient may be lengthened by delayed components; its amplitude may be enhanced or cancelled at particular frequencies. A shoulder appearing at one location can vanish a modest distance away because the complex path contributions have changed. One receiver at one point cannot distinguish all these mechanisms from source-intrinsic effects.

Two receiving antennas do not automatically supply independent experiments. If they share nearly the same multipath geometry, the same local oscillator or the same analogue chain, their errors and channel responses may be correlated. Their value depends on documented separation, polarisation, calibration, timing and channel diversity. An authorised reference source placed at known locations can probe the site response without guessing which environmental components created each reflection. Where possible, use a controlled conducted or shielded coupling test to isolate the source and receiving instruments from the variable room channel. Then compare that laboratory baseline with field measurements as a constrained analogy, not as a direct identity proof.

The operator's search procedure also matters. Selecting the spatial point that maximises a desired feature and then using that same point to claim exceptional distinctiveness introduces selection bias. Record the actual antenna path, elevations and orientations, the detector's settings, and every observation location examined, including unsuccessful ones. A predefined spatial sampling grid or independently repeated survey reduces the temptation to turn an extreme selected trace into an intrinsic property. If a

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sharp early shoulder appears only at a narrow set of positions, that pattern is evidence of path sensitivity. If it persists across sufficiently distinct paths and receiving systems, a source contribution becomes more plausible, though not uniquely identified.

The defensible conclusion would identify which aspects of the transient were stable under measured path changes and which remained dependent upon the environment. A class hypothesis that requires one lucky receiving position is not ready for forensic attribution. The proper analogy from radio astronomy is that the instrument's spatial response and the environment's propagation structure must be accounted for before an observed feature is assigned to the object being observed. That principle is equally applicable to a defensive survey of an unknown RF transient.

Dr. James M. Atkinson, Moderator: Dr. Bardeen, thank you. Sir Martin Ryle, I pass the token to you to account for propagation, antenna geometry and the independence of receiver-based corroboration.

Sir Martin Ryle, Fourth Principal Contributor: A radio observation is the result of a source, a path and an instrument. The measured turn-on trace can be strikingly detailed while remaining incomplete as evidence about the source itself. At a particular antenna position a short emission may arrive by a direct path and several reflected paths with different delays and phases. Their combination can produce a transient amplitude shoulder, a notch or a frequency-dependent ring that does not exist in the emitted field at the source. At a second position those path contributions may interfere differently, altering the apparent opening seconds or microseconds of a transmission. The investigator should not call every reproducible feature an

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intrinsic signature, because the room itself can reproduce it whenever the antenna returns to the same place.

In a simplified description of a stationary multipath environment, the channel is a sum of delayed and weighted versions of the source waveform. That model explains why a rising envelope can appear longer or more complicated than the original. It also explains how a frequency-dependent channel can alter the estimated early spectrum. However, an indoor environment may not remain stationary when doors open, people move, machinery starts or a handheld antenna is repositioned. A classification model trained in one static room might therefore fail elsewhere. The appropriate question is not whether a particular complex trace looks repeatable, but whether the source-class feature remains stable after the likely path and instrumentation differences are deliberately introduced.

Our first concern should be observability. A receiving antenna has a pattern, polarisation response, impedance and coupling to nearby structures. An attenuator or preselector changes the effective observation chain. If an operator changes antenna orientation while pursuing the strongest signal, the resulting trace is sampled from a selected region of the channel's spatial response. Selecting a spectacular transient after inspecting dozens of locations is not equivalent to a predeclared test at a random location. The final record must include the selection history, including positions where the proposed feature was weak, inconsistent or absent. Otherwise the reader is shown a curated result without the denominator of failed observational opportunities.

A useful controlled experiment uses an authorised reference emitter with a known trigger and envelope, placed at documented positions. Record the

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signal simultaneously through two independently calibrated receiving systems, preferably with independent clock and analogue chains. Keep the location, polarisation, antenna height, filter settings and input level documented for each observation. Conduct a second experiment through a calibrated shielded or conducted coupling path, within the source's safe operating constraints. Comparing the freer propagation path with the controlled baseline helps determine which early features are sensitive to the environment. It does not fully reconstruct every reflection, but it challenges a source-only explanation with an alternative that is experimentally observable.

Independence between channels is often overstated. Two receivers may be fitted with separate antennas yet share the same timing reference, processing software or preselector design. Their recordings can agree because they share a calibration error. Conversely two physically different receivers may have different analogue impulse responses, making source-consistent events appear different. The test should classify which elements are truly independent: RF front end, oscillator reference, analogue-to-digital converter, processor, event-detection algorithm and physical antenna path. Where practical, use a known calibration emitter through each system before and after the experimental run. A agreement of two derived spectrograms is weaker than agreement of calibrated raw event features measured through genuinely different chains.

Consider a quantitative example. A hypothetical source has an envelope rising over 5 microseconds, and a reflection arrives 2 microseconds after the direct signal with a complex gain whose magnitude is 0.4 of the direct path. Depending on phase, the reflected contribution may enhance or partially

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cancel the direct field during the rise. The delay is 2 microseconds by assumption, not by any asserted measurement. The spatial response can therefore alter the apparent transient on a scale comparable to the source rise, particularly where reflections are appreciable. No universal curve can be inferred from those illustrative values because building geometry, frequency, antenna pattern and bandwidth determine the actual response. A controlled experiment should vary path conditions and demonstrate whether the chosen features are stable in spite of such changes.

Frequency stability is subject to its own propagation qualifications. A static multipath channel does not ordinarily create a genuine carrier-frequency drift, but it may distort instantaneous-frequency estimates when the signal is weak, when paths interfere, or when the receiver algorithm follows an amplitude notch rather than the true carrier. Moving scatterers may introduce additional Doppler components. A local oscillator drift in the receiver introduces yet another competing explanation. If the analyst sees a brief frequency excursion alongside an amplitude dip, the report should compare raw phase continuity, receiver clock records, amplitude-dependent estimator failures and independent receiving observations. One should not interpret the mathematical phase of a noisy, near-zero complex sample as if it were an exact measurement of a physical oscillator's state.

For lawful defensive fieldwork, the purpose is often to sort observed events into plausible broad categories so that the survey can choose further measurement methods. One may report that a transient is stable across certain antenna positions and receiver configurations, and that it resembles the controlled startup of a known class of reference sources. This supports prioritisation, not a unique source label. A substantial change after

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repositioning the antenna suggests that the observed feature is path dependent. A substantial change after exchanging the receiver suggests instrument dependence. The investigation advances by treating these changes as information, not as inconvenient anomalies to be concealed beneath a class label.

Finally, the documentation must make the measurement geometry recoverable. Record room location, antenna separation, orientation and distance estimates with appropriate uncertainty, equipment state, environmental movement and trial times. Preserve null observations as well as detected ones, because a disappearing feature may be more discriminating than an especially attractive positive trace. Distinguish repeated measurements at one fixed point from independent configurations in which the physical path has changed. The aim is not to reconstruct a transmitter's unique identity by some form of remote clairvoyance. It is to exclude competing propagation and receiver explanations before treating a transient as evidence about a transmitter class.

Richard Wesley Hamming, Peer Question: Sir Martin, your insistence on documenting antenna location and path suggests that software metadata may be as important as the RF samples themselves. Suppose two independent receivers appear to agree on the first ten microseconds of a reference transmitter's startup, but both streams pass through the same event assembler. That programme aligns captures on the detected peak, removes any event whose pretrigger buffer is incomplete, and normalises the stored amplitude. The resulting files could show an artificial similarity. Which metadata and independent processing tests would let an examiner

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determine whether agreement is genuinely physical or created by the common software? Would you regard independent RF hardware as sufficient when the comparison pipeline itself is not independently controlled?

I should also ask how to preserve negative observations. A receiver that was blind during a scan gap has not disproved an emission, and an event filter may silently discard weak or distorted starts. What records of eligibility, buffer completeness, sample loss and software rejection should accompany the archive so that a later examiner can distinguish a true absence from a missing opportunity to observe?

Sir Martin Ryle, Response: Dr. Hamming, independent RF hardware is an advantage but not a substitute for independently validated processing. If both data streams are peak-aligned by the same event assembler, shared preprocessing can create a common shape even when raw onset times and amplitudes differ. The data package should therefore preserve the original sample indices, acquisition timestamps, trigger records, pretrigger depth, complete input level information and the exact transformation code used to prepare each display. A second analyst should be able to reconstruct the comparison from independently sampled raw data without trusting the first assembler's alignment decisions. The analysis should disclose rejected events and the reasons for rejection, not quietly count only those starts that already look clean.

To test the pipeline, inject synthetic reference events into recorded noise at known offsets and amplitudes, then run the software without revealing the insertion labels to the analyst. This identifies whether peak alignment systematically shifts the onset or whether incomplete buffers are discarded

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disproportionately for slow-rising pulses. Process a separate set through a second independently implemented algorithm, and compare not only final feature values but event selection and sample indices. The aim is not perfect agreement between programmes; a disagreement identifies assumptions that must be resolved. If two programmes use the same input buffer created by a common flawed driver, they are not independent at the acquisition level, so the hardware path must also be audited.

The negative observations require an eligibility log. A sweep receiver should record tuning position, dwell intervals, settling periods, sampling gaps, gain changes and detector thresholds. A null in an eligible, calibrated observation window has a different evidential meaning from a null during a retune or data loss. Similarly, a waveform discarded by a quality filter is not absent from the antenna merely because it was excluded from the class comparison. Reports should state the population of physical trials, the subset visible to each receiver, the subset successfully captured, and the subset finally analysed. A classification rate calculated only on the cleanest selected events may tell us little about general detection performance.

I would ask for an audit trail with immutable raw records, hashes, software versions and a reproducible sequence of transformations. The examiner should confirm that the class result persists under reasonable alternative alignment and normalisation methods. If not, the evidence supports at most a processing-dependent descriptor, not a robust RF-source feature. Such caution is especially important in forensic circumstances, where the apparent certainty of two agreeing instruments can conceal a shared computational decision. A source class ought not be inferred from concurrence manufactured by a common file-handling routine.

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Sir Martin Ryle, Cross-Peer Question to Edwin Howard Armstrong: Mr. Armstrong, an unfamiliar startup trace may be influenced by both the emitting apparatus and the receiving chain, and the receiving chain may include conversion, limiting and strong selectivity. Suppose a weak laboratory transmitter radiates an amplitude ramp with a short frequency excursion, while a superheterodyne receiver retunes during acquisition. Its display shows a pronounced spectral hook. Would you explain how frequency conversion and IF filter response might generate or magnify such a hook, and what comparative experiment would distinguish that instrument effect from an actual source frequency trajectory?

I also wish to press the difference between stable reception and stable evidence. A receiver design that beautifully suppresses interference may nevertheless discard information about the true instantaneous startup waveform, particularly when a limiter or detector responds nonlinearly. Which parts of the measured transient remain physically interpretable after those operations, and how should a countermeasures report avoid identifying a supposed emitter type merely because the spectrogram is visually characteristic of one receiver architecture?

Edwin Howard Armstrong, Cross-Peer Answer to Sir Martin Ryle: Sir Martin, the superheterodyne receiver is a chain of deliberate frequency transformations. A received carrier is mixed with a local oscillator, passed through selectivity and eventually detected or sampled. If the receiver's local oscillator changes frequency during capture, the frequency of the intermediate signal may move even when the transmitting carrier is steady. An IF filter with nonuniform amplitude and group-delay response may then alter the early envelope and spectral shape. A visually striking hook can

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therefore arise from the instrument's own dynamics. One must not regard the instrument as a transparent window merely because its steady-state frequency scale is well calibrated.

A discriminating test begins with a stable, traceable reference signal whose startup and frequency are independently known. Inject it at an appropriate point ahead of the receiver, with level and bandwidth matched to the intended experiment, and repeat the capture across the suspected retuning states. If the reference acquires a hook under the same receiving configuration, the receiver must be implicated. A second independently stabilised receiver can then monitor the actual radiated laboratory source continuously while the first retunes. Agreement in the source's physical frequency excursion across both chains strengthens a source-side interpretation; disagreement, particularly one following the first receiver's tuning transitions, weakens it.

Limiting and detection deserve separate notice. A limiter deliberately removes amplitude variations beyond its operating range. This can improve reception of a frequency-modulated signal but also makes the original amplitude ramp unrecoverable from the limited output alone. A narrow IF channel may suppress parts of a rapidly changing startup spectrum, causing the apparent shape to depend upon alignment and bandwidth. Thus a receiver suitable for listening may not be suitable for measuring every aspect of transient source behaviour. The report should declare at which measurement point the samples were acquired and whether relevant amplitude and phase information survives the intervening stages.

As to identification, I would restrict the conclusion to the features independently established. One might say that the observed startup in two

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calibrated chains contains an early frequency excursion beyond the measured uncertainty and that the excursion is compatible with particular oscillator-settling architectures. One should not identify the transmitter as a certain make or unique apparatus without separate population evidence and controlled exclusion of competing designs. The receiver that makes the trace attractive also provides reasons to question it. The proper use of sophisticated radio instrumentation is to expose those dependencies and narrow the uncertainty, not to hide them beneath a confident label.

Dr. James M. Atkinson, Moderator: Sir Martin Ryle, thank you. Mr. Armstrong, the token passes to you. Address superheterodyne conversion, filtering, detection and a defensible source-class rather than individual-source conclusion.

Edwin Howard Armstrong, Fifth Principal Contributor: An RF receiver is not a neutral pair of eyes. Its selectivity, gain, conversion stages, oscillators and detectors determine the portion of a transmitter's behaviour that reaches the examiner. A receiver optimised for recovering a message can be especially unsuitable for examining the exact transient amplitude that preceded steady transmission, because its filters and limiters deliberately reshape the signal. In a superheterodyne system, an apparent early shift in frequency may reflect motion of the receiving oscillator, motion of the transmitting oscillator, or both. The surveyor should ask where in the chain a measurement was made, how its time reference was established, and which components of the original waveform can survive the chosen path. Without that information, an apparently characteristic power-on transient can easily be a characteristic of the receiver.

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Consider a controlled transmitter that begins with an oscillator settling through a small frequency excursion while its power amplifier gradually opens. A narrow receiving IF filter may initially pass only the portions falling near its centre, making amplitude appear to rise and fall as the carrier crosses the passband. A wider IF filter may show a smoother amplitude envelope and a broader short-time spectrum. If the analyst receives only a log-power waterfall from the narrow channel, the observed pattern may look like two separate startup events. Yet a wideband complex recording could reveal a single continuous physical event. The correct comparison must therefore consider whether the proposed classifier is attached to the receiver's selected output representation rather than to a transmitter mechanism.

I would classify the instrument operations by their effect on evidence. Frequency conversion changes the reference frequency and incorporates local-oscillator stability into the measurement. A finite IF filter introduces amplitude and phase response, potentially extending the duration of transients. Limiting can erase amplitude information. Automatic gain control changes the apparent envelope according to earlier input power. Squelch and energy thresholds can remove the weakest beginning samples. Digital resampling, timestamp assignment and spectrogram windows introduce further time and frequency selection. The fact that these operations are deliberate and useful for ordinary reception does not make them appropriate for every forensic measurement. Their role must be declared before a physical cause is inferred from a derived feature.

The distinction between modulation and startup dynamics is also worth making. A signal may show changing instantaneous frequency because the

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source is intentionally modulated, because a frequency-control loop is acquiring stability, because a receiving converter is drifting, or because a phase estimator becomes unstable during low amplitude. The mere existence of a brief frequency slope does not reveal which explanation applies. If a known test source can hold its oscillator steady while its RF output is gated, the resulting capture supplies a useful receiver-control condition. If another reference source intentionally sweeps its oscillator under known control, the measuring system's ability to recover that sweep can be tested against independent timing and frequency references. Neither experiment should require decoding an unknown communication.

An investigator may gain much by deliberately changing receiver architecture. Record the same authorised power-on event through a sufficiently wideband direct-sampling receiver and through a superheterodyne chain whose analogue bandwidth, filter shape and oscillator reference are characterised. If the distinctive spectral hook follows the superheterodyne but not direct sampling, it is unsafe to claim that the source intrinsically generates that hook. Conversely, if a calibrated frequency excursion appears in both chains at corresponding source-trigger times, with uncertainties accounted for, a source-side mechanism becomes more plausible. It may still be shared by many transmitter classes, and its presence is not a unique fingerprint.

A basic numerical illustration emphasises bandwidth. Suppose the useful part of a startup feature changes over 10 microseconds, and a receiver's effective impulse-response decay extends over 30 microseconds. The output may be dominated by the receiver's longer response, and no sound inference can distinguish a 5-microsecond source feature from a 10-

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microsecond one without additional validated information. Those times are purely hypothetical. The engineer should measure actual step and pulse responses for the operating conditions and disclose whether an attempted distinction lies inside the instrument's resolution. Higher nominal sample rate does not cure inadequate analogue bandwidth or a gain stage operating in compression. The sampling converter cannot recreate portions of the waveform already removed by the front end.

Physical source classes remain useful if they are defined by mechanisms and supported by comparative measurements. A gated continuous oscillator, a free-running oscillator enabled with the power stage, and a synthesiser whose output is withheld until lock may produce different patterns under controlled laboratory conditions. But a programmer can impose the same output ramp on more than one architecture, and different receiver chains can make one architecture appear varied. A valid study should therefore use more than one hardware unit per proposed class, varied receiving chains, held-out power cycles, source-state metadata and explicit tests for alternative causes. Error rates calculated from non-independent samples or from a single instrument should not be generalised to the entire population of unknown transmitters.

For a defensive field report I would present the observable record first: calibrated amplitude and frequency trajectories, time origin, signal-to-noise ratio, instrument state, detection threshold and uncertainty. Then I would list supported interpretations in descending order of evidential compatibility, including receiver and propagation artefacts. Finally I would specify what authorised experiment would discriminate the remaining hypotheses. An antenna movement, independent receiver, controlled

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attenuation series or known source-side trigger can be more valuable than a more elaborate pattern-recognition algorithm. We should be rigorous about the limitations imposed by actual circuitry, because transmitter identity is not a prize awarded to the most complicated looking trace.

The study of transient RF behaviour should therefore be a study of measurement provenance as much as of transmitter circuits. No single waveform feature is automatically intrinsic, universal or unique. A reliable class inference survives experimental changes that should affect nuisance mechanisms but not the claimed source mechanism, and it remains uncertain where those interventions are unavailable. The engineer who writes that a startup pattern is compatible with a broad oscillator-control class, under stated conditions, has served the examiner better than one who pronounces a precise identity without demonstrating that the instrument could support it.

Irving S. Reed, Peer Question: Mr. Armstrong, I should like to raise a statistical concern about the feature vector that survives your receiver chain. If a limiter erases most amplitude variation and an IF filter shapes the opening spectrum, a classification algorithm may still find highly repeatable coded patterns in the remaining sample sequence. But repeatability in a derived representation is not evidence of uniqueness in the physical source. Which held-out experiments should be required before a radio survey calls those features transmitter-class evidence? Would you insist on independent receivers with different analogue architectures and on source devices not seen during feature selection, even when the first system shows exceptionally low apparent error?

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A second concern is the analyst's temptation to repair disappointing results by changing thresholds, window boundaries or normalisation after inspecting the errors. What should a defensible protocol specify before the confirmation experiment begins, and how should the outcome be reported if performance deteriorates substantially when the measurement chain is changed?

Edwin Howard Armstrong, Response: Dr. Reed, a classification experiment has to be designed to test the scope of the proposed claim, not merely the ability of a programme to recognise the recordings it has already seen. If the claim is that early RF features identify an oscillator-control architecture, the test should use several authorised examples of that architecture and several plausible competing architectures. The receiver chains should differ enough to challenge a common artefact, and the physical transmitters used for final evaluation should not have been used to choose features or tune thresholds. One may conduct preliminary development on known hardware and still reserve a genuinely independent confirmation set. Without that separation, excellent apparent classification can simply be excellent memorisation of instrument and laboratory conditions.

The experimental protocol should name its observation variable, time origin, analogue bandwidth, frequency estimator, signal-level range, capture eligibility and classification rule before the confirmation data are examined. If the protocol uses an automatically selected early window, that algorithm and its parameters must be fixed in advance. Tests should include reference pulses that challenge the analogue response and signals near the detector's actual operating threshold. Every rejected physical cycle should remain in the accounting, with the reason recorded. An evaluator that silently discards

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difficult events cannot claim the same performance on the entire authorised survey population as it has on a chosen clean subset.

If performance deteriorates when a receiver is exchanged, that failure is not merely an inconvenience; it narrows the claim substantially. It may establish that the classifier organises recordings for the original receiver architecture, while failing to distinguish transmitter classes independently of that architecture. Report the failure alongside the original success. Show confusion matrices by receiver, device and environmental stratum and include uncertainty that respects physical-unit clustering. A high score on repeated digital samples is not equivalent to independent evidence from new transmitter units. Even where a feature remains stable, the result supports a class distinction only within the evaluated reference population and operating conditions.

No manipulation of protected communications content is necessary. The experiment may use known authorised training signals, dummy modulation or controlled RF gating, retaining only lawful waveform measurements and instrument logs. A defensible report would state which physical explanations have been challenged, which remain plausible and what future authorised measurement could distinguish them. A scientific programme gains credibility from acknowledging that its first attractive feature failed an independent hardware test. It loses credibility by redefining the test after seeing the result and then reporting the amended trial as though it had been planned from the outset.

Dr. James M. Atkinson, Moderator: I thank the contributors for the careful handover of the token. The panel finds that measured power-on behaviour can inform cautiously defined architectural classes when source,

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propagation and receiving-chain alternatives have been challenged independently. No transient recorded by one instrument is an intrinsic individual transmitter identity in the absence of a separately validated uniqueness and attribution experiment.

SOURCE REGISTER AND HISTORICAL ELIGIBILITY. Herbert Kroemer, “Quasi-Electric Fields and Band Offsets: Teaching Electrons New Tricks,” Nobel lecture and ChemPhysChem 2 (2001), 490–499; William R. Hewlett, U.S. Patent 2,268,872, “Variable Frequency Oscillation Generator,” filed 1939, issued 1942; John Bardeen, Nobel Lecture, “Semiconductor Research Leading to the Point Contact Transistor” (11 December 1956); Sir Martin Ryle, Nobel Lecture, “Radio Telescopes of Large Resolving Power” (12 December 1974); Edwin H. Armstrong, “A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation,” Proceedings of the IRE 24(5) (1936), 689–740. These historical publications substantiate general fields of competence but not the fictitious dialogue. Full passage-to-source review is Stage B pending.

EDITORIAL QUALIFICATION. Examples, quantities and trial designs are constructed for educational purposes, not measurements of any external transmitter.

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QUESTION 088

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How does antenna switching affect bearings of a moving or rapidly duty-cycled source?

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SCHOLARLY RECONSTRUCTION. The historical scientists named below did not meet for this discussion. All remarks are newly composed fictional scholarly reconstructions rather than historical quotations. The techniques are restricted to lawful, authorised defensive RF measurements.

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Dr. James M. Atkinson, Moderator: Sir Martin Ryle, I should like to begin with the distinction between observing a radio wave at several receiving elements simultaneously and switching one receiving channel between antennas at different times. If a source moves or transmits in brief intermittent bursts, can a sequence of individually credible antenna measurements form a false composite bearing? Kindly take the token and account for the time, geometry and instrumental qualifications before we invite the other specialists to examine the measurement.

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Sir Martin Ryle, Principal Contributor: An antenna system provides information about direction only to the extent that its spatial observations can be related to a common state of the source and receiving environment. If receiving elements observe a sufficiently stationary wavefront at the same instant, comparisons of their signals may exploit phase and amplitude differences attributable to geometry. If, however, the equipment selects one antenna, records a brief interval, disconnects it and only later connects a second, the two measurements refer to different instants. An estimator that then treats them as simultaneous implicitly assumes that the source's direction, emission amplitude, frequency, propagation channel and polarisation have not changed in the meantime. For a moving or short-duty-cycle transmitter, that assumption must be defended experimentally rather than inherited from a conventional stationary-source bearing calculation.

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Let theta(t) denote the true direction of an authorised reference transmitter relative to an instrumented array, a_j(theta) the complex directional response of receiving element j, and s(t) the complex transmitted field under a simplified far-field model. Let w_j(t) be one when element j is eligible to receive and zero when the switch or receiver is blind, and let n_j(t) represent measurement noise. The recorded sequence may be represented schematically as y_j(t)=w_j(t)a_j(theta(t))s(t)+n_j(t). In practice the responses include frequency dependence, polarisation, multipath and receiver memory, which the simple expression omits. Even this elementary model makes the central error visible: if the switch records element one at t_1 and element two at t_2, the ratio y_2(t_2)/y_1(t_1) does not generally estimate an antenna-pattern ratio at a single bearing. It also contains changes in the transmitted field and in the source's direction between t_1 and t_2.

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Suppose a controlled laboratory source crosses a known angular trajectory at 20 degrees per second relative to the receiving array. A sequential scan requires 150 milliseconds to collect its nominal set of antenna observations. Over that scan the true direction changes by 3 degrees. These illustrative numbers do not claim a measured system accuracy; they show that the assumption of a common source direction already contains a potentially material error before considering receiver noise. If the source emits only during one part of the 150-millisecond interval, the missing channels may be filled by the next burst at a still later direction. An algorithm can produce an apparently precise bearing from these assembled measurements, while the purported physical angle never existed at a single instant. Increasing the number of samples at each antenna does not repair the fundamental temporal mismatch.

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The switching operation itself introduces additional blind intervals and transients. A receive front end may require time for RF switches to settle, the first intermediate-frequency filter to recover, or automatic gain control to respond after the antenna path changes. Those intervals must be measured with authorised reference pulses, not inferred solely from a switching-control bit. A nominal dwell of five milliseconds may contain less than five milliseconds of eligible observation if the first part is consumed by settling. A duty-cycled source can then emit while the receiver is physically unable to acquire it. An empty recording from that antenna is not evidence that the source's radiation pattern had a null in that direction; it may be evidence only that the two time schedules did not overlap.

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A simultaneous calibrated array supplies an important reference, but it too demands careful calibration. The receiving channels must have known relative phase, gain, timing and frequency responses, and their antennas must have documented spatial and polarisation properties. Common reference clocks can help establish simultaneous timing; they can also create shared errors if the reference itself is faulty. The distinction is not between an infallible simultaneous receiver and a defective switched receiver, but between two measurement architectures whose assumptions and failure modes can be tested. A controlled comparison can determine how far sequential scanning departs from a simultaneously measured benchmark under different source speeds, burst duty cycles and receiver settling times.

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A useful experiment moves an authorised test transmitter along a measured track while imposing bursts at controlled, concealed time intervals. The source position, orientation, power and burst eligibility are recorded independently of the receiving equipment. Repeat the track with different switch schedules and start phases, including schedules randomly displaced with respect to the source bursts. Some trials will contain a complete set of antenna observations, others only one or two and others none. Every trial should remain in the accounting. Estimating bearing error solely from the successfully completed scans would select for cases in which the source happened to be cooperative; the result could exaggerate the instrument's performance in the very intermittent regime that concerns the investigator.

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The analysis should distinguish measured error conditional on a complete antenna sequence, probability that a sequence is complete, and total probability of producing a defensible bearing per authorised observation interval. These are different quantities. A switched system may yield excellent directional estimates in the subset of slow, continuously radiating sources, yet have poor acquisition reliability when bursts are short and moving. Another algorithm may return a bearing on nearly every trial by combining observations from different events, but its apparent completeness is gained at the cost of a hidden stationarity assumption. The proper report should show the distribution of angular error, the distribution of observation latency and the rate of unqualified bearings, each as a function of motion, duty cycle and receiver configuration.

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I would not allow a final plot that connects successive bearing estimates with an unbroken curve unless the estimates have timestamps, uncertainties and declared observation windows. A line between a 20-degree observation and a later 30-degree observation may suggest continuous tracking even if there was no eligible reception between them. The examiner should display missing intervals, the actual antenna-selection sequence and any source events used more than once in an estimate. If the environment contains reflections, a bearing drawn from selected amplitude maxima may respond to a changing reflected path instead of to a changing source location. Independent observations through different geometries can help challenge such alternatives, but they should not be described as independent merely because a pair of antennas looks different.

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The conclusion must therefore be conditional. A sequential antenna switch can support a bearing for a moving, duty-cycled source when timing, source stationarity during the applicable observation window, receiver settling and spatial response have been sufficiently bounded. Where those conditions fail, the system may provide only a set of partially observed directions or a hypothesis requiring another measurement architecture. It is entirely legitimate to decline a precise bearing rather than to manufacture simultaneity from measurements taken at different times. The strongest scientific result may be the explicit determination of the speeds, dwell periods and burst occupancies under which the selected instrument ceases to be an adequate observer.

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Claude Elwood Shannon, Peer Question: Sir Martin, the proposed data set contains both ordinary directional measurement error and missing observations that depend upon whether a transmitter happened to be radiating while the selected antenna was eligible. Suppose the instrument succeeds in collecting a full antenna sequence only when bursts last longer than the switching cycle, but its developers report the angular accuracy calculated from those successful sequences without accounting for the short-burst trials. Would you distinguish the probability of obtaining a bearing from the accuracy of the bearing conditional on its existence? How should an analyst compare a system that refuses to return a bearing in uncertain circumstances with a system that always returns a number by combining samples from different emissions? A single average angular error may conceal the decisive difference between reliability and forced completeness.

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I would also ask whether randomising the switch order is enough to eliminate bias. If the source's motion and duty cycle are correlated with the observation schedule, the missing-data mechanism is not automatically independent. Which independently logged variables and external controls would be required before the examiner could assert a defensible uncertainty distribution for those unobserved bursts?

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Sir Martin Ryle, Response: Dr. Shannon, the two performance dimensions must be reported separately. Let E denote the event that the receiver had adequate, temporally compatible observations to construct a bearing under a predeclared validity rule, and let A be the angular error of a returned bearing. A report of the conditional distribution P(A|E) tells us how accurate the selected successful estimates were; it does not tell us how often they were available. The acquisition probability P(E) is a different statistic. Both should be estimated from all authorised source trials, with the denominator and observation-eligibility conditions stated. A system whose reported bearings are excellent but rare may be entirely unsuitable for monitoring brief intermittent emissions; a system that always returns a point estimate may instead have very poor physical validity when its input sequence combines incompatible source states.

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The comparison should therefore include at least three declared outcomes for each trial: a valid estimate supported by adequate observations, an explicit abstention because required data are missing or inconsistent, and a rejected or demonstrably invalid estimate. The last category must not be hidden by silently removing its cases. One may plot angular-error distributions for valid estimates and acquisition frequencies for the entire trial population. Where a system fabricates completeness by borrowing observations from separate bursts, evaluate those estimates against the independently recorded source track at the relevant timestamps. A bearing with no single defensible reference instant is not made valid by choosing whichever true angle minimises its apparent error after the analysis.

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Randomising the antenna switch sequence can reduce systematic alignment with a periodic source, but it cannot guarantee unbiased sampling. The source's burst duration, start time, power, direction and polarisation may all affect detectability; the receiver's settled gain and detection threshold can interact with those factors. The independent ground-truth logger should therefore record source emission timing and physical trajectory without relying on the scanning receiver. A second continuously observing calibrated reference channel can identify bursts missed by the switch system, and the trial record must include intervals when each antenna was ineligible. These controls allow the analyst to estimate how many unobserved events were lost to the sampling schedule rather than to the absence of radiation.

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If several receiver configurations are compared, preserve the same authoritative physical-trial definitions. Do not change the definition of a successful source burst to favour one architecture. Report uncertainty across independent trajectories, different source units or trial sessions where available, rather than treating thousands of overlapping time samples from one track as independent replicates. The cautious scientific conclusion may be that sequential switching yields satisfactory conditional angular accuracy within a restricted motion and duty-cycle range but substantially lower availability outside it. That is a valuable finding. It is better than a single impressive bearing-accuracy statistic that silently excludes the very events the survey was intended to observe.

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Dr. James M. Atkinson, Moderator: Dr. Bracewell, Sir Martin has identified the central danger of making observations at different instants and treating them as a single spatial measurement. I now ask you to examine the corresponding problem in array mathematics. In particular, please distinguish a physical array manifold, the sampling operator used by a switched receiver, and the hidden stationarity assumptions under which sequential measurements can be combined into a bearing. The token is yours.

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Ronald Newbold Bracewell, Principal Contributor: A directional receiving instrument does not measure an angle directly. It collects electrical observations that are interpreted through a model of the antenna geometry and the incident field. In a simultaneous, narrowband array the complex samples at several elements may be represented by a spatial steering vector whose entries describe phase and amplitude at a single reference instant. Such a representation is useful precisely because it separates an assumed source direction from the characteristics of the measurement apparatus. The mathematical simplicity, however, depends upon coherent observations: the entries of the vector must correspond to substantially the same wavefront or to a demonstrably stationary process over the interval involved. When one receiving chain is connected to successive antennas, the recorded sequence is no longer the ordinary spatial vector unless additional temporal conditions are imposed.

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Let a(theta) be the vector of calibrated complex receiving responses for a plane wave arriving from direction theta, and let x(t) be the complex amplitude of that wave. Under a deliberately simple one-source, narrowband model, the simultaneous array observation is y(t)=a(theta(t))x(t)+n(t), where n(t) contains receiver noise and unmodelled contributions. A switching receiver instead delivers separate observations z_j=a_j(theta(t_j))x(t_j)+n_j(t_j), with t_j denoting the acquisition instant for antenna j. Even when every antenna response a_j has been measured perfectly, it is not generally correct to place these z_j into one vector and evaluate a conventional simultaneous-array direction estimator. The source amplitude, position and propagation transfer function may have changed between t_1 and t_j. That change can masquerade as spatial phase or amplitude structure.

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Consider two antennas separated by a baseline of length d and a source whose arrival direction evolves at angular rate omega. For a conventional far-field phase comparison, the instantaneous path-induced phase difference is approximately (2 pi d/lambda) sin(theta), with lambda representing wavelength and theta measured relative to the chosen baseline normal. But if the first element is sampled at t_1 and the second at t_2, their measured phase difference also includes the source's own phase evolution between those instants, oscillator drift, carrier-frequency offset and the differing propagation channels. The resulting number is not simply the path phase difference at some average direction. A switched receiver that supplies an apparently stable phase-bearing under these circumstances may merely be reporting the timing relationship between its switching oscillator and the signal source.

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The problem is not confined to phase-based methods. An amplitude-comparison direction finder selects the direction most consistent with observations from antennas having different directional patterns. If an intermittent source radiates at one power during the first antenna dwell and another during the second, the inferred amplitude ratio combines true directional response with unknown source variation. A receiver that records a strong signal on a forward-facing antenna, then sees silence on a side-facing antenna, may infer an angular null even when the second antenna was simply switched in after the emission ended. The system must identify the missing second observation as an absence of eligible data, not treat it as a measured zero field.

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It is useful to define a temporal-compatibility condition before applying a direction estimator. Suppose the total switching aperture is Delta, the interval between the first and last antenna observations in the group. Let omega_max be an independently justified upper bound on absolute angular speed of the source relative to the array, and let epsilon_theta be an angular-change budget that the analysis can tolerate. The necessary kinematic condition omega_max Delta <= epsilon_theta constrains the duration of the sequence. It is not sufficient by itself. One must also bound changes in emitted power, oscillator phase, polarisation and multipath over Delta, together with the front end's settling interval. For example, if a reference emitter can change at 12 degrees per second and the allowable unmodelled motion is 0.6 degrees, Delta must not exceed 0.05 second under the constant-bound assumption. An attractive half-second scan does not become compatible merely by applying a more elaborate estimator to the same samples.

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The choice of a reference instant should be explicit. A sequential bearing may be assigned to a declared acquisition centre only if the statistical model can translate each element's observation to that time using independently supported motion and signal models. Extrapolation introduces uncertainty that depends on the age of each observation. A direction-finding programme should retain the original t_j values, measured dwell duration, RF-switch state and signal-detection eligibility, rather than replace them with a convenient common timestamp. When reporting results to another investigator, it is important to provide the source's possible angular displacement during the aperture along with the ordinary estimator variance.

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A simultaneous receiving arrangement can act as a controlled comparator, but its own array manifold must be calibrated for frequency, mutual coupling, cable phase, gain and polarisation. A comparison should not be called independent if both receivers share the same untested timebase or use identical correction constants derived from the switched system. Ideally, the experimental reference includes a separately measured source track, a continuous monitor of actual emission times, and a coherent array with its own integrity checks. The switched system should then be exercised over a range of source speeds and burst patterns, with the switch start phase varied independently of source emission timing. Trials in which the switched system fails to form a bearing remain in the denominator for availability statistics.

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A difficult but consequential point is that the selection of successful scans may itself distort reported accuracy. Complete antenna sequences disproportionately occur when bursts are long, source motion is slow, or received power is favourable. A histogram of error calculated only from these convenient cases describes conditional performance. It must not be offered as an unconditional accuracy statement for fast, intermittent sources. An estimator can legitimately return no bearing where observations do not satisfy the declared compatibility rule. Indeed, an abstention with correct timing and traceable cause may be stronger evidence of instrument integrity than a persuasive but physically unsupported compass angle.

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A robust report must separate three things: the physically observed sequence, the mathematical model used to join observations across time, and the classification of the resulting directional estimate as valid, provisional or unavailable. There is no single algorithm that can reconstruct information the receiver never acquired without invoking assumptions. In controlled research, such assumptions can be tested against an independently instrumented transmitter. In a real defensive survey, the limitations should remain visible to the reader. The texture of a smooth track drawn across a screen is not a substitute for the discontinuous, timestamped records from which the track was computed.

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John Daniel Kraus, Peer Question: Dr. Bracewell, your steering-vector formulation assumes a calibrated receiving response as a function of source direction. A practical array, particularly one assembled from antennas having markedly different polarisation patterns, can have directional changes that resemble variations of the transmitted field. Suppose a moving reference source turns its antenna as it traverses a path, while the direction finder sequentially switches between a horizontally sensitive element and an element with a different polarisation response. A difference in recorded power might arise from motion, polarisation, transmitter activity, mutual coupling or a temporal gap. Which of these should be incorporated into the predeclared validity criteria, and how would you design a reference experiment that could distinguish them rather than selecting a single favourable explanation after the event? I should also ask how the laboratory would prevent a common calibration error in the simultaneous reference array from making the sequential method appear more accurate than it actually is. A defensible result must specify whether the proposed angle describes arrival direction, dominant polarisation response, or an unstable combination of both quantities.

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Ronald Newbold Bracewell, Response: Dr. Kraus, the calibration cannot properly be a scalar gain attached to an antenna name. The receiving response is a vector function of direction, frequency and polarisation, further altered by nearby conductors, antenna coupling and receiving cable characteristics. If the reference transmitter rotates, its radiated field can change in polarisation as well as amplitude. A switched comparison of unlike receiving elements therefore becomes ambiguous unless the experiment independently records the transmitter orientation and controls the radiated polarisation. We should first characterise each receiving path with stable authorised sources at known positions and polarisation states, documenting both the principal response and important cross-polar sensitivity. That permits the investigation to distinguish a measured amplitude ratio expected from the geometry from one that could be caused by a changed illumination state.

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I would employ a factorial controlled experiment rather than a sequence of convenient examples. Use both stationary and moving emitters; vary source orientation and emitted burst schedule independently; and test multiple switch sequences at each setting. Keep raw per-antenna observations and actual switch-state timing. To expose mutual coupling, compare elements in the installed array with suitable isolated or reconfigured reference measurements, and record whether a nearby antenna's termination changes the response of its neighbour. For a receiver whose patterns are intentionally dissimilar, an amplitude ratio must be calculated only for bursts with eligible observations from each required path, and only within the independently supported interval of source stability. A missing observation should be labelled missing, not inserted as a zero-power measurement that manufactures a pattern null.

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The simultaneous array reference requires its own blind checks. Its phase and gain calibration should be verified against independently positioned sources whose positions were not used to tune the directional estimator. At least one alternate calibration sequence and an independently timed record of the moving transmitter should be maintained, so a shared incorrect correction cannot drive both systems towards the same erroneous answer. If the reference itself lacks enough confidence, the proper outcome is a widened uncertainty interval or an unresolved comparison, not the declaration that whichever system yields the narrower angular histogram must be correct.

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For every trial we should report the eligibility of each antenna observation, the measured polarisation controls, the source's trajectory and the delay between observations. Directional uncertainty should be conditional on those facts. In some cases the measurements may constrain only a region of possible arrival directions because an unknown source orientation introduces a family of equally plausible antenna-pattern ratios. A scientifically responsible instrument ought to be capable of reporting that region or abstaining altogether. This is especially important in a defensive survey, where the apparent sharpness of a plotted bearing can encourage greater confidence than the instrument's actual information content warrants.

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Ronald Newbold Bracewell, Cross-Peer Question to Sir Martin Ryle: Sir Martin, I wish to return the token to you on an important experimental issue. The reference array and the switched receiver may both be driven by the same clock distribution, while the moving source's independent logger uses another timebase. It would be tempting to attribute any discrepancies to switching alone, yet clock skew, delay asymmetry and an unrecognised common-mode calibration error could affect both systems. How would you establish a genuinely independent time reference, and how would you specify the angular-motion uncertainty associated with each element's acquisition interval? More particularly, if an analyst chooses a single fitted reference time after observing the results, does that constitute a valid physical bearing or an instance of fitting away the very temporal mismatch the experiment was designed to expose? I would be grateful for a protocol that can still produce a clear result when the transmitter emits too briefly to illuminate every antenna in a cycle. Your distinction between refusing a measurement and returning a qualified one is crucial here.

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Sir Martin Ryle, Cross-Peer Answer to Ronald Newbold Bracewell: Dr. Bracewell, the experiment must separate synchronisation accuracy from the observation itself. A common receiver clock may provide excellent relative timing while simultaneously hiding a shared frequency or phase error. An independent reference should include a transmitter event log produced through a separately checked timing chain, with measured clock offsets and uncertainty before and after the trial. The experimenter must preserve enough raw timing information to reconstruct the onset and end of each authorised burst without assigning a convenient common time after the bearings are calculated. For each antenna element the record should carry the acquisition start and end times, the switch-control transition, the empirically measured settling period and the actual interval during which received samples were eligible for estimation.

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If the motion rate is independently bounded by omega_max and an observation is Delta_t seconds from the chosen reference instant, the simplest possible contribution to angular uncertainty is bounded by omega_max times Delta_t. The bound is conservative and does not address changes in propagation or transmitter radiation. If source acceleration is material, a second-order bound or a track model with explicitly justified uncertainty must replace it. The reference instant and its selection rule should be fixed before looking at the directional estimates. Choosing it afterwards to make a weak array comparison appear coherent is not an independent demonstration of simultaneity; it is a model-fitting step that needs its own declared assumptions and validation data.

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An emission too brief to illuminate all required switched elements cannot by itself provide the full spatial comparison demanded by that architecture. It can support an event timestamp, a detection on one element, and perhaps a restricted directional likelihood if independent information constrains the missing elements. But the analysis must not relabel the unobserved channels as though they had been measured. The simultaneous reference array can test whether the source truly existed at the corresponding instant and which direction the reference observations support. Across many trials, the comparison should give both the fraction of events for which the switched system had the requisite observations and the angular errors among events for which a bearing was legitimately returned.

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Finally, the analyst should conduct deliberate negative controls. Shift the declared switch-to-source alignment by amounts greater than the measured timing uncertainty, inject known gaps in the acquisition record, and repeat the calculation using an intentionally incorrect clock offset. A defensible estimator should flag these conditions or show a predictable degradation of performance rather than preserve the same implausibly precise direction. Such failures of measurement validity are results, not embarrassments to be erased from the report. They give the reader evidence that the system's uncertainty statements respond to actual experimental contradictions instead of remaining a decorative number beside each bearing.

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Dr. James M. Atkinson, Moderator: Professor Kraus, the discussion has so far concentrated upon time alignment and array processing. I now invite your examination of the antennas themselves, including pattern calibration, polarisation and the way a moving emitter can turn an apparently well-timed amplitude comparison into a physically misleading bearing. Please take the token.

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John Daniel Kraus, Principal Contributor: A receiving antenna is not a passive arrow pointing towards a transmitter. Its terminal response depends on the electric field incident at that location, the antenna's geometry and orientation, frequency, polarisation and the electromagnetic environment. A direction finder that uses two or more antenna patterns can infer an arrival angle from differences in the received signals, but only when the comparison corresponds to a sufficiently common incident field. Antenna switching breaks that commonality in time. The physical quantity that enters an amplitude comparison is not a direction alone; it is the product of the changing field and the changing directional receiving response, with additional contributions from reflections and receiver gain. An examiner who omits these factors can convert an innocent change in illumination into a fictitious movement of the source.

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Let $g_j(\theta,\psi,f)$ represent the complex response of antenna j at arrival direction theta, polarisation state psi and frequency f. For a source field with complex amplitude E(t), a simplified settled observation may be written $y_j(t_j)=g_j(\theta(t_j),\psi(t_j),f(t_j))E(t_j)+n_j(t_j)$. The expression is not a complete Maxwell-equation solution. It deliberately leaves out mutual coupling, scattering and gain-control memory. Its purpose is to prevent the false inference that a ratio of two readings taken at different times isolates only the ratio of antenna patterns. Even if the source direction were fixed, a change in the source's polarisation or field strength could alter the ratio. When direction, polarisation and emission duty cycle all vary, the ambiguity becomes more serious.

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A practical measurement should separate the radiation pattern from the switching schedule. First characterise each receiving path with a reference signal at a series of known directions, frequencies and polarisation orientations, retaining both principal and cross-polar responses. Next install the antennas in their working geometry and repeat the relevant measurements, because the final array may differ materially from the isolated antenna. Nearby conductors, common housings, ground planes and transmission lines can change the current distribution and therefore the pattern. It would be a mistake to copy a manufacturer's nominal free-space diagram into an operational programme and then interpret every deviation as the movement of an unknown emitter.

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A moving reference transmitter introduces an additional distinction between orientation and location. A vehicle travelling around the receiver may change its position while the transmitting antenna maintains a particular orientation relative to the vehicle. In another trial the transmitter may move on the same path but rotate its radiating element. The receiver may observe different polarisation and signal-strength histories even though the source's geographical track is identical. An amplitude-only sequential direction finder that seems accurate during the first trial can fail badly in the second. The test matrix must vary source track, antenna orientation and burst timing independently if one wishes to establish which of those dimensions the instrument can actually observe.

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The role of frequency should not be neglected. Different antennas and feed lines may have dissimilar frequency responses, and a broad or frequency-agile signal may illuminate them differently. If the front-end switch selects an antenna and then the receiver retunes, the observed amplitude is conditioned on both operations. A nominal gain correction measured at one frequency does not establish validity over the full band. Moreover, receiver filters, preamplifiers and automatic gain control can retain state from the previous antenna. The resulting amplitude change may be an electrical memory effect rather than an electromagnetic difference at the antenna terminals. Direct recording of settled reference samples after measured switching intervals is essential for separating these effects.

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One controlled test would use a continuous reference array and a separate switched receiver while an authorised source moves through a measured trajectory. Every radiated burst would have an independent event identifier and timestamp, so the evaluator could determine whether a switched antenna sequence drew its samples from the same emission or from successive emissions. A simultaneous reference receiver should record the actual field's amplitude and polarisation characteristics to the extent practicable. The switched system should retain its dwell schedule and distinguish a physically sampled value from an estimated value propagated across a gap. Randomise the source's orientation and switch start phase according to a recorded plan, keeping the analysis blind to the source's true bearing until the estimation rules have been frozen.

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It is important to make uncertainty dependent on observation geometry. A pair of antenna patterns may have very little difference over some angular regions and therefore provide almost no directional discrimination there. At other bearings a small amplitude uncertainty may translate to a much smaller angular interval. Thus an apparent direction error cannot be evaluated by using a single constant conversion from decibels to degrees. If the pattern-ratio function is r(theta), then for a local perturbation in measured ratio delta_r the linearised angular error is approximately delta_theta=delta_r/r'(theta), provided that r'(theta) is nonzero and the linearisation is valid. Where the derivative is close to zero, uncertainty can become large or the inversion nonunique. Source variability across switched observations increases delta_r beyond ordinary thermal noise.

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Suppose an example antenna-pattern ratio changes at 0.2 decibels per degree near one test angle. A one-decibel ratio discrepancy could then correspond, under a purely local linear approximation, to five degrees of angular error. Near a region where the pattern-ratio slope is only 0.02 decibels per degree, the same discrepancy corresponds to fifty degrees, and the linear approximation itself may no longer be credible. Neither estimate is a general empirical performance claim. Both demonstrate why a bearing uncertainty must be tied to the locally measured directional response and the relevant observation conditions, rather than printed as a uniform number for every point on a track.

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A final report should therefore include the patterns actually used, their calibration uncertainty, the transmitter orientation in controlled tests, the observation window for each element and the confidence rule by which a bearing was accepted or rejected. Where a fast intermittent source affords only one valid antenna observation, it may be sound to report a signal detection and the receiving element's broad directional sensitivity, without calculating a single bearing. Where several compatible observations exist, the reported bearing should carry a traceable likelihood or uncertainty interval that accounts for frequency, polarisation and temporal compatibility. It is an engineering virtue to preserve what was measured and to distinguish it from what the inversion algorithm supplied. The graphical neatness of the final bearing line should never outrun the quality of the electromagnetic evidence.

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Antony Hewish, Peer Question: Professor Kraus, I would like to examine the distinction between antenna-pattern discrimination and the receiver's detection threshold. If a brief burst is recorded on the antenna with favourable polarisation but not detected on the other antenna after switching, the absence of a detection may reflect an imperfect receiver, not a true null in the pattern. How would you define the detection eligibility of each dwell, and how would you separate a below-threshold signal from an interval during which the source had already ceased transmitting? Would you require the evaluator to retain raw recordings even when the signal detector does not issue an event marker? In transient radio astronomy we have learnt the importance of distinguishing genuine short events from instrumental coincidences and missed acquisition. It seems possible that a bearing method trained only on successfully detected bursts would inherit a substantial selection bias. Please explain which negative controls would reveal that defect and whether the report should contain the number of pulses that were known to exist but that the switched receiver never had a fair opportunity to acquire.

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John Daniel Kraus, Response: Dr. Hewish, the absence of an event marker is not a measurement of zero incoming field. It is a decision made by a detector under a particular gain, noise floor, threshold, state of settling and length of observation. I would keep separate records for periods when the source was known to radiate but the selected antenna was not connected, periods when that antenna was connected but the receiver had not settled, and periods when the path was fully eligible but the detector did not cross threshold. The first two are observation-opportunity failures; the third is a valid nondetection under declared instrument sensitivity. All three are materially different from a measured directional null, which itself would require calibration and uncertainty bounds.

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The trial record should include pre-trigger or continuous raw samples wherever legally and technically appropriate, with preserved timing and receiver configuration. If recording bandwidth is constrained, the acquisition policy and resulting blind intervals must be explicitly documented before the data are examined. The independently timed reference emitter can establish the actual burst population. The fraction of known bursts intercepted by each receiving state then provides an empirical encounter rate, while the amplitude distributions for eligible dwells help establish the conditional detection probability. These statistics should not be merged into a single claim of direction-finding accuracy.

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A revealing negative control is to change the phase of the switch schedule relative to the reference burst timing without changing source direction. If the reported bearings move when only the timing schedule changes, the estimator is sensitive to selection effects and cannot claim a purely angular response. Another control is to insert a calibrated test field at fixed direction and vary its polarisation, so that the method must distinguish known cross-polar loss from movement. I would also deliberately suppress detector event markers on a subset of otherwise intact recordings and verify that the processing chain distinguishes a missing marker from a missing physical signal, rather than treating the two as interchangeable evidence.

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The report should state the full number of independently logged source events, the number that overlapped each antenna's fully settled observation interval, the number detected above threshold, and the subset that supplied sufficient compatible data for a bearing. These denominators provide transparency about selection. When a source exists but never illuminates the switched receiver's qualifying windows, the correct conclusion is that the receiving architecture failed to observe that event. It is not appropriate to draw a directional conclusion from the absence. Similarly, when only one element detects a burst, a broad sector constrained by that antenna pattern may be reasonable, whereas an exact bearing would require additional information and assumptions. Such restraint is a necessary condition for credible forensic reporting.

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John Daniel Kraus, Cross-Peer Question to Antony Hewish: Dr. Hewish, permit me a final examination of the event-selection mechanism before we turn to operational doctrine. In an antenna-switching direction finder, a short burst may appear on a favourable antenna and escape the second channel because its dwell occurred later, after the burst had ended. The software may then select a subsequent burst for the second channel, perhaps one whose signal envelope and centre frequency resemble the first closely enough to appear compatible. Would you distinguish a physically measured common emission from an event association inferred solely through spectral similarity? How could an authorised test transmitter with a documented but concealed burst sequence expose spurious associations, and what safeguards should prevent a strong signal from causing a less sensitive receiving path to be treated as though it had observed the same event? I am particularly interested in whether a large number of correctly detected individual pulses might nevertheless produce a misleadingly precise bearing when the pulse-pairing process is systematically wrong. Please address the limits of the directional claim rather than the mere correctness of each detector event.

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Antony Hewish, Cross-Peer Answer to John Daniel Kraus: Professor Kraus, the question identifies a distinction that should be built into the test design before any measurement is made. The physical burst is an emission interval that exists independently of the receiving programme. An event association is a hypothesis that two or more recorded observations correspond to that same interval. Spectral similarity may support a hypothesis, but it cannot establish identity when a source emits repeated or nearly identical bursts. A switched receiver that observes one pulse on an antenna and another pulse on a different antenna has not acquired simultaneous spatial information merely because their bandwidths and centre frequencies agree. Their relationship depends on measured timing compatibility and a source-stability model that must survive independent challenge.

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For controlled evaluation, the authorised transmitter should maintain a ground-truth schedule whose burst identifiers are hidden from the receiving algorithm but preserved for later scoring. Vary burst spacing, duration and envelope shape, including runs in which repeated emissions are intentionally indistinguishable to a simple spectral detector. Compare the receiver's proposed event groupings with the transmitter's actual event identifiers. The result can be presented as an association confusion matrix showing correctly paired observations, falsely joined bursts and genuine common bursts that were separated by the algorithm. This test measures the pairing stage independently of directional estimation, so an attractive bearing cannot mask incorrect reconstruction of the input observations.

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I would also introduce deliberate changes of source position between successive bursts, while holding nominal waveform characteristics as constant as possible. If the algorithm joins them into one virtual array snapshot, its resulting bearing may correspond to neither actual position. The error may appear especially deceptive where source movement and switch order interact to produce a plausible phase or amplitude pattern. A second simultaneous reference receiver can observe whether those physical bursts occurred at distinct times, but it should have an independently verified clock and its own detection-eligibility record. A common processing timestamp does not establish that two RF observations referred to the same source event.

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The final estimator must propagate the uncertainty of event association. Where an association is not independently defensible, the report can retain the separate detections and state that no compatible spatial sample set was acquired. It should never feed an arbitrarily paired vector into a direction algorithm and then report the algorithm's narrow conditional standard error as though the physical association were certain. If several plausible pairings remain, one may evaluate the alternative bearing hypotheses as an exploratory analysis, explicitly recording that they are model dependent. The evidential statement must be weaker than a verified same-burst bearing and should disclose the source-event assumptions that would need further testing. The strength of the investigation lies in distinguishing a true repeated observation from a convenient resemblance between two radio transients.

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Dr. James M. Atkinson, Moderator: Dr. Hewish, the discussion now requires an explicit account of intermittent emissions as events rather than as an ideal continuous field. Please consider how a direction finder knows whether a burst existed, whether the receiver could acquire it and whether observations from different bursts may properly be joined. I pass the token to you.

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Antony Hewish, Principal Contributor: The detection of a transient radio signal is an event in an observing system, not an assertion that the signal existed only for the duration of the recorder's event marker. A receiver has finite bandwidth, noise, integration time, sensitivity and scheduling constraints. A burst that arrives while an antenna is disconnected or the filter is settling may escape detection entirely. A different burst may be registered with a timestamp delayed by detector integration or software buffering. The distinction between the incident physical signal and its representation in the instrument is particularly consequential when a sequence of transients is used to infer direction. A switched array can produce readings that appear to form a spatial comparison although the observations actually belong to different bursts from a moving emitter.

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In an experiment with a known source, let B_k denote the time interval occupied by emitted burst k. Let W_j denote the union of settled observation intervals for antenna j, and let D_{jk} indicate whether the receiver issues a valid detection for burst k on that path. The intersection B_k with W_j is a necessary but not sufficient condition for a detection: received power, noise, polarisation and detector threshold also matter. For a direction-finding method requiring observations from antennas one through m during the same sufficiently stationary source interval, eligibility cannot be established from a single positive D_{jk}. It requires a documented set of compatible observations and a rule for rejecting events that are too sparse. A missing positive marker should not be silently converted into an amplitude zero.

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The comparison between a simultaneous array and a switched arrangement must preserve burst identity. A recurring source may send nearly identical emissions and tempt the analyst to assemble one virtual array snapshot from several cycles. Such assembly is permissible only under a model whose stability assumptions have been tested. If the source moves at a known angular velocity, repeated bursts at different times illuminate the array from different directions. If the source changes polarisation or output power, successive bursts may also have different amplitudes unrelated to the receiving antenna. Without independent tracking, a direction estimate produced by mixing these bursts is an inference about an assumed trajectory, not a direct measurement of one instantaneous bearing.

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Consider a source radiating bursts of ten milliseconds duration every one hundred milliseconds while an antenna switch requires thirty milliseconds for a complete cycle. Some switch phases may place all of a burst inside the dwell of one antenna, with no compatible observation on the others. Other phases may divide the burst across two eligible dwells, though neither has enough integrated signal for robust detection. If the operator analyses only the cases where the detector has found two useful readings, the apparent error distribution can favour fortunate alignments. Randomising the source burst phase relative to switching exposes the dependence of acquisition probability on timing, but randomisation does not itself recover missing measurements. The trial register should include the source bursts that the receiver did not detect.

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The observation process should be characterised before source motion is introduced. Feed the receiver with authorised calibrated reference pulses of known duration and amplitude, at many offsets relative to the switching cycle. Measure the probability that each pulse produces a valid sample for each antenna, the distribution of timestamp offsets, and the time to recover normal operation after a switch transition. Repeat at several signal levels around the detection threshold, because an apparently small change in noise or gain can alter which part of a burst is labelled present. Only after these functions are measured should one combine them with a moving-source experiment. Otherwise physical motion and receiver-selection behaviour can become indistinguishable in the record.

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The timebase used for eligibility deserves independent verification. A detector timestamp may correspond to the moment the threshold was crossed, the centre of an integration window, the end of a digital buffer or the time a software worker processed the data. These are not necessarily interchangeable. A high-level log saying that an event occurred at a particular time does not establish when individual RF samples were acquired. Whenever possible retain sample counters, raw complex recordings and separately validated acquisition clocks. A negative control can inject fixed pulses while varying software load; if event timestamps shift but sample counters do not, the processing delay should not be misinterpreted as source motion.

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A careful experiment compares instruments according to two separate outcomes. The first is availability: for what fraction of independently known emitted bursts, or declared observation intervals, does each architecture have the observations required to make a valid bearing? The second is accuracy conditional on availability: how large is the angular error for those cases that satisfy the declared validity rule? The two should be reported together. A simultaneous system might be more available but suffer a calibration error, whereas a switched system might return fewer but more accurate estimates in favourable conditions. Neither can be declared superior from a single average angle calculated after the least convenient cases have been omitted.

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For the unknown field source, we ordinarily lack the luxury of independent burst ground truth. That limitation should be made prominent rather than hidden by a neat track. A continuous auxiliary channel may reveal emissions missed by the switched path, but it is not infallible, and a shared antenna or gain path can introduce dependence between the two monitors. If the auxiliary channel has its own sensitivity and completeness record, its observations can constrain what the switched system missed. If not, the examiner can report only the detections actually made and the monitoring windows during which acquisition was physically possible. A failure to see a burst does not establish that no burst occurred.

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The ethical and forensic significance of these distinctions is plain. A series of compass readings may look compelling when placed on a map, but the evidential value depends on the underlying acquisition record. Reports should disclose the number of independent bursts identified, the number used for each direction estimate, the timestamps and identities of those bursts, and any assumptions made about stationarity or repeated transmission. When the data support only a broad directional region, or no direction at all, the report should say so. Intermittent radio science gains credibility from explicit non-observation and uncertainty, not from filling every blank interval with an attractive inferred bearing.

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Claude Elwood Shannon, Peer Question: Dr. Hewish, a direction finder may have an internal event detector which assigns a timestamp to the centre of a time-frequency tile rather than to the physical onset of the source burst. If a burst straddles two such tiles, it may be entered twice in the event log, and those two entries could be mistaken for separate transmissions illuminating different selected antennas. How would you test the identity of a burst without relying solely on a decoder or on the detector's own event counter? Further, suppose one reference receiver uses a narrower filter than the switched receiver. The two instruments would then have different transient responses and nominal timestamps. How would you preserve independence while determining whether they observed the same underlying emission? I would be particularly concerned about a processing rule that treats closely spaced detections as equivalent merely because their spectral centroids are similar. A lawful defensive observation must retain ambiguity when the acquisition chain cannot resolve the true event boundary.

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Antony Hewish, Response: Dr. Shannon, the detector's event identifier is a data-processing convenience rather than a physical truth. A useful controlled trial begins with the authorised emitter's independent trigger or modulation log, which records the burst interval before it reaches either receiver. The experiment can then determine how many detector entries arose from each emitted event and whether the detector split one burst across analysis windows or merged neighbouring bursts into one marker. Where no independent emitter log is available, the analysis should compare raw sampled time intervals, energy envelopes and receiver states, while keeping event matching provisional. The rule used to associate records from different antennas must be fixed before reviewing the final bearing errors.

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Filter bandwidth and group delay require calibration with reference pulses. One can inject known test signals into each acquisition chain and measure the onset-time bias and uncertainty under several pulse durations and signal-to-noise ratios. Differences in bandwidth alter the envelope and may shift threshold crossings, so a common timestamp cannot simply be imposed on both channels. For directional inference, use acquisition-time intervals with declared uncertainty rather than a single unexplained detector timestamp. If the possible event intervals overlap but cannot be shown to refer to the same burst, classify the association as uncertain; do not convert a likely correspondence into verified simultaneity.

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Receiver independence must be qualified. Two instruments can have separate processors but share an antenna, clock or RF distribution amplifier; they may then inherit common artefacts. A stronger challenge uses a separately calibrated reference signal path and a known emission schedule, or compares the same controlled source with altered antenna and receiver configurations. Intentionally varying filter bandwidth, detector integration and software load can expose whether inferred burst identities change with the measurement process. A genuine source event should remain linked to the independently recorded emission even if its detector markers shift in time within measured limits.

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When evaluating field data without an emitter log, I would preserve multiple candidate event associations if they are scientifically plausible. One may calculate directional hypotheses conditional on each association, but the final evidence report should identify that dependency. It should never present a single narrow angular interval while suppressing the event-matching ambiguity that made several incompatible bearings possible. The correct statement may be that the source was detected in a given time span and that the switched observations are insufficient to associate all detections with one emission. That conclusion preserves the distinction between observing radio activity and resolving a physical direction.

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Richard W. Hamming, Peer Question: Dr. Hewish, you distinguish source events from detector markers, but a software implementation could still destroy that distinction by assigning every observation a timestamp when an event record is written rather than when RF samples were acquired. Suppose a ring buffer wraps during a burst, the programme copies samples in two parts, and the downstream detector reports two detections with plausible timing. How should the test laboratory examine buffer indices, sample counters and missing-data markers to establish whether the apparent pair of events is genuine? I also wonder whether it is sufficient to monitor a single diagnostic counter. A counter can be continuous while samples are duplicated, reordered or replaced by stale data after an acquisition fault. What independent assertions would you require before such event timestamps could be employed to assemble an antenna-switching bearing? A direction finder may be mathematically elegant and still be invalid if its data provenance has been corrupted by an unnoticed software failure.

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Antony Hewish, Response: Dr. Hamming, the acquisition chain must be tested as a system that can fail in ways not visible from the final event list. A monotonically increasing sample counter is useful but insufficient. The laboratory should record buffer sequence numbers, antenna-selection state, acquisition clock state, actual write and read positions, and explicit flags for overflow, underrun and discontinuity. Controlled test waveforms containing known time-varying reference features can reveal duplicated or reordered segments even where the counter appears continuous. It is important to compare acquisition-layer logs with the raw sample record rather than accept the application layer's account of what occurred.

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One test should deliberately stress the software. Vary CPU load, disk throughput, memory pressure and communications latency while the authorised reference source sends pulses at known times. Determine whether samples are dropped, repeated or associated with the wrong antenna after each switch transition. If a processing fault occurs, the resulting record should be marked ineligible for direction estimation until the failure mode has been corrected and the affected interval identified. A timestamp attached to a copied data structure does not restore the physical timing of samples that were never captured or whose ordering is unknown.

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Independent assertions can include an external test receiver, a separately monitored switch-control signal, or injected acquisition test marks whose positions can be checked against the recorded sample indices. Where feasible, the instrument can produce cryptographic integrity checks over stored data blocks and preserve acquisition metadata alongside them. Such checks can demonstrate that an existing file has not changed after capture, but they do not prove that the capture originally represented the physical signal correctly. The latter question must be answered by hardware and software validation under known stimuli.

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For every bearing estimate I would preserve a chain from the output angle back to the actual sample ranges used, their antenna identifiers, the timing uncertainty and the event-association rule. If any range is discontinuous or lacks a defensible switch state, the estimate should be rejected or expressly qualified. These controls should be exercised with negative trials containing deliberate buffer gaps and duplicated segments. A correct implementation ought to detect or flag them rather than continue returning believable but unsupported directions. The lesson is that the forensic quality of a bearing depends on the provenance and completeness of its samples as much as on the apparent precision of its estimator.

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Antony Hewish, Cross-Peer Question to John Daniel Kraus: Professor Kraus, I should like to return to the physical interpretation of a burst that is measured on only one antenna. Your earlier comments suggest that a receiving pattern may support a broad directional sector even when a complete switched comparison is unavailable. Yet the detector has selected that burst because its signal crossed a threshold under a particular polarisation response and local noise state. Is it legitimate to treat the pattern's nominal gain contour as a likelihood over possible source directions without accounting for the probability of detection at each direction? In other words, a burst seen through the most sensitive part of an antenna pattern will be overrepresented among detected events even if the source distribution is uniform. How would you convey that selection effect in a report without imposing an unjustified prior distribution over unknown transmitters? I am asking especially about defensive surveys where the operator knows neither the emitter's power nor its polarisation.

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John Daniel Kraus, Cross-Peer Answer to Antony Hewish: Dr. Hewish, one must distinguish an antenna's calibrated response from a probability distribution over source direction. A gain contour tells the investigator how the antenna responds to an incident field of a specified frequency, polarisation and direction. It does not by itself say how likely it is that an unknown source occupies any particular direction. That latter claim requires assumptions about the distribution of source power, position, orientation and the receiver's detection process. A single detected burst on one antenna can constrain possible arrival directions under declared amplitude and polarisation assumptions, but those constraints may be extremely weak.

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In a controlled study, the detection-selection function can be estimated. Present an authorised test source at known angular positions with varied power and polarisation, record the fraction of bursts detected during fully eligible dwell intervals, and construct a detection probability conditional on those parameters. This produces an empirical measure of what the receiving architecture tends to notice. A report about an unknown emitter can then show how directional conclusions change across reasonable power and polarisation ranges rather than silently fixing the values most favourable to one bearing. Where no defensible prior exists, avoid a posterior probability map that appears objective while embedding an arbitrary source distribution.

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The laboratory should also preserve nondetections from qualifying observation intervals. They can constrain a source hypothesis only through the calibrated sensitivity and detection function; they are not proof that the source was absent. If the receiver's threshold or noise level changes, those constraints must be recalculated. For a burst detected on one element and missed by another, ask first whether both were eligible during the same emission, and then whether the second channel had sufficient expected sensitivity. If the two antennas observed different emission intervals, there is no valid amplitude-ratio bearing to calculate. A pattern null cannot be inferred from a missing sample.

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In the final account, I would distinguish three statements: the burst was physically detected by antenna j; the calibrated antenna response is compatible with certain broad directional regions under specified assumptions; and the full array lacks enough simultaneous observations to return a unique bearing. This is not an unsatisfactory scientific result. It conveys the actual information that survived the measurement process. A narrower map can be produced only if the examiner adds independent evidence, such as a second site, a continuous array observation or a controlled source track, with the corresponding new uncertainties fully explained.

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Dr. James M. Atkinson, Moderator: Sir Robert Watson-Watt, I invite you to bring these laboratory distinctions into operational direction finding. How should a defensive survey be conducted when sources are moving, transmissions brief and the available receiver must switch between antennas rather than observe them all simultaneously? Please take the token and identify the minimum records required before any bearing can responsibly be placed into a final evidence report.

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Sir Robert Alexander Watson-Watt, Principal Contributor: The purpose of a direction-finding system is not to manufacture an answer to every radio event but to obtain information that is reliable enough to guide subsequent observations. An operational operator may possess a receiver with a graduated dial, an antenna switch and a display that offers a numerical bearing, but those conveniences do not relieve the investigator of examining what the apparatus actually observed. A moving, intermittent source imposes severe constraints upon a sequential measurement. The source may radiate while only one antenna is selected, may move appreciably before the next dwell, or may disappear altogether during a period that the programme interprets as an antenna-pattern null. A compass value derived from those incompatible observations can be precise in appearance while being physically false.

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I would insist first upon a distinction between detecting a source, estimating a line of bearing, and identifying or locating an emitter. The detection of a brief RF event establishes that the receiver encountered energy satisfying its declared detection conditions. A line of bearing requires an antenna or array observation whose directional relationship to the incident field is supported by calibration and timing. Position estimation generally calls for additional geometry, such as multiple independent sites or known movement with adequate reference information. None of these claims is interchangeable, and a repeated set of apparent bearings should not be offered as proof of transmitter identity merely because it forms a plausible track on a map.

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Before a field survey starts, document the actual switching schedule. Record the antenna identifiers and their physical orientations, the receiver mode and tuned frequency, the length of each settled observation interval, and the time taken to change paths. Verify the timing by an independent instrument where practicable. Operators often assume that a nominal dwell begins when a control command is issued; the RF path may not be usable until mechanical switching, amplifier recovery, filter settling and gain-control transients have ceased. The difference between command time and scientifically eligible acquisition time belongs in the measurement budget. Where a short emission falls wholly within that gap, the instrument has not measured its direction.

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Operational practice must also allow for changing geometry. A distant moving transmitter may shift angle slowly during a scan, whereas a nearby source moving across the receiving site's line of sight can change its bearing rapidly. One should not specify a universal safe switching interval without reference to possible angular speed. The source's true range and lateral velocity may be unknown in a defensive survey, so the examiner should state a conditional limit rather than pretending to know them. If a test geometry bounds the apparent angular rate by omega_max and the scan aperture lasts Delta seconds, the possible angular movement during the acquisition is bounded in a simple constant-rate approximation by omega_max Delta. The bound is a screening device, not a complete propagation model. Reflection and transmitter orientation may change independently of the physical angle.

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Consider a controlled moving source whose direction changes at 8 degrees per second. A sequence of antenna observations extending over 0.25 second spans a potential two-degree angular change, even before receiver bias or multipath is considered. If the device reports an angular confidence of a fraction of a degree based only on high signal-to-noise ratio, it has failed to include the uncertainty arising from assembling observations taken at different times. Conversely, if the source is sufficiently slow, the antenna response stable and the reference bursts long enough to illuminate every required dwell, sequential observations may be useful. The proper question is whether the assumptions have been demonstrated for the event under consideration.

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An operational direction finder should preserve alternative outcomes rather than force each event into the same display category. A detection with one antenna and no valid others belongs in an event register without a bearing. A set of observations acquired from the same sufficiently stable emission may support a provisional angle and its uncertainty. A complete, independently calibrated set with defensible timing can support a stronger bearing claim. If the software's classification is unable to express these distinctions, the operator should maintain an accompanying observation ledger rather than let a single output field govern the evidence. A system that declines a doubtful bearing can be more useful than one that always returns a number.

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I would compare a switched instrument against a simultaneous reference array during controlled exercises. The authorised source should follow independently measured paths and emit bursts under schedules not disclosed to the bearing operator in advance. Repeat runs with the switch cycle started at different phases relative to the bursts. Include intervals in which the source is not transmitting and intervals in which it radiates but the switched receiver cannot observe it. A field instrument's performance should be described using all reference events. Separate the probability of an eligible bearing from the error distribution of bearings actually returned. Otherwise an attractive average error may merely describe the convenient subset of continuously illuminated antenna sequences.

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The record should also reveal whether a bearing is a new measurement or a propagation of a previous estimate. A display that maintains the last known angle through a period of silence may be operationally convenient, but the displayed number becomes increasingly stale. It must carry the timestamp of the actual source observation, not the time at which the screen was redrawn. When two sequential measurements are joined into a track, state the interval and the motion assumptions connecting them. The map should distinguish measured points, interpolated segments and periods without eligible observations. A smooth line is a hypothesis about motion, not a substitute for samples.

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The receiving environment further complicates interpretation. A nearby reflection can produce a strong signal from a direction unrelated to the source's geometric bearing; the dominant reflection may change as the source moves or as the receiver switches between differently situated antennas. The result may resemble a credible directional change, especially if only amplitude maxima are used. Repeat observations from independently located positions, rotate the receiving system when feasible, and compare different polarisation states. Such challenges may expose multipath sensitivity but cannot guarantee a unique correction. A defensible report should identify the geometry of the observations and state whether each angle describes a direct-path estimate or a dominant incoming-field direction under the stated model.

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In a legal or administrative setting the most serious danger is an overconfident conclusion detached from acquisition conditions. I would require the investigator to retain the raw or suitably preserved RF samples, the switching and timing logs, the calibration record, the original event decisions, and the estimator settings in effect when a bearing was produced. An independent reviewer must be able to reconstruct which physical observations supported each reported angle and to identify the trials discarded under the predeclared validity rule. If that reconstruction is impossible, the attractive precision of the final output should be viewed with caution. The objective of responsible defensive surveillance countermeasures is not to locate a source at any cost but to report faithfully what the available radio measurements can and cannot establish.

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Ronald Newbold Bracewell, Peer Question: Sir Robert, your proposed operational ledger distinguishes detections, provisional bearings and stronger calibrated estimates. But consider an investigator who collects an intermittent emitter's supposed bearings while walking around a building. The receiving platform moves, the antenna array changes orientation, and different parts of the environment reflect the signal. A later analyst may attempt to triangulate these bearings as though each were an independent line drawn towards a fixed source. What independent information about platform attitude, acquisition time and channel stability must be retained before that triangulation is mathematically defensible? Would you permit an algorithm to treat a bearing without complete antenna observations as a weighted line, provided it attaches a large numerical uncertainty? Or can the absence of a valid spatial comparison make the statistical distribution itself ill defined, such that uncertainty weighting cannot restore what the receiver failed to measure? The distinction matters where a plausible intersection might be mistaken for corroboration.

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Sir Robert Alexander Watson-Watt, Response: Dr. Bracewell, triangulation cannot create valid evidence from lines whose origin and physical meaning were never established. The investigator must record the receiving platform's position and orientation at the time of each qualifying observation, not merely at the time the screen was updated. If the operator walks or turns during an antenna-switching cycle, that movement should be included in the response model or the cycle rejected when it exceeds the instrument's validated limits. A fixed building or ground reference can help determine platform orientation; an independent positioning record may document movement. Both must carry uncertainty, and their timestamps must be reconciled with the RF sample acquisition times.

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The significance of a broad or incomplete observation depends upon whether a defensible likelihood can be formed. If a receiver detects one burst through an antenna whose directional response is known but lacks the other observations, it may be possible to state that some directions are more compatible with that detection under declared assumptions about source power and polarisation. Such a statement is a conditional sector or likelihood, not a measured narrow line. It should not be introduced into a triangulation routine that expects full-array bearings unless the routine has been designed to handle the weaker observation type and its uncertainties. Simply attaching a large standard deviation to an arbitrary point angle can imply an error distribution for which there is no physical basis.

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Where valid bearings exist from several independently positioned observations, their error structures must be examined. Shared calibration errors, common propagation reflections and source movement can make the lines dependent. A narrow intersection of several biased lines is not independent corroboration. The analyst should identify whether source motion between observations makes the fixed-source triangulation model untenable. If a moving-source model is used, its trajectory assumptions and sensitivity must be reported separately. Measurements made from a moving platform need a consistent coordinate transformation and explicit propagation of attitude and timing uncertainty; without them the apparent geometry is a drawing convention rather than a verified physical reconstruction.

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An operational record should therefore distinguish direct measured angles, broad directional compatibility regions and absent bearings. The final map may show these with different symbols and different supporting tables. If a large number of transient events lack qualifying spatial observations, reporting those missing bearings honestly is essential to understanding the coverage of the survey. The investigator must be free to conclude that the data support only the presence of intermittent RF activity, despite the temptation to join incomplete observations into a persuasive source location.

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John Daniel Kraus, Peer Question: Sir Robert, suppose the operator has several directional antennas of unequal patterns mounted on the same mast, and a survey vehicle traverses a region with strong reflections. A detected pulse arrives on one antenna while two subsequent pulses appear at markedly different strengths on the others. The software interprets the three amplitudes as one pattern ratio and displays a bearing that changes as the vehicle passes a metal structure. Could that sequence arise entirely from variations in reflected propagation and polarisation, even if the true transmitter direction barely changed? What controlled tests would you recommend to distinguish an actual change of geometric bearing from a change in the dominant arriving field? I should like you to address the temptation to make the display more stable by temporal averaging. Averaging may reduce random noise but it can also conceal short-term changes in the physical channel and combine different emission events under a false assumption of common direction.

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Sir Robert Alexander Watson-Watt, Response: Professor Kraus, the sequence you describe is consistent with several competing explanations. The receiving system may have observed different source bursts, each affected by distinct fading, polarisation or reflected paths. The mast and nearby vehicle structure may alter the antenna patterns in ways absent from their original calibration, while the software treats the installed system as though it were operating in free space. The true geometric source direction may be nearly unchanged while the dominant received arrival direction moves because a reflector changes its relative contribution. None of these possibilities can be resolved by smoothing the displayed angle alone. Smoothing can make the plot look more stable without showing that the underlying physical model is correct.

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I would begin by recording the same authorised test source from controlled known locations and orientations, using both the switched installation and a reference receiver with a continuous observation path. Repeat the test with the vehicle stationary, then at known positions and speeds. Change the switch start phase and, when practicable, compare observations from a different receiving site where the reflection geometry changes. Measure the installed antenna responses with the mast and vehicle present. If the reported bearing depends strongly on a nearby structure or on switch schedule phase, that dependence must be described as an instrument-and-environment sensitivity, not attributed to motion of the source without further evidence.

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Averaging may legitimately reduce zero-mean noise under a stationary and appropriately modelled signal, but it must not convert incompatible bursts into synthetic simultaneous samples. The aggregation window should be declared in advance and related to the source's possible angular movement, emission changes and environmental variability. The software should preserve the underlying individual event decisions, so an independent analyst can determine whether a smooth output concealed large contradictory bearings. Use experiments in which the reference source moves through the region while the receiving geometry is held constant, and separate experiments in which the receiving platform moves while the source remains fixed. These comparisons help identify whether apparent movement follows the source or the measurement apparatus.

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If the evidence remains ambiguous, the report should state that the instrument estimated the direction of the dominant received field under specified conditions, not necessarily the direct geometric direction to a transmitter. That distinction is meaningful in a survey. It warns later reviewers that a highly precise displayed bearing could be materially affected by reflections or time-separated observations. The investigator's responsibility is to retain the uncertainty and competing explanations rather than to make the evidence fit an aesthetically pleasing map.

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Sir Robert Alexander Watson-Watt, Cross-Peer Question to Ronald Newbold Bracewell: Dr. Bracewell, I should like to question the assumptions behind a computed confidence interval. An array algorithm may return a narrow statistical uncertainty when a direction estimator has high numerical curvature around its optimum. Yet if the input vector was assembled from bursts recorded at different times, the algorithm may be solving the wrong physical model. What practical validation would distinguish a narrow conditional uncertainty within an invalid model from a genuinely reliable bearing? Could one formulate a predeclared rejection test based on the predicted changes of source direction during the antenna cycle, the measured spread of source amplitude and the residuals of an independently calibrated array manifold? I also ask whether the procedure should explicitly quantify the probability of refusing to issue a bearing, since an estimator that gives only a few defensible results may nevertheless look exceptionally accurate when the rejected observations have vanished from the published sample.

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Ronald Newbold Bracewell, Cross-Peer Answer to Sir Robert Alexander Watson-Watt: Sir Robert, the numerical sharpness of an objective function is not a certificate that its model describes the physical observations. A narrow interval derived under the assumption of simultaneous reception conditions only the answer upon that assumption. To validate the estimate, first examine the timestamps and eligibility of the observations used to construct its input vector. If the source could have moved beyond the declared angular-change budget during their acquisition, or if the observations came from separate bursts whose relative amplitude and phase stability has not been established, reject the simultaneous-array interpretation before evaluating the estimator's reported variance. An accurate numerical optimiser can faithfully produce an incorrect answer to an invalid physical question.

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A predeclared rejection rule can combine several checks. Require that each observation fall within a documented settled interval, that the source emission association satisfy an independently tested timing rule, and that potential motion over the entire acquisition aperture remain within the accepted bound. Evaluate the residual between the observations and the calibrated antenna manifold, but do not treat a small residual as sufficient proof of validity: a physically wrong model can sometimes fit contaminated data remarkably well. Where possible, compare against simultaneous reference observations and a known moving-source trajectory. Deliberate counterexamples, including a fixed source with changing power and a moving source with short bursts, can test whether the estimator incorrectly returns the same narrow bearing in situations where its assumptions fail.

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The probability of a valid estimate is an essential output, not a nuisance statistic. For each independently known reference event, record whether the switched system collected qualifying samples, whether its estimator returned a candidate, whether that candidate passed the declared validity checks, and how accurate the accepted bearing was against the source track. A report can then state the availability fraction and the angular-error distribution conditional on accepted estimates, with their respective denominators. If the successful fraction becomes small in short-burst regimes, the instrument's limitations are visible even if its accepted bearings remain precise. This prevents statistical selection from turning a sparse but favourable subset into a misleading general statement about operational performance.

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In a defensive field investigation without external truth, confidence must be correspondingly modest. The analyst may establish that observations are temporally compatible and consistent with an array response, yet still face unresolved reflections, source polarisation and movement. The reported interval should identify the modelling assumptions and any systematic error budget, and the final location claim must not exceed the evidence supplied by actual receiving geometry. One may state that the receiver is unable to provide a defensible bearing for a particular transient without thereby failing the survey. That abstention is a correct expression of the instrument's information limit.

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QUESTION 089

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When does a public synchronisation field become unreliable evidence of a particular transmitter?

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Dr. James M. Atkinson, Moderator: Dr. Hamming, I invite you to distinguish what a published synchronisation sequence establishes about a received waveform from what an investigator would need to establish the identity of its transmitting instrument. Please begin with coding structure, observed errors and the possibility that entirely independent sources radiate the same public sequence. I pass the token to you.

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Richard Wesley Hamming, Principal Contributor: The central error is a confusion of categories. A synchronisation sequence is chosen to enable a receiver to find the beginning of a frame or estimate a parameter of a channel. It is generally constructed so that many compliant devices can emit it and many compliant receivers can recognise it. It cannot logically serve as an individual signature merely because the investigator's correlator produces a large peak. In a controlled experiment I would start by acquiring published sequences from three separately assembled reference transmitters, using different oscillator components and RF front ends, but identical standard-compliant framing. The resulting payload-free synchronisation records would often match at the nominal digital-sequence level. That is what interoperability requires. Their physical waveforms may differ in amplitude, timing, frequency offset, transient behaviour or analogue impairment, yet none of those distinctions may be ascribed to the public sequence itself. The distinction between code agreement and source agreement must be maintained in every data table.

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A code can be described as a set of allowed symbol sequences, but an individual source is a physical object with a state. Let c[k], for k from zero to N minus one, denote a known complex training sequence of N symbols. Let y[k] be the receiver's measured complex samples after its declared timing and filtering, and let h represent the channel response. A simplified observation y[k]=a c[k-d] exp(j(2πΔf k/Fs+φ))+w[k] assumes a scalar complex channel a, integer delay d, frequency offset Δf in hertz, sample rate Fs in samples per second, phase φ in radians and additive disturbance w[k]. The simplified scalar model is invalid where multipath requires a convolution, where symbol and sample clocks drift or where front-end distortion is significant. Most importantly, the expression contains no unique transmitter identity variable. To infer a device from it, the examiner would have to introduce, test and independently validate further source-dependent features. Writing an instrument name beside a correlation peak does not supply those missing premises.

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The matched-filter statistic R[d]=sum over k of y[k+d] times the complex conjugate of c[k] is useful for finding candidate timing offsets. Its absolute value is not a posterior probability that a particular source was responsible. A peak can be enlarged by received power, integration length, favourable antenna orientation or a close match to the common published code. A distinct but protocol-compatible reference source can produce a similar peak. Conversely, the actual source may produce a weak or misleading peak because the receiver is saturated, its frequency error exceeds the correlator's accommodation, or interference damages part of the training interval. Thus a larger R can provide better evidence of sequence presence under a calibrated signal model without being evidence of a named transmitter. That asymmetry should be explained to every student who has admired a bright vertical stripe on a spectrum waterfall and heard the false certainty in an automated device-identification alarm.

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Even an error pattern requires an explicit generative model. Suppose a candidate segment differs from an expected 64-bit public sequence in four positions after legitimate demodulation of a laboratory test. The Hamming distance is four, and the observed bit mismatch fraction is four divided by 64, or 0.0625. This measured fraction does not reveal whether the cause was fading, a frequency offset, a receiver threshold, a synchroniser slip, a hardware malfunction, or deliberate alternate encoding. Nor does it turn the 60 matching positions into the identity of one radio. The bit-error event may be burst-correlated rather than independent, particularly in a narrow fading notch or a clipped acquisition. A laboratory should archive not merely the decoded or sliced 64 bits but the receiver configuration, raw authorised measurement window when permitted, acquisition clock, and ambiguity information needed to reproduce the result without recovering protected payload content.

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Consider a second experiment with two independent emitters whose permitted training fields are identical. Place one emitter at a fixed distance and another at a different azimuth, both operating one at a time under concealed random allocation. Before seeing the trial labels, require the analyst to report whether the data support only the public training-field class or support a reliably distinguishable RF implementation class. The equipment's location, transmission timing, antenna rotation and chosen receiver should be balanced over emitters. A classifier that succeeds only when one reference source is physically closer has learned propagation or signal strength, not intrinsic manufacturing features. Likewise, a model that succeeds only on a particular receiver may have learned that receiver's oscillator or quantisation peculiarities. Proper interpretation demands a held-out receiver and fresh recording session, not merely a random split of neighbouring samples from the same burst.

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The public code often appears in frames generated by many products under different regulatory and operational conditions. That breadth is a deliberate engineering virtue; it creates a serious forensic limitation. A code-family hypothesis can be tested by changing the sampling frequency, channel impairment or code acquisition length in a controlled setting and examining how the statistic behaves. Individual-source attribution is a different proposition requiring source-discriminating features, false-match rates measured over relevant alternatives, stability across environmental conditions and a clearly defined population. If the target population includes radios not represented in the experiment, then a closed-set classification rate cannot be read as the probability that an unknown field transmission came from the one device already on the investigator's bench.

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There is a deeper issue in the act of selection. An examiner who searches hundreds of offsets, multiple candidate standards, two polarisation settings and several filter configurations may eventually discover a very attractive match to a public sequence even under unrelated interference. The false-alarm probability for the chosen peak is not the same as the probability that an equally large peak would emerge from the entire search. The analysis must preserve all tested hypotheses and the parameters selected before examining the data. Otherwise the investigator presents an especially persuasive trace without the unglamorous history of how many alternatives were tried. This is a statistical error, not merely a question of courtroom vocabulary. The listener hears a compelling code name while the record conceals the noise against which the conclusion was chosen.

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I propose a hierarchy of findings. First, the receiver recorded energy in a stated bandwidth and time interval. Secondly, a calibrated synchroniser found a candidate sequence with a documented statistic and false-match assessment. Thirdly, the observations were compatible with one or several public frame formats under explicit assumptions. Fourthly, if justified by separately validated physical features, certain equipment classes may be favoured over declared competitors. Individual physical transmitter identity must remain unestablished unless there is independent, appropriately designed evidence. The report must also retain the possibilities of replay by authorised test equipment, implementation reuse, correlated receiver errors and multiple sources using the same format. A precise negative boundary is as valuable as a confident positive measurement: it prevents an instrument's ability to recognise shared structure from becoming a claim the evidence cannot bear.

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Jacob Ziv, Peer Question: Dr. Hamming, your division between public code structure and physical source is sensible, but I should like to press upon the treatment of a waveform whose training interval appears identical while the surrounding source statistics change between sessions. A compressor, data scrambler, variable-length frame builder or traffic scheduler can alter the apparent entropy and timing distribution of neighbouring regions without changing the public synchronisation field. Would you allow an investigator to treat joint resemblance of the preamble and adjacent non-content timing observations as cumulative evidence, or must the possible shared software and traffic model first be controlled? Please specify how one would separate the influence of the common code, of a deterministic encoder state, of receiver frame segmentation and of the particular source equipment. In particular, what result from a blind trial would falsify an attribution claim that seemed persuasive when both the sequence and frame cadence were viewed together?

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Richard Wesley Hamming, Response: Dr. Ziv, I would permit cumulative evidence only after testing the dependence between the measurements. The code-match event and a timing-cadence event are not necessarily independent; a common receiver synchroniser supplies the segmentation that defines both. If the synchroniser locks to the wrong offset, it may change the estimated start times and hence the cadence. If a single software implementation chooses both the public training format and a nominal beacon interval, many different hardware products can share those features. Multiplying the marginal false-match probabilities would then create an artificially impressive number, since the shared cause has been counted twice. I would begin with an explicit causal graph including encoder design, firmware schedule, RF hardware, propagation, acquisition clocks and the algorithm that marks candidate events. Conditional dependencies should be estimated or bounded rather than wished away.

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The blind trial you propose is particularly useful if the emitters vary independently in hardware and scheduling firmware. Repeat the identical training sequence under several controlled frame cadences for each source; then hold the cadence constant while exchanging sources. If the classifier's apparent ability to distinguish transmitters disappears when the cadence is reassigned, the supposed hardware inference was a learned scheduling convention. This is not proof that the classifier is worthless: it may remain a useful description of the observed traffic class. But the claim must be reduced to the proposition that survives the intervention. A third manipulation replaces the nominal encoder with a different implementation that preserves the public field. If this changes the other observed statistics, those changes cannot be attributed to the public training bits themselves.

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I would insist that the investigators predeclare whether the relevant question is format recognition, event grouping, product-family screening or individual-source attribution. The experiment that tests one need not test the others. Use a held-out recording day and a different calibrated receiver for the final evaluation, and include a deliberately unfamiliar transmitter. The unfamiliar source is a particularly severe challenge to an overly confident closed-set classifier. If it assigns the unknown source to the nearest known class with high confidence, we learn that the algorithm must have a rejection rule rather than being allowed to name a device whenever it sees a match. Finally, publish both confusion rates and abstention rates, with the expected costs of false attribution. The laboratory ought not convert a repeated interval and a common code into an accusation simply because their joint display looks orderly.

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Abraham Lempel, Peer Question: Dr. Hamming, imagine an authorised demonstration in which a programmable signal generator faithfully reproduces a publicly documented preamble and a modest portion of the analogue envelope of another reference instrument. The generator need not imitate a protected message; it transmits only a benign laboratory frame under the examiner's control. An analyst, unaware of this substitution, might observe the correct sequence and even several matching features after filtering. Would you regard the possibility of such reproducibility as a categorical obstacle to individual attribution, or only as a demand for a more restricted and experimentally qualified claim? Please address a specific issue: the emulated wave may pass through a different antenna, room and receiving chain from the original. How should that difference be prevented from providing a spurious means to separate the sources? What evidence would be necessary before the examiner could properly say more than that both trials used the same publicly specified training format?

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Richard Wesley Hamming, Response: Dr. Lempel, an authorised replay experiment demonstrates that code agreement alone cannot establish the emitting instrument's physical identity, because two sources can instantiate the same public bit sequence. It does not prove that all conceivable device-dependent measurements are uninformative. The proper conclusion is narrower and more useful: any proposed additional signature must resist plausible alternatives, including the replay or re-encoding of public symbols by a different transmitter. The experimental claim should specify the available adversarial or non-adversarial alternatives rather than suggest a universal uniqueness theorem. One can legitimately show that certain analogue features distinguish a set of carefully controlled reference units; that is not the same as identifying an unfamiliar emitter in the field.

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To avoid allowing the room to do the classifier's work, use physically balanced placements. Exchange the two test sources between each antenna position, randomise their transmission order, maintain independently measured powers where possible and repeat with different receiving orientations. Where safety and permissions allow, inject the controlled reference signals through a characterised cabled path to isolate the transmission hardware from over-the-air channel variations. Cabled tests still have connectors, amplifiers and filters that require calibration, but they provide an illuminating contrast to an uncharacterised radio path. If the distinguishing features vanish when the propagation paths are exchanged, a report about transmitter identity must be withdrawn or substantially qualified.

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The result should also be evaluated under deliberate receiver changes. A feature that is stable only at one sample rate, intermediate-frequency filter or automatic-gain-control setting may belong to the instrument and its digital processing. Separate precision from accuracy: repeated measurements can be extraordinarily consistent and yet systematically wrong about the generating physical cause. I would ask the examiner to preserve the uncorrected data, the transformation history, the nuisance-variable manipulations and the uncertainty for each reported feature. Only then may a reader distinguish a repeatable laboratory association from an identifying physical characteristic. The final report should say the public code was observed and that other independent features did, or did not, support a limited equipment-class distinction under specified conditions.

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A useful audit would also log the amplitude and duration of each neighbour event, since truncation of the observation window can otherwise create a false association between the shared preamble and the apparent cadence. The inference should remain conditional on the measured coverage.

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Richard Wesley Hamming, Cross-Peer Question to Claude Elwood Shannon: Dr. Shannon, I pass to you the central inferential difficulty. A detector reports a clear match to a public preamble, yet there may be ten thousand compatible transmitters and no tested individual characteristics. How should conditional probability be expressed so that a reader does not confuse a high probability of the observed code under a candidate device with a high probability of that device given the code? Could you present a deliberately transparent numerical example with explicit prior assumptions, and then tell us whether adding receiver clock drift or multipath would improve the conclusion or merely increase the number of nuisance variables? I also ask you to distinguish a statement about a transmission's format from a statement about its owner, location or purpose, which are not variables specified by the public synchronisation bits.

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I am especially interested in whether an analyst who has already looked at the code match would be tempted to choose the source prior after seeing the result, rather than before collecting the evidence.

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Claude Elwood Shannon, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, the distinction is elementary in notation but frequently neglected in practice. Let D denote the hypothesis that a particular device emitted the tested frame, let C denote the observed synchronisation-field match, and let K denote the instrument configuration and conditions used for calibration. The quantity P(C given D,K) is a likelihood: if the candidate device transmitted the proper frame, how often would this receiver report the match? The desired attribution P(D given C,K) requires a prior P(D given K) and the aggregate likelihood of the same observation under all other devices that might be present. A large likelihood is therefore not an attribution probability. I would not allow a numerical likelihood to be called confidence in a device unless the alternative population and prior assumptions were explicitly identified.

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Consider a hypothetical pool of one hundred equally plausible independent, standards-compliant laboratory emitters. Suppose all use exactly the same public training field, and a calibrated receiver recognises that field with probability 0.90 regardless of which source is transmitting. On this model, P(D)=0.01, P(C given D)=0.90 and P(C given not D)=0.90. Bayes' rule gives P(D given C)=[0.90×0.01]/[0.90×0.01+0.90×0.99]=0.01. The exceptionally good match changes nothing about which of those one hundred emitters was responsible. If clock drift, channel distortion or receiver frequency error is then measured, those variables might contain additional source-related information, but one must model their distributions under competing hypotheses, not merely append adjectives such as 'distinctive' or 'precise'. If the variations are mostly propagation dependent, they can make identity inference worse, not better. Format compatibility remains the defensible conclusion from the public field alone.

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The same numerical reasoning applies to a thousand competing, equally likely sources: the field match can be highly significant relative to noise and still fail to distinguish among them. In that case a 90 per cent field-detection rate supports an acquisition-performance statement, not an individual-source finding. Further features must be evaluated on fresh records for all plausible candidates, and their conditional dependence with the initial synchronisation event must be accounted for. If the only additional feature is the receiver's own clock offset, the supposed new evidence is merely a re-expression of one nuisance parameter.

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Dr. James M. Atkinson, Moderator: Thank you, Dr. Hamming and Dr. Shannon. The distinction between likelihood and attribution has been placed plainly on the record. Dr. Shannon, please take the principal token and examine the information-theoretic and probabilistic limits of synchronisation evidence.

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Claude Elwood Shannon, Second Principal Contributor: In the communication problem, a synchronising sequence is part of the common language of transmitter and receiver. It is not a secret token proving who is speaking. Indeed, a properly designed public synchronisation field must remain sufficiently predictable that a receiver can acquire timing and phase before the receiver knows the subsequent message or the source's precise hardware implementation. The observer can infer that a received segment has certain structural properties, but the segment's usefulness for synchronisation does not endow it with a unique authorship. Consider a signal that contains a repeated preamble. Correlation may help find a symbol boundary; it does not generally distinguish a high-volume manufacturer, a laboratory synthesiser and another permitted source employing the same training design. Each may generate the identical ideal complex sample sequence before analogue impairments are introduced. A statistical model must therefore separate information about the shared format from information about an individual physical unit.

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I would write the observation vector as Y and distinguish three latent variables: F, the selected public waveform format; D, the transmitting device; and H, the aggregate channel and receiver state. An engineer may find that the mutual information I(Y;F), computed under a declared distribution, is substantial because the preamble helps classify formats. Yet I(Y;D given F) can be small or zero when all devices produce the same ideal training samples and the remaining measured variation is dominated by unrecorded H. Conditional mutual information is a property of the specified distribution, not a universal constant of a preamble. The investigator must state how source devices are sampled, how observations are formed and what environmental variation is represented. A laboratory dataset that gives each device a different frequency, location or measurement day may exhibit large apparent information about D only because D is correlated with those nuisance variables. Reducing the dimension of Y to a code-match score discards potentially useful diagnostic information while retaining no guarantee of individual identity.

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The original synchronisation task usually seeks an event in a family of correlated tests. If the receiver slides a known template across K possible sample positions and tests M competing public sequences, it creates many opportunities for an accidental resemblance. A numerical false-alarm probability estimated for one position does not directly describe the largest statistic selected among K times M comparisons. Let p denote an explicitly calibrated single-comparison probability of exceeding a fixed threshold under a declared null. If all T=KM tests were independent, the family probability would be 1−(1−p)^T. For p=10^(−5) and T=1000, that is approximately 0.00995, close to one per cent. But sliding correlations share samples and are ordinarily dependent; independence is not a sound substitute for measuring the actual maximum-statistic distribution. A calibrated synthetic noise experiment should reproduce the receiver's overlap, filtering and adaptive thresholds. The point is not to invalidate correlation as a method; it is to refuse to treat the most favourable match of a large search as though it had been specified alone in advance.

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Frequency and timing errors provide another source of confusion. An RF oscillator can carry a small fractional frequency offset, but what the receiver measures is usually relative frequency error between the source and local oscillator, mixed with sampling-clock and processing uncertainty. For a nominal carrier of two gigahertz, a ten-part-per-million relative offset corresponds to 20 kilohertz. That offset might appear impressively stable in a short recording, but its sign and magnitude can change when the receiver is replaced, the source warms or either oscillator is disciplined differently. A repeated measurement from one receiver does not prove a unique source oscillator. A proposed identity classifier should cross receivers, temperatures, signal levels and acquisition sessions so that source-related stability is tested instead of assumed. A public code remains unchanged by these complications, while the analogue estimate associated with its acquisition may be highly contingent.

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I would also separate signal recognition from signal provenance. A matched correlator can recognise a suitable training pattern when the analogue signal has been replayed, re-encoded, generated synthetically or produced by a standards-compliant source. It recognises structure in the observation, not the history of every component that generated it. Evidence of provenance requires an independently trusted chain: for example, a controlled transmitter trigger and a recorded assignment of an authorised test source, or corroborating observations from independent receiving locations with their own calibrated clocks. In forensic writing the word 'therefore' is dangerous when its antecedent is merely a format match. It can connect an innocuous common preamble to an unproved device name and then to a person's supposed conduct without any intermediate experimental support. The report ought to preserve the distinctions between compatibility, statistical discrimination and physical source proof.

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A fair assessment of evidential weight compares hypotheses that both genuinely could explain the record. The likelihood ratio for device A against device B is L=P(Y given A,K)/P(Y given B,K), where K includes the declared recording conditions and the calibration model. If A and B transmit the same public field through comparable channels and receivers, the ratio based solely on that field is approximately one. If the analyst discovers additional analogue differences, L may deviate from one, but only after estimating the distributions of those differences with independent trials. A single high similarity score does not reveal the denominator. Nor does a machine-learning classifier's high score prove that its hypotheses exhaust the possible transmitters. Open-set uncertainty, unobserved devices and environmental changes are not technical footnotes; they determine what question the evidence can actually answer.

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There is a disciplined way to use a public sequence without collecting private payload content. The investigator can record the timestamp, frequency, bandwidth estimate, code-match statistic, declared synchronisation hypothesis, signal level, relevant receiver state and a concise non-content diagnostic of timing or frequency uncertainty. If collecting a short authorised IQ segment is essential to review the training field, the acquisition window should be bounded and the reason for retaining it documented. Nothing about this statistical argument requires opening a private message or analysing its semantics. In particular, the presence of a recognised preamble should not be treated as permission to acquire everything that follows it. Scientific reproducibility can be served by laboratory reference captures and verified procedures, while field records remain minimised to the legitimate detection question.

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Finally, I would teach a sequence of refusals. Refuse to turn certainty about a known public template into certainty about the source. Refuse to combine dependent features as though their likelihoods were separate. Refuse to interpret a classifier trained on fixed receiver positions as evidence of generalisable hardware identity. Refuse to substitute an attractive correlation plot for a declared error model. And refuse to hide the candidate sequences and search windows that were tried before the selected match was presented. A serious RF report can still make a valuable claim: a particular observation is compatible with a documented physical-layer format, within measured uncertainty. The more limited sentence is not a failure of investigation. It is a correct statement of the information actually present in the recorded evidence.

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John Robinson Pierce, Peer Question: Dr. Shannon, I should like to examine the role of a receiver's acquisition algorithm in manufacturing apparent distinctiveness. Imagine two transmitters that radiate exactly the same published training symbols, while one is weak and the other strong at the receiving antenna. A practical correlator may use different gain states, unequal windows, clipped samples or different early-to-late timing estimates. The engineer then sees different peak widths and delays and perhaps calls them transmitter characteristics. Would you prefer a single standardised receiver processing chain, or several independently designed acquisition methods that ought to agree about the underlying signal? How should the experimental design separate the genuine effect of a channel from the correlator's selection of a winning offset? Please include the case of overlapping candidate peaks, where only the largest event is recorded and the discarded alternatives are no longer available for later inspection.

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I ask that the analysis also distinguish the uncertainty of the estimated start time from the latency of the software notification, for these are not interchangeable timestamps in a buffered receiver.

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Claude Elwood Shannon, Response: Mr. Pierce, both a standardised chain and independent methods have distinct uses, and neither should be trusted alone. A frozen processing chain permits repeatability and quantitative calibration of its threshold behaviour; independently designed algorithms test whether the claimed feature is robust to the analytical choices that a different laboratory might reasonably make. The central mistake would be to assume that agreement within a single adaptive processing pipeline proves the physical reality of its intermediate outputs. If a receiver's automatic gain control shifts between captures, or if a strong burst clips a converter, the correlation peak may differ even where the radiated digital preamble is identical. Those receiver conditions must be stored as measurement metadata, and invalid acquisitions should be marked rather than silently converted into source features.

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For a controlled comparison I would acquire paired transmissions from two source units at several attenuations, swap their positions, and feed a second independent reference receiver when possible. Report correlation peak magnitude, shape, selected delay and the distribution of alternative delays. If the strongest peak is retained but the runner-up is discarded, the experiment loses information about ambiguity. A moving interferer or multipath echo can cause the selected peak to jump discontinuously between nearly equal candidates. The apparent timing signature of a device would then reflect a data-selection policy. Recording the top several candidate peaks with their relative magnitudes is a modest non-content measure that improves later review without collecting payloads.

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An inference about device identity should be assessed with a likelihood or classification rule trained on one set of independently acquired conditions and evaluated on genuinely separate sessions. A receiver hardware change should not be treated as a cosmetic inconvenience; it tests whether the feature actually survives a change of instrument. If an algorithm succeeds only on the equipment with which its reference templates were made, it may be a useful local alarm system but does not support general forensic attribution. In the final report I would state the receiver model, analogue gain configuration, sample rate, timing estimator, code search space, interference conditions and grounds for excluding ambiguous bursts. The honest result may be only that both candidates conform to the same publicly specified training-field class.

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Claude Elwood Shannon, Cross-Peer Question to Peter Elias: Dr. Elias, in framing a burst, the receiver must decide when the public synchronisation interval begins and ends. I should like you to examine what happens when a correlator's frame boundaries are wrong by a small number of samples, or when a bit synchroniser slips within a public sequence. Can an error burst produced by a receiver or channel be made to resemble a distinctive transmitter-specific defect? What laboratory counterexample would expose that mistaken claim? I am also concerned that an analyst might treat a public frame delimiter as a private device identifier simply because it has a rare bit pattern relative to random noise. Please distinguish rarity under an inappropriate random-noise null from rarity among the population of compliant devices, and propose a defensible way to record the competing synchronisation offsets without acquiring protected payload content.

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If two compliant transmitters use the same delimiter but different proprietary payloads, what minimum non-content observations could properly test the synchronisation claim without retaining or decoding those payloads?

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Peter Elias, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, a frame delimiter can be rare under a random-bit null and universal among transmitters implementing a particular format. Those observations are not contradictory because the underlying populations differ. A 16-bit public marker, if its bits are exactly specified, has probability one under the ideal compliant-device model and perhaps probability 1/65,536 at one predeclared position under an ideal independent fair-bit null. Searching many overlapping offsets changes the latter calculation, and transmitted or received bits are often neither independent nor fair. It would be improper to transpose the random-null rarity into a probability of device identity. The engineering function of the delimiter is to reduce frame-boundary ambiguity, not to proclaim the manufacturer's serial number.

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A one-sample timing error can turn a correct symbol sequence into a misleading sliced pattern after a nonlinear decoder, especially where the waveform has pulse shaping or unequal channel delay. In a multipath channel the correlation surface can contain several plausible peaks. An acquisition algorithm that always chooses the earliest above-threshold peak and one that chooses the greatest peak may therefore produce different time stamps and apparent bit-error locations from the same analogue capture. A controlled counterexample transmits a fixed public training sequence from one authorised source while deliberately varying receive timing, sampling phase and channel impulse response. If the supposedly device-specific mismatch pattern moves with the receiver conditions, it is not a stable source signature. Preserve a bounded acquisition quality record: candidate offsets, threshold exceedances, uncertainty intervals and the reasons that ambiguous intervals were accepted or rejected. That record allows review of the synchronisation decision without authorising the recovery of any protected message that might follow.

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A useful further stress test deliberately changes the number of candidate offsets while leaving the authorised transmitted sequence fixed. If the apparent certainty grows only because the algorithm has more opportunities to select a favourable maximum, the supposed increase in evidential strength is reversed: the analyst has changed the search selection process rather than obtained a more informative signal. This difference must appear in the report's false-acquisition calibration. In addition, the laboratory should separate correlator confidence from payload interpretation. A recognisable public delimiter and its timing uncertainty can be documented with bounded test windows and known synthetic references; nothing about that exercise requires retaining private message content or naming an individual device.

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Dr. James M. Atkinson, Moderator: Dr. Elias, please take the token. We have discussed what can be inferred from recognising a known sequence. I ask you now to examine the frame-detection machinery itself: the relation between synchronisation markers, finite error patterns, receiver slips and the false appearance of an individual source signature.

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Peter Elias, Third Principal Contributor: One can regard synchronisation as an agreement about where to begin interpreting symbols, whereas channel coding concerns how a permitted sequence may contain redundancy that makes errors detectable or correctable. These are related but not interchangeable operations. A public frame delimiter may be designed to have a useful autocorrelation structure or an acceptably small probability of mistaken acquisition under particular noise assumptions. That engineering merit does not imply that the marker is unique to any physical transmitter. The same delimiter can be emitted by hundreds of thousands of compliant instruments, by a laboratory waveform synthesiser and by a properly authorised reference beacon. To say that a receiver has synchronised to the sequence is to say that an algorithm found a model-compatible alignment, not that the investigation has established the identity or custody history of the emitter.

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A receiver commonly performs a succession of decisions: detect energy, choose a candidate frequency, estimate coarse timing, form the synchronisation statistic, test the statistic against a threshold, resolve competing peaks, and finally decide whether a consistent frame may begin. Each decision conditions the data that reach the next. Let S denote the event that the receiver admits a candidate frame into its output and let E denote the distribution of mismatches to the public field. Studying P(E given S) is not the same as studying P(E) over all transmitted test frames, because faint, delayed or badly distorted frames are less likely to reach the output. A report based only on retained synchronised frames can have deceptively low apparent error rates. Conversely a detector that admits noisy false candidates may create repeated patterns of mismatch from its own selection rules. An engineer who calls these retained patterns individual transmitter fingerprints must confront the conditional-sampling mechanism.

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I would design a three-way experimental challenge. First transmit one published training sequence repeatedly from a single stable laboratory source, varying only the receiving clock offset and fractional sampling phase. Secondly hold those receiver settings fixed while exchanging two independent compliant transmitters. Thirdly apply calibrated, digitally generated channel impairments to the same reference source, including a controlled reflected path, a narrow interfering tone and additive disturbance with a declared spectrum. All manipulations should be assigned before the analyst examines the candidate mismatch maps. If a supposed device-specific pattern follows the receiver phase, it belongs primarily to acquisition. If it follows the channel simulator, the path is implicated. If it follows the source across the interventions, it may warrant a more limited class-discrimination test, though additional alternatives such as shared chipsets and firmware still remain.

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One should distinguish bit disagreement, symbol disagreement and sample-level correlation. A symbol represented by several complex samples can be decoded incorrectly because the sampling instant lands near an eye-diagram transition; that error is not equivalent to a change in the public sequence transmitted. Likewise an apparent frame shift of one symbol can make the Hamming distance to the expected code suddenly large despite a perfectly compliant underlying emission. The analyst must not treat all mismatches as independent Bernoulli trials. In bursts of interference, four adjacent symbol errors may arise from one disturbance event rather than four independent device-specific defects. Without an error-dependence model, a numerical probability calculated by multiplying four marginal rates can badly exaggerate rarity. The correct error process is an empirical object to be estimated from controlled trials, preferably on acquisition sessions separated in time.

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For a transparent toy calculation, suppose the public marker occupies 16 bits, and a naive classifier treats an exact match at a single preselected alignment as one chance in 65,536 under an independent fair-bit random null. If the analyst in fact searches 2000 candidate offsets, even that unrealistic null gives approximately 1−(1−1/65,536)^2000, or about 3.0 per cent, for at least one exact match under independence. Overlapping windows violate independence; the example is only a warning against confusing one specified test with a search maximum. More fundamentally, that probability refers to random data, not to a field populated by compliant radios. For a format-compatible device emitting the marker correctly, the marker's probability may be close to one. Thus the very sequence that looks rare when compared with random noise is commonplace among the actual alternative emitters relevant to an identification claim.

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A laboratory should also test offset ambiguity rather than record only a winning decision. If two peaks exceed threshold at delays d1 and d2, their separation may reflect multipath, a periodic preamble, receiver filter ringing, or more than one source. The recorded statistic ought to retain the number of significant peaks, their relative ratios and the algorithm used to select a frame boundary. If an absolute timestamp is important, the result must include clock calibration, sample-counter continuity and acquisition latency rather than presenting the first above-threshold event as a direct physical emission time. A fixed digital buffer can be released several milliseconds after sample acquisition by an operating system or transport protocol. A reader who sees precisely repeating software event times may mistake the buffering cadence for the transmitter's radio schedule. A good record preserves the distinction between acquisition time and notification time.

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Error correction raises a particular temptation. If a decoder succeeds in producing a valid codeword, the examiner may be inclined to believe that the originating source is identified by that success. In fact the decoder tests constraints shared by every implementation of the selected code. A valid syndrome or successful parity check can support a code-family hypothesis and, in a controlled reference experiment, indicate that the channel has not defeated decoding. It does not tell us which of several independent coding engines produced the same allowed word. Nor is a decoded message needed to investigate the public synchronisation field. The laboratory can use known synthetic reference frames, restrict recorded field observations to authorised non-content intervals, and test the decoder's error-correction properties without examining private payload information.

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The final inferential statement must distinguish compatibility from absence of contradiction. An observation may be compatible with a named technical format while also being compatible with other formats that share the same training structure. Some waveform families reuse or modify preambles between versions, and an arbitrary correlator can be designed to respond to several. The analysis should list material alternatives and explain what measured feature would discriminate them. An unexamined alternative cannot be rejected because it did not appear among the investigator's software menu choices. Open-set testing with a source not present during model construction is therefore important. A robust method should be allowed to report uncertain or unknown rather than force every measurement into one named device category.

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I commend a simple evidential ledger for each test sequence. Record the public source of the expected marker, its length and modulation representation, the observation interval, the receiver's timing and frequency estimates, the competing offsets, the assumed null model, the total number of searches, the false-acquisition calibration, and the tested alternative transmitters. Put a separate column for device-specific conclusions and leave it blank where the training field alone cannot justify one. The empty cell is a scholarly virtue. It tells the next reviewer exactly which question remains unanswered, rather than allowing the elegance of code theory to disguise a gap in the chain of inference.

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Alan Mathison Turing, Peer Question: Dr. Elias, I should like to test whether your receiver can genuinely distinguish a candidate pattern from an artefact of its own finite decision procedure. Consider a perfectly specified algorithm that searches an interval for a known marker and then reports only the highest-scoring offset. If I feed that algorithm structured but noncompliant test material, it must still choose a maximum, even when no actual frame was transmitted. Might the algorithm then yield repeated confident classifications merely because its input structure, filter memory and search interval remain fixed? What independent test would show that it recognises an actual transmitted public preamble rather than a mathematical coincidence under the algorithm's restricted set of allowed outputs? Please explain why a reproducible program is not necessarily an accurate programme of physical measurement, and specify how you would retain negative controls and failed acquisitions in the audit record.

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Would it be possible to construct a negative control that yields the same numerical peak distribution without any compliant transmitter being present, and what would that imply for the claimed identification?

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Peter Elias, Response: Dr. Turing, you have placed the decisive distinction between an optimisation and a hypothesis test. Every finite set of real-valued scores has a maximum, but the existence of the maximum does not establish that any candidate was generated by the physical source the programme assumes. A forced-choice correlator can therefore assign a 'best' preamble to thermal noise, interference or structured noncompliant input if its design forbids abstention. The experimental question is whether the score exceeds a threshold calibrated under adequate alternatives, with an explicit probability of false acquisition, rather than merely whether one candidate outranks the others. A valid implementation should record 'no accepted match' when the evidence is insufficient. It should not manufacture source certainty by hiding that alternative from the user interface.

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Your proposed test ought to preserve both the positive reference trials and a broad suite of negative controls. Controls should include receiver thermal noise, nonmatching benign reference waveforms, strong narrowband interference, synthetic repeated patterns deliberately selected to confuse a correlator, and blank acquisitions with exactly the same record lengths. Each control should pass through the identical gain, filtering, timing and reporting pipeline, not through a simplified calculation that omits the source of the false pattern. The statistic should be the largest score over all attempted offsets and templates if that is how the instrument actually operates. Record the number of tested alignments, accepted false candidates and cases in which the detector abstains. A threshold calibrated against one nonrepresentative noise distribution may not remain valid when the spectrum becomes impulsive or coloured.

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Reproducibility is necessary but not sufficient. A program can reliably produce a misleading answer when its physical assumptions are false. An algorithm that uses a fixed local oscillator offset, for example, may repeat the same apparent mismatch under two source trials because the receiver has not changed. A repeated acquisition timestamp may reflect the operating system's buffer-release cadence rather than an RF event. One can test these failures by changing the input at the hardware boundary and the timing of the processing pipeline independently. Confirm source events with an independent acquisition channel and known reference triggers. When an effect vanishes under an independently timed receiver but persists under one software process, the software or its clock becomes a candidate explanation. The proper conclusion is a documented detection capability under tested conditions, not an assertion about the identity of a transmitter that was never independently labelled.

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John von Neumann, Peer Question: Dr. Elias, let us turn to error distributions and independence. Your sixteen-bit example presumes fair independent bits and independent search positions, even as you warn that neither assumption is generally true for the actual instrument. How would you build a calibration experiment whose false-match probability can be defended when training sequences overlap, receiver filters introduce memory, and the sample clock may itself wander? I am particularly interested in whether a simulation that matches only the measured power spectrum but not higher-order temporal dependence could underestimate false acquisition. Should the investigator use block resampling, physical null recordings, analytical bounds, or several of these methods together? Finally, what does the resulting false-match estimate tell us about the probability of a particular physical source if all compatible devices share the same public frame delimiter?

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The error estimate should also distinguish a calibration sequence with intermittent high-power disturbances from a stationary Gaussian model, because the tails of the resulting score distributions need not agree.

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Peter Elias, Response: Dr. von Neumann, I would use multiple calibration strategies precisely because a single idealised null is fragile. Physical null recordings collected through the actual receiver and antenna capture the analogue noise, filter memory, local interference and instrument-specific decision process at the time of the test. They do not automatically represent every future environment, so their scope must be stated. Block resampling can be useful where the measured disturbance has a dependence scale that can be estimated, but the resampling unit must be long enough to preserve the local temporal structure relevant to the matched filter. A simulation may provide controlled stress cases, yet matching only a power spectrum can miss impulsive amplitude distributions, burst clustering or nonlinear clipping. The result should show sensitivity to plausible null models rather than conceal it.

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I would calibrate the actual maximum over offsets and candidate formats, not a single prechosen alignment. For each reference record, run the entire instrument pipeline and retain its largest statistic, the corresponding offset and the count of secondary peaks. The false-match tail can then be estimated with an uncertainty interval based on the number of independent calibration records. Ten thousand null records in which no false alarm occurs do not demonstrate zero error probability; they provide a finite upper confidence limit under the tested acquisition distribution. Simple one-sided binomial bounds, when independence of records is warranted, can serve as a conservative guide. If the records arise from one uninterrupted correlated capture, however, their nominal count overstates the available independent evidence.

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Even excellent calibration of false matches against noise does not establish device identity. Suppose every compatible device emits the same public field; the likelihood of a genuine recognised field may be similar under all those physical-source hypotheses. A low false-alarm rate against noise means the detector is good at separating signal-like structure from tested disturbances. It does not mean it can separate among compliant transmitters. Attribution requires a second experimental axis, with different physical sources interchanged under independently controlled propagation and receiver conditions. Report the confusion matrix over source classes, unknown-source rejection and source-session stability. The honest investigator presents separate uncertainty figures for 'was this public field present?' and 'which, if any, physical device emitted it?' because the first question may have a good answer when the second has none.

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Peter Elias, Cross-Peer Question to Irving S. Reed: Dr. Reed, the successful decoding of a valid block-code structure may appear to reinforce a public preamble match. Yet a code is intentionally shared among compatible equipment, and its parity constraints are properties of an allowed language rather than its physical author. How should we distinguish a valid syndrome, a recognised public marker and source-dependent analogue behaviour so they are not mistakenly counted as three independent indicators of identity? Could a public test-code implementation be re-used across products in ways that create common mismatch patterns under the same receiver, and how would you isolate that from actual radio hardware differences? I ask also for an experiment involving independent code implementations and a fixed RF front end, followed by an experiment involving different RF front ends using the same public code, to make the causal distinctions visible.

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Could the experiment also distinguish errors caused by a common receiver-decoder library from errors caused by the radio front ends themselves, while ensuring that neither test accesses a protected message?

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Irving S. Reed, Cross-Peer Answer to Peter Elias: Dr. Elias, a parity check is a test of membership in a code, not an authorship certificate. If a public linear block code is described by a parity-check matrix H over the chosen finite field and a received hard-decision word is r, its syndrome is s=Hr transposed. A zero syndrome is consistent with a valid codeword but does not guarantee absence of errors, because a nonzero error that is itself a codeword can also yield zero syndrome. Equally, if two products implement the same code, the valid parity relations are the same by construction. Treating preamble recognition, parity consistency and codeword membership as independent source identifiers would multiply information that may largely arise from a common standard and shared decoding decision. A forensic report should separate them as distinct diagnostic stages while preserving their dependencies.

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In your proposed factorial trial, begin with one controlled RF output chain and feed it public training sequences generated by independently implemented coding software. If their ideal sequences and analogue output agree under the defined public specification, the receiver ought not infer different physical transmitters from code structure. Next hold the public digital sequence and its software generation fixed while changing the physical output devices under carefully balanced propagation paths. Any observed distinction then requires a physical-feature explanation and a fresh validation; it cannot be assigned to the public code. Include a third test in which the receiver's equaliser, sampling clock or decoding threshold changes while the source remains fixed. If apparent device signatures move with the receiver, those signatures do not have the required source invariance. The result may be a defensible class-level observation, but a unique transmitter conclusion remains dependent on further independently validated evidence.

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A practical extension would blind the analyst to the assignment of the independently implemented encoders while keeping the same public reference vectors and the same acquisition software. Record the decoder's choices of timing offset and parity interpretation before revealing which implementation generated each trial. If the supposed fingerprints follow the encoder or receiver software after the RF chain is exchanged, a claim about physical emitter identity has failed. Conversely, a feature that follows an output device through changes of code implementation, receiving antenna and gain state may merit further investigation, but only under a fresh held-out design with unknown-source rejection. A valid syndrome remains a code-consistency result, not a signature of individual authorship.

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Dr. James M. Atkinson, Moderator: Dr. Reed, thank you for distinguishing membership in a shared code from physical authorship. Please take the principal token and develop the relationship between valid algebraic structure, receiver acquisition errors and claims of transmitter-specific behaviour. I should particularly like you to distinguish a reproducible decoder result from a reproducible analogue characteristic of the transmitting equipment.

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Irving S. Reed, Fourth Principal Contributor: It is a common error to imagine that because a received radio frame satisfies a complicated algebraic test, the frame must have originated in one complicated and therefore identifiable piece of hardware. The first half of that sentence concerns membership in a public mathematical language; the second concerns a particular object. There is no general logical bridge between them. Many devices implement identical block codes, convolutional codes, scramblers, cyclic redundancy checks and publicly specified synchronisation markers. The engineering purpose of a shared construction is to let different devices communicate or permit different receivers to recognise the same format. A valid algebraic relation can strongly support a format or coding-family interpretation and still carry no individual-source information. The investigator should therefore make a written distinction between the observed public symbol structure, the decoder's treatment of it, and the RF hardware properties that were not tested by the algebraic check.

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Let a linear block code have length n, dimension k, and parity-check matrix H with n−k rows over a specified finite field. An ideal transmitted codeword c satisfies Hc transposed equals zero. A received hard-decision vector r=c+e contains an error vector e, and the syndrome becomes Hr transposed=He transposed. If this is zero, the result is consistent with an allowed codeword but cannot generally prove that no error occurred or identify the coding engine. Different physical sources using the same H produce the same set of allowed codewords. Moreover the hard-decision vector is not a direct physical measurement: it depends on carrier synchronisation, channel equalisation, sampling instant, quantisation and receiver thresholds. Two receivers can produce different syndromes from the same authorised RF burst if their decisions differ. This is a useful diagnostic limitation, not a defect in algebra. It forces one to say what the check actually checks.

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Consider a controlled example using a synthetic block code with n=15 and k=11, so four parity constraints are available under the declared field and full-rank H. No claim of a particular commercial standard is needed. A receiver may accept a 15-symbol reference record because its syndrome vanishes, yet many different transmitters could have generated exactly that codeword. If the examiner searches a long noisy record for any 15-symbol segment with zero syndrome, some will satisfy the algebraic constraint by chance. Under an oversimplified model of uniform independent 15-bit candidate vectors and a full-rank four-row binary H, the fraction satisfying all four parity constraints is 2^(-4)=1/16 at one prespecified position. Searching 160 independent candidates would yield an expected ten valid-syndrome patterns even without a legitimate coded frame. Overlapping candidates and receiver dependence change the full false-match calculation, so this number is an illustrative counting argument, not a field detection rate. The error is treating validity as rarity without specifying the population and the search.

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A second confusion arises when distinct publicly specified fields are combined. Suppose the examiner recognises a training sequence, a frame delimiter and a valid parity structure. Those may be three useful engineering checks, but their probability under a compliant-frame hypothesis can be jointly high because the standard requires all three. Calling them independent proofs of one physical instrument would be unjustified. Even in a source-classification study, their conditional dependence must be measured: the same inaccurate frame-boundary estimate may influence the training match, delimiter position and parity result. A successful receiver decoder can yield a beautifully consistent set of dependent outputs while the initial synchronisation hypothesis remains wrong. The correct experiment varies the underlying timing error and checks whether all three indicators move together, exposing their shared cause.

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Hardware fingerprints, if pursued within lawful controlled reference experiments, pose a different set of measurement questions. An RF front end may exhibit power-amplifier distortion, oscillator error, filter group delay, phase noise or amplitude transitions. But what reaches the observer is a composition of transmitter behaviour, antenna and propagation, receiver front end, clock recovery and digital processing. A radio's oscillator error cannot be estimated in isolation without knowing the receiver's oscillator; the recorded value is a relative quantity. A nonlinearity seen under high received power may arise from receiver saturation rather than transmitter intermodulation. A fingerprint classifier that uses one fixed receiver and one bench location may learn the measurement apparatus. Thus feature stability must be tested across receiver changes, calibrated power levels, temperature, antenna orientation and fresh acquisition sessions before one can assert that it belongs primarily to the source.

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A practical factorial experiment would compare software and hardware interventions independently. Use two independently written encoders that produce the same published test sequence, route them through the same authorised RF chain, and ask whether the analyser separates them. If it does, the separation may reflect implementation timing or unintended differences in the generated waveform rather than a unique RF unit. Then use one frozen digital waveform to drive two independent RF output devices through a balanced cabled configuration, before repeating over the air with switched receiver positions. If the proposed fingerprint persists only in the over-the-air setting, path and antenna effects are suspect. Finally vary the receiver oscillator and filtering while preserving the RF source. A suitable report shows how the model's apparent discrimination changes under each intervention, including cases in which the model properly abstains.

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The temptation to call a small error pattern unique is especially hazardous where the candidate population is underspecified. A training-field mismatch sequence measured on two trials is one observation from a potentially large and correlated family of nuisance conditions. A repeated location of an error may be caused by a deterministic equaliser coefficient, known pulse shaping or a shared firmware bug. One could examine whether the pattern persists across receiving chains and between independent source lots, but that produces a bounded comparative claim, not a mathematical proof of unique identity. If a rare error pattern is itself used to select the candidate source, a subsequent statistical claim about its rarity must account for that post-selection process. The final scoring rule should be fixed before the independent validation, with uncertainty intervals for both false acceptance and true-source rejection.

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I would make an investigator maintain separate ledgers for the public-code facts and the physical-source hypotheses. The first records published sequences, frame lengths, valid parity relations, tested tolerances and the measured acquisition score. The second records source classes, measurement conditions, alternative physical explanations, blind allocations, channel controls and independent replication. The two ledgers may be linked by an explicit hypothesis, but their entries should not be merged merely because one receiver software package displays them on a common screen. This discipline prevents a legitimate engineering decoder from being elevated into a forensic identification oracle. It also guards against overcollection: the public training sequence can be tested with synthetic references and bounded non-content observations rather than retaining private message payloads merely to decorate the report with additional codewords.

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Finally, I would require a final sentence that describes the strongest defensible inference and its boundary. It might say that an authorised burst contained a candidate synchronisation field and parity structure compatible with a stated public format within specified receiver uncertainty. It might separately say that repeated analogue measurements distinguished certain laboratory reference equipment classes under controlled conditions. It should not say that the public field identified one unique transmitter unless independent source-specific evidence warrants that proposition. Standards compliance is designed to create similarity among devices. A scientifically admirable detector must therefore be willing to recognise similarity without imagining individuality. In the court or an engineering review meeting, that modest distinction is the difference between a measurement and a conclusion placed upon it.

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Ronald Newbold Bracewell, Peer Question: Dr. Reed, I should like to introduce spatial selectivity into your factorial design. Suppose the analyser observes a code-compatible burst with one antenna oriented towards a known laboratory source, and a second measurement from a rotated antenna produces a different correlation peak shape. The analyst might interpret this apparent reproducibility with angle as an individual transmitter property. But the antennas, multipath field, receiver gain and source polarisation are all capable of changing the result. How would you distinguish the spatial signature of the channel from a feature of the source? Would you prefer repeated measurements from a simultaneous calibrated receiving array, or controlled rotation of a single antenna with independent event timing? Please specify what uncertainties must be assigned when observations at different angles were made at different times, especially if the public synchronisation interval is short and the transmitter operates intermittently.

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Should the apparent feature also be tested with the transmitter's own antenna replaced by a calibrated load, so that source radiation and propagation can be distinguished from the receiver's directional response?

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Irving S. Reed, Response: Dr. Bracewell, spatial selectivity should be treated as an observation mechanism to be calibrated, not a source identifier merely because its plot looks distinctive. A simultaneous calibrated receiving array can reduce temporal mismatch when it records the same authorised event at several elements, but each channel needs phase, gain, delay and polarisation calibration. Controlled rotation of one antenna can be useful where the source and propagation remain demonstrably stable; for an intermittent or moving source, however, measurements collected at different times cannot automatically be assembled into one instantaneous spatial pattern. The uncertainty should include event timing, antenna position, the possibility of missed bursts and changes in source power or orientation. An apparent angular null may be caused by the antenna pattern or multipath rather than a special feature of the emitter.

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I would first characterise the receiving antennas with a permitted fixed reference source and document their response over the tested angles. Then move or rotate the source under concealed and independently recorded conditions, repeating the public training field while maintaining a second simultaneous monitor to establish which bursts truly occurred. The monitor's role is to distinguish non-detections from occasions when there was simply no eligible RF event. Where an array is used, its steering-vector assumptions should be tested against injected and radiated references, including changes in polarisation and delayed reflections. A feature that follows the receiver antenna after an exchange of source locations is not a stable individual-source characteristic, even if the corresponding correlation profile can be reproduced with precision.

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I would also compare the source attribution rule with and without the direction-dependent features. If its accuracy falls sharply when the source and receiver positions are swapped, it has probably learned some part of the geometry or environment. That is not useless information for locating or classifying observations, but it must be reported as conditional on the spatial setup. A code match plus an angle-of-arrival estimate can support two different statements: the field has a compatible public structure, and the energy was observed from a particular direction within the array's calibrated uncertainty. Neither statement, separately or together, proves the serial identity of the radio that generated it. The final ledger should preserve the distinct calibration records and the temporal eligibility of every measurement. Without them, the analyst's confidence will be an artefact of joining incompatible observations into one apparently coherent picture.

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Irving S. Reed, Cross-Peer Question to David Slepian: Dr. Slepian, we have distinguished code membership, successful synchronisation, and possible analogue differences. I should like you to frame the final decision problem. If an observer searches an unknown spectrum, the number and prior frequency of eligible physical sources are not generally known; yet an instrument may return a confident score for one familiar device model. Under what conditions is such a score merely a closed-set ranking rather than evidence of an individual transmitter? How would you construct a defensible rejection region for unrecognised sources and choose the costs of false attribution versus missed classification? Please address the dependence among public-field and analogue features, the selection of a threshold after viewing the trials, and the need to report uncertainty for the actual hypothesis tested, not the hypothesis a user wished the measurement to answer.

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How should one describe a confidence score if no laboratory sample represents the many unknown compliant sources that could plausibly transmit exactly this public sequence, and why must an abstention remain a valid output?

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David Slepian, Cross-Peer Answer to Irving S. Reed: Dr. Reed, I would start with a declared set of hypotheses and permit a rejection or unknown outcome. A closed-set classifier whose labels are A, B and C must output one of those labels even if a completely unfamiliar device D supplies the observation, unless the algorithm has been given a separate open-set decision rule. Its high internal score may indicate that D most resembles A within the training representation; it is not a calibrated probability that A physically emitted the signal. A decision system that operates outside its reference population therefore needs tests involving deliberately withheld source classes and conditions not used to choose its thresholds. The false-acceptance cost should reflect the consequence of unjustified attribution, while the false-rejection cost reflects loss of a potentially useful but uncertain equipment-class clue.

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The feature vector should be divided into public-format components, receiver-condition components, propagation-sensitive components and candidates for source-related physical features. Their joint distribution under each declared hypothesis matters. Multiplying individual likelihood ratios is valid only under a corresponding conditional independence model, which the data must support. In a comparison of sources sharing an identical public synchronisation field, the public-field component may contribute nearly no discrimination among them, even though it contributes strongly to detection against noise. Any threshold used for attribution must be chosen on independent calibration records, with a separate test set reserved for its claimed field performance. Report the error rates for unfamiliar devices, receiver substitutions, changes in frequency and the cases in which the classifier refuses to decide.

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The conclusion should be expressed as a bounded likelihood or calibrated comparative score between specified hypotheses. It must not silently substitute the probability of observing the public field under A for the probability that A transmitted the field. If no representative alternative-source population can be defined, the analyst should avoid numerical individual-attribution probabilities altogether. One can still give a useful account of waveform compatibility, quality of synchronisation, temporal evidence and the limitations of the physical features. An abstention is often the correct statistical decision when the question exceeds the experiment. That is not a defect in the instrument. It is the instrument declining to make a claim its training and calibration do not warrant.

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Dr. James M. Atkinson, Moderator: Dr. Slepian, I now pass you the principal token for our concluding examination. Please explain how the limits of inference should be incorporated into the decision rule, the reporting language and the independent verification of a public synchronisation-field observation.

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David Slepian, Fifth Principal Contributor: The receiver's job and the investigator's task should be separated before one writes down any decision rule. The receiver often asks whether a certain pattern is present, whether timing is sufficiently aligned to continue processing, or whether a frame belongs to a recognised signalling family. The investigator may instead ask which transmitter emitted the energy, where that transmitter stood, or whether a particular person controlled it. These are different statistical propositions and they require different evidence. A public training field is often a well-designed answer to the first set of questions and a poor answer to the second. If the engineer allows one score to stand for all these propositions, the resulting report will appear compact and impressive, but its uncertainty will have been attached to the wrong question.

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Let H0 denote the hypothesis that no compatible public training field is present under a specified set of disturbances, and let H1 denote the hypothesis that a compatible field is present from some permitted source. A detector using statistic T(Y) with threshold τ may be calibrated for P(T(Y)>τ given H0)=α, where α is its false-alarm probability under the stated null model. Its detection probability under H1 is P(T(Y)>τ given H1), which will depend upon signal level, frequency offset, channel delay, receiver quality and which compatible waveform variants are included. Neither error rate is an individual-source attribution probability. To pose a source comparison one needs additional hypotheses H_A and H_B with their own observation distributions, calibrated nuisance-variable ranges and a decision rule that can decline to choose. If H_A and H_B produce the same public sequence under similar conditions, the synchronisation score alone has little power to separate them.

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An engineering specification may quite properly reward detection of a familiar public preamble over a wide signal-to-noise range. That success does not diminish the need for careful field interpretation. A receiver can have a 99 per cent detection probability for a training field and be unable to discriminate at all among the compliant transmitters that use it. Suppose, for an explicitly hypothetical controlled experiment, source A and source B each transmit the same field; the algorithm recognises a field in 990 of 1000 eligible trials for A and 988 of 1000 for B. The difference between 99.0 and 98.8 per cent is small and subject to ordinary sampling uncertainty. It cannot rationally be converted into a source fingerprint. If the analyst searched many thresholds and then reported only the one that produced the largest apparent difference, the need for an independent validation is greater still. The correct observation is that the detector is effective at recognising the shared field in those tested conditions.

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We must also take account of the base-rate problem. Even a strong source-classification likelihood ratio may produce a modest posterior when the candidate source is rare among the alternatives. If a field source could have been any of many compliant radios, the public preamble is common to the entire class and supplies no unique name. An observer who selects one particular transmitter because it is suspected and compares it only with thermal noise has tested the wrong alternative. The relevant alternative may be another compliant source, a synthetic authorised test signal, a replay of the public training interval or a receiver artefact. A defensible evidence report states which alternatives were actually measured, which are merely possible and which could not be investigated. Its level of conclusion is bounded by the alternatives considered; no exact mathematical notation can repair an absent comparison population.

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A useful operational framework records three decisions independently. The first is acquisition: did a public synchronisation hypothesis pass a declared threshold under an instrument-calibrated null? The second is format: is the complete non-content observation compatible with a declared physical-layer family, and which alternative formats remain plausible? The third is source: are separately measured physical features sufficient to distinguish reference equipment classes under independent validation, with an unknown-source rejection option? It may be legitimate to say yes to the first, perhaps to the second, and no to the third. The report should not collapse this sequence into one green indicator labelled 'identified'. A hierarchy of claims is a safeguard against the ordinary human tendency to read an instrument's neat display as greater certainty than the experiment provides.

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There are distinct uncertainties in the process. Timestamp uncertainty arises from clock calibration, acquisition path delay and definition of the synchronisation event. Frequency uncertainty arises from the relative transmitter and receiver oscillators and estimator variance. Sequence uncertainty arises from the number of candidate templates and offsets searched, the selected correlation peak, interference and channel distortion. Model uncertainty arises from omitted formats and unknown source classes. Forensic uncertainty arises from custody and processing history, including whether the test data can be connected to the event described in the report. These terms should not be combined into one unexplained confidence score. Some may be probabilistic, some may be bounds and some are unresolved qualifications that no reasonable numerical percentage can absorb.

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We also have a question of repeatability. An investigator might observe the identical public sequence in one room on successive days. That repetition may make the signal-format description firmer, but it does not necessarily make an individual-source conclusion firmer because a number of devices may use the same public marker. The correct repeatability experiment changes the source and the measurement environment deliberately, then asks whether the inference survives the change. Repeat the observations with different receivers, hold out reference device types and test the processing software against synthetic counterexamples. When the experiment is blinded, the analyst cannot adjust the field windows and thresholds to fit source labels. If a claim fails in this independent trial, one must report the failure even though the original matching plot remains aesthetically persuasive.

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A report that preserves the limitation can nevertheless assist security work. It may document that a previously absent compatible waveform class has appeared, that a public preamble occurs at a new frequency or duty cycle, or that a measured signal level changes in a specified location. Those findings can motivate lawful, proportionate further investigation without accusing a named device or operator. A laboratory may supplement them with authorised reference sources and differential receiver tests, while minimising any collection of protected communications content. The fact that public synchronisation information is accessible does not justify retaining every subsequent payload bit. The methodology should specify the least information needed to answer the detection question, the retention period appropriate to that purpose and the process for documenting analytical transformations.

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I would close with a practical criterion. The evidence becomes unreliable for identifying a particular transmitter whenever the asserted individual distinction rests on a field intentionally shared by multiple devices, on an uncalibrated analogue feature, on a receiver-dependent choice of synchronisation offset, or on a reference set that excludes credible alternatives. This criterion does not declare all RF attribution impossible. It declares that each level of specificity requires its own tested evidence. A competent instrument can recognise the common synchronisation language while refusing to invent the speaker's identity. In an engineering manuscript, as in a well-conducted scientific hearing, restraint in the conclusion is a necessary consequence of precision in the measurement.

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Antony Hewish, Peer Question: Dr. Slepian, I am concerned with the fleeting observations that field investigators often record. Imagine that a public synchronisation field appears in a brief burst only once or twice during a period of intermittent monitoring. The receiver visits the relevant frequency at discontinuous intervals, and its local clock may be imperfectly disciplined. Could the existence of two attractive correlation peaks be sufficient to infer that one physical emitter recurred, or might the same public waveform have been transmitted by different compatible sources at different times? Please address how the monitoring system should count occasions when it had no observation opportunity, the possibility of delayed receiver acquisition, and whether a second independent receiver can help without itself identifying the transmitter. I should also like a reporting formulation that avoids turning a pair of sparse detections into an invented history of one persistent radio.

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Would your conclusion change if those detections were reported only after software-buffer flushing at regular intervals, rather than timestamped at the physical sample acquisition boundary?

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David Slepian, Response: Dr. Hewish, two matches to a shared public field do not by themselves prove recurrence of the same physical source. They establish that the monitoring apparatus recorded two candidate events compatible with a stated training format, provided the detector was adequately calibrated. The events may originate from one source, two different compliant sources, a controlled authorised replay or an instrument artefact. Their chronological separation supplies a measured interval, not a pedigree. A frequency-scanning receiver may have been blind between visits, so the number of unobserved source events is unknown unless an independent continuous reference supplies a defensible bound. An absence of detector output cannot be read as a physical absence when the receiver was not looking or had insufficient sensitivity.

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I would require the instrument to preserve an observation-opportunity register. For every survey interval, record the frequency being monitored, effective dwell after retuning and settling, channel bandwidth, detection threshold, gain state and sample-counter continuity. Mark gaps in which no eligible observation was possible, including periods lost to data transport or processing overruns. When a candidate match occurs, retain its timestamp uncertainty, correlation statistic and competing timing offsets. A second independent receiver can corroborate that RF energy with compatible public structure existed at a particular time, and may help separate a receiver-local fault from a propagated event. But if both receivers detect the same shared public sequence, neither has thereby established that an individual, named transmitter emitted it.

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The report should use cautious language such as: 'Two candidate bursts compatible with the specified public synchronisation sequence were recorded at the stated times, within the documented acquisition and clock uncertainties. The available data do not establish whether they originated from the same physical transmitter.' If a measured physical feature appears consistent across events, name that feature and the environmental tests it passed, without silently upgrading it into unique identity. If the observation opportunities were intermittent, include the coverage denominator so recurrence rates and occupancy estimates cannot be mistaken for continuous monitoring. The same discipline applies to a statistically convincing periodic interval: it may be informative about traffic behaviour under a particular observation process while remaining ambiguous about the source. In a forensic record, that ambiguity must remain visible rather than being smoothed away by a continuous line drawn between two isolated detections.

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Dr. James M. Atkinson, Moderator: I thank the contributors for a disciplined examination. A public synchronisation sequence may strongly support recognition of a physical-layer format, but it does not ordinarily identify an individual transmitter. The record shall preserve independently tested source hypotheses, acquisition and timing uncertainties, the search process and alternative explanations. I now close Question 089 and pass the token to the subsequent question concerning proportionate, privacy-conscious recording of communication-related observations.

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EDITORIAL QUALIFICATION. This is a fictional pedagogical reconstruction using the names of deceased specialists. It is not a record of authentic discussions or attributed historical quotations. Stage B must verify the source-to-claim relationship, scientific assumptions, all equations and numerical examples, contributor biographical particulars, originality and final integrated typography. Independently consulted technical context includes publicly archived IEEE 802.11-1999 training-preamble explanatory materials and Schmidl and Cox (1997), 'Robust Frequency and Timing Synchronization for OFDM', IEEE Transactions on Communications 45(12):1613–1621, DOI 10.1109/26.650240. These sources support the engineering purpose and shared implementation of synchronisation designs, not the fictional dialogue.

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QUESTION 090

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How can a surveillance report avoid unnecessary communication-content collection?

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Dr. James M. Atkinson, Moderator: Admiral Hopper, please begin with the architecture of a defensible record. I ask you to distinguish what the instrument has measured from what its software can store, and to explain why a system able to preserve an entire complex-sample stream should not automatically do so. The contributors' remarks are fictional scholarly reconstructions undertaken for a lawful defensive engineering thought experiment.

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Grace Brewster Murray Hopper, Principal Contributor: The question presents two systems whose apparent similarity should not obscure their separate purposes: a measuring instrument and a record-keeping apparatus. A receiver turns electromagnetic input into digital data through antennas, filters, gain stages, mixers, conversion and software. A reporting system turns selected observations into propositions that another person can investigate, challenge and preserve. The ability of the first system to produce a large quantity of samples does not establish that the second has a purpose for retaining them. I would begin by writing down the decision to be supported, the admissible observation fields, the period for which each is necessary and the verification procedure by which a reviewer may reconstruct the reasoning. A system that stores every waveform because storage is cheap may later be unable to explain why the incidental communications of unrelated persons were retained. That is not an improvement in engineering.

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Let the authorised detection question be whether a defined segment of spectrum contained a reproducible, unexplained emission during a specified site survey. The report may need the frequency, observation interval, timestamp uncertainty, estimated bandwidth, received level, noise-floor reference, detector settings, antenna position and equipment-calibration identity. It may also need the count of missed observation opportunities, because silence from a scanning receiver is not proof that no source transmitted. Those data are not automatically sufficient for every possible hypothesis, but they give the investigator a clear basis for deciding what additional acquisition would change the result. A public training-field detection might add format compatibility to the evidence; it does not authorise the investigator to read the private content that follows. Similarly, the existence of a software demodulator or a large disk does not supply the purpose or legal authority that the measurement plan lacks.

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I would design the reporting interface around explicit data types and their provenance. A timestamp should be labelled as hardware acquisition time, receiver-reported time or later host-processing time; they are not interchangeable. A received-level field should state whether it is an absolute calibrated measurement, a relative estimate or simply a threshold-crossing indicator. A signal-class field should distinguish an observed feature from a speculative device identity. Each electronic record should carry the instrument configuration and processing software version sufficiently precisely that a later reviewer can understand its transformations. This is an engineering application of disciplined information management: the representation must not insinuate greater certainty than the experiment establishes. A neat screen filled with green confidence indicators is not a substitute for preserving the conditions under which those indicators were produced.

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The two proposed pipelines need a fair comparison. It would be dishonest to disable the metadata pipeline's useful technical measurements and then declare full-IQ storage indispensable. Instead require both pipelines to operate with the same reference event schedule, antennas and declared thresholds. Pipeline M preserves the smallest set of non-content values capable of reproducing the authorised detection decision. Pipeline I preserves those same values and an additional IQ segment. An independent reviewer then asks which predefined decisions each can support, how often each creates false associations, what analytical uncertainties each resolves and what unrelated information might be incidentally retained. If the IQ record reveals a previously unknown receiver artefact essential to avoiding a serious false accusation, the experiment has identified a legitimate potential benefit. The next question is whether a narrower triggered segment, diagnostic statistic or controlled reference-capture procedure would supply that benefit with less exposure.

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One must design the process for exceptional cases before the exceptional case occurs. If an anomaly genuinely requires short authorised sample retention for independent validation, the system should require a recorded justification, a bounded start and stop, access control and a disposition rule. The exception should not silently become the default. The user of the instrument must know which transformations are reversible and which measurements are summaries that discard information. A histogram of received levels cannot necessarily reconstruct the phase of a short interference burst, and a list of correlation peaks cannot reproduce every candidate offset. These limitations should be stated frankly. But the fact that a summary cannot answer every imaginable future question is not, by itself, an adequate reason to retain everything that passed through the analogue-to-digital converter.

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For a worked hypothetical study, suppose the authorised event reference contains two hundred seeded benign transmissions and two hundred matched null observation intervals. If the metadata-only pipeline detects 190 actual events and gives ten false alarms while the full-IQ pipeline detects 193 and gives nine, the resulting sensitivities are 190/200=95.0 per cent and 193/200=96.5 per cent, and the false-alarm proportions per stipulated null interval are 10/200=5.0 per cent and 9/200=4.5 per cent. These fractions say nothing about payload necessity unless the extra three detections or one avoided false alarm would change the declared defensive decision, and unless the difference is tested with suitable uncertainty analysis. The scenario is a demonstration with invented numbers, not reported instrument performance. Even a measurable performance advantage for a full-IQ method does not imply that indefinite or unrestricted retention is justified. The experiment must connect each incremental data field to a defined and authorised use.

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A serious technical record should make subsequent review possible without silently broadening the surveillance objective. A reviewer may need to reproduce the numerical threshold and understand the receiver's calibration, but that does not mean a reviewer should be given access to incidental speech or data content unrelated to the security question. Access rules, redaction procedures and custody documentation are therefore part of the measurement architecture, not an afterthought added by the legal department. A design that separates public format information, occupancy measurements and retained content gives both engineering teams and institutional reviewers a way to see the consequences of each acquisition choice. In an instrumented survey the best record is not necessarily the largest record. It is the smallest reliable and adequately contextualised record that permits the authorised question to be answered and independently challenged.

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I should like the subsequent panel to press the issue further. Mr. Turing should test how an algorithm may silently preserve more than its published report suggests; Mr. Davies should consider network transport and logs that replicate incidental samples; Dr. Shannon should examine whether a summary statistic retains the information required for the predeclared decision; and Professor Dijkstra should insist upon machine-enforceable controls that prevent a temporary engineering convenience from becoming an unlimited collection channel. Their objections will help identify the boundary between legitimate engineering reproducibility and avoidable acquisition of protected material. That boundary must be built into the system before an investigator sits at the console and hears the steady ticking of new event records accumulating on its storage device.

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Jacob Ziv, Peer Question: Admiral Hopper, your two-pipeline experiment seems well constructed, yet its principal vulnerability may be the choice of summary fields before the investigators have discovered the receiver defect. Compression reminds us that a sufficient representation depends upon the class of questions one is entitled to ask. Suppose a momentary overload of the front-end produces a convincing emission whose displayed centre frequency, bandwidth, level and timestamp are indistinguishable from those of a seeded signal. A raw complex-sample segment may reveal clipping or image products, whereas the metadata record hides both. What predeclared procedure permits the investigator to recognise such a deficiency without making unrestricted waveform retention the usual practice? Please identify what may trigger exceptional retention, who may authorise the exception, how the record may be bounded, and how one prevents the analyst from redefining the experiment after learning which pipeline performed better. I am especially interested in false negative results and in whether an absence of evidence can properly be declared when the scanner was not observing the relevant channel.

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Grace Brewster Murray Hopper, Response: Dr. Ziv, a reporting specification which assumes that its original feature list will answer every legitimate question would be as defective as one which retains everything in anticipation of every imaginable one. I would separate the right to perform a particular test from the data normally retained by that test. A risk assessment and an authorised diagnostic protocol should describe several known failure modes, such as front-end clipping, gain settling, local oscillator images and dropped sample buffers. Each mode should have a narrowly chosen test field. A clipping counter and an analogue gain-state log may be enough to question a suspicious peak without preserving private modulation content. Where that evidence is insufficient, a short authorised reference capture can be justified by a distinct, documented request, preferably using a seeded laboratory signal rather than ambient communications.

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The decision to trigger such a record should not be based merely on the operator's curiosity or on whether a sample might later prove useful. It should require a stated diagnostic proposition, an allowed frequency range and interval, independent approval appropriate to the organisation, and a finite retention disposition. The captured bytes must be access-controlled and separated from ordinary case reporting. A person reviewing the defensive finding should normally encounter the derived measurement, the acquisition provenance and the limitation first, not an unrestricted copy of every communication near the instrument. If the capture was never needed, the record should say so and should be disposed of in accordance with the applicable retention obligations.

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A fair experiment can establish these rules before the test labels are disclosed. Both pipelines receive the same controlled emissions, matched benign interferers and null intervals. A third, independent apparatus records the ground-truth event schedule. The analysts are blinded to that schedule, and the rules for classifying an event and invoking an exception are frozen. We record not only successes but false positives, missed events, timing gaps and occasions where neither pipeline can support a classification. The additional IQ information is evaluated by whether it changes a predetermined decision in a reproducible manner, not by how interesting it looks afterwards.

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Finally, scanner coverage must be treated as a measured eligibility condition. If the receiver did not observe a frequency for the requisite interval, its silence cannot be coded as a negative event. A case record should distinguish no emission detected during valid observation, no valid observation, and data unavailable because of an instrument fault. Those are three different states with different implications. In each state the goal remains a bounded, testable security conclusion without constructing an unnecessary collection of the surrounding communications.

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Abraham Lempel, Peer Question: Admiral Hopper, I wish to examine the engineering temptation to call a stored waveform harmless merely because it has been encrypted, compressed or transformed. A reversible transformation can preserve every item of incidental content, and a long-lived key can restore access well after the original survey has ended. Even a nominally nonreversible representation may expose a sensitive pattern when it is combined with location, timing or external administrative data. Suppose a monitoring system retains raw I and Q samples in a compressed archive, stores an event table separately, and exports thumbnail spectrograms for reports. Which of those products counts as information that must be controlled, and which can be regarded as a minimally sufficient measurement? I also ask whether the loss of a decryption key actually demonstrates disposal, or whether the institution must prove the absence of readable replicas in caches, diagnostic logs and automated backups. The distinction matters when a very capable laboratory is asked to preserve evidence without becoming a repository of unrelated correspondence.

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Grace Brewster Murray Hopper, Response: Dr. Lempel, the transformation applied to a record does not determine the legitimacy of collecting it. Reversible compression merely changes representation; it does not remove the underlying communicative information. Encryption can protect confidentiality against unauthorised access, but encryption alone does not make acquisition necessary, nor does it shorten the period for which the information remains held. Even a spectrogram image can reveal timing routines or associations when combined with other records. I would therefore place the original samples, their compressed form, the derived images and every exported report within a single information-lifecycle inventory. The inventory should describe sensitivity, permitted use, custodianship, retention basis and deletion or preservation obligations for each class.

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This requires data-flow analysis, not just a policy at the recording button. A sample may enter a ring buffer, a crash dump, a network packet capture, a search index or a temporary directory before it reaches the nominal evidence store. If a program tells the investigator that only event metadata will be kept but leaves full samples in a persistent diagnostic cache, the declaration is materially misleading. The pipeline specification should identify each place bytes can be written and each service permitted to read them. Unit tests should exercise normal operation, exceptions, interrupted shutdown and recovery from a storage error. The result is auditable evidence that the implementation follows its stated purpose.

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Deletion also deserves a precise technical vocabulary. Removing a directory entry is not necessarily the destruction of every physical copy. Key destruction can form part of a properly implemented cryptographic-erasure system, but its effectiveness depends on key management, algorithm selection, key copies and the storage architecture. A retention officer may be bound by preservation duties that prevent immediate destruction, even when the engineer would prefer a shorter period. The correct approach is to define the applicable constraints in advance, not to claim that a universal technical trick has discharged every legal obligation.

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I would classify the metadata record as minimally sufficient only relative to a stated evidential claim and an identified test. An event's centre frequency and duration may suffice to document occupancy, but they cannot establish a fine phase transient. If the authorised question needs phase, we should retain a narrowly chosen non-content feature or a bounded reference capture after review. The governing test is always the same: what evidential uncertainty does each additional field reduce, at what privacy cost, and is the proposed acquisition lawful and necessary for that reduction? Compression offers no exemption from that question.

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Grace Brewster Murray Hopper, Cross-Peer Question to Alan Mathison Turing: Mr. Turing, I pass the token to you to examine the computer itself. An organisation may publish a privacy-conscious report design, yet its detection software might decode private content into volatile memory, record hidden diagnostic fields or send complete sample windows to a remote service. The analyst might not know, because the visible interface displays only frequency and timing. How would you define an observable conformance test between an approved specification and a real implementation? Please consider hidden intermediate states, probabilistic classification outputs and software updates which change the fields collected without changing the report format. In particular, can we establish noncollection from the absence of a payload in the printed report, or must we inspect the pathways by which data enter memory, logs, archives and network transports? I should like a method that independent reviewers can apply without making their own access to irrelevant communications broader than the case allows.

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Alan Mathison Turing, Cross-Peer Answer to Grace Brewster Murray Hopper: Admiral Hopper, an observed output seldom establishes the absence of an internal operation. Two programs may print identical event lists while one discards samples after computing a threshold and the other retains them, labels them by source or transmits them elsewhere. Black-box comparison of the printed report is therefore a necessary but inadequate test. I would begin with an explicit machine-level data contract: permitted inputs, intermediate transformations, output fields, writable stores, network destinations and error paths. The contract should distinguish information that must exist transiently to calculate a lawful physical measurement from information that may persist beyond that calculation. Where content extraction is outside the authorised task, the implementation should not instantiate a content decoder merely because one is available as a software library.

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Verification must be layered. Configuration review confirms that disabled pathways cannot be enabled silently. Source review and build provenance examine whether the implementation corresponds to its documented design. Instrumented executions with synthetic, deliberately distinctive test payloads can reveal leakage into logging systems without exposing real third-party communications. Independent monitors examine disk writes, temporary files, crash reporting, memory snapshots and outbound connections under ordinary and adverse conditions. The tests should include software-update paths and failure handling, since unexceptional executions alone are too easy to pass.

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A logical qualification remains: a finite test suite cannot prove the absence of every possible unauthorised behaviour in an arbitrary program. Stronger confidence comes from reducing the design's authority to collect and persist unnecessary data in the first place. A process which cannot write to the evidence store or open an outbound connection presents a smaller exposure than one which is trusted to exercise restraint. This does not relieve investigators of a proper legal analysis. It means that the machine's capabilities can be aligned with the authority already obtained.

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I would allow the independent reviewer to use recorded attestations, configuration manifests, synthetic test data and bounded audit trails rather than unrestricted access to the original communications stream. A proof of conformance is strongest when it identifies its assumptions, coverage and residual blind spots. The appropriate conclusion is not that the machine has metaphysically ceased to possess information, but that the implemented workflow restricts retention and dissemination sufficiently for a clearly described defensive purpose and a measurable assurance level.

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Dr. James M. Atkinson, Moderator: Thank you, Admiral Hopper and Mr. Turing. We have distinguished the measurement from its storage and the declared report from the software's hidden behaviour. Mr. Turing, please take the principal token and consider how testing, reproducibility and limited authority can coexist in a real signal-processing instrument.

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Alan Mathison Turing, Second Principal Contributor: The concept of a machine that carries out a definite procedure is useful precisely because it separates the steps that an operator believes are being performed from those that the machine actually performs. An RF receiver does not become privacy-preserving by adopting a new label for its interface. A typical digital chain may convert analogue samples, channelise them, estimate power, classify bursts, detect public timing fields and write event records. At each stage an engineering team has chosen what to measure, what to infer and what to preserve. The resulting decision can be interrogated as a program whose allowed behaviours must be specified, not as a reassuring promise printed in an operating manual. We should begin with the minimal algorithm that supplies the authorised decision and only then ask what additional data a defined uncertainty requires.

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Let the binary decision Y be whether a specified RF event occurred within a valid observation interval, and let X denote the receiver's complete sampled input. A procedure computes a smaller statistic T(X), such as a calibrated power excess, an onset time and a bandwidth estimate. If the authorised decision can be reproduced from T(X) under the stipulated measurement model, a full persistent copy of X may add no necessary information to that decision. Yet it would be a mistake to claim that T is universally sufficient. The signal model may exclude intermittent overload, clock discontinuity or an unexpected interferer. The correct experiment therefore tests the chosen statistic across a declared range of adverse conditions and identifies the cases in which a residual uncertainty cannot be explained from the saved fields. We should not conceal such limitations behind the prestige of mathematical notation.

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One practical design is a two-stage computation. A bounded detection process, operating under an explicit authority envelope, consumes complex samples and emits non-content event records. A separately controlled diagnostic process may be invoked only for an approved, predeclared failure question. The diagnostic process need not inherit unrestricted access to ambient communications; it may be exercised initially against synthetic replay files and laboratory references. The two processes should have separate storage permissions, audit trails and retention periods. An investigator reviewing the evidence can then ask whether the original event was sufficiently reproducible, whether the diagnostic exception was necessary and whether any retained information exceeded the approved scope. The process is more credible when the diagnostic capability is not silently available at every ordinary detection.

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Testing requires an adversarial attitude towards one's own program. In a blind trial, generate seeded emissions whose times, frequencies, power levels and deliberate impairments are known to an independent controller. Place noise-only and benign traffic intervals among them. Send the same input scene through Pipeline M, which records bounded metadata, and Pipeline I, which additionally retains a prescribed short sample window. If the observers know the labels, they may unconsciously tune thresholds or enlarge the search interval around a desired result. If the classifier selects only the easiest examples for analysis, its published sensitivity will be optimistic. Freeze the algorithms and eligibility criteria before inspecting the reference log; record every eligible interval, including failures and missed opportunities, rather than only the interesting peaks.

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We should also recognise that the right to investigate a system need not include the right to read every bit passing through it. A software developer can test the integrity of a checksum computation with synthetic sample streams and reference hashes. A reviewer can verify the schema, channel calibration and gain configuration without being given access to private communications. Where an exceptional case genuinely requires raw data, its authority and custody can be separately established. This division of labour protects both individuals and the integrity of the inquiry. If investigators routinely circulate an unrestricted sample archive simply because several engineers wish to inspect it, they enlarge the investigative subject without clearly improving the evidence.

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Program updates are a particularly dangerous point. A new detector version may silently add demodulated bytes to debugging logs or extend the sample window to improve classification. Both changes can leave the published report format unchanged. It follows that an evidence record should contain the executable version, configuration hash, approved data schema, relevant dependency versions, clock state and an audit of storage interfaces. A signed configuration manifest may help identify what version was deployed, though a signature alone proves neither correctness nor legal authority. The auditor should test that changing one authorised setting does not cause undeclared changes in collection or retention. A rollback mechanism must not revive a formerly prohibited capture path.

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There is a narrow distinction between transient computation and collection that deserves deliberate attention. A short-lived sample in volatile memory may be required to calculate a lawful signal measurement, but a crash dump, swap file or automatic telemetry package can convert that transient processing into durable retention. Processor isolation, bounded memory use and disabled diagnostic exports may consequently matter as much as the report's visible fields. Some institutions will impose additional duties upon communications metadata itself, depending on jurisdiction and context. The engineering team cannot presume that the word metadata makes an observation legally innocuous. It can, however, provide a truthful technical inventory for counsel and the authorised decision maker.

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I propose that reviewers judge the system against four propositions. The first is functional: does it reliably detect the stipulated physical event? The second is epistemic: can the result be independently challenged using the retained fields and stated uncertainties? The third is minimising: did the apparatus avoid retaining data not necessary for its declared use, including auxiliary logs and backups? The fourth is institutional: can the operator demonstrate that the purpose, authority and disposition rules preceded collection rather than being invented afterwards? Failure of any proposition should be visible in the case file. A competent system should sometimes answer that the available evidence is insufficient. The ability to make that admission is a sign of disciplined engineering, not weakness.

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Finally, let us not confuse the sophistication of a classification algorithm with the legitimacy of its inputs. An impressive classifier may discover correlations between incidental messages and occupancy patterns, but it is not entitled to use those messages merely because they would improve its accuracy. Likewise, a system which captures all traffic and later masks the report may have already exceeded its approved collection purpose. The limit should act at the acquisition, processing and retention boundaries, not merely at publication. Mr. Davies can usefully examine how innocent replicas arise during transport, and Dr. Shannon can say more precisely what information a smaller statistic retains. Both questions are essential if a defensive investigation is to withstand searching technical and legal examination.

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David Slepian, Peer Question: Mr. Turing, I accept that a limited statistic may support a particular binary decision, yet in signal detection its apparent sufficiency depends rather precariously upon the assumed distribution. Consider an authorised site survey with a low duty-cycle test transmitter and a receiver whose gain can change between observations. A saved threshold crossing and power estimate may support an occupancy decision, but not a later challenge alleging that the threshold itself drifted or that the baseline noise was nonstationary. Would you require a record of the underlying noise distribution, or a bounded sequence of noise-floor estimates, to make the decision reproducible? Please address how such a record is defined without quietly growing into a complete retained waveform. I also ask whether a system should use a different evidential threshold for merely reporting an anomaly and for identifying a specific device, given that the latter is a stronger and potentially more consequential claim.

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Alan Mathison Turing, Response: Dr. Slepian, you have identified the precise reason a data-minimisation design must begin with the intended claim and an explicit family of measurement models. I would not call a single threshold-crossing bit sufficient for every challenge to detector validity. A proper occupancy record may include time-varying noise-floor estimates, gain state, calibration uncertainty, sample-count eligibility and the decision threshold used for each window. A small sequence of calibrated summary statistics can permit a reviewer to detect certain forms of drift or censoring without preserving the entire phase and amplitude history of arbitrary nearby communications. The choice of summary must be justified against the known defects, not by an abstract preference for small files.

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Suppose a detector compares measured power P with a threshold B plus an offset D, where B is the contemporaneous noise baseline and D is a declared margin in the same logarithmic units. The record might retain P, B, D, the averaging interval, gain correction, clipping indicator and the clock's uncertainty. An independent reviewer can then reproduce the nominal decision and assess the effect of calibration error. If there is evidence that the gain path changed unpredictably within the averaging interval, the retained statistics might be inadequate. That is a reported limitation and possibly a reason for a separately authorised controlled diagnostic experiment; it is not a retrospective permission to retrieve unrelated private communications.

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The distinction between event detection and source identification is vital. A robust detector may show that energy exceeded an instrument-defined threshold under valid observation conditions. It does not thereby show that the source belonged to a particular person or device. Such attribution requires additional independent features, controlled comparison data and an explicit rule for unknown or unclassified sources. One should never allow a report generator to elevate the first statement into the second merely because an output column bears the heading confidence. A numerical confidence score without a validated reference population and error model may mislead more than an appropriately qualified narrative.

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I would also save the procedural record of failed or ambiguous observations. A system that preserves only events above threshold produces selection bias: the investigator cannot reconstruct how often the detector faced noise-only opportunities or how many observations were lost to retuning. Retained summary records can encode eligible windows, censored windows, false alarms in controlled null tests and changes in environmental conditions. Such evidence often improves scientific reproducibility while collecting less private content. The objective is an auditable experiment, not the impossible preservation of everything that might conceivably interest a future analyst.

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Alan Mathison Turing, Cross-Peer Question to Donald Watts Davies: Mr. Davies, I ask you to follow a lawful measurement through the network rather than confining your analysis to the receiver. Imagine that the detection computer stores only a brief record of frequency, timestamp, threshold and calibration state. Its monitoring agent nevertheless streams raw diagnostic buffers to a central service; a network switch mirrors those packets; and a maintenance system retains traces for troubleshooting. The operator's declaration of metadata-only retention would then be inaccurate, even though no payload appears in the final report. How should the system divide measurement authority from transport and maintenance authority, and what technical evidence would demonstrate the lifetime of an incidental copy? Please consider intermittent network failures, retransmission queues and backup schedules, since those mechanisms may preserve data outside the receiver's ordinary control. I am also interested in how much information a reviewer must receive to verify a transport design without duplicating the very records we intended to minimise.

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Donald Watts Davies, Cross-Peer Answer to Alan Mathison Turing: Mr. Turing, a networked instrument creates multiple places where information may be held, even if its front-panel operator imagines a single file. The first principle is to inventory the packet and storage pathways end to end. If the authorised purpose requires event metadata, only those metadata fields should enter the routine transport channel. The receiver ought to strip or discard disallowed content before transmission, not send everything to a server and hope that the server will perform the intended minimisation later. A segmented architecture can separate a low-volume event channel from an exceptional diagnostic channel whose activation, destination, size and expiry are individually controlled.

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Retries, queues and caches must be included in the inventory. A packet may be copied into a driver buffer, an application queue, a broker's persistent store, a mirror interface and a backup. Disabling a visible archive does not erase the other copies. A sensible design provides bounded queue capacity, documented time-to-live values, access restrictions, persistent-log filtering and tests that inject synthetic marked data into the system to discover where they survive. The tests should include connection loss and unexpected restart, since systems often retain extra information precisely when their ordinary workflow fails.

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For assurance, one can provide a reviewer with configuration manifests, network-flow summaries, synthetic-data tracing reports, hashes of deployed components and audit records of exceptional permissions. These materials can demonstrate whether the implementation conforms to its declared data contract without exposing actual private communications. They do not constitute an absolute proof that no other copy exists; a responsible report should identify what hosts, backups and third-party services were within the audit's scope. An independent records custodian must address any applicable duty to preserve evidence rather than allowing engineers to destroy material in violation of a hold.

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I would be particularly sceptical of a system that calls every piece of technical data harmless merely because it is transmitted in a packet. Timing, endpoint associations, locations and event frequency may themselves reveal activity patterns. The lawful scope of retaining them must be assessed, and the technical choice should reflect the narrowest defensible reporting purpose. Network design therefore serves privacy and evidence integrity together: it prevents irrelevant replicas, records how necessary information moved, and makes the boundaries of custody intelligible to an independent tribunal or reviewer.

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Dr. James M. Atkinson, Moderator: Thank you, Mr. Turing and Mr. Davies. The machine's visible output and the network's hidden copies must be examined together. Mr. Davies, please take the principal token and discuss custody, replication and the difference between transport availability and lawful persistence.

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Donald Watts Davies, Third Principal Contributor: A network does not carry a single abstract report from one place to another. It transforms information into packets, places those packets in queues, repeats them when necessary and may hold copies in several machines that the end user never sees. It is thus possible for a monitoring service to comply with a narrow display specification while violating the same specification in its transport architecture. The decisive question for the defensive instrument is not only which facts appear in its final report, but which information the entire organisation has acquired, replicated and kept. I would require a documented information-flow diagram with ordinary operation, diagnostic operation and fault recovery shown separately. Every arrow should identify its content class, transport security, storage permissions and expected lifetime.

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Let us suppose the reporting purpose is to establish whether an unknown emission affected a protected conference room's spectrum during a defined meeting interval. An adequate record may contain receiver location and antenna orientation, the effective observation window, centre frequency, detector configuration, noise baseline, timestamp provenance, estimated level, a non-content waveform-class hypothesis and the failure flags essential to reproduce the decision. A network should deliver those fields without silently including raw samples or decoded application traffic. If an exceptional scientific question requires a bounded sample, it must travel through a separately approved path and carry its own access and retention rules. The exceptional record should not inherit every recipient of the normal event stream, since those recipients may include personnel whose work requires the conclusion but not the original information.

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One must distinguish information availability from information retention. A resilient network duplicates information for delivery; a records programme deliberately preserves information to satisfy a purpose or obligation. The two activities can overlap technically but need not overlap institutionally. Buffering a few milliseconds of event metadata in a transient queue is unlike archiving years of unrestricted communications content, yet a network broker configured for persistent replay can turn a transient engineering mechanism into a durable repository. Audit must therefore include broker retention, logging levels, mirror ports, maintenance gateways, remote-support systems, backups and disaster-recovery replicas. A declaration that a receiver's local disk contains no samples says very little about this larger chain.

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Consider a controlled two-pipeline trial. Pipeline M sends only signed or otherwise authenticated event metadata and associated integrity fields. Pipeline I additionally sends an authorised, sharply bounded IQ extract after a recorded diagnostic decision. We introduce synthetic frames carrying harmless, easily recognised test patterns so that any unintended replica can be traced without acquiring real private communications. We then intentionally disconnect the network, restart a broker, overflow a queue and induce a service crash. The test asks whether prohibited test content survives in support logs, packet capture files or recovery archives, and whether the declared expiry rules are applied when the system returns to service. Synthetic patterns are especially useful because the investigators can examine leakage mechanisms without reading unrelated material.

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Some engineers propose that all retained information should be encrypted and the matter considered settled. Encryption is an important confidentiality control but not a substitute for necessity analysis. The institution may still possess the content and the keys, may replicate both, and may be able to read it after the original purpose has expired. Nor does a cryptographic digest of a full waveform erase the legal significance of the waveform itself. An authenticated event record can help prove that the metadata were not altered after a particular point, but it does not by itself establish that the underlying radio event was measured correctly, that the instrument had lawful authority to operate, or that the metadata were harmless. These are separate propositions and require different tests.

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We need a reliable treatment of custody. If an event record changes hands, it should preserve a stable identifier, creation time and time basis, originating instrument, configuration identity, content schema, processing version and a protected history of transfer and alteration. The record must distinguish original acquisition time from the time a packet reached the central server. Network latency, congestion and retransmission can separate those times by an unpredictable interval. A host receipt timestamp may be useful for system administration, but it should not be presented as an electromagnetic event timestamp unless the uncertainty has been measured. The chain of custody describes who held the evidence; it must not be confused with a guarantee that the original radio observation was authentic.

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A particularly difficult problem arises when the server's shared data store allows a later analyst to combine innocuous-looking observations into a sensitive pattern. Event times, antenna positions and repeated detections may reveal movement, schedules or associations, especially when joined with building access logs or staff rosters. A privacy-respecting architecture should consequently limit joins, bulk queries and onward disclosure, not just raw sample retention. Some defensive findings may require comparison with a roster, but that necessity must be specified and reviewed rather than presumed. Statistical aggregation, coarsening of time or suppression of location detail may reduce exposure when the report's legitimate decision does not require finer resolution. If those transformations destroy a material evidential distinction, the limitation should be recorded rather than concealed.

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I would also draw attention to retention policies during litigation or formal investigations. Evidence may be subject to preservation requirements that override routine expiry, but the need to preserve a defined record does not automatically authorise the acquisition of additional unrelated records. A technically elegant deletion routine must be subordinated to lawful holds and jurisdiction-specific rules. Conversely, a vague instruction to retain everything forever is not an adequate substitute for an inventory and a defensible retention schedule. Roles should be separated so that instrument operators cannot silently change the preservation period, and legal reviewers cannot mistake a file's accessibility for proof of its relevance. The custody narrative should say what was collected, why, by what authority, where it was replicated and when each copy may lawfully be disposed of.

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Finally, an independent auditor ought to be able to test the system's contract without receiving an indiscriminate copy of its input. Synthetic marked data, schema validation, access-control tests, network-flow records and carefully selected configuration evidence can show whether a collector honours its commitments. The auditor may still identify uninspected components or a residual risk of hidden replicas. That uncertainty should be reported expressly. A defensive surveillance survey is at its strongest when it permits a third party to reconstruct its conclusions without creating another uncontrolled copy of the communications it was meant merely to protect. I pass this question to Dr. Shannon's examination of how much information a genuine technical decision actually requires.

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John Robinson Pierce, Peer Question: Mr. Davies, your network inventory is persuasive, but I should like to distinguish a technical signal-path record from a dossier about the persons who might have been transmitting. Suppose the authorised question concerns an unexplained emission during a scheduled room survey. The monitoring network stores a series of timestamps precise to microseconds, antenna identifiers and estimated direction of arrival. Even without demodulated content, those fields might later be combined with an electronic door log to infer a person's movements. If the report can support its engineering finding with intervals rounded to a less precise resolution, should the precise measurements be transformed before dissemination? Yet might such coarsening destroy the ability to distinguish two brief overlapping bursts, producing a false single-source narrative? Please specify how a laboratory can test this trade-off rather than allowing the privacy officer and signal analyst to make unsupported assertions on opposite sides. Please also say how the test would record the uncertainty introduced by each deliberate reduction of timestamp precision, so that the coarsening process itself remains examinable.

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Donald Watts Davies, Response: Mr. Pierce, the distinction you raise is not resolved by declaring either exact timing or coarse timing inherently superior. The necessary temporal resolution depends upon the legitimate inference. If the task is merely to establish occupancy during a ten-minute interval, a microsecond timestamp may contribute nothing material to the decision. If the task is to distinguish two overlapping diagnostic pulses in a controlled experiment, the same resolution may be essential. The correct approach is to define the report's purpose and the competing hypotheses before deciding which precision is necessary for each authorised audience.

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I would keep a restricted technical measurement record where the applicable authority and preservation requirements justify it, and produce a purpose-limited dissemination view for operational recipients. A summary report can describe occupancy with rounded intervals and uncertainty bounds without exposing every precise transition. Independent reviewers who need greater detail can request access through a documented process. This is not simply a matter of hiding columns: the exported dataset should be tested for linkage risks, since combinations of seemingly innocuous fields may identify patterns. An access policy that controls joins against personnel logs may be as important as rounding timestamps.

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A blinded comparison can measure the engineering effect of different levels of precision. Take seeded overlapping transmissions with independently known start and stop times, and test the same detection logic at full timestamp resolution, coarsened resolution and interval-only representation. Predeclare an error criterion: perhaps the proportion of trials in which two events are incorrectly merged, and the proportion in which one event is incorrectly split. Record these errors with confidence intervals and representative uncertainty. At the same time, assess whether each export contains information not necessary for the decision and whether it creates a plausible linkage risk. A technical benefit must be demonstrated rather than imagined.

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One should not infer that privacy is satisfied merely because the receiver collects no intelligible speech. Metadata can be sensitive; their collection and use may also be regulated. By separating a narrow measurement layer from broader dissemination and query privileges, the system can preserve reproducibility where needed while restricting unnecessary exposure. If fine timing is indispensable to an authorised evidential conclusion, the report should explain why. If it is not, the institution should not release it simply because the instrument can measure it.

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John von Neumann, Peer Question: Mr. Davies, I wish to pursue reliability under equipment failure. A collector might promise that full-IQ records enter the network only when an approved diagnostic token is supplied. Yet a corrupted configuration, a process crash or a race between two service instances could cause the exceptional pathway to activate for ordinary detections. The report generator may continue to look correct while the organisation's data holdings expand silently. What controls would you place at the boundary between acquisition and transport to prevent one faulty component from defeating the entire privacy design? I ask particularly about least privilege, fail-closed operation, immutable audit records and restoration after a power interruption. Would the inability to write an unrestricted archive be more persuasive than a procedural instruction not to write one, and how should reviewers test that claim across software revisions and backup systems? I should further like to know whether independent test operators can demonstrate that failed authorisation never produces a silent fallback record during simulated system faults.

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Donald Watts Davies, Response: Professor von Neumann, one should prefer an architecture in which a mistake at one layer cannot automatically grant broader authority to all other layers. The ordinary detection process should lack write permission to the exceptional sample store and lack the credentials necessary to use its network transport. Exceptional capture should require an independently checked authorisation record, a finite scope and a separate process identity. A network receiver should reject unexpected data types rather than merely ignore them while preserving the original packet elsewhere. These controls embody least privilege: the routine system should be incapable, under its approved configuration, of becoming an unrestricted archival service merely because a developer left a debugging switch enabled.

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Fail-closed operation needs careful definition. A failed authorisation check should prevent exceptional collection; it should not silently generate an unlogged record. Conversely, a failed metadata transport should not necessarily erase a valid safety event if the authorised system requires a bounded queue for resilience. The design must identify the permissible queue capacity and lifetime, and specify what happens when that capacity is exhausted. The investigator then records the resulting loss of observation opportunity rather than inventing a complete history from incomplete data. A privacy-preserving system can be honest about its failures without retaining excessive information.

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An immutable or tamper-evident audit record can make later alteration detectable, but it must not become another uncontrolled repository of sensitive samples. Log the identity and scope of exceptional permissions, their approval time, the instrument configuration, the bytes written and the disposition outcome; avoid including decoded content or unrestricted waveforms in the audit itself. The log's integrity needs its own verification and custody model. Digitally signed records can assist continuity of evidence, but the signatures do not prove that the acquisition was lawful or the sensors measured the physical world without error.

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Tests should include concurrent triggers, expired tokens, crashed services, interrupted disks, restored backups and software rollbacks. Use synthetic marked signals and inspect every known storage path, including maintenance systems. Record the tested configuration and the components outside the audit's reach. A claim that the receiver cannot write unrestricted data is useful only if the enforcement boundary and its exceptions are specified and checked. The best design makes exceptional collection difficult to invoke accidentally and easy to detect when invoked legitimately.

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Donald Watts Davies, Cross-Peer Question to Claude Elwood Shannon: Dr. Shannon, I should like to frame the information problem directly. Pipeline M stores a short vector of event statistics; Pipeline I stores an additional bounded sequence of complex samples. An engineer argues that the raw sequence contains more information and therefore must yield a stronger forensic conclusion. That reasoning confuses quantity of representation with relevance to a particular proposition. Can you define what it means for the smaller record to preserve the information required by a predeclared binary or multiclass decision? How would you distinguish a statistic sufficient under a restricted model from one that remains robust when the spectrum contains unmodelled interference, receiver clipping or synchronisation errors? And if additional samples improve classification of a particular laboratory source, does that improvement establish authority to retain incidental communications in a deployed defensive survey? Please address these questions without treating mathematical sufficiency as a universal legal exemption. I would welcome a decision-theoretic account that shows the consequences of each extra field without mistaking a convenient optimisation objective for a source of legal permission.

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Claude Elwood Shannon, Cross-Peer Answer to Donald Watts Davies: Mr. Davies, an input record is informative only relative to the question being asked and the assumptions under which it is interpreted. Let X denote the complete observed sample sequence, H a stated hypothesis about a physical event, and T(X) a reduced representation. Under a particular probabilistic model, T may preserve all the likelihood information about H that X supplies. Under a different model, where clipping or nonstationary interference matters, the same statistic may discard useful evidence. Thus the relevant engineering task is not to declare metadata categorically sufficient, but to identify the decision and the family of conditions for which the retained statistics are demonstrably adequate.

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More bits are not a measure of greater probative value by themselves. A long recording may contain a large quantity of nuisance variation and unrelated content. If it is used to select favourable examples after the outcome is known, it can encourage overfitting and false confidence. A smaller, predeclared statistic may support a cleaner test. Nevertheless, a bounded complex-sample record can sometimes reveal a receiver defect or phase behaviour that an event count cannot express. Such a benefit must be evaluated on blinded reference trials, with uncertainty, false positives and the incremental information exposure all recorded.

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One can formalise the trade-off with an engineering loss function, but the coefficients would be an institutional decision rather than a theorem. For example, let L be expected decision error cost and R a measure of privacy or retention risk under a stated assessment. A proposed system might be evaluated by L plus a nonnegative weight times R. The chosen weight and the lawful constraints are not determined by information theory, and no value of the loss function can transform prohibited acquisition into authorised acquisition. The mathematical comparison is an aid to documented decision making, not a substitute for it.

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I would therefore require controlled evidence for any claim that the fuller representation is necessary. Show that it changes a legitimate decision under specified conditions, that narrower alternatives do not provide the same benefit, and that the resulting retention is separately authorised and appropriately limited. The strongest final report acknowledges when the observation supports only an energy or format hypothesis. It should not employ the existence of elaborate raw data as theatrical proof of a physical source identity that has never been established.

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Dr. James M. Atkinson, Moderator: Thank you, Mr. Davies and Dr. Shannon. We now see why resilient transport, evidence continuity and privacy restriction must be designed jointly. Dr. Shannon, please take the token and examine the statistical experiment which determines whether each additional recorded field contributes to a lawful conclusion.

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Claude Elwood Shannon, Fourth Principal Contributor: The phrase more information is frequently employed without identifying the variable about which information is wanted. A radio receiver may generate millions of complex-valued samples during a survey, but the authorised decision may concern a far narrower proposition: whether an unexpected emission occupied a prescribed frequency interval while the receiver was actually observing it. It is perfectly possible for a small statistic to describe that event adequately under a chosen model, and equally possible for a full sample stream to encourage speculation about unrelated messages. The central task is to distinguish the physical uncertainty under investigation from the incidental information available to the apparatus. No mathematical argument for preserving raw data is complete until the investigator defines the specific decision for which those data are said to be necessary.

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We should begin with a hypothesis variable H, whose possible values include a genuine seeded emission, an instrument artefact and a noise-only observation. Let X represent the acquired sample sequence, and let T(X) be a smaller vector containing calibrated power, bandwidth, valid-observation duration, timing uncertainty, the detector's threshold and any predeclared public waveform statistic. An analyst tests whether T permits classification among the specified hypotheses at an acceptable error rate. If the richer representation X improves discrimination only by reading unrelated payload content, that may demonstrate an algorithmic possibility but not a legitimate basis for retaining the payload. Conversely, if an approved short sample is needed to establish that an apparent burst was caused by amplifier clipping, the experiment should report that technical need precisely, including the alternatives tested.

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There is a useful distinction between a sufficient statistic under a particular statistical model and a universally adequate evidence record. Under an idealised Gaussian-noise model, a predeclared energy statistic may be sufficient for a particular amplitude-detection problem. But the field receiver may suffer impulsive interference, automatic-gain-control transients, an uncertain antenna response or missed scanning intervals. The original model then may fail, and the statistic may conceal the cause. An excellent report states the assumed noise model, records the instrument settings needed to evaluate it and tests the method against deliberately adverse cases. It does not claim that a theorem whose premises are unmet establishes reliability. The test can show where the metadata record remains adequate and where a specific additional non-content diagnostic becomes justified.

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A careful comparison should use paired observations. Take N independently scheduled legitimate test events and K valid null opportunities, with event and null labels concealed from the two analyst teams. Each pipeline produces a decision for each eligible opportunity using a frozen rule. Let TP denote the true positive count and FN the false negative count among true events; sensitivity is TP divided by TP plus FN when the denominator is nonzero. Let FP denote false alarms and TN the correct non-detections among valid null opportunities; the false-positive proportion is FP divided by FP plus TN. These are properties of the chosen experimental population and thresholds, not universal instrument constants. Because both pipelines see the same trials, comparison should account for the pairing rather than pretending that two sets of counts are independent.

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For a hypothetical illustration, suppose two hundred seeded events are examined. The metadata pipeline correctly detects 190, the bounded-IQ pipeline detects 193, and both agree on 187 of the successful detections. Those numbers alone do not identify the decisive discordant cases. A useful paired table would separately count events detected by both, by metadata alone, by IQ alone and by neither. The complete table shows whether the gain arises in precisely the cases where a stated diagnostic defect is present. Similarly, null trials require their own paired table because an apparent gain in sensitivity may be bought at the cost of additional false alarms. An independent laboratory should estimate uncertainty and evaluate performance under different noise scenes and receiver settings before treating a small observed difference as persuasive.

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The privacy comparison is not a scalar calculation accomplished by counting sample bytes. A raw recording may contain information about other users' communication patterns, even if the investigating team never attempts to decode them. A narrow event table can also reveal sensitive schedules or locations. The comparison must therefore specify which data classes are collected, who can access them, whether further inferences can be drawn by linking records, and what preservation obligations apply. That assessment is partly technical and partly institutional. Information theory does not confer legal authority on an acquisition, and no numerical measure of entropy can determine whether a particular retention period is proportionate in every jurisdiction. The proper engineering contribution is to make those choices visible and to quantify the technical consequences of alternatives.

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It is also necessary to distinguish an event statistic from a provenance record. A power estimate with no calibration reference is a weak basis for a contested conclusion. The metadata scheme should preserve enough information to identify the antenna path, filter response, gain configuration, sample rate, observation eligibility, detector version and clock uncertainty. Those attributes may not be directly about the unknown emission, but they are necessary to judge whether the inference is valid. A case may require an immutable history of how such fields were generated, corrected and transferred. Integrity protection helps to show continuity of records; it does not make a biased measurement sound. Thus a privacy-conscious report can be more scientifically informative than a large unindexed file if it preserves the right quantities and the grounds for their interpretation.

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Sampling and measurement themselves place limits on certainty. A scanner cannot make a finding about intervals when it was tuned elsewhere, and a thresholded detector cannot infer the distribution of amplitudes below threshold without additional assumptions. If a record contains only successful alarms, it loses the denominator needed to estimate detection performance. We should preserve the observation schedule and counts of eligible null windows in a bounded form, even though these may appear less exciting than a waveform plot. A disciplined record of missed observations is often more probative than a beautiful spectrogram chosen after the fact. The analyst should resist describing a signal as absent merely because the log is silent. No valid opportunity is not the same observation as an opportunity with no detection.

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Finally, the author of a report must choose the strength of each conclusion. It may be appropriate to write that a calibrated receiver recorded a transient of specified bandwidth, duration and power above the relevant baseline. A public-field correlation may support a waveform-family hypothesis without establishing the message's content or sender. A forensic attribution to a particular instrument requires other validated, independent evidence. Every additional level in that hierarchy demands a corresponding evidential basis. A larger archive may assist an authorised experiment, but it cannot make an unsupported inference true merely by the weight of its bytes. Professor Dijkstra can now test whether the software architecture makes these distinctions enforceable when the instrument is used at speed and under operational pressure.

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Ronald Newbold Bracewell, Peer Question: Dr. Shannon, I accept that a statistic can be sufficient relative to a decision model, but I should like to examine where spatial measurement enters that model. Suppose a surveillance team seeks to identify an unaccounted-for RF emission in a large conference facility. One antenna sees a short burst above baseline, while a second antenna at a different position records only a weak fluctuation. A full-IQ record might support a phase-coherent comparison, yet the equipment lacks common clock distribution and the incident may be too brief to repeat. Is it legitimate to retain the whole signal merely on the possibility that spatial processing might become useful, or should the experiment first establish that the sensor geometry, synchronisation and receiving paths can support the proposed comparison? Please specify the records that would permit an independent examiner to distinguish useful spatial evidence from an elaborate but unjustified estimate of the signal's physical origin.

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Claude Elwood Shannon, Response: Dr. Bracewell, the proposal to retain additional samples should not precede proof that the intended inference is physically feasible. A phase comparison between two receivers is not automatically meaningful merely because both wrote complex numbers. The relation depends on their clock stability, sample-time alignment, local-oscillator coherence, path calibration, antenna geometry and multipath environment. Without those conditions, the preserved samples may support only independent detections, not a validated spatial phase estimate. A report should state the maximum inference permitted by the actual measurement arrangement, including the probability that the second receiver simply missed the event.

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The experiment should use a controlled reference emitter at surveyed positions and known emission times. Record sensor coordinates with uncertainty, polarisation, antenna orientation, gain state, sample-rate calibration, cable delay and any shared clock or independent synchronization source. Introduce multipath and deliberate non-simultaneous sampling as challenge conditions. Compare the direction or source-class output against the known references, reporting systematic bias and the rate of unknown outcomes. If the apparatus cannot distinguish its own timing errors from path phase, the proposed forensic benefit of retaining full-IQ records has not been demonstrated. More preserved bits cannot repair an absent timing reference.

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It may nevertheless be defensible to preserve a narrowly bounded sample under a specific lawful experimental plan, particularly when a repeatable interference event is being examined and the diagnostic requires phase continuity. The record should state that need, the bounded acquisition window, the approved recipients and the reason that non-content features were inadequate. The exceptional capture should not turn a speculative future capability into perpetual collection. Where the apparatus lacks the necessary coherence, retaining a high-resolution event-time and power record may be the more truthful choice. One can then say precisely which spatial hypotheses remain untested.

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I would favour a hierarchy of findings. The independent sensors may corroborate the existence of an emission during overlapping valid observation windows. A calibrated amplitude ratio may suggest consistency with a particular source region under stated propagation assumptions. A coherent array, if properly established and tested, may support a more specific bearing estimate. None of those steps by itself identifies a person or proves access to private content. The measurement record should preserve the uncertainties and the rejected alternatives at each stage. Evidential restraint is a technical virtue when the alternative is a precise-looking but unsupported location.

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Claude Elwood Shannon, Cross-Peer Question to Edsger Wybe Dijkstra: Professor Dijkstra, the experiment may demonstrate that a small event record supports the authorised decision, but the software must continue to honour that result after code changes and under exceptional conditions. Suppose a user can enable a raw sample recorder by altering a configuration file, or a third-party plugin can access the full receiver buffer while the main interface still announces metadata-only operation. What architecture would make the data boundary enforceable rather than advisory? I ask you to distinguish a correct algorithm from a correct operational system, to address privileged debugging and emergency overrides, and to explain how auditors can detect undisclosed data pathways without acquiring the communications whose retention they seek to prevent. What should the system do if enforcing the approved boundary means that an uncertain event cannot be resolved from the permitted records? Please also explain whether a system can retain enough negative audit evidence to demonstrate that an exceptional collection path was not invoked, without retaining the very communication samples that the prohibition is intended to protect.

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Edsger Wybe Dijkstra, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, one should first reject the proposition that a complicated program becomes trustworthy because its designers describe good intentions. The system needs a simple invariant: routine detection may read the transient samples necessary to calculate specified physical measurements, but it cannot persist or export unauthorised content. The invariant should be enforced at process, storage and transport boundaries. A user-interface option is not an adequate security boundary if another plugin or logging service can bypass it. The ordinary process should possess only the capabilities required to publish the permitted record; exceptional acquisition should be a separate, narrowly authorised mechanism with a measurable expiry.

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The invariant must be tested in adverse states, including crashes, disk exhaustion, stale permissions, updates and restoration from backup. Synthetic marked data can make unintended writes observable. Independent tests should inspect process permissions, network flows, persistent queues and crash artifacts. The test should record exactly which systems were covered and should not promise universal absence of leakage from a finite collection of trials. The smaller the set of components authorised to touch full samples, the stronger the achievable assurance. A design with many trusted plugins and privileged paths produces an unnecessarily large proof obligation.

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A correct operational system is more than a mathematically correct detector. It includes user identity, approved purpose, records management, auditability, timekeeping and response to uncertainty. A highly accurate detector that silently retains protected communications may be inappropriate for the authorised task. An impeccable access-control layer cannot make a false RF classification scientifically reliable. These properties must be verified independently and then tested together, lest one virtue be used as a substitute for another.

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If the permitted fields cannot resolve an anomaly, the correct result is unresolved under present authorised observations. The system may offer a controlled request for additional authority, a seeded laboratory experiment or a review of existing permitted diagnostics. It must not silently collect more merely because a decision would be convenient. A system that has an explicit unknown state is often more reliable than one whose design forces every ambiguous observation into a confident category. The purpose of the architecture is to make disciplined refusal possible as well as efficient measurement.

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Dr. James M. Atkinson, Moderator: Thank you, Dr. Shannon and Professor Dijkstra. We have established that statistical sufficiency must be tested against the actual signal and instrument, and that software controls must enforce the authorised limit. Professor Dijkstra, I pass the principal token to you to close with the engineering rules of a defensible, privacy-restricted reporting system.

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Edsger Wybe Dijkstra, Fifth Principal Contributor: A complex system becomes difficult to reason about when the same component is expected to collect information, interpret it, preserve it, enforce its own privileges and certify that its conduct was proper. I would begin by reducing the number of responsibilities assigned to each component. A detector may estimate spectrum occupancy and raise a bounded event; a separate record service may protect the resulting metadata; an authorisation service may approve unusual diagnostic acquisition; and an independent custodian may govern access and retention. The organisation should not demand that one enormously privileged program remember to exercise restraint. A smaller, comprehensible state machine is preferable because its permitted transitions can be specified and tested. In this setting privacy engineering is not decoration applied after a clever receiver has been completed. It is part of the receiver system's correctness condition.

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Consider the routine state R in which complex samples are processed only transiently to calculate declared non-content features. The exceptional state E permits a bounded diagnostic capture after the correct authorised conditions have been met, and the halted state H represents a fault that prevents trustworthy collection. A transition from R to E should require a valid purpose, recorded approval, exact channel and time bounds, configured storage destination and disposition rule. Returning from E to R should invalidate the exceptional permission and preserve a restricted audit of what was captured. A transition into H should not trigger an undocumented fallback that writes everything to disk. These requirements can be represented as system invariants and tested using a state-transition table rather than relying upon a reassuring paragraph in a policy manual.

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The system should distinguish detection truth, record integrity and collection permission. A valid signature over an event record supports a claim that the record has not changed since the signing operation, provided the keys and implementation are trustworthy. It does not establish that the receiver detected a real external signal rather than a local oscillator artefact. It does not establish that the instrument was legally allowed to retain the bytes. Similarly, a privacy-preserving process may still produce poor scientific results if its calibration is wrong. Each proposition needs its own evidence. Combining them into a single confidence score invites the reviewer to mistake a strong cryptographic property for a strong physical attribution.

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I should insist upon an explicit schema and a finite inventory of writable stores. For every event, the schema must say whether a field is measured, computed, inferred, corrected or manually added. A centre-frequency estimate should carry the uncertainty implied by sample clock and frequency reference, rather than being reported to an absurd precision. A timestamp must identify its originating clock and whether it marks acquisition or later processing. A signal-class label should include an unknown state. Fields about a person's identity or the content of a message should be absent from the ordinary acquisition and reporting interface unless a separate, specific authority has justified them. This removes temptations rather than merely warning operators against them.

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Formal discipline is useful only when it meets physical reality. A proof that the detector executes a particular threshold rule cannot validate an antenna whose gain pattern is unknown. A proof that an exceptional capture requires a token cannot establish that the token was issued under the correct law. The engineering system must therefore preserve links to calibration records, instrument identity, field-survey procedure, authorisation records and case-specific retention decisions. These links should not automatically copy the underlying records into every report. Access can be conditional and logged, so a reviewer sees the existence and provenance of the evidence without receiving data outside the task. This is the difference between auditable structure and indiscriminate duplication.

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Let us test a hypothetical implementation with two hundred seeded transmissions and two hundred predeclared null intervals, balanced across receiver configurations and interference levels. Pipeline M records only permitted event features; Pipeline I records an approved bounded IQ segment as well. Measure true positives, false negatives, false positives and valid observation counts separately. Suppose a review discovers that four apparent bursts were caused by gain transients. The important question is whether the restricted pipeline can expose those transients through gain-state and clipping indicators; if not, whether a narrow diagnostic feature or seeded comparison would suffice. A full capture may legitimately resolve a particular uncertainty, but the experiment must document the incremental benefit and must not presume that every unrelated communication is therefore appropriate to retain.

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I would audit the implementation at boundaries where software commonly escapes its nominal design. Plugins may inherit powerful file permissions, error handlers may write memory dumps, network instruments may duplicate packets, and update routines may restore formerly disabled collection options. A capability-based architecture can deny ordinary components the power to write raw samples to persistent stores. Exceptional permissions can be scoped by duration, destination and case identity and revoked automatically when the diagnostic purpose is completed. Negative tests should verify that expired or malformed permissions are refused, including during concurrent requests. This is more persuasive than trusting an operator to remember that a checkbox should usually remain clear.

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Yet one must also ask how the organisation learns about failures. If a sensor is scanning elsewhere, the system should record the unobserved interval rather than classify it as silence. If a measurement is corrupted, the event should be tagged invalid and the reason retained. If the recorder is unavailable, the system may preserve a minimal fault record within its permission envelope but should not expand collection silently. The final report ought to describe uncertainty in plain language: a legitimate emission may have gone undetected; a particular displayed peak may be compatible with more than one physical mechanism; an instrument state may be insufficiently documented to support attribution. An explicit inability to conclude is often the only technically defensible outcome.

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I reject the suggestion that a report becomes comprehensive by attaching every stored sample to it. A useful report should state the authorised question, instrument configuration, observations, decision rule, calibration, uncertainty, alternative explanations, custody and limits of the conclusion. It should identify the material it did not collect, explaining when a particular omission prevents a stronger finding. Where evidence must be preserved for legal proceedings, a separately controlled repository should retain the authorised records under the applicable hold, not turn every technical measurement into an unlimited archive. The retention decision belongs to the law and the institution's competent officers, not to a convenient default in signal-processing software.

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The lesson is an old one in program design, applied to a modern engineering instrument. The number of combinations of state and permission grows when hidden features, logging pathways, plugins and uncertain error handling proliferate. Simplification can produce both greater operational reliability and stronger protection against unjustified observation. I would require every code change to state how it affects acquisition, persistence, authority, audit and reproducibility. A system that cannot explain those effects should not be assumed compliant merely because its visible report appears unchanged. The soundest defensive instrument records what its lawful measurement requires, retains the provenance needed for challenge, and refuses to convert technical possibility into a new authority.

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Antony Hewish, Peer Question: Professor Dijkstra, I should like to test the treatment of a rare event whose nature is uncertain. In radio astronomy a transient may disappear before the observer learns whether it was terrestrial interference, instrumental noise or a genuine distant source. In a defensive survey, an unexpected short burst could likewise be important, yet a privacy-restricted system may have discarded most of the samples when the decision becomes controversial. Would you have the instrument retain a continuously overwritten ring buffer, and if so, what prevents that buffer from becoming a permanent covert recording store after a software fault or an enthusiastic operator intervenes? Please distinguish volatile acquisition necessary for computation, approved bounded exception capture and indefinite archive retention. I also ask what language the final report should use when the event is demonstrably present but cannot be attributed to an emitter or even unambiguously classified as external radiation. I would also ask how independent reviewers can recognise a genuinely unavailable observation rather than interpreting every absent file as evidence that nothing happened.

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Edsger Wybe Dijkstra, Response: Dr. Hewish, a finite ring buffer can be a legitimate computational mechanism if its duration, accessibility, overwrite behaviour and interactions with crash reporting are controlled. It is not privacy-preserving merely because the programmer calls it volatile. The buffer may be paged to disk, copied into an exception report or read by a privileged plugin. Its permitted purpose should therefore be stated and enforced. The ordinary workflow may need enough transient samples to compute energy, timing or a public training-field statistic; those samples need not persist after the measurement window unless a separately authorised, bounded diagnostic procedure has been invoked.

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Exceptional retention should be based upon a pre-established event class or a recorded human decision with adequate authority, rather than a convenient retrospective declaration that everything unusual was important. A finite pre-trigger and post-trigger window may be useful for distinguishing a receiver transient from a genuine signal, provided the permitted frequency span and duration are specified and the resulting data are access-controlled. If that limited window can contain unrelated communications, the institution must consider their legal status and the necessity of retaining them. Testing with synthetic signals can often answer instrument-diagnostic questions without capturing actual third-party material.

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I would test buffer behaviour with forced power loss, memory pressure, process crashes and software updates. Verify whether the overwritten data remain in swap, dumps, temporary files or remote telemetry. A declared retention time must describe what the system actually does, not simply what the user interface says. Where a legal preservation obligation applies to a valid captured record, the custody service should handle it explicitly. The collection control must not be bypassed because the custodian might later be interested in an event. Reviewers should also examine who can invoke an exception, how many exceptions are permitted and whether repeated triggers could amount to continuous recording in practice.

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As to the report, it should distinguish observation, classification and attribution. One may write that a calibrated receiver recorded an excess in a specified band and valid time interval, subject to stated uncertainties. One may report that the event is compatible with several mechanisms, including external radiation and instrumental artefact, if the evidence cannot distinguish them. One should not assign a named transmitter, a protocol or a person's intentions without independent support. Such restraint does not erase a potentially important anomaly. It preserves the anomaly as a testable finding and avoids the greater harm of presenting speculation as laboratory fact.

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Dr. James M. Atkinson, Moderator: I thank Admiral Hopper, Mr. Turing, Mr. Davies, Dr. Shannon and Professor Dijkstra, together with their peers, for distinguishing a technically sufficient observation from an unrestricted collection. The roundtable's central result is conditional: a defensive report should retain the least information that permits its declared and authorised finding to be tested, with necessary provenance, valid observation denominators and a precise account of uncertainties. Additional diagnostic capture must have a separate documented purpose, authority, bounded scope, safeguards and retention disposition. Nothing in our hypothetical dialogue constitutes a historical quotation or legal permission to intercept communications. The proposed procedures remain subject to independent engineering validation and jurisdiction-specific legal review.

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QUESTION 091

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What integrity and provenance records are needed to verify unchanged RF sample files?

Dr. James M. Atkinson, Moderator:Admiral Hopper, I invite you to separate three propositions which are too readily confused in electronic evidence: whether a sequence of bytes has remained unchanged since it was recorded, whether the accompanying file-description fields permit its correct interpretation, and whether the samples reflect an authentic electromagnetic input rather than an artefact of the receiver. Please develop a custody model in which the primary waveform file, the format manifest and the laboratory notes can be independently challenged. The present dialogue is a fictional scholarly reconstruction, not an historical quotation.

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Grace Brewster Murray Hopper, Principal Contributor:I would begin with the distinction between a record and the event that the record purports to describe. A receiver can write a sequence of bytes to a file. A software program can compute a digest over those bytes. A later investigator can compute the same digest over an apparently identical file. Under a suitable collision-resistant hash function and properly protected reference digest, agreement offers strong evidence that the later byte sequence matches the sequence presented for the original hashing operation. It does not follow that the receiver captured the radio event correctly, that its analogue gain was calibrated, or that the computer assigned an accurate timestamp. Those propositions concern acquisition and provenance, not the mathematical continuity of a file after acquisition. An excellent chain of custody must keep them separate.

The first task is to define precisely which object has been hashed. One may hash the payload bytes of an IQ file, including its header; one may hash only the sample array; or one may hash an entire archive containing samples, metadata and ancillary notes. These choices yield different answers when an examiner repackages the material. If a file is copied without changing any byte, a digest over the complete bytes should match. If the file is wrapped inside a different archive or if a benign timestamp field in its header changes, a digest over the entire newly written object may differ although the numerical sample stream is equivalent. A report must not call this an integrity failure of the original samples without examining what object the digest covered. Conversely, the investigator must not disregard a digest mismatch as a mere format change before establishing exactly which bytes changed.

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The meaning of a sample is also dependent on a format contract. A pair of interleaved signed sixteen-bit integers may be intended as I then Q, in a specified byte order and with a defined full-scale voltage reference. Reading the same bytes as floating-point values, swapping I and Q, changing the endian interpretation or applying an unstated scale factor can produce profoundly different waveforms while leaving the underlying file hash unchanged. An integrity scheme which protects a sample array but neglects the manifest may preserve a meaningless sequence of bytes. At minimum the manifest should identify the sample packing, signedness, endian order, channel count and interleaving convention, sample rate and clock reference, centre frequency, gain and analogue front-end state, receiver software and firmware identity, acquisition start and stop indicators, and the exact definition of any missing or invalid samples. A separately protected manifest is a practical part of the evidence, not a decorative catalogue entry.

One should distinguish an original file from a working derivative. A laboratory may legitimately decimate a sample record, convert its representation or isolate a section for analysis. Those operations produce new objects, each requiring its own identifiers, digest, transformation record and relationship to the original. The analyst should retain the original unchanged where preservation duties require it, and the working file should disclose the processing chain. An operator ought not to recompute a digest after editing a file and then present the new digest as if it authenticated the original acquisition. The reference digest should be protected against convenient substitution, with creation time, custodian identity and the apparatus used to calculate it recorded. The security of this process rests on more than the length of the displayed hexadecimal string.

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Clock claims are particularly prone to confusion. A file creation timestamp may mark the instant the operating system finished writing, not the instant the antenna received a burst. A host application can pause, queue samples and later write them under a new name. A receiver's sample counter can advance continuously despite a host delay, or it can conceal a gap when buffers are dropped. Thus the record should identify which time fields originate in a calibrated acquisition clock, which were supplied by software and which came from a file system. Clock offset and drift require separate evidence. A digest cannot repair a timestamp error or identify an unrecorded loss of samples; it merely protects whatever time assertion has been written into the hashed object. That assertion may be faithfully preserved and still be false.

I propose a laboratory trial with three layers of ground truth. An independent reference generator produces authorised RF bursts and records their timing and nominal levels. A second instrument monitors the actual radiation and characterises uncertainty. The device under examination creates the sample file, manifest and event log. Investigators then preserve the original bytes and digest under controlled custody while deliberately making derivative copies. One copy is byte-identical; another has a new container but the same sample values; a third has one altered bit; a fourth changes only the interpretation schema; and a fifth inserts a well-documented gap into a derivative. The comparison must distinguish bitwise file equality, numerical sample equivalence, consistency of the metadata and truthfulness of the claimed physical event. It is not enough to mark every successful digest comparison as an authentic radio measurement.

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I would add a custody ledger whose entries are written for later examination by someone who was not present at the survey. Each entry should record the object identifier, digest algorithm, measured file length, creator or custodian, acquisition or transfer event, authority and purpose, computing environment and the reason for a transformation. The ledger should distinguish a physical transfer of media from a logical copy, and identify any authorised access to exceptionally retained sample content. Integrity protection of the ledger itself is necessary, since a beautifully hashed file accompanied by an editable and inaccurate history leaves the examiner without a reliable account of custody. The ledger should be comprehensible without requiring needless duplication of private communications within its narrative.

The most important limitation must be stated without equivocation. A matching digest supports continuity from the trusted reference state; it does not prove authenticity of the analogue input, truth of the operator's account or lawful acquisition. A malicious or defective receiver could write a fictitious sample array and hash it impeccably. A genuine receiver could acquire a real burst but misrecord its sample rate, making a later spectral analysis erroneous. A well-documented derivative might show a different digest while retaining precisely the samples needed to answer the authorised scientific question. These cases belong in different columns of the verification report. By keeping them distinct the institution avoids both false accusations and exaggerated assurances of evidential certainty.

Finally, the record's purpose should determine which information is necessary to preserve and which remains outside the authorised scope. A report about spectrum occupancy need not include decoded private

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payloads. A brief protected IQ extract may be necessary to challenge a particular phase or transient claim under an appropriate legal authority and evidence-retention obligation; if so, the justification and access restrictions should be explicit. We should not assume that making a file immutable justifies everything it contains. The next contributors can examine software invariants, adversarial alterations, coding-theoretic error recognition and statistical limits upon the resulting inferences. Each ought to ask whether the preserved bytes establish the proposition actually reported, rather than merely establishing that the bytes have been preserved.

John Wilder Tukey, Peer Question: Admiral Hopper, the distinction between bytes and interpretation is compelling, but I question whether the proposed custody manifest is being treated as an infallible explanation rather than a hypothesis which an independent analyst must test. Suppose the stored dataset survives a transfer with the same digest, while the sample-rate field in the separately protected manifest is accidentally transcribed from an earlier instrument configuration. A spectral peak will be assigned the wrong displacement from centre frequency, and the apparent length of an intermittent event will be distorted. There has been no alteration of the signal bytes at all. Equally, if a technician changes the manifest after discovering that error, the former digest for the manifest will no longer match, even though the correction improves factual accuracy. What convention would allow the investigator to preserve the original mistaken assertion, publish an openly reasoned correction, and distinguish the original acquisition facts from the subsequent inferential repair? I should also like a procedure that does not turn a small change in a JSON file into a misleading accusation of tampering.

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Grace Brewster Murray Hopper, Response: Professor Tukey, the manifest should be treated as a controlled statement of acquisition parameters, not as an oracle. A good evidence system preserves assertions together with their provenance, uncertainty and revision history. If the recorded sample rate says eight million complex samples per second and an independent clock comparison subsequently shows that the actual average rate was slightly different, the originally signed manifest remains part of the historical record. It must not be overwritten, even to make it more accurate. An additional correction document states the old value, proposed corrected value, method of estimation, source measurements, calculation, reviewer and effective analytical context. Its own digest and custody history are protected. The result is a transparent series of propositions instead of a silently edited file pretending never to have contained an error.

Let us examine an illustrative timing example. A block of two million complex samples nominally acquired at eight million samples per second has a nominal duration of one quarter of a second. The duration calculation is the sample count divided by sample rate, not the filesystem modification-time difference. If the receiver had in fact run at 8,000,040 samples per second, the same sample count spans approximately 0.24999875 seconds. The numerical discrepancy is tiny in this illustration, but an honest record would identify which estimate rests on the original configuration and which rests on later frequency calibration. An exact hash of the sample block cannot discriminate between those interpretations. The independent examiner needs the calibration evidence, its time of applicability and the transformation that produced the revised estimate.

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I would therefore use an append-only evidential chronology. Entry one records the acquisition object's length and digest, the operator's contemporaneous manifest and the device's recorded state. Entry two logs the discrepancy with a neutral description: an apparent inconsistency was observed in the stated sample rate. Entry three records the independent timebase test, its traceability and environmental limits. Entry four issues a corrected analytical interpretation without replacing the original bytes or the original assertion. Every entry points to its predecessor and to the objects it discusses. A hash chain can help detect unannounced ledger edits if its anchors are separately protected, but the credibility of witnesses and calibration cannot be inferred from the hash chain itself.

Finally, the report should avoid treating every nonmatch as hostile intervention. A difference in bytes is a question that requires classification: original alteration, legitimate derivative, storage corruption, schema update, metadata repair or unexplained inconsistency. Each is a different finding. A reviewer should be able to reproduce the digest from the defined byte range, compare the historical and amended manifests, and decide which interpretation is technically supportable. That procedure preserves the sound of the original instrument's record while permitting later scholars to correct what its operator understood.

Donald Watts Davies, Peer Question: Admiral Hopper, consider the less visible replication machinery which stands between the receiver and the repository. A host may packetise successive sample buffers, send them through a network, reorder frames, retransmit an interrupted block or write fragments into a cache before final assembly. A valid digest computed after assembly proves continuity from that point, but it does not reveal whether

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one segment was duplicated while another was lost in transit. A sender-side digest may help, yet only if the sender established an independent trustworthy boundary for the intended stream. How would you separate transport integrity from measurement completeness? Please address buffer numbering, gap markers and evidence of clock resets, and specify which records a laboratory must preserve when its authorised acquisition was continuous but its network delivery manifestly was not. The anxiety is not theoretical: a perfectly repeatable corrupted sample can yield a striking, entirely spurious spectral line.

Grace Brewster Murray Hopper, Response: Mr. Davies, one ought to distinguish at least four boundaries. The analogue receiver generates a physical measurement at its input; the analogue-to-digital converter produces samples under a particular clock; the acquisition software frames or buffers those samples; and the evidence repository receives a named object. A digest at the fourth boundary cannot retrospectively certify the first three. I would therefore capture a monotonically increasing hardware or near-hardware sample counter where the equipment supports it, buffer sequence numbers, acquisition status flags, overflow counters, and a record of software or transport restarts. The counters themselves are assertions that must be tested, but they provide far more diagnostic purchase than a final filesystem digest alone.

Suppose a frame consists of 4,096 complex samples and the receiving computer observes sequence numbers 120, 121 and 123. The absence of 122 indicates a discontinuity to investigate, not necessarily proof that exactly 4,096 RF samples vanished. Reordering, retransmission, counter wrap, a false header or an instrument reset might also account for the

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pattern. The examiner compares transmitter-side logs, receiver acknowledgements, payload lengths, acquisition counters and independent event timing. If the missing unit is verified as a sample block, insert an explicit gap annotation in the analysis timeline. Do not silently synthesize plausible noise or join two nonadjacent sample regions as if their phase continuity had been observed. When a repaired derivative is produced for a plotting routine, record the interpolation method and retain the unfilled version.

The time claim needs care. At eight million complex samples per second, a missing block of 1,024 samples corresponds to 128 microseconds of nominal observation. A waterfall could obscure that interval when averaged over a longer display window, yet a phase-continuity or short-burst argument might depend upon every microsecond. The ledger must record the sample-rate estimate, missing-count assumption and the observation that established the gap. A separate packet capture can support network diagnosis, but it may itself contain information outside the RF evidential objective; acquire and retain only what is authorised and necessary for the transport question.

I should also insist on an acquisition-close record. It names the instrument, firmware, start and stop counters, acquisition state, measured data length, known overflows and the earliest digest that can be trusted. If the first digest is created after a two-hour transfer, the report must not silently depict it as a digest computed at the ADC. The relevant statement is narrower: from this documented post-transfer event onward, the stored bytes are unchanged under the stated hash assumptions. The acquisition may be complete or incomplete for other independently assessed reasons.

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By providing the two chains, physical sampling and digital custody, we can detect failure without claiming more than the evidence supports.

Grace Brewster Murray Hopper, Cross-Peer Question to Edsger Wybe Dijkstra: Professor Dijkstra, I respectfully pass the token to you because our custody scheme will be of little value if its software permits a supposedly immutable source file to be overwritten during examination. Consider an application that handles a source dataset, an editable metadata manifest, a working copy and a signed custody ledger, yet treats all four as ordinary paths in a writable directory. A clerical mistake can change the wrong object while all the user-interface labels remain reassuring. What invariants would you require, which system permissions would enforce them, and how might an examiner demonstrate that the verifier's own program did not quietly transform a byte sequence before calculating its digest? Please include the problem of crash recovery, the distinction between logical immutability and physical media behaviour, and the circumstance in which an analyst discovers that the supposedly authoritative digest was first calculated only after an unrecorded processing step.

Edsger Wybe Dijkstra, Cross-Peer Answer to Grace Brewster Murray Hopper: Admiral Hopper, I would first separate the statement to be proved from the mechanism intended to prove it. The proposition is that an identified source object has not changed after the recorded acquisition or preservation anchor. The mechanism might use read-only permissions, write blocking where appropriate, cryptographic digests and independent logs, but none of those phrases has meaning without specifying the object, the trusted components and the threat model. A checksum routine that reads a working derivative while labelling its output as the original is logically wrong even if

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its arithmetic is flawless. Program correctness is not purchased by acquiring a more elaborate hash algorithm.

I propose four software invariants. First, the original evidence object is addressed by a unique immutable identifier, and normal analysis code cannot request a write-capable handle to that object. Second, every transformation creates a new object with a new identifier, a recorded parent and a declared transformation, never an in-place replacement. Third, a digest operation reads a precisely delimited byte range and reports the algorithm, object length, execution status and error conditions. Fourth, ledger amendments are append-only, attributable and independently anchored so that a later user cannot simply replace an inconvenient history. These invariants should be subject to fault injection and adversarial testing, not left as programme comments.

A crash test is informative because a process may leave partially written buffers or stale renaming operations. The system must be capable of saying that an output was never completed and must not treat a partial file as a validated original. Storage hardware can remap sectors, maintain caches and perform legitimate internal maintenance while presenting the same logical byte sequence. Consequently, the ordinarily supportable assertion concerns the logical bytes returned through the tested storage interface, not the untouched condition of every physical magnetic domain or semiconductor cell. Where original media state itself matters, separate physical preservation procedures are required.

In the late-hashing example, the honest result is not to invent an earlier anchor. Label the earliest demonstrably trustworthy digest with its real date and scope. The chain before that point remains supported only by other

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evidence: acquisition logs, access records, independent copies, image histories and witness testimony. A later identical digest is powerful evidence about continuity from an actual reference state; it is no time machine. We should construct software so that it is difficult to make the mistaken inference, and reports so that the residual gap is visible rather than dressed in the language of mathematical certainty.

Dr. James M. Atkinson, Moderator: I thank Admiral Hopper and Professor Dijkstra. Their exchange locates a crucial boundary between an immutable byte object and a reliable explanation of its creation. Professor Dijkstra, please take the principal token and examine the programme invariants, state changes and fault conditions that would make this custody architecture independently auditable.

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Edsger Wybe Dijkstra, Second Principal Contributor: I should reject the practice of treating the existence of a hexadecimal digest as the architecture of an evidence system. A digest is the output of one calculation upon one defined object. An evidential workflow is a composition of acquisition, naming, transformation, verification, access control and truthful reporting, each capable of failing independently. The design should therefore begin with states and transitions, not screen colours or reassuring slogans. A source object enters a protected state only after a declared acquisition-close operation, a defined byte-range calculation and a recorded custody event. If those operations have not completed successfully, the system must label the object unanchored or provisional. It should not present a green verification symbol merely because a pathname exists and a digest field contains text.

There are at least five useful states: acquiring, closed but unanchored, anchored original, authorised derivative and quarantined discrepancy. Acquisition writes may be legal and necessary while a stream is arriving; the immutable-original rule cannot apply before the stream is closed. Once the source is anchored, ordinary analysis must employ read-only access or an exported working copy. A derivative may carry modified samples, new metadata, filtered or decimated representations and its own digest; it must retain a machine-readable link to its parent and a human-readable explanation of the transformation. A quarantined discrepancy is not automatically evidence of malice. It indicates that an asserted invariant has failed or cannot presently be verified, and it prevents silent promotion of that object to authoritative status.

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A crucial invariant concerns the difference between identities. The filename is not the object identity, because a rename may be lawful and file paths can be reused. A content digest is also not the whole identity, because two identical files can have different custody histories and different legitimate evidential roles. I would use an evidence-object identifier, content digest, object length, acquisition reference, scope definition and custody sequence together. If a new archive wraps exactly the same dataset bytes, the archive's whole-object digest changes, while a separately calculated digest over the unchanged embedded dataset should agree if the extraction boundaries are correctly documented. Both facts should be recorded without calling the repackaging either an attack or a proof of authenticity.

The schema must be explicit. Suppose complex samples are stored as signed sixteen-bit I and Q components in little-endian order, interleaved as I1,Q1,I2,Q2. The file may have no header, and the manifest supplies a conversion scale, sample rate, centre frequency and receiver gain state. A parser should refuse to proceed if a required datatype field is missing; it should not guess a common format and thereby manufacture a plausible waterfall. If the sample count implied by payload size is not an integer under the declared packing rule, that inconsistency deserves a diagnostic status. Nevertheless, divisibility alone is weak evidence: a truncated file can still contain an exact multiple of four bytes. Each check confirms a limited proposition and should be described accordingly.

Worked calculation one can be used as a software assertion. A complex sample comprising one sixteen-bit I value and one sixteen-bit Q value occupies four bytes, since sixteen plus sixteen bits equals thirty-two bits and eight bits make one byte. At ten million complex samples per second, a 2.5-

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second acquisition should therefore contain 10,000,000 times 2.5 times four, or 100,000,000 payload bytes, assuming no gaps, padding, compression or headers. If a manifest predicts that quantity and the storage object contains fewer bytes, the program should halt its complete-capture assertion and investigate. Exact agreement is necessary under those assumptions, yet it remains insufficient to prove that the RF input was real or that the declared sampling clock was correct.

The hash verifier must itself be tested. Feed it known public test vectors, deliberately truncated data, a single-bit alteration and a file changed during reading. If it calculates hashes on asynchronously changing material, the result need not represent any stable state. Reading through a verified immutable snapshot or a source held against modification reduces that ambiguity. The audit must also record software version, algorithm choice, input-range definition and whether errors occurred. A verifier that catches an access exception, reports success and leaves a previous digest on screen fails the most elementary condition of truthful operation. A digest comparison needs an independently protected expected value; otherwise an adversary able to alter both file and reference can create a new perfectly matching pair.

Canonicalisation requires another controlled boundary. A JSON metadata document can be rewritten with different whitespace, key order or equivalent number formatting while conveying the same intended fields. Hashing the raw bytes will detect such changes, which is entirely proper if the claim is raw-file identity. If an organisation additionally wants a canonical semantic representation, it must specify a deterministic canonicalisation algorithm and version, make its treatment of numbers,

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Unicode, duplicate keys and missing values explicit, then hash the resultant canonical bytes as a separate object. It must never retroactively replace a raw-file digest with an allegedly equivalent semantic digest. A parser which silently drops unknown fields may create a serious false equivalence between documents with different meanings.

Consider error handling. Loss of a clock reference, buffer overflow, unexpectedly changed receiver gain or a restart of a network acquisition service should produce visible state transitions and quality flags. A receiver may still emit bytes after one of these events, but the output's interpretation has changed. The custody chain can preserve those imperfect bytes faithfully. It cannot transform an overloaded analogue front end into an accurate measurement. Every alert should identify the affected sample interval when possible, the evidence available for the diagnosis, and the uncertainty in locating the interval. An examiner deserves to know whether a power-on transient has been observed at the antenna or produced by an unnoticed retuning of the local oscillator.

I would require independent checks of the programme's ability to enforce its restrictions. Use a synthetic dataset containing a unique test pattern and attempt to modify the anchored source through every advertised analysis route. Force crashes during digest calculation and while derivative objects are being committed. Revoke storage permissions, exhaust temporary space, change locale settings and swap endian declarations. Observe whether the system fails closed, preserves a complete audit entry and leaves the original object unmodified. The result of such tests is evidence about the implementation under the tested conditions, not a proof of perfection in every possible environment.

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Finally, there is a governance invariant. The object must be lawfully acquired for a declared purpose, even if its preservation is flawless. The record must name the authority and access constraints where required, minimise unnecessary communications content and distinguish scientific observations from classifications or attributions. Technical correctness and permission are separate obligations which should meet in the release gate. The next principal contributor should challenge whether the software tests actually establish the advertised custody properties and whether a convincing reproduction can be manufactured by a program that controls all the records it is asked to authenticate.

David Harold Blackwell, Peer Question: Professor Dijkstra, your machine has useful discrete states, but statistical evidence rarely arrives as an unequivocal success or failure. A clock's stability may be known only within a confidence interval; a buffer-loss counter might have an undocumented wrap; two supposedly independent copies may have travelled through the same defective software path. If every uncertainty causes quarantine, an ordinary laboratory will find itself unable to conclude anything. If every uncertainty is simply converted into a warning, on the other hand, an overconfident reviewer may ignore it. How would you allow the provenance ledger to represent graded support for distinct claims without confusing that grading with the binary question whether the file's bytes match a trusted reference? Please address how instrument uncertainty and investigator discretion ought to appear before a supposedly deterministic verification program certifies a later analysis. An examiner must also distinguish a defensible conditional conclusion from a claim that several

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uncertain measurements have somehow become independent merely because they have separate database entries.

Edsger Wybe Dijkstra, Response: Professor Blackwell, the programme should not attempt to make every proposition binary merely because a comparison operator produces TRUE or FALSE. It can be precise about the question it is answering while leaving evidential questions appropriately qualified. A digest over a fixed sequence can be compared with its expected value deterministically, subject to the assumptions about stable reading and trustworthy reference data. A timebase measurement carries an uncertainty interval established by calibration and observation. Whether two custody narratives are independent may require investigation of their common infrastructure. The system should assign those claims different types rather than manufacturing a single composite score whose arithmetic conceals their meaning.

I would treat verified byte continuity, verified schema interpretation, documented acquisition circumstances and validated physical signal attribution as separate report fields. For the first, record exact hash equality or inequality, algorithm, input scope and the identity of the expected digest. For the second, record parser conformance, the tested metadata version, whether all required fields were present and any ambiguous representations. For the third, record named event logs, operator declarations, instrument configuration and defects noted during acquisition. For the fourth, state observations, alternative explanations, measurements and the strength of the inferential method. These dimensions are related, but none can be replaced by a convenient green box on the computer screen.

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A failure to resolve clock drift should limit the time claims, not necessarily make every sample useless. A recorder whose exact time is uncertain may still contain an unaltered spectrum segment supporting a frequency-domain calculation, provided that the sampling-rate uncertainty is included and the relevant frequency calibration is adequate. Conversely, byte equality does not make a corrupted calibration file trustworthy. The reviewer may approve a narrow proposition, such as continuity of a particular byte range since a specified evidence-lock event, while withholding a broader proposition, such as an absolute onset time to the nearest microsecond. A well-designed record makes such partial conclusions easier rather than forcing an investigator to choose between absolute certainty and silence.

Statistical grades should identify their denominator and experimental protocol. Suppose two independently designed validators agree on all one hundred controlled test datasets, including deliberate corruption and representation changes. That is useful performance evidence against the tested cases; it does not establish a universal zero failure probability, especially if the tests share code libraries or if actual failures differ from the designed set. The report should disclose common dependencies and untested assumptions. In this manner software invariants and statistical uncertainty coexist: the invariants define what must not happen, while experiments describe where confidence in their implementation has and has not been earned.

John von Neumann, Peer Question: Professor Dijkstra, a hash function is usually evaluated as a mathematical transformation, whereas an evidential repository is a physical computation carried out by processors, memory controllers, storage devices and operating systems. A memory fault,

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malicious firmware or silently substituted executable can make the reported input different from the bytes a reviewer thinks were hashed. In addition, a hash may be computed at the correct instant but the stored digest may later be replaced alongside the data. It is tempting to add another layer of hashes, yet that can merely reproduce the same trust defect at a larger scale. Where should one place the trust boundary, what independent witnesses can test it, and how should the report express an assurance argument without assuming that a single machine can certify itself? Might a hardware-backed attestation or separately witnessed acquisition record improve the case, and what errors would each still be incapable of detecting?

Edsger Wybe Dijkstra, Response: Professor von Neumann, you have identified the reason to distinguish a formal statement about an algorithm from an assurance claim about an entire computer. A mathematically specified SHA-256 function takes an identified bitstring and returns a 256-bit digest. A real forensic workstation must obtain the intended bitstring from storage, execute the intended program and store the expected digest where an unauthorised user cannot conveniently alter it. If any of those surrounding operations are unreliable, the mathematics may remain correct while the evidential assertion fails. The answer is not an infinite regress of self-signed messages, but an explicit, finite trust model with independent controls and acknowledged residual risks.

For example, an acquisition system may create a digest at source close, an independent protected repository may verify it upon receipt, and a later analyst may verify the exported read-only object in another controlled environment. If the original digest is placed in a separately protected

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custody register before a disputed alteration, the later comparison has stronger significance than two values printed by the same mutable application at the same instant. Multiple custody events should include the identities of the systems, operators, versions, permissions and exception statuses. A mismatch must be preserved and investigated. It should never be erased by replacing the baseline with the latest calculated number merely to restore visual agreement.

I should also require reproducible validation of the verifier. Its source and build record, known-answer tests, input-range behaviour and failure handling need independent examination. One can use a second implementation to check selected files, but if both draw input from the same compromised storage translation layer, the supposed independence is limited. Where warranted, custody controls can include a write-protected acquisition image, a separately generated digest, independent copy comparison and tamper-evident access records. Each layer should answer a stated failure mode rather than increasing complexity for its own sake. Excessive verification machinery can be a source of mistakes if operators cannot understand it.

The report's assurance statement should therefore be deliberately narrow. It may say that two defined byte streams were read in separate controlled systems and produced equal digests under an identified approved algorithm, with the reference value secured at a documented prior time. It should not say that the electromagnetic source was authentic, that every circuit was free of defects or that an adversary was physically incapable of interference. We avoid both credulity and metaphysical scepticism by demanding an explicit chain from measured event to digital object to later

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inference, and by marking the points at which direct observation gives way to an assumption.

Edsger Wybe Dijkstra, Cross-Peer Question to Alan Mathison Turing: Mr. Turing, I pass the token respectfully to you. Suppose a laboratory operates two independent hash utilities that agree on the bytes currently held in its evidence repository. The instrument firmware, however, could have converted samples to a different numeric representation before the first acquisition log was written; the host could also have assigned a fictional start time. The verification system might execute exactly as specified while affirming an inadequate narrative of the data's origin. What independent test architecture would challenge the software's correspondence to the physical acquisition, and how would you avoid confusing verification of a later program with validation of an earlier measurement? I invite you to consider deliberate faults, trusted reference signals, reproducible computational tests, versioned software builds and the uncomfortable possibility that a suspicious result is reproducible only because the same defect is reproduced. I ask particularly whether the reference generator, recorder and independent observer share software dependencies that could disguise a common error as agreement.

Alan Mathison Turing, Cross-Peer Answer to Edsger Wybe Dijkstra: Professor Dijkstra, the distinction between programme verification and experimental validation is fundamental. The statement that an algorithm produces a digest according to its specification is not equivalent to the statement that the physical receiver produced a faithful measurement of its analogue input. To challenge the latter, the experiment must be arranged so that some relevant facts are established outside the device under examination. A

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calibrated reference signal can establish an expected frequency and timing interval, while a separate instrument and clock provide observations against which the receiver's file can be compared. The aim is not to assume that the independent apparatus is omniscient, but to expose the dependency structure and measure disagreements.

I would design a controlled trial with hidden event labels. An RF generator produces permitted test bursts, null periods, frequency steps and deliberate amplitude changes. The sample recorder acquires them under documented settings, including gain, filtering, oscillator reference and software version. The reviewer receives the original dataset, manifest, digest and custody chain, but the reference generator's schedule is withheld until the receiver reconstruction has been made. Comparing the reconstruction with that independent schedule tests a proposition about signal acquisition, rather than merely testing whether a later copy reproduces the same bytes. Deliberately induce dropped buffers, clock offsets, front-end overload and a restart. The programme should report the consequent limits rather than producing smooth, apparently complete data.

Software builds require their own provenance, including source revision, toolchain, configuration and executable digest. A digest of the acquisition application can demonstrate that a later executable file matches a recorded build, but does not prove that the source code was correct or the processor executed it without fault. Known-answer tests of the hash implementation and format parser should be separated from instrument-validation experiments. A pair of independent parsers can help reveal endian or scale errors, yet they may share mistaken documentation. The procedure must

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compare both to a controlled known sample array whose intended numeric interpretation is independently specified.

Finally, scientific reproducibility includes reproducibility of failure. If every restart yields the same spurious transient because the receiver's gain loop follows the same sequence, repeating the observation does not establish an external transmitter. Change the receiver configuration, reference input, front end and measurement path where authorised. Record failures with the same diligence as successes. The final report should say exactly which propositions have been supported by the direct physical controls and which are only supported by continuity of the subsequent digital representation.

Dr. James M. Atkinson, Moderator: Thank you, Professor Dijkstra and Mr. Turing. We now have a distinction between an auditable programme and a validated measurement process. Mr. Turing, please take the principal token to develop an adversarial, reproducible test strategy for both the digital evidence system and its RF acquisition boundary.

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Alan Mathison Turing, Third Principal Contributor: The word verification has become dangerously elastic when used to describe digital evidence. An investigator may verify that two files have identical digest values, verify that a parser produces expected samples for known test data, or verify that a particular RF transient occurred at the antenna of a known receiver. These are different questions with different witnesses. A machine cannot supply all its own foundations simply by printing the word passed. We should begin with an experimental model whose hypotheses are narrow enough to be falsified and whose records can survive review by someone with no loyalty to the original operator.

Let there be a hypothetical evidence record E containing a raw byte object B, a metadata statement M, a custody history C and a set of physical-acquisition observations P. One may calculate H(B), the digest of the raw bytes, and H(M), the digest of the exact manifest file. Matching a later H(B) to a protected original value supports continuity of B after the anchor event. It says nothing by itself about whether M is true. Matching H(M) supports continuity of the manifest's bytes, but not truth of their contents. The physical observation set P can include an independent reference source, measured timebase errors, gain calibration and a second receiver's observations. The custody history C documents who made, transferred, examined and transformed each object. An evidential claim should cite the elements relevant to it rather than invoking the entire bundle as if every component proved every other.

A practical verification suite ought to contain attacks which do not require a malicious outsider. An analyst renames a file; the whole-file content digest should remain unchanged, though path metadata and custody entries may

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differ. The analyst copies identical bytes to a new medium; equality is expected under successful copying. The analyst puts the same sample array in a differently structured container; a digest of the new whole object changes, while a properly delimited extracted sample digest may agree. The analyst changes one bit in the payload; a correctly operating secure digest should ordinarily change, but the scientific conclusion must remain probabilistic with respect to collisions, and a recorded nonmatch needs investigation. The analyst edits only the declared sample rate in a separate manifest; the raw sample-byte digest need not change at all. These tests are stronger than an attractive demonstration in which every file is either wholly identical or obviously destroyed.

Consider a concrete interpretation test. Four stored bytes are 01 02 FF 7F in hexadecimal, and the declared format is one complex sample containing two signed sixteen-bit integers. Interpreted little-endian, the I component is hexadecimal 0201, decimal 513, and the Q component is hexadecimal 7FFF, decimal 32,767. Interpreted big-endian, the I component is hexadecimal 0102, decimal 258, while the Q component is hexadecimal FF7F, the signed decimal value negative 129. The identical four bytes support radically different numerical values depending upon byte order. Both parsers can compute an identical hash of the file because neither has altered a byte. The relevant test is therefore to verify the declared schema against a known reference stream, not to ask whether the digest is equal.

A second test should distinguish logical acquisition time from host time. Suppose a sample with hardware index four million follows an established time origin on a device running at eight million complex samples per second. Its nominal offset is one half-second, since index divided by sample

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rate gives elapsed sample time. A file's modification timestamp might be several seconds later because the programme wrote asynchronously. Neither the correct sample offset nor the equal hash validates the absolute time origin; that needs evidence of clock synchronisation and trigger alignment. A host filesystem timestamp should never be silently used as a substitute for a tested acquisition-clock timestamp.

The integrity software also needs adversarial operational tests. Remove permission to read a file halfway through a digest calculation; the verifier must fail, not show an old success result. Change the file while it is being streamed into the algorithm; the verifier must detect that its snapshot assumptions were broken or operate on an immutable snapshot. Introduce a truncated final sample pair and demand a clear parsing failure. Change a metadata schema version and verify that unknown critical fields are not discarded. Test a duplicate-key conflict in a machine-readable manifest and require deterministic rejection or a documented, carefully controlled rule. A document accepted by one parser and interpreted differently by another cannot be treated as unequivocally reproducible.

I should caution against the fetish of bitwise equality. If a scientist intentionally converts signed sixteen-bit complex samples into a documented floating-point derivative, the bytes naturally change. The transformation may preserve the underlying numerical values within the converter's precision and rounding properties, but that equivalence requires a separate numerical test. If decimation or filtering is applied, some information is deliberately discarded, and the derivative no longer proves that every property of the original waveform has survived. The proper ledger preserves the original and records the operation, parameters,

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software, validation examples and resultant digest. A later analyst should never have to reverse-engineer why two files differ.

For an acquisition validation experiment, use an authorised shielded or otherwise controlled laboratory configuration. Set a reference generator to produce programmed bursts at independently logged times and frequencies; include matched null conditions, deliberate source-level changes and benign interference. Measure the generator through a second instrument whose own limitations are documented. Do not train the device or its interpreting software on the final blind validation sequence. Compare recovered timing, measured bandwidth, sample continuity and phase behaviour against the reference record, stating uncertainty and the categories of error. A digest protects the post-acquisition evidence object, while the independent measurements test whether that object corresponds to the claimed physical process.

The chain of custody must survive routine human behaviour, including interrupted transfers, shift changes, a changed laboratory clock and later correction of a manifest error. Every source file should have an object identifier, digest algorithm and scope, data length, custody event, protected expected digest and relevant permissions. Every derivative should name its parent and transformation. Preserve conflicting observations instead of selecting whichever produces the most dramatic attribution. Software itself should make the modest conclusion easy to report: the identified bits match the protected reference since a stated event; the authenticity of the acquired RF phenomenon has been separately assessed, remains uncertain, or was not assessed.

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My proposed release test is not whether the examiner can reconstruct an impressive plot. It is whether a second qualified examiner, using the preserved original bytes, declared schema, reliable tools and separately supported calibration and timebase records, can challenge each inferential step and obtain an appropriately qualified result. An absent manifest, an unexplained gap or an undefined reference plane should not be hidden by the mathematical precision of a digest. Mr. Reed should now examine what error-detecting codes can and cannot contribute to this architecture and whether a corrected stream can honestly be called the original.

Peter Elias, Peer Question: Mr. Turing, a digital evidence system can preserve a bitstring faithfully while applying an error-correcting code during transmission or storage. The decoded output may differ from the received symbols, yet the code may have repaired a genuine transmission error according to its declared error model. An archivist may then preserve only the corrected result and claim, rather carelessly, that the evidence has not changed. Is it intellectually defensible to use a corrected digital object for later RF analysis when the uncorrected received bytes have been lost? I ask you to distinguish what a code's algebra proves about the declared channel from what it says about the analogue waveform that entered the ADC. Would you require preservation of parity information, syndrome records and correction counts, or can a carefully documented corrected object stand as the earliest available anchor? Please consider the danger that a plausible reconstruction might conceal an interval in which the original instrument never actually measured the signal being inferred.

Alan Mathison Turing, Response: Professor Elias, a correction procedure and a preservation claim have different time origins. Error-correcting storage

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may be a perfectly legitimate part of a digital recorder. If the instrument generates a logical data stream, passes it through a code and later reconstructs that stream after encountering a correctable storage fault, the investigator can report that the recovered logical content is consistent with the recorded codeword and its correction model. However, the proposition is not that every physical storage symbol remained untouched. It is that the storage system reconstructed an intended logical sequence under specified assumptions. If the recording architecture retained parity, syndromes and controller error counters, those data may strengthen an explanation of what happened; if not, the examiner must be clear that the earliest visible object may already be a recovery product.

The original acquisition boundary still matters. Suppose an ADC writes an incorrect numerical sample because its analogue front end saturated. An error-correcting code in the storage path will faithfully preserve that incorrect number; it cannot identify the true unsaturated voltage. Equally, if an acquisition application drops 1,024 complex samples and then writes a seamless-looking stream, the later storage code has no basis to reconstruct the omitted physical measurements. Coding theory concerns redundancy deliberately introduced into a representation. It is not permission to invent signals which were never acquired. The evidence report should therefore separate ADC or acquisition completeness from downstream storage recovery and from subsequent forensic file integrity.

Where possible I would preserve a protected source object at the earliest practical logical boundary, including acquisition counters and storage-health indicators. If error correction occurred before any examiner could access the file, the report should name the correction layer and identify which

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telemetry is available. A derived file can be analytically usable even if its pre-correction symbols were not retained, but a claim of bit-for-bit identity to inaccessible original symbols is unsupported. Compare the recovered object against independent contemporaneous copies where such copies exist. Where no independent comparison is possible, do not disguise absence of evidence with a claim of absolute fidelity.

A hypothetical laboratory can demonstrate the distinctions. Record a known complex-sample pattern, introduce a correctable storage error, and show that decoding produces the original sample bytes while a controller logs a correction event. Then alter a sample intentionally before it enters the coding stage; the storage system should preserve that deliberately incorrect sample without objection. Finally, omit a sample interval upstream of the coding stage; no parity scheme designed for downstream storage errors can establish the missing analogue values. The experiment reveals three locations of failure, and each merits a different qualification. It illustrates why the object and instant of hashing must be stated as carefully as the properties of the error-correcting code.

David Lennox Mills, Peer Question: Mr. Turing, the custody ledger may describe a timestamp as acquisition time, yet in a networked laboratory several clocks can be involved. An RF recorder may label samples with a hardware counter, a host may label files with its wall clock, a network transfer may add another receipt time, and a trusted service may later apply an authenticated timestamp to a digest. These quantities are often printed together in a report as if they arose from the same temporal reference. How should the investigator distinguish the observed time of an RF event from the date a custody statement was created? Please explain how offset, drift,

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leap-second handling, trigger latency and uncertainty should be represented. In particular, I should like a procedure for a file whose bytes match perfectly but whose original wall-clock record was wrong by an unknown amount. Does a later authenticated timestamp upon the hash offer any admissible evidence about the earlier RF event, beyond establishing a bound on the existence of the subsequently preserved object?

Alan Mathison Turing, Response: Dr. Mills, there is no reason for an evidence system to pretend that all clocks answer the same question. The sample counter identifies ordering in a sampled stream and, given an appropriately qualified sample-rate model, relative time. A hardware reference and trigger mark may permit that stream to be placed upon an absolute time scale. A host operating-system clock labels the occurrence of host events such as writing or closing a file, and its offset from the acquisition clock may be substantial. A protected timestamp over a digest records that the digest or attested object existed before or at a documented certification event under the service's stated trust assumptions. It does not transform the digest into a precise RF-event timestamp. These should be typed as separate fields with explicit provenance.

The rate relation is simple, but its assumptions must be recorded. For a sample index n, nominal sample rate f_s samples per second and reference origin t_0, the nominal sample time is $t(n)=t_0+n/f_s$. An illustrative index of 4,000,000 at eight million complex samples per second yields 0.5 seconds after the defined origin. If t_0 has an uncertainty of two milliseconds, the arithmetic cannot eliminate that uncertainty by printing more decimal places. If the oscillator has a bounded error, its contribution grows with the duration of the record. As an example, a relative rate error of two parts per

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million persisting for ten seconds represents approximately twenty microseconds of accumulated timing error, subject to sign, stability and the precise clock model. The numbers belong in an uncertainty budget, not in a claim that the file hash somehow measured them.

For the case of an incorrect original wall-clock field, preserve it as originally recorded and issue an attributed correction supported by independent time evidence. Useful sources may include a separately logged reference pulse, a calibrated timing input, generator event logs or a recognised time-transfer comparison. A network timing packet alone may not show the actual ADC conversion instant, especially when the acquisition path buffers samples. If no reliable evidence can resolve the offset, a defensible report may retain precise relative timing and state that absolute time is not established within the desired tolerance. There is nothing improper about uncertainty honestly bounded; the impropriety would be to replace it with an invented exact instant.

The custody system should record at least four temporal events: the acquisition event or interval under the instrument's timing model; the closure of the digital object; the creation of its earliest protected digest; and each subsequent transfer or examination. When these events cannot be aligned precisely, list the known sequence and the unresolved intervals. Clock corrections need versioned records, just as manifest corrections do. An accurate digest over a byte sequence containing a wrong timestamp perfectly preserves the wrong timestamp. It does not correct it. A court, auditor or engineering reviewer will be better served by this modest formulation than by an immaculate but unsupported chronology.

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Alan Mathison Turing, Cross-Peer Question to Irving S. Reed: Dr. Reed, I respectfully pass the token to the specialist in the design and interpretation of error-detecting and error-correcting codes. In the controlled experiment, imagine an RF dataset that has been divided into numbered blocks, protected with per-block checks and then archived under one whole-file cryptographic digest. A later read reports a recovered block following a correctable storage error; another read produces a complete file whose digest differs by one bit; a third file contains the right length but repeats an earlier sample block while omitting a later one. How can an investigator discriminate these conditions without exaggerating what a code can repair? Please distinguish a random storage fault from a deliberately altered but internally consistent file, a checksum from a cryptographic hash, and coding redundancy from physically observed RF redundancy. I would welcome a worked method for identifying a sample gap without asserting that the unknown RF values can be conjured out of parity generated after acquisition.

Irving S. Reed, Cross-Peer Answer to Alan Mathison Turing: Mr. Turing, the first discipline is to identify the channel for which a particular code was designed. A parity check on a stored block can reveal certain patterns of errors within that block, and a correcting code may reconstruct symbols when the actual number and pattern of errors are within its correction capability. Neither statement is a claim about the truth of the analogue signal that the ADC purported to measure. If erroneous samples were already present when the redundancy was calculated, the code can preserve them perfectly. If a sample block was never delivered to the coding process,

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the scheme cannot recover the missing RF observation unless independent information exists beyond the stated storage code.

A whole-file cryptographic hash answers another question. Compared with a protected reference, it is an integrity indicator for the specified byte sequence, with security depending upon the hash function and protection of that reference. A simple checksum may detect common accidental changes but may be easy to manipulate or collide under adversarial conditions. A correcting code seeks structured reconstruction of data through redundancy, and a digest seeks evidence of equality or change; their purposes are complementary rather than interchangeable. In the one-bit experiment, the correct interpretation is that a controlled bit alteration should produce a digest mismatch in the overwhelming ordinary case, and the laboratory should independently verify that it did so in the actual test. The digest does not reveal which physical cause changed the bit.

The repeated-block case is especially instructive. A file can have the expected length and every local sample-packing field can be syntactically valid while containing a duplicated earlier block instead of a later one. If acquisition buffer counters and per-block identifiers were preserved under trustworthy conditions, the substitution might be evident. If those markers are also rewritten consistently, a later verifier can establish continuity of the substituted file from its later anchor, but it cannot recover the missing historical fact solely from a matching fresh hash. A second independently captured stream or an authenticated contemporaneous acquisition log may establish the discrepancy. The report must acknowledge when no such witness survives.

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I would preserve original, corrected and derived objects separately when the recording technology exposes these layers, with their digests, error telemetry, correction algorithm and software version. A correction should be described as a computational transformation supported by the code's assumptions. It should not be represented as a fresh observation of an RF waveform. That distinction enables an analyst to exploit reliable coding technology without presenting mathematical reconstruction as if it were unmediated physical evidence.

Dr. James M. Atkinson, Moderator: Thank you, Mr. Turing and Dr. Reed. The discussion has exposed how a completely preserved file may contain an imperfect observation, and how correction of stored data differs from recovery of unobserved RF samples. Dr. Reed, please take the principal token and address block validation, error correction, sample gaps and adversarial modification in a forensic receiver chain.

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Irving S. Reed, Fourth Principal Contributor: In a forensic radio recorder, the phrase error-free has no useful meaning until one names the boundary across which freedom from error is asserted. A cryptographic hash can support a comparison between two byte sequences; a storage code can correct certain corrupted symbols in a declared channel; an RF calibration procedure can estimate the accuracy of an analogue measurement. These mechanisms live in different layers. The investigator must not carry a guarantee from one layer into another merely because it is expressed by mathematics. A code can preserve a false statement perfectly, just as a correct chain of custody can preserve an authentic file containing samples produced by an overloaded front end.

I would divide the recording chain into acquisition frames, transport frames, storage objects and analytical derivatives. Where supported by the instrument, an acquisition frame includes a monotonic hardware sample index, expected number of complex samples, clock and configuration state, overflow status and a means of associating the frame with the overarching acquisition session. Transport adds its own sequence information, packet integrity checks and retransmission history. Storage produces a durable logical object, possibly supported by an error-correcting storage controller. The analysis layer extracts intervals, converts sample representations, filters and measures. An original file hash should be made at a declared boundary; hashes at later boundaries document later continuity, not the earlier success of every preceding stage.

The simplest useful arithmetic is a dimensional check. Let N be the count of complex samples, b_I and b_Q the bits allocated respectively to in-phase and quadrature components, and f_s the nominal complex-sample rate. For a

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packed representation without padding or headers, file payload length is N times (b_I+b_Q) divided by eight bytes, and acquisition duration is N divided by f_s seconds. If N is one million, b_I=b_Q=16 and f_s is two million samples per second, the expected length is four million bytes and nominal duration is one half-second. These calculations are necessary consistency checks. They do not reveal whether the samples were generated by a real antenna, whether the clock was calibrated or whether an omitted earlier block was replaced by a fabricated one.

An especially revealing failure is a repeated block. Suppose the sequence should contain A, B, C, D but the repository contains A, B, B, D. All four blocks may have the proper length and acceptable numeric values. A digest computed after the substitution can agree forever with later copies, while a contemporaneous source-side digest would reveal a mismatch if the intended original was recorded and protected. Frame counters and independent logs may expose the wrong sequence, although a damaged or maliciously constructed log can defeat that evidence. One cannot simply inspect a smooth waterfall and infer that C must have been present. A scientifically honest analyst marks the discontinuity, preserves the observed bytes and avoids joining phases across the unknown interval without a separate evidential basis.

A correcting code requires a model of errors and erasures. If a codeword of a known family is received with corruption within its designed capability, decoding can produce a candidate original codeword, and syndrome or correction counters can record the process. The statement should specify the code, parameters, detected fault, corrected symbol count and residual failure probability where assessable. Correction is not equivalent to forensic

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authenticity. A deliberately forged stream with newly computed parity can pass code checks because the code has no independent knowledge of the signal's lawful origin or physical truth. Likewise, the code's ability to correct storage bits says nothing about a drifted local oscillator during acquisition.

Consider the difference between an accidental one-bit change and a controlled rewrite. In a hypothetical laboratory, a single bit of an originally preserved file is flipped and the known expected SHA-256 digest is compared against the newly calculated digest. The experiment should observe a nonmatch; the analyst records the actual digest values and test method. A second trial rewrites a complete sample frame and recalculates a fresh digest. That new digest is internally valid for the altered bytes, yet comparison against the securely retained old reference should disclose the alteration. If the attacker can replace the original reference as well, digest equality to the substituted reference proves little about the history. The custody system must protect expected values, with independent witnesses when feasible.

Timing offers another calculation. A verified omission of 1,024 complex samples at an eight million-sample-per-second rate represents a nominal interval of 0.000128 second, or 128 microseconds. The word verified matters: a missing sequence number alone may reflect packet reordering or a reset rather than a confirmed gap in ADC output. The analysis should first reconcile the device's hardware sample indices, buffer logs and transport retransmission record. If the gap is real, a derivative may insert an explicit missing-data mask to preserve downstream alignment. Such a mask describes absence, not reconstructed RF values. An interpolation may be

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useful for a visual demonstration, but its output requires a separate object identity and conspicuous qualification.

Some investigators conflate a cryptographic digest with an error-locating code. SHA-256 produces a 256-bit output, displayed commonly as sixty-four hexadecimal characters, but a difference in its output does not itself identify which byte changed. Block-level hashes can help localise a mismatch if protected reference values were established for each block and the block scheme is robustly specified. Even then, a block match confirms only equality of the defined block bytes. A changed manifest may make the same samples represent different voltages, frequencies or times, while all block digests remain equal. Conversely, an innocuous change in an enclosing file header can change a whole-file digest without touching the sample block bytes. State the scope before interpreting the comparison.

A useful design pairs per-block sample counters with an independently retained acquisition-close record and a whole-object digest. A session manifest declares format revision, channel packing, signedness, endianness, sample rate, clock basis, gain, filtering, centre frequency, missing-data conventions and known validity limitations. When a valid derivative is created, the laboratory records parent-child identifiers, transformation parameters, code version, new length and new digest. It is also prudent to log storage health and corrected-error events because they help explain why a later reconstruction may depend upon error correction. Such records are diagnostic witnesses, not substitutes for the actual preserved bytes or a properly bounded observation of the physical signal.

Finally, an evidential conclusion should differentiate agreement, consistency and identification. A matching digest is agreement between defined digital

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objects under stated assumptions. Agreement of calculated sample duration with the recorded event interval is a consistency check. Agreement of the resulting spectral features with a known source in a controlled test may support that specific identification under the experimental limits. None of these alone identifies an unknown emitter in the field. The editor should resist colourful but unsupported rhetoric, particularly when spectral artefacts, overload, multipath and sample-clock errors can create compelling appearances. We should next ask Dr. Hamming to assess the practical consequences of imperfect data, finite numerical precision and the reproducibility of derived measurements.

Claude Elwood Shannon, Peer Question: Dr. Reed, a preserved RF sample stream can be compressed, resampled or passed through a finite-precision transform before an analyst sees its waterfall. In the favourable case, a reversible encoding merely changes the arrangement of bytes while preserving the entire logical sample sequence. In other cases the transformation is intentionally lossy, and the apparent shape of a weak burst depends upon its quantisation and filtering errors. How should the custody record state what information has survived a transformation, rather than using the imprecise word unchanged for both byte-identical and information-equivalent objects? I should also like you to address a derivative whose displayed spectrum matches the source in ten ordinary laboratory cases but fails for a rare narrow transient. Can a small empirical validation set justify an assertion that the new representation preserves every evidentially relevant property? What is the proper response when the preservation objective is known only after a later investigator proposes a different hypothesis?

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Irving S. Reed, Response: Dr. Shannon, the decisive distinction is among byte identity, lossless reversibility under a defined representation, and preservation of some particular analytical features within a measured tolerance. These relations cannot be treated as synonyms. A simple file rename may leave its content bytes identical; a different archive format changes the archive object while retaining identical extracted sample bytes; a documented endian conversion changes payload bytes but may preserve signed numeric sample values if conversion is executed correctly. A lossy quantiser, decimator or compressor can change numerical samples and irreversibly remove information. Every derivative must declare which kind of equivalence, if any, the author intends to defend, and supply a test suited to that claim.

If a laboratory promises lossless conversion, it should verify the exact output of a round trip against a defined original, considering numeric type, finite values, NaNs where relevant, channel ordering, byte order and metadata. For an explicit sample-array equality test, decode both objects into the same documented canonical numeric representation and compare the ordered sequence under a specified equality relation. That test is distinct from comparing whole-object digests. An archive can contain the same sample stream while its compression headers, timestamps or filenames change. The new archive requires its own hash and custody event, and the extracted samples require their own reference scope if comparison is the claimed objective.

If the conversion is lossy, the claim should be narrower. Define frequency resolution, amplitude or phase error bounds, transient-duration range and the permitted inference before testing. For example, a decimator may

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preserve a slowly varying baseband component under an appropriately designed antialias filter while removing frequencies outside its retained passband. It would not preserve every possibility of a later short-pulse or adjacent-channel investigation. Ten demonstrations without difficult corner cases could support the observation that those ten worked, but they cannot establish universal preservation. Blind reference cases should include near-threshold events, impulses, saturation, frequency-edge features and counter discontinuities relevant to the authorised questions.

I would therefore mark derivatives as fit for stated purposes, not equivalent in the abstract. The protected original sample object, if lawfully retained, permits a later authorised examiner to test another claim. If the original was never retained because the permitted operation was narrowly limited to aggregate measurements, the institution should report that limitation rather than reconstruct an imaginary full-rate dataset. Forensic honesty is sometimes the statement that a later question cannot be answered from the retained evidence. No compression theorem or integrity digest can replace information deliberately or accidentally discarded before the evidential anchor.

Irving S. Reed, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, I pass the token with respect to your long concern for numerical computation and the dependability of data. The archive may consist of an unchanged raw file, a protected manifest and an apparently impeccable series of hashes, yet a later analyst can reconstruct the same incorrect spectrum by consistently misreading the sample format or using a wrong scaling convention. Conversely, a legitimate conversion from signed integer to floating point can change every output byte while preserving the useful

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sample values within a stated tolerance. What practical numerical acceptance tests would you require before calling such a derivative reproducible? Please examine finite-precision arithmetic, IQ channel order, clipping, power normalisation and the distinction between an exactly reproducible mistake and a validated measurement. I should be grateful if you could also say how to document the inevitable uncertainty without burying a forensic report in insignificant decimal places.

Richard Wesley Hamming, Cross-Peer Answer to Irving S. Reed: Dr. Reed, a numerical result does not acquire physical truth merely by being repeatable to the last printed digit. If the input bytes are read under a mistaken schema, two laboratories using the same flawed parser may agree exactly and still be wrong. The first safeguard is a set of known-value test vectors that exercise the extremes of each supported numeric type, both byte orders, signs, zero, saturation values and the declared I/Q ordering. Include a synthetic complex sinusoid with known frequency offset, phase evolution and amplitude, plus null and deliberately clipped cases. A parser should be required to produce the expected samples before any expert interpretation of field data is accepted.

The arithmetic acceptance test must name its tolerance and reference plane. Conversion of an integer sample into floating point may reproduce each integer exactly for sufficiently small widths under a supported floating-point format, but later filtering, resampling or power calculation can introduce rounding errors. Report the software version, precision, order of operations and test results. If two computational routes differ, determine whether the difference falls within a justified numerical error budget. Do not declare equivalence merely because two waterfalls look similar to the eye. A

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display's colour scale and averaging can hide an error that materially affects a short transient.

Take the question of power. A squared complex amplitude depends upon I squared plus Q squared, but converting that quantity into watts or dBm requires a physical scale and a defined reference impedance or calibrated instrument convention. An ADC integer alone does not supply those quantities. If the gain state changed or the analogue input clipped, the numerical magnitude can be precise while the inferred input power is unsound. Record calibration, gain, attenuation, detector treatment and the effect of window normalisation. The original bytes and manifest are necessary evidence for the computation, but their digests do not validate the analogue chain or the chosen physical units.

The practical result should be a reproducibility dossier rather than an exaggerated certificate. Preserve the source dataset; name each derivative and its transform; protect source and output digests; supply sample schema, selected reference vectors, numerical tolerances, algorithm parameters and test logs. A second qualified examiner should be able to reproduce the calculation and deliberately vary the interpretation to see how the finding changes. Where the precise phase, absolute time or power is not defensible, state the narrower observation that is defensible. Good engineering does not suppress uncertainty; it gives uncertainty an address and a unit.

Dr. James M. Atkinson, Moderator: I thank Dr. Reed, Dr. Shannon and Dr. Hamming. We have separated exact byte continuity from correction, reversible representation and valid physical interpretation. Dr. Hamming, please take the fifth principal token and give the panel a concluding

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technical discipline for finite precision, experimental controls and forensic reporting.

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Richard Wesley Hamming, Fifth Principal Contributor: The strength of a measurement is not determined by the number of digits it prints or the size of the file that contains them. A forensic SDR system can generate terabytes of perfectly preserved samples and yet fail to establish a single disputed timing or power proposition, because the instrument state, interpretation schema or independent reference was inadequately recorded. Conversely, a short well-characterised sample interval with a clear uncertainty statement may support a reliable and modest conclusion. We should judge the evidence system by the claims it makes possible to test, not by the magnificence of its storage machinery.

I would begin every significant reproduction with a format test, an instrument test and an inference test. The format test uses known byte sequences to check signedness, endian order, channel interleaving, numeric scale, headers and sample count. The instrument test uses calibrated or otherwise independently characterised reference stimuli to test gain, timing, frequency response, phase and overload behaviour. The inference test asks whether the specific conclusion follows from the recorded measurements when alternative explanations and uncertainty are considered. The file hash belongs principally to the continuity of the digital object. It must be present and protected, but it cannot substitute for the other tests.

A full-scale integer conversion offers a simple illustration. Suppose a file contains signed sixteen-bit I and Q samples. The declared digital range extends from negative 32,768 to positive 32,767 for each component, but those raw integers are not voltages until a scaling rule has been specified and validated. The physical range represented by full scale depends upon the converter, analogue gain, reference setting and any digital rescaling. If

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the analyst multiplies by the wrong scale factor, the reconstructed graph may look entirely plausible while its power labels are materially wrong. The error will be faithfully reproducible from an unchanged file. The reviewer must demand the instrument scale and the calculation, not merely inspect a matching hexadecimal digest.

Suppose a receiver writes 1.5 million complex samples per second, each sample represented by two thirty-two-bit floating-point components. Each complex sample then occupies eight bytes. A sixty-second uninterrupted payload should contain 1,500,000 times sixty times eight, or 720,000,000 bytes, equal to approximately 686.65 mebibytes when divided by 1,048,576. These are decimal and binary unit conventions that should not be confused. The byte count can help detect gross truncation, but a different packing rule, compression, gap annotation or header naturally changes the calculation. State the format assumptions whenever quoting expected size; a coincidentally correct length is not proof of correct content.

Error budgets should be constructed from independently identified mechanisms, with correlation considered rather than every uncertainty being combined mechanically. An acquisition time may have a trigger uncertainty, reference-clock offset, sample-clock drift, buffering uncertainty and subsequent software labelling error. A frequency estimate may depend on clock calibration, FFT-bin resolution, window leakage, front-end nonlinearities and estimator bias. A measured received level may depend on the antenna factor, cable loss, input attenuation, gain calibration, detector and reference impedance. Each input must be connected to the actual claim. It is misleading to present a single generic plus-or-minus figure which does

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not identify whether it is a tolerance, standard uncertainty, expanded uncertainty or merely a manufacturer's typical specification.

The distinction between a correct copy and a correct measurement can be tested with deliberately contrary examples. In one trial, copy a valid RF dataset byte-for-byte to another medium; a secure digest should match and a correctly implemented parser should recover the same numerical sequence. In another, alter a single bit; the comparison should detect that the content differs, while an independent analysis determines whether the physical interpretation changes significantly. In a third, retain every byte but swap the declared I and Q interpretation; the hash remains unchanged while certain phase and frequency-sign conclusions may reverse. In a fourth, preserve all bits from an overloaded receiver; the file remains authentic as a record of what the receiver output, but the nonlinear distortion can make inferred external signals unreliable. These counterexamples prevent the report from treating continuity as a synonym for truth.

A simple numerical clock test can sharpen the discussion. Let a sampling clock have a nominal rate of ten million complex samples per second and a relative systematic error of five parts per million. The magnitude of its rate error is approximately fifty samples per second, assuming the stated relative error applies to sampling frequency. Over a two-second interval the cumulative discrepancy would be approximately one hundred sample intervals under a constant-error model. The experiment must distinguish the sign and stability of the error and relate the sample count to an independent time reference. Nothing about the unchanged sample file

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resolves that calibration question. Repeating the same reconstruction under the same mistaken ten-million rate will reproduce the same mistake.

Consider also a deliberately bounded diagnostic extraction. Suppose an authorised experiment retains one half-second before a benign trigger and one second after it at five million complex samples per second with four bytes per sample. The payload is 1.5 times 5,000,000 times four, or 30,000,000 bytes, before container overhead. That calculation informs storage planning and the scope of retained data. It does not by itself determine the legal or ethical propriety of retaining the contents. The custody record should identify the actual authorised purpose, capture bounds, operator and resulting file length. If the result contains unrelated private material, that question requires a separate lawful minimisation decision, not a mathematical assurance about the hash.

I am equally concerned by overinterpretation of checksums. A SHA-256 digest is a fixed 256-bit result, typically written as sixty-four hexadecimal characters. It should be compared with an expected digest protected independently of the contested bytes. The probability of accidental equality under a naive random-output model is astronomically small, but neither that idealisation nor the format of the digest permits a conclusion of absolute impossibility, and the trustworthiness of the reference state remains decisive. We should employ a suitable contemporary approved hash algorithm, document the implementation and verify its known-answer tests. That is a strong continuity control, but its evidential claim begins at the first trustworthy anchor and goes no further backwards.

The weakest numerical practice is to give a precise answer to a poorly posed question. A waterfall reconstructed with the wrong window and scale may

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support an exact but irrelevant power estimate. A post-processing programme can silently interpolate missing samples and present a visually continuous line which was never measured. A device may report excellent frequency resolution while its front-end intermodulation products imitate real emissions. The forensic report should identify what was directly measured, what was calculated, what was inferred, what was corrected and what remains unknown. Where one cannot reconstruct a timing edge or absolute amplitude from the retained evidence, the right conclusion is that the proposed determination is not supportable from those records.

For independent reproducibility I would retain a compact set of carefully chosen known-answer cases and boundary cases with the programme and manifest. Include positive and negative signed integer extremes, two byte orders, interchanged I/Q channels, a known sinusoid, a clipped waveform, an intentional missing block, a metadata change with identical sample bytes, a legitimate container conversion and a one-bit payload change. A second examiner should verify both successful reconstructions and expected failures. Beyond the bits, disclose acquisition hardware, firmware, analogue configuration, calibration provenance, clock source, software versions and authorised purpose. These facts are neither decoration nor excuses; they define the claim's limits.

My conclusion is intentionally restrained. An unchanged RF sample file, established by a defined digest comparison and trustworthy custody reference, supports continuity of that digital representation since its documented anchor. It does not alone certify an honest operator, authentic antenna input, correct acquisition clock, calibrated analogue measurement, lawful collection or correct scientific inference. Those propositions require

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their own controls and independent witnesses. When the institution separates them, it gains a record that is genuinely testable, even when the final answer is uncertain. That is a far stronger forensic achievement than an apparently perfect graph accompanied by an overconfident certificate.

Dr. James M. Atkinson, Moderator: I thank Admiral Hopper, Professor Dijkstra, Mr. Turing, Dr. Reed, Dr. Hamming and the participating peers. This discussion is an explicitly fictional scholarly reconstruction and not a record of their actual speech. The defensible conclusion separates exact continuity of a defined byte object from correctness of a format interpretation, completeness of acquisition, calibration of the RF measurement and lawful provenance. A matching protected digest is powerful evidence within that limited scope, but every additional proposition must be supported by independent data and an identified uncertainty. The panel's worked calculations are hypothetical laboratory illustrations rather than observations of any unknown emitter. The author will retain the Stage B requirements for source-to-claim correspondence, historical suitability, independent technical examination, semantic distinctiveness and whole-volume production proof.

QUESTION 091. TECHNICAL SOURCE NOTES: NIST FIPS 180-4, Secure Hash Standard (https://csrc.nist.gov/pubs/fips/180-4/upd1/final); NIST SP 800-86, Guide to Integrating Forensic Techniques into Incident Response (https://csrc.nist.gov/pubs/sp/800/86/final); Signal Metadata Format (SigMF) specification, datatype and capture metadata (https://sigmf.org/sigmf-spec.pdf). These contemporary publications support technical background only and are not historic statements by the named participants. Individual source-to-claim verification and legal review remain for Stage B.

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EDITORIAL QUALIFICATION. The dialogue is a modern fictional reconstruction. Its examples concern controlled, authorised and hypothetical RF measurement; none constitutes proof of an unknown emitter or permission to capture protected communications. Stage A mechanical review does not certify independent physical authenticity, historical quotations, legal accuracy, complete mathematical correctness, semantic originality, or publication-ready pagination.

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QUESTION 092

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Which configuration values are indispensable for reproducing a waterfall determination?

Dr. James M. Atkinson, Moderator: Professor Dijkstra, the panel has just examined preservation of RF sample files. I invite you now to address a distinct but related question: what must the examiner record so that an independent laboratory can reproduce a specific waterfall determination from the same lawful sample data? The display may resemble a meticulously coloured chart, yet its apparent peaks, durations and background noise are calculated through a succession of choices. Please distinguish the raw object, the measurement process, the processing recipe and the displayed image. This is fictional scholarly dialogue, not a historical statement by the participants.

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Edsger Wybe Dijkstra, Principal Contributor: I would begin by asking the investigator to specify the property to be reproduced. Recreating a similar-looking screen is not the same thing as reproducing an estimate of power spectral density, centre frequency, onset time or occupied bandwidth. A waterfall is a representation generated from samples by algorithms and display conventions. Its coloured rectangles are not physical quantities in themselves. If the claim is that a frequency interval exceeded a noise-relative detection threshold for a stated duration, then the reproduction protocol must define that threshold, its reference population, the valid observation intervals and the statistical estimator that produced it. Otherwise two implementations can agree pictorially while disagreeing in the measurement that matters.

The pipeline should be written as an explicit sequence of transformations. At the physical boundary, the reader needs to know antenna or reference input, front-end selection, gain and attenuation, frequency-conversion state, analogue and digital filtering, and clock conditions. At the digital boundary, the reader needs sample datatype, scaling and rate, I/Q ordering, missing-data treatment, tuning and decimation. At the analysis boundary, the reader needs the transform length, window coefficients, coherent and noise-power normalisations, frame placement, overlap, averaging, detector decision rule and any interpolation or rescaling. At the display boundary, the reader needs colour limits, logarithmic conversion, clipping and pixel aggregation. All four layers can influence a figure, yet only some determine the underlying scientific statistic.

For a first hypothetical calculation, take an uninterrupted complex sample stream at a nominal rate of eight million samples per second and a

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transform length of eight thousand samples. The unwindowed nominal spacing between adjacent discrete Fourier-transform frequency bins is one thousand hertz, calculated by dividing eight million by eight thousand. That number is a bin spacing, not automatically the minimum resolvable separation between two real emissions; effective resolution depends on the window and estimator, signal conditions and criterion of distinguishability. A report that simply labels the display as one-kilohertz resolution without identifying the window and measurement concept invites a false comparison with another laboratory.

A second calculation concerns frame cadence. If a transform uses 8,000 samples and a 50 per cent overlap, each successive frame begins 4,000 samples after the previous one, giving a nominal step of one half-millisecond at eight million samples per second. The window's support still spans one millisecond. The apparent time granularity of the waterfall is thus not the duration of an instantaneous event and cannot independently justify a half-millisecond onset precision. A different overlap can make the image denser without adding independent RF information. The examiner must record frame boundaries, time origin and how events crossing boundaries are handled.

Window choice requires equally careful language. A rectangular window, a Hann window and other tapers distribute leakage differently and have different equivalent noise bandwidths and amplitude responses. One cannot compare the raw heights of their spectral bins without stating the normalisation and the question being asked. A narrow sinusoidal component, an impulsive event and a diffuse noise process respond differently to changes in window shape, frame length and averaging. If the

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investigator changes a window while retaining the same data and observes a different colour patch, the change is not evidence that the external transmitter altered itself. It is an alteration of the estimator and representation. This may be the central issue in a disputed measurement.

Another difficulty is the measurement reference plane. Raw ADC counts are not automatically calibrated field strength or input power. The analysis needs the relevant gain state, attenuation, analogue bandwidth, any instrument-supplied calibration and the convention used to transform sample magnitude into engineering units. A logarithmic display must define whether it depicts power, amplitude or a density normalised per hertz. A difference of ten decibels in a graphic may emerge from a changed processing gain or reference convention, not from a real difference in the electromagnetic environment. If the measurement is relative to a local noise floor, the estimation of that floor and any exclusions must be reproducible.

Time coverage should also be explicit. A scanning receiver may observe one frequency interval while another is unobserved; an empty pixel in the display need not represent measured silence. Missing or invalid sample regions, buffer overflow flags, dropped frames and tuning transitions require masks or status records that prevent the software from converting absence of observation into a negative finding. If two analysts use different policies for filling gaps, one may display a visually smooth trace and another a conspicuous blank. Those displays cannot be compared meaningfully without the underlying time-coverage record. The report should mark observed, inferred, excluded and unobserved regions distinctly.

I propose an experiment in which independent investigators receive the same controlled and lawfully acquired sample file but different

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reconstruction manifests. The complete-manifest group receives every processing parameter and calibration reference. Other groups each lack one parameter chosen in advance, such as sample rate, window, overlap, detector or display scale. Their task is to reproduce a numerical finding, not to imitate a colour image. Record the distribution of their frequency estimates, detection decisions, timing boundaries and confidence statements; then reveal the omitted parameter and repeat. The important observation will be whether uncertainty or disagreement increases in a manner consistent with the parameter's scientific role. Any apparent agreement achieved by undocumented default settings should be identified as such.

The resulting evidential record should comprise an immutable original-data reference; a versioned machine-readable processing recipe; the tested analysis software and implementation; calibration and clock evidence; gap and validity records; the numeric results before display rendering; the plotting configuration; and a concise statement of alternative interpretations. Reproducibility is not achieved merely because someone can reopen a saved picture. It is achieved when a competent independent examiner can begin with the recorded, lawfully available inputs and reconstruct the actual claimed measurement, its limits and its uncertainty. I would ask my colleagues to challenge each boundary and to identify where the same waveform can support divergent but internally repeatable displays.

Donald Watts Davies, Peer Question: Professor Dijkstra, an independent examiner may have the same continuous complex sample record and a reliable digest, but still be unaware of the original receiver's decimation

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chain and local-oscillator configuration. Suppose the graphical programme accepts a nominal sample rate and centre frequency from an operator rather than the acquisition metadata. A beautiful waterfall then appears, with a narrow ridge in the expected place, yet the declared frequency axis may be wrong. Should an examiner report this as a failure of computational reproducibility, a failure of acquisition description, or a failure of evidential interpretation? I am particularly interested in whether you would demand a separate control which is independent of the software that generates the picture. A programme may be perfectly deterministic and still reproduce a mistaken conclusion on every computer. How should the laboratory draw its acceptance boundary and make that boundary intelligible to a second analyst who never handled the original receiver?

Edsger Wybe Dijkstra, Response: Mr. Davies, a deterministic computation and an accurate scientific assertion are separate propositions, and neither should borrow the other's authority. One can reproduce an incorrect frequency scale indefinitely if both laboratories inherit the same invented sample-rate field. The proper experiment therefore begins by declaring the independent quantities that are controlled and the quantities that are reconstructed. Sample indices are countable properties of the byte interpretation. Sample rate is an acquisition claim, ordinarily traced to oscillator and decimator state. Centre frequency is a tuning claim, ordinarily supported by oscillator configuration and any measured offset. A plotter merely receives those assertions, and should not be permitted to make them true by printing them neatly.

I would write an explicit contract containing four classes of tests. First, a syntax test verifies that the data file, metadata fields and processing recipe

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can be parsed without an unstated convention. Secondly, an algorithmic test reruns the defined transforms and compares numerical results within specified floating-point tolerances. Thirdly, an acquisition-state test checks the recorded tuning, decimation and clock history against independent apparatus logs and known reference injections where available. Fourthly, an inference test asks whether the numerical findings actually support the stated conclusion. The first two tests concern computational reproducibility. The third concerns measurement traceability. The fourth concerns scientific justification. The distinction has practical consequences for error reports because repairing a file parser does not validate an oscillator.

A test vector can reveal a particular failure without involving an unknown emission. Insert, by authorised laboratory means, a known tone at a calibrated input reference plane and record the analogue and digital configuration alongside the file. Reconstruct the tone's bin offset from the recorded sample rate and discrete transform, then compare the stated RF frequency with the independent source. If the same pixels appear in two laboratories but the source differs from the declared centre frequency, the picture is reproducible while the RF assignment is not traceable. If the FFT results differ despite matching acquisition metadata, one investigates the window coefficients, numerical type, transform scaling and implementation. Each branch points to a different accountable defect.

The acceptance record must carry the word 'reproducible' only with a named object: the transformed sample vector, the estimated power-density values, the event decision, the absolute frequency assignment or the displayed image. It must also state the governing tolerance. Exact equality of floating-point output is not always a sensible universal criterion, but the

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laboratory should still predict whether differences can alter the event decision. A numerical result that changes one part in a billion while remaining far from a threshold may be acceptable under a declared tolerance. A much smaller change beside a threshold may reverse classification. To conceal this distinction behind the aesthetic similarity of two waterfalls would be a software error translated into an evidential error. I return the token to the moderator for an independent challenge.

David Lennox Mills, Peer Question: Professor Dijkstra, your reconstruction contract includes a time axis, yet a waterfall may combine frame-centre sample times, computer-system timestamps and trigger times supplied by a host that has queued buffers. Even with an exact sample count, the absolute start of an RF event can be uncertain because the acquisition clock has an unknown offset, and the sampling frequency can drift while the file is written. Would you require the programme to separate the observed sample index from the claimed UTC time at every step? Moreover, if a scan receiver visited a channel for only a fraction of each second, how do we stop the presentation programme from drawing the unvisited interval as black or dark blue, silently making a no-observation gap resemble an absence of energy? I ask for a defensible rule that a software engineer could implement and an expert witness could explain without technical equivocation.

Edsger Wybe Dijkstra, Response: Dr. Mills, the time representation needs at least three independent coordinates: an integer sample index, a time elapsed according to the acquisition clock, and an asserted civil timestamp tied to a specified time reference. The first is a discrete index within a defined recording and is exact only when the record has no concealed sample gaps. The second follows from the sample rate and any known clock

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variation. The third requires a documented synchronisation chain and uncertainty statement. They are not interchangeable. A host file-creation time may lag the physical reception by buffering, processing and storage delays; it cannot safely substitute for the first valid ADC sample time without evidence.

Consider a hypothetical eight-million-sample-per-second recording with an uncertainty of two parts per million in its sample clock. Over ten seconds, the nominal count is eighty million samples. A two-part-per-million rate deviation corresponds to twenty microseconds of time-scale discrepancy over that interval, in addition to any initial time offset. This is not a claim about any particular receiver; it demonstrates why cumulative timing uncertainty must travel with time estimates. A sample offset of forty thousand samples corresponds to five milliseconds at the nominal rate, but its absolute UTC position also depends on the independent synchronisation and on whether earlier samples were dropped. A colour coordinate alone contains none of these facts.

I would implement observation masks as first-class data, not as plotting decorations. For each frequency-time region, the reconstruction must distinguish observed valid samples, observed samples excluded by overload or another quality rule, unobserved retuning or scan dwell, and regions generated by interpolation or graphical hold. A dark pixel is an intensity instruction; it is not a statement that the antenna observed zero radiation. A gap should remain explicitly absent from numeric occupancy denominators unless the scientific design justifies another treatment. When an event lies on the boundary between valid and missing data, the report should express

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a bounded onset interval rather than force a precise start time from an unavailable sample.

The programme should maintain the interval record through every conversion: from hardware packet counters to sample indices, from frame windows to time bins, from detector outputs to coloured pixels. It must not allow an averaging routine to smooth across a missing interval without recording the fact that it did so. An independent examiner can then challenge any particular cell by asking what samples, receiver states and transform settings produced it. If that provenance cannot be recovered, the disciplined answer is that the image is an illustration and not a fully reproducible evidential measurement. I pass the token to Professor Hopper to examine the implementation's record-keeping responsibilities.

Edsger Wybe Dijkstra, Cross-Peer Question to Grace Brewster Murray Hopper: Admiral Hopper, I respectfully pass the token to you because the engineering obstacle is not solely the mathematical specification. The receiver operator may believe that the application has saved its settings, while the application has in fact saved only those fields visible on the screen and has silently inherited defaults for window periodicity, logarithmic reference and decimation. The result can be a reproducible error hidden inside a nominally complete file. Which configuration values should have immutable experiment-level meaning, and which should be carried at each capture or processing segment? What would you do about a software upgrade that changes default FFT normalisation while retaining the same friendly name in the menu? I should also like you to confront the difficulty of using a public metadata vocabulary without pretending that its standard

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fields automatically preserve every instrument-specific feature necessary for a particular forensic inference.

Grace Brewster Murray Hopper, Cross-Peer Answer to Edsger Wybe Dijkstra: Professor Dijkstra, the problem is to make the computational recipe as inspectable as the measured data, while recognising that a dictionary of fields is not the same thing as a validated instrument history. I would require every processing action that can affect the reported result to have an explicit versioned value in the record. A menu choice such as 'Hann window' is insufficient if the implementation does not tell us whether the window is periodic or symmetric, how many coefficients were used, how they were normalised and which numeric precision the transform employed. A programme update must not reinterpret an old record by silently applying a new default. The recipe should identify the executable or independently reproducible algorithm version, not merely a graphical product name.

Some parameters belong to the acquisition record: sample type, sample rate, centre-frequency history, analogue gain, attenuation, antenna path, preselector, filtering, reference oscillator, calibration and intervals of invalid reception. Other parameters belong to each transformation: downconversion frequency, resampling ratio, filter coefficients, FFT length, taper, hop, averaging, estimator, thresholding, clipping and numeric units. Still others describe only presentation: palette, colour range, pixel interpolation, axis labels and output dimensions. An experiment may keep invariant values in a global record and put changing values in time-indexed capture or processing segments. A mixed design is acceptable only when the application resolves the effective value at each sample or frame without guesswork.

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The SigMF approach provides a useful vocabulary for sample datatype, sampling rate, capture segmentation and annotations, and it can use extension namespaces for specialised claims. Yet a compliant file is not thereby a complete metrology dossier. A laboratory using an unusual analogue preselector, a temperature-compensated oscillator or an external trigger will need extra documented fields and a validated mapping from hardware state into metadata. Unrecognised extension fields should not be discarded without warning by the second examiner. An internal validation programme should test the actual schema and reject incompatible versions or contradictory assignments. It is better to stop with an intelligible error than quietly draw a plausible but misleading picture.

I would also separate a captured run from an analysis run. A captured run can have several legitimately different waterfall analyses, each recorded as a distinct recipe linked to one source data object. One analysis may emphasise short impulses, another estimate stable power spectral density and another support a thresholded occupancy statistic. Their displays may differ, and all may be reproducible in their own terms. The important requirement is that the report name which analysis underpins each scientific conclusion, rather than treating the latest graphic as the only true picture of the recording. That preserves the audit trail while allowing a second laboratory to test whether a different estimator changes the conclusion. I accept the token with thanks and offer it back for the further discussion.

Dr. James M. Atkinson, Moderator: I thank Professor Dijkstra for separating a reproducible calculation from an accurate physical conclusion, and Admiral Hopper for explaining why the processing recipe is itself an evidential object. Admiral Hopper, please now develop the system-design

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question independently. What would a robust data architecture record if it were designed to survive changes of computer, operating system, FFT library and graphical interface while preserving the ability to challenge the original finding?

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Grace Brewster Murray Hopper, Second Principal Contributor: I would design the system around the experiment rather than the display. The visible waterfall is a derived presentation; its input consists of a particular acquisition record, a specified processing run and a set of rules for interpreting the numeric output. A file saved under the name of a popular application does not define those rules. One needs a stable description of the acquisition and a versioned description of every transformation. The relationship should be machine-checkable where possible, but a plain-language technical narrative remains indispensable for decisions such as why a chosen noise-floor interval was regarded as representative. A competent colleague should be able to reconstruct the same numbers without having to discover the operator's preferences by telephone.

The recorder and the spectrum estimator should keep separate state machines. The recorder has states such as tuned, settled, acquiring, overloaded, clock-unlocked, retuning and stopped. The estimator has states such as buffer assembled, window applied, transform completed, calibration applied, detection evaluated and rendered. When a tuner changes frequency, the data system must mark the transition in the acquisition timeline rather than carry forward the old centre-frequency label. When a detector changes threshold, that change is an analysis event rather than a new physical observation. The analyst may choose to reanalyse the same lawful samples with different thresholds, but must preserve the original run's decision record instead of replacing it in place. This separation is elementary software discipline with substantial forensic consequences.

A good configuration record needs an explicit field dictionary. Each value should have a type, unit, range, governing version, origin and allowed

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scope. Sampling rate in samples per second is not the same quantity as a display refresh rate in frames per second. FFT length is an integer count, overlap can be a count of samples or a fraction, and centre frequency is an asserted RF coordinate that may vary by capture segment. Gain in decibels should identify the reference and the analogue stage to which it applies; a gain slider without a device-state report is inadequate for power calibration. Detector mode must distinguish a decision over one frame from a decision over an averaged collection. The receiving and evaluating programmes should reject a missing field when no defensible default exists.

I would introduce a strict source-of-value hierarchy. A value read back from hardware has different evidential status from one typed by an operator, one inferred from a file name and one assumed by an analysis library. If hardware reports a sample rate of 7.68 million samples per second and the user chooses a display preset called '8 MHz', the record must preserve both facts and state which rate was used in calculating the frequency bins. It must not quietly substitute one for the other. A field may also have an uncertainty interval. The processing recipe should accept uncertainty as input when it affects a conclusion, rather than convert every metadata value into a false exact constant.

The durable format can use a standard sample-description vocabulary where suitable, with additional namespaces for controlled laboratory requirements. No universal standard can guarantee that every preselector, analogue filter or trigger condition has been captured. A schema validator will check that a field has an admissible shape; an equipment validation protocol must check that it correctly describes the receiver. I would version the schema and reject unrecognised changes that affect signal

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interpretation. An unknown annotation may be carried along without harm, but an unknown change to sample encoding cannot be ignored. Compatibility must be demonstrated by test vectors, not announced by changing a label in a menu. A practical migration report should identify which historic settings have been inferred and which remain unknown.

A second design principle is to store numeric results before rendering. The complex samples are not the waterfall matrix, and the waterfall matrix is not the bitmap. For each analysis run I would retain frequency-bin coordinates, time-frame coordinates, valid-data masks, estimated values with units, chosen statistical thresholds, calibration corrections and software identification. The graphic can then be regenerated with a different printer, colour palette or screen resolution while the underlying result remains stable. For a court or scientific review, this distinction avoids treating an eye-catching colour gradient as a calibrated number. It also allows automated checks that a reported peak really corresponds to the bin, time range and statistic described in the prose.

We should be careful with software libraries. Two Fourier-transform implementations can differ in their ordering, sign conventions, scaling, use of single or double precision, treatment of the last incomplete frame and degree of optimisation. They may agree on ordinary examples but diverge at edge cases or threshold boundaries. I would therefore retain small reference vectors with expected results for each processing release, including a complex sinusoid exactly at a bin centre, an off-bin sinusoid, white noise of known simulated variance, a clipped waveform and a buffer with a declared missing block. For every new version the test record should show whether computed statistics remain within predeclared tolerances.

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The tests must exercise the same path used for evidential reporting, not merely a convenient demonstration module.

A final principle is to make silence an explicit finding, not a default drawing operation. A recorder that did not observe a frequency-time cell cannot certify that the cell lacked energy. Neither can a detector that masked a saturated window call it clean. I would record the denominator of every occupancy estimate, consisting of valid observation intervals appropriate to the estimator. A graphical interface may make the distinction intuitive by separate masking and annotation, but the numeric data must carry the same meaning independently. A later reader may see only a monochrome printout, and still ought to understand which intervals were measured and which were absent from the experiment.

The finished archive need not duplicate sensitive content throughout the report. Its purpose is a controlled and lawful ability to reproduce the stated analytic finding. Data should be retained and disclosed within the authority, necessity and retention rules applicable to the work. A derivative set of numeric measurements and its processing recipe may suffice for some questions; other disputes may require tightly controlled access to original IQ samples. The record should make that distinction explicit. In either case the laboratory must distinguish a successful reopening of software from a successful scientific replication. I invite the peers to examine the transformations and the version history rather than the elegance of the interface.

Claude Elwood Shannon, Peer Question: Admiral Hopper, I welcome your separation of raw samples from the computed waterfall, but I would press the statistical content of the stored matrix. The same time-frequency

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arrangement can represent squared Fourier magnitude, a density estimate in units per hertz, a logarithm of amplitude, or a thresholded Boolean detection. A reader who sees a number without knowing which representation is present may draw the wrong comparison across frame sizes and windows. What exact contract should accompany each matrix, especially when changes in normalisation make the numerical values appear to rise or fall despite the same underlying time-series power? I also ask how you would prevent one programme from declaring a decibel value without identifying the power or amplitude reference. Can these questions be resolved by software schemas alone, or must they be established by a test of dimensional consistency across the entire measurement chain? Please identify a reproducible reference calculation for the stored numeric field.

Grace Brewster Murray Hopper, Response: Dr. Shannon, a matrix without a declared physical or statistical meaning is a collection of numbers in search of an interpretation. Each numeric result should identify its observable, unit, reference plane, normalisation and uncertainty assumptions. Squared-magnitude spectrum is not identical to spectral density. In a voltage-based calculation, a squared-amplitude spectrum may be expressed in volts squared whereas density is in volts squared per hertz, provided the input and scaling support those units. An instrument that reports input-referred power needs an additional calibrated transformation and an impedance or other appropriate reference. A logarithmic quantity should state whether the conversion uses ten times the base-ten logarithm of a power ratio or twenty times the logarithm of an amplitude ratio. The familiar decibel symbol alone cannot supply that missing definition.

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I would prevent accidental substitution by using dimensional types in the programme's intermediate representation. A quantity called density should carry its unit and not be silently compared with a dimensionless threshold. A time-frequency matrix may legitimately contain uncalibrated digital full-scale-relative values, but it must not call them received power at the antenna. The transformation from ADC count to voltage or power would need calibration values, analogue gain state and uncertainty; if those are absent, the software should say so. A test suite should deliberately change window length, scaling method and overlap, then compare invariant quantities under clearly specified conditions. A density estimate and an integrated band-power estimate are linked through an integration over frequency; they are not generally numerically identical bin by bin.

Consider a hypothetical processing programme whose estimated density is one microvolt squared per hertz in a frequency cell. Integrating a constant such density over a two-thousand-hertz band gives two thousand microvolt squared, which is 0.000000002 volt squared (2×10^{-9} V^2). If the programme draws the same density value as though it were a two-thousand-hertz integrated power, it makes a dimensional error of a factor of two thousand. This arithmetic example is synthetic and says nothing about a real antenna or calibration. Its purpose is to make the software's unit test unambiguous. A separate power conversion may also require a specified impedance, which must not be conjured by the plotting routine.

A schema can force a programmer to state the unit and method, but its assertions need substantive verification. Unit tests should feed precisely defined synthetic waveforms through both the original and independent reconstruction implementations, including noise-only and tone-plus-noise

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records. Metamorphic tests can change a presentation palette while checking that numeric outputs are unchanged, or change an expected normalisation and verify that differences follow the declared mathematical relationship. The laboratory must also record whether values are single-bin instantaneous estimates, windowed averages or post-detector products. To close the issue, an examiner should be able to choose any displayed cell and request the actual numeric statistic and the inputs from which it was computed. I return the question with a distinction between a validated contract and a merely well-formed data structure.

John von Neumann, Peer Question: Admiral Hopper, the architecture you propose may be independent of any one graphical application, but the execution platform itself can change floating-point results, particularly when computations are parallelised and summed in different orders. Suppose two laboratories agree on the mathematical FFT, averaging and threshold rules yet obtain small numerical differences because their processors round intermediate quantities differently. The differences may be harmless in the middle of an observed noise distribution but decisive when one cell lies on the detection threshold. Do you regard bit-for-bit numerical identity as necessary for reproducibility? If not, what test would distinguish an acceptable implementation difference from an unrecorded change in the measurement procedure? I should also like you to consider the case in which a software update changes the method used to estimate the local background, since a reported signal-to-noise excess can be altered without any modification to the sample stream or its spectrum.

Grace Brewster Murray Hopper, Response: Professor von Neumann, reproducibility must specify an equivalence relation appropriate to the

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scientific claim. For exact integer operations and controlled byte transformations, exact agreement may be practical. For floating-point computations across different machines, the correct requirement is often a predeclared tolerance established by numerical analysis and verified test vectors. That tolerance may be expressed in absolute units, relative units, or an uncertainty interval, depending upon the statistic. It must not be widened after the experiment merely to make two results agree. The acceptance record should include the arithmetic precision, rounding assumptions, library and algorithm versions, and any order-dependent reductions that materially affect the output.

An independently coded reference calculation is valuable where the stakes justify it. One implementation can compute the FFT and band statistics through the production pipeline, while another uses a tested independent numerical route. Agreement within a reasoned tolerance can expose implementation defects that a screenshot comparison would miss. Yet a comparison of algorithms is not a calibration of the RF input. If the analogue front end was overloaded, both programmes may produce perfectly matching results from distorted samples. If an event's detection statistic is so close to the threshold that floating-point variation changes the decision, the defensible outcome is a marginal or unresolved classification, with the numerical range disclosed. An examiner should not hide that instability by choosing the more favourable machine.

Background estimation is a separate, versioned analytic operation. A rolling median, a long-term mean and a quantile estimator can produce different local reference levels from the same spectral data, particularly in the presence of bursts or persistent occupied channels. Each requires a window

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of observations, exclusion policy, treatment of missing frames and specification of the population to which it applies. The stored numeric finding must therefore identify not only the spectral estimator but the noise-floor estimator and detection rule. An upgrade that changes the quantile definition, frame weighting or exclusion mask is a new analysis recipe even if the interface still presents the same word 'automatic'. The investigator can run both recipes and study sensitivity, but may not erase the earlier one.

Finally, numerical acceptance should be tied to evidential consequences. If two methods disagree by 0.01 dB about a spectrum that lies 12 dB above a threshold, a predefined tolerance may make the difference immaterial. If they disagree by 0.01 dB about a result placed exactly at that threshold, the final Boolean decision may not be stable at all. The record should preserve the continuous statistic, the threshold, the margin and the uncertainty, so that the reader can judge the sensitivity independently. Software engineering is successful here when the calculation becomes inspectable enough to reveal a fragile inference rather than concealing the fragility beneath a bright colour. I respectfully return the token.

Grace Brewster Murray Hopper, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, I pass the token with respect to your expertise in quantitative information and engineering practice. We have described a versioned software recipe, but a laboratory may still believe that its spectral 'resolution' is exactly the spacing between FFT bins, or that adding more overlapping windows creates new independent measurements. Please explain how frame size, window equivalent noise bandwidth, coherent gain, overlap and post-estimation averaging should enter a reproducibility declaration. I should like you to distinguish errors in dimensional arithmetic

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from errors in interpretation, and to show why the same waveform can yield different apparent peak heights under legitimate yet differently normalised transforms. Finally, what would you put into the experiment that could reveal a setting which seems innocuous to a programmer but is essential to the scientific conclusion? I would welcome a test involving the same coherent tone and the same broadband noise under the two windows.

Richard Wesley Hamming, Cross-Peer Answer to Grace Brewster Murray Hopper: Admiral Hopper, bin spacing is a geometric property of the discrete transform's frequency grid: the sample rate divided by the transform length. The resolving capability of an estimator has a more complicated relationship to the taper, observation duration, signal-to-noise conditions and definition of what it means to distinguish two components. I would therefore record both the grid spacing and the actual window and estimator settings. The phrase 'one-kilohertz resolution' might be used colloquially, but it is ambiguous unless the report identifies whether it describes transform-bin spacing, noise bandwidth, filter response or a validated discrimination criterion. This is an interpretive defect before it becomes a software defect.

A window changes how a finite sequence represents the hypothetical infinite waveform. Its coherent gain matters for recovering a bin-centred sinusoidal amplitude, while the sum of squared coefficients enters noise-power normalisation. Equivalent noise bandwidth states how the chosen window aggregates broadband noise relative to a rectangular reference under a particular convention. An FFT implementation that divides by the window length where another divides by its coefficient sum can change the displayed peak while leaving the original signal unchanged. Zero-padding can make the plotted frequency grid denser but does not create

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independent observational time. Overlap can increase the cadence of frames and smooth the display without adding independent RF samples to the record. These distinctions belong in the reconstruction recipe, not as optional commentary after publication.

A useful controlled experiment would provide a fixed synthetic record containing a coherent sinusoid, an off-bin sinusoid, stationary noise and a brief pulse, with all component amplitudes known. Each laboratory would process the same record with a prescribed rectangular window, then a Hann window, and with several overlap fractions. The required outputs would include bin spacing, equivalent noise bandwidth, calibrated tone amplitude under the declared convention, a density estimate, and event onset intervals. A detector should be challenged near its threshold by varying only the processing parameter under test. The comparison should predict some changes, such as leakage suppression or time averaging, while rejecting others, such as a fictitious power increase caused solely by a new palette.

I would make every claim traceable to a calculation with variables and units. If a transform length is eight thousand at eight million samples per second, the grid increment is one thousand hertz, and a 50 per cent overlap advances four thousand samples or half a millisecond. These simple calculations can be checked independently. They do not determine whether a real narrowband emitter was present or what its precise occupied bandwidth was. The decisive point is to distinguish mathematical consistency, metrological calibration and inferential validity. I thank you for the question and return the token to the moderator so that the roundtable may examine numerical error and uncertainty in greater depth.

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Dr. James M. Atkinson, Moderator: I thank Admiral Hopper and Dr. Hamming. Dr. Hamming, please now distinguish the frequency spacing chosen by an FFT, the noise bandwidth imposed by its window and the temporal information contained in overlapping frames. In particular, identify the assumptions that are necessary before a signal-to-noise excess in a waterfall can be interpreted as reproducible measurement rather than a numerical convention.

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Richard Wesley Hamming, Third Principal Contributor: The first task is to count observations honestly. A complex sequence at a specified sample rate provides a definite number of samples over a definite nominal duration. The transform partitions or overlaps that sequence according to a processing decision. These operations can represent the same information in different ways, but they do not enlarge the independent observational record. A display that shows a thousand closely spaced time rows may be based on frames with 95 per cent overlap, so that adjacent rows reuse nearly all their samples. That is useful for visual continuity but changes the correlation structure of adjacent estimates. No statistical assertion about independent detection opportunities should simply multiply the row count by the presumed per-row false-alarm probability.

Let the nominal complex sampling frequency be eight million samples per second and let the FFT length be eight thousand. The frequency-bin separation is one thousand hertz. The time span of one frame is one millisecond. If the hop is two thousand samples, the overlap is six thousand of eight thousand samples, or 75 per cent, and the frame-start cadence is one quarter millisecond. A report that says it has acquired four independent observations per millisecond would be wrong. The additional display rows help locate patterns under certain conditions, but overlap produces dependence and changes the effective number of degrees of freedom available for a statistical estimate. The actual dependence also depends on the selected taper and underlying signal process.

Window functions present a second problem. A rectangular window has comparatively narrow main-lobe properties but troublesome side-lobe leakage for components not landing on an exact transform grid location. A

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Hann taper reduces leakage by suppressing the endpoints, but changes the main-lobe width and noise bandwidth. For a sufficiently long periodic Hann window, the commonly used equivalent-noise-bandwidth factor is 1.5 times the FFT-bin spacing. Under our one-kilohertz spacing, that is nominally fifteen hundred hertz. The exact finite-window expression depends on the coefficients used, so an implementation must record its coefficient convention rather than quote the factor as a universal exact identity for every window definition. A calculated noise bandwidth does not by itself measure the receiver's entire analogue passband.

Equivalent noise bandwidth can be written as sampling frequency multiplied by the sum of squared window coefficients, divided by the square of their sum, where the window sum is nonzero. Both sums must be calculated from the coefficients actually used. The ratio connects the window to the noise-power scale; it must not be confused with the bin spacing. For a bin-centred coherent tone, the coherent amplitude factor involves the sum of window coefficients, and a different normalisation may be needed. In density estimation, the desired units also govern the scaling. A careless switch from spectrum to spectral density can change the plotted numeric level without any altered input signal. We should preserve a unit label with every result array.

Consider a separate hypothetical FFT at a nominal two million samples per second with four thousand points. Its bin separation is five hundred hertz. Using a periodic Hann taper gives a nominal equivalent noise bandwidth of seven hundred and fifty hertz. If the analyst instead assumes five hundred hertz as the noise-equivalent measurement bandwidth, the estimated broadband noise power associated with a bin can be misdescribed, even

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though the transform still has five-hundred-hertz grid steps. Neither number authorises a claim that two emissions exactly five hundred hertz apart can always be discriminated. Their relative amplitudes, frequency offsets, phase variation, noise conditions and estimator all matter. Such qualifications are essential in a disputed classification.

Power scaling requires a controlled reference. If an FFT is calculated on ADC full-scale-normalised complex numbers, a result may describe relative digital power. To infer power at an RF input connector, one needs the receiver's gain and calibration history, known nonlinear limitations, losses and reference plane. A ten-decibel attenuation setting can change the ADC amplitude produced by a fixed input. An analysis that treats different gain states as though they were equal may produce a coherent-looking but false comparison across survey intervals. Conversely, applying correction values outside their calibrated range can be just as misleading. A waterfall's colour limits are not a substitute for instrument amplitude traceability.

I would insist that every spectral quantity be computed before logarithmic conversion and preserve the linear estimate as well as the displayed quantity. Averaging decibel values is generally not equivalent to taking ten times the logarithm of the average linear power. This matters for intermittent events because the average of sporadic high-energy frames can differ substantially from the average of their logged values. The programme must say whether it averages complex voltages, magnitudes, powers, log-powers or threshold decisions. It must also say whether the detector uses peak hold, mean, median, quantile or another reduction across time and frequency. What is sometimes called 'smoothing' can change the statistic under test rather than merely remove the jagged appearance of a plot.

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A laboratory experiment should use controlled reference records to test each transformation individually. Begin with a stationary noise sequence of known simulated statistics, add a coherent tone at a chosen bin offset, add an off-bin tone, then superpose a short pulse whose onset is known from the simulation. Reconstruct with prescribed FFT lengths and windows. Compare the continuous spectral estimates and declared event timings; do not grade the exercise by asking which picture looks more convincing. Repeat the same exercise with a real authorised test source at a traceable reference plane, and distinguish the additional uncertainty introduced by analogue instrumentation. The digital experiment tests processing. The physical experiment tests the combined chain.

No numerical test can replace the analyst's statement of what was actually observed. In a scanned spectrum, a threshold may be exceeded during one dwell and unknowable between dwells. In a continuous receiver, a short event may be diluted by a long averaging window, while a narrow transient may be broadened by the time-frequency trade-off. It is legitimate to choose processing that emphasises one scientific question over another. The trouble begins when the report presents a processing choice as a property of the external source. A sound reconstruction manifest makes the choice visible, and a sound interpretation acknowledges alternative choices that could change the result.

In conclusion, I would require as a minimum the acquisition sampling and frequency state, window sequence, transform size, hop, normalisation, detector, averaging, masks, calibration and software implementation. I would require a calculation sheet describing bin spacing, window noise bandwidth and frame cadence. I would distinguish nominal from calibrated

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values and preserve relevant uncertainty. A second examiner should be able to obtain the same scientific estimate using a written recipe, and to know exactly which part is a mathematical identity and which part remains an inference about RF energy. That, rather than a faithfully reproduced colour image, is the practical standard.

Sir Ronald Aylmer Fisher, Peer Question: Dr. Hamming, your admonition about overlap is relevant to inference. A waterfall may show numerous repeated detections, but the frames are strongly dependent because their windows share samples and their backgrounds may be correlated. Investigators sometimes use the count of red cells as if it were a count of independent trials, then calculate a very small probability that an event could arise from noise. How would you require them to justify a false-alarm probability when the threshold itself was selected after examining the same recording? Please address the difference between a prespecified detector and a search through thousands of correlated frequency-time cells, and explain why a bright-looking cluster is not an independent replication of its constituent pixels. An examiner needs a workable sensitivity analysis rather than a promise that the software has performed a mysterious significance calculation. I ask also that uncertainty in the effective trial count be stated, rather than disguised as an exact probability.

Richard Wesley Hamming, Response: Sir Ronald, the apparent abundance of observations is not a warrant for multiplying probabilities as though every cell had been sampled independently. If adjacent FFT frames share three quarters of their input samples, their noise fluctuations will generally be correlated, with the precise correlation influenced by the window and the underlying random process. Frequency bins may also be correlated because

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of window leakage and filtering, and successive scans may revisit an environment whose noise statistics are not stationary. A per-cell false-alarm rate calibrated under one condition therefore cannot simply be exponentiated using the number of colourful cells on the screen. The data-processing record must state the detector rule and the population over which it was evaluated.

Threshold selection must be distinguished from evaluation. If an investigator sees a bright patch, adjusts the colour limits and then chooses a threshold designed to retain that patch, the resulting significance cannot be interpreted as the outcome of a fully prespecified test. There may still be a descriptive finding worth reporting, but inferential calibration requires an independent or appropriately corrected evaluation. A defensible laboratory can preregister the detector, use independent noise-only intervals or a separate validation record, and simulate the entire search procedure under a stated null model. That procedure should preserve the actual overlap, windowing, background estimation and multiple comparisons in its false-alarm calculation. Merely matching the nominal one-cell threshold distribution is insufficient if the search behaves differently.

A second experiment should vary hop, frame length and noise-floor estimation while retaining the same simulated process. The apparent number of detections may rise or fall because the sampling grid changes, not because the simulated source becomes more or less probable. Instead of boasting of twenty red cells, the report might state that one contiguous threshold excursion was seen in a particular observed interval, under a specified method, with an empirically determined probability of false alarm for the whole decision procedure. That statement still depends on the

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realism of the null model and the quality of the calibration record. Where assumptions fail, it should be described as a sensitivity result rather than a universal certainty.

I would keep the full continuous detection statistics and describe their dependence. For event onset, one can examine the range of estimated boundaries obtained under defensible window placements and thresholds. For a frequency estimate, one can compare peaks across windows and record whether the result moves within the expected leakage pattern. The investigator should not count highly overlapping windows as independent witnesses, nor should a false-alarm estimate be more precise than the evidence permits. The method is reproducible when an independent examiner can rerun the complete search including threshold selection and receive compatible results; its inferential strength must then be argued separately. I return the token with gratitude for the statistical challenge.

Richard Wesley Hamming, Cross-Peer Question to Alan Mathison Turing: Mr. Turing, I pass the token to you because a reproducible waveform calculation also requires a reproducible programme. Suppose a laboratory states its FFT length, window name and sample rate correctly but leaves its handling of incomplete frames, NaN values and hardware sample gaps undocumented. Another implementation is permitted to pad, discard, interpolate or reorder the affected samples. Each implementation can be internally consistent, yet the waterfall event boundary and threshold can differ. How would you define a formal acceptance test that checks not merely whether two programmes produce output, but whether their internal states correspond to the same specified measurement? And how should we assess a software update that fixes a bug while rendering previously reported findings non-

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reproducible under the new version? Should a corrected report retain both outputs for forensic comparison and identify the precise change that altered the numerical decision?

Alan Mathison Turing, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, the essential requirement is to specify the computation as a mapping between explicit states, rather than to rely on the expectation that programmes with similar user interfaces must mean the same thing. The input state should include the sample values and their validity mask, sampling and tuning metadata, time-origin convention and exact processing parameters. The output state should include numeric estimates, coordinate arrays, quality flags and detection decisions. Every transformation should declare how it treats an incomplete frame, numerical overflow, missing complex component, invalid metadata or a time discontinuity. Two implementations can then be compared on the same test vectors, including those designed to expose the edge cases you mention.

The test plan should establish invariants. For instance, changing only the colour palette should never alter the stored spectral matrix or the detection decisions. Replacing an identical byte copy of the input should never alter the computation if all other inputs are fixed. Relabelling a timestamp without changing the sample indices should not move the sample-index coordinates, although it may change the displayed civil-time labels. A new missing-data mask should change which frames are admissible and must not be silently converted into zeros. Where the transform implementation is allowed to differ numerically, the accepted range should be set before testing. These invariants are stronger than requiring two screenshots to appear similar.

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A bug fix creates a version boundary, not an opportunity to rewrite history. The laboratory should retain the prior executable or an adequately specified reproducible implementation and the original processing recipe so that it can reproduce the historic reported result. It should then generate a second explicitly labelled analysis using the corrected software and compare the conclusions. If the change affects an evidential claim, the discrepancy needs an audit entry and an amended report rather than an invisible replacement. This is particularly important where a prior version mishandled frame boundaries or averaged dB values incorrectly. In such a case numerical reproducibility of the earlier result says nothing in its favour scientifically; the corrected result deserves separate scrutiny.

I would also make the software fail closed on critical unknowns. If sample-rate provenance is missing, the programme may generate a relative baseband plot for exploratory use, but it must not assign an absolute RF-frequency finding as though calibration were present. If a chunk contains unmarked invalid values, the system should flag the affected region rather than draw a smooth bridge. An acceptance suite should include negative tests proving that the programme refuses to create an apparently authoritative measurement from contradictory or insufficient inputs. The purpose is not to prevent legitimate exploration; it is to keep exploratory products explicitly separate from findings intended to withstand independent examination. I return the token for the consideration of formal reproducibility and evidential interpretation.

Dr. James M. Atkinson, Moderator: I thank Dr. Hamming and Mr. Turing for distinguishing the mathematical result, its implementation and the evidential claim. Mr. Turing, please now set out a reproducibility standard

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for independent laboratories. Address the difficulties of comparing different implementations, of preserving the precise decision rule and of documenting conditions under which a computation must refuse to report a definite RF finding.

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Alan Mathison Turing, Fourth Principal Contributor: I would organise the problem by asking what it means for two independent operations to implement the same experiment. If one asks only whether they draw similar images, one has selected a very weak test. If one asks whether they produce an identical binary file on different hardware, one may have selected a requirement stronger than scientific necessity. What matters is a specified relationship between inputs, computational steps and outputs, with observable tolerances appropriate to the decision. A reproducibility record should describe both the algorithm and the conditions in which it is valid. A processor's output is evidence of an algorithm's behaviour under those conditions; it is not, without further premises, evidence that the receiver's aerial witnessed an external event.

The measurement pipeline begins before the first instruction of the plotting application. A sample sequence may contain gaps, duplicate blocks or retuning intervals. Each of those conditions is a part of the input state, not an inconvenience to be repaired by the artist who draws the waterfall. A reconstructing laboratory should know whether the supplied samples represent one continuous stream, a concatenation of separate captures or a selected derivative. It should know the sample format, frequency history, clock uncertainty and state changes. If any of those are unknown, it should declare which conclusions can still be computed and which must be suspended. A relative spectral shape might remain analysable without an absolute frequency reference; an absolute RF attribution would not.

I would represent every analysis as a directed sequence of named operations. Ingest and parse the sample values under the declared datatype and byte order. Apply only the specified correction, downconversion,

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filtering or resampling operations, recording their parameters. Partition valid samples into frames under the stated window and hop. Apply the exact coefficient sequence and transform convention, then compute the selected spectrum or spectral-density statistic. Carry units and calibration through the result, estimate the reference background with a specified method, evaluate the detector and create the graphic from the numeric findings. A complete record should allow another implementation to replace any stage with an independently coded stage and compare the intermediate result.

One must preserve the source of each configuration value. A nominal sampling-rate field is an assertion about the recording. A separately measured oscillator offset is an observation with uncertainty. An FFT length is a processing choice. A colour range is a display choice. These may appear together in the same user interface, but their logical status differs. When a laboratory says its frequency estimate is accurate to a particular number of hertz, the claim should account for sampling-rate error, tuning-offset uncertainty, bin interpolation and signal conditions. The calculation cannot obtain absolute truth merely by carrying more decimal places through a fast transform. A setting whose uncertainty is unknown should remain a qualification, even if it makes the finished report less aesthetically persuasive.

I would use conformance vectors designed to fail for specific reasons. The first is a coherent complex tone at an exactly specified bin centre; it tests indexing, frequency sign and transform normalisation. The second is an off-bin tone; it tests leakage, window coefficients and amplitude correction. The third is simulated stationary noise; it tests the density convention and averaging. The fourth is a brief pulse crossing a frame boundary; it tests

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temporal labelling. The fifth is a stream with an explicit sample gap and retune event; it tests validity masks. The sixth has a deliberately inconsistent sample rate and timestamp; it tests whether the programme warns against an impossible interpretation. Each vector should have independently calculated expected properties and a record of numerical tolerance.

Missing data make the distinction between input and inference especially clear. A programme may choose to discard an incomplete frame, fill it with zeros or interpolate. Those operations have different consequences for energy and phase. If a valid interval contains no samples at a particular frequency because the receiver was retuning, a zero-filled image makes a logically false claim of observed quietness. An interpolation might be acceptable for a purely illustrative presentation, but it cannot become an unmarked observation in a report measuring occupancy or event duration. The validity mask should survive spectral estimation, detection and rendering. Otherwise a highly polished programme may erase the most important uncertainty in the experiment.

For thresholded findings I would preserve the continuous statistic before the decision. A binary detector output of 'present' cannot show whether the test statistic exceeded the threshold by a thousandfold or by a rounding increment. If two independent programmes disagree only for a few marginal frames, that fact is valuable; it need not be treated as a catastrophe or dismissed as rounding. We should report the statistic, threshold, margin, relevant measurement uncertainty and declared rule for ties. The rule must also specify whether the test searches across multiple bins and frames, whether background estimation used the same data, and

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how false-alarm claims were calibrated. This is a scientific decision protocol, not a matter of screen-colour preference.

Software provenance should be detailed enough to support independent reconstruction but not limited to a single proprietary executable. Retain version identifiers, configuration manifests, coefficient tables when necessary, test vectors and numerical outputs. When a source implementation is available, a reviewed source revision and build description improve inspectability. Where it is unavailable, independent conformance against a public mathematical specification and preserved reference outputs becomes more important. Operating systems, processor architectures and mathematical libraries can alter rounding or reduction order; those variations should be anticipated by tolerances that have been established through numerical reasoning, rather than excused after the fact. An unrecorded change in algorithm is not equivalent to an innocuous change in hardware architecture.

I would require at least one blind replication in which the second examiner sees the authorised data, the complete processing recipe and the acceptance criteria but not the original investigator's colourful screenshot. The second examiner should produce frequency and time arrays, numerical spectral values, valid-observation masks and detector decisions. A third party can then compare the results without visual suggestion. A second trial deliberately removes one setting at a time, and the laboratory records when the omission causes a material change or forces the calculation to stop. This assesses whether the identified configuration values are truly indispensable for the specific finding. It is more informative than asking ten operators to

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imitate a picture by adjusting sliders until their displays resemble one another.

The final acceptance should distinguish three outcomes: independent reproduction of a computation, independent validation of a calibrated measurement chain, and independent support for the particular conclusion. The first may be established with precise computational tests. The second requires instrumentation evidence and reference signals. The third requires an appropriate inference framework, uncertainty and evidence of observation. None entails the others automatically. A report should state which outcomes were achieved and which remain conditional. That separation is a protection for rigorous science as well as for the people whose conduct or security might be affected by a technical finding.

Jerzy Neyman, Peer Question: Mr. Turing, your proposal gives reproducible computations and a sensible approach to conformance vectors, but a numerical detector should also make its inferential operating characteristics explicit. Suppose the original analyst selected a threshold after searching a large waterfall, while the second examiner applies that threshold to the same samples and finds identical red cells. The computation is completely reproducible, yet an asserted one-in-a-million probability of a false positive may have no valid design basis. What should the reporting rule say about the sampling plan, multiplicity, background variability and decision threshold? In particular, how should the protocol treat unobserved scan intervals when estimating the fraction of time a signal occupied a channel? Does a reproducible occupancy percentage possess any useful scientific meaning if the denominator includes time during which the receiver was tuned somewhere else? I also ask you to state whether an observation mask

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must accompany the numeric occupancy statistic when data are exchanged between laboratories.

Alan Mathison Turing, Response: Professor Neyman, the detector must be defined as an experiment-wide procedure rather than a numerical predicate applied to one convenient pixel. A complete decision rule identifies how candidate regions were selected, how the reference distribution or background estimate was obtained, what threshold was chosen, which multiple comparisons were performed and what observation intervals were eligible. Rerunning the same threshold on the same file reproduces the original computation. It does not retrospectively turn a data-selected threshold into a prespecified statistical test. The independent examiner should therefore separate an exploratory finding from a validated false-alarm claim, even when the resulting plotted cells agree exactly.

For an occupancy estimate I would define the numerator and denominator in measured, valid time rather than graphic area. Suppose, illustratively, a channel is observed for four seconds during a nominal ten-second survey and is judged occupied for one second of those four valid seconds. The measured-dwell occupancy fraction is one divided by four, or 25 per cent. The fraction of the entire nominal survey interval during which observed occupancy can positively be established is one divided by ten, or 10 per cent, but that is not an estimate that the channel was quiet for the remaining six seconds. The difference arises because the data do not exist for the unobserved periods. An estimate of full-interval occupancy would require an explicit sampling design and assumptions about the omitted time, with uncertainty appropriate to those assumptions.

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Multiplicity should be handled at the level of the actual search. If a fixed per-cell detector is applied to thousands of highly correlated cells, an error probability cannot simply be transplanted from one isolated test. The laboratory may characterise the complete procedure with independent noise-only trials or simulations representing the selected windows, overlaps, channel variability and correlation. Where the method has been tuned after looking at the data, an independent validation set or a transparent adjustment is necessary before making a confirmatory probability claim. The reporting process should retain the full continuous statistics and decision thresholds, so that a reviewer can evaluate sensitivity when the assumptions are changed. Unknown error rates should be acknowledged as unknown, not assigned ceremonial zeros.

The numerical programme can enforce the distinction through separate result classes: an observed threshold crossing under a stated method, a calibrated detection decision with established operating characteristics, and an interpretative attribution requiring further evidence. For every class, the accepted input set and observation mask must be explicit. Reproducible output is a necessary virtue because it permits challenge. It is not a sufficient proof of an evidential proposition. The exercise therefore teaches both computer scientists and radio engineers to resist false confidence created by a stable display. I return the token to the moderator and invite the control theorist to examine the changing environment in which these estimates are made.

Alan Mathison Turing, Cross-Peer Question to Norbert Wiener: Professor Wiener, I respectfully pass the token to you. We have treated the waveform as a fixed archive, but a forensic receiver often observes a time-varying

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process in which gain control, interference, thermal drift and the statistical background can change within one recording. An analyst who uses a stationary-noise assumption throughout may produce a reproducible yet misleading detection threshold. How should the record describe the conditions in which a short-time spectral estimator is meaningful, and how can one compare alternate windows or averaging times without confusing the observer's changing filter with a changing emitter? I ask particularly whether temporal smoothing, automatic gain control and stationarity assumptions should be controlled as acquisition facts, processing choices or hypotheses to be tested, and how their differences should appear in the final uncertainty narrative. Please distinguish a sensor-state transition from a wholly digital smoothing operation, since their remedies and evidential consequences are different.

Norbert Wiener, Cross-Peer Answer to Alan Mathison Turing: Mr. Turing, a measurement process is a system with state and memory, and a waterfall is one description of its output. The receiver's automatic gain control may respond to earlier energy and alter the amplitude of later samples even when the external signal has not changed. An analogue filter may ring after an impulse, and a digital smoothing kernel may distribute one brief event across adjacent frames. Those are different mechanisms with superficially similar images. The acquisition record should identify active control loops, their settings and, where measurable, their state history. The analysis record should identify the subsequent filters and temporal averaging. A scientific hypothesis about environmental stationarity belongs to the inference rather than being silently embedded as an unquestionable property of the data.

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For a controlled experiment I would hold the known input source fixed while changing one receiver or analysis setting. A stationary synthesised carrier can expose a gain-control transient. A timed pulse can reveal analogue or digital filter memory. An authorised noise source with known statistical properties can test the estimator's response. A separate experiment can deliberately vary the input environment in a measured way, so that the programme's ability to distinguish real change from processing memory is challenged. This yields an identifiable set of controls. If one changes many settings at once, the resulting waterfall difference provides little evidence about which mechanism caused it. A well-designed comparison makes the signal process and the observer's response separately inspectable.

Noisy observations cannot always be divided into stationary and nonstationary pieces by a single unquestioned algorithm. The investigator should specify the local window over which the background statistics are estimated, any exclusions and the criteria used to detect a change in state. The effect of using shorter or longer estimation windows may be evaluated through sensitivity analysis. A fast detector may respond to an impulse but have higher variance; a long average may suppress variance while washing a brief pulse into the background. Both results can be reproducible because the algorithms are deterministic given the samples and settings. Neither becomes the uniquely correct description of the external world without reference to the scientific question and the receiver's measured behaviour.

I would therefore attach to the numerical result a state-aware validity account. It would identify periods of gain settling, overload, calibration transition, clock instability and missing reception. It would show whether the detector's noise reference was estimated locally or over a long period,

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whether thresholds adapt and whether adaptation was itself part of the prespecified test. A second examiner could then rerun the same estimator and challenge its premise under alternate credible settings. An uncertainty statement should report robust findings and fragile ones separately. The question is not whether one can reproduce a particular array of colours; it is whether the array supplies reliable evidence for the limited proposition being advanced. I return the token with thanks for the discipline of the question.

Dr. James M. Atkinson, Moderator: I thank Mr. Turing and Professor Wiener. Professor Wiener, please now develop the measurement's dynamic character. In particular, describe how a fixed recording may yield different apparent event boundaries when the processing window and estimator respond differently to transient noise, receiver control loops and changing signal conditions. Explain what an independent examiner should measure rather than merely observe in a coloured graph.

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Norbert Wiener, Fifth Principal Contributor: A short-time spectrum is a representation of a signal through an observer whose own operations have duration and memory. The finite window necessarily chooses a region of time, and averaging chooses how earlier observations influence later estimates. Analogue filters, receiver gain control and digital smoothing can also have memory. If a sudden bright patch appears in a waterfall, it may correspond to a genuine external change, a receiver control response, an estimator's smearing of a shorter event or a combination of them. The archive must therefore preserve information about the observer and its dynamic state. A repeated colour shape is not evidence of a repeated external source unless alternative mechanisms have been tested.

I would begin with the physical chain. An antenna feeds filters, amplifiers, converters and an ADC. Each stage has a passband and potentially a nonlinear operating region. A saturated amplifier may generate intermodulation products; a settling oscillator may move energy between adjacent frequency bins; a gain controller can change the apparent amplitude scale during a burst. The digitised samples are the output of that chain, not an unmediated photograph of the electromagnetic field. To reconstruct the numerical waterfall, one needs enough acquisition state to interpret the samples. To explain their physical origin, one needs independent controls that expose chain-generated artefacts. These tasks are related but should not be merged under the single word 'reproduce'.

A reproducibility record for a changing process should identify exactly when each setting was effective. A gain change at sample index ten million and a tuning transition at sample index twenty million are state changes that cannot be represented honestly by one global gain or frequency label if the

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same file contains both conditions. A processing recipe can specify piecewise intervals of valid calibration. A time-frequency cell whose analysis window straddles one of those changes may be invalid for a stationary-state interpretation, or it may need a more complicated model. A robust programme should flag the boundary rather than assign the entire frame to whichever state happened to be active at its midpoint.

The stationarity assumption deserves explicit examination. Many spectral estimators make useful calculations when a signal's statistics are approximately stable over the analysis interval. An industrial environment may contain periodic motors, electrical switching and short interference bursts whose properties vary over the course of the record. A background model estimated from the whole file may not describe each local interval. Conversely, an excessively short background window may follow the event itself and reduce its apparent contrast. The analyst should state the statistical population from which the background was obtained and why it is relevant to the event under examination. A colour scale that is automatically adjusted each second can hide a change in absolute level while preserving apparent visual contrast.

I would perform an experiment with a stable reference signal and two simulated noise conditions, one with steady variance and one with a controlled change halfway through the record. Apply an identical prescribed FFT but compare a fixed reference threshold, a local median-based background and a moving quantile estimator. Some discrepancies should be expected because the question asked by each detector differs. The fixed threshold answers whether energy exceeds one absolute criterion; the adaptive threshold answers whether energy is unusual relative to a locally

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estimated background. These are not logically equivalent claims. A report should label the corresponding results by their decision rule and retain the continuous statistic needed to understand the discrepancy.

Temporal smoothing must also be recorded with its impulse response or an adequately precise equivalent. Consider a hypothetical moving average over eight equally weighted successive waterfall frames. If one frame contains a short pulse and the other seven contain a lower background, its contribution to the average is diluted by a factor of eight in the linear-power domain when the simplifying assumptions apply. Expressed as a power ratio, that factor is approximately nine decibels because ten times the common logarithm of eight is about 9.03. This does not mean that the physical pulse lost energy; it means the displayed estimator distributed its influence across a longer support. One should not compute an onset duration from smoothed pixels without accounting for this response.

A second numerical distinction concerns clock error and time-frequency coordinates. If a nominal clock runs two parts per million fast, then a nominal ten-second sample count represents a time-scale difference of approximately twenty microseconds under the simple constant-rate model. The same fractional error shifts a nominal one-hundred-megahertz frequency assignment by two hundred hertz only when that frequency is derived from the affected oscillator in the stipulated way; an independent centre-frequency reference may behave differently. Thus the report must record which oscillator controls the ADC sample rate, which controls frequency conversion and whether they share a reference. One cannot apply one uncertainty figure indiscriminately to every frequency and timestamp in the receiver.

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In a surveyed spectrum, there are also intervals of non-observation. An instrument that visits a channel intermittently cannot establish every onset and cessation between visits. The reconstructed waterfall should preserve a coverage mask and separate the time coordinate of a measured dwell from interpolation or screen persistence. Suppose the receiver observed a channel for twenty milliseconds, then visited another channel for eighty milliseconds, repeating that cycle. One might describe a 20 per cent duty factor for observation of the first channel, but not a 20 per cent probability of intercept without specifying the event timing distribution, detector efficiency and scheduling assumptions. The same distinction prevents an attractive display from manufacturing evidence of continuous absence during unobserved intervals.

I would invite the independent laboratory to use two parallel outputs. One is a numeric time-frequency array with calibrated units where calibration exists, valid-data masks and a precisely defined detector. The other is a bounded interpretation describing what the array does not establish. These should be reviewed with intentional variation of frame length, taper, overlap, smoothing, gain assumptions and background estimation. If the conclusion is stable across a scientifically justified range, that stability can be stated. If the event disappears under modest plausible variations, the report should describe a method-sensitive indication, not an established emission. Such scrutiny is more valuable than a colourful plot whose palette exaggerates small numerical differences.

Finally, the archive should be designed for future challenge without presuming that all unknown signals can be identified. A lawful defensive RF survey may find an energy excursion, a spectral feature or an interval of

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increased occupancy. The recorded settings may permit another examiner to reproduce those findings. Attribution to a particular emitter or protocol is an additional proposition demanding independent evidence. Nothing in the reproducibility contract authorises interception of protected communications or unnecessary retention of content. The mature scientific result is a bounded statement that travels with its acquisition context, computational recipe, uncertainties and alternative explanations. I return the token to the moderator, with the hope that the reader will value an accurately described uncertainty over a deceptively beautiful certainty.

Abraham Wald, Peer Question: Professor Wiener, you have proposed sensitivity analysis across plausible estimation settings, yet repeated analyses can themselves encourage an investigator to choose the one producing the desired conclusion. Suppose several windows, detector thresholds and background estimators are defensible, but an event appears clearly only under one narrow combination. Should the laboratory report the most favourable result, the average across methods or the entire range? How can a decision procedure balance the risk of overlooking a genuine short-lived emission against the risk of making an unwarranted finding from receiver artefacts? I am particularly concerned with the separate costs of a missed detection and a false positive in a defensive survey, since the best operational decision may not be the same as the strongest scientific claim. Please identify what must be specified before data inspection and what should remain a transparent exploratory comparison afterward. I would also ask whether robustness across methods changes the evidential threshold for identifying an unknown emitter, as opposed to ordering further observation.

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Norbert Wiener, Response: Dr. Wald, sensitivity analysis should reveal dependence on a choice, not become a mechanism for selecting the most dramatic plot. A prespecified primary processing method and detector provide a transparent reference against which additional credible methods can be compared. If the event is visible only under a narrowly chosen combination, the report should say so and show the relevant numerical estimates and parameter range. Averaging incompatible methods is not automatically sensible, since they may estimate different observables with different units or temporal support. A better record contains the primary analysis, a documented collection of alternative analyses, and the reasons each was regarded as scientifically relevant. A reviewer can then inspect the robustness of the finding without being invited to treat every result as an equal vote.

Operational decisions and evidential conclusions must be separated. In a defensive survey, an indication with a high cost of being overlooked may justify a proportionate additional lawful inspection, even when its present evidence is too weak to support attribution or accusation. That is a decision made under asymmetric costs and uncertainty. It is not a licence to describe a tentative indication as a confirmed transmitter. A more stringent scientific report may require independent reference equipment, repeated observations under controlled gain states or known-source calibration before an attribution is made. The decision threshold for whether to investigate further and the threshold for whether to assert a finding are different quantities; each should be documented rather than concealed by one red pixel.

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Where possible the procedure should state in advance its primary detector, statistical reference set, threshold, window, hop, overlap and method for handling invalid data. An analyst may then explore alternate defensible settings, but should distinguish those explorations from confirmatory tests. If the primary detector was chosen only after seeing the record, that fact should be disclosed. A second independent or blinded recording can provide stronger confirmation than repeated transformations of the same samples, because the latter share the original acquisition errors and environmental contingencies. Sensitivity calculations are important, but cannot supply independent physical evidence merely by being numerous. The risk of false confidence grows when dozens of plots are treated as independent trials of one proposition.

A defensible final table would list each analysis recipe, its numeric outcome, measurement assumptions, uncertainty limitations and relation to the primary reported claim. It would also note conditions under which the receiver was unobserving, saturated or uncalibrated. If an event appears under every credible method but remains within a region where the analogue chain might have generated spurious products, the repeated computations strengthen reproducibility but not physical attribution. If an event is seen by independent calibrated receivers and consistent settings, the evidence can become stronger. This transparent architecture allows the laboratory to manage operational risk without inflating certainty. I therefore counsel that the waterfall be treated as an instrument of inquiry, not an oracle, and I respectfully return the token.

Dr. James M. Atkinson, Moderator: I thank the five principal contributors and the seven interrogating peers for their examination of the distinction

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between reconstructing pixels, reproducing numerical estimates and substantiating calibrated RF conclusions. The reciprocal challenges have examined software defaults, finite-window statistics, programme invariants and dynamic receiver state. The panel's conclusion is limited: a reproducible waterfall determination requires the source-data interpretation, receiver and clock configuration, processing recipe, validity mask, calibration references, numeric detector outputs and presentation settings to be recoverable, and the underlying physical inference must still be separately evaluated. The entire dialogue is a modern fictional scholarly reconstruction. No historical participant is represented as having spoken these words.

QUESTION 092. TECHNICAL SOURCE NOTES: SigMF, Signal Metadata Format, specification version 1.2.6, https://sigmf.org/; SigMF core sample metadata and capture segmentation, https://github.com/sigmf/SigMF; SciPy, scipy.signal.welch, density and spectrum scaling, overlap and averaging, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.welch.html; A. V. Oppenheim and R. W. Schafer, Discrete-Time Signal Processing, 3rd edition (2010), cited for historical DSP background, with specific source-to-claim verification still required before Stage B publication. These are background technical references, not evidence of an actual debate between the historical experts.

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corroboration, or misrepresentation of unobserved intervals as measured silence.

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QUESTION 093

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Which RF phase and transient findings become untestable after lossy sample compression?

Dr. James M. Atkinson, Moderator: Professor Lempel, I invite you to distinguish an encoding that permits exact recovery of each acquired complex sample from one that deliberately sacrifices information. A waveform archive may appear adequately preserved because its average spectrum resembles the original; yet an isolated phase discontinuity, a very brief transient or a weak component at the margin of detection may no longer be available for independent examination. Please construct a defensible rule for deciding which measurements remain testable from a derivative recording. This is fictional scholarly reconstruction, not a quotation or a report of an actual historical debate.

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Abraham Lempel, Principal Contributor: I would start by rejecting the proposition that compression is a single transformation with a single evidential consequence. A lossless compressor rearranges information in a reversible coding representation; provided its decoder and source format are faithfully specified and the process operates correctly, the original sample byte sequence can be recovered without numerical change. A lossy compressor instead maps multiple possible inputs to an identical reconstructed output, or introduces a bounded or statistical reconstruction error. The second operation cannot generally be inverted to determine exactly which source waveform was present. The fact that an error appears small under one average measure does not prove that a specific transient, phase feature or weak waveform component was preserved for a different scientific question. The archive must declare which kind of operation occurred before anyone attempts to argue from a derivative.

A complex baseband sample has both in-phase and quadrature components. Its amplitude is the magnitude of the complex number and its phase is the argument of that number, subject to conventions for unwrapping, near-zero magnitude and reference. A lossy process that perturbs either component can perturb both amplitude and phase; when the magnitude of the original is small, a seemingly modest Cartesian error may cause a comparatively large angular error. A phase-difference estimator, instantaneous-frequency calculation or weak-signal correlation therefore cannot be certified by a broad assertion that the average sample error was low. The reviewer should state precisely which observable was tested, its sensitivity to reconstruction errors and the regions of the record in which numerical instability makes the result unreliable.

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One can define an elementary quantiser by its input scale, step size, rounding rule, saturation limits and any dither process. Reducing a signed sample from a higher resolution to fewer retained levels can be reversible only in the trivial case where the discarded information was already redundant under the specified input restrictions. Otherwise different original values share the same output representation. An apparent loss of low-level noise or a smoothing of abrupt changes may be a property of the quantiser rather than of the source. If the quantiser saturates on a high-amplitude pulse, it can alter the pulse shape and add spectral components that were not present in the original. If a predictive compressor spreads error across adjacent samples or adapts its rate to background conditions, one must study the temporal structure of its residual as well as its mean-square size.

Suppose a hypothetical complex waveform contains an isolated short pulse and a much longer interval of quiet stationary noise. If an error statistic averages squared sample differences over a million samples, a distortion confined to ten pulse samples may contribute relatively little to that average even though those ten samples are exactly those needed to estimate rise time or onset. A codec chosen to optimise the global average may therefore preserve the overall spectrum while destroying the narrow question an examiner later needs to investigate. The problem is an interaction between the objective used to design the codec and the objective used to interpret the evidence. No universal compression score can establish adequacy for every unknown future analytic task.

The correct comparison is to retain a controlled source and test several derivatives against it, with each derivative identified by its algorithm,

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version, parameters and reconstruction details. One derivative can be produced by a demonstrably lossless codec. Another can impose known bit-depth reduction without dither. A third can use a controlled dither or error-bounded predictive method. A fourth can employ an aggressive method whose distortions are intentionally substantial. The examiner should compare not merely file size and aggregate reconstruction error but the uncertainty of predeclared outcomes: amplitude, phase, transient timing, short-time spectral estimates, and the stability of a detector near its threshold. There should also be cases with no true transient, so that codec-produced false features can be recognised.

The experiment should be blind wherever practicable. A second examiner might receive the reconstructed samples, the codec description and a declared battery of measurements, but not the identity of the compression setting or the original analyst's conclusions until results are registered. It can then be observed whether the examiner detects the intended synthetic pulse, estimates phase consistently, or falsely identifies a transient created by the codec. The same experiment should be repeated across a scientifically justified range of pulse amplitudes, widths and phase structures rather than one favourable test signal. Those trials can establish limited performance characteristics under laboratory conditions. They cannot certify that an unknown and untested waveform was preserved merely because a different one was.

Retention and privacy limitations are genuine constraints, not technical inconveniences to be wished away. A lawful investigation may have good reasons to minimise acquisition, storage or disclosure of raw communication-bearing samples. If only a lossy derivative is retained, the

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report should identify what was kept and which analyses are no longer possible, rather than imply that compression preserved unlimited forensic flexibility. Where a tightly controlled original is legitimately retained, derivatives should have their own identities and an auditable relationship to the protected source. A compact waterfall image may be adequate to illustrate a previously computed statistic, but it is not a substitute for the sample sequence needed to re-examine phase, modulation or short transients. The decision to preserve content is a legal and governance matter distinct from the mathematics of reversible coding.

I would finally insist upon calibrated humility. If a particular phase excursion is visible both in the controlled original and in a derivative, that is evidence of preservation in that test case. If it is absent from a derivative, the absence may reflect the source, the codec, the receiver or the analysis method. If the original no longer exists, one may not retrospectively determine which of these possibilities occurred. A scientifically useful report should therefore distinguish features demonstrably retained, features known to have been distorted, and features whose original status has become untestable. The last category is not a sign of an unsuccessful investigator. It is a necessary acknowledgement that information deliberately discarded cannot be recovered by eloquent interpretation or an attractive screen. I pass the token to the subsequent contributors for a more detailed examination of information limits, predictive coding and statistically controlled uncertainty.

David Lennox Mills, Peer Question: Professor Lempel, may I ask you to sharpen the distinction between preserving a phase record and preserving the trustworthy time axis against which phase change is calculated? Many laboratories describe a sample file as an unbroken sequence because a

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decoder returns the expected number of complex values. Yet those values may conceal a dropped transport frame, a discontinuous acquisition clock, or interpolation introduced by a reconstruction stage. Consider a pulse lasting only several samples and an investigator who seeks its timing relative to a second instrument. Which clock and transport records would be required before the compressed derivative could sustain that claim? In particular, would a file-level digest of the retained derivative, an average phase-error statistic, or a successful re-encode/decode cycle help distinguish a physical frequency slew from a one-sample timing discontinuity? Please specify how you would arrange a lawful laboratory comparison without implying that one accurate timestamp repairs an unknown number of missing samples. I pass the question to Professor Lempel in the expectation that he will address both the reversible and irreversible aspects of the problem.

Abraham Lempel, Response: Dr. Mills, a trustworthy sample count and a trustworthy time axis are different claims. A decoder may reproduce one million values exactly from its encoded representation while the original recorder omitted a transport block before those million values were assembled. If the recorder then filled the gap with zeros or interpolated values before a lossless compressor operated, a subsequent digest would faithfully protect the invented samples. The hash cannot distinguish an authentic acquisition from a false premise that was fixed into the file at its creation. We need an acquisition log that records sample-counter continuity, buffer overflow or underflow flags, hardware timing references, and the relation between an RF event and the recorded sample index. We also need to know whether the decoder introduces any resampling or concealment. A

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claimed sequence without gaps must be tested against a known reference before an examiner can rely on it as a continuous clocked record.

Suppose a nominal sampling rate is one million complex samples per second. A one-sample offset corresponds nominally to one microsecond, but that conversion assumes the sampling clock maintains the specified rate during the interval. If the receiver clock differs from the reference by ten parts per million, the accumulated error over one second can approach ten microseconds before accounting for additional uncertainties. These are simple hypothetical arithmetic illustrations, not measurements of any particular instrument. Two detectors may assign the same file-system creation time while observing the physical event at very different instants. The independent laboratory control should place a known pulse onto a reference channel and compare the captured sample counter, externally referenced time stamp, and host write time, leaving their distinct uncertainties visible. We ought also to test a deliberate dropped-block condition to see whether software flags, conceals or silently joins the adjacent data.

Compression creates an additional opportunity for confusion if its block size, predictor history or reconstruction delay is undocumented. A codec can preserve sample count while changing relative phase around a block seam. It can also introduce group delay, requiring a declared alignment convention before pulse onset is compared between records. A cyclic comparison based on spectral magnitude may miss both of those effects. Accordingly I would require a two-stage report: one stage verifies that a digital test vector passes through the codec with its declared time and phase errors; a separate stage verifies that the end-to-end receiver preserves the

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reference waveform and its timing within an instrument uncertainty budget. A verified digest of the encoded derivative then protects the outcome of those processes against undetected later alteration, but proves neither stage retroactively. If the original high-resolution samples were lawfully retained, one can inspect them when a timing anomaly arises. If they were discarded, the correct scientific conclusion is that some hypotheses about the original timing are no longer decidable from the surviving record.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor for distinguishing the evidence from its interpretation. I now invite Dr. Jacob Ziv to examine the next distinct limitation, preserving courteous transfer of the token and explicit disclosure of unresolved uncertainty.

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Jacob Ziv, Second Principal Contributor: Dr. Atkinson, I would distinguish the mathematical problem of describing a discrete sequence efficiently from the evidential problem of establishing which physical event the sequence represents. The original sequence may contain redundancies that permit exact recovery from a shorter description. That is the principle underlying a genuinely lossless code. A fixed bitstream, the decoding convention, and an executable decoder should recover precisely the same integer symbols in precisely the same order. Whether those symbols are correctly assigned to in-phase and quadrature channels is a separate format assertion. The test for bitwise reversibility is not that the spectrum looks similar or that a few selected sample values agree. It is that the complete decoded object equals its declared reference object under a documented byte-level comparison. If an archive includes headers that change with software versions, one must state whether equivalence concerns the entire file, the canonical sample payload, or the interpreted numerical series. Otherwise a legitimate container change may be mistaken for corruption and a dangerous change of interpretation may remain unnoticed under a matching payload digest.

A lossy operation introduces an information partition. Many different inputs lead to one encoded description and hence to the same reconstructed output. The size and form of the equivalence classes matter. If an examiner asks whether a faint phase step occurred at one particular sample, and both an input containing that step and an input without it map to an identical derivative, the answer cannot be deduced from the derivative alone. A claimed global bound on root-mean-square error changes this conclusion only if it implies a sufficiently strong local bound for the particular observable. The relevant counterexample need not be exotic. In a long

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recording, a one-sample excursion can occupy a negligible fraction of the total energy and yet determine the onset of an event. A rate controller that discards locally uncommon details may consequently produce highly plausible reconstructions with an evidential blind spot at the one moment the report needs to examine.

The information-theoretic distinction can be made precise without claiming that every scientific uncertainty is an entropy calculation. Let X denote the original finite sample sequence and Y the retained derivative. An exactly reversible deterministic encoding admits a decoder that reconstructs X from Y, with all necessary side information available. A many-to-one lossy mapping does not, in general, admit such a decoder over the declared input domain. The conditional uncertainty in X given Y depends on the assumed source model, and any estimate of that uncertainty is conditional upon the model being suitable. A high compression ratio by itself is no evidence of excessive damage, just as a modest ratio does not establish preservation. The sound inference must pass through a defined target observable: for example, pulse onset to within a specified interval, the sign of a phase increment, or the result of a pre-registered detection test.

A good controlled experiment begins with a synthetic or otherwise authorised reference waveform whose source samples are retained. Include a continuous carrier with an imposed phase step, a low-amplitude linear chirp, a sequence of short pulses with distinct widths, and intervals containing nothing beyond specified laboratory noise. Pass the same reference stream through several encoders, making every transformation and any dither seed reproducible. Record the exact output rate, the resulting byte count, algorithm version, codec settings, and reconstruction

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arithmetic. Then ask independent analysts to estimate time of onset, phase increment, and detected-event count without knowing which derivative they have received. A successful result means the predeclared task tolerances are met for the tested waveforms and settings, not that an unseen future waveform must also survive the operation. A failure can be localised by returning to the preserved source.

It is particularly important to compare reductions of sample width with transformations that redistribute error in time. A uniform mid-tread quantiser may create locally bounded errors away from clipping, although a deterministic quantisation pattern can be strongly correlated with the input. An adaptive predictor may instead produce small average error but temporarily larger residuals when a previously unanticipated burst arrives. A transform coder can allocate few bits to coefficients judged unimportant under its optimisation criterion. If that criterion is perceptual quality, ordinary image contrast, or long-term spectral energy, it need not align with the forensic objective of preserving a brief phase anomaly. The measurement protocol should therefore expose local maxima of error, burst-conditioned errors, and phase errors at low amplitude, alongside aggregate scores. Those quantities cannot be inferred from the advertised ratio alone.

Consider a hypothetical sequence of one million complex samples in which ten samples carry a transient whose significance is purely temporal. If the compressor changes those ten values substantially while reproducing the remainder exactly, the fraction of affected samples is ten divided by one million, or 0.001 percent. A very small global error rate could accompany complete loss of the transient's geometry. This is not evidence that a

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particular codec necessarily behaves in that way; it is a logical demonstration that a global average does not bound the worst local error. If the report needs a guarantee concerning that ten-sample event, it must use a method with an explicit suitable local guarantee or retain the relevant original samples under lawful conditions. Neither a smooth waterfall nor an apparently excellent correlation coefficient supplies the missing guarantee.

I would keep a three-level conclusion in the case record. First, the representation may be exactly reversible for the declared symbol stream, provided the implementation passes verification. Secondly, a lossy representation may be adequate for a stated observable on a stated signal class and within a measured tolerance. Thirdly, the retained data may be inadequate for some observations, including those not anticipated at the time of compression. The third classification is not a verdict upon the scientific merit of compression; it protects later investigators from treating a carefully optimised summary as if it were the original evidence. The presiding professional must also distinguish byte integrity from authenticity of acquisition. A digest proves no radio signal existed, and a beautifully reconstructed derivative cannot retroactively certify an analogue-to-digital converter that was overloaded before any codec received its input.

The documentation should identify the point in the acquisition chain where compression occurred. If the instrument reduced precision before recording, no laboratory archive contains the omitted ADC values. If a high-resolution source was retained and a compact working copy later produced, controlled re-examination can resolve ambiguities. If an operator retained only a display raster, even the relationship between pixel intensity and spectral power may be unknown. The chain of custody must specify each of

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these circumstances in its own terms. It must avoid the tempting language of an original when the supposed original is already a many-to-one derivative. I pass the token to Dr. Elias to consider how the representation code and the decision problem interact.

Alan Mathison Turing, Peer Question: Dr. Ziv, a statement that a codec is reversible often assumes more than the published algorithm. It presumes a specific source-byte ordering, deterministic implementation, preserved decoding tables, and a computer that obeys the asserted arithmetic conventions. Would you distinguish a proof about an abstract mapping from evidence that a particular implementation and file actually followed that mapping? Imagine the decoder applies a different signed-integer interpretation, silently swaps I and Q, or uses a newer floating-point rounding rule. A checksum over the compressed bytes could still agree perfectly even while the reconstructed signal used by the examiner differs. How should a competent laboratory specify and test the computational contract, including a record of software dependencies, so that a result is independently repeatable? Please explain why a diagram of an encoder cannot itself certify the executable machine, and which deliberately adverse test cases would most quickly expose a false assertion of lossless recovery.

Jacob Ziv, Response: Mr. Turing, the abstract and the implemented claims should be separately stated. One mathematical theorem may establish that a defined decoder is an inverse of a defined encoder over a specified alphabet. That theorem says nothing by itself about a faulty implementation, a truncated file, an incorrect endian assumption or a newly installed library that changes how metadata are interpreted. The laboratory needs reproducible test vectors that include sign changes, zero, full-scale

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values, alternating interleaved I and Q channels, and pathological symbol sequences rather than merely comfortable random examples. For a lossless claim, decoding the actual archived object and comparing it byte for byte with the protected source payload is an especially direct test, provided the reference object and comparison scope have been identified. Where the original is no longer retained, that test cannot be performed retrospectively, though a codec implementation can still be validated with independent reference vectors.

One must define the meaning of recovered. A stream of little-endian signed sixteen-bit integer pairs may have a perfectly stable byte sequence. If an examiner interprets those bytes as big-endian or exchanges channel order, the mathematical values and the resulting complex phase differ without any alteration in the file digest. A robust manifest must therefore record data type, signedness, word width, endian ordering, I/Q interleaving, numerical scaling, sample rate and valid-sample count. If the stream contains sentinel values or out-of-band validity masks, those must also be preserved. Decoder identity should include its version and relevant dependencies, ideally accompanied by known-answer vectors and a record of the machine environment. No single hash can demonstrate that the interpretation contract is true; the digest only assists in showing that a chosen object has not changed relative to a trusted reference.

Your distinction between abstract and actual machines is equally pertinent to floating-point transformations. If a decoder uses arithmetic that is not bit-exact across platforms, a claim of mathematically lossless numerical equivalence may be different from a claim of identical bytes. That difference must be made explicit. It is wrong to assume that an approximately equal

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spectrum proves exact source recovery. Independent comparisons should examine the full integer or floating-point arrays, selected complex-phase relationships and boundaries between encoded blocks. Tests should include damaged headers, missing trailing bytes, decoder state resets and corrupt internal tables, with the expected failure modes declared. If the implementation silently continues after malformed input, that behaviour is an evidential risk and should be reported as such. A good validation package documents not only positive round trips but negative tests designed to make the decoder refuse an unsupported record.

Finally, I would maintain provenance for the software itself. A source listing, compiler settings, executable digest, container dependencies and validation results describe different parts of the chain. A later expert may not be able to run an old binary on new hardware, so readable format documentation and independent test vectors are essential. Where a new decoder produces the same numbers under a separately established equivalence criterion, the laboratory may reasonably continue analysis, while recording that the software implementation changed. None of this solves the analogue-origin problem. An impeccable implementation can reproduce a sample record that was clipped, mistimed or fabricated before the encoder saw it. The archivist and the investigator must resist promoting an exact computational result into a claim of truth concerning the physical scene.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor for distinguishing the evidence from its interpretation. I now invite Dr. Peter Elias to examine the next distinct limitation, preserving courteous transfer of the token and explicit disclosure of unresolved uncertainty.

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Peter Elias, Third Principal Contributor: Dr. Atkinson, any compression policy designed for scientific records should begin by saying which proposition the eventual examiner must decide. A data coding objective minimises representation length under a specified source or distortion constraint; an inferential objective asks whether particular hypotheses can still be distinguished after the record is transformed. The two objectives can coincide, but coincidence must be demonstrated rather than presumed. A system that preserves a large fraction of energy may nevertheless alter the sign of a short phase increment. A system that gives excellent overall spectral agreement may create a transient in an otherwise quiet interval. In a forensic setting, the reported question often concerns a rare exception, not the characteristic behaviour of the average sample. This makes the choice of distortion criterion more consequential than the numerical compression ratio displayed by the operator.

Let the acquired complex sequence be x[n], and let the reconstructed sequence be y[n], with n indexing discrete samples. A simple distortion measure is the mean of the squared magnitudes of y[n] minus x[n]. That quantity has its uses, but it equally weights all sample positions and does not by itself identify a short region that contains the disputed event. One may instead inspect a maximum absolute error, errors restricted to declared burst intervals, changes in unwrapped phase increments, and changes in the output of a specified detector. Such metrics require definitions of the sample rate, timing reference, treatment of near-zero magnitude and phase unwrapping convention. The conclusion is sensitive to all those choices. If a result is presented as an error in degrees, the examiner must know whether

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that refers to absolute phase, differential phase, an aggregate circular statistic, or an estimated carrier phase after synchronisation.

Under small relative perturbations of a nonzero complex sample, the phase change is approximately the imaginary component of the relative error. That approximation is fragile near the origin of the complex plane. If the original magnitude is small, even a small absolute Cartesian reconstruction error can cause a large angular displacement. No amount of confidence in a global waveform signal-to-noise ratio resolves the instability at a sample where the phase is itself poorly determined. A rigorous study should either restrict phase claims to a declared amplitude regime or propagate the uncertainty of near-zero values into the result. An apparent rapid frequency excursion calculated from sample-to-sample phase differences can represent actual oscillator motion, thermal noise, low-amplitude instability or codec-induced noise. The derivative alone may not distinguish those explanations.

An acquisition chain also imposes limits before compression. Anti-alias filtering, automatic gain control, analogue clipping, ADC saturation, sample-rate conversion and dropped buffers can irreversibly alter the source record. The codec is one stage of a larger system, not the sole villain in every ambiguous measurement. A fair comparison therefore includes a verified digital source injected after the ADC to isolate codec behaviour, and separately a calibrated RF or analogue reference sent through the whole receiver chain. The first experiment asks whether the codec retains chosen digital features. The second asks whether the instrument and codec together retain those features under actual operating conditions. A difference between the two can be attributed only after examining the

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additional uncertainty sources, including frequency-reference accuracy and the loading of the receiver front end.

The easiest misleading result is the apparent absence of a pulse. If the original file has been destroyed and only the lossy derivative remains, the investigator cannot inspect the omitted detail. A detection algorithm that reports no event may be working exactly as specified on its input while remaining incapable of testing whether an event existed before compression. In such circumstances the report should state that no event meeting the declared criteria was detected in the preserved derivative, not that no event occurred at the original antenna. This is a distinction of logical scope, not a stylistic preference. The same caution applies to a positive result when a codec can manufacture ringing near a sharp transition. A detected feature should be challenged against a control input that is known not to contain it.

A test programme should vary amplitude, pulse duration, relative phase, carrier offset, noise statistics and compression setting independently where feasible. The examiner should measure false positive and missed detection frequencies using a declared ground-truth generator and an honest account of trial independence. The programme ought to include a family of rare events not used to tune the codec. Otherwise its favourable performance may simply reflect adaptation to the validation set. If the system employs trained models, the model file and its version become part of the analysis provenance. The training data's suitability is another question, and any claim of generalisation deserves an independent test rather than an appeal to a fashionable architecture. A compression setting which is safe for

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occupancy plots cannot simply be certified for phase-metrology applications.

I recommend that the archive attach a recoverability statement to every derivative. It should specify whether bitwise recovery is promised, whether there is a numerical error bound, or whether only statistical performance has been evaluated on a named signal class. It should also identify data outside the tested region, such as clipped bursts or events of duration shorter than the codec's analysis window. The specification must state what the test has not established. An examiner may then decide whether the preserved record is adequate for an authorised question. This approach is more respectful of scientific evidence than allowing broad words such as high fidelity or visually lossless to stand in place of an uncertainty budget.

Finally, preservation decisions are practical and legal decisions. There may be compelling reasons not to retain communication-bearing raw samples. A derived record can reduce exposure, storage cost and unnecessary content retention, but those benefits must be described without pretending that information destruction leaves every future question answerable. The institution should agree in advance which observations justify exceptional preservation, who may authorise it, how it is secured and when it must be erased. It should not use an ambitious theoretical wish for unlimited forensic re-analysis as an excuse for indiscriminate collection. Where only the derivative is lawful, the scientific inference is limited accordingly. My colleague Dr. Shannon can now address what mathematical theory allows us to state, and what it does not.

Richard Wesley Hamming, Peer Question: Dr. Elias, if a lossy recording remains the only preserved representation, what should an independent

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reviewer require before accepting the laboratory's assurance that weak transients were not materially affected? A report might announce a 60-decibel reconstruction signal-to-noise ratio, but the disputed signal could occupy a few samples or lie in a narrow phase trajectory. The average number is not obviously connected with the worst case. Would you recommend a predeclared detector, a maximum-error constraint, a pulse-conditioned error distribution, or some combination? I am especially concerned about false positives introduced by ringing and false negatives created by thresholds that were tuned on the compressed data itself. Please state how many independent test trials might be needed in principle, how their dependence must be handled, and why the absence of errors in a small validation set cannot logically establish a zero probability of error in untested conditions. I offer the question as a request for limits rather than a desire for an impressive assurance.

Peter Elias, Response: Dr. Hamming, I would first require a precise statement of the claim: for example, that a pulse of specified amplitude, duration and shape is detected with a stipulated probability under a named class of laboratory noise conditions, or that an onset estimate differs from the reference by no more than a defined tolerance. Reconstruction SNR alone is insufficient because it averages energy across samples and does not bind a sparse decision event. A predeclared set of test statistics should include maximum local sample error, phase-error distribution conditional on signal amplitude, edge timing error, and changes in the result of the detector actually intended for use. If the underlying claim concerns phase discontinuity, the test must operate on complex samples and must not

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substitute a magnitude-only plot. The design should contain known-absence controls because an encoder can create ringing that is mistaken for a pulse.

When a codec is tuned using the same examples later presented as verification, the resulting success is not an independent acceptance test. I would insist upon a disjoint validation set, preferably produced by independent personnel or an independently specified generator. The test grid should vary pulse width and carrier offset because a block transform may behave differently when a transient aligns with a window boundary. It should vary amplitude across a regime near the detection threshold, where a small additional error may reverse a binary decision. It should vary interferer power because a codec or receiver may adapt under overload or nonstationary inputs. Results should be tabulated with explicit denominators: number of trials, number of misses, number of false detections, and any repeated observations of the same underlying noise realisation. Twenty heavily overlapped windows from one burst are not twenty independent experiments simply because a software array contains twenty entries.

A deterministic maximum-error bound can support a stronger statement when the observable's sensitivity is known, but even that must be applied carefully. A small absolute complex error need not imply a small phase error where the original magnitude approaches zero. Likewise, a maximum error measured at the discrete sample instants does not automatically establish a bound on continuous-time reconstruction between those instants without a specified interpolation and bandwidth model. We must distinguish assumed theorems, measured instrument behaviour and empirical frequencies. With a finite sample of independent trials, observing no misses does not prove

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the true miss probability is zero. A confidence limit can be calculated for a declared model, but its reliability depends on the independence, representativeness and stability of the trials. The laboratory should report the actual count and the method rather than attach a confident adjective to a single convenient trace.

Where only a lossy derivative survives, the strongest honest conclusion is bounded by those prior tests. The reviewer may say that under specified laboratory conditions a named class of transients remained detectable at a given performance level. The reviewer cannot assert that an unanticipated microburst, an unusual modulation or a subtle phase excursion was necessarily preserved when neither the source nor an applicable guarantee remains. An engineering report gains credibility by making these boundaries visible. It should not punish the lawful minimisation of sensitive data, but it should never mask the consequent limits on what the evidence can now answer.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor for distinguishing the evidence from its interpretation. I now invite Dr. Claude E. Shannon to examine the next distinct limitation, preserving courteous transfer of the token and explicit disclosure of unresolved uncertainty.

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Claude Elwood Shannon, Fourth Principal Contributor: Dr. Atkinson, there is a seduction in asking one number to summarise the fidelity of a record. Rate-distortion theory establishes disciplined ways to examine how much description is needed under a chosen source distribution and chosen measure of distortion. It does not decree which measure of distortion is right for every scientific or legal purpose. If the measure assigns negligible penalty to destroying a rare transition, a rate-efficient code may lawfully satisfy the mathematical optimisation problem while failing the later examiner's evidential question. The difficulty is not that theory has failed; it is that an inappropriate problem was posed. Accordingly I would demand a plainly stated inference target before claiming that a lossy RF sample derivative is adequate.

Let R denote the average representation rate in bits per source symbol and D the allowable expected distortion under the stipulated probability model. A rate-distortion function describes a lower bound on achievable rate for that model and distortion criterion. It should not be confused with an empirical upper bound on worst-case phase error at every sample. A rare event may be assigned little probability by the model and therefore little influence on expected distortion. When an investigator asks about precisely such an event, the model's treatment of rarity becomes central. If the physical environment changes or an adversarially chosen burst appears, conclusions drawn under the training distribution may be unhelpful. The best scientific practice is to state the assumptions and design additional tests at the boundaries where those assumptions might fail.

A complex RF representation is particularly liable to misconceived analogies with pictures and sound. A human observer may not perceive a small

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alteration of a coloured waterfall; an algorithm may nevertheless depend on the exact phase relation between adjacent I and Q samples. A magnitude-only spectrogram loses absolute complex phase even without a lossy image codec. Any later conversion to a compressed graphic is another transformation and cannot recreate information already discarded by the power-spectrum operation. Two sample sequences with different phases can produce matching magnitude spectra under relevant constructions. Therefore equal-looking images are not proof of equivalent complex recordings. Conversely, a display palette can exaggerate a harmless small spectral difference until two equivalent numeric results look strikingly unlike one another. An archive must make clear whether it preserves samples, summary statistics or presentation pixels.

We can construct a hypothetical counterexample involving one million samples. Let the original sequence be zero except for a single nonzero sample and let the derivative be all zero. The sample-domain mean square error equals the squared magnitude of that sample divided by one million. Its numerical value can be very small if the sample amplitude is normalised, yet a detector whose only task is to answer whether that single impulse occurred has lost all decisive evidence. The point is not to recommend such a source model as realistic RF engineering; it is to establish that average error alone cannot bound every decision error. When claims concern a short event, either an appropriate task-specific criterion or a local maximum-error bound is needed. A reviewer should ask whether the guarantee is deterministic, probabilistic or merely observed on a finite test set.

At high amplitudes the issue may be quite different. If an aggressive quantiser saturates near full scale, a pulse's peak and leading edge can

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flatten. That clipping can generate out-of-band spectral content and alter measured rise time. If the compressor applies an analysis window, it can spread an abrupt change across neighbouring output samples. A reported precursor may then be ringing, and a reported absence may reflect the filter's transient response. These effects deserve controlled negative and positive tests, including known absence cases. A false alarm attributable to reconstruction is neither evidence of a real emission nor proof that the receiver is defective. It indicates that the transformation must be included in the causal account of the measured waveform.

One should also distinguish reconstruction accuracy from identity of source. Even a perfect reversible code cannot prove that an RF sample file was produced by a genuine antenna, that it was acquired under the stated legal authority or that the receiver clock was correct. It can only recover the declared digital object. Cryptographic integrity checks support continuity from a secured reference point, and a chain-of-custody ledger explains possession and transformations. Both remain vulnerable to false premises concerning the event before the reference point. The investigator should therefore verify the instrument configuration and calibrations separately from the integrity of its stored sequence. A persuasive report should not collapse all these propositions into the unqualified word authentic.

The uncertainty statement must be conditional on the retained representation. For a full-complex reference with verified acquisition, one may estimate phase noise, transient timing or coded-waveform structure subject to instrument limitations. For a derivative whose maximum complex-sample error is suitably bounded, one may propagate that bound through an analysis where the relevant denominator stays away from zero. For a

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perceptual or learned codec lacking a task-specific guarantee, one may report only the observed performance of the chosen validation set, with explicit uncertainty about unseen signals. For an image-only record, one cannot recover independent sample-level phase tests at all. None of these statements means that lossy recording is universally improper. They describe distinct inferential powers that should not be conflated.

I would end with a caution about precision of language. The defensible phrase is that a given feature was preserved within a stated uncertainty on a declared class of tests. It is not that no information of possible forensic interest was lost. A study cannot test all future questions, and the mathematical existence of distinct sources mapping to one derivative shows why that absolute promise cannot generally be made. We should design records, controls and reports that make their own limitations legible. Dr. Reed may now explore how deliberately introduced redundancy and error recognition relate to irreversible loss of sample information.

John von Neumann, Peer Question: Dr. Shannon, please address a persistent confusion between a mathematical rate-distortion result and a forensic guarantee concerning a particular waveform. An optimisation may minimise expected squared error under a probability law learned from ordinary traffic, while the only event later disputed is extremely rare under that law. If the model assigns vanishing importance to the event, how can the archive declare an acceptable distortion criterion without assuming away its own investigation? Is a visually faithful spectrogram an acceptable surrogate for phase continuity, and would a compression system trained to preserve typical spectra necessarily preserve an unforeseen chirp or discontinuity? I ask also whether a validation programme can compensate for a wrong

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objective function, or whether the responsible institution must identify categories of future questions that will simply become unanswerable if only a derivative is retained. Please distinguish mathematical possibility, operational verification and lawful retention authority.

Claude Elwood Shannon, Response: Professor von Neumann, a rate-distortion calculation answers the question that was mathematically specified, not every question one might wish had been specified. The relevant source distribution and distortion measure are not decorative parameters. They are premises governing the conclusion. If the expectation assigns little weight to a rare event, the optimal code may rationally allocate little rate to that event while still satisfying the chosen mean-distortion requirement. The archive must not then claim that it guaranteed retention of all rare anomalies. To support a specified forensic decision, the institution should choose a distortion criterion that reflects the decision's sensitivity and should test that criterion against appropriately challenging examples. Where it cannot foresee the question and must discard original information, some future distinctions inevitably become impossible. This limitation follows from the many-to-one nature of irreversible encoding rather than from a weakness of the examiner.

A spectrogram image should be treated as a visual summary whose construction must be documented. It commonly maps a complex waveform to local spectral magnitude or power, often followed by logarithmic scaling, thresholding and a colour palette. Phase information discarded by the magnitude operation cannot be recovered from the pixels. Additional image compression may change colours, edges or small isolated regions. A visual resemblance therefore does not establish preservation of sample-level

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phase. Even a spectrum with an unchanged average power distribution need not preserve the temporal ordering of short events. If the later task is to determine phase continuity, the evidence requires an appropriate complex representation or another specifically validated measurement of that observable. We should ask what the derivative contains rather than how convincing its display looks.

A validation programme is necessary but cannot logically redeem a definition of fidelity that ignores the target scientific question. If an organisation knows it may need pulse rise-time measurements, then it can include onset and shape distortion in the acceptance criterion and provide representative high-amplitude, low-amplitude and block-boundary tests. If it knows it may need modulation analysis, it can include complex-correlation and phase-error measures over a specified amplitude regime. But no finite laboratory collection proves adequate retention for every waveform, especially a signal class deliberately excluded from the model. One must distinguish average observed success from a worst-case guarantee and identify the class within which either is asserted. Where the codec supplies only a mean-square objective, an investigator should not silently reinterpret that as a maximum instantaneous phase-error bound.

The separate question of lawful retention must remain separate. There may be legitimate reasons to preserve only power summaries and destroy content-bearing raw samples. That choice does not contradict mathematics; it narrows the questions later answerable. A defensible governance policy can distinguish routine data minimisation from a tightly authorised exception for retaining a short complex sample extract when an important ambiguity must remain open to independent review. It should record why

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the retained scope is necessary and who may examine it, without treating a scientific wish as a legal entitlement. A report produced solely from a lossy record ought to say so and identify material uncertainties. Such candour is far more useful than an unsupported statement of perfect fidelity based upon a favourable average statistic.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor for distinguishing the evidence from its interpretation. I now invite Dr. Irving S. Reed to examine the next distinct limitation, preserving courteous transfer of the token and explicit disclosure of unresolved uncertainty.

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Irving S. Reed, Fifth Principal Contributor: Dr. Atkinson, an engineer can build strong methods of detecting or correcting errors in stored digital representations, yet those methods must not be mistaken for a cure for intentional loss of information. Error-correcting codes add constrained redundancy so that specified transmission or storage errors can be found or repaired. A lossy encoder removes distinctions among source sequences before the protected codeword may ever be formed. A perfectly corrected archive can consequently reproduce a lossy approximation without recovering the values discarded at its creation. The two operations solve different problems. We may require excellent channel integrity and still have no basis for inferring a short RF transient that the source encoder suppressed.

Suppose a recorder quantises complex samples from a fine grid to a coarse grid, then applies a strong error-correcting code to protect the resulting bits during storage. After a disk upset, the code may reconstruct every coarse-grid bit exactly. That is a genuine achievement of the preservation system, and it can be established by a verified decoder and protected digest. But several different fine-grid samples may have led to the same coarse-grid pair. Nothing in the correction code selects which fine-grid value was acquired. A case report should not say that the original waveform was recovered merely because the archive passed its integrity checks. It should say that the encoded derivative was preserved and decoded correctly to its declared precision, with the pre-compression uncertainty explicitly retained.

The converse mistake is to treat every discrepancy between original and derivative as a storage fault. A mathematically specified quantiser is expected to change many sample values. Those deliberate transformations

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should appear in the derivative's provenance and uncertainty budget. Storage corruption, omitted bytes, reordered blocks and a codec's legitimate changes should be separately diagnosable where possible. If a file checksum differs unexpectedly, the examiner should first identify whether the checked object is the compressed bitstream, the decompressed output or a container with changing metadata. A mismatched digest is a reason for investigation, not an automatic verdict about which part of the RF chain failed. That investigation should never repair evidence invisibly: any corrected or reconstructed file must remain a separately identified product.

Rare transient studies require deliberate stress cases. A detector may rely on phase continuity across a block boundary, and predictive encoders may restart their internal state at such boundaries. An unnoticed reset can produce a step in phase or amplitude that resembles an external transient. A packet lost in a network transport can create a gap that a decoder conceals with interpolation. A compression engine with a long analysis window can smear a short pulse into neighbouring samples. An examiner must distinguish each of these artifacts from input features by using known reference streams and inspecting reconstruction residuals. Testing at only a convenient mid-band frequency and generous amplitude is inadequate when the intended findings concern weak, unpredictable or nearly instantaneous events.

I propose a two-axis acceptance matrix. One axis concerns storage continuity and technical reproducibility: the encoded bytes are protected, the decoder and version are known, metadata are independently secured, and the same derivative can be reconstructed. The second axis concerns fitness for inference: pulse width, onset time, differential phase, frequency

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slew and detector decisions are checked under declared conditions. A system may pass the first axis and fail the second. That result should be considered informative, not paradoxical. The report should state which axis each control addresses, so that a cryptographic success is not casually promoted into a claim that a physical feature must have survived compression.

Uncertainty should include sample-clock and front-end state even in a pure digital comparison. In a laboratory code test, exact reference samples can be generated numerically and do not require assumptions about an antenna. In an end-to-end instrument test, the timing of a pulse is dependent upon the ADC clock, trigger, transfer buffering and any resampling stages. If the original record already has missing samples, lossless compression can preserve the omission faithfully. If the original record contains clipping, lossless compression can preserve the clipped values faithfully. Thus even zero numerical compression error leaves measurement uncertainty from the acquisition path. A careful writer should not imply that lossless encoding alone establishes the truth of a report about external electromagnetic events.

A particular difficulty arises when investigators compare waveform derivatives that were produced with different starting states. A predictor whose internal state is initialised at the beginning of one file and carried across a continuous stream in another can produce different errors despite nominally identical codec settings. Dither applied without a recorded seed may make a trial irreproducible, though reproducibility of the seed does not by itself validate the method. Calibration of absolute amplitude may differ between instrument gain settings, and high-level pulses can invoke

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automatic gain changes that alter subsequent samples. These factors must be entered in the controlled matrix if claims of receiver fidelity are being made. A qualified expert should be able to reconstruct not only the derivative bytes but the conditions under which the transformation ran.

Finally, the analyst must specify the limits of a negative finding. If a weak phase feature is absent from a lossy derivative, the record may not support a conclusion that the original signal lacked it. If a phase feature is present, confirmation may still require proof that the codec did not produce it through ringing, prediction error or block seams. The strongest defensible inference comes from converging controls: a preserved source when lawful, independent analogue measurement, a known input test, and reconstruction residual analysis. Where privacy or retention law makes some controls unavailable, the claim must be narrowed, not expanded by speculation. This is the responsible application of coding expertise to forensic measurement: protecting precisely what is known, identifying what was intentionally transformed, and refusing to infer a vanished original detail from a corrected but lossy representation. I return the token to the moderator for testing these principles against the practical objections of the panel.

Sir Ronald Aylmer Fisher, Peer Question: Dr. Reed, I should like you to address the statistical meaning of an apparently favourable reconstruction trial when its sampling scheme has not been explained. A laboratory may test one hundred overlapping windows from a single waveform, observe no missed transients, and report one hundred successful detections as though each were an independent Bernoulli trial. Yet the windows may contain substantially the same pulse, noise excursion and predictor history. How

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should the examiner specify the unit of replication, the independence assumptions and the uncertainty attached to such a result? Please discuss the difference between an error rate among selected window positions and an event-level probability of detection under future conditions. I also invite you to distinguish a predeclared decision threshold from one chosen after inspecting the compressed record, and explain why statistical confidence cannot arise solely from a large number of correlated display frames. I pass the token with particular interest in controls that an independent laboratory could reproduce.

Irving S. Reed, Response: Sir Ronald, the number printed at the bottom of a table does not define the experimental unit. If one hundred windows are drawn from one continuous burst, all may depend on the same RF source event, the same noise realisation, the same codec state and the same receiver gain excursion. A count of one hundred does not convert these shared dependencies into one hundred independent replications. The laboratory should state whether the test unit is a separate synthesised burst, a separate acquisition run, a distinct environmental condition, or an independently generated noise record. The appropriate choice depends on the proposed inference. A claim about detection of new events should ordinarily be evaluated using new events, with any repeated windows from the same event handled as a correlated group. A claim about file-level byte preservation instead calls for byte-level comparisons and may have a different unit altogether.

Threshold selection deserves equally careful treatment. If an analyst views all compressed traces and then chooses a threshold that produces no false alarms in those particular examples, the apparent validation performance is

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optimistically biased. The threshold must be fixed on a separate development set or specified before the acceptance set is examined. The acceptance experiment should contain positive and negative reference cases, with the analyst unaware of their identities where practicable. Errors must be reported against the ground truth established by the reference generator, not against labels inferred from the lossy trace itself. Otherwise a codec-induced transient may be treated as a true event and inflate the success count. Such a circular exercise can produce beautiful summary statistics while offering no independent evidence that the original features survived.

One may calculate statistical uncertainty for a specified model, but the model must be credible. Independent binary trials admit familiar binomial analyses; clustered or serially correlated observations generally require a different treatment. If zero misses are observed among a small number of independently generated bursts, the estimated fraction is zero in that sample, but the upper uncertainty limit for the underlying miss probability is not zero. If those bursts represent only one pulse width and one carrier offset, the result cannot be projected to all possible transients. I would encourage a factorial design that deliberately varies pulse duration, phase step, noise level, block alignment and codec setting, while retaining enough independent repetitions to estimate variability. A study that cannot afford those trials should declare its scope accordingly rather than use the appearance of precision as a substitute for measurement.

The preservation system must also maintain a record of adverse results. If compression damages narrow pulses near a block boundary, that failure should remain in the audit with the exact codec setting and reference

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waveform. Deleting inconvenient test cases would undermine the chain of inference even if every surviving file were cryptographically intact. The independent examiner needs the trial plan, original authorised laboratory test vectors, relevant logs, algorithms, decision thresholds and failures as well as successes. A sound report then distinguishes the codec's error-correction success in storage from its empirical fidelity for scientific decisions. It should be possible to state that the bits were preserved perfectly but the uncertainty of a phase-transient conclusion remains unacceptable. There is no inconsistency in that finding; it is a properly separated measurement of different engineering properties.

Jerzy Neyman, Peer Question: Dr. Reed, I would extend the statistical issue to the language of acceptance. Suppose a manufacturer asserts that a derivative is adequate because fewer than one event in a thousand was missed during a selected trial programme. Such a statement can be interpreted as an observed fraction, a probability estimate under a model, or a claimed universal bound. The three are not equivalent. How should the examiner formulate a decision rule before the experiment, identify false-positive and false-negative consequences, and express the uncertainty of an empirical result? What happens when one class of weak burst is absent from the training and validation sets, or when the instrument's noise environment shifts after the acceptance programme? I ask you to treat a negative finding with particular care, because an archival system that quietly loses small phase discontinuities may present the investigator with an unjustified appearance of clean evidence. Please conclude with words a responsible expert could actually place in a forensic report.

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Irving S. Reed, Response: Professor Neyman, acceptance begins with a stated claim and a declared rule for rejecting it. We should not formulate the claim after viewing the data. Let the laboratory specify the class of test signals, the relevant noise and interference conditions, the codec configuration and the event-level test statistic. Before running the blind acceptance trials, it must also specify what constitutes a false alarm, what constitutes a miss, and what failure rate or confidence criterion will be considered unacceptable. A finding of ten misses in a thousand independent trials is an observed rate of one percent in that experiment. It is not, without additional assumptions and uncertainty analysis, a universal probability of missing every possible future pulse. This remains so even when the observations are genuinely independent; dependence only complicates the interpretation further.

We must not confuse error rates for two distinct decisions. A detector might reliably classify the presence of a large injected burst but fail to estimate its onset to within a specified number of samples. Another method might preserve amplitude while corrupting differential phase. A single binary acceptance stamp cannot replace a table that identifies each required observable. The cost of a false positive may differ from the cost of a false negative, and those consequences should influence the declared decision rule without retrospectively changing the data. If a rare weak-burst class was not represented, the report should expressly exclude that class from its empirical claim. An attempt to extrapolate beyond the tested domain requires a separately defended model, not an unspoken appeal to the size of the archive.

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Environmental drift must be considered even for stable codec software. A receiver may change gain, experience a stronger nearby interferer or operate with a noisier sampling clock. The resulting input distribution can move outside the region used to tune the compressor. A predictor that performs well under stationary noise can behave differently after a sudden overload event, while a block transform can distort an unexpected short pulse. An acceptance programme should include a reasoned range of foreseeable operating states and periodic verification when the system configuration changes. Where that is impracticable, the forensic expert should distinguish the archived derivative's measured characteristics from any assertion about its original analogue source. Provenance should identify the instrument, its state and the version of every transformation that could influence the finding.

I would use report language of the following form: 'The retained recording is an explicitly lossy derivative. In the stated laboratory tests, using the specified reference pulse family and decision threshold, the following numbers of event-level detections, misses and false alarms were observed. These results support a bounded assessment of performance under the tested conditions; they do not establish that all unrecorded phase or transient features of the original acquisition were preserved. No conclusion regarding features that could have been removed by the compression stage is drawn from their absence in this derivative.' Such language is neither timid nor evasive. It supplies the actual evidential scope. It also permits a court or technical reviewer to ask for the test set, the dependence analysis and the measurement uncertainty rather than accept an unqualified adjective such as faithful.

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Abraham Wald, Peer Question: Dr. Reed, the panel has addressed the integrity of a stored derivative and the empirical error of its reconstruction, but a survey officer must make decisions while an authorised examination is actually under way. Continuing to record high-resolution complex samples may impose significant storage cost, power consumption and privacy risk. Yet discarding them can prevent later investigation of a rare transient. Would you outline a prospective decision policy that does not simply collect everything on the possibility that it could prove useful? In particular, how should an organisation decide when a narrowly bounded original excerpt may be retained, when a lossy summary is sufficient, and when the appropriate conclusion must remain untestable? I ask for a principled distinction among collection authority, the engineering value of an observable and the decision maker's tolerance for irreversible uncertainty. Please include a means of preventing an adaptive retention algorithm from quietly becoming a mechanism for unauthorised content capture.

Irving S. Reed, Response: Dr. Wald, the decision policy must begin with lawful purpose and minimisation, not with a limitless aspiration to retain every waveform that technology can collect. A survey may need only a record of authorised spectrum occupancy or a summary of interference energy. In that case, preserving decoded communication content or extensive raw sample histories may have no justified role. A prospective policy can specify which features are needed for the defined investigation, which instruments and sample rates are permitted, and which derivative statistics provide adequate evidence for those features. A decision to retain original complex samples must be separately authorised, justified by a defined necessity and limited in time and scope. Engineering convenience is

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not a substitute for authority. The policy should record the control point at which data are converted to summaries and the point at which any unneeded raw buffer is destroyed.

An adaptive retention system deserves special scrutiny because its trigger may depend on the same uncertain waveform features under examination. A detector might preserve a short raw excerpt when a predeclared event criterion is met, but its threshold and allowed retention window should be documented and independently reviewed. The system must not silently decode payloads or expand its collection merely because a codec performs poorly. A ring buffer can be configured to hold only a tightly limited pre-event interval, with post-event duration and maximum total retention also bounded by policy. Even this arrangement may require legal review depending on the jurisdiction and the nature of the signals. If the trigger fails to fire, the institution must accept that the raw transient was not retained; it cannot reconstruct the missing original data from a subsequent compact visualisation.

The scientific side of the policy is an explicit hierarchy of observables. Routine questions about approximate occupancy may be answered from appropriately calibrated spectral summaries. Questions about phase continuity, ultra-short transients or uncertain modulation may need complex time-series samples or independent measurements, but only where obtaining and keeping them is authorised. The report should distinguish features the record directly measures from features for which it serves merely as an indicator. The decision maker can then compare the value of retaining a narrowly targeted original against its cost and lawful handling obligations. If retention is not justified, the correct consequence is

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a limited conclusion. The professional should neither imply that the summary answers everything nor insist that scientific curiosity overrides all other considerations.

The record should contain a defensible audit trail for every retention decision. Identify the approved measurement purpose, the configured trigger, the algorithm version, any operator override, the retained interval and its provenance. Protect the manifest and custody log against convenient alteration, and enforce access restrictions proportionate to the record's sensitivity. If a derivative is later produced, its codec and numerical error characteristics should be recorded as separate facts. Independent reviewers should be able to discover that some details were deliberately discarded without being misled into believing that an unaltered digest implies their survival. A measured, prospective policy is superior to either indiscriminate capture or a blanket assertion that a compressed archive always retains everything that matters. It is more effective both scientifically and institutionally because it acknowledges the cost of irreversible uncertainty before the evidence has vanished.

Dr. James M. Atkinson, Moderator: The five principal accounts and seven direct peer examinations are now before the panel. I invite reciprocal examination of claims about statistical bounds, error correction, representation provenance and complex-phase geometry. Each designated respondent shall answer before the token moves to the next speaker.

Jacob Ziv, Cross-Peer Question to Claude Elwood Shannon: Dr. Shannon, I should like to test the boundary between an information-theoretic guarantee and a task-specific engineering guarantee. Suppose an organisation preserves only a lossy derivative and publishes a low average

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squared-error figure obtained under a reference distribution. A later examiner seeks one short differential-phase transition, the very kind of event that the source model assigned negligible probability. Can any bound on expected distortion alone compel a reliable conclusion about that particular transition, or does the many-to-one mapping require a counterexample analysis? Please distinguish the possibility of designing a new encoder whose distortion measure deliberately protects such transitions from the logically different assertion that an existing archive already protected them. I also ask you to address a frequent rhetorical error: that a high compression ratio should itself be evidence of successful modelling, and hence of fidelity. Under which assumptions, if any, could a probability model support a limited inference without smuggling an unsupported certainty about unusual future RF phenomena into the report?

Claude Elwood Shannon, Cross-Peer Answer to Jacob Ziv: Dr. Ziv, expected distortion is an average defined with respect to both a source model and a distortion measure. It is not a universal bound on each realised waveform, much less on every later scientific decision. If the model makes a phase transition extremely unlikely and the distortion criterion values only average squared sample error, a code may suppress that transition while remaining rate-efficient under its specified objective. This observation is not a defect in coding mathematics; it is a consequence of the assumptions. An examiner asked whether a rare transition occurred must not infer its absence from a derivative that could have mapped both the transition-bearing source and a transition-free source to the same reconstruction. The many-to-one structure supplies the central logical objection even before the empirical validation programme is examined.

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One could, of course, choose a different design. A constrained encoder might preserve selected event windows without loss, supply a certified maximum local complex error, or include phase-sensitive distortion terms over a declared signal class. A probabilistic guarantee might be established for a bounded population of test conditions. None of those alternatives tells us that an old derivative created by a different encoder possesses the same property. The guarantee belongs to a defined transformation, source class and decision criterion; it cannot migrate by analogy from one codec to another. Even a maximum complex-error bound must be propagated through the requested observable. Phase error can become arbitrarily ill-conditioned near zero amplitude, and an apparent instantaneous frequency obtained by differencing noisy phases may have uncertainties not captured by a single average figure. The report must account for those sensitivities explicitly.

Compression ratio is a particularly poor proxy for fidelity. A very predictable discrete source may be compacted exactly by reversible coding, while a genuinely unpredictable input may resist substantial lossless reduction. A lossy codec may also produce an enormous reduction by destroying all distinctions of interest. Thus ratio measures data economy relative to the chosen input and representation, not truthfulness of a physical measurement. It should be reported as a storage characteristic alongside, but never in place of, measured distortion and task performance. If an operator quotes a pleasing rate and a visually smooth image, the independent expert should ask for the source object, decoder specification, error metrics and event-level tests before accepting any phase inference.

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For a limited probabilistic statement, one must establish that the conditions of the recording are sufficiently represented by the tested model, that the detector and threshold were fixed before evaluation, that the test observations are handled according to their dependence structure, and that uncertainty is stated on the claimed scale. A strong result may then justify an operational assertion about the tested pulse family. It does not warrant the unconditional sentence that no unanticipated phase event has been removed. Some observations remain untestable when the original is unavailable. Candour about that boundary honours the science better than a promise of infinite recoverability.

Peter Elias, Cross-Peer Question to Irving S. Reed: Dr. Reed, I invite you to distinguish the ability of error-correcting storage to repair a damaged derivative from the ability of an RF examiner to reconstruct omitted source details. Consider an encoded file with two layers: irreversible quantisation of complex samples followed by a forward-error-correcting block code. If the stored data experience bit flips, a correct decoder may restore the quantised representation exactly. Some authors might announce that the original signal has therefore been recovered without error. Why is that expression wrong? What evidence would be needed to show both that the storage code performed correctly and that the earlier source transformation preserved a particular pulse or phase measurement? Please include the case of a compression state reset that creates a phase seam while the encoded bytes are perfectly intact, and address how the chain of custody should describe corrected versions without silently replacing the retained object.

Irving S. Reed, Cross-Peer Answer to Peter Elias: Dr. Elias, the expression fails because recovery is always recovery of something specified. An error-

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correcting code may reconstruct the originally stored codeword or its encoded message, subject to the declared error conditions and decoder operation. If that message represents complex samples already reduced to a coarse quantisation grid, the code corrects errors in those coarse symbols. It cannot infer which of the many possible fine-grid samples produced them. The investigator should therefore speak of successful decoding of the protected derivative, not automatic restoration of the analogue or high-resolution source waveform. The distinction is as fundamental as the difference between a clean photocopy of an incomplete page and the missing words that were never copied.

There should be separate verification at each stage. The storage layer calls for tests of codeword integrity, known-answer vectors, recorded error flags and an audit trail of corrections. The source-representation layer calls for a comparison of complex samples or task-specific observables against a retained and lawfully acquired reference. The instrument layer calls for calibration and timing tests against an independent physical reference where RF claims are being made. A single successful hash verification is useful at one of those stages but cannot substitute for the others. If the source record no longer exists, the uncertainty created by irreversible quantisation remains. A report should not quietly replace that missing reference with a waveform reconstructed from the only surviving compressed object.

The compression state-reset example is instructive. A predictive or block codec may initialise its internal state at a file boundary, and the reconstruction can carry a small phase or amplitude seam that was absent from the source. A strong storage code can preserve that seam with perfect

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fidelity, because the seam is part of the derived numerical representation. An investigator might then identify a false transient even though there was no storage error at all. A controlled test must send known continuous-phase reference signals through the encoder and decoder, including several block alignments and state-reset conditions. The residual around each boundary should be examined alongside a declared detector's output. The fact that a file's stored bytes are unchanged does not make a reconstructed seam a physical event.

If any repair or error correction occurs during storage recovery, preserve the damaged source object when lawful and practicable, together with its digest, diagnostic log and a separately named corrected derivative. The record must identify which bytes were corrected, what algorithm and version performed the operation, and whether the corrected output was independently checked. Never substitute a modified file under the original identity and then describe the resulting digest as though it were created at acquisition. Where a forward-error-correcting decoder silently conceals an unrecoverable block, the report must mark that interval as uncertain rather than treat interpolated samples as ordinary measured ones. These precautions distinguish honest preservation practice from an attractive but scientifically misleading assertion of perfect waveform recovery.

Irving S. Reed, Cross-Peer Question to Abraham Lempel: Professor Lempel, I wish to press the meaning of lossless when metadata and sample values travel through different custody paths. Imagine that the compressed payload bytes can be restored exactly, but the manifest loses the original I/Q ordering, signedness, sampling rate, centre-frequency setting and invalid-sample mask. The remaining numerical array may be reproducible

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while its physical interpretation is not. How should a laboratory distinguish integrity of byte sequences, integrity of the description needed to interpret them, and authenticity of the analogue input? Would hashing a manifest and payload together solve the entire problem, or merely protect a particular pair of assertions from alteration after the hashing event? Please also consider a derivative that uses a new container while keeping the sample array numerically identical. In that case which digest should be expected to change, and what evidence prevents a legitimate repackaging event from being mistaken for either corruption or a guarantee of physical fidelity?

Abraham Lempel, Cross-Peer Answer to Irving S. Reed: Dr. Reed, lossless is not a complete description until the object of recovery has been defined. If a codec reproduces every payload byte exactly but its manifest is unavailable, the bytes may not be sufficient to reconstruct a meaningful complex waveform. A signed integer interpreted as unsigned, a byte order reversed or an I/Q pair exchanged changes the numerical interpretation without altering the payload itself. Missing sample-validity information can likewise convert a concealed gap into an apparent physical discontinuity. Thus I would separate three assertions in the report: the archived byte sequence is unchanged relative to the trusted reference; the protected format description permits a specified reconstruction; and an independent acquisition record supports the assertion that the numerical samples originated from a properly configured receiver observing an authorised external input. Each assertion requires different evidence.

Hashing a manifest and the payload together is useful insofar as it fixes their association at the time the digest was created. It does not prove that

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the manifest's centre frequency was entered correctly, that the receiver's analogue stage was calibrated or that the claimed data were lawfully acquired. A false manifest, once hashed, can remain immutably false. The custody record should therefore identify the source of each important metadata field, such as a receiver register readback, an operator entry or an independently measured clock reference. A third party should be able to test a critical claim rather than merely admire its inclusion in a protected file. A digital signature or secured ledger may add accountability for who made an assertion, but it cannot turn an unverified assertion into an objective physical fact.

Repackaging illustrates why digest scope must be explicit. If the whole container is hashed, changing a header, padding or archive wrapper will generally change the digest even if the payload samples are identical. A digest over the canonical sample payload may remain the same provided the canonicalisation rules are independently defined and applied correctly. Numerical equivalence can sometimes be established despite different byte representations, but that is a separate test requiring known data types and conversion rules. A derivative should have its own digest and an explicit link to the original object, with a transformation record that states whether the process was reversible, lossy, or merely a container change. No analyst should quietly overwrite the original digest with one calculated after a conversion.

The practical solution is layered provenance, not a single purportedly magical check. Keep the retained source where lawful, register the source object's digest and length, protect the format manifest, preserve receiver configuration and clock evidence, and record each derivative separately. The

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analysis report must explain which layer supports which conclusion. A matching payload digest demonstrates continuity of the specified bytes from the protected reference state. It does not establish preservation of a pulse after earlier analogue clipping, nor does it reveal lost phase information after an intentionally many-to-one transformation. The challenge is to maintain those conceptual boundaries as rigorously as the machine maintains a sequence of bits.

Abraham Lempel, Cross-Peer Question to Peter Elias: Dr. Elias, let us close with a numerical question of practical consequence. A complex sample has an original magnitude A and the compressor introduces a complex error e. One sometimes sees a proposed angular guarantee derived merely from the absolute error magnitude, without acknowledging that the sample may approach zero. Could you explain which assumptions permit a bound on the change of phase, and why those assumptions fail for weak samples? Please include a checkable hypothetical example in which the complex error is small compared with a full-scale receiver range but large relative to a very weak signal. I also ask whether sample-by-sample phase bounds alone establish a sufficiently accurate frequency-transient estimate when phase differences are taken across time. State what separate timing, bandwidth and unwrapping conventions must be known before an apparent frequency excursion is interpreted as a physical event. Distinguish a mathematical error bound from an independently calibrated observation.

Peter Elias, Cross-Peer Answer to Abraham Lempel: Professor Lempel, the error cannot be assessed in isolation from the sample magnitude. Let x denote a nonzero complex source sample, y the reconstructed sample and e the difference y minus x. If the absolute error magnitude is E and E is strictly

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smaller than the original magnitude A, geometry of the complex plane yields a maximum possible angular displacement no greater than arcsine of E divided by A, under the usual principal small-angle interpretation. This follows from the tangent to the disk of possible y values centred on x, provided that disk does not contain the origin. As A approaches E, the bound approaches ninety degrees; when E is at least A, the disk reaches or crosses the origin and no such useful small angular guarantee remains. A zero-magnitude source sample has no well-defined phase at all. A report giving only E therefore lacks the denominator needed to turn an absolute sample error into a reliable angular statement.

For a checkable hypothetical example, take a source magnitude A of 0.001 relative to full scale and an error bound E of 0.0001. The ratio E divided by A is 0.1, so arcsine of 0.1 is approximately 0.10017 radians, or 5.739 degrees. If the same absolute error applies at A equal to 0.0001, the ratio becomes one and the geometric bound ceases to be useful for precise phase metrology. These examples are calculations about stipulated complex numbers, not measured performance of an RF codec. They show why a small error expressed as a fraction of full-scale ADC input can still be unacceptable for a weak waveform whose own magnitude is much smaller. The appropriate test must consider signal-relative error and an amplitude threshold below which phase claims are withheld or specially qualified.

Instantaneous frequency estimated by phase differencing introduces another layer. Suppose the unwrapped phase samples are phi[n] and the sampling rate is fs samples per second. A simple discrete estimator of frequency deviation uses fs times the difference phi[n] minus phi[n-1], divided by two pi. If individual phase errors fluctuate independently within

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some angular bound, their difference can be substantially larger than either individual error; if errors are correlated, different behaviour arises. Increasing fs changes the frequency scaling of the same angular difference, while resampling or a timing discontinuity can create an apparent excursion without a physical frequency jump. Phase unwrapping can also insert or remove integer multiples of two pi when the data are noisy. A single-sample phase-error statistic cannot therefore certify the behaviour of a derivative frequency estimator without specifying its algorithm and temporal assumptions.

The acceptance study should include known reference carriers and deliberately imposed phase steps, vary the signal magnitude across the weak-sample regime, and inspect both original and reconstructed phase differences under a declared unwrapping convention. It should also document the receiver clock, missing-sample treatment, resampling filter and any codec block boundaries. Where the original is lost, a derivative may still support a qualified observation about its own reconstructed samples, but it cannot establish that a vanished source phase transition was absent. The most defensible conclusion is conditional: a specified angular or timing accuracy was observed or guaranteed within a defined amplitude and operating domain. Beyond that domain, particularly near zero magnitude or around undocumented sample gaps, the desired physical claim remains untestable from the derivative alone.

QUESTION 093. TECHNICAL SOURCE NOTES. Source-to-claim verification is still required at Stage B. Historical expert dialogue is fictional and does not constitute quotations or jointly authored findings. Candidate technical background: Jacob Ziv and Abraham Lempel, “A Universal Algorithm for

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Sequential Data Compression," IEEE Transactions on Information Theory 23(3) (1977), 337–343, DOI 10.1109/TIT.1977.1055714; Claude E. Shannon, "A Mathematical Theory of Communication," Bell System Technical Journal 27 (1948), 379–423 and 623–656; context-aware lossy RF compression review, https://pmc.ncbi.nlm.nih.gov/articles/PMC10098950/. These references support discussion context but do not individually certify the hypothetical instrument cases, precise analogies or publication completeness.

EDITORIAL QUALIFICATION. This is a fictional, modern pedagogical exchange attributed to deceased historical specialists, not recorded testimony. All numerical examples are hypothetical calculations, not observed RF survey results. The manuscript does not identify an unknown transmitter, decode protected communications or establish legal authority for sample retention. Stage A verifies structure and bounded numerical examples only; independent source-to-claim, historical, technical, legal, semantic and whole-volume production review remain pending.

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QUESTION 094

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How should conflicting clocks and sample dropouts be represented in a multi-receiver chain of custody?

Dr. James M. Atkinson, Moderator: Dr. Mills, the panel must reconcile three instruments that report apparently concurrent RF events while relying on different sampling oscillators, transport paths and host clocks. An analysis application can paint their waterfalls onto one attractive time axis, but that image may conceal a receiver that lost samples, another whose system time stepped unexpectedly and a third whose sample oscillator slowly drifted. Please distinguish the time actually established by each instrument from the timeline the investigator reconstructs. Explain how the chain of custody should preserve native ordering, clock quality, missing observations and the provenance of later corrections. This conversation is fictional pedagogical reconstruction, not a quotation or an account of an actual historical meeting.

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David Lennox Mills, Principal Contributor: I would begin with a warning about the word simultaneous. Two receivers may produce samples described by identical timestamp strings without having observed the same physical instant. A timestamp can refer to the antenna input, an analogue trigger, an ADC sample index, a digital processing block, an operating-system buffer, a file write or an eventual graphical display refresh. Each location in the chain has a different delay and a different relationship to the oscillator that actually sampled the RF waveform. A disciplined report must identify which event a timestamp represents and which evidence supports the mapping. The fact that a computer presents several values in the same time format does not make their underlying clocks coherent. Indeed, uniform formatting can conceal the differences the expert most needs to understand.

I would first preserve each receiver's own native history, without resampling it onto an invented common grid. That history should contain a monotonic sample counter if the instrument provides one, hardware acquisition timestamps if available, explicit buffer or frame sequence numbers, the original numerical samples where their retention is lawful and necessary, and every quality flag indicating overflow, resynchronisation, clock unlock or loss of reference. The investigator should record the clock source declared by the instrument, the firmware and relevant software versions, and the path by which timing metadata reached the archive. If these fields are absent, the deficiency itself belongs in the report. One should not silently replace an unknown continuity condition with a software assumption that all samples were present simply because the file is longer than expected.

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To translate a native sample index into an estimated common time, I propose a segment-specific model. Let k denote the sample index recorded by receiver i. Let alpha_i denote an estimated origin time for one valid segment of that receiver, and beta_i its estimated seconds per sample for that segment. An elementary mapping is t_i(k) = alpha_i + beta_i k, plus a residual term representing random and unmodelled timing error. The mapping is only as good as the measurements used to estimate its constants. If the oscillator drifts with temperature, the model may require several segments or a higher-order description. If the host system clock steps, the analyst must not force the ADC sample timeline to inherit that step unless the hardware evidence shows that the sample clock itself changed. Different clocks can disagree without either original file being corrupt.

The familiar distinction between clock offset and clock frequency error is especially important. Two clocks may differ by an almost fixed offset while maintaining nearly identical rates. Alternatively, they may agree at the beginning of an observation and gradually diverge. A receiver clock that runs ten parts per million faster than a reference accumulates an idealised ten-microsecond discrepancy in one second if the relative rate error remains constant. That arithmetic is simple; the evidential work lies in showing that the stated error belongs to the actual sampling clock, rather than to a nearby host oscillator or an unrelated network timing service. The reference itself has uncertainty, cable delays can contribute offsets, and the delay between an analogue event and a timestamp register may depend on configuration. None of those limitations is repaired by rounding the displayed result to six decimal places.

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A missing interval must be represented as missing, not as radio silence. Suppose a receiver nominally acquires one million complex samples per second and records a hardware-confirmed loss of 2,048 consecutive samples. On the nominal scale, those samples represent 2.048 milliseconds of unobserved input. The gap does not prove that the antenna received no energy during those milliseconds. It means the file cannot answer questions requiring those samples. Inserting zeros may be useful for a particular visual alignment if the substituted values are distinctly marked, but it creates a derivative. Interpolation between adjacent observed values can be useful for graphing and similarly cannot reconstruct an unforeseen microburst or a sudden phase excursion. Both operations require separate derivative identifiers and an unambiguous gap mask that survives subsequent export and analysis.

It is tempting to regard a network synchronisation protocol as an absolute cure. Such a protocol estimates timing relationships among participating clocks subject to network delay, asymmetry, implementation and quality of the relevant reference sources. It does not automatically timestamp the ADC aperture of every attached receiver. A host can be well synchronised while its USB receiver streams samples from a free-running oscillator with an entirely different frequency error. Conversely, an RF instrument disciplined by a precision reference can produce accurate hardware sample indices even when its associated computer writes the file under an inaccurate wall clock. Therefore the report should distinguish network clock state from acquisition-clock state and record the measured link between them rather than inferring one from the other. One unverified declaration of synchronised is not an uncertainty budget.

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Multi-receiver phase comparisons impose an additional requirement beyond aligning coarse event times. Two receivers can share a pulse-per-second signal and still possess separate local oscillators whose relative phase wanders. Aligning their sample indices within a microsecond may be sufficient for some event-correlation tasks and wholly inadequate for coherent phase summation. The laboratory must identify the observable first. If it merely asks whether two independently recorded energy bursts overlap within a specified time interval, bounded offsets and uncertainty intervals may suffice. If it asks for a phase difference or a direction-finding inference derived from coherent samples, it needs evidence concerning the relative sampling phase, local-oscillator behaviour, channel delays and calibration. A common numerical timeline alone supplies none of those missing guarantees.

The chain of custody must record when reconciliation begins. The original individual streams should be identified and protected; the matching process should produce a separate synchronisation manifest containing reference events, the estimated alpha and beta for each valid segment, uncertainty estimates, accepted or rejected alignment observations, the treatment of gaps and the software used to perform the fit. If an analyst later corrects a mapping because a timing offset was discovered, the earlier mapping must remain recoverable as a prior interpretive state. The corrected product should identify its relationship to the original. A checksum over the corrected timeline can show that it has not changed since correction, but it cannot prove that the correction was physically correct. That question requires independent reference and calibration evidence.

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I would insist on an adverse laboratory trial, not merely a successful demonstration with everything connected ideally. Send a known test pulse to two or three properly authorised receivers and document its passage through independent paths. Introduce a controlled packet loss into one transport stream, a deliberate host-time adjustment into another and a bounded sampling-clock deviation into a third. Ask analysts to produce a common-time account with uncertainty intervals and explicit missing segments. Compare the result against an independent reference record, and inspect whether any graphing software silently fills the introduced gap. Repeat with changing event spacing and with a reference outage. A system that honestly declares certain observations unknowable has passed an important forensic test even if its final plot looks less complete.

Finally, scientific uncertainty and lawful retention are not interchangeable. A precise clock model does not authorise capture of communication content. The organisation may choose, or be required, to retain only the minimal timing evidence and energy statistics relevant to an authorised survey. In that event the conclusion must be limited to those records. Where retention of raw I/Q segments is explicitly justified and authorised, the custody and access controls must protect their contents and the independent metadata needed to interpret them. What matters is that the expert tell a future reader what each receiver truly observed, what was inferred by alignment and what disappeared before it could ever become evidence. A clean-looking common trace is a useful illustration only when it does not erase those distinctions. I respectfully pass the token to the remaining panel to challenge the assumptions about network clocks, computational invariants, physical frequency standards and evidential provenance.

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Claude Elwood Shannon, Peer Question: Dr. Mills, I wish to distinguish a time estimate that looks exact from one that is scientifically well supported. Consider three receivers observing the same authorised reference pulse. The first reports native sample counters against a disciplined hardware reference; the second records arrival times only after an operating-system queue; the third has valid native indices but loses its external clock reference. The displays place all three transients within one microsecond after a software offset correction. What can we infer without confusing a fitted alignment with a verified common time? How would you state uncertainty where an independent reference waveform is distorted by unequal analogue filter delays, or where two similar pulses could have been matched incorrectly? I ask also whether the investigator may legitimately report that the devices were synchronised during the interval merely because their host computers showed the same wall-clock time. Please separate timing resolution, offset uncertainty, rate uncertainty, phase coherence and source-event identity, since each may bear upon the exact forensic proposition under examination.

David Lennox Mills, Response: Dr. Shannon, the first issue is the definition of each timestamp's origin. In the first receiver, a documented device counter tied to a tested reference offers a defensible mapping from native sample index to a stated time coordinate, subject to the uncertainty of the calibration and the physical signal path. In the second, an operating-system arrival time directly measures a later software event and offers no independent proof of when the ADC took its sample. In the third, the device may remain internally continuous while its relationship to a reference clock becomes increasingly uncertain. The common statement is therefore

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modest: each may have recorded a transient compatible with a laboratory event within the uncertainty interval that the corresponding observation actually supports. A graph displaying the traces within one microsecond does not establish that the true RF apertures were separated by one microsecond or less.

The alignment algorithm must report how it chose corresponding pulses, what alternate alignments remain plausible, and whether the fit reused the event it now purports to validate. A separate reference pulse recorded with independently characterised latency helps avoid that circularity. When analogue filter delays differ, the experiment must either calibrate their contributions or enlarge the uncertainty of the inferred physical event times. The location of a peak is not an instrument-independent event marker. A strong and a weak test pulse may cross a threshold at different relative moments because the front-end response and the detector operate on different waveform features. The reconstruction should specify the chosen feature and its calibration conditions rather than give an unexplained timestamp.

Precision, in the sense of a small scatter or fine numerical resolution, is not accuracy. A clock can produce repeatable values with a systematic offset from the desired reference. Synchronisation is a measured relation between clocks over a stated interval; frequency agreement describes their relative rates; coherence demands further conditions for phase-based analysis. Equal wall-clock displays establish none of these properties for the ADC unless a measured mapping connects them. A valid report may offer a time interval for each detection and a bounded statement about overlap, but it should not declare a common physical instant when the intervals are too

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broad or their error terms correlated. The status of a disciplined host does not transfer automatically to an undisciplined sampling oscillator.

I would preserve the raw observations and a dated alignment manifest, including each receiver's calibration events, clock-state transitions and model residuals. If a later recalibration reveals that a cable introduced a delay previously omitted, the new model must be identified as a revision, not smuggled into the original sample record. The best examination question is not whether an image looks convincing but whether an independent examiner can change an assumption and reproduce the resulting change to the conclusion. Uncertainty is an essential property of the claimed alignment, not an embarrassment to be removed by formatting.

Dr. James M. Atkinson, Moderator: I thank the preceding specialist for preserving the distinction between measured samples and reconstructed time. With respectful transfer of the token, I invite Donald Watts Davies to examine the next evidence layer, while retaining the limits of every clock and loss assertion.

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Donald Watts Davies, Second Principal Contributor: Dr. Atkinson, a multi-receiver recording should be approached as a distributed measurement system whose evidence travels through queues before a human investigator sees it. Each queue has a different clock and a different possibility of loss. The sample clock governs analogue-to-digital conversion, whereas a transport packet may be dated by device firmware, a network interface, a kernel driver, a user process or a file system. A timestamp assigned at the last stage may accurately describe receipt of a block without accurately describing the instant of its first sample. An investigator who merges the labels as though they were equivalent has rewritten the physical history before the analysis has begun. The correct practice resembles a carefully maintained packet trace: preserve the original capture sequence and record every subsequent interpretation as a separate, attributable operation.

I should distinguish four classes of discontinuity. First, an acquisition gap occurs when an ADC stream or its necessary internal buffering fails to produce valid samples; that is a failure of observation. Second, a transport gap occurs when samples were acquired but not delivered to the host, so their possible survival in hardware must be established rather than assumed. Third, a storage gap occurs when the host received data that were not durably written, which may leave intact upstream records. Fourth, a time-description discontinuity occurs when the host clock jumps or its epoch changes while a native acquisition counter continues. These events may coincide, but they need different evidential labels because they imply different limitations. They also generate different remedies. A surviving hardware ring buffer may permit re-export after a storage interruption,

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whereas genuinely unsampled RF cannot be recovered from the appearance of a later graph.

A robust acquisition interface should expose a native sample-start counter, an observed sample count for each block, any device-declared loss or overflow condition, and a boot or reset epoch. The interface ought to state the semantics of these fields. A USB packet sequence number identifies neither the number of complex samples transmitted nor the oscillator phase at which sampling began unless the manufacturer defines those relationships and a laboratory verifies them. A transport layer can fragment one sample buffer into many packets or coalesce many buffers into one. Repeated packets may produce duplicated payloads; missing packets may conceal otherwise valid acquisition data. The evidence processor must therefore reject the facile inference that every sequence-number discontinuity establishes one missing sample interval. Counters are observations at a nominated boundary, not universal metaphysical markers of time.

I propose a test in which each receiver records a controlled reference signal under lawful laboratory conditions, while an independent monitoring channel preserves the generator's event schedule. Before introducing failure, we establish the native meaning of every counter by varying capture-buffer lengths, host load and transfer size. We then cause separate, documented perturbations: a hardware FIFO overflow, a dropped transport packet, a delayed disk write, and a wall-clock adjustment that does not alter the reference signal. If two perturbations produce the same visible break in a waterfall, the exported low-level logs must still distinguish them or the limitation must be recorded as unresolved. We should insist on seeing the

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difference at the level of preserved data objects, not merely a console warning printed during the experiment. An ephemeral warning lost when the application exits contributes little to a forensic audit.

For illustration, a receiver sampling at two million complex samples per second covers 4,096 samples in 2.048 milliseconds. This is nominal arithmetic, not a finding about a particular instrument. If hardware counters show a discontinuity of 8,192 sample indices, the missing native-index span corresponds nominally to 4.096 milliseconds. Whether all those indices denote unavailable observations depends on the precise definition of the counter and the capture boundary. A packet loss of 8,192 bytes, by contrast, has no such direct duration until the sample representation and packet structure are established. If each complex sample occupies four bytes, 8,192 payload bytes represent 2,048 complex samples, not 8,192. Such dimensional distinctions are essential whenever an expert is asked to calculate the length of an unobserved RF interval.

I further insist on preserving the distinction between a sequence containing zeros and a sequence containing no samples. Zero-valued complex samples may be actual quantised observations, deliberate fill symbols, or artefacts introduced by a processing library. They are not interchangeable. The original record should carry a validity mask or segment ledger that indicates where samples are absent and where samples were present but saturated, clipped, out of lock or otherwise compromised. A plotted blank region may be an excellent way of representing a gap; a plotted line at the receiver's estimated noise floor may falsely portray an observation. Spectral integrations should state whether unobserved intervals were omitted from

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denominators and whether the omitted time changes any claimed occupancy fraction.

The custody records should preserve the exact relationship among acquisition objects, transport objects and derived analytical products. I would keep a protected acquisition ledger consisting of native block identifiers and length fields, status, device epoch and reference-state identifiers; a protected data manifest identifying original byte sequences or legally minimised event records; and an interpretation ledger explaining each alignment transform and exclusion. If an expert later discovers that a counter increments before acquisition rather than afterward, the correction belongs in the interpretive ledger, with a link to the documented test that established its meaning. The older result should remain recoverable so a tribunal or technical peer can discover what the organisation originally believed. Nothing is gained by rewriting the old timeline and offering the corrected file as though it were the contemporaneous native record.

Network discipline adds complexity. The clock synchronisation protocol may correct the host's time estimate using round-trip exchanges, but transport asymmetry and processing delay may remain significant. It does not follow from a small network-clock offset estimate that the RF ADC aperture is aligned to the same tolerance. The laboratory needs a traceable mapping between sample counters and reference events measured in the acquisition domain. When a PPS event reaches a GPIO connector and is registered by the hardware, that registration offers a stronger bridge than an unspecified host callback, but its propagation, timestamp-latch and counter semantics still require examination. In a complex receiver, analogue filter group delay

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and digital decimation latency also affect a reported event time without changing the clock itself.

I would conclude by requiring the reviewer to distinguish four propositions in each final finding: what each receiver actually stored, what it reported about losses and reference state, what a separate reference independently established, and what the analyst inferred by reconstruction. If the second receiver has an unobserved three-millisecond gap, the report should say that the presence or absence of a short burst during that interval cannot be established from that receiver alone. Where the first receiver supplies a valid observation, it may support a limited separate conclusion, but it does not cause the missing samples to reappear in the second. Reconstructing time is permissible; inventing observation is not. I respectfully pass the token to Dr. Dijkstra to examine the software invariants that would prevent such errors from being laundered into a polished record.

John von Neumann, Peer Question: Mr. Davies, suppose the exported recording consists of blocks with a purported sample-start counter, a number of complex samples, a packet identifier and a host receipt timestamp. The producer may split or coalesce transfers, the host may reorder completions, and the device may reset a finite-width counter without an independent boot identifier. How can a test engineer articulate a continuity invariant that is strong enough to identify missing observations but cautious enough not to invent them? I should also like to know how an examiner should handle duplicate packets and intervals in which firmware reports a nominal overflow without specifying the exact number of unavailable samples. Can a write-once acquisition register and a versioned interpretation register coexist without making later corrections appear to

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alter original evidence? Please describe a controlled failure-injection programme that would distinguish acquisition failure, transport loss and host storage interruption, rather than relying on the intuitive smoothness of the completed trace.

Donald Watts Davies, Response: Professor von Neumann, we should define the invariant against a verified hardware contract, not against the attractive names that software gives its fields. If a native counter indexes successive acquisition samples, a contiguous pair of valid blocks should satisfy the relation that the second start index equals the first start index plus the first block's valid sample count. A violation is a discontinuity under those premises. If the counter numbers USB transfers instead, the same arithmetic says nothing directly about sample continuity. The acceptance test must first establish which stage generates the value, whether it increments for data lost internally, and how it behaves at wrap, restart and channel reconfiguration. Only after that calibration may the invariant support a statement about unobserved RF samples.

Duplicate packets should remain distinguishable from newly acquired repeated values. Identical sample payloads can arise naturally with a constant laboratory waveform, so a checksum alone is not a unique block identifier. Source-native sequence and epoch fields help identify a repeated transfer. When no such fields are available, the analyst may detect a plausible duplicate pattern but should describe its ambiguity. If the firmware reports an overflow without a loss count, the report may say that continuity was compromised during a certain indicated region, without assigning an invented number of missing samples. A numeric estimate

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based on transfer timing can be given separately as an estimate with its own assumptions. A field called overflow is not a calibrated stopwatch.

I propose to preserve a first ledger containing contemporaneous device records and payload references, protected under access and hashing controls. A second, append-only ledger would describe subsequent interpretations: a gap is inferred, a packet is identified as likely duplicated, a counter reset is established, or a common-time transform is revised. A correction in the second ledger never erases the first. It must identify the operator, method, reason, affected range and relationship to earlier versions. If the revised interpretation changes the temporal ordering of alleged events, the report should flag the substantive change instead of issuing a silently corrected picture. This is particularly important where an earlier finding may already have influenced an organisational decision.

The adverse test programme would generate a controlled RF pulse train monitored independently, then disturb one layer at a time. Force a hardware acquisition overflow without interrupting host storage, drop a transport object while retaining its device-side source evidence, suspend the file writer while leaving the receiver active, and step the host system clock without changing the ADC sample reference. Compare resulting files, counters and fault flags with the independently preserved reference. Repeat at different host loads, packet sizes and device reset conditions. The acceptance criterion is not that the plot automatically looks complete; it is that every known failure either becomes an explicit auditable exception or is identified as a limitation that prevents certainty. Such discipline converts a fragile graphic into a scientifically examinable record.

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Dr. James M. Atkinson, Moderator: I thank the preceding specialist for preserving the distinction between measured samples and reconstructed time. With respectful transfer of the token, I invite Edsger Wybe Dijkstra to examine the next evidence layer, while retaining the limits of every clock and loss assertion.

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Edsger Wybe Dijkstra, Third Principal Contributor: Dr. Atkinson, the first danger in a multi-receiver timeline is an ambiguous data type masquerading as a complete specification. Many programs represent a sample as a complex number and its time as a floating-point value. That representation says nothing about whether the time came from a calibrated hardware counter, a host callback, an interpolated mapping, or a figure-caption convenience. It likewise says nothing about whether the sample is valid, missing, duplicated, resampled or synthetic. A programmer who erases these distinctions in the data structure cannot expect the final report to recover them by editorial honesty. The design must make forbidden states difficult to express and forbidden conversions explicit enough to be audited. Mathematical elegance is no excuse for obscuring the experimental origin of the variables.

I would define separate types for a native acquisition sample, a native block event, a clock reference observation, a proposed segment mapping and a rendered presentation point. An acquisition sample is indexed in a device-specific clock epoch and references a source object; its existence denotes a measurement made by the instrument under stated quality flags. A missing segment is not a vector filled with some pleasing numerical substitute. It is an interval in the device index domain accompanied by a reason, confidence, provenance and a statement of whether the number of omitted samples is known. A segment mapping describes how native indices are provisionally related to an external time coordinate. An exported common timeline is a derived object that references the mapping used to construct it. The type system should prevent a derived pixel from being treated as a raw voltage observation.

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There is a useful local invariant. If block j begins at acquisition index k_j and contains n_j genuinely observed samples, then uninterrupted subsequent acquisition would begin at k_j plus n_j. That relation is not universal; it depends on whether the device counter advances for dropped samples, whether gaps are represented as indexed intervals, and whether a counter wraps or resets. The contract must state these premises. Where the premises hold and a different successor index is observed, an exception should be raised and retained, not covered by appending data. An unknown counter epoch must be tagged unknown. Assigning a convenient epoch because the plotted waveform looks reasonable is an illicit inference. Formal verification requires not only proving a relation from premises but also testing the premises against the actual hardware.

A second invariant concerns the custody of transformations. Let an original object O be identified by a digest and defined byte count, and let a derivative D be formed by a disclosed transform F with parameters P and software version V. The ledger should record O, F, P, V and D together. A later investigator can check that applying the declared operation to O reproduces D within the specified numerical tolerance, but must not conclude that the transform's assumptions are physically valid merely because its implementation is deterministic. A common-time alignment produced by interpolation is a derivative. If the algorithm imputes a missing waveform, that imputation requires an additional data lineage and must not be encoded as a native sample. One cannot repair missing evidence by making the repair procedure repeatable.

I would separate an algorithm's functional correctness from an instrument's metrological validity. A transformation can be mathematically correct for its

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input assumptions and scientifically unsound because its inputs represent the wrong clocks. For example, the program may minimise squared differences between nominally corresponding pulse timestamps and return a precise offset. If the pulses were identified through the same shared display whose correctness is in question, the fitting has become circular. Software tests should introduce independent reference pulses and deliberately include ambiguities: two plausible matching pulses, a missing reference, a hardware counter reset and an oscillator rate change. The algorithm should either return bounded, defensible alternatives or refuse to declare a single aligned solution. A fail-closed result is preferable to a confidently wrong time base.

It may be useful to define a segment-specific clock function $T_i(k)$ with estimated parameters and a separately propagated uncertainty. That function should be valid only for a declared interval of native index k, and only while its assumptions remain supported. After an unknown reference outage, extrapolation can be a legitimate calculation, but the uncertainty must reflect the oscillator stability, the last calibration observation and all systematic delays included or omitted. A string of digits produced by the computer is not a proof of those conditions. Nor does the mere mathematical continuity of T_i across a gap establish acquisition continuity. In a strongly typed record, the domain of an observed sample and the domain of a time mapping are related but distinct.

Concurrency is another peril. Some systems process received buffers on separate threads and then arrange them by host completion time. If block B finishes decoding before block A, a naive writer can reverse their apparent chronology. Sequence numbers may detect this if their semantics are sound;

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sorting by wall-clock receipt time may exacerbate it when the host clock steps. I would require immutable source order and an explicit reconstruction order with conflict reports. Two devices are not a single sequential process. Their events form partially ordered histories until independent synchronisation evidence permits limited cross-device ordering. That description is intellectually less comfortable than a single line running across the page, yet it is more honest about what the evidence establishes.

The acceptance tests should be designed as adversarial specifications. Generate controlled streams with known gaps, duplicates, reset epochs, wrapping counters, timestamp reversals and a deliberately altered sample-rate claim. For each disturbance, define the expected report before executing the program. Confirm that the stored native record remains unchanged, that any repaired mapping is represented as a derivative, and that no graph silently converts missing intervals into zero-valued samples. The tests should include one event shorter than a deliberately missing interval so the analyst is forced to say unknown. They should also include a false positive caused by an interpolation artefact, testing whether the system flags it as a visual aid rather than a recovered emission. These are not peculiar edge cases; they test the logic of evidential speech.

There is a jurisprudential analogy in the duty to disclose one's assumptions. A court receiving an expert conclusion does not merely need a stable final figure. It needs the conditions under which that figure would cease to follow. The software's provenance ledger can furnish those conditions if it records which native observations supported each estimate, which confidence model was used and which tests failed. A hash over the final PDF

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may preserve a precisely worded mistake. Our responsibility is to preserve the chain of reasoning as well as the chain of bytes. An adverse correction should add an explanatory version and leave the earlier one traceable, not rewrite history in place. My closing point is a rule for disciplined computation: no function should silently promote an absent observation to a measured one, and no formatter should promote an estimate to an unqualified fact. I hand the token to Professor Ramsey, whose physical standards must eventually decide whether our numerical timing claims are plausible.

Sir Ronald Aylmer Fisher, Peer Question: Dr. Dijkstra, your programme supplies formal rules, but a rule cannot determine the truth of its assumptions. Suppose two clock mappings fit the observed calibration pulses with nearly equal residual error, while one implies that receiver A led receiver B and the other implies the reverse. A least-squares routine can report a beautifully precise estimate by imposing a prior constraint the operator did not disclose. How should the system prevent such hidden statistical choices from becoming a categorical finding? I also ask whether missing observations should be treated as random loss for uncertainty calculations when loss may be correlated with overload, thermal stress or burst intensity. If the gap mechanism is not independent of the signal, an apparently standard confidence interval may be grossly misleading. Please distinguish a validated computational invariant, a statistical model requiring evidence and a scientific conclusion conditional upon both. Would an apparent error bar remain defensible if its missing-data assumption were contradicted by the controlled fault-injection experiment?

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Edsger Wybe Dijkstra, Response: Professor Fisher, the programme ought to expose the logical status of its inputs. The invariant can be proved about data meeting a specified contract, but it cannot prove that the hardware implemented the contract faithfully. A statistical estimation procedure can minimise an objective function, but that minimisation does not prove that its model describes the experiment. The code should therefore attach distinct provenance and validity fields to the raw observation, the model assumption and the resulting estimate. For example, two candidate alignments should be retained when their evidence does not discriminate adequately. The user interface should not permit an analyst to choose the version producing the desired event order without recording that selection and its basis.

If missingness is associated with strong input signals because a receiver overloads or its transport fails under particular processing loads, the missing intervals are not safely treated as a random subset of a stationary record. A calculation that silently assumes independence can underestimate uncertainty and bias occupancy or coincidence estimates. The correct software action may be to decline the requested statistic, present a sensitivity analysis over plausible missing-event rates, or clearly identify that the result depends upon an untested missingness mechanism. A claimed confidence interval is meaningful only inside the model and sampling design that produced it. It should not be recast as a universal physical bound.

I would encode those limitations as part of the processing contract. Every alignment object should name its source reference events, its fitting model, parameters, excluded observations, residual diagnostics and anticipated failure conditions. When an alternative model is defensible, it can be an explicit competing derivative rather than an invisible knob in a settings

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dialogue. Automated tests should include ambiguous pulse matches, nonstationary drift, a reset that mimics a wrap, and a gap triggered by a deliberately high-power laboratory pulse. A robust implementation will identify the ambiguity or refuse a categorical ordering claim. The error message is itself useful evidence of a boundary, not a defect to be suppressed.

The most serious mistake is a silent promotion between levels of knowledge. A native record is a source assertion about what a device stored. A validated calculation is an assertion about the consequence of specified data and rules. A metrological finding states how those abstractions relate to an external physical event, and it demands independent calibration. A legal or administrative finding imposes still further requirements. A software function cannot move a proposition from one level to the next merely by returning a non-null number. The record must show which authority, test and assumption support that promotion. When a conclusion remains conditional, its condition belongs in the final prose.

Dr. James M. Atkinson, Moderator: I thank the preceding specialist for preserving the distinction between measured samples and reconstructed time. With respectful transfer of the token, I invite Norman Foster Ramsey Jr. to examine the next evidence layer, while retaining the limits of every clock and loss assertion.

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Norman Foster Ramsey Jr., Fourth Principal Contributor: Dr. Atkinson, the measurement problem becomes clearer when one distinguishes a frequency reference, a clock epoch and the phase of an RF carrier. A receiver may be connected to a highly stable reference oscillator and therefore maintain a repeatable nominal sampling rate. That circumstance does not, by itself, provide a common epoch at which sample zero was acquired. Two oscillators can have excellent frequency stability and still begin with unknown phase. Two receivers may accept the same one-pulse-per-second signal yet have different trigger latches, filter delays or local oscillator phases. A valid engineering claim must name the physical quantity being synchronised. The word locked is insufficient unless it specifies what is locked to what, over which time span, with what residual uncertainty and under which environmental conditions.

The timing chain begins with the reference event and ends with a recorded sample index. Between them lie connector propagation, input circuitry, threshold crossing, synchroniser logic, possible metastability resolution, digital signal processing and buffering. A short cable delay may be estimated from length and propagation velocity, but a quoted physical length alone is not a full timing calibration. Filter group delay can depend upon the spectral content and configuration. A comparator can respond at different instants to pulses with different rise times or amplitudes. In a properly designed comparison experiment, those contributions are measured or bounded rather than hidden inside a fitted constant that is later described as the clock's absolute error. The main uncertainty budget should distinguish random timing variation from systematic, repeatable delay.

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Let $t_i(k) = \alpha_i + \beta_i k + \epsilon_i(k)$ denote an illustrative mapping from receiver i's native sample counter k into a reference time coordinate. α_i expresses an origin for a particular stable segment, β_i an estimated interval per sample, and ϵ_i the residual mapping error. Those variables should be accompanied by estimates and uncertainty statements rather than displayed as exact constants. A change in β_i denotes a sampling-rate change or model revision, not necessarily a loss of samples. A step in α_i may reflect a new timing epoch or revised alignment, not necessarily a physical event at the antenna. If a counter resets, the segment must be given a fresh epoch identifier. No smooth polynomial fitted through that discontinuity can prove that the missing interval was observed.

Suppose a receiver nominally samples at one million complex samples per second. Under an illustrative rate error of plus eight parts per million relative to the comparison reference, a constant-rate model predicts an eight-microsecond timing difference after one second if the initial origins coincide. Over a ten-second span that model predicts eighty microseconds. These numbers do not establish that the oscillator truly exhibits constant error. Temperature, ageing, power fluctuations and reference steering may cause the rate to vary over the observation. An uncertainty budget should explicitly distinguish the measured interval, the specified environmental conditions and the extrapolation interval. When a reference signal has been lost, an uncertainty that remains deceptively constant for hours is a warning that the model has been applied beyond its supported range.

One can test a calibrated time-origin claim by sending an independently monitored pulse through known RF paths to all receivers and observing the

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resulting native indices. The exercise must not treat every detected pulse peak as an ideal physical event marker. A channel's impulse response can broaden or shift the maximum, and a threshold detector can respond differently under changing signal-to-noise ratio. We must therefore define the event feature being timed, such as a calibrated threshold crossing of a known test waveform, and validate its expected delay and scatter. The uncertainty attached to that event feature belongs beside the uncertainty of the clock reference. Repeating at several levels and frequencies can reveal systematic bias that a single test pulse would conceal.

The more exacting case is coherent phase analysis. For an RF frequency f, a timing error delta_t produces an idealised phase shift of 2 pi f delta_t radians for a pure sinusoid, provided the comparison model is otherwise valid. This illustrates why a delay that is negligible for detecting a long burst may be intolerable for phase-sensitive direction finding. At one megahertz, an unknown one-microsecond delay corresponds to one full cycle or 2 pi radians, even though the time may seem small on a wall-clock plot. At a much higher carrier frequency the same delay spans many cycles, with phase ambiguity and calibration obligations that cannot be wished away by resampling. The comparison must also account for each receiver's independent local oscillator, not merely its ADC clock.

I would ask the group to treat traceability as a chain of physical and documentary relationships. The reference oscillator has a calibration history and specified performance under conditions; the receiver has a documented reference distribution path; the timestamp latch has a validated relationship to sample index; the test event has a known generation and observation process; and the final record contains the results together with uncertainty.

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If any link is absent, the report should identify that omission. An instrument bearing the label disciplined does not exempt it from the ordinary requirements of calibration, and an elegant estimate from a multi-receiver alignment routine does not replace the physical reference evidence.

A laboratory should test the hard case: temporary loss of external discipline followed by reacquisition. It should log reference-state transitions and compare the native sample counter with an independent monitor across the outage. A device may free-run smoothly, make a controlled frequency correction, step its time counter, or reset processing buffers. Those behaviours are instrument-dependent and must be observed rather than assumed. The test should measure whether the manufacturer's status fields permit an analyst to detect the transition after the event, perhaps months later when the original engineer is absent. What is not reproducible from preserved records should not be promoted to a precise forensic claim.

Finally, scientific practice demands that we report the physical proposition rather than an impressive display. Where one receiver plainly observed a burst while another had a marked dropout, we may report one observation and one absence of evidence. We cannot prove simultaneous reception in the missing channel, and we cannot infer that the second antenna was silent. When all receivers have valid data but uncertain clock offsets, we can perhaps report overlap within specified time bounds; we cannot assert an exact sequence if those bounds overlap. A careful result is not weakened by acknowledged uncertainty; it becomes more useful because future investigators know which claims survive independent challenge. I return the token to the moderator for a final inquiry into documentary provenance and institutional control.

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Jerzy Neyman, Peer Question: Professor Ramsey, I want an experiment that can falsify an overly optimistic uncertainty budget. Assume two receivers claim a shared pulse-per-second reference, but their timestamp-latch delays, filter responses and local oscillator phases were never separately measured. A laboratory sends a calibrated pulse at several signal levels, then deliberately removes the reference for a period and restores it. What observations would distinguish a fixed offset, drifting sample rate, threshold-dependent timing bias and discontinuous re-locking behaviour? How should repeated observations and independent calibration enter the construction of uncertainty bounds rather than leaving the engineer to choose a narrow figure from one successful run? Please also clarify why simultaneous pulse detection is insufficient proof of coherent carrier phase. In a court-facing report, the temptation to call two events simultaneous often follows from their rounded timestamps, even though the actual uncertainty ranges overlap substantially. What additional evidence would you require before describing that ordering as experimentally resolved rather than merely plausible?

Norman Foster Ramsey Jr., Response: Dr. Neyman, the test must be structured around observables whose physical meaning is known. I would begin by distributing an independently monitored reference pulse along controlled paths to both receivers and recording native sample indices at which a defined event feature is detected. The event feature should be specified, for instance a calibrated crossing of a known waveform's threshold rather than an unspecified largest sample. Vary pulse amplitude, rise time and frequency while preserving an independent monitor record. A shift correlated with amplitude suggests detector time walk or front-end

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response variation; a repeatable difference between receivers suggests a fixed path or latch offset; a difference that increases approximately with elapsed time suggests relative sample-rate error. One may encounter several effects at once, in which case the observations should not be forced into a single explanation.

Next, disable the common reference deliberately while preserving device status records, and continue transmitting independent timed calibration events. A stable offset during the outage may support a bound over that observed period, but it should not justify indefinite extrapolation. Compare the receiver mapping before, during and after reacquisition. A discontinuity at restoration can reveal a phase or counter step, whereas a smooth but changing offset may show free-running frequency error. Temperature, supply state and reference-distribution configuration should be recorded because they can affect oscillator behaviour. Repetition across the relevant operating envelope is essential to distinguish robust performance from one fortunate trial.

For uncertainty, the laboratory must account for the calibration reference, path-length and filter-delay uncertainty, event-detector variability, timestamp quantisation, clock-model fit and any common-mode correlations. If both receivers rely on the same imperfect reference, their errors are not automatically independent. A small scatter across repeated trials does not exclude a common systematic bias. The uncertainty interval used in a report should reflect the physical conditions actually tested, and a revised interval should be issued when new calibration evidence contradicts the old estimate. Reproducing a spreadsheet is not enough if the spreadsheet omits a dominant physical term.

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Carrier-phase coherence is a separate proposition. A shared one-pulse-per-second trigger may align event epochs while leaving each RF local oscillator with an independent phase. Even sharing a frequency reference does not necessarily establish a known constant phase after arbitrary receiver resets, synthesiser tuning or phase-locked-loop reacquisition. Coherent comparison requires calibration of relevant frequency, phase and channel-delay relationships over the observation window. Thus two energy bursts may be simultaneous within bounded timing uncertainty while their complex sample phases remain unsuitable for coherent summation. In the final report I would state the strongest conclusion supported by the particular calibration, and I would expressly refuse any stronger claim about emitter identity or direction that depends on unverified phase relations.

Dr. James M. Atkinson, Moderator: I thank the preceding specialist for preserving the distinction between measured samples and reconstructed time. With respectful transfer of the token, I invite Grace Brewster Murray Hopper to examine the next evidence layer, while retaining the limits of every clock and loss assertion.

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Grace Brewster Murray Hopper, Fifth Principal Contributor: Dr. Atkinson, the problem is not merely to compute a clock correction but to explain exactly which record a later expert can trust. Evidence handling often begins after a device has already made hundreds of undocumented choices: which clock it queried, which buffers it accepted, what it did when data were late, and whether it padded an output file. Once those choices are compressed into a single array of complex samples and a single timestamp, much of the history has disappeared. A conscientious institution designs the recording system before the investigation so that its behaviour can be tested and its limitations displayed. The object is not ceremonial paperwork. The object is to preserve sufficient information to challenge the conclusion without requiring blind trust in the original operator.

I recommend three linked evidence registers. The acquisition register records receiver identity, device state, sample counter epochs, declared sampling rates, gain, reference source, firmware and hardware status, together with a minimal description of observed gaps. The custody register records file identifiers, digest algorithm and scope, protected reference digests, transfer events, authorised access, storage location and derivative creation. The interpretation register records every time-alignment estimate, its supporting reference observations, uncertainty assumptions, exclusions, software version and reviewer decision. Each register may have several versions, but its changes must be traceable. The fact that a file has an unchanged cryptographic digest since the original hashing event establishes byte continuity under the stated trust assumptions; it does not establish an authentic RF input or a truthful clock mapping.

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There are practical reasons to keep sample bytes and metadata as separately protected but linked objects. A file of interleaved I and Q values may be bitwise intact yet interpreted with the wrong byte order, signedness, sample rate or start epoch. A host clock correction might cause a file's creation time to change without altering its RF payload. Conversely, an operator could create a new file with the same nominal timestamps after discarding inconvenient samples. A manifest therefore needs to declare exactly which bytes were hashed and how the samples are to be interpreted. If a derivative changes the byte representation but preserves the numerical sample values, the transformation should be documented and the derivative hashed under its own identifier. Cryptographic equality and scientific equivalence answer different questions.

One of our principal threats is the retrospective repair that becomes indistinguishable from the original. An analyst discovers that receiver B lost a block and inserts a row of zeros so two plots will have matching lengths. Another analyst later sees the convenient file and interprets the zero row as radio silence. If the first analyst retained a separate gap mask and labelled the zeros as a display-only fill, the transformation could be legitimate for an explicitly defined graphic. If those labels were discarded and the corrected file supplanted the native record, the institution has damaged the evidence. The integrity problem therefore includes the preservation of meaning, not merely the preservation of bits. We should be able to reconstruct which samples were measured and which points were invented by presentation software.

The same applies to an operator's statements of synchronisation. Imagine an audit log recording synchronised at 12:00:00. That log may mean that the

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host operating system accepted a network-time update, that an ADC sampling oscillator locked to a ten-megahertz reference, or that a device registered a pulse-per-second edge. Each proposition is different. The log should name the source of the status, the measurement interface and the time at which the state was observed, including whether the reported state could be stale. A later investigation should distinguish reported status from independently verified performance. Passing a vendor self-test is useful evidence about a declared condition; it is not proof of absolute timing accuracy for every waveform captured during the subsequent hour.

Suppose an authorised laboratory collects a controlled reference pulse with three recorders. The first reports a hardware counter continuous across the test. The second reports an overflow, with a 4,096-sample gap at a nominal two-million-sample-per-second rate. The third reports host time moving backward while its device counter continues monotonically. A correct custody account would preserve these three different observations. It would describe the second receiver's unobserved interval as nominally 2.048 milliseconds under the stated sample rate, while refusing to claim that the receiver was quiet during that interval. It would identify the third receiver's host-time change as a separate metadata event, then test whether the ADC timing actually changed. It would not overwrite the records so that all three appear to tell the same story.

I would use an append-only interpretation history to record each scientific revision. The first analyst may estimate one offset from a single reference pulse. A second may later discover a cable delay and revise that estimate. A third may find a reference outage during which the oscillator drifted. All three interpretations may be intelligible stages in an investigation, provided

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none is presented as an original observation and each points to the evidence supporting its revision. The ledger should indicate whether a revision changes a displayed timeline, a quantitative event-order claim, or merely an administrative timestamp. Such distinctions are essential when a report has already been circulated and recipients must understand whether its conclusion has materially changed.

Security and privacy must be designed into this process. More metadata can improve scientific accountability, but it can also expose locations, personnel schedules or private communications. Retain the information necessary to support an authorised technical purpose, control access to samples that may contain protected content, and document why particular fields were collected. A chain-of-custody record is not a licence for indefinite retention. If legal authority allows only occupancy statistics or selected event times, the organisation should preserve that authorised scope and acknowledge that it cannot later conduct tests requiring unavailable I/Q samples. The correct wording is that the evidence does not support the broader question, not that the broader question has been answered in the negative.

For publication, I would insist that another laboratory repeat the adverse tests from the retained documentation. Can it reproduce the disclosed sample-index mapping? Can it distinguish a host clock step from a true acquisition gap? Can it demonstrate that the common-time trace was generated from a particular set of source objects and a particular transform? Can it confirm that a missing interval remains explicitly missing after file export, visualisation and report preparation? Where the answers are uncertain, the editor should state that uncertainty plainly. A polished picture and an untouched hash do not substitute for these tests. Our

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ultimate duty is to protect not only the data but the separation between observation, computation and assertion. I courteously return the token to Dr. Atkinson and invite scrutiny of the chain by the remaining peers.

Abraham Wald, Peer Question: Admiral Hopper, I propose to examine a difficult inference that can arise when missing intervals are not evenly distributed through a survey. Suppose the three receivers are watching an authorised test emitter with unpredictable short bursts, and the second receiver is most likely to drop buffers when the input becomes strong enough to overload its front end. The file may contain many apparently quiet intervals precisely because some of the most informative moments have been lost. How should a custody record distinguish observed silence, an unsuccessful detection during valid capture, an undocumented failure of acquisition and a device-reported gap? Can a later analyst legitimately estimate a burst probability from the surviving time alone, and how should an institution document the assumptions that would be required? Finally, when a second independent receiver did observe activity during the first receiver's gap, is it permissible to use that observation to fill in the absent waveform, or should the reports retain two distinct claims?

Grace Brewster Murray Hopper, Response: Dr. Wald, I would first require the custodian to preserve the validity of each time interval as an explicit evidential property. A valid acquisition with no detected burst is not automatically the same as true RF silence; it may simply be a below-threshold observation. A device-reported overflow is an acknowledged failure, while an unexplained discontinuity in a hardware counter is an anomaly requiring investigation. A file with no diagnostic fields may make even the distinction between valid capture and an unrecorded interval

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uncertain. These categories should be represented separately in both the protected manifest and any derived graphical product. If they are merged into the single value zero, a subsequent analyst cannot know whether the receiver measured zero, the detector reported no event, or the system supplied a convenient placeholder.

A burst probability estimated from surviving intervals needs a defined sampling frame and a defensible explanation of missingness. If strong RF causes more gaps, the surviving record systematically underrepresents periods of interest. The investigator should state that conditional dependence rather than treat the available intervals as an ordinary random sample. One may produce conditional estimates for explicit hypothetical scenarios, or bounds where enough independent constraints exist, but the original evidence must not be edited to look as though those assumptions were observations. In particular, a confidence interval computed from surviving windows alone may mislead if the capture failure mechanism is unknown. This is a scientific limitation of the experiment and a documentary obligation of its custodians.

Where receiver A is missing data and receiver B observed a burst, B's valid observation may support a statement that B detected an event within its own timing uncertainty. It does not give A the lost complex samples, A's actual analogue response, or an independent A-channel measurement. A model may simulate what A might have observed if its parameters and propagation channel were known, but the synthetic result needs a separate provenance label and must not be incorporated into A's raw file. The same distinction applies when several receivers agree: agreement can make an external event hypothesis more plausible, but it does not transform a

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missing observation into physical data. The ledger should maintain the boundaries between receiver-specific findings and system-level inferences.

For institutional practice I would create a small controlled vocabulary that travels with every data product: observed valid, observed invalid, known missing, suspected missing, derived estimate and unknown. The event-detection report would identify which category justified each analysed time span. A later human reviewer should be able to reconstruct the denominator of any duty-cycle or probability calculation and determine whether it excluded missing periods or incorrectly treated them as quiet. A graphics application should be prohibited from dropping the uncertainty labels when exporting a plot. Such an arrangement protects a lawful and modest inference against the temptation to make a continuous line seem more complete than the original measurement chain.

Sir Karl Raimund Popper, Peer Question: Admiral Hopper, your three registers distinguish observation from interpretation, but institutional habit can make a register seem authoritative merely because it is elaborate. What experiment would expose a false assurance generated by a perfectly protected file whose clock metadata were wrong from the beginning? I am especially concerned about circular verification: one software programme reports a hardware status, another reads that status from the first programme's log, and a later reviewer treats both as independent confirmation. How should the report disclose this dependence? Suppose a correction to the clock model reverses a finding that event A preceded event B. Is the earlier finding simply erased as a typographical error, or must the conflicting versions and their evidential bases remain visible? Finally, can a witness defend a conclusion that an event did not occur if every receiver

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failed to observe during the period in question? I ask for a practical test capable of refuting, rather than merely illustrating, the system's claim to accurate chronology.

Grace Brewster Murray Hopper, Response: Professor Popper, an effective test challenges the system's history with an independent source of truth. In a laboratory, we can produce reference RF pulses whose timing is monitored by an apparatus outside the logging path under examination. We can then cause deliberate errors in one receiver's sample-rate metadata, change the host wall clock, interrupt its reference and introduce a known gap. The acceptance criterion should be specified before the trial: the resulting files and ledgers must preserve enough native evidence either to reconstruct event order within stated uncertainty or to flag that the order cannot be established. A programme that always reports a confident chronological sequence, regardless of its inputs, is failing this test. Its certainty is not an achievement but a sign that it has no representation for ignorance.

The source of each apparent corroboration should be displayed. If two applications read the same firmware status register, they are not independent witnesses to the actual oscillator condition. Their agreement may verify that the status value was transferred faithfully, but not that the value corresponded to physical timing performance. A second instrument monitoring the reference event or a separately measured pulse train can provide an independent constraint, although that instrument has its own calibration uncertainty. The audit must record common dependencies rather than multiply the same assertion into an impressive-looking collection of checks. In software terms the evidence graph is directed, and several

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downstream nodes cannot be counted as distinct roots merely because their filenames differ.

If a corrected clock model reverses an event-order finding, the revision is substantive. The original interpretation and its supporting assumptions should remain available with clear notice that the conclusion was superseded. The new report should identify the corrected reference measurement, the parameter changed, the effect on the ordering and any downstream decisions that might require reconsideration. A footnote that the chart was updated would be insufficient where readers might continue relying on the earlier ordering. We should not make a false statement permanent, but neither should we destroy the history of how it arose. Transparent revision is the proper answer to error, not a silent overwrite.

Finally, if every receiver has an unobserved interval, there is no evidential basis for asserting that no external event occurred within it. The proper finding is that the record contains no valid observation for that interval, perhaps with an accompanying statement about operational status and the system's independently characterised detection capability outside the gap. Absence of recorded evidence is not evidence of physical absence when the instrument was not observing. An adverse test should deliberately place a brief reference pulse inside a known acquisition gap. The correct processing system must not report the pulse as measured, and must not report its absence as an established fact. It should declare that the available receiver data cannot answer the question.

Charles Sanders Peirce, Peer Question: Admiral Hopper, consider the language of the final report as a system of signs that may be less precise than the underlying measurements. A table says receiver A saw a pulse at

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12:00:00.000001 and receiver B at 12:00:00.000002, yet its footnote reveals an uncertainty of twenty microseconds in each clock's mapping. A reader may wrongly infer that the order is established by the printed digits. What conventions should compel the author to separate an observed sample index, a calibrated event-time estimate, a hypothesised cross-device match and a conclusion about sequence? Should the report give interval bounds rather than unsupported point times, and how should it identify intervals where the clock reference was lost? I would also ask how the chain of custody can remain intelligible to a future reviewer who does not have the original manufacturer's proprietary software or the individual engineer who operated the system. The goal is not just numerical exactness, but reproducible meaning.

Grace Brewster Murray Hopper, Response: Professor Peirce, the report's notation should communicate the kind of claim being made before the reader reaches a technical appendix. I would use separate columns for the native device counter, source-record identifier, time-mapping version, estimated reference time, uncertainty interval and observation-validity state. A point estimate may be useful for indexing and presentation, but when the inferred order is smaller than the unresolved timing uncertainty, the narrative should say that the order is not established. Placing six digits after the decimal point is merely a formatting decision; it does not reduce the error budget. A labelled interval is more intelligible than an unjustifiably exact number, particularly when several receivers share a calibration source and their errors are correlated.

Each period of reference loss should receive a defined segment identifier, start and end conditions, and the method used to estimate the relationship

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between native indices and the reference clock. Where the boundary is only known within a range, that uncertainty should be stated rather than rounded away. The analyst should retain the versioned mapping and its validation results so that an independent reviewer can reproduce the displayed time coordinates. If a model extrapolates through a reference outage, the report must say extrapolated and specify which oscillator performance assumptions govern the widening uncertainty. Likewise, if the receiver stopped acquiring, its missing observation interval cannot be replaced with a continuous trajectory merely because a clock model remained calculable.

Long-term intelligibility requires open or fully documented representation of critical evidence fields. The institution should preserve a specification of the sample format, endian order, numeric type, interleaving, reference-clock flags, hardware counter semantics, missing-data conventions and the meanings of status words. It should retain the original bytes under lawful controls and, when appropriate, a separate independently readable export whose transformation has been validated and recorded. An exported CSV or report is not self-authenticating merely because it can be opened without a vendor application; it still needs source identifiers and an explanation of how each value was derived. The custodian should also preserve enough test vectors and quality checks to distinguish a future parser defect from a genuine anomaly in the original recording.

The written conclusion ought to have layers of certainty. One layer states what the device recorded. Another states how an external time was estimated. A third compares independently observed events within their uncertainty intervals. A fourth considers whether those observations justify

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attribution, event ordering or other legal and technical inferences. Each step should identify its premises and surviving alternatives. This produces prose that may be less spectacular than a unified waterfall with razor-thin markers, but it is far stronger under scrutiny. By preserving the relation between numbers, observations and interpretation, the organisation permits future readers to understand exactly what was known and what remained uncertain at the time of the report.

Dr. James M. Atkinson, Moderator: We have heard five principal contributors and seven immediate peer examinations. I now pass the token for four reciprocal questions directed to four distinct named respondents. No speaker should claim that an estimated alignment restores observations lost at acquisition, and each reply must answer the preceding peer before our final technical qualifications.

Edsger Wybe Dijkstra, Cross-Peer Question to Norman Foster Ramsey Jr.: Professor Ramsey, I challenge a common assumption in timing software. An alignment routine may produce a numerically continuous mapping through a reference outage, and the operator may conclude that no physical discontinuity occurred because the fitted function is smooth. Suppose the device's oscillator made a brief frequency step at the moment it lost its reference, but the available calibration pulses fall well before and after that step. What metrological observation would distinguish the smooth model from a piecewise model, and what should the software do when the available evidence cannot decide? I also ask how one might quantify the practical meaning of an interval of uncertain event order without pretending that all error contributions are independent or normally distributed. If the final inference depends on coherence of two RF local oscillators, must an

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independently measured phase relation be treated as a separate datum rather than inferred from common pulse-per-second labels? I invite a reply identifying the limits of the measurement rather than the aesthetic properties of the fitted curve.

Norman Foster Ramsey Jr., Cross-Peer Answer to Edsger Wybe Dijkstra: Dr. Dijkstra, the smoothness of a mathematical mapping is no substitute for a physical observation during the uncertain interval. Calibration events before and after an outage constrain the average behaviour of the clock over the intervening period, but they may not identify the time at which a transient frequency step occurred. Two different piecewise models can reproduce identical endpoint observations while assigning different intermediate event times. To discriminate them, the laboratory needs additional reference observations inside the interval, sufficiently informative device-state logging, or an independent physical measurement of the relevant oscillator. Without those constraints, the correct result is a family of admissible time mappings or a bounded uncertainty envelope, not an invented unique history. A statement that a model fits the known points is not equivalent to proof that it followed the true path between them.

The uncertainty should be based on explicitly justified physical contributions. Some arise from measurable distribution delays, others from repeated event-detector scatter, and still others from unobserved oscillator behaviour. Their combination depends on dependence, distribution and the kind of bound being asserted. If two receivers share the same timing reference, common errors may shift both together. Treating those terms as independent can give a falsely narrow range for some propositions and a needlessly conservative one for others. Where the relation is not

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characterised, one can report conservative intervals based on established worst-case bounds or present alternative scenarios rather than invent a precise statistical distribution. If the temporal ordering changes across plausible scenarios, the order is unresolved. That is a substantive scientific result.

The distinction between epoch alignment and phase coherence is fundamental. A pulse-per-second source can provide a repeatable time marker for device counters without determining the RF local oscillator phase at each receiver's input. Even a common frequency reference may leave phase offsets due to independent synthesisers, tuning operations, distribution lines and acquisition restarts. The laboratory should record a separate phase-calibration observation, using an authorised reference waveform distributed through measured paths and inspected over the relevant interval. If this information is absent, the report may support an event-time comparison without supporting coherent combining or phase-sensitive attribution. A program should refuse to turn a claim of clock alignment into a claim of phase coherence unless the necessary physical evidence is present. The strongest software design is one that communicates precisely when a requested conclusion requires an observation that the laboratory did not make.

Norman Foster Ramsey Jr., Cross-Peer Question to Grace Brewster Murray Hopper: Admiral Hopper, a scientific correction often occurs after files have been copied, hashes computed, and conclusions circulated. Suppose a later calibration establishes that receiver B's event detector introduced a systematic delay that the original common-time model neglected. A new estimate reverses the ordering of two observed transients. What revision

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record is necessary so that an independent expert can determine whether the raw sample bytes remained unchanged, which version of the clock model was used for each public conclusion, and whether downstream summaries need correction? I am also concerned that preserving every intermediate derivation may create unnecessary copies of sensitive RF material. Can an institution maintain defensible provenance while retaining only the authorised minimum of waveform content? Please explain how the custodian should distinguish a correction to metadata interpretation from an alteration of source evidence, and how a later reviewer could reproduce the calculation without accepting the analyst's personal testimony as the sole account of what occurred.

Grace Brewster Murray Hopper, Cross-Peer Answer to Norman Foster Ramsey Jr.: Professor Ramsey, the correction should be documented as a new, traceable interpretation of unchanged source objects. The original dataset would retain its original byte digest, length, acquisition manifest and device-native indices. The first time-alignment model would remain identified by a version and protected copy of its parameters, calibration observations, software code or executable provenance, and the report that relied upon it. A second model would identify the new detector-delay measurement, explain how it alters the mapping, and record which reported event times or ordering propositions change. If the ordering of consequential events reverses, the revision must be described as a material correction and communicated to parties relying on the earlier report; it is not a typographical adjustment. The custodian need not surrender the physical raw record merely because its interpretation improved.

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The provenance chain should identify each source and derivative by a stable logical identifier, with a separately protected digest for the exact bytes stored. The revised model may require an updated clock manifest but no rewrite of the I/Q samples. A reproducibility package can contain a narrowly authorised test extract, numerical reference-event table, calibration coefficients, program revision, and expected output, all linked to the more restricted original by controlled identifiers. Where security or privacy rules prohibit redistribution of the full waveform, a qualified independent reviewer can verify it under controlled access or evaluate a properly disclosed derivative, acknowledging any limits that decision creates. The objective is to avoid uncontrolled duplication of potentially protected content while preserving the evidence needed to challenge material claims. The institution should document why it retains each object and who has authority to inspect it.

An append-only revision history is valuable because its chronology cannot be reconstructed reliably from a folder containing only the newest files. Each entry should say who approved the transform, what assumptions changed, when the revision was made, which source version was used, and whether the earlier report is superseded. The mechanism protecting the ledger should itself be described, since a perfectly hashed source file accompanied by a freely editable custody narrative offers weak assurance. A new digest authenticates the new derivative from its reference state; it does not cause an inaccurate clock claim to become historically true. The original observation, the original interpretation and the revised interpretation remain separate objects.

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Finally, documentation should let a technically qualified reviewer reproduce the key inference without personally trusting the first analyst. That requires sufficient description of sample-format semantics, calibration measurements, transform parameters, missing-data masks and numerical tolerance for the relevant computation. A closed software product may remain necessary to read a proprietary recording, but the organisation should preserve its version and appropriate test vectors, or make a independently readable validated export where possible. It is better to present an intelligible restricted-access audit trail than to preserve every raw sample indefinitely or to delete the evidence of a consequential correction. Custody concerns what was preserved and how it was treated; metrology concerns what the preserved record actually establishes.

Grace Brewster Murray Hopper, Cross-Peer Question to David Lennox Mills: Dr. Mills, consider a file whose native sample counter is trustworthy but whose host timestamps came from a network clock that experienced a step adjustment while the acquisition proceeded. An analyst might correct all historical host times by subtracting the observed step, creating a perfectly smooth plot. Can that operation be justified for every sample, and what independent evidence would establish where the step occurred relative to the sample sequence? Suppose the network-time service reports low offset and jitter both before and after the event, but the application buffered sample blocks for variable durations. How should the report distinguish synchronisation of the host system clock from synchronisation of the receiver's sample aperture? I also ask whether a monotonic device counter can by itself determine absolute time, and how the uncertainty should be represented after loss of an external clock reference. We need a correction

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procedure that protects device-native chronology without publishing a false aura of sub-microsecond alignment.

David Lennox Mills, Cross-Peer Answer to Grace Brewster Murray Hopper: Admiral Hopper, subtracting an observed host-clock step from a sequence of host timestamps is at best a model-based correction. It may be legitimate for an explicitly described derivative if the step boundary, relevant clock domain and transport-latency behaviour have been established, but it should not silently replace the original records. The application must first identify whether each timestamp was assigned in the host before or after the adjustment, and whether buffering displaced the relationship between timestamp assignment and ADC acquisition. A smooth corrected plot is insufficient evidence of the boundary. If the host clock changed while the device's sample counter remained continuous, the ADC did not necessarily experience any corresponding change. The device history and the host history should be preserved separately, then joined through measured reference events.

A small network-time offset estimate means that a particular system-clock discipline model was reporting a relation to its selected references under its protocol assumptions. It does not mean that a queued data block arrived without latency, nor does it tell us the aperture time of an arbitrary RF sample. Network paths are subject to queue variation and asymmetry, and applications observe their own scheduler delays. The proper report identifies the clock being disciplined and the traceable link between that clock and a device counter. Where no such link was measured, host timestamps may order logged software events but cannot support a stated aperture-level precision. In particular, low clock jitter should not be

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confused with the latency distribution between an ADC and the point at which a file writer stamps its output.

A monotone counter provides a native ordering and, where its increment semantics are validated, a measure of elapsed sample intervals. It does not intrinsically supply a UTC epoch. Absolute timing requires an origin mapping to a traceable reference and allowance for systematic delays and clock frequency error. During a reference outage the last known mapping can be extrapolated under stated oscillator assumptions, but uncertainty generally grows as knowledge of current rate and offset weakens. It may be possible to bound that growth with prior measurements and documented oscillator performance, yet an instrument's advertised specification should not be confused with direct proof of the particular field conditions. If the counter resets or its epoch becomes unknown, a new segment must be created rather than extending the earlier mapping by convenience.

I would preserve the original device counters and status flags, the host time log before correction, the independently measured reference events, and the algorithm and assumptions behind the new mapping. A finding could then state that a burst was acquired at native index k, and that under alignment model version two its estimated reference time lies within a specified interval. If different defensible models give different event orders, that ambiguity must be reported. There is no defect in a report that stops at the limit of supported inference. The failure would be to confuse a convenient graphical normalisation with the discovery of facts about physical time which the receivers never measured.

David Lennox Mills, Cross-Peer Question to Donald Watts Davies: Mr. Davies, I wish to test the boundary between network observation and physical

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acquisition. A multi-receiver system presents an uninterrupted display, yet a packet trace shows a loss during one receiver's USB transport, and the source hardware declares that it continued sampling into a ring buffer. Under what conditions may the investigator treat the RF data as continuous, and what records would demonstrate that the missing transport object was retransmitted rather than replaced by an interpolation? Alternatively, if the ring buffer overflowed and the native sample counter skipped, can neighbouring receivers prove the missing instrument's antenna saw the same waveform? Please distinguish genuine recovery of already captured samples from an attempt to infer absent measurements. I also ask what the acceptance test should report when the firmware offers no trustworthy acquisition counter and returns only transfer timestamps. In that case an attractive alignment could conceal a complete uncertainty about the source interval.

Donald Watts Davies, Cross-Peer Answer to David Lennox Mills: Dr. Mills, a transport packet's disappearance does not by itself establish a loss of physical acquisition. If the receiver buffered the actual samples and subsequently delivered them intact, with source-native block identifiers, verified content lengths and valid continuity counters, the recording may indeed be complete after recovery. The proof should not rest on the application's statement that a retransmission occurred. The recovered objects must be identifiable as the original acquisition blocks, and their native sequence and checksums or protected source digests should be checked against the device's declared behaviour. A later file may have a different container hash from an earlier partial file, but the preserved samples and restoration operation can still be explained precisely through

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the derivative ledger. This is a recovery of existing data, not a recreation of measurements.

If the acquisition buffer itself overflowed, there may be an interval for which the receiver obtained no usable data or could not preserve what it obtained. Neighbouring receivers can supply independent observations of the external test event, within their own calibration limitations, but cannot establish the absent receiver's actual response. Different antennas, gain settings, filters, multipath and overload states can produce different complex samples even for a common external transmission. Replacing the missing portion by another receiver's data would create a modelled composite with different provenance and should never be labelled the original receiver's stream. It may be useful for a separately disclosed simulation, but it cannot support a statement that the missing instrument measured the substituted waveform.

Where only transfer timestamps survive, the limit must be recorded frankly. A host log may show receipt of certain blocks and their wall-clock times; without validated acquisition identifiers or measured delay it cannot establish the exact sample counter history. We may compare file size, packet order and device status to estimate possible loss, but a conclusion about continuity remains conditional. An acceptance test should expose this uncertainty by deliberately dropping transport, overfilling buffers and changing the host clock, then observing whether the software falsely declares uninterrupted acquisition. If the status fields cannot disambiguate the conditions, the test report should say that the instrument architecture does not support the required evidential claim at the specified confidence. A gap in the evidence is a design limitation, not a licence for invention.

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The central lesson is to distinguish physical acquisition, transfer, preservation and representation. Each can fail while another succeeds. A sound multi-receiver history keeps those stages visible and provides the technical reviewer with the native objects, status evidence and transformations necessary to decide what actually occurred. No participant should be asked to certify more than his observations establish. When a system cannot distinguish a legitimately recovered buffer from synthetic fill, it must either be redesigned for that duty or described as unsuitable for the stronger conclusion. That decision is more valuable than any smoothly rendered waterfall.

QUESTION 094. TECHNICAL SOURCE NOTES. This contemporary dialogue is fictional scholarly reconstruction, not an actual historical exchange or quotation. Selected technical background references: David L. Mills et al., RFC 5905, Network Time Protocol Version 4: Protocol and Algorithms Specification (June 2010), https://www.rfc-editor.org/rfc/rfc5905; Karen Kent, Suzanne Chevalier, Tim Grance and Hung Dang, NIST Special Publication 800-86, Guide to Integrating Forensic Techniques into Incident Response (2006), https://csrc.nist.gov/pubs/sp/800/86/final; IEEE 1588 precision time synchronisation standards where appropriate to the actual equipment and revision. RFC 5905 documents system-clock discipline, not a universal warrant of ADC aperture alignment. NIST SP 800-86 provides broad forensic documentation guidance, not an RF sample-clock calibration protocol. Instrument-specific claims require independent checking.

EDITORIAL QUALIFICATION. The imagined deceased expert dialogue is a pedagogical reconstruction, never archival testimony. All examples and numerical input values are hypothetical; they are not measurements of an

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unknown emitter. Source-to-claim verification, clock metrology, historical and legal review, complete semantic novelty assessment and continuous whole-volume publication proof remain pending. The source and derivative distinction is mandatory: neither interpolation nor agreement among other instruments recreates an absent receiver sample.

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QUESTION 095

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What makes a software-defined receiver processing pipeline independently reproducible?

Dr. James M. Atkinson, Moderator: Dr. Dijkstra, a software-defined receiver can transform the same saved complex sample stream into apparently identical waterfalls on two computers while using different numerical libraries, software revisions or decision thresholds. A later forensic examiner may be impressed by the similarity of the images without discovering that the signal classifiers took different computational paths. I invite you to distinguish bitwise, numerical and scientific reproducibility; specify which original observations and configuration details must be preserved; and define a controlled second-host experiment that can detect a substantial error despite the resemblance of the final visualisation. This discussion is a fictional educational reconstruction, not an archival exchange among the historical experts.

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Edsger Wybe Dijkstra, Principal Contributor: Reproducibility is not one property but a family of claims whose preconditions must be stated. A bitwise reproduction asserts that a specified computation on a specified byte sequence produces an identical byte sequence under declared conditions. Numerical reproduction asserts that relevant values agree within a tolerance that has been justified for the method and decision being tested. Scientific reproduction asks whether the experiment, including acquisition and calibration, supports the same physical inference under independently controlled conditions. These claims differ in their logical strength and in their objects of comparison. A programme may reproduce every byte of a flawed output perfectly, while a correctly calibrated receiver operated under different environmental circumstances may yield numerically different but scientifically consistent observations.

The first necessity is a defined original object. A set of complex samples without its format contract cannot be interpreted unambiguously. The manifest must specify whether each component is a signed integer or floating-point quantity, its byte order, arrangement of I and Q, sample rate, nominal centre frequency, scale and associated device epoch. If an acquisition driver silently writes invalid samples after an overflow, the manifest should preserve the fault and not recast those values as reliable input. The chosen byte-level hash covers a precisely identified object; agreement on that digest provides continuity from the nominated reference state but does not establish that the receiver's analogue front end measured the physical world accurately. For that separate question we need calibration, known reference signals and a verified understanding of every transformation before digitisation.

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I next require a computational graph, not merely an application's name. The graph states each stage in order, including filtering, frequency translation, resampling, decimation, windowing, Fourier analysis, averaging, thresholding and plotting. Each stage should have declared input and output conventions, numerical precision and parameter values, including coefficients that the graphical interface may not display. A software version string is useful but is not enough if the same version can invoke a different FFT library, a hardware-accelerated kernel or a configuration file changed after the capture. Nor is a source repository commit sufficient if the binary used at the scene was compiled with different flags, bundled proprietary libraries or a modified FPGA image. A genuine reproducibility record has to bridge source intent and executed implementation.

There is an important distinction between an RF sample record and the executable environment. The first is an evidence object originating from hardware and an acquisition operation. The second is a computational environment that interprets that object. Both require traceable identifiers, but they must not be merged into a single assurance such as 'the file was unchanged'. A captured IQ record may be untouched while a changed filter coefficient alters its apparent bandwidth. Conversely, a deterministic filter may be recompiled into a numerically different implementation yet continue to produce a result consistent within an explicitly justified tolerance. The audit must state which guarantee is being sought. Where legal or technical consequences turn on a small threshold difference, an unexamined change in numerical rounding is not a decorative detail.

For the second-host experiment, begin with a protected reference IQ file acquired during a lawful laboratory test whose source waveform and

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instrument state have independent documentary support. Freeze the format specification, processing graph, coefficients, dependency versions, source and binary identifiers and hardware-acceleration configuration. Run the pipeline on a second computer and compare not only the final picture but selected arrays after each consequential stage. Record the size, type, scaling and tolerance used for those comparisons. If exact agreement is required, describe why it is realistic; if bounded numerical differences are permitted, justify a bound tied to the detector's sensitivity and final conclusion. An unexplained mismatch at an intermediate stage is not cured by selecting a colour scale that makes the plots look alike.

The laboratory should also test whether the verification has power to discover errors. Change the interpretation of interleaved I and Q, alter one filter coefficient, substitute a different FPGA image identifier and insert a known sample discontinuity. A well-designed reproducibility test will reject at least those substitutions which violate the declared computational contract, even if the output retains superficial visual similarity. A negative control is particularly valuable: a detector that claims to have verified an identical processing chain while failing to notice a changed decision threshold has demonstrated that its evidence is insufficient. The acceptance test should declare its sensitivity to the perturbations chosen, rather than promise omniscience about all possible deviations.

I would encourage a small collection of canonical numerical test vectors, with expected intermediate results, carefully stated input types and measurement tolerances. These provide a way for an independent examiner to test a new platform without assuming that a proprietary graphical interface is itself a standard of truth. The vectors do not replace instrument

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calibration or proof of lawful data acquisition. They test the computational interpretation of specified inputs. The same distinction applies to a digital signature or protected digest over the processing recipe. It can attest to the continuity of the documented recipe under suitable trust conditions, but cannot prove that the recipe answers the right scientific question. Software integrity and scientific validity are related, not synonymous.

When the object of the inquiry is a particular detection decision, the comparison must include the decision threshold, estimated noise floor, data-exclusion rules and handling of missing or invalid samples. Two waterfall displays can be made visually similar through independent choices of averaging or colour scaling while reporting different event durations. A disciplined reviewer must be able to reproduce a numerical decision in the same stated units and challenge the assumptions behind it. One useful form is a report of the input record identifier, processing graph version, intermediate numeric diagnostic, final detection value, threshold, uncertainty and exact reason that a segment was excluded. Such a record is more informative than a screenshot bearing only a date and a frequency label.

Finally, I would require preservation of corrections without silent replacement of original analysis. If a computational dependency is found to have changed or a converter is discovered to have reversed I and Q, issue a revised derivative with a new identifier, retain the original and document the effect on every substantive finding. In no case should a programme be allowed to assert that a reproducible output is a faithful RF observation simply because repeated runs agree. The honest conclusion may be that one calculation is repeatable while its scientific interpretation remains

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unverified. The ability to make that distinction should be designed into the software as carefully as the mathematics of the transform itself. I respectfully return the token to Dr. Atkinson for the remaining experts to challenge the compiler, storage, statistical and formal-verification assumptions.

Jerzy Neyman, Peer Question: Dr. Dijkstra, you require a predetermined comparison tolerance, but I am concerned by how one chooses that tolerance without looking at the troublesome data first. Suppose two receiver pipelines calculate the same spectral score to four decimal places on most test vectors, yet disagree on several weak synthetic bursts deliberately placed close to the decision boundary. It would be tempting to choose a tolerance wide enough to make the entire table agree, then announce an independent reproduction. That would confuse a retrospective accommodation with an externally justified acceptance criterion. How should an engineer design a test collection that separates routine numerical discrepancies from differences consequential to false-alarm probability? Please distinguish the numerical tolerance for an intermediate floating-point array from the inferential threshold that determines whether an event is reported. I also wish to know whether the laboratory must reserve new data after selecting its comparison rules, and how it should document decisions made while debugging a failed acceptance test. A later court or academic reader must not mistake the final successful run for the whole experimental history.

Edsger Wybe Dijkstra, Response: Professor Neyman, your objection exposes the danger of allowing a tolerance to function as an eraser. The engineering contract should specify both numerical and inferential criteria before the

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independent comparison. For example, an intermediate array might be compared under a declared absolute error and relative error rule, with special handling of values near zero. That rule should follow from numerical analysis of the algorithm, the stated precision, and verification on known test vectors. Separately, a classifier may apply a statistical threshold derived from a specified noise model and the number of opportunities for false detection. It is a category error to adjust the first rule merely because the second produces an inconvenient disagreement. The tolerance verifies that the numerical implementations are sufficiently equivalent for the intended purpose; it does not independently validate the purpose.

I would use three distinct datasets. A small canonical set contains analytically predictable values and exposes representation, indexing and scaling errors. A development set permits programmers to inspect and correct their implementation, but its results cannot thereafter be described as a blind confirmatory test. A reserved acceptance set remains inaccessible to those making the last substantive parameter choices until the procedure and tolerances are frozen. If the two programmes disagree on near-threshold examples, preserve the full numeric score and the decision from both systems. A stable comparison of intermediate arrays does not imply a stable decision when the threshold is narrow. Where a discrepancy crosses the reporting boundary, the correct result is a qualified failure or an indeterminate classification, not an enlarged error allowance.

Debugging history is an evidential record. Each failed run should retain the source input identifier, software and library versions, test settings, exact discrepancy, proposed cause and corrective action. A fixed bug may be deployed in a new build, but that build receives a new identifier and a fresh

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acceptance run on a still-independent set where available. The former failure cannot vanish merely because the latest release succeeds. An auditor should know whether the discrepancy arose from floating-point evaluation order, an incorrect window, a changed threshold or a failure to preserve a sample gap. If the investigator changes the intended specification after seeing the results, that change needs its own rationale and should trigger renewed independent testing.

One should also make the statistical proposition explicit. A nominal false-alarm rate is not guaranteed by repeating the same dataset through equivalent algorithms. It depends on how the detection rule was chosen, which hypotheses and time-frequency cells were considered, how correlated observations were handled and whether the assumed background distribution was plausible. An exact reproduction of a retrospectively tuned threshold can reproduce an invalid inference with extraordinary precision. The acceptance report should therefore provide separate findings on computational agreement and on the calibration of inferential risk. The first answers whether the calculation repeats; the second asks what its answer means. Neither should borrow authority from the other's success.

Abraham Wald, Peer Question: Dr. Dijkstra, let us examine the practical order in which an independent examiner should test a pipeline. A receiver programme may contain tens of stages, and the analyst may decide to stop investigating as soon as its final output resembles a reference. This creates a selective testing problem: failures that are inconvenient may receive additional trials, whereas successes are accepted at once. If one test vector contains a known signal and another includes deliberate overload or lost samples, a programme might pass the first and silently misinterpret the

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second. What sequence of checks would you require so that the stopping rule itself cannot hide the weakness of the evidence? In addition, how should the examiner account for test cases that were added after an earlier version failed? Does a succession of corrected builds create a new inferential burden, or may one reasonably accept the eventual passing build without describing its predecessors? Finally, specify the minimal documentary record that a second institution would need to repeat the acceptance decision without access to the first institution's informal notes.

Edsger Wybe Dijkstra, Response: Professor Wald, the proper answer begins with a test protocol that has explicit completion and stopping criteria. The examiner should not stop upon seeing one appealing result. The protocol should identify the full matrix of test inputs, required stage comparisons, expected pass and fail behaviour, numerical tolerances and final acceptance decision before the run begins. All designated cases should execute, including malformed metadata, declared overloads, discontinuities, zero-amplitude inputs, phase-reversed tones and near-threshold synthetic events. If the software crashes or the environment fails, the event remains recorded as a test result requiring explanation. One may later rerun the case under controlled conditions, but the first outcome cannot be expunged from the audit trail.

A reasonable order separates foundational defects from subsequent inference. Verify first the byte identity and format contract of the original sample object. Then confirm that the processing programme loaded its declared configuration and binary dependencies. Next compare stage-level numerical results on simple canonical vectors, before moving to complicated known RF patterns. Only after these prerequisites should the

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examiner assess detector labels on a blinded held-out suite. This order prevents a classifier from receiving credit for a plausible label when its internal frequency axis is wrong. Yet the protocol should still preserve the complete test inventory rather than skipping downstream tests without a formal status such as blocked by prerequisite failure.

When a failed case leads to a code change, the new executable is a new subject of validation. The repaired build may ultimately be accepted, but its history must show the fault, the corrective change and the evidence that the correction did not create regression elsewhere. A test introduced in response to a failure can be valuable as a regression test, but it is no longer blind evidence that the team had no opportunity to tune the product to it. Keep it in the permanent suite and procure fresh independent cases when claiming generalised acceptance. The distinction is not punitive. It is how one avoids confusing learning from errors with an objective estimate of performance on unseen conditions.

The minimal reproducibility dossier includes the input identifiers and checksums, format contract, test vector generation method, executable and dependency identities, exact command or workflow used, stage parameter manifest, expected numeric outputs and acceptance tolerances. It also contains observed outputs, environment details, failure reports, code-change records and an explanation of any excluded case. Where a protected IQ sample cannot lawfully be shared, an authorised independent auditor may execute the test in a controlled environment with auditable access. If some stage remains proprietary or inaccessible, the report must state which portion of the computation could not be checked. The evidence is more

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credible when its limits can be understood without personal acquaintance with the original programmer.

Dr. James M. Atkinson, Moderator: I thank Edsger Wybe Dijkstra for identifying the evidence boundary. With respectful passage of the token, I invite Grace Brewster Murray Hopper to examine the next distinct technical layer. The historical specialists are participating in a fictional modern educational discussion, not an actual recorded meeting.

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Grace Brewster Murray Hopper, Second Principal Contributor: Dr. Atkinson, an independently reproducible receiver pipeline must be described as an executed programme rather than a comforting account of what the programmer intended to execute. In a software-controlled instrument, the same named application can act differently because its configuration was read from another directory, a dynamically linked numerical library changed, the device driver negotiated a different sample format, or an FPGA image altered the transformation before the software received the first complex sample. A printed programme listing is not the machine state. A forensic examiner must therefore distinguish source code, executable binary, load-time dependencies, run-time configuration, device firmware and the actual record of operations. The last item is difficult, since an ordinary log shows what its author chose to log, not necessarily every branch that executed.

My first proposal is an acquisition manifest with explicit typed fields rather than a prose assurance that settings were standard. The fields should include instrument make and model where confidentiality permits, unique device identity, analogue preselector selection, gain and attenuation, nominal centre frequency, sampling clock source, bandwidth, ADC scaling, overload indication, channel count, complex-sample packing, interleaving, byte order and any declared discontinuity. Each capture epoch requires a reference to the hardware and firmware state under which it was generated. Such a manifest can be written using a documented format; an existing metadata standard may provide a useful base, but investigators must identify which extra records are required for their apparatus. An identifier pointing to an unavailable private configuration file is not adequate. A

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reviewer must be able to retrieve or reconstruct the specified configuration under controlled permission.

Next I would identify the program artefacts by cryptographic digest, build provenance and dependency inventory. A source revision number alone can omit uncommitted changes, generated files and build-time substitution. A binary digest identifies a particular byte sequence, provided that its reference was generated and preserved under trustworthy procedures; it does not tell us whether that binary executed without modification or whether the operating system loaded the library that the investigator expected. Record the interpreter or compiler version, compilation and linking flags, CPU architecture, accelerator runtime, numerical libraries and container image where one was employed. A software bill of materials is useful, but should not be mistaken for a complete proof of execution. Dynamic environment variables, external calibration files and operator selections must also be captured.

I would design the signal-processing graph as a sequence of contracts. A stage receives a well-defined typed vector and configuration, and produces a well-defined vector and diagnostic record. A resampler requires its rational rate relationship, filter coefficients and initial state; a Fourier estimator requires transform length, window weights, scaling convention, segment overlap and averaging definition; a classifier requires its threshold, noise estimator, exclusion policy and treatment of ties. Where state carries between blocks, a file of input samples and the current block's settings may be insufficient to reproduce the output. The initial state and preceding samples, or an explicit reset event, belong to the computational description.

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It is entirely possible for two programmes to process the same block differently because their filters entered the block with different memories.

The laboratory should establish golden vectors whose expected intermediate answers are independently derived. A single pure tone is too indulgent; it can allow errors of normalisation, conjugation or clipping to go unnoticed. Include a complex sinusoid of known relative phase, an impulse, a stepped amplitude, two adjacent tones, calibrated noise, a buffer boundary, an overflow marker and a deliberately malformed metadata record. These are test vectors, not a simulation of an unknown radio emitter. The specimen should state whether outputs are compared bit for bit or within a justified tolerance, and which comparison is relevant to the reported scientific claim. Exact binary identity is often appropriate for file provenance, whereas floating-point values obtained on different architectures may require controlled tolerances. One cannot approve every difference merely by declaring numerical algorithms approximately equal.

A useful exercise is to modify exactly one filter coefficient while leaving the displayed colour limits unchanged. The final waterfall may look unaltered on a small monitor, yet the numeric power near a detection boundary may move sufficiently to reverse a classification. Therefore the acceptance procedure must compare arrays before display mapping, not only their rasterised colours. Another negative control is to swap I and Q interpretations while preserving the same data bytes. For some magnitude-only summaries this error may be hard to see, but frequency-sign and phase conclusions can change. The validation should report whether the test detects that substitution. An accepted pipeline that fails to discover known

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false inputs has not established the independence that its polished user interface suggests.

I would further require the programme to write a machine-readable decision record. For each declared finding it should identify the input digest and byte scope, processing recipe identifier, relevant intermediate measurements, thresholds, decisions and uncertainty assumptions. A signal-detection decision must include the time and frequency interval actually examined. The record should say whether intervals were excluded owing to missing or invalid samples, overload or incomplete observation. A plot that fills an unavailable interval with a dark colour is a representation choice and must not imply that silence was measured. Likewise a remembered threshold displayed in a settings panel is not evidence that the same threshold was applied during an earlier run. The operative parameter value belongs in the decision record.

Independent reproducibility means that a competent person outside the original programming team can follow documented instructions, obtain the authorised inputs, execute a controlled version of the pipeline and account for differences. It does not mean that sensitive recordings should be published indiscriminately. The institution can arrange secure access, minimised excerpts, test vectors and segregated legal authority while retaining proper auditability. If access restrictions prevent an examiner from reproducing a claim, the final report should identify that limitation. Privacy, reproducibility and lawful authority are related governance problems, not reasons to conceal an unexamined algorithm behind an impressive certificate.

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Finally, every correction should preserve its ancestry. A changed firmware image, revised calibration or repaired overflow handler should produce a newly identified processing environment and a new derivative record. It must not overwrite the historic computation and then assert that the original was always correct. A system that preserves the wrong answer and explains how it was wrong is often more useful to forensic review than one that silently replaces a difficult record with a tidy result. My recommendation is to treat the reproducibility dossier as an executable specification of the calculation, a provenance record of the input, and an honest inventory of what the software cannot prove. I pass the token to the experts who will test whether the specification actually determines the result.

Sir Karl Raimund Popper, Peer Question: Admiral Hopper, your proposed execution dossier is thorough, but I would ask whether it can survive an adversarial attempt to falsify its central claim. It is easy to select two familiar test recordings, reproduce their visible output and infer that the whole receiver pipeline is reliable. That inference may be unjustified. A concealed dependency could alter a detection threshold only in a narrow frequency range; a faulty driver could corrupt data solely when buffers overflow; a proprietary FPGA image might be replaced while preserving an apparently identical software version string. Which trials would you demand expressly because they could refute, rather than merely confirm, the asserted equivalence? How should investigators handle a procedure that cannot be tested independently because part of its executable environment is unavailable? And would you agree that reproducing the precise errors of a defective instrument is sometimes useful evidence of computational

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continuity, even though it does not validate the physical conclusion? Please explain how the report should distinguish these propositions for a reader who sees only the polished final waterfall.

Grace Brewster Murray Hopper, Response: Sir Karl, a meaningful test must be capable of detecting the departures it claims to rule out. I would write the assertion first: for these fixed input bytes and this declared processing recipe, the second system will calculate matching stage outputs within the published tolerance and reach the same decision except in the explicitly identified indeterminate zone. Next I would enumerate plausible counterexamples. Replace the recorded firmware digest with that of a different image; alter a filter coefficient; exchange I and Q; change the sample rate metadata; suppress a buffer-discontinuity flag; and substitute another detector threshold. The harness should report which counterexample it actually detects. If it fails to notice a change that affects the scientific conclusion, it has not vindicated the assertion. That is a falsifiable engineering statement, not a declaration that an application is reliable in every imaginable circumstance.

A single waterfall image is a poor comparison oracle because it is deliberately lossy. Colour quantisation, limited screen resolution and plotting scales can make different numeric spectra appear nearly identical. I would retain numerical arrays before the colour mapping, a compact set of intermediate stage digests where exact comparison is meaningful, and explicit detector scores with their thresholds. An altered window may affect leakage near a weak adjacent tone while leaving the dominant signal's colours unchanged. An altered threshold may leave the entire image unchanged while reversing a flag in the event register. A genuine negative-

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control test should be chosen to expose that separation. The evaluator must not let an operator's visual judgement substitute for a quantitative result.

Proprietary parts need carefully defined treatment. A manufacturer might provide a reproducible binary image and a signed technical description without exposing all source code. That can permit tests of image continuity and external behaviour, but it cannot amount to an independent formal audit of an unavailable algorithm. The examiner should report which contracts were tested as black boxes, which internals were inspected, and what residual uncertainty remains. Where the FPGA image cannot be preserved or identified at all, one cannot later claim the same execution environment was reconstructed. Such a limitation is not cured by a manufacturer's assurance that the receiver was set to its usual configuration.

As to reproduced errors, I agree they can be illuminating. If two controlled replays reproduce a known sign inversion or a scaling defect, they may show that an earlier erroneous calculation was executed consistently. The finding belongs in a historical reconstruction of the evidence, not in an assertion of correct RF interpretation. Preserve both the original derivative and any corrected derivative with separately protected identifiers, and explain the effect of the fault on prior reported conclusions. The institution should resist the temptation to hide defective calculations once a correction is available. Independent reproducibility is strongest when it preserves uncomfortable evidence and makes clear precisely which claim each experiment did, or did not, establish.

Dr. James M. Atkinson, Moderator: I thank Grace Brewster Murray Hopper for identifying the evidence boundary. With respectful passage of the token,

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I invite Alan Mathison Turing to examine the next distinct technical layer. The historical specialists are participating in a fictional modern educational discussion, not an actual recorded meeting.

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Alan Mathison Turing, Third Principal Contributor: Dr. Atkinson, a reproducible computational process is one whose relevant operations have been described sufficiently precisely for another computing system to carry them out, but the word relevant requires attention. If a practical receiver employs an adaptive filter, randomised estimation or parallel execution, it may not generate identical machine words on every occasion. The investigator must therefore state whether the proposition concerns identity of execution, equivalence of mathematical operations, or robustness of a scientific decision. A machine that gives the same answer because a programming error recurs has exhibited repeatability, not validity. Conversely, two calculations that differ in their final decimal place may agree in every physically meaningful respect. The rigorous question is what observations and transformations determine the conclusion, and what tolerance a contrary outcome would have to cross.

I should begin with a state-transition description. Let a computational stage receive an input vector, a set of coefficients, an internal state and a declared numerical model. Its output is determined, or described as random under a fully specified stochastic model, only when those components are known. An adaptive noise estimator may depend on earlier blocks, rejected observations and reset policy. It is insufficient to preserve the short interval in which a peak appeared if the noise threshold was derived from the preceding half-hour. Likewise, when samples are missing, the application may hold its filter state, reset it, interpolate or process a synthetic zero sequence. Each choice changes the result. The replay record should include the initial and final state of consequential stages or enough earlier observations to reconstruct them.

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A modern pipeline is also a set of transformations between representations, and errors are particularly likely where one representation meets another. Complex samples may be stored as signed little-endian integers yet consumed as floating-point values after scaling. The scale factor could be voltage per code, relative full scale or an arbitrary software convention. An FFT implementation may return unnormalised complex coefficients while a later power calculation assumes unitary scaling. A frequency display might place the zero-frequency bin in the centre after an FFT shift, whereas a classifier could operate in unshifted order. If the internal contract is ambiguous, two teams can each produce a plausible plot while assigning different frequency labels to an identical bin. A formal example should expose the conventions rather than conceal them beneath an application's name.

Consider an authorised test stream with nominal complex sample rate 2,000,000 samples per second and a transform length of 4,096. The nominal bin spacing is 2,000,000 divided by 4,096, or 488.28125 hertz. If a second application mistakenly imports a sample rate of 1,920,000, it will assign 468.75 hertz between bins, even though it computes an identical transform array. An image configured to show only relative bin numbers can mask the disagreement. This is a transparent hypothetical calculation, not a measurement of actual hardware accuracy. A proper test preserves the sample rate provenance and checks the physical frequency axis as well as the arithmetic output. The error demonstrates that repeatability of the FFT is not repeatability of the frequency determination.

My second thought concerns the words exact and equivalent. Floating-point arithmetic is sensitive to order of summation, rounding mode, compiler

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optimisations and instructions that combine multiplication with addition. A parallel reduction may sum small powers in a different order from a serial programme. That need not invalidate a measurement, but one cannot infer acceptance from a vague statement that computers differ. For every critical output define an absolute tolerance, a relative tolerance where sensible, and a special rule near zero or a decision boundary. Document the maximum observed discrepancy on a frozen suite of test vectors. Where a small discrepancy can reverse a classification, the test must disclose that instability instead of enlarging the tolerance until all desired results pass.

I propose a decision-oriented validation experiment. Freeze a reference IQ input and all explicitly modelled parameters. Execute it on two independently prepared systems, compare exact input bytes, compare decoded numerical samples, compare each stage's output within its declared contract, then compare event labels. Introduce a synthetic event deliberately placed above the nominal threshold, another below it and a third nearly equal to it. The laboratory should report the margin between score and threshold for each event. If two systems agree on the far cases and disagree on the near case, the result reveals a precision-limited decision boundary that deserves disclosure. It is not repaired by taking a majority vote or ignoring the inconvenient case.

The negative controls should probe causality. Deliberately alter a window normalisation constant, reverse the byte order, change a resampler's initial condition and substitute a different threshold file. For each alteration predict which intermediate checks will fail and which final metrics might remain unaffected. A test suite that detects only gross corruption is not equivalent to a proof that all processing states are identical. The most

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convincing evidence is not that the systems pass, but that the checks fail when the specified contract is violated. If the final colour map is unchanged while numeric arrays diverge, the test should name the stage at which the divergence first appears.

There is, however, a boundary between mathematical reproducibility and the origin of the data. An algorithm receiving the same fabricated IQ stream may calculate it flawlessly on both systems. No amount of internal agreement establishes that the samples arose from the antenna, that the analogue gain was correct or that an alleged time marker was calibrated. To test those separate propositions the laboratory needs an independently characterised reference source, suitable monitoring equipment, a documented uncertainty budget and the receiver's acquisition history. A complete scientific account therefore contains two experiments: one reproduces the processing of fixed bytes, and another checks the acquisition system against controlled physical stimuli. Neither experiment substitutes for the other.

I would treat the final report as a set of propositions each accompanied by the evidence that supports it. Proposition one: this exact byte sequence was preserved from a recorded custody event. Proposition two: this decoding contract converts it into the stated numerical sample array. Proposition three: the named computational graph produces stage outputs consistent with the comparison specification. Proposition four: an independently calibrated acquisition supports the asserted physical interpretation within the stated uncertainty. If the fourth proposition is not tested, the report must not borrow certainty from the first three. A responsible scientific manuscript can be elegant while preserving every necessary caveat. I pass

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the token to the coding specialists to examine corrupted records and error detection.

Charles Sanders Peirce, Peer Question: Mr. Turing, you describe a hierarchy of computational, numerical and physical claims. I wish to examine the step from a series of successful repetitions to a warranted general rule. If two machines return matching spectra on a collection of laboratory vectors, the evidence supports those tested conditions, but does it support a claim that an unknown receiver capture was correctly interpreted? What of a test suite chosen because the available instruments happened to perform well upon it? A programme that treats an invalid interval as zero may nevertheless pass all cases lacking dropouts. How should the investigative institution enlarge the range of circumstances in a principled way without announcing universal accuracy? I am also interested in the status of a surprising but repeatable observation. Can the analyst classify it immediately as an emitter, or should it remain a hypothesis until independent acquisition and reference-plane controls are applied? Please answer in terms a forensic examiner can record as distinct stages of inquiry.

Alan Mathison Turing, Response: Mr. Peirce, one must distinguish a general assertion about a programme from a statement about the data on which that programme has been tested. A finite set of successful trials supplies evidence of correct operation under the covered conditions; it cannot demonstrate correctness for all possible inputs, implementations or physical circumstances. We can strengthen the evidence by selecting a test collection that exercises defined failure classes, including discontinuities, large and small magnitudes, sign changes, boundary conditions, reference-clock deviations and saturation. We can also compare the output with an

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independently implemented calculation based on the same mathematical specification. Still the proper report says exactly which classes were examined and which assumptions were left untested. It should not treat the familiar phrase 'industry standard' as a substitute for that inventory.

Where test cases have been selected after observing performance, preserve that history. A set assembled to accommodate the device's limitations can serve as a development exercise, but it is weak evidence for reliability under conditions never included. A reserved challenge suite assembled by an independent party would be more probative. One can also use controlled perturbations to test whether the programme responds in the expected direction: double the amplitude of a small synthetic input within the linear range and examine the change in spectral power under a declared scaling; alter the sample rate label without changing the bytes and check whether frequency labels change while raw FFT coefficients remain fixed; insert a gap marker and ensure that the decision process excludes observations that were never made. These tests are valuable because their expected effects can be derived in advance.

A repeatable anomaly should begin as an observation with a bounded claim. If an unexpected spectral line appears in the output on every replay of a saved IQ file, we have evidence that the saved bytes and pipeline reliably produce that line. We have not yet established that the originating analogue event was a distinct external transmitter. A receiver intermodulation product, clock spur, data-format error or front-end overload may create the same pattern. The next phase is independent acquisition under altered antenna, gain, attenuation or reference conditions with an appropriate lawful authority. If the anomaly persists in a form that survives those

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controls, the set of plausible hypotheses can be narrowed. The document must not silently promote an image feature into an attributed emitter.

I would maintain an evidence ledger with four fields for every substantial proposition: the asserted fact, the specific supporting observation or computation, the competing explanation that remains plausible, and the proposed independent control. That structure makes inferential progress visible without pretending that uncertainty is failure. A second evaluator can then reproduce the calculation, challenge the control and adjust the interpretation without rewriting the original observation. The method is applicable to ordinary receiver engineering as well as forensic examination. Its central virtue is to turn a surprising but reproducible result into a testable question rather than a prematurely completed story.

Dr. James M. Atkinson, Moderator: I thank Alan Mathison Turing for identifying the evidence boundary. With respectful passage of the token, I invite Richard Wesley Hamming to examine the next distinct technical layer. The historical specialists are participating in a fictional modern educational discussion, not an actual recorded meeting.

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Richard Wesley Hamming, Fourth Principal Contributor: Dr. Atkinson, a receiver reproducibility programme ought to distinguish corruption in transmission or storage from a mistake in interpretation, since the remedies are altogether different. A digest of an input archive can reveal that its bytes no longer match a protected reference, subject to the cryptographic assumptions and custody procedure employed. A conventional error-detecting code can discover selected classes of accidental alteration; an error-correcting code may recover some corrupted symbols within a stated model. Neither mechanism can establish that an ADC was correctly configured or that a signal originated from the emitter later named in a report. The forensic failure occurs when the word integrity is applied indifferently to all these propositions.

Begin with the exact object being compared. If two investigators compute digests over different containers, the difference may arise from metadata serialization, timestamps or padding rather than from a changed numerical sample sequence. One must not discard the mismatch, but must identify its scope. A rewrapped copy could preserve every complex sample while changing an archive header; a swapped-endianness manifest could leave every original byte unchanged while changing the decoded waveform. Thus there are at least three levels of comparison: exact file bytes, decoded sample values under a named format contract, and physically interpreted measurements under a named calibration model. Every level requires its own test oracle. An equality assertion at one level does not automatically propagate to the next.

I would give the laboratory three deliberately adversarial objects. The first is a bit-for-bit clone of the nominated IQ file with a separately copied manifest.

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The second is a legitimate representation conversion, with values carried exactly where the target type permits, but with different file bytes. The third is the original file with a single inverted bit at a documented location. The full-file digest should recognise the clone and reject the changed bytes; the numerical equivalence test should admit the properly specified conversion where it is exactly reversible; and the provenance check should require that the conversion be a named derivative rather than passing it off as an unchanged original. These are different expected outcomes, and the acceptance harness should demonstrate all three.

We must also examine latent algorithmic corruption. If a file remains intact but the software reads signed sixteen-bit integers as unsigned sixteen-bit integers, no file-integrity mechanism will report an error. The decoded samples themselves are wrong. A robust test vector should contain positive values, negative values and boundary magnitudes so the mistake becomes visible. An IQ swap or conjugation can likewise alter phase and frequency sign while leaving some magnitude-only summaries approximately unchanged. Include a tone at a known positive frequency offset and another at a negative offset. The stage-level checks should identify which interpretation was applied, and the decision record should show whether a physical statement depended on that sign.

Bit errors and numerical precision have different practical signatures. A single corrupted high-order sample bit may produce an impulsive disturbance in the waveform and broad spectral leakage. Small floating-point rounding differences ordinarily produce much smaller and more distributed discrepancies, although threshold decisions can amplify even a tiny numerical difference into a changed label. Therefore a comparison of

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images or a single mean squared error can conceal both problems. I favour a suite that checks exact input digests, maximum sample difference, relative error of selected measurements, phase residuals and decision disagreements. Each test must state why its threshold was selected. If the laboratory sets a liberal tolerance solely to make a failed comparison pass, it has not validated the original claim.

Consider the effect of decimation. A receiver may reduce a complex sample rate by a rational factor after applying an antialias filter. Reproducing the output requires the actual filter coefficients, passband response, stopband response, rounding behaviour and delay convention. Two resamplers can produce similar-looking reduced-bandwidth records while differing materially near a narrow interferer or a short transient. A finite impulse response filter may also straddle a sample gap. If the replay tool simply joins the surviving blocks, it creates artificial adjacency and may smear a transient across a discontinuity. The gap mask should survive through the pipeline, with a declared rule for any output block influenced by invalid inputs. A file digest cannot reveal that an unobserved interval was silently treated as silence.

A reproducible programme should preserve evidence of negative results, not only successful event detections. If an overloaded front end or saturated ADC made a portion of the record unsuitable, that state must remain traceable even when the processed plot appears clean. Record the overload flag and its known limitations, the channel gain, any clipping count and the conditions under which valid samples were rejected. An engineer may choose to exclude a defective interval or apply a recovery method to a derivative, but those choices must be declared and must not be described as

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restoration of original RF information. Reprocessing is not the same as recovering a past observation that the instrument failed to acquire.

Testing error detection itself is a scientific question. A validation team should flip individual bits, truncate files at known boundaries, duplicate a block, shuffle blocks and change the manifest without changing the samples. The expected response is not identical for every fault. A protected digest should fail when its covered bytes change. A sequence checker should identify an impossible transition when device counters support that inference. A metadata-contract validator should reject an unsupported type or sample-rate declaration. An RF-level verifier should assess whether reference tones appear at the expected nominal frequencies under known conditions. A successful isolated check cannot certify the performance of the other checks. The test report should use a matrix of faults, applicable detectors, expected warnings and observed warnings.

I would close with the burden of explanation. An independent examiner must be able to say whether a discrepancy is one of custody, representation, algorithm, calibration or inference. Those categories make disagreements resolvable. A report that simply says that two programmes produced the same spectrum has discarded much of the information necessary to know what was repeated. Our object is not to make every file a permanent scientific truth; it is to preserve the conditional logic by which a particular measurement was interpreted. That logic may be challenged and improved without falsifying the original record. I respectfully yield the token for a wider examination of systems architecture and verification.

Bertrand Russell, Peer Question: Dr. Hamming, I should like to identify precisely what is meant by the assertion that a stored file is unchanged. A

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cryptographic digest over the file bytes might agree perfectly between two investigators even though one interprets the representation as signed integers and another as unsigned integers. A derivative archive might have different bytes yet contain sample values that are equivalent under a documented conversion. How would you write an integrity claim that does not confuse identity of symbols with identity of their meaning? And how would you explain the status of an erroneous but faithfully preserved manifest? I am especially concerned with the familiar slide from 'we reproduced the calculation' to 'we reproduced the physical event'. There seems to be an unstated premise that the source data and its calibration reflect the world. Could you formulate the necessary assumptions and suggest a practical test that reveals whether those assumptions are being smuggled into the conclusion? Please include the case in which one receiver silently drops samples but later writes a continuous-looking file.

Richard Wesley Hamming, Response: Lord Russell, one must attach the word unchanged to an identified object and a defined period. If a suitably protected reference digest was calculated over a particular sequence of bytes at a specified custody event, and a later digest over the same scope agrees under a secure algorithm, that supports the proposition of byte continuity from that reference state. It does not prove that the originating file was genuine or that the accompanying metadata was accurate. If the original manifest declared the wrong signedness, a perfect copy can perpetuate the mistake. Thus the record should retain separate identifiers and integrity protections for the raw sample object, its descriptive manifest, its custody history and each subsequent analytic derivative. A reviewer can then distinguish a faithful but false description from a later alteration.

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Numeric equivalence requires an explicit decoding rule. Signedness, byte order, complex channel order, saturation, scaling and invalid-sample markers must be part of the contract. A representation conversion may be mathematically reversible for the values present while changing the file bytes. The examiner should state that the derived samples are numerically equivalent under the described conversion, not that the source file remained byte-identical. If quantisation or rounding discards information, the converted values cannot simply be called identical; record the error bound and any scientific consequence. The programme can verify each level with its own test: byte digest, decoded-vector comparison and calibrated reference experiment. No level permits unexamined inferences about the others.

The source-to-world inference needs at least an acquisition chain model. A named receiver, antenna and preselector must have been operated in a known configuration; the relevant analogue gains and calibration must be supported; the timing and sample-rate assumptions must be qualified; and the occurrence of overload, clipping or dropped samples must be checked. A controlled laboratory tone, independently observed where practical, can test parts of that model. If a receiver drops samples and writes a continuous-looking file, matching the final file digest on every replay establishes only that the already truncated sequence is stable. The missing interval remains absent. A native sample counter or documented overflow indicator may expose the omission, but if no such record exists the investigator should not invent a loss duration.

A useful cross-check is to alter one fact at a time. Keep the file bytes constant but change the signedness field and verify that the decoded

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sample comparison rejects the mismatch. Preserve the correct manifest but invert a selected bit, and verify that the protected file digest changes. Feed an authorised reference signal under a different gain setting and examine whether the calibrated output changes in the predicted manner. Introduce a deliberate buffer loss, then confirm that the downstream graph marks the gap instead of creating fictitious zero samples. Each test challenges a particular premise. In the final report, write every conclusion with its conditions: given the nominated bytes, the stated interpretation, the executed recipe and the calibration evidence, this value was obtained. The assumptions are not a nuisance attached after the result; they are part of the result's meaning.

Dr. James M. Atkinson, Moderator: I thank Richard Wesley Hamming for identifying the evidence boundary. With respectful passage of the token, I invite John von Neumann to examine the next distinct technical layer. The historical specialists are participating in a fictional modern educational discussion, not an actual recorded meeting.

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John von Neumann, Fifth Principal Contributor: Dr. Atkinson, there is a temptation to describe the receiver as a single programme, but a modern SDR is a system of interacting machines. Analogue components condition the electromagnetic field before digitisation, programmable logic may filter or decimate samples, driver software transfers buffers, a host processor computes spectral estimates, and an operator interface selects what is displayed. Each component possesses a configuration and, often, a history-dependent state. A reproducibility argument that begins only when the host application receives bytes may be sufficient for reproducing an offline calculation; it is not sufficient to establish that a past observation was made under the stated RF conditions. We must draw the system boundary explicitly.

I propose a provenance graph in which every substantial evidence object and computational transformation is a node. The raw sample file, protected acquisition metadata, calibration certificate, firmware and FPGA identities, driver, processing code, numerical libraries and analysis recipe are referenced by verifiable identifiers. Directed edges show which versions and inputs produced each derivative. This is not a mystical diagram: it must be backed by actual stored objects and recorded operations. A hash of one node protects a specified byte sequence from unnoticed change under stated custody assumptions, while a signed manifest may connect nodes if its signing keys and controls are trustworthy. The graph itself should preserve previous versions so that a later correction does not erase the history of the analysis.

The graph needs to state which transformations are pure and which are stateful. A pure numerical transform on a declared vector and parameters is

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comparatively straightforward to reproduce. A block processor that adapts its noise estimate over time has hidden state unless its starting state and processing history are recorded. A receiver that changes gain automatically is not processing the same physical quantity throughout the capture unless the gain changes and settling periods are identified. An FPGA that applies a decimation filter with an unknown initial state may produce a brief boundary transient that no downstream replay can reproduce from the exported samples alone. The report must distinguish what was observed from what cannot be reconstructed without unavailable state.

Timing is another hidden connection between subsystems. The nominal sample rate printed by the host does not by itself establish the ADC aperture times. Host clock timestamps may describe transfer completion rather than acquisition. If the sample counter advances across a dropout while the file writer omits bytes, subsequent processing must retain an explicit gap. Interpolated values may be useful for certain exploratory displays but cannot become evidence of a received signal during the missing interval. In an independent replay the gap mask is an input with the same importance as the sample data. A system that discards it cannot truthfully reproduce the scientific meaning of its time axis.

Consider three forms of replication. In the first, the same executable and inputs are run twice on identical hardware, yielding exactly the same bytes. That demonstrates a constrained form of determinism. In the second, an independent implementation of the stated algorithm processes the fixed source data and agrees within an appropriate numerical tolerance. This gives stronger protection against common implementation errors, though the two implementations may share assumptions. In the third, a calibrated

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experimental setup creates a new authorised RF stimulus and the receiver system produces a result consistent within measurement uncertainty. This tests acquisition and physical interpretation, not identity of the original historical samples. A defensible monograph should keep all three tests distinguishable.

The acceptance programme should include a calculation whose output is independently predicted. At a nominal complex sample rate of 2,000,000 samples per second and an FFT length of 4,096, the nominal bin spacing is approximately 488.28125 hertz. A script that changes the rate metadata to 1,920,000 while leaving the complex samples fixed produces a nominal spacing of 468.75 hertz. The transform's complex coefficients may be identical while the physical frequency labels differ. This hypothetical example can be checked without requiring any knowledge of a real emitter. A test harness should therefore compare not merely arrays but also units, axis definitions and reference-plane calibration. Where the source was not actually clocked at its nominal rate, further uncertainty must be included.

I would not demand bitwise equality where the scientific claim does not require it. An order-of-operations difference in floating-point accumulation can change the least significant digits of an average. If the same detector's score is far from a threshold, such variation may be immaterial. If the score lies near the threshold, a tiny difference can reverse the reported result, and that instability is material. The proper acceptance criterion is a predetermined tolerance connected to measurement uncertainty and decision risk, not a tolerance invented after viewing the outputs. For critical outcomes, report the numeric score, threshold, uncertainty and classification from both systems. If they disagree, retain the disagreement

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as evidence that the purported conclusion is not stable under the tested conditions.

We should distinguish systematic faults from random variation. A mismatched calibration constant can bias every estimate in one direction while leaving repeatability excellent. A changed FFT window alters leakage and effective noise bandwidth in ways that may affect short bursts or nearby tones. A threshold selected retrospectively to make an observed event look significant invalidates simple prospective false-alarm interpretations, even if that threshold can be replayed exactly. The test of a processing pipeline is therefore not only whether the calculations repeat; it also asks whether the chosen procedure was fixed independently of the outcome and whether the calibration and statistical assumptions remain sound. The reviewer should have access to both the development record and the final decision rule.

The most instructive experiment is blind. A second laboratory receives a protected copy of the IQ dataset, the processing contract, a declared software environment and a list of expected output types, but not the original analyst's final classifications. It produces intermediate numeric products and a decision record; a custodian compares them against the reference using thresholds agreed in advance. Next the custodian gives several intentionally altered configurations, including an IQ swap, an outdated filter coefficient, an omitted gap mask and a changed display palette. The system should identify substantive changes without treating a harmless colour difference as a numerical failure. This tests the discrimination of the verification procedure, not just the compliance of participants.

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Finally, governance must be visible in the evidence trail. An analyst may be fully entitled to process an authorised defensive capture without being entitled to retain decoded private communications indefinitely. Reproducibility can be achieved through minimally necessary inputs, secure access and well-documented protected test vectors. The custody ledger must identify the legal authority, access history and transformations but should avoid unnecessary reproduction of communications content. Scientific reproducibility is a demanding standard precisely because it forces institutions to describe what was done, what was preserved, what could not be repeated and why. I return the token to the moderator with a recommendation: validate each link in the computational chain and refuse to let a polished final image substitute for those links.

George Edward Pelham Box, Peer Question: Professor von Neumann, your provenance graph may be exact and still encode a model that is only approximately appropriate. A receiver's noise may not be stationary, its clipping indicator may miss brief nonlinear events, and a windowed spectral estimator can report a stable line where the input actually varies between short observation periods. If two laboratories use the same flawed noise model, they may reproduce a statistically misleading threshold while believing that numerical agreement constitutes an independent verification. What would you place in the acceptance report to distinguish a successfully reproduced model from evidence that the model describes the acquisition circumstances? I also ask about correlation between overlapping FFT segments. Could a programme create hundreds of nearly identical plotted frames from one short observation and then report hundreds of independent confirmations? Finally, explain how an analyst should revise a

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detection rule after discovering model inadequacy without retroactively assigning its new false-alarm properties to the original exploratory search.

John von Neumann, Response: Professor Box, the model must be treated as a proposition under examination, not as a ceremonial credential. The acceptance dossier should state the noise and signal assumptions used by the detector, what observations were used to choose parameters, how often those assumptions were checked, and which conditions would invalidate them. A computational replay can establish that both laboratories applied the same estimated noise variance and threshold. It cannot, merely by agreement, establish that the background was stationary or that the selected distribution described the actual observations. That requires a separate model-checking exercise on appropriate independent data. The report should not use the word verified without specifying whether it means verified calculation or supported physical model.

An overlapping FFT estimator illustrates the problem well. Suppose a 4,096-sample window advances 1,024 samples at each frame. Consecutive frames then share 3,072 samples, or 75 percent of the samples in each window. The numerical result may be useful for display continuity or improved temporal sampling of a spectral estimate, but those frames are not independent experiments. Counting them as independent confirmations can produce overconfident significance statements. The actual dependence depends on the window and signal process; a simple count of frames is not an effective sample size without further analysis. A sound pipeline records the window length, hop, window coefficients, averaging rule, frame count and exclusion of invalid intervals, and it keeps the inferential analysis separate from the graphical convenience of overlapping views.

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I would require a controlled residual analysis. Apply the detector to background-only records from the actual class of environment where it will be used, inspect variation over time and frequency, and compare observed false alarms against the prospective expectation. Use synthetic perturbations to test clipping, clock spurs, gain changes and nonstationary interference. Reserve at least part of the evaluation data outside the selection process. Where the background changes materially, the report should say that the originally specified false-alarm calibration is not established for those conditions. If the apparatus includes an adaptive estimator, its adaptation and reset policy are part of the computational graph. The numeric values may repeat faithfully while the statistical reasoning requires revision.

When a detection rule is revised, preserve the original rule, outputs and exploratory history. The new rule receives a version and is evaluated prospectively on new or appropriately reserved data. One may recalculate the old record as a transparent derivative and explain how conclusions change, but it is invalid to assign a post-selection prospective error rate to an already inspected search. A good archive enables later investigators to see both the computation that generated a suspicion and the separate experiment that tested it. I would regard this division as an essential feature of independent scientific reproduction. It prevents the authority of a repeatable programme from being mistaken for authority over the statistical premises that programme happened to employ.

Walter Andrew Shewhart, Peer Question: Professor von Neumann, I would ask how the institution should manage a receiver pipeline whose environment changes gradually rather than through an obvious software

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release. A calibration coefficient may be updated after a service visit, a numerical library may change when the operating system updates, and a filter may acquire a slightly different response as the analogue hardware ages. The monitoring team may continue to see familiar waterfalls and assume that the system remains stable. What control measurements and change records would distinguish ordinary variation from a change that invalidates comparability with historic observations? I am also concerned with the practical moment of release. Which reference checks should block acceptance when a revision crosses a predeclared limit, and which discrepancies may be documented as harmless without quietly relaxing the standard? Please address the case of a receiver that passes a routine tone check yet responds incorrectly to a brief broadband pulse, since a stable mean value may disguise a serious transient fault.

John von Neumann, Response: Dr. Shewhart, a maintained receiver pipeline should have both configuration control and periodic physical performance control. A change ledger names software dependencies, executable artefacts, firmware and FPGA images, calibration constants, hardware servicing, sampling-clock references and the identity of the operator or automated deployment process. The ledger is not merely an inventory: each relevant change triggers a predefined regression suite. A library upgrade might require renewed numerical comparison of known test vectors; a change of analogue filter or gain calls for RF calibration checks; an alteration to capture buffering requires a gap-detection test. The test selected must correspond to the part of the chain that could have changed.

I would distinguish reference controls for steady-state and transient response. A continuous tone at a known nominal frequency can detect

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certain scaling or frequency-axis errors, but it may not exercise an overload-recovery path, an impulse response or short-burst capture behaviour. A step, a brief pulse or a controlled multitone signal can challenge those mechanisms in a lawful laboratory. An independent monitor should confirm the applied stimulus where meaningful, and test records should state the operating gain, bandwidth and clock conditions. Calibration cannot simply be presumed stable because a single displayed line stays in place. Measurements near the detector's operational limits deserve explicit controls rather than an attractive chart.

Before release, declare limits derived from the actual required measurement performance. The laboratory should identify which failures block the build and which bounded discrepancies are acceptable under a defensible uncertainty budget. A changed numerical output that remains within tolerance may be recorded as numerical equivalence; if the tolerance was not fixed before the test, acceptance is not yet established. A failed transient check should not be overridden because the average tone check passed. Nor should an operator hide a material difference behind a favourable selection of display scale. A programme may be released with a stated restricted scope if the evidence supports that restriction and relevant authorities accept it, but the restriction must travel with the data and any report relying on the programme.

Long-term comparability requires preserved versions of the reference experiments, not just a running success indicator. A later examiner should be able to see whether an historical measurement used calibration coefficient A rather than coefficient B, and which numerical library and sample decoder were operative at the time. New analysis may be performed

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on the original data under a new pipeline, but it must be labelled as a derivative. That separation allows the institution to investigate drift without falsifying history. The strongest form of process control is not never observing a change; it is detecting a change, understanding its consequence and preventing unqualified comparison until the new conditions have been validated.

Dr. James M. Atkinson, Moderator: The five principal contributions and seven answered ordinary peer questions have separated bitwise file equality, software execution and calibrated RF inference. I now pass the token through four reciprocal examinations of four different named respondents. Each reply shall address its immediately preceding question, without claiming that repeatability alone authenticates a physical source.

Alan Mathison Turing, Cross-Peer Question to Grace Brewster Murray Hopper: Admiral Hopper, your operational dossier contains source revisions, executable digests and device identities, yet I should like to know whether it records the actual computational route taken during an adaptive decision. Imagine two installations loading nominally the same classifier but using different CPU vectorisation instructions. Both pass a reference tone and present essentially identical waterfalls. During a rare buffer discontinuity, however, a fallback branch executes on one machine and not the other, producing a different threshold decision. Would you treat the two pipelines as independently reproduced if their usual-case outputs matched? How would you capture the path through conditionals, state changes and exception handlers without logging every sensitive sample twice? I also ask what should happen when the same software release dynamically selects between two FFT backends. A simple version number does not resolve which

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backend was invoked. Please explain how you would audit the operative branch and prove that the evidence record is not merely a list of intended settings.

Grace Brewster Murray Hopper, Cross-Peer Answer to Alan Mathison Turing: Mr. Turing, I would not call the pipeline independently reproduced for that exceptional case merely because the ordinary case passed. The claimed equivalence must be scoped to conditions actually exercised. Where the branch is relevant to a reportable detection, record the transition condition, branch or backend identifier, numerical input and output summaries sufficient to examine the decision, and the configuration hash or signed code version that governs the branch. This can be done without copying protected communications content into every diagnostic log. The analyst may preserve a protected reference to the original sample interval, a fixed numerical checksum over an intermediate array, a record of the state-transition event, and the exact parameter values used. The technical log should distinguish data needed to reproduce the algorithm from personal content not needed for the authorised purpose.

A dynamic dispatch mechanism must be made explicit. If the application chooses an FFT implementation according to CPU architecture or available accelerator, the actual selected backend and library build should be logged. The acceptance suite must test the numerical equivalence of each supported branch under the desired tolerances. It is insufficient to claim that the backends implement the same mathematical Fourier transform; their scaling, ordering, precision, rounding and exceptional-value behaviour may differ. If one code path has never been validated on the relevant input class, the report should say so. The fact that a fallback is rarely entered does not

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convert an unknown into a proven condition. A rare path may be precisely where missing samples or overload produce a serious evidential error.

I would also record state transitions independently of the final plot. A filter reset, an overflow marker, a change in gain, a threshold adaptation and a change of FFT backend can each alter the meaning of subsequent outputs. A compact event log with monotonically ordered identifiers and links to source sample offsets may provide adequate reconstruction, provided its own reliability was tested. It should record absence or failure of logging as a condition, not silently assume that no recorded event means no event occurred. A later examiner must be able to discover that the programme's diagnostic channel had been disabled. The controls protecting these logs are part of the evidential chain; a self-reported event log generated by an untrusted programme is not independent attestation of its own correctness.

To test the system, force the normal and exceptional branches with controlled synthetic IQ data and induced buffer conditions. The independent examiner should predict which path will run, verify the emitted identifier, compare intermediate arrays and check the final decision. Repeat the test on both processor architectures and record every discrepancy. If a decision disagrees under a permissible numerical tolerance because its score lies near threshold, the correct classification may be indeterminate rather than a forced equivalence. Corrected builds receive new identifiers and must be rerun. I would consider the pipeline reproduced only to the level supported by these experiments. One tested configuration cannot grant blanket assurance to unexecuted code paths, particularly where those paths alter evidence exclusion or threshold decisions.

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Grace Brewster Murray Hopper, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, let us suppose our source IQ bytes are hashed and unchanged, but a later investigator discovers that the original manifest declared the wrong full-scale reference. A new derivative corrects the voltage scaling, and the spectral power values shift in an entirely predictable way. The new calculation produces different numerical arrays yet is arguably a more accurate interpretation of the historical record. How should an evidence system maintain both versions without describing the correction as a tampering event? What kinds of checksum and semantic checks would distinguish byte continuity from a correction to the interpretation contract? I also wish to ask whether a small numerical error bound is adequate when the processing graph includes a nonlinear detector that turns a slight difference into a new event label. Please distinguish a benign conversion from loss of information and give a suitable acceptance test that an external examiner could reproduce without needing to trust the original programmer.

Richard Wesley Hamming, Cross-Peer Answer to Grace Brewster Murray Hopper: Admiral Hopper, the evidence system should preserve the original sample bytes and their original reference digest, the historic manifest and its own integrity record, and the revised manifest with a dated explanation of the scaling correction. A newly generated derivative carries a new object identifier, revised processing recipe and digests of its actual bytes. The old result remains discoverable and labelled as superseded or qualified; it is not erased. If the raw samples remain unchanged, that fact may be established independently of the changed voltage interpretation. An analyst can therefore say that byte continuity was maintained while a documented

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correction altered the physical scale. The distinction avoids both false allegations of tampering and false claims that nothing substantive changed.

I would have the verification suite compare sample arrays at the stage where conversion takes place. If integer codes are unchanged and only a linear voltage-per-code factor is corrected, a reference vector containing positive, negative and boundary values can show that the transformation obeys the new scale. If earlier processing clipped, quantised or resampled the data, the revised scale cannot recover values already discarded. The report should not pretend that a mathematically reversible unit conversion restores missing analogue information. It is essential to identify the reference plane for the claimed voltage and to verify that the hardware's calibrated gain actually supports it. The numerical conversion is testable on stored bytes; the analogue calibration may require separate instrument evidence.

Checksum equality has no general semantic implication. A protected digest verifies bytes over its declared scope. It cannot say whether a voltage factor is correct, whether the sample rate was calibrated, or whether I and Q were reversed during acquisition. A metadata-contract validator can catch contradictions between fields and a known equipment specification, but even a syntactically valid manifest may contain a false value. Negative controls should alter the scale, signedness and byte order independently while leaving raw bytes fixed, and confirm that the appropriate stage comparison detects each change. A clean programme should also reject a manifest whose version or required fields it cannot interpret. Quietly supplying default values is convenient in consumer software but hazardous in a forensic measurement chain.

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As to the detector, a small numerical difference is not necessarily a small inferential difference. If the original power score barely exceeded a threshold, a corrected scaling may reverse the reported event flag. The acceptance test therefore needs both a numerical tolerance for the stage values and a separate criterion for decision agreement, including a specified region of uncertainty near the threshold. Compare the old and new score, threshold, measurement uncertainty and decision, and disclose any changed conclusions. A false-alarm rate selected or calibrated for the old units cannot simply be carried forward to a different physical scale without checking the detector model. An independent examiner should be able to reconstruct each calculation and understand why the improved one differs. That is responsible correction, not a defect in preservation.

Richard Wesley Hamming, Cross-Peer Question to John von Neumann: Professor von Neumann, I ask about the provenance graph when it contains many linked artefacts but no independent check of the actual acquisition hardware. A system may retain every software binary and digest, yet a frequency offset in the sampling clock could cause all subsequent FFT frequency labels to be biased. Another system might reproduce the identical bias with impeccable computational fidelity because it uses the same incorrect rate metadata. How should the graph distinguish the experimental claim that a physical signal occupied a particular radio frequency from the computational claim that a fixed array maps to a particular nominal bin? Must the original calibration and reference measurements become first-class evidence objects rather than administrative attachments? I also ask how one should handle a revised uncertainty model: if an engineer later discovers that the reference-clock stability had been overstated, can the

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original calculations remain reproducible while the historical interpretation changes? The archive must surely allow that distinction without claiming to have measured the past a second time.

John von Neumann, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, calibration and reference observations must indeed be first-class nodes in the provenance graph. A claim about nominal bin location is determined by the stored sample array, transform length and declared sample rate, but a claim about actual radio frequency also depends on the accuracy of the acquisition clock and frequency reference, the receiver's tuning state and the conversion chain. Their documentary support cannot be relegated to a filename called 'calibration' without identifying which instrument was tested, when, under what conditions and with what stated uncertainty. The graph should connect the particular capture epoch to the applicable calibration evidence and indicate any assumptions needed to transfer that calibration to the field measurement.

If the nominal sample rate is wrong, an independently repeated FFT may still produce identical complex coefficients. The frequency axis constructed from the wrong metadata will be consistently wrong as well. That is precisely why an experiment using a known physical reference stimulus belongs beside the offline replay. A second-host calculation tests the processing of fixed bytes; a calibrated stimulus and an independent monitor test elements of the physical acquisition model. If the original capture cannot be repeated, one may test similar hardware to inform uncertainty, but that does not amount to recreating the historical electromagnetic event. The report should distinguish the provenance and relevance of any later measurement from the specific evidence acquired at the earlier time.

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A revised uncertainty model can be incorporated without overwriting the historic result. Retain the original calibration statement and the original calculation, then publish a new interpretive derivative explaining why the prior clock uncertainty was understated. The new version should include its assumptions, updated uncertainty calculations and effect on each reported frequency or timing claim. A statement that a historic line was observed at a precisely asserted frequency may need to be weakened to a broader interval. The fact that the original numerical processing remains bitwise reproducible does not immunise the physical conclusion against later corrections. Science gains credibility when it can revise interpretations while preserving its observation record intact.

For acceptance, I would define separate evidence gates: integrity of the original bytes; consistency of representation and processing; calibration and clock traceability; and sufficiency of the inference for the authorised reporting purpose. A failure at the physical gate cannot be cancelled by passing the computational gate. Conversely, a changed software library need not negate a physical observation if an independent algorithm reproduces the pertinent measurement within justified tolerance. The graph should expose both dependencies to the reviewer. Its value lies not in making every connection unquestionable but in allowing the investigator to identify exactly which connection supports a contested proposition and which connection remains uncertain.

John von Neumann, Cross-Peer Question to Edsger Wybe Dijkstra: Dr. Dijkstra, we have considered exact byte identity, numerical tolerance, software configuration and calibrated experiments, but a final methodological danger remains. A laboratory may implement every check

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you propose and still report one undifferentiated word, 'reproduced', on the cover of its report. In particular, a black-box comparison may establish matching output over a fixed suite without exposing the state transitions that gave rise to it. How should a formal assurance statement separate the existence of the original source file, the computational equivalence of its interpretations, the stability of detection decisions and the validity of an emitter inference? I also ask what evidence would lead you to refuse an unqualified conclusion even if all visible tests had passed. A thoughtful reviewer must know whether successful testing is sufficient merely for a bounded engineering statement or for a much stronger assertion about an event beyond the receiver. Please specify the narrowest honest vocabulary the institution should employ.

Edsger Wybe Dijkstra, Cross-Peer Answer to John von Neumann: Professor von Neumann, I would forbid the unqualified word because it conceals the predicate. We should instead write 'the nominated bytes were identical to the protected reference', 'the specified decoding produced equal complex sample values', 'the named processing stages agreed within declared tolerances', or 'the independent laboratory obtained a consistent measurement of the authorised reference stimulus within stated uncertainty'. These are testable statements with different premises. A detection classification should be described separately, with its score, decision boundary and sensitivity to numerical variation. An emitter attribution involves additional physical and contextual evidence and must not be inferred from a matching waterfall. Precision in language is a form of engineering control when the words govern legal and operational decisions.

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The assurance record should include the input object's identity and hash scope, the complete decoding contract, the graph version and executable environment, the comparison metrics at consequential stages, and the test inventory including deliberately failing controls. It should identify which cases were not run and why. If a black-box element cannot expose sufficient internal state, the permitted claim may be limited to externally observed equivalence on the tested vectors. The inability to inspect its logic is not necessarily a reason to discard every result, but it is a reason to refuse an assertion that the internal implementation was independently verified. A conscientious researcher does not extend a finite experiment to universal certainty through an adjective.

A report also requires a record of the experiment's prior decisions. The acceptance tolerance should be published before the blind comparison. The classifier threshold and statistical model should not be retroactively chosen after seeing the event. If the team changed the processing recipe during debugging, it should preserve the older run and assign a new identifier to the repaired one. A failing near-threshold case cannot be made to disappear by silently changing rounding policy or excluding the interval. The result may legitimately be indeterminate; that is a scientific outcome rather than an embarrassment. Unqualified conclusions should be withheld when a material decision depends on an unverified branch, a disputed clock, an unexplained sample gap or a calibration outside its established validity.

Finally, my assurance vocabulary would separate computation from observation and observation from inference. The first describes actions performed on bytes; the second concerns a physical event observed through instruments; the third connects that observation with a proposition

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about an external source. A programme can be perfectly deterministic while the observation is corrupted; an observation can be reliable while a downstream classifier is mistaken; and a correct classifier can identify a waveform family without identifying its owner. Each transformation between those propositions calls for evidence. The strongest roundtable conclusion is not that modern software can guarantee the truth, but that a well-designed record permits a later independent examiner to locate the exact boundary between proven continuity, validated calculation and residual doubt.

QUESTION 095. TECHNICAL SOURCE NOTES. This contemporary dialogue is a fictional scholarly reconstruction and does not represent quotations or an historical exchange among its deceased experts. Selected technical background references: National Institute of Standards and Technology, NIST SP 800-86, Guide to Integrating Forensic Techniques into Incident Response (2006), https://csrc.nist.gov/pubs/sp/800/86/final, a general digital-evidence process guide rather than RF measurement validation; Signal Metadata Format, SigMF Specification Version 1.2.6, https://sigmf.org/, providing metadata fields and a structure for recorded samples but not guaranteeing correctness of physical capture; SciPy v1.18.0 signal.welch documentation, https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.welch.html, documenting power spectral density conventions and Welch processing parameters. Engineering claims about calibration, actual firmware behaviour, legal authority and proprietary numeric implementations require separate instrument-specific source checks.

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QUESTION 095. TEN WORKED CHECKS. Each variable is defined within its example. All numbers are hypothetical and must not be presented as measured radio-frequency evidence. These checks verify limited arithmetic relations, not full software or measurement validity.

EXAMPLE 1. Hypothetical FFT bin spacing: for a nominal complex sample rate F_s = 2,000,000 samples/s and N = 4,096 FFT points, $\Delta f = F_s/N$ = 2,000,000/4,096 = 488.28125 Hz. This is an axis calculation, not a verified ADC clock calibration.

EXAMPLE 2. Changed metadata only: if the same complex samples are labelled F_s = 1,920,000 samples/s with N = 4,096, Δf = 1,920,000/4,096 = 468.75 Hz. Identical FFT coefficients can therefore receive different nominal frequency labels.

EXAMPLE 3. Overlap of windowed frames: with frame length N = 4,096 samples and hop H = 1,024 samples, overlap N−H = 3,072 samples and fractional overlap (N−H)/N = 3,072/4,096 = 0.75 = 75%. The two frames are not statistically independent by virtue of being stored separately.

EXAMPLE 4. Capture duration: for S = 16,384 consecutive valid complex samples at F_s = 2,000,000 samples/s, duration $T = S/F_s$ = 16,384/2,000,000 = 0.008192 s = 8.192 ms. Missing samples require a distinct gap record.

EXAMPLE 5. Power-ratio conversion: a power ratio R = 2 corresponds to G = 10 log10(R) = approximately 3.0103 dB, not 6.0206 dB. Voltage and power gain conversions must not be conflated.

EXAMPLE 6. Density integration over a nominal flat band: $P = S_p B$, where $S_p = 1\times10^{-10}$ V^2/Hz and B = 1,000 Hz gives $P = 1\times10^{-7}$ V^2; the approximation

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assumes constant density over the band and appropriate reference impedance/measurement conventions.

EXAMPLE 7. Raw-file size: for N_s = 1,000,000 complex samples stored as interleaved 16-bit I and 16-bit Q, bytes per sample = 2 + 2 = 4 and total size = $N_s \times 4$ = 4,000,000 bytes before any headers.

EXAMPLE 8. Raw throughput: at F_s = 2,000,000 complex samples/s and 4 bytes/complex sample, throughput = $F_s \times 4$ = 8,000,000 bytes/s, excluding framing, overhead and recording duplicates.

EXAMPLE 9. Power SNR: if signal power P_s = 1,000 arbitrary matched units and noise power P_n = 100 of the same units, the ratio is P_s/P_n = 10, giving SNR = 10 log10(10) = 10 dB, contingent on matched measurement bandwidth.

EXAMPLE 10. Clock-rate offset: a nominal F_s = 2,000,000 samples/s with an actual relative rate deviation $\varepsilon = 1\times10^{-6}$ implies absolute rate difference $F_s\,\varepsilon$ = 2 samples/s. This is a sample-count drift illustration, not a measured timebase uncertainty.

EDITORIAL QUALIFICATION. All deceased-expert speech in this modern fictional symposium was composed for the textbook and is not archival testimony. Byte-level continuity, numerical repeatability, acquisition authenticity, emitter attribution and legal permissibility are separate propositions. Stage A verifies specified structural requirements only; source-to-claim correspondence, historical suitability, mathematical and electronic-engineering correctness, broader semantic novelty and full continuous publication proof remain outstanding. Sample content must be minimised and preserved only with appropriate authority.

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QUESTION 096

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Why must exploratory threshold adjustment be separated from confirmatory RF tests?

Dr. James M. Atkinson, Moderator: Professor Neyman, a receiver operator can examine a broad waterfall, adjust a threshold until several intriguing patches become visible, then report that the same display offers statistically significant evidence of discrete transmissions. Yet the choice of threshold may depend upon the very fluctuations the operator seeks to evaluate. I invite you to separate exploratory discovery from prospective confirmation, explain the effect of multiple time-frequency comparisons and correlated windows, and propose a lawful calibration experiment in which software-defined receivers are evaluated on genuinely independent test records. Please distinguish the physical acquisition chain from the statistical decision rule, and be especially careful not to convert the visual appearance of a signal into an unsupported claim identifying its source. This is a fictional scholarly debate written for the present textbook.

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Jerzy Neyman, Principal Contributor: Dr. Atkinson, the central confusion arises when one treats a rule selected after inspection as though it had been prescribed independently of the observations. A statistical test requires a defined question, a test statistic, an acceptance or rejection region, a background model and a decision rule whose performance is to be evaluated. If a receiver analyst looks at a recording, experiments with a succession of thresholds and chooses the one that makes a particular peak appear exceptional, the resulting decision is conditioned on a selection process. The reported nominal probability calculated for one fixed threshold does not describe the probability that the entire search procedure would have produced at least one apparently exceptional event. Computational repeatability cannot remove that distinction. A second computer can reproduce the retrospectively selected threshold to the last digit while reproducing the same inferential error.

Consider a receiver that inspects many frequency bins at many successive times. Under a simplified model, let p denote the false-alarm probability of a single prespecified test under its background-only hypothesis. If one had m independent opportunities, the probability of at least one false positive would be $1 - (1 - p)^m$. That formula is illustrative because real waterfall cells are generally correlated through windows, filters, spectral leakage, overlap and a common environmental background. It does, however, expose why a seemingly stringent single-cell threshold may not provide the same error control across a large search. A nominal p of 0.01 applied to 100 independent opportunities produces a familywise probability of about 0.634 that at least one will exceed the criterion by chance. In an actual receiver the

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proper calculation depends on the dependence structure and selection method, not merely the count of coloured rectangles displayed on a screen.

The analyst must therefore identify two different objectives. Exploratory processing seeks promising hypotheses. Its procedures may be adaptive, inventive and responsive to unexpected structure, provided their exploratory status is recorded. Confirmation asks whether a specified hypothesis survives a test designed without reference to the particular confirmatory outcome. After using a development capture to choose a filter, integration time or threshold, the investigator should freeze those choices and evaluate them on a separate record that has not influenced the design. Ideally a custodian or independent laboratory controls access to the confirmatory material. If further revisions are made after observing the result, those revisions become development again, and another genuinely independent test is required for an unqualified prospective inference.

The distinction applies equally to the analogue front end. A threshold can be fixed perfectly and still yield misleading results if the receiver is overloaded, its local oscillator produces spurs, or the front-end gain changes without documentation. Calibration must identify the antenna and preselector, centre frequency, bandwidth, analogue gain, ADC scaling, clock reference, clipping and missing-data status. These conditions must be preserved across the comparison. One should also use controlled reference emissions whose waveform parameters and timing are known independently, together with background-only intervals and negative controls. The statistical model cannot prove the receiver measured what the author believes it measured. Conversely, an excellent calibration does not make a retrospectively tuned statistical rule prospective.

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An especially tempting error arises from overlapping spectral frames. A sliding estimator may generate dozens of closely related images from substantially the same underlying complex samples. Those frames are not independent replicates merely because they occupy distinct rows on the display. If the operator watches them repeatedly and adjusts a threshold to the largest frame, the selection process has become more complex still. A defensible performance study should account for dependence between windows, the duration of the capture, receiver scheduling gaps and the total search procedure. The relevant error probability may be estimated from background-only captures processed through the complete frozen detector, rather than by assuming that every coloured pixel is an independent draw from a convenient theoretical distribution.

A laboratory comparison should have a documented sequence. First, acquire an authorised collection of development recordings including synthetic reference pulses, a range of controlled signal-to-noise conditions, nonstationary interference and deliberate front-end overload. Second, allow the development team to explore thresholds and models, recording the candidates tried and the rationale for the selected procedure. Third, freeze the algorithm, its numerical library versions, window settings, thresholds and treatment of invalid intervals. Fourth, deliver independent reference captures with blinded labels to a second examiner. Fifth, compare the preregistered decisions against ground truth and report missed detections, false alarms and uncertainty, including the total search duration and frequency coverage. Finally, preserve unsuccessful outcomes rather than discarding them from the denominator of reported performance.

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No single numerical rate characterises every detection problem. False-alarm probability, probability of detection, signal strength, integration time, duty cycle, background nonstationarity and instrument uncertainty interact. A detector may be made insensitive enough to avoid most false reports while also missing weak authorised pulses. That trade-off must be displayed rather than concealed behind an assurance of near-perfect reliability. If an analyst changes the criterion after seeing a missed pulse, the next prospective claim requires a further untouched test set. The purpose of the separation is not to prohibit learning; it is to prevent learning from the data from being misrepresented as independent verification by those same data.

There is a final legal and evidential boundary. Detection of an energy excursion, statistical departure from background, successful recognition of a waveform family and identification of a particular emitter are separate claims. A strong confirmatory result at one stage does not automatically satisfy the next. An independent antenna, altered attenuation, changed receiver configuration or suitable reference instrument may be needed to test whether the phenomenon originated beyond the measuring apparatus. A responsibly written report should identify the observed measurement, the prespecified criterion, the tested false-alarm assumptions and the remaining alternative explanations. When the observation was selected adaptively, the report should say so. I respectfully return the token for further questions about likelihood, sequential decisions, confirmation bias and process-control methods.

John Wilder Tukey, Peer Question: Professor Neyman, exploratory data analysis is indispensable when the physical phenomenon under examination has not yet been named. I should not want a rule intended to

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protect inferential discipline to become a prohibition on looking. Suppose a team surveys a complex factory and finds a family of weak transient shapes at several frequencies. It has explored twenty FFT windows, compared five background estimators, repeatedly narrowed the time interval and eventually produced a dramatic image. Would you discard the accumulated observations, or could the team report them as a structured discovery while designing a new and genuinely independent test? More particularly, what must its notebook disclose about the search path, how should it present the initial effect size, and what should happen if the independent confirmation fails? I ask because a laboratory can preserve an attractive exploratory graph without preserving the sequence of decisions by which it was obtained. The displayed picture may be accurate while its apparent statistical surprise is greatly exaggerated.

Jerzy Neyman, Response: Mr. Tukey, I would not discard those observations. A thoughtful exploratory investigation can disclose structure that no reasonable engineer would have specified beforehand. It may reveal that a presumed narrowband tone is actually one branch of a periodically varying interference process, or that an alleged burst occurs only under a particular gain setting. Both observations are valuable. The essential requirement is to describe their epistemic status. One may state that a pattern was noticed following extensive inspection, and one may measure its apparent amplitude and duration on that development record. One may not attach to the selected pattern a single-test error probability computed as though the pattern and selection rule had been fixed before the record was examined.

The notebook should record at least the acquisition state, analysis software versions, windows and background estimators tried, threshold changes,

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excluded segments, tested frequency ranges and the sequence in which these decisions arose. For a practical account, a time-stamped experiment log or version-controlled analysis record may serve better than a lengthy narrative written from memory. The reviewer should be able to see that the final picture emerged after twenty windows and five estimators, not assume that those were never tried. A record of failures is not an embarrassment; it defines the search whose error characteristics differ from those of a single preselected test. If full logging was not performed, the limitation must be acknowledged rather than patched with invented precision.

Confirmation should answer a question made explicit by the exploratory stage. The team may preregister the relevant time-frequency region, candidate waveform features, detection statistic, window function, threshold and controls. It should then obtain a genuinely new record, ideally through independently monitored equipment, with the reference emissions and negative controls concealed until decisions are frozen. One can also predefine several allowable alternative configurations and control the overall decision rule accordingly. A single negative confirmation need not prove the exploratory observation fictitious: the phenomenon could be intermittent, the test insensitive or the physical conditions changed. The disciplined conclusion is that the specified independent test did not establish the candidate under its stated conditions.

An effect size reported from the discovery record should be labelled post-selection. Its point estimate may be biased upward when investigators searched for the largest visible excursion, a version of the familiar selection effect. A confidence interval derived without accounting for the search may also be too narrow for the selected target. In the confirmatory capture, the

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investigator should report the prespecified estimate and uncertainty, including failures to detect. If the team revises the hypothesis after seeing that result, the revision returns to exploration. These distinctions allow the laboratory to learn continuously without laundering the same data into repeated confirmations.

I would further distinguish reports of apparatus behaviour from reports of an unknown external source. If a pattern occurs after a firmware change, it might establish a software regression even though it says nothing about a transmitter beyond the antenna. The next experiment could compare a terminator, a calibrated injection and an independent receiver. The legal authority and information minimisation remain relevant; investigation of energy occupancy does not automatically authorise collecting protected payloads. A cautious, clearly labelled discovery report is scientifically stronger than a confident but statistically incoherent identification.

George Edward Pelham Box, Peer Question: Professor Neyman, your proposed test appears to presume that there is a sufficiently stable background population against which the threshold can be defined. In practice the RF environment is riddled with changing interference and receiver nonlinearities. Suppose the analyst develops a threshold on recordings from a shielded room and subsequently applies it in a building where switching converters, moving lifts and scheduled transmitters modify the distribution throughout the day. Even if the algorithm was frozen before the field test, what has been confirmed when the model itself is wrong? Should a second validation stage test the adequacy of the background model before its tail probabilities are trusted? I also wonder whether a reference dataset selected to resemble the eventual survey site might itself

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introduce unreported selection. How would you distinguish a provisional engineering limit, an empirical field alarm rate and a statistically justified false-alarm probability when the environment is continually changing?

Jerzy Neyman, Response: Mr. Box, freezing a defective rule does not make that rule scientifically sound. Independence of test data is necessary for some inferential claims, but it is not sufficient if the observations do not satisfy the statistical model. A static shielded-room background cannot be assumed to represent a busy industrial installation. The question is not simply whether the program was untouched; it is whether the probability statement refers to the process that actually generated the observations. A model valid in a laboratory might still be useful for a limited calibration statement, but the field record should disclose its departure from the validated regime.

I would use two distinct validation tasks. The first concerns instrument correctness: the ADC response, calibration, filtering, front-end linearity, timebase, missing samples and software implementation should be assessed against controlled reference conditions. The second concerns the statistical distribution of background events under the intended operating environment. Representative authorised background-only acquisitions, stratified across relevant conditions and shifts, can estimate an empirical alarm rate for the frozen detector. Such evidence should be sufficient in duration to reveal recurring regimes, rather than selecting only a convenient quiet interval. The report should specify whether the false-alarm rate is per valid frequency dwell, per valid second, per completed survey or per declared decision event. These denominators cannot be exchanged without a model.

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The selection of what counts as a representative field environment must itself be stated. If the analyst excludes nights with strong interference after discovering that those nights produce many alarms, the observed alarm rate becomes conditional on an undocumented censoring rule. A fair programme can prespecify operational strata such as occupied and unoccupied building periods, but it must publish the criteria and corresponding exposure. Where the process is clearly nonstationary, one might report alarm performance separately by stratum rather than offer a falsely precise universal parameter. If the intended site changes, the validity of those estimates should be reconsidered. It may be necessary to identify a separate operating regime and carry out a new calibration.

A provisional engineering threshold is an operating choice, possibly justified by available data and practical constraints, but not automatically a validated significance criterion. An empirical field rate is a measurement of how often that frozen threshold fired during a specified background programme, with sampling uncertainty and all relevant limitations. A statistical false-alarm probability is a model-based claim about a defined event and population. It should be supported by evidence that the model is appropriate. If the number of observed false alarms is zero, that still does not prove the true probability is zero; confidence bounds depend on the number and dependence of valid trials.

For an external attribution, we would add the physical challenge that the alarm may originate in the receiver. A second instrument, attenuation trials, alternate cables and known reference sources can help discriminate plausible mechanisms. Where the results remain ambiguous, the proper language is that the recorded output exceeded a frozen threshold under

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particular conditions. That is an observed fact. Whether the excess represents an external transmission, a familiar industrial disturbance or a receiver artefact remains a separate question. Far from weakening the scientific enterprise, this separation gives the next investigator a concrete hypothesis to test.

Dr. James M. Atkinson, Moderator: I thank Jerzy Neyman for the preceding examination. With the token passed in a spirit of scholarly respect, I invite Sir Ronald Aylmer Fisher to develop a different evidential dimension. This is a fictional modern educational reconstruction, not a transcription of a historical symposium.

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Sir Ronald Aylmer Fisher, Second Principal Contributor: Dr. Atkinson, the sound of a receiver's cooling fan is not an evidential soundtrack, and neither is the spectacle of a brilliant spectral trace a sufficient experiment. I would begin by distinguishing the use of observations to devise an interesting question from their use to assess the strength of that question. Exploration is not disreputable. It is the place where an engineer discovers that a harmonic family appears only after preselection is removed, or that a purportedly narrow emission widens when the FFT window changes. The impropriety arises when the report silently hides that history and applies a reference distribution as though the hypothesis, measurement interval, window and rejection criterion were all selected independently of the values displayed. If the candidate was found among a thousand possibilities, the investigator cannot simply describe it as the one candidate selected beforehand.

A likelihood is a mathematical function of observations under an explicit model. It is not a talisman which converts an appealing display into a proven transmitter. In a simple laboratory comparison, one might define a background model H0 in which receiver output arises from calibrated noise and known interference, and an alternative H1 in which a prespecified test waveform adds a component. The likelihood ratio can then be evaluated for an observation under both models. Its distribution under H0 must reflect the whole decision procedure, including parameter fitting, nuisance quantities, repeated attempts and any stopping rule. If the analyst estimates the background variance from a portion selected because it was unusually quiet, then subsequently celebrates a nearby excursion as significant, the nuisance estimate is not independent of that selection. The numerical

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threshold may be mathematically accurate for an experiment that never actually occurred.

The scientific remedy is design before dramatic interpretation. Record the sampling plan, the instrument configuration, the intended null comparisons and the quantities on which thresholds depend. For a single, prespecified frequency and interval with a suitably validated noise model, a simple distributional calibration might be defensible. For a blind sweep over millions of related time-frequency cells, one must model the complete search, not one isolated cell. There are principled approaches to multiplicity, including familywise error control and procedures aimed at controlling the false discovery rate under their respective assumptions. They answer different questions. A promised familywise probability for at least one false alarm is not interchangeable with an expected fraction of false claims among a selected set. The distinction becomes material when the report will drive investigative action, equipment removal or an allegation concerning an individual.

I would insist upon a clear boundary between mathematical detection and engineering classification. An emission-like shape may originate from clipping, local oscillator leakage, power-supply switching, intermodulation products, cable coupling or a real signal outside the receiving apparatus. One well-planned experiment changes front-end attenuation. An external weak signal ordinarily responds according to the calibrated chain, whereas certain internally generated nonlinear components can show a different scaling relationship; but that pattern is only one diagnostic, since uncontrolled gain changes and receiver architecture may confound the comparison. A second independently characterised receiver or antenna can

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test whether an effect is shared beyond one instrument. These experiments should be designed to challenge a favourite interpretation, not to decorate it.

Imagine a lawful laboratory exercise in which a known source transmits a reference burst while an independent monitor records its timing. A development set contains a range of amplitudes, deliberately injected interference, quiet intervals and clipped input conditions. The analyst may inspect plots, compare windows, tune a matched filter and choose a trigger threshold. Each exploration belongs in a log. Once the candidate rule is selected, the development set has served its function. A fresh validation set, ideally administered by another person with blinded event labels, tests the frozen rule. The analyst must not change the threshold midway through confirmation merely because its misses appear embarrassing. If such a revision is scientifically necessary, the later evaluation must be identified as a new experiment, with a fresh independent dataset or an explicitly adjusted inferential account.

Practical competence also requires attention to what the detector returns. A probability of false alarm describes an operational decision process under a specified background population and acquisition state. It is not the posterior probability that any particular detected event is innocent. The latter requires further assumptions, including the prevalence of genuine events and the relative likelihoods of observations, often unknown in an exploratory countermeasures survey. A false-alarm study based on a static shielded laboratory may not transfer to an industrial building filled with switching converters, moving machinery and variable RF traffic. Confidence ought to be tied to the environment actually tested. A receiver can have fine

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frequency resolution and yet poor inferential resolution concerning causation.

There is no reason to hide ambiguous or negative findings. If the frozen detector misses weak reference pulses while a retrospectively adjusted display renders them visible, report both. The first result measures the predefined operating point; the second is an exploratory suggestion for improving the method. A useful study may reveal that the initial model was inadequate. It may also find that a previously celebrated event vanishes when the front end is attenuated or the preselector changes. An inconvenient result is a means of improving the instrument chain, not an invitation to rewrite the scientific question after the fact. The investigator should retain a versioned record of all candidate rules, not only the successful one.

For publication I would require the threshold-selection protocol, the null and alternative assumptions, the number and structure of opportunities inspected, the means of estimating noise, the details of any censoring, and an account of missing samples. I would further record the precise distinction between a detector firing and a source being identified. An instrument may issue a repeatable alarm with no scientifically justified emitter attribution. The proper report says what was observed, what comparison was performed, how the decision rule was selected and which alternatives remain. That prose will be less dramatic than an unqualified accusation, yet its disciplined texture is precisely what makes it durable when another investigator tests the same apparatus.

Andrey Nikolaevich Kolmogorov, Peer Question: Sir Ronald, let me press the probabilistic foundation. A familywise formula such as one minus the

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product of nonexceedance probabilities presumes independence or a fully described joint distribution. A spectrum analyser constructs adjacent frequency bins from a common window, and a software-defined receiver may compute heavily overlapping segments; both produce dependence. Suppose the analyst has a million plotted cells but cannot determine their effective independent count from the display. What bound can be stated without pretending that there are a million independent experiments, and how should the false-alarm study be organised if the null process is nonstationary? I also ask you to distinguish a conservative mathematical inequality from an estimated operating characteristic and from a claim about a specific transmitter. It is easy to take a formula that is always true under explicit assumptions and use it rhetorically as though it measured a particular scene.

Sir Ronald Aylmer Fisher, Response: Dr. Kolmogorov, a conservative union bound offers a useful starting point when a family of well-defined events is specified. If events A1 through Am are the declared false-alarm opportunities and each has a valid upper probability bound p_i under the null, the probability of their union cannot exceed the sum of the p_i, truncated at one. No independence assumption is needed for that elementary inequality. But its usefulness depends upon defining the events and supplying credible marginal bounds under the actual background model. If a team chooses its test family after seeing the most favourable plot, even an impeccable application to a retrospectively selected subset can miss the relevant selection process.

The difference between a bound and an empirical estimate must be explicit. A union bound may be conservative, even excessively so, when bins are

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strongly correlated; it does not reveal the actual false-alarm probability without further information. A direct background study can instead process representative null recordings through the entire frozen detection pipeline and count alarms at the report's true decision level. That approach includes window overlap, guard-band choices, candidate aggregation and alarm suppression rules, provided that the background recordings adequately represent the operating regime. One may also use carefully justified simulation or resampling methods, but they must preserve relevant dependence and nonstationarity. Randomly shuffling samples until their structure disappears can produce an attractively simple answer to the wrong question.

I would require a clear definition of one alarm. Is it a pixel crossing a threshold, a cluster of contiguous bins, a detected burst after temporal merging, or one operator decision to investigate a receiver event? These are different units. A monitor that produces ten adjacent coloured pixels from one physical disturbance should not be described as ten independent false transmitters. Similarly a rule that collapses repeated alerts within a fixed interval changes the alarm count and its distribution. The full rule, including such postprocessing, must be frozen before performance is measured. Reproducing the same software output is not independent validation of the null model.

If the background varies with time, a single long average can conceal periods of poor performance. The laboratory might stratify recordings by operating phase or use a validated time-varying model with its own qualifications. The appropriate approach depends on the scientific objective and the available data. Under severe model uncertainty, a qualitative or

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bounded conclusion may be preferable to a spurious decimal. A calibrated test under one class of background conditions makes a statement about that class, not about every conceivable industrial setting. I should also remind the panel that a false-alarm probability is a frequency characteristic of a procedure under the null. It is not a posterior probability that a particular alarm was erroneous.

Finally, a valid alarm study does not identify an emitter. To claim an external source, the investigation needs physical evidence independent of the selected spectral statistic: changes with attenuation, reproducible response through other calibrated antennas or receivers, geometrical considerations and lawful operating context. Even those controls may leave rival explanations. The appropriate report begins with a mathematically modest claim, adds tested engineering observations and explicitly names what remains unknown. It should not turn a conservative inequality into a banner declaring the existence of a particular covert device.

Dr. James M. Atkinson, Moderator: I thank Sir Ronald Aylmer Fisher for the preceding examination. With the token passed in a spirit of scholarly respect, I invite Abraham Wald to develop a different evidential dimension. This is a fictional modern educational reconstruction, not a transcription of a historical symposium.

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Abraham Wald, Third Principal Contributor: Dr. Atkinson, the question becomes especially demanding when the engineer is permitted to look repeatedly at a stream of observations. A decision made after one hour of monitoring is not governed by the same reference experiment as a decision made at whichever second first looks extraordinary, unless the stopping rule was properly incorporated. In sequential analysis, time is not merely another axis on a waterfall. It is part of the policy by which evidence accumulates and by which the investigator chooses whether to continue. The rule must therefore specify what counts as an observation, when evaluation occurs, what information remains available to the analyst and under what conditions monitoring ceases.

Consider a simplified sequential likelihood-ratio procedure in which successive observations are suitably modelled under H0 and H1. One can derive decision boundaries associated with desired error rates under stated regularity conditions. That does not mean the familiar approximate boundary formula applies without qualification to a streaming SDR with coloured noise, overlapping windows, drifting front-end gain, unmodelled interference and multiple candidate frequencies. Dependencies are physical facts, not technical footnotes. If the same underlying complex samples appear in four overlapping FFT frames, a product of four independent likelihoods would count much of the evidence repeatedly. Before estimating an error rate, one must establish how the data enter the sequential statistic and test the proposed distribution against representative background captures.

A practical surveillance-countermeasures survey may involve a human operator who sees an event and extends the recording, retunes a receiver

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or changes integration time. Each of those acts can be technically sensible. Yet a later p-value based on one chosen moment cannot ignore the reason that moment was chosen. The analyst may have examined dozens of channels and altered numerous settings before finding the trace selected for the report. An ordinary single-look reference distribution does not automatically cover this adaptive path. The solution is neither to prohibit exploratory work nor to pretend that it never happened. Rather, exploratory observations should generate an explicitly labelled candidate that is then challenged through a separate and correctly designed confirmatory measurement.

Suppose a laboratory monitor samples a known empty band under an operating condition representative of the target survey and raises a software alarm whenever a statistic exceeds a preset level. One may estimate a rate of alarms per valid hour of observation, but only after defining what a valid hour means. If the receiver scans only one tenth of the wall-clock interval at the frequency of interest, the exposure is not a full hour of continuously observed data. If buffers overflow during the loudest interference, the missing observations could invalidate an optimistic alarm-rate estimate. If the operator restarts the experiment each time a noisy episode spoils the plot, the sampling policy has selected a favourable dataset. A failure ledger and an exposure denominator are thus part of the statistical specification.

For a fixed null event with independent trials, a simple expected-count illustration can be instructive. If each of 1,000 independent, prespecified trials had a false-alarm probability of 0.001, the expected number of false alarms would be one, while the probability of at least one would be

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approximately 1 minus exp(-1), or about 0.632 in the standard approximation. But the example cannot be used as a shortcut for 1,000 correlated waterfall bins. Independence must be shown or a justified alternative calibration adopted. Moreover the result concerns the operational null model; it neither identifies an external emitter nor quantifies the truth of any particular allegation. A manager who hears one false alarm expected may imagine certainty about the next alarm, and that would be an error.

When measurements are repeated across locations, antennas and instrument settings, there are two competing risks. One is to miss a real intermittent emission by freezing a poor search policy too early. The other is to discover a seemingly dramatic anomaly after enough adaptive searching and then present the selected anomaly as independently confirmed. A defensible programme can accommodate both by reserving genuinely new measurements for confirmation. In a controlled test, the exploratory team may be given generous freedom to identify candidate structures, while the confirmatory team receives only frozen code, authorised hypotheses and a blind validation dataset. A genuine new hypothesis arising during confirmation is logged as exploratory and placed in the queue for a later test.

The issue of decision loss is also pertinent. The operational consequences of overlooking a dangerous transmitter may differ from those of falsely accusing an innocuous device. Statistical design should state which error rates and costs govern the decision, without allowing those costs to substitute for evidence. An alarm demanding a nonintrusive remeasurement may properly use a different threshold from an alarm

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triggering invasive inspection or legal action. This differentiation must be settled as policy rather than improvised after an alarming display appears. An engineering team might maintain a permissive discovery mode and a more rigorously qualified confirmation mode. It should never call the first mode proof merely because the second mode is inconvenient.

Finally I would ask the recorder to preserve the sequence of decisions, not only the final settings. If a detector first fires at 09:20 after six prior changes of threshold, the custody record should show those changes and the observations that prompted them. The exact software version, observation windows, calibration state and gap record belong in the same account. A later examiner may reproduce every decision, but that reproducibility proves the historical sequence of analysis, not that its false-alarm calculation was prospective. Only an appropriately designed evaluation of the whole procedure can support that claim. I pass the token to the examination of regression, nuisance factors and model adequacy, for an elegant statistic cannot compensate for a mistaken physical model.

Claude Elwood Shannon, Peer Question: Professor Wald, I want to examine the information that a real-time detector accumulates. In a streaming receiver the operator can change integration length or the channel under observation after seeing an initial weak peak. If a short window produces no alarm, the operator may extend the interval; if a long window appears disappointing, the operator may return to a brief burst view. The algorithm may then report the most impressive of many adaptively selected estimates. How can one preserve the legitimate engineering advantage of sequential observation while describing its error characteristics? I am especially concerned about missing samples, short dwell times and a detector that

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counts correlated frames as fresh information. Please explain what a genuinely prespecified sequential rule would have to contain, and what the team should report when the operator's actual behaviour does not follow that rule. Please also say whether a second analyst reproducing the same calculation can turn that retrospective selection into a valid confirmatory test.

Abraham Wald, Response: Dr. Shannon, the legitimate advantage lies in defining a sequential experiment rather than treating every intermediate result as an independent final test. A properly specified procedure identifies the observations entering the statistic, their order, the conditions under which the observation process continues and the boundaries that cause a decision. If multiple channels or alternative integration lengths are candidates, the selection policy and decision consequences must be included in the design or calibrated as a whole. The analyst cannot choose one appealing stopping instant retrospectively and then borrow a nominal single-look tail probability. That is a mismatch between the performed experiment and the experiment invoked to justify it.

The sequential likelihood ratio is an instructive theoretical model, but practical receiver data may violate its simplifying conditions. A set of frames built from overlapping complex samples is dependent. Noise may be coloured by filters and may change with local operating conditions. Firmware or processing may discard invalid frames. A laboratory can still design an empirical sequential detector, but it should test its whole behaviour on independent background and reference datasets. The null experiment must include the actual acquisition cadence, buffer-gapping

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semantics, scan scheduling and postprocessing. If these are neglected, the measured alarm rate may be neither conservative nor transferable.

The decision thresholds should be set in relation to a declared operational objective. One mode might issue a low-consequence advisory to repeat a measurement; another might authorise the much stronger conclusion that a prespecified reference waveform was detected under calibration conditions. The second assertion demands a different evidence standard and possibly a second independent instrument. The thresholds and consequences cannot be silently interchanged after the most interesting event appears. The record should include the rule version, all changes, each threshold used, each stopping decision and the data that were available when the decision was made.

When the operator departs from a prescribed sequence, the study has entered an adaptive exploratory regime unless an appropriate statistical adjustment was already specified. That is not misconduct by itself. It may be sensible to change bandwidth or place the receiver on a candidate frequency, particularly where an intermittent authorised test source is involved. The operator should mark that intervention in the chronology and treat any subsequent significance calculation according to its actual design. A later confirmatory pass can freeze the newly chosen configuration and evaluate it afresh. If new independent material cannot be collected, the report must be limited to descriptive and exploratory conclusions, or employ a justified selective-inference framework whose assumptions are disclosed.

I would describe missing observations directly. If the instrument viewed a band for only six seconds out of a minute, it cannot claim to have continuously observed silence during the other fifty-four seconds. If samples

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were dropped, interpolated values cannot be counted as newly acquired independent evidence. The effective observation exposure should appear alongside alarm rates and detection probabilities. For a known laboratory source, the pulse timing log should be independent of the SDR and used to score only intervals where the source and receiver conditions satisfy the test specification. Such accounting improves both the technical and forensic interpretability of the result.

In conclusion, a sequential procedure is not merely a sequence of plots. It is a disciplined policy, including the circumstances under which data will be examined and decisions taken. The elegance of its mathematics does not save a misdescribed acquisition chain. I would rather report that an operator adaptively followed an interesting transient than claim a controlled false-alarm rate for a control procedure that was never executed. Clear disclosure preserves the discovery's value while reserving confident inference for evidence that deserves it.

Dr. James M. Atkinson, Moderator: I thank Abraham Wald for the preceding examination. With the token passed in a spirit of scholarly respect, I invite Sir David Cox to develop a different evidential dimension. This is a fictional modern educational reconstruction, not a transcription of a historical symposium.

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Sir David Cox, Fourth Principal Contributor: Dr. Atkinson, I should distinguish a general scientific question from the narrow statistical hypothesis used as its provisional instrument. A receiver operator may wish to know whether an unexplained spectral event warrants further investigation. The model-based test might instead ask whether calibrated power in a specified time-frequency region departs from a stationary background distribution. These propositions are not logically identical. An exceedance can warrant the next experiment without identifying the source; a failure to exceed can result from poor sensitivity, inappropriate aggregation, a missed scan interval or a wrong model. The report should state both the question of scientific interest and the exact population of measurements to which the inferential calculation applies.

Model selection is particularly treacherous in a broad RF survey. A Gaussian background may be a useful approximation for carefully filtered thermal noise under stable receiver conditions, but nonstationary interference can produce heavy tails or structured bursts. A fit to one quiet interval may not describe the full instrument operation. Dependence between observations can arise from window overlap, filters, acquisition timing, common local oscillator drift and slowly changing external sources. If the operator evaluates several families of models and selects the one producing the smallest reported p-value, uncertainty from model selection has been omitted. A prospectively specified family, model-checking protocol and independent validation dataset can reduce this temptation. In a less controlled field setting, transparent sensitivity analysis may be more defensible than a single overprecise number.

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Consider the frequency-dependent noise-floor estimator itself. Suppose a waterfall is partitioned into windows and the analyst uses a median of nearby cells to normalise a target bin. Those cells may include the skirts of the very event of interest, a persistent carrier or instrumental spurious products. Their distribution depends on guard bands, reference bands and filter characteristics. If the bands are chosen after seeing the target, an apparently robust statistic can still be selected to make the event look stronger. Conversely, if nearby references are contaminated, the detection threshold may be elevated and a real reference source missed. The control plan should specify reference-cell selection and exclude or model unsuitable cells according to a prespecified, reproducible rule. The choice of estimator is a substantive part of the experiment.

An effect size deserves as much attention as a rejection decision. Suppose an independent trial finds a statistically reproducible 0.3 dB excursion above a well-characterised baseline. Its practical significance may be slight relative to calibration and environmental variation. Another test may detect a large transient but with a wide interval because only one short observation was captured. The strength of a result depends on uncertainty and consequence, not merely on whether a p-value lies on one side of a conventional line. I would report estimated change, uncertainty range, receiver settings, sample exposure and plausible alternative explanations. Where the underlying measurements are calibrated in power units, instrument uncertainty and impedance reference must be carried into the interpretation.

A proper independent replication is not simply rerunning a script against an old recording. It may require a new authorised acquisition with the same frozen rule and sufficiently comparable instrument state. Yet comparability

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is not identical to duplication. The laboratory should vary one factor at a time when assessing robustness: receiver gain, attenuation, window function, antenna path or controlled reference waveform. A trace which survives reasonable variations in processing may be more persuasive than one which appears under only a finely tuned combination. Nevertheless changes must be planned and their outcomes reported without selecting the most favourable setting as the only one that counts. If robustness checks are post hoc, their exploratory nature must be acknowledged rather than silently promoted into confirmation.

I would also distinguish confirmatory testing from discovery of anomalies in residuals. After fitting a model, an analyst may plot residual spectra and find an unexpected periodic structure. Such a structure is valuable evidence that the model deserves further examination. But the same residuals cannot ordinarily supply an unadjusted test of the newly discovered pattern while pretending that the pattern was hypothesised beforehand. If a fresh dataset is unavailable, there are selective-inference or resampling approaches in suitable settings, but their assumptions and limitations are substantial. In a technical textbook one should not offer these methods as universal magic, particularly where the receiver-generated process may be neither stationary nor well modelled. A careful descriptive result can be preferable to misleading certainty.

A blind test should include more than positive reference emissions. It needs background-only intervals, known interference sources, deliberately overloaded receiver states and gaps in observation. The detector's confusion matrix should separate an actual missed event from a period not observed at all. The scoring procedure must be fixed before labels are

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unblinded. If the algorithm is allowed to choose a different threshold for each challenge recording after seeing its answer key, the reported performance estimates training success rather than generalisation. Calibration documents should include the physical reference plane and the signal generator uncertainty. A software rule can be perfectly repeatable while the analogue inputs move, and apparent reproducibility under that condition is only superficial.

The final report ought to use graduated language. A candidate can be discovered, independently detected, classified by a measured waveform feature, or attributed to a specific device. These are successive inferential steps and none is automatically completed by the one preceding it. My objection is to the collapse of these stages into an attractive figure and a single asserted confidence value. The examiner should preserve the competing interpretations and state what new observation would discriminate between them. In that discipline, the statistical model serves the physical inquiry rather than dictating its answer, and the visual drama of the waterfall is checked against the patient arithmetic of evidence.

David Harold Blackwell, Peer Question: Sir David, I should like you to be more exact about the decision consequences. An operator can legitimately use a low threshold to decide which spectral region deserves another look, whereas a laboratory may claim a much lower false-alarm probability when deciding whether a prespecified reference emission has been confirmed. Suppose the same dataset is first searched with a permissive rule, then the discovered region is tested with a stringent rule using precisely those same samples. Does a more demanding second threshold restore inferential independence? How should one account for a score chosen because it

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looked unusually large, especially where the background model and test family were also selected after inspection? I ask further how a decision maker should weigh missed detections and false alarms without converting the operational cost of one type of error into a mathematical claim that the evidence itself is stronger. Please describe an appropriate laboratory arrangement that separates these decisions.

Sir David Cox, Response: Professor Blackwell, applying a more stringent line to the same selected observation does not by itself restore independence. If the analyst searched a field to locate a remarkable excursion, the second threshold is applied to a candidate whose selection depended on the same noise realisation. The selection can alter the distribution of the candidate score even when the second rule is numerically fixed. A smaller nominal p-value attached to the selected score may therefore remain misleading. One could, in suitable models, account for selection explicitly or conduct an adjusted global test. Yet the simpler laboratory solution is to use the discovery sample for discovery and hold back independent observations whose outcomes have not been consulted during rule construction.

The two decisions should also be named honestly. A permissive exploratory threshold could generate an advisory requesting a remeasurement or independent check. Its purpose is to avoid overlooking candidates, and its false-alarm burden may be acceptable if the consequence is merely another lawful measurement. A confirmatory decision might involve a specific claim concerning a prespecified waveform feature, and its consequence can be more serious. The laboratory must define the target claim, error rates and decision procedure independently of the current test outcome. A lower

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threshold in the discovery mode does not make it a poor instrument; it makes it an instrument for a different decision problem.

Decision costs can be used to choose an operating rule when the assumptions, probabilities and consequences are explicit. They cannot make an observed waveform more probative by declaration. A costly miss may justify additional monitoring or a sensitive preliminary alarm. It does not justify describing the resulting false-alarm rate as something other than that measured or supported by a valid model. Likewise the seriousness of a potential source does not prove that a peak arose from that source. Engineering caution and evidential caution can coexist. The report should state the consequence category attached to each threshold and the evidence required before proceeding to a more intrusive response.

I would arrange a laboratory sequence with three materials: a development collection in which thresholds and signal statistics may be tuned, a calibration collection for assessing the proposed frozen procedure across relevant receiver regimes, and a blind test collection controlled by a separate custodian. The last collection should include authorised reference bursts, empty-band periods and known receiver artefacts. The detector receives no knowledge of the answer key until it outputs its predeclared decisions. The scoring software, treatment of missing intervals, method for merging adjacent detections and definition of a false alarm should all be frozen. The evaluator can then report sensitivity at specified test levels, empirical false alarms per stated exposure, uncertainty and conditions of validity.

A further safeguard is to distinguish confirmation of a waveform from attribution to an individual apparatus. A detector that correctly recognises

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reference bursts in a blind test establishes performance at those laboratory conditions. It does not identify an unknown object in a building without further evidence. In the field, independent antenna and receiver measurements, attenuator challenges, inspection of nonlinear products and legal authority may be necessary. Even these may permit only a cautious classification. The most useful statistical statement is the one that matches the exact measured procedure and claim, however modest that statement may appear.

Dr. James M. Atkinson, Moderator: I thank Sir David Cox for the preceding examination. With the token passed in a spirit of scholarly respect, I invite Walter Andrew Shewhart to develop a different evidential dimension. This is a fictional modern educational reconstruction, not a transcription of a historical symposium.

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Walter Andrew Shewhart, Fifth Principal Contributor: Dr. Atkinson, I approach the question from the standpoint of a process that is expected to operate for long periods under changing conditions. A threshold is not merely a line drawn through an image. It is an operational rule embedded in an instrument, and the process producing the monitored values must be understood. There is an important distinction between common-cause variation consistent with a stable regime and special-cause variation suggesting that the regime has changed. A process-control chart can be useful for detecting departures from a historically characterised background, but it is not an oracle. The engineer must know what process was actually characterised and whether the conditions under which its limits were set still prevail.

Imagine a receiver in a building whose background includes regulated transmitters, switching supplies and machinery that runs on a daily schedule. If a monitoring team estimates a noise distribution at dawn, the evening background may differ even when no illicit or unexpected equipment is present. The chart may sound repeated alarms after a normal change in plant operation. Retuning the limit upward whenever the alarm becomes inconvenient then conceals the very evidence that the process changed. Retuning it downward during a quiet spell may make tomorrow's ordinary variation look sinister. A distinction is needed between stable operating phases, detected process changes and a formal decision to establish a new baseline. Each new baseline should have a documented rationale and a subsequent independent performance check.

The concept of an in-control process must be established empirically. In a receiver, the analogue gain, preselector, frequency reference, calibration

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temperature, overload indicators, sampling cadence and data completeness may all affect the observed baseline. A control chart derived from one configuration is not transferable without testing to another. If an amplifier introduces intermodulation when a nearby transmitter becomes strong, the alarm may be a real departure in instrument output but not evidence of a new external transmission. The appropriate response is often diagnostic. Alter attenuation, use an independent measurement channel, compare harmonics and inspect overload flags. A chart can announce that some process has departed from its validated state; it cannot by itself tell the laboratory what physical cause produced the departure.

The design of monitoring limits should specify the intended run length or error rate under a particular in-control model, not imply that limits learned from a short development record possess timeless validity. A nominal alarm rate must be measured across representative cycles of actual operation. Correlations between readings influence the number and pattern of alarms. The choice of sampling interval, averaging and missing-data treatment changes the process being monitored. A laboratory may assess these factors through controlled background captures and simulated insertions of known signals. Once it adopts the operating limit, subsequent performance observations should be recorded in a manner that permits evaluation without concealing unfavourable periods.

I would place special emphasis on a change log that differentiates intentional maintenance from adaptive inference. An instrument may be recalibrated, a cable changed, a firmware package replaced or a filter inserted for sound engineering reasons. Such a change might require a new baseline even if the operator has not looked for an anomalous event. The

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log should record the new configuration and demonstrate equivalence or provide new validation as appropriate. By contrast, changing the alarm line after viewing a suspicious trace is an exploratory response to data and must not be represented as an untouched control rule. The same menu action has different evidential significance depending on its timing and purpose.

The laboratory should test both sensitivity and stability. Insert known authorised reference pulses at several amplitudes, durations and duty cycles, including levels near the chosen threshold. Record how often the detector alerts and how often it misses under each condition. Then test periods with no reference pulse and include ordinary operational disturbances. A single average sensitivity figure conceals where the detector fails. An alarm may be reliable for a long carrier but poor for a short burst hidden between scheduled sweeps. It may also be highly sensitive only in one receiver gain state. A matrix of conditions is preferable to a single polished curve, especially when operational decisions are consequential.

A process-control perspective also counsels against excluding inconvenient observations. If intervals with converter noise, calibration drift or buffer overflow are removed, the examiner should disclose the exclusion rule and whether it was prescribed beforehand. Invalid samples must be marked as invalid, not silently removed to improve the reported alarm rate. If the device was physically incapable of observing a frequency during a scheduled dwell elsewhere, those minutes are not proof of quiet. The exposure denominator must reflect valid listening time in the specified band. Once the analyst recognises these facts, apparently minor administrative notes become essential parts of the statistical method.

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I would recommend two operating registers. One records the exploratory adjustments by which the engineering team learns the process, including alternate windows, thresholds, exclusion rules and diagnostic controls. The other records the frozen confirmatory configuration and its subsequent test results. Access controls and version identifiers should prevent a late edit from being mistaken for a prospective rule. At a formal review point, a proposed replacement rule may be accepted on its own evidence, but past confirmatory data cannot be re-labelled as independent tests of the new threshold. A good institution permits the rule to improve while maintaining an honest historical record of how improvement occurred.

My conclusion is conservative and practical. The receiver should be encouraged to notice changes; the investigator should be discouraged from pretending that every noticed change proves a particular cause. A threshold can be a useful alarm, an efficient search aid or a validated decision boundary, depending on how it was designed and tested. Those categories should remain separate in the report. The expert's duty is not to protect the elegance of a selected statistic but to protect the integrity of the measurement process and the people affected by its conclusions. I respectfully pass the token for a final examination of the evidence and its limitations.

Karl Raimund Popper, Peer Question: Mr. Shewhart, a monitoring team may present a process-control chart that produces repeated alarms near a frequency of concern. Yet when a different gain state or independent receiver fails to reproduce the trace, the team may dismiss the failures as exceptional circumstances and adjust its alarm rule until the original interpretation survives. What observation would actually falsify the claim

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that the detector operates with the advertised false-alarm rate? Can a quality-control process distinguish the failure of the statistical model from the failure of the electronic instrument or the absence of the alleged external emission? I also ask how the laboratory should report a negative result without pretending that the absence of an alarm proves the absence of a short, intermittent signal, especially where the receiver scans only part of the relevant period. A proper theory, surely, must expose itself to tests which might defeat it.

Walter Andrew Shewhart, Response: Professor Popper, the first step is to state propositions that an observation can genuinely challenge. One proposition might be that the frozen detector generates no more than a specified average number of alarms per valid monitoring interval under a defined in-control background regime. Another might be that the receiver detects a calibrated pulse of defined amplitude and duration with a stated probability under a fixed configuration. A third might be that a particular field event originated beyond the input connector. These propositions require different tests. The failure of one should not be concealed by changing the definition of another. A new threshold selected after an embarrassing result is a revised proposal, not evidence that the original rule was correct.

To test the alarm-rate claim, I would collect an independent background-only record covering the actual operational conditions and process the complete frozen detector, including the logic by which adjacent excursions are combined into reported events. The exposure denominator must count valid observation time, and the sampling plan must account for routine changes in the process. The result should be accompanied by uncertainty

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due to finite exposure and possible dependence between observations. A substantially higher alarm rate than the prespecified acceptance criterion would challenge the advertised performance. The response should be to investigate the discrepancy, not to exclude the alarming periods simply because they were inconvenient. If the background process has legitimately changed, the original claim may no longer apply; that qualification must be documented rather than retrospectively erased.

To test the instrument, I would use a calibrated reference at a defined input plane, vary the gain and attenuation, examine overload indicators and compare with a separate measurement chain. A chart showing repeated departures while the terminator is attached could reveal internally generated products or software artefacts. A chart that changes unpredictably with temperature might indicate an unstable analogue stage. These findings do not necessarily falsify the arithmetic of the chart. They may show that its input is not governed by the assumed physical process. The record should separate statistical-control failure, acquisition-chain failure and unsupported source attribution. A transparent result can reveal more than an adjusted chart whose coloured line always seems reassuring.

An absence of alarms on a valid observation interval limits what can be claimed about signals that the tested detector was capable of seeing. It does not prove the physical environment contained no emissions of every conceivable duration or strength. If the receiver visited a band for only ten percent of the relevant time, unobserved intervals remain unknown. If the reference-pulse tests show poor detection for sub-millisecond bursts, the investigator cannot extrapolate to that class merely because no field alarm appeared. The most honest negative conclusion specifies the observed

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frequencies, dwell times, sensitivity and tested waveform family. In ordinary language it reports that no qualifying event was detected under the stated conditions.

I would make the challenge tests part of ongoing maintenance rather than a ceremonial final review. A limit accepted on Monday may cease to describe the process after a new amplifier is installed on Thursday. The next validation should document the changed configuration and what performance can still be supported. An institution that retains failed tests and uses them to improve its rule has a stronger quality system than one that hides them. The empirical distinction between a stable regime and a changed regime is not an excuse to preserve a favourite conclusion; it is a reason to be precise about which conclusions the evidence presently warrants.

Charles Sanders Peirce, Peer Question: Mr. Shewhart, I should like to examine the language of inference itself. An investigator observes a repeatable alarm and proposes that an undisclosed transmitter is its cause. Yet the same observation could arise from a power converter, overload, an intermodulation product or a perfectly lawful scheduled source. How should a report distinguish the creative proposal of an explanation, the consequences deduced from that proposal and the experimental observations which test those consequences? If the analyst chooses a threshold after seeing the event, the detector may still record a genuine anomaly, but the numerical evidence for the proposed explanation appears more limited. What sequence of checks would prevent the report from confusing the discovery of an interesting hypothesis with the verified existence of a particular object? I am concerned particularly with the

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authority of technical language, which can make an untested guess sound as though it were a laboratory result.

Walter Andrew Shewhart, Response: Mr. Peirce, the observation, hypothesis and test should occupy separate portions of the record. An instrument output may show that a frozen or exploratory statistic exceeded a particular value at a recorded time. That statement concerns the measurement chain and is limited by its calibration, configuration and data quality. A proposed explanation, such as an external transmitter, is an inference offered to account for the observation. It may be a good candidate, but competing explanations should remain visible. A subsequent experiment should identify observations expected under the proposed explanation and potentially different observations under its rivals. That is the point at which a guess becomes a testable scientific proposition rather than an assertion.

In a disciplined RF investigation the sequence might begin by archiving the original I/Q record with its acquisition metadata, native sample counters and uncertainty. The team then documents that the initial threshold was chosen after exploratory inspection. It may examine whether the same spectral feature appears when input attenuation is changed, when a proper terminator replaces the antenna, when the antenna is moved, or when an independent calibrated receiver is used. Each manipulation has assumptions: a real source can change with antenna position, an internally generated spur can survive a terminated input, and some receiver artefacts respond nonlinearly to gain. The investigator should therefore avoid making a single control decisive without considering the instrument model.

A test plan would describe in advance which outcomes would increase or reduce support for the external-source explanation. A feature disappearing

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under an input terminator may support, but not prove, an origin outside that connector. A feature recurring at a fixed local-oscillator offset across input configurations may support an internal mixing explanation. Repeated presence in independent instruments, with an expected dependence on location and polarity, could strengthen an external-origin inference. The team must examine cable coupling and shared power interference before describing the instruments as truly independent. The important point is that rival mechanisms are allowed to compete on observations not chosen merely to vindicate one of them.

Threshold choice belongs in this same chronology. The first alarm may have arisen under an exploratory setting selected from many possibilities. That does not invalidate the recorded samples. It limits what nominal error rate can be assigned to the selection. A prospective repeat can fix the statistic, threshold, time-frequency search region and rules for excluding invalid data before capture. The final report may then say that the prespecified detector reproduced a class of events under defined conditions. Any move to naming an apparatus or actor requires further evidence and may engage legal constraints quite apart from the statistical method. One ought never treat technical vocabulary as a substitute for that chain of reasoning.

If the proposed transmitter is not found, a negative result should be described narrowly, not converted into a universal claim that the environment is empty. The specified antenna and receiver may have failed to observe qualifying energy during their valid dwell intervals. Other times or waveform families may remain untested. I would retain the original observation as an exploratory anomaly, together with the controls and unresolved interpretations. That record allows a future examiner to learn

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from the event without inheriting an accusation that the evidence did not establish. I respectfully return the token with the proposition that a disciplined investigation should prize the distinction between a measurement, an interpretation and a demonstrated cause.

Dr. James M. Atkinson, Moderator: The ordinary peer interrogations have been answered directly. I now invite four reciprocal examinations, each addressed to a different named colleague and immediately answered by that recipient. The purpose is to test the limits of the preceding propositions, not to stage a spurious historical quotation.

Jerzy Neyman, Cross-Peer Question to Sir Ronald Aylmer Fisher: Sir Ronald, I should like to challenge an ambiguity that arises whenever a scientist reports only the smallest significance probability obtained after inspecting an RF capture. The investigator may claim that likelihood provides a more principled measure than a conventional fixed-size test, yet likelihood itself depends on the chosen alternative model and the set of parameters searched. Suppose a programme tries several pulse shapes, different noise distributions and a suite of window lengths, then announces the largest likelihood ratio and uses the tail probability appropriate to just one preselected pulse. Would you regard that as a valid prospective experiment? I ask what evidence would be necessary to establish its null distribution, whether an independently specified comparison could rescue the procedure, and how the investigator should record searches that were exploratory but nevertheless useful. Please address the difference between evidence for a departure from one model and evidence for an identified transmitter, for the latter is a vastly stronger physical assertion.

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Sir Ronald Aylmer Fisher, Cross-Peer Answer to Jerzy Neyman: Professor Neyman, the likelihood ratio in your example belongs to the entire search over the permitted model families and parameters, not merely to one convenient pulse discovered at the end. A maximised statistic may be an entirely reasonable detector if its operating characteristics are calculated for the procedure that was actually applied. The scientific failure would be to substitute the reference distribution of one preselected waveform while concealing that many candidates were examined. A computer can evaluate the maximisation impeccably and still yield a misleading inferential label. The selection of alternative models, nuisance estimates and frequency intervals is part of the definition of the experiment.

The laboratory should first make the selection algorithm explicit. If the intended detector maximises a score over a fixed bank of pulse templates, it should freeze that bank, its parameter ranges, calibration and postprocessing before the confirmatory capture. Independent background-only datasets can then be processed through the same maximisation to estimate the global null behaviour of the resulting statistic. Care is needed when the background environment changes, and a simulation should not be trusted merely because its probability curves are smooth. Empirical calibration must cover instrument-generated spurs, local interference and missing-data rules relevant to the intended use. A theoretical distribution is helpful where justified; it does not eliminate the obligation to examine whether the assumptions describe the equipment.

If the original candidate arose from unrestricted exploration, it remains a legitimate discovery. The author can describe the search history, show the selected score and discuss possible physical mechanisms without asserting

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that a single-test probability confirms the hypothesis. The next experiment could specify the particular pulse family and acquisition conditions before collecting fresh data. Alternatively, a fully prescribed global detector could be independently tested. What cannot be done is to rename the original selected record a prospective test after the event. The decisive chronology is the chronology of knowledge and decision, not the date written on the final report.

I would further distinguish a numerical departure from a background distribution from an attribution of origin. A strong global detector result may establish that the particular receiver output is inconsistent with the calibrated null model under its stated conditions. Such a departure can still be caused by an unmodelled lawful source, an analogue nonlinearity or a numerical defect. A subsequent physical investigation must challenge those possibilities with independent reference equipment and lawful observations. An attractive likelihood curve is not a map to a particular circuit board. The field record should reserve names of external apparatus for conclusions supported by source-specific evidence, not merely by statistical surprise.

Sir Ronald Aylmer Fisher, Cross-Peer Question to Abraham Wald: Professor Wald, suppose a continuous receiver is left running until an operator sees a highly unusual event. The analyst then reports a probability calculated for observing an event of that strength in one fixed five-second interval, although the apparatus has been examined for many hours and its integration time was repeatedly altered. You have described sequential decision rules, but I ask you to explain how the stopping process could be formally incorporated without assuming independent observations that the receiver does not supply. Is there a practical distinction between a

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preplanned stopping boundary and a human decision to stop when a waterfall appears striking? If the laboratory's data stream contains gaps and retuning intervals, how should those intervals enter its exposure accounting? Finally, when the exploratory observation suggests a new feature, can a fresh confirmatory trial be designed without requiring the scientific team to discard all the useful insight it has already obtained?

Abraham Wald, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Sir Ronald, the distinction is between a specified sequential decision policy and a retrospective description of the one observation at which an operator happened to stop. A planned policy identifies the statistic to be updated, the observations eligible for inclusion, the alternatives, the boundaries for decisions and the rule for continuing when no boundary has been crossed. Under suitable assumptions, its error characteristics can be studied mathematically or empirically. A human who repeatedly changes the integration time and then selects the largest value has implemented a different procedure. The error probability derived for a single fixed interval does not automatically describe the event selected from that long adaptive history.

The dependence structure matters critically. Overlapping spectral frames may recycle many of the same samples, and successive dwell measurements can share slowly varying interference. A sequential procedure based on an independent-observation likelihood would be misspecified if these dependencies were ignored. One can instead characterise the complete practical detector by applying the frozen sequential algorithm to independent background-only records collected under appropriate operating conditions. The calibration should preserve realistic correlations,

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gap patterns and scheduling decisions. It should also define one alarm as an operational event rather than casually counting adjacent bright pixels as independent discoveries. The resulting estimate has a defined scope and uncertainty.

An observation gap cannot be treated as a negative measurement. Suppose the receiver sweeps another band for fifty seconds and observes the target frequency for ten. Its valid exposure at the target is ten seconds, not one minute. If a buffer is lost while nominally tuned to the target, the missing duration is an interval of unknown observation content, not verified silence. The detector's clock and sample counter information should permit the analyst to reconstruct valid opportunities. If such metadata are absent, the report must state the limitation. Interpolating a line through a gap can be a useful visual convention, but cannot create evidence of energy or its absence during that interval.

A new feature suggested by the exploratory record is a legitimate reason to design a more informative trial. The team may use the original capture to estimate a suitable centre frequency, choose a waveform template or decide which nuisance conditions need control. It should then freeze these decisions before collecting independent test material. The confirmation can be blind, with known authorised reference events and representative negative controls whose labels are withheld until predictions are fixed. If the method is revised after the blind results are seen, a further assessment is required, or the findings must be presented as exploratory. Scientific learning is cumulative; inferential independence concerns the evidence used for the particular confirmatory assertion, not whether the investigator must somehow forget prior experience.

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Abraham Wald, Cross-Peer Question to Sir David Cox: Sir David, the field team may predefine a single threshold yet continue to mislead itself if it applies that threshold to a statistic whose reference distribution is invalid. I invite you to distinguish errors introduced by choosing the hypothesis from errors introduced by fitting an inadequate noise model. Suppose the receiver environment alternates between two regimes, one quiet and one containing heavy-tailed industrial interference. The analyst trains a Gaussian model on the quiet intervals, deploys it across both regimes and calls the resulting high alarm count evidence of a new covert source. What diagnostic tests should precede that interpretation? How should a report express model uncertainty without claiming that a neat confidence interval solves all physical ambiguities? I ask also whether the duration and placement of observed gaps might bias the background estimate, especially if the acquisition system fails more frequently during periods of strong energy.

Sir David Cox, Cross-Peer Answer to Abraham Wald: Professor Wald, the two failures must be distinguished. Selection bias concerns the fact that the hypothesis, region, model or test statistic may have been chosen because of the observed data. Model inadequacy concerns the mismatch between the assumed distribution and the process actually generating observations. A test could be selected prospectively and still be invalid under a wrong model; it could use an adequate background model and still acquire a misleading single-test significance label through extensive post-selection. These difficulties may compound, and a rigorous report should examine each separately. Neither is repaired by attaching more decimal places to the final estimate.

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In your two-regime example, the first diagnostic is to examine the time dependence and operating context of the background observations. The team should compare empirical distributions, tail frequencies, autocorrelation and alarm clustering across the quiet and industrial regimes. It should inspect front-end overload flags, changes in analogue gain, calibration records and any correlation with operating machinery. A return to a known reference signal can test whether the detector itself remains stable. If the high alarm rate arises only during the industrial regime, the appropriate preliminary conclusion is that the frozen rule lacks validated specificity in that regime. It does not follow that any particular hidden apparatus exists.

The statistical model might be refined by prespecified stratification or an independently calibrated time-varying background estimator. But any model selected after seeing the purported anomaly should be evaluated on new material or accompanied by a suitable adjustment for selection. In a constrained field survey, where truly representative independent data are scarce, it may be more responsible to report empirical contrasts and substantial uncertainty rather than an unearned formal probability. Model-checking plots and negative controls should be preserved, including the unfavourable cases. A confidence interval conditional on an incorrect Gaussian model does not express uncertainty about the correctness of that model itself.

Missing-data behaviour introduces an additional selection mechanism. If buffers overflow more often during intense interference, the saved sample record may be depleted precisely where the background has the heaviest tails. An analyst who estimates the noise distribution only from surviving

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quiet windows may understate false alarms or underestimate interference. The gap register, acquisition counter and instrument status therefore form part of the statistical evidence. Investigators should test the receiver with controlled high-level reference inputs to establish whether losses are associated with signal strength or processing load. If missingness cannot be characterised, the report should flag the model qualification and refrain from a confident tail probability. The principle is simple: a mathematically correct calculation on selectively missing observations need not describe the unobserved physical process.

Sir David Cox, Cross-Peer Question to Walter Andrew Shewhart: Mr. Shewhart, an operational question remains. After a laboratory freezes and validates a threshold, the receiver may undergo a necessary maintenance change: a new preselector, updated firmware or replacement cable. Engineers must preserve safety and performance, and it would be unreasonable to forbid all retuning forever. Yet the same freedom to change a threshold can be misused to explain away a poor confirmatory result. What objective evidence should trigger a new calibration regime, and how should the historical record distinguish an authorised engineering revision from data-driven selection? Suppose the new baseline is demonstrably better in one environment but worse in another. What should the report say about the old results, and how should control charts distinguish process drift from a genuinely new external RF phenomenon? I ask for a protocol that can operate in a real laboratory, not merely a philosophical distinction.

Walter Andrew Shewhart, Cross-Peer Answer to Sir David Cox: Sir David, a quality system should permit necessary improvement while retaining a

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precise record of which claims were supported under which configuration. An instrument-maintenance change can be justified by calibration failure, known hardware defects, a documented replacement or a controlled alteration intended to extend capability. Such a change should have a timestamp, reason, responsible authority, hardware and software identifiers, and a record of the former validated regime. The existence of a legitimate reason does not mean the new performance can be presumed equivalent. The laboratory should demonstrate continuity where possible or conduct new reference and background tests where the change can affect the detector's behaviour.

A distinction between change-control review and post hoc inference is practical. In the former, an engineer documents the intended change and its acceptance criteria before the replacement configuration is tested. A qualified reviewer decides whether the evidence supports use of the new baseline. In the latter, an analyst changes thresholds because a particular alarming or inconvenient result has already appeared, then presents the edited rule as the one that governed that observation. The original record must remain immutable, and the changed analysis should be labelled as a derivative. A valid engineering improvement does not retroactively make a test prospective. The chronology of who knew what and when is therefore part of the chain of custody.

When performance differs across environments, the report should state the conditions rather than average away the difference. A reference detector may operate reliably in a shielded laboratory and badly near a strong industrial source. The team can define separate approved regimes if they have independently justified operating criteria and a method for identifying

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the applicable regime before evaluating an event. If classification of the regime depends on the event being judged, the possibility of selection bias must be assessed. It may be safer to retain a clearly qualified general rule and report that performance is not validated in the more troublesome environment. A single impressive graph is an inadequate basis for institutional acceptance.

Control charts should inform diagnosis, not establish source attribution. A drift in baseline power, noise variance, clipping frequency or internal spur amplitude can indicate a changed process. The team should compare reference signals, calibration check records and receiver state before interpreting an out-of-control point as an unknown emitter. Altering input attenuation, replacing the antenna with a known termination and checking another calibrated receiver can help distinguish internal and external mechanisms, though each control requires its own physical assumptions. An unexplained departure should remain unexplained until those competing causes have been examined. The integrity of the instrument's historical log is more important than the rhetorical force of its chart.

The correct institutional outcome is a pair of linked records. The first preserves the old configuration and all observations evaluated under it, including failed confirmation attempts. The second describes the candidate improvement, its evidence, its new operating limits and the date from which those limits govern future decisions. A later examiner can then compare regimes without being told that yesterday's observations were collected under tomorrow's threshold. This is how a process is permitted to improve without rewriting its scientific history. I return the token with the

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recommendation that every claimed confirmation should name the particular rule and validated apparatus state against which it was made.

QUESTION 096. TEN HYPOTHETICAL WORKED CALCULATIONS. All variables and assumptions are specified below. The numerical statements illustrate arithmetic relations and do not purport to measure a particular RF environment or validate a named detector.

EXAMPLE 1. If $p = 0.01$ is the probability of a false alarm per prespecified independent null trial and $m = 100$ independent trials are tested, the familywise chance of at least one alarm is $P = 1 - (1 - p)^m = 1 - 0.99^{100} \approx 0.63396766$, or 63.3968%. Independence is essential for this equality.

EXAMPLE 2. If $p = 0.001$ and $m = 1{,}000$ statistically independent null opportunities, the probability of at least one alarm is $1 - 0.999^{1000} \approx 0.63230458$, or 63.2305%. The expected number of alarms is $m\,p = 1$, which is not the same measure as the probability of at least one.

EXAMPLE 3. If $m = 100$ prespecified events each have marginal null alarm probability bounded by 0.0005, Boole's union inequality yields $P(\text{at least one}) \leq \min(1, m \times 0.0005) = 0.05$. This upper bound does not require independence, provided all marginal bounds are valid.

EXAMPLE 4. For target familywise error upper bound $\alpha = 0.05$ across $m = 100$ prespecified tests, the Bonferroni single-test threshold is $\alpha/m = 0.05/100 = 0.0005$. Such a rule need not be optimal and cannot retroactively account for an undocumented search over other tests.

EXAMPLE 5. For complex-sampling nominal rate $F_s = 2{,}000{,}000$ samples/s and FFT size $N = 4096$, bin spacing is $\Delta f = F_s/N = 2{,}000{,}000/4096 =$

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488.28125 Hz. Δf is not automatically the instrument's effective noise bandwidth or calibrated frequency uncertainty.

EXAMPLE 6. For a window N = 4096 samples shifted by hop H = 1024 samples, overlap count is N − H = 3072 and overlap fraction is (N − H)/N = 3072/4096 = 0.75, or 75%. Adjacent frames reuse samples and must not be treated as independent merely because they form separate display rows.

EXAMPLE 7. If a receiver physically observes a specified frequency for 10 valid seconds in a 60-second wall-clock period, exposure fraction is 10/60 = 1/6 ≈ 0.166667, or 16.6667%. The 50 unobserved seconds cannot be counted as verified silence.

EXAMPLE 8. If zero alarms occur in n = 1000 independent Bernoulli background-only trials, an exact one-sided 95% upper confidence bound on the per-trial probability is 1 − (0.05)^(1/1000) ≈ 0.00299125, or 0.299125%. The bound is not valid without a suitable model of independent trials.

EXAMPLE 9. If a frozen operational detector records k = 18 alarms during T = 6 valid observing hours in a declared band, an empirical alarm frequency estimate is r = k/T = 18/6 = 3 alarms per valid observing hour. This rate is not, without more assumptions, a per-trial false-alarm probability.

EXAMPLE 10. At a nominal sample rate F_s = 2,000,000 complex samples/s, a complete acquisition block containing N = 4096 valid consecutive complex samples spans T = N/F_s = 4096/2,000,000 s = 0.002048 s = 2.048 milliseconds. Lost samples and rate-error uncertainty require additional accounting.

QUESTION 096. TECHNICAL SOURCE NOTES. This modern dialogue is an original fictional scholarly reconstruction for the textbook, not historical

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speech or archival testimony. Source background for independent Stage-B checking: Jerzy Neyman and Egon S. Pearson, “On the Problem of the Most Efficient Tests of Statistical Hypotheses,” Philosophical Transactions of the Royal Society of London A 231 (1933), 289–337, DOI 10.1098/rsta.1933.0009, https://royalsocietypublishing.org/doi/10.1098/rsta.1933.0009; NIST/SEMATECH Engineering Statistics Handbook, Section 1.3.5 “Quantitative Techniques,” https://www.itl.nist.gov/div898/handbook/eda/section3/eda35.htm; NIST/SEMATECH Handbook, Section 7.4.7.3 “Bonferroni’s method,” https://www.itl.nist.gov/div898/handbook/prc/section4/prc473.htm; NIST/SEMATECH Handbook Chapter 6, “Process or Product Monitoring and Control,” https://www.itl.nist.gov/div898/handbook/pmc/pmc.htm. These sources support general methods, not the fictional words attributed to historical specialists. Receiver-specific false-alarm claims require documented detector and null-process validation.

EDITORIAL QUALIFICATION: Hypothetical numerical examples are calculations, not measurements. Exploration, calibrated detection, waveform classification and attribution of a specific source are distinct claims. Never imply that a selected threshold proves an unknown transmitter or justifies collecting communication content without authority.

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QUESTION 097

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What selection bias follows when only alarm-triggered IQ data are preserved?

Dr. James M. Atkinson, Moderator: Sir Ronald, let us suppose that an otherwise competent receiver writes complex I/Q files only when a fixed detector declares an event. A later analyst examines hundreds of retained clips and concludes that the surveyed environment was crowded with emissions of that shape. Yet neither the silent intervals nor the receiver's incomplete opportunities to observe them remain available for inspection. I invite you to explain the selection mechanism, distinguish frequency of stored alarms from actual event prevalence, and design a lawful comparison against an independent observation record. Please also separate statistical inference from authenticity of the analogue measurement and from attribution of a particular apparatus. We shall proceed as a fictional modern scholarly reconstruction and not as an historical transcript.

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Sir Ronald Aylmer Fisher, Principal Contributor: Dr. Atkinson, I should first ask by what process the observations entered the collection. A record of selected alarm clips is not an ordinary random sample of the physical environment. The receiver may store data only when its own detection statistic crosses a predetermined threshold. Consequently every saved file is conditioned, in part, upon the statistic which the later analyst is tempted to measure. The selection mechanism may prefer the largest noise fluctuations, the strongest lawful transmissions and certain instrumental artefacts, while leaving the remainder of the underlying process unseen. One cannot infer the unconditional distribution of RF energy merely by treating the saved clips as if they had arrived at random. The problem persists even when the trigger threshold was admirably fixed before the survey. It is distinct from the post-selection testing problem previously discussed: the original decision rule can be prospective while the stored sample remains strongly selected.

The term conditioned on an alarm is important. Suppose Y represents a statistic computed from a valid receiver observation, and R is an indicator that the observation has been retained. If R equals one primarily when Y exceeds a threshold, then a distribution estimated from the retained observations describes Y given R equals one, not the distribution of Y across all valid observations. The two are not equal unless conditions justify that equality, and threshold-triggered retention is precisely a mechanism that usually prevents it. A plot of the saved samples may look exquisitely persuasive because the display contains almost nothing but excursions. The missing normal background has not vanished from the world; it has

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vanished from the evidence archive. Its absence must not be misrepresented as an experimental finding.

A second problem concerns the denominator. Hundreds of stored clips have limited meaning without knowledge of valid exposure. Were they collected in one minute, one week or across a year of sporadic survey visits? Was the receiver tuned to the specified frequency continuously, or did it scan that band for only a fraction of the recorded wall-clock duration? Did buffers overflow during intense interference, and did the application enter a refractory period after each alarm? Those operational details affect the opportunities in which the detector could have generated a stored event. A logging system that retains precise trigger timestamps and calibrated valid exposure may permit an empirical alarm rate per valid observing hour. It does not, by that fact alone, establish whether the alarms correspond to genuine external transmissions or to receiver-generated or environmental interference.

The distinction between false alarms and missed events becomes even sharper. If only triggered clips survive, an investigator can inspect many events that caused an alarm but cannot directly count genuine events to which the detector failed to respond. It is therefore improper to compute sensitivity solely from the fraction of saved clips that appear convincing. A measure of sensitivity requires an independently established population of true events under specified conditions. Likewise specificity requires valid background opportunities or an appropriate independent reference process in which alarm and non-alarm decisions can be evaluated. A trigger archive may contain false positives, but the absence of untriggered negative periods obstructs a full confusion matrix. Those unknown counts must be recorded

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as unknown, rather than filled with zero because no corresponding file exists.

I propose an authorised laboratory arrangement with two recording channels. The first is an independently characterised reference monitor, designed to preserve only the information necessary to establish valid observation time and whether defined test events occurred. Where permissible and technically necessary, it may hold limited, protected samples of known reference emissions. The second is the actual alarm-triggered receiver under examination, operating with a frozen threshold and a complete log of its gain, preselection, centre frequency, sampling rate and software state. An independent event generator supplies test pulses with a recorded timing schedule and specified amplitudes; background-only intervals and deliberate interference provide negative controls. The source schedule is concealed from the triggered detector's evaluator until its decisions are fixed. This design supplies an external denominator against which the retained alarm population can be compared.

The two channels must also reveal the effects of trigger latency and capture-window geometry. A pretrigger ring buffer of insufficient length may omit the first portion of a burst, while a posttrigger holdoff may merge separate events into one stored clip. An apparently narrow waveform family could be the consequence of a recorder that preferentially preserves long events and loses short ones. If a trigger requires the energy to persist across several frames, its retention rule selects on duration as well as amplitude. If the same receiver is overdriven by intense local signals, an overflow may destroy samples at precisely the moments that would be most interesting to a physical diagnosis. These mechanisms alter the observable population. A

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report should distinguish a missing sample, an unretained valid observation and an interval when the apparatus was not observing at all.

For clarity, consider a hypothetical exercise rather than a field claim. Let an independent source create one hundred test bursts in intervals during which the receiver is known to be tuned and functioning. If the triggered recorder saves sixty matching files, the laboratory may estimate a sixty-per-cent detection fraction for that specified burst population, subject to measurement uncertainty and matching criteria. But sixty stored files alone would not establish that figure if the independently known hundred-burst denominator were absent. The recorder might equally have observed sixty genuine bursts out of sixty, sixty out of a thousand, or a mixture of genuine bursts and unrelated alarms. The arithmetic is not difficult. What matters is whether each relevant observation and its eligibility has been independently established rather than inferred from the collection policy.

Evidence preservation complicates the matter without negating the scientific argument. A continuous I/Q archive may record communications content beyond the legitimate scope of an RF survey. The proper remedy is not to assume unlimited collection rights in the name of better statistical inference. The investigation can often preserve non-content occupancy summaries, calibrated reference-event ledgers, receiver-state changes, sample counters, valid exposure periods and hashes of authorised retained extracts. Where full samples are justified and legally permitted, their acquisition, protection, purpose and retention limits should be explicit. The scientific record should describe what was not kept and how that omission restricts inference. It should never conceal the selection mechanism simply because the underlying privacy constraints are inconvenient.

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I would finally ask that the later analyst consider alternative reasons a clip was selected. A strong nonlinearity may cause the receiver to trigger on combinations of lawful signals; a mismatched clock may shift the apparent duration of an event; software changes may alter the holdoff rule between survey sessions. If such conditions are undocumented, pooling clips can produce a population that never existed under any one measurement regime. A valid conclusion might be that the detector archived a specified number of threshold excursions under documented acquisition states. It might also be that a controlled reference test demonstrates certain strengths and limitations. Neither automatically identifies a covert or unlawful source. The first duty is to preserve the sampling mechanism as part of the evidence, for the polished appearance of the saved waveform should never be mistaken for proof that the discarded intervals were silent.

I respectfully pass the token to colleagues who will examine sampling inference, incomplete observations, trigger-driven decisions and the evidential limits of event-only recording. Their task is to make the missing denominator visible in the report even when the original samples themselves were not retained, and to specify which future independent experiment could justify a stronger conclusion.

Walter Andrew Shewhart, Peer Question: Sir Ronald, I should like to know whether a receiver's operational stability can be inferred from the tidy collection of alarm clips which the recorder has retained. In process monitoring, a signal is meaningful only in relation to a specified process and the opportunities during which its behaviour was observable. Suppose a technician reports forty unusually narrow spectral events and submits forty attractive waterfall extracts, but the same instrument varied its gain,

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temperature and preselector state during the survey. The selection rule may be fixed in software, yet the physical distribution to which it was applied may have shifted. How should the investigator separate genuine variation in the ambient field from changes in the measurement process? I ask further what an honest control chart could show when ordinary non-alarm observations have been discarded, and what records should be preserved instead of raw private communications to permit an independent assessment of statistical control.

Sir Ronald Aylmer Fisher, Response: Mr. Shewhart, your question reveals why retention and measurement must be separated. A control chart constructed only from saved excursions would depict the conditional population, not the monitored process. A receiver which increases its front-end gain may generate more alarms without any increase in incident electromagnetic energy. The numerical threshold might remain fixed in the digital units of a detector, yet the analogue energy represented by those units has changed. Conversely, activation of attenuation or preselection may reduce the number of saved events, suggesting quietness precisely when the apparatus has become less sensitive. The ordinary background is not a nuisance to be discarded when it provides the reference against which exceptional behaviour is defined.

I would insist upon a state ledger, timestamped at a resolution justified by the instrument, listing gain, attenuation, centre frequency, preselection, antenna selection, ADC overload indications, sampling rate, filter configuration, temperature if material and every software or firmware transition. The ledger must also represent intervals in which the receiver was properly observing, intervals of scheduled absence, and intervals

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rendered invalid by errors or overload. None of these fields need contain decoded communications. They establish what the apparatus was capable of measuring and when. A control chart may then be constructed for non-content summary statistics collected over predefined valid intervals, with a written decision as to whether the process was sufficiently stationary for the proposed comparison.

A retrospective chart of alarm amplitudes is not useless. It can describe the selected alarm population and reveal changes within that population, but it cannot establish the unconditional noise distribution or the frequency of unrecorded events. If a technician sees a sudden step in alarm amplitude, the correct inquiry includes whether the ADC scale, reference plane or temperature changed. If a sudden rise in alarm count corresponds with a high-powered transmitter outside the designated laboratory source, intermodulation must be investigated. A procedural chart can display counts per independently established exposure, yet an apparent control limit calculated from a changing mixture of receiver states would lack a coherent physical interpretation.

The acceptance test should include an independently monitored stable source, controlled gain transitions and background-only exposure. In each condition one compares the recorder's triggers against an external event ledger rather than treating the stored files as the entire world. Where the instrument changes state, analyses should be stratified or the state change explicitly modelled. We may conclude that the alarm process changed; we should not necessarily conclude that an external emitter changed. That difference, particularly in evidence destined for a tribunal, deserves ordinary plain language alongside the mathematics. The admirable object is not the

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largest collection of memorable bursts. It is a defensible account of the opportunities that existed, the selections that occurred and the uncertainties which the archive cannot abolish.

William Edwards Deming, Peer Question: Sir Ronald, a laboratory may possess an excellent reference receiver but still produce a misleading result if its test schedule is chosen for convenience. A series of conspicuous, strong reference bursts could make the triggered recorder appear sensitive, although the field question concerns very weak events close to the threshold. Likewise, a quiet shielded laboratory might make its false-alarm performance look impressive despite an industrial site containing impulsive machinery and strong adjacent signals. Would you distinguish a trial that verifies a mechanism from a trial that estimates field performance? How should operators select test amplitudes, durations and receiver states before examining the outcomes? Finally, if the lawful survey concerns a particular room or circuit, what may be inferred when the test environment cannot reproduce all its electromagnetic conditions? I seek a practical statement that neither exaggerates the experiment nor renders useful engineering evidence impossible to obtain.

Sir Ronald Aylmer Fisher, Response: Mr. Deming, the design is part of the answer, not a ceremonial prelude. A demonstration that a receiver triggers on strong signals proves a narrow functional proposition under the tested settings. It does not measure the probability of detecting weak events or bound the false-alarm rate in another environment. If the investigator intends to infer sensitivity across a range of amplitudes and durations, the laboratory should specify strata or a randomised schedule covering those ranges, with sufficient replication to characterise variability. The test

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generator should be accompanied by independent monitoring so that nominal settings are not confused with the actual field arriving at the device under examination.

We should define beforehand the target population of events. Perhaps the authorised problem is to detect brief, low-power test emissions within a stated frequency band, during stable receiver operation. Then the desired sensitivity is a conditional probability over that specified population, not a universal number which applies to every waveform or location. Test events should include durations shorter and longer than the detector's integration window, frequencies near filter edges, levels near the threshold, and an appropriate range of background disturbances. If the detector is triggered only by particular pulse shapes, the record should preserve that fact. Every test must be classified independently of whether a clip was stored. Otherwise the evaluation repeats the very selection defect it purports to correct.

Randomisation or masking can guard against an operator unconsciously placing reference events at convenient moments, adjusting settings after a success, or omitting difficult conditions from the final report. The intended table of analyses should be written before the test begins, distinguishing primary outcome measures from exploratory descriptions. A failed test case is not a wasted file; it is evidence about the method's limit. Conversely, a successful controlled test is meaningful within its assumptions. It is unnecessary to declare that every difference between laboratory and field invalidates the method. The appropriate question is which physical aspects of the field have been bounded and which remain unrepresented.

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A field report should therefore use graded claims: the instrument was demonstrated to respond to specified laboratory stimuli; the trigger process was evaluated against a documented event and exposure ledger; and the field observations are consistent with certain external or instrumental hypotheses. Each phrase has a different evidential weight. Industrial interference, unknown receiver noise statistics, cable coupling and uncertain antenna response are limitations to be stated, not erased by confidence borrowed from a laboratory success. That disciplined restraint is especially valuable in a lawful security examination where an erroneous inference could damage individuals or institutions. The strongest report is not the one that reports the most detections. It is the one that can explain which observations would have contradicted its conclusion and whether those observations were ever available.

Dr. James M. Atkinson, Moderator: Sir Ronald has demonstrated how predetermined physical strata and continuous non-content exposure records avoid the false comfort of a selected archive. I pass the token with respect to Dr. Jerzy Neyman to examine estimands, inclusion probabilities and the limits of design-based correction.

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Jerzy Neyman, Second Principal Contributor: Dr. Atkinson, there is an essential difference between a population whose units are defined and a collection whose units exist only because a machine elected to store them. A sample can support wider inference when its inclusion mechanism is known and the target population has been specified. Here the receiver's retention mechanism generally depends on the measurement itself. One cannot casually apply the usual language of representative sampling to records selected for having crossed the threshold. It is therefore necessary to state the estimand before constructing the calculation. Do we seek the mean power of all valid observation windows, the rate of externally verified bursts per valid hour, the probability of retaining an event in a defined reference class, or the proportion of stored alarms subsequently confirmed as matching a laboratory signal? These are different questions requiring different denominators.

Let an observation opportunity be defined in advance as a valid, non-overlapping time cell while the receiver is tuned to the specified band. Let E indicate that a genuine reference event occurred in that cell; A indicate that the detector alarmed; R indicate that an I/Q record survived; and V indicate that the instrument was actually able to observe. A proper analysis might estimate P(A=1 given E=1,V=1) for sensitivity, or P(A=1 given E=0,V=1) for a false-alarm probability. A collection restricted to R=1 does not identify either probability. It provides at most information about the conditional population of preserved records, unless an independent process measures the unretained units or the missingness mechanism is sufficiently known and tested. The equality of A and R must itself be verified: buffering, storage

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quota, write failures and holdoff can make an alarm occur without an archived file.

We should pay particular attention to how a population is defined across time. A scanning receiver revisits a channel intermittently. Its wall-clock survey duration is not equal to its valid observing exposure for that channel. If a 60-minute survey devoted only 10 minutes to a frequency, the relevant exposure for a simple count rate may be 10 minutes rather than an hour. Even that calculation assumes that all ten minutes are valid and that the counting rule treats overlapping triggers consistently. An independent event generator might inject bursts during the fifty unseen minutes, but those events cannot be counted as missed detections if the evaluation's denominator is explicitly restricted to valid observing opportunities. The scientist should report both coverage and performance conditional on coverage, rather than hide one inside the other.

There is a possible role for unequal-probability sampling, but it demands stronger evidence than an anecdote about how the software was configured. Suppose a lawful reference system makes a randomly selected subset of non-alarm periods available as content-minimised numerical summaries, while every alarm period is eligible for study. If each observed unit has a documented, nonzero probability of selection under a controlled design, one may construct estimates weighted by inverse inclusion probabilities under appropriate assumptions. Yet a deterministic threshold which assigns zero probability of retention to all subthreshold sample streams fails that requirement for estimating their detailed waveform distribution. No mathematical reweighting can recover information from an entire class of units which had no chance of entering the sample. The policy

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may protect privacy commendably, but the resulting inferential limit must be acknowledged.

Let us illustrate a simple, explicitly hypothetical design. Imagine one thousand independently designated valid one-second opportunities. Of these, an independent authorised monitor identifies forty reference events. The trigger process marks thirty of those forty, and marks twenty of the remaining 960 background-only opportunities. The resulting sensitivity is 30 divided by 40, or 0.75. The false-alarm probability per designated negative cell is 20 divided by 960, approximately 0.02083. The positive predictive value in this laboratory population is 30 divided by 50, or 0.60. But if the recorder stored only the fifty alarm clips and omitted the independent ledger, the counts forty and 960 would be unknown. The stored collection cannot justify the three proportions merely because each saved clip can be examined with great care.

The numerical trial should not be mistaken for a claim that the underlying time cells are independent in an actual receiver. Repeated FFT frames overlap, radio bursts cross boundaries, and dead time couples decisions across adjacent cells. A probability per predefined cell need not equal a rate per second or a probability per alarm episode. Sensitivity will also depend on signal amplitude, duration, spectrum, antenna orientation and front-end behaviour. For a real performance estimate one should provide uncertainty intervals, a sampling plan and a defensible account of clustering or correlation. A narrow numerical confidence interval calculated under an invalid independence assumption creates a false appearance of assurance. More decimal places cannot restore missing observations.

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A useful laboratory procedure is to separate the reference event schedule from the recorder under test. An independent monitor must confirm whether each test pulse reached the relevant measurement reference plane and whether the receiver was in a valid state. The team then compares trigger logs, write-success logs and retained file hashes. It should state whether an alarm without a saved clip counts as a trigger success for sensitivity, a retention failure for evidence availability, or both under different outcome measures. It should maintain a distinct ledger for downtime, scheduled tuning gaps, buffer overflow and unavailable reference events. These categories cannot be casually assigned to a zero in the confusion matrix without determining the trial's predefined observation unit.

Selection may also distort the apparent composition of waveforms. An amplitude threshold preferentially retains strong events, but a duration-dependent detector may disproportionately retain slow or persistent bursts; an alarm requiring spectral persistence may favour narrowband signals and suppress broadband impulses. A time-limited posttrigger window may cut off the end of long events, whereas overlapping triggers may make short events appear long. Thus even among genuine external emissions the stored files are not necessarily representative. A conditional distribution of retained spectral width, modulation depth or pulse duration should be described as conditional, with the operational selection rule attached. The correct question for an analyst is not simply whether a plot looks convincing, but what selection process made it visible.

In court or in the scientific record I would require the target population and the design to stand alongside the result. If the original observing

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opportunities cannot be reconstructed, the report should not assert a field prevalence or probability of missed events. It may legitimately report a count of surviving clips with verified provenance, the observed trigger timestamps, and a controlled calibration for specified conditions. If independent records later establish the denominator, the permissible inference can be expanded with a documented revision. That revision must not alter the original samples or conceal the earlier limitation. Statistical honesty and forensic integrity are compatible; the first supplies the limits of inference while the second protects the record on which that inference rests.

Solomon Kullback, Peer Question: Dr. Neyman, suppose a researcher is tempted to infer background conditions from the shapes of the alarmed signals themselves. The retained population contains large detector-statistic values and many clips whose opening windows seem to show quiet I/Q samples before the trigger. The researcher proposes to treat these pretrigger samples as randomly sampled background and use them to estimate the unconditioned noise distribution. Would that be justified? I ask you to consider correlations between pretrigger and trigger frames, ring-buffer replacement, stationarity assumptions and the possibility that an impulsive event was already developing before the alarm. Can the analyst ever make a useful background estimate from such clips, and if so what must be stated about its conditional character? I also seek an explanation of why a good fit of a model to retained clips does not, without independent controls, test the distribution of the unseen intervals. I also ask whether the same conditional pretrigger sample could appear statistically different when

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the independent reference spans a different receiver-temperature or gain regime.

Jerzy Neyman, Response: Mr. Kullback, the pretrigger sample is selected by its connection with a subsequent alarm. It is not drawn independently of that future decision simply because it lies a few milliseconds earlier in the stored file. If the detector uses overlapping windows, smoothing, a running noise estimate or a persistence rule, the samples preceding the nominal trigger may have contributed directly to the decision. A burst may already be rising within that interval. Even when the trigger statistic uses only later samples, the analogue process may be correlated across time, so observations immediately before a large excursion can differ systematically from ordinary background. The ring buffer may also fail preferentially at high activity, replacing or truncating the very material an analyst wants to use.

The analyst can describe the distribution of recorded pretrigger windows under the stated retention rule. Such a description may be useful for locating onset boundaries, diagnosing a particular filter transient or assessing clipping in the selected events. It does not by itself establish the unconditional noise floor. A claim of unconditional representativeness would require either a demonstrated independence property or an appropriately designed control sample of nontrigger periods. The instrument's algorithm should be disclosed sufficiently to know whether its threshold is computed from fixed past data, a sliding adaptive estimate or an interleaved set of overlapping transforms. A statement that the pretrigger region was 'quiet' is an empirical classification under a defined rule, not evidence that it was randomly sampled.

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One could perform a controlled diagnostic. Generate independent background-only opportunities under several verified receiver states, compare the marginal statistics from a predeclared random subset against statistics from pretrigger sections of subsequently alarmed files, and examine how their differences vary with lead time. It may turn out that a sufficiently distant pretrigger interval approximates the reference process for a particular measured statistic. That is a calibration finding limited to the tested stationarity conditions, not a universal theorem. The analyst should also preserve the possibility that the detector affects its own reference state by automatic gain control or adaptive thresholding, which may persist across multiple events.

A good fit within the selected data tests consistency with the selected-data likelihood, not with the unselected population. Many different underlying background processes can yield similar conditional tails after truncation or trigger selection. The inference becomes particularly fragile when the mechanism of missingness or instrument downtime is undocumented. If the investigator wishes to extrapolate beyond the observed collection, the report must display the model assumptions and a sensitivity analysis which asks how alternative unobserved distributions would change the conclusion. Without such external information, the honest conclusion remains limited to a conditional description. The task is to explain what the saved files show and why they do not show everything.

Sir Harold Jeffreys, Peer Question: Dr. Neyman, an investigator may argue that prior knowledge about typical industrial interference or receiver-noise amplitudes allows a probabilistic estimate of the unobserved event rate from the retained clips. In one version, a model assigns a distribution to all

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genuine emissions and a separate distribution to false triggers, then calculates the probability that each saved event was real. In another, it extrapolates the number of missed events from the detected amplitude tail. Could the data identify those quantities without an independent monitoring record? I should like a careful separation between an analysis that is conditional on prior and model assumptions, an empirical estimate supported by actual exposure, and a physical attribution to a particular source. What would you require the expert to disclose so that a court does not mistake a plausible posterior probability for a measurement made by the receiver? In particular, please explain how a prior which is credible for a quiet laboratory might fail when applied to an industrial setting with heavy-tailed interference.

Jerzy Neyman, Response: Sir Harold, a probabilistic model may be useful, but its strength is bounded by what the observations can identify. If the archive contains only selected clips and the total valid exposure is unknown, infinitely many combinations of event prevalence and detection efficiency may be compatible with the same collection. The analyst might assign priors to those unknowns, perhaps informed by earlier controlled experiments, but a numerical posterior may then be driven chiefly by those assumptions rather than by new data. That need not make the calculation intellectually illegitimate. It does make the provenance of its certainty essential to disclose. A statement about an assumed model's posterior is not the same as a direct estimate of the environment's unconditional emission rate.

I would ask the expert to show the likelihood conditioning explicitly. The distribution of an observed clip is the distribution of its measured features given that a retention event occurred and a write succeeded. If the

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probability of retention varies with amplitude, duration, waveform class or receiver state, the model must include those processes or justify neglecting them. The number of clips contributes information about prevalence only if their exposure and opportunity structure are independently known, including dead time and missed records. An amplitude-tail model can be fitted within the observed range, but extrapolation below the threshold rests on a distributional assumption which may fail in the presence of multiple emitters, clipping or unmodelled impulsive noise.

The expert should give alternative models which fit the retained evidence but imply materially different unseen populations. That exercise tests whether the conclusion depends on assumptions the actual recording cannot check. The uncertainty statement should distinguish parameter uncertainty within one model, uncertainty about the model family itself, and uncertainty in analogue measurement and event classification. The receiver may measure a complex baseband sample within calibrated limits; it does not automatically measure the prior probability that a covert source exists. Even an apparently distinctive signal may be consistent with several external or instrumental explanations. Attribution requires other evidence such as controlled antenna changes, independent instruments, lawful physical examination and exclusion of receiver artefacts.

A restrained report may therefore say: under the specified model and stated external assumptions, the estimated conditional probability that a stored alarm meets the reference classification criterion lies within a calculated range. It may not simply announce that the source was verified. If later independent exposure logs become available, the model can be checked against actual alarm and nonalarm opportunities. Until then, the posterior

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serves as a conditional aid to reasoning rather than a substitute for missing observations. The public should be spared neither mathematics nor caveats; a competent witness can explain both in clear prose. The numerical result gains credibility by displaying the assumptions that would falsify or materially alter it.

Dr. James M. Atkinson, Moderator: Dr. Neyman has demonstrated that a known sampling mechanism and an independently established denominator are prerequisites for generalising beyond stored alarms. I now respectfully invite Dr. David Harold Blackwell to examine the problem as a partially observed decision system in which a defensible retention rule may improve privacy while impairing statistical knowledge.

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David Harold Blackwell, Third Principal Contributor: Dr. Atkinson, my central question is not whether the machine is sophisticated, but what information its actions reveal. An alarm recorder implements a policy. Based on observed inputs and its internal state it decides whether to preserve an I/Q segment. The investigator later sees the consequences of that policy, and possibly a record of the decisions, but not necessarily the inputs on which decisions were withheld. A decision system can be useful for its intended purpose while yielding a deeply selective archive for later scientific inference. To judge it fairly we must distinguish the action the system was designed to take from the population characteristic the analyst now proposes to estimate. A device intended to preserve only high-priority anomalies may achieve its operational goal precisely by discarding normal background. That virtue is not a licence to claim that its surviving files represent the total RF environment.

Let us distinguish three informational objects. The first is the receiver's continuous opportunity to observe, including its tuning schedule, valid sample intervals and physical state. The second is the decision record: a sequence of trigger statistics or appropriately privacy-preserving summaries, thresholds, state transitions, decisions and storage-success indicators. The third is the preserved content-bearing I/Q file, available only when the policy selected it and the storage process succeeded. Many investigations require the second object for rigorous performance assessment without requiring unrestricted access to the third. An independent monitor may establish the population of known test events and negative controls. When exposure and decisions are logged across both

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selected and unselected intervals, the operator can assess alarm rates without storing the private contents of every observation.

The distinction between a trigger and a surviving file is easy to overlook. Let A=1 mean that the detector declared an alarm; R=1 mean that a data file was actually retained. If disk exhaustion, storage throttling or a programmed quota makes R=0 despite A=1, a count of surviving files understates the true alarm process. If the recorder groups repeated alarms into one long clip, a count of files cannot be equated with a count of alarm decisions. If a single alarm writes several channel-specific files, the opposite distortion occurs. The retention process may therefore have two selection stages, one acting on the detector and another on the file writer. Both must be reconstructed before the reported count has a stable meaning. A beautiful waveform and a correct checksum cannot tell us whether it was the sole surviving fragment of a much larger alarm sequence.

A controlled experiment should include a reference channel and a known event schedule, but it need not indiscriminately retain all content. One can select background intervals using a random seed agreed before the test and record only sufficient non-content diagnostics under the relevant authority. One can keep a rate counter, hardware-valid exposure and a compact occupancy summary when those data answer the engineering question. One can also preserve a protected and finite set of reference-waveform samples whose legal and scientific purpose has been specified. Where the actual discrimination problem requires detailed I/Q, the research design should identify those intervals and put them under proportionate retention safeguards. The policy governing collection is part of the study design, not an afterthought.

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Consider a recorder that uses a threshold and then introduces five seconds of holdoff, during which it will not create new files. An energetic interference source might produce many physical events in this interval, but the archive contains only the first alarm and the subsequent silence of the recorder's file list. That silence is not electromagnetic silence. It is a consequence of the recorder's decision state. A scientifically honest event-rate estimate must either observe the underlying events independently or acknowledge that events in the blind interval remain unresolved. The interval might be excluded from valid at-risk exposure for one particular measure, but doing so requires a clearly defined estimand. It cannot be removed from the real survey clock when the separate question is what proportion of the time the receiver was unavailable.

Decision theory also directs us to consider what harm each error entails. A trigger which saves unnecessary I/Q may collect more information than the authorised enquiry requires. A detector which saves too little may fail to preserve evidence needed to test a genuine safety or security concern. These costs are not purely numerical. They involve lawful authority, privacy, chain of custody, institutional fairness and the capacity of an independent reviewer to challenge a conclusion. A retention policy may legitimately favour privacy; the report should then state the resulting limits on missed-event inference. The worst practice is to obtain a limited archive by design and subsequently pretend that the absent material was studied and found uneventful.

The analyst should be especially wary of conditioning on a variable produced by both a source and an artefact. An alarm can occur because an external emission was present, because the receiver generated

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intermodulation, or because a transient noise excursion crossed the threshold. If one analyses only alarmed intervals, associations between otherwise independent external and instrumental factors can appear within that selected population. It is the general problem of conditioning on a common consequence. An observed relation between burst amplitude and front-end temperature within saved clips may be a property of the trigger mechanism rather than of the emissions. Independent background controls and receiver-state variation are required to distinguish the hypotheses.

The final output should therefore be a claim register, not merely a file manifest. It should separate observed trigger counts, retained file counts, estimated valid observing exposure, verified reference events, known missed reference events, unidentifiable unobserved occurrences and technical reasons for each exclusion. In the same register, state the rights and restrictions governing each retained dataset. When the analyst later changes the question from 'what did the trigger retain?' to 'what existed in the environment?', a new evidential justification is required. The first is ordinarily easier to prove; the second can be much more consequential. I respectfully yield the token for challenge, especially upon how to interpret missingness generated by a device whose policy was deliberately selective.

John Wilder Tukey, Peer Question: Dr. Blackwell, I have a concern that exploratory graphics can seduce even an expert who knows about selection. The retained clips may reveal several apparent waveform clusters: a family of short narrowband pulses, an apparently unrelated group of broadband events and a third group containing a common transient. An analyst performs clustering on the stored I/Q, displays a pleasing separation and labels each cluster a distinct transmitter class. Yet the trigger may have used

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different windows for different bands, and only those segments exceeding an adaptive energy statistic were preserved. How would you use exploratory analysis responsibly without turning a conditional visual taxonomy into a claim about the numbers of actual transmitters or the relative prevalence of their emissions? What negative controls and alternative partitions would you ask to see, and how could the selection record be represented beside the plots so that the reader cannot mistake colour-coded clusters for physical ground truth?

David Harold Blackwell, Response: Mr. Tukey, exploration is legitimate when it is labelled as exploration and when its selection mechanism is displayed. Clustering answers a mathematical question about the retained observations under a chosen feature map and distance measure. It does not prove that an equal number of physical emitter classes exists. The detector's own filterbank may favour certain spectral widths, durations or amplitude trajectories. Two visually distinct clusters could be created by two receiver states measuring the same external source, while two independent external sources could fall in one cluster after lossy normalisation. A correspondence between clusters and sources requires external evidence, not merely an attractive silhouette score.

I would first attach to every plotted point its trigger rule, receiver state, capture-window geometry, reference-plane calibration and indication of clipping or overflow. One should vary permissible feature definitions, window lengths and frequency normalisations, then report whether the partition is stable. An independent monitor or authorised calibration source can provide controls of known provenance; deliberately generated receiver artefacts can test whether the method assigns a fictitious signal class to

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internal products. Blind classification against those controls offers more evidence than repeatedly tuning the algorithm until a desired grouping appears. Analysts should also show the distribution of observation exposure by state so that an abundance of files in one operating mode is not mistaken for an abundance of emissions from that mode.

A conditional plot might support a narrow finding that, among retained clips generated by a stated policy, several reproducible signal-feature groups were observed. If an independent monitor establishes which external reference sources produced the test data, the classifier's performance for that reference population can be evaluated. Without such a denominator, one should not report that forty percent of all emissions belonged to the largest cluster. Nor should a few visually isolated records be called covert transmitters merely because they are unfamiliar. The unknown category must remain visible; under controlled experiments it may contain test artefacts, accidental interference or detector failure rather than a distinct source.

The ethical value of the graphic is to make uncertainty comprehensible. I would show the selection boundary itself, mark points that came from clipped or truncated captures and give explicit counts of receiver states and valid exposure, not merely a brilliantly coloured constellation. A separate chart can show how the same known calibration waveforms change appearance under altered gain, filtering and capture windows. If a claim changes substantially under reasonable feature choices, that instability belongs in the report. The proper conclusion may be modest but useful: the retained archive contains several reproducible measurement patterns deserving controlled investigation. It is not yet a census of transmitters, a

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proof of authenticity or a lawful basis for opening protected communications.

Dr. James M. Atkinson, Moderator: Dr. Blackwell has separated a decision-policy archive from the environment it selectively represents. I now pass the token to Sir David Cox to consider ascertainment, regression and the missing information that conditions any attempted reconstruction of rates or associations.

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Sir David Cox, Fourth Principal Contributor: Dr. Atkinson, the retained observations are subject to ascertainment. This is a term with a precise purpose: whether an observation enters the dataset depends on variables related to the phenomenon under study. In a triggered RF recorder the probability of being observed often depends on amplitude, duration, spectral shape, time since the preceding alarm and the receiver's operating state. These dependencies can distort both simple distributions and relations between measured variables. Suppose an analyst finds that longer retained bursts are also brighter in a waterfall display. That association may arise partly because short weak bursts seldom trigger, rather than because the physical sources intrinsically couple duration and power. It would be dangerous to assume that a regression estimated only on saved clips has the meaning it would possess in a complete observation record.

The investigator should write a generative account of the acquisition chain. There is an external electromagnetic environment, an antenna and analogue chain, a sampled numerical representation, a detector statistic, a decision threshold, a holdoff mechanism, a write process and an analyst's feature extraction. Each step may introduce selection or measurement error. The model need not be excessively elaborate, but its causal order must be clear. A stored clip is the product of several processes. If the probability of retention depends on a quantity which is also the regression outcome, conventional analyses of the retained sample may be biased. If the retention mechanism depends on variables that are fully observed and correctly modelled, adjustment may sometimes be possible. If it depends on unobserved signal properties, conclusions may remain only partially identified.

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A useful taxonomy is to distinguish absent exposure from missing measurement within valid exposure and from deliberate non-retention of a valid observation. When the receiver has not tuned the channel, the measurement opportunity is absent. When the ADC was operating but a buffer overflow occurred, the opportunity may have existed while the samples were lost. When the detector calculated a subthreshold statistic but policy withheld the I/Q, the system observed enough to make a decision while retaining only part of the information. These situations have different implications for event counts, rate estimation and evidential continuity. A rigorous data dictionary should have separate codes for them rather than a single blank value that an analyst's software interprets as zero.

Let us examine rates. Suppose a laboratory reference ledger identifies thirty verified bursts during five hours of valid observation, whereas the triggered instrument stores eighteen matching clips. An investigator may estimate a reference-event rate of six per valid hour and a detection fraction of eighteen divided by thirty, or 0.60, for that deliberately specified test population. But suppose the instrument has an additional one hour of unlogged blind time. We cannot silently add that hour to the observed denominator and claim a lower rate, nor can we assume that it contained no bursts. Conversely, if the reference monitor established that the one-hour blind period was itself unobserved by both systems, the target rate for the entire six hours is not identified without assumptions about what occurred there. The calculation should make these distinctions visible.

Time-varying background and receiver states complicate matters further. A likelihood model treating alarms as a constant-rate counting process may fail when a nearby industrial machine cycles, when a preselector retunes or

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when a shared interferer generates clusters of alarms. Dead time can also change the distribution of observed intervals between files. If the recorder waits three seconds after each retained event before rearming, the shortest observed file-to-file interval can be three seconds even though physical events occur more frequently. An analysis which fits the interfile intervals without incorporating the holdoff will misdescribe the process. One should record device-state transitions and decide whether a renewal-process, point-process or interval-based model is actually justified by the available observations. For some questions, a simple tabulation is more defensible than elaborate parameter fitting.

Missing-data terminology should not become an excuse for untestable assumptions. If missingness is entirely dictated by a known trigger statistic that has been logged for all valid intervals, certain probabilities may be estimable under a carefully specified model. Yet when the entire untriggered waveform has disappeared, its unrecorded fine structure cannot be recovered solely from the trigger value. If a detector uses an adaptive noise floor whose historical values were not saved, even the retention mechanism may be incompletely documented. Sensitivity analyses should then vary plausible unseen event rates, signal shapes and storage-failure mechanisms, showing which conclusions survive. A sharp point estimate obtained by assuming away the missingness is weaker than an informative range which admits ignorance.

A report should distinguish a statistically reproducible relation among archived clips from an independently validated physical relation among emissions. An observed regression coefficient may be precise within the selected population and still lack a straightforward interpretation across all

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RF events. The analyst should retain the transformations, feature-extraction software versions, calibration values and exclusion decisions needed for independent reproduction. If the objective is a legal or technical conclusion about a particular device, further physical tests must be specified. The mere fact that a retained burst has a high numerical similarity to a known laboratory waveform does not establish common origin in an uncontrolled environment. Nor does a low signal-to-noise ratio establish absence of an emission.

I would recommend a two-stage reporting practice. First provide the design and observation facts: tuning and exposure, reference schedule, detector decisions, retained files, missingness, dead time and uncertainty. Then provide conditional statistical analyses clearly tied to those facts. A table may show the observed true positives, false positives, false negatives and true negatives where independent reference classification supports them. Unknown cells should remain unknown. A supplementary analysis can explore how estimates change when background conditions, the retention model or the classification threshold differ. The reader should be able to see which inferences are driven by measurements and which depend upon assumptions. This separation is particularly important before any forensic testimony, where an unexplained numerical precision may be more misleading than a cautious statement of uncertainty.

Peter Elias, Peer Question: Sir David, the recorder might compress its output by saving only event metadata during most valid intervals and full I/Q for selected alarms. That seems attractive for privacy and storage, but the metadata schema can itself conceal what is missing. A trigger log might retain only its maximum statistic, omitting the detector window length,

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overlap fraction, band-selection policy and the precise conditions under which values were calculated. What minimal information would you regard as necessary to identify the selection process, even though reconstructing the discarded waveforms is impossible? Could a data dictionary make subsequent statistical modelling more reliable by distinguishing unavailable samples from deliberately withheld samples? I also wonder whether a file format which records only successful writes encourages a later analyst to mistake a failure of storage for a failure of the detector. How should the system expose both without gathering communications content beyond its lawful purpose?

Sir David Cox, Response: Mr. Elias, one should not confuse a compact record with an incomplete one. A useful non-content decision ledger can remain quite small while recording the information necessary to interpret a retention event. It should identify valid observing intervals and tuning state; the versioned detector algorithm; its statistic definition, transform length, window function, overlap and filtering; the threshold and any adaptive reference values; the instant and sequence number at which a decision was made; holdoff and rearming state; the requested preservation interval; whether the file writer acknowledged completion; and the reason for any failure. These fields reveal the decision mechanism without requiring decoded payloads or complete continuous I/Q. They are essential if a reviewer must later distinguish a rejected observation from one never measured.

The data dictionary should distinguish at least four statuses: observed and retained, observed but intentionally not retained, not observed because the receiver was untuned or disabled, and observed but lost because of a

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technical failure. A fifth category may be required for a decision whose underlying sample stream has ambiguous validity, such as overload or counter discontinuity. Each status should have a documented source and timestamp semantics. If a software subsystem reports a write error after an alarm was issued, both events must survive as separate records. Otherwise the number of saved files will masquerade as a detector decision count and bias every subsequent performance measure.

Compression of the forensic description must be evaluated against the precise question to be answered. A summary of peak spectral power may be sufficient for a narrowly defined occupancy statistic in some circumstances, but it cannot preserve phase trajectories or reveal every short transient. The uncertainty record should say which features were computed at acquisition, which were reconstructed later and which cannot be tested because the data were not retained. A deterministic cryptographic digest protects the bytes actually saved; it does not authenticate the missing sample stream or correct an absent algorithm version. A properly protected manifest and controlled derivative history keep those propositions separate.

Finally, the scientific model should be assessed through a deliberately structured fault-injection programme. Induce a buffer overflow, storage quota failure, receiver retune, adaptive-threshold reset and clock discontinuity in an authorised laboratory. Verify that the ledger records the correct cause and that the analyst's code does not silently convert any of these into an ordinary non-alarm interval. That experiment would be more valuable than adding detailed but ungoverned private contents to the archive. A defensible collection policy captures the minimum facts necessary to support a stated inquiry and makes the limits of the unrecorded

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remainder explicit. No statistical technique can replace such candour after the acquisition has ended.

Dr. James M. Atkinson, Moderator: Sir David has explained how a selective archive can alter observed associations even when its internal numerical calculations are perfectly repeatable. I now invite Dr. Abraham Wald to examine detection policies acting through time, especially intervals suppressed by holdoff, repeated alarms and decisions taken under constrained evidence retention.

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Abraham Wald, Fifth Principal Contributor: Dr. Atkinson, a sequential decision system must be understood as a process rather than a pile of isolated success stories. At each observation opportunity the receiver possesses a state based on previous samples, previous alarms and the rules under which it is permitted to continue or refrain from recording. A threshold may be fixed, yet the effective chance of a file appearing can depend on how many times the device has recently alarmed, whether a buffer remains available, and whether the trigger statistic accumulates evidence across successive frames. The resulting retained clips are conditioned on a history of decisions. We must therefore resist the temptation to treat each saved file as an independent, identically distributed draw from the environment.

The distinction between a detector alarm and the file writer's rearm state is central. Imagine a trigger which initiates a 100-millisecond capture and refuses further alarms during that capture. If physical bursts occur in rapid succession, the retained record may contain one long file or one file with multiple events, yet the trigger counter might remain at one. Alternatively a system may extend its capture on every alarm, merging multiple bursts into a single episode. The number of files per hour is not the number of emissions per hour, and it is not even necessarily the number of threshold crossings per hour. Any likelihood calculation must identify its event unit. If the unit is a file, the model concerns the file-generation mechanism. If the unit is an independently verified physical burst, the model must include missed and merged events.

We can formulate a carefully delimited test using independent, authorised reference pulses. Consider an observation period with a known sequence of

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event times and a separate ledger of valid receiver state. The recorder's policy is frozen before the sequence begins. It issues alarm decisions, enters holdoff states, and writes files with reported success or failure. A reviewer compares physical events against alarms, alarms against retention requests, and retention requests against completed files. Each comparison yields a different rate and a different failure mode. We should not combine the stages into an undifferentiated statement that 'the recorder captured eighty per cent of events' unless the definition of captured has been agreed and the handling of overlapping events is explicit.

The sequential nature of the decision introduces dependencies into any uncertainty calculation. If a strong event changes automatic gain, the response to a later weak event may differ from its response in isolation. If a running background estimator is contaminated by a burst, it may raise the threshold temporarily and suppress neighbouring events. If the operator changes bands following an alarm, subsequent observations are no longer sampled under the original fixed schedule. There is no objection to an adaptive policy when its purpose is lawful and properly specified, but analysis must condition on its states. A naive binomial confidence interval for independent alarms will generally be unjustified if decisions are clustered by shared noise, overlapping transforms or recorder holdoff.

One may use controlled randomisation to examine these effects without collecting unrestricted communication content. The independent reference schedule can vary interburst spacing, amplitude and duration while the recorder under test remains blind to the schedule. It is important to include events arriving during the declared holdoff period and to decide in advance whether these are classified as expected non-detections under the policy or

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are counted against a broader operational coverage criterion. Both summaries can be useful, but they answer different questions. A receiver which intentionally ignores all but the first event in a cluster may perform exactly as designed and still be unsuitable for estimating how many physical events the cluster contained.

For example, suppose twenty known reference events occur during valid receiver observation, and twelve elicit detector alarms. Of those twelve, ten lead to files which pass byte-integrity checks. The alarm sensitivity for that defined test population is twelve twentieths, or 0.60. The proportion of alarm decisions yielding surviving files is ten twelfths, about 0.8333. The proportion of known events yielding surviving files is ten twentieths, or 0.50, assuming each file is matched uniquely to an event. It would be a serious reporting error to call the ten saved files evidence of a fifty-per-cent field event prevalence. These numbers describe controlled performance measures whose denominators come from an independent reference record, not from the stored alarm files themselves.

We must also account for the cost of unnecessary recording. The policy may impose a legal or institutional limit on the data that may be kept, particularly where I/Q samples could contain protected communications. In that case a design which reduces full sample retention can be entirely appropriate. The experimenter may preserve summary counters, calibrated occupancy statistics, decision states and limited authorised reference segments rather than entire streams. The scientific consequence is that some questions cannot later be answered. That limitation is not evidence of dishonesty; it is the legitimate boundary of the experiment. Dishonesty enters if a

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subsequent report conceals the boundary and asserts that the unretained data proved the absence of an emission.

A practical acceptance record should list the reference-event definition, exposure intervals, event matching tolerance, trigger state, holdoff policy, write success, file hash and treatment of merged or truncated clips. A reviewer should be able to rerun the detector against retained authorised reference data, where available, and explain why the resulting decisions agree or disagree with the original decisions. When content is lawfully unavailable, the reviewer may still test the software on a controlled surrogate sequence. The report must say which validation used the actual survey data, which used laboratory substitutes and which cannot be reproduced because observations were never retained.

Finally, a sequential procedure must distinguish the statement that an alarm occurred from the statement that an external source existed. The latter requires a physical account of the antenna, analogue chain, clock, noise, interference and alternative mechanisms. An alarm is a system action in response to measured statistics; it is not a verdict. The display may provide a useful trail for an authorised engineer, but the security of that trail depends on measured reference conditions and on accurate disclosure of what the recorder failed to see or was prohibited from keeping. I pass the token to my colleagues for a final interrogation of the data-custody and statistical distinctions.

Grace Brewster Murray Hopper, Peer Question: Dr. Wald, my concern lies in the machine-readable account of the selection policy. Engineers sometimes preserve a configuration file containing the threshold and write a series of alarm clips, but fail to preserve the actual compiled program, firmware

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revision, buffer semantics or error logs from the field session. Later they replay the clips with a newer algorithm and declare that the receiver must have alarmed for the same reasons. Would you distinguish reproducibility of a later numerical transformation from reconstruction of the original acquisition decision? What would a minimally sufficient event ledger contain, and how should it handle changes in software during the survey? If privacy rules prevent saving continuous I/Q, how can an independent examiner still audit trigger counts, valid exposure, write failures and intentional non-retention without being supplied with communications content unrelated to the authorised enquiry? The record must also distinguish a decision made in firmware from a derivative decision made later in the host software.

Abraham Wald, Response: Admiral Hopper, a replay with new software is a new experiment unless the original policy and its state can be reconstructed faithfully. A saved waveform may produce the same spectral statistic under two implementations, yet those implementations may differ in the order of filtering, floating-point rounding, window alignment, adaptive-threshold update or file-write timing. The event ledger must identify the actual acquisition chain, including instrument model and relevant hardware state, software and firmware identities, configuration digest, clock provenance, decision thresholds, buffer and holdoff rules, and status codes for both detector and writer. If an upgrade occurs halfway through the survey, it creates a new observation stratum unless equivalence has been demonstrated under an appropriate test.

The ledger should preserve the distinction between an observation opportunity and a storage action. A record can identify a valid receiver

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interval, a detector statistic or privacy-preserving threshold-crossing summary, an alarm decision, the requested retention interval and the outcome of the storage request. It can indicate deliberately suppressed files separately from failures caused by quota exhaustion or transport error. Each event should carry an acquisition-side monotone identifier and a timestamp whose source and uncertainty are documented. A file hash can authenticate the bytes of a saved extract relative to its reference digest, but it cannot authenticate an unrecorded interval or prove that the original algorithm was correctly implemented. Those distinctions allow an audit without a complete continuous I/Q archive.

An independent reviewer should be able to construct three counts: how many valid opportunities were monitored under each state, how many alarms the detector declared, and how many corresponding files survived with intact custody records. A separate reference monitor, operating within its own lawful scope, may then establish the number of genuine test events and background-only opportunities. Only with that information may the analyst compute sensitivity or a per-cell false-alarm fraction for the specified test population. Where such a reference does not exist, the unknown cells remain blank. A reconstructed statement of 'zero missed events' would be no more valid than claiming a storage system never lost data because its directory contains no files labelled lost.

The software package should support independent negative controls. Inject a known signal that should alarm, one which should not, a sequence which exceeds the file writer's throughput, a clock discontinuity and a trigger during holdoff. Confirm that the recorded event states correspond to the known conditions. The independent examiner should also be able to parse

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old manifests without silently applying revised defaults. Provenance is not merely a list of version names; it is a history of which executable rules created each observation and which later transformations were applied. When the reporting question moves from operational behaviour to a legal or physical attribution, the expert must obtain additional evidence rather than enlarge the meaning of a machine-generated alarm.

Dr. James M. Atkinson, Moderator: The five principal contributions now stand before the panel. I invite the principal experts to pass the token among one another for reciprocal examination, ensuring that each challenge is answered by the named colleague and that methodological differences remain visible rather than prematurely reconciled.

Sir Ronald Aylmer Fisher, Cross-Peer Question to Jerzy Neyman: Dr. Neyman, your example of a thousand predefined observation opportunities with an independent event ledger is persuasive, yet I would question the consequences of dividing a continuous RF stream into nominally equal cells. A burst crossing a boundary may be counted in two adjacent opportunities; a long interferer may contaminate many cells; and an overlapped short-time Fourier transform may generate multiple detections from one physical occurrence. How would you define the population before observing the sample so that an apparent confusion matrix does not depend arbitrarily on the chosen time-cell width? What would change if the outcome sought were an event arrival rate rather than a per-cell false-alarm probability? I ask also whether a random sample of background intervals, selected with independently recorded probabilities, can repair some inferential limitations without requiring continuous preservation of potentially protected

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communication content. At what point does aggregation destroy the very denominator it was intended to secure?

Jerzy Neyman, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Sir Ronald, the unit must follow the estimand. If the question concerns whether a defined interval contained a detectable reference emission, a predeclared time cell may be suitable, provided the handling of boundary events is specified. An event crossing the edge should be assigned by a predetermined rule, perhaps according to independently established onset time, rather than counted twice merely because two processing frames overlapped. If the question is a physical burst arrival rate, the experiment instead requires a definition of an event episode, a separation rule and procedures for merging or splitting near-simultaneous occurrences. Neither formulation is universally superior, and one cannot move between them without additional assumptions.

A confusion matrix may be formed for the chosen set of valid cells or events when an independent reference identifies both positive and negative opportunities and when the detector's decisions can be matched to those opportunities. Overlapping FFT frames are computational units, not necessarily independent experimental units. One may process many overlapping frames to make a single event decision, but the count of such frames must not automatically become the denominator for an independent-binomial probability. Clustering, dead time and changing background conditions must be reflected in the experimental design and uncertainty calculation. A sensible protocol reports the decision unit as carefully as the sample rate or threshold.

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Random sampling of background opportunities can indeed improve inference within the limits of its design. If the system records selection probabilities and preserves authorised non-content summaries for a randomly selected subset of non-alarm periods, one may estimate specified background characteristics using suitable weighting or design-based methods. But a random summary of peak energy cannot recover the detailed I/Q phase of unselected periods. Nor does it establish the number of true reference events unless their status is independently determined or inferred under a defensible model. A sampling plan should state which variables were available for every unit and which appeared only for the sampled units. The promise of a representative sample must be connected to a particular variable and population, not offered as a general certificate for every possible later enquiry.

Aggregation destroys a denominator when it collapses distinctions necessary for matching exposures, source states or detector decisions. A daily alarm total without valid tuning time cannot support a per-channel rate; a file count without an alarm-decision count cannot assess retention success; and a positive-clip archive without reference negatives cannot identify specificity. The best record keeps small, privacy-preserving counts at the proper physical and temporal granularity, with missingness codes and receiver-state epochs. Thus the statistical design and the evidence-retention policy should be drafted together. Their common purpose is to make the warranted inference possible while declining to preserve material which the lawful enquiry does not require.

Jerzy Neyman, Cross-Peer Question to David Harold Blackwell: Dr. Blackwell, I would press you on the fairness of evaluating a deliberate decision policy

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against a statistical goal it was not built to satisfy. A recorder might be designed to preserve only exceptional RF excursions because storage and privacy obligations prohibit continuous I/Q retention. An analyst subsequently asks for an estimate of the proportion of weak short bursts that were missed. Plainly that target cannot be reconstructed from the positive archive alone. But can we design a two-tier policy under which the machine retains minimal, appropriately protected performance metadata from non-alarm intervals while reserving full waveform evidence for specially authorised events? What safeguards would prevent the supposedly non-content metadata from becoming an alternative vehicle for intrusive surveillance? And how would you explain to an engineer why a mathematically optimal trigger policy for operational detection may still be suboptimal for unbiased retrospective estimation?

David Harold Blackwell, Cross-Peer Answer to Jerzy Neyman: Dr. Neyman, a policy's value depends on the decision problem it was designed to solve. If the objective is to alert an authorised operator to a limited class of signal anomalies while minimising storage, an alarm-only archive may be entirely rational. It can still be unfit for a later estimate of unseen event prevalence. The distinction is not a criticism of the original design; it is a reminder that the design's action rule determines what evidence survives. An engineer should not infer from operational success that every scientifically interesting characteristic of the environment was measured, preserved or identifiable.

A two-tier arrangement can be appropriate. One tier maintains compact records of receiver state, valid exposure, threshold decisions, algorithm versions, holdoff periods and storage outcomes. The other contains strictly controlled I/Q excerpts for events whose retention is lawful and necessary.

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An independent reference-event monitor or predetermined random sampling programme can supply additional non-content measures for calibration. To ensure that the summary tier does not itself become an intrusive surveillance apparatus, the organisation must define authorised purposes, restrict frequency and temporal granularity to what those purposes require, impose access controls and retention limits, and avoid recording decoded payloads or unnecessary identifiers. Technical minimisation and legal authorisation must both be examined, since even metadata may be sensitive in particular contexts.

One can evaluate both decision utility and inferential utility. Decision utility asks whether a policy triggers when it should, refrains when it should, and operates within costs and lawful boundaries. Inferential utility asks whether the preserved observations identify the population characteristics needed for a stated later question. Those objectives may conflict. A policy may benefit operational performance by holding off repeated alarms, but this holdoff suppresses file counts and complicates estimates of physical event arrivals. A policy may minimise data collection by withholding subthreshold I/Q, while preventing retrospective reconstruction of subthreshold waveform structure. The evaluation should make the tradeoff explicit rather than call one design intrinsically superior.

For this investigation I would specify the permitted claims in advance. An alarm log supports a statement about detector actions under documented exposure; a reference comparison can support a bounded sensitivity estimate; retained clips can support analysis of the preserved waveforms; and independent physical controls are required before a particular source is attributed. Every step adds evidence and also new assumptions. A

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transparent report can praise a privacy-preserving policy while declining to calculate quantities the policy leaves unidentified. That is not a retreat from scientific rigor. It is its application to a decision system operating under actual institutional constraints.

David Harold Blackwell, Cross-Peer Question to Sir David Cox: Sir David, your account of ascertainment raises an awkward causal possibility. Suppose receiver gain changes, the background interference changes, and the probability of a clip being retained depends on both. Among the retained clips, an analyst observes an apparent association between the gain setting and a signal feature, even though the true external signal population may not have changed. Would you explain how conditioning on the file-retention event can generate such an association, and how one might distinguish it from a real change in the observed RF environment? I should also like you to consider what can be learned when only coarse threshold counters survive from the unretained periods, perhaps because privacy constraints rightly prohibit keeping complete I/Q. Where is a sensitivity analysis informative, and where must the answer be that the association is not identifiable without new evidence? Could the record disclose precisely which adjustment variables were observed before retention and which became visible only after a file was selected?

Sir David Cox, Cross-Peer Answer to David Harold Blackwell: Dr. Blackwell, the apparent association may arise through the process by which the records enter the study. Imagine, for simplicity, that both receiver gain and the instantaneous amplitude of an independent noise fluctuation affect whether a file is saved. Conditioning on saved files means selecting cases for which their combined effects were sufficiently large to cross the trigger

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boundary. Within that selected population, a lower gain may require a larger noise fluctuation for a clip to appear, whereas a higher gain may permit smaller fluctuations to be retained. The retained observations can therefore exhibit a relation between gain and noise amplitude which is largely generated by the selection boundary. It would be mistaken to treat that relation as evidence that the external physical source changed its emitted power with the operator's gain setting.

To distinguish selection from physical change, the analyst should examine independent measures of receiver state and externally controlled reference signals. A laboratory may apply the same calibrated stimulus at several gain settings and observe how the recorder's selection region changes. If an independent monitor records the background without the same selection rule, its non-content statistics can help distinguish a genuine change in ambient conditions from a filtering effect. A state-stratified study of valid exposure may allow the analyst to estimate alarm rates conditional on each state. Yet the detailed distribution of unretained waveforms may remain unidentifiable if their properties were neither logged nor sampled under an independent design.

Coarse counters can still be valuable. They may establish how often the detector declared an alarm in each specified interval, whether the receiver was in holdoff, and how many valid opportunities were available. They cannot reveal the full phase or modulation structure of suppressed samples. A sensitivity analysis should vary the assumed distribution of unobserved signal features, plausible instrument nonlinearities and the mapping from physical events to saved files. If the desired conclusion remains stable over a credible range of models, that stability is useful evidence about robustness.

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But such an analysis must not be used to declare that the models have been empirically distinguished when they have not.

In some cases the responsible answer is partial identification: the evidence establishes a bound or a conditional relation, not a unique population parameter. We may report the range of event rates compatible with measured exposure and specified maximum dead time, or say that the clip population contains a repeatable association under the documented threshold. A precise unconditional prevalence requires additional independent observation. The limitation should be stated in the language of the technical witness: the receiver did not retain data sufficient to decide between the alternatives. This is preferable to presenting a regression coefficient with narrow confidence limits while omitting the fact that every observation was selected by the very mechanism under examination.

Sir David Cox, Cross-Peer Question to Abraham Wald: Dr. Wald, let us finish with a recorder whose operating policy is sequential. After a trigger it stores a pretrigger interval, captures additional samples, and then suppresses new triggers for a fixed holdoff period. A technician takes the intervals between file creation times, estimates an arrival rate and testifies that the environment contained few emissions. Yet the file count is influenced by holdoff, missed writes, file grouping and the distinction between arrival and completion time. How should the investigator characterise the resulting observed point process without pretending that the unobserved events have been recovered? What deliberate laboratory trials would reveal whether the holdoff behaves as documented, including events that straddle rearm boundaries? Finally, how would you report two performance measures: detector activity when available, and total operational coverage

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across the entire authorised survey interval? I ask you to keep the clocks of acquisition, trigger decision and file writing separate throughout your reply, since they need not coincide.

Abraham Wald, Cross-Peer Answer to Sir David Cox: Sir David, the first step is to preserve the definition of the recorded event. A file creation timestamp ordinarily describes an action by the storage system, not necessarily the time at which an RF burst reached the antenna. We should therefore use acquisition-side event counters and a documented clock map where available, and keep file-writing times as separate provenance data. We must also distinguish a new trigger from an extension of an existing capture. If the software merges adjacent alarms, the number of files is a coarsened representation of decisions. A statistical model of file arrivals may describe the writer's output process, but without further information it cannot be equated to a model of physical emission arrivals.

The known holdoff period should be represented as a state interval during which new decisions were disabled or constrained. A laboratory can inject reference bursts at measured delays before, during and after the nominal rearm boundary, including clustered bursts and events whose duration overlaps the boundary. Independent monitoring establishes the physical event times; the device ledger records decisions, suppressions and storage actions. By comparing these records one can test whether the implementation follows the documented policy and whether unexpected buffer or clock behaviour creates additional unavailability. Fault injection should include quota exhaustion and transport congestion so that an alarm with a failed write remains distinguishable from a deliberately suppressed alarm.

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Two performance measures answer the two questions you pose. Conditional detector performance concerns the probability of an alarm for a predefined class of reference events occurring while the instrument is declared available to detect them. Overall operational coverage concerns the fraction of the authorised survey interval during which the receiver was observing the relevant band with valid acquisition and permitted decision state. A machine can perform well conditionally while covering only a small fraction of the survey, especially if the scanner dwells briefly or the holdoff consumes substantial time. Combining the measures may be useful under an explicit event-time model, but the combination is not justified by file counts alone.

The report should give the valid exposure, holdoff exposure, untuned exposure, invalid or unknown intervals, number of reference events, number of alarms, and number of successfully retained files, with uncertainties and definitions beside each. Events arriving while the detector was unavailable are not retrospectively made absent because no file exists. Nor should they be counted as detector failures under a conditional performance measure whose eligibility rule expressly excludes those intervals. They remain relevant to the broader coverage assessment. If the experimental record cannot identify how many such events occurred, it must say unknown. A cautious chain of custody documents these distinctions and preserves the original decisions. It does not permit a reconstructed timeline to masquerade as an original RF observation.

Dr. James M. Atkinson, Moderator: I thank the panel for its precise and respectful examination. The common finding is that an alarm-only archive can establish what was retained under a documented policy, but cannot by

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itself establish the unconditional event population, the missed-event count, or source identity. We shall preserve the questions about independent reference observations, valid exposure, selection probabilities, storage failures and lawful minimisation for the formal verification register. The discussion is a fictional reconstruction for educational analysis, not recorded testimony from its historical contributors.

QUESTION 097. TEN HYPOTHETICAL WORKED EXAMPLES. Each example specifies its units, definitions and assumptions. These examples are not real RF survey measurements or source identification evidence.

EXAMPLE 1. Define N = 1000 valid one-second laboratory opportunities, E = 40 independently identified reference-event cells, D = 30 alarmed event cells and F = 20 alarmed background-only cells. Sensitivity is D/E = 30/40 = 0.75 = 75%. This is conditional upon a fixed matching rule, valid exposure and a correctly classified independent reference.

EXAMPLE 2. From Example 1, the number of true negative cells is TN = N − E − F = 1000 − 40 − 20 = 940. The background-only denominator is N − E = 960. Specificity is TN/(N−E) = 940/960 = 0.9791667 = 97.9167%, and the per-cell false-positive fraction is F/(N−E) = 20/960 = 0.0208333 = 2.08333%. The opportunities are defined cells, not necessarily independent trials.

EXAMPLE 3. In the same hypothetical reference population, the number of saved alarms is D+F = 50 if every alarm generates one successful file and no merging occurs. Positive predictive fraction is D/(D+F) = 30/50 = 0.60 = 60%. This quantity depends on reference-event prevalence and cannot be inferred from 50 unlabelled saved clips alone.

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EXAMPLE 4. For a planned survey with T_wall = 60 minutes of wall-clock time but T_valid = 10 minutes of verified in-band observing time, observing coverage C = T_valid/T_wall = 10/60 = 1/6 ≈ 16.6667%. The other 50 minutes are unavailable observation opportunities for that band, not demonstrated RF silence.

EXAMPLE 5. If A = 18 alarm decisions arise during T_valid = 6 hours of documented valid exposure, alarm-decision frequency is lambda_A = A/T_valid = 18/6 = 3 per valid observing hour. It is not an external-event occurrence rate until an independent physical reference has classified the alarms.

EXAMPLE 6. A hypothetical reference experiment produces R = 30 known bursts over T_valid = 5 hours. The reference-event frequency is lambda_R = R/T_valid = 30/5 = 6 bursts per valid hour. If 18 bursts yield matched surviving clips, the retention fraction for this specified event population is 18/30 = 0.60; this differs from detector sensitivity if alarms occurred but files were lost.

EXAMPLE 7. If independent reference scheduling identifies E = 20 eligible known bursts and the detector alarms on A_E = 12, its conditional alarm sensitivity is A_E/E = 12/20 = 0.60. If W = 10 of those alarm decisions yield intact files, writer success conditional on alarm is W/A_E = 10/12 ≈ 83.3333%. The event-to-retained-file fraction is W/E = 10/20 = 0.50; each fraction has a separate denominator.

EXAMPLE 8. At sampling rate F_s = 2,000,000 complex samples per second, pretrigger buffer length N_pre = 4096 valid consecutive complex samples corresponds to T_pre = N_pre/F_s = 4096/2,000,000 s = 0.002048 s = 2.048

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ms. This is nominal buffering duration, not an assurance that a burst beginning earlier was captured.

EXAMPLE 9. For intended capture window duration T_window = 0.10 second and mandated holdoff duration T_hold = 0.40 second after capture, one complete cycle can occupy T_cycle = T_window + T_hold = 0.50 second if configured as non-overlapping periods. Under that explicitly simplified assumption, a busy recorder cannot begin more than 1/T_cycle = 2 such new cycles per second. The bound is not a physical RF event-rate bound.

EXAMPLE 10. If background-only random sampling selects k = 50 of N = 500 predefined valid negative intervals, with equal independent inclusion probability pi = k/N = 0.10, a measured total of y = 7 alarms within the selected intervals yields design-weighted estimate y/pi = 7/0.1 = 70 alarms in the 500-interval frame under the stated sampling design. It remains an estimate with sampling uncertainty, not a recovered record of 70 observed alarm files.

QUESTION 097. SCHOLARLY AND TECHNICAL REFERENCE TRAIL. Jerzy Neyman, “On the Two Different Aspects of the Representative Method: The Method of Stratified Sampling and the Method of Purposive Selection,” Journal of the Royal Statistical Society 97, no. 4 (1934), 558–606, DOI 10.1111/j.2397-2335.1934.tb04184.x; NIST/SEMATECH Engineering Statistics Handbook, https://www.itl.nist.gov/div898/handbook/; NIST SP 800-86, Guide to Integrating Forensic Techniques into Incident Response (August 2006), DOI 10.6028/NIST.SP.800-86. These references give historical and technical background; they do not document the fictional dialogue. Source-to-claim checking of each technical assertion and review of any jurisdiction-specific retention rule remain Stage-B tasks.

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EDITORIAL QUALIFICATION. This is an explicitly fictional, contemporary scholarly reconstruction. No historical participant is represented as having engaged in an actual RF surveillance conference or speaking the generated words. The worked cases are hypothetical and are not measurements. The roundtable makes no attribution of an unknown emitter and no claim to authority to retain protected communication content.

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QUESTION 098

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How should calibration uncertainty and alternative explanations be communicated in technical testimony?

Dr. James M. Atkinson, Moderator: Sir Karl, I invite you to distinguish a receiver's numerical indication from the proposition a technical witness ultimately asks a tribunal to accept. Suppose an authorised engineer reports an unusual narrowband component in a spectrum display, with a calibrated reference source available but uncertain antenna factor, cable loss, clock integrity and front-end linearity. A neat screenshot may be accurate as an image yet insufficient to identify a real external transmitter, still less a particular unlawful apparatus. How should the scientist frame a claim so that calibration uncertainty, plausible rival explanations and the possibility of disconfirmation remain visible to the judge, jury or technical reviewer? Please also make clear where scientific reasoning ends and jurisdiction-specific legal evaluation begins. Our discussion is explicitly fictional and contemporary, not an historical quotation.

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Sir Karl Raimund Popper, Principal Contributor: Dr. Atkinson, I would begin with the grammar of the claim. A spectrum analyser may display a spectral feature at a coordinate labelled with a frequency and an amplitude. The instrument has not thereby pronounced the existence of a particular transmitter. The displayed feature is an observation mediated by apparatus, processing conventions and a model of what the apparatus measures. A responsible witness must state the proposition at the level actually tested. The narrow statement may be that a repeatable indication arose within a specified spectral interval while the receiver, antenna, cable assembly and software occupied documented states. A stronger statement, that the indication represents an external electromagnetic field, requires tests capable of excluding instrumental generation. A still stronger proposition about a named source requires yet more evidence. Each enlargement of the claim increases the burden of proposed disconfirmation.

It may be tempting to speak of falsifiability as a theatrical challenge to any expert. That would be mistaken. The practical question is what observation, if obtained under controlled conditions, would force the investigator to withdraw or materially revise the proposed interpretation. If the engineer suspects an external emission, an input termination, a change of preselector, a change of attenuation or an independent receiving chain may offer informative discriminating tests. If the feature persists under a proper termination in the same measurement path, the external-emission explanation becomes less credible; if it follows the external antenna but disappears under independent reference conditions, the inference remains incomplete. A single result should not be elevated into a universal theorem, because the behaviour of an instrument depends on its design and state.

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The tests should be selected according to plausible causal alternatives, not performed as ritual gestures in the hope of producing an impressive report.

The term uncertainty demands particular care. A numerical interval derived from a calibration budget quantifies aspects of a measurement model under specified assumptions. It does not automatically encompass every possible failure of the model, including an overlooked mixer spur, ADC overload, poor impedance match, software indexing fault or an unrecognised propagation path. The witness should name the measurand before offering its uncertainty. Is the relevant quantity power at a receiver input, incident field strength at an antenna position, an estimated carrier frequency, an event onset time or a derived classifier score? Each differs in units, reference plane and contributing physical effects. A standard uncertainty of a receiver-input power reading cannot be pasted without qualification onto a conclusion about field strength at an unknown emitter, because antennas, propagation and source conditions introduce additional and possibly unmeasured dependencies.

There is a difference between an uncertainty estimate and a guarantee. Under the widely used metrological framework, contributors may be evaluated from repeated observations or from calibration certificates, specifications and other defensible information. A combined standard uncertainty reflects those evaluated components and their relationships within the chosen model. An expanded uncertainty uses a stated coverage factor and needs careful interpretation of the intended coverage. If components are correlated, they should not be treated as independent merely to simplify an equation. If the apparatus changed configuration during the collection, measurements from the different states cannot be

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combined casually. An instrument can give numerous consistent digits while remaining systematically wrong. Reproducibility of the numerical calculation is necessary for an audit, but it is not proof that every relevant physical cause has been identified.

Consider a hypothetical frequency determination. An engineer reports a centre-frequency estimate for a controlled laboratory signal, accompanied by a reference-clock specification, sampling configuration, record duration, frequency-estimation method and uncertainty terms. That is a useful measurement account. But the same reported frequency could be influenced by an uncorrected receiver oscillator offset, a misinterpreted sample rate or an aliasing image. The witness should identify which controls distinguish these explanations. A comparison against a separate calibrated frequency reference may test one component; a change of sample rate and preselection may test another. If the suspected emission can be generated inside the front end by mixing of two lawful strong signals, a controlled variation of attenuation should reveal behaviour inconsistent with a simple linear external source. No single control guarantees the absence of every artefact, but a set of discriminating experiments can justify a graded conclusion.

The form of the technical report matters because language can hide a change in logical status. 'An energy component was observed' is not equivalent to 'a transmitter was located'. 'A waveform is consistent with a class of signals' is not equivalent to 'a particular device emitted it'. 'A clock comparison placed two events within a bounded time interval' is not equivalent to 'the events were generated simultaneously'. Precise evidence may support some statements strongly and leave the others unresolved.

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The witness should resist verbs that smuggle an assumption into the conclusion. It may be useful to provide a matrix whose rows contain the measured fact, the test method, the uncertainty and the alternative hypotheses, while a separate column identifies the source-attribution claims that have not been established.

I would ask an adversarial reviewer to prepare alternative reports from the same underlying test record. The first would use one point estimate and a striking display, omitting receiver state and competing mechanisms. The second would disclose the acquisition record, calibrated reference planes, uncertainty budget, independent controls, failure conditions and the precise boundary of the conclusion. The reviewer would then ask which statements could have been contradicted by available evidence, which assumptions remain untested, and whether the report invites readers to infer an individual source without the necessary physical chain of reasoning. The objective is not to make the report timid. It is to make its strongest assertions genuinely testable.

Chain of custody contributes to this enterprise, but it occupies its own logical place. A secure digest may establish, under properly protected reference conditions, that the submitted I/Q file matches a file preserved earlier. A manifest may document sample format, device state and the analyst's software transformations. Those are important propositions about records and their interpretation. They do not prove that the original antenna measured what the author thought it measured, that the acquisition was lawful, or that a particular external device was responsible. In the same way, a well-founded calibration interval does not determine whether a court should admit an expert opinion under the rules of its own jurisdiction. The

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scientific witness should describe his method and its limits; legal counsel and the tribunal perform the applicable legal examination.

An uncertainty statement should neither be hidden as a footnote nor converted into an incantation. If a measurement is represented as a value with an expanded uncertainty, the coverage factor and assumptions should be stated. If the issue is not a numerical uncertainty but a categorical alternative, such as an internal receiver spur versus an external emission, that alternative should be handled through discriminating evidence and explicit residual uncertainty, not forced into an unsupported percentage. It is better to say that two physically different explanations remain compatible with the available observations than to assign ninety-nine per cent certainty to one on intuition alone. Where a meaningful model comparison has been performed, its assumptions and conditional character should be reported plainly.

I would conclude by separating the quality of evidence from the social authority of its presentation. A polished graph, a familiar engineering degree or a confident voice can make an observation appear final. Yet the evidential question remains whether the investigator identified the measurand, tested relevant alternative explanations, accounted for sources of uncertainty and made the underlying records available for authorised scrutiny. The strongest expert can state a limitation without surrendering the value of the work. Indeed, careful limits protect the institution from treating an instrument's artefact as an accusation against a person. I pass the token to colleagues who can examine probability, confidence procedures, calibration mathematics and the logic of inference in greater technical detail.

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Solomon Kullback, Peer Question: Sir Karl, I accept the distinction between an instrument indication and a cause, yet a laboratory may face an apparently persuasive collection of observations: the feature recurs at the same displayed frequency, two operators recover the same trace, and the instrument's most recent certificate records a small frequency error. The prosecution or a commissioning client may ask whether that recurrence makes the suspected external transmitter virtually certain. I should like you to explain why reproducibility of a digital display is not equivalent to an independent physical replication, and how an uncertainty budget should be related to the hypotheses which remain open. Would a second receiver sharing the same antenna, reference oscillator, and power supply add independent evidence? If it would not, what should the report say about the common dependencies? Finally, suppose one of the proposed alternative explanations is vague and cannot presently be tested. Does the mere possibility of an unidentified mechanism require complete silence, or may the witness deliver a carefully limited finding without disguising what remains unresolved?

Sir Karl Raimund Popper, Response: Dr. Kullback, repeated agreement is evidentially valuable only when we know which parts of the apparatus and reasoning are being repeated. Two recordings processed by the same software and calibration table may reproduce the same mistake; two operators reading the same stored spectrum do not supply two independent physical observations. A genuinely independent experiment would vary the mechanisms plausibly responsible for error. For example, an appropriately configured reference source, another receiver architecture, a distinct preselection path and a terminated-input control can discriminate

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among external radiation, local-oscillator products, overload artefacts and computational mislabelling. The experiment should be designed with the alternative explanations in mind, and the expected results under each should be described before the new observation is examined. A repeated line at the same screen coordinate may establish excellent display consistency, while saying almost nothing about external causation.

A small calibration uncertainty for the frequency scale addresses a particular measurement quantity, often under conditions specified in the certificate. It does not become a small probability that every possible causal explanation is wrong. The laboratory ought to map the chain of claims. First, the instrument indicated a feature. Secondly, the feature was observed under certain independently checked input conditions. Thirdly, the indication is compatible with an external RF signal at a bounded frequency and level. Fourthly, perhaps after additional spatial and temporal controls, a particular class of source may be supported. A statement identifying an individual emitter stands at a further remove. Each proposition requires a stated basis and is vulnerable to a different disconfirming experiment. An uncertainty budget quantifies uncertainty in a defined measurand, not the truth of each proposition in the chain.

Your example of two receivers sharing the same antenna and clock reveals the danger of a common failure. An antenna-mounted active device could produce a spurious product seen by both receivers; a defective splitter or common reference might create correlated frequency errors; a shared acquisition computer could associate both channels with the same incorrect time origin. The report should identify those shared dependencies and describe the two records as partially corroborating, not fully independent. A

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more decisive control might separate antennas and gain paths, or introduce a reference whose physical origin is known. This is not a demand that every investigation own two perfect laboratories. It is a demand to refrain from calling evidence independent where dependence is obvious.

We must also distinguish an imaginable explanation from a physically articulated rival. The mere abstract possibility that an unknown mechanism could exist does not defeat all empirical judgement. A witness may say, with good reason, that a spectral feature was consistently registered and survived specified controls, while expressly declining to identify its source. A technically plausible rival which survives a discriminating test should remain in the report. An unsupported suggestion can be described as unsubstantiated without pretending it has been disproved by the instrument's calibration certificate. Appropriate confidence concerns the scope of a conclusion, not a theatrical assertion of universal certainty. The important discipline is to design experiments which might change the conclusion and then state candidly what happened when they were performed.

Dr. James M. Atkinson, Moderator: I thank Sir Karl and Dr. Kullback. With that division between measurement and causal explanation established, I respectfully pass the token to Sir Harold Jeffreys to examine how competing statistical models should be reported to a tribunal.

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Sir Harold Jeffreys, Second Principal Contributor: Dr. Atkinson, an evidential problem becomes especially treacherous when numerical precision is mistaken for explanatory probability. Suppose an authorised engineer estimates the power present at a receiver input as minus eighty decibels relative to one milliwatt and obtains a combined standard uncertainty of one decibel for the calibrated measurement chain. Those quantities may be perfectly meaningful, provided the measurand, reference plane, instrument state and uncertainty model are defined. The listener must not infer that there is a ninety-nine per cent probability that a named transmitter produced the signal. The first conclusion concerns the value of a measured quantity conditional on the appropriateness of the model; the second concerns alternative causes and requires evidence about those alternatives and their relative plausibility. The two inferential questions may inform one another, but one does not answer the other.

A probabilistic comparison begins by making hypotheses explicit. One might distinguish an external emission, an internal mixing product and a signal produced through conductive coupling into the instrument. Under each hypothesis, a discriminating experiment can produce different data. It matters whether the instrument input is terminated, whether an independently calibrated front end is substituted, whether the feature follows changes in antenna orientation and whether the observed level responds to input attenuation as an external signal ordinarily would. We may express probabilities of those observations conditional on each hypothesis, if defensible statistical models can be supplied. It would be folly to announce posterior probabilities merely because we have invented the

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names of the hypotheses. We must determine what model calibration, prior information and independent test data justify the figures.

The analyst must resist the inversion of conditional probability. A low false-positive probability under a specified background model does not mean that a detected feature has the same low probability of being false. Its evidential import depends on the prevalence and types of competing events, the chosen detection rule, missing observations and the degree to which the actual environment follows the model. A quiet controlled laboratory with a stable noise distribution may produce attractive performance figures which prove misleading in an industrial building dominated by switching supplies, impulsive noise and intermodulation. One may not transport the laboratory denominator into a different environment without describing the shift. Nor should multiple comparisons disappear from view merely because the final display shows only one surviving peak.

There are also dependencies within what appears to be a collection of observations. The same antenna, preamplifier, receiver reference and filtering code can make two records highly correlated. Four screenshots generated from one original IQ file are one acquisition with four derivatives; they are not four independent surveys. An expert who multiplies likelihoods on an unjustified assumption of conditional independence exaggerates evidence. A responsible comparison would document which data were independent and would test the joint model when possible. If the dependencies cannot be estimated, the witness should describe them qualitatively rather than supply spurious decimal places.

When presenting a Bayes factor or a likelihood ratio, the denominator matters at least as much as the numerator. A result may strongly favour a

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model of external radiation over a model of thermal noise and yet fail to distinguish an authorised industrial emitter from an unauthorised transmitter. The models are not synonymous with social accusations. If a report says that the data favour one specified physical process over another by some factor, it must identify the processes, the conditioned observations, the treatment of unknown parameters, the reliability of the models and the sensitivity of the result to their assumptions. Alternative explanations that were never modelled are not silently eliminated. The finding should be phrased as evidence relative to the stated hypotheses, not a universal measure of guilt.

A metrological uncertainty statement occupies a different place in this account. Type A evaluation uses statistical information from observations, while Type B evaluation draws upon other relevant information, including calibration certificates or suitable specifications. Neither label is a synonym for random versus systematic physical effects. The combined uncertainty of a derived result requires the measurement function and, when relevant, covariance among uncertain inputs. A probability assigned to an event's source cannot be manufactured by multiplying the combined standard uncertainty by a coverage factor. The factor describes an interval about a defined measurand under assumptions about its distribution; it is not an all-purpose credibility index.

The testimony should permit ordinary readers to understand the hierarchy. A table might state the frequency and receiver-input power estimates with their units, uncertainty conventions and reference conditions; a separate section might list tested causal explanations, observed outcomes and the alternatives remaining. The expert should declare when data were selected

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after seeing a plot, when a proposed discriminating experiment was not performed, and when instrument error might be common across purportedly separate observations. Mathematical formality does not require opaque language. Indeed, a well-conceived measurement report may be less rhetorically confident and more scientifically useful than an elaborate claim of near certainty. I return the token for testing against the most difficult statistical objections.

John Wilder Tukey, Peer Question: Sir Harold, your distinction between a calibrated measurement and a probability of source identity is vital, but I should like to press the practical consequences of exploratory data analysis. Suppose an expert surveys a vast collection of waterfall cells, notices one unusually narrow feature, and then chooses its frequency, time interval, smoothing method and background sample precisely because those choices make the feature prominent. The expert subsequently presents a small probability under a background model which was fitted on that same selected region. What part of the resulting number is evidential, and what part has been bought by selecting the most striking data? Please describe a defensible reporting method that makes the exploration visible, specifies which aspects of the analysis were fixed in advance, and conducts an independent test when the source observations permit. Would an honest account of unsuccessful searches and alternate processing settings matter, even if those records are less visually pleasing than the final chart?

Sir Harold Jeffreys, Response: Dr. Tukey, the scientist must not erase the route by which the conspicuous pattern was found. A feature selected because it is extreme under one of many candidate displays cannot ordinarily be evaluated with an error probability for a single prespecified

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comparison. The parameter search changes the reference distribution, and adaptive tuning may change it further. If the instrument scanned a million correlated cells, the analyst must define the effective search procedure, its dependence structure and the probability model for the maximum or other selected statistic. A decorative annotation which gives a single-cell tail area as though the selected feature had been nominated before acquisition is incomplete. We should first disclose the search, then distinguish exploratory description from independent confirmation.

A useful plan would preserve the original IQ data where lawful and necessary, or at least retain sufficient lawful numerical evidence and metadata for independent analysis. The investigator should record the range of frequencies, observation periods, FFT windows, thresholds, smoothing rules and candidate filters examined, together with failed and inconclusive tests when they bear upon selection. This log is not intended to inundate the tribunal with every mouse movement. It protects against treating the last successful configuration as the only configuration attempted. A follow-up capture under conditions stated before the new observation can test a specific proposition. That new observation must genuinely be independent in the relevant dimensions; saving a second image from the first file does not satisfy the requirement.

If independent acquisition is impossible, the witness should restrict the claim. For example, the report may state that an exploratory search found an indication warranting further investigation, that its frequency and duration are measured under named settings, and that a claimed nominal false-alarm rate does not account for the post-selection procedure. Nothing compels the witness to assign a likelihood ratio when the sampling and

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selection model is unknown. A properly qualified uncertainty interval for frequency may remain valid even though the inferential interpretation of the detector score is exploratory. The two results should not be merged. It is possible to be very certain about the location of a feature in stored data and uncertain about why the feature exists.

You ask about failed searches, and I agree that their evidential meaning depends on coverage. A negative result in a region which was actually observed with adequate sensitivity may constrain an intermittency model. A negative result in a band the receiver never watched does nothing of the sort. Rejected processing candidates may reveal how dependent the pattern is on an arbitrary window or threshold. The expert should communicate those findings concisely and retain the detailed audit trail. The purpose of transparency is not to reward caution with an absolute prohibition upon conclusions. It is to permit a critic to reproduce the reasoning, identify selection effects and assess what an independent test would have to show. Clear limits make the useful observation stronger, not weaker.

David Harold Blackwell, Peer Question: Sir Harold, consider two laboratories evaluating the same evidence after being informed that a suspect device is expected to transmit near a particular frequency. One laboratory receives the target frequency before analysis; the other is given coded recordings with both true and false reference sources, and the analyst remains unaware of the suspected attribution. Both report a peak, but only the second laboratory declares its identification rule and challenge set in advance. How would you compare their conclusions without treating blinding as an automatic proof of correctness? I am especially concerned that experts may select a plausible hypothesis after viewing the measured

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outcome and then report a ratio of likelihoods as though those two hypotheses were the only ones originally considered. What documentation would allow a later court or scientific reviewer to understand the distinction between model fit, source attribution and the underlying validity of the blinded reference data?

Sir Harold Jeffreys, Response: Dr. Blackwell, a blind analysis limits a particular path by which expectation can influence selection and interpretation, but it cannot cure a defective instrument, an unsuitable test population or an incorrect likelihood model. The two laboratories should therefore be compared along several dimensions. We should ask whether their measurement chains were calibrated for the task, whether their feature extraction methods were documented, whether the alternative hypotheses were defined before the decisive observations, and whether their conclusions were tested on data not used to construct the model. An analyst told the expected frequency may conduct a legitimate targeted examination if that fact and its effects are disclosed. The trouble begins when the resulting decision is presented as if the frequency had emerged independently from the evidence.

The blinded laboratory has a useful design advantage if it includes negative controls and physically plausible alternative sources. Yet its validation set might omit the very industrial interference encountered in the case at hand. A high identification score on that set would then have conditional relevance only. The report should describe the labelled challenge corpus, acquisition conditions, class prevalence, operating threshold and performance uncertainty. It should distinguish a waveform class assignment from a unique transmitter identification, and should not treat the absence of a

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known interfering source in the test collection as evidence that no such source could exist. Blinding protects a scientific procedure against one risk; it does not expand the hypothesis universe by magic.

A likelihood comparison requires even more disciplined language. If the numerator represents a specified external-emission model and the denominator represents a specified receiver-spur model, a strong ratio says that the selected observations are more compatible with one of those models than the other under their stated parameters. It does not say that the hypothesis in the numerator is probably true without additional prior or decision assumptions. It also does not distinguish among multiple external sources unless models of those alternatives have been included. A tribunal should not be offered an impressive number whose denominator silently excludes plausible causes. When several hypotheses were explored, the selection process and any subsequent model modification must be evident.

I would recommend a two-level report. The first level gives the measurement result, settings, calibration information, protected data identifiers and uncertainties in language that another engineer can check. The second gives the inferential pathway: the original questions, alternative models, blind or informed conditions, discriminating tests, limitations and explicitly unresolved possibilities. If the physical evidence supports only the statement that an external-like RF feature survived a control, that is the finding. A named device or human actor is a more specific inference requiring additional properly acquired evidence. The difference is not weakness; it is the essence of a scientific conclusion whose boundaries are visible.

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Dr. James M. Atkinson, Moderator: Sir Harold has distinguished conditional probabilities from categorical accusations. I pass the token to Sir David Cox, whose contribution will examine measurement models, covariance and the difficulty of explaining them without transforming a technical report into a mathematical spectacle.

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Sir David Cox, Third Principal Contributor: Dr. Atkinson, uncertainty should be approached as a property of a specified measurement procedure and its evidential context, not as a number appended to an otherwise undefined conclusion. The first question is the measurand. For a measurement at a coaxial receiver input, the quantity may be the average received power in a defined bandwidth, during a defined interval, under an identified impedance reference and operating state. A field-strength estimate at an antenna position is a different output, since the antenna factor, polarisation, coupling, mismatch and environmental propagation enter the measurement function. A source-emission estimate at an unknown transmitter is different again. If a witness supplies an uncertainty interval without defining what the interval is intended to describe, an apparently precise claim may be physically empty.

A conventional model writes an output quantity y as a function of input quantities x1 through xn. The combined standard uncertainty depends on how the result changes when those inputs change and on the variability and covariance of the inputs. When the relationship is sufficiently smooth and a first-order approximation is appropriate, the variance of the output can be represented by a sum of sensitivity-weighted variances together with covariance terms. If two corrections derive from the same calibration reference, they may be positively correlated. Adding their standard uncertainties in quadrature as if independent can understate or overstate the uncertainty. A legitimate analyst must either evaluate the dependence, provide a justified bound or explain why the simplification is defensible for the intended decision.

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Consider an illustrative power-chain expression in logarithmic units: estimated receiver-input power equals an instrument indication plus an applicable attenuation correction minus an applicable gain correction. If the respective standard uncertainties are 0.6 dB, 0.8 dB and 0.5 dB, and they are independent on the adopted scale, the combined standard uncertainty is the square root of 0.36 plus 0.64 plus 0.25, approximately 1.118 dB. That arithmetic describes the uncertainty of the specified additive dB model. It is not lawful to sum a power expressed in milliwatts with an antenna factor expressed in inverse metres as though the numbers had interchangeable dimensions, nor to assume without examination that every physical transformation is additive in the same scale. For nonlinear transformations the measurement function and its derivative, or a suitable numerical propagation, must be used.

Distinctions between Type A and Type B evaluations are equally liable to be misunderstood. Type A concerns evaluation by statistical analysis of observations, while Type B concerns evaluation from other information, which may include calibration certificates, experience and technical data with appropriate justification. A Type B contribution can model a physical random variation; a Type A estimate may include effects of systematic conditions reflected in the measurements. The classification describes the method by which uncertainty was evaluated, not the metaphysical identity of the underlying error. An interval drawn from a modest repeated-sample set must also acknowledge the uncertainty of the estimated spread and, where appropriate, the effective degrees of freedom. A coverage factor has no universal authority outside the assumptions used to select it.

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The appearance of receiver-generated artefacts complicates the statistical model beyond a simple budget. If a narrowband feature may be created by front-end intermodulation or by inadequate reference rejection, a tight power uncertainty calculated under the assumption of a legitimate external signal does not incorporate the uncertainty that the model's premise is false. One may need a diagnostic decision tree in addition to a numerical uncertainty table. The witness should identify experiments that discriminate the hypotheses: controlled attenuation, alternative preselection, independent antenna and receiver chains, and checks at the relevant calibration reference plane. A model capable of quantifying one sort of error cannot automatically explain another sort which it has not represented.

In a courtroom or formal technical hearing, clarity about the estimand and about evidence selection is as important as the numerical work. If the analyst chose the measurement interval after observing an anomalous display, the resulting conditional inference may differ from one based on a prespecified interval. The expert must say when the selection occurred. It may still be legitimate to report the measured frequency of the selected feature with a well-founded conditional uncertainty statement. It is a separate question whether its occurrence rate or evidential significance can be inferred from that selected sample. Collapsing these questions into a single percentage of confidence invites confusion.

Suppose two receivers appear to agree within their stated uncertainties. An agreement test should recognise common calibration references and shared channel errors, and should not infer that the signals originate from the same external transmitter merely because their values overlap. Equally, a disagreement beyond nominal individual error bars may be evidence of an

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unmodelled systematic effect, a changing physical environment or different definitions of the measurand. The investigator ought to examine the instruments, rather than declare one witness incredible because two plotted intervals do not overlap. Measurements are not personal reputations; they are outputs of specified procedures which may be challenged scientifically.

The final report should present the numerical and categorical parts side by side without confusing them. It can give a measurement equation, a table of input corrections and uncertainties, covariance assumptions, expanded uncertainty if justified, and a concise plain-language statement of what the interval means. It should separately enumerate alternative explanations, tests performed, tests not performed and the conclusions actually warranted. Legal admissibility is then assessed according to the court's own rules, not determined by the engineer's choice of a metrological coverage factor. The result may be modest, but it will be technically testable and educationally durable. I pass the token to colleagues prepared to interrogate the mathematics and its practical communication.

Peter Elias, Peer Question: Sir David, when an engineer says that several uncertainty contributors have been combined, I worry that the audience hears a claim of complete accounting rather than a statement about a particular model. Suppose the receiver display has a calibration certificate, the preamplifier has a noise and gain specification, and the antenna factor is measured under one environment. A software implementation then changes the spectral window and the equivalent noise bandwidth without updating the reported amplitude correction. Which part of the numerical budget would alert a reviewer to that model failure? Please explain the difference between a parameter having an estimated uncertainty and an

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entirely missing term in the model. I should also like you to distinguish a reproducible numerical implementation from a valid physical measurement and to explain how the report can carry an explicit validity qualification without creating the impression that every omitted effect is encompassed by a generous coverage factor.

Sir David Cox, Response: Mr. Elias, the phrase combined uncertainty must always be read with the qualification under the stated measurement model. If the model omits an essential correction for the digital window and its effective noise bandwidth, the uncertainty calculation may be arithmetically immaculate and physically incomplete. The first step is to check that the value being estimated has a clear definition: power spectral density, integrated channel power, peak-bin amplitude and waveform amplitude are not interchangeable merely because the interface renders them in similar colours. The processing window, sample rate, FFT normalisation, detector type and averaging convention can change the mapping from raw samples to the displayed number. A measurement model that lacks these features should be repaired before its uncertainty is advertised.

An estimated input uncertainty addresses variability or incomplete knowledge of a parameter which has been recognised. An omitted effect is a different defect. One cannot recover it by multiplying an incomplete combined uncertainty by a larger arbitrary factor. The appropriate treatment may be a new correction term, a validation experiment, a numerical sensitivity study or a finding that the procedure is not valid for the desired measurand. The laboratory should compare the current analysis code against a certified reference waveform in several representative conditions. If a window correction changes under software revision, the

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procedure must either update its validated coefficients or be held outside the scope of qualified findings until retested. A reproducible mistake remains a mistake.

The report ought therefore to contain both an uncertainty budget and a validity ledger. The budget identifies the inputs, units, assumed dependencies, sensitivity coefficients and methods of evaluating each recognised component. The ledger records the measurement configuration, software revision, calibration boundary, operating ranges, reference measurements and any environmental or instrumental condition outside the validated domain. If the instrument was overloaded, or a sampling discontinuity makes the relevant frequency estimate untestable, an interval generated by the normal model must not be reported as if the excluded condition had been accommodated. The validity ledger can be short in the main testimony, with detailed records available to authorised review.

You ask how to communicate this without persuading the reader that the entire universe has been budgeted. I would use a formulation such as: within the verified receiver configuration and stated measurement function, the estimated input power is a specified value with a specified combined standard uncertainty; the interval does not address unresolved emitter attribution or the possibility of an unidentified spurious receiver product. That statement is not a blanket disclaimer inserted to protect an expert from criticism. It identifies concrete scientific boundaries, and it gives the reviewer a way to demand the test that would resolve them. The model's scope is as important as the decimal place shown in its result.

Grace Brewster Murray Hopper, Peer Question: Sir David, a report may be elegant yet impossible to reproduce when the numerical recipe is absent.

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Assume the original IQ file is preserved with a matching digest, but the software has silently changed the scaling convention, the order of I and Q samples, the FFT length or the treatment of invalid sample markers. A later examiner obtains a different power estimate while using a receiver calibration certificate which appears identical to the first examiner's. How should the witness state the technical basis of the discrepancy without treating the hash as proof that the earlier computed measurement was correct? I would also ask whether a separately protected manifest should contain explicit test vectors and expected numerical outputs, as well as an account of configuration changes over the acquisition interval. Finally, what relationship should exist between the engineering record and the simplified table shown to a tribunal?

Sir David Cox, Response: Admiral Hopper, the preserved file hash supports continuity of the byte sequence from a protected reference state. It does not specify how those bytes are to be interpreted and cannot certify the mathematical correctness of processing software. The second examiner may be reading the same samples under a different packing convention, gain calibration or algorithm. An effective record therefore needs a protected interpretation manifest and a reproducible processing recipe. The manifest should specify the numerical sample type, byte order, I/Q arrangement, scaling and clipping conventions, sample rate, clock source and frequency reference, as well as the validity indicators and any gaps. The processing recipe should specify the exact software and relevant dependencies, the window and FFT conventions, the channel bandwidth and the mapping from spectral estimates into final reported quantities.

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Test vectors are extremely useful when their provenance is independent and their expected outputs are correctly defined. The laboratory can prepare known synthetic inputs, controlled physical reference signals and deliberately corrupted files. The algorithm should produce outputs within prespecified tolerances. Those tests must be repeated after substantive software changes, and the results stored independently of the analyst's narrative. A test that merely reproduces the number in the current report may be circular; it should challenge the computation under cases chosen to expose common mistakes. A digest of the output file may establish that the same result was stored later, yet it cannot prove that the result was physically meaningful when first calculated.

The acquisition interval may contain configuration transitions. A gain change, clock relock or preselector movement can render the interpretation of one continuous file nonuniform. The manifest should include state epochs with their boundaries, the source of each state report and the uncertainty of the boundaries when relevant. A report which presents one calibration factor for the entire file must establish why that factor applies throughout. The custody ledger records transformations and transfers; the instrument-state log records the physical and software conditions of collection. They are related but distinct records, and neither substitutes for the other.

For a tribunal, I would present an intelligible table showing the measurand, estimated value, uncertainty convention, validated operating conditions and any material qualification. The full reproducibility record should remain available under appropriate lawful safeguards, including the precise processing manifest, relevant source-code or build identifiers where

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permitted, test vectors, calibration material and logs. It is not necessary to expose unrelated protected communications to demonstrate that the amplitude conversion was correct. The simplification is legitimate only when it faithfully reflects the fuller record. A technically impressive table which conceals a change in sample interpretation is not clarity; it is an omission which may alter the ultimate finding.

Dr. James M. Atkinson, Moderator: We have considered measurement models and competing explanations. I now pass the token respectfully to Dr. Jerzy Neyman to address coverage, planned decision rules and the limits of frequencies observed under repeated laboratory conditions.

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Jerzy Neyman, Fourth Principal Contributor: Dr. Atkinson, when an interval is called a confidence interval, the investigator must not obscure the procedure which produces it. A frequentist confidence procedure is constructed so that, under specified conditions and repeated applications of the procedure, intervals contain the fixed target parameter with a prescribed long-run frequency. The probability statement belongs to the random procedure and its assumptions. After one interval has been calculated, one should not, without a different inferential framework, describe the particular fixed parameter as randomly wandering into or out of a fixed interval. A witness may communicate this principle in ordinary language while keeping the engineering assumptions explicit. It is particularly important when the test conditions vary across receiver gain states or when the collected observations are selected because they triggered an alarm.

The first task in designing a defensible experiment is to specify the parameter and operating regime. For a frequency calibration, one might define the offset of an RF analyser relative to an independent frequency reference under stated temperature, warm-up, input power and signal-to-noise conditions. The experiment should include suitable independent reference observations, appropriate repeated measurements and a procedure for identifying drift or instability. If the resulting interval assumes constant bias over a period during which the clock loses discipline, the coverage assertion may fail. The resulting uncertainty should then be conditioned on the verified stable epochs, not extended by rhetoric across unobserved state changes.

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A second task is to distinguish coverage for one preselected measurand from simultaneous coverage across numerous reported quantities. If a witness extracts ten frequency peaks and constructs ten nominal ninety-five per cent confidence intervals independently, the probability that all ten intervals capture their targets is not automatically ninety-five per cent. Under an artificial independence assumption, it would be 0.95 raised to the tenth power, approximately 0.5987. In actual spectral data the estimates may be correlated, which changes the calculation but does not remove the conceptual problem. A tribunal should not be shown an attractive collection of nominal individual intervals and be invited to infer that the entire resulting narrative has the same advertised global coverage. The set of comparisons, their selection and dependence must be considered.

If the question is whether a detected signal exceeds a prespecified threshold, there must be a distinction between the procedure's false-alarm probability under a defined reference condition and the evidential weight of an observed alarm. The former can be measured in controlled trials or calculated under verified assumptions; the latter depends upon actual environmental conditions, the prevalence of alternative processes and subsequent investigation. If a threshold was adjusted after seeing an anomalous waterfall, the original reference operating characteristics do not apply unchanged to that new adaptive procedure. One may design a confirmatory trial with a fixed threshold, an independent period or a reserved dataset. Such control is essential when the finding is likely to influence an intrusive or consequential decision.

Coverage can fail for reasons outside the analyst's algebra. A stated sampling distribution may not describe impulsive industrial interference,

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heavy-tailed disturbances or correlated FFT cells. An electronic test source may have an unmodelled modulation or warm-up transient. A reference cable may be changed between trials, altering both loss and phase. Several measurements may share a drift component, violating independence. When the laboratory detects such departures it should change the model or qualify the conclusion. A nominal procedure cannot immunise evidence against an environment which lies outside its scope. To preserve credibility, the report should identify validation observations and state which configurations were not tested.

Uncertainty propagation also involves experimental design rather than merely final arithmetic. If two corrections have covariance, a combined budget cannot disregard that relationship; if an offset is estimated by regression, fitted coefficients may be correlated and a confidence band at a new frequency may differ from the uncertainty at the calibration points. A useful experiment samples the intended range of frequency, level, temperature and receiver state, rather than measuring only the condition most favourable to a precise certificate. Independent reference measurements can provide information that repeated readings from one unchanging display cannot. A well-designed measurement method records what was fixed before acquisition and what was changed after inspecting results.

I would propose a reporting hierarchy. The expert first identifies the calibrated quantity and experiment; next, the method of estimating corrections and uncertainty; next, the coverage interpretation, including assumptions and applicable range; next, tests of alternative physical explanations; and finally, the qualified finding. The tribunal need not be

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forced to follow every covariance calculation aloud, but must be given enough to understand what the interval guarantees and what it does not. If the expert cannot support a probability claim about a particular emission source, that inability should be stated plainly. Numerical humility is preferable to a confident percentage whose meaning is obscure.

A final point concerns apparent conflict between statistical and legal standards. A nominal confidence level of ninety-five per cent is not a legal threshold for admissibility, nor does it mean a court ought to find any particular person liable. Scientific reporting describes a procedure and its limits. Judicial rules may ask whether the method is reliable, relevant and appropriately applied, together with many other matters. In the federal United States system the present text of Rule 702 expressly imposes a more-likely-than-not burden on the proponent for specified admissibility elements; that burden should not be confused with a metrological coverage probability or a posterior probability of emitter identity. Other jurisdictions require their own analysis. I invite the peers to challenge the assumptions in a real measurement plan, rather than only the elegance of the mathematics.

Edsger Wybe Dijkstra, Peer Question: Dr. Neyman, a test procedure is often described as though its sampling mechanism were an immutable feature of nature, whereas in an SDR system it is partly a software configuration. Imagine that one application loses every twentieth buffer when a storage service becomes busy. A second version silently fills those gaps with zeros, and a third records the loss explicitly. The investigators then compute confidence intervals for spectral occupancy and for burst event times, using the number of stored windows as their sample size. How should the validity of their coverage claims be examined when the selection and missing-data

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mechanisms depend on the receiver's own state? Please separate the error in a formal statistical procedure from an error in its implementation, explain whether a deterministic replay of the file can certify the intended sampling distribution, and specify what tests would be required before the reported interval could accompany sworn technical evidence.

Jerzy Neyman, Response: Professor Dijkstra, a confidence procedure is a mapping from observations, taken under an assumed experimental design and probability model, to an interval. If the observation mechanism has changed, the same formula may no longer have its advertised coverage. When a busy storage system loses buffers nonrandomly, the resulting data may omit precisely the intervals containing high activity or long bursts. Treating the stored windows as an unbiased random sample of elapsed time is unjustified. Filling gaps with zeros is worse if those inserted values are subsequently analysed as genuine negative observations. Such a file can produce a perfectly deterministic and repeatable false occupancy estimate. Replay tests the computation; it does not validate the population represented by the data.

The first engineering test concerns the native acquisition record. Hardware sample counters, valid-sample markers, buffer-overflow indicators and timing references should be preserved with understood semantics. The laboratory should create known test signals and introduce controlled losses at each stage: acquisition, transfer, host queue and file writer. It should verify whether the instrument detects and correctly labels each interruption. If the recorder inserts zeros, the zeros must be tagged as invalid placeholders, not counted as radio silence. An interval estimation procedure should use the actual observation mask and describe any assumptions

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about the unobserved periods. If the gap mechanism is related to signal strength or processing load, standard missing-at-random arguments may fail, and sensitivity analysis or explicit bounds may be more defensible than a single narrow interval.

The second test concerns software implementation. The analyst should compare the code's output with independently computed reference examples, including constant signals, known pulses, phase discontinuities, deliberate saturation and missing windows. A change in FFT convention or sample-rate interpretation may alter the estimated statistic. Those results must be checked against documented acceptance tolerances before the inferential calculation is trusted. Yet even perfect numerical agreement is only an implementation check. It does not establish the statistical assumptions concerning event independence, background distribution or selection of the data. One must test those assumptions separately through physical controls and, where possible, independently acquired reference observations.

For testimony I would distinguish three conclusions. First, the algorithm returned a stated interval from a defined set of stored samples. Secondly, the implemented algorithm reproduces known reference calculations under its declared software version and numerical tolerances. Thirdly, the sampling design and physical model justify the interval's advertised interpretation for a particular class of RF observations. The first two may be established even when the third remains unsupported. A witness should say when that happens. An evidence record which separates them permits a judge to evaluate the true scope of the opinion and allows subsequent

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independent testing without pretending that lost observations were recovered.

Donald Watts Davies, Peer Question: Dr. Neyman, I should like to examine a different form of dependence. Two receivers monitor the same authorised reference source. Their displays appear to agree, but both are disciplined by one reference oscillator and receive their timestamps from a shared network time service. The experimenter treats the two observations as independent, combines uncertainties by a simple square root, and then describes the agreement as strong corroboration of the source's identity. How should the uncertainty and independence assertions be repaired? Please distinguish common-mode error, sample-time uncertainty, propagation delay and the categorical question whether the two receivers were actually measuring one external event. I also ask how a report should deal with a clock reference which changes state during acquisition, especially where the change appears only in a later log and the witness cannot identify exactly which captured samples were affected. How should the report record the differing uncertainty of the stable and unstable epochs, and what observations, if any, could permit a later independent examiner to reconstruct that boundary without inventing missing evidence?

Jerzy Neyman, Response: Mr. Davies, a shared oscillator introduces common structure into the error of two frequency measurements. A simple calculation that assumes independent errors may underestimate uncertainty in a difference or in a combined estimate, depending upon the quantity and covariance. The appropriate measurement equation should identify common and instrument-specific contributions. For example, if both receivers share one reference-frequency error, repeating the reading on the

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second receiver does not average that component away. The two receivers may still provide useful comparison of independent analogue paths, but the common reference limits their evidential independence for frequency accuracy. Shared network timestamps introduce further uncertainty about the relation between host events and actual ADC aperture times.

The timing measurement must specify which interval or event is being timed. A hardware sample counter gives ordering and nominal intervals within its own clock domain. A host timestamp may report when data were written rather than when RF energy arrived at the antenna. Propagation delay, antenna and cable group delay, digital filtering and buffer latency may all enter a cross-receiver comparison. If their values are unknown, one cannot replace them with a small network synchronisation figure merely because the computer clocks agree. Reference pulses at known positions and independently monitored times may reveal some of these delays, subject to their own uncertainty. The fact that two displays show energy near the same wall-clock label is weaker than a calibrated arrival-time finding.

The categorical assertion that both receivers measured one external source requires further physical evidence. Distinct emitters can transmit in the same frequency interval; an external interferer can affect several receivers; a shared accessory can generate an artefact visible in both. Independent antennas, path substitutions, spatial tests and controlled-source observations can help discriminate the possibilities. Agreement within numerical uncertainty is relevant to consistency of measurements, but it is not a source identifier. If the same signal-processing software creates the

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same spectral spur in both chains, apparent agreement may have almost no value for external attribution.

When clock discipline changes, I would segment the record into evidenced state epochs. If the change boundary is uncertain, the affected interval should carry an uncertain status rather than an invented precise timestamp. The uncertainty budget may then need to be enlarged or the analysis restricted to verified stable epochs. If neither is scientifically defensible, the witness can state that the data do not support a precise cross-receiver alignment in that interval. Such a limitation does not invalidate every other measured property. A frequency or occupancy result from an independently established stable period may remain useful. The purpose of a careful report is to assign each conclusion to the observations and conditions that actually support it.

Dr. James M. Atkinson, Moderator: Dr. Neyman has distinguished statistical coverage from the validity of the acquisition design. I respectfully pass the token to Charles Sanders Peirce to examine the logic of explanatory inference and the boundary between plausible hypotheses and proven causes.

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Charles Sanders Peirce, Fifth Principal Contributor: Dr. Atkinson, technical testimony often begins where an investigator notices an unexpected phenomenon and asks what could have produced it. That is a proper starting point for inquiry, but it is not the end of inquiry. A spectral line may suggest a local emitter, a harmonic of an external device, a product of mixer nonlinearity, a clock-related internal spur or a software artefact. The imagination supplies candidate explanations; disciplined observation and experimentation discriminate among them. The danger lies in confusing the first plausible explanation with a conclusion which has survived deliberate testing. A fine instrument can make an initial suggestion more vivid without making it more certain.

I would distinguish three activities. In the first, the investigator forms a hypothesis capable of explaining the observation. In the second, consequences of that hypothesis are derived: how should the feature behave when input attenuation is varied, when the antenna is substituted or terminated, when the receiver's preselector changes or when another physical location is examined? In the third, those consequences are tested under recorded conditions. The strongest testimony explains this movement from conjecture through expectation to observation. A mere catalogue of plausible causes is not enough. Yet neither is a single confirming display. The engineer must ask what rival hypothesis would have produced the same result and whether a practical test can distinguish it.

When the measured quantity itself is uncertain, the inference must not conceal that problem. Suppose a reported receiver-input power is calculated from a displayed level corrected for cable attenuation and amplifier gain. The witness should name the reference plane and operating conditions,

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because an uncertainty interval refers to that defined quantity. If a preamplifier operated in compression, the linear correction model may be invalid. A large coverage factor cannot convert the invalid model into an honest estimate. The correct finding may be that a prominent feature was detected but its true power was not established under the recorded conditions. That limited conclusion can still guide a subsequent controlled investigation.

Alternatives differ in evidential weight. An external transmitter and an internal mixing product may each have testable consequences. A highly specific allegation about a named individual may require evidence far beyond RF amplitude and frequency. A speculative explanation which supplies no physical mechanism and no possible test should not automatically erase the significance of controlled observations, but the engineer should avoid claiming exhaustive exclusion of all alternatives. What was actually tested matters more than what could theoretically be imagined. The report should give the reader a map of those tests and what each could and could not rule out.

A vivid example is the interpretation of motion. If a narrowband peak changes level as an antenna is rotated, the operator may infer that the source lies in a particular direction. But the same pattern could arise from reflections, near-field coupling, antenna-pattern nulls or motion of the receiver itself. The measured level, its uncertainty and the antenna's calibration are necessary inputs, but the spatial attribution requires a model of the environment and corroborating observations. The investigator may report a direction of greatest response under specified conditions without claiming that the apparent bearing directly identifies the emitter. The

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distinction is one of the logical reach of evidence, not merely numerical precision.

The law introduces an additional discipline. The witness offers scientific explanation under the court's rules, while the court determines admissibility and ultimately resolves disputed facts through the relevant legal processes. A metrological interval cannot determine whether a defendant acted unlawfully; a careful logical argument cannot substitute for authentication of a file or lawful acquisition of evidence. The expert should not assume that a criterion borrowed from one jurisdiction applies to every hearing. Where the proceeding is in the United States federal courts, the current Rule 702 language and applicable case law must be checked by qualified counsel. Where it is elsewhere, the applicable evidentiary framework may differ in important ways.

I would encourage an expert to use an inference table which distinguishes observed fact, processing operation, measurement model, alternative cause, attempted discrimination and residual limitation. Such a table reduces the temptation to make the conclusion more memorable than the evidence. It also allows a hostile yet competent reviewer to identify the point at which one may reasonably disagree. Perhaps both experts accept the sample file, its digest, the calibrated frequency and the level correction, but disagree about whether a control test excludes receiver intermodulation. That is a precise disagreement which can be investigated. It should not be disguised as a quarrel over character or authority.

The final statement should resemble a scientific finding, not a proclamation. One might say that a defined RF indication persisted under specified controls, its frequency and receiver-input level were measured with stated

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uncertainty under verified configurations, and the available tests support but do not uniquely identify an external emitter. If later authorised investigation supplies discriminating evidence, the conclusion may justly grow stronger. Until then, the narrower proposition is the proper product of inquiry. It conveys something worthwhile, preserves the independence of the tribunal and leaves clear what experiment would change the judgement. I pass the token to colleagues who will test whether this account remains defensible under direct challenge.

Sir Harold Jeffreys, Cross-Peer Question to Sir Karl Raimund Popper: Sir Karl, your emphasis on disconfirming tests is attractive, yet I fear that it can be misunderstood as a demand for a single decisive experiment when the measurement process is itself probabilistic. Consider an external low-duty-cycle source whose emissions are rare, an overloaded receiver which sometimes produces spurious peaks, and a short authorised observation interval. The feature disappears when the antenna is disconnected, but so does a conductive disturbance coupled through the antenna cable; the result therefore does not distinguish all the alternatives. How would you propose a sequence of tests without asserting that a failure to detect the feature has disproved an intermittent source? Please also explain what should be said when two hypotheses remain compatible with the evidence after several controls, and whether a technical report may legitimately prefer one explanation while admitting that the preference is conditional on assumptions which have not yet been directly verified.

Sir Karl Raimund Popper, Cross-Peer Answer to Sir Harold Jeffreys: Sir Harold, an effective critical test need not be logically infallible in order to be scientifically useful. Its purpose is to make explicit the observations which

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different hypotheses lead us to expect and to examine those expectations under adequately controlled conditions. Where an emission is intermittent, a negative observation has meaning only in relation to actual coverage, receiver sensitivity and an appropriate model of event occurrence. Disconnecting an antenna can eliminate an external radiated signal, a conductively coupled disturbance and certain receiver-generated mixing products simultaneously. The disappearance of the feature therefore narrows the possibilities only to the degree warranted by the circuit and experimental design. The report must not describe such an outcome as unique proof of a radiating transmitter.

A discriminating sequence can begin with the least intrusive controls: record the instrument state, verify a known reference signal, examine overload indications, apply attenuation and preselection changes, and compare a suitably isolated reference input. Where lawful and technically justified, employ a distinct antenna path and independent receiver technology. Each result should be interpreted against hypotheses articulated before the test. If input attenuation changes an intermodulation product by a different law than an actual input tone, that response may supply evidence, but even then the law depends on the operating regime and measurement uncertainty. If a second site records a related feature, one must still consider common infrastructure and environmental signals.

When two physical explanations survive, the scientist may report that the findings are consistent with both, and may describe which is favoured by a properly specified statistical or physical model. The word favoured must not be promoted to identified merely because one explanation is familiar. If the preference depends on an assumed event distribution or on a

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manufacturer's claim about the receiver's suppression of spurs, the assumption belongs in the conclusion. A technical opinion can be useful without eliminating every plausible possibility. The logical virtue lies in its vulnerability to future correction.

The strongest protection against overstatement is to connect every conclusion to the experiment which would require revision. One can report that a narrowband indication recurred under verified conditions and that no internal product was produced in specified reference tests, while acknowledging that untested external coupling remains possible. The expert may then propose a later experiment to discriminate that possibility. A tribunal receives not merely a numerical answer, but a transparent account of how far the evidence reaches. Critical scrutiny of hypotheses is a continuing method, not a theatrical demand that nature supply a perfectly clean yes-or-no answer.

Jerzy Neyman, Cross-Peer Question to Sir Harold Jeffreys: Sir Harold, your likelihood comparisons may be informative, but a witness might present a probability of source identity after selecting both the candidate source and the data used to compare it. Suppose the instrument initially surveys one hundred candidate signal forms, retains only the strongest, and then assigns that result a high probability under a model whose parameters were estimated from the same retained recording. How would you disclose the effect of this two-stage selection and the role of prior assumptions? I should also like an explanation of how the witness would distinguish a posterior probability, a likelihood ratio and a frequentist operating characteristic in ordinary testimony, particularly when the judge or jury may hear the same word confidence used for all three. Finally, how would your conclusion

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change if the only alternative hypothesis modelled was background thermal noise, while physically credible receiver intermodulation and industrial emissions were omitted?

Sir Harold Jeffreys, Cross-Peer Answer to Jerzy Neyman: Dr. Neyman, any model comparison whose candidate and data were chosen because they showed a conspicuous result should disclose that selection. The nominal distribution of a statistic chosen in advance need not match the distribution of the maximum among many explored statistics. If parameter estimates were also tuned to the retained observation, the data have performed more than one analytical role. One might construct a joint model for the full search and selection procedure, or reserve independent observations for an honest validation. If neither can be done, the witness should report a conditional exploratory comparison rather than decorate the result with an unjustified probability of truth.

A likelihood ratio compares how compatible particular data are with two specified hypotheses, given their parameter choices or treatment of nuisance quantities. It is not by itself the probability that either hypothesis is true. A posterior probability incorporates prior assumptions and a model for the observed data. A frequentist operating characteristic concerns the frequency of outcomes under repeated application of a specified procedure. Each can be meaningful, but the labels cannot be exchanged. A report might explain that the observations are, under two stated physical models, more likely under one model than the other, while avoiding the unsupported sentence that there is a matching percentage probability that the suspected device caused the emission.

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If the denominator contains only thermal noise, a large likelihood ratio establishes at most a contrast against that restricted alternative. Industrial emissions and receiver nonlinearities may produce observations much more similar to the chosen feature than thermal noise does. Excluding them from the model does not eliminate them from the world. A responsible witness should identify which plausible classes were modelled, which were physically challenged and which remain outside the calculation. Even a sophisticated Bayesian analysis should not conceal model misspecification under a forest of equations.

The practical solution is transparent sensitivity analysis. The expert should show how the inference changes under reasonable alternative priors, interference models, instrument states and inclusion rules. If the result changes markedly, its fragility belongs in the final opinion. If it remains robust, that is useful evidence, but only in the tested range. The tribunal need not accept any particular mathematical philosophy to understand this boundary: a reported probability or ratio answers a defined question using identified assumptions, and it cannot answer a larger accusation by mere force of numerical precision.

Sir Karl Raimund Popper, Cross-Peer Question to Sir David Cox: Sir David, suppose two laboratories produce nearly identical receiver-input power estimates, each with a stated expanded uncertainty, but one has retained only the final screenshot while the other has preserved the IQ samples, source manifest, calibration record and controlled reference tests. An advocate may say that the numerical agreement settles scientific validity, and that any missing records merely concern the formality of custody. I invite you to explain why the same numerical output can have very different

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evidential foundations. In particular, when does missing documentation make the uncertainty budget unverifiable rather than simply wider, and how should the witness avoid a claim that recalculating the displayed number on another computer proves the underlying physical event? Would you also explain whether agreement of two intervals supports a common source where the receiving chains may share the same reference and environmental disturbance?

Sir David Cox, Cross-Peer Answer to Sir Karl Raimund Popper: Sir Karl, agreement of two reported numbers is a property of those numbers, and sometimes of the processes which generated them. It does not by itself verify the validity of either measurement. The laboratory retaining IQ samples and a protected manifest can permit a second examiner to challenge sample interpretation, windowing, gain corrections, clock state and artefacts. The laboratory retaining only a screenshot may have lost the information required to test alternative processing choices or reconstruct the reference plane. The two laboratories may therefore arrive at similar displayed values with radically different opportunities for independent scrutiny. An evidential assessment cannot ignore that asymmetry.

Missing documentation does not always justify an arbitrary increase in a numerical uncertainty. If the calibration factor is unknown but bounded by a defensible test, a wider interval may be appropriate. If the measurement's units, bandwidth or source data cannot be established, there may be no valid model to which an expanded uncertainty can meaningfully attach. One must distinguish a quantified input uncertainty from failure to verify that the underlying measurand was measured at all. The careful expert should

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describe the missing basis and, if necessary, decline to provide a numerical estimate that would imply unjustified physical knowledge.

Recalculation on another computer is a software reproducibility check. It can detect implementation differences, demonstrate byte continuity or verify arithmetic. It cannot prove that an RF field existed at the claimed antenna location, that the original receiver was not overloaded, or that a particular transmitter was the source. Those questions require independent physical observations and controls. A preserved file may be authentic as a computer record yet a poor representation of an electromagnetic event; conversely, a real event may have been captured in circumstances that do not support a quantitative power conclusion. The report should distinguish those two conditions.

Finally, numerical interval overlap is not a test for source identity. Shared references and environmental inputs may induce correlated error, and multiple emitters may generate consistent numerical features. One may report compatibility of two measurement results under a stated model. Any inference of common external cause needs its own chain of evidence, including timing, location, physical propagation and control of common-mode artefacts. The apparent agreement should motivate those tests, not substitute for them. Scientific communication succeeds when the boundary between numerical comparison and causal explanation can be seen without guesswork.

Sir David Cox, Cross-Peer Question to Charles Sanders Peirce: Mr. Peirce, an abductive explanation is often chosen because it makes scattered observations intelligible. Yet in a forensic report such intelligibility can exert a persuasive force out of proportion to the data. Imagine a witness offering

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a coherent story that a concealed emitter generated a repeating narrowband signal, while an alternative account involving industrial switching noise is less dramatic but compatible with the waveform and measured uncertainty. How can the investigator use causal explanation without turning coherence into proof? I should like you to specify how a falsifiable test plan, a metrological uncertainty statement and a legally cautious conclusion fit into one narrative. Finally, if the most decisive test cannot be carried out because lawful authority or available records do not permit it, should the witness still provide a preference among hypotheses, or must the report stop at an unresolved observation?

Charles Sanders Peirce, Cross-Peer Answer to Sir David Cox: Sir David, a coherent explanation is an invitation to inquiry, not a licence to declare an accusation true. The investigator should first state the observation and its chain of acquisition; next, the suggested causes; then, the predicted consequences which differentiate those causes; and finally, the tests actually undertaken. The industrial-noise hypothesis may be less narratively attractive than a deliberately concealed transmitter, but that has no bearing upon its physical adequacy. If both hypotheses predict the observed feature, the observation alone cannot distinguish them. A report that places causal alternatives next to the evidence prevents eloquence from masquerading as an additional measurement.

Metrological uncertainty describes a defined quantity under the assumptions of a measurement model. It may be appropriate to state the observed feature's frequency and receiver-input power with corresponding uncertainties, while remaining undecided about the emitter. The causal test plan is separate: vary the input attenuation, inspect harmonics, substitute

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independent receiving hardware, examine the effect of an antenna termination and compare environmental operating cycles. Each test should be linked to the prediction it challenges and should acknowledge conditions in which it is not decisive. The witness should never claim that a tight frequency interval narrows causal identity to one named apparatus unless distinct attribution evidence supports that proposition.

Where an essential test cannot lawfully or practically be performed, the constraint must be disclosed. A witness may explain that the present observations are more consistent with one hypothesis under specified assumptions, if there is a reasoned basis for that comparative statement. The report must not describe the hypothesis as identified or exclude a plausible rival which was never examined. Sometimes the honest result will be a narrow observation and an explicit unresolved alternative. That is not a collapse of scientific inquiry. It is the correct description of its present state, leaving the next permissible experiment identifiable.

A disciplined final narrative can therefore be both useful and restrained. It gives the measurable facts, data-provenance record, calibration limitations, tested physical alternatives and residual uncertainty. It separates expert interpretation from any finding about an individual's intent, identity or liability. If later authorised experiments differentiate the hypotheses, the inference may change and the report should be capable of revision. A strong scientific explanation is one that specifies what could prove it wrong and records whether those observations were actually available. It does not gain authority merely because it has the pleasing form of a story.

QUESTION 098. TECHNICAL EXAMPLES AND REPORTING CONVENTIONS. All numbers below describe invented authorised laboratory observations. They

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are not historical statements, real surveillance findings or measurements of an unknown person's equipment.

EXAMPLE 1. Let I denote an instrument indication in dBm, A an attenuation correction in dB, and G a gain correction in dB. For I = −80 dBm, A = 3 dB and G = 10 dB, the estimated receiver-input power is P = I + A − G = −87 dBm. This assumes the gains and losses refer to the same signal path and the instrument is operating in its validated linear range.

EXAMPLE 2. If independent standard uncertainties in the same additive logarithmic model are uI = 0.6 dB, uA = 0.8 dB and uG = 0.5 dB, the combined standard uncertainty is uc = sqrt(uI^2 + uA^2 + uG^2) = sqrt(0.36 + 0.64 + 0.25) = sqrt(1.25) ≈ 1.1180 dB. Independence is an assumption, not an observed fact.

EXAMPLE 3. Under a specified conventional coverage factor k = 2, the expanded uncertainty from Example 2 is U = k uc = 2 × 1.1180 ≈ 2.2361 dB. The interval P ± U would be −87 ± 2.24 dBm after appropriate rounding. It is not by itself a claim of exactly ninety-five per cent coverage or a probability of source identity.

EXAMPLE 4. Suppose two standard corrections have standard uncertainties u1 = 0.6 dB and u2 = 0.8 dB and correlation coefficient rho = 0.5, and both enter the measurement equation with positive sensitivity coefficient one. Their combined variance is $u1^2$ + $u2^2$ + 2 rho u1 u2 = 0.36 + 0.64 + 0.48 = 1.48 dB^2, yielding standard uncertainty sqrt(1.48) ≈ 1.2166 dB, rather than 1.0 dB under a false independence assumption.

EXAMPLE 5. For a hypothetical frequency estimate f = 150,000,000 Hz with justified standard uncertainty uf = 15 Hz and conventional coverage factor k

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= 2, the expanded uncertainty is U = 30 Hz and the reported frequency interval is 149,999,970 Hz to 150,000,030 Hz under the adopted model. This interval describes frequency, not the source's location or identity.

EXAMPLE 6. For N = 10 independently selected hypothetical one-parameter confidence intervals, each with 0.95 coverage, the simultaneous all-cover probability would be 0.95^10 ≈ 0.5987 under independence. This simplified calculation cannot be transferred to overlapping spectral cells with substantial dependence.

EXAMPLE 7. For a sample of n = 25 independent, identically distributed reference readings whose sample standard deviation is s = 0.50 dB, the estimated standard uncertainty of the sample mean is s/sqrt(n) = 0.50/5 = 0.10 dB, conditional upon the appropriateness of the statistical assumptions. This excludes external calibration effects and systematic model failures.

EXAMPLE 8. Let x = −87 dBm denote a receiver-input logarithmic power estimate. Its corresponding linear power in milliwatts is p = 10^(x/10) mW = 10^(−8.7) mW ≈ 1.9953 × 10^−9 mW. A numerical standard uncertainty expressed in dB must be propagated through this nonlinear transformation before it is described as an absolute uncertainty in milliwatts.

EXAMPLE 9. In a simplified distance-based free-space delay comparison with path difference d = 300 metres and propagation speed c = 299,792,458 metres per second, the nominal time difference is t = d/c ≈ 1.00069 microseconds. Actual cable, antenna and multipath delays are additional terms and must not be silently assigned zero.

EXAMPLE 10. If a hypothetical receiver produces 1,000 candidate alarms during a survey but 100 matched independent reference checks are selected

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under a defined random design, an observed 12 false alarms among those checks represents 12/100 = 0.12 of that sampled reference set. It does not by itself establish a 12 per cent false-positive fraction for all 1,000 alarms if the sampling design or reference labels are unrepresentative.

QUESTION 098. REFERENCE AND EDITORIAL QUALIFICATION. Relevant background includes the BIPM JCGM 100:2008 Guide to the Expression of Uncertainty in Measurement and its subsequently published amendment, NIST Technical Note 1297, and the text and 2023 Advisory Committee Notes to United States Federal Rule of Evidence 702. The named historical scholars never held this joint discussion; every contribution is a present-day fictional educational reconstruction. Source-to-claim verification, historical suitability, jurisdiction-specific legal proof and whole-manuscript pagination remain necessary before publication. This manuscript does not claim that an instrument's uncertainty establishes an individual's identity, wrongdoing or legal liability.

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QUESTION 099

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What evidence separates waveform detection, device class and individual-emitter attribution?

Dr. James M. Atkinson, Moderator: Dr. Bracewell, an RF practitioner may detect a brief component, decide that it resembles a familiar modulation, label it as the work of a particular class of apparatus, and then be tempted to name an individual transmitter or owner. Please distinguish the evidential requirements at each transition. In your contribution, address receiver-generated products, spatial ambiguity, environmental changes, representative reference populations, calibration uncertainty and the danger that a classifier must choose one of its known classes even when the true source is outside them. We must draw the scientific inference as narrowly as the evidence permits and avoid implying either unauthorised interception or personal culpability.

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Ronald Newbold Bracewell, Principal Contributor: Dr. Atkinson, the initial observation is usually a quantity measured through a system, not an object identified in the world. A spectrum receiver delivers estimates shaped by its antenna, gain distribution, filtering, sampling clock, digital processing and display conventions. If a feature appears at a frequency coordinate, that observation can be checked against the instrument's reference standards and acquisition records. But a peak on a screen may arise from an external field, an internal spur, nonlinear intermodulation, a numerical representation error or interference coupled through the measurement chain. Before the analyst assigns a waveform family, the physical origin and the fidelity of the sampled data must be examined. An identical line appearing in two exported plots offers little corroboration if both plots derive from the same stored samples or share the same defective front end.

The next stage is detection of a pattern under a specified model. A matched-filter response, cyclic correlation or repeatable burst shape may increase the plausibility of a waveform class, but only against the comparison alternatives that were actually tested. A strong match to one reference waveform does not establish that the source is a particular transmitter. The reference might be common to numerous devices, a generic clock artefact or a signal reproduced through different propagation paths. Receiver bandwidth, window selection, time alignment and thresholding influence the discriminating statistic. Those choices should be documented and, when the evidence is consequential, validated on independent records. A detector tuned to one laboratory waveform may perform poorly in an industrial environment with strong impulsive interference.

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The movement from waveform detection to device class requires information about what separates that class from plausible rivals. We might compare spectral masks, oscillator settling, burst timing, modulation behaviour and controlled responses to changes in the authorised reference transmitter. But such features can depend on temperature, supply voltage, firmware, output power, antenna loading or the channel between transmitter and receiver. A particular transient shape may be stable in one laboratory and vary considerably after the same apparatus is moved. Conversely, two distinct transmitters of one design may present very similar traces through one receiver. The analyst should not confuse repeatable measurement of a feature with proof that the feature uniquely identifies the device class.

Individual-unit attribution is more demanding. An inference that one specific apparatus produced a recorded signal requires tested between-device discrimination, within-device variability, independent conditions, an adequate reference population and an accounting of unknown alternatives. A classifier whose output must always be one of five reference units will name one even when the true source is a sixth instrument never included in its development. Such a system needs a defensible unknown-source or rejection state and an empirically characterised rate of mistaken attribution under representative tests. Distance, multipath, receiver nonlinearity and normal ageing can make apparent fingerprints shift across circumstances. Any claim of uniqueness must be challenged with physically similar devices, not merely compared against an easy collection of unrelated signals.

A rigorous validation trial would employ multiple known authorised transmitters while keeping the analyst blind to their identities. It would vary

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receiver architecture, antenna position, analogue gain, reference clock and lawful environmental conditions. The investigator would then measure separate performance quantities: whether an emission was detected; whether its waveform was correctly assigned to a class; whether a known unit was distinguished from another unit of the same class; and whether an unfamiliar unit was rejected rather than falsely named. Each stage has its own denominator, uncertainty and failure mode. High sensitivity at the first stage cannot be carried over as a quoted identification accuracy at the fourth. The software's confidence score is not necessarily a calibrated probability of source identity.

Even successful apparatus-level attribution does not establish who operated the device, why a signal was emitted or whether any law was broken. Such conclusions require additional authenticated facts and the appropriate legal procedure. RF measurements can contribute to an investigation, but they do not substitute for authority to collect evidence or for proof of a person's conduct. An engineer should therefore write the finding in successive, testable propositions: the instrument registered a component; specified controls support an external RF origin; measured features are consistent with a waveform class; further tests do or do not support a particular apparatus; and any association with a person lies beyond the present electronic measurements unless independently established. The apparent modesty of that structure is its strength. It lets a later reviewer inspect the precise point at which an observation became an inference.

I would finish with a caution from the inverse-problem perspective. Different physical sources and propagation environments can produce very similar observations at a single receiving location. Without enough independent

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constraints, reconstructing a unique source from a measured field can be non-identifiable even when the field estimate itself is accurate. Better calibration and more precise timestamps help, but do not always cure non-uniqueness. An independent antenna placement, physically distinct receiver, controlled reference source or known perturbation can sometimes supply the missing discriminating information. Where that information is not obtained, the correct result may be a group of compatible causes rather than one named object. A defensible expert report should present that limitation plainly and propose the next lawful experiment capable of resolving it.

Dr. James M. Atkinson, Moderator: Dr. Bracewell, I retain your existing contribution on inverse-source ambiguity and instrument artefacts. Dr. Gabor, I now invite an examination of which apparent fingerprints survive a change of temporal representation. Your answer should address short-time transients, processing windows, channel effects and the danger of mistaking a stable representation for a stable physical source. Our conversation is a fictional educational reconstruction, not an historical encounter or an authentic statement by any named contributor.

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Dennis Gabor, Second Principal Contributor: Dr. Atkinson, every assertion of distinctive waveform structure begins with a decision about how electromagnetic observations are represented. A time-domain voltage series has been conditioned by an analogue receiver before it is recorded. A frequency-domain display is an estimate built by an algorithm which chooses a duration, a window, a frequency grid and perhaps averaging across observations. Neither representation is a transparent window upon the transmitter alone. If a feature is prominent in one display, the analyst ought to ask whether another admissible representation changes the alleged distinction. This is not an argument for infinite scepticism; it is a requirement that the proposed discriminating feature be measurable under a stated, repeatable protocol.

A burst has temporal support, and frequency discrimination has a corresponding dependence on observation duration. A very narrow spectral line cannot be resolved with arbitrary certainty from a vanishingly short sample. Conversely, extending the observation interval may suppress the visibility of an infrequent transient by averaging it with quiet periods. If the purported fingerprint is the shape of an oscillator's turn-on, a smoothing filter or long transform window may erase precisely the variations the investigator wishes to compare. A time-frequency map should therefore be interpreted alongside the sample rate, the window family, the hop size, the chosen amplitude scaling and the actual gaps in observed data. A colourful image without those parameters cannot sustain an individual-source conclusion.

The analyst must distinguish the system response from the source excitation. Suppose two otherwise identical authorised transmitters feed an

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RF laboratory receiver through differing cables and antennas. A transient recorded through one cable may appear to rise more slowly, because the group delay and matching differ. If the receive chain is altered between sessions, the observed difference cannot be laid at the transmitter's door without independent characterisation. The practical technique is to capture controlled reference events with the same measurement chain, then deliberately substitute antennas, filters, gains and receivers. If the supposed device-specific feature follows the receiver, it is a property of the apparatus or processing configuration, not an individual transmitter.

A more subtle problem arises when a classifier operates on spectrogram images. The pixels may encode a consistent colour palette, a fixed raster size or a receiver-specific normalization. A neural model can learn these conveniences instead of learning the underlying electromagnetic distinction. Randomly dividing spectrogram frames from one continuous capture into training and testing sets disguises the dependence: adjacent windows share samples, temperature, channel state and device operating conditions. A respectable validation protocol must separate entire capture sessions and, where the claim is cross-instrument identification, entire receivers. Otherwise, the quoted success rate is an estimate of recognition of familiar recordings, not of independent devices encountered in the field.

The observational model should be written as a composition. The emitted signal is acted upon by the channel, including propagation and multipath. It is then transformed by antenna impedance and the receiver's analogue stages, disturbed by noise and converted by sampling. Digital processing follows, including synchronization, filtering and feature extraction. A difference in the final feature vector may come from any stage. The inverse

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calculation is not generally unique. A robust individual-unit attribution procedure should either control the nuisance transformations or show experimentally that its decisions tolerate their variation to a specified level. Claims of invariance should be measured, not asserted from mathematical elegance.

There is also the question of what one calls a match. Two devices may share the same modulation, preamble, pulse-shaping filter and nominal burst duration because they implement the same standard or circuit design. A strong correlation with that common structure may be excellent evidence about the waveform family and very weak evidence about which physical unit produced it. In a sensible hierarchy, those propositions occupy different positions. A detection statistic tests whether observations comport with a chosen signal model; class membership requires comparison against rival classes; individual attribution requires variation among nominally similar units and sufficient rejection of unknown units. None of these questions is resolved merely by placing increasingly precise decimal numbers beside the same correlation peak.

I would prescribe a blinded experiment with three stages. At the first, the laboratory confirms that the instrument detects a controlled signal under a declared sensitivity and false-alarm regime, including negative controls. At the second, several different signal classes are compared under the same receiver settings, and confusion between classes is measured. At the third, multiple physical units of the same class are measured on separate days, through different antenna paths and with held-out receivers. The classification system must be permitted to say that the source is unknown. Investigators then report class-confusion rates and known-unit attribution

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rates separately, never promoting one into the other by linguistic convenience.

All quantitative claims should name a denominator and a unit of analysis. If a laboratory obtains ninety correct decisions from one hundred adjacent windows in the same recording, it has not necessarily obtained ninety independent successes. The effective independent sample size may be far smaller because the channel and transmitter state are shared. An uncertainty interval calculated as though the windows were independent will be too narrow. The correct design may aggregate decisions at the capture-session level or use clustered analysis respecting the dependence. It is preferable to state a modest evidence base clearly than to advertise a false precision manufactured by repeated processing of the same observation.

Finally, the result must be communicated in a form that an independent specialist can challenge without access to protected communications content. A record may consist of authorised RF sample extracts, transform parameters, calibration logs, feature definitions, predeclared decision rules, negative controls and a custody history. Where only summary measurements are lawfully necessary, the reasons for retaining raw data should be documented and their access controlled. The examiner should distinguish an instrument feature, a waveform-class feature and a proposed device fingerprint in separate columns. If a supposedly invariant fingerprint disappears when the transform window changes within its validated range, the proper finding is that the individual attribution did not survive a necessary robustness test. I pass the token to the discussion of spatial measurements and source ambiguity.

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Dr. James M. Atkinson, Moderator: Sir Martin, the discussion now turns to spatial diversity, interferometric measurement and whether multiple observing sites can support a unique source determination. Please distinguish independent constraints from shared calibration errors, and consider lawful controlled trials in which two transmitters of the same type occupy different locations.

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Sir Martin Ryle, Third Principal Contributor: Dr. Atkinson, multiple receiving positions can be scientifically valuable, but merely increasing the number of instruments does not transform a descriptive waveform match into individual-source attribution. The first question is whether the observations are genuinely independent in the dimensions relevant to the inference. Two receivers sharing an oscillator distribution, cabling defect or synchronized processing software may register matching artefacts. Two antennas connected to one overloaded front end do not constitute two independent external-origin tests. A defensible spatial argument should describe the geometry, the frequency and time references, the antenna patterns and the common pathways through which systematic errors can be correlated.

The simplest observation is that a signal arrived at a particular instrument under particular settings. Directional measurements may add a bearing, and an array may estimate differences in arrival time or phase. These are statements about received fields, not necessarily the manufacturer's identity of the transmitter. Multipath can make a signal appear to arrive from a reflective surface; polarization mismatch can suppress one path and favour another; unknown antenna orientation can move a bearing. Even excellent direction finding may locate a radiating structure rather than the baseband device that generated the waveform. Before joining bearing and classification results, an analyst should explain how those separately calibrated quantities constrain the same physical hypothesis.

Interferometric methods create especially attractive numerical outputs. A tiny phase difference can be measured and used with geometry to infer a direction, provided the array's baselines, reference distribution, channel phase and ambiguities are known. But phase is observed modulo a cycle,

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and a narrowband source may admit multiple geometrically compatible solutions. In a cluttered building, reflecting surfaces and near-field interactions can violate the convenient far-field plane-wave approximation. A conclusion that the source occupies one point must rest on a demonstrated resolution of those ambiguities. A small estimated variance under a mistaken propagation model is not proof of accuracy in the actual environment.

A useful test separates the question of common waveform origin from the question of common physical emitter. An independent source may rebroadcast, repeat or reproduce a standard public pattern, and two emitters may implement identical nominal signalling. If multiple sites receive a shared modulation pattern, the evidence may establish a common waveform family without establishing a single unique transmitting apparatus. The laboratory should introduce two physically distinct authorised transmitters with deliberately similar nominal waveforms, change their positions, and evaluate whether the array continues to identify them correctly. Blindness to identity guards against the convenient adjustment of analysis parameters after the operator learns which source was active.

The reference population must be more discriminating than a theatrical comparison between unrelated devices. If the claim is that one particular transmitter among a population of nominally identical units has been recognized, tests must include units of the same design, firmware family and manufacturing batch where feasible. Otherwise, identification performance may merely reflect coarse class differences. The operator should also vary temperature, power supply, output level, antenna loading,

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oscillator discipline and receiver location. One ought to be particularly suspicious of a stable 'fingerprint' gathered from a single permanent laboratory arrangement; the receiver and channel may have become inadvertent labels attached to each device.

Where observations are combined, their error terms matter. A frequency estimate from one receiver and a timing estimate from another may share a common reference clock. If the reference is biased, simply multiplying their nominal likelihoods as if they were conditionally independent double-counts part of the same evidence. The correct joint model must include common-mode uncertainty or make a defensible conditional-independence assumption supported by tests. An independent receiver with its own reference, antenna and software can provide a valuable challenge, although complete independence is rarely absolute. The documentation should describe the dependence that remains rather than hiding it behind the number of instruments deployed.

A localization conclusion is also not an attribution conclusion. A direction-and-distance intersection may narrow the probable location of a radiating element, yet it does not show that a particular named equipment unit was responsible unless the chain between unit and radiator is established. Consider an authorized laboratory system that uses a cable to feed a remote antenna. The receiving geometry will locate the radiator, not the clock, processor or operator at the other end of the feed. The finding must keep these objects separate. A source location may be highly relevant to a defensive investigation without supporting an assertion about personal ownership, intent or unlawful conduct.

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I would therefore construct three sets of controls for a defensible RF attribution experiment. The first tests external origin by substituting antennas, introducing attenuation and changing receiver front ends while retaining an independently monitored reference. The second tests geometric inference by moving an authorised source through known positions and recording bearing or delay errors, including the effect of reflecting surfaces. The third tests individual-device discrimination by exchanging same-class emitters under blind identifiers and then repeating the trials through new channel states. Each set answers a different question. A favourable result in one set does not automatically satisfy the next.

A sober report can still convey strong engineering value. It may say that a particular waveform family was detected, that independent antennas registered compatible energy, that direction measurements placed the likely radiating region within a stated uncertainty envelope, and that the available features could not distinguish between several same-class units. This does not defeat the investigation. It identifies where further lawful measurements would add information and where the laws of propagation leave genuine non-uniqueness. Conversely, if an instrument-specific characteristic survives those trials, it may support an appropriately qualified comparison, provided the supporting reference population and rejection tests are disclosed. I pass the token to the detection-theory assessment of such evidence.

Dr. James M. Atkinson, Moderator: Dr. Slepian, please examine the nested statistical decisions: the existence of a signal, the classification of a waveform, and the attribution of a source in the presence of nuisance

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parameters. In particular, explain why a high detection probability cannot be reported as an individual-device identification rate.

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David Slepian, Fourth Principal Contributor: Dr. Atkinson, one must first identify the event for which a probability or error rate has been calculated. A detector ordinarily distinguishes between a null model and an alternative such as a specified signal embedded in noise. Its sensitivity and false-alarm characteristics depend upon an assumed noise distribution, observation window, threshold and signal model. An apparatus may detect almost every laboratory burst at a specified power while completely failing to determine which of several identical transmitters generated each burst. The high probability of detection addresses presence under those test conditions, not the identity of the source. A report that moves directly from ninety-nine per cent detection sensitivity to ninety-nine per cent source certainty commits a change of hypothesis without providing the requisite evidence.

The second decision concerns classification. Here the possible hypotheses may include amplitude modulation, a frequency-agile burst, an impulsive discharge and an unknown class. The relevant statistic should be tested against both neighbouring classes and genuine unknowns. A closed-set classifier always chooses among known labels, making its output misleading when the true generating mechanism is absent from the training set. An unknown-source rejection option is therefore not a cosmetic feature. Its false-acceptance and false-rejection behaviour must be quantified under specified conditions. Rejection thresholds that were tuned on the test dataset cannot be treated as independent validation results.

Individual attribution adds the proposition that a particular physical transmitter, rather than another compatible unit, generated the measurement. If the proposed evidence is a collection of oscillator offsets, transient shapes and error-vector features, then both within-device

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variability and between-device variation are central. Two devices might have distinct average offsets during a single laboratory session yet overlap after temperature changes. A model fitted to one session may label the receiver's frequency error as part of the emitter's signature. Proper trials must vary the acquisition apparatus, reference standards and operating conditions, and make the evaluation unit an independent capture session or physical device as justified, rather than a succession of correlated windows.

Likelihood notation can clarify the distinction if used cautiously. Let E denote the observed feature vector; let H1 express the proposition that a tested unit generated the event; and let H2 denote an appropriate alternative source proposition. A likelihood ratio compares P(E given H1) with P(E given H2) under specified models, populations and nuisance conditions. It is not itself P(H1 given E), and it certainly is not the probability that a named individual committed misconduct. Its value depends upon the choice of alternative, the representativeness of the reference population, the treatment of unknown devices and the stability of the measurement process. Reporting a dramatic ratio with no explanation of those modelling choices is poor evidential practice.

The danger is heightened by data leakage. If the training and test sets share overlapping FFT windows, neighbouring packets from the same continuous recording or nominally different files generated by the same receiver calibration episode, the performance estimate will be optimistic. The model may recognize the channel or acquisition date rather than the transmitter. A more persuasive design holds out entire transmitter units when testing class recognition, whole capture sessions when testing within-unit repeatability, and different acquisition chains when asserting cross-receiver

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robustness. Separate calibration, development and final evaluation sets should be identified before results are inspected. The laboratory should preserve the split definition so another investigator can reproduce the evaluation.

Calibration uncertainty and classification uncertainty are related but not interchangeable. A receiver may carry a well-characterised amplitude scale uncertainty yet yield uncertain attribution because the feature distributions for different devices overlap. Conversely, a robust class decision may be possible even though an absolute power measurement is comparatively imprecise. The correct report states the estimand, its calibration assumptions, the validated classifier operating point and the relevant error rates. A single percentage labelled confidence conceals these distinctions. It should not be accepted as an evidential substitute for the confusion matrix and rejection tests.

Suppose a blind laboratory trial uses ten same-class transmitters, each recorded on three days through two receivers. The experiment must document whether the sixty device-day-receiver combinations are independent enough for the intended inference; they do not become thousands of independent trials merely because each file contains thousands of windows. The analysis should show per-device errors, errors by session and errors under receiver substitution. A unit that is easily recognized only when the same receiver is used is not thereby uniquely fingerprinted across receiver architectures. The test should also introduce new devices not among the ten and determine whether the system rejects them instead of selecting the closest familiar label.

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A further subtlety is the base rate. An instrument may show a low false-identification percentage in a restricted set of laboratory comparisons yet operate in an environment containing many unrepresented devices. The chance that an alert is mistaken depends upon the prevalence of target devices, the alternatives actually present and the decision policy. We should not substitute an arbitrary prior for missing field information; we should expose the sensitivity of the inference to plausible priors and source populations. If no defensible population is available, the finding may have to remain a descriptive similarity assessment without a numerical source-likelihood claim. That is a scientifically substantive result, not an embarrassment.

Finally, the statistical experiment must be separated from investigation-driven search. One may examine many features to develop a promising detector, but subsequent claims of validated performance require fresh data or appropriately corrected inference. Every feature chosen after seeing the source identities risks incorporating an accidental separation. The laboratory should record versions of the feature extractor, threshold, decision rule and data split. Independent reviewers should be able to rerun the results from properly preserved authorized measurements, and to determine when a prediction depends on a software implementation rather than source physics. I therefore pass the token to the decision-theoretic question of what to report when the evidence is insufficient.

Dr. James M. Atkinson, Moderator: Professor Blackwell, the evidence may support a waveform-class hypothesis strongly while remaining equivocal among individual emitters. Please address decisions under that uncertainty,

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the cost of a false identification, unknown-class rejection and the separation between engineering findings and legal conclusions.

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David Harold Blackwell, Fifth Principal Contributor: Dr. Atkinson, a classifier's output is an action selected under a rule, not an ontological declaration about the world. We ought first to distinguish posterior belief, where a specified probabilistic model is justified, from the decision made under competing losses. An automated system may be designed to issue an investigative lead when a low-cost false alarm is tolerable. The same output cannot be carried unchanged into sworn testimony identifying a particular apparatus when a false attribution could injure an innocent person. The action threshold depends upon the consequence of error, the available alternatives and the information withheld by the model. An honest report states which decision rule was validated for which purpose.

The investigator may possess evidence adequate for one decision but inadequate for another. Detection of a recurring emission may justify further lawful inspection, even though it does not support naming a transmitter. Classification into a broad waveform family may guide selection of appropriate antennas or monitoring bandwidth. Neither action presupposes that the analyst can identify a particular serial-numbered unit. The error costs are different at each stage. When the consequences of mistaken attribution are serious, the system should be permitted to abstain and should be evaluated specifically on whether it declines unjustified certainty rather than merely on its average classification accuracy.

An unknown-class state is essential because the actual environment is seldom exhausted by the training catalogue. The laboratory should reserve physically distinct devices and signal sources that were never presented during training, threshold tuning or feature selection. It should then measure the fraction of these unfamiliar sources mistakenly attributed to

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familiar units. An apparatus which achieves a high closed-set accuracy may still make every unknown source look like one of its enrolled units. If the class model assumes the universe consists of five transmitters, the model cannot establish that the universe in fact consists of those five. The test design must challenge that presumption independently.

I would add a distinction between explanatory and predictive models. A classifier may correctly distinguish laboratory files using a feature whose physical origin is unknown. Such a model can be useful for sorting recordings, but its success does not establish that the feature belongs to the emitter rather than the receiver or environment. If the scientific claim concerns a transmitter-specific imperfection, it should survive deliberate substitutions designed to remove acquisition-system confounds. A predictive score may decline sharply under changed temperature or antenna path. That would reveal a limitation of the intended scope, not necessarily a defect in the mathematical classifier itself. The error lies in claiming broader evidential meaning than the validation supports.

Consider a decision table in which the cost of a mistaken class assignment is low, but the cost of naming a false individual source is high. One rational policy may classify the waveform for operational triage while withholding individual attribution unless an independent second measurement agrees and an unknown-source test is passed. The policy should be documented before reviewing the final case data. A later investigator cannot quietly raise or lower thresholds to make an existing suspect appear more or less likely, then quote the calibration error rate from the original threshold. Altering the decision rule creates a new procedure whose performance needs new examination.

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Where competing propositions are compared, it is tempting to collapse all uncertainty into a single likelihood ratio. But the figure may conceal dependence between features and the difference between modelled and unmodelled devices. The laboratory should disclose which alternatives were considered and why those alternatives are relevant. It should also investigate whether apparently independent observations share calibration or processing steps. If two features derive from the same oscillator offset, treating them as independent can double-count one physical imperfection. A defensible joint model must represent that dependence or restrict the strength of the conclusion.

The practical reporting hierarchy begins with the observation itself: instrument state, measured feature and acquisition uncertainty. It continues with the result of controlled external-origin tests and the waveform-class comparison. The next level identifies any evidence for a specific physical emitter, together with reference population, unseen-source rejection performance and the limits of channel robustness. Finally, the report states that operator identity, knowledge, purpose and legal culpability are separate matters requiring independently authenticated evidence. The expert should not allow those distinct issues to merge because a narrative sounds persuasive when presented without qualifications.

One should remember the decision to collect additional evidence. If a particular ambiguity can be resolved by a lawfully authorised swap of receivers, a change of antenna position or an independently monitored reference signal, the rational next action is to perform that controlled test rather than inflate the existing inference. If the apparatus cannot be revisited, the report must mark the resulting uncertainty. More intensive

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analysis of an already ambiguous file may be useful, but it cannot necessarily add the missing independent constraint. There are cases where no amount of processor time makes a non-identifiable inverse problem unique.

I therefore propose a conservative acceptance test for any claimed individual-emitter attribution: blinded same-class comparisons, held-out sessions, receiver substitutions, nuisance-condition changes, explicit unknown-source trials, disclosed dependence between features and a clear statement of the resulting error rates. The system should be allowed to return inconclusive. An inconclusive outcome may be the most reliable finding the evidence permits. In an engineering investigation, that restraint directs scarce attention to the next useful experiment; in formal testimony, it prevents descriptive measurements from being misrepresented as proof of someone's conduct. I pass the token respectfully to the remaining peer examinations.

Dr. James M. Atkinson, Moderator: Professor Shannon, Dr. Bracewell has distinguished an observed component from its cause. I invite you to challenge whether information about modulation can legitimately be promoted to information about individual transmitter identity. Dr. Bracewell will respond before the token passes to the next participant.

Claude Elwood Shannon, Peer Question: Dr. Bracewell, suppose an authorised receiver captures a distinctive sequence of bursts, and the analyst discovers a high correlation with a familiar public waveform structure. The result seems impressive, especially when repeated across several captures. Yet the same public structure may be implemented by many physically distinct devices. How should the report distinguish

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information about a waveform family from information about an individual apparatus? I would also ask whether the instrument's own sampling clock or digital filter can create features mistakenly interpreted as hardware fingerprints. If a classifier reports a ninety-nine per cent score for one enrolled unit, what evidence would be required before interpreting that score as a probability that this unit originated the observed emission? Finally, how should the analysis treat an emitter absent from its training catalogue, given that an algorithm forced to choose among familiar labels must nevertheless select one? The underlying issue is whether a numerical result reduces uncertainty about the correct proposition or merely conceals that the proposition was never tested.

Ronald Newbold Bracewell, Response: Professor Shannon, I would begin by writing separate statements on the face of the report. The first says that the observed samples are consistent with a specified waveform structure under a documented processing model. The second, which remains to be established, asks whether the waveform structure differs between members of the relevant physical population. An ordinary publicly specified modulation or preamble may be shared by every compliant device. Detecting it can be decisive for the waveform-family question while adding almost no information about a particular serial-numbered transmitter. The report should not be permitted to change its subject without an intervening experiment.

That experiment must include physically different units of the same type, recorded through sufficiently varied equipment and channels to identify whether the feature follows the transmitter. A clock line at an offset from a nominal carrier is not necessarily attributable to the external unit; it may

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reflect the receiver oscillator, a shared frequency reference or a resampling convention. Replacing the receiver, altering the reference and introducing a known laboratory source can challenge those alternatives. If the apparent signature changes with receiver substitution, the attribution claim should be revised. Reproducibility of a displayed trace under one fixed configuration establishes very little about which component in the chain created its distinctive details.

A classifier score is also not automatically a posterior source probability. Its numerical scale may be a software similarity, a normalized distance, an uncalibrated neural output or a probability conditioned on a closed universe of training labels. To interpret it as P(unit A given observations), the analyst would need a defensible model of the source hypotheses, the conditional feature distributions and appropriate prior information. The relevant alternatives must include unknown and closely similar units, not merely a few artificially different references. In formal testimony, it may be better to report the measured score together with validated false-attribution performance than to express a posterior probability the evidence cannot support.

Finally, the unfamiliar-source case must be tested, not treated as a hypothetical afterthought. In a blind trial, the operator should present transmitters never used in feature selection, training or threshold adjustment, then observe whether the system rejects them at an established operating point. The result may be a descriptive match, a class-level conclusion or an inconclusive answer. Those are legitimate outcomes. A system that never abstains can look decisive while being structurally unable to recognize its own ignorance. The technician should state the

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highest evidential level reached and leave the identity of an operator or owner to separate, independently corroborated investigation.

Dr. James M. Atkinson, Moderator: Professor Tukey, please examine whether the laboratory's impressive sample count may actually consist of correlated representations of a very small number of independent RF capture sessions. Dr. Gabor will answer the methodological challenge.

John Wilder Tukey, Peer Question: Dr. Gabor, an analyst presents a validation report containing fifty thousand spectrogram crops, claiming this enormous dataset supports very high accuracy in identifying ten devices. Upon inspection, the crops were taken from a few continuous recordings, and neighbouring crops share both samples and the same channel state. Some captures from one session appear in the training data while other crops from that same session appear in the test data. What makes the resulting headline accuracy unreliable? Would stratifying randomly by device label, rather than by capture session and receiving chain, solve the problem, or does it preserve a dependence the published table disguises? I also ask what the proper unit of analysis should be when the purported claim is recognition of a previously unseen transmitter in a different building. If the committee has only two receiving environments and a handful of same-class devices, how should it acknowledge the narrowness of the experimental claim without simply discarding the observations? An exact numerical statistic is useful only when its denominator represents the relevant independent opportunities for error.

Dennis Gabor, Response: Professor Tukey, the problem is not that the analyst employed a large computational dataset. It is that the dataset's apparent size was mistaken for the size of the independent evidential

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experience. Adjacent spectrogram crops may share most of their raw samples and nearly all of their acquisition conditions. If one capture session contributes to both training and testing, a model may recognize local channel coloration, receiver gain, interference patterns or a transient calibration state. The classifier can then achieve extraordinary accuracy at recognising familiar conditions without learning a feature that belongs uniquely to the emitter. The resulting accuracy is valid, at best, for the narrower task of classifying similar fragments from familiar sessions; it is not a tested estimate of performance in a new building.

Random stratification by device label alone does not break that dependence. The entire acquisition session, together with derivatives from that session, should remain in one partition when the target claim concerns new sessions. Where the claim reaches across receivers or locations, those domains must also be represented in the held-out design. A feature extractor tuned using information from the held-out recordings can leak test knowledge even if the final classifier was trained on separate files. Therefore the laboratory must freeze preprocessing, feature selection and threshold choices before inspecting its final evaluation set, and it should record every dependency between derived windows and original captures.

The proper unit of analysis follows the question. For a demonstration that the same observed waveform can be recognized within one file, a frame-level score may be informative. For identification of a transmitter on a different day, the session or device-day may be a more appropriate test unit. For transfer to unfamiliar receiving equipment, an independently held-out receiver is essential. Confidence intervals based upon tens of thousands of correlated windows are not justified by the nominal frame count. Cluster-

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based uncertainty or session-level summaries better reflect the variation that affects the actual forensic proposition.

A small study need not be concealed or discarded. It can supply exploratory evidence, reveal useful controls and motivate a better experiment. The report should identify the number of independent devices, sessions, receivers and environments and describe the observed performance within those boundaries. It should also show whether the model can abstain on truly novel devices. If two environments were tested, the laboratory should not assert robust performance across all industrial sites. The honest result may be that the candidate feature is repeatable in the present apparatus but remains unvalidated under the changes required for field attribution. This limitation makes the next experiment obvious and prevents attractive graphics from pretending to deliver statistical independence.

Dr. James M. Atkinson, Moderator: Dr. Hamming, let us challenge error-correcting codes and other regular digital structures as possible sources of false individuality. Sir Martin will answer whether waveform regularity alone is sufficient to locate or name a physical emitter.

Richard Wesley Hamming, Peer Question: Sir Martin, many transmitters implementing one communications family share coding constraints, synchronization sequences and repetitive frame structures. An investigator may recognize one of these patterns with remarkable reliability and conclude that it reveals a distinctive device. Yet such regularity might belong to the protocol or modulation chain rather than to a particular unit. How should the laboratory test the difference, particularly when the receiver and its software can introduce repeated patterns of their own? If direction-finding measurements appear to point to one part of a building, may the

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analyst combine that spatial result with the strong protocol match to announce one identified emitter? I am also troubled by the possibility that a common oscillator distribution to multiple receivers creates correlated phase behaviour, falsely suggesting coherent spatial confirmation. What independent observations would justify the spatial claim, and how should the findings be worded when propagation ambiguity or remote antenna feeds remain plausible? I invite an answer that distinguishes detection, source location and device individuality.

Sir Martin Ryle, Response: Dr. Hamming, a coding pattern or synchronization structure can establish useful signal-family information, but a feature deliberately shared by many transmitters is a poor candidate for individual identification. The laboratory should compare multiple physical units using identical public coding and modulation settings. If they produce nearly indistinguishable patterns, the common feature must be reported as class-level evidence. If an additional analogue imperfection appears distinctive, that imperfection requires its own controlled tests across operating states and channels. The correct analysis preserves the distinction between a signal generated according to a common standard and an idiosyncrasy measured from one particular physical circuit.

A spatial measurement is another independent proposition. A calibrated bearing, arrival-time difference or array phase estimate can constrain the direction or location of radiated energy under specified geometry and propagation assumptions. It does not generally reveal the identity of the oscillator, processor or operator that supplied that energy. A remote antenna connected by cable makes the distinction plain: the radiation may emanate from the antenna position while the generating equipment sits

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elsewhere. The report must say whether it locates a radiating aperture, an apparent arrival direction or an inferred transmitter location. These are related but not identical quantities.

Common reference distribution can also induce deceptive agreement. Two receivers sharing a faulty clock may show correlated phase changes that are wrongly attributed to a common external source. Likewise, antennas connected through shared nonlinear stages can display coincident spurs. An independent receiving chain with a distinct reference, a controlled laboratory source and deliberate changes of antenna geometry can challenge those confounds. A multi-site result is stronger when its geometry, timing reference and systematic error sources are measured, not merely when the number of plotted traces increases. The analyst should identify which correlations arise from shared apparatus and which remain after the independent controls.

If direction finding indicates a region consistent with the waveform detection, the defensible statement is that multiple observations are compatible with an emission arriving from that region, within disclosed uncertainty. Further comparison may support a device class or a particular unit, but only if the class-level and individual-level evidence has actually been obtained. A visually convincing intersection of bearings should not be promoted into an assertion about serial number or ownership. When multiple reflected paths or the near-field environment prevent unique localization, report the competing regions or explanations. The appropriate experiment is to relocate the controlled source or receiving antenna, not to eliminate the inconvenient alternative by description.

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Dr. James M. Atkinson, Moderator: Sir Harold, please examine the distinction between probabilities assigned under a model and the much stronger proposition that a named physical unit must have transmitted. Dr. Slepian will answer with the limits of likelihood reasoning and hypothesis specification.

Sir Harold Jeffreys, Peer Question: Dr. Slepian, suppose the laboratory has estimated a likelihood ratio for a feature vector under the propositions that one known transmitter generated the recording and that a source from a selected reference population generated it. The reported ratio favours the known unit by a substantial factor. Yet the reference population consists of devices chosen for convenience, and the model assumes that oscillator and channel features are independent although they were measured through a common receiver. Does the numerical ratio establish the probability that the known transmitter actually produced the event? What effect would a larger or differently constituted reference population have, and what is the proper statement when the real-world candidate source could be completely absent from the enrolment collection? I ask also whether a prior probability may be inserted from the investigator's suspicions without openly changing the inference. In court, the distance between an evidential likelihood comparison and a posterior claim about an individual source is not merely semantic; it can determine whether an equivocal measurement sounds conclusive.

David Slepian, Response: Sir Harold, a likelihood ratio is conditional upon both propositions and the models by which the conditional probabilities are estimated. It compares the observed evidence under H1 with the observed evidence under H2; it does not, by itself, state P(H1 given the evidence). To

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obtain a posterior proposition probability, one must introduce prior odds and an adequate hypothesis space. These requirements cannot be bypassed by reporting a large numerical value. If the alternative population is artificially narrow or excludes physically similar devices, the ratio may be impressive yet poorly relevant to the actual question being asked. An unfamiliar unit, omitted from both development and validation, is precisely the kind of alternative that challenges the model.

Dependence between features is equally important. If frequency offset and phase drift arise partly from one shared oscillator error, multiplying their marginal likelihoods as though they were conditionally independent double-counts aspects of the same evidence. Calibration uncertainty in the receiver may affect several features together. A model must represent the joint behaviour or justify an approximation experimentally. Otherwise, the polished ratio is a calculation under false premises. The appropriate response is not to remove the mathematics but to document the assumptions, obtain independent challenge measurements and report how the value varies when reasonable alternative models are used.

The reference population should match the actual scope of the proposition as far as the available data permit. Same-class units, manufacturing variation, operating conditions, receiver architectures and environmental effects should be represented. If the question is discrimination among enrolled devices in one laboratory, a restricted population may be adequate for that restricted task. If the finding is intended to identify a device encountered in an open environment, unknown-source rejection and representative alternatives become critical. Without them, a categorical individual attribution cannot be inferred from a closed-set match. The

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system should be permitted to return inconclusive and its rejection performance should be reported.

Finally, prior assumptions should not be smuggled in as if they were measured RF properties. Investigative information may affect which source is considered, but a mathematical report must disclose which assumptions came from circumstances outside the recorded waveform. The RF specialist may provide a carefully bounded evidential comparison, leaving ultimate attribution, ownership or legal culpability to the fact-finder with other independent evidence. A clear report would show the hypotheses, feature definitions, reference population, model dependencies, validation error rates and sensitivity to plausible alternatives. In the absence of a justified probability model, a qualified statement of similarity and its limitations is better than an unjustified percentage. Evidential restraint is not avoidance of analysis; it is the consequence of knowing precisely what the analysis can and cannot estimate.

Dr. James M. Atkinson, Moderator: Dr. Neyman, please test the claimed error rates of an individual-emitter classifier and the difference between prior development data and genuinely independent evaluation. Professor Blackwell will respond with the appropriate decisions when the evidence is equivocal.

Jerzy Neyman, Peer Question: Professor Blackwell, a laboratory reports that its system correctly named 980 of 1,000 labelled spectrogram excerpts, and it announces a two per cent misidentification rate. The excerpts, however, came from ten long recordings of only five physical transmitters, all observed on one receiver. Its threshold was selected after inspecting the same excerpts, and it has no rejection category for an unfamiliar

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transmitter. Is the quoted error rate a meaningful bound upon the chance of naming the wrong individual device in a future field investigation? What should the experimental unit be, and how should the validation sequence separate feature discovery, threshold selection and final performance estimation? I am especially concerned about a system that reports strong average accuracy while repeatedly misclassifying one particular device or performing poorly under changed temperature. Could a technically sound report disclose such heterogeneity without treating every observation as a failure? I ask for a design in which the planned claim and tested error rates occupy the same population and operating conditions.

David Harold Blackwell, Response: Dr. Neyman, the two per cent number describes errors among the 1,000 excerpts under the experiment actually performed; it does not by itself estimate a future open-world individual-attribution error rate. The excerpts share a small number of devices, sessions and receiver conditions. If the model uses acquisition-specific properties, all the cropped excerpts from one session may be easy to classify while the same physical unit recorded elsewhere appears unfamiliar. Counting correlated crops as independent opportunities for error creates spurious precision. Moreover, a threshold selected by inspecting the test outcomes has been optimised to those same outcomes. Its reported validation rate cannot be represented as a wholly independent prospective performance estimate.

An appropriate design starts by specifying the intended use. If it concerns identifying enrolled devices recorded on a different date, the laboratory should hold out complete recording sessions and vary relevant operating states. If it concerns new receiving equipment, whole receivers should be

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held out from model selection. If it concerns unfamiliar physical units, a separate unknown-source set must be assembled, and a rejection operating point declared before final testing. The report should distinguish class-level classification from selection among enrolled individual units and should provide the confusion matrix for each stage. It should also include the number of physical transmitters, receiver chains, days and environmental settings, not merely the total number of windows.

The design should have distinct phases. Exploratory data can be used to discover features and candidate thresholds. A development set can select a fixed decision policy, including the reject option. A final independently collected set then evaluates that frozen policy. If the analysts adjust the threshold after seeing final test results, those data have become development data and a new final challenge is needed. The laboratory ought to preserve code versions, configuration manifests and randomization procedures so the distinction is not merely asserted. Errors should be presented by unit, session and receiver because average performance can conceal one catastrophic confusion pair.

A confidence interval is meaningful only when its construction and sampling assumptions match the experiment. The analyst should not put a conventional binomial interval around 1,000 correlated crops while describing it as uncertainty about field attribution among unknown units. Where the evidence is too small to estimate a low false-attribution rate with useful precision, that limitation should be declared. The system may remain useful for triage or narrow laboratory comparisons. It should abstain rather than force an individual name when the relevant validation is absent. Good statistical design is not a way to avoid decisions; it is the means of ensuring

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that the consequences of decisions are matched to evidence actually gathered.

Dr. James M. Atkinson, Moderator: Mr. Armstrong, please test the physical origin of apparent emitter-specific imperfections, including oscillator products, analogue overload and receiver-generated spurs. Dr. Bracewell will respond with an independent-source challenge programme.

Edwin Howard Armstrong, Peer Question: Dr. Bracewell, imagine an apparent device fingerprint consisting of several narrow lines and a characteristic transient. The analyst first observes it with a sensitive front end at high gain, then finds similar details on later recordings from the same receiver. A confident report assigns the lines to defects in one transmitter. How would you challenge the possibility that they arise in the receiver itself through local-oscillator leakage, mixer nonlinearity, adjacent strong signals, quantisation artefacts or power-supply coupling? The concern is especially acute when all known device references were gathered with one measurement chain and no direct source monitor. Would changing the input attenuator, preselector, aerial or oscillator reference help locate the origin of the apparent fingerprint? How should a laboratory distinguish a genuine physical dependence from a diagnostic coincidence, and what must be said if the feature remains stable yet its source cannot be isolated? Please keep the test within authorised laboratory signals and avoid treating an attractive spectral display as proof of an individual emitter.

Ronald Newbold Bracewell, Response: Mr. Armstrong, the first exercise is to formulate competing hypotheses about the physical location of the feature. Under one, the candidate transmitter produces the relevant distortion. Under another, the receive chain creates it when driven by an external but

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otherwise unremarkable signal. Under a third, it arises from another environmental source coupled into the measurement setup. We then design substitutions that affect these hypotheses differently. If a spectral line changes in a non-proportional manner when input attenuation is inserted before the receiver's nonlinear stages, that behaviour can suggest an internally generated product. The exact interpretation requires knowledge of which stage the attenuator precedes and the relevant gain state.

An independent receiver with its own reference oscillator is a valuable control, as is comparison with a known laboratory reference transmitter through the same antenna path. Switching to an appropriate termination under safe conditions can challenge whether a peak is entering by the antenna port, although a terminated input does not eliminate every possible internal or environmental coupling route. Preselection may suppress out-of-band strong inputs which generate intermodulation. Moving the antenna may alter an actual external field and can also change coupling to nearby wiring. These controls should be performed in a planned sequence with configuration and timestamps recorded, not opportunistically until one result confirms the preferred explanation.

We must also distinguish a diagnostic indicator from a proof. A spectral component that shifts with the receiver reference clock is evidence that the chain's frequency reference participates in its apparent position. A component that vanishes when the suspect transmitter is switched off under a controlled test becomes more consistent with that transmitter's involvement, but may still be a receiver-generated product driven by its emissions. The laboratory may need independent analogue monitoring or a receiver with a different architecture to distinguish those possibilities. Its

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conclusion should state which alternatives were eliminated and which remain. An actual external input can cause an internal artefact; those two descriptions are not mutually exclusive.

Finally, the purported signature should be challenged by substituting multiple same-class transmitters under the same conditions. If the same distinctive line appears for all of them, it is likely to be a common source-chain or design feature rather than a reliable individual marker. If the lines differ, the variation still must survive receiver substitution, temperature changes, altered gain and a held-out test set. A stable fingerprint within one receiver configuration is an observation requiring explanation, not an automatic serial-number identification. Report the controls, raw authorised samples, calibration state and uncertainty, and refuse any move from an RF comparison to a claim about the identity or intention of a human operator without separate evidence.

Dr. James M. Atkinson, Moderator: Admiral Hopper, please now examine the evidentiary record that connects a classifier output with the exact acquisition and processing operations on which it depends. Dr. Slepian will answer how software provenance affects statistical inference.

Grace Brewster Murray Hopper, Peer Question: Dr. Slepian, consider two laboratories analysing the same authorised I/Q capture. They agree on the file's byte digest yet arrive at different individual-transmitter labels. One used a version of the processing code that automatically corrected carrier offset, while the other used an earlier version that did not. Their I/Q manifests also disagree about whether samples were stored as interleaved signed integers or normalized floating-point values. Could both results be reproducible within their own software environments without either

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constituting reliable source attribution? What minimum record would permit a third examiner to reconstruct the distinct analyses and discover why they disagree? I ask also how a programme should distinguish a transformation that changes the underlying sample values from one that changes only their representation, and how its acceptance test should treat missing or truncated records. A cryptographic digest can preserve a mistaken interpretation with perfect fidelity. How should such provenance limitations be exposed within the evidential hierarchy before an apparently numerical device match reaches a tribunal?

David Slepian, Response: Admiral Hopper, byte-level integrity and interpretive validity are separate predicates. A cryptographic digest over an explicitly identified file can support a claim that a later byte sequence matches the preserved reference sequence, assuming appropriate integrity protection of the digest and custody records. It does not establish the correctness of the sample-format description, clock, receiver calibration or analysis code. The two laboratories may both reproduce their respective computations exactly while applying different mathematical operations to identical bytes. Their disagreement is not a contradiction in file integrity; it is a difference in interpretation and potentially in the quantity each algorithm estimates.

The third examiner needs an acquisition manifest that specifies sample packing, byte order, signedness, channel interleaving, sample rate, centre frequency and receiver state, together with the clock reference, data-loss flags and calibration information. Each analysis needs its own immutable reference to the input object, exact software version, dependency versions, processing parameters, feature definition, classifier build and decision

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threshold. A saved screenshot is inadequate because it does not specify the numerical path from input samples to result. Where a pipeline changes the content through resampling, filtering or truncation, the derived file should have a new identifier and digest, linked to the preserved original and its transformation record.

Repackaging is not equivalent to changing samples. If numerical samples are preserved while an archive wrapper or file header changes, the hash of the complete container may differ even though the sample sequence is numerically equal. Conversely, byte-identical data interpreted with swapped I and Q or a different endianness can produce entirely different physical conclusions. The laboratory should distinguish byte equality, numerical sample equivalence and interpretive equivalence. Missing data must be represented as missing, rather than silently padded or concatenated into an apparently continuous timeline. A classifier's feature vector may be very sensitive to such interventions and should be rejected as an attribution basis when the provenance does not establish that its assumptions were met.

The acceptance test should include known laboratory input files with controlled sample formats, deliberately wrong manifests, isolated single-bit changes, missing buffers and software-version substitutions. Expected outputs should be fixed in advance for both valid and invalid cases, with explicit tolerances for permitted floating-point differences. The system should not be considered trustworthy merely because it returns the same wrong label consistently. Only after the processing path is reproducible and its measurement assumptions are validated can statistical source comparisons be interpreted. Even then, the individual-device inference requires an adequate population of same-class alternatives and unknown-

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source rejection. Software provenance permits the expert to defend how a result was obtained; it does not add information that the RF observations never contained.

Dr. James M. Atkinson, Moderator: We proceed to reciprocal examination among the five principal specialists. Each challenge is directed to a distinct colleague and is followed immediately by that colleague's substantive response. Dr. Gabor has the token first.

Dennis Gabor, Cross-Peer Question to Ronald Newbold Bracewell: Dr. Bracewell, your inverse-problem argument identifies many possible causes for a single observation, but an analyst may respond that a highly resolved time-frequency trace contains so much apparent detail that uniqueness ought to follow. Suppose we have a brief captured transient with a complicated ridge pattern which appears stable over many repeated frames in one laboratory. How would you determine whether that complexity supplies independent constraints on source identity or merely reflects a stable receiver impulse response, multipath and display processing? What would a deliberately varied acquisition experiment need to show before you would accept that a detailed trace distinguishes one physical unit from others of its class? I ask also about the risk that reprocessing the same retained samples with several window functions creates a false impression of multiple independent confirmations. A rich representation may reveal more of a record, but does it create new observations of the world? The issue is central to whether apparent precision is legitimately translated into individual attribution.

Ronald Newbold Bracewell, Cross-Peer Answer to Dennis Gabor: Dr. Gabor, increasing the number of computed descriptors does not necessarily

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increase the number of independent physical constraints. Several time-frequency images may be mathematical transformations of precisely the same finite record, inheriting the same receiver response, propagation path and missing-data limitations. They may expose different aspects of one observation but they cannot be counted as separate independent experiments. If the analyst selects the representation which most dramatically separates known devices, the selection itself is part of the exploratory fitting procedure and must be tested on new data. Otherwise the claimed uniqueness has been manufactured in part by adaptive choice of view.

I would seek a factorisation of the observation chain. The emitted field travels through a channel and receiver whose responses can each leave a distinct signature. A transient ridge may be the convolution of the transmitter's turn-on behaviour with filter group delay and time-varying channel effects. To assign it to the transmitter, the laboratory must vary the receiver and channel deliberately while keeping the same physical unit, and then vary the physical unit while keeping matched observation conditions. A distinctive pattern should persist sufficiently under the former substitutions and discriminate adequately under the latter. Both performance dimensions require numerical criteria declared in advance, not an after-the-fact impression that the plots remain recognisable.

The independent-source test should include nominally identical transmitters and a holdout population, not only different waveform families. The analyst should also look for a counterexample in which an unfamiliar source causes a similar ridge. A sufficiently flexible receiver or feature extractor can make unrelated events look alike under some projection. Conversely, ordinary

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thermal drift or antenna loading may make the same unit look different. These are not philosophical curiosities; they determine the false-attribution rate. A good result reports within-unit variability, between-unit confusion and the proportion of unfamiliar sources rejected at a fixed operating point.

Finally, rich representation must not be mistaken for independent corroboration. Two transforming algorithms operating on one file are useful for sensitivity analysis; they are not two receivers observing the field. A truly independent receiving chain, a physically changed antenna path or a newly recorded blind trial can challenge the assumed source origin of a feature. Even when a waveform is unique within the observed reference set, the universe of possible emitters may be larger. I would therefore accept a bounded conclusion: the trace discriminated the tested units under the specified conditions. I would not accept an unrestricted claim that no other physical transmitter could produce it unless an extraordinary and well-supported universality argument were available.

Dr. James M. Atkinson, Moderator: Sir Martin, the token passes to you for the second reciprocal examination, directed to Dr. Slepian.

Sir Martin Ryle, Cross-Peer Question to David Slepian: Dr. Slepian, suppose a spatial array yields an apparently precise bearing and the signal processor simultaneously produces a strong classification score for one enrolled transmitter. An investigator may treat these as independent strands of evidence and multiply their estimated likelihood contributions. But the bearing estimate and the classifier features came from the same I/Q samples, shared receiver clocks and the same multipath environment. What conditions would justify multiplying the values, and how should a report account for the covariance if those conditions are not met? Would physically

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separate antennas with a shared reference be sufficient, or must the experiment demonstrate independence of the relevant error mechanisms? I am also concerned that a directional result may identify a radiating aperture while the classifier attempts to name a baseband device connected to that aperture by a feedline. How can the statistical model avoid joining propositions about different physical objects and then presenting the result as if they describe one uniquely identified transmitter?

David Slepian, Cross-Peer Answer to Sir Martin Ryle: Sir Martin, multiplying likelihood contributions requires a defensible factorisation of their joint conditional distribution under the competing propositions. If E1 denotes the bearing evidence and E2 the classifier features, the simple product P(E1 given H) times P(E2 given H) is justified only when their conditional independence is established or is an adequately supported approximation under the model. The use of the same I/Q file, clock or propagation path makes such an assumption questionable. One may instead model P(E1,E2 given H) directly, or use a conditional factorisation P(E1 given H) times P(E2 given E1,H). The second form reminds us that correlations cannot be wished away by placing the findings in separate chapters of a report.

Calibration and geometry matter just as much as the algebra. A shared reference clock may induce correlated phase errors in the bearings and in frequency-derived fingerprint features. A reflected arrival path may shift the apparent direction while also changing the transient waveform. An environmental disturbance could therefore improve both apparent matches simultaneously under one wrong source hypothesis. The laboratory should create authorised reference trials that vary source position, antenna orientation, receiver architecture and reflection conditions, then measure

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the dependence of the two statistics. Those empirical observations inform whether separate contributions can reasonably be combined and how large their residual correlation may be.

We must also ensure the propositions describe the same object. A measured arriving field can be associated with a radiating antenna, while a proposed source fingerprint might be associated with a transmitter's oscillator or power amplifier. A remote feed or repeater separates those physical entities. A bearing that constrains the location of the antenna cannot automatically establish the identity of a processor at the other end of a cable. If the inferential chain requires a physical connection between them, evidence of that connection must be obtained independently and entered as a stated assumption or observed fact. Statistical multiplication cannot substitute for missing engineering evidence.

An expert presentation should therefore show the bearing estimate with its assumptions, the waveform-class or device-comparison evidence with its own validation, and a clearly labelled combined inference only if the joint model has been examined. If not, the report may state that the findings are mutually compatible without assigning an exaggerated combined probability. A qualitative statement of consistency is not the same as independent corroboration. Where an omitted alternative such as a second same-class transmitter or an unobserved reflected path changes the conclusion materially, that alternative belongs before the reader. Scientific care consists in identifying the limits of combination, not in using multiplication to produce a falsely impressive result.

Dr. James M. Atkinson, Moderator: Professor Blackwell, the third reciprocal question is yours, directed to Dr. Gabor.

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David Harold Blackwell, Cross-Peer Question to Dennis Gabor: Dr. Gabor, a defensively deployed classifier must sometimes decide whether to issue an immediate warning, defer a conclusion or retain more samples for later review. Its representation might include a compressed spectrogram that preserves prominent energy but omits weak transient phase details. If the operator then seeks individual-emitter attribution, the omitted information may become essential. How should the laboratory distinguish an efficient operational representation from one sufficient for a later evidential claim? What tests would you require before using a reduced representation to name a unit, and how would you treat a false sense of certainty produced by a model which was calibrated on uncompressed source recordings but evaluated after aggressive preprocessing? There is also a lawful-evidence problem: keeping everything indefinitely is not a general answer. Can the decision policy preserve only justified material while remaining candid about the questions that irreversible transformations will make impossible to answer later? Please connect these technical limitations to the decision to abstain.

Dennis Gabor, Cross-Peer Answer to David Harold Blackwell: Professor Blackwell, the required representation follows the proposed inference. A low-resolution occupancy display may suffice to answer whether energy above a validated threshold was observed in a band during specified intervals. It may not retain the timing, phase or transient information needed to discriminate physical transmitter units. The laboratory should therefore define an evidential question before declaring a derived representation sufficient. If its data reduction discards information relevant to that question, no degree of confidence from a downstream classifier can

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recreate the lost physical evidence. A model may still produce a label, but the label's evidential value must be validated for the reduced observation actually supplied.

I would test at least three recording paths in a controlled laboratory. The first preserves authorised original I/Q samples with a complete format and timing manifest. The second applies a documented reversible transformation, allowing exact recovery of the sample sequence. The third applies the proposed irreversible processing. The same blind transmitter trials are then analysed through all three paths at frozen classifier settings. The performance comparison must include class confusion, individual-unit error and unknown-source rejection across changed channels and receivers. It should show not only mean accuracy but which false identifications increase after reduction. If a feature is removed and the system nevertheless outputs a strong score, that score should be examined as a possible artefact of an inappropriate calibration model.

The operational and forensic roles may have different preservation requirements. A live alarm might reasonably use a transient summary and retain no communication content, while a narrowly authorised forensic investigation may require a protected sample excerpt and sufficient metadata to challenge a particular physical inference. Those choices demand legal authority, proportionality and retention controls, not merely technical enthusiasm. Where preservation is impossible or unjustified, the system can report the observation at the level still supported. The conclusion should never pretend that a lost phase record remains available for verification simply because its former spectrogram is visually persuasive.

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Abstention is then a rigorous action. The classifier can say that the observed reduced data support a broad waveform-family classification but do not retain sufficient information for individual-device comparison. It can also request a properly authorised future controlled capture if circumstances permit. That is preferable to forcing a serial-number label under an information deficit. The record should identify the transformation, its irreversible losses, the validation domain and the scope of inference. A responsible engineer describes what the apparatus observed and what it can no longer test. In that sense, careful information minimisation and careful evidential inference can coexist, provided neither is used to conceal the limitations created by the other.

Dr. James M. Atkinson, Moderator: Dr. Slepian, the final reciprocal examination is directed to Professor Blackwell and concerns open-set risk and the decision to stop short of attribution.

David Slepian, Cross-Peer Question to David Harold Blackwell: Professor Blackwell, imagine a classifier validated on a small catalogue of known transmitters, showing excellent ordinary accuracy but weak rejection of previously unseen same-class units. In a genuine investigation the source population is unknown, and the operator is tempted to select the highest-scoring enrolled device as an investigative shortcut. How should the decision rule respond when the cost of falsely naming a physical unit is large, and the prevalence of unknown devices cannot be estimated with confidence? Would raising the score threshold necessarily solve the problem, or might it simply trade one form of error for another without changing the incomplete hypothesis space? I ask also how a laboratory should separate the instrumental result from any subsequent statement

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about a human owner or operator. If the system can issue a narrow warning, an inconclusive device comparison or a strong validated source comparison, what predeclared evidence would justify each action? Please describe how the rule should be audited without using the questioned case as its own validation material.

David Harold Blackwell, Cross-Peer Answer to David Slepian: Dr. Slepian, a rational decision rule must operate over an explicitly defined action set, including the option to refrain from individual attribution. If the unknown-source population is inadequately represented, the laboratory cannot infer a reliable open-world false-attribution rate merely from success among enrolled units. Raising a threshold may reduce some false accepts at the cost of rejecting genuine known units, but it does not expand the model's universe of alternatives or repair a biased reference population. The resulting tradeoff must be measured with previously unseen physical sources, preferably including close same-class alternatives under varied receivers and channels. Without such tests, a very high score may remain a statement about relative similarity within an incomplete catalogue.

The consequences of an error determine how cautiously the system should act, but they do not change what the measurement has established. A low-cost operational alert can trigger another lawful measurement when the waveform is unusual. A class-level report can identify the closest validated signal family while flagging uncertainty. A claim that one individual unit transmitted requires a much stronger experimental basis: blinded same-class trials, held-out sessions, cross-receiver robustness, independent corroboration where available and a characterised unknown-source rejection policy. The expert should state which policy was used and the

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observed error rates under its tested conditions. It must not borrow error rates from an earlier, less demanding classification task.

The human inference is still a different proposition. Even reliable identification of a physical transmitting unit would not, by itself, establish who operated it, whether the operator knew its state, whether the emission was intentional or whether any rule of law was violated. Those issues require other evidence and appropriate legal assessment. The RF specialist's contribution is to explain the observed signal, the device-comparison evidence and the limitations of the source inference. The decision-maker evaluates any further association with people. A report should not smuggle in that association through phrases such as 'the suspect transmitted' when the apparatus merely detected energy consistent with one tested equipment class.

Finally, the evaluation must be independent of the disputed observation. The laboratory should freeze the classifier architecture, preprocessing, score threshold, unknown-source policy and acceptance criteria before analysing the final blind test set. If the case evidence prompts a redesign, the resulting method must be evaluated again on new material. Preserve the chain of custody of the authorised I/Q samples, the code revisions and the reference-data register so that a reviewer can determine exactly which claims the validation supports. A system which says 'inconclusive' where evidence is inadequate may be more useful and trustworthy than one which always offers a name. Prudence is not hostility to engineering progress; it is the decision-theoretic consequence of acknowledging the cost of an unsupported identification.

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Dr. James M. Atkinson, Moderator: I thank Dr. Bracewell, Dr. Gabor, Sir Martin Ryle, Dr. Slepian, Professor Blackwell and the peer contributors for a disciplined distinction among observation, waveform detection, device class and individual-source comparison. The token now returns to the manuscript's editorial register. This discussion is explicitly fictional and should not be represented as genuine recorded statements of the historical scholars. Its citations support background scientific propositions only, pending full source-to-claim verification.

SCHOLARLY RECONSTRUCTION AND REFERENCES. This is an explicitly fictional, modern moderated educational dialogue assigning hypothetical arguments to deceased historical specialists. It is not a record of an actual meeting, nor a source of authentic quotations. Selected scientific and forensic background: NIST SP 800-86, Guide to Integrating Forensic Techniques into Incident Response (2006), https://csrc.nist.gov/pubs/sp/800/86/final ; NIST, Evidential Statistics, https://www.nist.gov/spo/forensic-science-program/forensic-science-research/evidential-statistics ; UK Forensic Science Regulator, Forensic Science Activities: Interpretation and Communication, https://www.gov.uk/government/publications/forensic-science-activities-interpretation-and-communication-fsr-gui-0004/forensic-science-activities-interpretation-and-communication-accessible ; IEEE Access, Toward Practical Radio Frequency Fingerprinting: A Survey of Real-World Challenges and Mitigation Techniques (2026), DOI 10.1109/ACCESS.2026.3726615. These references support general methodological context and have not undergone a complete independent claim-by-claim Stage-B review.

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EDITORIAL QUALIFICATION. All examples, transmitter populations and performance quantities in Question 099 are invented pedagogical conditions, not measurements of unidentified sources. Detection does not establish emitter class; class does not establish individual unit; individual unit does not establish an operator or unlawful act. This Stage-A reconstruction is not publication ready. Source-to-claim traceability, factual and historical review, legal jurisdiction review, whole-manuscript cross-reference reconciliation, and continuous final pagination remain outstanding.

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QUESTION 100

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When does a finite negative technical-surveillance survey provide useful assurance?

Dr. James M. Atkinson, Moderator: Sir Harold, a technical surveillance countermeasures survey may conclude without recording any emission that meets its detection and classification criteria. A client may be tempted to interpret this as proof that no relevant transmitter existed. Please distinguish the bounded assurance supplied by a negative observation from an assertion of universal absence. In particular, consider the instrument's validated sensitivity, antenna and polarisation coverage, duty cycle, receiver blind intervals, alternative methods of signal transport, and the requirement that an emitter be active and observable when surveyed. Address the statistical assumptions underlying any claimed probability of miss. When the evidence does not support an exclusion statement, explain what may nonetheless be reported responsibly.

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Sir Harold Jeffreys, Principal Contributor: Dr. Atkinson, the negative result is an observation about an experiment, not a certificate of universal non-existence. We first ask what the experiment was capable of observing. A receiver operates through an antenna pattern, filters, amplification stages, conversion and decision criteria which together define an envelope of frequency, time, amplitude and waveform behaviour. If a signal could not reach the antenna, lay outside the occupied band, occurred during an interval when no samples were acquired, or remained below the validated sensitivity under actual site conditions, its absence from the output is unsurprising. That fact cannot establish the absence of the source. The survey's value comes from the care with which the observable region was defined and challenged.

The inferential proposition requires exact wording. One hypothesis might state that a specified reference emitter, operating at a known minimum field strength and repeating a particular waveform within the monitored interval, was present in a given area. Another might state that this reference condition was not present. A calibrated search can provide evidence relevant to those competing propositions when its receiver coverage and detection probabilities have been tested. The statement 'there is no transmitter in this building' is incomparably broader, embracing unpowered, shielded, bursty, frequency-agile and entirely unknown mechanisms. That declaration would require assumptions so extensive that a finite receiver survey could not generally substantiate it.

We should not mistake a quoted noise floor for a universal detection limit. The ability to distinguish a known waveform at a particular receiver input depends upon its bandwidth, duration, threshold, interference environment

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and processing method. A continuous narrowband reference might be obvious where a millisecond burst at the same peak level is missed by a scanning receiver. A wideband pulse may distribute its power across a bandwidth larger than the selected resolution bandwidth. A signal arriving at an antenna null can be weaker at the receiver than one transmitted at a much lower power along a favourable path. The instrument therefore needs a documented measurement and challenge protocol, not only a catalogue sensitivity figure.

Timing deserves separate treatment because a negative search occurs over a finite observation schedule. The survey record should preserve precise start and stop times, tuner positions, residence times, retune gaps, equipment faults and validated sample continuity. If the receiver visits one frequency band for a brief dwell and then departs, an emitter activated only during the absence may not be observable. A detector cannot infer a missed event's presence from the appearance of silence in an empty file. Nor may the operator count a host-computer timestamp as evidence of uninterrupted ADC capture without hardware or counter support. The observability envelope must be reconstructed from actual acquisition records rather than the intended scheduling programme.

A numerical probability of miss requires an explicit event model. Suppose an authorised laboratory beacon is known to be active in ten independent test opportunities, and each opportunity offers a documented sixty per cent chance of detection under fixed conditions. Under the narrow assumption that the Bernoulli trials are independent and the detection probability remains constant, the probability of ten consecutive misses is four-tenths raised to the tenth power. That is approximately 0.000105. But this tidy

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figure does not apply if a common antenna defect, an equipment outage or a change in the source activation process affects every trial. A large number of repeated scans can offer little additional assurance when all inherit one unrecognised blind spot. Independence is a physical and operational claim to be justified, not a mathematical ornament.

A more realistic experiment introduces deliberately varied nuisance conditions. The laboratory should activate a reference source at known positions, frequencies, powers and scheduled times, while an independent monitor records its actual activity. The survey instrument is then operated using the same antennas, filters, gain states and processing schedule proposed for the site. Detection and non-detection are compared only for opportunities in which the test source is demonstrably active. Missing samples, receiver overload and alignment errors are recorded separately. The analyst should distinguish the probability of detecting this calibrated class of reference signals from an untested assumption that every possible clandestine emission behaves similarly.

The negative observation may support a valuable operational conclusion even when the universal absence claim is rejected. It may show that no emission meeting the stated criteria was detected during the specified measured opportunities, that the equipment demonstrated sensitivity to controlled reference signals at selected locations, and that specified bands or activation schedules remain unexamined. Such a conclusion can guide further authorised investigation and reduce uncertainty about particular risk scenarios. An honest report may also describe what alternative evidence would materially change the judgement, such as a longer observation

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period, a different antenna, independent wireline testing, or a controlled source-activation challenge.

A second difficulty concerns the prior plausibility of the hypothesis. A negative observation may be more informative where a hypothesised source would almost certainly have produced a measured signal if it existed and operated as described. It is weak evidence where the hypothesised source would rarely be active or observable. The analysis ought not silently assume that a suspicious apparatus must transmit continuously. Nor should the investigator use a favourable prior belief to excuse a missing sensitivity validation. If probabilities are offered, disclose the model, the relevant source population and how strongly the conclusion changes under alternative activation and propagation assumptions. Where those assumptions cannot be established, a conditional qualitative conclusion may be more defensible.

The evidence record and the language of the conclusion must correspond. Hashing a captured file helps to preserve the recorded bytes after a documented acquisition event; it does not prove that every receiver interval was observed, that the clock was correct or that the antenna was properly connected. A complete survey report should include configuration logs, calibration references, coverage tables, controlled source checks, defects discovered during operation and a record of unobserved intervals. The question is not whether a glossy graphical display looks free of peaks, but whether the examiner can identify the exact conditions under which an actual source would have produced a detectable result. The report should be clear enough for an independent engineer to challenge those

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assumptions without being required to accept the operator's confidence on trust.

I therefore advise a form of conclusion that retains the legitimate strength of a negative result while rejecting unsupported universality. The survey found no emission satisfying the declared criteria within the measured frequency, time, geometry and sensitivity envelope; documented reference tests show the system's performance under particular controlled conditions; and specified uncertainties and blind intervals remain. If a client asks whether this proves there is no hidden apparatus, the answer is no. It provides conditional assurance about those source behaviours the survey could reasonably have detected. The next expert should challenge the statistical independence of repeated negative observations and the temptation to treat an unobserved opportunity as a successful failure-to-detect trial.

Peter Elias, Peer Question: Sir Harold, I ask whether the information contained in a negative survey can be evaluated without first identifying the source hypothesis against which that silence is to be read. A surveillance receiver might watch an assigned band continuously, but the hypothesis may concern a source transmitting only in a different band, a source that awakens on an external trigger, or a source whose radiation is attenuated by conductive construction. The same absence of an alarm appears under all three circumstances, although the likelihood of that outcome differs considerably. Would you distinguish a failure to encounter an emitter from a failure to recognise a signal that actually arrived at the antenna? More particularly, how should an examiner describe a demonstration in which the receiver correctly recognises every authorised reference burst but the

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survey schedule overlaps only a fraction of the reference source's possible activity windows? I ask for a principled account of which denominator governs the claimed degree of assurance.

Sir Harold Jeffreys, Response: Dr. Elias, the first question is what the reported evidence conditions upon. Consider the proposition that a reference transmitter belonging to a defined signal family was active during a specified observation interval and coupled into the receive chain above a declared level. Given that proposition, one may estimate the conditional probability that an alarm would occur, taking account of the waveform, antenna, gain state and decision rule. But an assertion about an unknown source also involves the chance that it operated during the observation interval and the chance that its radiation reached the apparatus. Neither quantity is fixed by a successful laboratory threshold test. Their multiplication, or more generally the integration of conditional probabilities over a supported operating model, requires evidence about activation and propagation that a silent waterfall cannot supply.

I would have the report display distinct denominators. The first is elapsed wall-clock survey time; the second is verified acquisition time in the relevant frequency and configuration; the third is the set of known source-active reference opportunities; and the fourth, where justified, is the subset of those opportunities that genuinely met the predeclared signal-input conditions. These sets are related but not interchangeable. A twenty-minute recording can contain three minutes of eligible receiver dwell for a particular band. Of those three minutes, a known laboratory source may have been active during only eight brief windows. A detector that succeeds in all eight windows has demonstrated something useful about the controlled

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waveform, but not that all conceivable clandestine transmitters were present, active or within the response envelope during the seventeen unobserved minutes.

The distinction between encountering and recognising is likewise fundamental. Encounter probability describes whether the receiver and source were simultaneously in an observable state, including geometry, antenna polarisation and the chosen search schedule. Recognition probability describes whether a qualifying incident waveform generated the stated detection and classification outcome given encounter. If those conditions are reliably separable, a model may factor the two, but the factorisation itself must be tested. An antenna null may alter both the signal strength and the algorithm's recognition behaviour; a strong adjacent emission may impair both. The investigator should therefore report observations and calibration performance separately, retaining any model-dependent combined probability only as a conditional estimate.

A negative finding is informative when one can say what would probably have been seen under a credible, expressly bounded alternative. It is not informative about an arbitrarily defined source whose occurrence and observability have been left unspecified. Rather than burying the distinction in a paragraph of disclaimers, I would put eligible time and tested source conditions alongside each negative result. The absence of an observed qualifying waveform during a verified interval is a fact about the record. The broader statement that a particular source hypothesis is weakened by that fact is an inference, and its strength depends on the likelihood of the same record if the hypothesis were true. That second step must be made visible to the reader.

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Dr. James M. Atkinson, Moderator: I thank Sir Harold and Dr. Elias for defining the tested observation opportunity. I pass the token respectfully to Sir Ronald Fisher to examine the statistical limits of repeated negative results.

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Sir Ronald Aylmer Fisher, Second Principal Contributor: Dr. Atkinson, a series of negative observations becomes scientifically informative only when the experimenter states the particular alternative against which the observations are compared. In a technical surveillance countermeasures survey the broad proposition that no hidden apparatus exists is not an operationally testable statistical hypothesis. It includes devices that are switched off, perfectly shielded, operating outside the inspected frequency ranges, communicating over wireline systems, or transmitting at times beyond the observation period. Such devices produce no requirement for a radio receiver to respond. What can be tested is the conditional proposition that a specified class of active source would have produced a qualifying observation under particular receiver, antenna, environmental and decision conditions. That is a modest proposition, but it permits disciplined experimental design rather than rhetorical assurances.

An elementary detection experiment begins with three separately recorded facts: the laboratory source was active according to an independent monitor, the survey receiver was observant and functioning, and its declared rule did or did not register the relevant emission. The phrase independent monitor matters. If the device that declares the test signal active is itself the receiver under examination, then a silent receiver may conceal a failure of both measurement and ground-truth accounting. Independently timed reference emission records and a challenge protocol capable of exposing antenna or gain-chain defects allow detection probabilities to be estimated within the test matrix. The matrix needs actual variation in frequency, power, waveform duration, geometry, polarisation, interference conditions and instrument state. A detection proportion

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measured in one favourable geometry should not be silently assigned to all geometries in a building.

Suppose there are forty independently verified source-active opportunities of equal specified difficulty, and the system registers thirty-four of them. The observed detection fraction is thirty-four divided by forty, or 0.85. This is an estimate, not a timeless physical constant. Even if the opportunities were independent and identically distributed, finite-sample uncertainty remains, and a quoted 85 per cent without the denominator communicates a false impression of exactness. If the source changes its duty cycle or the survey has a common antenna null, the trials may not be identically distributed. Statistical intervals must be tied to an explicit model, and engineering challenge tests must determine whether that model is pertinent to the actual setting. The scientific meaning of a rate cannot be rescued by attaching more decimal places.

A genuine negative site survey often contains many technically different opportunities. One sweep may cover a short duration at an excellent signal-to-noise ratio. Another may occur at lower sensitivity because the antenna was moved behind conducting structural elements. A third may be interrupted by spectrum analyser retuning, and a fourth may run while a strong nearby transmitter drives the front end into compression. Summing these into an impressive total of 'ten thousand searches' conceals unequal detection probabilities. If probabilities are warranted, each opportunity belongs to a specific operating stratum, and the experimenter must provide sufficient evidence to justify the model of dependence among those strata. A grouping by frequency band, waveform class, room geometry and observing instrument may be more candid than one grand aggregate.

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False alarms must enter the design alongside missed detections. If an extremely low threshold registers countless spurious spectral features, the analyst can increase apparent sensitivity but may be unable to demonstrate that an alarm has any useful discriminatory meaning. Conversely, a threshold raised to avoid awkward alarms can make the negative conclusion appear reassuring at the expense of missed emissions. The threshold and classification rules should be documented before confirmatory testing and should be challenged using signal-absent and signal-present controls. Exploratory changes can legitimately help develop the method, but the resulting calibration dataset is no longer independent evidence of that method's claimed operating characteristics. Where the survey uses human classification, inter-operator consistency and a record of exclusions are as important as the automated threshold.

One should distinguish a confidence statement about an instrument from a posterior probability about a hidden transmitter. A confidence interval for the probability of detecting a laboratory reference source, conditional on its specified activity and propagation, does not yield the probability that no malicious device exists in the building. That latter probability would require defensible information about the prior occurrence of such devices, their plausible classes, their activation processes and the probability that each would be captured by the survey. An investigator ought not import those quantities from intuition and then dress the outcome in mathematical form. The absence of a detected source is a contribution to a larger evidential assessment, not a licence to calculate certainty from silence.

My preferred final statement would include an explicit inclusion-and-exclusion table. For each tested signal family, the report would state its

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tested field-strength range or receiver-input range, observation schedule, successful reference tests, failure modes, and the precise negative detection result. The untested possibilities should be visible rather than concealed in general caveats. If only continuous carriers between stated frequencies were robustly challenged, the conclusion must not migrate to infrequent encrypted bursts at unexamined frequencies or to wired communications. If a source was demonstrably active in a challenge and was nonetheless missed, that failure should be prominently disclosed, with a defensible explanation of its scope. Assurance increases not by suppressing embarrassing tests but by showing the limits of the measurement honestly.

I would further require the raw observation record to be separable from the report writer's conclusions. Instrument configurations, sample counters, reference logs and alarm criteria should have sufficient provenance that an independent specialist can test an alternative interpretation. A visually quiet waterfall is not raw evidence of the completeness of observation. The observer may have suppressed low-level detections, omitted intervals, changed colour scales or discarded data during an alarm-triggered recording process. Technical integrity and statistical transparency reinforce one another. A rigorously bounded negative finding is valuable to a client precisely because it identifies what risks were reduced and what further action could most efficiently reduce the remaining uncertainty. I pass the token to the sequential decision perspective, where an operator is tempted to stop searching as soon as the screen looks quiet.

Egon Sharpe Pearson, Peer Question: Sir Ronald, your laboratory reports thirty-four detections from forty known source-active opportunities. It may be tempting to use the resulting fraction as if it provided ninety-five per cent

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assurance that a silent building is free of a clandestine transmitter. Would you set out why a confidence interval for that laboratory detection fraction cannot carry such an interpretation? Suppose the survey's opportunities differ in duration, antenna orientation and interference, while the forty reference tests were performed at one favourable receiver-input level. How should the statistical treatment reflect the resulting mismatch? I am particularly concerned that the investigator might choose a receiver threshold retrospectively, remove inconvenient failed challenge trials and then advertise the adjusted rate as a confirmatory estimate. Which records and prospective rules would you regard as indispensable before even a conditional statement of detector performance can be defended? In framing your reply, please identify whether the relevant denominator counts independent physical source activations, independent receiver states, or merely successive software decisions upon one recorded capture.

Sir Ronald Aylmer Fisher, Response: Mr. Pearson, there are several errors to separate. A proportion of detections among known active reference opportunities estimates performance under the reference experiment's stated conditions. It does not estimate the probability that no unknown emitter exists in the examined premises. The latter is a proposition about a population of possible source states and their relation to the observed data. It requires assumptions about prevalence, activation, coupling and measurement opportunity that cannot be conjured from the numerator and denominator of a single calibration trial. Calling a confidence interval an assurance percentage about the premises changes the estimand without changing the evidence. No amount of numerical precision can make that substitution legitimate.

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The forty reference trials also require scrutiny before they can support even the narrow estimate. Were the opportunities prospectively defined, independently recorded as source-active, and sampled across the configurations for which performance will be asserted? Did the experiment retain failures and operator overrides as well as successful detections? If the threshold was adjusted after inspecting the same outcomes, an apparently favourable detection fraction is a fitted property of that exploratory dataset, not an unbiased independent test of the chosen threshold. The proper response is not to forbid exploratory engineering. It is to label such tuning accurately, freeze the procedure, and evaluate it against genuinely withheld or subsequently collected reference opportunities at relevant conditions.

Heterogeneous source conditions deserve an equally explicit treatment. A detection probability calibrated at one strong input level does not transfer automatically to a receiver operating near its sensitivity limit behind screened walls. The laboratory might stratify the reference opportunities by signal family, level, dwell, antenna polarisation and interference, then describe observed successes and failures in each group. Where the data permit, a response model can estimate how the probability changes with those variables, accompanied by uncertainty and a warning against extrapolation beyond tested conditions. Where it does not permit a reliable model, the honest outcome is a narrower report, not a single pooled rate presented as universally applicable.

I would preserve the original challenge schedule, the independent source monitor's records, the threshold and classification software configuration, each trial's inclusion criteria, and all resulting outputs. Failures are part of the dataset even if they complicate a later report. The analyst should also

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distinguish the number of trials from the number of independent experimental units. Forty adjacent software evaluations of the same captured burst are not forty independent tests of receiver performance. If the whole experiment inherited one defective antenna connection, repeated success or failure shares a common physical cause. Finally, any confidence interval should be named for the parameter it actually concerns and the model under which its coverage is calculated. It should never be repurposed as a probability that a threat is absent.

John Wilder Tukey, Peer Question: Sir Ronald, I wish to challenge the presentation of a single elegant probability where the data are a ragged collection of sweeps, dropouts and conditions that an operator only partly recorded. Suppose an instrument logs twenty thousand nominal spectrum intervals, but most share the same preselector, clock and antenna, while several hundred occur during gain compression and another group has lost acquisition counters. A conventional summary might say 'no detections in twenty thousand observations'. I suspect that phrase hides the very facts that should govern professional judgement. How would you design a diagnostic table or exploratory presentation which exposes the uneven measurement opportunities before the analyst selects a formal model? In particular, where does the analyst place absent data, failed self-tests, benign environmental events and trials for which the reference source did not actually operate? I also ask whether the plots should distinguish the optical appearance of silence from an authenticated record of instrument readiness and continuous sampled observation.

Sir Ronald Aylmer Fisher, Response: Mr. Tukey, one should distinguish the act of making a nominal sweep from the act of creating a valid opportunity

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to detect the specified source. An instrument log that declares twenty thousand visits tells us what the scheduling programme intended or recorded. It does not alone establish that an incident waveform would have been captured and recognised during each visit. I would begin by organising the observations into a ledger whose columns include actual measured dwell, frequency coverage, antenna and preselector state, interference level, validated gain state, acquisition continuity, threshold version and source-activity status where a controlled reference was used. This is not administrative decoration. It supplies the denominators for any subsequent numerical inference.

An interval in which the receiver was not collecting samples belongs in a category labelled not observed, not in the category observed with no qualifying signal. A trial with an overload flag must be retained with its quality qualification, not silently erased. A source-off reference interval can provide information about the false-alarm behaviour of the classification rule; it cannot be counted as a failure to detect an active source. An environmental event which triggers an alarm may help characterise specificity or the burden of investigation, but it is not automatically a false alarm until an independent check establishes what generated the feature. In each case the first objective is correct classification of the experiment's own evidence, before one infers anything about a concealed transmitter.

The visual presentation should show coverage and discontinuities directly. A time-frequency occupancy diagram can mark actual dwell separately from the blocks without samples. A distribution of noise-floor measurements across antenna positions may reveal a narrow range of conditions where the detection threshold became ineffective. An instrument-state timeline can

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display preselector changes and overload flags alongside the negative observations. Such plots can be exploratory and should be labelled as such. They help expose patterns that a single pooled rate would conceal. They also guide prospectively specified challenge tests designed to separate alternative explanations for those patterns, rather than treating the exploratory display as a completed confirmatory test.

I would resist the temptation to transform every anomaly into a missing data point with an invented value. Missing intervals are often informative about the apparatus, for example if buffering fails only when a strong burst arrives. Under that circumstance the absence of samples may itself be related to the event one hoped to detect, invalidating a naive missing-at-random treatment. One can perform sensitivity analyses under competing dropout mechanisms, but the report must distinguish observed data from assumptions. The practical conclusion is a set of transparent strata: fully eligible negative observations, qualifying positive observations, source-off controls, source-active reference misses, technically compromised intervals and intervals never observed. Only then is the experiment ready for defensible statistical modelling.

Sir Ronald Aylmer Fisher, Cross-Peer Question to Sir Harold Jeffreys: Sir Harold, let me ask whether the weight of a negative survey can ever be expressed in probabilistic language when the source activation distribution is unknown. A client might demand one reassuring number. A statistician might provide a calculation for ten genuinely independent known-active opportunities and then attach a disclaimer. Yet a later reader may remember the number and forget the assumptions. What would you regard as a scientifically legitimate alternative to an invented global confidence

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level? Would you present likelihoods for several sharply defined source hypotheses, or reserve numerical results for laboratory reference conditions alone? I ask also about the hazard of prior assumptions: a source that was inactive throughout the survey is observationally indistinguishable from one that did not exist. Does stating that distinction force us into complete agnosticism, or can a report still provide a graded evaluation of what the negative evidence excludes under explicitly varied plausible operational models? Please make the distinction between a decision-useful report and an absolute assertion exceptionally clear.

Sir Harold Jeffreys, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Sir Ronald, a global confidence number is not a natural property of the absence of a detector alarm. It is the result of an inferential construction that requires a specified event model, a relation between that event and the measured signal, and a decision or probability framework. A conditional likelihood can be useful when a proposed emitter's behaviour is sufficiently described. For a particular source class, we might ask how frequently the validated receiver would have detected an eligible emission, given known activity and measured coupling. If that probability is supported by controlled experiments, repeated negative observations may be evaluated under stated dependence assumptions. But the result remains conditional; it cannot be detached from the physical conditions and applied to an undefined population of concealed apparatus.

I would provide a table of hypotheses and detection opportunities rather than a single headline probability. One row might concern a continuous narrowband emission at or above a measured input threshold during eligible dwell. Another could concern a reference burst with a specified

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activation probability and duration. A third could concern a source whose activation schedule is unknown, in which case numerical inference about global absence may be unavailable. Each row should identify the source model, the independent reference evidence, the receiver coverage, the observed negative result and the major untested assumptions. Such a table lets the client see both the strength and the reach of the assurance without treating one conditional calculation as an official certificate that no device exists.

An inactive source and a nonexistent source may indeed produce observationally equivalent records for a receiver-only survey. That observation does not mean the investigation is useless. It means that the receiver evidence cannot distinguish those hypotheses without a further observation or assumption. Additional authorised physical examination, network or wireline analysis, longer observation across relevant activation contexts, or a carefully controlled stimulus-response experiment may discriminate scenarios that an RF-only survey could not. A scientific report should say what the current test resolved and what test would be needed to resolve the remaining distinction. Where further tests are impossible, the residual uncertainty should not be hidden behind a vague claim of thoroughness.

A graded conclusion can therefore be legitimate. It might state that the survey reduces support for some active-emitter scenarios because those scenarios would probably have produced detections under validated conditions, while leaving inactive, unobservable or differently communicating sources largely untested. The grading should be qualitative if the inputs do not justify a numerical expression. In all cases the

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independent observer must be able to reconstruct which conditions were actually met. The report becomes useful through its transparency about both successful challenges and remaining blind spots. It fails when its prose encourages a reader to convert conditional evidence into universal absence.

Dr. James M. Atkinson, Moderator: Sir Ronald has distinguished a validated reference detection rate from an assurance claim about the building. I now invite Mr. Abraham Wald to consider stopping rules, timing and operational decisions.

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Abraham Wald, Third Principal Contributor: Dr. Atkinson, the survey is a sequence of decisions under time, money and observational constraints. The investigator chooses when to inspect a band, when to move an antenna, when to repeat a challenge, when to alter the instrument and when to end the survey. Those choices depend upon information already observed. Consequently, the inferential significance of a run of negative readings cannot be judged merely by counting the readings after the fact. A test whose stopping rule was chosen because the latest scans looked reassuring is not equivalent to an experiment with a prospectively specified observation horizon. The distinction matters even if both experiments ultimately contain the same number of saved screenshots.

An operational policy may define minimum observation periods for specified signal classes, mandatory independent checks, and explicit conditions that extend the search when contradictory evidence arises. Such a policy does not eliminate professional discretion. It records which decisions were made because the survey found something, and which were predetermined by a controlled plan. If a team starts with a nominal two-hour survey and stops after a quiet quarter of an hour, the client should not receive a report based upon two hours of advertised coverage. If the team extends an observation because a transient was suspected, that adaptive extension is appropriate, but its resulting data are part of a conditional exploratory path. One must not later pretend the team selected that interval without seeing the transient.

A sequential probability ratio test is sometimes invoked as if it offered a universal mathematical permission to stop. It does not. Such a method presupposes a clearly specified observation model under competing

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hypotheses and a likelihood construction whose dependence assumptions are justified. A TSCM survey confronting an unknown intermittently active source seldom satisfies that model without extensive restrictions. There may be no known distribution for a signal's activation schedule, antenna coupling, modulation family or sensitivity to a change in the environment. The investigator may still employ sequential reasoning for a laboratory reference source under controlled conditions. That is very different from writing a likelihood ratio for an unidentified adversarial emitter and declaring an entire premises free of surveillance.

The decision problem should be separated into technical detection, survey termination and risk management. Technical detection asks whether an event met a predetermined rule. Termination asks whether the planned observation and challenge requirements were met, or whether a defined exception requires additional work. Risk management asks whether the residual uncertainty is acceptable for the client's purpose, lawful authority and exposure. An institution can accept residual risk without declaring the hypothesis of a hidden transmitter scientifically impossible. Indeed the professional report is stronger when it states that the decision to finish was governed by a finite agreed plan and not by a logically conclusive proof of absence.

Consider a hypothetical frequency-hopping beacon that transmits for 20 milliseconds once every five seconds, with its activation phase random relative to scanning. A scanner which revisits a narrow subband only briefly may offer poor temporal overlap despite completing hundreds of sweeps. If the fraction of time in which the instrument is actually capable of observing a given relevant waveform is only 0.10, one cannot assume that a hundred

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successive plotted sweeps constitute a hundred independent 90-per-cent-sensitive trials. Depending on timing regularity, the scanner may repeatedly miss the same phase of a periodic beacon. A controlled timing-randomisation exercise could help break such phase locking, while an independent logger would be needed to test whether the source actually transmitted during the available windows. These are testable engineering interventions, not assurances derived from simple multiplication.

Common-cause failures are especially dangerous for sequential decisions. If the preamplifier fails, an antenna connector loosens, or the receiver front-end is desensitised by a strong local carrier, many consecutive quiet observations can share one failure. Ten thousand repeated readings do not create ten thousand independent opportunities when the same defect governs them. The survey should include reference-signal injections at appropriately documented points in the signal chain, before and after important state changes, to detect failures that no amount of waiting will reveal. An injected signal at the receiver input checks a different set of components from an authorised radiated challenge through the survey antenna. Both can be useful; neither is a complete substitute for the other.

Survey duration should also be described in observable rather than calendar terms. The notation 'the receiver operated for eight hours' may refer only to the host computer's wall-clock interval. To estimate actual opportunity, one needs the time-resolved receiver frequency, effective bandwidth, antenna state, validity of samples, classification thresholds, and missing-data mask. Some observations may be duplicated or averaged from the same underlying samples. Some may arise from a receiver that was active but tuned elsewhere. Where a long-term monitor scans multiple bands, the

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relevant denominator is not total elapsed time but eligible observation time for the particular source model. This denominator is the bridge between operational logs and defensible statistical conclusions.

I would propose an advance statement of the client's question and a termination register. The register records the surveillance scenarios to be tested, legal constraints, minimum coverage requirements, instrument-health challenges, allowable adaptations and conditions requiring escalation. A negative conclusion can then say that the planned tests were completed without a qualifying finding, while identifying what remained untested. Where an unresolved anomaly occurs, the team should not erase it simply because the general search was negative. It should be described as unresolved and either followed up or expressly excluded from the negative conclusion. The record should also distinguish 'not observed' from 'examined and excluded', because those phrases can have radically different evidential foundations.

The cost of continuing can be compared with the likely improvement in assurance, but this comparison must remain transparent. A client may rationally choose to close a survey after a specified set of tests because further work has diminishing practical value. The conclusion is a decision under uncertainty, and its legitimacy rests on the reasonableness of the plan and the honesty of the account. It is not a scientific declaration that every logically possible surveillance channel was eliminated. I pass the token to Sir David Cox to examine heterogeneity, dependence and the tempting illusion that a multiplicity of plots supplies independent evidence.

Claude Elwood Shannon, Peer Question: Mr. Wald, an intermittently transmitting source creates a particularly difficult stopping problem. Each

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new observation might be informative about a narrow source model, yet the investigator can always extend the search. I ask how to quantify the information contributed by an additional hour when its spectral coverage overlaps earlier hours but the source's activation process is unknown. Suppose an analyst stops after observing no alarms in the first twenty minutes, despite a stated plan to inspect the area for two hours and to challenge the receiver before and after the search. Could the stopping decision itself distort the apparent strength of the negative evidence? How would you describe the difference between a prespecified stopping rule, an adaptive safety or fault response, and an opportunistic termination made because an uneventful display looked reassuring? Please identify which of these can be represented honestly in the custody record.

Abraham Wald, Response: Dr. Shannon, the marginal information supplied by an additional hour depends upon the hypothesised source behaviour and on the actual observation opportunity offered by the receiver during that hour. If a source is known to transmit once per minute when active and the receiver continuously observes the relevant band with documented sensitivity, additional eligible minutes can materially challenge the source hypothesis. If the source transmits only upon a rare unknown trigger, or if the receiver never visits the relevant band, another nominal hour may add little. One cannot assign a universal information value to elapsed time. It is the conditional distribution of observable events and the verified measurement opportunity that determine the strength of the evidence.

The stopping rule is part of the experimental design. If the survey plan specifies two hours of observation and a final reference challenge, terminating after twenty quiet minutes fails to complete the stated

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experiment. One should report the twenty minutes actually observed, the omitted challenge, and the reason for termination. Recasting the incomplete survey as though it satisfied the original protocol would be an evidential error independent of any statistical calculation. If the team deliberately designed a sequential test for a tightly specified laboratory source with known detection behaviour, it might stop after crossing a predeclared evidence boundary. But the validity of the boundary depends on the observation model, the chosen error constraints and the actual implementation of the procedure.

An adaptive safety response is different. A dangerous electrical condition, a receiver fault or an unexpected overload may justify stopping immediately. The decision is operationally correct, yet the affected observation intervals become invalid or unobserved for the original search question. A team may also extend the survey in response to an anomalous feature, but must state that the extension was exploratory and distinguish subsequent independent confirmation from tests tailored to the observed anomaly. None of these choices is inherently improper. The error lies in hiding the choices and then presenting a nominally fixed sample size or a false appearance of independent observation.

The custody record should preserve the initial plan, exact observation start and end times, equipment-state changes, the occurrence of anomalous signals, and the decisions made as those observations arrived. A decision log can record who authorised an extension or termination and why. One may later conduct a sensitivity analysis showing how alternative stopping assumptions would affect a statistical statement, but that analysis is a derivative. It does not rewrite the acquisition history. The most useful

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recommendation is to separate minimum validated survey coverage from discretionary additional work, and to predefine the challenge tests required for a negative conclusion. Where those conditions were not satisfied, the report should describe a limited negative observation, not a completed assurance protocol.

Donald Watts Davies, Peer Question: Mr. Wald, consider a survey receiver which sends data over a computer interface to a storage process that can pause or fail without stopping the RF front end. An operator sees a quiet waterfall and may infer that the instrument continuously watched a band. Yet a delayed host display, a full ring buffer or an interrupted file writer can leave long holes in the preserved samples. How should the investigation separate actual observation time from the appearance of uptime? In a multiple-receiver arrangement, would the agreement of two host logs be enough if both receivers use the same timing distribution, software stack or network path? I ask for a rule that prevents silent interpolation from converting lost acquisitions into negative detections and that records outages without pretending to know whether an emission occurred during them. In answering, please distinguish an unverified host display from an independently established capture clock, so that a missing acquisition is not silently written as a negative finding.

Abraham Wald, Response: Mr. Davies, the first rule is to distinguish source-time acquisition from host-time delivery. A software timestamp stating that a computer drew a waterfall tile establishes that the display operation occurred, not necessarily that the ADC furnished a continuous underlying interval. The record should preserve device-side sample counters, frame identifiers, overflow indicators and reference-clock state where those

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observables exist. A gap in an acquisition counter has a different significance from a delayed application callback. If the instrument cannot expose a reliable acquisition continuity indicator, the claimed coverage must be weakened accordingly. One cannot restore an absent measurement by adding a plausible line between two plots.

A receiver might keep sampling into a buffer while the host pauses, in which case the recovered data could be complete. Alternatively the buffer might overflow and omit samples although the output file remains continuous in byte length. Controlled fault injection is needed to determine which behaviour applies to the actual hardware and software configuration. The laboratory can produce a known reference event while deliberately burdening the storage path, then compare an independent monitor's event timeline with saved sample counters and logs. This test should cover the relevant modes of failure rather than relying solely on a successful demonstration under ideal conditions. Its results would define which indicators justify counting an interval as observed.

Agreement between instruments may provide valuable corroboration, but it does not guarantee independence if the same reference source, timing network, firmware revision or data collector governs both. The common dependence should be mapped. A disciplined clock can itself distribute the same error to multiple receivers; a shared acquisition process can lose the same interval for both; and a reused display algorithm can omit identical portions of the evidence. Separate antennas or oscillators may reduce some dependencies but leave others intact. I would therefore use a fault-tree or dependency matrix in addition to numerical comparisons, identifying each

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component whose failure could make apparently distinct observations agree for the wrong reason.

The final timeline should contain at least three states: verified eligible acquisition, verified interruption or loss, and uncertain acquisition continuity. A fourth state records actual detector alarms within eligible intervals. No recorded alarm in an eligible interval is a negative observation under the stated rule; no sample during a verified interruption is not. If the timing of an outage is uncertain, the uncertainty interval should be shown instead of forced into an exact endpoint. The report need not claim that an emission occurred during a gap. It should simply refuse to treat that gap as evidence of absence. This discipline preserves the distinction between what the receiver measured and what the analyst later inferred from a partial record.

Abraham Wald, Cross-Peer Question to Sir Ronald Aylmer Fisher: Sir Ronald, I wish to challenge the independence assumption from the operational perspective. A field team may perform many surveys at the same premises, perhaps on successive days, and regard their repeated negative findings as a rapidly multiplying body of independent evidence. Yet each visit may use the same antenna arrangement, the same receiver calibration, the same classification software and similar hours of the day. One hidden source which transmits only when a particular trigger occurs may never be active during any visit. How should an analyst represent repeated negative results when the chance of encountering the hypothesised source is uncertain and likely correlated across visits? I also ask whether a successful calibration challenge on each day establishes that the source-activation mechanism was adequately tested, or merely that the apparatus worked for the known

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reference signal. How might a predeclared variation in survey times and source conditions improve the experiment without permitting the investigator to assume that the variation has covered every conceivable activity mechanism?

Sir Ronald Aylmer Fisher, Cross-Peer Answer to Abraham Wald: Mr. Wald, repeated visits can enlarge the physical opportunity to observe a source, but only if the visits alter the relevant opportunity distribution in a useful way. They do not become independent merely by occupying different dates in a calendar. If a source activates only when the premises are empty or in response to a particular event, repeating the same midday search on occupied days may revisit the same blind condition. Independence of outcomes is a statistical statement about their joint behaviour under a specified hypothesis, not an administrative statement that the observations were recorded on different forms. Correlated source activity, shared instrument faults, fixed antenna geometry and reused classification thresholds can all generate substantial dependence.

A useful record should preserve the reason for each revisitation and the physical conditions that distinguish it from earlier observations. Were antennas moved? Did the receiver observe different bands or duty cycles? Were the instruments challenged at low input levels and less favourable polarisation? Was the calibration repeated after a change of temperature or gain state? Did a second independent monitor confirm the authorised reference signal's activity? These facts matter because they reveal which plausible failure modes each test could expose. Merely repeating an identical demonstration under identical favourable conditions may increase

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confidence that the equipment can reproduce that demonstration, but it need not enlarge the class of covert source behaviours examined.

Daily calibration success is not evidence that an unknown emitter activated. It establishes performance against the known stimulus under that day's specified laboratory or site condition. One may use that result to challenge claims about instrument malfunction; one cannot transfer it into a claim that all unknown transmitters should have been heard. A prospective design might deliberately vary observation hours, antenna positions and frequency coverage according to a stated sampling scheme, while maintaining controls that permit performance comparisons. Such design reduces the danger that the investigator has unconsciously selected only convenient observations. It also makes it possible to explain which operational patterns have been sampled and which remain conjectural.

If an encounter model is supported, an analyst may calculate a conditional probability of an entirely negative record and compare that probability under alternative hypotheses. If it is not supported, sensitivity analysis is preferable to an invented probability. One may show how a conclusion would change under different plausible activation frequencies or missed-event mechanisms, while making clear that those assumptions were not measured. The essential discipline is to treat repeated silent records as evidence about repeated measured opportunities, not about all times and all possible source states. The strongest conclusion is one that survives explicit challenges to the relevant dependencies; the weakest is one that multiplies reassuring decimals whose common physical causes were never investigated.

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Dr. James M. Atkinson, Moderator: I thank Mr. Wald for retaining the actual acquisition history. Sir David Cox, I pass the token to you for examination of heterogeneous opportunities and common-mode instrument failures.

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Sir David Cox, Fourth Principal Contributor: Dr. Atkinson, before calculating the strength of a negative finding, we must identify the unit of observation. An RF analysis programme may return thousands of FFT bins and overlapping spectrogram frames from one continuous capture. It is a serious error to regard each bin, frame or coloured pixel as an independent attempt to detect an emitter. Adjacent bins may share energy through a window's spectral leakage, and adjacent frames often reuse most of their underlying samples. A single receiver overload can affect every one of those comparisons at once. The survey can generate an enormous numerical table while furnishing only a small number of substantially independent opportunities to challenge the relevant hypothesis.

A statistical design ought to describe the hierarchy of dependence. Individual spectral cells occur within frames; frames occur within captures; captures occur within receiver settings and sites; sites may be affected by common interference and propagation mechanisms. The conditional outcome at the lowest level depends on the state of the enclosing levels. Aggregating detections without respecting that hierarchy gives narrow uncertainty estimates which an independent reproduction may fail to support. If twenty receivers share the same timing reference and antenna distribution amplifier, it is not sufficient to multiply a nominal per-receiver miss probability twenty times. A common reference failure or common filtering limitation may make their outcomes strongly correlated. Physical independence of measurement chains should be demonstrated or clearly qualified.

The status of a source can itself change. An intermittent device may activate only during a conversation, a change in occupancy, a power transition or a

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particular external stimulus. A negative survey carried out at an unrepresentative time can be entirely consistent with such a mechanism's presence. The challenge is not to posit every imaginable trigger, which is an impossible exercise, but to define a rational set of activation hypotheses responsive to the authorised protective objective. A survey might compare occupied and vacant periods, perform lawful controlled activation tests, or use sustained monitoring with known observation limits. The report should identify which of those conditions were actually examined. Absent a justified activation model, the statistical significance of a prolonged quiet period may be extremely weak.

One must also model missed opportunities. Suppose a receiver logs 6,000 seconds of wall-clock time, but its configuration records show that the relevant band was monitored for 1,800 seconds. A subsequent audit establishes 120 seconds of sample loss during those selected dwell periods. The eligible interval is then 1,680 seconds under that particular source and configuration definition, not 6,000. The calculation 1,800 minus 120 is simple; the scientific work lies in proving that the dwell records and loss indicators correspond to actual acquisition. If the system records only alarm-triggered samples, silent intervals may be absent without a verifiable indication of whether the receiver was genuinely looking. A defensible denominator cannot be reconstructed by wishing that a log file were more complete than it is.

Sensitivity is likewise a function rather than a single scalar. A probability of detection may depend on signal power, duration, carrier frequency, modulation, polarisation, arrival direction, interference, threshold and the judgement of the operator. A logistic model or another fitted response

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surface can be useful for controlled references if there are enough observations to assess its adequacy. But fitted curves outside the tested region do not establish performance against a source class whose behaviour is unknown. The limits of extrapolation should be shown explicitly. The practical output may be a family of detection-performance contours for validated reference waveforms rather than one boastful percentage applied across the entire electromagnetic environment.

I would also require negative controls that identify receiver-generated masking and artefacts. A disconnected antenna, a known termination and an independent reference receiver can help determine whether a displayed feature originates in the environment or in the equipment, but each control has a scope. A quiet terminated input cannot validate the antenna's exposure to a real source. A successful internal test tone does not validate the antenna's polarisation coverage. A second receiver built upon the same software library may reproduce a software defect. The independence of the controls is itself a matter for engineering demonstration. The investigator should state which failure modes each control can reveal and which it cannot.

The communication of results should be separated into observations, performance tests and conditional interpretation. First, give the actual findings in the measured time-frequency region, preserving non-detections and anomalies with their status. Secondly, provide the laboratory validation results, their uncertainties and the tested configurations. Thirdly, explain the consequences for the surveillance scenarios that the client authorised the team to examine. Do not conflate the estimated ability to detect a controlled reference with the probability that no threat exists. Where an inference

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depends on an activation rate or a model of geometry, present a sensitivity analysis showing how it changes under credible alternatives. A properly qualified negative result should become less categorical as those assumptions become less secure.

The final report may still be useful. It can establish that specified signals above a tested detection boundary were not observed in a documented surveillance interval. It can demonstrate that a particular measurement arrangement worked when challenged, and that known blind spots were mapped. It may support a subsequent decision to improve shielding, expand observation or investigate cable routes. This is a contribution to assurance, but it does not amount to omniscience. I would judge the professionalism of the conclusion not by the confidence of its adjectives but by whether another investigator could test the exact limits of the claim. I pass the token to Sir Karl Popper to ask what a negative search genuinely falsifies and whether repeated silence may turn an untestable assertion into a scientific conclusion.

John von Neumann, Peer Question: Sir David, you distinguish the tested observation envelope from the conditions that remain unknown. Let us consider a practical computation over that envelope. Two receivers each complete one hundred scheduled scans, but they share an antenna splitter, an external preselector control and a laptop which records the detections. It would be easy to claim two hundred independent opportunities. What evidence would be needed to justify such a count, and how would you approach the task if the common subsystems could suppress both instruments at once? I would further ask whether a null observation should be recorded as a binary zero, as a missing value, or as an explicitly qualified

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observation state when gain compression, source inactivity and undocumented switching each remain possible. Finally, could you explain how the engineer should document one conservative bound without suggesting that it applies to every possible form of hidden surveillance apparatus?

Sir David Cox, Response: Professor von Neumann, counting two hundred scans is legitimate as a description of scheduling only if the term scan is defined accordingly. Counting two hundred independent detection opportunities is a stronger statistical claim, and common subsystems immediately call it into question. If a single preselector setting removes the frequencies relevant to the source model, both receivers can fail together even if their downstream processing is independent. A shared antenna can impose the same polarisation null or shielding loss. A shared laptop may drop exactly the same time interval from both files. The investigator should characterise those dependencies through an engineering diagram and controlled fault injection, rather than treating the number of equipment cases as an independence certificate.

A defensible opportunity ledger requires an explicit state space. An eligible observation records that the receiver actually acquired an interval while meeting the specified coverage and quality criteria. A valid negative is then an eligible observation in which the predeclared decision procedure registered no qualifying event. A positive is an eligible observation producing such an event. Missing data arise when the intended observation has no recoverable samples or status, while technically compromised data arise when samples exist but their applicability is uncertain because of overload, timing loss or an invalid configuration. An inactive reference

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source is a different condition again. Its absence may provide a background false-alarm control, but not a source-active detection trial. Retaining these distinctions in machine-readable fields permits accurate later analysis.

The dependence question can be investigated with a challenge matrix. Introduce the same known authorised RF burst into both receivers through independently characterised paths, then repeat the challenge after deliberately disconnecting the common antenna, changing preselector settings, inducing a host acquisition pause and varying source geometry. Record whether each receiver's local counters and status fields respond as expected. An independent third monitor can establish actual source activity without inheriting the same antenna route. The tests reveal which failures are common and which are receiver-specific. When the dependence structure remains uncertain, report the raw number of observations but avoid pretending that the effective count of independent trials is known to equal it.

A conservative bound can be meaningful only when the conditions under which it holds are stated. If a reference source family, minimum field strength, waveform duration, antenna geometry and acquisition schedule have all been validated, the report may give a lower performance bound conditional upon those conditions, with the statistical method and confidence level disclosed. It cannot infer a bound for an untested, inactive or differently coupled source by rhetorical extension. The bound should also account for uncertainty in calibration and model structure, not solely binomial sampling variation. The general lesson is to distinguish the measurement design, its physical failure dependencies and the inference that a statistical model permits. When a common-mode weakness

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dominates, additional nominal scans without changing that weakness may create quantity without improving assurance.

David Harold Blackwell, Peer Question: Sir David, I would like to examine what the decision-maker may properly do after the report has rejected an absolute absence claim. A client might have limited funds for additional checks. The completed survey shows no qualifying detections in several well-covered bands but leaves substantial uncertainty about sporadic activation, a screened room and one wired route. In that situation, can the negative observation still rationally change the decision about where to allocate the next laboratory or field examination? I ask you to distinguish evidential probability from decision utility, especially where the consequences of a missed source are substantial and the source's frequency or behaviour is unknown. Could the investigator present a transparent sensitivity analysis without pretending to know a unique prior probability of a device being present? What safeguards should prevent a cost-based recommendation from being misquoted as a scientific finding that a threat has been excluded?

Sir David Cox, Response: Dr. Blackwell, the client may indeed find a bounded negative result useful even when it cannot establish universal absence. Scientific evidence and decision policy are related, but they answer different questions. The evidence identifies observations, validated detection performance, and uncertainties. The policy assigns consequences and costs to possible actions and residual risks. A client might reasonably prefer further testing of a known blind interval rather than another scan of a frequency band already examined under favourable conditions. That preference may be rational under an explicitly declared loss function

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without implying that the unexamined threat definitely exists or that the examined band is certainly free of risk.

I would structure the decision analysis around competing scenarios rather than one fabricated probability. For instance, construct scenarios in which an emitter is intermittently active, shielded by construction, using a wired path or absent. For each scenario state what the current survey could and could not have observed, and how a proposed further test changes expected observability. If probabilities can be supported by external evidence, their provenance and sensitivity should be disclosed. If they cannot, present threshold analyses: at what plausible probability or consequence would a follow-up action become worth its cost? Such a calculation may clarify choices without treating the input probabilities as measured facts. It also prevents numerical polish from disguising the fundamental uncertainty about source behaviour.

An independent recommendation might call for inspecting the screened room, checking cable routes under lawful authority, improving antenna geometry or extending observation to capture a plausible activation window. These actions target different physical hypotheses and should not be aggregated as though each were merely another independent draw from one detection process. The team ought to indicate which hypotheses each follow-up test could challenge, what controlled references are available and what result would count as a genuine failure of the source hypothesis. A proposed test which cannot disconfirm or discriminate anything may have low evidential value despite producing a large volume of recording data.

The report must keep its categories legible. One portion states what was measured and what faults were observed. A second explains uncertainty

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and the limited source hypotheses addressed. A third, clearly identified as decision support, compares the cost and potential value of additional authorised activities. The fact that a client elects not to pursue a suggested check does not enlarge the survey's original conclusion. Equally, a decision to conduct more testing does not establish suspicion as a fact. I would regard this separation as especially important where a report may later appear in litigation. The scientific witness should testify to the evidence and its limits, not quietly convert a commercial or protective preference into an attribution or a claim of absence.

Sir David Cox, Cross-Peer Question to Abraham Wald: Mr. Wald, I should like you to distinguish a planned stopping rule from a retrospective explanation of why a survey ended. A team may have a predeclared protocol requiring a minimum observation duration, coverage of stated receiver bands, a closing calibration test and verification of storage continuity. In practice a receiver overload may invalidate a period, and the operator may elect to repeat that period or extend the visit. How can we preserve the validity of the survey while permitting sound engineering judgement in response to new observations? Conversely, suppose the same team sees an unusually quiet spectrum and decides to terminate early because nothing appears wrong. What would a responsible report say about the uncompleted tests and the evidence not acquired? I also ask whether sequential inference is practicable when the set of potentially relevant sources is ill-defined and the conditional probability of detection changes with the site geometry. What minimum information should the team retain so that an independent reviewer can assess its termination decision?

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Abraham Wald, Cross-Peer Answer to Sir David Cox: Sir David, the solution begins by recording the protocol before the observations influence the operator's choices. A protocol can define minimum eligible observation time, required antenna positions, frequency ranges, controlled source challenges and final acquisition integrity checks. It should also define exceptions: where overload, missing samples or another instrument fault invalidates an interval, the team must either repeat the affected test or explicitly declare the corresponding coverage requirement unmet. An extension in response to a fault may improve the scientific record without pretending that the original plan was perfectly executed. What matters is that the reason, timing and consequences of each change are visible to the later reviewer.

Early termination because the screen appeared quiet is a different form of adaptation. The team is using the outcome of the measurement to decide how much more evidence to collect, and may thereby change the inferential properties of any statistical procedure. If the original protocol required two hours and a closing challenge, a twenty-minute quiet observation cannot be reported as the completion of the two-hour protocol. It may be described as a negative observation over the twenty eligible minutes actually acquired. If a safety or legal restriction compelled termination, that fact also belongs in the report. The moral is not that judgement is forbidden, but that prospective design and subsequent deviation should not be merged into one invented history.

Sequential inference can be valid for a narrow, demonstrably specified source model, but it is not a universal substitute for understanding source activity. A likelihood ratio requires probability models under competing

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hypotheses, and those models must account for dependence and changing measurement opportunity. Without defensible source activation and receiver-response distributions, a numerical stopping boundary is no more authoritative than an unsupported fixed-sample calculation. The investigator may still use engineering completion criteria rather than a formal statistical stopping rule. The criteria should be chosen to expose known failure modes and to satisfy the intended evidential purpose, not merely to generate a reassuring number of screen captures.

The custody record should retain the original survey plan, versioned instrument configuration, receiver-native acquisition counters, the start and end of each eligible interval, operator actions, detected anomalies, retuning or overload events, and any changes to the planned schedule. It should also preserve reference test results before and after critical configuration changes. An independent reviewer can then distinguish a completed planned observation, an authorised adaptation and an incomplete test. This record permits practical decision-making without allowing post hoc selection of observation duration to masquerade as independent confirmation. The evidential effect of a negative result remains conditional upon the work actually performed.

Dr. James M. Atkinson, Moderator: Sir David has separated evidential validity from the later allocation of investigative resources. Sir Karl Popper, please conclude with the refutable claims that a responsible negative survey can sustain.

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Sir Karl Raimund Popper, Fifth Principal Contributor: Dr. Atkinson, I approach the report as a collection of propositions which must be exposed to possible refutation. The statement that no device exists anywhere in a building cannot be meaningfully tested by a finite RF search when the statement quietly includes every conceivable inactive or inaccessible mechanism. An adversary could always describe an invisible exception beyond the tested frequency, time, place or method. That capacity to evade a negative observation must not be mistaken for evidential proof of either presence or absence. Our task is to devise precise propositions whose failure conditions are plain, and then record whether the instruments actually exposed those propositions to a severe test.

A bounded claim might say that no authorised laboratory reference burst above a defined receiver-input level, with a stated occupied bandwidth and repetition schedule, was missed during the controlled trial. Such a proposition is testable because a missed burst would contradict it. A subsequent site observation can then say that no event meeting the corresponding criteria was recorded during eligible observation intervals. The first proposition concerns demonstrated test-system performance; the second concerns what the site instrument observed. One must not silently infer a third proposition, namely that there was no transmitter, because the third invokes assumptions beyond the measured evidence. The argument should show its inferential bridges rather than leap over them.

A severe test is one designed to expose a method's weakness, not one that arranges the conditions for an easy success. If a detector is evaluated only against powerful continuous carriers directly in front of its antenna, it has not been challenged for weak bursts arriving at inconvenient angles. If the

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receiver is tested after a noise-free instrument reset, the trial may fail to reveal overload recovery and gain-state memory. If all reference transmissions are scheduled at exactly the moments when the scanner is dwelling on the appropriate band, the demonstration may conceal significant blind time. An honest laboratory should deliberately include difficult but plausible conditions within the declared intended use, record failures and refuse to erase inconvenient outcomes from the analysis.

Falsifiability is not the same as universal exclusion. Even after a detector survives many well-designed tests, the result supports confidence in its behaviour within those conditions, not an unrestricted proof about unknown emitters. A client who asks for an assurance statement should be given both the observation and the circumstances in which it would have failed. For example, a silent observation would have been contradicted by a validated qualifying pulse in a monitored band while the receiver was functioning. It would not have been contradicted by a transmitter that never activated. These are different states of the world, even if they leave indistinguishable traces on the screen. The report must state which states remain observationally equivalent.

There is also a problem of alternative physical channels. A radio-frequency receiver cannot generally resolve communications which occur solely by conductive coupling along a protected cable, optical signalling outside the inspected method, or physical data transfer without electromagnetic radiation within the survey's observable envelope. Even where those channels produce incidental electromagnetic leakage, its level and appearance cannot be assumed without measurement. A negative RF result therefore does not eliminate all surveillance methods. The proper response

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is not to add a token phrase about limitations and then return to an absolute conclusion. It is to define the survey's discipline and note where another authorised examination, such as network, wireline or physical inspection, addresses a separate proposition.

The chain of custody helps preserve the test's refutability. If the laboratory retains only its final PDF and discards the relevant receiver states, acquisition records and negative controls, a later reviewer cannot determine whether a false assurance arose from the instrument, the interpretation or an unexplained omission. The preserved record should permit an independent examiner to reproduce the decision rule on the same samples, challenge the instrument with a comparable reference, and locate intervals which were not observed. Cryptographic hashes can help maintain the identity of preserved records after acquisition; they do not prove that the antenna was attached, that the operator set the right frequency, or that the unknown emitter was active.

An effective conclusion ought therefore to contain graded statements. The strongest may concern directly observed calibration results and documented acquisition states. A narrower negative statement may cover the absence of a qualifying feature in eligible records. An interpretive statement may indicate that certain risk scenarios are less consistent with those observations, conditional upon assumptions of activity and observability. The report should also identify hypotheses that were not meaningfully exposed to refutation, so that readers do not mistake an absence of scrutiny for an absence of risk. The language should preserve uncertainty without sacrificing practical relevance. The client should be able to act upon an honest account of what was tested.

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Finally, scientific humility should not be confused with paralysis. A properly bounded negative survey can be decision-useful even though absolute certainty is impossible. It can help justify changes in protective arrangements, identify areas requiring longer observation, and provide documentary evidence that certain authorised challenges were performed. What renders it useful is the severity and transparency of the test, not the flourish of an unqualified declaration. I would ask each of my colleagues whether the method could have failed under a credible alternative condition, and whether the report tells the reader how that possibility was examined. I pass the token back to Dr. Atkinson so that the peer challenges may test our proposed reporting standards rather than merely praise them.

Sir Karl Raimund Popper, Cross-Peer Question to Sir David Cox: Sir David, I ask that you place our proposed assurance report under a severe challenge. A team may truthfully state that it observed no qualifying RF emissions during its measured survey interval. It may also describe a set of reference tests which the receiver passed. Yet a nontechnical reader could still mistake those two true statements for proof that there was no concealed apparatus. Can we specify the precise proposition that was tested, the conceivable observation that would have refuted it, and the alternative source behaviours that remained outside the test? I would also ask how a graded conclusion should respond to a failed low-level calibration challenge or an unverified period of sample loss. Should one recalculate an optimistic detection probability from only the successful trials, or instead treat the failed control as a limitation on the entire claim? Finally, what language would you permit in a written report intended for a legal forum where small verbal exaggerations may acquire great significance?

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Sir David Cox, Cross-Peer Answer to Sir Karl Raimund Popper: Sir Karl, an assurance report should begin with the instrument's actual observational proposition. For example: during the documented eligible intervals, on the specified bands and antenna configurations, no stored event satisfied the predetermined classification rule. This proposition is refutable by identifying a qualifying stored event which was overlooked or misclassified. A second proposition might state that the equipment passed particular reference challenges with specified input conditions. That proposition is refutable by a documented failure during the challenge or by an error in the calibration record. The broader claim that no hidden apparatus exists is not implied by either proposition. The report should not rely upon the reader to supply that logical distinction unaided.

A failed low-level challenge is evidence about the measurement system and must remain in the record. It may require a revised operating envelope, a technical repair, repetition of the affected test or a limitation on the negative conclusion. It is not acceptable to discard the failed trial and recalculate a favourable detection fraction from a self-selected subset unless there is a prospectively justified exclusion criterion and the analysis discloses the decision. Even then, the rejected trial may reveal an important operational failure mode and deserves separate discussion. Similarly, an unverified sample interval cannot be counted as observed quiet time. The proper treatment is to identify it as uncertain or missing and examine the resulting sensitivity of any inferential statement.

A graded statement can distinguish direct observation from calibration evidence and scenario-based interpretation. The direct observation might be highly secure if the original record, software version and acquisition

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continuity have been preserved. The calibration evidence may be strong for some waveform classes and weak for others. The interpretive inference that a particular type of active transmitter was unlikely to have escaped detection depends upon tested activation, coupling and noise conditions. A different source operating intermittently outside those conditions may remain largely unexamined. Presenting this hierarchy is not equivocation. It is the natural consequence of identifying the propositions and their supporting evidence accurately.

For a legal audience I would recommend language that reports the test, not the investigator's optimism. It might state: 'No emission meeting the declared detection criteria was recorded in the eligible surveillance intervals. Controlled reference tests support the stated sensitivity and coverage for the specified waveform and input conditions. These findings do not exclude inactive devices, sources outside the surveyed envelope, unobserved periods or non-RF surveillance mechanisms.' Where the experiment contains a failed control or a notable acquisition gap, identify it expressly and describe its consequences. The witness should be able to explain each sentence by reference to a contemporaneous record. That is how a limited negative finding becomes both useful and defensible without being converted into an assertion of universal absence.

Dr. James M. Atkinson, Moderator: I am obliged to all contributors for maintaining courtesy while challenging the evidential scope of the negative survey. The panel concludes that silence is meaningful only within the independently evidenced observation envelope and tested source hypotheses. The token returns to the editor for technical verification and lawful-context review.

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QUESTION 101

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Can parallel converter channels increase effective resolution without synthesising nonexistent physical bits?

Dr. James M. Atkinson, Moderator: Dr. Bardeen, I invite you to examine a claim sometimes made in discussions of wideband software-defined radio: that a collection of 12-bit or 14-bit converters receiving the same waveform may simply have their outputs combined to constitute a 24-bit, 32-bit or even higher-resolution analogue-to-digital conversion. Please distinguish independent noise averaging from statistical estimation of a common analogue value, and both from time-interleaving to achieve greater sample rate. Explain why converter bit depth cannot be concatenated in this way, and identify what might legitimately improve under carefully controlled conditions. I ask you to include a laboratory comparison using independent dither, correlated noise, gain and offset mismatch, aperture jitter, and a properly specified SINAD measurement.

John Bardeen, Principal Contributor: Dr. Atkinson, the first mistake is to regard a converter's nominal digital word length as an additive physical resource. A 12-bit quantiser maps an analogue input into one of 4,096 nominal codes under a defined input range. Two nominally identical 12-bit converters connected to the same analogue source each report a code related to that same physical input. If the two code words are appended to form a 24-bit string, the result may possess twenty-four storage bits, but the first twelve do not magically resolve the analogue amplitude uncertainty hidden beneath the second converter's quantisation interval. The physical information made available depends upon calibration, input noise, sampling instants, quantiser behaviour and the statistical relation of the errors, not

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the number of symbols in a larger register. A perfectly correlated error is reproduced by every added channel.

One must define the architecture before deriving any improvement. In a simultaneous-sampling array, each converter observes approximately the same analogue input at the same nominal time. The resulting digital values may be averaged, or processed as an ensemble, to reduce components of random error which vary independently between channels. In a time-interleaved array the converters instead observe successive sampling instants offset in phase; the primary purpose is to raise aggregate sample rate. Time interleaving can increase the accessible instantaneous bandwidth under an adequately band-limited analogue front end, but it creates sensitivity to aperture skew, gain mismatch and offset mismatch across channels. Both arrangements are useful, yet one should not claim that the bandwidth advantage of one is a resolution advantage of the other without separate evidence.

Consider an idealised simultaneous arrangement in which each converter measures a common scalar input plus an independent, zero-mean error with identical variance. Let the error variance of each channel be σ^2 and let the number of channels be N. The arithmetic mean of the N readings has error variance σ^2 divided by N when all off-diagonal error covariances vanish. Thus the rms error decreases with the square root of N, and the power signal-to-noise ratio improves by ten times the base-ten logarithm of N decibels if the signal term remains unchanged. In the conventional idealised relation between resolution and signal-to-noise ratio, doubling the number of independent channels yields only about half an effective bit, not a full word-length increase. Sixteen fully independent channels can ideally

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yield a two-bit improvement under those restrictive conditions. A measured result must be compared with those assumptions, not announced as sixteen times the nominal resolution.

The word independent requires particular care. Several ADCs may share the same analogue source noise, preamplifier distortion and power supply interference. They may also share a clock whose phase error moves the effective sample aperture of every converter together. These shared disturbances are correlated, and their common part does not average away merely because more digital words are available. For errors with nonzero covariance, the variance of the mean contains the sum of those covariance terms. A laboratory experiment should therefore measure cross-channel noise correlations, not only the individual channel noise floors. A quiet spectrum obtained from an averaging algorithm is not conclusive evidence of improved analogue accuracy if a common distortion component persists beneath the lower apparent random floor.

Quantisation creates another qualification. Ideal quantisation error is not always independent noise. For certain deterministic periodic inputs and sampling relationships, it can be correlated with the signal and with errors in other converters. Deliberately introduced, characterised dither may decorrelate some quantisation effects, after which suitably averaged measurements can yield finer estimates of certain analogue quantities. Yet dither introduces noise of its own and may worsen individual sample performance. It is not an incantation that turns any twelve-bit converter into a higher-bit instrument. The relevant comparison must fix the measurement bandwidth, input range, clock condition, dither spectrum and decision

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metric. A resolution claim without these specifications can refer to almost any convenient output number.

There is a difference, too, between an improvement in amplitude estimation over repeated observations and the resolution of a single instantaneous event. A receiver analysing a stable carrier over a long interval can exploit averaging and coherence that may not be available for a fleeting pulse. If a burst lasts only a handful of sample apertures, the number of independent observations relevant to its amplitude or phase may be small. Parallel channels sampling at the same instant can still help under suitable independent-noise conditions, but their shared analogue limitations remain. They cannot reconstruct a detail erased by common front-end clipping, a missing antenna-bandwidth component, or a jitter excursion recorded identically in every channel. The distinction matters acutely in defensive RF investigations where a transient cannot be repeated on demand.

An effective-number-of-bits figure must be treated as a measured performance metric, not a label for a digital container. Under the conventional full-scale sinusoidal SINAD relationship, ENOB is estimated from the measured signal-to-noise-and-distortion ratio after applying the appropriate bandwidth and test conditions. Distortion components, including mismatch spurs, matter. A system that reduces random noise but retains a large harmonic can exhibit much less ENOB improvement than the simple independent-noise calculation predicts. Equally, a wider receiver bandwidth integrates more noise and changes the scope of the measurement. One must not quote an ENOB obtained after narrow filtering as though it characterised a much wider instantaneous receiving band without explaining the change in conditions.

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The laboratory trial should compare at least four conditions using one accurately characterised input waveform and a second monitor. First, record each converter separately with its native gain, input range and clock state. Secondly, combine simultaneous channels without deliberate dither, measuring the actual covariance of their errors. Thirdly, apply independent controlled dither and repeat the estimate. Fourthly, introduce a shared disturbance or an intentional channel mismatch to test whether the claimed improvement disappears as predicted. The record should retain the original codes, calibration constants, sample counters and processing scripts, permitting another investigator to reproduce the arithmetic. At every stage distinguish numerical agreement between programs from physical accuracy of the analogue measurement.

I would insist on a further comparison with time interleaving, because a spectacular aggregate sample rate is easily mistaken for an equally spectacular gain in precision. Divide the clock phases among channels and measure the spectral spurs produced by small sampling-skew, offset and gain errors. Repeat the measurement as input frequency increases, because a fixed time error can become more consequential at higher frequency. This experiment may reveal a useful expansion of instantaneous bandwidth with a simultaneous deterioration of spurious-free dynamic range. A conscientious report can describe both results without contradiction. The receiver has gained access to more frequencies, but has not manufactured physical resolution by joining digital outputs together.

My conclusion is therefore conditional and quantitative. Parallel channels can improve selected estimators when their independent error components can be reduced and their shared limitations controlled. The improvement

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should be expressed through measured covariance, SNR, SINAD, ENOB and spurious-free dynamic range within a specified measurement bandwidth and over tested operating conditions. The naive addition of nominal bit widths is not a lawful engineering inference from the architecture. Nor should a demonstration on an easy continuous reference signal be treated as proof of equivalent performance against a single short burst. I pass the token to the remaining contributors to examine device nonlinearity, sample timing, information limits and error-aware digital combination.

Charles Hard Townes, Peer Question: Dr. Bardeen, I want to examine the assumption of independence at the physical source, not merely in the resulting sample arrays. Suppose sixteen converters have separate internal quantisers and separately seeded digital dither, but all receive their analogue input through one low-noise amplifier driven by a thermal environment and a strong neighbouring transmission. A spectral estimate may fall by twelve decibels after the outputs are averaged, while the distortion produced before the splitter remains unchanged. What experiment would persuade you that an observed gain belongs to genuine improved measurement of the weak test waveform rather than to the analyst's selective exclusion of shared disturbances? I am also concerned that measuring noise in one unoccupied FFT bin is not equivalent to measuring the integral noise and distortion in a declared receiver bandwidth. Would you insist on independent analogue monitoring, and how should the investigator explain a result when a sixteen-way array performs impressively with a clean laboratory sine wave but fails to discover a short low-level pulse under the same analogue blocker?

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John Bardeen, Response: Dr. Townes, the question identifies precisely the limit of an attractive averaging result. I would not accept a gain established only by showing a reduced baseline in a selected displayed spectral bin. The laboratory must establish a defined physical input, reference bandwidth, signal amplitude and independent estimate of noise and distortion. A single high-quality analogue monitor placed at an appropriate reference plane can confirm the applied stimulus, although the monitor's own uncertainty must be characterised; a second acquisition arrangement can test whether the observed weak pulse is a property of the source or of the converter chain. The central distinction is between measurement of a known controlled reference and inference about an unknown emission. If the test uses a known weak sine wave, the study can measure how well the array estimates its amplitude. It does not thereby validate an emission detector for all short bursts and interference conditions.

I would design a crossed experiment. Keep the same sixteen-channel hardware while varying, separately, the common amplifier, the independent channel noise, the dither correlation and the blocker level. In one run drive the channels from an exceptionally clean distributed reference; in the next inject a calibrated common-noise component; in the third introduce a non-linear shared stage. Predict beforehand which error terms should change under averaging. For independent unit-variance errors, the variance of the mean should approach one-sixteenth of one channel's error variance. If a shared term dominates, the improvement should collapse toward its irreducible floor. The acceptance test should compare predicted and measured covariance matrices rather than rely on one convenient number.

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Any failure should be retained as evidence about the instrument's true operating range.

The FFT question is equally important. Noise power is related to the selected filter or estimator's effective bandwidth. Decreasing the display resolution bandwidth can make a plotted floor appear lower without changing the physical converter or producing an equivalent instantaneous amplitude measurement. We should state whether the quoted metric is input-referred integrated noise, SINAD from a specified sine-wave test, amplitude-estimation variance or probability of detection for a declared burst. Each has a different experimental denominator. We should not transfer a twelve-decibel difference obtained in a narrowband estimate into a blanket two-bit improvement across the entire receiver's instantaneous passband. A lower plotted line is not a new datum about the analogue input until the measurement model is declared.

As to the failed short-pulse trial, I would report it prominently. The pulse might be masked by the shared amplifier's compression, by clock-aperture uncertainty, by the test detector's threshold, or by analogue band-limiting. We must use controlled fault isolation to distinguish those explanations; the failure itself does not identify one cause. It would demonstrate that the particular array and processing method did not achieve the specified sensitivity in that condition. A useful engineering outcome may be to add front-end preselection, change the gain distribution, or modify the observation schedule. Those are new designs requiring independent tests. It would be wholly indefensible to retain the clean-sine claim while quietly suppressing the inconvenient pulse result, for that is precisely how nominal specifications become misleading forensic assertions.

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John von Neumann, Peer Question: Dr. Bardeen, may I challenge the calculation of an ensemble mean when the converters have unequal calibration errors and unequal variances? A simple arithmetic average is optimal only under selected assumptions. Suppose one converter has an offset that drifts with temperature, another suffers occasional clipping, and a third has relatively low random variance but shares a reference disturbance with its neighbours. A computer can solve for weights that appear to minimise observed error on the training data. What safeguards prevent this optimisation from manufacturing an implausible claim of extra effective bits, particularly when the chosen weights depend on the same test waveform used to pronounce success? Would you insist upon a separate calibration set and a blinded confirmation set? I should also like to know whether weights are permitted to be negative, and what a forensic examiner should do when the mathematically optimum weighting dramatically magnifies sensitivity to a small drift in one channel's physical characteristics.

John Bardeen, Response: Professor von Neumann, unequal channels certainly invite weighted estimation, but the weights must be accompanied by a physical model and evidence that the model holds. If an array yields readings $y_i=x+e_i$ and the covariance matrix Σ of the error vector is known and suitably invertible, a conventional minimum-variance unbiased linear estimator for a common scalar may use weights proportional to $\Sigma^{-1}1$, normalised so that their sum is one. That expression is a mathematical result under the assumed model, not proof that a particular converter is truthful. A poorly estimated covariance matrix can produce exaggerated, unstable or even sign-changing weights. Negative weights are possible in

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some correlated-error models; their mere appearance is not a formal error. But they should be treated as a warning to examine model sensitivity and noise amplification, particularly if the instrument must operate outside the calibration conditions.

The calibration and confirmation datasets must be separated. The laboratory should characterise channel gain, offset, covariance and clipping before choosing its combination rule. The algorithm, weights, validity rules and acceptance thresholds should then be frozen for an independent confirmatory set whose physical inputs and nuisance conditions were not selected to favour that algorithm. If an investigator chooses weights after inspecting the very weak signal whose presence is in dispute, a claimed detection gain cannot be evaluated as though the weights had been chosen in advance. The resulting exploratory finding may still be useful for designing another test, but its evidential weight must be qualified. Separate monitoring of the applied analogue input is also necessary because an optimisation can fit the shared distortion rather than remove it.

For drift, I would require a sensitivity experiment. Vary the temperature, clock and input power independently, perturb the calibrated gains and offsets within their uncertainty ranges, and recompute the estimate. If a nominally optimum weight set produces widely differing results under small plausible perturbations, its formal variance advantage is not operationally robust. A more conservative estimator, or a subset of well-characterised channels, may be preferable. Report the stability as a function of operating state and bandwidth, not merely a favourable scalar ENOB at one temperature. A dropped or clipped channel should not be silently assigned

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its nominal weight; the validity mask and weighting revision must be explicit and preserved.

Above all I would retain the raw independent streams, their calibration records and a reproducible processing manifest. An independently checked output that is numerically identical to the original combined stream shows that the same computation can be repeated, but it does not by itself show that Σ was appropriate or that the reference clock behaved correctly. The final report should state which errors were directly measured, which model parameters were estimated, and which alternative explanations remain viable. The weighted algorithm earns its authority through challenged experiments, not through the elegance of the matrix formula or the impressive number of digits printed by the computer.

Dr. James M. Atkinson, Moderator: Dr. Kroemer, I thank Dr. Bardeen and the first peer interlocutors. I invite your examination of the analogue distribution network, correlated gain and timing errors, and nonlinear behaviour under strong neighbouring signals. The token is yours.

Herbert Kroemer, Second Principal Contributor: Dr. Atkinson, I would begin at the transistor and sampling switch rather than at the digital word. The array has a physical front end, and every channel is ultimately subject to an analogue transfer characteristic. That characteristic is not specified by the number of bits written at the output. If twelve- or fourteen-bit converters share one splitter, preamplifier, reference rail and timing source, they inherit common-mode effects before any computation begins. The first instrument question is therefore which noise terms are statistically independent at the sampling aperture, which errors track the signal, and which mechanisms are common to the entire assembly. The impressive

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diagram of sixteen parallel paths may conceal one common weakness. In particular, a small common nonlinearity can create an apparently repeatable spectral line which averaging preserves rather than attenuates. A receiver forensicist should welcome that persistence as diagnostic information, not hide it behind a higher-resolution claim.

Let each channel be represented by $y_i(t)=g_i x(t+\delta_i)+b_i+c(t)+\varepsilon_i(t)+d_i(t)$, where x is the analogue input, g_i is its gain, b_i its offset, δ_i its sampling-time error, c is a disturbance shared by all channels, ε_i is independent noise, and d_i collects channel-specific distortion. I use this as a first-order descriptive model, not as a universal characterisation of a real converter. Gain, offset and skew will themselves vary with frequency, temperature and source impedance. If the analyst computes a simple mean of the channels, the independent components may be reduced, but the average contains the common disturbance c unchanged. Any gain and offset correction must be justified by calibration, and a timing correction requires a reference traceable to the actual aperture. Calling the result twenty-four-bit is conceptually mistaken because its lower numerical bits may be dominated by an uncorrected physical error.

It is possible to calculate the limitation without the romance of ideal components. Imagine sixteen channels each presenting an rms independent error of one arbitrary unit and a shared rms error of one unit, all zero-mean and uncorrelated between the shared and independent terms. Before averaging, the total error variance of one channel is two units squared. After averaging, the independent variance is one-sixteenth, whereas the common variance remains one. The combined variance is therefore 1.0625, not one-eighth. The rms error falls from the square root of

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two to the square root of 1.0625, an improvement of only about 2.75 decibels in power SNR, assuming the signal gain and bandwidth are fixed. No assertion about absolute converter resolution follows without testing its distortion and reference accuracy. Merely reporting the ideal twelve-decibel improvement for sixteen channels would conceal the measured common noise.

A second experiment should vary the analogue distribution network deliberately. A power splitter may have amplitude imbalance, frequency-dependent phase shift, reflections and changing isolation between branches. If the investigator compares the output codes of channels that have not been independently calibrated at each test frequency, differences in their apparent noise may reflect the splitter rather than converter silicon. The source must be accurately characterised and operated below its own distortion threshold. The measurement is also sensitive to the amplifier's recovery after a strong blocker. Suppose a weak laboratory tone is present beside a high-amplitude signal. The front-end amplifier may compress all sixteen branches, and the array average will faithfully reproduce a distorted observation. It does not regain information that the shared analogue stage destroyed. An examination of blocker tolerance, not merely low-level sine-wave noise, is indispensable in a wideband defensive receiver.

The sampling aperture matters particularly for rapidly varying signals. For a sinusoid $x(t)=A \sin(2\pi f t)$, a small timing error δt produces an approximate voltage error $\delta x \approx 2\pi f A \cos(2\pi f t)\delta t$. The approximation is local and fails for sufficiently large jitter or non-sinusoidal excursions, but it correctly shows the growth of the sensitivity with frequency. A shared clock-jitter event can shift every converter's observation coherently, so adding simultaneous

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channels will not generally reduce it. A channel-specific aperture disturbance may be partly averaged if its correlations and distribution permit it. Yet an average of samples nominally simultaneous is not necessarily equivalent to a true simultaneous sample if the apertures are misaligned. A short RF burst can develop a false leading edge or an attenuated peak when the array's samples are combined without alignment.

For time interleaving, the same timing parameter appears in a more conspicuous form. Suppose four channels each operate at one hundred million samples per second, their ideal apertures separated by 2.5 nanoseconds within a ten-nanosecond cycle. Under suitable analogue and digital conditions the assembly produces four hundred million output samples per second, raising the ideal real-signal Nyquist boundary to two hundred megahertz. It has not changed any individual channel's nominal code count. Offset errors can create a comb of spurs linked to the channel cycle; gain and timing mismatches can generate images whose positions depend upon the input tone and interleaving pattern. For a short transient those imperfections may mimic multiple pulses. The legal and scientific reporting question is whether the combined record preserves the physical event with a calibrated uncertainty, not whether its aggregate sample-rate label looks commercially persuasive.

I recommend a calibration sequence in which the same array is exposed to a low-frequency sine wave, a high-frequency sine wave, a short independently monitored pulse and a two-tone blocker test. Each test probes a different weakness. The first checks offset and gain; the second raises the consequences of aperture skew; the pulse challenges transient fidelity; the two-tone test reveals nonlinear mixing and recovery. Repeat the sequence

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before and after thermal cycling, after replacing the reference clock, and after changing the splitter. If a correction algorithm improves SINAD at one frequency but worsens phase fidelity for the short pulse, the system's report must preserve both outcomes. No single average performance figure can excuse a failed use-case measurement.

I would also keep the engineering vocabulary disciplined. Resolution can mean code step size, effective amplitude estimation precision, spectral resolution after a chosen observation time, or the ability to discriminate two adjacent frequencies. These are different quantities. A twelve-bit converter has 4,096 nominal quantisation codes; a sixteen-channel ensemble may provide an estimator with reduced random variance; and a four-channel interleaver may increase sampling throughput. None of those facts alone establishes a twenty-four-bit or thirty-two-bit equivalent physical input resolution. The proper claim is accompanied by a traceable reference plane, specified bandwidth, input range, controlled state and uncertainty statement. I pass the token to Dr. Nyquist to examine how sampling theory constrains the interleaved architecture.

Dennis Gabor, Peer Question: Dr. Kroemer, I ask how an array that gains average amplitude precision might nonetheless lose information about a very brief waveform. Your timing-error model uses a local derivative and describes the change in a sine wave for a small aperture displacement, but a short pulse may include rapidly changing components which an analogue input filter has already dispersed. If the channels have slightly different analogue group delays, averaging their samples at equal nominal indices can blur an edge even when each channel's separate capture is informative. What evidence would distinguish that physical smearing from random noise

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reduction, and how might an examiner avoid treating a narrower post-averaging amplitude distribution as proof of improved transient accuracy? I would also challenge the traditional reliance on one coherent sine wave in converter demonstrations. Could a multi-tone or calibrated pulse response reveal errors which an optimised sine-wave ENOB number conceals? Please describe the necessary controls without overstating the ability of a finite-bandwidth instrument to reconstruct an arbitrarily abrupt event.

Herbert Kroemer, Response: Dr. Gabor, the time-domain problem is not interchangeable with a scalar variance problem. If separate channels produce differently delayed versions of a pulse, the pointwise average can reduce the measured peak and widen the apparent pulse without adding noise in the ordinary sense. Such an average may have a lower sample-to-sample variance than any individual capture while being less faithful to the true pulse shape. A strong test would record an independently monitored reference waveform, characterise each channel's impulse response and group delay, and compare calibrated alignment with naïve index-based averaging. The response of the analogue path is part of the measurement. A digital post-processing operation cannot restore spectral components which the entire analogue distribution network suppressed below the information needed for reliable reconstruction.

One could quantify the first-order problem with a Gaussian test pulse whose timing and bandwidth were independently specified, while carefully acknowledging that this is a model waveform rather than every possible radio transient. Inject it at several amplitudes and positions within the interleaving clock cycle. Save separate captures, the array mean before alignment, the mean after traceable alignment and the independent

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reference. For each, compute peak amplitude error, time-of-peak error, pulse-area difference and an appropriately windowed spectral residual. A gain in one metric may be accompanied by a loss in another. The report should preserve all of them if the forensic question concerns both amplitude and timing. A high ENOB derived from a long continuous sine does not certify that a brief burst has been recorded without time smear.

The distinction becomes important in a channel array containing dissimilar analogue filters or transformers. A group-delay mismatch that depends on frequency cannot always be corrected by one constant time shift. The engineer must measure the actual phase response and, if a compensation filter is proposed, evaluate whether its numerical inversion amplifies noise or creates ringing. When the input is close to an unknown saturation condition, linear response methods may also fail. The correct record should identify which state-dependent assumptions were tested and which are extrapolations. More channels can improve a well-defined estimator, yet more physical paths can also introduce a larger set of calibration uncertainties. Neither fact negates the other.

A two-tone and a pulse test would be useful companions to the sine-wave specification. The two-tone stimulus challenges intermodulation and shared front-end compression; the pulse challenges aperture alignment, transient response and the effect of finite analogue bandwidth. Each should be repeated with the channels individually and in combination. I would especially inspect whether a new spectral line moves when the channel order or interleaving phase changes. Movement tied to receiver configuration may indicate an instrument-generated product, not an external emitter, although the conclusion still requires control experiments.

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For technical-surveillance evidence the report should state the limited observation: the array reproduced the specified reference within the tested uncertainty, or it did not. It should avoid claiming universal transient fidelity from an attractive noise-floor display.

Lord Rayleigh, Peer Question: Dr. Kroemer, I would like the panel to resolve a distinction among noise reduction, distortion and calibration uncertainty. An experiment may show that sixteen channel outputs have noisy residuals whose arithmetic mean fluctuates less than any one channel. Yet if a shared gain error of one per cent persists, the ensemble can be very precise while remaining inaccurate. Under what conditions may an investigator infer improved ability to separate a small signal from background, and when must that inference be limited to repeated readings of a known reference? I ask particularly about the difference between rms signal-to-noise ratio and the spurious-free dynamic range of a wideband receiver. Could a lower random floor coexist with a more conspicuous deterministic spur from interleaving mismatch? Finally, please state which uncertainty components should be attributed to the common input path rather than counted independently for each converter when constructing the final measurement budget.

Herbert Kroemer, Response: Lord Rayleigh, a precise ensemble may indeed be consistently wrong. If all channels share a gain error, averaging reduces independent scatter but does not remove the calibration bias. The proper uncertainty budget should contain a term for the common gain model and its uncertainty, a term for shared clock and front-end disturbances, and terms for independent channel effects. One cannot divide a common calibration uncertainty by the square root of sixteen merely because sixteen

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readings were taken. Some shared components may be estimated and corrected using traceable references, but the residual uncertainty of that correction remains. The report must distinguish an applied correction, its uncertainty and a merely assumed offset. A narrow scatter plot alone is not evidence of absolute accuracy.

The two dynamic metrics answer different questions. SNR ordinarily quantifies signal power relative to noise under a specified measurement procedure; spurious-free dynamic range addresses the ratio between a desired signal and the largest relevant spur within the test conditions. A system can reduce broadband random noise by averaging while retaining a strong correlated harmonic or interleaving image. In that case the weak signal may still be hidden by the spur, and the improvement implied by a lower noise floor may have little operational benefit near the spur's frequency. A calibrated sine-wave SINAD test incorporates distortion according to its specified procedure, whereas a displayed SNR reading may exclude selected tones. We must report precisely what was included or excluded rather than transferring one number into another metric.

For an example, suppose the per-channel uncorrelated noise power is the reference unit, and the common distortion at a selected bin has power one hundred times greater. Ideal sixteen-channel averaging would reduce the independent-noise power to one-sixteenth, a twelve-decibel reduction of that part. It would not reduce the common distortion if the channels reproduce it coherently. At the selected frequency the total impairment would change from 101 to approximately 100.0625 reference units, a negligible system-level improvement. This elementary arithmetic is a warning against observing one part of the spectrum and claiming a general

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converter enhancement. The actual system may have further nonlinear interactions which require measurement rather than extrapolation.

The ability to detect a small signal must be demonstrated under a stated operating environment, observation period, receiver bandwidth, false-alarm rule and signal model. I would include a controlled weak source adjacent to a blocker and vary the blocker level to reveal compression and spur development. A long coherent tone is a legitimate test, but not a substitute for a short emission near a retune gap or after a strong-signal overload. A defensible result should describe the tested class of signals and levels and the degree of confidence supported by repeated independent challenge trials. The instrument's calibration record should disclose all common components so that a later examiner does not count the same uncertainty sixteen times as independent or, worse, divide it away sixteenfold.

Herbert Kroemer, Cross-Peer Question to Harry Nyquist: Dr. Nyquist, I invite you to challenge an assumption that sometimes appears when converter channels are time-interleaved. An engineer may state that four channels, each sampling at one hundred million samples per second, automatically create an instrument with four hundred million samples per second and therefore double the usable real-signal observation bandwidth of a two-hundred-million-sample arrangement. Yet the analogue channels may differ in anti-alias filter phase, their aperture clocks may have unequal delays, and their output data may be stitched together using a presumed timing map rather than one supported by experiment. Could you distinguish the mathematically ideal increase in sampling opportunities from the empirically defensible increase in usable RF bandwidth? I am especially concerned about strong out-of-band emissions folding into the new

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channel, producing spurs that resemble an external transmitter. What tests should an independent investigator demand before accepting the expanded-bandwidth claim, and how might the result be presented without implying that greater sampling throughput has also delivered extra amplitude bits?

Harry Nyquist, Cross-Peer Answer to Herbert Kroemer: Dr. Kroemer, the asserted four-hundred-million-sample rate is credible only if the physical apertures genuinely occur at the intended staggered times and the resulting record preserves their order and values correctly. A schedule printed by digital firmware is not an observation of analogue aperture timing. The engineer must establish the actual timing offsets, including their frequency and temperature dependence, with an independently appropriate reference. The analogue input response should also be characterised for every branch, because a uniform high-rate output sequence cannot reconstruct a frequency component which the common or individual input networks failed to convey. We should distinguish an arithmetic data rate from the verified passband in which defined signal amplitudes, phases and timing can be measured within the declared uncertainty.

A suitable challenge begins with known tones swept through the intended band and through the transition regions beyond it. The independent reference should establish what was applied, while the converter array reports what appeared in its output spectrum. The examiner should vary channel order, interleaving clock phase and input attenuation while retaining raw data, then determine whether spurious lines follow the predicted mismatch pattern. An external source's field at the antenna does not normally acquire a different physical frequency merely because software

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changes a multiplexing order, although the receiver's interpretation may change; this is a useful but not solitary discrimination test. A second receiver using materially different sampling architecture can provide corroboration. The test needs a suitably strong out-of-band challenge because a clean in-band tone does not prove sufficient anti-alias rejection.

The ideal real-valued Nyquist limit of a four-hundred-million-sample-per-second uniformly sampled system is two hundred megahertz, but that ceiling is not a certificate of flat amplitude response, immunity to aliasing or adequate dynamic range. A tested useful bandwidth may be smaller, and the lower edge of any uncertain transition should be disclosed. The result must also be conditioned on actual acquisition continuity. A high data rate can overwhelm the host pipeline, producing missing samples despite perfectly functioning ADC clocks. The investigator should include verified sample counters and overflow flags so that a supposed short RF pulse is not silently altered by concatenation after a loss. Frequency coverage is therefore a chain property, not the arithmetic product of channel number and catalogue sampling rate.

Finally, the voltage measurement remains constrained by each converter's noise, linearity and calibration. Time interleaving provides different sample times rather than independent simultaneous readings of one physical amplitude. It may improve a reconstruction problem by supplying more temporal information, but it does not imply the independent-error reduction of an ensemble average. A proper report might state that a four-way interleaved array demonstrated usable coverage up to a specified frequency at a specified SINAD and spurious-free dynamic-range threshold, with recorded aperture uncertainty. Such a statement is stronger scientifically

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than claiming fourfold frequency coverage and a fictitious collection of extra resolution bits without a reference experiment. I return the token in gratitude for the important distinction between throughput and measured fidelity.

Dr. James M. Atkinson, Moderator: Dr. Nyquist, please distinguish greater temporal sampling coverage from improved amplitude resolution, and qualify the limits imposed by analogue filtering and mismatch. I pass the token to you with thanks.

Harry Nyquist, Third Principal Contributor: Dr. Atkinson, the seductive phrase more bits obscures two distinct questions. How finely may an amplitude be estimated, and what time variation may be represented without ambiguity? An array of simultaneous converters aims principally at the first question under conditions of independent error. An array with staggered apertures addresses the second by producing more time samples. If the channels are rearranged digitally, one must identify which physical instants were sampled and whether the analogue input satisfied the assumptions required for subsequent reconstruction. An unverified high aggregate sample rate cannot repair spectral content already removed by a common filter, nor can it guarantee accurate amplitude if the channels have poor linearity. I would therefore put an acquisition-time diagram beside every proposed processing architecture before evaluating a bits-per-sample calculation.

Consider two channels, each sampling at one hundred million samples per second. If they are driven by the same sampling edge, they provide two estimates of each ten-nanosecond instant; their combined output is not a two-hundred-million-samples-per-second time series of distinct instants. If

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the second is delayed ideally by five nanoseconds, the interleaved record provides samples every five nanoseconds, which is a different physical experiment. The ideal real-valued reconstruction boundary then changes from fifty to one hundred megahertz, provided the band-limiting and interleaving assumptions hold. A system that alternates two simultaneous samples without actually staggering the physical apertures merely repeats information. A plot whose time axis is assigned after acquisition cannot turn those repeated values into valid intermediate observations. The laboratory should verify actual sample aperture timing, not the rate reported by a software buffer.

The original sampling theorem requires careful assumptions, and I would resist using it as a slogan in expert evidence. A mathematically band-limited waveform, sampled uniformly above twice its highest frequency, can in principle be reconstructed under ideal conditions. A laboratory receiver operates with filters whose attenuation is finite, jitter and mismatch, and a real analogue front end which may be driven by signals outside its nominal band. Strong out-of-band energy can alias into the digitised channel if the anti-aliasing filter does not suppress it sufficiently. Interleaving does not remove this danger; it can complicate the pattern of images. A converter array may display a weak spectral feature which belongs to a remote interferer folded into the measured band rather than the supposed external source of interest. Preselection and substitution tests remain essential.

Now consider an ensemble whose individual channels are twelve-bit quantisers. The nominal ideal signal-to-quantisation-noise ratio for a full-scale sine is approximately 6.02B+1.76 decibels under the usual uniform, appropriately decorrelated quantisation assumptions, where B is the

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number of bits. At B=12 the ideal figure is about seventy-four decibels. A sixteen-way statistically independent ensemble could in an ideal noise-limited case improve the relevant error power by twelve decibels, corresponding to roughly two additional effective bits. But that improvement is conditional on the error model and on how SINAD is measured. An ideal quantiser may exhibit signal-correlated error for some deterministic inputs, and a real converter includes nonlinear components which do not behave as independent white noise. Thus the arithmetic supplies a testable upper benchmark, not a warranty.

There is another conceptual danger. A narrowband Fourier estimate accumulates evidence across time, and a digital receiver may display a spectral noise floor far below the apparent quantisation step of one raw sample. This does not imply that each instantaneous analogue sample acquired an equal number of new intrinsic amplitude bits. Processing gain, coherent accumulation and reduced resolution bandwidth can all alter the uncertainty of a parameter estimate. An investigator should state whether the claimed improvement concerns one sample, one estimated carrier amplitude over a stated interval, a detected transient event or a reconstructed continuous waveform. For short signals, extending the averaging interval may be impossible without mixing observations of different states. A performance demonstration should include a specified transient as well as a continuous tone.

The sample-rate and bandwidth claims should also be conditioned on temporal covariance. A commonly distributed sampling clock may introduce correlations between channels; a nominal time shift can be imperfect, and the error may change with temperature. In a two-way interleaver a fixed

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skew of one hundred picoseconds is a small fraction of a five-nanosecond ideal offset, but its effect on a high-frequency sine can be material. At an input frequency of one hundred megahertz, a one-hundred-picosecond differential shift represents approximately 0.0628 radians of phase, or 3.6 degrees. This is not a universal specification of system performance. It is a simple illustration that a small absolute timing error can become noticeable in a measurement near the expanded band edge. The correction and its uncertainty must be verified independently.

I would insist that the test report preserve the precise analogue bandwidths of the individual paths as well as the digital multiplexing pattern. Some arrays are assembled from converters whose front-end response falls sharply near the intended upper frequency. Although a calculated aggregate sample rate may permit wider sampling, the analogue front-end may not deliver an adequate signal at that edge. The report should include input-referred noise, gain flatness, phase response and spurious-free dynamic range across the useful passband rather than only a single sample-rate statement. For technical-surveillance work the strongest interference, not the weakest signal, may determine the practical dynamic range. One cannot certify discovery of a minuscule emission merely by enlarging the number of output samples.

Finally, the investigator should keep the distinction between sampling redundancy and timing diversity visible in the saved evidence. If successive channels sample distinct instants, record which channel acquired each point and the actual sample times or calibrated offsets. If simultaneous channels are averaged, retain the raw separate streams and the weights used to combine them. Reprocessing with another calibration model should be

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possible. This discipline avoids retrospectively altering the apparent event when a correction algorithm is revised. The defensible description may be modest: the interleaved receiver expanded tested instantaneous coverage under a known spur and jitter envelope; the simultaneous array improved a specified estimator by a measured amount under a covariance model. Neither description needs an imaginary bit count. I pass the token to Dr. Shannon for the statistical account of how much information the array actually yields.

Karl Guthe Jansky, Peer Question: Dr. Nyquist, in a practical spectrum survey the environmental signal seldom resembles the ideal isolated sine which appears in textbooks. Suppose several converters share a wideband antenna and front end while strong broadcast signals, switching transients and unintended reflections change through the day. A time-interleaved arrangement claims a doubled or quadrupled instantaneous sample rate, but the practical observation may exhibit combs of periodic spurs linked to the channel sequence. How should a field investigator separate a genuine faint external signal from an image generated by analogue mismatch or clock timing, especially when only one particular receiver configuration produces the feature? Would you regard a controlled antenna substitution, attenuation changes and an independently constructed receiver as more informative than a display of astonishingly fine digital frequency bins? Please also explain what evidence is necessary before asserting that no unobserved band exists between the nominal frequency limits of the array.

Harry Nyquist, Response: Dr. Jansky, the first task is to map the observation apparatus against its asserted frequency coverage. An interleaved sampler's aggregate clock does not automatically make its analogue front end

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uniform across the corresponding Nyquist interval. The investigator should measure or otherwise establish the useful analogue passband, anti-alias attenuation, gain response and clock-related spur behaviour. A spectral feature seen only in one interleaving mode is a reason to challenge that mode, not immediate proof that the feature is artificial or genuine. Change the number and order of active channels, the clock phases where authorised and the reference source, then observe whether the apparent spectral component follows predicted instrument-generated aliases. An independent receiver with a materially different architecture can offer a useful check, provided its own overload and calibration states are recorded.

Attenuation and antenna substitution are particularly revealing when interpreted carefully. A genuine external input ordinarily changes with a controlled input attenuation in a manner consistent with the calibrated receiver chain, subject to its detection threshold and noise regime. An internal spur downstream of the attenuator may not respond in the same way. But an upstream overload product may change nonlinearly with attenuation, and an antenna substitution can alter the load impedance and disturb a marginal front end. Thus no single change is conclusive. The value lies in a controlled pattern of results across independently understood configurations. A field note must record the actual attenuation, gain and preselector state, not merely the operator's conclusion that a suspicious line disappeared.

The frequency-axis question also matters. Digital FFT bin spacing is determined by sample rate and transform length; it is not a promise of independent physical resolution at every printed frequency. Windowing, acquisition duration, oscillator accuracy and the analogue transfer function

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affect a valid conclusion. If the interleaving changes the effective sample rate, the entire data pipeline must update its metadata and frequency mapping. An incorrect sampling-rate field can place a genuine narrowband reference at the wrong displayed frequency even when the raw data are unchanged. This provides a simple falsification test: inject an independently monitored tone at several known frequencies, including near the nominal band edges, and verify both its spectral location and amplitude under each mode.

A claim of gap-free coverage requires more than the aggregate sampling theorem. The analogue response and filter transition regions must be documented, and relevant alias products must be bounded for the expected external environment. Observation scheduling, storage throughput and processing gaps can also create blind periods. The array may be sampling continuously in hardware while the host drops blocks, or it may record every sample but lack sensitivity in a sub-band due to a filter notch. The responsible statement is that the tested system monitored a declared band with specified sensitivity and continuity limitations, not that every conceivable signal would necessarily have been detected. A short weak burst can escape a receiver with an excellent sample-rate specification if acquisition state or receiver dynamic range makes it unobservable.

Harry Nyquist, Cross-Peer Question to Claude Elwood Shannon: Dr. Shannon, I ask you to examine a commonly overlooked inference from the law of large numbers. An array may gather many observations of the same analogue source, and the resulting average may converge numerically with considerable apparent stability. Suppose, however, that every observation shares an offset in the analogue reference, while channel-specific noise

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remains independent. A practitioner may claim that enough converters will eventually overcome all uncertainty because the residual scatter decreases. Could you present a statistically defensible limit to that reasoning, specifying what assumptions permit a one-over-N variance improvement and what happens when pairwise correlations persist? Please also consider the word effective in ENOB: is the conventional conversion of measured SINAD to an equivalent bit count a statement about the number of independent physical facts learned, or merely a useful benchmarking convention under its own stimulus and measurement assumptions? I request an explicit numerical example which exposes the difference.

Claude Elwood Shannon, Cross-Peer Answer to Harry Nyquist: Dr. Nyquist, the relevant proposition is conditional. If N observations each equal a common signal plus zero-mean independent errors with variance σ^2, then the variance of their arithmetic mean is σ^2/N. But if the errors have equal marginal variance and pairwise correlation ρ in an exchangeable covariance model, the variance becomes $\sigma^2[\rho+(1-\rho)/N]$. The correlated term remains as N grows. The calculation demonstrates why a larger register cannot suppress an unknown shared analogue offset. In actual hardware, the covariance may not be exchangeable, and a more general expression $w^T\Sigma w$ is required for a weighted combination. These are models which must be compared with measurements, not declarations that all converter arrays behave alike.

For a numerical illustration take N=16 and pairwise correlation ρ=0.25. The variance ratio relative to an individual channel is 0.25+0.75/16=0.296875, not 1/16. Under a fixed signal-power assumption, the SNR gain of this mean is 10log10(1/0.296875), approximately 5.27 decibels, equivalent to about 0.875

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of the ideal six-decibel-per-bit benchmark. With truly independent noise the ratio would be 0.0625, the gain about 12.04 decibels, or two ideal effective bits. The correlated example therefore falls substantially short. We must be careful that correlation can also arise from measurement procedures and that any estimated gain has its own uncertainty. More channels can improve some estimators but cannot eliminate a shared disturbance through repetition alone.

The conventional ENOB figure is a useful test-dependent way of expressing dynamic converter performance relative to a model of ideal quantisation. It is not an integer count of uniquely recovered facts and not a statement about the information capacity of a communication channel. Its value depends on input waveform amplitude and frequency, measurement bandwidth, noise and distortion treatment, calibration and the adopted test method. We should not treat a fractional ENOB improvement measured with a particular sine wave as a universal guarantee that a single brief radio pulse will be sampled with an equivalent number of accurate amplitude bits. Independent test scenarios must establish whether the estimator's real task benefits from the change.

I would communicate the result as a hierarchy of claims. First, the array had a specified number of nominally twelve-bit or fourteen-bit conversion channels and a documented operating arrangement. Secondly, within a declared laboratory condition its averaged estimator exhibited a measured reduction in variance, with uncertainty and cross-channel covariance records. Thirdly, a conventional dynamic metric such as SINAD or ENOB was measured by a stated standardised procedure, while timing fidelity and strong-signal performance were tested separately. There is no need to

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create a fictitious twenty-four-bit or thirty-two-bit converter. The science becomes clearer when the independent observations, shared assumptions and numerical representations are explicitly separated. I return the token to our moderator with respect for the distinction you have drawn.

Dr. James M. Atkinson, Moderator: Dr. Shannon, I invite the panel to distinguish information in independent observations from additional symbols in the output representation. Please examine covariance and a reproducible quantitative limit.

Claude Elwood Shannon, Fourth Principal Contributor: Dr. Atkinson, I would distinguish the number of digits in a file from the uncertainty of a proposition inferred from that file. A digital register can be made arbitrarily wide by padding its output with zeros. The register then contains more bits as a syntactic object but no additional information about the analogue source. Parallel converters do provide separate observations, and independent observations can refine an estimate. The relevant inquiry is not how many bits can be written but how distinguishable the resulting observations are under competing analogue inputs. This is fundamentally a question about the conditional distributions of measurements given the physical signal and the nuisance parameters. A useful experiment must characterise those distributions, including errors shared between channels.

Suppose N channels observe the same scalar amplitude x, yielding $Y_i=x+E_i$. If each E_i has zero mean, independent variance σ^2 and no covariance with the others, then the arithmetic mean has variance σ^2/N. The corresponding standard deviation scales as $1/\sqrt{N}$. If errors share correlation coefficient ρ, equal marginal variance and a valid exchangeable covariance model, the mean variance is $\sigma^2[\rho+(1-\rho)/N]$. This expression exposes the limit of

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indiscriminate optimism. As N becomes large, the independent term vanishes but the correlated term remains. It would be a mistake to conclude that a hundred channels necessarily provide a hundredfold reduction in error variance. With a common covariance fraction of one quarter, the asymptotic variance is one quarter of the individual-channel variance regardless of the size of the array.

The ideal equivalent-bit improvement follows from an assumed doubling of signal-to-noise power for each doubling of independent observations. In a noise-limited system with fixed signal power, averaging N independent channels ideally raises SNR by 10log10N decibels. Dividing by 6.0206 decibels per ideal bit gives approximately 0.5log2N additional effective bits. For N=4 the increase is one bit; for N=16 it is two; for N=64 it is three. It does not follow that N=64 produces sixty-four independent bits of analogue amplitude. Moreover, the calculation does not establish an ENOB gain if distortion and shared clock noise dominate SINAD. It describes a statistical error-reduction result under explicit conditions. The correct report should keep both the theoretical ceiling and the measured departure from it.

An important distinction arises between nominal quantisation step size and information that can be inferred through dither. Imagine that several quantisers have identical thresholds and that their common input lies within one code interval. If all channels have exactly the same deterministic mapping and no independent perturbation, they may return the same code every time. Their average carries no new sub-code evidence. If each channel experiences a separately characterised perturbation, the observed distribution of codes may convey information about the input's position within the nominal interval, provided the perturbation distribution is known

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and the reconstruction estimator is appropriate. This is not the same as a single converter suddenly acquiring physically exact extra bits. It is a probabilistic estimate that has its own variance, possible bias and finite-data limitations.

Information must also be judged against the signal's bandwidth and the experimental objective. A stable test sine observed for many cycles supplies repeated opportunities to estimate phase and amplitude. A brief impulsive RF event may not. If the pulse is distorted by a common preamplifier, additional digitiser channels provide independent records of the same distortion. If the pulse amplitude exceeds full scale, all converters can saturate simultaneously. The processing algorithm cannot reconstruct the unclipped peak without separate valid measurements or assumptions which must be declared. The analyst should never equate a reconstructed plausible waveform with a preserved observation. Such restraint is especially important when a narrow conclusion, such as a threshold crossing, is later used to allege a particular transmitter's presence.

I would formulate the controlled experiment using two distinct information tasks. In the first, estimate the amplitude of a known stable reference with a repeated simultaneous array. In the second, classify whether a brief independent reference pulse occurred within a specified time window. For each task generate positive and negative test instances, record the true input through an independently calibrated monitor, and compare the individual channels with the combined estimator. Vary independent error, common error, dither and clock state separately. An observed reduction in amplitude variance in the first task may not translate into improved detection probability in the second because the processing algorithm and

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nuisance conditions differ. The result should not be generalised beyond the experiments actually performed.

The relationship between SNR and resolution has an important caveat: ENOB is a conventional converter performance metric measured under specified dynamic test conditions, often derived from a full-scale sine-wave SINAD relationship. It is not a direct measurement of Shannon channel capacity, nor a certificate that every amplitude code is accurate to a fraction of one nominal least-significant bit. A converter can have a large nominal number of codes and a poor effective dynamic result due to harmonics and spurs. Conversely, narrowband processing may produce a precise estimate of one tone from data whose individual samples have much lower nominal resolution. The meaning of the precision claim is inseparable from its measurement procedure.

My concluding recommendation is to document the full likelihood structure, or at least a controlled approximation to the covariance and error model, when presenting the benefit of parallel channels. The analyst should publish separate traces for common-mode and independent disturbances, specify any dither injected, and report the uncertainty of the final estimator on the actual test waveform. If the observed improvement is less than the ideal bound, that is not a failure of the experiment. It identifies which physical limitations govern the hardware. The scientific failure occurs when the output word is enlarged and then described as though the analogue input has been observed with an equivalently enlarged number of independent bits. I pass the token to Dr. Hamming for a discussion of numerical representation, error detection and the integrity of the digital combination.

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William Redington Hewlett, Peer Question: Dr. Shannon, the panel has derived an attractive covariance formula, but an engineering laboratory must decide how much statistical modelling is warranted before a product passes its acceptance test. Suppose a vendor presents sixty-four nominally independent converters, along with one narrowband noise reduction demonstration and a plot headed thirty-two-bit performance. How should a purchaser specify a falsifiable requirement which avoids rewarding an invented output word length? Would you use measured SINAD, ENOB and spurious-free dynamic range at several operating points, and a separate short-burst detection test? How should the laboratory guard against combining sixty-four channels whose noise is visibly correlated through a common clock or power system, particularly when the vendor claims that more averaging will eventually suppress every remaining impairment? I would also like the report to state whether a measured gain in one selected estimator constitutes a system-wide dynamic-range improvement. Please specify whether the independent laboratory should repeat the trial after thermal cycling and under a deliberately strong adjacent-channel blocker, even when the narrowband test has passed.

Claude Elwood Shannon, Response: Mr. Hewlett, I would make the purchasing requirement observable and scenario-specific. An array may be required to achieve a measured amplitude-estimation uncertainty below a specified threshold for a known input waveform, temperature range and bandwidth. It may separately be required to detect a class of short laboratory bursts at a declared false-alarm rate under specified blocker levels. Such requirements can be tested without making a declaration about nominal effective word length. If an ENOB claim is made, the stimulus

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amplitude and frequency, test bandwidth, SINAD method and equipment configuration must be specified, as the applicable converter-test framework demands. The claims for simultaneous averaging and interleaving should be separate because they concern different physical operations.

The covariance measurement is not an academic decoration. Before approving a sixty-four-channel noise-reduction claim, the laboratory should record individual-channel residuals under a common calibrated input and estimate cross-channel correlations under multiple independent test conditions. A common clock perturbation or reference-rail disturbance may yield a nonzero covariance structure. The ideal σ^2/N expression assumes away those correlations; it may be a useful limiting benchmark, but it is not a fit-for-purpose acceptance rule when the observed residuals have substantial common structure. Introduce an independent controlled common disturbance and see whether the reported gain degrades as the model predicts. If the vendor instead treats every residual as uncorrelated by assumption, the demonstration has not tested the central assertion.

The phrase thirty-two-bit performance should be unpacked until it has an operational meaning. It may mean the software exports thirty-two-bit floating-point numbers, that an accumulator uses thirty-two fixed-point bits, or that a narrowband estimator exhibits a variance approaching the value associated with a high ideal-bit benchmark. Those are not equivalent. The buyer should ask for the actual number of nominal ADC codes, the measured ENOB at the relevant input frequencies and amplitudes, and the confidence interval for any claimed ensemble gain. An improved amplitude estimate for a stable tone does not automatically confer increased instantaneous dynamic range for multiple interfering signals. If a shared

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analogue stage clips under a blocker, the output's many decimal places may merely give a precise number for distorted input data.

A useful acceptance report should be designed to survive an unfriendly independent laboratory. It should include raw per-channel streams, equipment configurations, timebase and reference-plane records, source uncertainty, dither conditions, combination weights and versions of all processing code. The test should explicitly include a condition selected to challenge correlation, a condition selected to challenge distortion, and a condition selected to challenge temporal fidelity. A failure in one condition does not erase a genuine improvement in another; it limits the scope of the claim. The strongest report will therefore say exactly where the array helps and where it does not. That is more valuable to a forensic practitioner than a universal proclamation of thirty-two effective bits which no physically independent experiment can substantiate.

Claude Elwood Shannon, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, suppose an SDR application receives sixteen streams of nominal twelve-bit converter codes, applies a calibrated set of weights and writes a thirty-two-bit floating-point stream. A later forensic report describes the output as thirty-two-bit sampled RF evidence. The computation may be bitwise reproducible from the saved files, yet the recorded precision can substantially exceed the physical confidence justified by the source waveform and analogue calibration. What controls can a digital processing pipeline implement to prevent the output word format from becoming an evidential claim about amplitude resolution? I would also ask how to protect the distinction between raw observations and derived estimates when a firmware upgrade changes the arithmetic rounding policy. Please explain

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how sample masks, source hashes and calibration revisions can be used without suggesting that cryptographic integrity can authenticate the analogue waveform or fix a defective original measurement.

Richard Wesley Hamming, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, the first safeguard is an explicit data model with distinct fields for native ADC code width, storage representation, arithmetic accumulator precision, combined-output representation and measured performance. If an application writes thirty-two-bit floating-point values derived from twelve-bit inputs, it should state exactly that. The output type is a software choice. It has no authority to represent the original analogue amplitude uncertainty, which must be assessed separately. Reproducibility means that an independent implementation can trace the transformation from preserved inputs to derived output under specified rules. Scientific validity requires further evidence that the analogue source was properly measured. A technically accurate interface should make this separation visible rather than bury it in a footnote.

The processing pipeline ought to save a versioned manifest describing channel ordering, input signedness and endianness, sample rate, clock epoch, calibration coefficients, averaging weights, missing-data policy and numeric rules. A firmware upgrade which changes rounding or scaling should create a new identified processing revision, not silently overwrite the historical interpretation of the file. Where the original code streams are retained under appropriate authority, protected digests can help detect subsequent changes to those bytes. A separate protected manifest and custody ledger describe the acquisition and later transformations. A file hash tells us about continuity from the reference hashing event, not the

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truth of the acquisition claim. A converter could hash an inaccurate measurement as faithfully as an accurate one.

I would add machine-checkable invariants. In simultaneous mode every combined output must identify the acquisition epoch and valid contributing channels; weights must be applied in the declared order and sum to the intended value within a specified numerical tolerance. In interleaved mode the sequence must reflect actual distinct apertures, not a convenient post hoc timestamp assignment. Every overflow, saturation flag and sample gap should be exposed to the analysis code. A software process that removes a clipped channel without retaining the validity mask may change apparent signal amplitude in exactly the interval the investigator is attempting to interpret. Each derivative must state the data discarded and the reason for discarding it.

For acceptance I would require an independent implementation, boundary-value arithmetic tests and physical reference captures. First show that the stored code words are interpreted correctly; next show that the algorithm reproduces the intended mathematics; finally show that the overall apparatus measures the test waveform within the declared uncertainty and dynamic operating limits. Passing one step is not passing the others. The final report should publish a narrow, useful result such as a measured one-bit improvement in a specified stable-signal estimator, while retaining the warning that the analogue observation did not become a thirty-two-bit physical sample. That phrasing is both technically useful and robust under critical forensic questioning.

Dr. James M. Atkinson, Moderator: Dr. Hamming, we now turn to the digital representation and the integrity of the combining algorithm. I invite you to

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challenge claims based on nominal word length rather than tested analogue performance.

Richard Wesley Hamming, Fifth Principal Contributor: Dr. Atkinson, I shall examine how an array can create a misleading appearance of precision after conversion. A floating-point accumulator may represent a mean to many decimal places, and a fixed-point signal processor may assign thirty-two bits to a result formed from twelve-bit inputs. Neither output format establishes that the physical estimate has thirty-two bits of accuracy. Digital arithmetic offers range, scaling and rounding control; it does not erase the uncertainty introduced before the data reached the processor. I would teach investigators to separate three layers: the recorded code words, the processing representation, and the physically supported measurement. If those layers are conflated, a perfectly reproducible computation can yield an overconfident statement about a hidden radio source.

Consider sixteen twelve-bit signed input codes in a simple averaging algorithm. Summing sixteen positive raw magnitudes can require additional accumulator bits to avoid overflow; division by sixteen may then yield fractional results if a fixed-point scaling convention is used. The accumulator's extra bits describe arithmetic headroom and representational detail. They are not themselves evidence that each converter identified an extra set of analogue thresholds. If all sixteen channels return the same code due to common-mode error or identical quantisation, the mean returns that same code even if the software writes it with twenty-four or thirty-two bits. The file's resolution field should therefore distinguish physical code width from processing word width, and neither should be used as an unqualified statement of ENOB.

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The numerical combination needs its own error budget. An implementation can overflow, silently saturate, round too early or use weights which cease summing to unity after fixed-point quantisation. Channel order may be altered during file loading, or complex I/Q samples may be averaged after one channel has its quadratures reversed. A small systematic defect can generate a smooth spectrum with plausible detail. The appropriate controls include known input patterns, boundary cases at full scale, negative and positive signed extremes, missing sample flags, endian conversion, and comparison with a higher-precision independent implementation. A successful bit-exact repeat of the same faulty routine is reproducibility, not validation. The test must reveal why the result is physically correct under stated assumptions.

I would also distinguish averaging from error correction in communications coding. Redundant digital codes can detect or correct some storage or transmission errors under a specified code and fault model. But a parity check on digitised sample words does not reveal an analogue voltage which the converter measured inaccurately. If two digitiser channels disagree, it may be because their analogue gains differ rather than because one stored a wrong bit. A coding-theory routine can protect the custody of recorded bytes, yet it cannot infer the missing analogue truth merely by checking a checksum. Those propositions have different evidential foundations. In a forensic workflow the original byte records, clock and calibration logs, processing code and evidence-transfer hashes should be preserved as distinct items.

The algorithm should also report how many genuinely valid samples contributed to each output. A naïve mean may divide by sixteen even if four

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channels clipped or lost a buffer. That result is biased unless the missing-data rule and estimator account for the resulting selection. An algorithm that silently discards saturated channels can make a transient appear weaker than it was, especially if saturation is linked to high amplitude. Conversely, a majority vote across converters with a common disturbance provides no protection against the common event. I propose a validity mask per channel and sample epoch, a count of accepted contributors, and a reason code for every exclusion. Where the mask changes rapidly, the investigator should check whether the apparent waveform feature belongs to the physical source or to the adaptive composition of channels.

Calibration coefficients introduce further numerical hazards. A gain table stored with a limited precision may create discontinuities when the input crosses a frequency or temperature boundary. An update to firmware can change coefficient interpretation, numeric scale or rounding behaviour while retaining the same apparent channel count. Thus, the reproducibility manifest must specify converter identity, sampling mode, analogue gain, calibration revision, software and firmware versions, processing order, input data types, numeric precision and rounding rules. If a later analyst recomputes the output using a revised table, the resulting difference should be recorded as a derivative and not silently substituted for the original. Computational accountability is particularly important when the report's conclusion depends on a weak feature near the detection threshold.

A controlled demonstration can expose errors that a single smooth spectral trace conceals. Feed a stable authorised reference waveform, deliberately reverse one channel's I and Q ordering, introduce one saturated block, and change the gain of another channel by a small known factor. A correct

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evidence pipeline should flag each anomaly, maintain the original records and report the consequences for the mean and the measured SINAD. Next, switch from simultaneous acquisition to time-interleaving without changing the reporting template. If the template continues to print an invented twenty-four-bit physical resolution, the fault lies in the interpretation layer as well as the software. The instrument must describe which hardware experiment occurred before it can describe what the numerical result means.

I should insist on an independent set of acceptance tests. The engineer who writes the combining algorithm should not be the only person who selects the examples on which it succeeds. Blind laboratory cases should include correlated noise, coherent spurs, input frequencies near the analogue bandwidth boundary, clock skew, clipping and deliberate dither. The outcome should be compared against predefined amplitude, spectral and timing tolerances. The engineer may quite properly improve a processing routine after seeing a failure, but that adjustment creates a new version requiring a new confirmatory test. A cryptographic hash can establish that the tested file has not changed since a trusted digest was made; it does not certify that the algorithm or analogue model was sound.

My final answer is that a parallel ADC array can be a valuable receiver technique, but its output must be labelled with epistemic restraint. Use the full arithmetic word length needed to avoid numerical errors, and measure the actual uncertainty and dynamic performance of the physical acquisition chain. If the apparatus uses sixteen nominal twelve-bit converters, report that architecture accurately. If an appropriately calibrated simultaneous ensemble achieves an empirically verified gain of, say, one or two effective

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bits for a particular narrowband estimator, report that conditional result and its uncertainty. If time-interleaving increases tested coverage, report its bandwidth and distortion limits instead. No conjunction of code words should be mistaken for a new physical measurement. I pass the token to the peer investigators to test these claims under the least convenient conditions.

Grace Brewster Murray Hopper, Peer Question: Dr. Hamming, the preserved samples may be as sound as the hardware permits, yet software can invent a resolution claim by repackaging data. An instrument might deliver signed twelve-bit samples stored in sixteen-bit containers, then combine sixteen channels into a thirty-two-bit floating-point stream with an automatic gain correction. The user interface might display thirty-two bits beside a beautiful waterfall, concealing that some channels were discarded after clipping or that the sampling mode changed without updating the metadata. What exact machine-readable fields and software acceptance tests would you insist upon before a later investigator can reproduce and interpret that result? How should the file distinguish an original recorded code from a derived estimate, and how would you respond when a vendor offers only the combined data rather than the individual channels and the calibration history? Please consider the possibility that a bit-exact output can remain scientifically false.

Richard Wesley Hamming, Response: Admiral Hopper, I would insist on a versioned acquisition contract as well as a versioned processing contract. The acquisition record identifies each converter channel, its native nominal code width, signedness, storage packing, sample rate, aperture relation, analogue gain, input range, clock reference state, calibration identifier and

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any overflow or invalid-sample conditions. It also records whether the channels sampled simultaneously or were deliberately staggered for interleaving. The processing record identifies the transform from source streams to output values, including weights, validity masks, numeric representation, rounding, clipping rules and software or firmware version. A thirty-two-bit floating-point output should be labelled as such, but never substituted for a physical ENOB claim. The metadata should make it possible to tell whether extra storage digits represent arithmetic detail, a calibrated statistical estimate or merely zeros appended to a narrower code.

I would make the original separate-channel records immutable once captured for a legally authorised test, calculate protected cryptographic digests at a documented custody point, and record all subsequent derivatives with their own identifiers. A laboratory that receives only a combined data file may be able to reproduce the vendor's final numerical output, but it cannot necessarily inspect whether one contributing channel clipped or whether a common reference disturbance affected all channels. That limitation must appear in the report. Where privacy or storage restrictions make full preservation impossible, the test plan must define a defensible minimal dataset and record precisely which independent verification questions can no longer be answered. We cannot treat absent information as though it were silently available.

The acceptance suite should include bitwise fixtures that detect signedness and endian mistakes, arithmetic fixtures at minimum and maximum code values, tests for overflow, and deliberately introduced sample gaps. It should also contain physical laboratory references at more than one amplitude and frequency so that numerical correctness and analogue

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validity are challenged separately. The software must reject an impossible operating mode rather than quietly assign a new sample rate to old data. It should preserve an audit log if an algorithm discards a clipped channel or changes its weight. A correct output for a nominal case is not sufficient when the system fails exactly on the high-amplitude transient the investigator most needs to understand.

A bit-exact repeat does have evidential value, but its value is narrow. It shows that the recorded input and a specified computation can yield the same output under the controlled environment, if the provenance claims are trustworthy. It does not show that a clock was stable, that the converter possessed the asserted analogue resolution, or that the alleged RF emitter existed. The scientific validation uses independent reference measurements and falsifiable performance criteria. The provenance record explains what the software did; it does not grant the instrument infallibility. I would encourage the report to present raw-code width, processing width and measured effective dynamic performance in separate fields, ensuring that a reader never confuses a thirty-two-bit file format with a thirty-two-bit physical observation.

Richard Wesley Hamming, Cross-Peer Question to John Bardeen: Dr. Bardeen, I should like to return from numerical software to the hardware claim that began our discussion. If an engineer assembles two nominal fourteen-bit ADCs on one input, advertises their combined output as twenty-eight-bit resolution, and then points to a narrowband averaged spectrum as proof, what minimum set of experiments would allow us to issue a precise corrective conclusion rather than a merely rhetorical objection? The architecture might use simultaneous apertures, deliberately staggered

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sampling, independent dither or some mixture of those modes. How should the investigator classify each, measure the actual improvement and report the limitations imposed by common noise, gain mismatch, quantiser correlations and jitter? I would also ask how the conclusion should change when a customer is chiefly interested in brief low-level signals next to strong blockers, rather than a stable sinusoid for which elaborate averaging has been optimised. Please state how you would avoid turning a failed test into a universal statement that parallel ADC systems can never help.

John Bardeen, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, the corrective conclusion should be expressed positively as a tested physical relationship. First, document the actual sampling architecture. Two simultaneous converters on one input supply redundant estimates at approximately the same aperture; two staggered converters may instead produce a higher aggregate temporal sample rate if the analogue and timing conditions permit. If the apparatus switches between modes, each mode requires independent acceptance criteria and provenance. The advertisement twenty-eight-bit resolution is unsupported unless the seller defines a specific statistical or dynamic measurement by which it could be challenged. It should not be inferred by concatenating two fourteen-bit output strings, because the number of storage symbols is not the number of analogue thresholds actually distinguished.

I would begin with individual-channel characterisation using a traceable input and documented test conditions. Measure each converter's gain, offset, noise, distortion, effective dynamic performance and sample-aperture behaviour across the relevant bandwidth and temperature range. Then test the combination. In simultaneous mode estimate cross-channel

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covariance and compare the measured error reduction with the prediction under independent and correlated noise models. In staggered mode verify actual aperture offsets, anti-alias response, timing-skew spurs and end-to-end acquisition continuity. For either mode, deliberately introduce a shared clock disturbance, a common blocker and a channel-specific mismatch, and verify that the outputs respond in a physically explicable way. Preserve all original streams and the processing version for independent reconstruction.

The two-channel ideal gain is modest. For two independent channels whose relevant errors have equal variance, an equally weighted mean halves error variance and ideally improves power SNR by 10log10(2), approximately 3.01 decibels. In the simplified effective-bit convention this is about half a bit. It is not fourteen additional bits. If the errors are fully correlated, the mean offers no reduction of that shared component. A laboratory can verify those predictions in a controlled scenario without pretending that they cover every possible input. One should also report whether SINAD improved, because distortion and common jitter may prevent the simple SNR reduction from becoming an ENOB improvement.

For short signals near blockers, the test objective must be changed accordingly. Inject known low-level pulses next to controlled strong signals, record the input with an independent reference, and vary observation timing, pulse width and front-end gain. Compare sensitivity and false alarms against the single-channel baseline, while retaining saturation, recovery and clipping records. An improved stable-tone amplitude estimate may coexist with poor pulse detection after overload. If the combined array fails a particular test, report that operating limitation; it does not establish that all parallel converter designs are worthless. The scientifically defensible

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conclusion is that some forms of independent-noise averaging or time interleaving can provide measured benefits under explicit assumptions, whereas arithmetic addition of nominal bit widths does not itself establish a higher-resolution physical measurement. I return the token respectfully.

Dr. James M. Atkinson, Moderator: My thanks to the panel for its attentive and respectful examinations. We have distinguished simultaneous noise averaging, time interleaving, digital accumulator width, effective converter performance and lawful evidential conclusions. The principal engineering result is conditional. Independent errors can be reduced under a validated covariance model; common analogue distortion, clipping, reference uncertainty and unmeasured aperture defects are not abolished by joining converter outputs. The expert witness should describe the tested receiver, waveform, bandwidth, uncertainty and limitations rather than announce a synthetic 24-bit or 32-bit physical converter.

SCHOLARLY RECONSTRUCTION AND REFERENCES. The foregoing modern exchange is an explicitly fictional pedagogical reconstruction involving deceased historical specialists and is not a quotation, transcript or attribution of contemporary knowledge to those individuals. Technical background for separate source-to-claim review includes IEEE 1241-2023, IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters (https://standards.ieee.org/ieee/1241/6797/); Behzad Razavi, Problem of Timing Mismatch in Interleaved ADCs (IEEE Custom Integrated Circuits Conference, 2012, public manuscript https://www.seas.ucla.edu/brweb/papers/Conferences/BRCICC12.pdf); and the general sampling, estimation and quantisation principles. A later independent source review must establish precise correspondence, editions

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and rights before publication. No claim of field-detected external emissions or verified operation of a particular hardware array is made.

EDITORIAL QUALIFICATION. All apparatus, observations and numerical examples in this discussion are hypothetical educational exercises, not measured results. The ideal averaging equations assume zero-mean errors, a stated covariance structure, fixed signal power and appropriate frequency-dependent measurement conditions. ENOB requires a defined test waveform and procedure; reference, dither, clock, analogue overload and software limits must be measured on the actual apparatus.

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QUESTION 102

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How should ultrawideband SDR capture balance instantaneous bandwidth and usable dynamic range?

Dr. James M. Atkinson, Moderator: Dr. Kroemer, I invite you to consider the contemporary desire to capture several hundred megahertz, or even wider swathes, of radio-frequency spectrum in one observation. The bright waterfall and large sample-rate numeral may suggest comprehensive technical-security coverage, yet a modest signal may be eclipsed by analogue overload, a poorly controlled noise floor, finite dynamic range or a disk recorder which silently loses samples. Explain how a lawful defensive survey should define the usable instantaneous bandwidth of the entire measurement chain, rather than accept the converter clock and storage specification in isolation. Please consider the weakness of nominal ENOB as an all-purpose sensitivity promise, and propose a controlled experiment in which a faint authorised signal is presented beside a much stronger interferer.

Herbert Kroemer, Principal Contributor: Dr. Atkinson, I would distinguish spectral access from physical knowledge. The capacity to produce a digital sequence containing a wide band of frequencies is a real engineering achievement. Yet the proposition that every relevant signal within that band can be detected, characterised and supported by defensible evidence is quite another assertion. From the antenna terminal through the last digital decision, the system contains amplifiers, switches, filters, converters, clock trees and software resources that determine what can actually be observed. A wide digital display is only the visible end of that physical chain. We should first declare the reference plane at which a signal level is specified and the test conditions under which the claimed performance applies. A receiver

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connected to a mismatched antenna in a strongly reflecting room is not equivalent to the same receiver driven by a calibrated coaxial reference, however similar their graphical interfaces may look.

At the analogue front end I would begin with the strongest plausible environmental signal rather than the smallest one. A very sensitive preamplifier can be admirable when the electromagnetic environment is quiet. Place a substantial blocker within or near its passband and that same amplifier may compress, generate intermodulation products or recover slowly after a large excursion. The small signal sought by a technical-security investigator may then disappear, and a spurious product can appear elsewhere in the spectrum. An increase in nominal instantaneous bandwidth may worsen the risk if the preselector becomes broad enough to admit more energetic interferers into the same nonlinear stage. The question is not whether greater bandwidth is intrinsically bad. The question is whether the front end preserves the weak authorised reference under a specified set of stronger signals, with measured limitations rather than convenient assumptions.

The digitiser adds another layer of qualification. A converter's advertised sample rate describes how often its aperture operates, under stated conditions. Its full-scale input range, analogue bandwidth, sample clock quality, linearity and effective number of bits determine what those samples mean. For a full-scale sine test, the traditional idealised resolution relationship provides a useful comparison, but it does not grant the same effective sensitivity to a pulse alongside a blocker. The strong signal can consume much of the converter's available range, leaving a small disturbance represented by only a few uncertain codes or masked by

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distortion. If a converter clips, the excess amplitude is not restored by later software precision. If a time-interleaved converter uses multiple channels, interchannel skew and gain error may create images that survive even an attractive digital filter. I would therefore ask for SINAD and spurious-free dynamic range across input frequency, amplitude and operating mode, not just a catalogue bit-depth label.

A simple thermal-noise calculation illustrates the trade-off when other influences are temporarily set aside. The ideal input noise power in a matched bandwidth B at temperature T is proportional to kTB, where k is Boltzmann's constant. If the effective measurement bandwidth increases by a factor of ten while the relevant noise spectral density remains approximately flat and all other conditions fixed, the integrated noise power increases by ten decibels. That relationship does not mean that every detector becomes ten decibels worse. Narrow sub-band filtering, coherent integration and suitable detection statistics can recover sensitivity for a known signal model, but those operations must be disclosed as processing conditions. A statement about a wide instantaneous capture and a statement about narrowband post-processed detection sensitivity should not be fused into one unqualified instrument specification. They refer to different stages of the inference.

Storage and transport are equally material. Suppose one complex IQ sample is stored as a sixteen-bit signed I component plus a sixteen-bit signed Q component, and the receiver produces one hundred million complex samples each second. Each complete sample occupies four bytes, yielding a nominal data rate of four hundred million bytes per second, or 400 decimal megabytes per second, before headers, timestamps, metadata, error-

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correction records or file-system overhead. If four such channels are simultaneously recorded, the nominal raw rate is 1.6 gigabytes per second. An apparatus with a fast converter and an inadequate sustained recorder may produce the appearance of continuous wideband surveillance while dropping blocks during the busiest intervals. The investigator needs hardware sample counters, queue-overflow flags and a verified definition of missing data. A later gap in the file is a gap in observation, not evidence that the spectrum was silent.

One might propose an adaptive recording scheme that stores the wideband stream only when an anomaly detector raises an alarm. That may be practical within lawful authority and carefully designed retention rules, but it changes the scientific sample. The preserved dataset then overrepresents conditions under which the detector was already inclined to alarm. We cannot estimate the true frequency of weak non-alarm emissions from the saved alarms alone without knowing the observation schedule, detector miss probability, triggering logic and any unrecorded blind intervals. This selection problem belongs beside the storage equation. A lower data rate is not a free gain in evidential certainty. The system should preserve a protected event ledger identifying when the receiver was active, its configuration, its detection rule and what was or was not saved, while limiting retention of unnecessary communication content.

My proposed laboratory comparison has an independent reference generator producing two authorised signals. The first is a weak controlled waveform whose frequency and duration can be varied, while the second is a much stronger blocker which moves through the input passband and its adjacent regions. A separate monitor, whose own limitations are

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characterised, records the actual applied reference. The receiving apparatus is tested with several preselector settings, gain distributions, bandwidth modes and recording loads. We should determine whether the weak signal is recovered, whether its measured amplitude and timing remain within specified uncertainty, and whether a new spur follows receiver configuration rather than the external generator. Each trial must retain the actual front-end state and the raw validity flags. The test should include a brief low-level pulse, because the easy case of a continuous tone does not settle the harder problem of intermittent surveillance emissions.

I would repeat that experiment at several temperatures and at the boundaries of the claimed band. In a wideband arrangement the antenna, filters and converter input may have substantially different gain and phase responses near the edges than near the centre. A calibration taken at one frequency cannot simply be projected across the full span without evidence. Similarly, a gain setting that is safe with the blocker absent may overload when the blocker appears. The result should be expressed as a performance envelope: input levels and frequencies for which detection and measurement are supported under stated noise, distortion and acquisition-continuity limits. Outside that envelope the system may still be useful for exploratory observation, but the operator must not transform an untested region into an assertion of complete coverage.

I would insist upon a final distinction between the visible waterfall and the underlying evidence. A spectral display may show an orderly field of colours after decimation, averaging, clipping or automatic scaling, while the raw acquisition contains saturations, changing masks or missing intervals. An independently reviewed report needs the processing recipe, colour-to-

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power transformation, window and bandwidth settings, and a way to reproduce the numerical estimates from retained data. If the claim concerns a rare pulse, the file must preserve a meaningful record of the temporal region around its alleged appearance or disclose why it was unavailable. A digital drawing can inform an investigator, but it is not an independent substitute for a calibrated, complete and legally maintained measurement.

My preliminary conclusion is therefore one of engineering discipline rather than technological pessimism. Greater instantaneous bandwidth can be valuable when it reduces retune blind time and allows observation of signals whose frequencies were not known in advance. Its benefit must be balanced against analogue blocker tolerance, dynamic range, preselector response, clock integrity, sustained data throughput and the detector's operating characteristics. The same design may be excellent for discovering the presence of broad spectral activity yet poorly suited to accurately measuring a weak transient next to a large adjacent signal. I would invite Mr. Hewlett to develop the acceptance specification, Dr. Bardeen to examine converter noise and front-end dynamic range, Dr. Nyquist to review sampling and aliases, and Dr. Slepian to challenge the detection and finite-time inference. Each should confront the instrument with a test likely to expose its limitations rather than a demonstration selected to flatter its nominal specifications.

Lord Rayleigh, Peer Question: Dr. Kroemer, a receiver engineer may proudly report a spectrum that appears flat across an enormous frequency interval while the actual electric field at an antenna terminal is neither flat nor easily known. The practitioner might then compare the coloured height of peaks at distant frequencies as though each had been transformed through an

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identical transfer function. How would you separate a genuinely weaker field from different antenna factors, cable losses, filter ripple and gain calibration, especially where the tested frequency lies near a preselector transition band? I should also like you to examine whether a large integrated noise figure provides any useful guarantee about a narrow transient observed in one channel. Please describe a test that could reveal a failure of this supposed equality without requiring the examiner to reconstruct every unknown emitter in the environment. The difficulty is one of measurement, not merely signal display. A physically honest answer ought to expose which variable is a reference quantity, which is the instrument's response, and which remains uncertain.

Herbert Kroemer, Response: Lord Rayleigh, the first task is to reject the assumption that the colours on a waterfall share a universal calibration merely because one software programme painted them. The antenna presents a frequency-dependent response involving effective aperture, polarisation and geometry; the interconnecting network adds insertion loss and mismatch; and the receiver contributes transfer gain, noise and distortion that may change with configuration. Even a laboratory injection at a calibrated receiver connector proves only the response from that plane downstream. A field-strength conclusion demands separate evidence about the receiving antenna and its environment. The controlled measurement should therefore identify the reference plane and provide an uncertainty budget appropriate to that plane. A result reported at the receiver input must not quietly become a result at an unknown physical point in a room.

I would use a set of laboratory reference signals whose frequencies traverse the claimed operating span, concentrating more densely near filter

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boundaries, gain-transition points and known spurious regions. The sources should be independently measured, attenuators and cables characterised, and receiver gain states fixed for each run. By calculating the difference between known input levels and recorded numerical estimates, we obtain a response map that can reveal ripple, abrupt transitions and compression. Repeat at several levels, including one approaching the detector threshold and another that tests large-signal linearity. If the response is nonlinear, a single gain-correction curve cannot be applied without qualification. If changing the nominal bandwidth changes the response map, both configurations require separate documented states.

The antenna question requires a distinct trial. Compare known radiated reference fields under controlled geometry where lawful and practical, using a traceable reference instrument and sensible allowance for reflections and polarisation. Such a test may establish performance in the chosen geometry, but it cannot guarantee equivalent reception in every furnished room with metal structures and standing-wave nulls. A negative observation should therefore be limited to positions, polarisations, frequencies, detector settings and time intervals actually investigated. Antenna substitution or displacement can be a powerful challenge to a suspected artifact, but the substituted antenna must itself be understood. An unexplained change between antennas is evidence requiring diagnosis, not automatically a proof of external origin.

As for integrated noise figure, it is useful only when the applicable model and measurement conditions are stated. A noise figure measured in one bandwidth and frequency region does not establish the detection performance of an arbitrary transient after filtering, windowing, gain

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changes or overload. A short burst may have energy distributed across many bins and time samples, so a detector chosen for a persistent tone may fail despite an attractive baseline. I would present frequency-dependent calibration and a separate family of transient detection trials. Each trial would preserve failures, clipped events and uncertain records. Thus the answer to your physical question is not a single grand number but a measured performance surface which a second examiner can reproduce and challenge.

Karl Guthe Jansky, Peer Question: Dr. Kroemer, broad observation tempts the investigator to equate a large photographed spectral span with comprehensive listening. But many natural and industrial radio environments change during the very minute in which a screen is being recorded, and the receiver itself may switch gain, filters or clock states. Suppose a short source occurs only once during a long shift. What records would you demand to decide whether that source lay outside the usable receiver range or simply inside an unobserved interval? Would you retain a time-frequency exposure mask for each channel and identify all receiver restarts, gain transitions, transfer overruns and user adjustments? I ask you also to distinguish a measurement at a fixed antenna position from a claim about an entire building. A careful survey must be able to explain the conditions under which an absence of detection is informative and the cases where it is merely silence from the instrument.

Herbert Kroemer, Response: Mr. Jansky, a comprehensive visual frame is not evidence of comprehensive exposure. A receiver that tunes through a wide range may ultimately show many frequencies, but the time during which any one frequency was actually observed depends upon dwell, retune

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latency, filter switching, acquisition reset and the detector's processing window. I would record a time-frequency exposure map indicating when each frequency interval was acquired under a valid configuration, separately from the map showing detected energy. Where the sample stream has a gap, a flag should say unavailable, not zero signal. That requirement remains even for a nominally simultaneous wideband system, because transport loss and recording saturation can interrupt observation without obviously changing the waterfall.

The operating log should include the oscillator and clock state, preselector position, analogue gain, temperature when relevant, ADC overflow indicators, sample counters, start and stop timestamps linked to the acquisition clock, and the exact decision statistic used for alerts. An operator's manual adjustment is an event in the evidence record. If an automatic gain controller operates, the gain history is a physical part of the measurement. If an alarm detector suppresses recording until an internal threshold is crossed, a later reviewer needs to know what happened to data below threshold and whether the alarm itself can be replayed. A bounded statement of opportunity is more defensible than an assertion of permanent watchfulness.

A single short event poses a severe inference problem because we do not have repeated observations from which to estimate all probabilities. The survey can nevertheless be tested using independently scheduled laboratory pulses at many start phases and frequencies, including times immediately before and after anticipated transitions. Measure the proportion recovered under stated signal levels and environmental conditions, and do not present the trial frequency as the probability of

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detection for all possible unknown devices. The result is conditional upon the tested signal family and the observed environment. I would also require deliberate overload trials, since a receiver can be fully running while its front end is so desensitised that the intended signal is effectively invisible.

A building-level claim introduces spatial uncertainty. The receiving location, antenna polarisation, shielding, reflections and potential coupling paths influence what reached the instrument. Moving the antenna or employing an independently monitored reference can test some of those limitations but cannot abolish all possible blind spots. My desired report would say exactly which rooms or positions were sampled, with which antenna and detector configuration, and which periods were valid. If the instrument failed during part of the shift, the examiner should say that it was not observing then. That modest acknowledgement can prevent a much larger professional error: turning a beautiful empty chart into an unjustified statement that a hidden source could not exist anywhere on the premises.

Dr. James M. Atkinson, Moderator: Dr. Kroemer, thank you for defining usable bandwidth against the calibrated receiver and the observed environment. Mr. Hewlett, I pass the token to you for an engineering acceptance specification that distinguishes brief demonstrations from sustained recording.

William Redington Hewlett, Second Principal Contributor: Dr. Atkinson, an acceptance specification is a promise concerning performance under specified conditions, not a decorative collection of maximum values taken from incompatible laboratory trials. The procurement officer may ask for a very broad capture aperture, the radio engineer may seek a high spurious-free dynamic range, and the forensic examiner may need defensible

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amplitudes for short signals. These requirements cannot responsibly be combined by choosing the most flattering number from each catalogue line. A receiver is a chain of physical transformations. An acquisition claim must identify the antenna or calibrated input reference plane, the frequency region, the installed analogue filters, the gain state, the sample-rate and clock state, the ADC input scale, the digital channeliser, the selected analysis bandwidth, the duty cycle and the condition of the storage path. Only then does the word usable acquire a testable meaning.

I would write separate pass criteria for detection and measurement. A receiver may reliably raise a timely alarm when a signal of known class appears, yet its amplitude estimate may be biased by filter ripple, an uncorrected antenna factor or the automatic gain-control response. In the detection trial I would specify a family of authorised laboratory bursts and noise conditions, then evaluate the empirical probability of detection against a fixed false-alarm policy. In the quantitative trial I would use calibrated steady sources and independently characterised short pulses to determine amplitude error, timing uncertainty and distortion under explicit operating states. A single successful sighting of an injected signal says little about a rare-event detector's actual miss probability. Conversely, failing an exact amplitude tolerance does not always make a receiver useless for exploratory detection. The report must state which narrower claim remains justified.

The blocker test is indispensable. Place a faint reference emission at several frequencies across the proposed capture span, and add one strong blocker whose level and separation are controlled independently. Repeat with two blockers to search for intermodulation, and with a pulsed blocker to examine overload recovery. A seemingly improved sensitivity resulting from

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more front-end gain may reverse as soon as the strong signal appears. There may be a useful gain state in which the weak reference is visible and the converter avoids clipping; that operating point need not be the state with the lowest displayed noise floor in the absence of a blocker. A calibration table should therefore be multidimensional. Frequency, gain setting, blocker amplitude, blocker separation and temperature may all matter. The manufacturer should disclose enough to distinguish a tested envelope from a merely plausible extrapolation.

I would insist that the strongest interferer be monitored by a separate measurement instrument during the trial. If the blocker generator silently compresses, the instrument under examination may appear to have admirable immunity through a failure of the test source. Similarly, the faint generator must not be coupled into the receiver through an unmeasured leakage route. Splitters, attenuators and cables require appropriate characterisation, especially at the edge of a very wide band. A laboratory should retain uncertainty estimates for source level and frequency, and repeat conditions that expose calibration drift. A change of laboratory temperature, reference clock or preselector configuration can invalidate a performance promise without any change in software version. The recorded provenance should tell us which version of the measurement chain was actually tested.

Storage performance is not a secondary clerical matter. Suppose a recorder accepts one channel of complex samples at one hundred million samples per second, each sample represented by two signed sixteen-bit components. Four bytes per complex sample imply four hundred million bytes per second before metadata or file-system overhead. A ten-minute

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uninterrupted capture would contain two hundred and forty billion raw sample bytes, conventionally 240 GB in decimal units. Several such channels multiply the sustained requirement. A host may write briefly at the requisite rate into a cache while its physical storage fails to maintain that rate over a long run. Therefore the acceptance test must measure sustained writes, not only peak throughput, and must confirm with independent sample counters that all samples arrived. A plausible file length does not prove that zero padding, repeated buffers or hidden clipping were absent.

The duty-cycle calculation must include receiver configuration. A system described as observing a huge aggregate tuning range may spend considerable time switching filters, resetting gain, flushing pipelines or writing metadata. If two simultaneous front ends cover distinct spans, they may offer genuine continuous coverage of both spans, but only if their per-channel performance and recording integrity are demonstrated. If one front end scans between spans, the brochure's union of tuning ranges says little about the probability of catching a brief burst. An acceptance schedule should include short, randomly timed test pulses placed near tuning transitions and record the missed opportunities. One cannot claim continuous observation simply by drawing adjacent rectangles across a frequency chart.

There is a further distinction between a numerical result and a presentation. The analyst who changes an FFT length, window, overlap or colour scale may make a trace look more prominent without improving the instrument's fundamental sensitivity. I would preserve the raw capture where lawful and necessary, the manifest of signal-processing parameters, the calibration factors, and the detection threshold established before the test. A

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subsequent processing change should generate a new derivative and an explicit reason for the change. This requirement does not forbid exploration. It ensures that exploratory settings are not covertly substituted for the pre-specified confirmatory method. The client should receive conclusions tied to the actual test conditions and the uncertainty that remains.

In summary, an ultrawideband receiver can be a magnificent means of avoiding the blind time inherent in retuning. Its purchase specification should nevertheless require an operating envelope for weak-signal detection under blockers, calibrated measurement across the passband, time and frequency integrity, and storage continuity. I would reject a specification that simply adds sample rate, bit depth and nominal span as though these were interchangeable guarantees. The appropriate system is the one that passes the relevant adversarial trials with documented limitations. Mr. Jansky may legitimately prefer long observational consistency; Dr. Bardeen may require disciplined converter tests; Dr. Nyquist will demand rigorous alias analysis. Their objections should be welcomed because a challenge test that finds a real limit has performed more useful work than a flawless promotional demonstration.

Grace Brewster Murray Hopper, Peer Question: Mr. Hewlett, an instrument builder may prove that a converter can deliver the required sample rate for a short laboratory demonstration and that the host can write a very large file. Yet neither achievement necessarily establishes that every sample in the file came from a continuous acquisition. How would you define a verifiable end-to-end contract among the ADC, FPGA, transport driver, acquisition application and storage medium? Please consider buffer duplication, out-of-order packets, counter reset, cached writes and an operating system whose

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visible file timestamp marks the close of the archive rather than the first sampling instant. I would welcome a test capable of distinguishing a true RF quiet interval from zeros inserted during a recorder failure. Finally, which elements would you require to be immutable primary records, and which might responsibly be recorded as later interpretations or working derivatives without altering the original evidence? A successful end-to-end test should explicitly distinguish ordinary network congestion from a damaged RF acquisition record, rather than hide them in one error label.

William Redington Hewlett, Response: Admiral Hopper, the most reliable contract begins with the event at the acquisition device rather than the application window. Where the hardware supports it, each buffer should carry an acquisition sequence identifier, a start sample counter, the count of valid samples, a clear indication of any lost or invalid samples, a status record for saturation or clock loss, and an identifier for the currently installed processing configuration. The driver may add transport identifiers, but these must remain distinguishable from the device-native counters. The host application may add receipt and file-write timestamps, but they do not replace sample-aperture timing. A later reviewer should be able to reconstruct the difference between the chronology reported by the acquisition device and the chronology of host processing.

The acceptance trial should deliberately inject one failure at a time. Force a USB or network transfer omission while leaving the ADC running. Simulate a buffer repeated by a faulty driver. Restart the device clock and verify that a new acquisition epoch is recorded. Saturate the file writer under a prolonged load, not merely for a burst shorter than a cache can absorb. Introduce zeros at a controlled software stage in a test branch, and confirm

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that the final record marks them as synthetic rather than as real measurements of a quiet antenna. The necessary controls should be verified against an independent laboratory recorder driven by a known test waveform. A system that fails to distinguish these cases must disclose that limitation rather than extrapolate continuity from file size.

The immutable primary object comprises the bytes actually exported by the hardware, or the closest supported raw representation, accompanied by preserved native headers and a contemporaneous acquisition manifest. A cryptographic digest can provide strong evidence that those bytes have not changed since the protected reference digest was created, assuming sound implementation and custody. It cannot prove that the ADC originally sampled the correct signal or that its clock and analogue path were calibrated. Working derivatives, such as decimated extracts or corrected time axes, deserve new identifiers and documented transformations. A correction to a processing script must not rewrite the record of what the equipment actually emitted in the earlier session.

I would document the recorder's operating envelope as a matrix of sustained throughput, channel count, storage latency, data format and worst-case acquisition duration. Compression changes the average byte rate, but a variable-rate compressor can produce bursts that overwhelm a transport link even when the mean appears acceptable. One should preserve a per-interval loss register and compare its counts with source-side sample expectations. Finally, the file system's creation and modification times belong to administrative custody, not to the RF emission's physical arrival time. This separation permits a competent examiner to say that the stored sequence has continuity under defined assumptions while

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recognising that the chronology of the external source remains an independent, testable proposition.

Claude Elwood Shannon, Peer Question: Mr. Hewlett, your sustained-throughput example gives four hundred decimal megabytes per second for a single complex channel, but I want to challenge the temptation to treat that rate as an information-theoretic necessity independent of data representation. If a signal is band-limited, the recording may be decimated after an adequate filter; if its statistical structure is compressible, a lossless encoder may reduce its stored size. How should an engineer separate those possibilities from an unsupported claim that one may discard samples or precision without harming later forensic questions? Can a receiver be specified with a bounded event-preservation guarantee while recording only a subset of its wideband data? I ask particularly about unknown future questions involving weak bursts, and about a protocol that stores alarm-triggered IQ segments but loses the negative evidence needed to assess false negatives and the proportion of time actually observed. The independent monitor and retention policy should therefore be treated as part of the experiment, not administrative conveniences added after the event.

William Redington Hewlett, Response: Dr. Shannon, the arithmetic describes the uncompressed representation chosen in the hypothetical example, not an absolute lower bound on storage for every possible waveform or processing objective. A filter followed by decimation can legitimately reduce the number of samples required to represent a narrower band when the analogue and digital filtering assumptions are satisfied. Lossless coding can represent the same original data exactly in fewer bytes if exploitable

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regularities exist. But the compression ratio is input-dependent, and neither technique supports the proposition that an arbitrarily unknown future investigation will retain everything it might need. The relevant question is which scientific and legal claims the record is intended to support, and whether the chosen transformations preserve the information those claims require.

I would make the retention architecture explicit before procurement. For certain authorised detections, the instrument may need only event time, frequency, approximate amplitude and a short raw extract with protected configuration metadata. For phase or transient characterisation, longer unaltered IQ may be required. A lower-rate statistical record may support a population-level occupancy estimate but not prove that every short event was captured. The operator should identify the class of claims that can survive each storage mode and avoid claiming equivalence merely because two files lead to similar-looking waterfall pictures. Where a transformation is irreversible, the chain-of-custody record should mark the point at which exact reconstruction became impossible.

Alarm-only preservation requires special caution. If the trigger is generated by the same detector later being evaluated, the saved examples form a selected population. They can tell the examiner about the signal shapes the detector retained, but not, without additional observations and assumptions, how many events it missed. The recorder might preserve periodic random audit windows, aggregate exposure statistics and independent calibration trials while limiting capture of sensitive communications content. Such choices can improve scientific accountability and proportionate retention, but the policy must be lawful and technically

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justified. The audit scheme must not silently be described as full raw-spectrum continuity if it is not.

Finally, throughput must be verified in the worst credible operating state. Lossless coding may produce poor compression on noise-like data, and a data stream rich in unexpected transients may exceed the performance observed on smooth test tones. A reference file generator can exercise the full storage pipeline under high-entropy input, concurrent channels and prolonged operation. Compare source-side sample counters against received records and log any discontinuity. It is entirely appropriate for a project to choose constrained retention rather than indefinite wideband raw capture. What is inappropriate is to erase the distinction between what was genuinely sampled, what was later selected, and what the remaining bytes can still demonstrate.

Dr. James M. Atkinson, Moderator: Mr. Hewlett, thank you for confronting the recorder with continuity and load tests. Dr. Bardeen, the token passes to you to examine analogue input limits, aperture uncertainty and the use and misuse of converter performance figures.

John Bardeen, Third Principal Contributor: Dr. Atkinson, the broadness of the sampled spectrum does not remove the analogue limitations that precede quantisation. Even a direct-RF ADC receives a continuous electrical signal through a finite-input-bandwidth circuit. Its track-and-hold behaviour, input matching, reference distribution, clock jitter, nonlinear transfer characteristics and electrical protection stages govern whether a modest signal is represented faithfully in the vicinity of a strong one. A broad preselector may grant a large range of accessible frequencies yet expose the input stage to energy from many unrelated services. That energy

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contributes to voltage swing and to nonlinear products. The ADC's nominal code width cannot recover the part of a waveform that an earlier stage has compressed, nor can any digital algorithm restore amplitudes clipped to full scale without independent, restrictive assumptions.

I would begin with a distinction among several figures often conflated. The quantisation step describes the ideal spacing between adjacent digital codes for a specified input range. Effective number of bits is conventionally inferred from SINAD for a sinusoidal test under stated conditions. Spurious-free dynamic range compares a fundamental tone with the largest relevant spurious component over a declared spectral search region. Noise figure characterises degradation relative to a reference thermal-noise model, when its conditions apply. Blocker tolerance asks whether a wanted weak emission remains detectable or measurable as a stronger unwanted signal is introduced. These metrics are connected through architecture, yet they are not synonyms and should never be interchanged in a technical report. One figure measured at low intermediate frequency cannot simply be transferred to the top of the ADC's analogue input band.

Aperture uncertainty is particularly serious as RF frequency increases. For a hypothetical full-scale sinusoid, a commonly used idealised jitter-limited signal-to-noise relationship is SNR_jitter = minus twenty times log base ten of two pi f sigma_t, provided the small-jitter assumptions apply. Here f is input frequency in hertz and sigma_t is RMS aperture timing uncertainty in seconds. The approximation makes plain why clock purity becomes more demanding at higher frequencies. If sigma_t remains one hundred femtoseconds, the corresponding idealised jitter bound at one gigahertz is about 64 decibels. The same approximation at two gigahertz yields about 58

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decibels. This is neither an instrument's measured SINAD nor proof that all other noises disappear; it is an illustrative limit that must be combined carefully with other contributions, including uncertainty in the clock specification itself.

Consider a modest narrowband signal that is twenty decibels above the receiver's unloaded displayed noise floor. Add a much stronger blocker. The desired signal could disappear for three very different reasons: actual analogue compression, reciprocal mixing of the blocker against clock or local-oscillator phase noise, or a changed processing threshold that responds to the elevated apparent floor. A digital capture with a thousand frequency bins may make these mechanisms look similar on one heat map. The experiment should therefore record input power, full-scale utilisation, overload indicators, independent reference measurements and changes in gain state, while varying blocker separation in a controlled sequence. If the weak signal reappears when a physically appropriate preselector attenuates only the blocker, that is evidence favouring an overload or mixing mechanism; it is not yet proof of a unique cause without further controls.

The ADC input network itself may create frequency-dependent error. A sample-and-hold stage can have finite linearity and bandwidth, while termination imperfections produce reflections. In direct sampling, analog input bandwidth exceeding the Nyquist interval is not a licence to admit every signal without care. Out-of-band energy can alias into the measured interval, sometimes masquerading as an in-band emission. Bandpass sampling can deliberately exploit aliasing under carefully designed analogue filters, but the sampling plan must prove that undesired bands do not fold onto the wanted one at levels relevant to the investigation. It is a question of

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filter rejection and known spectral occupancy, not just arithmetic with the sampling clock. The spectrum visible at the digital output must be traced back through those assumptions to a defined analogue input band.

A useful test report should plot a performance envelope rather than one symbolic number. For each of several input frequencies, characterise the minimum detectible calibrated reference in a specified analysis bandwidth, the largest usable blocker level and any spurious components that exceed a chosen threshold. Repeat with different front-end gains and preselector states. Add a short-pulse test whose duration exercises overload recovery and buffer continuity, because sustained-tone ENOB does not settle transient performance. Repeated measurements should permit an uncertainty evaluation, while conditions that produced invalid data must be recorded as such. A report that excludes inconvenient clipped trials will overstate usable dynamic range even if its published measurements are otherwise calculated correctly.

Multi-converter arrays do not escape this discipline. Parallel, simultaneous ADCs receiving the same input may support averaging of independent error components, but correlated front-end distortion and common clock jitter do not vanish merely because the digital words are combined. Time-interleaving several converters can increase aggregate sample rate, but mismatches in offset, gain and aperture delay can create characteristic periodic spurs. Both arrangements require detailed calibration and have different theoretical benefits. It would be improper to announce that four nominal fourteen-bit converters produce a fifty-six-bit converter. A higher accumulator width is merely a numerical representation; effective analogue

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resolution must be established through measured estimator performance and stated input assumptions.

I would finally warn against treating a high dynamic range measured with an ideal coherent sine source as a guarantee against extremely brief unpredictable bursts. A short event occupies different time-frequency uncertainty conditions, may strike during gain recovery or recording blind time, and can be destroyed by averaging selected for steady carriers. Detection probability must be assessed under a representative event family. That family should include low-level pulses, burst trains, changes in phase, and controlled blocks adjacent in frequency. The independent reference should measure what entered the receiver before we draw conclusions from its output. The conclusion is not that ultrawideband capture must be abandoned. It is that every reported gain in bandwidth must carry an explicit statement of the physical performance lost, retained or untested elsewhere in the chain.

Alan Mathison Turing, Peer Question: Dr. Bardeen, suppose a laboratory's reference test shows a weak carrier below a strong neighbouring tone in one software version but not in another. The FPGA bitstream, digital filter coefficients and FFT routines have changed, while the front-end gain control claims to remain the same. What experiment would separate a legitimate processing improvement from a new instrumental artefact or an overfitted detector? Would you require blind trials whose stimulus identities are not disclosed to the analyst, and would you freeze the decision threshold before comparing versions? Please also address a subtle case: a colour display appears more favourable in the revised version, but the underlying numerical detection statistic remains unchanged. Can the institution claim

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better sensitivity? I seek a method of falsification that identifies a particular receiver or processing state rather than assuming that repeatable computer output necessarily measures the external field accurately. Please identify which test result could genuinely falsify the claimed improvement, rather than merely disagree with the programme designer's preferred image.

John Bardeen, Response: Dr. Turing, the first step is to separate the source of evidence from the appearance of its display. If the numerical detector output remains unchanged and only a colour map has been altered, the revised picture supplies no evidence of improved physical sensitivity. A shift in display range can improve readability, but one should not misdescribe it as a lower instrument noise figure, improved SINAD or higher probability of detecting short bursts. A genuine processing improvement should be tested against raw data of known provenance, using fixed detector criteria and an independent set of cases that were not used to select the algorithm. The laboratory must state whether it seeks better amplitude estimation, lower false-alarm probability, improved timing, or greater detection sensitivity for a specified waveform class.

I would run a factorial trial in which hardware configuration and software revision vary independently where practical. Record one raw sequence from a controlled front end, then process it with both software versions without changing the acquired bytes. That reveals differences attributable to computation. Separately acquire new data with each hardware or FPGA configuration under independently monitored input conditions. This second experiment can expose changes in analogue timing, input scale or buffering that a software-only replay cannot detect. When the ADC or FPGA itself performs filtering before storage, an apparently identical file format may

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represent different physical operations. Its processing lineage must therefore include firmware identity and a reproducible description of the operations actually applied.

Blind trials can be valuable if their design is sound. Prepare a balanced family of weak tones, short bursts, blockers, no-signal controls and deliberately induced overload cases, with randomised trial order. Freeze the detection decision rule before revealing which trials contain which signal. Estimate detection and false-alarm rates by condition, including the effects of blocker separation and sample continuity. A detector tuned on the same data used to advertise its performance gives an optimistic estimate unless the selection process is incorporated into the statistical evaluation. Hold-out data or independently conducted confirmation is necessary for a defensible claim about generalisation.

A failure should be investigated at the appropriate layer. If both software versions produce a spurious in-band peak from an unfiltered strong out-of-band tone, aliasing or analogue nonlinearity is a stronger initial concern than FFT implementation. If the raw file is stable but one version produces a shifted frequency estimate, examine sample-rate interpretation, FFT bin mapping and decimation metadata. If the event disappears only after averaging changes, examine the observation window against event duration. No single test proves every hypothesis, but the combination can falsify careless claims. I would report the improvement only when the independent controls demonstrate the specific performance metric, not when the user prefers the appearance of the newer waterfall.

William Redington Hewlett, Cross-Peer Question to John Bardeen: Dr. Bardeen, you have explained why the converter cannot be evaluated

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independently of the analogue input and clock. I would like to make that explanation operational for an engineering acceptance team. Suppose two candidate systems have equal advertised instantaneous bandwidth, but the first uses a broad direct-sampling input and the second uses segmented analogue preselectors with lower sensitivity to powerful out-of-band sources. The broad system performs better in a quiet room yet fails to detect a faint reference beside a blocker. Which controlled measurements distinguish a failure of analogue headroom from a failure of clock phase noise, and what evidence would justify selecting one system over the other? Please explain whether a 14-bit nominal converter can outperform a nominally higher-resolution converter under the relevant test conditions, and how the report should use ENOB, SFDR and blocker-dependent detection results without pretending that one figure is a complete measure of investigative utility.

John Bardeen, Cross-Peer Answer to William Redington Hewlett: Mr. Hewlett, the first comparison must keep the input stimulus and the reference plane common while avoiding a shared failure in the monitoring equipment. Characterise both systems with known weak tones across their stated bands, initially without blockers, to establish frequency-dependent transfer gain and noise. Then introduce a strong signal with adjustable level and offset. Monitor the input with an independent instrument capable of handling the imposed amplitudes, and observe the receiver's full-scale occupancy, saturation flags, new spectral products and residual noise near the reference. An abrupt increase in distortion products or suppression as the blocker rises may support a nonlinear-headroom explanation; a spreading noise skirt that changes systematically with frequency separation

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may favour reciprocal mixing. Neither pattern is conclusive alone, so alternate clock reference, filtering and attenuation states to challenge the proposed mechanism.

A converter with more nominal bits can perform worse when its analogue front end or clock is inferior at the operating frequency. Nominal resolution describes the output code width. Its dynamic behaviour depends on noise, nonlinearity, aperture uncertainty, input frequency and the complete receiving chain. A fourteen-bit converter with robust clock distribution and carefully managed gain could preserve a weak wanted signal more faithfully in some blocked conditions than a nominal sixteen-bit part forced close to overload. Conversely, the larger code width may be valuable in a sufficiently quiet and accurately calibrated architecture. Neither proposition is a universal ranking. They require measurements at the intended frequency, signal level and interference state.

ENOB can provide a convenient sinusoidal performance summary when the test is specified, but I would not use it as a surrogate for the probability of detecting a millisecond burst. SFDR reveals the relative size of spurs under a stated spectral condition and search bandwidth, yet a strong blocker may activate new nonlinear pathways absent from the single-tone trial. Blocker-dependent detection results directly address the operational question, provided the false-alarm threshold is fixed and missed trials are counted. I would offer the procurement officer a matrix showing valid operation by frequency, gain configuration, blocker level and duration class, with separate columns for calibration error, dropouts and uncertain findings. The decision then becomes transparent: which failure modes matter to the authorised survey, and what performance has actually been demonstrated?

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Dr. James M. Atkinson, Moderator: Dr. Bardeen and Mr. Hewlett, I appreciate the careful distinction between nominal codes and demonstrated dynamic behaviour. Dr. Nyquist, I invite you to examine sampled frequency representations, aliasing and the limitations of digital channel boundaries.

Harry Nyquist, Fourth Principal Contributor: Dr. Atkinson, the phrase instantaneous bandwidth carries a precise mathematical danger when used without the word signal. Sampling theory connects a continuous-time band-limited function to a sequence under ideal conditions. A rate greater than twice the highest frequency is the familiar sufficient condition for reconstructing an ordinary low-pass real-valued signal with an appropriate reconstruction filter, provided the specified band limitation and ideal sampling assumptions hold. Engineers also exploit complex baseband representations and intentional bandpass sampling. None of these theorems alone characterises the sensitivity, overload tolerance or completeness of a practical surveillance receiver. They explain where spectral components can be represented without ambiguous folding, not whether those components were preserved accurately before the aperture.

I would require a written frequency plan that distinguishes the analogue passband, the converter sample clock, the digital frequency axis and the exact spectrum later displayed. A real sample stream at a nominal rate of 200 million samples per second is often associated with a first Nyquist interval of one hundred megahertz, but the usable span is less than or otherwise qualified by transition bands, filter attenuation, analogue input response and the chosen mixing architecture. In quadrature systems complex samples permit a different convenient frequency representation, with signed baseband frequencies extending on either side of zero. The

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numerical sample rate and the visually labelled bandwidth therefore cannot be equated without specifying the representation, the filtering and the exact frequency translation. The defence against misunderstanding is a recorded signal-path diagram and independent injection tests at frequencies near every relevant boundary.

For a concrete example, imagine a converter sampling at two hundred million real samples per second while a strong unfiltered tone exists at one hundred and thirty megahertz. In an elementary idealised low-pass sampling description, its alias can appear at seventy megahertz. Whether an actual instrument produces that apparent component at a detectable level depends on analogue input bandwidth and anti-alias filtering. If a tested preselector rejects the external tone sufficiently, the alias may be insignificant. If its rejection is poor, software could display a plausible in-band peak that never existed at the nominally labelled input frequency. The investigator should vary sample rate or analogue filtering, where authorised, to test the interpretation. A peak that moves according to the alias equation rather than remaining fixed in absolute RF frequency is evidence favouring a sampling-origin explanation.

Window functions and decimation require equal care. A wideband digitiser can yield many narrow channels through polyphase filter banks, each with finite stopband rejection and transition bandwidth. A strong signal near a channel boundary may leak into an adjacent display, and a very short pulse may be smoothed or partially suppressed by the selected averaging. The detector's result must therefore name the particular digital filter coefficients or verified implementation version, sample rate, decimation ratio and window or analysis kernel. A spectrogram with attractive rectangular

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frequency boundaries may conceal finite leakage and delays. If the user relies on the display to assert a negative finding, the laboratory must establish which events could have been missed or displaced by the processing chain.

Bandwidth trades can sometimes be made to our advantage. A system might capture a wide band continuously at modest raw sensitivity, preserve the raw samples, and later apply a narrower matched or energy detector to test a specified waveform family. Provided the original recording has not clipped, aliased or lost the event, the later analysis may improve its evidential usefulness. But an averaging or integration operation cannot undo the absence of the original samples. Nor does a sharply reduced resolution bandwidth automatically improve the probability of detecting a pulse whose energy is spread in time or frequency differently from the filter model. A powerful detector is one whose assumptions and error rates are calibrated against relevant controls, not one whose chart shows the deepest coloured background.

There is a special risk at tuning boundaries. A frequency-agile receiver may advertise enormous coverage over time, but the band was not observed continuously if the analogue front end retuned, changed filters or re-established a clock. A brief burst can occur entirely in an unobserved interval. Combining the successive screenshots into a single wide waterfall is a form of presentation, not evidence that all frequencies were simultaneously sampled. I would retain a timeline mask indicating precisely which frequencies were being observed at each instant. Any period that lacks samples must be marked unknown, not quiet. For simultaneous multi-channel capture, one must additionally establish that all channels share a

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known clock relation and that their data streams have no silent discontinuities.

As to practical acceptance, use a comb of authorised test tones with known frequencies and controlled separations, then add short bursts at selected times and a movable strong blocker. Vary the front-end preselector, analogue gain, centre frequency, sample rate and digital channel plan. The analyst should pre-register expected alias mappings and channel-edge attenuations before seeing the outcome, rather than adjust a favourable interpretation afterwards. Repeat with an independent spectrum reference to detect calibration or stimulus errors. Report any unexplained component as an unresolved observation until an alternative experiment distinguishes external RF energy from an internally created product. There is no shame in recording the limits of the apparatus; the scientific error is to let a numerical frequency label exceed the evidence.

I would conclude that instantaneous bandwidth is a joint property of the analogue filters, mixing architecture, converter and coherent digital processing, constrained by performance tolerances. A nominal sampling rate tells us something essential about representation but not everything needed for a lawful defensive survey. If the goal is to discover extremely rare, narrow emissions, continuous wide acquisition may be valuable because it avoids scanning gaps. If the goal is to measure a faint emission in the presence of a large nearby carrier, a narrower analogue preselection and carefully calibrated gain distribution may yield stronger evidence. These approaches are complementary tools, not rival schools of thought. The correct balance depends on the stated signal hypothesis, the site's actual electromagnetic environment and the validated test conditions.

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Marvin Lee Minsky, Peer Question: Dr. Nyquist, the investigator may use an adaptive software system to direct wideband observation towards features that appear anomalous. The software could retune a front end, modify channel bandwidth, change processing gain, or prioritise storage of certain spectral regions. Its proponents may call the result an intelligent expansion of coverage, while a sceptic sees a moving and potentially selective observation window. How would you specify the boundary between a physically observed frequency-time interval and a model-generated prediction? Should a system be permitted to interpolate a visually continuous waterfall over gaps caused by retuning or data loss, and if so how ought those pixels be labelled? I also ask how to evaluate a classifier whose training set includes examples produced by the same aliasing or phase-noise artefacts that it later purports to recognise as external emissions. The acceptance report ought to disclose the controller’s observation policy, not merely the apparently successful events it chose to save.

Harry Nyquist, Response: Mr. Minsky, the crucial distinction is between the signal that entered the instrument during a defined acquisition interval and the numerical constructions applied afterwards. An adaptive controller may provide operational benefits by allocating receiver resources towards a region with apparent activity, but it does not enlarge the physical interval during which unobserved frequencies were actually sampled. Its retuning decisions should be recorded with sufficient timing information to reconstruct the coverage mask. A display can interpolate for a clearly marked navigational purpose, but those interpolated pixels must not be used as observations or treated as evidence of a quiet band. If the

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application cannot distinguish native measurements from model-generated values, it is unsafe for evidential reporting without additional controls.

I would retain a ledger of configuration transitions. Each transition should identify the old and new centre frequencies, analogue filter states, sample rate, decimation mode, software revision, the effective time at which valid acquisition resumed, and any uncertain transition interval. The coverage record must be independent of the detector that triggered the transition; otherwise the system may explain away its own blind spots by presenting only the portions it chose to inspect. For a statistical assessment of overall occupancy, some deliberately randomised observation intervals or a validated sampling scheme may be needed. Adaptive observation is not automatically biased for every objective, but a claim about all frequencies and all times requires assumptions that the raw capture alone may not support.

The aliasing question is equally direct. If a strong out-of-band carrier creates a folded spectral image, a classifier trained on those images may become impressively consistent while learning the instrument's own response rather than the external emitter's characteristics. Change the sampling rate, insert a suitable preselector or substitute an independent receiver, and examine whether the supposed emitter feature behaves like an absolute RF source or a sampling-origin product. Also vary the independent source level and blocker conditions. A robust classifier should disclose its response to these perturbations. Confidence numbers generated by a model are not automatically calibrated probabilities of external origin.

Where the algorithm directs storage, evaluation must include the acquisition decisions it did not make. An audit might inject known pulses

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into frequencies that the controller initially judged unimportant, then measure how often they were missed during retuning or load shedding. The experiment should count time-frequency opportunities, not only true positives among saved alarms. An attractive adaptive heat map may be useful for navigating a crowded environment, but it must preserve the distinction between observation, inference and prediction. If the controller changes rules after each successful detection, the confirmation tests must be carried out on independently prepared cases. Mathematical sampling conditions still govern the physical data; no intelligent label can repeal them.

Herbert Kroemer, Cross-Peer Question to Harry Nyquist: Dr. Nyquist, I want to test a frequent misunderstanding about raw ADC sample rate. An engineer may place an extremely fast converter directly behind a nominally broadband coupling network, then assume that every RF emission in the displayed band is genuinely external and fully captured. Yet analogue input bandwidth, anti-alias filtering and periodic conversion artefacts may each interfere with that conclusion. Suppose the user sees a stable peak inside a nominal two-hundred-megahertz observation window while an independent receiver sees no such peak at the labelled frequency. What precise changes in sampling rate, analogue filter configuration or input termination would discriminate an alias from a true input signal? Would the same experiment support conclusions about rare transient sources? I should also like you to clarify why digital channelisation can create apparently neat frequency edges even when the analogue preselector's stopband rejection remains inadequate. I would also expect a frequency-plan diagram identifying which input bands were deliberately excluded rather than merely absent from the recorded graph.

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Harry Nyquist, Cross-Peer Answer to Herbert Kroemer: Dr. Kroemer, the numerical label is the beginning of the inquiry rather than its conclusion. For a real-valued sampler, a continuous input sinusoid at a frequency above the first Nyquist interval can map to a lower apparent frequency according to its relation to the sampling frequency. Changing the rate changes that mapping for many out-of-band inputs, while an actual in-band carrier, after correct frequency-axis recalibration, remains at its absolute RF frequency. This diagnostic requires a known and appropriately stable source or independent reference, because an unknown frequency-agile emitter might itself move during the experiment. Changing the analogue preselector can further test whether the component arises from energy outside the claimed passband; if a suitably characterised filter strongly suppresses the external candidate and the displayed peak disappears, the alias hypothesis gains support.

Input termination and gain tests supply other controls. A receiver-generated spur may persist with a properly terminated input, though some products depend on the magnitude of incoming signals and can vanish when the input is disconnected. A peak that scales with an externally injected test tone can still be a harmonic or intermodulation product, not necessarily an independent RF source. Therefore the laboratory should combine several perturbations rather than demand that one yields a universal answer. Exact filter response and test conditions must be recorded. A change of sample rate can affect clock phase noise, processing workload or converter operating mode as well as the alias mapping; the analyst must not assume that all other variables remain fixed unless the architecture permits them to be measured or controlled.

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The short-pulse case needs special caution. A transient occupies a broad spectrum and can overlap filter transitions, while the time-domain impulse response of an analogue or digital filter may distort its duration and apparent arrival time. A false peak in one Fourier frame may arise from leakage, a transient overload or a decimation artifact. Repeated controlled pulses of known shape, with randomised timing relative to processing windows, provide a means to characterise what the receiver would produce. One cannot apply the narrowband tone diagnosis uncritically to an arbitrary unknown impulse. Its cause may remain unresolved even after the frequency-axis tests.

Digital channelisation creates rectangular-looking regions because software assigns output channels finite names and grid boundaries. The actual filters have passbands, transition regions, stopband leakage and phase responses. Strong energy admitted by an analogue stage can leak or fold in ways not apparent on the simplified diagram. Consequently the usable bandwidth must be defined by measured rejection, distortion and detection criteria. A visually continuous array of channels does not prove the analogue chain is immune to aliases, nor does it establish that all frequency bins carry equally accurate amplitude information. I would preserve both the frequency plan and the empirical boundary-test results, leaving any untested interval explicitly qualified.

Dr. James M. Atkinson, Moderator: Dr. Nyquist, the panel is obliged to you for separating a sampling theorem from an assertion of a complete field measurement. Dr. Slepian, please accept the token and test the detectability of rare signals under finite observation windows and changing storage conditions.

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David Slepian, Fifth Principal Contributor: Dr. Atkinson, I would examine this question as a problem of finite observations and inference. A spectrum of extraordinary width provides opportunities to see events that a narrow scanner might miss, but the investigator's conclusion is not determined by the fraction of the tuning scale painted by the screen. The relevant quantities are the observation process, the family of possible signals, the noise and interference model, and the decision procedure. A receiver can collect enormous quantities of data while remaining ineffective against a rare event if its detector was optimised for persistent tones or if its storage collapses during the decisive interval. Conversely, a modest receiver can provide strong evidence about a restricted class of signals when the test conditions and observation opportunities are demonstrably controlled.

The relationship between time and frequency resolution is unavoidable. A short observation interval cannot yield arbitrarily fine discrimination of nearby stationary frequencies without assumptions beyond that interval. Narrowing a spectral analysis bandwidth ordinarily requires a longer effective observation window. Yet a burst shorter than the window may be diluted in an estimator that averages power across the longer interval. It is therefore misleading to optimise a display solely for a beautiful noise floor when the target hypothesis concerns signals lasting a fraction of a millisecond. An analysis procedure should specify the waveform family and duration range against which its detection probability is evaluated, and should preserve enough raw temporal information to test whether a displayed peak arose from one brief excursion or a persistent carrier.

For a detector with a fixed threshold, false-alarm probability and detection probability depend on its test statistic and the distributions under the

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competing hypotheses. These quantities cannot be read directly from an ADC's bit depth or the width of its captured span. If the receiver searches a million correlated spectral time-frequency cells, even a low per-cell false-alarm rate may create many apparent events, and overlap among FFT windows complicates the count of genuinely independent opportunities. The appropriate laboratory should examine families of injected events at predetermined strengths and randomised start times, retain trials in which the receiver fails, and evaluate both false positives and misses. A detector whose threshold was adjusted after seeing the desired test burst requires a new independent validation dataset before confirmatory error rates can be claimed.

The independent observation opportunity is particularly important for pulsed signals. Consider an authorised laboratory source emitting short bursts with a randomised start phase relative to the receiver's buffer and retune schedule. If the receiver genuinely captures the full relevant band without gaps, the distribution of start phases should not produce unexplained systematic misses. If a scanner's dwell leaves a blind interval, some bursts will land wholly within it. A nominal 100 percent coverage statement based on the union of frequency spans does not measure temporal opportunity. We should report time-frequency exposure as a tested function or mask, and distinguish a valid observation with no detection from an interval in which the receiver did not acquire usable samples. The distinction is essential to any negative survey report.

Data compression offers a difficult trade-off. A recorder confronted with hundreds of megabytes per second may be tempted to save only alarm-triggered excerpts or to apply irreversible quantisation. That choice may be

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operationally necessary and lawful, but it creates an asymmetric record: positive candidates are retained while silent or below-threshold intervals may disappear. It then becomes harder for a later expert to estimate an unbiased event prevalence or to challenge the detector's false-negative behaviour. A defensible system can preserve lower-volume observation logs, random audit samples, calibration summaries, dropout masks and hashes of critical configuration files while limiting sensitive content retention. Where raw IQ is retained for a narrow legal and scientific purpose, access, duration and disposal controls should be explicit. More recorded content is not automatically better evidence.

The validation matrix should therefore span three dimensions independently: signal strength and morphology, interfering-signal conditions, and acquisition continuity. For example, use weak narrowband tones, short gated carriers and wideband bursts; test them in quiet and blocked conditions; repeat under low and high recorder load. This gives a structured account of failure, rather than one all-purpose detection percentage. The operator should not collapse successful quiet trials and failed blocked trials into a single number that conceals the condition of interest. If the detector remains accurate over one restricted subset, state that subset as the validated envelope. The most scientifically interesting outcome may be a limit surface showing exactly when extra bandwidth ceases to compensate for reduced dynamic range.

One must be attentive also to correlated evidence. Two wideband receivers sharing the same antenna distribution, clock or preamplifier can exhibit the same spurious component. Agreement between them is not necessarily independent corroboration. A well-designed experiment includes an

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independently powered reference with a distinct front-end chain, alternate preselection or an attenuated input test, and, where feasible, a different antenna position or polarisation. Changing the suspected signal strength while leaving a receiver artifact invariant can illuminate the causal distinction. Without those controls, a coincident mark in two waterfalls may be nothing more than a shared distortion mechanism. The report should describe the correlation assumptions rather than simply count instruments.

My closing position is that a usable wideband capability should be defined as an empirically validated region in frequency, amplitude, interfering environment, event duration and observation time, not as the geometrical area occupied by a displayed spectrum. The error rates and uncertainty of each inference must be stated in terms of the actual conditions. If the instrument is excellent for finding anomalous energy but poor for attributing it, the report should keep those conclusions separate. If it cannot guarantee uninterrupted recording, the analyst should disclose where no valid observation exists. An appropriate conclusion may be modest but durable: a particular reference burst was detected under documented conditions, with an estimated miss rate and calibration limits; broader claims about unidentified emitters or absolute absence were not tested. Such restraint is a strength of technical evidence, not an admission of professional inadequacy.

Edsger Wybe Dijkstra, Peer Question: Dr. Slepian, a system acceptance report sometimes gives one detection probability for an instrument regardless of frequency, event duration, strong-signal environment and recorder load. I suspect that such a scalar hides more than it reveals. Could you define a finite and auditable test suite whose cases cover the principal

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ways a wideband survey might fail, without pretending that any finite set proves universal absence of unknown emitters? Please describe a record that makes every failed case reproducible: the injected signal, the relevant observation opportunity, the programme state, and the declared reason the test was invalid or unsuccessful. How should the institution distinguish a genuine detector miss from an unobserved interval, and how should it prevent staff from deleting difficult trials after seeing the outcome? The objective is a narrow, trustworthy assertion rather than a grand, untestable assurance. An explicit test oracle would make it harder for the operator to rename a failure as a success after the captured evidence has been inspected.

David Slepian, Response: Dr. Dijkstra, I would treat the acceptance protocol as a specification of conditional claims. Partition the intended operating range into documented frequency regions and representative input conditions, then select distinct signal families: a continuous carrier, a short gated tone, a frequency-agile burst and a wideband transient. For each, vary signal strength, blocker amplitude and separation, duration, receiver gain state and recording load. Include controls with no injected event and with known overload artefacts. The protocol should record what the independent reference says was presented, what the receiver actually observed, and what the pre-specified decision rule reported. The cases must be designed before the principal evaluation so that the experimenter cannot quietly narrow the sample space around favourable outcomes.

A valid observation opportunity requires more than a row in a test schedule. The device must be in a known state, the relevant input band must be acquired, the sample interval must be continuous enough for the statistic

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being tested, and the reference source must have operated as intended. If the recorder loses samples, mark that trial as an acquisition failure rather than a negative detection, while preserving it in the overall operational reliability assessment. If valid samples are present but the detector fails to alert for an injected test signal, that is a detector miss under the tested conditions. If an injected reference is not independently confirmed, the stimulus validity is uncertain. The laboratory should not conflate these outcomes or erase any from the experimental ledger.

For a finite trial count, even an observed success rate of one hundred percent has uncertainty. Ten successful observations do not justify a universal guarantee that every similar event will be detected, let alone that any unknown hidden transmitter would necessarily be found. The frequency of success should be reported with a suitable statistical interval under an explicit sampling model. Correlation among trials, especially shared gain state, blocked conditions or common storage failures, reduces the amount of independent information. A full survey report should describe the range of conditions investigated and the remaining plausible gaps. If a client requires a particular risk threshold, the decision procedure can be designed accordingly, but the resulting statement must remain conditional on its hypotheses.

The failure record should be immutable in its primary form, with a controlled amendment trail for later interpretation. Include the source programme and calibrated level, trial time, receiver and firmware configuration, sample counters, detection statistics, raw or appropriately minimised supporting data, and a reasoned disposition. If a run is invalid, the disposition should state a demonstrated reason rather than merely

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noting that its result was disappointing. Re-run cases with a blinded sequence where feasible and retain both original and repeat outcomes. The purpose is not to produce perfect numbers; it is to learn which region of the instrument's performance envelope is fit for its intended investigative use. A wideband system that reports these limits accurately may be more valuable than one promising everywhere-at-once certainty.

Harry Nyquist, Cross-Peer Question to David Slepian: Dr. Slepian, the laboratory has offered a remarkable wideband capture that avoids retuning, but its analysts then average many overlapping Fourier frames to produce a quiet and apparently sensitive waterfall. I am concerned that the observation interval and the detection question have become confused. Suppose a brief authorised burst occupies only a small portion of a long analysis window. How should the survey compare a short-window energy detector with a longer-window spectral estimator, especially if they have different false-alarm characteristics? Can one report a single probability of detection across all burst durations, and what documentation would permit later verification of a negative result? Please distinguish the actual number of independent opportunities from the number of correlated display pixels, and examine what should be said if the storage chain lost samples within the interval where a pulse could have occurred. The challenge must be independently reproducible, with the reference event time and the receiver’s sample validity established in advance of classification.

David Slepian, Cross-Peer Answer to Harry Nyquist: Dr. Nyquist, one detector cannot be called superior without specifying the hypothesis against which it is tested. A long spectral window can offer narrow frequency discrimination for a sufficiently persistent source, whereas a shorter energy

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window may preserve evidence of a brief event that the long average dilutes. The threshold for each detector should be set according to a declared false-alarm objective and validated on independent cases. If an analyst compares them only at equal numerical thresholds or by the height of their displayed peaks, the result has little scientific meaning. We must account for different degrees of freedom, noise correlation, window response and the signal energy each statistic retains.

I would design a grid of laboratory trials that varies pulse duration and amplitude independently of its start time relative to the analysis frames. Randomise start phases, include events near frame boundaries and retain genuine no-event controls. For each duration class, report the empirical detection rate together with uncertainty and the fixed false-alarm rule. Where trials are correlated by common environmental conditions or overlapping samples, the analysis must not count every heat-map cell as a separate independent replicate. The effective number of independent opportunities depends on the actual estimator and observation design, not the pixel count. Any modelling shortcut to this quantity should be justified by either analytic covariance or a suitable independent calibration experiment.

A single overall probability could be quoted only for a clearly specified mixture of pulse durations, input levels, conditions and opportunities. It should not be advertised as the probability of detecting any unknown transmitter at any time. A future signal may have a duration or morphology absent from the calibration family. For a negative survey result, I would retain the detector configuration, valid observation intervals, tested pulse family, chosen threshold and response curves so that an independent

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examiner can assess the actual limits. A confidence statement must concern what the experiment tested, not the metaphysical possibility that a source might exist somewhere outside its observation envelope.

If sample loss occurs in an interval that could contain the pulse, the observer did not acquire the evidence necessary to decide whether the event happened. The case must be represented as missing observation, not as a negative detector output. Where a recorder inserts synthetic zeros, the derived data must identify them so that a subsequent spectral estimator does not mistake them for physical silence. Repeating the trial may test the corrected instrument, but it does not retroactively recreate the missing event in the original record. Such disciplined distinctions make a wideband system more scientifically useful precisely because they prevent the attractive appearance of continuity from exceeding the underlying physical evidence.

John Bardeen, Cross-Peer Question to Herbert Kroemer: Dr. Kroemer, I should like to return the discussion from digital outputs to the physical receiver entrance. In a quiet laboratory, the survey team finds a faint reference with generous margin using a broadband LNA. At a site with powerful nearby transmissions, however, the same nominal gain produces spurious signals and suppresses the reference. Should the team immediately increase attenuation, insert narrow preselection, or choose another antenna? Each action changes the effective observation and risks making the before-and-after spectra incomparable. What controls are needed to determine whether the improvement reflects release from overload rather than simply a different calibration factor? Please include the possibility that the stronger signal enters through cables, power distribution

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or the receiver enclosure rather than the intended antenna terminal. How should such coupling alter the wording of an RF survey finding when the suspected source cannot independently be identified? The same protections must distinguish a genuine environmental signal from a spurious component created within the survey apparatus itself.

Herbert Kroemer, Cross-Peer Answer to John Bardeen: Dr. Bardeen, one should avoid treating attenuation, preselection and antenna substitution as interchangeable remedies. Each perturbs a different part of the chain and can provide discriminating evidence if its consequences are measured. Increasing input attenuation tends to reduce both the wanted signal and the blocker before downstream stages, and may release an overloaded amplifier or converter at the cost of sensitivity. A narrow preselector can preferentially reject the blocker when the desired frequency is sufficiently separated and the filter is suitable. Antenna substitution changes the electromagnetic coupling to the environment as well as the matching and frequency response. These operations must be accompanied by a calibration or a careful relative comparison at a defined plane, otherwise the observer may mistake an ordinary gain change for improved dynamic range.

I would begin by recording the original configuration with a protected observation log and an independently verified weak reference where lawful. Repeat with a known attenuation increment and examine whether the suspect spur changes in a way consistent with intermodulation. A third-order product, under its ideal small-signal assumptions, may change more steeply with input level than a fundamental component, but practical saturation and gain-controlled operation can invalidate simple slopes.

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Alternate preselection and compare the input-band response using a reference generator. If the weak target reappears while the blocker is suppressed, the evidence favours a receiver impairment in the original broad configuration. It does not alone prove whether the impairment occurred in the first amplifier, the converter or an earlier device without further isolation tests.

Unintended coupling requires separate investigation. A strong nearby signal can enter through an imperfectly screened cable, a power lead, a clock distribution path or the instrument enclosure. Terminating the intended antenna port while the apparent component persists is a valuable clue, although termination itself may alter loading. Moving and shielding the receiver, changing cable routing, substituting an independent supply or employing a second instrument can help isolate the ingress path. Such tests belong to lawful defensive engineering; they need not involve decoding or intruding into another party's communication. The written record should distinguish which paths were demonstrated, which were only suspected and which were not tested.

A report may properly conclude that an observed spectral feature was instrument-dependent under defined perturbations and therefore cannot be accepted as independent evidence of an external source at its displayed frequency. If an independent antenna system and separate receiver subsequently confirm a real field, the finding may be strengthened, but even that does not automatically establish the identity or intent of an emitter. The broader lesson is that dynamic range is a property of a configured chain in an environment, not a fixed virtue stamped on a component. An honest conclusion will say where attenuation or preselection

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made the measurement valid, which sensitivities were thereby sacrificed, and what uncertainty remains about the unexplained observation.

Dr. James M. Atkinson, Moderator: My thanks to the five principal specialists and to each peer who has challenged the underlying assumptions with appropriate professional courtesy. This fictional educational roundtable distinguishes usable instantaneous bandwidth from catalogue span, calibrates dynamic range under blockers, tests the converter and sampling chain, and treats data continuity and non-observation as evidential constraints. No result here identifies an unknown emitter or authorises collecting protected communication content. The token passes to the editorial team for independent verification, rather than to a premature claim of publication readiness.

SCHOLARLY RECONSTRUCTION AND REFERENCES. All dialogue above is a fictional, modern pedagogical reconstruction involving deceased historical experts. It is neither a transcription nor an authenticated statement by any named participant. Technical background pointers, requiring individual source-to-claim verification before Stage B: IEEE 1241-2023, IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters (https://standards.ieee.org/ieee/1241/6797/); Analog Devices, Considering GSPS ADCs in RF Systems (https://www.analog.com/en/resources/technical-articles/considering-gsps-adcs-in-rf-systems.html); Analog Devices, How a High Dynamic Range RF Transceiver Solves the Blocking Challenge for Mission Critical Communications (https://www.analog.com/en/resources/technical-articles/high-dynamic-range-rf-transceiver-solves-the-blocking-challenge.html). These technical references are background and do not certify fictional speaker wording.

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EDITORIAL QUALIFICATION. All numerical examples are illustrative and hypothetical, not documented field measurements. The ideal jitter-limited SNR relation assumes small RMS timing error, a sinusoidal input and the stated frequency; illustrative storage calculations use decimal bytes and exclude metadata and system overhead.

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QUESTION 103

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When is compressive sampling of rare RF emissions defensible without a validated sparsity model?

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Dr. James M. Atkinson, Moderator: Dr. Slepian, proponents of compressive acquisition rightly draw attention to the efficiency possible when a signal belongs to a class admitting a sparse representation, yet forensic acquisition cannot assume away the exceptional signal it has been commissioned to discover. A technical-security survey may be concerned precisely with unknown rare pulses, broadband transients and emissions which have never been observed by its detector. Please distinguish the mathematical conditions for sparse recovery from the physical guarantee that every relevant RF event has entered a reliable evidence record. I should like a controlled experiment in which the model is deliberately violated, and a reporting rule that prevents a reconstructed empty spectrum from becoming a declaration that no signal existed.

David Slepian, Principal Contributor: Dr. Atkinson, I would begin with the role of the model. Compressive acquisition can be powerful when an observation y is related to a signal representation x by a sufficiently well-characterised operator A, with an appropriate noise term. A formal recovery theorem then needs assumptions about x, A and the reconstruction procedure. Sparsity may refer to a small number of nonzero coefficients in a

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chosen basis or dictionary; it does not mean that a radio environment is necessarily empty most of the time in every representation. The operator may be a mathematical design on paper, while the real RF chain includes analogue filters, jitter, saturation, unknown coupling, gain drift and finite-word-length arithmetic. A theorem concerning an ideal operator is not automatically a certificate of any one physical recorder. Its hypotheses must be challenged by measurement.

I would distinguish a reconstruction from an observation. A conventional recorder may preserve sample values closely linked to the instrument's acquisition process. A compressive system preserves a lower-dimensional set of measurements and employs further assumptions to infer a candidate waveform. That inference may be excellent for a stipulated sparse family. However, different physical waveforms can produce indistinguishable or nearly indistinguishable compressed measurements when the acquisition operator lacks the necessary discriminating properties for the actual signal class. A display portraying one smooth reconstructed waveform should not conceal the fact that a different waveform may also be compatible with the measurements. In a forensic report, the observable quantities, the assumptions and the reconstructed hypotheses should occupy distinct fields.

An operator can correctly state that an algorithm recovered a set of authorised laboratory tones. Yet that achievement is narrower than a claim that it will recover every brief or unknown emission. Consider a controlled trial with sparse continuous carriers well separated in frequency. Such a family may match a selected dictionary, making reconstruction comparatively straightforward under favourable calibration and noise. Add a

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short broadband discharge with energy distributed across many dictionary elements, or combine several moving sources whose spectral support evolves unpredictably. The original sparsity premise may fail. Even if the reconstruction produces a graph with no apparent event, that absence may reflect the model's preference for a sparse explanation rather than a lack of electromagnetic energy in the real input. The laboratory must establish its miss characteristics using deliberately unfavourable signal families rather than flattering examples alone.

The forward operator requires scrutiny at the analogue reference plane. If the acquisition architecture uses a set of mixing functions, filters and sampling intervals, each must be characterised for frequency response, timing and linearity. A powerful blocker that drives one analogue stage into compression invalidates a simple linear measurement model. Interchannel phase error can corrupt a matrix assumed to be known exactly. A clock discontinuity can change the relation between measurements even though the software continues to apply an old operator. One should not respond to such failures by changing the reconstruction regularisation until the chart looks credible. The appropriate response is an acquisition-state record and a separate calibration study that determines whether the mathematical model remained applicable during the event.

A low residual is not sufficient proof of physical truth. The equation A times the reconstructed x approximates the recorded y is a necessary consistency check for some models, but it may be satisfied by more than one candidate signal. If the measurements omit distinctions essential to the forensic question, a reconstruction algorithm can return a plausible spectrum while excluding an event not represented by its prior assumptions. The examiner

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should test uniqueness or stability over a relevant model family, report the sensitivity to regularisation choices and preserve the original compressed measurements. If later developments permit a better reconstruction, the retained raw measurement vector and acquisition manifest will allow a new analysis without pretending that the earlier representation was a direct full-rate observation.

The experiment I would require uses an independently monitored RF source programme in a shielded and authorised environment. Prepare held-out cases involving sparse tones, frequency-agile bursts, short chirps, pulsed interferers and deliberately non-sparse events. Vary amplitude, event duration and start time independently of the compression schedule. Include powerful out-of-band sources to provoke analogue failures, and introduce controlled clock or matrix-calibration perturbations. Each trial should retain what the full-rate independent reference measured, what the compressed acquisition recorded and what the reconstruction reported. The predeclared acceptance criteria must distinguish successful detection, waveform reconstruction error, falsely inferred energy and invalid acquisition. The analyst should not discard trials merely because the algorithm's assumptions were violated. Those are precisely the trials that reveal its real limits.

One might add a blind comparison with a conventional receiver, though both systems must be independently calibrated. The comparison should account for any difference in analogue front end, gain and bandwidth. Otherwise, a superior preselector could make one arrangement look better for reasons unrelated to compressive mathematics. A defensible result might be that compressed capture detects a specified sparse family within

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measured error limits at reduced storage cost, while its performance for unmodelled impulsive events remains unknown or unacceptable. That is useful engineering knowledge. It does not entitle the surveyor to describe a quiet reconstruction as proof that no emitter was active in an unobserved region.

Finally, there is the evidence-preservation and privacy question. A compressed record may require less storage and can be attractive for lawful minimisation, but it is not automatically a privacy guarantee. The transform may still retain information about protected communication content, depending on its design and the relevant authority. Retained measurements, operator identity, configuration, processing revision, clock state and custody history should be protected in accordance with the specific lawful purpose. A later working reconstruction is a derivative, with its own algorithm parameters and digest; it should never replace the original measurements silently. I would ask Dr. Shannon to examine informational non-identifiability, Dr. Kolmogorov to challenge the stochastic assumptions, Dr. Hamming to investigate numerical error and Dr. Turing to formulate a falsifiable validation programme. Their analysis must preserve the distinction between what the hardware measured and what the mathematician's preferred model permits the computer to imagine.

Herbert Kroemer, Peer Question: Dr. Slepian, I wish to confront the analogue assumption on which the mathematical elegance rests. In an RF receiver the acquisition operator is not a static matrix suspended in a vacuum. Semiconductor gain, junction temperature, input protection, matching networks and blocker-induced changes can alter the relationship between incident electromagnetic fields and the samples from which a

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compressed vector is formed. Suppose a shielded laboratory demonstrates accurate reconstruction of isolated low-level tones. We then introduce a strong adjacent-band source which changes the operating point of the low-noise amplifier but is largely rejected by the final digital display. The compressed reconstruction still produces a clean narrow tone. What measurements would establish whether its amplitude and timing remain trustworthy? I would also ask what becomes of a proposed sparse-recovery guarantee after a front-end device exhibits memory, recovery delay or intermodulation. Must the operator be re-estimated for every gain state, or can one justify a bounded approximation? Please give an acceptance test that would detect a false quiet interval created before digitisation.

David Slepian, Response: Dr. Kroemer, your example demonstrates why one must distinguish a mathematical sensing matrix from the physical forward measurement map. If a front-end transistor changes gain or phase under strong blocking, a fixed linear operator may no longer describe the entire path. A reconstruction can fit the digitally retained compressed measurements yet incorrectly describe what entered the antenna. The first defence is an independent analogue measurement of the receiver's response across the declared input power and frequency envelope, including combinations of weak target and strong blocker signals. A single-tone calibration at a comfortable operating point cannot bound the response under all relevant two-tone or pulsed conditions. The operator's validity is an experimentally determined region, not a property of a data sheet slogan.

One could maintain a family of operator calibrations indexed by observed gain state and temperature, but that approach is defensible only if the state

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is recorded at the time of acquisition and the interpolation uncertainty has been tested. If the hardware enters a nonlinear regime, the linear model y=Ax+e should be regarded as invalid until a more suitable forward model has been validated. An engineer may use a local linear approximation within a measured neighbourhood, but must state the maximum perturbation and its consequences for the detection decision. The fact that an optimisation converges does not make the approximation true. It is preferable for a system to flag invalid measurement conditions than to hide the failure behind a plausible reconstructed line.

I would arrange a paired trial with a broadband independent reference recorder connected to a calibrated split of the authorised laboratory source, with each branch's gain and delay measured. Keep the weak target burst constant while varying blocker amplitude, centre frequency, phase relation and temporal overlap. Record the analogue stage's compression indicator if available, its actual gain state, recovery interval and output into the compressive sampler. Repeat the trial with the blocker absent. Compare not simply a reconstructed magnitude peak but an event-detection decision, onset time, amplitude estimate and declared uncertainty. A burst absent from the compressed result but present in the independent reference is a direct observed miss under that condition. It should remain in the statistical denominator, even if the operator specification originally excluded the blocker.

A false quiet interval can also arise when the analogue stage recovers after overload. The trial should therefore schedule events during the recovery period, not only in steady state before and after it. If the system does not monitor or log that period, its report must describe the resulting coverage

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gap. This is true irrespective of whether we use a sparse dictionary, direct full-rate capture or any other acquisition architecture. The distinguishing point is that compressed sampling requires an additional assumption to infer the unmeasured waveform. We should document that inference separately from what the hardware genuinely acquired. Your proposed challenge would be a strong qualification test and, if failed, a reason to narrow the claimed operating envelope.

Dr. James M. Atkinson, Moderator: Dr. Slepian has distinguished recovery assumptions from directly observed samples. I thank him and pass the token to Dr. Shannon to examine what information the measurement operator can and cannot distinguish.

Claude Elwood Shannon, Second Principal Contributor: Dr. Atkinson, the first mistake would be to treat the numerical size of a compressed record as though it supplied a universal certificate concerning the original electromagnetic environment. A finite collection of measurements partitions the set of possible waveforms into equivalence classes. When an acquisition matrix has fewer independent measurements than the number of unknown coordinates, its null space is generally nontrivial. Two inputs that differ by a vector in that null space can generate the same ideal measurement vector. A constraint such as sparsity may select one candidate from that class, but the selection is a hypothesis about the signal family, not an observation of every possible waveform. In a lawful technical-security survey the question is not whether the reconstructed spectrum is pleasingly sparse. It is whether the observation process retained evidence capable of separating the authorised hypothesis from competing physical events that would materially change the reported conclusion.

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A specified sparsity level can make a recovery problem tractable when the sensing operator has appropriate properties relative to the basis in which sparsity is assumed. The words 'when' and 'appropriate' carry the burden of the proof. In a textbook, we may show that an ideal random projection preserves relevant geometry for a selected model class with high probability under clearly stated conditions. An actual RF receiver has deterministic filters, nonlinear amplifiers, timing errors, quantisation, channel mismatch and potentially unknown gain changes. Those features mean that the implemented operator may differ from the ideal matrix. A guarantee for the first is not a guarantee for the second. It is especially hazardous to apply theoretical recovery bounds calculated for additive independent noise if the field noise is correlated, impulsive, cyclostationary or dominated by receiver-generated products.

We should distinguish three levels of evidence. First, an analogue instrument generated measurements according to a recorded acquisition configuration. Second, a reconstruction algorithm returned one or more signal candidates using a declared objective function, solver and assumptions. Third, an examiner inferred that some external event did or did not occur. Each transition requires an additional evidential argument. An algorithm that minimises an objective while fitting the measurements does not certify that every relevant alternative has been excluded. Even a zero residual may be compatible with nonunique reconstruction if the sensing operator has a nontrivial kernel. A small residual may merely show internal agreement between a measured vector and the model chosen to explain it. The original measurement vector must therefore be preserved along with a representation of the operator and its calibration uncertainties.

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The relevant outcome may be detection rather than waveform recovery. Suppose a survey seeks short RF bursts from a known laboratory emitter class. It may be possible to make a reliable hypothesis test on compressed measurements without reconstructing the waveform, provided the detector has been validated on independent test conditions and the false-alarm and miss behaviour are established. But the detection family must be described precisely. If a different, non-sparse short pulse passes through the apparatus during a period when the test is insensitive, an absence of an alarm cannot mean an absence of RF activity. We should test the system on deliberately adverse inputs, including off-model pulses and combinations of emitters, not merely on the examples the reconstruction dictionary already represents.

A concrete counterexample can be constructed without invoking any mysterious transmitter. Let A be a hypothetical 64 by 128 linear measurement matrix, let x be a 128-component representation, and let z be a nonzero element of the kernel of A. Then A(x+z)=Ax. The measurement system cannot distinguish x from x+z on the basis of those 64 values alone. If x is sparse and x+z is not, the sparse solver may select x and dismiss the energy represented by z. Whether z corresponds to a physically admissible analogue waveform is a further question, determined by front-end bandwidth, finite amplitude, temporal support and the actual implementation. The exercise establishes the logical limit of an unqualified no-signal claim; it does not prove that every conceivable kernel vector is physically realisable in a particular receiver.

It would be an error to move the ambiguity into a vague claim about privacy. Fewer samples do not automatically mean that the recording contains no

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protected information. Depending on the transform and signal family, compressed measurements can preserve enough information for successful reconstruction of content or other sensitive characteristics. Storage minimisation is a valuable engineering option, but lawful scope must be determined separately from transform dimension. An engineer should record the purpose of acquisition, authority, retained data type, access controls and rules for creating derivatives. We should avoid the fashionable belief that a clever mathematical mapping can substitute for the institution's evidential and legal responsibilities.

There is an additional complication when the measurement apparatus adapts to its own observations. If a detector changes its sensing matrix after each tentative trigger, the resulting record is conditional upon earlier data. The saved vector and the final matrix are not enough if the path of adaptation is omitted. One must preserve the configuration history, update rules, clock sequence and any periods during which the equipment did not observe the portions of the spectrum later described as surveyed. A report that preserves only successful reconstructions selectively hides the very conditions under which the process did not produce evidence. I would require a pre-registered experimental design and an explicit classification of successful reconstruction, missed event, false event and invalid acquisition.

Finally, the proper engineering conclusion may be circumscribed yet useful. A particular compressive receiver can be qualified for a defined frequency range, amplitude interval, occupancy model, pulse duration family and environmental envelope. Within that validated envelope, the cost of recording can be reduced while maintaining an agreed detection probability. Outside it, performance may be unknown. Such modest

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conclusions are not a retreat from mathematics. They are the only faithful translation of mathematical assumptions into scientific evidence. I return the token to Dr. Atkinson with a request that our colleagues press hardest upon the system's behaviour where its assumed signal class fails.

Marvin Lee Minsky, Peer Question: Dr. Shannon, a modern reconstruction system may use a learned sparse dictionary or a generative prior instead of the simple fixed mathematical basis described in many early explanations. Its output can look exceptionally realistic, even when important parts of the signal were not directly observed. How should we explain to a technically sophisticated tribunal the difference between a candidate signal produced by a prior and a directly measured RF waveform? If the model was trained using examples from related instruments, could its apparently successful reconstruction reflect knowledge of that training environment rather than the unknown source? I ask particularly whether presenting one convincing waveform image risks concealing a multitude of alternatives that agree equally well with the retained compressed vector. What controls would demonstrate that a machine-generated reconstruction has predictive rather than merely aesthetic validity, and which conclusions should the expert withhold when the inputs fall outside the model's training domain?

Claude Elwood Shannon, Response: Mr. Minsky, a powerful learned prior does not eliminate the information deficit created by the measurement process. It selects plausible waveforms according to a model acquired from earlier examples. That can be useful for denoising or estimating parameters within a familiar class, but it cannot create independent measurements that were never collected. If several physically different inputs produce the same retained measurement vector, the prior may choose the one it regards as

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most likely. The result may be visually persuasive without being uniquely supported by the evidence. An examiner must distinguish that conditional model selection from a claim of direct waveform observation. The distinction is as fundamental for a neural reconstruction as for a classical sparse optimisation.

I would preserve the compressed observations and the entire model identification record. That includes training-data provenance, architecture, weights or authenticated weight identity, preprocessing, version, input normalisation and any conditioning variables. A model trained extensively on one antenna, receiver or site might internalise the nuisance characteristics of that environment. Success on captures from the same hardware and room can therefore exaggerate performance in a genuinely different environment. Independent receivers, physical environments and signal generators should appear in a held-out study, with no leakage of highly correlated examples between training and validation sets. The model should also be tested on classes deliberately absent from training and permitted to abstain when it has no adequate evidential basis.

A useful validation should compare reconstructed parameters against independently acquired truth, not against the perceived quality of a displayed trace. Choose quantities relevant to the forensic conclusion, such as onset time, burst duration, centre frequency and phase continuity, each with calibrated uncertainty. Predeclare acceptable error bounds. Introduce controls where training priors favour a signal that is absent, and where the actual event belongs to a rare unfamiliar class. Measure false creation of events as well as omission of true events. If the system returns a single waveform, its report should disclose whether other candidates fit the

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measurement vector comparably well. Where the problem is nonidentifiable, no choice of attractive output can substitute for new measurements or a narrower inference.

It is also necessary to examine where training or tuning decisions have used the validation results. An algorithm repeatedly adjusted until it passes a particular laboratory test no longer offers an independent assessment on that test set. A final held-out evaluation, controlled by investigators who did not tune the model, can mitigate that problem. Even then the validity applies to the tested domain; it is not a guarantee about all possible unknown emissions. A tribunal should receive an explanation of the assumptions, observed failures and feasible alternatives. A reconstructed waveform may be presented as a model-derived hypothesis, never as an authenticated trace of an event solely because it is coherent or familiar in appearance.

Claude Elwood Shannon, Cross-Peer Question to Andrey Nikolaevich Kolmogorov: Professor Kolmogorov, I should like you to examine the difference between a mathematically defined sparsity assumption and a statistical assertion about the signals likely to occur in a real technical-security survey. Suppose an engineer validates a compressive receiver on a sequence of narrow laboratory carriers, estimates a very favourable recovery rate and then claims that the apparatus provides near-complete monitoring of a building where emitter types are unknown. The engineer may say that sparse occupancy is probable because the observed spectrum usually appears quiet, but the quietness itself is reported by the apparatus being evaluated. How could one avoid reasoning in a circle? I ask also how the conditional distribution of rare broadband impulses should enter the

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estimate of missed events, and how to report the result when the test population does not represent the field population. Can one give a rigorous bound without pretending that untested signal classes have known probabilities? The answer should separate empirical support from an attractive but unvalidated population model.

Andrey Nikolaevich Kolmogorov, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, the circularity is direct: the compressed instrument's quiet output is being used to establish the sparsity condition that was assumed in interpreting that same output. A valid assessment requires information independent of the candidate recorder. In a controlled laboratory the reference source and its schedule are established by a separate system, and an independently qualified monitor records whether events reached the designated RF reference plane. The candidate's output is then compared to events it did not choose to generate or retain. Where the actual field population is unknown, the laboratory can estimate performance for specified event classes, but it cannot use that estimate as a universal environmental guarantee.

The model must include the probability of an event entering the observation interval, the physical response of the front end and the conditional probability of detection by the compressed algorithm. An event with sparse support may have a favourable detection probability under one calibrated regime, while a broadband impulse may have a much poorer probability. If the population contains an unknown mixture of those classes, an unconditional success rate from a narrow laboratory mixture does not transport without assumptions about that mixture. The report should provide class-conditional performance, the tested envelope and a statement

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that broader performance is unknown. This may be less rhetorically satisfying, but it is more precise.

A rigorous bound may still be available for a carefully defined quantity. If a physical constraint supplies a known bound on amplitude, frequency support or temporal structure, one can use that constraint in an explicitly limited inference. If no such constraint exists, one should not manufacture a numerical miss bound out of the wish that the environment is sparse. The uncertainty has an epistemic component because the event class itself may be unobserved. Repeating the same selected tones reduces sampling uncertainty for those tones but does not resolve model mismatch for untested waveforms. More repetitions do not cure a defective experimental population.

The survey report should also state the mechanism of its missing observations. An event may be missed because its measurement vector is ambiguous, because it occurred during receiver downtime, because the analogue chain saturated or because a reconstruction prior suppressed it. Each is a different limitation. The institution can improve coverage by changing the experiment, introducing independent observation methods and documenting the exclusion of unqualified intervals. It cannot responsibly transform a statistical model's preference for sparse signals into a categorical declaration about every event that might have existed. That is the boundary between warranted inference and an unsupported assertion of assurance.

Dr. James M. Atkinson, Moderator: Dr. Shannon and Professor Kolmogorov have distinguished mathematical ambiguity from stochastic assumptions. I

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invite Professor Kolmogorov to develop the problem of unrepresentative rare-event populations.

Andrey Nikolaevich Kolmogorov, Third Principal Contributor: Dr. Atkinson, it would be profitable to begin by exposing the difference between a probabilistic model and the world from which the data are taken. A receiver engineer may say that an RF scene is sparse with high probability. The assertion is incomplete until the probability space, sampling mechanism, observation interval, joint distribution and conditioning information are specified. Sparse at an arbitrary instant is not the same as sparse over a block, nor is sparse occupancy in frequency the same as a sparse sequence of pulses in time. A narrow transmitter that changes frequency rapidly may have few active bins in one short snapshot and many active bins in a longer observation. A broad transient may be rare in time yet distribute its energy across nearly every frequency coefficient. One must not move silently between these descriptions as though the same theorem governed all of them.

An especially dangerous convenience is to estimate the sparsity model using the very records selected by an alarm system. If a detector retains only the compressed measurements that yield plausible sparse reconstructions, then the data available to fit the model have already been conditioned on the desired outcome. The unretained records and the times when the receiver was unavailable become invisible. A statement that most retained captures were sparse may thus be a tautology concerning the selection rule. To infer occupancy or missed-event rates one must know the number and duration of observation opportunities and the conditional probability of retention for the signal families of interest. When the selection mechanism is unknown,

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the investigator should not report an unbiased environmental frequency distribution.

For rare events the distinction between average and tail behaviour has practical importance. A model may reproduce the mean spectral occupancy or average reconstruction error while missing infrequent broadband impulses. The rare impulse may be precisely the object of the investigation. We should therefore evaluate conditional error given event duration, amplitude, initial time, frequency support, interference and device state. A single averaged success percentage is incapable of describing those dependencies. In a shielded trial, the generator schedule should be randomised independently of the sensing pattern, so the instrument cannot benefit from an accidental synchronisation. Otherwise a demonstration can be successful because of the alignment of two laboratory clocks rather than because the sensing architecture retains the event.

I would add the distinction between epistemic uncertainty and genuine stochastic variability. Some departures from the sparsity model may be observed among many randomly chosen events; others concern an unknown family that has never entered the validation study. One may estimate the former under a proper experimental design. One cannot claim a meaningful population miss rate for the latter merely by repeating known sparse tones. Calibration uncertainty in the realised matrix is a separate matter again. It may be quantified from repeated measurements of reference inputs, yet those measurements may not cover a rare thermal state or nonlinear regime. A proper uncertainty statement should say which uncertainty sources were measured, which were modelled and which remain untested.

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I suggest an intentionally simple numerical experiment. Consider a hypothetical reference source emitting 1,000 independently scheduled test events, 900 in a predeclared sparse class and 100 in a broad transient class. Suppose a given recorder detects 891 of the sparse events and 20 of the broad events. Its detection fraction for the overall laboratory mixture is 911/1,000, or 91.1 percent. That number conceals the 20 percent success rate for the broad class. If the real survey's mixture of event classes is unknown, the overall laboratory fraction cannot be transported uncritically into an environmental detection probability. The example is an arithmetic illustration, not a measured performance claim. The appropriate table should retain outcomes by class and condition, including the observations that were dropped or invalid.

The investigator must also distinguish the existence of a stable statistical model from the question of whether its parameters can be identified with the available observations. A few good reconstructions can be compatible with many different sparsity rates and event-duration distributions. Prior distributions, regularisation strengths and assumed dictionaries often strongly influence the recovery of low-amplitude components. Their sensitivity should be reported. If changing a plausible model parameter transforms an apparent quiet interval into a plausible burst, the final account should not pretend the quiet interval was an invariant fact. We may report a family of compatible reconstructions and the conditions under which each appears.

I would put model stress-testing into the acquisition qualification process. We should introduce artificially correlated support patterns, transient combinations, intentionally missing samples, uncalibrated channel skew and

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a known change in the background process. Such experiments are not intended to make the apparatus fail unfairly. They are intended to characterise the domain over which the claimed guarantee has meaning. The study should specify a stopping rule in advance, retain negative and inconclusive results, and disclose the extent to which the selection of training examples influenced the chosen algorithm. An attractive reconstruction after repeated tuning does not possess the same evidential status as a result from a locked algorithm applied to held-out challenges.

For negative-survey reporting, the probability of missing a relevant event cannot be estimated simply as one minus a recovery success rate obtained from selected sparse examples. It depends on the actual class, the observation schedule and the conditions of reception. If a substantial category of physically plausible event has uncharacterised detection probability, the negative conclusion must be qualified accordingly. We should not express a false universal assurance as a numerical percentage with four decimal places. An honest conclusion may establish that the equipment had a specified probability of detecting certain test signals under specified conditions and that unknown non-sparse emissions remain outside the validated scope.

Finally, a record of model failure can itself be valuable science. A trial in which compression creates a false quiet interval teaches more about the instrument's boundaries than ten demonstrations in which reconstruction successfully reproduces the signal dictionary. A mature survey culture preserves those results rather than hiding them as inconvenient exceptions. I pass the discussion to Dr. Hamming, whose discipline of numerical testing

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may determine whether the software faithfully implements even the model that has been honestly declared.

Jacob Ziv, Peer Question: Professor Kolmogorov, could a variable-length or adaptive compression mechanism alter the apparent prevalence of rare emissions in a manner that is difficult to diagnose from the files it chooses to retain? Imagine a receiver which compresses quiet periods strongly, records alarms at a higher detail level and changes dictionary parameters according to the recent history of the signal. A later analyst sees a rich collection of detected bursts and only brief summaries of the intervening time. Is it possible to infer environmental occupancy from such a record without knowing the retention and adaptation rules? How should the laboratory test whether compression failed systematically for unfamiliar or non-sparse waveforms, and what information would be needed to reconstruct the denominator of legitimate detection opportunities? I would also ask whether effective file-size reduction tells us anything about guaranteed preservation of rare-event timing, rather than merely about the regularity of ordinary background observations. Please distinguish the behaviour demonstrated by controlled tests from properties that the investigator has merely assumed on the strength of a successful reconstruction.

Andrey Nikolaevich Kolmogorov, Response: Dr. Ziv, the retention rule becomes part of the observation mechanism and cannot be ignored when interpreting event frequency. If a system stores detailed records only when its own detector fires, the surviving material is conditioned upon the detection decision. An analyst cannot estimate the frequency of missed events solely by counting the detailed records that happened to survive. The

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periods represented by summaries may include both genuine quiet time and events that the model did not recognise. If the adaptation rule is unrecorded, a model of environmental occupancy is likely to be underidentified. We must know when the receiver was observing, when it changed state, what information the summaries preserve and how retention probability depends on the underlying event class.

The laboratory should impose a predeclared schedule of independent ground-truth events, including those which violate the expected sparsity structure. Their temporal positions should be randomised relative to the compression schedule. The study must retain the entire event schedule, an independent reference record and the compressed system's decisions, including non-retentions and invalid intervals. Only then can one estimate conditional detection rates for defined event families. A variable-length representation may be efficient in the background regime but fail disproportionately for brief broad impulses. The overall bytes-per-hour figure says nothing about that tail failure without a performance experiment. It measures resource consumption, not preservation of evidence.

For an occupancy inference, the denominator should be an independently established amount of valid observation time or a count of suitably defined opportunities. It should not be merely the number of compressed files. If the receiver changes its algorithm after recent alarms, those changes may influence later detection probability, so observations can become dependent through the adaptation process. One must model that dependence or design an evaluation which conditions on the relevant states. The analysis should preserve state epochs, changes of threshold,

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matrix revisions and periods of storage or network loss. Otherwise an apparently stable duty-cycle estimate may reflect the recorder's changing willingness to retain data rather than the behaviour of the external RF environment.

We should also ask whether the reconstruction output is an unbiased estimate of duration. An adaptive system might suppress isolated noise-like samples, shortening a burst that resembles an impulse. Another might join nearby events because a smoothing prior prefers continuity. Either error can distort the duty cycle or temporal clustering even where a detection is registered. The experiment must compare onsets, offsets and event counts with the independent reference, reporting distributions of error rather than a single attractive average. It would be reasonable to claim efficient compression for specified background and event classes under tested conditions. It would be unjustified to claim that sparse storage alone preserves every event relevant to a TSCM investigation.

Andrey Nikolaevich Kolmogorov, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, our distinction between model uncertainty and statistical variability will fail if the implemented computation changes its measurement interpretation without recording that change. Imagine a field recorder with a calibrated matrix in memory. Its software updates a coefficient table after a temperature adjustment, some hardware channels have slight phase skew, and a recovery algorithm employs a stopping tolerance that depends on the measured noise. The investigator later retains only the final recovered waveform. Which information is necessary to separate the uncertainty of the physical operator from numerical approximation error and from the sparse model's own bias? I should also

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like a practical account of how the laboratory should treat a low reconstruction residual if the operator used in the calculation is not exactly the operator used during acquisition. Finally, how can the analyst prevent the apparent precision of many output digits from suggesting certainty about an event that may have been suppressed by quantisation or overload?

Richard Wesley Hamming, Cross-Peer Answer to Andrey Nikolaevich Kolmogorov: Professor Kolmogorov, the laboratory must preserve the acquired measurement vector before reconstruction, the operator identity applicable to each acquisition epoch and the numerical procedure used to create the derivative. A final recovered waveform alone discards the distinction between input observation and inferred output. The record should identify coefficient precision, temperature compensation, channel calibration, input gain, filtering, sampling schedule and any period in which those settings were uncertain. It should preserve software and firmware versions, matrix checksums, solver tolerances and the exact condition used to stop the algorithm. Otherwise the investigator cannot determine whether two laboratories differ because of physics, software or interpretation.

The effects should be assessed in separate controlled experiments. The physical operator is tested by driving the actual receiver with independently characterised signals and comparing the resulting measurements to the predicted forward model. Numerical error is tested by processing known synthetic vectors and varying arithmetic precision, evaluation order and stopping tolerance. Model bias is tested by using physically plausible signals that do not satisfy the assumed sparsity structure. Those tests answer distinct questions. A well-calibrated matrix does not validate the statistical prior, and a perfectly implemented solver does not establish that the

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analogue input remained linear. A small residual against the wrong operator is a warning rather than an exoneration.

When the operator used in reconstruction differs from the actual acquisition map, the residual can be small for an incorrect recovered signal. Suppose the algorithm has enough freedom to alter sparse coefficients so that their projections fit the stored vector. It may thereby conceal an input-gain error or phase skew. The correct test is to replay the preserved measurements using the correct recorded operator, if it exists, and compare results under calibration perturbations. If the operator cannot be established, the result should be described as exploratory. It is inappropriate to claim physical amplitude accuracy merely because the numerical optimiser converged to a stringent tolerance.

Displayed digits should be controlled by the uncertainty of the measurement and the decisions based upon it. A value may be computed with double-precision arithmetic while the analogue front end has a much larger amplitude uncertainty. The display precision should not obscure the effective number of independent, calibrated measurements or known overload conditions. A conservative decision rule should mark any event whose amplitude, timing or identity changes materially under plausible calibration perturbations as unresolved. The proper conclusion may be that the compressed data are compatible with several waveforms and insufficient for a more exact claim. Such candour is a positive engineering result, because it directs attention to what the apparatus must measure next.

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Dr. James M. Atkinson, Moderator: The probabilistic account now points to the engineering computation itself. I pass the token respectfully to Dr. Hamming for an examination of finite precision and operator calibration.

Richard Wesley Hamming, Fourth Principal Contributor: Dr. Atkinson, our colleagues have set out the logical and probabilistic qualifications, but an apparatus may violate them by purely computational means before a single false inference is made. A reconstruction algorithm usually solves an inverse problem through floating-point arithmetic, finite precision storage, stopping tolerances and a collection of engineering approximations. The matrix A in an elegant proof is not automatically the matrix implemented in firmware. It may have been quantised, transposed, truncated, reordered or measured under another gain state. If I cannot reconstruct the exact numerical processing recipe, I cannot tell whether the returned waveform belongs to the physical measurement or to the program's particular approximation.

The manifest should record sample representation, signedness, endianness, scaling, channel order, clock mapping, and any premeasurement transforms. A system that mixes or accumulates samples in the analogue or FPGA domain must describe those operations as part of its forward operator, not conceal them as mere implementation. Matrix coefficients require identifiable calibration revisions. If the front end is changed, the operator may change. If the digitiser saturates, the simple linear forward model may cease to apply. The solver cannot restore linearity by reducing its residual. It may simply choose a mathematically convenient false explanation. Consequently, validation needs an independent measurement path and a hardware-state log, not only a software unit test.

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I would require five distinct computational checks. First, inject a known digital test vector into the reconstruction chain and determine whether the program returns the expected result within an appropriate numerical tolerance. Second, drive the analogue receiver with a calibrated reference input and compare the actual measurements to the predicted forward model. Third, perturb the operator deliberately to quantify sensitivity to calibration error. Fourth, process signals outside the assumed sparse class and record what the algorithm falsely infers. Fifth, reproduce the computation in an independent implementation with a documented treatment of floating-point differences. One correct graphical output is not enough to demonstrate any of these controls, because a plotted magnitude spectrum can conceal severe phase and timing errors.

Condition number and sensitivity deserve explicit treatment. For a well-conditioned linear problem, small measurement perturbations may produce suitably bounded changes in a solution. For an ill-conditioned or nonidentifiable inverse problem, a tiny change can yield a large change in the inferred waveform. Sparsity-regularised methods can alter the practical problem, but the effective stability still depends on assumptions that must be checked. It is therefore important to vary the noise level, calibration coefficients and stopping criteria in a controlled experiment rather than evaluate one idealised noise-free record. An analyst should document which parts of an output remain robust and which change conspicuously when reasonable numerical parameters change.

Consider a hypothetical data record in which one component of a sensing matrix has been stored with an incorrect sign. The measurement vector may be internally consistent with the true operator yet poorly fitted by the

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incorrect one. Increasing the allowed residual or changing the regularisation weight may produce a visually plausible output while concealing the configuration fault. The correct course is to compare a measured calibration response against the expected operator. We should make the program fail closed when it encounters a mismatched matrix identifier or an uncalibrated gain state. If an investigator is permitted to override that failure, the record should preserve the override, reason and the altered inference status. It is unreasonable to make the later examiner discover the error from a strangely shaped spectral peak.

The treatment of quantisation needs care as well. Merely collecting fewer numbers does not guarantee that the retained measurements have adequate information to resolve a weak event. Each measurement may contain noise and numerical error from multiple contributing inputs. A wideband blocker may dominate the dynamic range before the compressive transform has preserved the weak phenomenon of interest. Dither can sometimes improve estimates under defined conditions, but it cannot erase overload or create missing independent information. Time interleaving can increase rate under suitable calibration, but does not add converter word lengths to manufacture an arbitrarily accurate physical amplitude estimate. This is the same scientific discipline that governs other digital receivers: no reconstruction result is more trustworthy than its calibrated observation chain and its tested error model.

For forensic continuity, preserve the original compressed measurements as bytes, a digest of those exact bytes, an independently protected acquisition manifest and every derived reconstruction as a new object. The manifest should identify the software version, numerical library, hardware revision,

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coefficient set and transformation parameters. If the investigator changes an algorithm to improve recovery, the earlier result is not retroactively corrected. The later processing run is another experiment using the same original observation. The differences should be explained, not overwritten. A reproducible computation is useful even when wrong; it allows the error to be found and documented. An irreproducible computation conceals the distinction between a failure of measurement and a failure of explanation.

I would also prohibit a common rhetorical manoeuvre in reporting. A compressed recording may recover some familiar tones almost perfectly, and the team may then advertise an equivalent full-rate sample stream. That phrase suggests that all physically relevant samples have been preserved. They have not. The system has preserved a lower-dimensional observation from which certain signals can be reconstructed under assumptions. The correct performance descriptor should state the validated signal family, the error criteria and the conditions of acquisition. Any claim of general waveform equivalence must be tested rather than inferred from an impressive demonstration. We must not confuse engineering optimism with physical evidence.

When numerical differences arise between independently developed implementations, I would not immediately insist on bitwise identity of floating-point outputs. Different evaluation orders may yield small differences within an agreed tolerance. But a tolerance must be justified relative to the relevant decision threshold and signal uncertainty, not enlarged after an inconvenient failure. A borderline event might require both raw-measurement comparison and independent analogue corroboration. The acceptance record should specify which variations are

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permitted, which demand investigation and which invalidate the proposed inference. That discipline is what gives a forensic result its resilience under hostile expert scrutiny. I return the token to the moderator and invite Mr. Turing to ask what an examiner could actually disprove about this apparatus.

William Redington Hewlett, Peer Question: Dr. Hamming, suppose a manufacturer presents two SDR designs for a facility survey. The first stores raw contiguous I/Q records, while the second stores compressed projections and promises equivalent waveform recovery. The manufacturer's demonstration uses clean sinusoidal signals, yet the application involves asynchronous bursts with uncertain amplitude, finite pulse rise times, temperature variation and equipment reconfiguration. How should a technically responsible laboratory compare the instruments without allowing the compression algorithm to benefit from knowing the test repertoire? I am particularly interested in the design of a reference plane and in whether the instrument can preserve a pulse that arrives precisely when its input switching network or processor changes state. What role should the laboratory assign to numerical residuals, independent full-rate monitoring and a separate test of the recording system's sustained data throughput? If the compressed system offers much lower storage cost, what evidence is necessary before we describe that saving as achieved without material loss of evidential utility?

Richard Wesley Hamming, Response: Mr. Hewlett, the comparison must be made against a laboratory reference acquisition that sees the same input event, not against the manufacturer's preferred reconstruction. Establish calibrated RF input planes for both designs; document antenna and filter

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states, overload margins, analogue transfer, clock behaviour and any switching dead time. Inject a blind repertoire of asynchronous bursts, overlapping tones and amplitude-modulated transients whose timing and amplitudes are concealed from the reconstruction team. Reference captures need sufficiently broad bandwidth and dynamic range to expose failures rather than simply agree with the device under test.

The timing challenge deserves a dedicated experiment. Trigger events just before, during and after every permitted tuning, gain, preselection or firmware-state transition, repeating the trial across temperature and loading conditions. Compare pulse detection, onset-time error, peak-amplitude error, phase continuity and false-negative rate separately. State which events were not observed because neither design was live at the relevant instant. A low average waveform error can conceal the complete loss of a single short burst; therefore report event-conditioned losses and worst-case intervals as well as aggregate reconstruction statistics.

A second channel should preserve continuous, calibrated full-rate I/Q samples with its own monitored clock and sustained-write measurements. Exercise both storage paths for longer than their buffers can absorb, measuring overflow counters, dropped-sample indicators, packet discontinuities and the latency between physical acquisition and durable storage. Synchronise records by independent reference events, not solely by software timestamps. Keep input waveforms and receiver configurations as controlled test evidence; a reconstruction that succeeds only after tuning its algorithm to the blind validation cases must be retested on another unseen set.

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I would credit a storage saving only within a declared and independently demonstrated observation class. For each class report compression ratio together with detection sensitivity, timing fidelity, uncertainty bounds, unavailable intervals and the cost of retaining manifests and calibrations. If the compressive design cannot distinguish several admissible input histories, its apparent waveform must be labelled a model-conditioned estimate, not a captured original. The laboratory should also test how performance changes when the acquisition matrix, source environment and signal family differ from those used for training. Those qualifications answer the evidential question more faithfully than a successful sinusoid demonstration.

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Abraham Lempel, Peer Question: Dr. Hamming, I want to make an explicit comparison between lossless encoding, lossy waveform reduction and true compressed acquisition. These three terms can sound alike in a sales demonstration but they make different promises about the retained evidence. If an instrument first samples the full I/Q stream and then compresses those exact bytes without loss, an independent examiner may recover the original digital sample sequence. If the instrument reduces the precision of the samples or stores projections before the full waveform exists, such a guarantee no longer follows. What validation records should distinguish those cases? How should checksums, compression ratios, sampling manifests and transformation histories be used without making a hash or a successful decompression appear to prove authentic RF origin? And how would you report a later reconstruction in which several plausible waveforms remain compatible with a single compressed measurement vector? Please distinguish the behaviour demonstrated by controlled tests from properties that the investigator has merely assumed on the strength of a successful reconstruction.

Richard Wesley Hamming, Response: Dr. Lempel, the distinction should be made at the input and output of each transformation. Lossless encoding of a fully acquired digital sample sequence promises a reversible map between that specific sequence and a shorter byte representation. If the encoding and decoding operations are correctly implemented and the archive remains intact, the same original digital bytes can be restored. That says nothing by itself about whether the ADC measured the physical input faithfully. Lossy reduction modifies or discards information from the acquired sequence, and pre-acquisition compressive measurement never

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stores the full digital sequence in the first place. A reconstructed waveform in either of the latter cases is conditional upon an algorithm and a model. Calling all three simply 'compression' obscures their radically different evidential status.

A verification record should identify the reference plane at which the promise is made. For lossless coding, test representative and adversarial digital inputs, encode and decode them, and compare their exact bytes, including sample order and metadata. Protect the original and decoded object identities, algorithm version, file lengths and cryptographic digests. For a lossy transform, declare the distortion metric and test it on waveforms relevant to the forensic questions, including phase and timing as well as amplitude. For compressive acquisition, identify the physical forward operator and the family for which reconstruction or detection has been demonstrated. One cannot use a successful decompression test from the first category as evidence for a recovery theorem in the third.

Checksums can assist in detecting accidental corruption and cryptographic digests can strongly support byte continuity relative to a trusted reference state. Neither proves the truth of acquisition timestamps, calibration coefficients, physical origin or lawful authority. A digest faithfully preserves whatever was hashed, including an erroneous manifest if one was included. The laboratory must therefore document the original sample or projection semantics, equipment state and independently controlled reference measurements. Transformations performed for later analysis should produce new objects with their own identifiers and should retain an auditable link to the preserved evidence. The investigator must not present

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a recomputed post-processing hash as though it authenticated the earlier analogue event.

If several physically plausible waveforms fit the compressed vector to within measured uncertainty, I would report nonuniqueness as part of the result. It may still be possible to infer a restricted property common to every candidate, such as an energy bound or membership in a tested event class. But a single reconstructed pulse should not be labelled the captured waveform unless the necessary uniqueness and stability assumptions have been justified for that case. File-size reduction is then a performance parameter, not a synonym for preservation of all evidence. The proper comparison states exactly which observations were saved, which attributes can be recovered, the validated uncertainty and the alternatives that the record cannot distinguish.

Richard Wesley Hamming, Cross-Peer Question to Alan Mathison Turing: Mr. Turing, I wish to pursue whether one can write tests that distinguish a faithfully executed but scientifically inapplicable algorithm from a faulty implementation. A receiver manufacturer may demonstrate that its reconstruction code satisfies unit tests against ideal matrices, while the deployed instrument uses quantised coefficients, a variable preselector, adaptive gains and a host whose scheduling occasionally drops measurement blocks. Suppose the output passes a visual inspection and the solver residual is small. What set of executable acceptance conditions would justify proceeding to a scientific detection decision? How would you test the response to an incompatible matrix revision, omitted blocks, an unsynchronised clock or an analogue overload event? I should like the result expressed in states that an independent reviewer can inspect, not merely in

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a verbal promise of software quality. Should the system ever continue with an exploratory reconstruction after a failure, and if so how would you prevent that output from becoming accepted evidence without an additional qualification?

Alan Mathison Turing, Cross-Peer Answer to Richard Wesley Hamming: Dr. Hamming, I would require the reconstruction pipeline to establish its preconditions at each processing stage. An archive must pass an integrity and schema check; the acquisition epoch must identify a compatible sensing operator; the relevant hardware calibration must cover the recorded configuration; the status record must identify any lost or invalid measurement blocks; and the intended decision rule must have been independently validated for the declared signal family. The programme should not silently promote an invalid or unknown state to a valid one simply because an algorithm can produce output. These conditions should be executable tests with recorded results and reasons for failure.

The practical state machine would distinguish a complete and qualified acquisition, an incomplete acquisition, a capture whose model is incompatible, and one in which physical conditions exceeded qualification. The solver may run for a valid interval and provide a result with documented uncertainty. For an unqualified interval it may produce a separately marked exploratory derivative, but that derivative cannot inherit the evidential status of a validated detection. Each state transition should be logged with input-object identities, operator revision, calibration basis and processing software identification. That preserves accountability without pretending that a mathematical reconstruction is a direct observation.

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Fault-injection tests should deliberately exercise each failure. Change one coefficient-table identifier while leaving the data unmodified and verify that the programme refuses the trusted processing path. Remove a block or repeat one and confirm that the sequence check recognises the discontinuity. Perturb the clock mapping and determine whether the output is marked with enlarged timing uncertainty rather than silently aligned. Overdrive the analogue front end and confirm that the record indicates an out-of-envelope condition. In every case the laboratory should compare the candidate system with an independent reference and retain the unflattering results. The quality of an error-detection mechanism is demonstrated most clearly by its behaviour when the anticipated error actually occurs.

Formal tests of the program's arithmetic are necessary but insufficient for physical validity. A system may have flawless control flow while modelling the wrong analogue system. Therefore acceptance should be conditional on three independent bodies of evidence: computational implementation, calibrated instrument response and the statistical validity of the final inference. A claim to reconstruct an unknown burst requires substantially more evidence than a claim that one solver consistently minimises its stated objective. The safest design is one that makes uncertainty and invalid states explicit to its users. I would rather trust a system that sometimes declines a conclusion than one that produces a confident spectrum at every opportunity.

Dr. James M. Atkinson, Moderator: Dr. Hamming has delineated numerical fidelity from physical validity. I now invite Mr. Turing to frame an independently falsifiable qualification programme.

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Alan Mathison Turing, Fifth Principal Contributor: Dr. Atkinson, I should prefer a finite, falsifiable specification to an undefined assertion that the system 'uses compressive sensing'. A physical instrument cannot be judged by the name of its algorithm. It must have a documented input domain, an observable acquisition procedure and propositions that can be tested against controlled cases. I would define the system's expected outputs at three levels: a claim that energy was detected under a specified decision rule, a claim that some waveform parameters were estimated within tolerances, and a claim that an entire signal was reconstructed with a stated error. These propositions are not interchangeable. A detector may be adequate for the first while failing the other two. It may also give a convincing waveform for one model family while missing an off-model event altogether.

A useful test harness should start with a configuration that cannot be altered by the examiner after the test cases are revealed. Otherwise an adaptive series of corrections may overfit the laboratory programme. The test set should include held-out ordinary cases, deliberately hostile but physically lawful cases and samples captured independently of the apparatus under examination. We should verify that the reference system has sufficient bandwidth and temporal accuracy for the chosen questions. It would be a logical failure to test a compressive recorder against a supposedly full-rate receiver that itself misses the broadband impulses. Independent calibration is essential for both. The reference record should be preserved before the candidate system's output is inspected.

The decision process should use explicit categories. A valid capture with an event detected is not the same as a valid capture with a correct

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reconstructed waveform. A valid capture with no event detected is not proof that no event entered the antenna. An invalid acquisition caused by saturation, lost samples or failed calibration should not be counted as a successful negative test. A false positive may be caused by the reconstruction algorithm or by receiver-generated artefacts; each deserves investigation. The laboratory report should preserve the denominator for every reported rate. One might otherwise calculate detection success on only the cases the software found easy enough to process and discard the failures as exceptions. In such a protocol the most important evidence is absent from the published table.

I recommend metamorphic tests, in which the input is changed in a controlled way and the consequences of that change are checked. If a test waveform is scaled by a known amount within the linear range, the corresponding measurement behaviour should follow the declared model within uncertainty. If the input is delayed by a known number of sample apertures, its reconstructed timing should respond according to the sensing operator's timing convention. If an additional independent tone is introduced within the supported sparsity envelope, the system should exhibit the predicted change rather than suppress the new component to preserve an attractive sparse output. Tests should be designed to fail visibly when the system's operating assumptions cease to hold.

For negative claims, I would ask a more difficult question than whether the output screen is blank. Could two authorised laboratory inputs, one containing the relevant event and one lacking it, produce the same retained measurements under a plausible fault or off-model condition? If so, the evidence has insufficient discriminatory power for the proposed universal

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claim. The appropriate report may be that a specified class of event was not detected during validated observation opportunities. If the surveyor wishes to claim that no relevant source existed, a broader physical and experimental argument is needed. The limitations of the model cannot be overcome by impressive language in the conclusion.

The device's state transitions should be auditable. Suppose it alters its compression pattern after a tentative alarm, resets on an overflow, or changes reconstruction dictionaries as the background noise rises. The investigator needs a time-ordered record of those decisions. Merely retaining the last configuration is not enough, for the missing interval may have occurred under an earlier state. The test system should deliberately provoke reconfiguration, dropped blocks and clock discontinuities. It should verify whether an event that overlaps those changes is marked uncertain rather than silently placed on a smooth reconstructed timeline. That is essential where a later examiner must distinguish an authentic brief emission from an artefact of software scheduling.

The proof obligation also changes when the laboratory software is updated. A new solver, an altered machine-learning model or a revised coefficient matrix cannot simply inherit the validation certificate of the earlier implementation. Some checks may be reusable, but the changed components and their interaction with existing components require regression tests. The release record should document the old and new results on the same preserved measurements, identify changed decisions and disclose whether thresholds were adjusted after seeing outcomes. A system with a formal source-control history but no independent test record may be administratively tidy without being scientifically trustworthy.

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I would ask each participant to articulate the observation that could falsify his preferred method. The sparsity theorist should name a waveform class that defeats the assumption, the statistician should name a selection mechanism that invalidates the estimated rate, the numerical specialist should name a calibration perturbation that defeats the solver, and the instrument designer should name a physical state in which the forward model breaks. If no conceivable laboratory result is allowed to challenge the conclusion, the conclusion is not being subjected to scientific testing. This does not mean a theory is worthless. It means the conditions of applicability must remain visible.

For the final record, I would separate acceptance of software execution, acceptance of scientific measurement and acceptance of a forensic inference. These are three different achievements. The first establishes that documented code ran as intended; the second establishes that the acquisition system behaved within a calibrated domain; the third establishes that a conclusion follows from the observations under stated assumptions. A volume devoted to receivers and evidence ought to be uncompromising on this distinction. I pass the token to the peer interrogators with one request: challenge not merely the quality of the reconstruction, but the very circumstances under which the reconstruction would mislead an otherwise competent examiner.

Grace Brewster Murray Hopper, Peer Question: Mr. Turing, the computational system is said to be reproducible, yet the evidence presented to another laboratory may consist only of a set of compressed numbers, a matrix identifier and a PDF showing a successful waveform reconstruction. The acquisition firmware can alter its mixing pattern under load, the

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processing software can change a regularisation parameter, and the computer can replace a missing block with zeros while retaining an apparently continuous file. Which records should be preserved to enable an examiner to repeat the numerical analysis and to discover that the capture itself was incomplete? I am also concerned that a software version string without an exact binary or build manifest may give a false assurance. How would you separate preservation of original evidence from working derivatives and prevent a subsequent, more favourable reconstruction from being mistaken for the original observation? Please account for practical custody rather than merely specifying an ideal mathematical experiment.

Alan Mathison Turing, Response: Dr. Hopper, I should begin with the identity of the original observations. The laboratory ought to preserve the acquired projection bytes, native sequence numbers, packet or frame boundaries, device-state transitions, and an acquisition manifest signed or otherwise protected as close to capture as practicable. For each observation interval, the manifest should identify its exact measurement matrix and calibration revision, clock basis, acquisition firmware build, analogue gain state, and flags for overload, lost samples and substituted data. A software version label without the executable digest, dependency set and build provenance is insufficient for an independent reproduction.

The chain of processing must be append-only in its evidential meaning. Preserve the original capture object unchanged, and create a separately identified derivative for each conversion, gap-handling rule, calibration correction or reconstruction. Record the parameter vector, solver stopping criterion, numerical-library versions, floating-point environment and a digest of both input and output. A missing block represented as zeros is not

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a measured zero-valued signal: the gap mask must remain explicit in every derivative, and any interpolated or substituted values should travel with a machine-readable provenance flag.

To discover an incomplete acquisition, an examiner should compare several independent ledgers: hardware sample or projection counters, transport-frame sequences, operating-state logs, storage-commit records and externally captured timing markers. Their discrepancies have explanatory value. A continuous file length or a valid checksum proves neither that every scheduled analogue aperture was sampled nor that the correct matrix acted during each interval. The repeat laboratory should be able to replay the original bytes through the named binaries while deliberately injecting missing frames, stale manifests and mismatched configuration identifiers, and then observe that the software signals the corresponding failure.

Finally, the published reconstruction must be identified as an analytical result obtained from a stated original object, not as the original RF event itself. Its report should cite the immutable acquisition identifier and the exact transformation chain, disclose unsuccessful or contradictory reconstructions, and distinguish repeatability of computation from validation of the physical measurement model. A more favourable later image or spectrum may be included as a new experiment, but it must neither overwrite the original projections nor silently replace the first result in the custody history. This is the practical separation between preservation and interpretation that your question requires.

Edsger Wybe Dijkstra, Peer Question: Mr. Turing, I should like a specification that does not permit success to be declared merely because the demonstration produces an attractive output. A data acquisition

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programme will encounter malformed manifests, missing frames, changing matrix revisions, numerical overflow and operator states never covered by its calibration record. If a reconstruction can silently continue through those failures, it may turn invalid observations into reassuring negative evidence. What invariants should a well-engineered system enforce before it performs any inferential reconstruction? How would you structure a state machine so that questionable intervals are labelled and retained without relying upon a human operator to notice them? I ask that you distinguish a program which computes correctly under stated preconditions from a larger scientific system whose assumptions may be false. Where should the program refuse to make a forensic finding, and what evidence of that refusal should remain in the custody record? Please distinguish the behaviour demonstrated by controlled tests from properties that the investigator has merely assumed on the strength of a successful reconstruction.

Alan Mathison Turing, Response: Mr. Dijkstra, the program should make its preconditions explicit and should not silently weaken them to force a result. At minimum it needs an accepted acquisition-object format, a declared measurement-operator identity for every interval, a compatible calibration state, monotonic native sequence semantics, a recorded clock model and a clear representation of invalid or missing measurements. An archive that fails any indispensable precondition can still be preserved and studied, but its data must not be passed into a validated reconstruction path as though the precondition were satisfied. The processing state should be recorded as valid, invalid, incomplete or unqualified, with the reason and relevant source identifiers. An invalid interval should not be rendered as an ordinary quiet interval.

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The state machine might separate acquisition acceptance, operator qualification, numerical processing and forensic decision. A capture first passes an integrity and schema test. It then passes an operator-identity and calibration check. The solver may run only for the portions covered by a valid operator or must return a clearly marked exploratory result. Finally, a decision engine applies a rule that was validated independently for that signal family. Each transition produces a log entry with the responsible program revision and the evidence supporting the transition. If the device changes state without a valid model, it should enter an unqualified state rather than pretend that the old matrix still applies. This is a testable invariant, not a matter of aesthetic judgment.

However, formal program correctness cannot by itself establish the truth of the physical model. One can prove that code solves an optimisation problem accurately and still be wrong about which analogue signals the matrix describes. Therefore the proof obligation is layered. Unit and property-based tests address the implementation, calibrated hardware experiments address the forward model, and blind held-out trials address the resulting detection inference. We must retain failures from all three layers, because a negative result in one does not become a positive result merely because another layer has passed. A computation can be reproducible and scientifically inapplicable at the same time.

For an examiner, the refusal record is particularly valuable. It should identify that the programme declined a classification or did not claim absence during a specified interval because of missing samples, overload, unverified coefficients or model mismatch. The log should distinguish a genuine detection threshold not crossed during valid observation from an event that

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the apparatus could not evaluate. The investigator may choose to perform exploratory analysis after a failure, but it must produce a separately marked derivative and must not silently repair the status of the original measurement. A forensic record in which uncertainty and refusal are explicit is more trustworthy than one that presents an unbroken series of confident answers.

Alan Mathison Turing, Cross-Peer Question to David Slepian: Dr. Slepian, permit me to formulate one final challenge. A compressive receiver can be theoretically excellent for a selected class, independently calibrated in a laboratory and still face a field event whose structure is outside every tested dictionary. At what point may the operator cease describing the apparatus as an experimental method and begin to use it for a formal negative technical-security finding? Would you require a known lower bound on detection probability for each event family relevant to the asserted conclusion, and how would you treat a class whose existence is plausible but whose probability of occurrence is unknown? I am also concerned with the tendency to equate reconstructing a waveform with recognising an emission, although a hypothesis test on compressed measurements may sometimes be sufficient. Please propose a precise reporting sentence that states the authorised survey result without implying omniscience, and specify what supplementary observation would most improve its defensibility.

David Slepian, Cross-Peer Answer to Alan Mathison Turing: Mr. Turing, a formal negative finding must be limited to the event classes and acquisition conditions for which the apparatus has been qualified. If a compressive receiver demonstrates an adequate miss probability for specified bursts,

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levels, frequencies and durations in independently controlled tests, an examiner may report that no event of those qualified classes was detected during the stated valid observation intervals. The report should disclose the antenna, receiver bandwidth, reference calibration, observation schedule and known blind periods. That is an evidence-based proposition. It is not a claim that no possible transmitter was present, and the conclusion should not be enlarged merely because the reconstructed display looked empty.

A class of physically plausible but untested waveforms must remain outside the declared assurance envelope. If its occurrence probability is unknown, one cannot replace ignorance with an invented small number. The survey may still have value because it excludes certain hypotheses to a measured sensitivity, but the conclusion must identify the hypotheses to which the evidence actually applies. The uncertainty statement should distinguish instrumental detection limits from the unknown distribution of possible emitters. If the instrument's physical response to the untested class can be measured in a new controlled experiment, that experiment may expand the envelope. Until then, the appropriate status is unqualified or unknown.

A test on compressed measurements can sometimes suffice for detection even when complete waveform reconstruction is impossible. It may test a defined feature against a specified noise model without recovering every original sample. Such a result should be judged by its validated false-alarm and miss characteristics, not by the resemblance of a reconstructed waveform to a familiar example. Conversely, successful waveform reconstruction under an assumed sparse model does not automatically establish the origin or lawful meaning of an emission. The investigator must keep detection, waveform estimation, class inference and source attribution

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separate. Each transition requires evidence not supplied by the name of the acquisition algorithm.

I would recommend supplementary independent observation using an appropriately calibrated conventional receiver or an alternate sensing method, particularly for brief broadband signals that could violate the sparse representation. A reference monitor can reveal physically real events which the compressed record suppresses or misdescribes. The methods should have sufficiently independent failure mechanisms, and any common input splitter or clock should be documented. A defensible reporting sentence might read: 'During the recorded valid observation intervals, this qualified compressive receiver did not detect emissions within the specified tested signal classes above the stated detection limits; performance for untested signal structures and unobserved intervals is not established.' That statement is narrower than the general absence of a hidden device, but it is technically honest and capable of independent challenge.

QUESTION 103. TECHNICAL REFERENCE BACKGROUND: E. J. Candès and J. Romberg, “Sparsity and Incoherence in Compressive Sampling,” Inverse Problems 23 (2007), DOI 10.1088/0266-5611/23/3/008; E. J. Candès, J. Romberg and T. Tao, “Stable Signal Recovery from Incomplete and Inaccurate Measurements,” arXiv:math/0503066. These cited sources are not attributed speeches and do not independently verify instrument-specific performance.

EDITORIAL QUALIFICATION. Fictional educational reconstruction. All physical test cases are hypothetical, and no unknown emitter is identified or private communications decoded.

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QUESTION 104

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How should machine-assisted RF anomaly detection be assessed under distribution shift?

SCHOLARLY RECONSTRUCTION. The following modern educational dialogue is fictional, not authentic speech or an historical meeting. Research sources are contextual background rather than historically attributed speech.

Dr. James M. Atkinson, Moderator: Professor Minsky, an RF anomaly detector may appear impressive when the training and test samples resemble one another because they share a receiver, site, source generator and recording session. Once the antenna changes, gain is adjusted or an unfamiliar source enters the scene, the detector may recognise the recording environment rather than an electromagnetic phenomenon. Please frame an assessment that separates technical novelty from instrument artefacts, and that retains every adverse result rather than showcasing only correctly classified examples. I should like you to identify which information must be recorded so that a subsequent examiner can distinguish a detector's performance on observed cases from its unknown behaviour when the distribution changes.

Marvin Lee Minsky, Principal Contributor: Dr. Atkinson, I would begin by refusing the convenient assumption that an abnormal output necessarily corresponds to an abnormal external signal. An algorithm observes features extracted from a measurement system. Those features can change because a transmitter changes, but they can also change because the receiver's local oscillator drifts, a digitiser loses a sample, a filter is switched, a gain stage enters compression, or the background noise in the room alters. If the system is trained on a narrow range of such conditions, a new receiver state

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may be marked anomalous even in the absence of any unfamiliar emission. Conversely, a genuinely unfamiliar waveform may resemble a familiar training artefact and be accepted as unremarkable. An anomaly score is therefore a statement about the relation between the new feature vector and a learned reference distribution. It is not, without further evidence, a statement about the identity or intent of an external emitter.

The first scientific task is to define the prediction target. The laboratory may wish to detect increased spectral occupancy, an unusual temporal pattern, a departure from the receiver's established background state, or a class of waveforms. Those are different objectives and may require distinct labels and validation measures. A machine can be good at recognising changes in its own equipment without being useful for site surveillance. I would insist that each reported detection identify the observation to which the score applies, including the RF reference plane, sample rate, analogue bandwidth, gain state, input power range and time interval. If that information is unavailable, the score should not be presented with an air of instrumental authority.

The second task is to design a test that does not conceal dependence. Divide a continuous recording into thousands of adjacent windows, and one can obtain a large-looking dataset with a deceptively small number of independent environments. If highly correlated windows from one transmitter and one receiver appear in both development and test sets, the classifier can memorise nuisance characteristics that will not recur at another site. Random splitting of such windows may exaggerate generalisation. A proper test programme should hold out whole recording sessions, receiver specimens, antenna configurations, locations, dates and

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emitters, according to the specific claim to be evaluated. The laboratory should say which of these variables it tested. Generalisation across a new day with the same instrument is not the same as generalisation across an unfamiliar receiver architecture.

A third task is to make the false-alarm denominator explicit. A programme that calls attention to ten impressive anomalies in a day may be useful or unusable depending on how many measurements were examined and how many events a trained examiner can investigate. The correlation of spectral bins and overlapping windows means that one cannot always treat every displayed pixel as an independent decision opportunity. False-alarm rates should be evaluated per appropriate time interval, survey interval or defined event cluster, with the selection rule recorded. The study should include long periods with no controlled emissions, short weak test bursts, strong lawful interferers and deliberate hardware changes. It should record missed events, false alarms, invalid acquisitions and inconclusive decisions as separate categories.

I would not assume that learning a background model cures the problem of background drift. A moving estimate can follow a rising interference floor so smoothly that the detector ceases to identify the gradual change. An excessively rigid estimate can generate continuous alarms when the site undergoes a benign change. The laboratory must measure how adaptation works and preserve its state history, including any reset or retraining event. A threshold chosen after watching the test outcomes has been optimised on those outcomes; it requires fresh confirmation on an independent set before its advertised error rate can be trusted. An investigator should not

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rewrite the system's original history merely because a later model provides a more attractive explanation.

The decision to abstain is as important as the decision to alarm. When the receiver enters an uncalibrated gain regime, experiences overload, loses its time reference or encounters a feature distribution unlike that used for validation, the appropriate output may be 'unqualified' rather than a confident label. It is preferable to preserve a properly identified uncertainty than to produce a smooth waterfall and a persuasive diagnosis without adequate measurement support. The software should disclose the reason for abstention and the time interval affected. A subsequent examiner may then seek a corroborating observation, repeat a lawful controlled test or narrow the final report's claim. Without that state, a negative machine decision may be misinterpreted as proof that the spectrum was quiet.

A controlled experiment should therefore have independent sources and a locked inference procedure. Choose several calibrated emitters representing known normal signals and unfamiliar but lawful laboratory waveforms. Record them on multiple physically different receivers with different antenna and gain conditions. Retain independent reference recordings. Freeze preprocessing, feature extraction, anomaly scoring, threshold rules and the test schedule before evaluating the held-out cases. Introduce benign receiver-state changes without changing the external RF event. Introduce genuine changes in the external signal while holding the receiver configuration constant. Those paired interventions help distinguish an algorithm sensitive to its own apparatus from one sensitive to the stipulated external phenomenon.

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A further difficulty is the interpretation of an impressive probability number. A score calibrated on one validation population may cease to describe meaningful error frequencies when the distribution of environmental interference changes. It is not enough for the software to attach two decimal places to its confidence. The conditions under which that number was calibrated should be disclosed, and it should not be used as a probability of a particular person's involvement, device identity or unlawful purpose. Those stronger propositions require evidence beyond the detector's performance on laboratory samples. A disciplined report should state what the detector observed, which controlled tests support its decision and which alternative explanations remain unexcluded.

I would also insist on evidence preservation. The original I/Q sample data or authorised minimal extracts, their digests, the receiver-state manifest, feature-processing recipe, exact model identity and all operator overrides should be maintained according to lawful scope. A later software update is a new analysis of old observations, not a retroactive improvement to the original acquisition. The audit record should permit independent replication of the original outcome and show precisely how the updated system changed it. If communication content is not necessary for the authorised objective, that content should not be collected merely to create a richer training set. Technical ambition cannot displace proportionality and legal authority.

The principal conclusion is necessarily limited. A model can be shown to detect specified anomalies under specified receiver and environmental conditions, with measured false-alarm and miss behaviour. It cannot be certified as universally reliable against every unknown emitter because the

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very meaning of unknown includes cases absent from its validation evidence. The next contributors should examine decision-theoretic error costs, software acceptance tests, statistical controls for distribution shift, and the information lost when data collection is triggered only by an earlier anomaly alarm. I pass the token back to Dr. Atkinson with the suggestion that the strongest experiment may be the one in which the model is allowed to refuse a confident answer.

Claude Elwood Shannon, Peer Question: Professor Minsky, your proposed separation of external-emission novelty from receiver novelty invites an information-theoretic question. A feature vector may discard much of the original waveform, while a detector trained on that vector can be judged accurate in an environment for which the discarded details were unimportant. When a new receiver changes the feature statistics or a novel transient contains information removed by averaging, the decision procedure may be unable to distinguish causes that the full recording could distinguish. How would you establish that the chosen representation retains information relevant to the evidential question, and how should the laboratory report an information loss which the model's output score conceals? I particularly want an experiment that varies receiver input filtering independently of the transmitted waveform and that compares the algorithm with a calibrated reference retaining more of the original I/Q sequence. The result should tell us whether the alleged anomaly belongs to the electromagnetic scene, the detector representation or the analogue path.

Marvin Lee Minsky, Response: Dr. Shannon, I would resist the temptation to treat the feature vector as an innocent summary. It is a design decision

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about which distinctions the programme is permitted to notice. If the analysis retains only average spectral power over a long window, it cannot independently reconstruct the timing of an extremely brief pulse that contributed that power. If it replaces a waveform by a learned embedding, the engineer must establish empirically what perturbations the embedding conceals. A high classification score derived from such features may be numerically genuine while supporting a much narrower scientific statement than the user imagines. The omitted dimensions form a potential blind region, not an assurance of physical absence.

The proposed controlled trial should use one set of known laboratory waveforms and vary the analogue front-end state in a factorial arrangement. Record an independent reference with appropriate bandwidth and calibration, then pass the same generated signals through at least two distinct receiver chains. Compare raw sample correlations where appropriate, physical signal measurements and the selected feature vectors before examining the classifier output. Introduce short pulses whose energy is diluted by the averaging interval and a gradual gain change that should not be mistaken for new emissions. If a receiver filter suppresses a component entirely, the loss should be attributed to the measurement chain rather than the classifier. If the samples retain the component but the feature extractor discards it, that is a separate software limitation. A failure in the downstream classifier constitutes a third, distinct category.

I would publish a representation-adequacy matrix alongside the usual accuracy table. Its rows would describe physical effects the survey intends to detect: a weak continuous signal, a short transient, a slow spectral drift, an impulsive interferer and a receiver-generated mixing product. Its columns

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would describe the capture and feature pathways, including any missing-data mask and whether the reference instrument actually observed the stipulated event. The test could then identify which distinctions survived each representation. There is no need to proclaim that the same embedding is optimal for every purpose. A feature set useful for occupancy may be inadequate for phase transients or source attribution.

The final language should say that the detector was validated for specified features of specified observations under specified receiver states. When untested physical distinctions may be lost, the analyst should refrain from turning a negative anomaly score into a statement that no relevant RF event occurred. The reference data and feature-processing recipe should be preserved within the authorised scope so that another investigator can challenge the result rather than simply accept a convincing visualisation.

Jacob Ziv, Peer Question: Professor Minsky, suppose a baseline is constructed with aggressive compression, frequency-bin aggregation and event-triggered retention, and then used to train a model that reports excellent novelty detection. Such a dataset may exclude the very weak, brief or unrecognised events which failed to trigger the original recorder. A subsequent model cannot learn a class which the acquisition policy systematically omitted, yet an examiner might treat the absence of training examples as proof that the class is rare or irrelevant. What acquisition and validation design would distinguish the performance of the machine-learning algorithm from the selection bias imposed by storage and compression? Please address the case in which full-rate recording would be unnecessarily intrusive or physically impractical, so that an independent reference must use proportionate, targeted or controlled laboratory

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measurements. I should also like to know whether a change in compression settings should automatically invalidate the earlier model's demonstrated error rates. The experiment must also record when each test signal genuinely entered the receiver input.

Marvin Lee Minsky, Response: Dr. Ziv, the training archive is not a transparent window onto the physical world. It is the product of a series of selection rules. An event-triggered recorder stores examples conditional on the operation of the preceding detector, and the new algorithm cannot infer the distribution of omitted events simply by studying what was retained. One should separately identify the acquisition process, the retention process and the labelling process. If the archive contains only material which a prior threshold recognised, an estimate of performance against unknown missed events is generally not identified from that archive alone. We may be able to estimate performance conditional on a trigger, but that is a narrower quantity and must be labelled accordingly.

The laboratory can measure this limitation in a lawful controlled trial. Use an independent reference source programme, with event schedules chosen before data acquisition and independent of the system under examination. For each trial, record whether the authorised reference event occurred, whether the receiving hardware produced valid samples, whether the first-stage trigger fired, whether storage completed and whether the later classifier recognised the event. These form a sequence of conditional probabilities, not one magic accuracy figure. Include weak transmissions deliberately placed near trigger thresholds and disturbances which cause the acquisition hardware to overload or drop data. A failure to record must be distinguished from a recorded negative classification. The reference need

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not retain private communications; calibrated laboratory signals and appropriately minimised measurements can establish much about the detection chain.

Compression is a further intervention. If a feature compressor removes sample phase or averages away narrow events, the replacement model may operate on data with a different physical meaning. A change in representation can alter both the prevalence of apparently anomalous patterns and the sensitivity to genuine signals. The new model's performance should be tested on paired data recorded before and after the compression modification, or on an independently monitored stimulus reproduced under both configurations. The change may be harmless for one declared target class and serious for another. The acceptance decision should refer to that declared target rather than to compression ratio alone.

I would ask the editor to retain a table showing where evidence first became unavailable. An unobserved interval remains unobserved, even if a later learning procedure assigns a smooth probability to it. A detector may be valuable when it states that it recognises a certain proportion of controlled authorised events under a specified recording policy. It ceases to be scientifically careful when it presents its selected archive as an unbiased survey of all electromagnetic events that could have occurred.

Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I now pass the token respectfully to Alan Mathison Turing for a distinct examination of the evidence.

Alan Mathison Turing, Second Principal Contributor: Dr. Atkinson, I would begin not with a claim that a machine has learned the spectrum but with a

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precise specification of what the machine is being asked to decide. The problem is not merely computation. It is whether an observation is represented by the stipulated input variables, whether the apparatus supplies those variables reliably, and whether the decision procedure responds to the relevant change rather than an incidental feature of the apparatus. A model that correctly separates laboratory samples by the identity of the instrument used to record them may be a remarkable instrument classifier and a useless emission detector. Its impressive results are therefore evidence for the wrong proposition. Each proposed use requires a distinct acceptance criterion, and the acceptance test should be capable of demonstrating failure.

In constructing such a test I would distinguish the observed data, the true physical intervention, and the software judgement. The intervention might replace a known test waveform with a held-out waveform while keeping the receiving apparatus untouched. Another intervention might replace an antenna, attenuator or clock while transmitting the same waveform. The first tests sensitivity to an external event; the second tests susceptibility to an instrumental nuisance. If an algorithm responds in much the same way to both changes, the examiner has not established that the anomaly score measures the intended physical phenomenon. A useful formal design crosses several waveform families with several receiver specimens and multiple sessions; each cell is recorded even if its result contradicts the designer's expectation.

The dataset must have provenance at the level of the acquisition event. A convenient random split of windows does not isolate a new environment if neighbouring windows share a continuous oscillator drift, multipath

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configuration or repeating reference waveform. A demanding experiment withholds complete devices, complete sessions and whole locations. Its test schedule and final thresholds should be fixed before the withheld observations are revealed. The requirement to abstain is not a weakness. An algorithm which declares its operating conditions unqualified may preserve the integrity of an investigation more effectively than one which assigns an apparently confident but poorly calibrated label to an unprecedented input.

I would require a programme specification that makes every transformation auditable. The input manifest identifies complex sample format, endianness, sampling clock, analogue gain, RF centre frequency, filter state and any missing-sample mask. The feature extractor specifies spectral windows, overlap, scaling and averaging. The statistical model has a version identifier, parameters, training-data lineage and an immutable calibration record. Finally, the decision layer specifies threshold, hysteresis, event-clustering rules and the mapping from numerical scores to written conclusions. An examiner should be able to rerun this chain without consulting the developer's memory, even when the rerun produces a result that embarrasses the original report.

Adverse tests should be built in at the outset. Alter the centre frequency by a documented small amount; introduce a controlled buffer overflow; vary the preamplifier attenuation; substitute one calibrated receiver for another; change background interference while keeping the target emission constant. A reliable implementation must either preserve the intended distinction or report that the new state lies outside its demonstrated domain. One can also challenge the parser with malformed but validly documented files and with a corrupted metadata field. The test should

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establish whether the model raises an anomaly because the RF scene changed or because the software misunderstood its evidence. These possibilities have quite different implications for a forensic conclusion.

There is a temporal complication which should not be disguised as data volume. A million overlapping windows from one event do not constitute a million independent challenges. A test designed around complete events, device episodes and separate days gives a more meaningful estimate of repeatability. The time between tests may expose ageing and oscillator changes absent from a single afternoon. Conversely, a detector may appear unstable merely because its adaptation policy resets after a gap. The software should retain the adaptive state at each decision, since a fixed mathematical model and a model which updates continuously on the observed stream do not make the same claim.

The evaluator must confront the difference between correct implementation and correct inference. Two independent programmes can reproduce the same numerical anomaly score and still be wrong if both implement a biased feature definition. A receiver can present faithfully digitised data that fail to describe the external signal because of saturation, aliasing or an inaccurate clock. The hierarchy of claims therefore runs from bytes preserved, to computation reproduced, to physical measurements validated, to external cause corroborated. Skipping a rung cannot be justified by the elegance of the algorithm or the sophistication of its internal mathematics.

I should specify a stopping rule for the test programme. Before evaluation begins, define tolerable false alarms per useful survey interval, tolerable misses for held-out reference events, the range of instrument states, and the circumstances requiring abstention. Do not move the decision boundary

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after examining disappointing tests and then report the resulting figures as independent validation. A revised rule may be worth adopting, but it needs another genuinely held-out trial. The acceptance document should identify the exact model to which the result applies. Changing a firmware register or preprocessing library can be material even when an application still displays the old product version.

Finally, the output must be understandable to someone who was not present at the acquisition. The report should say that the model marked a stated numerical observation anomalous relative to a specified reference population under specified instrument conditions. It should disclose which competing explanations were challenged, which were not and whether independent apparatus observed corroborating energy. It should not transform a difference from training data into a device identity, a communication's content or an accusation of intent. I return the token with the proposition that a falsifiable software claim is better than a theatrical claim of artificial intelligence.

Abraham Lempel, Peer Question: Dr. Turing, I wish to investigate the portability of the proposed validation method. Two receiving stations might share the same nominal signal-analysis software while storing samples in different binary formats, using different scaling conventions and applying distinct approaches to missing buffers. If an evaluator converts both datasets to a common display format, some differences may vanish, whereas others may be introduced by the conversion itself. How would you construct a blind test in which the model cannot learn the provenance of a file wrapper instead of the radio signal? The test should not merely rename files, because a software parser may infer the receiver from byte order,

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acquisition metadata or systematic numerical rounding. I also ask how the examiner should treat model failures caused by an undocumented software update which changes the pipeline without changing the visible application version. These are reproducibility questions as well as generalisation questions, and they may be difficult to disentangle.

Alan Mathison Turing, Response: Dr. Lempel, the solution begins by treating representation as a controlled experimental factor. A training set whose examples carry unique device-specific headers can leak the receiver label even if the analyst has not consciously supplied it. A binary format may also encode padding, quantisation steps or compression signatures that the classifier learns indirectly. The experiment should compare at least two versions of each observation: the original protected acquisition object and a documented, validated normalised representation whose numerical semantics are defined. This does not mean normalisation is always safe. Conversion should have acceptance tests for signedness, endianness, scaling, I/Q order, sample counts and time continuity. Each derivative must remain linked to its original, with separate integrity digests.

For a blind study, partition the observations by hardware specimen and acquisition session before transformations are applied. Otherwise, a converted copy of an old observation may appear in the test set while the original is in training, creating a remarkable but meaningless result. One may conduct a secondary experiment in which metadata fields are removed from model inputs, but the researcher must verify that this operation did not discard information required to calibrate the measurements. The better objective is to prevent the classifier from exploiting accidental proxies for

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the target claim, not to conceal necessary instrument-state evidence from the forensic analyst.

Software revisions should be explicit in the experimental design. Record the executable and dependency hashes, model parameters, preprocessing configuration, device firmware, programmable-logic revision and important register settings. Change one component at a time where possible and rerun fixed control stimuli. If the nominal application version remains unchanged while a filter library is replaced, the experiment may discover an output difference that could have been wrongly attributed to a shift in the external spectrum. That difference belongs in the software provenance record, and the earlier validation remains applicable only to the chain actually tested.

The ultimate acceptance criterion is a reproducible causal distinction. In one set of trials the waveform changes while the receiving and representation systems remain stable; in another, the representation or receiver changes while the waveform does not. A model that reacts identically to both interventions cannot support a strong source-attribution claim. It may still be useful as a broad anomaly indicator, provided the report describes its scope. A failed portability experiment should not be repaired by hiding the results. It should motivate a narrower claim, an improved measurement protocol or a fresh independent validation.

Irving S. Reed, Peer Question: Dr. Turing, suppose a receiver loses a small number of complex samples and its host software silently interpolates across the gap before sending the waveform to an anomaly model. A classifier might regard the interpolated segment as smooth and unremarkable, or it might detect the interpolation artefact rather than the

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absent signal. Either outcome could be mistaken for evidence about the transmitter. How can an acceptance test distinguish a correct error flag from an invented sample sequence, and what confidence should be assigned to decisions whose time windows overlap known data loss? I would also challenge a common analogy with error-correcting codes. In a communications link, redundancy intentionally added by the sender may permit recovery of specific lost bits; an arbitrary external RF event carries no such guaranteed redundancy for the forensic examiner. What negative test would demonstrate that the model is not exploiting an unjustified recovery assumption? The examiner should disclose which interventions directly measured the equipment fault.

Alan Mathison Turing, Response: Dr. Reed, the essential fact is that a missing acquisition interval is not the same as a corrupted but recoverable word in a deliberately redundant code. The recorder may not possess enough information to reconstruct the unobserved samples. Interpolation creates a working hypothesis, with a smoothing rule and an uncertainty that depends upon the unknown content of the gap. If a brief burst occurred entirely inside the absent interval, a smooth interpolation cannot establish either its presence or its absence. A classifier should receive a validity mask separate from the numerical sample values. When the mask intersects an event window materially, the software ought to abstain or qualify the outcome rather than interpret reconstructed values as direct measurements.

A controlled trial should begin with an independently measured reference waveform. Deliberately remove short and long segments at a range of temporal positions, including positions that coincide with known authorised

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test pulses. Compare the model's original decision, its decision on a masked input, and its decision on one or more explicitly identified interpolated derivatives. Record the point at which a decision changes. A robust detector may decline to classify windows containing too much missing data; that is an appropriate outcome. The test must report both false alarms caused by artificial discontinuities and missed events caused by the concealment of genuine content through interpolation.

The test should also exercise firmware and transport failure modes. A missing block can be announced by a hardware counter jump, a driver overflow flag or an application write failure. These do not all have the same relationship to the ADC input. A host file may pause writing while hardware continues storing valid samples in a separate ring buffer. Conversely, software may write continuously while silently discarding samples. The acquisition state model must identify which layer supplies the evidence for a real sample gap. A data integrity digest can preserve the resulting file but cannot certify that its purported acquisition chronology is true.

I would impose a contractual rule on the model output: no positive or negative classification may silently cross an interval marked unknown by the acquisition layer. A derivative reconstruction can be analysed for a clearly labelled secondary question, such as how the numerical method responds to a stipulated interpolation, but it cannot replace the original evidential uncertainty. If a receiver or processing system is incapable of distinguishing observed from invented values, that incapacity is a limitation of the instrument rather than a reason to report a confident conclusion. Such discipline is particularly important where the operational search concerns rare emissions which could disappear entirely inside a short gap.

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Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I now pass the token respectfully to Edsger Wybe Dijkstra for a distinct examination of the evidence.

Edsger Wybe Dijkstra, Third Principal Contributor: Dr. Atkinson, the programme ought to begin with invariants. A receiver analysis cannot become trustworthy merely because its user interface is persuasive. Every stage of a processing pipeline should state the assumptions under which its outputs have meaning, and the programme should make departures from those assumptions observable rather than silently delivering the usual graph. A frozen model may perform exactly as implemented yet fail scientifically because its input parser has interchanged I and Q or interpreted signed samples as unsigned. A correct software process does not rescue an incorrect description of the measurement. Engineering correctness, data integrity and evidential validity are distinct claims.

I propose an explicit typed acquisition state. The record should distinguish receiver identity, analogue signal path, calibration interval, sample-counter continuity, clock reference, sample format and processing revision. A downstream transformation should not accept a state flagged as clipped, missing or uncalibrated without passing that limitation into its output. A software system which converts invalid acquisition into an apparently normal floating-point vector has already committed an evidential error, even if its classifier produces mathematically consistent scores. The user interface should display a third state, neither positive nor negative: inference invalid or not established under the current acquisition conditions.

Anomaly models are especially vulnerable to undocumented preprocessing. Consider two analysts using the same neural network weights. One

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subtracts a rolling median before computing the spectrogram; the other subtracts a fixed training-set reference. A slow increase in interference floor may disappear in the first system but remain visible in the second. If a later version modifies interpolation at missing samples, the time-frequency image may acquire artificial discontinuities. Reproducibility demands the code, dependency versions, parameter values, calibration artefacts and order of transformations, not merely the published name of the final model. A deterministic programme without its full configuration is no reproducibility guarantee.

The test suite should have invariants both before and after the classifier. Input transformations known to be harmless in a stated measurement model should not change decisions outside a justified tolerance; deliberate changes of physical content should produce appropriately testable changes. For example, a byte-for-byte copy of a recording with identical manifest ought to yield the same numerical feature vectors under deterministic execution. An intentional reversal of I and Q should be detected as a format or interpretation change, not treated as a mysterious new transmitter. An altered gain register must either be accounted for by calibration or cause the result to be marked unqualified. The test suite must distinguish semantic invariance from an accidental invariant of one software build.

There is a tendency to obscure experiment design with a large number of performance measures. I would require an acceptance table for each requirement: the claim, the test fixture, the independent reference, the permitted deviation and the response to failure. A test of software parsing cannot establish false-alarm performance in the RF environment. A test of one receiver under one background regime cannot establish hardware

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independence. A test using generated events cannot automatically establish performance on naturally occurring interference with a different noise process. Each is useful evidence when reported within its declared scope, and potentially misleading evidence when it is reported without that scope.

The system must preserve the distinction between model discovery and model evaluation. If operators inspect every failure and alter a threshold until the errors vanish, the same observations become part of development and cannot independently attest to generalisation. The software should preserve the pre-change configuration and a complete record of overrides. A changed model is a new object; a changed calibration is a new interpretation of measurements; neither should silently rewrite the historical decision. This is both a technical and a chain-of-custody requirement. The ability to replay the former analysis remains important even if the newer analysis is demonstrably better.

Adversarial testing here need not mean an intelligent human adversary. Ordinary environmental changes can defeat a poorly specified detector: a power supply ripple adds a periodic feature, a temperature shift changes oscillator offset, or a strong legitimate transmitter causes intermodulation. A particularly telling test is to insert a source-free instrument fault that produces a large anomaly score. The result should cause the analyst to examine the measurement chain, not to announce an unknown emitter. A second telling test supplies a genuine weak held-out signal while introducing an innocuous hardware change. If the detector attends only to the larger hardware change, the experiment reveals a practical blind spot.

I would use an event ledger with stable identifiers rather than overwrite a single dashboard record. Each event records the raw observation interval,

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missing-data mask, initial model score, receiver state and any authorised derived evidence. Later human annotations and model reruns are appended as separate events linked to the original. The ledger should make it possible to reconstruct why an alarm was or was not raised at that time. A conclusion reached from data observed after an alarm must not be backdated as though it were available to the original detector. Similarly, silence caused by absence of recording must not be rendered as a negative classification.

My final requirement is modest but severe. Before the instrument may produce a report suitable for external reliance, another competent engineer should be able to challenge the software, replace the receiver with a calibrated alternate, introduce known errors and observe a declared failure mode. No acceptance document should use the words tested and validated as though they meant universally correct. A theorem about a software component may be formally proved; an RF inference still requires physical evidence and an examination of its alternatives. I pass the token on the condition that we do not confuse a long test report with a valid one.

Peter Elias, Peer Question: Professor Dijkstra, consider an adaptive anomaly detector whose model is retrained after each night's observations. A reviewer later reruns last week's stored samples using the present model and finds no alarm where the operator's log records one. The operator might conclude that the first alarm was a mistake, but the current model and the historical model need not implement the same decision rule. What records are necessary to reproduce the original event exactly, and how should a later model's revised interpretation be distinguished from a correction of the historical record? I should like an answer that covers the model weights, calibration data, operator override, threshold history and

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randomisation state. I also ask whether the eventual report should present both outcomes, or whether one may supersede the other when a scientifically superior method becomes available. The distinction is consequential for an investigation based on a particular date and set of instrument conditions.

Edsger Wybe Dijkstra, Response: Dr. Elias, the historical event should be preserved as a statement about what a particular system did with a particular input at a particular time. A later model may provide a more scientifically useful interpretation, but it cannot change the historical fact that the earlier system raised an alarm. The audit system therefore needs an immutable acquisition identifier, the original sample object or properly scoped reference, the exact software build and feature recipe, the model weights, calibration files, adaptation state, threshold and relevant operating status. If randomised computation affects results, its seed and execution environment should be documented to the extent needed for repetition. A checksum of one component is insufficient to identify the entire chain.

The original decision should be represented as an event entry linked to the precise observation interval. A subsequent rerun under a revised model is another event with its own timestamp, model identifier and explanation. Neither should silently overwrite the other. If the first alarm was technically invalid because the receiver was overloaded, the analyst may issue a correction explaining that limitation, but the correction still belongs as a new and attributable record. The evidential chain should enable a court, reviewer or independent laboratory to see what was observed, what the machine inferred then and what investigators concluded later. This is

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especially important when a model's adaptation process absorbs a formerly novel interference pattern into its normal baseline.

An acceptance test can demonstrate the difference. Freeze a reference capture and execute it under the historical weights, then under the updated weights, recording the output scores and every preprocessing change. Where software libraries use nondeterministic parallel arithmetic, define acceptable numerical tolerances and distinguish tiny floating-point differences from a threshold-crossing discrepancy. If the later system has adopted a new event clustering rule, a changed count of alarms may reflect counting semantics rather than changed recognition. The report should not imply that numerical agreement of a few test scores establishes interchangeability across all inputs.

Which result should be used in the final report depends upon the question. If the issue is why an operator initiated a lawful follow-up at a given time, the historical alarm and its then-available evidence matter. If the issue is the best currently supported scientific explanation of the captured waveform, a properly validated later analysis may be more relevant. Both can be described, with uncertainty and version boundaries clear. I would not permit the programme to rewrite its own past simply because the present model is more convenient to defend.

Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I now pass the token respectfully to Sir Ronald Aylmer Fisher for a distinct examination of the evidence.

Sir Ronald Aylmer Fisher, Fourth Principal Contributor: Dr. Atkinson, an anomaly detector operating under changing conditions is a statistical

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experiment before it is an engineering product. The sampled population must be defined. If a laboratory reports that ninety-nine per cent of test cases were correctly labelled, I ask what constituted a case, how those cases were selected, whether neighbouring observations shared a common generating process, and whether the instrument states resembled the intended deployment. A large apparent sample size cannot overcome a selection mechanism which excludes difficult conditions. The distinction between random variation and systematic bias is fundamental. An estimator may have tiny reported variance while being directed at the wrong population.

I would design a factorial experiment rather than a gallery of favourable examples. Vary receiver specimen, antenna configuration, room, date, waveform family and signal-to-noise regime, with the combinations balanced where practical and recorded where not. Randomisation can prevent the order of laboratory trials from confounding instrument warm-up with waveform identity. Replication across independent acquisition sessions helps estimate variation that repeating windows within one file cannot. A training partition, a tuning partition and a final blinded hold-out partition should have distinct functions. The final partition may not be inspected repeatedly while the operator adjusts the score threshold. Each inspection capable of influencing the decision rule reduces its claim to independence.

The denominator of a false-alarm rate must be chosen to correspond to the operational burden. A claim of one false alarm in a million spectral bins sounds impressive, but a system can examine billions of correlated bins and still overwhelm an examiner with thousands of alarms. Conversely, an

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event-clustering rule may merge numerous adjacent threshold crossings into one case requiring one investigation. We need a declared observation opportunity, cluster definition and reporting unit. A detector might be evaluated per fifteen-minute monitoring period, per calibrated reference event and per instrument-change episode. These measures answer different questions and ought not be collapsed into a single accuracy percentage.

The sensitivity of an anomaly detector also depends on what it has been allowed to learn. If rare anomalies are retained only after the preceding version of the detector sounded an alarm, the evaluation data are conditional on a selection rule. The unretained observations may contain exactly the misses we most need to count. A prospective trial should therefore retain a lawfully authorised independent reference channel or scheduled calibration snippets that are not gated by the detector under examination. If privacy constraints prohibit general content collection, one can still design proportionate reference events and limited, authorised retention. The experimental design should be declared before the conclusions are sought.

Distribution shift can involve the class proportions, the form of the observations given a class, or the meaning of the labels themselves. Those distinctions are not interchangeable. A new site may have more legitimate interferers while the features of a specified waveform remain stable; that changes alarm burden without necessarily changing waveform recognition. A new receiver may transform the same waveform features and break recognition even if class proportions remain constant. A new emissions technology may fail to belong to any recognised category. The validation report must state which shifts were induced and how the model reacted to

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each. A vague assertion of robustness across environments is not a measurable claim.

I would insist on confidence limits for the reported rates, with dependence properly handled. If the test observes no misses among a small number of laboratory bursts, a point estimate of zero misses is not proof of a zero population miss rate. The interval must recognise the finite sample and the relevant unit of independence. When recordings share the same receiver and room, clustering by instrument or session may greatly widen uncertainty compared with treating every spectrogram tile as independent. A report which cannot identify its independent units should resist precise confidence claims. The permissible error measure must be selected in advance and aligned with the survey's decision consequences.

Sequential operation creates further difficulty. The algorithm may update its background model after each new event, so its predictions on Tuesday depend on the observations of Monday. A performance table pooled across the week can conceal substantial temporary loss of sensitivity immediately after an environmental change. Time-stratified analysis and predeclared change-detection controls are therefore essential. The evaluator should preserve the adaptation state and the exact decision history. A new threshold reached by studying the same week cannot be treated as though it had been prospectively tested across that week. To validate the revised rule, obtain new independent data under conditions that challenge the original limitation.

There must be explicit negative controls. Disconnect the aerial through a characterised load while leaving the receiver electronics running; operate a known external generator at a permitted frequency; modify the instrument

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gain without altering the generator; and conduct observations under intentionally different levels of benign background interference. These interventions help disentangle apparatus artefacts from external emissions. Every result, including a failure to detect a known reference, belongs in the report. The difficult cases are not statistical embarrassments to be discarded. They are observations defining the true range of the instrument's performance.

My conclusion is not that statistical methods cannot evaluate a detector outside its familiar environment, but that the study must acknowledge the environment to which inference extends. One may report evidence that a frozen algorithm attained stated false-alarm and detection rates across specified held-out instruments and sites. One may not infer universal performance on every unknown emitter or location. The appropriate language of a negative test is conditional, finite and transparent about blind periods. I pass the token for a further challenge: whether a mathematical model fitted to yesterday's interference should be permitted to govern tomorrow's legal conclusions.

Richard Wesley Hamming, Peer Question: Sir Ronald, a laboratory reports a nominal false-alarm probability of one in a hundred thousand windows after processing many thousands of recordings with overlapping FFT frames. The figure seems rigorous, yet most windows are correlated, the threshold was revised repeatedly after inspecting failures, and the deployment site differs materially from the calibration site. I question whether the reported probability has any operational meaning. Could you explain how the unit of observation, the independent sample size and the process of threshold selection change the inferential claim? I would also like a worked numerical

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illustration showing why a low nominal false-alarm probability per window can still produce a large number of alarms in a long monitoring programme. The calculation should be explicitly hypothetical and should not assume independence merely to make the detector appear precise. It must distinguish expected counts under a stipulated mathematical model from real instrument performance, which requires empirical validation.

Sir Ronald Aylmer Fisher, Response: Dr. Hamming, a false-alarm probability is not a floating property of the algorithm independent of its experiment. It is defined for a specified decision procedure under a specified reference distribution and counting unit. If overlapping windows share samples, their detections are correlated; one may still compute a rate per window, but treating the windows as independent trials when calculating a confidence interval will exaggerate the amount of evidence. The laboratory should predefine whether the operational quantity is threshold crossings, merged events, examiner reviews or alarm-bearing survey intervals. The denominator and the cluster rule must be reported together. An acceptance criterion developed for one counting convention cannot silently be transferred to another.

Consider a purely hypothetical receiver making one million tested decisions during a survey, with an assumed marginal false-alarm probability of one in one hundred thousand per decision. Linearity of expectation gives ten false alarms under that mathematical model, regardless of whether the decisions are independent, provided each has the assumed marginal rate. Dependence does affect the distribution, clustering and uncertainty of the total. If the windows overlap heavily, those ten expected threshold crossings may be concentrated in a small number of episodes. It would be an error to

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claim ten independent false events or to compute an uncertainty interval as if each window supplied a fresh experiment. One must validate the marginal probability and the event-clustering behaviour against the actual instrument conditions.

Repeated threshold revision adds selection bias. A researcher who studies the same held-out observations and repeatedly chooses the rule with the best performance has converted those observations into development data. The performance obtained on that set is no longer a clean test of the final rule. The scientifically disciplined remedy is to freeze the threshold and preprocessing on a new independent test programme with appropriately distinct receiver specimens, sessions and environments. Where a genuinely independent trial is impractical, the laboratory must disclose that limitation and avoid strong generalisation claims. A complicated resampling analysis may help quantify some uncertainty, but it cannot manufacture omitted site or hardware variation.

A change in deployment environment may alter both the background score distribution and the frequency of genuine events. Therefore, a well-calibrated rate in one laboratory is not automatically a rate applicable to an unfamiliar installation. The examiner should measure performance under controlled shifts, monitor the applicability of calibration conditions, and preserve an abstention state for unqualified receiver configurations. The operational report may properly say that no alarm occurred under a specified validated rule during a measured observation interval. It may not turn that statement into proof that no external emission existed.

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Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I now pass the token respectfully to George Edward Pelham Box for a distinct examination of the evidence.

George Edward Pelham Box, Fifth Principal Contributor: Dr. Atkinson, all statistical models are approximations, and a receiver environment supplies an unusually energetic demonstration of that principle. A background process constructed from yesterday's spectra will generally fail to incorporate every oscillator harmonic, intermittent industrial controller, moving vehicle, power-line disturbance and change in antenna coupling encountered tomorrow. The valuable model is not one that claims to be a perfect likeness of the spectrum. It is one whose deficiencies are tested against the decision it is expected to support. A modeller who never tests the residuals may have produced an elegant distribution for the wrong phenomenon.

I would first plot residual behaviour by receiver state and survey episode. A persistent residual associated with a gain change suggests instrumental structure; one associated with a particular location suggests an environmental dependency. A sudden increase in the upper tail of the anomaly-score distribution could reflect a new external signal population or a measurement-chain failure. A drift monitor may flag the change, but the flag is a reason to investigate, not a device identification. I would ask for a paired experiment in which the external source is controlled while the analogue chain is perturbed, and the chain is controlled while the source class is altered. Without that experiment, the analyst can too easily name the symptom rather than its cause.

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There is a practical danger in continuously refitting a background model. A slowly increasing interferer may be absorbed by the adapting baseline until it appears normal, while a brief but harmless calibration pulse may appear extraordinary. Adaptation rate is therefore a substantive parameter, not a cosmetic setting. It should be frozen or declared for the acceptance trial. The evaluator should report performance at the beginning of deployment, during a controlled drift and after retraining. A system that performs well only once its operators have inspected the new site is not automatically ready to report unbiased first-day findings at the next site.

The importance of experimental scale should not be overlooked. One may test tens of thousands of simulated spectra and still fail to reproduce analogue compression from a real blocker or a transient reference-clock fault. Simulation is valuable for sweeping known factors but cannot replace physical fault injection. Conversely, a small laboratory with actual instrumentation may provide excellent mechanistic evidence for some failure modes while lacking the scope necessary to estimate rare false-alarm frequencies. Those two forms of evidence should be recorded together without pretending that one proves what only the other could show. The model must be confronted both with controlled hardware and with independent field-like variation.

Anomaly detection creates a particular problem of reference classes. What the algorithm calls unusual may be simply unusual among the data chosen for development. If the baseline omits an ordinary industrial installation, the system may fill the report with false alarms at that installation. If the baseline includes weak emissions of concern, they may be learned as normal. An apparently clear separation in a two-dimensional embedding is

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not proof of a physically meaningful boundary. The reviewer should inspect the original RF evidence, documented receiver state and controlled alternative explanations before granting a semantic label to any cluster or outlier.

I would design an explicit programme of sensitivity analysis. Change the assumed noise family, the amount of temporal averaging, the missing-data treatment, the feature normalisation and the event-clustering rule within scientifically justified alternatives. If the conclusion changes materially, the report should say so. One must not select only the model specification that gives the desired result, then present that result as robust. An ensemble of similar models trained on the same biased captures may agree precisely because they share the same blind spot. Agreement among mathematical procedures is not independent evidence when their inputs and assumptions are common.

A noteworthy model failure need not lead to abandonment. It may lead to a narrower claim or a better measurement design. If an anomaly detector works across six specified receivers but fails whenever a particular preselector is switched, the next engineering step might be to model the switch state explicitly and verify the revised procedure on fresh trials. The published result should preserve the failed version's performance and the conditions of its failure. An instrument cannot be treated as an immutable object when both its firmware and its adaptive model change. Its calibration, training and operational histories form part of the evidence.

I would require the post-test review to distinguish three residual uncertainties. One concerns statistical generalisation: how variable are the outcomes among the environments actually sampled? The second concerns

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physical model adequacy: can unexamined receiver faults or propagation effects generate the same features? The third concerns interpretive scope: does an anomaly establish an unknown waveform, an emitter class or merely a change in measured data? There is no obligation to force all three into one scalar confidence. Indeed, that compression may destroy the distinctions on which an accurate report depends. A narrative uncertainty register can be more honest than a deceptively precise percentage.

The final report should therefore be useful without being grandiose. It may conclude that a particular frozen model gave a specified alarm rate for calibrated laboratory events under a measured variety of receiver states and sites; it may identify new regimes requiring abstention or human review. It should retain the troublesome observations and the predeclared decision rules so that another laboratory can attempt to refute it. It should be particularly cautious when a negative model outcome is used to support a negative site-survey conclusion, because a missed event and an unobserved interval can appear identical on a polished display. A model becomes trustworthy through the quality of its challenges, not through the absence of visible exceptions.

David Slepian, Peer Question: Professor Box, your emphasis on the inadequacy of models suggests a particular difficulty with RF anomaly detection based upon low-dimensional features. A model may give a plausible reconstruction of an event from a narrow dictionary yet be incapable of representing unusual short signals which distribute energy across many coefficients. Its residual can remain small if the acquisition measurements themselves have omitted the relevant distinctions. How would you distinguish a good fit to the model from evidence that the model

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is adequate for the physical search? I would like an experiment that includes deliberately non-sparse broadband impulses and time-varying interference, as well as familiar narrowband sources. The receiver should be independently monitored and calibrated. Please explain which failures would justify a revised dictionary, which would require improved physical acquisition, and which would oblige an investigator to withhold the inference entirely. A polished reconstruction cannot, on its own, settle these questions. A negative result under those conditions must remain expressly conditional.

George Edward Pelham Box, Response: Dr. Slepian, one should begin by identifying the space in which adequacy has been tested. A low residual relative to a reduced measurement vector does not prove that every physically relevant distinction survived the acquisition. If the analogue front end suppressed a transient or the feature extractor discarded phase, the reconstruction cannot recover that fact merely by finding a neat mathematical solution. Conversely, a poor fit may arise from a badly chosen model despite excellent raw data. The engineer must isolate the acquisition operator, representation and inference model as separate sources of possible inadequacy. There are at least three different repairs, and it matters greatly which one is attempted.

The proposed experiment should create a controlled matrix of authorised laboratory signals. Include sparse continuous carriers, clusters of short chirps, an impulse whose time-frequency support is broad, and a mixture containing a strong blocker. Record the actual input independently using a calibrated receiver with sufficient bandwidth and linearity for the test. Then examine the candidate system's raw compressed measurements, its

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reconstructed samples and its final anomaly score. If the raw measurement vector lacks the distinctions needed to identify the event, changing the reconstruction dictionary alone is not evidence that the event was recoverable. If the raw data contain the relevant information but the chosen dictionary fails to represent it, a new model may be useful, subject to a fresh test.

The reviewer should inspect failures case by case. A reconstruction with small residual and wrong physical interpretation is especially instructive: it shows that the measurement model may admit multiple plausible explanations. A reconstruction which invents a narrow spectral line under a broadband impulse demonstrates an interpretive artefact. An event missing because the ADC saturated is a hardware limitation. An event missing because the software masked a sample dropout is a processing and provenance limitation. These outcomes should not be aggregated into a single general accuracy percentage, because their remedies and evidential implications differ. It may be sensible to stop claiming that the system detects a broad category of rare RF activity and instead validate a narrower, explicitly sparse family.

Finally, the output should tell the examiner what was directly measured, what was inferred from a model and what remains unobserved or unidentifiable. A later model can reinterpret protected measurements without pretending that its reconstruction was the original physical capture. A model which fails an adversarial test may still be valuable within its demonstrated scope, and its failure should be published as part of that scope. What is indefensible is to use a favourable reconstruction to claim the absence of a phenomenon the apparatus was never capable of observing.

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The successful model is the one which helps the investigation make statements proportionate to its actual evidence.

Dr. James M. Atkinson, Moderator: I thank all five principal contributors. Four reciprocal examinations now test contested assumptions without claiming that the deceased scholars actually participated in a modern conference.

Alan Mathison Turing, Cross-Peer Question to Sir Ronald Aylmer Fisher: Sir Ronald, I ask whether the phrase independent test continues to have meaning when the system learns during deployment and the evaluator may inspect its alarms before the formal trial has concluded. The sequence of observations is not exchangeable if the state changes after every unusual event; a later observation is processed by a different model from an earlier one. Suppose the investigator declares a fixed threshold but permits unattended adaptation of the score distribution, and then quotes a false-alarm probability calculated for the original baseline. What statistical estimand, if any, does that number represent for the adapted system? I would also like to know how a trial could separate the improvement produced by genuine learning from the optimism introduced by examining and selecting among several adaptive policies. The eventual report must contain a statement useful to a field examiner rather than only a theoretical caveat. Which independent observations and predeclared rules should govern acceptance and subsequent withdrawal of approval?

Sir Ronald Aylmer Fisher, Cross-Peer Answer to Alan Mathison Turing: Dr. Turing, a fixed numerical threshold does not constitute a fixed test if the mapping from observations to scores changes. An adaptive algorithm is a sequence of decision rules indexed by the information available before each

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decision. Its performance can be studied prospectively, but the quantity of interest must be defined accordingly. One might measure the frequency of false alarms per complete monitoring interval during operation under a stipulated adaptation policy. One might measure misses among controlled reference events introduced at predeclared times. Neither quantity is automatically equal to a false-alarm probability estimated for the frozen initial model. The evaluator should record the adaptive state at each decision and describe its update mechanism.

The trial must be designed before the adapting policy is exposed to the final observations. Reserve independent receiver-day combinations and source schedules, and compare a fixed baseline against the adaptive policy under matched acquisition conditions. Randomise the order of test stimuli where possible so that time trends do not become confounded with waveform classes. Include periods in which the background changes without a new target emission, and periods in which the target changes against a stable background. An adaptation policy which absorbs a gradually emerging genuine signal into its baseline may show an attractive low alarm count and a serious detection failure. The comparison should count that failure rather than praise the reduced alarm burden.

There is no universal requirement that performance remain constant across time, but the governing acceptance criterion must correspond to how the system will actually be used. One might permit automatic adaptation within prevalidated bounds and require human review or abstention when calibration indicators depart from those bounds. A revised adaptation policy selected after viewing failures requires another independent evaluation. The uncertainty statement should recognise clustering by receiver and

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observation session, rather than counting millions of overlapping windows as independent replicates. When the available study is too small to estimate very rare failures, the published conclusion should say so.

For a field report I would recommend a limited formula: the identified model and adaptation policy achieved specified results on specified held-out devices, sites and authorised test sources, and the current receiver state falls within or outside those tested conditions. A negative event score cannot certify universal absence. A system which can identify its own out-of-domain operation and refuse an unqualified assertion is more defensible than one which produces a numerical confidence unsupported by its continuing calibration.

Sir Ronald Aylmer Fisher, Cross-Peer Question to Edsger Wybe Dijkstra: Professor Dijkstra, the systems engineer has proposed an immutable audit ledger, but I wonder whether the ledger can preserve a scientifically misleading classification with exact fidelity. If the gain setting is wrong, the clock reference has failed or the feature extractor uses a stale calibration table, the programme may faithfully record its own error. What software-level conditions are necessary for a later statistician to reanalyse the case without mistaking the model's input as an accurate physical measurement? I would like you to distinguish integrity of a file from validity of its contents, and to consider a protocol in which raw I/Q samples are minimised for legal reasons. In that setting, which reduced technical evidence can demonstrate instrument state and known limitations without becoming an unjustified surrogate for absent observations? Please address the governance of software updates and the problem of a developer's enthusiastic claim that every earlier alarm has been corrected by a new version of the model.

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Edsger Wybe Dijkstra, Cross-Peer Answer to Sir Ronald Aylmer Fisher: Sir Ronald, file integrity is a necessary but very incomplete layer of the evidence system. A cryptographic digest can protect an array of bytes against unnoticed later alteration under its stated trust assumptions, but those bytes may be a perfectly preserved record of an overloaded receiver, incorrect endianness or fabricated values. The measurement claim requires instrument provenance, calibrated reference planes and a demonstrated account of the capture process. The analyst should distinguish the acquisition object, its interpretation manifest, the computational derivative and the scientific finding. Each has a separate version and a separate evidential function. A ledger that combines them into one unexplained success flag is not rigorous.

An independent reviewer should be able to identify the actual input path, attenuator and preselector state, oscillator and sampling-clock references, firmware and programmable logic, receiver temperature where material, and any lost samples or invalid intervals. The manifest should specify the complex-sample packing, scaling and timing conventions. If these fields were never recorded, the software cannot reconstruct them by confidence alone. The reviewer may infer some parameters from reference events, but that inference has its own uncertainty and must not be substituted silently for a missing observation. A corrected interpretation is a derivative linked to the original record, not a new history of what the instrument actually did.

Data minimisation must not be confused with destroying all means of independent challenge. In an authorised survey, one can retain calibrated control-source traces, narrow justified I/Q extracts, acquisition-state summaries and cryptographically protected software identifiers when those

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are sufficient for the legitimate technical question. The precise scope depends upon law and the purpose of the investigation. The important scientific requirement is that a report must not claim waveform-level certainty when only an alarm count survives. If a particular conclusion cannot be challenged without raw observations that were not lawfully retained, the conclusion must be narrowed rather than supported by invented reconstruction.

Finally, new software may correct an established defect without erasing the old result. Retain the versioned defect report, affected event identifiers, new analysis outputs and the reason for the correction. The former alarms remain historical facts about the system's operation; their scientific interpretation may change. A reviewer should be able to execute a controlled replay under both versions and determine whether differences arise in parsing, feature extraction, model state or decision logic. The published conclusion should be the current best-supported one with an auditable history, not the newest convenient assertion.

Edsger Wybe Dijkstra, Cross-Peer Question to George Edward Pelham Box: Professor Box, model validation often becomes a catalogue of numerical performance metrics, each designed to summarise one aspect of the experiment. Yet a model can have an excellent average miss rate and fail catastrophically during a rare hardware transition. If I require a software acceptance predicate, should it be based upon a single weighted score or a set of separate non-negotiable conditions? Consider a system that correctly detects most reference bursts but mislabels an amplifier recovery transient as a transmitter, and another that is cautious enough to abstain whenever the preselector changes. How should the modeller decide which

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performance limitations deserve explicit disqualification rather than a small penalty in a composite statistic? I am particularly concerned that averaging across familiar situations conceals the state transition that a forensic examiner most needs to understand. Your answer should separate statistical convenience from a scientifically justified reporting standard and include a controlled test capable of falsifying the broader claim.

George Edward Pelham Box, Cross-Peer Answer to Edsger Wybe Dijkstra: Professor Dijkstra, a weighted score is convenient for ranking candidate designs, but convenience does not make it an adequate public statement of performance. Certain failures should be treated as disqualifying for a stated application. A receiver that cannot identify its own saturation may generate spectral features with a plausible shape and a false external interpretation; an algorithm that converts missing samples into silence may produce a false negative with no visible warning. Averaging such failures with thousands of easy correct classifications can make the overall percentage look outstanding. The acceptance rule should identify critical physical invariants and their failure responses separately from aggregate detection performance.

I would propose a hierarchy of tests. At the first level, verify acquisition validity: sample counters, overload flags, clock state, analogue gain and format interpretation must meet stipulated requirements or the result becomes unqualified. At the second level, validate the detector's statistical operation on relevant independent event units, including false alarms, missed controlled bursts and reaction to receiver-state interventions. At the third level, investigate alternative physical explanations for the reported anomaly using an independent receiver or a deliberately changed analogue

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path. A system may pass the first two levels yet remain unable to attribute a particular unknown emitter. The intended claim should say exactly which level is supported.

The experiment should make failure visible. Introduce a controlled amplifier overload followed by its recovery transient, then remove the external source while maintaining the instrument transition. A detector that continues to call the transient an unknown transmission has failed a material confound test. Next present known weak pulses while switching the preselector, including cases where the instrument reports invalid data. A system that abstains at the transition may be behaving correctly within its specified capabilities, although excessive abstention would diminish operational usefulness. These outcomes ought to be counted separately. The modeller should not hide them by assigning an arbitrary numerical penalty and producing a single favourable grade.

The final decision may balance costs of investigation against detection benefit, but the trade-off should be explicit and justified for the lawful application. When a failure threatens the basic distinction between instrument and external emitter, the proper response may be restriction of use or further engineering rather than a modest reduction of an average score. I would report the full profile by hardware state, site and source family. Such a profile is less elegant than one number, but it is far more informative to the expert who must defend the scientific meaning of a particular recorded event.

George Edward Pelham Box, Cross-Peer Question to Marvin Lee Minsky: Professor Minsky, I wish to close by challenging the human-machine boundary. An investigator may see an apparently striking anomaly score,

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inspect a waterfall in which the colour scaling accentuates the feature, and then construct a narrative about a hidden transmitter. The human decision is no longer independent of the machine's suggestion. How should the experiment distinguish true machine assistance from confirmation bias induced by the display, especially when the same human labels the training examples and adjudicates the final test? I would favour an exercise in which independent examiners review blinded reference cases with and without algorithmic prompts. Please specify how one should measure false attributions, abstentions and changes of mind, and how those outcomes should be recorded when the machine is eventually used in a forensic report. Does the programme's confidence score ever justify the examiner's confidence in a named external source? The reference record must also reveal whether an examiner encountered actual missing data or inferred silence from a display.

Marvin Lee Minsky, Cross-Peer Answer to George Edward Pelham Box: Professor Box, the display is part of the decision system, and its persuasive appearance deserves testing. A spectrum image has a colour scale, integration interval, dynamic range and event-selection policy. Two displays of identical samples can produce very different impressions, although the underlying measurements have not changed. An anomaly score shown in large type may anchor an examiner's interpretation even when the score was calibrated in another environment. The appropriate experiment does not merely test the software in isolation. It studies a combined human-machine procedure with a defined division of responsibility and explicit opportunities to reject the machine's suggestion.

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I would use blinded, independently generated reference cases. Randomly assign suitably qualified examiners to a condition in which they assess a complete but appropriately minimised technical record without model prompts and another in which they receive the model score and a documented explanation. A third condition might provide a deliberately misleading score to measure susceptibility to suggestion, subject to a carefully designed study protocol. The evaluators should record external-source detection, classification, unsupported individual attribution, requests for more evidence and explicit abstention. The study should measure not simply apparent agreement with the machine but whether the resulting conclusions match the authorised independent reference and appropriate evidential standards.

The interface should help the examiner recognise the limits of the measurement. It should display acquisition validity, missing-sample intervals, calibration state, the model version, the tested operating domain and relevant alternative explanations. It should not produce an unqualified confidence percentage about a named person's conduct or a particular hidden device when the underlying classification merely marks an unusual feature vector. If a model is uncalibrated under a new receiver state, the interface ought to say so visibly rather than hide the qualification behind an information menu. The human must retain responsibility for deciding what the observed evidence supports.

Finally, disagreements between human and machine should become reviewable evidence rather than administrative embarrassments. Preserve the initial machine score, the examiner's independent observation, any later corroborating measurement and the reason for a changed conclusion. One

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should not retrain the algorithm on the final test cases and then claim that the original trial validated the improved system. The strongest defensible outcome may be a narrow statement: machine assistance improved detection of a specified family of laboratory anomalies under tested conditions while leaving individual-emitter attribution to independent physical investigation. An unexplained anomaly is not an identified device, and a convincing plot is not proof of intent.

Dr. James M. Atkinson, Moderator: The discussion has established that an RF anomaly score is conditional upon the acquisition chain, selected representation, tested model and reference distribution. The correct response to unqualified hardware states or material distribution shift is further controlled measurement, appropriately limited inference or abstention, not an invented emitter identity. I formally close Question 104 and pass the programme to the next question.

QUESTION 104. SOURCE AND VERIFICATION NOTES. Contextual sources: NIST Artificial Intelligence Risk Management Framework 1.0, January 2023 (https://doi.org/10.6028/NIST.AI.100-1), particularly the Measure function on independent tests, monitoring and limitations of generalisability; NIST AI RMF Playbook, Measure guidance. These support general evaluation practice, not invented historical dialogue or any particular hypothetical RF observation.

EDITORIAL QUALIFICATION. All proposed signal measurements and calculations are illustrative. The discussion does not identify an unknown emitter, recover protected communications or approve an unlawful surveillance technique.

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QUESTION 105

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What must an SDR recorder prove about firmware, FPGA bitstreams and runtime configuration?

SCHOLARLY RECONSTRUCTION. This dialogue is a fictional modern scholarly exchange among deceased historical specialists, not authentic quotations, recollections or a meeting that occurred. Legal authority and scientific validity remain distinct from software integrity.

Dr. James M. Atkinson, Moderator: Admiral Hopper, a receiver may report a reassuring software version while its FPGA image, register values and analogue state differ from what the display suggests. What evidence is required to reconstruct the exact acquisition chain, and how should the chain-of-custody record represent uncertainties that no checksum can resolve?

Grace Brewster Murray Hopper, Principal Contributor: Dr. Atkinson, a receiver does not become reproducible merely because two copies of its user-interface program have the same version number. The electromagnetic input is successively transformed by analogue filters, gain stages, conversion clocks, digital downconversion, channel filters and recorders. In a programmable instrument, some of those transformations may reside in firmware, configurable logic or registers that the application does not expose. Consequently, a file labelled as a recording from a named receiver model is not a sufficient description of the acquisition chain. A defensible record must identify which executable and configurable elements were actually active when the sample stream was obtained.

I would establish three distinct objects for custody. The first is the acquired evidence: the original sample bytes, timestamps, acquisition counters and

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contemporaneous instrument-status reports. The second is the acquisition manifest, describing the meaning of those bytes and the state of the apparatus. The third is the software and firmware provenance package, identifying binaries, programmable-logic designs, register maps, build environments and any calibration tables which materially affected sample generation. Each object should have an independently protected identity and a documented relationship to the others. Protecting the sample digest while allowing the manifest to be altered would preserve data whose interpretation may have changed without warning.

A build identifier is valuable only if its referent is defined. The label 'firmware 3.2' may correspond to a release package, while a field unit contains a hotfix, an altered coefficient table or an FPGA bitstream compiled from a different source revision. Where an instrument permits cryptographic measurement of executable objects, the measurement should identify the exact byte sequence and the trust assumption under which that measurement was produced. A checksum calculated by software which an attacker or defect can modify does not itself constitute independent evidence of what executed. A chain of trust may be useful, but its boundaries and failure modes must be stated. Nor can a signed file certify that the analogue input was calibrated or that its clock was accurate.

I would ask the engineer to record the runtime state, not just the installed software. Centre frequency, input attenuation, automatic-gain-control state, digital decimation, sampling rate, oscillator selection, clock discipline, FPGA decimator coefficients and event-trigger configuration can all change the observable waveform. A boot-time register dump may not represent the register state during a rapidly retuned acquisition. If the apparatus allows

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state changes during capture, the record should tie each state transition to a native sample index or a calibrated time interval. The data should distinguish state requested by the host from state acknowledged and applied by the hardware. An attractive dashboard may show the former while the ADC continued operating under the latter.

The controlled experiment should begin with a reference unit and an independently monitored authorised RF stimulus. Freeze the analogue input and change exactly one firmware or programmable-logic element at a time. Record the output samples, spectral response, impulse response, group delay, gain, overflow behaviour and relevant timing. Run a second trial keeping the software constant while modifying one documented register. In a third trial, leave the registers untouched but vary input power until the analogue front end approaches compression. The observed differences establish which aspects of the measurement depend upon each class of state. An update that changes sample packing without changing the external input has evidential significance even if a waveform viewer continues to display something plausible.

I would especially challenge the claim that two files with equal cryptographic digests prove a correctly recorded radio event. Equality of appropriate protected digests provides strong evidence that the byte sequence remained unchanged from a trusted reference state. It does not prove that the bytes were collected lawfully, that the analogue input reflected the asserted source, or that the receiver's internal processing was the version the operator believed. An incorrect firmware build can write a consistent, reproducible and perfectly hashed output. The manifest and independent measurements are required to assess the physical truth of its asserted

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acquisition. Conversely, two valid acquisitions of the same signal may have different digests because of quantisation noise or differing starting phases.

There should be explicit failure handling in the software interface. If the FPGA identity cannot be read, the application should not silently substitute a default identifier. If a calibration file is missing, the numerical level may need to be reported as uncalibrated or withheld entirely. If a sample counter jumps, the report should preserve the discontinuity and prevent it from being disguised by interpolation. Where a configuration register is undocumented, the engineer may conduct controlled black-box tests, but the evidential claim must remain limited by that opacity. A product's commercial reputation is no substitute for accessible verification records.

The provenance record should survive legitimate maintenance. Each authorised update creates a new version with its own measured artefacts, approval history, rollback capacity and validation data. A later scientific analysis may show that the older algorithm produced a systematic amplitude bias. That discovery should lead to a linked correction, not deletion of the original event or a fiction that the new configuration had been running at the time. One should retain the original objects and the derivative with their separate digests and processing histories. Where rights or security restrictions prohibit disclosure of code, an independent expert still needs sufficiently detailed behavioural tests and documented limitations to challenge the claims derived from that code.

I would conclude by requiring an acquisition-completeness statement: the laboratory should identify each component capable of materially changing the samples and state what evidence establishes its identity, state and calibration during the relevant interval. Anything not observed should be

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listed as unknown. A complete inventory does not establish that the receiver detected every possible signal; it does establish which parts of a particular acquisition chain can be reproduced and which remain assumptions. The most professional report often contains an unglamorous qualification about a register or clock rather than an eloquent certainty unsupported by the apparatus.

Jacob Ziv, Peer Question: Admiral Hopper, I am concerned that a provenance package might preserve a software name without identifying the processing which actually transformed the samples. A receiver may boot from one signed image, load a different FPGA configuration later, and finally write an archive whose metadata reports only the application release. An investigator could then reproduce the wrong signal path with perfect attention to the recorded settings. How should the manifest treat the time of each configuration transition, the distinction between signed installation and actual execution, and the possibility of stale information from a cached device query? I should also ask whether configuration digests ought to cover coefficient memory and runtime registers separately from the executable bitstream. In some designs the bitstream remains identical while a register changes channel filter bandwidth, a frequency conversion constant or sample scaling. The record must support a reconstruction of acquisition state rather than merely demonstrate that approved software once resided on the instrument.

Grace Brewster Murray Hopper, Response: Dr. Ziv, the manifest needs an explicit concept of operative state during a sample interval. An installed release is a software inventory item; it is not an acquisition chronology. Each meaningful change should have an event record describing the requested

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command, the device's acknowledgement, any verification readback and the native sample interval affected. If a register change alters the filter or mixer, the recorder should start a new acquisition epoch or annotate the transition and settling period. A single session label cannot stand for all those epochs when the signal chain varies. The same principle applies to an FPGA image loaded after boot. Its identity must be connected to when it became active, not merely to its existence on storage media.

Digests should be scoped. A hash of the executable logic file does not capture separately loaded coefficient tables, calibration records or mutable state. One may compute and protect identifiers for those objects independently, then bind their known versions in an acquisition manifest. The manifest should also distinguish readback measured at the relevant time from a cached value or an intended value. If direct readback is unavailable, the omission is an evidential limitation. A laboratory may employ independent behavioural tests to infer the likely active path, but an inference made after the event should not be represented as contemporary direct observation. Signed metadata can preserve a false value as reliably as a true one.

I would conduct a version-transition trial with a stable reference source and an independent receiver. Start with a known bitstream and calibrate its response. Change only a coefficient table, then only a clock-selection register, then the bitstream itself, while retaining the raw output and status history. Include one deliberately delayed command acknowledgement and one stale cached register report. The expected result is not that the instrument always prevents changes, but that it records the differences or clearly identifies unqualified intervals. A later examiner should be able to

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reconstruct which configuration affected the portion of the file used for a particular scientific claim.

The manuscript should retain the key distinction between software authenticity and waveform truth. A protected configuration history may strengthen confidence in how samples were produced. It cannot establish the physical emitter, the truthfulness of an operator or the legality of collection. Those stronger propositions require independent evidence. If a device conceals its active FPGA configuration, an expert may still report constrained measurements under controlled black-box validation, but not a level of reproducibility that the instrumentation does not allow.

Abraham Lempel, Peer Question: Admiral Hopper, suppose an SDR recorder stores complex samples in a compressed container but provides a cryptographic digest only for the container and a short label stating that the FPGA performed lossless decimation. There are at least two problems. The container can change without changing its intended numerical sample stream, and a decimator is generally not invertible over its discarded bandwidth even when the stored data are compressed without further loss. How should the investigator identify the exact bytes protected, the numerical representation after FPGA processing and the physical information which the acquisition never preserved? Could the programmer produce a derivative in another file format without confusing legitimate repackaging with alteration of the original? Finally, how should the record treat a firmware revision which changes byte order, interleaving or compression but displays the same waterfall? These distinctions are essential to a future forensic challenge of an otherwise beautifully preserved recording.

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Grace Brewster Murray Hopper, Response: Dr. Lempel, the terms compression and decimation must not be allowed to obscure the transformation. A lossless container compression process may preserve the numerical values of its specified input sequence, whereas decimation discards samples or frequency content relative to a higher-rate representation, subject to its filter and sampling design. The preserved object is whatever bytes the digest actually covers. A digest of an archive protects that archive from undetected alteration under the assumed trust conditions; it does not prove that an upstream FPGA preserved a particular band or transient. The acquisition manifest should say which signal domain the samples represent after filtering and downconversion. If an external event fell outside that domain, the absence of its energy from the recorded data is not proof that it never occurred.

A correct manifest would describe I/Q order, numeric type, endianness, channel count, full-scale convention, sample rate, centre frequency, digital filter and decimation settings, along with the relevant analogue input path. Where digital filtering alters group delay or pulse shape, those characteristics should be measured for the intended use. A firmware revision that changes how data are packed but leaves their numerical interpretation equivalent can be validated with known test vectors. The old container and the new derivative would still possess different byte digests and separate custody records. The analyst must never call a format-converted derivative the untouched original. Equally, a changed display alone is an inadequate criterion for determining whether the underlying samples are identical.

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I propose a controlled conversion test: preserve an original byte sequence; make an exact copy; repackage the numerical sample array with an explicit, reversible schema change; alter one bit; and change only interpretation metadata. Compute the appropriate digests for each defined object. Then test the numerical values under documented decoding procedures. A digest mismatch of the entire archive is expected after legitimate repackaging, but the original sample values may remain equivalent. The one-bit mutation has a different meaning, while a metadata change can make identical bytes appear to represent a different waveform. These cases should occupy separate fields in the evidence report.

The physical claim remains limited. Neither an excellent compression ratio nor successful decompression provides evidence that a receiver saw every relevant emission. The upstream filter response, saturation state, sample losses and clock fidelity must be validated. A technically responsible file can preserve reduced-band data impeccably while conceding that the omitted analogue information is unrecoverable. Such a concession protects the investigator against an attractive but unsupportable assertion about an unknown source.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor and respectfully pass the token to Edsger Wybe Dijkstra for a distinct investigation of the recorder and its evidential limits.

Edsger Wybe Dijkstra, Second Principal Contributor: Dr. Atkinson, configuration is a programme state and must be treated as such. The common practice of saving a human-readable settings file and calling it an acquisition manifest is insufficient when the instrument possesses hidden registers, asynchronous commands, firmware-managed transitions and

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calibrated coefficients. An acceptable system needs invariants connecting the operator's requested state, the hardware's acknowledged state and the sample intervals actually collected. A software engineer should be able to express those invariants so clearly that a failure appears as a reported condition rather than a silently smoothed plot. If there is no such design, the programme does not know what it knows.

I would define the capture as a sequence of epochs. Within an epoch the receiver state has a declared interpretation: the ADC clock reference, sample format, analogue gain path, mixer configuration, FPGA filter response and output channel mapping are known or expressly unqualified. Each transition starts a new epoch and is linked to an acquisition counter. A host command asking for a new frequency is merely an intention; a device acknowledgement and a verified settling interval establish when the new regime begins. The system should not report the samples acquired during an unsettled transition as though they belong to one stable setting. This matters especially when searching for short bursts whose entire duration might coincide with reconfiguration.

The manifest should have a machine-verifiable schema. It ought to represent bitstream and firmware identifiers, protected digests, build revision, device serial, register snapshot, calibration reference, power state, firmware update event and relevant environment. A field whose value cannot be retrieved should be absent with an explicit reason, rather than filled with a plausible default. A signed manifest is useful if the signature verification chain and signer's authority are established; it is not magical proof that every field is true. An instrument may honestly sign a stale record because the firmware never queried the hardware after an update. A

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challenge test must examine whether reported and actual configuration can diverge.

I would insist upon a reproducible state-transition test harness. Before an authorised test signal is transmitted, place the instrument in a known configuration and read back the relevant registers. Then command a bandwidth change, decimation change or gain step while the test signal remains constant. Record native sample indices and detect the exact boundary after which the new behaviour appears. Independently measure amplitude, timing and spectral changes. Repeat under heavy host load and with the transport queue deliberately stressed. The purpose is not to force every transition to be instantaneous; it is to establish a truthful state history and appropriate invalid intervals.

Firmware and FPGA updates should be modelled as changes to the measurement apparatus. A new bitstream may alter filter coefficients, digital frequency conversion, rounding behaviour or timestamp insertion even when the host application and analogue front end are unchanged. These operations can change the measured spectrum and the apparent width of transient pulses. The verification programme must compare known reference stimuli under each accepted configuration and document the differences. A successful software installation message is not a calibration. The correct test includes a rollback to the old version and checks whether the earlier response is restored, subject to changes in temperature and reference state.

It is tempting to declare a protected execution environment trustworthy when its measured boot succeeds. Yet attestation describes selected software and configuration artefacts according to a defined root of trust. It

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does not prove that the antenna received the signal claimed, that the instrument was linear, or that the clock met the needed uncertainty. The application should keep those propositions in separate fields. An authenticated recording of a receiver-produced intermodulation line is still a recording of a spurious line. A firmware root of trust may protect acquisition integrity against some alterations but cannot independently settle an RF source-attribution question.

A useful failure matrix would include malicious alterations where lawful and harmless in the test environment, ordinary corruption, incorrect register-map revisions, stale metadata, transfer loss, clock interruption, gain-state ambiguity and ADC clipping. For each fault, state the expected invariant violation and whether the instrument should stop, flag, abstain or continue with a qualified measurement. The absence of an alarm is not a pass unless the expected fault was independently established and the system's specified response observed. A test performed only on the successful path confirms little about the failure behaviour that matters most in a forensic context.

I would prevent later analyses from rewriting acquisition events. Original files and configuration records should be immutable under the custody protocol, while analyst annotations, corrected metadata interpretations and new scientific conclusions are stored as linked derivatives. Each has a creator, time, reason, software identity and digest. A revised FPGA interpretation may materially change a claimed frequency or amplitude, but it should not make the prior interpretation vanish. Independent challenge requires both records. The complete trace should show exactly which measurements remain reliable after the correction and which cannot be repaired because a relevant state was never recorded.

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My closing rule is that an instrument must demonstrate not only reproducibility of its output but reproducibility of its failure distinctions. If invalid samples, unknown state and valid quiet observations are rendered identically, the system has discarded essential evidence. A disciplined recorder may be inconvenient, because it exposes uncertainty and asks the user to resolve it. That inconvenience is an engineering virtue when the alternative is confident testimony about a signal that the apparatus may never have measured accurately.

Peter Elias, Peer Question: Professor Dijkstra, I should like to challenge your epoch model with a receiver capable of autonomous retuning. Its FPGA may change frequency in response to a threshold-crossing event, while the host software receives the change notification several buffers later. If a short burst spans the boundary, a file may contain samples from two frequency settings under one host timestamp. What invariant is sufficient to detect this inconsistency, especially if the hardware offers no atomic snapshot of all relevant registers? Should a device carry an acquisition-state identifier inside each native sample block, or should the investigator depend upon a reconstructed sequence of commands and acknowledgements? Please consider an experiment which intentionally delays host messages, changes the threshold trigger and causes a buffer overflow during a retune. A system that records only a successful command response may hide a significant portion of invalid or ambiguous evidence. The examiner should document the independent hardware reference used to evaluate the claimed state.

Edsger Wybe Dijkstra, Response: Dr. Elias, an acquisition-state identifier associated with the hardware's own sample blocks would be preferable

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when the architecture supports it, but the value of that identifier depends on how it is assigned. If it increments when a host command is queued rather than when the FPGA actually changes, the apparent precision is illusory. A rigorous contract should define when each state becomes operative and how the recorder marks transition samples. Where there is no atomic snapshot, the design should adopt a conservative interval of uncertainty bounded by the last known old state and the first verified new state. That interval should not be silently attributed to one setting. An incomplete observation may remain usable for some questions, but only within a clear qualification.

The acceptance test must introduce controlled timing stress. Supply a known authorised RF burst with independently measured timing, command a frequency change or allow an internal trigger to initiate one, and deliberately delay the host notification. Compare the hardware's native counters, state acknowledgements and observed frequency response. Repeat with a simultaneous transport overflow and with a reset of the device's time reference. If the programme cannot determine which settings affected the burst, it should flag that portion of the record as state-ambiguous. The fact that the application eventually displayed the correct frequency does not repair the uncertainty of earlier samples.

I would maintain two related but distinct timelines. The first represents physical acquisition as far as the hardware can verify it, with sample indices and state epochs. The second records host commands, transfer events, file writes and later analyst actions. A temporal join between them is a documented calculation, using measured offsets and uncertainty where required. When the join is underdetermined, the software must not

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fabricate an exact boundary. The custody record should preserve the original logs even if a later reconciliation improves the mapping. An event-driven recorder which writes after a trigger may also have blind intervals before the trigger; those cannot be treated as observed silence.

The key invariant is that every reported valid sample range must be tied to an adequately known configuration. The implementation may satisfy this with per-block identifiers, readback and independently verified transition tests, or a combination appropriate to its hardware. If it cannot satisfy it, the correct report is an interval with qualified settings rather than an invented precise state. This is a measurable property of the design, not a matter of confidence in the application vendor.

David Slepian, Peer Question: Professor Dijkstra, a system might retain the exact FPGA bitstream and all relevant settings, yet its numerical output could still be nonreproducible across nominally identical units because of analogue transfer functions, converter mismatch and thermal drift. How should the engineer separate deterministic execution from a reproducible physical measurement? Consider two devices running the same image and receiving the same authorised reference waveform, but one has a slightly different anti-alias response and a less stable sampling clock. Their output bytes will differ. Would the correct acceptance rule demand identical numbers, a specified tolerance in physically meaningful derived quantities, or agreement after a calibration transformation? I would also ask how to identify parameters which cannot legitimately be calibrated away, such as previously unrecorded clipping or irretrievably lost samples. A report of 'validated firmware' should not be stretched into a guarantee that every analogue receiver chain performs identically. The examiner should

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document the independent hardware reference used to evaluate the claimed state.

Edsger Wybe Dijkstra, Response: Dr. Slepian, deterministic software execution and measurement equivalence are different properties. A particular implementation may produce bit-identical results when given bit-identical inputs under fixed conditions, but two analogue receiving chains will not generally produce identical sample sequences for the same external RF experiment. Noise realisations, clock phase, gain and filter differences all matter. The useful acceptance criterion is tied to the physical quantity of interest and a measured uncertainty model. If the task is calibrated spectral amplitude, compare amplitude response across the specified frequency and level range. If the task concerns transient timing, compare event timing and group delay under a common reference. A blanket demand for identical bytes is neither necessary nor usually achievable.

Calibration can legitimately transform a measured quantity to a common reference plane, but its validity depends upon stated assumptions. A gain correction determined using a stable low-level carrier might not remain valid in compression, and a frequency-response correction cannot restore an event that the analogue filter entirely removed. Missing samples cannot be recreated with physical certainty by interpolation unless the problem contains validated redundancy sufficient for the particular inference. Each correction should be stored as a derivative with the original observation and the applied calibration identified. The uncertainty following correction may exceed the uncertainty of the calibration itself because of environmental change or unmodelled effects.

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A responsible experiment would measure several devices under matched but independently monitored reference stimuli. Vary frequency, amplitude, pulse duration, temperature and gain state. Hold the FPGA image fixed while comparing unit-specific response, then vary the FPGA image within one unit to isolate digital changes. Quantify which differences arise from analogue hardware and which from programmed transformations. Include deliberately bad conditions so that the boundaries of the calibration model become visible. The report might establish that a given software build preserves defined numerical properties within tested error limits on specified hardware, not that all receivers loaded with it are physically identical.

The correct software invariant is traceability of the declared transformation and explicit handling of conditions outside validation. A state marked overloaded, missing or clock-unqualified cannot be rescued by a statement that the program executed correctly. The final report should identify what was measured directly, what was calibrated and what was inferred. With those distinctions, reproducibility can be judged scientifically rather than reduced to a file-comparison contest.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor and respectfully pass the token to Alan Mathison Turing for a distinct investigation of the recorder and its evidential limits.

Alan Mathison Turing, Third Principal Contributor: Dr. Atkinson, the problem can be stated as one of verification under partial observation. The operator sees a named application and a display; the actual sample stream depends upon a chain of states which may be only incompletely visible. The scientist wishes to know whether a given physical input would produce the specified

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digital evidence under the configuration asserted. That claim is not proved by comparing the display with a familiar illustration. It demands controlled stimuli, a formal record of the apparatus and negative tests capable of revealing how the claim fails. In other words, the recorder must have a testable specification, not simply a plausible operating manual.

I would separate the hypotheses. One concerns software integrity: did the expected code and programmable-logic image execute? A second concerns configuration truth: were the operative registers and calibration settings those recorded? A third concerns measurement validity: did that chain preserve specified amplitude, timing and spectral properties within stated uncertainties? A fourth concerns evidential provenance: were the resulting bytes and their associated metadata protected after acquisition? A system may satisfy the first and fourth while failing the second or third. The report should avoid presenting these different tests under one vague certification of authenticity.

The experimental apparatus should use a reference waveform source monitored independently. Stimuli must include continuous carriers for gain and frequency measurement, short pulses for time-domain fidelity, two-tone combinations for nonlinear behaviour, and changes at channel boundaries where the FPGA channeliser may behave unexpectedly. Record each trial with a controlled software build and a full state manifest. Then deliberately vary one material element: a bitstream, decimation ratio, mixer register, sample format or input attenuation. The reference instrument supplies an independent account of what physically entered the receiver. Without that comparator, a programme which agrees with itself may validate only its own assumptions.

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The problem of timing deserves special consideration. An application timestamp may indicate when a buffer was written, while the ADC aperture occurred earlier. A firmware revision can change the relation between a hardware sample counter and a host event without changing the displayed wall-clock time. A test should therefore inject a known timing event, measure analogue latency and examine whether the exported time field refers to a calibrated physical sample instant. During sample loss, the recorder must say what is absent rather than concatenate surviving blocks into a false continuous time series. A hash cannot restore a missing portion of the electromagnetic observation.

One should also challenge build reproducibility. Two artefacts compiled from the same source may differ in binary details because of toolchain versions, compiler options, build timestamps or external dependencies. The provenance record should specify the actual released binary and its protected digest, with source revision and build recipe as supporting evidence. Where rebuilding the bitstream cannot produce bit-identical output, functional equivalence may be tested against a declared behavioural specification rather than asserted from identical labels. An independent laboratory should know which claim was made: binary identity, source lineage, tested functional equivalence or merely vendor endorsement.

An adversarial but authorised trial should include a counterfeit manifest: describe one known bitstream while loading another, or state a gain value inconsistent with the hardware setting. Observe whether the recorder catches the discrepancy. A successful signature over the counterfeit manifest would demonstrate the difference between authenticating an assertion and verifying its truth. Another trial should make a legitimate

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update while the recorder is active and determine whether the log records an epoch boundary. The software should not preserve the fiction that every sample arose under one stable configuration merely because the acquisition session had one filename.

I would insist on a protected observation log for each state transition. This log should tie requested changes, hardware acknowledgements, register readbacks, sample index ranges and status flags to one timeline. The system should be tested after clock loss, power interruption and buffer overflow. Some quantities may remain recoverable, such as the ordering of retained samples; other quantities, such as absolute event time, may be irretrievably uncertain. A correct programme reports that distinction. A later analyst can use an independent reference to infer a likely offset, but an inference with uncertainty should never be silently substituted for a missing contemporary state record.

The laboratory should compare the recorder's behaviour before and after updates without claiming that every difference is a fault. An improved digital filter may intentionally reduce aliasing or change group delay. The update is acceptable if the new measurement properties are documented and calibrated for the intended use. In contrast, an unexplained spectral peak associated with an FPGA revision requires investigation before it is labelled an external source. A final test should swap the analogue receiver path while keeping the digital processing constant and then swap the processing while keeping the analogue path fixed, to isolate causes.

The conclusion should be bounded. The best-supported claim may be that a named receiver, loaded with a measured firmware and bitstream combination, acquired specified authorised test signals within stated

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tolerances under a recorded range of operating states. That is a valuable finding. It is not proof that every unknown emission was detected, nor that every observed spectral feature came from outside the apparatus. The system becomes fit for forensic challenge when its provenance and limitations are measurable, and when its operator can answer an inconvenient question without inventing certainty.

Hendrik Wade Bode, Peer Question: Dr. Turing, I would like to focus on the analogue implications of a digital update. A new FPGA channeliser may achieve a mathematically attractive stopband specification under ideal test vectors, yet a strong blocker can still overload the preamplifier or mixer before digital filtering begins. An operator might see the blocker disappear from the waterfall and interpret the cleaner display as improved physical dynamic range. What test should demonstrate the actual receiver-input performance, rather than the output of one filter in isolation? Please distinguish noise-limited sensitivity, intermodulation behaviour and the recovery after strong pulses. I also ask whether a successful software attestation can ever certify the analogue calibration and whether independent preselection or attenuation changes remain necessary to challenge a supposed unknown RF emission. The issue is central to a recorder whose digital processing is updated more frequently than its analogue front end. The examiner should document the independent hardware reference used to evaluate the claimed state.

Alan Mathison Turing, Response: Dr. Bode, a digital filter cannot undo distortion that has already occurred upstream. If the analogue amplifier or mixer generates intermodulation products, a downstream channeliser can suppress some visible components while preserving others that fall inside

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the selected passband. A quieter display does not, by itself, establish greater usable dynamic range. The controlled experiment should place a calibrated reference source at the receiver input, use a two-tone or multitone blocker programme and measure output products across a defined range of input levels. Repeating the test before and after a firmware update can reveal whether the changed digital chain altered the visibility of products without changing their analogue origin.

I would measure several properties separately. Noise-limited sensitivity depends upon the receiver noise and effective bandwidth under the stated gain and filtering conditions. Strong-signal performance concerns compression, intermodulation and recovery, which may have different frequency and time dependencies. A short strong pulse may cause a gain-control or overload transient lasting beyond the pulse itself. If the revised firmware changes the time-windowing or detector logic, it may alter the displayed duration without changing the physical recovery of the analogue chain. An adequate acceptance trial must include time-domain reference observations as well as spectral measurements. A single catalogue dynamic-range figure cannot substitute for this operating-envelope test.

Attestation of code or programmable logic may support confidence that a specified digital transformation executed, but it cannot certify the analogue input conditions. Receiver-state records should include relevant attenuator, preselector, gain and calibration settings. For a suspicious feature, an independent antenna or receiver, or a carefully chosen change of input attenuation, may test whether the feature is external or internally generated. The precise diagnostic depends upon the physical case. An engineer must not declare a named transmitter merely because the

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software reports a stable frequency across repeated captures made under the same potentially defective chain.

I would integrate the tests in a provenance report with two linked parts. One establishes the identity and state of the digital processing, including its filter response and numerical behaviour. The other establishes measured analogue performance at the defined reference plane. A firmware update may improve one while leaving the other unchanged. The final conclusion should specify the improvement actually demonstrated and the limitations that remain. That is a stronger claim than saying simply that the receiver had the newest software.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor and respectfully pass the token to Irving S. Reed for a distinct investigation of the recorder and its evidential limits.

Irving S. Reed, Fourth Principal Contributor: Dr. Atkinson, I approach the problem by examining what can be detected from redundancy and what cannot. An SDR acquisition chain often transfers blocks equipped with counters, checksums, framing fields or error-detection codes. These may reveal transmission corruption or ordering faults within the digital apparatus, but they are not a guarantee that the analogue waveform was represented correctly. An ADC can clip a burst and emit perfectly well-formed, checksummed samples. An FPGA can apply the wrong filter coefficients and package the result with a valid frame checksum. The engineer must distinguish protected transport integrity from physical measurement validity.

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A scientifically useful recorder should preserve native sequence counters, valid-sample counts, overflow and synchronisation flags, and explicit descriptions of any inserted or invalid values. If software rewrites missing samples as zeros, later analyses may infer a quiet interval where none was observed. If the hardware increments a transfer counter but not a sample counter, the significance of gaps may be different. Therefore the specification must identify which component assigns each field and which errors it is capable of detecting. A monotonically increasing number may be useful, but it is not evidence of continuous acquisition if the firmware can reset or advance that number independently of the ADC.

Programmable logic presents further subtleties. A filter may implement a mathematical transfer function in fixed-point arithmetic with finite word length, saturation, rounding and pipeline delays. Changing the bitstream can alter those details while leaving the nominal filter specification unchanged. Under weak input conditions the difference may be negligible, but a strong blocker can drive an internal accumulator into saturation and produce spurious features. A controlled trial must therefore include varying signal levels, mixed tones and transients, not simply an ideal single carrier at one convenient power. The report should identify the conditions where quantisation and finite-word effects materially change the inference.

I would have the laboratory build a known-good acquisition fixture. Feed a calibrated waveform through the receiver, monitor the input with an independent instrument and verify the output frame structure against the documented sample count and rate. Introduce a controlled dropped buffer, a one-bit storage corruption, a wrong-endianness declaration and a known firmware reset. Each fault should have an expected symptom. A frame

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checksum may detect the one-bit alteration but not a truthful packet containing wrong metadata. A protected manifest digest may detect later changes but cannot guarantee that the receiver truthfully recorded its register state. The negative tests must therefore be designed to expose the different limits of each protective layer.

There is no universal decoder capable of reconstructing arbitrary missing RF content. Error correction works where the transmitted or stored representation contains known redundancy and a validated error model. An unpredictable external transient with no guaranteed code structure may be fundamentally unrecoverable after acquisition loss. The investigator should avoid treating interpolation or model-based prediction as restoration of original observations. If the manufacturer uses a proprietary loss-concealment algorithm, its behaviour should be characterised in a controlled trial, and the resulting samples marked as derived or synthetic where distinguishable. Failure to distinguish observed from reconstructed values destroys important forensic information.

Timing integrity is similarly layered. A time label may originate from a disciplined hardware counter, a transport timestamp or the host filesystem. Those clocks need not coincide. A firmware update can alter buffering depth or interrupt timing without changing the external source. The acceptance trial should measure the interval from a known reference pulse at the input to its labelled sample index across several configurations. A sample-counter discontinuity and a wall-clock correction should be recorded separately. If a timing reference is lost, a physically valid local sequence may continue while absolute time uncertainty grows. The recorder ought to express that growth rather than preserve unwarranted nanosecond precision.

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The provenance register should include the FPGA configuration digest, logic build identifier, firmware revision, register readback method, calibration coefficients and the boundary of each acquisition epoch. The method of checking those values should itself be challenged. A readback supplied only by potentially faulty firmware can be useful but may not be independent. An external programming interface, secure measurement mechanism or behavioural fingerprint from controlled stimuli can provide supplementary evidence, each with defined limitations. More assurance is possible through independent checks, but there is no justification for claiming that a checksum proves the entire chain of electromagnetic causation.

A repair or update after acquisition creates a new analytical context. The original data, their original state records and custody history should remain protected; a later reconstruction or reinterpretation should be stored as a derivative with its own processing record. If the instrument's FPGA configuration was unknown during the original survey, an identical future test cannot prove which configuration had been present then. It can establish that one candidate configuration is consistent with a subset of observations, subject to uncertainty. Such retrospective inference should be written as a hypothesis rather than as a recovered historical fact.

I conclude with a recommendation for an error-detection table. For each fault class, identify whether the receiver's own fields can detect it, whether an independent laboratory can reproduce it, and which scientific claims remain supportable after the fault. The table should distinguish digital corruption, metadata error, acquisition dropout, analogue distortion and reference-clock uncertainty. A properly preserved sample file can be

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insufficient for source attribution. A correctly reported limitation is not a failure of forensic science; it is evidence of its discipline.

Norbert Wiener, Peer Question: Dr. Reed, what should a forensic engineer conclude when a receiver's native sample counter is continuous but a transport packet is corrupted, or when the packet checksums are valid while an ADC overflow has silently removed part of the physical observation? A particularly subtle design might compute a checksum after a firmware interpolation stage, thereby protecting invented values as if they were observations. Can a hierarchy of counters and error flags distinguish these situations, and should the laboratory test the integrity of the status reporting itself? I would like you to consider an authorised laboratory programme that injects faults at the analogue, ADC, FPGA, transport and file-storage stages separately. A successful test must not merely show that the application continues running; it must demonstrate that each fault is detected or that its possible invisibility is accurately disclosed in the instrument's evidential limitations. The examiner should document the independent hardware reference used to evaluate the claimed state.

Irving S. Reed, Response: Dr. Wiener, the example illustrates why a checksum is neither an instrument calibration nor a universal guarantee of continuity. It tests a defined relationship between a protected sequence and its check value. If the FPGA created incorrect values before computing the checksum, both may agree perfectly. If a transport packet was altered after checksum generation, an appropriate check may detect it. The chain must therefore identify where each checksum is calculated and what bytes it covers. Similarly, a counter may refer to ADC apertures, completed FPGA blocks, transport packets or file writes. A continuous host sequence cannot

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prove that no ADC samples were lost unless the architecture establishes that relationship and the test has verified it.

I would construct a failure matrix with known injected faults at each layer. At the ADC-to-FPGA boundary, force or simulate overflow under a controlled reference waveform. At the FPGA output, alter a framing field and check the declared validity. During transport, drop, duplicate or reorder packets. At storage, interrupt writes and compare original block identities with what reached disk. For each intervention, preserve an independent account of the true fault, the receiver's own status, and the final sample file. The acceptance rule should specify whether the system ought to identify missing data, halt, abstain or permit a qualified continuation. Absence of an error message is a failure to detect a known fault, not evidence that the fault never occurred.

Invented or reconstructed samples should never be silently merged with directly observed samples. A packet may contain a placeholder zero, repeated value or interpolated result; those operations can be useful for display continuity but they change the meaning of the file. The manifest should identify the affected sample indices and the method of reconstruction. A later analysis may explore the implications of a stipulated interpolation, but it cannot determine an arbitrary unknown RF transient from information that was never acquired. A cryptographic digest can protect the derivative against alteration while leaving its status as a derivative explicit.

For the forensic report, preserve the original block sequence, counter conventions, status flags, file digests and the independent reference tests. A chain-of-custody record should also say which person or system handled

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each object and why a transformation was performed. Such documentation cannot guarantee perfect reception, but it allows a reviewer to distinguish an observed event from a storage artefact and to identify intervals on which the apparatus offers no defensible conclusion.

Dr. James M. Atkinson, Moderator: I thank the preceding contributor and respectfully pass the token to Richard Wesley Hamming for a distinct investigation of the recorder and its evidential limits.

Richard Wesley Hamming, Fifth Principal Contributor: Dr. Atkinson, engineers frequently confuse the number of digits displayed by software with the accuracy of the measurement from which those digits were derived. Firmware and FPGA design can change fixed-point rounding, accumulation width, digital filter response and amplitude scaling without changing the apparent number of sample bits. An SDR that reports sixteen-bit I and Q components may nevertheless have a much lower useful effective resolution because of analogue noise, distortion and clock jitter. A revision might move a numerical error from one stage to another. The recorder therefore needs both a digital provenance record and a quantitative physical acceptance test, not merely a release note.

I propose a staged error budget. Start at the calibrated receiver input and consider noise figure, analogue bandwidth, gain distribution, intermodulation and compression. Continue through ADC aperture uncertainty, quantisation, converter nonlinearity and clock phase noise. Then examine FPGA digital downconversion, decimation, finite-word arithmetic, coefficient quantisation and transport. Each stage contributes a different kind of error, and some errors are correlated. A single root-mean-square combination may be inappropriate when a deterministic spur or an

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overloaded front end dominates the output. The report must record the assumptions of any combination rule rather than bury them in a convenient effective-number-of-bits summary.

A firmware change can be quantitatively subtle. Suppose a digital filter coefficient is rounded differently and a narrow signal near a channel edge changes amplitude by a small fraction. The difference may be negligible for a broad occupancy survey but material for a calibrated amplitude comparison. If the firmware alters group delay, it may change the reconstructed arrival time of a short pulse without altering its central frequency. The acceptance standard must be linked to the intended scientific question. A firmware update is not automatically better in every respect simply because one benchmark shows less noise. Engineering trade-offs should be measured across the frequency and power ranges relevant to use.

The laboratory should conduct a before-and-after design with a fixed, independently monitored test source. Use a weak carrier, a two-tone input, a short burst and a broadband transient. Record output amplitude, spectral leakage, channel-edge response, spur levels, timing offsets, lost-sample flags and receiver temperature. Repeat at a series of analogue input levels spanning the intended operating range, including conditions close to compression. An apparent improvement in a digital noise-floor plot may coincide with worse analogue distortion at higher levels. These observations should be reported separately, with the firmware and FPGA images identified exactly.

The numerical illustration must avoid invented precision. For a hypothetical uniform white-noise quantisation model, averaging sixteen statistically

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independent observations of the same quantity reduces the variance of the average by a factor of sixteen and its root-mean-square random noise by a factor of four. The corresponding amplitude-ratio improvement is about twelve decibels, or approximately two ideal bits under an appropriate quantisation-limited model. This does not permit sixteen nominal fourteen-bit converters to be declared a two-hundred-and-twenty-four-bit converter. Shared analogue distortion, coherent quantisation error and common clock jitter may prevent the ideal averaging benefit. The real chain must be characterised by measurement.

Configuration provenance must include not only the firmware version but the compilation details which determine numerical behaviour. Changes in filter coefficients, coefficient-word lengths, accumulator saturation modes and ordering can affect rare transients. An analyst who retains only the display may never discover that a burst was broadened by a different pulse-shaping algorithm. Forensic evidence should preserve an interpretable acquisition representation and the precise processing recipe. If the recorder writes already-decimated samples, the unrecorded wideband details are not recoverable merely by installing a newer FPGA image later.

I would test fault behaviour deliberately. Force a buffer overflow under a controlled input and examine whether the sample counters and status flags identify the gap. Introduce a reference-clock interruption and assess how absolute event time uncertainty changes. Load a known incorrect coefficient set in an authorised laboratory and determine whether the configuration record detects the deviation. When a malformed calibration file is supplied, the instrument should fail visibly rather than produce a plausible gain correction. These tests reveal whether the recorder can distinguish valid,

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invalid and indeterminate measurements. An apparatus incapable of expressing indeterminacy will tempt its user to overstate conclusions.

Two programs that produce identical samples from a recorded file can demonstrate computational reproducibility but not the authenticity of the original analogue input. Conversely, the same authorised RF test repeated on different days will naturally differ in noise realisations and perhaps in environmental coupling. The acceptance comparison should define tolerances derived from physical uncertainty rather than demand byte-for-byte identity where none is expected. A protected digest is suitable for testing whether a particular preserved object changed after hashing, not whether a separately acquired waveform should have identical bytes. The distinction must remain apparent in testimony.

My conclusion is that version identification and measurement validation must be joined without being conflated. The recorder should identify exactly which firmware and programmable logic produced each valid sample interval and should demonstrate, through documented trials, the limits of its amplitude, timing and spectral fidelity. The investigator should then use those limits in deciding what claims the file supports. An unqualified hardware state or an untested software revision should produce a qualification, not a more confident conclusion.

Rudolf Emil Kálmán, Peer Question: Dr. Hamming, your staged uncertainty budget is persuasive, but I question whether a firmware update can sometimes change the apparent state of a dynamic receiver in a way that a static calibration misses. An automatic gain controller is a feedback system; a clock-disciplining loop also changes its state over time. An FPGA revision might alter filter delay or the timing of state updates, causing a brief test

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pulse to be recorded differently depending upon what the receiver observed immediately beforehand. How should validation account for that history dependence? I would like a sequence of experiments which tests both steady-state and transient behaviour, including a change from strong to weak inputs and the loss of an external timing reference. A simple comparison of spectral amplitudes averaged over a long interval may conceal the very problem under examination. The examiner should document the independent hardware reference used to evaluate the claimed state.

Richard Wesley Hamming, Response: Dr. Kálmán, the receiver must indeed be regarded as a dynamic system where memory and state can matter. An automatic gain controller may react to a strong signal and reduce gain for a period after that signal disappears. A later weak burst may therefore be attenuated or missed even though the hardware's steady-state sensitivity is excellent. A clock loop may move between disciplined and holdover modes, changing the uncertainty of subsequent timestamps. A firmware revision can alter control-loop parameters, filter delay or transition timing. These effects require tests with controlled temporal sequences, not merely isolated signals allowed to settle between trials.

I would specify a sequence beginning with a stable low-level reference, followed by a strong legitimate blocker, then a known weak pulse after several chosen delays. Repeat under each firmware configuration and record gain commands, hardware acknowledgements, sample counters and actual output amplitude. The test should include different blocker durations and a retune event because internal processing pipelines may have memory of previous frames. For clock behaviour, use an independent reference

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event, remove the timing discipline for a measured interval and examine the growth of offset and phase uncertainty in holdover. The comparison should separate ordinary thermal drift from a discrete software state change.

The uncertainty budget must identify which effects may be treated as random and which are systematic or conditional upon state. It is unsafe to combine every observed difference as though it were independent white noise. A deterministic group-delay change can create a systematic event-time bias; an overloaded accumulator can create spurious spectral content. A suitable test should measure those biases directly and report their dependence on input level and configuration. If a model corrects a known delay, its calibration and residual uncertainty belong in the derivative processing record. It cannot correct an unknown missing interval or reconstruct an unobserved pulse by virtue of the loop model alone.

I would accept the update only for the operating conditions in which these dynamics have been examined. The report should identify the initial state of the receiver, the sequence of changes, and the time over which transient effects are material. A model may work well for steady-state spectral occupancy while remaining unsuitable for nanosecond-level event timing. The configuration record must allow an independent examiner to know which physical state and firmware logic produced the relevant samples. That distinction is more informative than any single statement that an update improved receiver performance.

Dr. James M. Atkinson, Moderator: I now invite four reciprocal questions, each immediately answered by the named specialist, to examine the unresolved relationship between code provenance and an authentic physical measurement.

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Grace Brewster Murray Hopper, Cross-Peer Question to Alan Mathison Turing: Dr. Turing, suppose the field receiver records a cryptographically signed manifest identifying a permitted firmware release and a formally approved FPGA image. An examiner then discovers that an otherwise valid acquisition contains a transient line at a frequency where no authorised reference source was present. It would be tempting to reason that the signed configuration excludes an instrument artefact and therefore supports an external emitter. I question that inference. How would you design a falsifiable experiment that challenges the signal's origin without treating software provenance as an RF source detector? Please address changing the analogue input attenuation, substituting another receiver, checking local oscillator products and repeating controlled stimulus measurements. I also want the test to distinguish a truly identical firmware image from a different runtime register state, because both might produce a reassuring signature. Which result would justify a positive finding, which a mere unresolved observation, and which would oblige a technical correction to the acquisition record?

Alan Mathison Turing, Cross-Peer Answer to Grace Brewster Murray Hopper: Admiral Hopper, the signature and the observed spectral line support quite different propositions. The signature, under a verified trust mechanism, may establish that a particular digital object was authorised or measured. It does not establish that the analogue circuitry was linear, that its calibration remained valid or that an unknown line arose outside the receiver. The first step is to preserve the original samples and the exact configuration state, together with the signed manifest and the means by which its signature was checked. The investigator should then formulate competing hypotheses:

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external emission, receiver-generated intermodulation, oscillator-related mixing, transport artefact or an error in the digital processing path.

A discriminating laboratory sequence would begin by substituting a characterised input load or an independent antenna, changing input attenuation in measured steps and recording how the suspect line responds. A genuine external component and an internally generated product may respond differently, but no one such response is universal proof. Altering preselection or using a second independently calibrated receiver can help test the explanations. A controlled tone pair may reveal whether intermodulation products appear near the suspect feature under related input conditions. The aim is not to produce an attractive alternative explanation but to design observations that could refute each hypothesis. The evidence should include all unsuccessful controls as well as successes.

The FPGA and register state deserve a parallel investigation. If the signed bitstream was active but a runtime mixer or filter register had an unexpected value, the software lineage may remain valid while the recorded spectral axis is wrong. If a supposedly unchanged image produces a different known-reference response, the examiner should investigate the analogue chain, calibration and environmental conditions before inferring tampering. The report must separate what is directly known from what is inferred retrospectively. A protected digest may help demonstrate that an image did not change between two trustworthy measurements, but it does not replace contemporaneous register readbacks or calibrated sample timing.

The strongest support for an external emission would be convergent, independently challenged measurements under specified conditions, with

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receiver artefacts and plausible competing explanations tested to the extent practicable. If the controls remain inconclusive, the correct conclusion is an unidentified measured feature whose origin is unresolved. If a processing defect is demonstrated, the original finding should be corrected through an attributable new report, not silently erased. A proper software provenance system makes such correction traceable; it does not prevent a scientific investigator from admitting uncertainty.

Alan Mathison Turing, Cross-Peer Question to Irving S. Reed: Dr. Reed, an engineer may be impressed by a long list of checksums, protected boot records, sample-block sequence numbers and supposedly immutable custody entries. Yet each protective mechanism has a particular scope. I ask you to construct a failure case in which all the visible checks pass while the recorded waveform differs materially from the true analogue input, and another case in which the checks reveal alteration but the physical sample content remains numerically equivalent after a legitimate representation change. How should the report distinguish those circumstances? It should not use the phrase data integrity without identifying the data object, hashing event and trust boundary. I also ask what test could establish the limitations of a proprietary FPGA pipeline that performs undocumented interpolation or error concealment. A future expert must be able to tell observed complex samples from computational substitutes even if the substitutes were produced by officially approved firmware.

Irving S. Reed, Cross-Peer Answer to Alan Mathison Turing: Dr. Turing, the first failure case is straightforward. An ADC clips a strong input transient, and the FPGA faithfully collects the clipped values into packets with valid sequence numbers and checksums. The host hashes the resulting file, signs

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a manifest and stores everything in an impeccable custody ledger. All those protections can function correctly while the file fails to preserve the peak amplitude and possibly the waveform shape of the physical event. The proper report would say that the bytes have a protected continuity history and the acquisition was invalid for peak-amplitude inference because of clipping. The security mechanisms did not fail; the false conclusion would arise from assigning them a physical measurement meaning they never possessed.

For the second case, a laboratory legitimately changes an IQ file from one byte order to another while preserving the intended numerical sample sequence. A digest over the complete original bytes will differ from the digest over the converted file. That is not evidence that the original samples were illicitly altered. It is evidence that the new object has different bytes, and the conversion must be documented as an authorised derivative. The reviewer can compare decoded numerical values under the respective schemas and verify that the conversion is reversible or accurate within a stated tolerance. The original file and the derivative retain their separate identities and their separate digests.

Proprietary interpolation requires a controlled stimulus study and an explicit limitation. Use an independently monitored input with known short pulses, deliberately induce dropouts at several points and observe the exported samples and flags. If the firmware fills missing intervals, compare the output against the independent reference and determine whether the invented values are marked. If the system conceals the operation and no accessible status identifies it, the engineer must say that the output may contain samples not directly measured by the ADC. The absence of a visible

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discontinuity is not evidence of complete acquisition. One should not claim waveform-level authenticity where the firmware cannot be independently characterised to a suitable degree.

The final evidence record must label each protection by what it establishes: bit-level continuity of a defined object, declared software identity, ordering of recorded blocks, or measured physical fidelity within tested conditions. A valid checksum is not a validation of the analogue input, and a changed checksum need not be evidence of changed physical information. For a credible forensic conclusion, those distinctions are more valuable than a large number of undifferentiated green integrity indicators.

Irving S. Reed, Cross-Peer Question to Edsger Wybe Dijkstra: Professor Dijkstra, I would like to challenge the implementation of fail-closed behaviour in a receiver which must continue monitoring an authorised site through intermittent clock or transport faults. If the application stops recording whenever one status bit becomes uncertain, it may create long blind intervals; if it continues without qualifications, it may create false evidence of continuity. How should a state machine distinguish valid acquisition, qualified acquisition, invalid acquisition and unobserved intervals? Please account for the difference between a missing status packet and a confirmed lost sample block, and the distinction between an acquisition clock in holdover and a failed ADC clock. Can an operator override an automatic stop, and if so what must be retained? The answer must be precise enough to support an implementation test, yet flexible enough to permit engineering judgement where different claims require different tolerances. The answer should also identify which original acquisition objects remain protected for a later independent challenge.

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Edsger Wybe Dijkstra, Cross-Peer Answer to Irving S. Reed: Dr. Reed, fail-closed need not mean that every uncertainty requires a complete physical shutdown. It means that the software must not produce a conclusion stronger than the conditions permit. A receiver may continue preserving raw samples during loss of absolute time discipline while refusing precise interstation arrival-time claims. A gain-state uncertainty may invalidate calibrated amplitude but leave coarse occupancy observations useful. The state machine should therefore associate validity with the intended measurement, not simply with a global running flag. It can distinguish capture continuing, data completeness, timing qualification, amplitude calibration and the ability to draw specific scientific conclusions. An interval of unknown observation cannot be silently labelled quiet.

I would specify a transition table. For each fault, record the triggering condition, detector evidence, sample index interval, applicable qualification and permitted actions. A confirmed ADC overflow produces an actual missing-data mask. A lost host status packet may produce a state-uncertainty interval without proving that samples were lost. A clock entering holdover can preserve sample ordering while enlarging absolute time uncertainty; an ADC clock stopping has more serious consequences. These distinctions should be exercised by controlled fault injection. The implementation passes when it produces the declared record, not merely when an alarm lamp illuminates. A fault which the architecture cannot detect must be disclosed in the qualification documentation.

Operator override should be attributable and limited. The application could allow an authorised operator to continue storing samples while requiring that the resulting data carry the unresolved fault designation. The override

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should record identity, time, reason and the state before and after the action. It should not change existing samples or falsely convert an invalid interval into a valid one. A later expert may determine that a subset of measurements remains fit for a narrow purpose, but that judgement is a separate derivative assessment with supporting evidence. It should not be disguised as the instrument's original state.

The test programme should include both overcautious and undercautious responses. If a harmless temporary delay in a host message causes a complete blind interval, the system may be operationally poor even though it is conservative. If a true ADC loss is concealed, it is evidentially unsafe. The goal is a truthful, appropriately granular state model whose limitations can be challenged. Such a model allows the investigator to continue work lawfully while protecting the integrity of conclusions made from incomplete or uncertain data.

Edsger Wybe Dijkstra, Cross-Peer Question to Richard Wesley Hamming: Dr. Hamming, a receiver vendor might claim that a new FPGA build improves converter resolution because its output has more bits, a smoother noise floor or a larger digital accumulator. As you have explained elsewhere, those numerical changes do not automatically imply additional independent information about the analogue input. How should an acceptance programme distinguish word-length expansion, digital averaging, decimation and genuine improvement in useful RF measurement performance? The answer should account for shared analogue noise, correlated converter errors, deterministic spurs and gain-control history. I would also ask what evidence an expert witness may properly offer when a record lacks the original high-rate samples and contains only the post-

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update decimated stream. Could an improved algorithm reconstruct an unknown short transient that the acquisition process never preserved? Please make the limits explicit enough that an impressive number of displayed bits cannot overwhelm the scientific analysis. The answer should also identify which original acquisition objects remain protected for a later independent challenge.

Richard Wesley Hamming, Cross-Peer Answer to Edsger Wybe Dijkstra: Professor Dijkstra, the word length of the data representation is not identical to the information content of the physical observation. A digital accumulator may need extra bits to avoid internal overflow and retain numerical accuracy, but those bits do not repair an ADC's analogue noise, clipping or aperture jitter. Averaging can reduce independent random noise under appropriate assumptions, yet shared distortion and coherent errors may survive unchanged. Decimation can improve in-band resolution for a defined band if appropriate filtering and sample-rate conditions hold, but it also removes information about omitted bands and transients. Therefore the acceptance experiment must measure useful sensitivity, noise, distortion and timing under documented input conditions rather than infer performance from an output bit count.

Consider a purely hypothetical array of sixteen nominally identical channels measuring the same scalar quantity with equal variance and independent zero-mean noise. The average has one-sixteenth the variance and one-quarter the root-mean-square noise amplitude of one channel. In decibels that ideal amplitude improvement is about twelve decibels. Under a suitable quantisation-limited model this corresponds to approximately two additional effective bits, not a sum of sixteen nominal converter bit widths. If

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the channels share clock jitter or front-end nonlinearities, the improvement can be smaller. A real instrument must establish the correlation structure empirically, and its output may exhibit systematic spurs that are poorly represented by a simple random-noise formula.

A controlled trial should examine input amplitude over a large range, apply two-tone blockers to reveal intermodulation, and use short reference pulses to measure group delay and recovery. Hold the analogue front end fixed while changing the FPGA build; then hold the build fixed while changing the input conditions. If the update changes only how a spectral estimate is displayed, it may make the chart appear quieter without changing the available physical evidence. If it changes digital filtering or decimation, the laboratory should document passband ripple, stopband attenuation and delay. The acceptance report should say which performance measure improved and under which calibration assumptions.

Finally, a post-update stream cannot restore information that was never preserved in the original acquisition. A new reconstruction may produce a plausible model-dependent estimate of an omitted transient, but plausibility is not observation. The file's original sample rate, bandwidth, validity masks and processing history define what can be challenged. An honest witness can state that the system recorded a specified reduced-band waveform and that a later algorithm analysed it under declared assumptions. The witness cannot infer an exact unknown wideband event from those data alone or treat a larger stored word length as proof of high-resolution RF truth.

Dr. James M. Atkinson, Moderator: The principal finding is that authentic software and firmware lineage, validated receiver state and a physically defensible observation are separate requirements. The manuscript now

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turns to conditional forecasts of future receiver technology without claiming that digital word length is equivalent to independent analogue information.

QUESTION 105. SOURCE AND VERIFICATION NOTES. NIST SP 800-193, Platform Firmware Resiliency Guidelines (2018), https://doi.org/10.6028/NIST.SP.800-193, provides contextual principles for protecting, detecting changes in and recovering platform firmware. NIST SP 800-86 (2006), https://doi.org/10.6028/NIST.SP.800-86, provides background on digital forensic preservation and investigation; neither establishes that a hypothetical RF recording is an accurate measurement nor verifies the fictional historical dialogue.

EDITORIAL QUALIFICATION. All test vectors and numerical examples are illustrative. An authenticated binary does not establish analogue fidelity, external emitter identity, legal authority or that data loss never occurred. Stage A mechanical validation does not mean publication-ready; independent Stage-B scholarly, historical, source-to-claim, technical and legal review remains outstanding.

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QUESTION 106

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Which design decisions permit rigorous one-, five-, ten- and twenty-year receiver projections?

SCHOLARLY RECONSTRUCTION. The following dialogue is fictional and written for contemporary study, not genuine historical quotations. The horizons 2027, 2031, 2036 and 2046 are scenario review dates relative to a 2026 baseline, not product promises.

Dr. James M. Atkinson, Moderator: Professor Kroemer, I invite you to distinguish physically justified receiver development scenarios from extrapolation of nominal chip specifications at one, five, ten and twenty years. Please keep every numerical claim conditional upon a measurable design and calibration envelope.

Herbert Kroemer, Principal Contributor: Dr. Atkinson, a receiver forecast ought to begin with the physical device rather than an attractive trend line. Semiconductor performance is governed not only by the number of available transistors but by noise, parasitic capacitance, device breakdown, linearity, heat, interconnect delay and the energy needed to acquire and move information. An engineer might reasonably expect continuing progress in some of these quantities; it is not scientifically permissible to infer a constant improvement in all of them. A twenty-year projection should therefore be an explicit family of conditional engineering scenarios with mechanisms, limiting factors and observable milestones. The word forecast should never conceal the assumptions on which it depends.

I would organise the programme around a 2026 baseline, with one-, five-, ten- and twenty-year observation horizons corresponding to approximately 2027, 2031, 2036 and 2046. The first horizon can focus on near-term product

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qualification and supply availability. The five-year horizon can examine plausible integration and packaging changes, provided they are expressed as hypotheses rather than promises. At ten years, untested process and architecture combinations enlarge uncertainty. At twenty years, a single numerical receiver specification would be more a story than a measurement. The uncertainty should widen with horizon, and the forecaster should state what discoveries or obstacles would cause an earlier revision.

The analogue front end is likely to remain decisive even if digitisation becomes faster. The antenna, preselector, limiter, gain stages and converter input must tolerate strong legitimate signals without generating distortion that masquerades as an unknown emitter. A high sampling rate cannot recover a waveform that an input amplifier has already clipped. Likewise, a nominally greater bit depth does not imply proportional improvement in effective dynamic range under strong blocking. A useful forecast tracks calibrated receiver-input sensitivity, third-order intermodulation behaviour, compression, phase noise and recovery from transients, not merely converter sample rate and memory size.

We should also distinguish direct RF sampling from frequency conversion as design choices rather than treat one as historically destined to replace the other. Direct sampling can eliminate certain analogue conversion stages, yet it presents demanding requirements for anti-alias filtering, clock performance and a wide input dynamic range. A carefully engineered superheterodyne or hybrid architecture may remain advantageous when strong out-of-band energy coexists with very weak signals of interest. The forecast should include architecture envelopes: which regimes favour each

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choice, what calibration burden is imposed and how the measured result would change if a physical assumption fails. There is no universal receiver architecture independent of its use case.

Power consumption matters because a survey receiver must operate as an instrument rather than as a catalogue entry. Increasing instantaneous bandwidth can multiply digital sample transport, processing and storage loads; the thermal consequences may change oscillator stability and analogue drift. An integrated photonic or advanced packaging approach might redistribute some energy and interface limitations, but it introduces its own calibration problems and does not automatically overcome weak-signal dynamic range. Future predictions should therefore include watts per useful, validated unit of bandwidth and the thermal stability of the complete receiver. Counting digital operations without measuring their energy cost can produce an infeasible field design.

I would require a physical benchmark plan at each horizon. Test a defined set of weak carriers, strong blockers and short pulses through a calibrated reference plane, recording noise, spur production, timing, missed-event behaviour and data loss. Specify environmental temperatures, vibration and supply conditions. Compare the actual instrument to its earlier version under matched conditions, distinguishing differences attributable to analogue hardware from those due to digital algorithms. If an innovation improves one metric while compromising another, the report should preserve both. Engineering progress is multidimensional, and a forecast that selects only improving dimensions is not useful for defensive surveillance.

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There is particular danger in claiming a future ADC will combine a sampling rate and effective resolution already demonstrated separately by different devices. Such a combination may face simultaneous constraints involving aperture jitter, thermal noise, input bandwidth and power. Performance points from distinct products are not interchangeable components of one projected machine. A sound scenario includes a feasible device architecture and a total system budget. If the forecast assumes a dramatically better clock and a dramatically more linear front end, those are explicit dependencies requiring independent evidence. The failure of either dependency invalidates the corresponding system-level performance claim.

The one-year forecast should therefore be close to a procurement and qualification plan. The five-year forecast may place measured improvements and plausible product development into broad scenario bands. At ten years the laboratory should explore alternative technologies and identify falsifying benchmarks. At twenty years it should emphasise conditional capacities and critical uncertainties rather than precise dates. Each forecast should be revisited when actual measurements become available. A programme that cannot explain why an old projection was wrong is not practicing engineering foresight; it is keeping an ornamental timeline.

My conclusion is that future receivers should be judged by physically useful information acquired per unit of cost, energy and uncertainty. An instrument that samples more of the spectrum but makes unsupported claims from intermodulation products has not necessarily improved forensic capability. The best receiver is the one whose calibrated measurement chain can preserve and explain the relevant evidence. I pass the token to the next

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colleagues to examine how those system-level demands should guide design, testing and future investment.

Irving S. Reed, Peer Question: Professor Kroemer, a common forecasting method treats converter sampling speed, nominal resolution and power efficiency as independently improving trends, then combines their most optimistic projections into one future receiver. In actual circuits, those properties interact, and improved sample rate may make clock jitter, front-end bandwidth and interconnect losses more consequential. What experimental evidence would justify a joint forecast rather than a collection of unrelated component curves? I would particularly like a disciplined way to identify a physically impossible combination before an organisation purchases equipment or promises a particular detection performance. Please address whether parallel converters can resolve this trade-off and how mismatch, correlation and calibration effort should enter the scenario. A receiver survey requires more than high throughput: its weak-signal performance under strong blockers must be tested at the reference plane. How should the engineer choose the one-, five-, ten- and twenty-year milestones to avoid quietly turning several best-case component claims into a single unsupported system?

Herbert Kroemer, Response: Dr. Reed, the correct unit of projection is a physically specified receiver architecture under a defined load, not an imaginary component assembled from independent catalog maxima. A joint forecast should trace every performance measure through the same design. If a faster converter requires a wider analogue input, the front-end noise and linearity must be reconsidered. If a larger sample rate increases digital power, cooling and supply noise may change the very clock and analogue

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performance on which the sample-quality forecast depends. The validation programme should identify these couplings and test them with realistic reference stimuli. A benchmark conducted at one input frequency and one temperature cannot justify claims about the entire operating envelope.

Parallel converters can help under particular configurations, but the benefits differ between interleaving and averaging. Interleaving phases samples to increase effective aggregate rate, introducing timing skew, gain mismatch and offset errors which can create spurs. Averaging multiple simultaneous measurements can reduce sufficiently independent random noise, but common aperture jitter or analogue distortion may remain correlated. Neither architecture permits one simply to add nominal bit widths. A projection ought to specify whether the intended benefit is wider usable bandwidth, lower random noise, more independent spatial channels or redundancy against failure. Each has a different physical calibration and evidence requirement.

I would construct a design-dependency ledger. One entry might state that a future direct-sampling receiver needs an input clock meeting a measured jitter envelope at its highest relevant input frequency. Another might require a preselector whose blocker rejection prevents front-end compression. A third might require sustained data transfer without sample loss for the proposed number of channels. Failure of any critical dependency should invalidate the claimed system-level performance, even if a different component exceeds its individual target. The milestone is then a passable experiment, not a publication date.

At one year, use available devices and measured integration tests. At five years, condition proposed gains on demonstrated prototypes and

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environmental qualification. At ten years, retain multiple architectural possibilities and wider uncertainty intervals. At twenty years, identify limits and alternative physical mechanisms rather than promise a precise chip. Report what actually improves the lawful survey: fewer missed controlled events, smaller calibrated uncertainty or better resistance to strong-signal artefacts. A forecast that only increases a digit in a catalogue is not evidence of progress.

Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I respectfully pass the token to William Redington Hewlett for a distinct examination of future instrumentation.

William Redington Hewlett, Second Principal Contributor: Dr. Atkinson, a twenty-year receiver programme must be understood as a system engineering and procurement problem, not solely a semiconductor research project. An organisation may be able to purchase a very fast converter and still lack a reliable recorder because data transport, storage endurance, calibration, software maintenance and operator competence are insufficient. The forecast should therefore distinguish what can be built as a laboratory demonstration from what can be fielded and independently qualified. A successful prototype is not yet a defensible TSCM instrument. The gap between those conditions can dominate the adoption timetable.

I would begin with a requirements document expressed in measurement outcomes. For each intended task, specify frequency range, instantaneous usable bandwidth, required probability of detection for controlled reference events, tolerable false-alarm burden, analogue dynamic range, timing uncertainty and lawful data-retention limits. Then construct alternative receiver architectures that could meet those requirements. A five-year

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forecast that simply multiplies the current sampling rate is inadequate if the relevant task requires improved preselection, stable calibration or more independent monitoring locations. System optimisation must identify the limiting component and the uncertainty of that diagnosis.

At the one-year horizon, the primary gains may come from better testing and configuration management rather than entirely new chips. Existing equipment can be arranged with improved input filtering, properly matched antennas, independent reference sources and robust sample-counter records. The operator can compare known signals across two independent receivers and reduce false attribution to a particular device. Those improvements are realistic because they depend upon operational discipline and available test methods rather than speculative inventions. A forecast should count such procedural gains alongside circuit-level changes, while distinguishing them from physical increases in sensitivity or bandwidth.

By five years, integration, interconnect and compute architectures may change the economic balance between many moderate receivers and one exceptionally wideband receiver. Parallelism can be valuable for continuous coverage of multiple bands or directions, but it is not free. Channel count introduces calibration requirements, clock distribution, phase consistency and fault monitoring. A system of sixteen modest receivers may offer better simultaneous spatial or spectral coverage than one expensive wideband channel, yet it also creates more configuration and data-management work. The forecast should compare complete architectures under identical authorised measurement tasks, not merely list their nominal aggregate sampling rates.

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At ten years, one should explore whether improved processing can reduce the need to preserve every raw sample without sacrificing the evidence required for foreseeable challenges. Event-based capture, spectral summaries and adaptive scheduling may be attractive under storage and privacy constraints. Yet each introduces selection bias or blind time unless its detection and retention policy are tested. I would make data minimisation a design requirement, not a post hoc excuse for deleting inconvenient results. A demonstrably limited and lawful preservation policy can coexist with reproducibility if its limits are honestly stated and protected reference measurements are retained where necessary.

At twenty years, organisational design may be as important as electronics. If instruments update themselves, use machine learning and exchange data across many sites, a laboratory must preserve model identity, firmware and FPGA provenance, independent calibration and decision logs. The cost of maintaining independent challenge may rise even as individual sensor prices fall. Therefore I would forecast personnel training, calibration fixtures, secure update infrastructure and archival formats alongside hardware. A system that cannot be maintained or audited after several years may be an expensive liability despite its high initial specifications.

The economic scenario requires explicit variables. Capital expenditure covers receivers, antennas, preselectors, reference sources, networks and storage. Operating expenditure covers power, calibration, maintenance, staff and retention obligations. Performance should be evaluated per validated surveillance objective, such as the fraction of an authorised test schedule observed with stated detection uncertainty. Forecasts must not quietly omit cooling, rack space, lawful storage controls or the cost of

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examining false alarms. A low-cost instrument with poor error characterisation can impose high downstream forensic costs and risks of mistaken conclusions.

I recommend milestones rather than promises. At one year, complete traceable comparison of the existing architecture; at five, demonstrate a defined gain in independently measured coverage or dynamic range; at ten, qualify new integrated architectures against accepted reference tests; at twenty, reassess whether the original measurement objectives remain appropriate. Every milestone should have a stop condition, including evidence of unacceptable noise, power, data loss or uncorrectable bias. A laboratory should be willing to conclude that a proposed architecture does not meet its task, rather than redesign the task to flatter the architecture.

My closing observation is that the future should be purchased as verifiable capability, not as a collection of impressive components. The historian may celebrate the first appearance of a device, but the forensic engineer must ask whether it can be calibrated, maintained, challenged and understood. That is the stronger criterion by which a receiver forecast should be judged.

Peter Elias, Peer Question: Mr. Hewlett, the practical system may generate a remarkable flow of complex samples, yet its storage and review capacity can be much smaller. A forecast based on converter throughput may assume that the future recorder will simply archive everything, although the lawful purpose may not justify retaining protected communication content and the disks may not sustain the write rate for days. How should a system architect distinguish instantaneous capture bandwidth, sustained lossless acquisition, retention policy and the cost of independent forensic examination? I would like a quantitative planning example expressed in plainly defined decimal

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units, with no implication that the numbers describe any particular commercial device. Please also address the risk that event-triggered recording gives an illusion of continuous observation when the detector silently discards intervals in which a short emission may have occurred. The choice between more receiver channels and fewer wideband channels should be tested against physical coverage and operational workload, not merely raw data volume.

William Redington Hewlett, Response: Dr. Elias, the first step is to draw four separate boundaries. The analogue front end defines which electromagnetic information can reach a converter. The digitiser and sample transport define what is acquired without loss. The storage policy defines what is retained. The analysis and legal review define what can be examined and disclosed. Confusing those boundaries leads to false claims. A receiver may continuously analyse a broad band but preserve only short authorised excerpts; that can be a legitimate design, but it must report its selection policy and the limits of what later reviewers can verify. A recorder which silently drops buffers while maintaining a polished waterfall has a different, unacceptable problem.

Consider a hypothetical complex recorder producing 100 million IQ pairs each second, each pair containing two sixteen-bit integers. At four bytes per pair, the raw output is 400 million bytes per second before container overhead. Over one hour that is 1.44 trillion bytes, or 1.44 terabytes in decimal units. Ten such streams would create 14.4 terabytes per hour. These numbers are pure arithmetic and do not establish that a particular disk, processor or network can sustain the rate. They show why the engineering

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budget must include continuous write performance, buffering, storage failure modes, power and an appropriate lawful retention plan.

The acceptance test should operate under the worst sustained load the system claims to support, not just a short demonstration. Use native sample counters to verify completeness; stress the file system and transport; simulate disk-full and power-recovery conditions. If event-triggered capture is employed, compare it with an independently monitored authorised source schedule and measure missed events near trigger boundaries. A saved file is not an observation of the time before the trigger unless the ring-buffer history actually preserves that interval. The report must distinguish unobserved time from observed silence, and it should limit retention to information necessary for the authorised task.

Architecture choice then becomes an optimisation under measurable constraints. Several narrowband receivers can provide continuous simultaneous observations where one scanner cannot, while a wideband converter may offer flexible software processing but impose heavy data and dynamic-range burdens. The future programme should compare both options using identical controlled events, measured blind time, calibration effort and lifecycle costs. The winner is the system that meets the scientific requirement with reliable evidence and lawful governance, not the one with the largest advertised data rate.

Norbert Wiener, Peer Question: Mr. Hewlett, as receivers become more autonomous, the distinction between the device's measurements and the software's scheduling decisions may become increasingly difficult to trace. A controller may retune one channel, reduce gain on another, trigger storage on a third and update an anomaly model while the operator sees only a

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consolidated display. How should the next twenty years of development be planned so that such an instrument remains independently auditable? I would like you to consider software provenance, feedback-control state, sensor scheduling, power consumption and network transport together. If a future system claims continuous coverage, what operational test should establish the actual blind time and missing intervals? And if an autonomous controller changes its own detection threshold, how should its claimed false-alarm rate be qualified? The engineer ought to design for trustworthy failure behaviour, not merely for increasingly impressive automation. The acquisition-state log must also capture automatic retuning and software adaptation boundaries.

William Redington Hewlett, Response: Dr. Wiener, autonomy alters the system architecture as well as the workflow. A controller making its own scheduling and gain decisions must record those actions with a relation to native acquisition time or sample indices. A human operator may otherwise see a continuous interface while different channels are observing different bands or recovering from automatic gain changes. The claim of continuous coverage is a claim about actual valid acquisition, not display continuity. It should be tested with a controlled schedule of authorised reference emissions whose timing and frequency are independently known. The test should reveal missed events at retune boundaries, sample loss under data-load stress and periods where the instrument could not satisfy its calibration requirements.

The architecture should maintain a configuration and decision ledger. Record software and firmware identities, instrument and antenna routing, clock state, gain settings, trigger conditions, model version and operator

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overrides. An adaptation policy that modifies its threshold after observing a new background changes the decision procedure; its false-alarm rate cannot be assumed identical to the rate measured for the original rule. A future receiver should be able to abstain when the observed configuration lies outside its validation domain. The ledger should preserve the original machine decision and any later reinterpretation as separate events rather than rewrite history to match the latest software.

A forecasting programme can evaluate autonomy against human-controlled alternatives on the same physical task. Use identical reference events and known interference under matched constraints, and compare usable observation time, detection, false alarms, power and evidence preservation. If automation reduces the number of recordings but increases selection bias, the trade-off must be reported. If it improves coverage but creates an unreviewable black-box decision path, independent forensic use may remain inappropriate. Data storage and communication should be designed for lawful minimisation, with authorised raw excerpts preserved only when their scientific purpose justifies retention.

At one year, the institution may implement better logs and deterministic replay on existing instruments. At five years, it can trial bounded autonomous scheduling with explicit validity masks. Ten-year and twenty-year plans should be scenario studies with testable milestones, not predetermined announcements that humans will become unnecessary. The enduring design criterion is whether a qualified independent examiner can reconstruct what was observed, what the system decided and which physical explanations remain unresolved.

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Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I respectfully pass the token to Norman Foster Ramsey Jr. for a distinct examination of future instrumentation.

Norman Foster Ramsey Jr., Third Principal Contributor: Dr. Atkinson, timing and frequency reference quality should occupy a central place in any receiver forecast. The stability of a nominal oscillator may be excellent under one laboratory condition while its phase noise, environmental sensitivity or holdover behaviour imposes serious uncertainty upon a wideband acquisition. It is not enough to project the converter's sample rate without specifying the reference that drives it. The acquisition clock governs not only the time coordinate of samples but also their instantaneous aperture uncertainty, which can degrade signal-to-noise ratio at high input frequencies. Future systems must distinguish a high-frequency digital clock from an accurate and traceable time measurement.

A useful illustrative model of jitter-limited signal-to-noise ratio for a sinusoidal input is SNR approximately equal to minus twenty times the base-ten logarithm of two pi times input frequency times root-mean-square aperture jitter, under assumptions of small, effectively random timing error and the stated waveform. Let input frequency be one gigahertz and RMS jitter one hundred femtoseconds. The dimensionless timing product is approximately 0.000628; the idealised jitter limit is about sixty-four decibels. At ten gigahertz with the same jitter, the limit falls to roughly forty-four decibels. These are hypothetical calculations, not measured specifications of any receiver, and other noise and distortion mechanisms can impose lower usable performance.

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That scaling demonstrates why a forecast about much faster direct sampling must include a clock roadmap. To retain the same jitter-limited ratio at ten times the input frequency, the RMS timing uncertainty would need to fall by a factor of ten under the simplified model. Achieving such a reduction throughout a distributed receiving system is not the same as demonstrating a low nominal jitter in one isolated clock component. Clock distribution, phase alignment, thermal drift and converter aperture behaviour may add uncertainty. A product data sheet's best number under selected conditions should not be propagated uncritically into a complete multi-channel system estimate.

The one-year programme should establish the current reference-plane measurements and their uncertainty. Record phase noise, frequency stability, time-transfer error, oscillator holdover and environmental sensitivity for the actual receiving chain. A controlled reference pulse can test the relation between analogue arrival and exported sample time, while a calibrated frequency reference supports spectral-axis verification. Where GPS or another external timing signal is used, distinguish disciplined operation from holdover and document the consequences of losing it. No timestamp field should be treated as physically accurate merely because it contains many decimal places.

At the five-year horizon, forecasts may consider better integrated clock distribution, lower-noise oscillators and improved calibration protocols. Such possibilities should be expressed with explicit target ranges and validation methods. At ten years, alternative frequency-reference technologies might become practical for applications that presently require bulky or expensive equipment, but no particular commercial timetable

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should be assumed. At twenty years, the scientific limits remain relevant even if components change radically. Future claims should be framed around traceability, uncertainty and environmental performance rather than around unqualified promises of perfect synchronisation.

Distributed arrays add another layer. Two receivers can each possess excellent local frequency stability and yet have an uncertain relative time offset. Time-transfer methods depend on propagation, cable delay, network asymmetry and reference-distribution geometry. Phase-coherent combination also requires attention to differential path and frequency response. The forecast should therefore identify whether the task is spectral occupancy, frequency measurement, time difference of arrival or coherent phase processing. Each imposes different clock requirements. A technology improving the first two does not automatically solve the latter two.

One must also consider the dynamic response to reference changes. A clock that locks to an external discipline may experience a transient frequency adjustment. If that adjustment occurs during an RF burst, the extracted phase history may be distorted without any change in the external source. An acquisition system should record clock-control state changes and test their effects using independently monitored reference signals. The future receiver may use sophisticated self-calibration, but the state history must remain interpretable to a later investigator. Otherwise automated correction can erase the very evidence needed to explain a measurement.

I would require each forecast band to contain an explicit timing uncertainty budget. List intrinsic source noise, distribution effects, converter aperture behaviour, synchronisation uncertainty, environmental drift and calibration residuals. Not every contribution is independent or Gaussian, and some may

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be deterministic biases. Combine them only under justified assumptions. At a future review date, compare measured results with the predicted envelope and document which dependencies held or failed. A forecast should improve through examination of error, not through rewriting history after the outcome is known.

The final answer is that clock quality is an enabling condition rather than a decorative accessory. Faster digitisation creates new opportunities only when frequency and timing uncertainty remain compatible with the signal and the intended inference. The prudent forecast specifies the measured reference properties needed to exploit hypothetical future converters, and it acknowledges the cases in which reference limitations will remain dominant.

Richard Wesley Hamming, Peer Question: Dr. Ramsey, I should like to challenge the widespread assumption that a better frequency standard automatically produces better timing evidence at the antenna. A receiver may possess a superb local oscillator while its analogue filters, buffering and software timestamps introduce unmeasured delay. Even a perfectly accurate clock can timestamp the wrong event precisely. How should a twenty-year forecast separate oscillator stability, sampling aperture jitter, relative station synchronisation and the actual uncertainty of an RF event's arrival time? I also invite a simple worked example showing how jitter-limited sinusoidal SNR depends upon input frequency, with all variables defined and the assumptions clearly stated. A forecasting committee might compare a one-gigahertz and a ten-gigahertz input using the same hypothetical timing uncertainty and incorrectly claim the resulting difference is a commercial device specification. What validation would establish the physical

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relationship in an actual receiving chain? The test should identify which error source is actually dominant for the specified receiver configuration.

Norman Foster Ramsey Jr., Response: Dr. Hamming, the timing problem has several layers. Oscillator stability concerns the evolution of the reference frequency; aperture jitter concerns the uncertainty of the converter's sample instant; interstation synchronisation concerns the relative time scales of separate instruments; and arrival-time measurement includes propagation and analogue path delays. These quantities can interact but are not interchangeable. A coherent reference distribution may be excellent while one channel has an unmeasured group delay. A host timestamp may be precise to many decimal places while referring to a buffer write rather than the arrival of electromagnetic energy. Any future specification should identify its actual physical reference point and calibration method.

For the illustrative jitter limit, let f be a sinusoidal input frequency in hertz and let sigma_t denote RMS aperture-time uncertainty in seconds. Under the simplified small-jitter model, SNR_j is approximately minus twenty times log base ten of two pi f sigma_t, expressed in decibels. At f equal to one billion hertz and sigma_t equal to one hundred femtoseconds, two pi f sigma_t is approximately 0.000628, yielding a jitter-limited SNR near sixty-four decibels. At ten billion hertz with the same assumed jitter, it is approximately 0.00628 and the limit falls near forty-four decibels. These are model calculations, not field measurements; analogue noise and distortion can produce lower overall performance.

A calibrated laboratory would use reference sources, phase-noise measurements, controlled pulse timing and independent acquisition paths to characterise the actual system. One should determine whether the

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manufacturer quoted integrated clock phase jitter, aperture jitter at the converter or some other quantity. The applicable bandwidth and correlation of errors matter. A comparison made with a single ideal sinusoid does not automatically establish timing accuracy for short complex bursts. Repeated tests across temperature, input frequency and clock state help define the real operating envelope. The result may be a useful, uncertain range rather than one immaculate figure.

For forecasting, specify which physical bottleneck must improve to support a proposed receiver task. At one year, measure the existing chain and correct its calibration deficiencies. At five years, test improved distribution and clock components. At ten and twenty years, retain explicit alternative assumptions about oscillator technology, converter aperture behaviour and system integration. A successful future clock innovation will matter only to the extent that the rest of the receiver preserves the improvement. The instrument should always record when it loses discipline and enters holdover, because an uninterrupted clock display is not proof of uninterrupted timing accuracy.

Rudolf Emil Kálmán, Peer Question: Dr. Ramsey, a future multi-receiver array may rely upon sophisticated clock correction loops and software models to maintain apparent synchronisation. Yet an attractive time plot can conceal a transient reference failure, a loop adjustment or differential path delay. Could you identify which dynamic state variables a forecast ought to include when projecting one-, five-, ten- and twenty-year improvements in coherence and arrival-time measurement? I would like an acceptance trial involving a known reference pulse, deliberate loss of an external clock and different lengths of holdover. The result should distinguish what the

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estimator predicted from what an independent instrument observed. A forecaster might promise almost perfect distributed synchronisation because nominal local oscillators become more stable, but the receiver array may still have unmeasured analogue latency and network asymmetry. How would a defensible uncertainty budget prevent that mistake? A calibration should record the actual event reference plane and distinguish predicted from observed time.

Norman Foster Ramsey Jr., Response: Dr. Kálmán, an apparently smooth estimated timeline is not proof of a correct physical time coordinate. The dynamic state may include clock offset, frequency offset, drift, phase behaviour, reference-lock state and relevant path delays. Their uncertainties can evolve differently during disciplined operation and holdover. A filtering model may predict these quantities, but its prediction depends upon an assumed state evolution and observation-noise model. A receiver's actual propagation and analogue delays must be measured independently where possible. The report should distinguish an instrument observation from a model-based time correction, and it should preserve the raw native sample indices for later challenge.

The controlled trial should start with a reference pulse delivered through a characterised path to several receivers, using an independent monitor to record actual event timing. Then remove or disturb one reference source for measured intervals while leaving others disciplined. Record clock-control state and compare predicted offsets against independent measurements. Vary temperature or supply conditions where relevant. The trial should include a return-to-lock event, since the control loop may introduce a transient adjustment that changes phase or frequency during a burst. These

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states should be labelled rather than concealed under one general word such as synchronised.

The uncertainty budget should include clock source instability, reference distribution, converter aperture timing, analogue group delay, timestamp semantics and network time-transfer asymmetry where applicable. Some components are correlated because receivers share a clock or calibration path. One cannot assume independence merely to obtain a smaller root-mean-square uncertainty. At the one-year horizon, measure the existing system and correct its most important calibration gaps. At five years, evaluate improved reference hardware under controlled conditions. Ten-year and twenty-year projections should present conditional ranges whose success depends upon measured improvements in every material layer, not simply one oscillator's nominal specification.

The final evidence statement ought to specify the time reference and supported physical proposition. A receiver may detect the same controlled event as another without proving coherent phase or precise time difference of arrival. An improved oscillator may reduce one error term while a previously neglected analogue delay remains dominant. The prudent future system is one whose state and uncertainty remain inspectable when the reference behaves badly, not one whose smoothest graph hides the uncertainty of its own timing model.

Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I respectfully pass the token to Claude Elwood Shannon for a distinct examination of future instrumentation.

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Claude Elwood Shannon, Fourth Principal Contributor: Dr. Atkinson, I would distinguish the growing capacity to transport and process symbols from an increase in the amount of physical information available at the receiver input. A faster converter may produce more bits per second, but those bits can include noise, repeated representations of a limited bandwidth and artefacts introduced by the chain. The sampling theorem describes recovery of an appropriately bandlimited signal under its assumptions; it does not promise recovery of a signal which the analogue front end clipped or filtered away. A receiver forecast must be written in terms of physically meaningful information, signal classes and uncertainty, not just transport rates.

Consider storage demand. A complex receiver delivering one hundred million complex samples per second with sixteen-bit I and sixteen-bit Q ordinarily produces thirty-two bits per complex sample before container overhead. That idealised raw stream is 3.2 billion bits per second, or approximately four hundred million bytes per second using decimal units. Ten such channels would produce roughly four gigabytes per second before metadata, buffering and redundancy. Those values are arithmetic planning examples, not promises of sustained device performance. A system design must consider continuous writes, storage wear, thermal conditions and whether a lawful preservation policy needs every sample.

At the one-year horizon, there may be substantial gains in architecture without a radical converter advance: use more appropriate analogue filtering, compress representations losslessly where useful, retain selected diagnostic measurements and schedule capture with explicit accounting for blind intervals. These measures can improve usable scientific coverage and reduce interpretation errors. A good forecast must not count saved storage

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as additional physical sensitivity. It should state whether the system gained detection performance, efficiency, evidence quality or merely a smaller archive. Distinguishing these outcomes prevents attractive but misleading comparisons between successive generations.

At five years, processing and storage economics may favour wider instantaneous captures or more simultaneous receiver channels. But the net benefit depends on whether the increased observation rate can be transported and analysed without loss. A recorder that advertises a gigahertz of bandwidth while dropping buffers under sustained load may provide less reliable evidence than a narrower system with validated continuity. The forecast should therefore include accepted data-loss limits, time-to-detection, event-clustering behaviour and a tested file-provenance mechanism. A system which cannot distinguish a missing buffer from measured silence is not scientifically improved by its greater raw bandwidth.

At ten years, more sophisticated processing may permit efficient detection of specified signal families with less data retention. Compressive and event-driven techniques are plausible research paths, but their benefits rely on tested signal models and detection policies. A sparse reconstruction may perform beautifully on familiar narrowband carriers and miss an unmodelled broadband transient. A neural detector may reduce an archive while introducing new selection bias. The forecast should specify which physical events are preserved and which may be omitted. It is not enough to project increased algorithmic accuracy without a predeclared, independent experiment including signals that violate the model's favourable assumptions.

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At twenty years, the data architecture itself may be different. Compute may move closer to an antenna, networks may aggregate distributed sensors, and autonomous instruments may adapt their settings. Nevertheless, the same inferential questions remain. What was physically observed? At which reference plane? Under what calibration and legal authority? Which samples and states were preserved? Can independent investigators reproduce the decision? These are not temporary software questions but structural constraints on scientific evidence. A model's output is useful only in proportion to the validated information it extracts from its observation.

I would resist a simple projection of aggregate converter bit depth. Combining multiple twelve-bit or fourteen-bit channels does not add their nominal word lengths into one physically independent twenty-four-bit or thirty-two-bit observation. Under appropriate assumptions, averaging independent noise can improve estimation, but common errors and correlated distortion can defeat the ideal gain. Similarly, interleaving channels can increase sample rate at the cost of calibration challenges; it does not necessarily increase instantaneous amplitude resolution. Each architectural claim should be tested against measured error and information limits rather than inferred from the number of installed converters.

The forecast should contain scenarios for both success and failure. If storage density improves rapidly but analog input linearity changes little, choose a receiver design that avoids collecting larger volumes of distorted data. If timing references improve but preselector switching continues to create blind time, prioritise coverage and scheduling. If AI software improves classification but cannot explain distribution shift, retain

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independent reference observations and abstention rules. The programme should identify which dependency is most likely to determine performance for a particular task and then revise its forecast as those measurements accumulate.

In conclusion, the future of SDR is not one number. It is a change in the set of questions that a calibrated, lawful, reproducible receiving system can answer. The scientist should forecast that set in conditional terms and preserve the distinction between bits transported, observations retained and inferences warranted. The most impressive numerical trend is not necessarily the most important improvement in knowledge.

David Slepian, Peer Question: Dr. Shannon, future receivers may use compressive acquisition, event-driven processing and machine-assisted selection to reduce the enormous sample volumes that broader bandwidths produce. Yet the signal of interest in a technical-surveillance investigation may be precisely an unknown, brief, non-sparse event that a fashionable model was never trained or designed to preserve. How should a technology forecast distinguish computational efficiency from a scientifically meaningful probability of detecting unanticipated RF activity? In particular, what must be measured before a planner can claim that selective recording retains the evidence needed for independent challenge? I ask also whether claims of increasing information content should be evaluated against the analogue reference plane or merely against the ability to produce more digital bits. A forecast may look impressive because a compressor writes fewer bytes, but the reduced archive could have discarded the only event capable of distinguishing an external source from a receiver artefact. The acceptance

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criteria must include a held-out signal that deliberately violates the favourable model.

Claude Elwood Shannon, Response: Dr. Slepian, a reduction in retained data is not itself an increase in information about the physical phenomenon. It is an engineering choice which may preserve particular quantities at lower cost while discarding others. If a model assumes sparsity in a chosen dictionary, it can be excellent for the signal classes matching that model and unreliable for a broadband transient outside it. A low reconstruction residual does not prove that the acquisition distinguished every possible input. The forecast should separate the direct measurement vector, the signal model, the reconstruction and the subsequent detection decision. Each layer needs a validation programme for the specific inference the user wishes to make.

I would require an independent controlled test including both favourable and deliberately unfavourable signals. Use sparse tones, frequency-agile bursts, short chirps, impulses and strong legitimate blockers. Vary arrival time relative to the capture schedule and include intentional sample loss. An independent calibrated reference should establish which authorised events actually entered the receiver input. Compare the stored observations and the algorithm's decisions against that reference, reporting missed events, false alarms, invalid captures and unresolved cases separately. The acceptance criteria should be fixed before inspecting the held-out results. A method that performs well only after changing its thresholds on the final test data has not demonstrated independent generalisation.

The information budget also includes physical dynamic range. A converter may produce an increased number of bits while its input noise and

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distortion remain unchanged. If the front end clips, the lost amplitude details are unavailable to any later computer. If an algorithm stores only averaged spectral bins, the phase history of a brief transient may be irrecoverable. These are not defects of a particular storage technology but consequences of the measurement chosen. Therefore future performance ought to be expressed in terms of validated observable quantities and detection opportunities, not merely sample output or compression ratio.

Selective retention can be defensible where it follows lawful scope and where its blind regions are honestly characterised. Some investigations need only narrowband occupancy statistics; others require a protected original waveform excerpt for phase or transient challenge. The laboratory should declare those needs in advance. When a forecast suggests that future AI will replace preservation of raw evidence, it must explain how independent examination will remain possible and which claims become untestable. Better computation may improve the use of observations, but it cannot create information that the receiver never acquired.

Dr. James M. Atkinson, Moderator: With thanks for the preceding analysis, I respectfully pass the token to John Bardeen for a distinct examination of future instrumentation.

John Bardeen, Fifth Principal Contributor: Dr. Atkinson, a receiver forecast which lacks a credible account of materials, devices and fabrication is merely an extrapolation of wishes. The useful performance of an ADC or low-noise front end depends upon thermal behaviour, transistor noise, parasitic capacitances, power handling, matching and the complexity of packaging. A device can be fast but noisy, linear but power-hungry, compact but difficult to cool. Future circuit architectures may redistribute those compromises, yet

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they do not remove the need to measure them. I would therefore insist that system-level projections be grounded in plausible physical mechanisms and an uncertainty budget that includes the complete analogue path.

At the one-year horizon, the most credible forecast uses demonstrated devices and changes that can be qualified in the laboratory. A receiver can be improved through better preselection, gain distribution, shielding, power supply design and calibration even without a new converter. The test should measure noise figure, input compression, intermodulation and the response to short strong pulses. A cleaner spectral display produced by a digital update is not sufficient evidence of reduced analogue distortion. An engineer must know where the limitation occurs before assigning credit for an apparent improvement.

At five years, packaging and integration may permit closer coupling of converter, clock and signal-conditioning circuitry. That proximity can reduce some interconnect parasitics but can also increase thermal coupling and electromagnetic interference within the package. High-speed digital switching near a weak analogue input poses a problem that geometry and shielding must address. A forecast should compare complete implementations under matched input signals and environmental conditions. One should not assemble the best published performance point from several different components into an imaginary product which simultaneously possesses all their virtues.

At ten years, novel materials or device structures may become commercially useful, but a credible forecast must identify the path from device physics to a qualified receiver. A research demonstration may show an excellent noise property in one component without establishing manufacturability,

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reliability, frequency coverage or power handling at system scale. Likewise, an innovative photonic interface can alter sampling or transport constraints while introducing calibration and synchronisation requirements of its own. The forecast should distinguish exploratory science, engineering prototypes and accepted field instrumentation. The dates of adoption should be scenario bands, not statements of certainty.

At twenty years, entirely different system partitioning is conceivable. One might place digitisation near antennas, use distributed sensor nodes or integrate signal analysis with adaptive front ends. Yet external electromagnetic signals will still encounter nonlinear components, imperfect references and noise. The scientific challenge will remain to separate energy that actually entered the measurement reference plane from features created internally. The greater complexity of autonomous systems may increase the difficulty of provenance and maintenance. A future device that measures broadly but cannot explain its operating state would not be preferable for forensic inference.

I recommend projecting power and reliability together. Additional converter channels, high-rate data links and processing accelerators generate heat. Temperature changes can affect oscillator behaviour, input matching, gain and filter response. Even if a chip specification improves under laboratory cooling, its performance inside a field enclosure may be materially different. Therefore the programme should track validated performance across environmental conditions and the cost of keeping the instrument within its characterised limits. A design with slightly lower peak bandwidth but excellent stability may produce more defensible multi-hour or multiday records.

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The physical test programme should use controlled source signals over frequency, level and time. It should include weak carriers for noise and sensitivity, strong blockers for nonlinear response, and short transients for recovery. It should also measure behaviour across temperature, vibration and supply variations where relevant. Repeated measurements on multiple specimens are necessary to distinguish an isolated prototype from reproducible manufacturing performance. A forecast that assumes all future devices will achieve the best observed laboratory result is not a forecast of a deployable population. The uncertainty of unit-to-unit variation belongs in the scenario.

Converter specifications deserve particular caution. Nominal resolution is the number of output codes, whereas effective performance is limited by noise and distortion under specified test conditions. Wider bandwidth and higher input frequency make aperture and clock imperfections more consequential. One can improve digital arithmetic, but one cannot eliminate analogue uncertainty by retaining additional zeros in a computer word. Parallel averaging may improve certain noise-limited measurements when errors are sufficiently independent. It cannot be treated as a deterministic path from fourteen bits to thirty-two accurate physical bits.

I would conclude by requiring each future milestone to identify a reference-plane improvement that can be independently demonstrated. An engineering forecast is valuable when it anticipates constraints, not when it supplies false precision about distant products. The analyst should revise forecasts as measurements mature, preserve failed hypotheses and ask which technology most improves lawful, calibrated observation. That

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question will remain useful long after the names of today's converter architectures have changed.

Hendrik Wade Bode, Peer Question: Dr. Bardeen, a forecast for a future SDR is sometimes written as if greater digital capability makes analogue filters obsolete. However, strong out-of-band emissions can drive an input amplifier or mixer into nonlinear operation long before the converter or FPGA applies a digital stopband. A new processor may hide the offending source from a waterfall while leaving its internally generated products. What circuit and system measurements should form the baseline for the one-, five-, ten- and twenty-year projections? I would also like a test which deliberately places weak authorised signals alongside much stronger blockers, then compares direct sampling and frequency-converting architectures with equal attention to preselection, gain and calibration. What evidence could establish an actual improvement in usable dynamic range, as distinct from a cleaner appearance on the display? Please specify an independent analogue input measurement rather than relying on a digital chart. Explain calibration uncertainty during sustained heating and strong blocker tests.

John Bardeen, Response: Dr. Bode, the physical sequence of operations is decisive. A digital filter operates only on information that the analogue chain and converter have delivered. If a preamplifier is driven into compression or creates intermodulation products, downstream processing cannot know with certainty which spectral components were external and which were internally generated without additional challenge tests. Some products may be rejected by digital filtering, but others can fall inside the band of interest. A wider converter does not eliminate the need to consider the input

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impedance, preselection, gain distribution, limiting and nonlinear response of the front end. These remain important across every plausible forecast horizon.

The laboratory should establish a calibrated input reference plane and use a controlled weak carrier together with one or more strong blockers. Measure the weak carrier's recoverability as blocker level changes, record the onset of compression and intermodulation, and test recovery after short strong pulses. Repeat with appropriate analogue preselection and with the preselector bypassed where safely possible. Compare a direct-sampling chain with a heterodyne chain on the same task, correcting for differing gain and filter bandwidths. The result should be a set of operating envelopes showing sensitivity, dynamic range, spurs and timing behaviour, not simply one manufacturer's nominal bandwidth figure.

Forecasting should then identify the physical limitations the future architecture must overcome. At one year, improved layout, shielding and filtering might offer the greatest practical gain. At five years, integration may alter the balance among front-end stages but will still require calibration. At ten years, different device or packaging technologies may change achievable performance points; those claims should remain conditional on measured noise, linearity and power. At twenty years, novel solutions are conceivable, but the need for a truthful analogue reference-plane model remains. Greater digital processing will not change the fact that a missing or saturated physical observation cannot be restored with certainty.

The final comparison should include reliability and environmental performance. A wideband high-power receiver may heat its oscillator and

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analogue input, degrading stability during long surveys. A narrower but more stable architecture might yield better evidence over days. The preferred future system depends on the specific scientific question and the legal purpose, not on an abstract race for larger bandwidth. A demonstrated improvement is one that survives independent measurement, documented uncertainty and the relevant strong-signal challenge.

Dr. James M. Atkinson, Moderator: I now invite four reciprocal questions addressed to four distinct colleagues, with immediate responses and no assertion that these historical figures ever conducted such a modern discussion.

Herbert Kroemer, Cross-Peer Question to Claude Elwood Shannon: Dr. Shannon, a committee may say that the amount of digital information stored by a future receiver will double repeatedly, and then mistake that growth for a corresponding improvement in knowledge of unknown RF emissions. I ask you to identify exactly where this inference fails. Suppose future hardware records many more quantised samples but the analogue input remains limited by strong-signal distortion, antenna coupling and clock uncertainty. Conversely, suppose an efficient detector permits careful study of a narrow authorised signal class while storing far fewer bytes. Which architecture has increased useful information for the intended scientific claim? I want a conditional forecast that distinguishes observation, preservation, reconstruction and attribution. Please also explain why combining many nominal fourteen-bit converters may improve some statistical estimates without creating a mathematically guaranteed thirty-two-bit measurement of a single physical amplitude. The planning conclusion must not depend on a particular hypothetical product becoming

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commercially available. Please distinguish the forecast of stored bits from the forecast of independently calibrated measurements.

Claude Elwood Shannon, Cross-Peer Answer to Herbert Kroemer: Professor Kroemer, the number of stored bits is a property of the chosen representation and acquisition process, not a direct measure of the information available about an unknown physical event. When the analogue path has clipped a transient, no increase in downstream word length can restore its lost peak. When an input filter has removed a frequency band, recording more samples from the remaining band does not document what happened in the omitted band. When a feature extractor averages across a brief pulse, the stored summary may be useful for mean occupancy while inadequate for event timing. Thus the forecast must state the class of questions the receiver can answer and the constraints under which the answer is identifiable.

Consider two hypothetical designs. The first records an enormous stream of samples but frequently overloads under legitimate nearby blockers, and the recorder loses unmarked buffers. The second records fewer samples while maintaining a calibrated analogue path, valid sample counters and a tested event schedule for the authorised task. The second may provide better evidence even though it writes fewer bytes. Conversely, for a task requiring unpredictable short transients across a wide band, aggressive event-triggered retention may make the first design superior if it truly observes continuously without loss. One cannot rank them by byte count alone. The laboratory must test relevant controlled events, blind periods, false alarms and preservation of the quantities needed for independent challenge.

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The matter of parallel converters is similar. Suppose several simultaneous channels measure the same scalar input with independent random errors of equal variance. Averaging can reduce the variance, with an ideal improvement related to the number of genuinely independent observations. But common clock jitter, analogue distortion, gain error and deterministic quantisation patterns can remain correlated. The numerical output of an average may have a longer word length for arithmetic reasons while possessing less physical precision than the word length suggests. Interleaving converters to increase aggregate sampling rate addresses a different objective and introduces phase, gain and offset mismatch. A claim of thirty-two accurate physical bits from several fourteen-bit channels requires experimental evidence that the necessary noise and error assumptions hold, not merely arithmetic addition.

The future programme should therefore forecast tested inference capacity. At each horizon it should identify the waveform families, environmental conditions, reference plane, uncertainty and lawful retention necessary to support its proposed observations. A stronger model may extract more defensible information from the same physically adequate data, but it cannot create an event never measured. That distinction protects the institution against spectacular numbers unaccompanied by meaningful scientific improvement.

Claude Elwood Shannon, Cross-Peer Question to John Bardeen: Dr. Bardeen, semiconductor and packaging research may enable substantial changes in the partition between analogue and digital circuitry, yet a system forecast can become exaggerated when it assumes that the most favourable individual device improvements will coexist without additional heat,

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coupling or calibration burdens. What physical experiment would demonstrate that a future integrated front end genuinely improves usable weak-signal dynamic range rather than merely shifting noise or spurs to another part of the spectrum? Please consider strong blockers, intermodulation, thermal drift and the converter's actual effective performance at high input frequencies. How should the forecast handle a research prototype whose laboratory noise figure is excellent but whose yield, reliability or calibration stability has not been established? I also ask whether photonic or quantum-assisted approaches should be evaluated against the same reference-plane standards as conventional receivers or given a different standard simply because their physical principles are novel. I ask that the reply separate scientific feasibility from manufacturing qualification and deployment.

John Bardeen, Cross-Peer Answer to Claude Elwood Shannon: Dr. Shannon, the comparison must be conducted at an equivalent physical reference plane. A proposed integrated device should be presented with known authorised test signals spanning the intended frequency, amplitude and time ranges. The laboratory should measure weak-signal sensitivity, compression, intermodulation products, transient recovery and environmental stability, then compare those quantities with the established receiver under matched conditions. A reduced noise figure at one frequency does not establish better sensitivity when the test contains strong out-of-band blockers that create distortion or force protective attenuation. Likewise, a digital output with a flatter spectrum might reflect altered filtering rather than a real improvement in analogue measurement.

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Thermal and electrical coupling are especially important in integrated designs. Shorter interconnects can reduce parasitic effects, but fast digital switching near sensitive analogue nodes can introduce interference. Heat from data transport and processing may affect gain, oscillator stability and reference distribution. A useful qualification test should operate at sustained load and realistic enclosure temperatures, not only at the brief and carefully cooled conditions of an initial demonstration. It should also measure variation among multiple specimens, since a single exceptional chip is not proof of reproducible manufacturing performance. Calibration stability through ageing and environmental change belongs in the evidence.

A research prototype can establish a mechanism without establishing procurement readiness. The forecast should label technology stages: scientific feasibility, engineering prototype, reproducible manufacture, calibrated deployment and long-term maintenance. Each has distinct evidence requirements. A ten-year scenario might assume a new device structure reduces one limitation, but the system-level benefit still depends on packaging, supply, input protection, clock quality and calibration. At twenty years, alternative physical principles might become useful, yet a precise market date or combined specification remains speculative. The probability of success is not established by the elegance of the underlying physics alone.

Photonic or quantum-assisted components should be judged by the same fundamental scientific question: what electromagnetic information did the complete apparatus observe, with what uncertainty, under what conditions? Their mechanisms may require different calibration instruments and failure tests, but novelty does not exempt them from independent verification. A

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receiver should earn acceptance by reproducible physical measurements, not by the fashionable name of its technology. The forecast can embrace research ambition while refusing to treat an unqualified laboratory demonstration as a field-ready forensic instrument.

John Bardeen, Cross-Peer Question to William Redington Hewlett: Mr. Hewlett, I would like to address the capital and maintenance consequences of the technology choices we have discussed. A receiver programme may pursue maximum instantaneous bandwidth by installing very fast converters, yet the operating institution must sustain storage, cooling, calibration, software provenance and independent legal review. At the same time, several moderate receivers may provide better spatial or continuous coverage but require a complex reference distribution and more personnel. How should an investment decision compare these alternatives over one-, five-, ten- and twenty-year horizons without embedding an unsupported assumption that every technical improvement will reduce total cost? Please specify which measurements should trigger continued investment, which should trigger an architecture change and which should terminate the experiment. I want the cost model to include the labour of investigating false alarms and maintaining evidence integrity, not merely the purchase price of hardware. The institution should also record which costs would be incurred by qualified independent review.

William Redington Hewlett, Cross-Peer Answer to John Bardeen: Dr. Bardeen, I would use lifecycle cost tied to verified scientific outcomes. The programme should quantify capital expenditure for receivers, antennas, filters, clocks, storage and networks, but also operating expenditure for power, cooling, calibration, software updates, protected evidence retention

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and expert review. A wider sample stream can raise costs throughout the chain. Conversely, additional narrowband receivers can multiply configuration and maintenance work. The comparison should therefore use the same authorised reference events and decision requirements for both architectures. The denominator is not simply dollars per nominal megahertz; it is cost per validated surveillance capability under defined uncertainty and operational coverage.

At one year, the institution can benchmark its existing equipment, identify the actual bottleneck and repair procedural deficiencies before buying new components. At five years, it can compare prototype architectures under a controlled test programme, measuring observed blind time, weak-signal recovery, false alarms and sustained data throughput. At ten years, a technology scenario should include replacement cycles, software provenance obligations and the risk that a promising component does not reach reliable production. At twenty years, the uncertainty is too large for a single procurement forecast. Scenario envelopes and revisable decision points are more useful than a confident budget line pretending to know future products and prices.

Milestones must be falsifiable. If a proposed wideband architecture cannot operate continuously without losing sample blocks at its advertised rate, the project should be redesigned or stopped for that purpose. If an integrated analogue front end produces unacceptable intermodulation under the site's blocker environment, its nominal converter speed cannot justify deployment. If autonomous screening reduces stored data but prevents independent challenge of significant events, the retention architecture needs revision. Positive results should be measured by independent

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calibration and tested observation intervals, not by a vendor demonstration selected for favourable conditions.

The cost of mistaken interpretation deserves explicit treatment. False alarms consume expert time, can trigger intrusive follow-up and may damage confidence in the investigation. A missed authorised reference event may reveal an unacceptable blind region. Calibration and provenance costs protect against both. A prudent organisation should sometimes choose a less spectacular system whose measurement limitations are known and whose operating history can be defended. Such an investment is not technically conservative in a pejorative sense; it is rational when the intended output is credible evidence.

William Redington Hewlett, Cross-Peer Question to Norman Foster Ramsey Jr.: Dr. Ramsey, the final technology roadmap must make a practical choice about reference distribution. An institution may wish to operate hundreds of geographically separated sensors, yet disciplined clocks can lose their external reference and network timing can suffer asymmetric delays. A future design could place an expensive common reference at every site, distribute timing over optical links or accept lower accuracy while emphasising continuous spectral coverage. How should the chosen application determine which approach is justified? I would like a predeclared experiment that compares measured arrival-time accuracy during normal operation, deliberate reference loss and restoration, and varying environmental conditions. What is the correct report when the local oscillator remains stable enough for spectral occupancy but no longer supports the time-difference-of-arrival precision claimed for localisation? A single word such as synchronised seems quite inadequate for procurement

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or forensic conclusions. Please distinguish local oscillator stability from interstation timing accuracy during reference loss.

Norman Foster Ramsey Jr., Cross-Peer Answer to William Redington Hewlett: Mr. Hewlett, reference design must follow the measurement requirement. A receiver used to determine coarse spectral occupancy may need adequate frequency calibration without requiring the submicrosecond interstation alignment demanded by some arrival-time methods. A coherent spatial array can impose tighter relative phase and path-delay conditions still. Therefore the procurement document should specify the physical quantity, its reference plane, accepted uncertainty and intended duration of operation. A common clock may reduce one source of relative error while creating correlated failures across sensors; independent clocks can offer resilience but require more complex synchronisation. No architecture is best without defining the desired inference.

The acceptance trial should use known reference signals observed through characterised paths. Compare actual arrival-time estimates under disciplined conditions, then remove a timing reference for increasing holdover intervals and measure how offset uncertainty evolves. Include thermal variation, network congestion where relevant and the restoration of discipline after the outage. The system's internal clock-status logs should be compared against independent observations. A smooth software time display is not sufficient evidence of correct acquisition time. If a reference change introduces a phase or frequency transient during a burst, the affected interval must be marked and analysed separately.

The forecaster should distinguish stability from accuracy. A local oscillator may continue at a remarkably stable rate while possessing an unknown

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offset from a common time scale. That might preserve useful within-receiver time differences and frequency estimates, subject to calibration, while limiting absolute timestamps or interstation localisation. The report should state that the receiver remained fit for specified occupancy measurements but lacked adequate evidence for a claimed arrival-time difference. It should not convert a successful local frequency check into certification of the entire spatial reconstruction. Analogue cable and filter delays require their own calibration even when the clocks agree.

At one year, measure existing performance and identify dominant uncertainty. At five years, test available reference improvements against the full chain. At ten and twenty years, forecast alternative architectures under scenarios of component advance, operational failure and cost. A plan that can preserve honest uncertainty when the clock loses its reference is better than one which assumes perfect discipline because the projected oscillator is impressive. The instrument's reliability includes the clarity of its limitations.

Dr. James M. Atkinson, Moderator: The joint conclusion is conditional. Engineering forecasts must state a physical reference plane, demonstrable measurement target, assumptions, uncertainty, dependencies and falsifying milestones. Numerical representations and sample throughput are not substitutes for validated observation. This closes Question 106 and passes the token to the final discussion on the combined evidential standard.

QUESTION 106. RESEARCH NOTES. IEEE 1241-2023, Standard for Terminology and Test Methods for Analog-to-Digital Converters, establishes a framework for ADC performance testing, https://standards.ieee.org/ieee/1241/6797/. Its applicability to specific future

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architectures must be examined. All scenarios are hypothetical and are not claims that particular future converter products exist.

EDITORIAL QUALIFICATION. Horizon years are illustrative review dates; no product or technological breakthrough is guaranteed. Calculations of sample throughput and jitter-limited SNR are conditional examples and do not establish measured RF performance.

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QUESTION 107

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What combined evidential standard should close a complex TSCM receiver investigation?

SCHOLARLY RECONSTRUCTION. This is fictional educational dialogue between deceased historical specialists. It is not genuine testimony, an account of an actual meeting, or evidence that any named participant endorsed contemporary techniques.

Dr. James M. Atkinson, Moderator: Sir Karl, I invite you to propose the final inference hierarchy that should govern lawful TSCM receiver investigations. Please distinguish observation, calibrated measurement, external-source identification, device attribution and legal conclusions, and identify the limits which prevent a stronger finding.

Sir Karl Raimund Popper, Principal Contributor: Dr. Atkinson, the final report should be organised around propositions that can be challenged, not around the grandeur of the instrumentation deployed. A survey may employ twenty receivers, multiple antennas and extensive digital analysis, yet the underlying proposition might remain modest: during a specified observation interval, one receiver recorded a feature consistent with a transient RF emission. The stronger proposition that an identified external device produced the feature requires additional discriminating evidence. The still stronger proposition concerning a person's conduct or intention lies beyond the output of the receiving apparatus. A correct investigation must not elevate a signal detection into an attribution merely because the evidence file is voluminous.

I propose an explicit hierarchy of findings. The first level describes instrument operation and acquired data: which physical quantities the

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apparatus measured, at which reference plane, under which configuration and validity conditions. The second level describes the waveform characteristics justified by those data, such as frequency range, bandwidth, timing and uncertainty. The third addresses external physical causation, distinguishing an incident emission from intermodulation, oscillator leakage, coupling or processing artefacts. The fourth concerns source class or location, which requires controlled spatial or comparative evidence. Individual-device attribution and legal conclusions require still stronger foundations. Each ascent should be marked as a new inference, not concealed in an adjective such as confirmed.

The decisive experiments are those that can embarrass the preferred account. If a spectral line is thought to originate from an external transmitter, the investigators should examine whether it persists with a characterised input load, changes under attenuation in the manner expected from an instrument-generated product, or appears independently on another receiver. A controlled reference signal may test the frequency and amplitude calibration. Changing antenna position, polarisation or location may provide spatial information, but those changes must be interpreted in the relevant propagation environment. A negative result from one control does not prove a competing explanation false if the control itself has a blind spot. The report should retain every material contrary result.

A negative survey conclusion demands equal restraint. If no qualifying emissions were detected, the investigator should state the observation period, bands, receiver sensitivity under tested conditions, scan dwell, blind intervals and the classes of emission the method was capable of detecting. The statement must not become an assertion that no hidden apparatus

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existed at any time. A device might have remained silent, transmitted outside the observed bands or produced an event inside unobserved time. The appropriate assurance is conditional upon a defined search protocol and demonstrated detection opportunities. The limitations are not footnotes to be concealed from a client; they delimit the scientific meaning of the finding.

I would require the report to identify alternative hypotheses by their testable predictions. An intermodulation product might change nonlinearly with input attenuation. A local oscillator leakage feature may remain associated with the receiver under antenna substitution. An external source might exhibit spatial variation, though reflections and near-field conditions can complicate that inference. A data-processing artefact may disappear under a different validated algorithm. These patterns are not infallible signatures, but they guide experimental challenges. If the evidence is compatible with more than one hypothesis after appropriate tests, the conclusion should remain unresolved rather than select the most dramatic explanation.

The forensic record must separate acquisition, analysis and interpretation. Original samples and metadata should be preserved under lawful authority and proportional retention, with the extent of any content capture justified. Derivatives should record processing methods, parameters, software versions and their relation to originals. A verified digest can support continuity of a defined byte sequence from a documented reference event; it cannot prove physical authenticity or legal authority. A scientifically valid measurement can also be obtained under unlawful conditions, and its

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admissibility is a distinct question for the competent jurisdiction. An expert must not let a technical signature settle matters entrusted to law.

I would involve independent examiners before the narrative is frozen. Give them a blinded case file containing the relevant data, calibration history and alternative hypotheses, while withholding the preferred investigator's conclusion where feasible. Ask each to articulate the strongest supported finding and what further observation would change it. Compare their reasoning, not simply their final labels. If disagreement arises because an instrument state was never recorded, that is an enduring limitation; no amount of confident prose repairs it. If disagreement arises because a mathematical method was inadequately explained, the study may need clearer assumptions and an independent computational replication.

A proper closing conference should state what would falsify the conclusion and whether that test was conducted. When it was not, say why. The report can contain strong affirmative results where multiple independent and discriminating observations converge, and it can contain scientifically useful qualified negatives. It should never imply that completeness of paperwork establishes completeness of the electromagnetic search. The quality of a TSCM investigation is revealed by its treatment of uncertainty and adverse evidence, not merely by the expense of the instruments or the elegance of the final illustrations.

My recommendation is therefore a modest but exacting doctrine: conclude at the highest level of inference actually supported, preserve the path by which that level was reached, and disclose the competing explanations that remain viable. A finding that survives a meaningful attempt at refutation deserves greater confidence than one which has never been challenged.

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When a fact is unknown, preserve the unknown rather than use engineering jargon to turn it into certainty.

David Slepian, Peer Question: Sir Karl, I wish to challenge the final evidential ladder with the case of a receiver which never possessed the information necessary for a particular conclusion. A narrowband system might accurately preserve a carrier's frequency yet lack the bandwidth or sample history needed to evaluate a brief transient. A compressive recorder might retain a mathematical projection adequate for detecting known sparse tones but inadequate for an unmodelled burst. How should the expert distinguish a testable hypothesis from one that the available data cannot discriminate, and how should that difference appear in the final findings? It is tempting to propose an elaborate reanalysis of retained data, but no algorithm can conjure an unobserved event into evidence without substantive assumptions. Please explain when further analysis can legitimately reduce uncertainty and when the proper response is to qualify the finding or conduct another authorised measurement. The final report must not confuse mathematical elegance with physical identifiability. Please specify which data are native measurements and which are model-dependent derivatives, and whether a subsequent replication could ever recreate missing historical RF information.

Sir Karl Raimund Popper, Response: Dr. Slepian, the correct answer begins with the scope of the observation. If a receiver preserved only a narrow band, a later algorithm cannot establish the detailed content of a transient outside that band. It may test hypotheses about the retained band, or produce model-dependent inferences about a broader signal under specified assumptions. The expert must not describe those inferences as

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though a complete waveform was measured. In a compressive acquisition, the recorded projections and the signal model should remain separate. More than one physical event may be compatible with the same compressed data when the acquisition operator lacks sufficient discriminating power. A small reconstruction residual does not abolish that non-uniqueness.

The final report should attach each claim to the information actually retained. Frequency occupancy can sometimes be established from validated spectral estimates without preserving communication content. Phase and precise transient timing may require original samples and clock information that the archive lacks. Source localisation may require independent receivers, spatial calibration or time references not available in one instrument's file. The reader should see a clear boundary between direct observation, mathematical derivative and physical interpretation. Where the required information was not collected, the investigator may state a limited result rather than press the algorithm into producing a more dramatic answer.

A controlled new measurement may reduce uncertainty when the underlying phenomenon can be recreated or when an authorised reference source can challenge the instrument's response. Such a test can evaluate whether an alternative explanation is plausible, but it does not recreate the historical unknown event. If a firmware flaw is discovered later, reproducing it under laboratory conditions may show that an earlier feature could have been an artefact; whether it actually was requires additional evidence. The report must preserve the temporal distinction. A later experiment is an examination of a hypothesis, not a time machine.

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I would therefore structure the final finding in terms of possible falsification. Specify what observations would be expected under each hypothesis and which were actually obtained. If the existing data cannot distinguish them, state that limitation. A scientifically responsible conclusion is not weakened by identifying a question that the apparatus could not answer; it is strengthened by refusing to assert what was never observed.

Hendrik Wade Bode, Peer Question: Sir Karl, a receiver-generated intermodulation product may closely resemble a real transmitted signal, and a stable spectral peak can arise from an oscillator or an electrical contact as easily as from a concealed apparatus. If a final report uses the words external emission, what minimum challenge tests should have been considered before those words appear? I do not suggest that every possible artefact can be ruled out, but the report should document why alternative receiver mechanisms have been treated as less plausible. Please explain the value and limitations of changing input attenuation, antenna substitution, preselection and independent receiver architecture. A control whose own effect on gain or bandwidth is poorly characterised can mislead the examiner. What should the finding say if the line survives several tests but a material intermodulation hypothesis remains unresolved? The difference between technical confidence and unjustified certainty is central to professional TSCM practice. I also ask how an independent laboratory would identify shared front-end nonlinearities when a second receiver supplies apparently corroborating but technically dependent evidence.

Sir Karl Raimund Popper, Response: Dr. Bode, the phrase external emission should be used only with an account of why a solely internal receiver origin has been challenged. Changing input attenuation can help reveal some

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nonlinear products because their levels may respond differently from the fundamentals that generate them. But the expected response depends upon where the attenuation lies relative to the nonlinear stage, and a poorly characterised change is not conclusive. Antenna substitution may help distinguish environmental energy from receiver leakage, yet the replacement antenna has its own pattern, sensitivity and coupling characteristics. Preselection can suppress interfering inputs and remove intermodulation; it also changes what the receiver can observe. Each control must therefore be interpreted under a known measurement model.

An independent receiver with different analogue architecture can provide stronger corroboration, provided its measurement errors and reference sources are not fully shared. Two instruments fed by one defective splitter or common clock may agree because of a common failure. Spatial relocation and polarisation changes may also help, but reflections and near-field coupling can make their interpretations ambiguous. The investigator should record the full controlled sequence and not select only those steps supporting the preferred theory. A genuine external signal can disappear under an antenna or filter change if the new configuration is insensitive to it; that outcome must not be treated automatically as proof of internal generation.

For the final report, I would distinguish an observed spectral feature from the inference of external origin. One may state that a feature was detected at a defined receiver reference plane and appeared under several independent configurations, with controlled tests failing to reproduce it as a specified internal product. That is meaningful evidence, though it may not identify a transmitter. If a material intermodulation hypothesis remains

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viable, the report should retain it and explain what additional experiment would discriminate it. Words such as confirmed external transmitter or uniquely identified device should be reserved for stronger evidence.

The scientific standard is not that every imaginable alternative must be disproved, which is impossible. It is that the important alternatives suggested by the physics and apparatus are explicitly considered and challenged proportionately to the claim. When a conclusion remains conditional, the condition should be visible in the main finding rather than concealed in a footnote. That is how an engineer avoids turning a polished instrument trace into an accusation that the trace itself cannot support.

Dr. James M. Atkinson, Moderator: Thank you for the preceding analysis. I respectfully pass the token to Sir David Cox to examine a distinct component of the final evidential and publication standard.

Sir David Cox, Second Principal Contributor: Dr. Atkinson, the end of an investigation is a decision under uncertainty, but the relevant probabilities must be attached to clearly stated questions. A false-alarm rate for a spectral detector is not the probability that a named device was responsible for a particular event. A confidence interval for received frequency does not describe the probability that an individual acted unlawfully. The data-generating process, selection mechanism and alternative explanations determine which statistical proposition can be estimated. When the final report combines several layers, the uncertainties must not disappear merely because the paragraph uses one polished conclusion. I would require a question-by-question evidential accounting.

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The measurement data should be partitioned into valid observations, invalid acquisition intervals and genuinely unobserved periods. A recorder may have been collecting samples continuously but dropped buffers under load. A scanner may have revisited a frequency only intermittently, leaving long blind intervals. An event-triggered archive may preserve only observations selected by a prior threshold, thereby excluding misses from subsequent performance estimates. These conditions have different statistical meanings. A quiet displayed waterfall can be a true low-energy observation or the absence of a valid observation. No estimate of detection probability can be trusted if the relevant denominator has been misdescribed.

A probabilistic model for missed events should begin with an explicit population of opportunities. If an authorised laboratory emits known test pulses at predeclared times, the observed detection fraction estimates performance for that tested family and environment, subject to uncertainty. It does not automatically describe devices that transmit at unknown times using different modulation or power. Correlation among nearby windows further reduces the effective amount of information available for confidence statements. The investigator should report counts by independent session, receiver state and source class. A million overlapping windows from one experiment cannot stand in for a million independent tests of the system's generality.

Where the report invokes multiple hypotheses, it should distinguish goodness of fit from evidential discrimination. A model of external transmission may explain a spectral feature well; a model of receiver intermodulation may also explain it. A small residual does not show which explanation is correct if both predict the observed quantities. The

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investigator should design or identify measurements on which the predictions differ, such as a controlled attenuation change, independent receiver observation, spatial relocation or calibration stimulus. If such tests were not possible, the report should say that the alternatives remain unresolved. Mathematical sophistication does not create identification when the data do not distinguish the hypotheses.

I would require the technical summary to include the uncertainty budget for each reported measurand. Frequency calibration, spectral resolution, clock integrity, gain, antenna factor, cable loss and environmental effects may all be relevant, depending upon the claim. Correlated uncertainties from shared references should not be counted as independent support. A measurement from two receivers driven by the same defective clock is not fully independent timing corroboration. Confidence language should reflect both statistical variability and possible systematic effects. No honest interval can compensate for an unrecognised bias, so the report should document challenge tests for significant potential systematic errors.

Sequential analysis must be identified. A team may adjust thresholds after examining early alarms, change antenna configurations in response to suspected sources and extend the survey when a pattern appears. Such adaptive investigation can be sensible, but the final statistical claims must acknowledge the selection process. A rate computed from trials chosen after the event may not have the error properties of a predeclared experiment. The report should identify exploratory discoveries, confirmatory tests and subsequent follow-up separately. Stronger inferences may be possible after an independent confirmation, but the discovery data should not be quietly relabelled as independent validation.

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The legal decision may be different from the scientific estimate. Standards for expert admissibility, proof and disclosure vary by jurisdiction and type of proceeding. The expert may explain methods, limitations, calibration and what the observations support; the court or other competent decision-maker determines the legal consequences. The report should not use a statistical confidence percentage as though it established a legal burden of proof. A technically accurate negative survey may provide limited assurance for a client without proving that an alleged offence did not occur. Appropriate language keeps the domains separate.

I would propose a structured final table. Each claim has a source observation, method of analysis, calibration basis, independent corroboration, error or uncertainty estimate, tested alternatives and unresolved qualifications. The table also identifies whether the claim is direct measurement, statistical estimate, source classification or legal inference. Reviewers should be able to contest one row without dismantling the rest of the investigation. A correction to a time offset need not erase a valid qualitative detection, but it may invalidate a localisation claim depending on that offset. Such modularity makes reports more resilient to honest scientific revision.

The final conclusion should be neither evasive nor overconfident. It may state that a specified RF event was observed with validated frequency and timing measures, while its source remains unidentified. It may state that no qualifying events were detected within a bounded surveyed domain and known detection limits. It may state that a claimed emitter hypothesis was contradicted by a controlled receiver challenge. Each outcome can be

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valuable. What cannot be justified is collapsing these different propositions into a single assertion of certainty unsupported by the study design.

Norbert Wiener, Peer Question: Sir David, the final survey may be based on an autonomous collection system whose gain, channel schedule and anomaly thresholds changed in response to earlier observations. The investigator may then aggregate its alarms into one impressive statistic, although different intervals were governed by different decision rules. How should the final statistical report account for this adaptive process? In particular, what is the appropriate observational denominator when the receiver was retuning, overloaded, in clock holdover or storing only selected alarm intervals? Please explain why a model's false-alarm estimate measured under one laboratory regime cannot simply be attached to every alert generated later at an unfamiliar site. The report should distinguish the machine's historical decision from an updated model's subsequent classification. It must also consider whether an apparent lack of alarms proves anything about the periods when the machine was not qualified to observe the intended band. Please explain whether adaptive thresholds and feedback can change the relevant observation opportunities, and what contemporaneous control record makes those adaptations independently auditable.

Sir David Cox, Response: Dr. Wiener, an adaptive system is a sequence of potentially different decision procedures applied to a sequence of changing observations. Its final analysis should identify each operating regime and the rule in force, including the model version, threshold, gain state and valid observation interval. A pooled alarm count alone is not enough to assess performance. We need to know which opportunities were observed, under

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what sensitivity, and which apparent negatives were simply missing or invalid. A retune gap is not a quiet spectral measurement. An overloaded converter may produce data that are unsuitable for the inference even if the recorder continued. A clock in holdover may support frequency occupancy while failing a tighter interstation timing requirement.

The false-alarm denominator should correspond to a specified operational unit, such as a validated event cluster or a complete survey interval in a stable configuration. Overlapping FFT windows can be highly correlated, and their number should not be treated as independent experiments. If the system updates thresholds prospectively under a specified policy, one may evaluate that policy on independent held-out sessions; one cannot apply the original frozen-model false-alarm rate to every later decision without checking whether the relevant score distribution and threshold relationship remained stable. Historical alarms should retain the model and state under which they were generated.

When a later software version reclassifies preserved samples, it creates a derivative analysis with its own assumptions. It does not change whether the original system raised an alarm at the time. The report may explain that a newer, validated method provides a different scientific interpretation, but it should preserve the earlier event and its provenance. This is particularly important where the survey's actions were influenced by the historical decision. A final confidence statement that suppresses the acquisition or selection history will be misleading even if the last model itself is mathematically sound.

For a negative finding, I would quantify actual valid observation time and the tested detection probability for relevant reference events. Blind time,

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invalid data and untested waveforms must remain explicit. When the system's adaptive procedure has not been independently evaluated at the site, the report should say that the error rates are uncertain under that shift. A useful technical conclusion may remain possible, but its strength must be linked to the experiment actually conducted rather than to a number borrowed from a more comfortable environment.

Rudolf Emil Kálmán, Peer Question: Sir David, two receiving stations may present a narrow source-localisation region generated by an estimator whose covariance matrix assumes independent timing errors. In reality, both receivers share a timing reference, their cable lengths were not recently measured, and their propagation environments produce related multipath. How should the final report communicate the uncertainty of localisation when the apparent mathematical precision rests on possibly correlated and biased inputs? I should like an explanation of the difference between estimator covariance under a chosen model and actual accuracy under the full physical experiment. Please also consider a blind validation in which controlled emitters occupy known positions distinct from those used to tune the estimator. What should the investigators conclude if the calculated confidence region frequently excludes the independent known positions? This question bears directly upon whether a geometric diagram should appear as an evidential location claim or merely as a model-dependent investigative lead. In particular, should estimable clock offsets be separated from model error and unknown acquisition gaps, and how would that separation survive a later change of processing software?

Sir David Cox, Response: Dr. Kálmán, a covariance matrix is informative only relative to its stated model and the observations used to estimate it. If

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timing errors share a clock component, their correlation must be accounted for. If cable delays, analogue group delays or multipath biases are omitted, the resulting region may be much smaller than the true uncertainty. A visually narrow ellipse is not proof that the physical source lies inside it. The first task is to identify what each time measurement means, its reference plane and its calibration. The second is to propagate the uncertainties and relevant correlations through the localisation model, with alternative systematic effects examined where practicable.

Independent validation should use authorised emitters at known positions and a blind analysis procedure. Reserve some positions, signal forms and receiving configurations from model tuning. Ask analysts to estimate locations without access to the withheld ground truth, then compare nominal uncertainty regions with actual containment and systematic errors. If a purported confidence region repeatedly excludes the true reference positions, the model is miscalibrated for those conditions or the interpretation of its uncertainty is defective. The appropriate response is correction of the measurement and modelling process, followed by a fresh independent trial, not an artistic enlargement of the displayed region until it seems plausible.

The report should distinguish statistical variability from potential systematic bias. Repeating observations at one source location can yield a small spread while every estimate is displaced by the same uncalibrated delay. A method can be precise but inaccurate. Conversely, a broad region may correctly reflect limited information caused by antenna geometry or multipath. The investigator should preserve the input timing observations, clock states, calibration histories and processing recipe. A later reviewer should be able

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to reproduce the model-dependent region and challenge the assumptions that produce its shape.

Where the validation fails or the necessary calibration is missing, localisation should be treated as an investigative hypothesis rather than an established physical location. Other evidence may support a bounded source region, but no diagram should disguise the limitations of its measurements. The final technical finding should say whether the result was directly verified on comparable controlled cases, inferred under a model with acknowledged uncertainties, or left unresolved. That wording enables scientifically responsible decisions without pretending that numerical resolution is equivalent to evidential confidence.

Dr. James M. Atkinson, Moderator: Thank you for the preceding analysis. I respectfully pass the token to Sir Ronald Aylmer Fisher to examine a distinct component of the final evidential and publication standard.

Sir Ronald Aylmer Fisher, Third Principal Contributor: Dr. Atkinson, a final evidential standard must confront experimental design before it praises statistical calculation. If the investigators chose the measurement locations, observation times and thresholds only after seeing suspicious patterns, their eventual performance figures may reflect those choices. An impressive p-value or low estimated false-alarm rate can be meaningless when the trial was not conducted under the decision rule for which the mathematical error rate was derived. I would require the team to distinguish exploratory work from a fresh, independently designed confirmatory test wherever the conclusion demands such support. The integrity of the test design belongs at the centre of the final review.

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Randomisation and counterbalancing can reduce confounding in controlled laboratory experiments. When comparing receiver chains, rotate the order of apparatus, source levels and environmental conditions so that warm-up drift does not masquerade as a device difference. Repeat across independent acquisition sessions and specimens, rather than accumulating thousands of overlapping windows from one recording. Use independent reference sources and blinded examiners where feasible. The result should reveal whether the reported detection survives ordinary changes in hardware, location and background interference. A test constructed only from favourable examples should be labelled as a demonstration, not as general proof.

The correct sampling unit must be defined. A receiver can process millions of FFT cells per hour, but many share samples and environmental conditions. Treating them as independent will make confidence intervals artificially narrow. One might instead measure the fraction of controlled authorised events detected, the number of false alarm clusters per valid monitoring hour, or the proportion of complete sessions meeting a specified performance criterion. These answer distinct questions. The chosen denominator and clustering rule should be established before viewing the final evaluation data. An event that occurs during known blind time cannot be counted as a true negative merely because the recorder contains no corresponding file.

Absence of an observed false alarm is not proof that the population false-alarm probability is zero. Similarly, successful detection of every burst in a short laboratory trial is not a guarantee against missed field events. Confidence intervals and uncertainty bounds must be reported with

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assumptions and effective sample size explicit. The team should resist taking a favourable point estimate from a small set of related observations and extrapolating it to every waveform family or site. Operational conditions can change the background distribution and detector sensitivity. A final report should give the conditions demonstrated, the conditions untested and the reasons for treating any extension as plausible.

Alternative physical causes require experiments that can discriminate them. A spectral peak could arise from an external emission, local oscillator mixing, power-supply interference or a software processing artefact. A receiver substitution, input-load test or calibrated attenuation change may produce distinct predictions under some hypotheses. Yet each experiment has assumptions: reflections, nonlinear stages or internal coupling can confound a simple interpretation. The investigator should specify why a control is informative in the case under examination and what a contrary result would imply. An experiment does not become valid merely because it has an elaborate name.

I would include explicit stopping and revision rules. A team may decide that enough evidence exists to report a bounded negative, that a source attribution requires further measurements, or that a faulty instrument makes some results unusable. Those decisions should be documented before a final narrative is constructed. If a new instrument defect is discovered after the draft report, the affected claims should be reassessed rather than defended by inertia. An honest correction is better than preserving a misleading conclusion for the sake of consistency. The record should disclose the changed analysis and the observations upon which it rests.

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The problem of multiple comparisons cannot be ignored. Searching thousands of frequencies, time intervals and receiver combinations creates many opportunities for apparently exceptional patterns. Thresholds chosen for one isolated comparison need not maintain the same overall false-alarm behaviour across the search. Appropriate error control depends upon the selection and dependence structure, and it may be more illuminating to separate discovery from independent confirmation than to force one number onto the entire search. The survey should declare whether its probability calculations concern bins, event clusters, sessions or a predeclared hypothesis. The presentation of a rare score is not proof of a rare external source.

Expert testimony should then follow the measurements. The scientist may describe the experimental programme, data, uncertainties and extent to which alternatives were challenged. The scientist should not imply that a detector's error rate is a probability of legal guilt or that an inconclusive instrument observation proves covert intent. Those propositions belong to different reasoning and legal standards. The report's credibility depends upon precise language which permits a competent reviewer to identify where observation ends and interpretation begins.

I would close with a practical demand: disclose every material failed test, invalid acquisition and protocol deviation that bears on the claim. A perfectly formatted evidence package can conceal bad experimental design; a small but well-controlled experiment may provide a stronger inference. The final standard should reward the latter by requiring clear units of observation, predeclared rules, independent challenges and proportional conclusions. The soundness of a finding is not measured by the length of the report.

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Charles Hard Townes, Peer Question: Sir Ronald, I am concerned that a laboratory may use thousands of spectral tests to discover a rare-looking peak, select that peak for further examination, and then report the statistical significance originally calculated for one preselected frequency. The selection procedure itself created many opportunities for an exceptional value. How should the end-of-investigation review distinguish a legitimately exploratory discovery from an independently confirmed RF event? I would like you to address the physical challenge tests that might accompany statistical confirmation, including controlled receiver attenuation, independent frequency measurement and scrutiny of oscillator-related products. A technical report should not merely attach a very small number to a highlighted waterfall pixel. Please explain what the calculation's denominator, counting unit and null model must be, and what should be said when the underlying noise is impulsive or otherwise poorly represented by the chosen distribution. Would you distinguish energy recorded at a defined receiver reference plane from proof of a particular external physical source when propagation and local oscillator behaviour are incompletely tested?

Sir Ronald Aylmer Fisher, Response: Dr. Townes, the problem is selection. A threshold or significance calculation designed for one predeclared comparison need not retain its stated error rate when applied after searching many frequencies and time windows. The more opportunities the investigator examines, the more likely an apparently exceptional observation may arise by chance or by an unmodelled instrumental effect. Correlation among overlapping windows and spectral bins complicates the calculation further. The final report should declare the search space,

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selection policy, reference distribution and event-clustering rule. It should not report a post hoc selected result as though the frequency and time were fixed before observing the data.

Exploratory discovery is valuable when followed by an appropriate independent test. One might freeze the candidate frequency and analysis rule, then obtain a fresh authorised recording under controlled receiver conditions. A second receiver or changed analogue configuration can test the external origin of the feature. Known-reference stimuli can challenge frequency and amplitude calibration. Tests for local oscillator leakage, intermodulation and processing artefacts should be selected according to the apparatus and observed phenomenon. An impressive score from the original search remains part of the discovery history, not independent proof of the selected external cause.

The chosen null model is central. A Gaussian thermal-noise assumption may be useful under appropriate conditions but misleading when the background contains switching interference, lightning-like impulses or strong-signal mixing products. The laboratory should inspect relevant residuals and compare models under held-out conditions. If the false-alarm rate is uncertain because the background distribution was not characterised, the report should state that uncertainty rather than quote several false decimal places. Independent confirmation may be based on a physical intervention as well as statistical replication; the two address different but complementary weaknesses.

I would recommend a final classification of claims: exploratory anomaly, independently confirmed instrument observation, externally incident emission supported by discriminating controls, or source attribution

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requiring still greater evidence. The statistical finding must not be promoted beyond the physical tests. A rare-looking measurement is not by itself a rare device or a sign of illicit purpose. Appropriate error control and independent challenge turn an observation into a more defensible conclusion, while preserving the negative and ambiguous cases that an honest experiment inevitably encounters.

Dr. James M. Atkinson, Moderator: Thank you for the preceding analysis. I respectfully pass the token to Sir Harold Jeffreys to examine a distinct component of the final evidential and publication standard.

Sir Harold Jeffreys, Fourth Principal Contributor: Dr. Atkinson, the responsible analysis must recognise that alternative explanations can remain plausible even after the data are measured with great precision. A narrow confidence interval around a frequency estimate may leave uncertain whether the observed line arose from a transmitter or an internal spur. One can be certain about a conditional calculation while uncertain about the model's applicability. Bayesian reasoning can make assumptions explicit, but the resulting conclusions depend upon the chosen hypotheses, likelihoods and prior information. No numerical posterior should be displayed as though those choices were facts established by the receiving instrument itself.

The first task is to define the evidence and the competing accounts. An event may be explained by a lawful nearby communication, a receiver-generated intermodulation product, leakage from laboratory equipment, an unknown external emitter or a processing defect. Some accounts can be rejected by controlled tests; others may remain indistinguishable within the present data. If a model of one account omits material mechanisms, a

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comparison may unfairly favour the more elaborate model. A responsible analyst should test the sensitivity of conclusions to reasonable changes in assumptions and say when the evidence cannot discriminate among causes. Model uncertainty is not the same as uncertainty about the measured frequency or power.

Prior information may be relevant, but it should never be smuggled into the instrument output. A site history might suggest that particular equipment is commonly present; a client might suspect an exotic hidden transmitter. Neither is direct RF evidence of that device. The scientist should separate background knowledge from new observations, and examine how alternative prior choices affect a conditional inference if a formal probabilistic comparison is used. A posterior ratio can be mathematically correct under stated assumptions while being unhelpful if the proposed source classes are incomplete or the measurement model is not validated for the relevant receiver state.

Negative surveys illustrate the difficulty. The absence of an alarm is more informative when the detector has a known, high probability of detecting the stipulated source class during actual observed intervals. It is much less informative when the suspected source may be silent, the scan is intermittent, or the signal class is outside validation. The investigator should account for the observation schedule and detection probability before making an assurance claim. One cannot legitimately transform no file retained into no emission occurred if the recorder stored only alarm-triggered data. A large amount of quiet screen time may contain little information about rare events if much of that time was unobserved.

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I would present alternative explanations in an evidence matrix, documenting the measurement each predicts and the test outcome. If a suspicious line persists with a dummy input load, an internal origin gains plausibility, subject to the load and coupling design. If an independent calibrated receiver observes the same emission under a sufficiently distinct analogue path, an external cause becomes more credible. Yet correlated clocks, shared antennas and common software can compromise independence. The expert should describe these dependencies rather than count instruments as independent votes. Convergent evidence is persuasive when its errors and failure modes are sufficiently distinct.

The likelihood model, if employed, requires a defensible account of the data-generating process. Noise may not be stationary or Gaussian; spectra may be correlated across windows; and threshold-triggered selection may censor the archive. A likelihood fitted to ideal thermal noise does not necessarily describe impulsive interference or strong-blocker regimes. A sensitivity analysis should vary plausible noise models and detection policies. When the conclusion changes materially under those variations, report the instability. One may still make a qualitative finding, but a spurious precise probability would be less useful than a clearly bounded verbal assessment.

Timing and spatial reconstruction add further dependencies. A receiver may have an excellent internal clock yet an uncertain analogue group delay; a bearing may be biased by multipath or incorrect array geometry. Combining these measurements into a source location without propagating their correlations can give a misleadingly narrow region. The final report should identify each calibrated reference, its uncertainty and any shared systematic effects. A location ellipse is a mathematical derivative of assumptions and

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measurements, not a direct visualisation of an emitter's true position. A lawfully and independently corroborated observation may be needed before a source attribution is warranted.

I would preserve the reasoning history. An initial hypothesis may have been stimulated by a detector alarm, followed by tests that changed the investigator's view. Later software can reprocess protected samples, but it cannot retroactively alter what the original receiver observed or what the initial model output meant at the time. Store each interpretive step with its evidential basis and uncertainties. A future reviewer should be able to challenge the current explanation without guessing which alternatives were dismissed, when and why. The custody of the reasoning is nearly as important as the custody of the files.

My final proposition is that disciplined uncertainty can coexist with useful conclusions. A report may state that an externally incident emission was strongly supported by independent challenge tests while the individual transmitter remained unidentified. It may state that a negative search provides limited assurance within defined bands and times. It may state that data are insufficient for attribution. The conscientious investigator does not fill the remaining gap with a probability whose assumptions are untested. Such restraint is a strength of science, not a defect in its language.

John von Neumann, Peer Question: Sir Harold, the final case file may include a complex probabilistic reconstruction which assigns a high posterior weight to one particular source hypothesis. Yet the algorithm's candidate list may exclude relevant internal artefacts or unidentified benign emitters, and its likelihood model may rely on a noise distribution which the receiver never validated. Under such conditions, the posterior can be precise relative to the

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wrong question. How should a reviewer challenge the completeness of the hypothesis set and the sensitivity of a final attribution to modelling assumptions? I would also like to know whether two agreeing algorithms provide independent corroboration if both consume the same samples, calibration tables and prior information. Please describe a controlled test that could expose a shared modelling failure. The report must distinguish a model comparison from direct physical evidence of an individual emitter, especially where a legal allegation might follow. Please explain what the acceptance test should do when a recorded checksum is intact but the firmware state, sample continuity or acquisition clock reference cannot be established.

Sir Harold Jeffreys, Response: Professor von Neumann, a high conditional probability can be mathematically correct while resting on an incomplete or inappropriate model family. If the candidate list excludes the true source mechanism, the algorithm will distribute weight among the remaining options and may appear confident in the least wrong one. An RF case can contain receiver intermodulation, oscillator leakage, environmental interference or other explanations not represented in the preferred model. The reviewer should therefore ask which alternatives the model considered, which material mechanisms it excluded and what independent evidence justifies those exclusions. A posterior is conditional upon its hypotheses, likelihoods, prior assignments and the observed data; it is not a direct property of the electromagnetic source.

I would test sensitivity by varying scientifically plausible likelihood structures, noise assumptions and prior information. A conclusion that changes substantially under reasonable alternatives should be reported as

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model-dependent. More importantly, the laboratory should design controlled physical interventions which produce different predictions under the candidate explanations. An input-load test, attenuation change or independently calibrated receiver may discriminate an external source from an internal product in suitable circumstances. The intervention's assumptions must also be documented. A polished computation cannot substitute for a missing discriminating observation.

Agreement among algorithms is not necessarily independent support. Two programmes may share the same uncalibrated time axis, input samples or feature representation and therefore repeat the same bias. Even models developed by separate teams can be mutually dependent if they rely on one common reference source or defective calibration table. An independent corroboration claim should identify the distinct instruments, signal paths, reference sources and analysis assumptions that make an error less likely to be shared. If these are not sufficiently independent, the report should describe agreement between analyses, not independent physical confirmation.

The final attribution must respect these limits. It may be defensible to report that an observed event is more consistent with one tested physical explanation than with another, subject to the available controls. It is a stronger and often unsupported claim to identify one particular device or person. Where the hypothesis space is incomplete or the likelihood model poorly validated, the correct report is a bounded inference or an unresolved source. Numerical confidence without an adequate account of alternative physical mechanisms is not scientific certainty.

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Dr. James M. Atkinson, Moderator: Thank you for the preceding analysis. I respectfully pass the token to W. Edwards Deming to examine a distinct component of the final evidential and publication standard.

W. Edwards Deming, Fifth Principal Contributor: Dr. Atkinson, quality is not established by inspecting a finished report after an undisciplined acquisition. It arises from the design and control of the entire process: authority to examine, calibration, instrument preparation, acquisition, logging, analysis, independent challenge, preservation and communication. A laboratory which repairs a defective file at the final editorial stage has not necessarily repaired the observation that was never properly made. I would therefore propose a process-capability model for the investigation, with each critical step documented and subject to corrective action. The final report should reflect what the process actually achieved, including its limitations.

Begin with responsibility. Identify who authorised the survey, who configured each instrument, who calibrated the reference, who acquired and transferred evidence, and who interpreted the result. These roles may overlap in a small team, but the record should not conceal the overlap where independence is claimed. When an expert conducts the entire workflow alone, a second reviewer should examine the measurements and the alternative hypotheses before final approval. The system should also preserve changes made by operators to gain, preselection, software thresholds and record retention. The record needs to be clear enough that another competent laboratory could perform a meaningful challenge.

Calibration has a lifecycle. A certificate from a distant date is not proof that an instrument remained correct throughout a particular event. A practical

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quality system uses scheduled calibration, interim performance checks, environment records and response to detected drift. A reference signal before and after a survey may help identify changes in frequency, gain or timing response, though it cannot establish continuous correctness between checks without assumptions. The laboratory should document those assumptions and any evidence of shock, temperature excursion, firmware update or unexpected behaviour. If the instrument falls outside its verified regime, the affected observations require explicit qualification.

I would establish control charts or other process-monitoring tools for appropriate stable reference quantities, but not treat every observed variation as random noise. A sudden gain shift after a cable replacement may be an assignable cause; a systematic offset after a firmware change demands investigation. A long-term monitoring process may exhibit drift that invalidates an earlier threshold calibration. Process records should permit the team to distinguish such changes from actual external RF events. A busy dashboard with thousands of alarms is not evidence of an effective process if its false-alarm burden prevents timely examination. The cost of poor quality includes wasted attention and potentially unjustified conclusions.

The laboratory should plan its evidence products before acquisition. A frequency-occupancy study may require calibrated spectral summaries, while an investigation of phase, pulses or modulation may need narrowly scoped original I/Q samples. Retention must follow legal authority and proportionality; collecting communication content simply because storage is inexpensive is not a quality objective. The file manifest should include time, location where appropriate, instrument and firmware identity, sample

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format, clock state, reference-plane calibration and missing-data information. Every working derivative needs a traceable processing history. An immaculate digest cannot cure an initial failure to document the receiver's operative state.

I would insist on internal audit and corrective action. When a receiver-generated artefact is misreported as an external source, the institution should not merely correct the sentence. It should identify why the challenge test failed, whether similar cases were affected, and which controls would prevent recurrence. If sample gaps were rendered as silence, the software and review process need repair, not just the chart caption. A structured nonconformance report can preserve the incident, scope, remediation and verification of effectiveness. This is how a laboratory learns rather than repeats an elegant mistake under a new version number.

A final report should be modular. Each finding has an observation source, analysis method, calibration status, verification outcome, residual uncertainty and reviewer sign-off. That arrangement allows a correction to one timing estimate without rewriting unaffected measurements. It also prevents the roundtable's scholarly dialogue from being mistaken for actual evidence. The historical contributors imagined in this educational discussion do not authenticate a modern field result; only the recorded measurements and actual independent reviewers can do that. The review apparatus should be clear about which evidence exists and which is illustrative.

The final decision can be a bounded affirmative, bounded negative or inconclusive report. None of these labels is inherently a sign of failure. A process that accurately reports its limits is more valuable than one that always produces an impressive attribution. Decision-makers need to

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understand what the survey covered, what it did not cover and what further investigation would materially reduce uncertainty. Where legal duties or evidence-retention limits prevent additional testing, that constraint belongs in the report. Quality is not the manufacture of certainty; it is the reliable production of justified findings.

My closing recommendation is a final release gate which checks the original evidence, instrument and software provenance, calibration, mathematical reasoning, legal scope, independent review, and the accuracy of the language used for conclusions. Failed controls must block unsupported claims even when the manuscript itself is handsome. A reviewer should be able to trace every important sentence to a measurement, a defined inference or an expressly identified assumption. Only then should the institution close the investigative file.

Dennis Gabor, Peer Question: Mr. Deming, the technical report may contain hundreds of pages of calibrated measurements, receiver screenshots, software logs and custody signatures. Yet an independent reviewer may still be unable to trace a major conclusion to the particular samples or tests that support it. How should a quality system distinguish genuine evidential completeness from administrative volume? Please define the final release gate so that a finding about a short RF pulse is checked for bandwidth, windowing, clock integrity and data continuity, while an attribution finding also faces external-source and alternative-hypothesis controls. I would also challenge an institution which deletes failed laboratory tests from its publication package because they appear untidy. How can the report remain readable without omitting adverse evidence, and how should corrective action be documented if a flaw is discovered after formal issuance? I would

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also ask what a time-frequency chart can legitimately preserve when its window suppresses a brief impulse or when the instrument archives only selected trigger intervals.

W. Edwards Deming, Response: Dr. Gabor, the number of pages does not demonstrate process capability. A final quality gate must be linked to the type of claim being made. A short-pulse timing claim needs evidence concerning sample-clock behaviour, group delay, acquisition completeness, windowing and any processing that altered temporal shape. An amplitude claim needs a calibrated reference plane and the appropriate uncertainty budget. An external-source claim requires challenges to receiver artefacts. Individual-device attribution requires more particular and sufficiently discriminating evidence. The release checklist should prevent a weak evidence item from borrowing authority from unrelated sections of a very large manuscript.

I would create a claim-to-evidence register. Each consequential sentence in the conclusions would refer to the original observation or lawful derivative, the acquisition manifest, calibration status, analysis method, independent challenge and remaining limitations. The register should distinguish accepted evidence, unverified assumptions and invalid observations. A signed custody form is important but does not establish analogue fidelity. A numerical computation can be correct but irrelevant to the physical cause. The system should be capable of failing a conclusion even when every administrative document is present, because technical validity cannot be manufactured by paperwork.

Adverse tests must remain accessible. If a receiver generated an intermodulation product under controlled stimulation, that result may

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qualify an earlier attribution even if it makes the report less decisive. A failed calibration, unknown FPGA image, sample loss or inconsistent clock should be identified in the relevant finding, not buried in an appendix that the reader is unlikely to examine. A readable report can give the conclusion and limitations concisely while linking to the full traceable record. There is no necessity to repeat every log line in the narrative, but the evidence must remain available for independent challenge within lawful retention boundaries.

After issuance, a new defect should initiate controlled correction. Identify the affected claims, preserve the original report, record the discovered error, perform a documented reanalysis and issue an attributable revised conclusion. A correction should not silently rewrite what the instrument recorded or what the original author said. If the error is systemic, the laboratory should evaluate whether other investigations used the same deficient method. This turns a mistake into process improvement and protects future work. A scientifically responsible institution is not one which never encounters an error; it is one which discovers, discloses and corrects it.

Dr. James M. Atkinson, Moderator: With respect to each principal contribution, I invite four reciprocal challenges addressed to four different colleagues. Each respondent will answer immediately before the token passes onward.

Sir Karl Raimund Popper, Cross-Peer Question to Sir David Cox: Sir David, I ask you to examine the danger of presenting a statistically exceptional receiver observation as a uniquely identified source. The finding may contain a well-calibrated frequency estimate, a small nominal false-alarm

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probability and agreement between two analysis programmes. Yet the programmes may use the same samples, and the detection model may never have been challenged against a physically plausible intermodulation mechanism. What can a careful statistician say about the resulting evidential strength, and which new experiment would materially improve it? Please distinguish uncertainty about a measured quantity, uncertainty in the competing models and the much broader problem of attribution to a named apparatus. I should also like a decision rule which allows a report to close with an unresolved source without treating that outcome as a professional failure. An expert whose scientific methods are excellent must still know which propositions those methods did not test. Please identify a falsifiable alternative hypothesis and an independent test that would prevent the team from confusing a persuasive narrative with a measured external-source finding.

Sir David Cox, Cross-Peer Answer to Sir Karl Raimund Popper: Sir Karl, the statistical result must be attached to the proposition for which its calculation was designed. A low false-alarm probability for a stipulated noise model may indicate that the observed score was unusual under that model. It is not automatically a probability that a particular transmitter generated the event, nor proof that the model adequately represents impulsive interference or receiver nonlinearities. A precise frequency measurement establishes a physical parameter within its uncertainty and calibration conditions. It does not by itself discriminate between a genuine external signal and an internally generated product at the same frequency. The final report should therefore keep measurement uncertainty, model uncertainty and source attribution in distinct columns.

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Agreement between analysis programmes can support reproducibility of a computational result, but it may not provide independent physical corroboration. If both use identical samples, time references and calibration tables, a shared bias will survive. The stronger test would alter a relevant part of the measurement chain or introduce an independent observation whose error mechanisms differ. For example, changing input attenuation at a known reference plane and using a second receiver architecture can challenge intermodulation explanations, with the precise physical predictions stated beforehand. A suitable control may fail to discriminate because of propagation or configuration limits; that failure should be reported rather than treated as confirmation by default.

I would separate the investigative decisions. One may close the data-analysis phase when the measured quantities and their processing are reproducible. One may close the physical-origin question when adequate controls support an external cause. One may leave individual-device attribution open if the data are compatible with several devices. Each decision has different evidential conditions. A report that states an identified feature of unresolved source, along with the controls performed and the additional test that might distinguish alternatives, is scientifically useful. It is not defeated because it declines to name an apparatus without sufficient information.

The mathematical conclusion should describe the operating conditions and selection rules. An exceptional score discovered after a broad search cannot necessarily be evaluated with the false-alarm probability of one prespecified comparison. A model fitted after inspecting the event may need independent confirmation. These are not mere legal caveats; they

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determine the scientific meaning of the statistic. A careful report prevents a reader from converting a valid calculation for one claim into unearned certainty about another.

Sir David Cox, Cross-Peer Question to Sir Harold Jeffreys: Sir Harold, suppose an investigation compares a small number of named source hypotheses and obtains a very large posterior probability for one of them, but the candidate list omits an internal oscillator product and the receiver was operated near compression. I would be concerned that the model is confident because the relevant cause was excluded before computation began. How should a reviewer evaluate a Bayesian attribution where the hypothesis set is incomplete and the likelihoods were fitted to benign laboratory data? I would also ask whether a posterior can be responsibly reported when the prior information comes largely from a client's suspicions rather than from independent evidence. The final evidential standard should not prefer one statistical school over another if both recognise limitations of the underlying observations. What claims would remain supportable, and what physical test should be proposed before an attribution is made? I particularly want the expert report to distinguish a conditional inference from an unconditional probability of source identity, and to identify the population of observation opportunities.

Sir Harold Jeffreys, Cross-Peer Answer to Sir David Cox: Sir David, a posterior distribution is conditioned upon its model and prior assumptions. When the physical source mechanism is absent from the hypothesis set, the calculation may assign high relative probability to one available alternative simply because every other considered alternative fits worse. That does not establish that the selected hypothesis is true. An important internal source

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mechanism, such as oscillator leakage or intermodulation in a nonlinear receiver state, must be considered when the apparatus makes it plausible. If it was omitted, the report should explain the omission and reassess the inference. No mathematical school can recover information that the experiment did not preserve or correct a physical model whose major causes were ignored.

Prior knowledge should be disclosed distinctly from measured evidence. A client's suspicion may motivate a lawful investigation but does not become an RF observation merely because it is used as a prior weight. If several reasonable prior assignments produce materially different conclusions, the instability should be reported. Likewise, a likelihood model calibrated under quiet laboratory conditions may not describe a strong-blocker field environment. One can conduct sensitivity analyses of noise assumptions and prior structures, but the value of those analyses depends on whether the candidate physical mechanisms were sufficiently represented in the first place.

The useful next step is an experiment which makes different physical explanations predict different observations. If internal nonlinear mixing is plausible, a controlled attenuation and multitone test may reveal its behaviour, subject to the amplifier stages and reference plane. An independent receiver path can provide additional evidence if its errors are sufficiently different. A calibrated source at the antenna input can challenge the proposed frequency and amplitude transformations. The investigator must preserve the adverse outcomes and the tests not performed. A prior belief that the client is right cannot substitute for those measurements.

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The supportable conclusion may be that a measured spectral event is consistent with a stated waveform or source class under a validated receiver configuration, while its individual origin remains unresolved. If a Bayesian comparison is retained, the report should label the hypothesis set and assumptions and avoid translating a conditional posterior into an unconditional statement of fact or legal responsibility. Honesty about that boundary is more useful than a spectacular probability that conceals an incomplete model.

Sir Harold Jeffreys, Cross-Peer Question to W. Edwards Deming: Mr. Deming, uncertainty may be correctly expressed in a technical annex while the executive summary still gives a stronger message than the evidence warrants. A client might read a statement that no suspicious transmitter was detected as assurance that no transmitter existed, or might read a source-location diagram as proof of one particular room despite unmeasured multipath. How should the quality-release process verify that the central conclusions, tables and visualisations remain consistent with the detailed limitations? I would particularly welcome a process for examining negative findings, digital evidence provenance, model-dependent reconstructions and post-publication corrections. The final document must be intelligible without sacrificing scientific accuracy. Is it possible to maintain strong editorial control over the prose while preserving enough original evidence for an independent laboratory to challenge a finding? Please identify the stopping conditions that should prevent release of an unsupported attribution even when the report is otherwise beautifully produced. Please explain how the release reviewer should handle a visually convincing result

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which depends critically on untested prior assumptions or an undisclosed acquisition gap.

W. Edwards Deming, Cross-Peer Answer to Sir Harold Jeffreys: Sir Harold, the release review must begin with the claims that a decision-maker will actually encounter. Read the executive summary, captions, tables and conclusion in isolation, and identify the physical proposition each communicates. Then trace the proposition through the claim-to-evidence register to the original observation, the acquisition manifest, calibration, processing and alternative-hypothesis tests. If the detailed record says only that no qualifying signal was observed during limited bands and times, the summary cannot say that no hidden device existed. If a localisation region is valid only under a stated multipath model, the map caption must display that qualification in understandable language. Editorial accuracy is a technical control, not a decorative exercise.

I would establish mandatory release gates for significant claims. A measured frequency or power requires appropriate reference-plane calibration and uncertainty. A transient-timing claim requires valid sample continuity, clock and group-delay evidence. External source attribution requires material receiver-generated artefacts to have been challenged. An individual-device claim requires more discriminating evidence and independent review. A legal conclusion cannot be smuggled into a technical label. Failure of a relevant gate should block the stronger claim, though a narrower finding may still be published. The review should record who approved the adjustment and why.

The source files, derivatives and logs should be preserved according to lawful authority and proportionate retention. A digest over an original

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object can help detect later alteration, but the record must also identify the sample schema, firmware and FPGA state, clock reference, missing-data flags and transformations. Reviewers should have a reproducible path from the original observation to the finding, where permissions and security controls allow. If crucial data are unavailable, the report should identify that limitation instead of constructing a hypothetical waveform and calling it original evidence. The same applies to simulated examples and fictional scholarly discussion, which must not be confused with actual field testimony.

If a defect is discovered after release, the institution should preserve the issued report, identify the affected conclusions, issue a controlled correction and examine whether the same fault affected related investigations. Corrections should be attributable and supported by new analysis or measurements. A quality system is not one which prevents all error but one which exposes and repairs it transparently. That process makes the final report reliable to readers who were not present at the survey and enables a future expert to challenge it fairly.

W. Edwards Deming, Cross-Peer Question to Sir Ronald Aylmer Fisher: Sir Ronald, I should like a final word on a question frequently obscured by publication pressure. A laboratory may be asked to issue a decisive conclusion after a technically extensive but adaptively conducted survey. The operators changed thresholds, revisited promising frequencies, replaced equipment and finally selected the most remarkable observation for the report. That can be proper investigative practice, yet it complicates every conventional error-rate calculation. How should the closing review distinguish useful exploratory work from independently validated

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confirmation and decide whether a fresh trial is required? I would also ask how to represent adverse findings and known blind periods without turning the executive summary into an impenetrable catalogue of caveats. The report must be honest and useful, not merely legally defensive. Please describe the minimum evidential wording for an affirmative observation and a bounded negative when no appropriate independent confirmation was obtained. I also ask for a release-control rule identifying what must be corrected in the instrument process rather than merely edited in the final narrative.

Sir Ronald Aylmer Fisher, Cross-Peer Answer to W. Edwards Deming: Mr. Deming, adaptive investigation is not inherently defective, but its statistical consequences must be recognised. Changing the threshold after seeing the data, examining many frequencies and selecting one exceptional feature means that the final selected event has been subjected to a discovery process. One cannot automatically evaluate it using the error probability of a single comparison specified in advance. The report should preserve the search method, decision history and selection rules. Where the final claim depends heavily on the rarity of an event, an independent prospective test using a frozen rule is often a stronger basis than a post hoc calculation applied to the discovery data.

An affirmative conclusion can be phrased at several levels. The analyst might state that a calibrated receiver recorded a spectral feature at a specified frequency and time under an acquisition state found valid for that measurement. If independent controls establish an external component, the report can say so and identify the tests. If individual-device attribution is unverified, that limitation should appear immediately beside the stronger

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claim rather than in an obscure footnote. The summary need not repeat every calibration constant, but it should lead the reader to the traceable record and should not omit the most consequential uncertainty.

A bounded negative should likewise identify coverage. It might state that no emissions meeting a specified detector rule were observed during the valid monitoring intervals and surveyed bands, with sensitivity and blind time described. If the detector was tested only for particular authorised waveform families, the report should not imply that all imaginable transmissions would have been found. A finite survey cannot exclude events occurring in unobserved intervals or sources that remained silent. The result may still provide practical assurance within its declared limits. The quality of the conclusion lies in the fit between the wording and the actual experiment.

Adverse tests and deviations should remain part of the record. A failure to detect one known reference pulse may materially limit a claim of sensitivity; a firmware state ambiguity may invalidate one timing analysis while leaving other observations intact. The release reviewer should apply those effects to the affected findings rather than delete inconvenient data. If further confirmation cannot lawfully or practically be obtained, report the unresolved proposition. An honest inconclusive outcome is preferable to an impressive statement supported by an experiment whose error properties have not been established.

Dr. James M. Atkinson, Moderator: This concludes Question 107 and the one-hundred-discussion Stage-A drafting programme. All findings remain subject to actual source-to-claim verification, mathematical review, factual checks, independent evidence assessment, and complete manuscript

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production proof. A fictional scholarly consensus must never be presented as a field observation or as genuine historic testimony.

QUESTION 107. RESEARCH NOTES. JCGM 100:2008, Evaluation of measurement data, Guide to the expression of uncertainty in measurement, DOI 10.59161/JCGM100-2008E; NIST SP 800-86, Guide to Integrating Forensic Techniques into Incident Response; SWGDE 18-F-002-2.0, Best Practices for Digital Evidence Collection (30 June 2025). These sources support background metrology and digital-evidence principles, not the fictional speech or the correctness of a particular field measurement.

EDITORIAL QUALIFICATION. The manuscript contains 100 substantive Stage-A discussion drafts following the seven authorised deletions. This structural milestone is NOT Stage-B publication approval. Every cited proposition, historical attribution, engineering calculation, legal claim, cross-reference, layout and continuous page number requires a separate whole-volume verification. Independently developed Phase-I core expansions remain unverified for integration.

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EDITORIAL RESEARCH ANCHORS FOR QUESTIONS 051–107

These sources guide subsequent technical verification. No contributor is represented as having personally read publications issued after their death.

VI. Timing references and traceability: https://www.nist.gov/publications/handbook-frequency-stability-analysis ; https://www.nist.gov/pml/time-and-frequency-division/popular-links/time-frequency-z

VII. Coupling, front-end and analyser diagnostics: https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-5-combined-standard-uncertainty ; https://standards.ieee.org/ieee/1815/6797/

VIII. Rare-event detection and inference: https://www.itu.int/rec/R-REC-SM.1880-3-202608-I/en ; https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-d4-measurand-defined-measurement-method

IX. Waveform and communication-class indicators: https://www.itsoc.org/profile/8796 ; https://news.mit.edu/2001/elias

X. Forensic provenance, uncertainty and reporting: https://nvlpubs.nist.gov/nistpubs/ir/2022/NIST.IR.8387.pdf ; https://www.swgde.org/documents/published-complete-listing/22-f-003-best-practices-for-remote-collection-of-digital-evidence-from-an-endpoint/

XI. Receiver architectures and long-horizon synthesis: https://standards.ieee.org/ieee/1815/6797/ ; https://www.nist.gov/publications/handbook-frequency-stability-analysis

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Volume Assessments

This section contains 350 items: 100 multiple-choice, 100 fill-in-the-blank, 50 essay and 100 discussion. Choose one best answer for each multiple-choice item. Supply the requested technical term, quantity or condition for each blank. For essay and discussion responses, explain the governing mechanism, assumptions, evidence and limits of the claim. Numerical assessment cases use hypothetical inputs unless an item explicitly identifies a published source. Retain units and distinguish power, voltage and logarithmic quantities. Answers, rationales and response guidance follow the complete question set; their review links lead to the supporting text.

The volume set combines material across the sixteen chapters. A satisfactory synthesis must preserve each model’s assumptions, reference plane, receiver state and evidential scope when connecting the chapters.

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Multiple-Choice Questions

V011-VOL-MCQ-001. A survey needs antenna-terminal power, but its software reports receiver-plane power after an undocumented automatic gain change. What is the first defensible action?

A. Recover or bound the applicable state and path correction before forming the requested quantity

B. Treat receiver-plane power as antenna-terminal power because both use dBm

C. Apply the nominal gain and enlarge uncertainty until the result looks stable

D. Average more displayed levels to remove the unknown state

Answer: A. A correction inverse needs the actual state and named planes; covariance propagation cannot repair an inapplicable correction. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: Recover or bound the applicable state and path correction before forming the requested quantity.

Distinguishing consideration: compare this with option B, “Treat receiver-plane power as antenna-terminal power because both use dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 13 — Define a complete path at named planes; Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 13 — Define a complete path at named planes; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-MCQ-002. A matched fixed-state path has dimensionless power transfer 10, output power 1.5 nW and a separately characterized output-referred additive power 0.5 nW with zero cross-power. What input signal power should enter the calibrated result?

A. 1.0 nW

B. 0.2 nW

C. 0.1 nW

D. 10 nW

Answer: C. Subtract physical powers first, then divide by transfer; a later logarithm requires the positive difference. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: 0.1 nW.

Distinguishing consideration: compare this with option A, “1.0 nW”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-MCQ-003. Two accepted equal-duration intervals have corrected input powers 1 nW and 9 nW. Which aggregate preserves their physical mean?

A. 3 nW from the geometric mean

B. 5 nW followed by any declared log conversion

C. The arithmetic mean of their dBm labels interpreted as mean power

D. 9 nW because the larger state dominates

Answer: B. Duration weighting applies to corrected linear powers; logarithmic averaging defines a different statistic. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: 5 nW followed by any declared log conversion. Distinguishing consideration: compare this with option A, “3 nW from the geometric mean”; that competing statement does not meet the question’s stated requirement. Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

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V011-VOL-MCQ-004. A trace can be corrected numerically after clipping, but only saturated samples remain. What claim is unsupported?

A. Retaining a lower-bound or limited observation when justified

B. Reviewing the configured state and clipping flags

C. Reporting that clipping occurred

D. Recovery of the original waveform by an ordinary gain inverse

Answer: D. A correct scalar arithmetic operation cannot restore discarded waveform information. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: Recovery of the original waveform by an ordinary gain inverse.

Distinguishing consideration: compare this with option A, “Retaining a lower-bound or limited observation when justified”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 10 — Quantization, Clipping, and Converter Performance.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 10 — Quantization, Clipping, and Converter Performance.

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V011-VOL-MCQ-005. A gain change is logged at a command time but settles later. How should those records contribute to coverage?

A. Use demonstrated valid intervals and preserve the transition exclusion

B. Count the whole command interval as calibrated exposure

C. Delete transition metadata after applying a static correction

D. Use the average of the two gain labels for every sample

Answer: A. Configuration validity and acquisition opportunity must share the actual time boundary. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: Use demonstrated valid intervals and preserve the transition exclusion.

Distinguishing consideration: compare this with option B, “Count the whole command interval as calibrated exposure”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from….

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-MCQ-006. A power-only record supports a valid average level but has lost phase. What additional inference cannot be recovered from that scalar alone?

A. Its calibrated level at the declared plane

B. Inter-record coherent phase alignment

C. The stated positive average power

D. The fact that the original result was power-only

Answer: B. A recoverable quantity can coexist with permanently lost information needed for coherence. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: Inter-record coherent phase alignment.

Distinguishing consideration: compare this with option A, “Its calibrated level at the declared plane”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state.

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V011-VOL-MCQ-007. For two matched fixed-state stages with first-stage noise temperature 50 K, second-stage noise temperature 200 K and first-stage power gain 10, what total input-equivalent noise temperature follows?

A. 70 K

B. 25 K

C. 250 K

D. 2050 K

Answer: A. The later temperature is divided by preceding gain; the result still needs the declared state and bandwidth. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: 70 K.

Distinguishing consideration: compare this with option B, “25 K”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.

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V011-VOL-MCQ-008. The same stages must meet 70 K, requiring gain at least 10, but blocker loading allows gain at most 8. What is the design conclusion?

A. Choose gain 8 and claim 70 K through digital scaling

B. The feasible gain interval is empty and another condition or architecture must change

C. Choose gain 10 because noise always takes priority

D. Choose gain 9 as an acceptable average compromise

Answer: B. Noise and loading constraints must both hold; a midpoint does not satisfy incompatible bounds. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

Why the selected alternative fits: The feasible gain interval is empty and another condition or architecture must change.

Distinguishing consideration: compare this with option A, “Choose gain 8 and claim 70 K through digital scaling”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval; Chapter 11 — Dynamic Range Is a Family of Conditions.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval; Chapter 11 — Dynamic Range Is a Family of Conditions.

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V011-VOL-MCQ-009. A matched passive power loss $L=2$ at 300 K precedes a fixed-state chain with input-equivalent noise temperature 50 K. What total input-equivalent noise temperature results?

A. 400 K

B. 100 K

C. 650 K

D. 350 K

Answer: A. The loss adds 300 K and refers the chain backward as 100 K; a signal correction alone does not remove this noise cost. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: 400 K.

Distinguishing consideration: compare this with option B, “100 K”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 13 — Treat connections and unused branches as part of the network.

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V011-VOL-MCQ-010. Why can a preselector improve a weak-signal observation despite increasing desired-band loss?

A. Any desired loss automatically lowers receiver noise temperature

B. Its rejection value should be added to desired sensitivity

C. Its blocker rejection can restore upstream linear validity while the noise penalty is accounted for

D. A downstream filter can reconstruct earlier clipped samples

Answer: C. Follow desired transfer and blocker admission separately and validate the weak reference. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

Why the selected alternative fits: Its blocker rejection can restore upstream linear validity while the noise penalty is accounted for.

Distinguishing consideration: compare this with option A, “Any desired loss automatically lowers receiver noise temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Use preselection as a measured transfer function; Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Use preselection as a measured transfer function; Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-VOL-MCQ-011. A narrow final filter removes a blocker from the display but the remote amplifier is already compressed. Which remedy addresses the causal boundary?

A. Treat the clean display as proof of linearity

B. Apply the desired-frequency gain correction to the blocker

C. Increase digital averaging after the filter

D. Reduce admitted loading before that amplifier and revalidate desired response

Answer: D. Later filtering cannot reconstruct distortion generated at an earlier vulnerable stage. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why the selected alternative fits: Reduce admitted loading before that amplifier and revalidate desired response.

Distinguishing consideration: compare this with option A, “Treat the clean display as proof of linearity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Find the first stage that can lose validity; Chapter 13 — External Preamplifiers, Bias, and Stability; Chapter 11 — Compression and Gain Change.

Review: Chapter 3 — Find the first stage that can lose validity; Chapter 13 — External Preamplifiers, Bias, and Stability; Chapter 11 — Compression and Gain Change.

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V011-VOL-MCQ-012. A protection device survives a pulse. Which separate evidence is still required before accepting nearby weak events?

A. Only another survival rating from a catalog

B. Only the final record's hash

C. Observable-specific recovery and usable acquisition intervals

D. Only a steady center-frequency tone measured much later

Answer: C. Hardware survival, leakage and restored measurement validity are distinct. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why the selected alternative fits: Observable-specific recovery and usable acquisition intervals.

Distinguishing consideration: compare this with option A, “Only another survival rating from a catalog”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from....

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-MCQ-013. If receiver added temperature is positive and source temperature differs from 290 K, which comparison requires care?

A. Noise factor versus a dimensionless quantity

B. Reference noise factor versus actual SNR degradation

C. Source noise versus any physical temperature

D. Gain versus a numerical setting label only

Answer: B. F_0 uses 290 K, while actual degradation uses the actual positive source temperature. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: Reference noise factor versus actual SNR degradation.

Distinguishing consideration: compare this with option A, “Noise factor versus a dimensionless quantity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-MCQ-014. A hot/cold test uses T_h 600 K, T_c 300 K and true T_e 300 K at constant gain. What ratio should appear?

A. 0.5

B. 2.0

C. 1.5

D. 3.0

Answer: C. The fixed-state ratio is(600+300)/(300+300); gain changes would invalidate this cancellation. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why the selected alternative fits: 1.5.

Distinguishing consideration: compare this with option A, “0.5”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Invert the same model with two source temperatures; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-MCQ-015. In a matched hot/cold Y-factor noise test, hot-state gain doubles while cold gain stays fixed. Why is averaging more ratios insufficient for the common-transfer inversion?

A. The cold source temperature automatically doubles too

B. More averaging always restores a common gain

C. The ratio becomes a valid direct noise-factor measurement

D. The model's common-transfer assumption is broken systematically

Answer: D. A state-dependent model or restored equal gain is needed before inversion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why the selected alternative fits: The model's common-transfer assumption is broken systematically.

Distinguishing consideration: compare this with option A, “The cold source temperature automatically doubles too”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Invert the same model with two source temperatures; Chapter 14 — Calibrate noise without confusing it with detection; Chapter 5 — Model 5A: an identified one-pole gain-control response.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 14 — Calibrate noise without confusing it with detection; Chapter 5 — Model 5A: an identified one-pole gain-control response.

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V011-VOL-MCQ-016. A valid two-stage noise calculation omits an unmodeled mixer image-noise path. What must happen before using it as a system sensitivity prediction?

A. Double every gain term regardless of sideband admission

B. Assume the image disappears when a digital spectrum is one-sided

C. Establish a channel/sideband noise law applicable to the actual conversion architecture

D. Insert any catalog SSB or DSB figure without checking convention

Answer: C. The scalar cascade's domain excludes unmodeled image contributions.

Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: Establish a channel/sideband noise law applicable to the actual conversion architecture.

Distinguishing consideration: compare this with option A, “Double every gain term regardless of sideband admission”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 4 — Model 4A: a declared conversion map; Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 4 — Model 4A: a declared conversion map; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-MCQ-017. Two equal desired-gain layouts place attenuation before or after a nonlinear amplifier. What can differ materially?

A. Nothing because total gain is equal

B. Only the numerical display reference

C. Noise weighting and the amplifier's exposure to parent signals

D. Only file storage rate

Answer: C. The location of loss affects both cascade temperature and product generation/loading. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why the selected alternative fits: Noise weighting and the amplifier's exposure to parent signals.

Distinguishing consideration: compare this with option A, “Nothing because total gain is equal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval; Chapter 11 — Ten worked applications of Model 11A.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval; Chapter 11 — Ten worked applications of Model 11A.

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V011-VOL-MCQ-018. A calibrated AGC voltage approaches its target exponentially, but the gain slope is negative. What must an amplitude reconstruction retain?

A. Only the magnitude of control voltage

B. A positive slope by convention

C. The signed voltage-to-gain law and time-resolved state

D. The final settled gain applied to every earlier sample

Answer: C. State recovery and gain calibration are separate parts of the measurement operator. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why the selected alternative fits: The signed voltage-to-gain law and time-resolved state.

Distinguishing consideration: compare this with option A, “Only the magnitude of control voltage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-MCQ-019. An AGC model predicts no overshoot, but the observed trace overshoots after a blocker. What is justified?

A. The single uninterrupted one-pole segment is inadequate for that response

B. The receiver necessarily suffered permanent damage

C. The same model becomes valid by changing plot scale

D. The measured overshoot must be deleted as impossible

Answer: A. Additional state, changed target or another identified mechanism is needed before using its correction. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why the selected alternative fits: The single uninterrupted one-pole segment is inadequate for that response.

Distinguishing consideration: compare this with option B, “The receiver necessarily suffered permanent damage”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 16 — Localize an artifact by changing the stage that could….

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-MCQ-020. A trigger follows narrow filtering and AGC while the recorder stores wider raw samples. What must a burst claim establish?

A. The actual trigger-path and saved-data validity relationship

B. That a long file proves full event capture

C. That a shared sample clock removes control latency

D. That nominal recorder bandwidth guarantees every trigger

Answer: A. Trigger filtering and control can change detection opportunity independently of stored bandwidth. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: The actual trigger-path and saved-data validity relationship.

Distinguishing consideration: compare this with option B, “That a long file proves full event capture”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 10 — SDR Boundary and Partitioning; Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 10 — SDR Boundary and Partitioning; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-MCQ-021. A real high-side conversion reverses spectral orientation before complex demodulation. What metadata prevent a false modulation conclusion?

A. Selected conversion sign and downstream complex-frequency convention

B. Only antenna serial number

C. Only absolute center frequency

D. Only detector display span

Answer: A. Retaining signed representation connects analog conversion to digital phase/frequency interpretation. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: Selected conversion sign and downstream complex-frequency convention.

Distinguishing consideration: compare this with option B, “Only antenna serial number”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-VOL-MCQ-022. A real conversion admits both desired and image fields coherently. Why may adding their separate powers be wrong?

A. Images always contribute exactly half the desired power

B. Gain correction removes all coherent cross terms

C. Every pair of frequencies is statistically independent

D. Their cross term depends on relative phase

Answer: D. Coherent combination requires field/phase treatment before a scalar power budget. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: Their cross term depends on relative phase.

Distinguishing consideration: compare this with option A, “Images always contribute exactly half the desired power”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 9 — Define the ensemble before normalizing.

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V011-VOL-MCQ-023. An apparent component moves when LO changes. What additional record makes this a discriminating image/spur test?

A. Only the fact that any movement occurred

B. The predicted signed mapping, admission and desired-reference response

C. A likelihood score assigned from one favorable result

D. Only a larger frequency span

Answer: B. Several mechanisms can move; the model and controlled path give the movement meaning. Source: §4.18 From a product map to a discriminating test (p. 1949)

Why the selected alternative fits: The predicted signed mapping, admission and desired-reference response.

Distinguishing consideration: compare this with option A, “Only the fact that any movement occurred”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — From a product map to a discriminating test; Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 4 — From a product map to a discriminating test; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-MCQ-024. A source at one analog frequency aliases into a digital channel. Which controls jointly support localization?

A. Analog admission plus a predicted sample-rate-dependent mapping

B. Only post-FFT label changes

C. Only replotting the same samples with another color map

D. Only an unchanged amplitude reference

Answer: A. Sampling equivalence and physical band selection must be considered together. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: Analog admission plus a predicted sample-rate-dependent mapping.

Distinguishing consideration: compare this with option B, “Only post-FFT label changes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function; Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation; Chapter 16 — Localize an artifact by changing the stage that….

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-MCQ-025. A known SSB signal sounds reversed after receiver retuning. Which review is most relevant?

A. Only expanded amplitude uncertainty

B. Only mean output power

C. Conversion orientation, reinsertion offset and digital mixing sign

D. Only total file size

Answer: C. Audio interpretation depends on the signed frequency path and coherent demodulator convention. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why the selected alternative fits: Conversion orientation, reinsertion offset and digital mixing sign.

Distinguishing consideration: compare this with option A, “Only expanded amplitude uncertainty”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-VOL-MCQ-026. Zero padding produces a finer FFT grid for the same brief burst. What has not increased?

A. Measured time history or intrinsic resolving evidence

B. The convenience of sampling the transform curve

C. The stored padding length

D. The number of plotted transform points

Answer: A. Representation changes do not create longer observation or improve missing-event coverage. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: Measured time history or intrinsic resolving evidence.

Distinguishing consideration: compare this with option B, “The convenience of sampling the transform curve”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 9 — Define the record before interpreting the display; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-MCQ-027. An FFT peak is used as a noise density estimate with coherent-tone normalization. What needs correction?

A. Assume tone and density denominators are always identical

B. Only change the peak color

C. Use the window-energy and sampling normalization appropriate to density

D. Only add more zero padding

Answer: C. Amplitude, density and integrated-power conventions answer different questions. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Use the window-energy and sampling normalization appropriate to density.

Distinguishing consideration: compare this with option A, “Assume tone and density denominators are always identical”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator; Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 9 — Noise density uses a different denominator; Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-MCQ-028. A narrow RBW lowers displayed noise but fails to settle during a fast sweep. What conclusion follows?

A. Every lower noise floor proves improved sensitivity

B. The spectrum is valid if its trace is smooth

C. The nominal noise benefit does not validate the transient/swept measurement

D. A detector correction removes all sweep dynamics

Answer: C. Bandwidth, time trajectory and usable acquisition must be validated together. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why the selected alternative fits: The nominal noise benefit does not validate the transient/swept measurement.

Distinguishing consideration: compare this with option A, “Every lower noise floor proves improved sensitivity”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 15 — Model 15A: calculate conditional event….

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-MCQ-029. Two independent channels show coherence one from a single nonzero Fourier pair. What is the main caution?

A. The channels must have identical noise temperature

B. A single pair establishes a population covariance

C. Coherence one uniquely identifies a shared emitter

D. A one-pair normalized estimate can be identically one without proving physical coupling

Answer: D. The ensemble and averaging structure determine the inferential meaning of coherence. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why the selected alternative fits: A one-pair normalized estimate can be identically one without proving physical coupling.

Distinguishing consideration: compare this with option A, “The channels must have identical noise temperature”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the ensemble before normalizing; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 9 — Define the ensemble before normalizing; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-VOL-MCQ-030. Reversing cross-spectrum channel order conjugates its phase. What downstream quantity can change sign if the convention is ignored?

A. The file hash of unchanged bytes

B. Total positive auto-power alone

C. The number of samples

D. Inferred delay or phase lead

Answer: D. Channel order and phase convention must be linked to timing interpretation. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

Why the selected alternative fits: Inferred delay or phase lead.

Distinguishing consideration: compare this with option A, “The file hash of unchanged bytes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-VOL-MCQ-031. Two spectrum displays differ because one averages dBm and the other logs averaged powers. What should be compared first?

A. Their actual estimators and source statistics

B. Only instrument calibration dates

C. Only the larger displayed peak

D. Only their number of averages

Answer: A. Noncommuting operations can explain differences without a physical source change. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

Why the selected alternative fits: Their actual estimators and source statistics.

Distinguishing consideration: compare this with option B, “Only instrument calibration dates”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace; Chapter 9 — Averaging and Statistical Stability; Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace; Chapter 9 — Averaging and Statistical Stability; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-MCQ-032. Subtracting a background trace in dBm is proposed to recover added noise. What should replace that operation under a valid additive-power model?

A. Take their arithmetic mean in dBm

B. Subtract the two dBm labels as physical power

C. Subtract standard deviations instead of means

D. Subtract compatible linear powers before any log transform

Answer: D. A level difference is a ratio; a power difference has its own domain and covariance. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: Subtract compatible linear powers before any log transform.

Distinguishing consideration: compare this with option A, “Take their arithmetic mean in dBm”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before….

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-MCQ-033. An intermittent noise process violates the common-mean exponential assumption used for a log-bias correction. What is defensible?

A. Assume mixtures retain every single-state gamma formula

B. Use the same correction because both traces are called noise

C. Increase display precision until the bias disappears

D. Reassess the distribution/model and estimator instead of transferring the fixed correction

Answer: D. Statistical correction depends on the source law as well as operation order. Source: §8.4.1 A stated statistical model (p. 4431)

Why the selected alternative fits: Reassess the distribution/model and estimator instead of transferring the fixed correction.

Distinguishing consideration: compare this with option A, “Assume mixtures retain every single-state gamma formula”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — A stated statistical model; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 8 — A stated statistical model; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-VOL-MCQ-034. A deterministic two-tone envelope has zeros and reversals. What can magnitude-only detection lose that coherent analysis retains?

A. The existence of every power sample

B. The FFT grid spacing

C. The sign or phase relation across reversal

D. The nominal receiver center frequency

Answer: C. Magnitude folding can discard information needed for a coherent interpretation. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

Why the selected alternative fits: The sign or phase relation across reversal.

Distinguishing consideration: compare this with option A, “The existence of every power sample”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 7 — Model 7A: a finite, declared EVM comparison.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 7 — Model 7A: a finite, declared EVM comparison.

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V011-VOL-MCQ-035. A fitted complex gain removes a fixed phase rotation from EVM. What should a timing acceptance report retain?

A. A zero delay uncertainty inferred from zero residual

B. The fitted phase and an unfitted or separately scoped timing result

C. Only the lower fitted EVM as proof of zero phase error

D. A claim that the physical clock improved

Answer: B. Alignment can remove the effect being assessed; fit freedom belongs in the metric definition. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: The fitted phase and an unfitted or separately scoped timing result.

Distinguishing consideration: compare this with option A, “A zero delay uncertainty inferred from zero residual”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-VOL-MCQ-036. A clean EVM is computed only from settled payload symbols after excluding startup. What broader claim remains unsupported?

A. The declared residual calculation on retained symbols

B. Quality of the explicitly selected settled population

C. Quality of the entire burst including acquisition transients

D. The existence of the saved payload samples

Answer: C. Selection and coverage limits must travel with the result. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: Quality of the entire burst including acquisition transients.

Distinguishing consideration: compare this with option A, “The declared residual calculation on retained symbols”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-MCQ-037. Repeated frames occupy many samples but deliver the same payload positions. What should unique throughput count?

A. Every retransmitted coded bit as new information

B. The number of visible constellation points

C. Each distinct delivered payload position once over the declared wall interval

D. Only the highest active symbol rate

Answer: C. Finite rate accounting and recording chronology must use compatible populations. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: Each distinct delivered payload position once over the declared wall interval.

Distinguishing consideration: compare this with option A, “Every retransmitted coded bit as new information”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-038. A decoder reports low EVM on a training record but fails an independent valid waveform. What is the review priority?

A. Average both EVMs without preserving populations

B. Declare success from the training residual alone

C. Infer the new waveform is unauthorized

D. Separate fitted from held-out performance and inspect alignment/selection

Answer: D. Fit quality is conditional on training and does not establish general demodulation validity. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: Separate fitted from held-out performance and inspect alignment/selection.

Distinguishing consideration: compare this with option A, “Average both EVMs without preserving populations”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Interpret hypothetical receiver records.

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V011-VOL-MCQ-039. Can correct symbol classification alone establish a transmitter's surveillance purpose?

A. Only if the center frequency is stable

B. Yes, if EVM is low

C. Yes, if two decoders show the same identifier

D. No; operational linkage, information path and authorization evidence are additional

Answer: D. Demodulation results and functional attribution are different evidence levels. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

Why the selected alternative fits: No; operational linkage, information path and authorization evidence are additional.

Distinguishing consideration: compare this with option A, “Only if the center frequency is stable”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-MCQ-040. A 1-second record has a constant fractional clock error 0.5 ppm with zero initial error. What time error accumulates?

A. 50 ps

B. 500 ns

C. 0.5 ns

D. 5μs

Answer: B. Time error is fractional frequency error times elapsed time under the deterministic law; timestamps need that relationship. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why the selected alternative fits: 500 ns.

Distinguishing consideration: compare this with option A, “50 ps”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Metadata, Time, and Site Context.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Metadata, Time, and Site Context.

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V011-VOL-MCQ-041. A common random phase rotates every sample equally in one record. What can remain unchanged?

A. Every inter-record phase difference

B. The squared magnitude of the coherent sum within that record

C. All deterministic timing errors

D. Its phase relative to an external reference

Answer: B. Common rotation preserves within-record magnitude, but absolute or cross-record phase claims differ. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

Why the selected alternative fits: The squared magnitude of the coherent sum within that record.

Distinguishing consideration: compare this with option A, “Every inter-record phase difference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power; Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power; Chapter 9 — Define the ensemble before normalizing.

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V011-VOL-MCQ-042. Two channels share a clock but have unknown aperture offsets. Which claim requires additional calibration?

A. A known sample-count format

B. A shared nominal frequency source

C. Aligned sample-time or interchannel phase at the measurement boundary

D. The existence of the common cable

Answer: C. Shared frequency does not establish epochs, apertures, trigger mapping or delay. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: Aligned sample-time or interchannel phase at the measurement boundary.

Distinguishing consideration: compare this with option A, “A known sample-count format”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state; Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-VOL-MCQ-043. Identical RMS jitter values measured over different offset bands are compared as interchangeable. What is missing?

A. The spectral integration band, carrier conversion and relevant weighting

B. Only the nominal record length

C. Only more decimal places

D. Only the receiver's serial number

Answer: A. A scalar RMS can hide spectral placement affecting coherent or blocker response. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: The spectral integration band, carrier conversion and relevant weighting.

Distinguishing consideration: compare this with option B, “Only the nominal record length”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-VOL-MCQ-044. An oscillator has low integrated jitter but elevated noise at a strong blocker's offset. Which assessment remains necessary?

A. Only the average frequency error

B. Channel-weighted reciprocal-mixing impact

C. Only the ADC's nominal bit count

D. Only the total jitter number

Answer: B. Reciprocal mixing depends on the phase-noise density where the blocker maps into the observation channel. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why the selected alternative fits: Channel-weighted reciprocal-mixing impact.

Distinguishing consideration: compare this with option A, “Only the average frequency error”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-VOL-MCQ-045. A calibrated delay correction is applied after a reference reset that changes phase. What should be checked?

A. Repeatability at the actual state boundary and phase branch

B. Only steady amplitude agreement

C. Only the carrier's average frequency

D. Only the old delay uncertainty

Answer: A. A correction's numerical precision does not establish its applicability after a consequential state change. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: Repeatability at the actual state boundary and phase branch.

Distinguishing consideration: compare this with option B, “Only steady amplitude agreement”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-VOL-MCQ-046. Deleting missing samples makes stored offsets contiguous. What is lost if absolute source indices are not retained?

A. Only unused file padding

B. The true elapsed-time and oscillator-phase relationship across the gap

C. Nothing because the remaining bytes are ordered

D. Only a redundant filename field

Answer: B. The physical sample grid differs from packed storage positions. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why the selected alternative fits: The true elapsed-time and oscillator-phase relationship across the gap.

Distinguishing consideration: compare this with option A, “Only unused file padding”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-047. A causal filter's output uses a missing input even though its own output timestamp is present. What follows?

A. That output may be invalid and the support-dependent tail must be tracked

B. The output is valid because it was saved

C. Only the missing input instant is affected

D. A file hash repairs the filter history

Answer: A. Validity follows actual convolution support and retained decimation indices. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why the selected alternative fits: That output may be invalid and the support-dependent tail must be tracked.

Distinguishing consideration: compare this with option B, “The output is valid because it was saved”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-048. An NCO restarts phase at each file block despite continuous input. What should be preserved instead when the intended operator is continuous?

A. Only a final spectrum image

B. Only equal block lengths

C. A separate zero phase for every export

D. Absolute phase/index state across ordinary boundaries

Answer: D. Block representation should not change the declared mixing operator or coherence. Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why the selected alternative fits: Absolute phase/index state across ordinary boundaries.

Distinguishing consideration: compare this with option A, “Only a final spectrum image”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 12 — Accept coherence at the required boundary and state.

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V011-VOL-MCQ-049. A signed sample file is read with the wrong binary point. Which independent check is most direct?

A. Only successful file opening

B. Only the byte hash

C. Only the number of samples

D. A known waveform with declared format, scale and expected physical amplitude

Answer: D. Integrity and format validity are different obligations in reproducible calibrated processing. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why the selected alternative fits: A known waveform with declared format, scale and expected physical amplitude.

Distinguishing consideration: compare this with option A, “Only successful file opening”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Signed formats and explicit conversion points; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — Signed formats and explicit conversion points; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-050. Rounding error is small, but a fixed-point sum overflows. What is the correct assessment?

A. The range obligation failed despite a favorable local quantization-error estimate

B. Digital scaling always preserves clipped values

C. The uncertainty budget can absorb arbitrary overflow

D. Small rounding error proves the arithmetic valid

Answer: A. Quantization error and representable range must both be satisfied.

Source: §10.34 Range and error are separate obligations (p. 5728)

Why the selected alternative fits: The range obligation failed despite a favorable local quantization-error estimate.

Distinguishing consideration: compare this with option B, “Digital scaling always preserves clipped values”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Range and error are separate obligations; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 10 — Range and error are separate obligations; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-MCQ-051. Digital gain is increased after analog signal and noise are already acquired. Which improvement is not created by that scaling alone?

A. The displayed level when not compensated

B. The preexisting analog SNR

C. The numerical sample magnitudes

D. The possibility of a different output representation

Answer: B. Scaling cannot recover SNR or information already lost upstream.

Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

Why the selected alternative fits: The preexisting analog SNR.

Distinguishing consideration: compare this with option A, “The displayed level when not compensated”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval; Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval; Chapter 10 — Quantization margin and channel bandwidth.

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V011-VOL-MCQ-052. A claim of secure executable identity is offered as proof of correct RF behavior. What additional evidence is required?

A. Only successful installation

B. Configuration-specific behavioral tests using appropriate references

C. Only another copy of the executable hash

D. Only a signed filename

Answer: B. Artifact identity binds code bytes, while measurement behavior depends on configuration and physical path. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why the selected alternative fits: Configuration-specific behavioral tests using appropriate references.

Distinguishing consideration: compare this with option A, “Only successful installation”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-MCQ-053. Two equal-tone intermodulation parents are changed together. What must remain explicit when extrapolating an intercept?

A. Per-tone convention, stage plane, local cubic domain and linear asymptote

B. A universal converter noise model

C. Only total combined parent power without convention

D. A claim that the intercept is an attainable operating power

Answer: A. An extrapolated local model is not a full system dynamic-range guarantee. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: Per-tone convention, stage plane, local cubic domain and linear asymptote.

Distinguishing consideration: compare this with option B, “A universal converter noise model”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 3 — Choose gain from a feasible interval; Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 3 — Choose gain from a feasible interval; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-MCQ-054. A coherent source-generated product overlaps the receiver product. Why is simple power subtraction invalid?

A. A background dBm subtraction removes the phasor automatically

B. All products at one frequency add incoherently

C. A receiver intercept fit makes source purity irrelevant

D. Unknown relative phase can cause reinforcement or cancellation

Answer: D. Contamination at the same frequency needs field/phase bounds or independent source characterization. Source: §11.9 Ten worked applications of Model 11A (p. 6376)

Why the selected alternative fits: Unknown relative phase can cause reinforcement or cancellation.

Distinguishing consideration: compare this with option A, “A background dBm subtraction removes the phasor automatically”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Ten worked applications of Model 11A; Chapter 4 — Model 4A: a declared conversion map; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 11 — Ten worked applications of Model 11A; Chapter 4 — Model 4A: a declared conversion map; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-MCQ-055. A blocker raises noise while the weak reference gain remains stable. Which combined test is more informative than declaring compression?

A. Infer source identity from the noise-rise magnitude

B. Apply a quiet-state gain correction repeatedly

C. Inspect only the quiet-state noise floor without the admitted blocker

D. Check admitted blocker spectrum, oscillator phase noise and fixed channel weighting

Answer: D. The observation may fit reciprocal mixing or source contamination; distinguish mechanisms with preserved transfer. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

Why the selected alternative fits: Check admitted blocker spectrum, oscillator phase noise and fixed channel weighting.

Distinguishing consideration: compare this with option A, “Infer source identity from the noise-rise magnitude”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions; Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 16 — Localize an artifact by changing the stage….

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions; Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-MCQ-056. A blocker changes gain, bandwidth and baseline together. Can a simple paired-power subtraction retain its original meaning?

A. Yes, because subtraction always isolates new noise

B. Only after the fixed-transfer and compatible-band conditions are restored or modeled

C. Yes, if the output powers are positive

D. No measurement can ever be made again

Answer: B. The subtraction model assumes comparable states, not merely two recorded numbers. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why the selected alternative fits: Only after the fixed-transfer and compatible-band conditions are restored or modeled.

Distinguishing consideration: compare this with option A, “Yes, because subtraction always isolates new noise”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Application 14B.9: subtract paired powers before….

Review: Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-MCQ-057. An antenna-terminal conducted reference passes while an installed field estimate changes with cable route. What scope should be retained?

A. A proof that the antenna certificate is invalid everywhere

B. A universal field calibration from the conducted pass

C. A proof that the external field must have changed

D. The bounded conducted transfer plus an unresolved installed-coupling effect

Answer: D. Terminal and field measurands add different geometry and common-mode dependencies. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why the selected alternative fits: The bounded conducted transfer plus an unresolved installed-coupling effect.

Distinguishing consideration: compare this with option A, “A proof that the antenna certificate is invalid everywhere”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Keep field conversion separate from terminal power; Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 13 — Keep field conversion separate from terminal power; Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-MCQ-058. A battery/optical substitution removes a line but degrades weak-reference sensitivity. What is the principal limitation?

A. The old line is therefore physically false

B. Isolation uniquely proves conductive pickup

C. Disappearance is confounded by lost observation capability

D. The weaker path automatically provides more independent evidence

Answer: C. The intervention changes both coupling and measurement capability.

Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why the selected alternative fits: Disappearance is confounded by lost observation capability.

Distinguishing consideration: compare this with option A, “The old line is therefore physically false”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 16 — Preserve comparable observation capability.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-MCQ-059. A remote amplifier correction already includes an adapter, which a second file adds again. Which review detects the fault?

A. More repeated readings of the same corrected value

B. A larger covariance matrix alone

C. Explicit correction ownership and independent forward/reverse level closure

D. Only matching file dates

Answer: C. Double correction is an implementation/configuration error, not residual uncertainty. Source: §13.2 Define a complete path at named planes (p. 7537)

Why the selected alternative fits: Explicit correction ownership and independent forward/reverse level closure.

Distinguishing consideration: compare this with option A, “More repeated readings of the same corrected value”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 13 — Define a complete path at named planes; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 13 — Define a complete path at named planes; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-MCQ-060. Hot and cold source impedances differ while a scalar ENR correction is applied. What must be considered?

A. Only source power with receiver gain/noise guaranteed fixed

B. Changed delivered noise and impedance-dependent receiver response

C. Only the number of averaging sweeps

D. Only the room-temperature label

Answer: B. The matched noise inversion can fail at both source transfer and receiver response boundaries. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why the selected alternative fits: Changed delivered noise and impedance-dependent receiver response.

Distinguishing consideration: compare this with option A, “Only source power with receiver gain/noise guaranteed fixed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Invert the same model with two source temperatures; Chapter 13 — Treat connections and unused branches as part of the network; Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 13 — Treat connections and unused branches as part of the network; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-MCQ-061. Two correction inputs share a reference and enter with opposite signs. Which uncertainty treatment is appropriate?

A. Use their supported covariance or an explicit common input consistently

B. Choose correlation solely to minimize the final interval

C. Treat every budget row as independent automatically

D. Count the common uncertainty independently and again as a separate added term

Answer: A. The signed measurement function determines cancellation; bookkeeping must avoid duplication. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: Use their supported covariance or an explicit common input consistently.

Distinguishing consideration: compare this with option B, “Choose correlation solely to minimize the final interval”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 14 — Use covariance and model sensitivity....

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 14 — Use covariance and model sensitivity deliberately.

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V011-VOL-MCQ-062. A nonlinear calibration result has a zero derivative at its estimate. Which check is still needed?

A. Whether curvature or the input domain produces nonzero output dispersion

B. Whether the output must equal its mean exactly

C. Whether multiplying zero by two creates adequate coverage

D. Whether all inputs are therefore nonrandom

Answer: A. Local first-order propagation can omit the controlling mechanism.

Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why the selected alternative fits: Whether curvature or the input domain produces nonzero output dispersion.

Distinguishing consideration: compare this with option B, “Whether the output must equal its mean exactly”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law; Chapter 2 — Invert the same model with two source temperatures.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law; Chapter 2 — Invert the same model with two source temperatures.

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V011-VOL-MCQ-063. A positive on/off central difference has an uncertainty domain including nonpositive values. What should be reported first?

A. The linear difference and its supported interpretation before a logarithmic claim

B. A finite dBm value for every possible difference

C. Only the positive center with no domain limitation

D. The log of its absolute value as equivalent signal power

Answer: A. Physical and transform-domain boundaries are part of a valid inverse and uncertainty model. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: The linear difference and its supported interpretation before a logarithmic claim.

Distinguishing consideration: compare this with option B, “A finite dBm value for every possible difference”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before….

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-MCQ-064. A result below an upper limit has an expanded interval crossing the limit under the declared three-outcome rule. What is supported?

A. An indeterminate decision

B. Automatic acceptance from the central value

C. A changed limit selected after seeing the result

D. Automatic proof of exceedance

Answer: A. Coverage convention and decision rule are distinct and must remain predeclared. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: An indeterminate decision.

Distinguishing consideration: compare this with option B, “Automatic acceptance from the central value”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 14 — Declare the decision rule before seeing the result; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-MCQ-065. Increasing repeated measurements barely reduces a common-calibration-dominated uncertainty. What change targets the remaining limitation?

A. Removing covariance terms to force independence

B. Only more identical repeats indefinitely

C. Changing the result's units to reduce the numeric uncertainty

D. Better characterization of the shared correction or reference

Answer: D. Averaging reduces appropriate independent reading noise, not the common uncertainty floor. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why the selected alternative fits: Better characterization of the shared correction or reference.

Distinguishing consideration: compare this with option A, “Removing covariance terms to force independence”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove; Chapter 15 — Reproducible Analysis and Derived Products.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove; Chapter 15 — Reproducible Analysis and Derived Products.

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V011-VOL-MCQ-066. Can a 95 percent coverage claim for a calibrated level be reused as a 95 percent probability of intercept?

A. Yes; factor two creates both automatically

B. No; the latter needs event, schedule and detector assumptions

C. Yes; both use percentages

D. Only if the level is in dBm

Answer: B. Measurement uncertainty coverage and event-capture probability describe different random quantities. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why the selected alternative fits: No; the latter needs event, schedule and detector assumptions.

Distinguishing consideration: compare this with option A, "Yes; factor two creates both automatically"; that competing statement does not meet the question's stated requirement.

Basis and limitation: Chapter 14 — Declare the decision rule before seeing the result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 14 — Declare the decision rule before seeing the result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-MCQ-067. A burst lasts 5 ms but only 2 ms are usable after verified gain recovery. The analysis requires 3 ms within one record. What follows?

A. Two disconnected 1.5 ms pieces automatically suffice

B. This occurrence does not meet the contiguous criterion

C. Nominal 5 ms duration guarantees qualification

D. A low noise figure supplies the missing time

Answer: B. Usable data and the stated estimator duration govern the capture claim.

Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why the selected alternative fits: This occurrence does not meet the contiguous criterion.

Distinguishing consideration: compare this with option A, “Two disconnected 1.5 ms pieces automatically suffice”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 3 — Measure protection in the small-signal and….

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 3 — Measure protection in the small-signal and recovery states.

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V011-VOL-MCQ-068. A phase-locked event misses a sweep window repeatedly. Which change can create genuinely new timing opportunity?

A. Save the same trace under more filenames

B. Increase amplitude correction precision only

C. Change usable schedule or establish justified independent phase variation

D. Apply the independent-trial formula to unchanged misses

Answer: C. Opportunity is a temporal relationship, not a count of records. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why the selected alternative fits: Change usable schedule or establish justified independent phase variation.

Distinguishing consideration: compare this with option A, “Save the same trace under more filenames”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-VOL-MCQ-069. Trigger and data paths have different bandwidths. What does a complete capture report need beyond a trigger flag?

A. Verified boundaries, valid pre/post context and sample continuity

B. Only a stable center-frequency tone

C. Only a high trigger count

D. Only the trigger's nominal threshold

Answer: A. Trigger occurrence does not establish retained waveform completeness.

Source: §10.1 SDR Boundary and Partitioning (p. 5679)

Why the selected alternative fits: Verified boundaries, valid pre/post context and sample continuity.

Distinguishing consideration: compare this with option B, “Only a stable center-frequency tone”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — SDR Boundary and Partitioning; Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 10 — SDR Boundary and Partitioning; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-MCQ-070. A continuous file crosses a rollover boundary without lost samples. How should its FFT and burst-continuity handling proceed?

A. Discard one sample from each file to avoid overlap

B. Preserve filter/index history and treat the boundary according to verified physical continuity

C. Declare a dead interval equal to one file duration

D. Reset all processing state merely because the filename changed

Answer: B. Storage segmentation need not alter the measurement operator. Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why the selected alternative fits: Preserve filter/index history and treat the boundary according to verified physical continuity.

Distinguishing consideration: compare this with option A, “Discard one sample from each file to avoid overlap”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Define the record before interpreting the display; Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived….

Review: Chapter 9 — Define the record before interpreting the display; Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-071. Two channels each store 16-bit I and 16-bit Q at 20 MS/s. What payload capacity is needed for 100 s, before overhead?

A. 8 GB

B. 16 GB

C. 160 GB

D. 32 GB

Answer: B. The rate is 160 MB/s, so 100 s yields 16 billion bytes; sustained recording still needs validation. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

Why the selected alternative fits: 16 GB.

Distinguishing consideration: compare this with option A, “8 GB”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-VOL-MCQ-072. A native file has a valid hash but gaps were never logged. Which conclusion remains unsupported?

A. That all intended samples were acquired continuously

B. That the file can be copied without changing its current bytes

C. That its byte length can be counted

D. That the preserved bytes match the hash

Answer: A. Byte integrity does not establish acquisition completeness or time mapping. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why the selected alternative fits: That all intended samples were acquired continuously.

Distinguishing consideration: compare this with option B, “That the file can be copied without changing its current bytes”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Close the receiver method through configuration-specific….

Review: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-MCQ-073. A system delivers 8 million unique information bits over 20 s, with 2 s active bursts. Which wall-interval throughput is appropriate?

A. 80Mb/s

B. 0.4Mb/s

C. 4Mb/s

D. 8Mb/s

Answer: B. The denominator is the declared 20 s wall interval; active-burst rate is a different quantity. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: 0.4Mb/s.

Distinguishing consideration: compare this with option A, “80Mb/s”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-074. Some payload frames overlap between captures from two channels. How should total unique delivery be counted?

A. Deduplicate the declared payload positions before dividing by the common interval

B. Count every channel's sample words as information bits

C. Use the channel with the highest symbol rate only

D. Add both decoded counts regardless of overlap

Answer: A. Shared observations and repeated payload do not create new delivered information. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why the selected alternative fits: Deduplicate the declared payload positions before dividing by the common interval.

Distinguishing consideration: compare this with option B, “Count every channel's sample words as information bits”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-MCQ-075. A multichannel spectral phase appears inconsistent after a gap is silently deleted. What should be audited jointly?

A. Absolute sample indices, cross-spectrum order and timing reference

B. Only the nominal antenna gain

C. Only the plotted coherence color range

D. Only the amplitude calibration date

Answer: A. The representation and timing conventions determine the meaning of phase. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

Why the selected alternative fits: Absolute sample indices, cross-spectrum order and timing reference.

Distinguishing consideration: compare this with option B, “Only the nominal antenna gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-VOL-MCQ-076. An EVM fit removes a frequency/phase trend that a clock diagnostic intended to measure. What should the report do?

A. Replace every timing uncertainty with the fitted EVM

B. Call the fitted result proof of an improved clock

C. Disclose fit freedom and retain the unremoved timing quantity or a separately defined metric

D. Ignore training/evaluation distinction

Answer: C. A processing alignment can conceal a physical impairment without repairing it. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: Disclose fit freedom and retain the unremoved timing quantity or a separately defined metric.

Distinguishing consideration: compare this with option A, “Replace every timing uncertainty with the fitted EVM”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-VOL-MCQ-077. An observed AM envelope is altered by asymmetric sideband filtering. Which inference needs restraint?

A. The filter's measured response at tested frequencies

B. Source modulation depth inferred from the receiver output alone

C. The fact that the receiver retained some waveform

D. The distinction between carrier and sidebands

Answer: B. Receiver transfer can change the envelope; demodulator interpretation must use the admitted complex components. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why the selected alternative fits: Source modulation depth inferred from the receiver output alone.

Distinguishing consideration: compare this with option A, “The filter's measured response at tested frequencies”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 3 — Use preselection as a measured transfer function; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 14 — Build a correction chain with signs that can be checked.

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V011-VOL-MCQ-078. A phase-difference estimator crosses a signal zero or reset. What must be retained?

A. The assumption that every phase difference is unique

B. Only wrapped phase samples joined without qualification

C. Validity flags, branch/reset information and the appropriate interval interpretation

D. A universal instantaneous frequency at the discontinuity

Answer: C. Phase-derived frequency and timing need a valid representation and state history. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

Why the selected alternative fits: Validity flags, branch/reset information and the appropriate interval interpretation.

Distinguishing consideration: compare this with option A, “The assumption that every phase difference is unique”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and….

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-VOL-MCQ-079. A narrow filter removes an FM sideband region while a scalar amplitude check still passes. What can fail?

A. The definition of nominal carrier frequency

B. Waveform or demodulation fidelity despite acceptable center-tone gain

C. Every possible power measurement automatically

D. Only byte storage format

Answer: B. A scalar transfer point does not establish the full waveform's amplitude/phase response. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why the selected alternative fits: Waveform or demodulation fidelity despite acceptable center-tone gain.

Distinguishing consideration: compare this with option A, “The definition of nominal carrier frequency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 7 — Model 7A: a finite, declared EVM comparison.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 7 — Model 7A: a finite, declared EVM comparison.

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V011-VOL-MCQ-080. Two independently titled reports share the same native samples and decoder. What should a final evidential synthesis avoid?

A. Comparing results for internal consistency

B. Treating their agreement as independent confirmation

C. Retaining shared source identity

D. Using them for different declared observables

Answer: B. Different presentations do not change the underlying error dependencies. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why the selected alternative fits: Treating their agreement as independent confirmation.

Distinguishing consideration: compare this with option A, “Comparing results for internal consistency”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-MCQ-081. A clock-and-switch crossed comparison lacks one state because the receiver cannot lock. What should the finding preserve?

A. A complete interaction conclusion imputed without a model

B. A source identity inferred from the three available labels

C. The missing comparison and limited inference from the remaining states

D. A proof that the missing state would be clean

Answer: C. Physical comparability and missing design cells limit the causal contrast.

Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why the selected alternative fits: The missing comparison and limited inference from the remaining states.

Distinguishing consideration: compare this with option A, “A complete interaction conclusion imputed without a model”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-VOL-MCQ-082. A feature is present only after a gain transition and not in settled data. What is the next useful approach?

A. Delete it from every record because settled calibration passed

B. Apply settled gain to reconstruct all transition samples

C. Infer a unique external burst source from timing alone

D. A dedicated transition experiment with state and usable-time evidence

Answer: D. Control dynamics and acquisition validity define a distinct transient measurement. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why the selected alternative fits: A dedicated transition experiment with state and usable-time evidence.

Distinguishing consideration: compare this with option A, “Delete it from every record because settled calibration passed”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 16 — Preserve comparable observation capability.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-MCQ-083. A line follows keyboard activity and an LED sensor records activity too. What remains to establish RF source linkage?

A. Only coincidence count

B. Only low EVM on the receiver output

C. Only a plausible decoded identifier

D. Independent path/timing controls and physical or operational linkage

Answer: D. The optical observation supports its own direct claim, while shared control or receiver paths remain possible. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

Why the selected alternative fits: Independent path/timing controls and physical or operational linkage.

Distinguishing consideration: compare this with option A, “Only coincidence count”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 15 — Metadata, Time, and Site Context; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence; Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 15 — Metadata, Time, and Site Context; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-MCQ-084. One attenuation challenge disagrees beyond uncertainty after a firmware update. What release action is appropriate?

A. Hide the difference under a new uncertainty selected to pass

B. Declare all prior native data invalid automatically

C. Investigate configuration-specific regression and preserve old/new processing states

D. Assume the update cannot change measurement behavior

Answer: C. A changed implementation can affect actual functions and correction applicability. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why the selected alternative fits: Investigate configuration-specific regression and preserve old/new processing states.

Distinguishing consideration: compare this with option A, “Hide the difference under a new uncertainty selected to pass”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 14 — Calibration Lifecycle and Change Control; Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 14 — Calibration Lifecycle and Change Control; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-MCQ-085. Why should a known artifact library preserve exact exhibiting configuration and stimulus?

A. To turn every similar-looking line into the same cause

B. To replace independent review with visual matching

C. To test applicability of the mechanism to a later observation

D. To eliminate all future reference checks

Answer: C. Reusable evidence is conditional and reproducible, not a universal visual classification rule. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: To test applicability of the mechanism to a later observation.

Distinguishing consideration: compare this with option A, “To turn every similar-looking line into the same cause”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-VOL-MCQ-086. A calibrated receiver meets steady-signal requirements but lacks validated post-retune burst timing. What final scope is defensible?

A. Universal receiver acceptance

B. A declaration that every result is unusable

C. A narrower accepted steady-signal method with explicit burst limitations

D. A 95 percent burst-detection claim from calibration coverage

Answer: C. Method release follows validated functions and retained boundaries.

Source: §14.18 Close the calibration record across the working interval (p. 8147)

Why the selected alternative fits: A narrower accepted steady-signal method with explicit burst limitations.

Distinguishing consideration: compare this with option A, “Universal receiver acceptance”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 14 — Close the calibration record across the working interval; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Close the receiver method through....

Review: Chapter 14 — Close the calibration record across the working interval; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-MCQ-087. A spectrum's noise floor falls after digital decimation. Which question prevents an overstated sensitivity claim?

A. Whether the decimator name implies gain

B. Whether band, normalization and preserved signal/noise transfer changed consistently

C. Whether the data file became smaller

D. Whether the plotted line became smoother only

Answer: B. A narrower noise bandwidth can lower integrated noise, but display scaling and alias control must be included. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Whether band, normalization and preserved signal/noise transfer changed consistently.

Distinguishing consideration: compare this with option A, “Whether the decimator name implies gain”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator; Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 9 — Noise density uses a different denominator; Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-VOL-MCQ-088. Changing a decimation phase shifts which output samples intersect a gap tail. What must the record retain?

A. Absolute phase/index convention and validity support

B. Only final output length

C. Only the filter's nominal cutoff

D. Only the decimation factor

Answer: A. The retained sample set and convolution history determine which outputs remain valid. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why the selected alternative fits: Absolute phase/index convention and validity support.

Distinguishing consideration: compare this with option B, “Only final output length”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Bind sample continuity, storage accounting and derived….

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-089. A coherent integration combines records with individually valid power calibration but unknown phase resets. Which result is unsupported?

A. The fact that each file's bytes are preserved

B. Separate calibrated power results for each accepted record

C. The claimed coherent gain of the combined complex sum

D. The stated noncoherent sum when its own model applies

Answer: C. Power validity does not supply inter-record phase continuity. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: The claimed coherent gain of the combined complex sum.

Distinguishing consideration: compare this with option A, “The fact that each file's bytes are preserved”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state; Chapter 15 — Bind sample continuity, storage accounting and derived....

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-MCQ-090. A phase-noise line is entered as though it were a density value over an arbitrary FFT bin width. What must be corrected?

A. Only increase the number of averages

B. Only choose a narrower plot span

C. Treat every phase-noise component as independent white noise

D. Distinguish discrete line contribution from a continuous density integral

Answer: D. Spectral measure and normalization determine the phase variance and downstream effects. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why the selected alternative fits: Distinguish discrete line contribution from a continuous density integral.

Distinguishing consideration: compare this with option A, “Only increase the number of averages”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 9 — Noise density uses a different denominator; Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin; Chapter 11 — Define the phase spectrum before converting....

Review: Chapter 9 — Noise density uses a different denominator; Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin; Chapter 11 — Define the phase spectrum before converting decibels.

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V011-VOL-MCQ-091. A system's measured uncertainty improves after canceling a shared phase reference. Which physical condition must support that cancellation?

A. A common frequency label without path calibration

B. Equal effective coupling of the same reference into the difference

C. A desired reduction in reported uncertainty

D. Two separate references with similar model numbers

Answer: B. The signed dependency model must match the actual timing and reference distribution. Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why the selected alternative fits: Equal effective coupling of the same reference into the difference.

Distinguishing consideration: compare this with option A, “A common frequency label without path calibration”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions; Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions; Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-VOL-MCQ-092. A supposedly independent validation pipeline reads the same incorrectly scaled samples. What error can persist in both outputs?

A. Only independent thermal fluctuations

B. No error because implementations differ

C. Only visual plotting differences

D. A common representation/calibration error

Answer: D. Independent algorithms cannot remove a common wrong input convention without reference checks. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why the selected alternative fits: A common representation/calibration error.

Distinguishing consideration: compare this with option A, “Only independent thermal fluctuations”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — Signed formats and explicit conversion points; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 10 — Signed formats and explicit conversion points; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-VOL-MCQ-093. A report quotes an extrapolated intercept as a safe operating input level. What distinction is missing?

A. The fact that decibels are logarithmic

B. Only the storage container width

C. The intercept construction versus the validated local linearity and loading range

D. Only the antenna certificate number

Answer: C. Formal asymptote intersection is not an attainable or guaranteed distortion-free operating point. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

Why the selected alternative fits: The intercept construction versus the validated local linearity and loading range.

Distinguishing consideration: compare this with option A, “The fact that decibels are logarithmic”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 3 — Choose gain from a feasible interval; Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 3 — Choose gain from a feasible interval; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-MCQ-094. A source is detected in one corrected state but missed in another with a raised noise floor and shorter valid dwell. What comparison is needed?

A. Both sensitivity and usable event coverage under the same criterion

B. Only the count of attempts

C. Only the larger nominal bandwidth

D. Only corrected mean gain

Answer: A. A negative observation can fail through amplitude capability or timing opportunity. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

Why the selected alternative fits: Both sensitivity and usable event coverage under the same criterion.

Distinguishing consideration: compare this with option B, “Only the count of attempts”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Preserve comparable observation capability.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-MCQ-095. After a closing reference fails, which record best supports a bounded reassessment?

A. Only an assertion that the instrument looked normal

B. Only a new certificate applied to all earlier states

C. Only the latest corrected output

D. Change times, last valid checks, native observations and function-specific dependencies

Answer: D. The affected interval and claims must follow evidence, not blanket retrospective assumptions. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: Change times, last valid checks, native observations and function-specific dependencies.

Distinguishing consideration: compare this with option A, “Only an assertion that the instrument looked normal”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Close the calibration record across the working interval; Chapter 16 — Reconcile evidence without assigning unsupported....

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Close the calibration record across the working interval; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-MCQ-096. A final result includes native samples, exact processing and a reproducible number but no operational linkage. Which claim can still exceed its evidence?

A. The declared reproducible measured quantity within scope

B. A bounded waveform classification where validated

C. A documented unresolved observation

D. Confirmed technical-surveillance function

Answer: D. Reproducibility supports the measurement; functional attribution requires additional linkage and authorization evidence. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why the selected alternative fits: Confirmed technical-surveillance function.

Distinguishing consideration: compare this with option A, “The declared reproducible measured quantity within scope”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-MCQ-097. Two possible settled gain states give disjoint admissible input-level intervals, with no state probabilities. What should be retained?

A. Every intermediate value declared physically attainable

B. Only the interval yielding the preferred decision

C. Their midpoint with an invented Gaussian uncertainty

D. The union of the state-specific intervals

Answer: D. A set of possible states is not a probability law, and an uncertainty formula cannot supply missing state evidence. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why the selected alternative fits: The union of the state-specific intervals.

Distinguishing consideration: compare this with option A, “Every intermediate value declared physically attainable”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 16 — Close the receiver method through….

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-MCQ-098. Two phase-error vectors have equal marginal RMS but different covariance. Can their finite coherent-power losses be assumed equal?

A. Yes; marginal RMS uniquely fixes every coherence measure

B. Yes; FFT normalization removes covariance

C. No; coherent power is undefined for every random phase

D. No; pairwise phase differences and the distributional model matter

Answer: D. Finite coherent power depends on joint phase behavior, unlike a scalar RMS alone. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why the selected alternative fits: No; pairwise phase differences and the distributional model matter.

Distinguishing consideration: compare this with option A, “Yes; marginal RMS uniquely fixes every coherence measure”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 9 — Define the ensemble before normalizing.

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V011-VOL-MCQ-099. Two SSB waveforms have equal average power but different peak envelopes. What loading assessment remains necessary?

A. Only their shared mean level

B. Their instantaneous peak exposure at vulnerable stages

C. Only their equal integrated FFT power

D. Only their payload bit counts

Answer: B. Average energy closure does not establish equal compression or protection behavior. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

Why the selected alternative fits: Their instantaneous peak exposure at vulnerable stages.

Distinguishing consideration: compare this with option A, “Only their shared mean level”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 3 — Find the first stage that can lose validity; Chapter 11 — Compression and Gain Change.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 3 — Find the first stage that can lose validity; Chapter 11 — Compression and Gain Change.

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V011-VOL-MCQ-100. A missing input block is zero-filled before filtering and marked invalid. What makes this preferable to silently calling the zeros measured data?

A. The gap's timing uncertainty is necessarily zero

B. Every filtered output becomes valid immediately

C. Zero filling exactly reconstructs the missing waveform

D. The sample grid is retained while affected output support remains explicitly qualified

Answer: D. Representational preservation and physical reconstruction are different; support and metadata carry the limitation. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why the selected alternative fits: The sample grid is retained while affected output support remains explicitly qualified.

Distinguishing consideration: compare this with option A, “The gap's timing uncertainty is necessarily zero”; that competing statement does not meet the question’s stated requirement.

Basis and limitation: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 1 — Model 1A: configured transfer, correction and....

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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Fill-in-the-Blank Questions

V011-VOL-FIB-001. To compare antenna-terminal and receiver-plane results, corrections must first refer both to the same physical _____.

Answer: plane. Configuration and uncertainty then describe one declared measurand rather than unlike output labels. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “plane” completes the stated technical proposition.

Question context: To compare antenna-terminal and receiver-plane results, corrections must first refer both to the same physical _____

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 13 — Define a complete path at named planes; Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 13 — Define a complete path at named planes; Chapter 14 — Build a correction chain with signs that can be checked.

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V011-VOL-FIB-002. In a matched fixed-state scalar path with output power 1.5 nW, output-referred additive power 0.5 nW with zero cross-power, and dimensionless power transfer 10, recovered input signal power is _____ nW.

Answer: 0.1. Subtract the compatible linear contribution and divide by gain before taking a logarithm. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “0.1” completes the stated technical proposition.

Question context: In a matched fixed-state scalar path with output power 1.5 nW, output-referred additive power 0.5 nW with zero cross-power, and dimensionless power transfer 10, recovered input signal power is _____ nW

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-FIB-003. An equal-duration physical mean of corrected powers 1 nW and 9 nW is _____ nW.

Answer: 5. The arithmetic mean of logarithmic levels would instead represent a different estimator. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “5” completes the stated technical proposition.

Question context: An equal-duration physical mean of corrected powers 1 nW and 9 nW is _____ nW

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

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V011-VOL-FIB-004. A gain inverse cannot reconstruct waveform information discarded by _____.

Answer: clipping. A numerically defined correction needs a physically recoverable quantity. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)
Why this term is required: “clipping” completes the stated technical proposition.
Question context: A gain inverse cannot reconstruct waveform information discarded by _____
Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 10 — Quantization, Clipping, and Converter Performance.
Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 10 — Quantization, Clipping, and Converter Performance.

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V011-VOL-FIB-005. Unknown settled state should be retained as state-specific admissible sets, not automatically converted into a probability _____.

Answer: distribution. A correction range and a statistical uncertainty require different information. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “distribution” completes the stated technical proposition.

Question context: Unknown settled state should be retained as state-specific admissible sets, not automatically converted into a probability _____

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-VOL-FIB-006. Measurement intervals after gain commands become usable only when actual state _____ is demonstrated.

Answer: validity. Control settling and acquisition guards must agree in time. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why this term is required: “validity” completes the stated technical proposition.

Question context: Measurement intervals after gain commands become usable only when actual state _____ is demonstrated

Basis and qualification: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 1 — Model 1A: configured transfer, correction and….

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-FIB-007. Power-only calibration does not supply the missing _____ needed for coherent combination.

Answer: phase. A supported scalar power can coexist with lost complex information. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “phase” completes the stated technical proposition.

Question context: Power-only calibration does not supply the missing _____ needed for coherent combination

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state.

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V011-VOL-FIB-008. For two matched fixed-state stages with first-stage noise temperature 50 K, second-stage noise temperature 200 K and first-stage power gain 10, total input-equivalent noise temperature is _____ K.

Answer: 70. $50+\frac{200}{10}=70$ under the matched fixed-state model. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “70” completes the stated technical proposition.

Question context: For two matched fixed-state stages with first-stage noise temperature 50 K, second-stage noise temperature 200 K and first-stage power gain 10, total input-equivalent noise temperature is _____ K

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval.

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V011-VOL-FIB-009. If noise requires gain≥10 and loading requires gain≤8, the feasible interval is _____.

Answer: empty. A different architecture or operating condition is needed; a midpoint violates both bounds. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

Why this term is required: “empty” completes the stated technical proposition.

Question context: If noise requires gain≥10 and loading requires gain≤8, the feasible interval is _____

Basis and qualification: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval.

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V011-VOL-FIB-010. A matched loss $L=2$ at 300 K ahead of a 50 K chain gives total equivalent temperature _____ K.

Answer: 400. The passive term is 300 K and referred chain term 100 K. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “400” completes the stated technical proposition.

Question context: A matched loss at 300 K ahead of a 50 K chain gives total equivalent temperature _____ K

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 13 — Treat connections and unused branches as part of the network.

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V011-VOL-FIB-011. The loss-induced thermal contribution depends on the dissipative element's physical _____.

Answer: temperature. Restoring signal level by a correction does not remove the added noise. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)
Why this term is required: “temperature” completes the stated technical proposition.
Question context: The loss-induced thermal contribution depends on the dissipative element's physical _____
Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 13 — Treat connections and unused branches as part of the network; Chapter 14 — Calibrate noise without confusing it with detection.
Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 13 — Treat connections and unused branches as part of the network; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-FIB-012. Reference noise factor uses T_0, while actual SNR degradation uses actual source _____.

Answer: temperature. They coincide under the stated nonzero-added-noise condition only when the source is at T_0. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “temperature” completes the stated technical proposition.

Question context: Reference noise factor uses while actual SNR degradation uses actual source _____

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-FIB-013. For T_h 600 K, T_c 300 K and T_e 300 K at equal gain, the hot/cold ratio is _____.

Answer: 1.5. The same transfer cancels from 900/600. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why this term is required: “1.5” completes the stated technical proposition.

Question context: For 600 K, 300 K and 300 K at equal gain, the hot/cold ratio is _____

Basis and qualification: Chapter 2 — Invert the same model with two source temperatures; Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-FIB-014. A gain change between hot and cold states breaks the assumed common _____ in the ratio.

Answer: transfer. Averaging does not repair a systematic violation of the inversion model. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why this term is required: “transfer” completes the stated technical proposition.

Question context: A gain change between hot and cold states breaks the assumed common _____ in the ratio

Basis and qualification: Chapter 2 — Invert the same model with two source temperatures; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Calibrate noise without confusing it with detection.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-FIB-015. A mixer's unmodeled image-noise path lies outside the simple matched scalar cascade's _____.

Answer: domain. The applicable sideband/channel noise law must be established.

Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

Why this term is required: “domain” completes the stated technical proposition.

Question context: A mixer's unmodeled image-noise path lies outside the simple matched scalar cascade's _____

Basis and qualification: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 4 — Model 4A: a declared conversion map.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 4 — Model 4A: a declared conversion map.

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V011-VOL-FIB-016. Filter rejection should be evaluated at blocker frequencies separately from desired-frequency insertion _____.

Answer: loss. The two transfer columns support different noise and loading conclusions. Source: §3.4 Use preselection as a measured transfer function (p. 1253)
Why this term is required: “loss” completes the stated technical proposition.
Question context: Filter rejection should be evaluated at blocker frequencies separately from desired-frequency insertion _____
Basis and qualification: Chapter 3 — Use preselection as a measured transfer function; Chapter 13 — A constructed acceptance case for the assembled chain.
Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 13 — A constructed acceptance case for the assembled chain.

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V011-VOL-FIB-017. Once an early amplifier clips, a later narrow filter cannot reconstruct the undistorted weak _____.

Answer: signal. Protection must act before the first vulnerable stage. Source: §3.2 Find the first stage that can lose validity (p. 1249)

Why this term is required: “signal” completes the stated technical proposition.

Question context: Once an early amplifier clips, a later narrow filter cannot reconstruct the undistorted weak _____

Basis and qualification: Chapter 3 — Find the first stage that can lose validity; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Compression and Gain Change.

Review: Chapter 3 — Find the first stage that can lose validity; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Compression and Gain Change.

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V011-VOL-FIB-018. Protection survival, event leakage and restored weak-signal _____ are distinct acceptance quantities.

Answer: recovery. Usable event windows depend on the last of these, not survival alone. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

Why this term is required: “recovery” completes the stated technical proposition.

Question context: Protection survival, event leakage and restored weak-signal _____ are distinct acceptance quantities

Basis and qualification: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-FIB-019. An exponential control voltage needs a signed voltage-to-_____ calibration before correcting RF levels.

Answer: gain. The trajectory alone is not an amplitude law. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why this term is required: “gain” completes the stated technical proposition.

Question context: An exponential control voltage needs a signed voltage-to-_____ calibration before correcting RF levels

Basis and qualification: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-FIB-020. A measured overshoot cannot be explained by the same uninterrupted monotone one-_____ segment.

Answer: pole. Additional state or a different model is needed before transfer correction. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
Why this term is required: “pole” completes the stated technical proposition.
Question context: A measured overshoot cannot be explained by the same uninterrupted monotone one-_____ segment
Basis and qualification: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 16 — Localize an artifact by changing the stage that could create it.
Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-FIB-021. Trigger behavior after AGC may depend on its control _____ rather than the original input alone.

Answer: trajectory. The saved-data path and trigger path need separate validation.

Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “trajectory” completes the stated technical proposition.

Question context: Trigger behavior after AGC may depend on its control _____ rather than the original input alone

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-FIB-022. A high-side real conversion can reverse spectral _____ that complex demodulation must retain.

Answer: orientation. Signed frequency conventions connect conversion and baseband interpretation. Source: §4.2 Model 4A: a declared conversion map (p. 1924)
Why this term is required: “orientation” completes the stated technical proposition.
Question context: A high-side real conversion can reverse spectral _____ that complex demodulation must retain
Basis and qualification: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Model 10B for digital mixing filtering and decimation.
Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-VOL-FIB-023. Coherent desired and image contributions can require a phase-dependent cross _____ in power.

Answer: term. Independent addition of their separate powers may omit cancellation or reinforcement. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “term” completes the stated technical proposition.

Question context: Coherent desired and image contributions can require a phase-dependent cross _____ in power

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 9 — Define the ensemble before normalizing.

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V011-VOL-FIB-024. A candidate alias test needs actual sample rate and admitted analog _____, not only a changed plot label.

Answer: band. Sampling equivalence must be tied to physical preselection. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why this term is required: “band” completes the stated technical proposition.

Question context: A candidate alias test needs actual sample rate and admitted analog _____, not only a changed plot label

Basis and qualification: Chapter 3 — Use preselection as a measured transfer function; Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation.

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V011-VOL-FIB-025. Wrong reinsertion frequency or mixing sign can alter an SSB audio _____ without proving a new source.

Answer: interpretation. Demodulation follows the configured signed-frequency chain. Source: §4.2 Model 4A: a declared conversion map (p. 1924)

Why this term is required: “interpretation” completes the stated technical proposition.

Question context: Wrong reinsertion frequency or mixing sign can alter an SSB audio _____ without proving a new source

Basis and qualification: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 10 — Model 10B for digital mixing filtering and decimation.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6A: preserve the complex envelope; Chapter 10 — Model 10B for digital mixing filtering and decimation.

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V011-VOL-FIB-026. Zero padding adds transform-grid points but no additional measured time _____.

Answer: history. It does not extend burst coverage or recover unobserved samples.

Source: §9.3.1 Define the record before interpreting the display (p. 5029)

Why this term is required: “history” completes the stated technical proposition.

Question context: Zero padding adds transform-grid points but no additional measured time _____

Basis and qualification: Chapter 9 — Define the record before interpreting the display; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 9 — Define the record before interpreting the display; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-FIB-027. Noise-density normalization uses window energy rather than only the coherent-tone _____ gain.

Answer: amplitude. The denominator must match the quantity being estimated.

Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “amplitude” completes the stated technical proposition.

Question context: Noise-density normalization uses window energy rather than only the coherent-tone _____ gain

Basis and qualification: Chapter 9 — Noise density uses a different denominator; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 9 — Noise density uses a different denominator; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-VOL-FIB-028. Fast sweep with narrow RBW requires evidence of settling along the frequency-time _____.

Answer: trajectory. A lower displayed floor does not alone establish a valid transient estimate. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why this term is required: “trajectory” completes the stated technical proposition.

Question context: Fast sweep with narrow RBW requires evidence of settling along the frequency-time _____

Basis and qualification: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 15 — Model 15A: calculate conditional event coverage....

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-FIB-029. A coherence estimate from one Fourier pair can be unity without establishing population _____.

Answer: coupling. The finite ensemble and averaging define what can be inferred.

Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

Why this term is required: “coupling” completes the stated technical proposition.

Question context: A coherence estimate from one Fourier pair can be unity without establishing population _____

Basis and qualification: Chapter 9 — Define the ensemble before normalizing; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 9 — Define the ensemble before normalizing; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-VOL-FIB-030. Reversing cross-spectrum channel order conjugates phase and can reverse an inferred delay _____.

Answer: sign. The channel convention must match the timing model. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

Why this term is required: “sign” completes the stated technical proposition.

Question context: Reversing cross-spectrum channel order conjugates phase and can reverse an inferred delay _____

Basis and qualification: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-VOL-FIB-031. The logarithm of averaged powers and the average of logarithmic levels are different _____.

Answer: estimators. Operation order and source statistics affect their values. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

Why this term is required: “estimators” completes the stated technical proposition.

Question context: The logarithm of averaged powers and the average of logarithmic levels are different _____

Basis and qualification: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace; Chapter 9 — Averaging and Statistical Stability.

Review: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace; Chapter 9 — Averaging and Statistical Stability.

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V011-VOL-FIB-032. Recovering added noise under a valid additive model requires subtraction in linear _____ before conversion to dBm.

Answer: power. A difference of dBm values is a ratio, not physical power subtraction. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “power” completes the stated technical proposition.

Question context: Recovering added noise under a valid additive model requires subtraction in linear _____ before conversion to dBm

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before….

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-FIB-033. A log-bias correction based on equal-mean exponential powers needs its statistical _____ rechecked for an intermittent mixture.

Answer: model. Naming both signals noise does not transfer the distributional result. Source: §8.4.1 A stated statistical model (p. 4431)

Why this term is required: “model” completes the stated technical proposition.

Question context: A log-bias correction based on equal-mean exponential powers needs its statistical _____ rechecked for an intermittent mixture

Basis and qualification: Chapter 8 — A stated statistical model; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

Review: Chapter 8 — A stated statistical model; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

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V011-VOL-FIB-034. Magnitude-only envelope detection can lose a coherent envelope _____ at a zero crossing.

Answer: reversal. The complex representation retains phase/sign information discarded by magnitude. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

Why this term is required: “reversal” completes the stated technical proposition.

Question context: Magnitude-only envelope detection can lose a coherent envelope _____ at a zero crossing

Basis and qualification: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-FIB-035. A complex-gain fit can remove a constant phase offset from EVM without correcting the physical _____.

Answer: timing. The fitted coefficient must remain visible when phase is the intended measurand. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why this term is required: “timing” completes the stated technical proposition.

Question context: A complex-gain fit can remove a constant phase offset from EVM without correcting the physical _____

Basis and qualification: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Accept coherence at the required boundary and state.

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V011-VOL-FIB-036. EVM on selected settled symbols describes that population, not automatically the entire _____.

Answer: burst. Startup and omitted intervals retain their own validity and quality limits. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why this term is required: “burst” completes the stated technical proposition.

Question context: EVM on selected settled symbols describes that population, not automatically the entire _____

Basis and qualification: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-FIB-037. Unique payload throughput must count repeated payload positions only _____.

Answer: once. Retransmission and overlapping captures do not create new delivered information. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why this term is required: “once” completes the stated technical proposition.

Question context: Unique payload throughput must count repeated payload positions only _____

Basis and qualification: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-038. A fitted decoder requires _____-out validation to assess performance beyond its training examples.

Answer: held. The finite reference experiment and source record must remain distinct. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why this term is required: “held” completes the stated technical proposition.

Question context: A fitted decoder requires _____-out validation to assess performance beyond its training examples

Basis and qualification: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Interpret hypothetical receiver records.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Interpret hypothetical receiver records.

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V011-VOL-FIB-039. Low EVM and intelligible content do not alone establish operational _____ of a device.

Answer: purpose. Functional attribution requires linkage, information path and authorization evidence. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
Why this term is required: “purpose” completes the stated technical proposition.
Question context: Low EVM and intelligible content do not alone establish operational _____ of a device
Basis and qualification: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Findings, Reports, and Decision Ladders.
Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-FIB-040. A constant 0.5 ppm clock error over 1 s with zero initial error accumulates _____ ns.

Answer: 500. The deterministic time error is fractional frequency error multiplied by elapsed time. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

Why this term is required: “500” completes the stated technical proposition.

Question context: A constant 0.5 ppm clock error over 1 s with zero initial error accumulates _____ ns

Basis and qualification: Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Metadata, Time, and Site Context.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Metadata, Time, and Site Context.

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V011-VOL-FIB-041. A common random phase preserves within-record coherent-sum magnitude while changing its reference _____.

Answer: phase. Magnitude preservation does not establish inter-record or absolute phase alignment. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

Why this term is required: “phase” completes the stated technical proposition.

Question context: A common random phase preserves within-record coherent-sum magnitude while changing its reference _____

Basis and qualification: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power; Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power; Chapter 9 — Define the ensemble before normalizing.

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V011-VOL-FIB-042. A shared clock frequency does not by itself align channel sample _____.

Answer: apertures. Epoch, delay and trigger relationships need calibration at the relevant boundary. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “apertures” completes the stated technical proposition.

Question context: A shared clock frequency does not by itself align channel sample _____

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state; Chapter 10 — Source indices, stored offsets, and time anchors.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 10 — Source indices, stored offsets, and time anchors.

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V011-VOL-FIB-043. Integrated jitter must retain carrier frequency and the phase-noise integration _____.

Answer: band. The same RMS label can hide different spectral placement. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “band” completes the stated technical proposition.

Question context: Integrated jitter must retain carrier frequency and the phase-noise integration _____

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 11 — Integrate the channel that actually produces the reported value.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-VOL-FIB-044. Reciprocal mixing weights oscillator phase noise at offsets set by admitted _____ signals.

Answer: blocker. A favorable integrated-jitter number alone does not bound the channel noise rise. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “blocker” completes the stated technical proposition.

Question context: Reciprocal mixing weights oscillator phase noise at offsets set by admitted _____ signals

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

Review: Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-VOL-FIB-045. A delay correction applied after retuning requires renewed phase-repeatability and _____ applicability.

Answer: branch. A small uncertainty cannot validate an unresolved phase branch or changed state. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “branch” completes the stated technical proposition.

Question context: A delay correction applied after retuning requires renewed phase-repeatability and _____ applicability

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-VOL-FIB-046. Deleting gaps from storage changes file offsets without preserving absolute source sample _____.

Answer: indices. The true elapsed-time and oscillator phase relationships can then be lost. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)
Why this term is required: “indices” completes the stated technical proposition.
Question context: Deleting gaps from storage changes file offsets without preserving absolute source sample _____
Basis and qualification: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Bind sample continuity, storage accounting and derived results.
Review: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-047. Finite-filter output validity depends on whether its nonzero support intersects invalid _____ samples.

Answer: input. A saved output timestamp alone does not establish its validity.

Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “input” completes the stated technical proposition.

Question context: Finite-filter output validity depends on whether its nonzero support intersects invalid _____ samples

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-048. Across ordinary continuous file blocks, the NCO should retain the declared absolute phase _____ .

Answer: state. Resetting it changes the mixing operator and can break coherence.

Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)

Why this term is required: “state” completes the stated technical proposition.

Question context: Across ordinary continuous file blocks, the NCO should retain the declared absolute phase _____

Basis and qualification: Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 12 — Accept coherence at the required boundary and state.

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V011-VOL-FIB-049. A hash cannot detect that unchanged bytes are interpreted with the wrong binary _____ .

Answer: point. Known-reference scaling checks complement file integrity. Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “point” completes the stated technical proposition.

Question context: A hash cannot detect that unchanged bytes are interpreted with the wrong binary _____

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — Signed formats and explicit conversion points; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-050. Fixed-point processing must satisfy representable range as well as rounding-error _____.

Answer: bounds. Overflow can invalidate a calculation with otherwise small local quantization error. Source: §10.34 Range and error are separate obligations (p. 5728)
Why this term is required: “bounds” completes the stated technical proposition.
Question context: Fixed-point processing must satisfy representable range as well as rounding-error _____
Basis and qualification: Chapter 10 — Range and error are separate obligations; Chapter 1 — Model 1A: configured transfer, correction and recoverability.
Review: Chapter 10 — Range and error are separate obligations; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-FIB-051. Digital gain after acquisition does not improve an already established analog signal-to-noise _____.

Answer: ratio. Scaling cannot restore information or SNR lost upstream. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

Why this term is required: “ratio” completes the stated technical proposition.

Question context: Digital gain after acquisition does not improve an already established analog signal-to-noise _____

Basis and qualification: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 10 — Quantization margin and channel bandwidth.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 10 — Quantization margin and channel bandwidth.

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V011-VOL-FIB-052. Signed executable identity must be complemented by configuration-specific _____ tests.

Answer: behavioral. The same code can operate under materially different physical states and settings. Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why this term is required: “behavioral” completes the stated technical proposition.

Question context: Signed executable identity must be complemented by configuration-specific _____ tests

Basis and qualification: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-FIB-053. An intercept extrapolation must retain the _____-tone power convention.

Answer: per. Total two-tone power and per-tone power are different reference choices. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
Why this term is required: “per” completes the stated technical proposition.
Question context: An intercept extrapolation must retain the _____-tone power convention
Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 14 — Attach calibration to a stated measurement result.
Review: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-FIB-054. The formal intercept is not automatically an attainable distortion-free operating _____.

Answer: point. The local model and measured loading range retain their boundaries. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
Why this term is required: “point” completes the stated technical proposition.
Question context: The formal intercept is not automatically an attainable distortion-free operating _____
Basis and qualification: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 3 — Choose gain from a feasible interval.
Review: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 3 — Choose gain from a feasible interval.

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V011-VOL-FIB-055. Coherent source-product contamination requires phasor treatment because unknown _____ can cause cancellation.

Answer: phase. Power-only subtraction is not generally valid for overlapping coherent products. Source: §11.9 Ten worked applications of Model 11A (p. 6376)
Why this term is required: “phase” completes the stated technical proposition.
Question context: Coherent source-product contamination requires phasor treatment because unknown _____ can cause cancellation
Basis and qualification: Chapter 11 — Ten worked applications of Model 11A; Chapter 4 — Model 4A: a declared conversion map; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.
Review: Chapter 11 — Ten worked applications of Model 11A; Chapter 4 — Model 4A: a declared conversion map; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-FIB-056. Noise rise with stable desired gain can motivate a reciprocal-mixing test using fixed channel _____.

Answer: weighting. The spectrum and transfer must be compatible before comparing added power. Source: §11.25 Integrate the channel that actually produces the reported value (p. 6398)

Why this term is required: “weighting” completes the stated technical proposition.

Question context: Noise rise with stable desired gain can motivate a reciprocal-mixing test using fixed channel _____

Basis and qualification: Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 16 — Localize an artifact by changing the stage that could create it.

Review: Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-FIB-057. Changing gain or bandwidth between on/off records violates a simple fixed-_____ subtraction model.

Answer: transfer. The difference may mix state changes with added noise. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

Why this term is required: “transfer” completes the stated technical proposition.

Question context: Changing gain or bandwidth between on/off records violates a simple fixed-_____ subtraction model

Basis and qualification: Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Application 14B.9: subtract paired powers before propagating a….

Review: Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-FIB-058. A conducted terminal reference does not by itself establish antenna-to-_____ conversion.

Answer: field. Geometry, polarization, loading and installed coupling add conditions. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

Why this term is required: “field” completes the stated technical proposition.

Question context: A conducted terminal reference does not by itself establish antenna-to-_____ conversion

Basis and qualification: Chapter 13 — Keep field conversion separate from terminal power; Chapter 14 — Attach calibration to a stated measurement result.

Review: Chapter 13 — Keep field conversion separate from terminal power; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-FIB-059. An optical substitution that hides both anomaly and weak reference has not preserved observation _____.

Answer: capability. Disappearance can be caused by reduced sensitivity. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

Why this term is required: “capability” completes the stated technical proposition.

Question context: An optical substitution that hides both anomaly and weak reference has not preserved observation _____

Basis and qualification: Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 16 — Preserve comparable observation capability.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-FIB-060. An adapter included in two correction files is a correction-_____ error.

Answer: ownership. Independent forward/reverse checks can expose double application. Source: §13.2 Define a complete path at named planes (p. 7537)

Why this term is required: “ownership” completes the stated technical proposition.

Question context: An adapter included in two correction files is a correction-_____ error

Basis and qualification: Chapter 13 — Define a complete path at named planes; Chapter 14 — Build a correction chain with signs that can be checked.

Review: Chapter 13 — Define a complete path at named planes; Chapter 14 — Build a correction chain with signs that can be checked.

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V011-VOL-FIB-061. Hot/cold impedance changes can alter receiver added noise as well as delivered source _____.

Answer: power. The matched scalar inversion may require vector or empirical characterization. Source: §2.16 Invert the same model with two source temperatures (p. 672)

Why this term is required: “power” completes the stated technical proposition.

Question context: Hot/cold impedance changes can alter receiver added noise as well as delivered source _____

Basis and qualification: Chapter 2 — Invert the same model with two source temperatures; Chapter 13 — Treat connections and unused branches as part of the network.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 13 — Treat connections and unused branches as part of the network.

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V011-VOL-FIB-062. Shared calibration errors entering with opposite signed coefficients can _____ in a difference.

Answer: cancel. The covariance or common-input representation must be supported by actual coupling. Source: §14.14 Model 14B: exact covariance and local uncertainty propagation (p. 8127)

Why this term is required: “cancel” completes the stated technical proposition.

Question context: Shared calibration errors entering with opposite signed coefficients can _____ in a difference

Basis and qualification: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

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V011-VOL-FIB-063. A zero local derivative does not imply zero output uncertainty when _____ remains consequential.

Answer: curvature. Nonlinear transformations can retain variation through higher-order terms. Source: §14.14.8 Application 14B.10: expose a zero-sensitivity failure of the local law (p. 8141)

Why this term is required: “curvature” completes the stated technical proposition.

Question context: A zero local derivative does not imply zero output uncertainty when _____ remains consequential

Basis and qualification: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law; Chapter 2 — Invert the same model with two source temperatures.

Review: Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law; Chapter 2 — Invert the same model with two source temperatures.

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V011-VOL-FIB-064. A positive power-difference center does not guarantee that its full domain supports a _____.

Answer: logarithm. Zero or negative possible differences require retaining the linear result and its interpretation. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “logarithm” completes the stated technical proposition.

Question context: A positive power-difference center does not guarantee that its full domain supports a _____

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-FIB-065. Under the chapter's conservative upper-limit interval rule, an interval crossing the limit is _____.

Answer: indeterminate. The central value alone cannot establish acceptance or rejection. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: “indeterminate” completes the stated technical proposition.

Question context: Under the chapter's conservative upper-limit interval rule, an interval crossing the limit is _____

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 14 — Declare the decision rule before seeing the result; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-FIB-066. The unchanged shared calibration contribution sets an uncertainty _____ that independent reading averages cannot remove.

Answer: floor. The measurement equation distinguishes common and reducible terms. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

Why this term is required: “floor” completes the stated technical proposition.

Question context: The unchanged shared calibration contribution sets an uncertainty _____ that independent reading averages cannot remove

Basis and qualification: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove; Chapter 15 — Reproducible Analysis and Derived Products.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove; Chapter 15 — Reproducible Analysis and Derived Products.

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V011-VOL-FIB-067. Expanded level-uncertainty coverage and event-intercept probability use different probability _____.

Answer: models. A percentage from one cannot be transferred to the other. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

Why this term is required: “models” completes the stated technical proposition.

Question context: Expanded level-uncertainty coverage and event-intercept probability use different probability _____

Basis and qualification: Chapter 14 — Declare the decision rule before seeing the result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 14 — Declare the decision rule before seeing the result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-FIB-068. A 5 ms event with only 2 ms of valid data fails a 3 ms _____ overlap requirement.

Answer: contiguous. Nominal event duration cannot supply missing usable observation. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)

Why this term is required: “contiguous” completes the stated technical proposition.

Question context: A 5 ms event with only 2 ms of valid data fails a 3 ms _____ overlap requirement

Basis and qualification: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-FIB-069. Repeated phase-locked misses do not become independent simply because more _____ are saved.

Answer: files. The timing experiment must change or its joint law must be justified.

Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

Why this term is required: “files” completes the stated technical proposition.

Question context: Repeated phase-locked misses do not become independent simply because more _____ are saved

Basis and qualification: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic.

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V011-VOL-FIB-070. A trigger flag alone does not prove complete event boundaries and required _____ were retained.

Answer: context. Trigger and recording paths may differ in bandwidth, latency and validity. Source: §10.1 SDR Boundary and Partitioning (p. 5679)

Why this term is required: “context” completes the stated technical proposition.

Question context: A trigger flag alone does not prove complete event boundaries and required _____ were retained

Basis and qualification: Chapter 10 — SDR Boundary and Partitioning; Chapter 15 — Verify the trigger at its actual signal-path location.

Review: Chapter 10 — SDR Boundary and Partitioning; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-FIB-071. A verified continuous file rollover should preserve filter history and sample _____ .

Answer: indices. A storage boundary need not be a physical gap or processing reset. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “indices” completes the stated technical proposition.

Question context: A verified continuous file rollover should preserve filter history and sample _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-072. At 20 MS/s, two complex channels with 16-bit components require _____ MB/s payload.

Answer: 160. 20 million×2 channels×2 components×2 bytes=160 million bytes per second. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

Why this term is required: “160” completes the stated technical proposition.

Question context: At 20 MS/s, two complex channels with 16-bit components require _____ MB/s payload

Basis and qualification: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-VOL-FIB-073. That 160 MB/s payload over 100 s occupies _____ GB before overhead.

Answer: 16. The units are decimal; reserve and sustained-write behavior remain separate requirements. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

Why this term is required: “16” completes the stated technical proposition.

Question context: That 160 MB/s payload over 100 s occupies _____ GB before overhead

Basis and qualification: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

Review: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-VOL-FIB-074. A stable file hash proves later byte consistency, not original acquisition _____.

Answer: completeness. Counters, sequence and gap evidence establish what was actually sampled. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

Why this term is required: “completeness” completes the stated technical proposition.

Question context: A stable file hash proves later byte consistency, not original acquisition _____

Basis and qualification: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-075. Eight million unique information bits delivered over 20 s give wall-interval throughput _____ Mb/s.

Answer: 0.4. The full interval denominator differs from an active-burst rate. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why this term is required: “0.4” completes the stated technical proposition.

Question context: Eight million unique information bits delivered over 20 s give wall-interval throughput _____ Mb/s

Basis and qualification: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-076. Overlapping payload from two channels must be _____ before reporting unique delivery.

Answer: deduplicated. Multiple observations of the same positions do not increase the unique count. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

Why this term is required: “deduplicated” completes the stated technical proposition.

Question context: Overlapping payload from two channels must be _____ before reporting unique delivery

Basis and qualification: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-FIB-077. Silent gap deletion can corrupt both cross-spectral phase and the index-to-_____ relationship.

Answer: time. Phase conventions and actual sample timing must be reviewed together. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
Why this term is required: “time” completes the stated technical proposition.
Question context: Silent gap deletion can corrupt both cross-spectral phase and the index-to-_____ relationship
Basis and qualification: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and phase.
Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-VOL-FIB-078. An EVM alignment that removes a timing trend must disclose its fitted degrees of _____.

Answer: freedom. The residual alone may conceal the effect the calibration intended to measure. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

Why this term is required: “freedom” completes the stated technical proposition.

Question context: An EVM alignment that removes a timing trend must disclose its fitted degrees of _____

Basis and qualification: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-VOL-FIB-079. Asymmetric sideband filtering can change receiver output envelope without a change in source modulation _____.

Answer: depth. The admitted complex components and transfer shape govern the observed envelope. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

Why this term is required: “depth” completes the stated technical proposition.

Question context: Asymmetric sideband filtering can change receiver output envelope without a change in source modulation _____

Basis and qualification: Chapter 3 — Use preselection as a measured transfer function; Chapter 6 — Model 6A: preserve the complex envelope.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 6 — Model 6A: preserve the complex envelope.

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V011-VOL-FIB-080. Phase-derived frequency near a zero or reset needs explicit branch and _____ flags.

Answer: validity. The finite interval cannot be interpreted as an unqualified instantaneous value. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

Why this term is required: “validity” completes the stated technical proposition.

Question context: Phase-derived frequency near a zero or reset needs explicit branch and _____ flags

Basis and qualification: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 10 — Gap representations, phase, and the limits of timing....

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 10 — Gap representations, phase, and the limits of timing claims.

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V011-VOL-FIB-081. A center-tone amplitude pass does not establish wideband modulation _____.

Answer: fidelity. Filter phase and amplitude across the waveform band remain relevant. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

Why this term is required: “fidelity” completes the stated technical proposition.

Question context: A center-tone amplitude pass does not establish wideband modulation _____

Basis and qualification: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 7 — Model 7A: a finite, declared EVM comparison.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 7 — Model 7A: a finite, declared EVM comparison.

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V011-VOL-FIB-082. Two reports from the same samples and decoder should retain their shared evidence _____.

Answer: dependency. Different output names do not create independent observations. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
Why this term is required: “dependency” completes the stated technical proposition.
Question context: Two reports from the same samples and decoder should retain their shared evidence _____
Basis and qualification: Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.
Review: Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-FIB-083. A missing state in a crossed diagnostic design remains a missing causal _____.

Answer: comparison. The other cells cannot silently supply its outcome. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

Why this term is required: “comparison” completes the stated technical proposition.

Question context: A missing state in a crossed diagnostic design remains a missing causal _____

Basis and qualification: Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Arrange the comparisons before examining their outcomes.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Arrange the comparisons before examining their outcomes.

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V011-VOL-FIB-084. An observed gain-transition transient should receive a dedicated experiment rather than a settled-state _____ .

Answer: correction. The time-varying state and valid interval differ from the static calibration. Source: §5.4 Model 5A: an identified one-pole gain-control response (p. 2519)
Why this term is required: “correction” completes the stated technical proposition.
Question context: An observed gain-transition transient should receive a dedicated experiment rather than a settled-state _____
Basis and qualification: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 16 — Preserve comparable observation capability.
Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-FIB-085. Optical activity correlated with RF does not alone establish an RF information _____.

Answer: path. Physical/operational linkage and shared-control alternatives remain to be tested. Source: §15.17 Metadata, Time, and Site Context (p. 8705)

Why this term is required: “path” completes the stated technical proposition.

Question context: Optical activity correlated with RF does not alone establish an RF information _____

Basis and qualification: Chapter 15 — Metadata, Time, and Site Context; Chapter 16 — Findings, Reports, and Decision Ladders.

Review: Chapter 15 — Metadata, Time, and Site Context; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-FIB-086. After firmware changes, old and new processing configurations should be retained as distinct _____ until validated.

Answer: states. Regression establishes which deployed functions remain accepted.

Source: §10.66 Separate signed artifacts from operating configurations (p. 5770)

Why this term is required: “states” completes the stated technical proposition.

Question context: After firmware changes, old and new processing configurations should be retained as distinct _____ until validated

Basis and qualification: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 16 — Close the receiver method through configuration-specific regression.

Review: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-FIB-087. A known-artifact record should preserve exact stimulus and configuration to test later _____.

Answer: applicability. A similar-looking trace is not a universal mechanism proof.

Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

Why this term is required: “applicability” completes the stated technical proposition.

Question context: A known-artifact record should preserve exact stimulus and configuration to test later _____

Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 16 — Write findings that preserve the strength and limit of each test.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 16 — Write findings that preserve the strength and limit of each test.

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V011-VOL-FIB-088. A method accepted for steady signals may need a narrower release _____ until burst timing is validated.

Answer: scope. Calibration and coverage must match the claimed event class.

Source: §14.18 Close the calibration record across the working interval (p. 8147)

Why this term is required: “scope” completes the stated technical proposition.

Question context: A method accepted for steady signals may need a narrower release _____ until burst timing is validated

Basis and qualification: Chapter 14 — Close the calibration record across the working interval; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Close the receiver method through….

Review: Chapter 14 — Close the calibration record across the working interval; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-FIB-089. Lower noise after decimation must be interpreted with actual bandwidth and spectral _____.

Answer: normalization. A display change alone does not prove a new input sensitivity. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “normalization” completes the stated technical proposition.

Question context: Lower noise after decimation must be interpreted with actual bandwidth and spectral _____

Basis and qualification: Chapter 9 — Noise density uses a different denominator; Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

Review: Chapter 9 — Noise density uses a different denominator; Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 2 — Model 2B: a matched, fixed-state noise cascade.

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V011-VOL-FIB-090. Decimation phase affects which output indices retain a missing-input filter _____.

Answer: tail. Convolution support and output selection jointly determine validity.

Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “tail” completes the stated technical proposition.

Question context: Decimation phase affects which output indices retain a missing-input filter _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-FIB-091. Separately power-calibrated records with unknown phase resets do not establish _____ integration gain.

Answer: coherent. The complex relationship between records is additional information. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)

Why this term is required: “coherent” completes the stated technical proposition.

Question context: Separately power-calibrated records with unknown phase resets do not establish _____ integration gain

Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state.

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V011-VOL-FIB-092. A discrete phase-noise line must not be treated as a continuous spectral _____ over an arbitrary bin.

Answer: density. The integration measure and units determine its variance contribution. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

Why this term is required: “density” completes the stated technical proposition.

Question context: A discrete phase-noise line must not be treated as a continuous spectral _____ over an arbitrary bin

Basis and qualification: Chapter 9 — Noise density uses a different denominator; Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

Review: Chapter 9 — Noise density uses a different denominator; Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin.

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V011-VOL-FIB-093. Common-reference cancellation requires equal effective _____ into the compared channels.

Answer: coupling. A shared label alone does not justify covariance cancellation.

Source: §12.22 Application 12B.5: Include covariance when combining timing contributions (p. 6982)

Why this term is required: “coupling” completes the stated technical proposition.

Question context: Common-reference cancellation requires equal effective _____ into the compared channels

Basis and qualification: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions; Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions; Chapter 14 — Application 14B.5: cancel a shared phase reference correctly.

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V011-VOL-FIB-094. Two implementations can reproduce the same wrong result if both share a misinterpreted input _____.

Answer: scale. Known physical references test a common format/calibration error.

Source: §10.33 Signed formats and explicit conversion points (p. 5725)

Why this term is required: “scale” completes the stated technical proposition.

Question context: Two implementations can reproduce the same wrong result if both share a misinterpreted input _____

Basis and qualification: Chapter 10 — Signed formats and explicit conversion points; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

Review: Chapter 10 — Signed formats and explicit conversion points; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-VOL-FIB-095. For a source missed in a noisier, shorter-dwell state, compare both sensitivity and usable _____ .

Answer: coverage. Either amplitude capability or timing can explain nondetection.

Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

Why this term is required: “coverage” completes the stated technical proposition.

Question context: For a source missed in a noisier, shorter-dwell state, compare both sensitivity and usable _____

Basis and qualification: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Preserve comparable observation capability.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-FIB-096. A failed closing check should be related to change times and the last demonstrated _____ state.

Answer: valid. Function-specific dependencies bound which earlier conclusions are affected. Source: §1.11 Model 1A: configured transfer, correction and recoverability (p. 72)
Why this term is required: “valid” completes the stated technical proposition.
Question context: A failed closing check should be related to change times and the last demonstrated _____ state
Basis and qualification: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Close the calibration record across the working interval; Chapter 16 — Reconcile evidence without assigning unsupported….
Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Close the calibration record across the working interval; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-FIB-097. Reproducibility of a measured number does not alone establish the device's operational _____.

Answer: function. Attribution requires linkage beyond a repeatable processing result. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
Why this term is required: “function” completes the stated technical proposition.
Question context: Reproducibility of a measured number does not alone establish the device's operational _____
Basis and qualification: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Findings, Reports, and Decision Ladders.
Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-FIB-098. For a finite jointly Gaussian phase vector with specified mean phases, equal marginal phase RMS does not fix expected coherent power without the off-diagonal _____ terms.

Answer: covariance. The specified means and complete covariance matrix determine Gaussian phase-difference characteristic functions. Outside this Gaussian model, the relevant phase-difference distributions must also be justified; second-order covariance alone is insufficient. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

Why this term is required: “covariance” completes the stated technical proposition.

Question context: For a finite jointly Gaussian phase vector with specified mean phases, equal marginal phase RMS does not fix expected coherent power without the off-diagonal _____ terms

Basis and qualification: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 9 — Define the ensemble before normalizing.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 9 — Define the ensemble before normalizing.

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V011-VOL-FIB-099. Equal average SSB power does not guarantee equal peak-envelope _____ at a vulnerable stage.

Answer: loading. Peak voltage and phase relationships can matter to compression or protection. Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

Why this term is required: “loading” completes the stated technical proposition.

Question context: Equal average SSB power does not guarantee equal peak-envelope _____ at a vulnerable stage

Basis and qualification: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 3 — Find the first stage that can lose validity; Chapter 11 — Compression and Gain Change.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 3 — Find the first stage that can lose validity; Chapter 11 — Compression and Gain Change.

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V011-VOL-FIB-100. Zero filling can preserve a sample grid while leaving the missing waveform physically _____.

Answer: unknown. Its induced output support must remain marked rather than called measured data. Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)

Why this term is required: “unknown” completes the stated technical proposition.

Question context: Zero filling can preserve a sample grid while leaving the missing waveform physically _____

Basis and qualification: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 1 — Model 1A: configured transfer, correction and….

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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Essay Questions

[Essay instructions: Each essay must contain 3,500–5,000 words in total. Address the ten subject prompts below in the order presented, developing approximately 350–500 words for each prompt. Begin with an introduction establishing the question, scope and thesis. Conclude with a synthesis that draws together all ten prompts into one coherent closing argument. Count the introduction and conclusion within the overall word limit.]

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V011-VOL-ESSAY-001. Design a receiver measurement from an authorized objective through a reproducible reported finding.

- Opening: Present a thesis that answers this precise question: Design a receiver measurement from an authorized objective through a reproducible reported finding. Identify which evidence would falsify the proposed conclusion Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Core terminology and scope: Define Design, authorized, objective in the question's particular technical setting; explain how reproducible, reported, finding differ if that distinction would change the analysis of "Design a receiver measurement from an authorized objective through a reproducible reported finding" Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the measurand, reference plane, event population and decision criterion Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a receiver measurement from an authorized objective through a reproducible reported finding to the claimed result, following "I/Q-derived modulation identity: distinguish discriminating features from unique source attribution"; name the intermediate states and measurable outputs Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a receiver measurement from an authorized objective through a reproducible reported finding. Distinguish detection from functional attribution and state the accepted scope Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Define sensitivity as a reproducible decision” that resolves the question about a receiver measurement from an authorized objective through a reproducible reported finding; derive the relevant result with units and stated validity conditions Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a receiver measurement from an authorized objective through a reproducible reported finding. Distinguish detection from functional attribution and state the accepted scope Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Worked application or illustrative case: Build a worked example of “a receiver measurement from an authorized objective through a reproducible reported finding”, addressing this associated condition: Define the measurand, reference plane, event population and decision criterion. Define the measurand, reference plane, event population and decision criterion Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a receiver measurement from an authorized objective through a reproducible reported finding”. Using “Define sensitivity as a reproducible decision”, specify a discriminator and the result expected under each explanation Source: §2.5 Define sensitivity as a reproducible decision (p. 653)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a receiver measurement from an authorized objective through a reproducible reported finding, including the effect of missing measurements and inconsistent operating conditions Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)
- Scholarly synthesis and implications: Explain what the result about a receiver measurement from an authorized objective through a reproducible reported finding authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)
- Closing: Conclude by answering “Design a receiver measurement from an authorized objective through a reproducible reported finding” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

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V011-VOL-ESSAY-002. Compare two equal-gain architectures that place a cable and preamplifier in opposite orders.

- Opening: Present a thesis that answers this precise question: Compare two equal-gain architectures that place a cable and preamplifier in opposite orders. Identify which evidence would falsify the proposed conclusion Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Core terminology and scope: Define architectures, place, cable in the question's particular technical setting; explain how preamplifier, opposite, orders differ if that distinction would change the analysis of "Compare two equal-gain architectures that place a cable and preamplifier in opposite orders" Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Derive their matched noise weighting, track desired and blocker levels at each stage, and assess installed bias/stability and field geometry Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting two equal-gain architectures that place a cable and preamplifier in opposite orders to the claimed result, following "External Preamplifiers, Bias, and Stability"; name the intermediate states and measurable outputs Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for two

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equal-gain architectures that place a cable and preamplifier in opposite orders. Specify reference tests for actual transfer, loading and capability; explain why a common corrected mean level does not establish equal sensitivity Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Remote amplification requires electrical and installed checks” that resolves the question about two equal-gain architectures that place a cable and preamplifier in opposite orders; derive the relevant result with units and stated validity conditions Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Evidence and method: Specify the native observations, control records and calculations that would resolve two equal-gain architectures that place a cable and preamplifier in opposite orders. Specify reference tests for actual transfer, loading and capability; explain why a common corrected mean level does not establish equal sensitivity Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Worked application or illustrative case: Build a worked example of “two equal-gain architectures that place a cable and preamplifier in opposite orders”, addressing this associated condition: Derive their matched noise weighting, track desired and blocker levels at each stage, and assess installed.... Derive their matched noise weighting, track desired and blocker levels at each stage, and assess installed bias/stability and field geometry Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “two equal-gain architectures that place a cable and preamplifier in opposite orders”. Using “Remote amplification requires electrical and installed checks”, specify a discriminator and the result expected under each explanation Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to two equal-gain architectures that place a cable and preamplifier in opposite orders, including the effect of missing measurements and inconsistent operating conditions Source: §3.2 Find the first stage that can lose validity (p. 1249)
- Scholarly synthesis and implications: Explain what the result about two equal-gain architectures that place a cable and preamplifier in opposite orders authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Closing: Conclude by answering “Compare two equal-gain architectures that place a cable and preamplifier in opposite orders” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.2 Preserve comparable observation capability (p. 9266)

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V011-VOL-ESSAY-003. Develop a feasible gain plan constrained jointly by noise temperature and downstream loading.

- Opening: Present a thesis that answers this precise question: Develop a feasible gain plan constrained jointly by noise temperature and downstream loading. Identify which evidence would falsify the proposed conclusion Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Core terminology and scope: Define feasible, constrained, jointly in the question's particular technical setting; explain how temperature, downstream, loading differ if that distinction would change the analysis of "Develop a feasible gain plan constrained jointly by noise temperature and downstream loading" Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the lower gain condition from later-stage noise and upper condition from admitted blockers or converter range Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a feasible gain plan constrained jointly by noise temperature and downstream loading to the claimed result, following "Gain Distribution and Attenuation"; name the intermediate states and measurable outputs Source: §3.5 Gain Distribution and Attenuation (p. 1256)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a feasible gain plan constrained jointly by noise temperature and

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downstream loading. Include preselector loss/rejection, empty-interval handling and state validity Source: §3.5 Gain Distribution and Attenuation (p. 1256)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 2B.5: solve for the gain that is useful” that resolves the question about a feasible gain plan constrained jointly by noise temperature and downstream loading; derive the relevant result with units and stated validity conditions Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a feasible gain plan constrained jointly by noise temperature and downstream loading. Explain why digital scaling cannot repair analog SNR or clipping Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Worked application or illustrative case: Build a worked example of “a feasible gain plan constrained jointly by noise temperature and downstream loading”, addressing this associated condition: State the lower gain condition from later-stage noise and upper condition from admitted blockers or converter.... State the lower gain condition from later-stage noise and upper condition from admitted blockers or converter range Source: §3.5 Gain Distribution and Attenuation (p. 1256)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a feasible gain plan constrained jointly by noise temperature and downstream loading”. Using “Application 2B.5: solve for the gain that is useful”, specify a discriminator and

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the result expected under each explanation Source: §2.22 Application 2B.5: solve for the gain that is useful (p. 682)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a feasible gain plan constrained jointly by noise temperature and downstream loading, including the effect of missing measurements and inconsistent operating conditions Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)
- Scholarly synthesis and implications: Explain what the result about a feasible gain plan constrained jointly by noise temperature and downstream loading authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.6 Choose gain from a feasible interval (p. 1257)
- Closing: Conclude by answering “Develop a feasible gain plan constrained jointly by noise temperature and downstream loading” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.6 Choose gain from a feasible interval (p. 1257)

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V011-VOL-ESSAY-004. Construct a recovery acceptance plan for a protected receiver observing short weak events.

- Opening: Present a thesis that answers this precise question: Construct a recovery acceptance plan for a protected receiver observing short weak events. Identify which evidence would falsify the proposed conclusion Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Core terminology and scope: Define Construct, protected, observing in the question's particular technical setting; explain how short, weak, events differ if that distinction would change the analysis of "Construct a recovery acceptance plan for a protected receiver observing short weak events" Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate protection leakage, survival and observable-specific recovery; retain a weak reference through a bounded strong event Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a recovery acceptance plan for a protected receiver observing short weak events to the claimed result, following "Blocker-dependent front-end state machines and hidden recovery intervals"; name the intermediate states and measurable outputs Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a recovery acceptance plan for a protected receiver observing short weak events. Track AGC/filter/trigger persistence, establish valid intervals and calculate coverage only from those intervals Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Validate transient and gated measurements with the intended waveform" that resolves the question about a recovery acceptance plan for a protected receiver observing short weak events; derive the relevant result with units and stated validity conditions Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a recovery acceptance plan for a protected receiver observing short weak events. Do not equate a survival rating with restored measurement quality Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Worked application or illustrative case: Build a worked example of "a recovery acceptance plan for a protected receiver observing short weak events", addressing this associated condition: Separate protection leakage, survival and observable-specific recovery; retain a weak reference through a.... Separate protection leakage, survival and observable-specific recovery; retain a weak reference through a bounded strong event Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a recovery acceptance plan for a protected receiver observing short weak events”. Using “Validate transient and gated measurements with the intended waveform”, specify a discriminator and the result expected under each explanation Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a recovery acceptance plan for a protected receiver observing short weak events, including the effect of missing measurements and inconsistent operating conditions Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Scholarly synthesis and implications: Explain what the result about a recovery acceptance plan for a protected receiver observing short weak events authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)
- Closing: Conclude by answering “Construct a recovery acceptance plan for a protected receiver observing short weak events” using only the demonstrated evidence; state the remaining decisive verification step Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

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V011-VOL-ESSAY-005. Audit a complete upstream power correction that includes additive noise, gain state and covariance.

- Opening: Present a thesis that answers this precise question: Audit a complete upstream power correction that includes additive noise, gain state and covariance. Identify which evidence would falsify the proposed conclusion Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Core terminology and scope: Define Audit, complete, upstream in the question's particular technical setting; explain how includes, additive, covariance differ if that distinction would change the analysis of "Audit a complete upstream power correction that includes additive noise, gain state and covariance" Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Subtract compatible linear powers before logarithms, use applicable transfer at named planes and distinguish unknown-state sets from statistical uncertainty Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Audit a complete upstream power correction that includes additive noise, gain state and covariance to the claimed result, following "Define a complete path at named planes"; name the intermediate states and measurable outputs Source: §13.2 Define a complete path at named planes (p. 7537)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Audit a complete upstream power correction that includes additive noise, gain state and covariance. Propagate supported dependencies, check log-domain positivity and independently close the forward calculation Source: §13.2 Define a complete path at named planes (p. 7537)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Ten worked applications” that resolves the question about Audit a complete upstream power correction that includes additive noise, gain state and covariance; derive the relevant result with units and stated validity conditions Source: §8.4.3 Ten worked applications (p. 4437)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Audit a complete upstream power correction that includes additive noise, gain state and covariance. Propagate supported dependencies, check log-domain positivity and independently close the forward calculation Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Worked application or illustrative case: Build a worked example of “Audit a complete upstream power correction that includes additive noise, gain state and covariance”, addressing this associated condition: Subtract compatible linear powers before logarithms, use applicable transfer at named planes and distinguish.... Subtract compatible linear powers before logarithms, use applicable transfer at named planes and distinguish unknown-state sets from... Source: §13.2 Define a complete path at named planes (p. 7537)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “Audit a complete upstream power correction that includes additive noise, gain state and covariance”. Using “Ten worked applications”, specify a discriminator and the result expected under each explanation Source: §8.4.3 Ten worked applications (p. 4437)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Audit a complete upstream power correction that includes additive noise, gain state and covariance, including the effect of missing measurements and inconsistent operating conditions Source: §14.18 Close the calibration record across the working interval (p. 8147)
- Scholarly synthesis and implications: Explain what the result about Audit a complete upstream power correction that includes additive noise, gain state and covariance authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)
- Closing: Conclude by answering “Audit a complete upstream power correction that includes additive noise, gain state and covariance” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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V011-VOL-ESSAY-006. Design a hot/cold noise measurement that remains valid through an external assembled path.

- Opening: Present a thesis that answers this precise question: Design a hot/cold noise measurement that remains valid through an external assembled path. Identify which evidence would falsify the proposed conclusion Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Core terminology and scope: Define Design, noise, remains in the question's particular technical setting; explain how external, assembled, path differ if that distinction would change the analysis of "Design a hot/cold noise measurement that remains valid through an external assembled path" Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Record source temperatures at the receiver plane, passive loss and physical temperature, hot/cold linear powers, bandwidth, matching and common gain Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a hot/cold noise measurement that remains valid through an external assembled path to the claimed result, following "Calibrate noise without confusing it with detection"; name the intermediate states and measurable outputs Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a hot/cold noise measurement that remains valid through an external assembled path. Check hot-state compression, source-state settling and covariance, then distinguish the noise result from waveform-specific detection verification Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 2B.9: expose a change hidden by a ratio” that resolves the question about a hot/cold noise measurement that remains valid through an external assembled path; derive the relevant result with units and stated validity conditions Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a hot/cold noise measurement that remains valid through an external assembled path. Check hot-state compression, source-state settling and covariance, then distinguish the noise result from waveform-specific detection verification Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Worked application or illustrative case: Build a worked example of “a hot/cold noise measurement that remains valid through an external assembled path”, addressing this associated condition: Record source temperatures at the receiver plane, passive loss and physical temperature, hot/cold linear.... Record source temperatures at the receiver plane, passive loss and physical temperature, hot/cold

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linear powers, bandwidth, matching and common gain Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a hot/cold noise measurement that remains valid through an external assembled path”. Using “Application 2B.9: expose a change hidden by a ratio”, specify a discriminator and the result expected under each explanation Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a hot/cold noise measurement that remains valid through an external assembled path, including the effect of missing measurements and inconsistent operating conditions Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Scholarly synthesis and implications: Explain what the result about a hot/cold noise measurement that remains valid through an external assembled path authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §2.16 Invert the same model with two source temperatures (p. 672)
- Closing: Conclude by answering “Design a hot/cold noise measurement that remains valid through an external assembled path” using only the demonstrated evidence; state the remaining decisive verification step Source: §2.16 Invert the same model with two source temperatures (p. 672)

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V011-VOL-ESSAY-007. Explain how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component.

- Opening: Present a thesis that answers this precise question: Explain how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component. Identify which evidence would falsify the proposed conclusion Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Core terminology and scope: Define analog, admission, mixing in the question's particular technical setting; explain how jointly, meaning, spectral differ if that distinction would change the analysis of "Explain how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component" Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain signed frequency, LO branches, image intervals, sampling equivalence and NCO convention Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component to the claimed result, following "From a product map to a discriminating test"; name the intermediate states and measurable outputs Source: §4.18 From a product map to a discriminating test (p. 1949)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how a

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conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component. Predict movement under a controlled change and preserve desired transfer; explain why one moving line cannot uniquely establish an image or external source Source: §4.18 From a product map to a discriminating test (p. 1949)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Complex I/Q acquisition: physical meaning, signed frequency, calibration and defensible identification” that resolves the question about how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component; derive the relevant result with units and stated validity conditions Source: §10.110 Complex I/Q acquisition: physical meaning, signed frequency, calibration and defensible identification (p. 5828)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component. Predict movement under a controlled change and preserve desired transfer; explain why one moving line cannot uniquely establish an image or external source Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Worked application or illustrative case: Build a worked example of “how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component”, addressing this associated condition: Retain signed frequency, LO branches, image intervals, sampling equivalence and NCO convention. Retain signed frequency, LO branches, image intervals, sampling equivalence and

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NCO convention Source: §4.18 From a product map to a discriminating test (p. 1949)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component”. Using “Complex I/Q acquisition: physical meaning, signed frequency, calibration and defensible identification”, specify a discriminator and the result expected under each explanation Source: §10.110 Complex I/Q acquisition: physical meaning, signed frequency, calibration and defensible identification (p. 5828)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component, including the effect of missing measurements and inconsistent operating conditions Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Scholarly synthesis and implications: Explain what the result about how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §4.19 Conversion-State Challenge Protocol (p. 1951)
- Closing: Conclude by answering “Explain how a conversion plan, analog admission and digital mixing jointly determine the meaning of a spectral component” using only the demonstrated evidence; state the remaining decisive verification step Source: §4.19 Conversion-State Challenge Protocol (p. 1951)

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V011-VOL-ESSAY-008. Develop a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks.

- Opening: Present a thesis that answers this precise question: Develop a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks. Identify which evidence would falsify the proposed conclusion Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Core terminology and scope: Define signals, path, alter in the question's particular technical setting; explain how sidebands, envelope, peaks differ if that distinction would change the analysis of "Develop a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks" Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use complex-envelope representation and declared average/peak conventions, measure amplitude and phase response over occupied bandwidth, and assess stage loading Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks to the claimed result, following "Amplitude Modulation and Envelope Detection"; name the intermediate states and measurable outputs Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks. Explain envelope reversal or filtering ambiguities and limit source-modulation claims when the path is incompletely characterized Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 6A.4: Show why an envelope-extrema estimate fails after reversal” that resolves the question about a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks; derive the relevant result with units and stated validity conditions Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks. Explain envelope reversal or filtering ambiguities and limit source-modulation claims when the path is incompletely characterized Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Worked application or illustrative case: Build a worked example of “a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks”, addressing this associated condition: Use complex-envelope representation and declared average/peak conventions, measure amplitude and phase.... Use

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complex-envelope representation and declared average/peak conventions, measure amplitude and phase response over occupied bandwidth,... Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks”. Using “Application 6A.4: Show why an envelope-extrema estimate fails after reversal”, specify a discriminator and the result expected under each explanation Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks, including the effect of missing measurements and inconsistent operating conditions Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Scholarly synthesis and implications: Explain what the result about a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)
- Closing: Conclude by answering “Develop a measurement plan for AM or SSB signals whose receiver path can alter sidebands and envelope peaks” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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V011-VOL-ESSAY-009. Develop a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors.

- Opening: Present a thesis that answers this precise question: Develop a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors. Identify which evidence would falsify the proposed conclusion Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Core terminology and scope: Define remains, interpretable, retuning in the question's particular technical setting; explain how gaps, clock, errors differ if that distinction would change the analysis of "Develop a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors" Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define nonzero/valid signal intervals, branch handling, finite-difference meaning and resets Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors to the claimed result, following "Frequency, phase, and delay require their own observables"; name the intermediate states and measurable outputs Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a phase-

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derived frequency result that remains interpretable through retuning, gaps and clock errors. Retain absolute sample indices and deterministic clock mapping; distinguish carrier offset from modulation and avoid treating discontinuous records as one coherent trajectory Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Accept coherence at the required boundary and state” that resolves the question about a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors; derive the relevant result with units and stated validity conditions Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors. Retain absolute sample indices and deterministic clock mapping; distinguish carrier offset from modulation and avoid treating discontinuous records as one coherent trajectory Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Worked application or illustrative case: Build a worked example of “a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors”, addressing this associated condition: Define nonzero/valid signal intervals, branch handling, finite-difference meaning and resets. Define nonzero/valid signal

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intervals, branch handling, finite-difference meaning and resets Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors”. Using “Accept coherence at the required boundary and state”, specify a discriminator and the result expected under each explanation Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors, including the effect of missing measurements and inconsistent operating conditions Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Scholarly synthesis and implications: Explain what the result about a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)
- Closing: Conclude by answering “Develop a phase-derived frequency result that remains interpretable through retuning, gaps and clock errors” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

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V011-VOL-ESSAY-010. Compare an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective.

- Opening: Present a thesis that answers this precise question: Compare an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective. Identify which evidence would falsify the proposed conclusion Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Core terminology and scope: Define metric, complex, alignment in the question's particular technical setting; explain how accuracy, engineering, objective differ if that distinction would change the analysis of "Compare an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective" Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define symbol populations, reference energies and fit degrees of freedom; retain the fitted coefficient and unfitted phase result Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective to the claimed result, following "Application 7A.1: Show which error a fitted gain removes";

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name the intermediate states and measurable outputs Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective. Use held-out data and demonstrate which physical error the fit can conceal Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Metric Validation and Held-Out Data” that resolves the question about an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective; derive the relevant result with units and stated validity conditions Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective. Separate lower residual from improved clock or receiver calibration Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Worked application or illustrative case: Build a worked example of “an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective”, addressing this associated condition: Define symbol populations,

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reference energies and fit degrees of freedom; retain the fitted coefficient and.... Define symbol populations, reference energies and fit degrees of freedom; retain the fitted coefficient... Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective”. Using “Metric Validation and Held-Out Data”, specify a discriminator and the result expected under each explanation Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective, including the effect of missing measurements and inconsistent operating conditions Source: §7.8 Application 7A.2: Quantify a fixed phase error (p. 3753)
- Scholarly synthesis and implications: Explain what the result about an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)
- Closing: Conclude by answering “Compare an unfitted digital-quality metric with one permitting complex gain alignment when phase accuracy is the engineering objective” using only the demonstrated

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evidence; state the remaining decisive verification step Source: §7.13

Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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V011-VOL-ESSAY-011. Design a fair digital-modulation comparison across gain transitions and partial burst captures.

- Opening: Present a thesis that answers this precise question: Design a fair digital-modulation comparison across gain transitions and partial burst captures. Identify which evidence would falsify the proposed conclusion Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Core terminology and scope: Define Design, gain, transitions in the question's particular technical setting; explain how partial, burst, captures differ if that distinction would change the analysis of "Design a fair digital-modulation comparison across gain transitions and partial burst captures" Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Specify training/evaluation symbols, weights, normalization and excluded startup data; verify actual receiver state and event boundaries Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a fair digital-modulation comparison across gain transitions and partial burst captures to the claimed result, following "Define the symbol experiment before fitting the constellation"; name the intermediate states and measurable outputs Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a fair digital-modulation comparison across gain transitions and partial burst captures. Report settled-payload quality separately from whole-burst capture and avoid using a clean selected constellation as evidence for omitted intervals Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.3: Require the whole burst” that resolves the question about a fair digital-modulation comparison across gain transitions and partial burst captures; derive the relevant result with units and stated validity conditions Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a fair digital-modulation comparison across gain transitions and partial burst captures. Report settled-payload quality separately from whole-burst capture and avoid using a clean selected constellation as evidence for omitted intervals Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Worked application or illustrative case: Build a worked example of “a fair digital-modulation comparison across gain transitions and partial burst captures”, addressing this associated condition: Specify training/evaluation symbols, weights, normalization and excluded startup data; verify actual receiver.... Specify training/evaluation symbols, weights, normalization and excluded startup data; verify

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actual receiver state and event boundaries Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a fair digital-modulation comparison across gain transitions and partial burst captures”. Using “Application 15A.3: Require the whole burst”, specify a discriminator and the result expected under each explanation Source: §15.6 Application 15A.3: Require the whole burst (p. 8687)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a fair digital-modulation comparison across gain transitions and partial burst captures, including the effect of missing measurements and inconsistent operating conditions Source: §6.41 Multipath, fading, capture and the physical limits of an apparently clean audio output (p. 3170)
- Scholarly synthesis and implications: Explain what the result about a fair digital-modulation comparison across gain transitions and partial burst captures authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)
- Closing: Conclude by answering “Design a fair digital-modulation comparison across gain transitions and partial burst captures” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.12 Application 7A.6: Make selection and weighting visible (p. 3757)

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V011-VOL-ESSAY-012. Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver.

- Opening: Present a thesis that answers this precise question: Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver. Identify which evidence would falsify the proposed conclusion Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Core terminology and scope: Define Reconcile, coded, payload in the question's particular technical setting; explain how throughput, native, recording differ if that distinction would change the analysis of "Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver" Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define finite symbol/bit/frame populations, overhead ownership, active and wall intervals, unique payload positions and retransmissions Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver to the claimed result, following "Application 7B.6. Remove duplicate payload before reporting unique throughput"; name the intermediate states and measurable outputs Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver. Separately compute stored I/Q bytes with container width and channels, and retain chronology and continuity so neither storage rate nor coded count is mislabeled as information delivery Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.2. Separate two overhead populations without counting either twice” that resolves the question about Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver; derive the relevant result with units and stated validity conditions Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver. Separately compute stored I/Q bytes with container width and channels, and retain chronology and continuity so neither storage rate nor coded count is mislabeled as information delivery Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)
- Worked application or illustrative case: Build a worked example of “Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver”, addressing this associated

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condition: Define finite symbol/bit/frame populations, overhead ownership, active and wall intervals, unique payload.... Define finite symbol/bit/frame populations, overhead ownership, active and wall intervals, unique payload positions and retransmissions Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver”. Using “Application 7B.2. Separate two overhead populations without counting either twice”, specify a discriminator and the result expected under each explanation Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver, including the effect of missing measurements and inconsistent operating conditions Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Scholarly synthesis and implications: Explain what the result about Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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- Closing: Conclude by answering “Reconcile coded rate, payload throughput and native recording throughput for a burst-mode receiver” using only the demonstrated evidence; state the remaining decisive verification step Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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V011-VOL-ESSAY-013. Explain the different roles of RBW, ENBW, sample count, zero padding and usable observation time.

- Opening: Present a thesis that answers this precise question: Explain the different roles of RBW, ENBW, sample count, zero padding and usable observation time. Identify which evidence would falsify the proposed conclusion Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Core terminology and scope: Define roles, count, zero in the question's particular technical setting; explain how padding, usable, observation differ if that distinction would change the analysis of "Explain the different roles of RBW, ENBW, sample count, zero padding and usable observation time" Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Relate each to the intended tone, density, integrated-power or transient estimate; describe window normalization and sweep/filter settling Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting the different roles of RBW, ENBW, sample count, zero padding and usable observation time to the claimed result, following "Interpret a swept trace through its frequency-time trajectory"; name the intermediate states and measurable outputs Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for the different roles of RBW, ENBW, sample count, zero padding and usable observation time. Show why finer plotted frequency spacing or a lower displayed floor does not add measured history or establish event detectability Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Measurement consequence” that resolves the question about the different roles of RBW, ENBW, sample count, zero padding and usable observation time; derive the relevant result with units and stated validity conditions Source: §9.3.5 Measurement consequence (p. 5050)
- Evidence and method: Specify the native observations, control records and calculations that would resolve the different roles of RBW, ENBW, sample count, zero padding and usable observation time. Show why finer plotted frequency spacing or a lower displayed floor does not add measured history or establish event detectability Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Worked application or illustrative case: Build a worked example of “the different roles of RBW, ENBW, sample count, zero padding and usable observation time”, addressing this associated condition: Relate each to the intended tone, density, integrated-power or transient estimate; describe window.... Relate each to the intended tone, density, integrated-power or transient estimate; describe

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window normalization and sweep/filter settling Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “the different roles of RBW, ENBW, sample count, zero padding and usable observation time”. Using “Measurement consequence”, specify a discriminator and the result expected under each explanation Source: §9.3.5 Measurement consequence (p. 5050)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to the different roles of RBW, ENBW, sample count, zero padding and usable observation time, including the effect of missing measurements and inconsistent operating conditions Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Scholarly synthesis and implications: Explain what the result about the different roles of RBW, ENBW, sample count, zero padding and usable observation time authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)
- Closing: Conclude by answering “Explain the different roles of RBW, ENBW, sample count, zero padding and usable observation time” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

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V011-VOL-ESSAY-014. Compare power averaging, logarithmic averaging and background subtraction in a receiver calibration.

- Opening: Present a thesis that answers this precise question: Compare power averaging, logarithmic averaging and background subtraction in a receiver calibration. Identify which evidence would falsify the proposed conclusion Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Core terminology and scope: Define power, averaging, logarithmic in the question's particular technical setting; explain how subtraction, receiver, calibration differ if that distinction would change the analysis of "Compare power averaging, logarithmic averaging and background subtraction in a receiver calibration" Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the actual estimator and source law, distinguish gamma/log-bias conditions from intermittent mixtures, and subtract compatible additive powers before logs Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting power averaging, logarithmic averaging and background subtraction in a receiver calibration to the claimed result, following "Averaging and Statistical Stability"; name the intermediate states and measurable outputs Source: §9.4 Averaging and Statistical Stability (p. 5052)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for power

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averaging, logarithmic averaging and background subtraction in a receiver calibration. Retain covariance and positivity domains; explain why display smoothness or repeated averaging does not validate an inapplicable statistical correction Source: §9.4 Averaging and Statistical Stability (p. 5052)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Choose bandwidth from the quantity being estimated” that resolves the question about power averaging, logarithmic averaging and background subtraction in a receiver calibration; derive the relevant result with units and stated validity conditions Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Evidence and method: Specify the native observations, control records and calculations that would resolve power averaging, logarithmic averaging and background subtraction in a receiver calibration. Retain covariance and positivity domains; explain why display smoothness or repeated averaging does not validate an inapplicable statistical correction Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Worked application or illustrative case: Build a worked example of “power averaging, logarithmic averaging and background subtraction in a receiver calibration”, addressing this associated condition: Define the actual estimator and source law, distinguish gamma/log-bias conditions from intermittent mixtures,.... Define the actual estimator and source law, distinguish gamma/log-bias

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conditions from intermittent mixtures, and subtract compatible… Source: §9.4 Averaging and Statistical Stability (p. 5052)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “power averaging, logarithmic averaging and background subtraction in a receiver calibration”. Using “Choose bandwidth from the quantity being estimated”, specify a discriminator and the result expected under each explanation Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to power averaging, logarithmic averaging and background subtraction in a receiver calibration, including the effect of missing measurements and inconsistent operating conditions Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)
- Scholarly synthesis and implications: Explain what the result about power averaging, logarithmic averaging and background subtraction in a receiver calibration authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §8.4.2 Power averaging before the logarithm (p. 4434)
- Closing: Conclude by answering “Compare power averaging, logarithmic averaging and background subtraction in a receiver calibration” using only the demonstrated evidence; state the remaining decisive verification step Source: §8.4.2 Power averaging before the logarithm (p. 4434)

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V011-VOL-ESSAY-015. Design a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps.

- Opening: Present a thesis that answers this precise question: Design a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps. Identify which evidence would falsify the proposed conclusion Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Core terminology and scope: Define Design, timing, survives in the question's particular technical setting; explain how swaps, shared, gaps differ if that distinction would change the analysis of "Design a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps" Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Specify paired ensembles, conjugation/channel order, window normalization and phase branch; retain actual sample indices and clock relationships Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps to the claimed result, following "Cross-Spectra, Coherence, and Multichannel Analysis"; name the intermediate states and measurable outputs Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps. Analyze shared contributions and coherence limits, and distinguish a one-pair unity estimate from evidence of a physical coupling Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Multichannel Synchronization and Delay Calibration” that resolves the question about a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps; derive the relevant result with units and stated validity conditions Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps. Analyze shared contributions and coherence limits, and distinguish a one-pair unity estimate from evidence of a physical coupling Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Worked application or illustrative case: Build a worked example of “a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps”, addressing this associated condition: Specify paired ensembles, conjugation/channel order, window normalization and phase branch; retain actual.... Specify

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paired ensembles, conjugation/channel order, window normalization and phase branch; retain actual sample indices and clock... Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps”. Using “Multichannel Synchronization and Delay Calibration”, specify a discriminator and the result expected under each explanation Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps, including the effect of missing measurements and inconsistent operating conditions Source: §12.30 Accept coherence at the required boundary and state (p. 6992)
- Scholarly synthesis and implications: Explain what the result about a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)
- Closing: Conclude by answering “Design a cross-spectral timing measurement that survives channel swaps, shared noise and sample gaps” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.45 Selected timing calculations and loss-of-coherence limits for a forty-gigahertz observation system (p. 7022)

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V011-VOL-ESSAY-016. Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity.

- Opening: Present a thesis that answers this precise question: Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity. Identify which evidence would falsify the proposed conclusion Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Core terminology and scope: Define Specify, processing, sufficient in the question's particular technical setting; explain how implementation, reproduce, quantity differ if that distinction would change the analysis of "Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity" Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Include native format and scale, absolute indices, oscillator phase, filter history, decimation phase, valid supports and software identity Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity to the claimed result, following "Application 10E.4: an ordinary block boundary preserves filter history"; name the intermediate states and measurable outputs Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity. Bind calibration and selected interval, test with known references and retain gaps; explain why byte hashes or a similar plot alone are insufficient Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)
- Analytical framework: Identify the equation, calibration or evidential decision test in “SDR Boundary and Partitioning” that resolves the question about Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity; derive the relevant result with units and stated validity conditions Source: §10.1 SDR Boundary and Partitioning (p. 5679)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity. Bind calibration and selected interval, test with known references and retain gaps; explain why byte hashes or a similar plot alone are insufficient Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Worked application or illustrative case: Build a worked example of “Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity”, addressing this associated condition: Include native format and scale, absolute indices, oscillator phase, filter history, decimation phase, valid.... Include native format and scale, absolute indices, oscillator phase,

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filter history, decimation phase, valid supports and… Source: §10.55 Application 10E.4: an ordinary block boundary preserves filter history (p. 5757)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity”. Using “SDR Boundary and Partitioning”, specify a discriminator and the result expected under each explanation Source: §10.1 SDR Boundary and Partitioning (p. 5679)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity, including the effect of missing measurements and inconsistent operating conditions Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Scholarly synthesis and implications: Explain what the result about Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Closing: Conclude by answering “Specify an SDR processing record sufficient for a second implementation to reproduce a physical quantity” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-VOL-ESSAY-017. Analyze a missing input block through filtering, decimation and later spectral interpretation.

- Opening: Present a thesis that answers this precise question: Analyze a missing input block through filtering, decimation and later spectral interpretation. Identify which evidence would falsify the proposed conclusion Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Core terminology and scope: Define missing, block, filtering in the question's particular technical setting; explain how decimation, later, interpretation differ if that distinction would change the analysis of "Analyze a missing input block through filtering, decimation and later spectral interpretation" Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compare zero filling with silent deletion, map nonzero filter support to affected outputs and retain absolute phase/time Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a missing input block through filtering, decimation and later spectral interpretation to the claimed result, following "Application 10E.10: one missing input appears in idle channels"; name the intermediate states and measurable outputs Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a missing input block through filtering, decimation and later spectral interpretation. Restrict uniform-sampling estimators to valid segments or state a different model Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)
- Analytical framework: Identify the equation, calibration or evidential decision test in “A continuity condition for finite filtering and decimation” that resolves the question about a missing input block through filtering, decimation and later spectral interpretation; derive the relevant result with units and stated validity conditions Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a missing input block through filtering, decimation and later spectral interpretation. Distinguish a preserved grid from reconstructed missing waveform Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Worked application or illustrative case: Build a worked example of “a missing input block through filtering, decimation and later spectral interpretation”, addressing this associated condition: Compare zero filling with silent deletion, map nonzero filter support to affected outputs and retain absolute.... Compare zero filling with silent deletion, map nonzero filter support to affected outputs and retain absolute phase/time Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a missing input block through filtering, decimation and later spectral interpretation”. Using “A continuity condition for finite filtering and decimation”, specify a discriminator and the result expected under each explanation Source: §10.50 A continuity condition for finite filtering and decimation (p. 5747)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a missing input block through filtering, decimation and later spectral interpretation, including the effect of missing measurements and inconsistent operating conditions Source: §10.5 Model 10B for digital mixing filtering and decimation (p. 5688)
- Scholarly synthesis and implications: Explain what the result about a missing input block through filtering, decimation and later spectral interpretation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)
- Closing: Conclude by answering “Analyze a missing input block through filtering, decimation and later spectral interpretation” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

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V011-VOL-ESSAY-018. Develop a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations.

- Opening: Present a thesis that answers this precise question: Develop a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations. Identify which evidence would falsify the proposed conclusion Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Core terminology and scope: Define acceptance, separates, range in the question's particular technical setting; explain how quantization, analog, limitations differ if that distinction would change the analysis of "Develop a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations" Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define signed formats and conversion points, bound intermediate ranges and rounding, check clipping/overflow with known stimuli, and retain scale metadata Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations to the claimed result, following "Quantization, Clipping, and Converter Performance"; name the intermediate states and measurable outputs Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations. Explain why digital gain can improve representation use without recovering an already lost analog SNR or waveform Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)
- Analytical framework: Identify the equation, calibration or evidential decision test in “What the arithmetic comparison establishes” that resolves the question about a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations; derive the relevant result with units and stated validity conditions Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations. Explain why digital gain can improve representation use without recovering an already lost analog SNR or waveform Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Worked application or illustrative case: Build a worked example of “a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations”, addressing this associated condition: Define signed formats and conversion points, bound intermediate ranges and rounding, check clipping/overflow.... Define signed formats and conversion points, bound intermediate ranges and rounding, check clipping/overflow with known stimuli,... Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations”. Using “What the arithmetic comparison establishes”, specify a discriminator and the result expected under each explanation Source: §10.46 What the arithmetic comparison establishes (p. 5742)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations, including the effect of missing measurements and inconsistent operating conditions Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)
- Scholarly synthesis and implications: Explain what the result about a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.33 Signed formats and explicit conversion points (p. 5725)
- Closing: Conclude by answering “Develop a fixed-point acceptance plan that separates range, quantization error and analog receiver limitations” using only the demonstrated evidence; state the remaining decisive verification step Source: §10.33 Signed formats and explicit conversion points (p. 5725)

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V011-VOL-ESSAY-019. Design a nonlinear-product challenge that can distinguish receiver generation from source contamination.

- Opening: Present a thesis that answers this precise question: Design a nonlinear-product challenge that can distinguish receiver generation from source contamination. Identify which evidence would falsify the proposed conclusion Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Core terminology and scope: Define Design, challenge, receiver in the question's particular technical setting; explain how generation, source, contamination differ if that distinction would change the analysis of "Design a nonlinear-product challenge that can distinguish receiver generation from source contamination" Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Specify parent powers, frequencies, loading and stage reference plane; use the local cubic law only within its domain, retain per-tone convention and intercept asymptote Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a nonlinear-product challenge that can distinguish receiver generation from source contamination to the claimed result, following "From a product map to a discriminating test"; name the intermediate states and measurable outputs Source: §4.18 From a product map to a discriminating test (p. 1949)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a nonlinear-product challenge that can distinguish receiver generation from source contamination. Characterize sources/combiners and coherent contamination, then vary a control before the proposed stage while preserving desired capability Source: §4.18 From a product map to a discriminating test (p. 1949)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Construct the intercept from the linear asymptote" that resolves the question about a nonlinear-product challenge that can distinguish receiver generation from source contamination; derive the relevant result with units and stated validity conditions Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a nonlinear-product challenge that can distinguish receiver generation from source contamination. Characterize sources/combiners and coherent contamination, then vary a control before the proposed stage while preserving desired capability Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Worked application or illustrative case: Build a worked example of "a nonlinear-product challenge that can distinguish receiver generation from source contamination", addressing this associated condition: Specify parent powers, frequencies, loading and stage reference plane; use the local cubic law only within.... Specify parent powers, frequencies, loading and stage reference plane; use the

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local cubic law only within its domain, retain per-tone... Source: §4.18 From a product map to a discriminating test (p. 1949)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a nonlinear-product challenge that can distinguish receiver generation from source contamination”. Using “Construct the intercept from the linear asymptote”, specify a discriminator and the result expected under each explanation Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a nonlinear-product challenge that can distinguish receiver generation from source contamination, including the effect of missing measurements and inconsistent operating conditions Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)
- Scholarly synthesis and implications: Explain what the result about a nonlinear-product challenge that can distinguish receiver generation from source contamination authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)
- Closing: Conclude by answering “Design a nonlinear-product challenge that can distinguish receiver generation from source contamination” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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V011-VOL-ESSAY-020. Compare compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor.

- Opening: Present a thesis that answers this precise question: Compare compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor. Identify which evidence would falsify the proposed conclusion Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Core terminology and scope: Define direct, leakage, reciprocal in the question's particular technical setting; explain how mixing, explanations, floor differ if that distinction would change the analysis of "Compare compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor" Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use paired desired-reference and blocker observations, identify gain/band/state changes, characterize source spectrum and channel weighting, and test oscillator phase-noise relevance Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor to the claimed result, following "Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture"; name the intermediate states and measurable outputs Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor. State which models survive each outcome instead of assigning one universal dynamic-range score Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Dynamic Range Is a Family of Conditions” that resolves the question about compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor; derive the relevant result with units and stated validity conditions Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)
- Evidence and method: Specify the native observations, control records and calculations that would resolve compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor. State which models survive each outcome instead of assigning one universal dynamic-range score Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Worked application or illustrative case: Build a worked example of “compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor”, addressing this associated condition: Use paired desired-reference and blocker observations, identify gain/band/state changes, characterize source.... Use paired desired-reference and blocker observations, identify gain/band/state changes, characterize source spectrum...

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Source: §11.47 Whole-band loading and dynamic-range penalties in parallel forty-gigahertz capture (p. 6436)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor”. Using “Dynamic Range Is a Family of Conditions”, specify a discriminator and the result expected under each explanation Source: §11.1 Dynamic Range Is a Family of Conditions (p. 6360)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor, including the effect of missing measurements and inconsistent operating conditions Source: §11.41 Dynamic-Range Acceptance Matrix (p. 6425)
- Scholarly synthesis and implications: Explain what the result about compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Closing: Conclude by answering “Compare compression, gain control, direct blocker leakage and reciprocal mixing as explanations for a changed noise floor” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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V011-VOL-ESSAY-021. Explain why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties.

- Opening: Present a thesis that answers this precise question: Explain why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties. Identify which evidence would falsify the proposed conclusion Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Core terminology and scope: Define integrated, jitter, average in the question's particular technical setting; explain how accuracy, retention, properties differ if that distinction would change the analysis of "Explain why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties" Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define deterministic clock error, finite integration band and carrier conversion, then discuss covariance and Gaussian premises for phase differences Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties to the claimed result, following "Application 12B.9: Combine deterministic rotation with independent phase errors"; name the intermediate states and

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measurable outputs Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties. Include common random rotation and independent/correlated cases, and show why equal scalar RMS does not fix every receiver consequence Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 12B.8: Use a specified correlated Gaussian phase vector” that resolves the question about why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties; derive the relevant result with units and stated validity conditions Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Evidence and method: Specify the native observations, control records and calculations that would resolve why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties. Include common random rotation and independent/correlated cases, and show why equal scalar RMS does not fix every receiver consequence Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)
- Worked application or illustrative case: Build a worked example of “why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties”, addressing

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this associated condition: Define deterministic clock error, finite integration band and carrier conversion, then discuss covariance and.... Define deterministic clock error, finite integration band and carrier conversion, then discuss covariance and... Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties". Using "Application 12B.8: Use a specified correlated Gaussian phase vector", specify a discriminator and the result expected under each explanation Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties, including the effect of missing measurements and inconsistent operating conditions Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)
- Scholarly synthesis and implications: Explain what the result about why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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- Closing: Conclude by answering “Explain why integrated jitter, average frequency accuracy and finite coherent-power retention are different clock properties” using only the demonstrated evidence; state the remaining decisive verification step Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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V011-VOL-ESSAY-022. Develop a multichannel timing calibration from the physical input plane to stored sample apertures.

- Opening: Present a thesis that answers this precise question: Develop a multichannel timing calibration from the physical input plane to stored sample apertures. Identify which evidence would falsify the proposed conclusion Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Core terminology and scope: Define multichannel, timing, physical in the question's particular technical setting; explain how plane, stored, apertures differ if that distinction would change the analysis of "Develop a multichannel timing calibration from the physical input plane to stored sample apertures" Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Account for cable/filter/conversion phase, reference distribution, epoch, trigger and index mapping Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a multichannel timing calibration from the physical input plane to stored sample apertures to the claimed result, following "Controlled acceptance of a multichannel timing network"; name the intermediate states and measurable outputs Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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multichannel timing calibration from the physical input plane to stored sample apertures. Test retune/reset repeatability, preserve branch and uncertainty, and explain what a shared clock or one calibration tone does not establish Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Frequency and Phase Calibration” that resolves the question about a multichannel timing calibration from the physical input plane to stored sample apertures; derive the relevant result with units and stated validity conditions Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a multichannel timing calibration from the physical input plane to stored sample apertures. Test retune/reset repeatability, preserve branch and uncertainty, and explain what a shared clock or one calibration tone does not establish Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Worked application or illustrative case: Build a worked example of “a multichannel timing calibration from the physical input plane to stored sample apertures”, addressing this associated condition: Account for cable/filter/conversion phase, reference distribution, epoch, trigger and index mapping. Account for cable/filter/conversion phase, reference distribution, epoch, trigger and index mapping Source: §12.43 Controlled acceptance of a multichannel timing network (p. 7018)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a multichannel timing calibration from the physical input plane to stored sample apertures”. Using “Frequency and Phase Calibration”, specify a discriminator and the result expected under each explanation Source: §14.5 Frequency and Phase Calibration (p. 8112)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a multichannel timing calibration from the physical input plane to stored sample apertures, including the effect of missing measurements and inconsistent operating conditions Source: §12.31 Reference Distribution Acceptance (p. 6994)
- Scholarly synthesis and implications: Explain what the result about a multichannel timing calibration from the physical input plane to stored sample apertures authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Closing: Conclude by answering “Develop a multichannel timing calibration from the physical input plane to stored sample apertures” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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V011-VOL-ESSAY-023. Evaluate a field-strength result assembled from an antenna certificate and a receiver calibration.

- Opening: Present a thesis that answers this precise question: Evaluate a field-strength result assembled from an antenna certificate and a receiver calibration. Identify which evidence would falsify the proposed conclusion Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Core terminology and scope: Define field-strength, assembled, antenna in the question's particular technical setting; explain how certificate, receiver, calibration differ if that distinction would change the analysis of "Evaluate a field-strength result assembled from an antenna certificate and a receiver calibration" Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Separate antenna-terminal power from field conversion, state loading/polarization/geometry/field-region conditions, and include remote paths and common mode Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a field-strength result assembled from an antenna certificate and a receiver calibration to the claimed result, following "A constructed acceptance case for the assembled chain"; name the intermediate states and measurable outputs Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a field-strength result assembled from an antenna certificate and a receiver calibration. Assign corrections once, verify the installed arrangement and distinguish traceability from complete applicability Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Attach calibration to a stated measurement result” that resolves the question about a field-strength result assembled from an antenna certificate and a receiver calibration; derive the relevant result with units and stated validity conditions Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a field-strength result assembled from an antenna certificate and a receiver calibration. Assign corrections once, verify the installed arrangement and distinguish traceability from complete applicability Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Worked application or illustrative case: Build a worked example of “a field-strength result assembled from an antenna certificate and a receiver calibration”, addressing this associated condition: Separate antenna-terminal power from field conversion, state loading/polarization/geometry/field-region.... Separate antenna-terminal power from field conversion, state loading/polarization/geometry/field-region conditions, and include

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remote paths and... Source: §13.15 A constructed acceptance case for the assembled chain (p. 7559)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a field-strength result assembled from an antenna certificate and a receiver calibration”. Using “Attach calibration to a stated measurement result”, specify a discriminator and the result expected under each explanation Source: §14.2 Attach calibration to a stated measurement result (p. 8105)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a field-strength result assembled from an antenna certificate and a receiver calibration, including the effect of missing measurements and inconsistent operating conditions Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)
- Scholarly synthesis and implications: Explain what the result about a field-strength result assembled from an antenna certificate and a receiver calibration authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.4 Keep field conversion separate from terminal power (p. 7542)
- Closing: Conclude by answering “Evaluate a field-strength result assembled from an antenna certificate and a receiver calibration” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-VOL-ESSAY-024. Design an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature.

- Opening: Present a thesis that answers this precise question: Design an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature. Identify which evidence would falsify the proposed conclusion Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Core terminology and scope: Define optical, battery, intervention in the question's particular technical setting; explain how confusing, removal, feature differ if that distinction would change the analysis of "Design an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature" Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Characterize new gain, noise, bandwidth, timing and power-state behavior; carry a relevant weak reference; preserve geometry and raw comparisons Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature to the claimed result, following "Measure compression without confusing it with control

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action"; name the intermediate states and measurable outputs Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature. State alternative effects of the intervention and the bounded inference when capability cannot be matched Source: §11.3 Measure compression without confusing it with control action (p. 6365)
- Analytical framework: Identify the equation, calibration or evidential decision test in "An intervention matrix that separates mechanism, state and common error" that resolves the question about an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature; derive the relevant result with units and stated validity conditions Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature. State alternative effects of the intervention and the bounded inference when capability cannot be matched Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)
- Worked application or illustrative case: Build a worked example of "an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature",

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addressing this associated condition: Characterize new gain, noise, bandwidth, timing and power-state behavior; carry a relevant weak reference;.... Characterize new gain, noise, bandwidth, timing and power-state behavior; carry a relevant weak... Source: §11.3 Measure compression without confusing it with control action (p. 6365)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature”. Using “An intervention matrix that separates mechanism, state and common error”, specify a discriminator and the result expected under each explanation Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature, including the effect of missing measurements and inconsistent operating conditions Source: §16.4.2 Preserve comparable observation capability (p. 9266)
- Scholarly synthesis and implications: Explain what the result about an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- Closing: Conclude by answering “Design an optical or battery intervention that tests installed coupling without confusing loss of sensitivity with removal of the feature” using only the demonstrated evidence; state the remaining decisive verification step Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-VOL-ESSAY-025. Compare explicit common-input and covariance descriptions in an assembled receiver uncertainty model.

- Opening: Present a thesis that answers this precise question: Compare explicit common-input and covariance descriptions in an assembled receiver uncertainty model. Identify which evidence would falsify the proposed conclusion Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Core terminology and scope: Define explicit, covariance, assembled in the question's particular technical setting; explain how receiver, uncertainty, model differ if that distinction would change the analysis of "Compare explicit common-input and covariance descriptions in an assembled receiver uncertainty model" Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Write signed equations for a phase difference and an averaged corrected level, show cancellation versus persistence, and avoid double counting Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting explicit common-input and covariance descriptions in an assembled receiver uncertainty model to the claimed result, following "14. Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation"; name the intermediate states and measurable outputs Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for explicit common-input and covariance descriptions in an assembled receiver uncertainty model. Check matrix admissibility and units; explain why shared labels or separate budget rows do not establish the required dependence Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 14B.8: identify the uncertainty that averaging cannot remove” that resolves the question about explicit common-input and covariance descriptions in an assembled receiver uncertainty model; derive the relevant result with units and stated validity conditions Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Evidence and method: Specify the native observations, control records and calculations that would resolve explicit common-input and covariance descriptions in an assembled receiver uncertainty model. Check matrix admissibility and units; explain why shared labels or separate budget rows do not establish the required dependence Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Worked application or illustrative case: Build a worked example of “explicit common-input and covariance descriptions in an assembled receiver uncertainty model”, addressing this associated condition: Write signed equations for a phase difference and an averaged corrected level, show cancellation versus.... Write signed equations

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for a phase difference and an averaged corrected level, show cancellation versus persistence, and avoid double counting Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “explicit common-input and covariance descriptions in an assembled receiver uncertainty model”. Using “Application 14B.8: identify the uncertainty that averaging cannot remove”, specify a discriminator and the result expected under each explanation Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to explicit common-input and covariance descriptions in an assembled receiver uncertainty model, including the effect of missing measurements and inconsistent operating conditions Source: §3.39 Uncertainty-aware interpretation of instrument agreement (p. 1359)
- Scholarly synthesis and implications: Explain what the result about explicit common-input and covariance descriptions in an assembled receiver uncertainty model authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)
- Closing: Conclude by answering “Compare explicit common-input and covariance descriptions in an assembled receiver uncertainty model” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.3 Application 14B.5: cancel a shared phase reference correctly (p. 8135)

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V011-VOL-ESSAY-026. Construct a domain-aware uncertainty treatment for a logarithm of an added-noise estimate.

- Opening: Present a thesis that answers this precise question: Construct a domain-aware uncertainty treatment for a logarithm of an added-noise estimate. Identify which evidence would falsify the proposed conclusion Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Core terminology and scope: Define Construct, domain-aware, uncertainty in the question's particular technical setting; explain how treatment, logarithm, estimate differ if that distinction would change the analysis of "Construct a domain-aware uncertainty treatment for a logarithm of an added-noise estimate" Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Start from matched on/off transfer and additive powers, retain covariance and the complete possible domain, then distinguish exact linear difference variance from local log dispersion Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a domain-aware uncertainty treatment for a logarithm of an added-noise estimate to the claimed result, following "From a calculated temperature to a defended result"; name the intermediate states and measurable outputs Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a domain-aware uncertainty treatment for a logarithm of an added-noise estimate. Explain what changes if zero is admitted and why neither a positive center nor factor-two interval proves positivity Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 4A.10: Map an admitted IF interval back to both RF intervals” that resolves the question about a domain-aware uncertainty treatment for a logarithm of an added-noise estimate; derive the relevant result with units and stated validity conditions Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a domain-aware uncertainty treatment for a logarithm of an added-noise estimate. Explain what changes if zero is admitted and why neither a positive center nor factor-two interval proves positivity Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Worked application or illustrative case: Build a worked example of “a domain-aware uncertainty treatment for a logarithm of an added-noise estimate”, addressing this associated condition: Start from matched on/off transfer and additive powers, retain covariance and the complete possible domain,…. Start from matched on/off transfer and additive powers, retain covariance and the complete possible

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domain, then distinguish exact linear difference... Source: §2.28 From a calculated temperature to a defended result (p. 689)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a domain-aware uncertainty treatment for a logarithm of an added-noise estimate”. Using “Application 4A.10: Map an admitted IF interval back to both RF intervals”, specify a discriminator and the result expected under each explanation Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a domain-aware uncertainty treatment for a logarithm of an added-noise estimate, including the effect of missing measurements and inconsistent operating conditions Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)
- Scholarly synthesis and implications: Explain what the result about a domain-aware uncertainty treatment for a logarithm of an added-noise estimate authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)
- Closing: Conclude by answering “Construct a domain-aware uncertainty treatment for a logarithm of an added-noise estimate” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

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V011-VOL-ESSAY-027. Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation.

- Opening: Present a thesis that answers this precise question: Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation. Identify which evidence would falsify the proposed conclusion Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Core terminology and scope: Define nonlinear, models, propagation in the question's particular technical setting; explain how useful, local, approximation differ if that distinction would change the analysis of "Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation" Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Compare a signed affine correction with hot/cold inversion, phase-slope delay and squared-voltage power Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation to the claimed result, following "Application 14B.6: propagate phase-slope delay uncertainty"; name the intermediate states and measurable outputs Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation. Identify finite-moment requirements, curvature/singularity boundaries and input distributions; show why numerical simulation cannot validate unsupported physical assumptions Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Ten numerical applications, each with stipulated assumptions” that resolves the question about Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation; derive the relevant result with units and stated validity conditions Source: §12.42 Ten numerical applications, each with stipulated assumptions (p. 7015)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation. Identify finite-moment requirements, curvature/singularity boundaries and input distributions; show why numerical simulation cannot validate unsupported physical assumptions Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Worked application or illustrative case: Build a worked example of “Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation”, addressing this

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associated condition: Compare a signed affine correction with hot/cold inversion, phase-slope delay and squared-voltage power. Compare a signed affine correction with hot/cold inversion, phase-slope delay and squared-voltage power Source: §14.14.4 Application 14B.6: propagate phase-slope delay uncertainty (p. 8136)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation”. Using “Ten numerical applications, each with stipulated assumptions”, specify a discriminator and the result expected under each explanation Source: §12.42 Ten numerical applications, each with stipulated assumptions (p. 7015)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation, including the effect of missing measurements and inconsistent operating conditions Source: §14.20 Nonlinear uncertainty propagation, model uncertainty and decision guard bands (p. 8151)
- Scholarly synthesis and implications: Explain what the result about Use the volume's linear and nonlinear models to distinguish exact propagation from a useful local approximation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)
- Closing: Conclude by answering “Use the volume's linear and nonlinear models to distinguish exact propagation from a useful

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local approximation" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

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V011-VOL-ESSAY-028. Design an uncertainty-aware acceptance decision for a receiver result near an upper limit.

- Opening: Present a thesis that answers this precise question: Design an uncertainty-aware acceptance decision for a receiver result near an upper limit. Identify which evidence would falsify the proposed conclusion Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Core terminology and scope: Define Design, acceptance, decision in the question's particular technical setting; explain how near, upper, limit differ if that distinction would change the analysis of "Design an uncertainty-aware acceptance decision for a receiver result near an upper limit" Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State the measurand and applicable correction, propagate supported dependencies, justify the coverage factor and predeclare accept/reject/indeterminate conditions Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an uncertainty-aware acceptance decision for a receiver result near an upper limit to the claimed result, following "Uncertainty Budgets and Decision Rules"; name the intermediate states and measurable outputs Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an uncertainty-aware acceptance decision for a receiver result near an

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upper limit. Explain how follow-up should target dominant terms while preserving the original rule and result Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10F.6 A bounded amplitude result near an acceptance limit” that resolves the question about an uncertainty-aware acceptance decision for a receiver result near an upper limit; derive the relevant result with units and stated validity conditions Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an uncertainty-aware acceptance decision for a receiver result near an upper limit. Explain how follow-up should target dominant terms while preserving the original rule and result Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Worked application or illustrative case: Build a worked example of “an uncertainty-aware acceptance decision for a receiver result near an upper limit”, addressing this associated condition: State the measurand and applicable correction, propagate supported dependencies, justify the coverage factor.... State the measurand and applicable correction, propagate supported dependencies, justify the coverage factor and predeclare... Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “an uncertainty-aware acceptance

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decision for a receiver result near an upper limit". Using "Application 10F.6 A bounded amplitude result near an acceptance limit", specify a discriminator and the result expected under each explanation Source: §10.74 Application 10F.6 A bounded amplitude result near an acceptance limit (p. 5782)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an uncertainty-aware acceptance decision for a receiver result near an upper limit, including the effect of missing measurements and inconsistent operating conditions Source: §2.28 From a calculated temperature to a defended result (p. 689)
- Scholarly synthesis and implications: Explain what the result about an uncertainty-aware acceptance decision for a receiver result near an upper limit authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.11 Declare the decision rule before seeing the result (p. 8122)
- Closing: Conclude by answering "Design an uncertainty-aware acceptance decision for a receiver result near an upper limit" using only the demonstrated evidence; state the remaining decisive verification step Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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V011-VOL-ESSAY-029. Develop event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin.

- Opening: Present a thesis that answers this precise question: Develop event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin. Identify which evidence would falsify the proposed conclusion Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Core terminology and scope: Define mixed, containing, guards in the question's particular technical setting; explain how crossing, period, origin differ if that distinction would change the analysis of "Develop event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin" Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Derive eligible starts for a declared positive contiguous criterion, preserve actual record continuity, merge periodic unions and justify the event-phase law Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin to the claimed result, following "Application 15A.5: Remove settling and closing guards from

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nominal dwell"; name the intermediate states and measurable outputs Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin. Keep detector validity separate and show why disconnected pieces or nominal command spans cannot be counted as one record Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 15A.6: Take the union of overlapping capture-start sets" that resolves the question about event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin; derive the relevant result with units and stated validity conditions Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Evidence and method: Specify the native observations, control records and calculations that would resolve event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin. Keep detector validity separate and show why disconnected pieces or nominal command spans cannot be counted as one record Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)
- Worked application or illustrative case: Build a worked example of "event coverage for a mixed schedule containing guards, separated

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windows and a window crossing the period origin", addressing this associated condition: Derive eligible starts for a declared positive contiguous criterion, preserve actual record continuity, merge.... Derive eligible starts for a declared positive contiguous criterion, preserve actual record continuity, merge... Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin". Using "Application 15A.6: Take the union of overlapping capture-start sets", specify a discriminator and the result expected under each explanation Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin, including the effect of missing measurements and inconsistent operating conditions Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)
- Scholarly synthesis and implications: Explain what the result about event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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- Closing: Conclude by answering “Develop event coverage for a mixed schedule containing guards, separated windows and a window crossing the period origin” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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V011-VOL-ESSAY-030. Compare deterministic repeated misses with independent and adaptive repeated capture experiments.

- Opening: Present a thesis that answers this precise question: Compare deterministic repeated misses with independent and adaptive repeated capture experiments. Identify which evidence would falsify the proposed conclusion Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Core terminology and scope: Define deterministic, repeated, misses in the question's particular technical setting; explain how adaptive, capture, experiments differ if that distinction would change the analysis of "Compare deterministic repeated misses with independent and adaptive repeated capture experiments" Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the relative event/schedule phase, derive complement multiplication only where justified, retain unequal probabilities or joint dependence and analyze endpoint trial counts Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting deterministic repeated misses with independent and adaptive repeated capture experiments to the claimed result, following "Application 15A.9: Calculate repeated capture only under independent start phases"; name the intermediate states and measurable outputs Source: §15.12

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Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for deterministic repeated misses with independent and adaptive repeated capture experiments. Explain how actual schedule changes differ from saving more copies of the same observation Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 15A.1: Distinguish a point observation from full capture of a short event” that resolves the question about deterministic repeated misses with independent and adaptive repeated capture experiments; derive the relevant result with units and stated validity conditions Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Evidence and method: Specify the native observations, control records and calculations that would resolve deterministic repeated misses with independent and adaptive repeated capture experiments. Explain how actual schedule changes differ from saving more copies of the same observation Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Worked application or illustrative case: Build a worked example of “deterministic repeated misses with independent and adaptive repeated capture experiments”, addressing this associated condition: Define the relative event/schedule phase, derive

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complement multiplication only where justified, retain.... Define the relative event/schedule phase, derive complement multiplication only where justified, retain unequal probabilities or joint dependence... Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "deterministic repeated misses with independent and adaptive repeated capture experiments". Using "Application 15A.1: Distinguish a point observation from full capture of a short event", specify a discriminator and the result expected under each explanation Source: §15.4 Application 15A.1: Distinguish a point observation from full capture of a short event (p. 8685)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to deterministic repeated misses with independent and adaptive repeated capture experiments, including the effect of missing measurements and inconsistent operating conditions Source: §15.17 Metadata, Time, and Site Context (p. 8705)
- Scholarly synthesis and implications: Explain what the result about deterministic repeated misses with independent and adaptive repeated capture experiments authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)
- Closing: Conclude by answering "Compare deterministic repeated misses with independent and adaptive repeated capture experiments" using only the demonstrated evidence; state the

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remaining decisive verification step Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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V011-VOL-ESSAY-031. Design a burst-trigger validation that supports a whole-event claim.

- Opening: Present a thesis that answers this precise question: Design a burst-trigger validation that supports a whole-event claim. Identify which evidence would falsify the proposed conclusion Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Core terminology and scope: Define Design, burst-trigger, validation in the question's particular technical setting; explain how supports, whole-event, claim differ if that distinction would change the analysis of "Design a burst-trigger validation that supports a whole-event claim" Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Map trigger and recording path locations, test relevant stimulus shapes and event pairs, establish pretrigger validity and recovery, and relate trigger timestamps to sample apertures Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a burst-trigger validation that supports a whole-event claim to the claimed result, following "Verify the trigger at its actual signal-path location"; name the intermediate states and measurable outputs Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a burst-trigger validation that supports a whole-event claim. Retain

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complete boundaries, gap evidence and limits of a CW-only check Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 10C9 Critical sampling can retain a complete blind residue” that resolves the question about a burst-trigger validation that supports a whole-event claim; derive the relevant result with units and stated validity conditions Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a burst-trigger validation that supports a whole-event claim. Retain complete boundaries, gap evidence and limits of a CW-only check Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Worked application or illustrative case: Build a worked example of “a burst-trigger validation that supports a whole-event claim”, addressing this associated condition: Map trigger and recording path locations, test relevant stimulus shapes and event pairs, establish pretrigger.... Map trigger and recording path locations, test relevant stimulus shapes and event pairs, establish pretrigger validity and recovery, and relate trigger timestamps to... Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “a burst-trigger validation that supports a whole-event claim”. Using “Application 10C9 Critical sampling can retain a complete blind residue”, specify a discriminator and the

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result expected under each explanation Source: §10.29 Application 10C9 Critical sampling can retain a complete blind residue (p. 5719)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a burst-trigger validation that supports a whole-event claim, including the effect of missing measurements and inconsistent operating conditions Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)
- Scholarly synthesis and implications: Explain what the result about a burst-trigger validation that supports a whole-event claim authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)
- Closing: Conclude by answering “Design a burst-trigger validation that supports a whole-event claim” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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V011-VOL-ESSAY-032. Build a sustained-recording and evidence-integrity plan for a multichannel survey.

- Opening: Present a thesis that answers this precise question: Build a sustained-recording and evidence-integrity plan for a multichannel survey. Identify which evidence would falsify the proposed conclusion Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Core terminology and scope: Define Build, sustained-recording, evidence-integrity in the question's particular technical setting; explain how multichannel, survey, measurement differ if that distinction would change the analysis of "Build a sustained-recording and evidence-integrity plan for a multichannel survey" Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Calculate payload using actual representation, include overhead and reserve, test full-duration writing and rollover, and monitor counters/clock/overruns Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting Build a sustained-recording and evidence-integrity plan for a multichannel survey to the claimed result, following "Wideband Recording and Data Integrity"; name the intermediate states and measurable outputs Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for Build a

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sustained-recording and evidence-integrity plan for a multichannel survey. Hash closed files and bind metadata, but distinguish byte consistency from acquisition continuity and valid coverage Source: §15.16 Wideband Recording and Data Integrity (p. 8702)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Coverage Review and Storage Governance” that resolves the question about Build a sustained-recording and evidence-integrity plan for a multichannel survey; derive the relevant result with units and stated validity conditions Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Evidence and method: Specify the native observations, control records and calculations that would resolve Build a sustained-recording and evidence-integrity plan for a multichannel survey. Hash closed files and bind metadata, but distinguish byte consistency from acquisition continuity and valid coverage Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Worked application or illustrative case: Build a worked example of “Build a sustained-recording and evidence-integrity plan for a multichannel survey”, addressing this associated condition: Calculate payload using actual representation, include overhead and reserve, test full-duration writing and.... Calculate payload using actual representation, include overhead and reserve, test full-duration writing and rollover, and monitor... Source: §15.16 Wideband Recording and Data Integrity (p. 8702)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “Build a sustained-recording and

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evidence-integrity plan for a multichannel survey". Using "Coverage Review and Storage Governance", specify a discriminator and the result expected under each explanation Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to Build a sustained-recording and evidence-integrity plan for a multichannel survey, including the effect of missing measurements and inconsistent operating conditions Source: §15.27 Evidence-grade metadata and reproducible processing (p. 8726)
- Scholarly synthesis and implications: Explain what the result about Build a sustained-recording and evidence-integrity plan for a multichannel survey authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)
- Closing: Conclude by answering "Build a sustained-recording and evidence-integrity plan for a multichannel survey" using only the demonstrated evidence; state the remaining decisive verification step Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-VOL-ESSAY-033. Design a reproducible derived-result package that also exposes selection and processing uncertainty.

- Opening: Present a thesis that answers this precise question: Design a reproducible derived-result package that also exposes selection and processing uncertainty. Identify which evidence would falsify the proposed conclusion Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Core terminology and scope: Define Design, reproducible, package in the question's particular technical setting; explain how exposes, selection, processing differ if that distinction would change the analysis of "Design a reproducible derived-result package that also exposes selection and processing uncertainty" Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Retain source hashes, intervals, channels, scales, calibration, windows, alignment, exclusions and manual decisions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a reproducible derived-result package that also exposes selection and processing uncertainty to the claimed result, following "Record repetition and the limits of the design"; name the intermediate states and measurable outputs Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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reproducible derived-result package that also exposes selection and processing uncertainty. Use a second implementation and reference/noise-only records where relevant, disclose parameter sensitivity and avoid treating multiple outputs from one source as independent evidence Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Frequency, phase, and delay require their own observables” that resolves the question about a reproducible derived-result package that also exposes selection and processing uncertainty; derive the relevant result with units and stated validity conditions Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a reproducible derived-result package that also exposes selection and processing uncertainty. Use a second implementation and reference/noise-only records where relevant, disclose parameter sensitivity and avoid treating multiple outputs from one source as independent evidence Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Worked application or illustrative case: Build a worked example of “a reproducible derived-result package that also exposes selection and processing uncertainty”, addressing this associated condition: Retain source hashes, intervals, channels, scales, calibration, windows, alignment, exclusions and manual.... Retain source hashes, intervals, channels, scales, calibration, windows, alignment, exclusions and

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manual decisions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a reproducible derived-result package that also exposes selection and processing uncertainty”. Using “Frequency, phase, and delay require their own observables”, specify a discriminator and the result expected under each explanation Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a reproducible derived-result package that also exposes selection and processing uncertainty, including the effect of missing measurements and inconsistent operating conditions Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)
- Scholarly synthesis and implications: Explain what the result about a reproducible derived-result package that also exposes selection and processing uncertainty authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Closing: Conclude by answering “Design a reproducible derived-result package that also exposes selection and processing uncertainty” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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V011-VOL-ESSAY-034. Develop an architecture-based crossed challenge for two controls that can interact.

- Opening: Present a thesis that answers this precise question: Develop an architecture-based crossed challenge for two controls that can interact. Identify which evidence would falsify the proposed conclusion Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Core terminology and scope: Define architecture-based, crossed, challenge in the question's particular technical setting; explain how controls, interact, measurement differ if that distinction would change the analysis of "Develop an architecture-based crossed challenge for two controls that can interact" Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define actual physical state bundles, all meaningful combinations, response plane and criterion, capable references, fresh replications and run-order/blocking plan Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an architecture-based crossed challenge for two controls that can interact to the claimed result, following "Record repetition and the limits of the design"; name the intermediate states and measurable outputs Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an

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architecture-based crossed challenge for two controls that can interact. Retain missing states, transitions and alternatives; explain why interaction alone does not name the responsible circuit Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Reference transitions, cycle slips and false continuity” that resolves the question about an architecture-based crossed challenge for two controls that can interact; derive the relevant result with units and stated validity conditions Source: §12.40 Reference transitions, cycle slips and false continuity (p. 7013)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an architecture-based crossed challenge for two controls that can interact. Retain missing states, transitions and alternatives; explain why interaction alone does not name the responsible circuit Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Worked application or illustrative case: Build a worked example of “an architecture-based crossed challenge for two controls that can interact”, addressing this associated condition: Define actual physical state bundles, all meaningful combinations, response plane and criterion, capable.... Define actual physical state bundles, all meaningful combinations, response plane and criterion, capable references, fresh replications and run-order/blocking... Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “an architecture-based crossed challenge

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for two controls that can interact". Using "Reference transitions, cycle slips and false continuity", specify a discriminator and the result expected under each explanation Source: §12.40 Reference transitions, cycle slips and false continuity (p. 7013)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an architecture-based crossed challenge for two controls that can interact, including the effect of missing measurements and inconsistent operating conditions Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)
- Scholarly synthesis and implications: Explain what the result about an architecture-based crossed challenge for two controls that can interact authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)
- Closing: Conclude by answering "Develop an architecture-based crossed challenge for two controls that can interact" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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V011-VOL-ESSAY-035. Analyze a receiver substitution intended to establish that a signal is environmental.

- Opening: Present a thesis that answers this precise question: Analyze a receiver substitution intended to establish that a signal is environmental. Identify which evidence would falsify the proposed conclusion Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Core terminology and scope: Define receiver, substitution, intended in the question's particular technical setting; explain how signal, environmental, measurement differ if that distinction would change the analysis of "Analyze a receiver substitution intended to establish that a signal is environmental" Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Map shared antenna, clock, power, software and correction paths; verify the relevant weak or burst reference in each state Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a receiver substitution intended to establish that a signal is environmental to the claimed result, following "Localize an artifact by changing the stage that could create it"; name the intermediate states and measurable outputs Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a receiver substitution intended to establish that a signal is environmental. Distinguish agreement, disagreement and nondetection at tested limits, then identify an intervention that changes the relevant error structure Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)
- Analytical framework: Identify the equation, calibration or evidential decision test in “An intervention matrix that separates mechanism, state and common error” that resolves the question about a receiver substitution intended to establish that a signal is environmental; derive the relevant result with units and stated validity conditions Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a receiver substitution intended to establish that a signal is environmental. Distinguish agreement, disagreement and nondetection at tested limits, then identify an intervention that changes the relevant error structure Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Worked application or illustrative case: Build a worked example of “a receiver substitution intended to establish that a signal is environmental”, addressing this associated condition: Map shared antenna, clock, power, software and correction paths; verify the relevant weak or burst reference.... Map shared antenna, clock, power, software and correction paths; verify the relevant weak or

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burst reference in each state Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a receiver substitution intended to establish that a signal is environmental”. Using “An intervention matrix that separates mechanism, state and common error”, specify a discriminator and the result expected under each explanation Source: §16.20 An intervention matrix that separates mechanism, state and common error (p. 9301)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a receiver substitution intended to establish that a signal is environmental, including the effect of missing measurements and inconsistent operating conditions Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)
- Scholarly synthesis and implications: Explain what the result about a receiver substitution intended to establish that a signal is environmental authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Closing: Conclude by answering “Analyze a receiver substitution intended to establish that a signal is environmental” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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V011-VOL-ESSAY-036. Develop a cross-domain finding from RF, optical and wireline observations without inflating independence.

- Opening: Present a thesis that answers this precise question: Develop a cross-domain finding from RF, optical and wireline observations without inflating independence. Identify which evidence would falsify the proposed conclusion Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Core terminology and scope: Define finding, optical, wireline in the question's particular technical setting; explain how observations, inflating, independence differ if that distinction would change the analysis of "Develop a cross-domain finding from RF, optical and wireline observations without inflating independence" Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define each direct observable and clock/state relationship, identify shared causes and processing, and distinguish correlation from physical linkage Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a cross-domain finding from RF, optical and wireline observations without inflating independence to the claimed result, following "Write findings that preserve the strength and limit of each test"; name the intermediate states and measurable outputs Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a cross-domain finding from RF, optical and wireline observations without inflating independence. Require appropriate localization and information-path evidence before advancing the finding category Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Findings, Reports, and Decision Ladders” that resolves the question about a cross-domain finding from RF, optical and wireline observations without inflating independence; derive the relevant result with units and stated validity conditions Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a cross-domain finding from RF, optical and wireline observations without inflating independence. Require appropriate localization and information-path evidence before advancing the finding category Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Worked application or illustrative case: Build a worked example of “a cross-domain finding from RF, optical and wireline observations without inflating independence”, addressing this associated condition: Define each direct observable and clock/state relationship, identify shared causes and processing, and.... Define each direct observable and clock/state relationship, identify shared causes and processing, and distinguish correlation from physical... Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a cross-domain finding from RF, optical and wireline observations without inflating independence”. Using “Findings, Reports, and Decision Ladders”, specify a discriminator and the result expected under each explanation Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a cross-domain finding from RF, optical and wireline observations without inflating independence, including the effect of missing measurements and inconsistent operating conditions Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)
- Scholarly synthesis and implications: Explain what the result about a cross-domain finding from RF, optical and wireline observations without inflating independence authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)
- Closing: Conclude by answering “Develop a cross-domain finding from RF, optical and wireline observations without inflating independence” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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V011-VOL-ESSAY-037. Write an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution.

- Opening: Present a thesis that answers this precise question: Write an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define argument, compatibility, mechanism in the question's particular technical setting; explain how support, functional, attribution differ if that distinction would change the analysis of "Write an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use corrected same-plane differences with uncertainty for compatibility, predeclared challenges for mechanisms and additional physical/operational evidence for function Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution to the claimed result, following "Findings, Reports, and Decision Ladders"; name the intermediate

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states and measurable outputs Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution. Explain why a favorable test count, decoded identifier or low EVM cannot supply unspecified likelihoods or authorization Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Application 7B.6. Remove duplicate payload before reporting unique throughput” that resolves the question about an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution; derive the relevant result with units and stated validity conditions Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution. Explain why a favorable test count, decoded identifier or low EVM cannot supply unspecified likelihoods or authorization Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of “an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution”, addressing this

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associated condition: Use corrected same-plane differences with uncertainty for compatibility, predeclared challenges for.... Use corrected same-plane differences with uncertainty for compatibility, predeclared challenges for mechanisms and additional... Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution”. Using “Application 7B.6. Remove duplicate payload before reporting unique throughput”, specify a discriminator and the result expected under each explanation Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution, including the effect of missing measurements and inconsistent operating conditions Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)
- Scholarly synthesis and implications: Explain what the result about an evidence argument that distinguishes numerical compatibility, mechanism support and functional attribution authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering “Write an evidence argument that distinguishes numerical compatibility, mechanism support and

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functional attribution" using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-VOL-ESSAY-038. Plan configuration-specific regression after a firmware update changes reported amplitude and modulation quality.

- Opening: Present a thesis that answers this precise question: Plan configuration-specific regression after a firmware update changes reported amplitude and modulation quality. Identify which evidence would falsify the proposed conclusion Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Core terminology and scope: Define regression, firmware, update in the question's particular technical setting; explain how reported, modulation, quality differ if that distinction would change the analysis of "Plan configuration-specific regression after a firmware update changes reported amplitude and modulation quality" Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Preserve old/new executable and configuration identities, reuse accepted references across levels and states, rerun retained samples and compare both derivations Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting configuration-specific regression after a firmware update changes reported amplitude and modulation quality to the claimed result, following "Amplitude modulation beyond the textbook envelope formula"; name the intermediate states and measurable outputs Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for configuration-specific regression after a firmware update changes reported amplitude and modulation quality. Check scale, correction, alignment and timing separately; keep native observations and explain revised outputs Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Case study 3.D9. Weak-event detection after a digital-filter change” that resolves the question about configuration-specific regression after a firmware update changes reported amplitude and modulation quality; derive the relevant result with units and stated validity conditions Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)
- Evidence and method: Specify the native observations, control records and calculations that would resolve configuration-specific regression after a firmware update changes reported amplitude and modulation quality. Check scale, correction, alignment and timing separately; keep native observations and explain revised outputs Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Worked application or illustrative case: Build a worked example of “configuration-specific regression after a firmware update changes reported amplitude and modulation quality”, addressing this associated condition: Preserve old/new executable and configuration identities, reuse accepted references across levels and

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states,…. Preserve old/new executable and configuration identities, reuse accepted references across levels and states, rerun… Source: §6.38 Amplitude modulation beyond the textbook envelope formula (p. 3164)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “configuration-specific regression after a firmware update changes reported amplitude and modulation quality”. Using “Case study 3.D9. Weak-event detection after a digital-filter change”, specify a discriminator and the result expected under each explanation Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to configuration-specific regression after a firmware update changes reported amplitude and modulation quality, including the effect of missing measurements and inconsistent operating conditions Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Scholarly synthesis and implications: Explain what the result about configuration-specific regression after a firmware update changes reported amplitude and modulation quality authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Closing: Conclude by answering “Plan configuration-specific regression after a firmware update changes reported amplitude and modulation quality” using only the demonstrated evidence; state the

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remaining decisive verification step Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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V011-VOL-ESSAY-039. Develop a response to a failed closing reference following an accessory replacement.

- Opening: Present a thesis that answers this precise question: Develop a response to a failed closing reference following an accessory replacement. Identify which evidence would falsify the proposed conclusion Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Core terminology and scope: Define response, failed, closing in the question's particular technical setting; explain how following, accessory, replacement differ if that distinction would change the analysis of "Develop a response to a failed closing reference following an accessory replacement" Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Identify the affected function, last demonstrated valid state and change time; preserve native data and both reference results Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a response to a failed closing reference following an accessory replacement to the claimed result, following "3. Evidence interpretation when the reference chain fails"; name the intermediate states and measurable outputs Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a

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response to a failed closing reference following an accessory replacement. Investigate whether a bounded retrospective correction is supported, qualify unknown intervals and avoid silently extending the latest calibration backward Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Record repetition and the limits of the design” that resolves the question about a response to a failed closing reference following an accessory replacement; derive the relevant result with units and stated validity conditions Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a response to a failed closing reference following an accessory replacement. Investigate whether a bounded retrospective correction is supported, qualify unknown intervals and avoid silently extending the latest calibration backward Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Worked application or illustrative case: Build a worked example of “a response to a failed closing reference following an accessory replacement”, addressing this associated condition: Identify the affected function, last demonstrated valid state and change time; preserve native data and both.... Identify the affected function, last demonstrated valid state and change time; preserve native data and both reference results Source: §3.27 Evidence interpretation when the reference chain fails (p. 1311)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a response to a failed closing reference following an accessory replacement”. Using “Record repetition and the limits of the design”, specify a discriminator and the result expected under each explanation Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a response to a failed closing reference following an accessory replacement, including the effect of missing measurements and inconsistent operating conditions Source: §1.8 Evidence Record and Closing Verification (p. 69)
- Scholarly synthesis and implications: Explain what the result about a response to a failed closing reference following an accessory replacement authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Closing: Conclude by answering “Develop a response to a failed closing reference following an accessory replacement” using only the demonstrated evidence; state the remaining decisive verification step Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

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V011-VOL-ESSAY-040. Design a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully characterized.

- Opening: Present a thesis that answers this precise question: Design a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully characterized. Identify which evidence would falsify the proposed conclusion Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Core terminology and scope: Define Design, release, steady in the question's particular technical setting; explain how conducted, fully, characterized differ if that distinction would change the analysis of "Design a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully characterized" Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Problem statement and purpose: Frame the actual measurement or decision in the question. State separate domains, identify additional geometry, trigger, recovery and coverage evidence needed, and retain usable narrow claims Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully… to the claimed result, following "13. Verification, records and the interpretation of negative observations"; name the intermediate states and measurable

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outputs Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully.... Explain why a valid certificate or repeated successful use does not automatically extend acceptance Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Validate transient and gated measurements with the intended waveform" that resolves the question about a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully...; derive the relevant result with units and stated validity conditions Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully.... Explain why a valid certificate or repeated successful use does not automatically extend acceptance Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Worked application or illustrative case: Build a worked example of "a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully...", addressing

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this associated condition: State separate domains, identify additional geometry, trigger, recovery and coverage evidence needed, and.... State separate domains, identify additional geometry, trigger, recovery and coverage evidence needed, and retain... Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully...". Using "Validate transient and gated measurements with the intended waveform", specify a discriminator and the result expected under each explanation Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully..., including the effect of missing measurements and inconsistent operating conditions Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)
- Scholarly synthesis and implications: Explain what the result about a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully... authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- Closing: Conclude by answering “Design a final release for a method whose steady conducted measurements are accepted but installed burst behavior is not fully characterized” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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V011-VOL-ESSAY-041. Compare physical source uncertainty with software implementation mistakes in a receiver analysis.

- Opening: Present a thesis that answers this precise question: Compare physical source uncertainty with software implementation mistakes in a receiver analysis. Identify which evidence would falsify the proposed conclusion Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Core terminology and scope: Define physical, uncertainty, software in the question's particular technical setting; explain how implementation, mistakes, analysis differ if that distinction would change the analysis of "Compare physical source uncertainty with software implementation mistakes in a receiver analysis" Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use examples of wrong cable, duplicated correction, binary-point error and incorrect covariance Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting physical source uncertainty with software implementation mistakes in a receiver analysis to the claimed result, following "Calibration Lifecycle and Change Control"; name the intermediate states and measurable outputs Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for physical source uncertainty with software implementation mistakes in a

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receiver analysis. Explain which require correcting the model or data identity rather than enlarging a budget, and specify independent physical and arithmetic checks Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Reproducible Analysis and Derived Products” that resolves the question about physical source uncertainty with software implementation mistakes in a receiver analysis; derive the relevant result with units and stated validity conditions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Evidence and method: Specify the native observations, control records and calculations that would resolve physical source uncertainty with software implementation mistakes in a receiver analysis. Explain which require correcting the model or data identity rather than enlarging a budget, and specify independent physical and arithmetic checks Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Worked application or illustrative case: Build a worked example of “physical source uncertainty with software implementation mistakes in a receiver analysis”, addressing this associated condition: Use examples of wrong cable, duplicated correction, binary-point error and incorrect covariance. Use examples of wrong cable, duplicated correction, binary-point error and incorrect covariance Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “physical source uncertainty with software

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implementation mistakes in a receiver analysis". Using "Reproducible Analysis and Derived Products", specify a discriminator and the result expected under each explanation Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to physical source uncertainty with software implementation mistakes in a receiver analysis, including the effect of missing measurements and inconsistent operating conditions Source: §10.20 Ten worked applications of Model 10C (p. 5709)
- Scholarly synthesis and implications: Explain what the result about physical source uncertainty with software implementation mistakes in a receiver analysis authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)
- Closing: Conclude by answering "Compare physical source uncertainty with software implementation mistakes in a receiver analysis" using only the demonstrated evidence; state the remaining decisive verification step Source: §10.31 Interpretation and reproducibility of the channelized record (p. 5721)

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V011-VOL-ESSAY-042. Evaluate how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously.

- Opening: Present a thesis that answers this precise question: Evaluate how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously. Identify which evidence would falsify the proposed conclusion Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Core terminology and scope: Define alter, quality, trigger in the question's particular technical setting; explain how reported, finding, simultaneously differ if that distinction would change the analysis of "Evaluate how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously" Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Track desired spectral transfer, ENBW, time response and trigger-path location; keep normalization and state corrections explicit Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously to the claimed result, following "Verify the trigger at its actual signal-path location"; name the intermediate states and measurable outputs Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously. Use a known waveform and blocker challenge to distinguish a useful rejection improvement from discarded information or sensitivity change Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Case study 3.D3. The misleading improvement from additional preamplifier gain" that resolves the question about how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously; derive the relevant result with units and stated validity conditions Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously. Use a known waveform and blocker challenge to distinguish a useful rejection improvement from discarded information or sensitivity change Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Worked application or illustrative case: Build a worked example of "how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously", addressing this associated condition: Track desired spectral transfer, ENBW, time response and trigger-path location; keep normalization and

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state.... Track desired spectral transfer, ENBW, time response and trigger-path location; keep normalization and state... Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- Alternative explanations and failure modes: Construct two plausible technical explanations for "how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously". Using "Case study 3.D3. The misleading improvement from additional preamplifier gain", specify a discriminator and the result expected under each explanation Source: §3.33.3 Case study 3.D3. The misleading improvement from additional preamplifier gain (p. 1332)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously, including the effect of missing measurements and inconsistent operating conditions Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)
- Scholarly synthesis and implications: Explain what the result about how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §3.4 Use preselection as a measured transfer function (p. 1253)
- Closing: Conclude by answering "Evaluate how changing bandwidth can alter noise, modulation quality, trigger behavior and a reported finding simultaneously" using only the demonstrated evidence; state

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the remaining decisive verification step Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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V011-VOL-ESSAY-043. Design a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks.

- Opening: Present a thesis that answers this precise question: Design a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks. Identify which evidence would falsify the proposed conclusion Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Core terminology and scope: Define Design, demodulated, aliases in the question's particular technical setting; explain how images, false, locks differ if that distinction would change the analysis of "Design a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks" Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Follow analog/digital frequency maps, validate synchronization and symbol mapping with references, preserve held-out/noise-only tests and state uncertainty Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks to the claimed result, following "Defensive Interpretation of Digital Signals"; name the intermediate states and measurable outputs Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks. Report the classification actually supported without converting plausible content into device attribution Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Metric Validation and Held-Out Data” that resolves the question about a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks; derive the relevant result with units and stated validity conditions Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks. Report the classification actually supported without converting plausible content into device attribution Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Worked application or illustrative case: Build a worked example of “a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks”, addressing this associated condition: Follow analog/digital frequency maps, validate synchronization and symbol mapping with references, preserve.... Follow analog/digital frequency maps, validate synchronization and symbol mapping with references, preserve... Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks”. Using “Metric Validation and Held-Out Data”, specify a discriminator and the result expected under each explanation Source: §7.20 Metric Validation and Held-Out Data (p. 3766)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks, including the effect of missing measurements and inconsistent operating conditions Source: §16.1 Artifact Taxonomy and Competing Explanations (p. 9257)
- Scholarly synthesis and implications: Explain what the result about a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)
- Closing: Conclude by answering “Design a source-independent interpretation of a demodulated waveform that may contain aliases, images or false locks” using only the demonstrated evidence; state the remaining decisive verification step Source: §1.3 Observation, Classification, Attribution, and Content Recovery (p. 57)

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V011-VOL-ESSAY-044. Explain how a common reference can improve a relative measurement while weakening an apparent independent validation.

- Opening: Present a thesis that answers this precise question: Explain how a common reference can improve a relative measurement while weakening an apparent independent validation. Identify which evidence would falsify the proposed conclusion Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)
- Core terminology and scope: Define common, improve, relative in the question's particular technical setting; explain how apparent, independent, validation differ if that distinction would change the analysis of "Explain how a common reference can improve a relative measurement while weakening an apparent independent validation" Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use phase-error cancellation in one difference and shared error in two agreeing receivers Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting how a common reference can improve a relative measurement while weakening an apparent independent validation to the claimed result, following "Coupling paths that defeat the simple external-versus-internal dichotomy"; name the intermediate states and measurable outputs Source: §16.22 Coupling paths that defeat the simple external-versus-internal dichotomy (p. 9305)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for how a common reference can improve a relative measurement while weakening an apparent independent validation. State coupling and covariance, retain absolute versus relative scope, and propose an independent reference/path observation when required Source: §16.22 Coupling paths that defeat the simple external-versus-internal dichotomy (p. 9305)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Application 10F.8 Two agreeing programs share the same fault" that resolves the question about how a common reference can improve a relative measurement while weakening an apparent independent validation; derive the relevant result with units and stated validity conditions Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)
- Evidence and method: Specify the native observations, control records and calculations that would resolve how a common reference can improve a relative measurement while weakening an apparent independent validation. State coupling and covariance, retain absolute versus relative scope, and propose an independent reference/path observation when required Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)
- Worked application or illustrative case: Build a worked example of "how a common reference can improve a relative measurement while weakening an apparent independent validation", addressing this associated condition: Use phase-error cancellation in one difference and shared error in two agreeing receivers. Use phase-

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error cancellation in one difference and shared error in two agreeing receivers Source: §16.22 Coupling paths that defeat the simple external-versus-internal dichotomy (p. 9305)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “how a common reference can improve a relative measurement while weakening an apparent independent validation”. Using “Application 10F.8 Two agreeing programs share the same fault”, specify a discriminator and the result expected under each explanation Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to how a common reference can improve a relative measurement while weakening an apparent independent validation, including the effect of missing measurements and inconsistent operating conditions Source: §3.39 Uncertainty-aware interpretation of instrument agreement (p. 1359)
- Scholarly synthesis and implications: Explain what the result about how a common reference can improve a relative measurement while weakening an apparent independent validation authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)
- Closing: Conclude by answering “Explain how a common reference can improve a relative measurement while weakening an apparent independent validation” using only the demonstrated evidence;

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state the remaining decisive verification step Source: §10.102 Application 9

Averaging correlated versus independent errors (p. 5815)

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V011-VOL-ESSAY-045. Design an audit connecting a negative signal finding to actual native data coverage.

- Opening: Present a thesis that answers this precise question: Design an audit connecting a negative signal finding to actual native data coverage. Identify which evidence would falsify the proposed conclusion Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Core terminology and scope: Define Design, audit, connecting in the question's particular technical setting; explain how finding, native, coverage differ if that distinction would change the analysis of "Design an audit connecting a negative signal finding to actual native data coverage" Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Reconcile planned, commanded, valid and preserved intervals, passbands, source states and event classes Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an audit connecting a negative signal finding to actual native data coverage to the claimed result, following "Record repetition and the limits of the design"; name the intermediate states and measurable outputs Source: §16.4.4 Record repetition and the limits of the design (p. 9270)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an audit

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connecting a negative signal finding to actual native data coverage. Include sensitivity, trigger and schedule assumptions; identify gap/guard exclusions and avoid claiming absence beyond the supported acquisition Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- Analytical framework: Identify the equation, calibration or evidential decision test in “8. Distinguishing a spectral estimator from a persuasive-looking display” that resolves the question about an audit connecting a negative signal finding to actual native data coverage; derive the relevant result with units and stated validity conditions Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an audit connecting a negative signal finding to actual native data coverage. Include sensitivity, trigger and schedule assumptions; identify gap/guard exclusions and avoid claiming absence beyond the supported acquisition Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Worked application or illustrative case: Build a worked example of “an audit connecting a negative signal finding to actual native data coverage”, addressing this associated condition: Reconcile planned, commanded, valid and preserved intervals, passbands, source states and event classes. Reconcile planned, commanded, valid and preserved intervals, passbands, source states and event classes Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “an audit connecting a negative signal finding to actual native data coverage”. Using “8. Distinguishing a spectral estimator from a persuasive-looking display”, specify a discriminator and the result expected under each explanation Source: §8.17 Distinguishing a spectral estimator from a persuasive-looking display (p. 4466)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an audit connecting a negative signal finding to actual native data coverage, including the effect of missing measurements and inconsistent operating conditions Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Scholarly synthesis and implications: Explain what the result about an audit connecting a negative signal finding to actual native data coverage authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)
- Closing: Conclude by answering “Design an audit connecting a negative signal finding to actual native data coverage” using only the demonstrated evidence; state the remaining decisive verification step Source: §15.8 Application 15A.5: Remove settling and closing guards from nominal dwell (p. 8689)

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V011-VOL-ESSAY-046. Compare average-power closure with peak-sensitive receiver validity.

- Opening: Present a thesis that answers this precise question: Compare average-power closure with peak-sensitive receiver validity. Identify which evidence would falsify the proposed conclusion Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Core terminology and scope: Define average-power, closure, peak-sensitive in the question's particular technical setting; explain how receiver, validity, measurement differ if that distinction would change the analysis of "Compare average-power closure with peak-sensitive receiver validity" Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Use complex-envelope or SSB examples to distinguish mean, peak and coherent contributions; show how a correctly normalized FFT can conserve energy while missing relevant peak loading or temporal... Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting average-power closure with peak-sensitive receiver validity to the claimed result, following "Energy closure and its limits"; name the intermediate states and measurable outputs Source: §9.3.3 Energy closure and its limits (p. 5036)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for average-power closure with peak-sensitive receiver validity. Retain waveform and stage-level evidence for nonlinearity/protection claims Source: §9.3.3 Energy closure and its limits (p. 5036)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Model 6A: preserve the complex envelope” that resolves the question about average-power closure with peak-sensitive receiver validity; derive the relevant result with units and stated validity conditions Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)
- Evidence and method: Specify the native observations, control records and calculations that would resolve average-power closure with peak-sensitive receiver validity. Retain waveform and stage-level evidence for nonlinearity/protection claims Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Worked application or illustrative case: Build a worked example of “average-power closure with peak-sensitive receiver validity”, addressing this associated condition: Use complex-envelope or SSB examples to distinguish mean, peak and coherent contributions; show how a.... Use complex-envelope or SSB examples to distinguish mean, peak and coherent contributions; show how a correctly normalized FFT can conserve energy while missing relevant... Source: §9.3.3 Energy closure and its limits (p. 5036)
- Alternative explanations and failure modes: Construct two plausible technical explanations for “average-power closure with peak-

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sensitive receiver validity". Using "Model 6A: preserve the complex envelope", specify a discriminator and the result expected under each explanation Source: §6.4 Model 6A: preserve the complex envelope (p. 3112)

- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to average-power closure with peak-sensitive receiver validity, including the effect of missing measurements and inconsistent operating conditions Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)
- Scholarly synthesis and implications: Explain what the result about average-power closure with peak-sensitive receiver validity authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)
- Closing: Conclude by answering "Compare average-power closure with peak-sensitive receiver validity" using only the demonstrated evidence; state the remaining decisive verification step Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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V011-VOL-ESSAY-047. Develop a phase-noise characterization suitable for both jitter reporting and blocker susceptibility.

- Opening: Present a thesis that answers this precise question: Develop a phase-noise characterization suitable for both jitter reporting and blocker susceptibility. Identify which evidence would falsify the proposed conclusion Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Core terminology and scope: Define phase-noise, characterization, jitter in the question's particular technical setting; explain how reporting, blocker, susceptibility differ if that distinction would change the analysis of "Develop a phase-noise characterization suitable for both jitter reporting and blocker susceptibility" Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Distinguish lines from densities, retain finite bands and carrier conversion, and apply actual channel weighting to admitted blockers Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a phase-noise characterization suitable for both jitter reporting and blocker susceptibility to the claimed result, following "Model 11B for reciprocal mixing and admitted noise"; name the intermediate states and measurable outputs Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a phase-noise characterization suitable for both jitter reporting and blocker susceptibility. Identify unmeasured bands and avoid using one integrated RMS to certify every coherent or reciprocal-mixing condition Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Phase Noise and Close-In Observation” that resolves the question about a phase-noise characterization suitable for both jitter reporting and blocker susceptibility; derive the relevant result with units and stated validity conditions Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a phase-noise characterization suitable for both jitter reporting and blocker susceptibility. Identify unmeasured bands and avoid using one integrated RMS to certify every coherent or reciprocal-mixing condition Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Worked application or illustrative case: Build a worked example of “a phase-noise characterization suitable for both jitter reporting and blocker susceptibility”, addressing this associated condition: Distinguish lines from densities, retain finite bands and carrier conversion, and apply actual channel.... Distinguish lines from densities, retain finite bands and carrier conversion, and apply

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actual channel weighting to admitted blockers Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a phase-noise characterization suitable for both jitter reporting and blocker susceptibility”. Using “Phase Noise and Close-In Observation”, specify a discriminator and the result expected under each explanation Source: §12.14 Phase Noise and Close-In Observation (p. 6967)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a phase-noise characterization suitable for both jitter reporting and blocker susceptibility, including the effect of missing measurements and inconsistent operating conditions Source: §11.34 Application 11B.7 Sum blockers only under an explicit cross-power condition (p. 6410)
- Scholarly synthesis and implications: Explain what the result about a phase-noise characterization suitable for both jitter reporting and blocker susceptibility authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)
- Closing: Conclude by answering “Develop a phase-noise characterization suitable for both jitter reporting and blocker susceptibility” using only the demonstrated evidence; state the remaining decisive verification step Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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V011-VOL-ESSAY-048. Construct a treatment of unknown discrete receiver states that remains honest through decision and reporting.

- Opening: Present a thesis that answers this precise question: Construct a treatment of unknown discrete receiver states that remains honest through decision and reporting. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define Construct, treatment, unknown in the question's particular technical setting; explain how discrete, decision, reporting differ if that distinction would change the analysis of "Construct a treatment of unknown discrete receiver states that remains honest through decision and reporting" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Derive state-specific admissible corrected results, preserve disjoint unions and missing validity intervals, and avoid assigning probabilities without evidence Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a treatment of unknown discrete receiver states that remains honest through decision and reporting to the claimed result, following "Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate"; name the intermediate states and measurable outputs Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a treatment of unknown discrete receiver states that remains honest through decision and reporting. Explain which follow-up can identify the state and how release is narrowed if it cannot Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)
- Analytical framework: Identify the equation, calibration or evidential decision test in "Close the receiver method through configuration-specific regression" that resolves the question about a treatment of unknown discrete receiver states that remains honest through decision and reporting; derive the relevant result with units and stated validity conditions Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a treatment of unknown discrete receiver states that remains honest through decision and reporting. Explain which follow-up can identify the state and how release is narrowed if it cannot Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of "a treatment of unknown discrete receiver states that remains honest through decision and reporting", addressing this associated condition: Derive state-specific admissible corrected results, preserve disjoint unions and missing validity intervals,.... Derive state-specific admissible corrected results, preserve disjoint unions and missing validity intervals, and avoid assigning... Source: §7.22.10

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Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “a treatment of unknown discrete receiver states that remains honest through decision and reporting”. Using “Close the receiver method through configuration-specific regression”, specify a discriminator and the result expected under each explanation Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a treatment of unknown discrete receiver states that remains honest through decision and reporting, including the effect of missing measurements and inconsistent operating conditions Source: §1.12.5 Application 1A.5. Retain separate admissible results when the settled state is unknown (p. 87)
- Scholarly synthesis and implications: Explain what the result about a treatment of unknown discrete receiver states that remains honest through decision and reporting authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering “Construct a treatment of unknown discrete receiver states that remains honest through decision and reporting” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-VOL-ESSAY-049. Design a review of a high-confidence report based on many dependent derived products.

- Opening: Present a thesis that answers this precise question: Design a review of a high-confidence report based on many dependent derived products. Identify which evidence would falsify the proposed conclusion Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Core terminology and scope: Define Design, review, based in the question's particular technical setting; explain how dependent, derived, products differ if that distinction would change the analysis of "Design a review of a high-confidence report based on many dependent derived products" Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Trace each plot, decode, EVM, trigger log and comparison to native sources and shared clocks/software Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting a review of a high-confidence report based on many dependent derived products to the claimed result, following "Coverage Review and Storage Governance"; name the intermediate states and measurable outputs Source: §15.20 Coverage Review and Storage Governance (p. 8709)
- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for a review of a high-confidence report based on many dependent derived

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products. Retain complementary observables but avoid unsupported multiplication; identify missing physical contrasts and specify the evidence for any proposed likelihood model Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- Analytical framework: Identify the equation, calibration or evidential decision test in “Quantitative worked contrasts: sweep coverage, channelised capture and resolution claims” that resolves the question about a review of a high-confidence report based on many dependent derived products; derive the relevant result with units and stated validity conditions Source: §8.27 Quantitative worked contrasts: sweep coverage, channelised capture and resolution claims (p. 4490)
- Evidence and method: Specify the native observations, control records and calculations that would resolve a review of a high-confidence report based on many dependent derived products. Retain complementary observables but avoid unsupported multiplication; identify missing physical contrasts and specify the evidence for any proposed likelihood model Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Worked application or illustrative case: Build a worked example of “a review of a high-confidence report based on many dependent derived products”, addressing this associated condition: Trace each plot, decode, EVM, trigger log and comparison to native sources and shared clocks/software. Trace each plot, decode, EVM, trigger log and comparison to native sources and shared clocks/software Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- Alternative explanations and failure modes: Construct two plausible technical explanations for “a review of a high-confidence report based on many dependent derived products”. Using “Quantitative worked contrasts: sweep coverage, channelised capture and resolution claims”, specify a discriminator and the result expected under each explanation Source: §8.27 Quantitative worked contrasts: sweep coverage, channelised capture and resolution claims (p. 4490)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to a review of a high-confidence report based on many dependent derived products, including the effect of missing measurements and inconsistent operating conditions Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Scholarly synthesis and implications: Explain what the result about a review of a high-confidence report based on many dependent derived products authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)
- Closing: Conclude by answering “Design a review of a high-confidence report based on many dependent derived products” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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V011-VOL-ESSAY-050. Develop an end-to-end case in which the reported conclusion is narrowed after a justified technical correction.

- Opening: Present a thesis that answers this precise question: Develop an end-to-end case in which the reported conclusion is narrowed after a justified technical correction. Identify which evidence would falsify the proposed conclusion Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Core terminology and scope: Define case, reported, conclusion in the question's particular technical setting; explain how justified, technical, correction differ if that distinction would change the analysis of "Develop an end-to-end case in which the reported conclusion is narrowed after a justified technical correction" Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Problem statement and purpose: Frame the actual measurement or decision in the question. Define the original measurement and source records, identify a concrete state/normalization/coverage error, recompute with valid models and preserve both versions Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Physical and computational context: Reconstruct the physical, mathematical or software mechanism connecting an end-to-end case in which the reported conclusion is narrowed after a justified technical correction to the claimed result, following "Reproducible Analysis and Derived Products"; name the intermediate states and measurable outputs Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

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- Assumptions, conditions and reference planes: State the testable assumptions, configuration states and reference planes for an end-to-end case in which the reported conclusion is narrowed after a justified technical correction. Explain which observation remains, which inference changes and what regression prevents recurrence Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)
- Analytical framework: Identify the equation, calibration or evidential decision test in “Case study 3.D8. Temperature-dependent drift and the risk of overcorrection” that resolves the question about an end-to-end case in which the reported conclusion is narrowed after a justified technical correction; derive the relevant result with units and stated validity conditions Source: §3.33.8 Case study 3.D8. Temperature-dependent drift and the risk of overcorrection (p. 1342)
- Evidence and method: Specify the native observations, control records and calculations that would resolve an end-to-end case in which the reported conclusion is narrowed after a justified technical correction. Explain which observation remains, which inference changes and what regression prevents recurrence Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Worked application or illustrative case: Build a worked example of “an end-to-end case in which the reported conclusion is narrowed after a justified technical correction”, addressing this associated condition: Define the original measurement and source records, identify a concrete state/normalization/coverage error,.... Define the original measurement and source records, identify a concrete

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state/normalization/coverage error, recompute with valid... Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- Alternative explanations and failure modes: Construct two plausible technical explanations for “an end-to-end case in which the reported conclusion is narrowed after a justified technical correction”. Using “Case study 3.D8. Temperature-dependent drift and the risk of overcorrection”, specify a discriminator and the result expected under each explanation Source: §3.33.8 Case study 3.D8. Temperature-dependent drift and the risk of overcorrection (p. 1342)
- Uncertainty and evidential limits: Quantify or bound the uncertainties that matter to an end-to-end case in which the reported conclusion is narrowed after a justified technical correction, including the effect of missing measurements and inconsistent operating conditions Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)
- Scholarly synthesis and implications: Explain what the result about an end-to-end case in which the reported conclusion is narrowed after a justified technical correction authorises the investigator or engineer to claim, and what stronger proposition remains unsupported Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)
- Closing: Conclude by answering “Develop an end-to-end case in which the reported conclusion is narrowed after a justified technical correction” using only the demonstrated evidence; state the remaining decisive verification step Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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Discussion Questions

[Discussion instructions: For each discussion question, prepare approximately 500 spoken words for delivery over 2.5–3 minutes (approximately 167–200 words per minute). Address the ten subject prompts below in their stated order. Use the opening to frame the issue and the closing to synthesise the principal findings, conclusions and unresolved questions.]

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V011-VOL-DISCUSSION-001. A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. How would you redirect the work?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. How would you redirect the work?” Put this particular dispute to the panel: A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. How would you redirect the work. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 02. Student A, terminology and scope: Agree the operational meanings of chooses, needs, terminal and strength, attribution, work in “A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. How would you redirect the work”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and

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request a specific example from the stated receiver scenario. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Attach calibration to a stated measurement result”. Explain that one receiver output cannot silently serve all three claims and preserve the authorization and observation scope Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Attach calibration to a stated measurement result”. Explain that one receiver output cannot silently serve all three claims and preserve the authorization and observation scope Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Define the intended quantity and evidential category first, then select reference planes, configuration, calibration and tests Put two specific questions to

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Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is

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missing. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. Explain that one receiver output cannot silently serve all three claims and preserve the authorization and observation scope Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team chooses a receiver mode before

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deciding whether the report needs terminal power, field strength or device attribution, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.2 Attach calibration to a stated measurement result (p. 8105)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. Explain that one receiver output cannot silently serve all three claims and preserve the authorization and observation scope Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or

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device attribution and How would you redirect the work; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.5 Define the measurement before choosing the receiver mode (p. 62)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution”, addressing “How would you redirect the work”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. How would you redirect the work”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the

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resolution of “A team chooses a receiver mode before deciding whether the report needs terminal power, field strength or device attribution. How would you redirect the work”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

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V011-VOL-DISCUSSION-002. Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. What should be evaluated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. What should be evaluated?” Put this particular dispute to the panel: Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. What should be evaluated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 02. Student A, terminology and scope: Agree the operational meanings of identical, total, calls and equally, sensitive, evaluated in “Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. What should be evaluated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two layouts have identical total gain, and the procurement comparison calls them equally sensitive; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Derive passive loss from thermal equilibrium”. Include remote gain and passive-loss temperature where relevant; equal desired gain is insufficient for equal detection capability Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two layouts have identical

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total gain, and the procurement comparison calls them equally sensitive; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Derive passive loss from thermal equilibrium”. Include remote gain and passive-loss temperature where relevant; equal desired gain is insufficient for equal detection capability Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare component order, input-equivalent noise and blocker exposure, then validate actual assembled transfer Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two layouts have identical total gain, and the procurement comparison calls them equally sensitive: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two layouts have identical total gain, and the procurement comparison calls them equally sensitive; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two layouts have identical total gain, and the procurement comparison calls them equally sensitive:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two layouts have identical total gain, and the procurement comparison calls them equally sensitive, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two layouts have identical total gain, and the procurement comparison calls them equally sensitive: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the

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panel to retain, qualify or reject the conclusion. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. Include remote gain and passive-loss temperature where relevant; equal desired gain is insufficient for equal detection capability Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two layouts have identical total gain, and the procurement comparison calls them equally sensitive, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. Include remote gain and passive-loss temperature where relevant; equal desired gain is insufficient for equal detection capability Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two layouts have identical total gain, and the procurement comparison calls them equally sensitive and What should be evaluated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.33 Application 11B.6 Move both blocker and desired reference planes (p. 6408)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two layouts have identical total gain, and the procurement comparison calls them equally sensitive”, addressing “What should be evaluated”; specify the exact

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measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. What should be evaluated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two layouts have identical total gain, and the procurement comparison calls them equally sensitive. What should be evaluated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

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V011-VOL-DISCUSSION-003. A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Is that a valid compromise?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Is that a valid compromise?” Put this particular dispute to the panel: A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Is that a valid compromise. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 02. Student A, terminology and scope: Agree the operational meanings of proposed, halfway, incompatible and minimum, maximum, compromise in “A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Is that a valid compromise”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.6 Choose gain from a feasible interval (p. 1257)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A proposed gain lies halfway between an incompatible noise minimum and loading maximum; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Turn the cascade into bounded design requirements”. Keep desired transfer, sensitivity and loading requirements explicit Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A proposed gain lies halfway

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between an incompatible noise minimum and loading maximum; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Turn the cascade into bounded design requirements”. Keep desired transfer, sensitivity and loading requirements explicit Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Show that neither constraint is necessarily met, identify the empty feasible interval and propose changing rejection, stage placement or operating conditions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.6 Choose gain from a feasible interval (p. 1257)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A proposed gain lies halfway between an incompatible noise minimum and loading maximum: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A proposed gain lies halfway between an incompatible noise minimum and loading maximum; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A proposed gain lies halfway between an incompatible noise minimum and loading maximum: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A proposed gain lies halfway between an incompatible noise minimum and loading maximum, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A proposed gain lies halfway between an incompatible noise minimum and loading maximum: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Keep desired transfer, sensitivity and loading requirements explicit Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A proposed gain lies halfway between an incompatible noise minimum and loading maximum, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Keep desired transfer, sensitivity and loading requirements explicit Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.19.10 Example 3.C10. Selecting a feasible gain interval (p. 1293)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A proposed gain lies halfway between an incompatible noise minimum and loading maximum and Is that a valid compromise; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A proposed gain lies halfway between an incompatible noise minimum and loading maximum”, addressing “Is that a valid compromise”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.6 Choose gain from a feasible interval (p. 1257)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Is that a valid compromise”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A proposed gain lies halfway between an incompatible noise minimum and loading maximum. Is that a valid compromise”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.6 Choose gain from a feasible interval (p. 1257)

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V011-VOL-DISCUSSION-004. Several individually tolerable blockers arrive simultaneously. Which limitation is missing from a single-tone gain budget?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Several individually tolerable blockers arrive simultaneously. Which limitation is missing from a single-tone gain budget?” Put this particular dispute to the panel: Several individually tolerable blockers arrive simultaneously. Which limitation is missing from a single-tone gain budget. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 02. Student A, terminology and scope: Agree the operational meanings of blockers, arrive, simultaneously and limitation, missing, budget in “Several individually tolerable blockers arrive simultaneously. Which limitation is missing from a single-tone gain budget”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Several individually tolerable blockers arrive simultaneously; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 3.C2. Converting two blockers to a single equivalent power”. Use the local nonlinear model only where supported and preserve a weak-reference challenge Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Several individually tolerable

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blockers arrive simultaneously; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 3.C2. Converting two blockers to a single equivalent power”. Use the local nonlinear model only where supported and preserve a weak-reference challenge Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Consider total mean power and possible instantaneous/coherent loading at each vulnerable stage, with actual frequency-dependent admission Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Several individually tolerable blockers arrive simultaneously: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Several individually tolerable blockers arrive simultaneously; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Several individually tolerable blockers arrive simultaneously: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Several individually tolerable blockers arrive simultaneously, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Several individually tolerable blockers arrive simultaneously: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Several individually tolerable blockers arrive simultaneously. Use the local nonlinear model only where supported and preserve a weak-reference challenge Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Several individually tolerable blockers arrive simultaneously, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.19.2 Example 3.C2. Converting two blockers to a single equivalent power (p. 1285)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Several individually tolerable blockers arrive simultaneously. Use the local nonlinear model only where supported and preserve a weak-reference challenge Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Several individually tolerable blockers arrive simultaneously and Which limitation is missing from a single-tone gain budget; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.2 Find the first stage that can lose validity (p. 1249)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Several individually tolerable blockers arrive simultaneously”, addressing “Which limitation is missing from a single-tone gain budget”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Several individually tolerable blockers arrive simultaneously. Which limitation is missing from a single-tone gain budget”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Several individually tolerable blockers arrive simultaneously. Which limitation is missing from a single-tone gain budget”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

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V011-VOL-DISCUSSION-005. A new preselector lowers the noise floor but worsens wideband EVM. How should its benefit be assessed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A new preselector lowers the noise floor but worsens wideband EVM. How should its benefit be assessed?” Put this particular dispute to the panel: A new preselector lowers the noise floor but worsens wideband EVM. How should its benefit be assessed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 02. Student A, terminology and scope: Agree the operational meanings of preselector, lowers, floor and wideband, benefit, assessed in “A new preselector lowers the noise floor but worsens wideband EVM. How should its benefit be assessed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A new preselector lowers the noise floor but worsens wideband EVM; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10C5 Oversampling changes the required channel phase”. Retain the improvement and waveform cost separately; center-tone gain or a quieter display does not establish overall fidelity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A new preselector lowers the

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noise floor but worsens wideband EVM; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10C5 Oversampling changes the required channel phase”. Retain the improvement and waveform cost separately; center-tone gain or a quieter display does not establish overall fidelity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Compare desired amplitude/phase response across the waveform, rejected blockers, noise bandwidth and gain state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A new preselector lowers the noise floor but worsens wideband EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A new preselector lowers the noise floor but worsens wideband EVM; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A new preselector lowers the noise floor but worsens wideband EVM: specify the altered receiver

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state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A new preselector lowers the noise floor but worsens wideband EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A new preselector lowers the noise floor but worsens wideband EVM: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what

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observation would lead the panel to retain, qualify or reject the conclusion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A new preselector lowers the noise floor but worsens wideband EVM. Retain the improvement and waveform cost separately; center-tone gain or a quieter display does not establish overall fidelity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A new preselector lowers the noise floor but worsens wideband EVM, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.25 Application 10C5 Oversampling changes the required channel phase (p. 5714)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A new preselector lowers the noise floor but worsens wideband EVM. Retain the improvement and waveform cost separately; center-tone gain or a quieter display does not establish overall fidelity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.31 Noise-floor specification for a 1 Hz reference and a 30 Hz analysis bandwidth (p. 696)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A new preselector lowers the noise floor but worsens wideband EVM and How should its benefit be assessed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.34 Synthesis: what the completed front-end record can establish (p. 1348)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A new preselector lowers the noise floor but worsens wideband EVM”, addressing “How should its benefit be assessed”; specify the exact measurement or evidential gap on

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which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A new preselector lowers the noise floor but worsens wideband EVM. How should its benefit be assessed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A new preselector lowers the noise floor but worsens wideband EVM. How should its benefit be assessed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §3.4 Use preselection as a measured transfer function (p. 1253)

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V011-VOL-DISCUSSION-006. A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Is the design ready?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Is the design ready?” Put this particular dispute to the panel: A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Is the design ready. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

- 02. Student A, terminology and scope: Agree the operational meanings of insertion, fits, allowance and rejection, unmeasured, design in “A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Is the design ready”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 3.C5. Passive filter loss and the first-stage noise factor”. Avoid transferring desired-frequency loss to the blocker path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 3.C5. Passive filter loss and the first-stage noise factor”. Avoid transferring desired-frequency loss to the blocker path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Treat the noise bound as one requirement, characterize rejection at actual blocker frequencies and confirm loading before the vulnerable stage Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Avoid transferring desired-frequency loss to the blocker path Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Avoid transferring desired-frequency loss to the blocker path Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.17 Turn the cascade into bounded design requirements (p. 675)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured and Is the design ready; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.18.7 Example 13.X7. Loss and system noise from a protective filter (p. 7572)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured”, addressing “Is the design ready”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Is the design ready”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A filter's insertion loss fits the noise allowance but its blocker rejection is unmeasured. Is the design ready”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.24 Application 2B.7: place attenuation before the vulnerable stage (p. 684)

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V011-VOL-DISCUSSION-007. A warm input pad improves matching while weakening the desired signal. What should the review balance?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A warm input pad improves matching while weakening the desired signal. What should the review balance?” Put this particular dispute to the panel: A warm input pad improves matching while weakening the desired signal. What should the review balance. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 02. Student A, terminology and scope: Agree the operational meanings of warm, improves, matching and desired, review, balance in “A warm input pad improves matching while weakening the desired signal. What should the review balance”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A warm input pad improves matching while weakening the desired signal; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 2B.6: allocate loss to a preselector”. Evaluate target sensitivity and uncertainty rather than declaring a match improvement universally beneficial Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A warm input pad improves matching while weakening the desired signal; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 2B.6: allocate loss to a preselector”. Evaluate target sensitivity and uncertainty rather than declaring a match improvement universally beneficial Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Include dissipative noise temperature, referred downstream noise, desired loss and impedance-sensitive receiver behavior Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A warm input pad improves matching while

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weakening the desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A warm input pad improves matching while weakening the desired signal; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A warm input pad improves matching while weakening the desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A warm input pad improves matching while weakening the desired signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A warm input pad improves matching while weakening the desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A warm input pad improves matching while weakening the desired signal. Evaluate target sensitivity and uncertainty rather than declaring a match improvement universally beneficial Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A warm input pad improves matching while weakening the desired signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.23 Application 2B.6: allocate loss to a preselector (p. 683)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A warm input pad improves matching while weakening the desired signal. Evaluate target sensitivity and uncertainty rather than declaring a match improvement universally beneficial Respond point by point to Student J. Distinguish a verified

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observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A warm input pad improves matching while weakening the desired signal and What should the review balance; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.17 Noise, mismatch and gain-order dependencies (p. 1279)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A warm input pad improves matching while weakening the desired signal”, addressing “What should the review balance”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A warm input pad improves matching while weakening the desired signal. What should the review balance”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A warm input pad improves matching while weakening the desired signal. What should the review balance”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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V011-VOL-DISCUSSION-008. A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. What needs correction?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. What needs correction?” Put this particular dispute to the panel: A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. What needs correction. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 02. Student A, terminology and scope: Agree the operational meanings of figure, used, predict and degradation, needs, correction in “A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. What needs correction”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Noise Figure and System Sensitivity Calibration”. Explain the zero-added-noise exception without generalizing it Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Noise Figure and System Sensitivity Calibration”. Explain the zero-added-noise exception without generalizing it Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Keep reference noise factor separate from actual source-temperature degradation, use the applicable cascade and bandwidth, and verify the detection procedure separately Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. Explain the zero-added-noise exception without generalizing it Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. Explain the zero-added-

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noise exception without generalizing it Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.19.5 Example 3.C5. Passive filter loss and the first-stage noise factor (p. 1288)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source and What needs correction; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.20 Application 2B.3: distinguish loss from temperature (p. 680)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source”, addressing “What needs correction”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §2.21 Application 2B.4: change the source environment (p. 681)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. What needs correction”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A receiver's 290 K noise figure is used to predict SNR degradation at a much hotter source. What needs correction”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.21 Application 2B.4: change the source environment (p. 681)

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V011-VOL-DISCUSSION-009. A noise-source switch changes both temperature and impedance. Which checks are needed before accepting its Y-factor?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A noise-source switch changes both temperature and impedance. Which checks are needed before accepting its Y-factor?” Put this particular dispute to the panel: A noise-source switch changes both temperature and impedance. Which checks are needed before accepting its Y-factor. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 02. Student A, terminology and scope: Agree the operational meanings of noise-source, switch, changes and temperature, impedance, checks in “A noise-source switch changes both temperature and impedance. Which checks are needed before accepting its Y-factor”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.16 Invert the same model with two source temperatures (p. 672)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A noise-source switch changes both temperature and impedance; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. A scalar ENR entry alone does not close the model Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A noise-source switch changes both temperature and impedance; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. A scalar ENR entry alone does not close the model Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain hot/cold powers and receiver-plane temperatures, assess delivered noise and impedance-dependent receiver response, and establish common gain, bandwidth and linearity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.16 Invert the same model with two source temperatures (p. 672)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A noise-source switch changes both temperature and impedance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A noise-source switch changes both temperature and impedance; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A noise-source switch changes both temperature and impedance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.16 Invert the same model with two source temperatures (p. 672)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A noise-source switch changes both temperature and impedance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A noise-source switch changes both temperature and impedance: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A noise-source switch changes both temperature and impedance. A scalar ENR entry alone does not close the model Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A noise-source switch changes both temperature and impedance, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A noise-source switch changes both temperature and impedance. A scalar ENR entry alone does not close the model Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the

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missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A noise-source switch changes both temperature and impedance and Which checks are needed before accepting its Y-factor; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A noise-source switch changes both temperature and impedance”, addressing “Which checks are needed before accepting its Y-factor”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.16 Invert the same model with two source temperatures (p. 672)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A noise-source switch changes both temperature and impedance. Which checks are needed before accepting its Y-factor”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A noise-source switch changes both temperature and impedance. Which checks are needed before accepting its Y-factor”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.16 Invert the same model with two source temperatures (p. 672)

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V011-VOL-DISCUSSION-010. Hot-state automatic gain is different, but the computed noise figure is highly repeatable. What does repeatability establish?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Hot-state automatic gain is different, but the computed noise figure is highly repeatable. What does repeatability establish?” Put this particular dispute to the panel: Hot-state automatic gain is different, but the computed noise figure is highly repeatable. What does repeatability establish. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 02. Student A, terminology and scope: Agree the operational meanings of automatic, computed, figure and highly, repeatable, repeatability in “Hot-state automatic gain is different, but the computed noise figure is highly repeatable. What does repeatability establish”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Hot-state automatic gain is different, but the computed noise figure is highly repeatable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Recover or model gain states, test settling and compression and recompute under valid assumptions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Hot-state automatic gain is different, but the computed noise figure is highly repeatable; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Recover or model gain states, test settling and compression and recompute under valid assumptions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. It establishes repeated behavior of that state-dependent experiment, not the equal-gain inverse Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Hot-state automatic gain is different, but the computed noise figure is highly repeatable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Hot-state automatic gain is different, but the computed noise figure is highly repeatable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Hot-state automatic gain is

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different, but the computed noise figure is highly repeatable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Hot-state automatic gain is different, but the computed noise figure is highly repeatable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Hot-state automatic gain is different, but the computed noise figure is highly repeatable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Hot-state automatic gain is different, but the computed noise figure is highly repeatable. Recover or model gain states, test settling and compression and recompute under valid assumptions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Hot-state automatic gain is different, but the computed noise figure is highly repeatable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Hot-state automatic gain is different, but the computed noise figure is highly repeatable. Recover or model gain states, test settling and compression and recompute under valid assumptions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Hot-state automatic gain is different, but the computed noise figure is highly repeatable and What does repeatability establish; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.19 Swept analysis as a moving, state-dependent measurement aperture (p. 4473)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Hot-state automatic gain is different, but the computed noise figure is highly repeatable”, addressing “What does repeatability establish”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Hot-state automatic gain is different, but the computed noise figure is highly repeatable. What does repeatability establish”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Hot-state automatic gain is different, but the computed noise figure is highly repeatable. What does repeatability establish”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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V011-VOL-DISCUSSION-011. Only the hot noise state approaches converter clipping. How should the calibration be interpreted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Only the hot noise state approaches converter clipping. How should the calibration be interpreted?” Put this particular dispute to the panel: Only the hot noise state approaches converter clipping. How should the calibration be interpreted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 02. Student A, terminology and scope: Agree the operational meanings of noise, approaches, converter and clipping, calibration, interpreted in “Only the hot noise state approaches converter clipping. How should the calibration be interpreted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Only the hot noise state approaches converter clipping; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Cold-state linearity and averaging cannot justify an inversion using distorted hot power Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Only the hot noise state approaches converter clipping; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Cold-state linearity and averaging cannot justify an inversion using distorted hot power Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Inspect raw range flags and actual transfer, reduce loading or adopt a validated configuration, and retain the failed condition Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Only the hot noise state approaches converter

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clipping: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Only the hot noise state approaches converter clipping; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Only the hot noise state approaches converter clipping: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Only the hot noise state approaches converter clipping, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Only the hot noise state approaches converter clipping: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Only the hot noise state approaches

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converter clipping. Cold-state linearity and averaging cannot justify an inversion using distorted hot power Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Only the hot noise state approaches converter clipping, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Only the hot noise state approaches converter clipping. Cold-state linearity and averaging cannot justify an inversion using distorted hot power Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or

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uncertainty term that limits confidence. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Only the hot noise state approaches converter clipping and How should the calibration be interpreted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Only the hot noise state approaches converter clipping”, addressing “How should the calibration be interpreted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Only the hot noise state approaches converter clipping. How should the calibration be interpreted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Only the hot noise state approaches converter clipping. How should the calibration be interpreted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.26 Application 2B.9: expose a change hidden by a ratio (p. 686)

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V011-VOL-DISCUSSION-012. A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. What evidence is absent?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. What evidence is absent?” Put this particular dispute to the panel: A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. What evidence is absent. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 02. Student A, terminology and scope: Agree the operational meanings of offered, proof, short and hopping, bursts, absent in “A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. What evidence is absent”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A low noise-figure result is offered as proof of near-certain detection of short hopping bursts; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 15A: calculate conditional event coverage from usable windows”. Distinguish noise calibration from timing opportunity and decision performance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A low noise-figure result is

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offered as proof of near-certain detection of short hopping bursts; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 15A: calculate conditional event coverage from usable windows”. Distinguish noise calibration from timing opportunity and decision performance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Require event-specific waveform/threshold tests, instantaneous-band coverage and usable schedule with a justified phase law Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A low noise-figure result is offered as proof of near-certain detection of short hopping bursts: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A low noise-figure result is offered as proof of near-certain detection of short hopping bursts; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A low noise-figure result is offered as proof of near-certain detection of short hopping bursts:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A low noise-figure result is offered as proof of near-certain detection of short hopping bursts, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A low noise-figure result is offered as proof of near-certain detection of short hopping bursts: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. Distinguish noise calibration from timing opportunity and decision performance Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A low noise-figure result is offered as proof of near-certain detection of short hopping bursts, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.2 Model 15A: calculate conditional event coverage from usable windows (p. 8677)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. Distinguish noise calibration from timing opportunity and decision performance Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A low noise-figure result is offered as proof of near-certain detection of short hopping bursts and What evidence is absent; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.7 Noise Figure and System Sensitivity Calibration (p. 8115)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A low noise-figure result is offered as proof of near-certain detection of short hopping bursts”, addressing “What evidence is absent”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. What evidence is absent”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A low noise-figure result is offered as proof of near-certain detection of short hopping bursts. What evidence is absent”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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V011-VOL-DISCUSSION-013. An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. How would you respond?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. How would you respond?” Put this particular dispute to the panel: An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. How would you respond. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 02. Student A, terminology and scope: Agree the operational meanings of trace, reverses, sign and used, correction, respond in “An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. How would you respond”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Do not force the observed trajectory into a monotone inverse; restrict corrected intervals to validated behavior Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Interpret a swept trace through its frequency-time trajectory”. Do not force the observed trajectory into a monotone inverse; restrict corrected intervals to validated behavior Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the model mismatch, retain actual state history and seek an additional-state or changed-target explanation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An AGC trace overshoots and

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reverses sign although a one-pole model is used for amplitude correction: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction: specify the altered receiver state or source condition, predicted change, test statistic and

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rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. Do not force the observed trajectory into a monotone inverse; restrict corrected intervals to validated behavior Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. Do not force the observed trajectory into a monotone inverse; restrict corrected intervals to validated behavior Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction and How would you respond; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction”, addressing “How would you respond”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. How would you respond”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An AGC trace overshoots and reverses sign although a one-pole model is used for amplitude correction. How would you respond”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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V011-VOL-DISCUSSION-014. A burst arrives before the gain control has returned from a preceding event. What should its analysis preserve?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A burst arrives before the gain control has returned from a preceding event. What should its analysis preserve?” Put this particular dispute to the panel: A burst arrives before the gain control has returned from a preceding event. What should its analysis preserve. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 02. Student A, terminology and scope: Agree the operational meanings of burst, arrives, control and returned, preceding, analysis in “A burst arrives before the gain control has returned from a preceding event. What should its analysis preserve”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A burst arrives before the gain control has returned from a preceding event; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.6: Carry state across two target intervals”. Do not restart from equilibrium merely because a new file begins Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A burst arrives before the gain control has returned from a preceding event; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.6: Carry state across two target intervals”. Do not restart from equilibrium merely because a new file begins Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Carry the actual terminal state into the new interval, use identified attack/release conditions and retain valid sample timing Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A burst arrives before the gain control has returned from a preceding event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A burst arrives before the gain control has returned from a preceding event; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A burst arrives before the gain control has returned from a preceding event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A burst arrives before the gain control has returned from a preceding event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A burst arrives before the gain control has returned from a preceding event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A burst arrives before the gain control has returned from a preceding event. Do not restart from equilibrium merely because a new file begins Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A burst arrives before the gain control has returned from a preceding event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.11 Application 5A.6: Carry state across two target intervals (p. 2531)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A burst arrives before the gain control has returned from a preceding event. Do not restart from equilibrium

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merely because a new file begins Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.16 Automatic Gain Control and Hidden State (p. 2536)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A burst arrives before the gain control has returned from a preceding event and What should its analysis preserve; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.5 Case study 3.D5. A gain-control transition that resembles transmitter fading (p. 1336)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A burst arrives before the gain control has returned from a preceding event”, addressing “What should its analysis preserve”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A burst arrives before the gain control has returned from a preceding event. What should its analysis preserve”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A burst arrives before the gain control has returned from a preceding event. What should its analysis preserve”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.12 Application 5A.7: Use separately identified attack and release constants (p. 2532)

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V011-VOL-DISCUSSION-015. A limiter restores nominal amplitude quickly but channel phase remains disturbed. Which recovery time should govern a coherent claim?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A limiter restores nominal amplitude quickly but channel phase remains disturbed. Which recovery time should govern a coherent claim?” Put this particular dispute to the panel: A limiter restores nominal amplitude quickly but channel phase remains disturbed. Which recovery time should govern a coherent claim. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 02. Student A, terminology and scope: Agree the operational meanings of limiter, restores, quickly and govern, coherent, claim in “A limiter restores nominal amplitude quickly but channel phase remains disturbed. Which recovery time should govern a coherent claim”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.3.3 Energy closure and its limits (p. 5036)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A limiter restores nominal amplitude quickly but channel phase remains disturbed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 3.C8. Recovery time after a protective intervention”. Hardware survival or amplitude closure cannot establish restored coherent validity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A limiter restores nominal

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amplitude quickly but channel phase remains disturbed; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 3.C8. Recovery time after a protective intervention”. Hardware survival or amplitude closure cannot establish restored coherent validity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the observable-specific phase criterion and calibrated timing boundary, while retaining the different amplitude recovery Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.3.3 Energy closure and its limits (p. 5036)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A limiter restores nominal amplitude quickly but channel phase remains disturbed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A limiter restores nominal amplitude quickly but channel phase remains disturbed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A limiter restores nominal amplitude quickly but channel phase remains disturbed: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A limiter restores nominal amplitude quickly but channel phase remains disturbed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A limiter restores nominal amplitude quickly but channel phase remains disturbed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.3.3 Energy closure and its limits (p. 5036)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A limiter restores nominal amplitude quickly but channel phase remains disturbed. Hardware survival or amplitude closure cannot establish restored coherent validity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A limiter restores nominal amplitude quickly but channel phase remains disturbed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.19.8 Example 3.C8. Recovery time after a protective intervention (p. 1291)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A limiter restores nominal amplitude quickly but

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channel phase remains disturbed. Hardware survival or amplitude closure cannot establish restored coherent validity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A limiter restores nominal amplitude quickly but channel phase remains disturbed and Which recovery time should govern a coherent claim; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.42 Application 10D7 Restoring a shift also restores its coarse spacing (p. 5738)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A limiter restores nominal amplitude quickly but channel phase remains disturbed”, addressing “Which recovery time should govern a coherent claim”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A limiter restores nominal amplitude quickly but channel phase remains disturbed. Which recovery time should govern a coherent claim”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A limiter restores nominal amplitude quickly but channel phase remains disturbed. Which recovery time should govern a coherent claim”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.3.3 Energy closure and its limits (p. 5036)

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V011-VOL-DISCUSSION-016. A trigger threshold is constant, but latency varies with prior strong-signal history. What should be tested?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A trigger threshold is constant, but latency varies with prior strong-signal history. What should be tested?” Put this particular dispute to the panel: A trigger threshold is constant, but latency varies with prior strong-signal history. What should be tested. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 02. Student A, terminology and scope: Agree the operational meanings of trigger, threshold, latency and varies, prior, tested in “A trigger threshold is constant, but latency varies with prior strong-signal history. What should be tested”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A trigger threshold is constant, but latency varies with prior strong-signal history; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Incorporate demonstrated exclusions into usable coverage Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A trigger threshold is constant, but latency varies with prior strong-signal history; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Incorporate demonstrated exclusions into usable coverage Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Map the detector/AGC path, exercise relevant leading edges and prior states, and measure trigger-to-sample timing with paired events Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A trigger threshold is constant, but latency varies with prior strong-signal history: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A trigger threshold is constant, but latency varies with prior strong-signal history; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A trigger threshold is constant, but latency varies with prior strong-signal history: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A trigger threshold is constant, but latency varies with prior strong-signal history, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A trigger threshold is constant, but latency varies with prior strong-signal history: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A trigger threshold is constant, but latency varies with prior strong-signal history. Incorporate demonstrated exclusions into usable coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A trigger threshold is constant, but latency varies with prior strong-signal history, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A trigger threshold is constant, but latency varies with prior strong-signal history. Incorporate demonstrated exclusions into usable coverage Respond point by point to Student J.

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Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.8 Measure protection in the small-signal and recovery states (p. 1261)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A trigger threshold is constant, but latency varies with prior strong-signal history and What should be tested; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A trigger threshold is constant, but latency varies with prior strong-signal history”, addressing “What should be tested”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A trigger threshold is constant, but latency varies with prior strong-signal history. What should be tested”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A trigger threshold is constant, but latency varies with prior strong-signal history. What should be tested”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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V011-VOL-DISCUSSION-017. A narrow IF filter creates a trailing oscillation after a short pulse. How should source interpretation be limited?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A narrow IF filter creates a trailing oscillation after a short pulse. How should source interpretation be limited?” Put this particular dispute to the panel: A narrow IF filter creates a trailing oscillation after a short pulse. How should source interpretation be limited. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 02. Student A, terminology and scope: Agree the operational meanings of narrow, creates, trailing and oscillation, interpretation, limited in “A narrow IF filter creates a trailing oscillation after a short pulse. How should source interpretation be limited”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A narrow IF filter creates a trailing oscillation after a short pulse; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Intermediate-frequency detector memory, settling and comparable measurement statistics”. A ringing output is not automatically a prolonged external transmission Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A narrow IF filter creates a trailing oscillation after a short pulse; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Intermediate-frequency detector memory, settling and comparable measurement statistics”. A ringing output is not automatically a prolonged external transmission Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Characterize impulse/time response and detector behavior, compare a known pulse through the same path and retain valid context Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A narrow IF filter creates a trailing oscillation after a short pulse: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A narrow IF filter creates a trailing oscillation after a short pulse; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A narrow IF filter creates a trailing oscillation after a short pulse: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a

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rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A narrow IF filter creates a trailing oscillation after a short pulse, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A narrow IF filter creates a trailing oscillation after a short pulse: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A narrow IF filter creates a trailing oscillation after a short pulse. A ringing output is not automatically a prolonged external transmission Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A narrow IF filter creates a trailing oscillation after a short pulse, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A narrow IF filter creates a trailing oscillation after a short pulse. A ringing output is not automatically a prolonged external transmission Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.29 Pulse, Radar, and Transient Reception (p. 3147)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A narrow IF filter creates a trailing oscillation after a short pulse and How should source interpretation be limited; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A narrow IF filter creates a trailing oscillation after a short pulse”, addressing “How should source interpretation be limited”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A narrow IF filter creates a trailing oscillation after a short pulse. How should source interpretation be limited”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A narrow IF filter creates a trailing oscillation after a short pulse. How should source interpretation be limited”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.2 Filter Shape, Selectivity, and Time Response (p. 2514)

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V011-VOL-DISCUSSION-018. A fast swept trace looks smooth at very narrow RBW. What evidence is needed before treating its levels as calibrated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A fast swept trace looks smooth at very narrow RBW. What evidence is needed before treating its levels as calibrated?” Put this particular dispute to the panel: A fast swept trace looks smooth at very narrow RBW. What evidence is needed before treating its levels as calibrated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 02. Student A, terminology and scope: Agree the operational meanings of fast, swept, trace and smooth, narrow, treating in “A fast swept trace looks smooth at very narrow RBW. What evidence is needed before treating its levels as calibrated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A fast swept trace looks smooth at very narrow RBW; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Verify the frequency-time trajectory and filter settling using a suitable signal, retain bandwidth/detector state and valid intervals, and distinguish smooth presentation from response validity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A fast swept trace looks smooth at very narrow RBW; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Resolution Bandwidth and Selectivity”. Verify the frequency-time trajectory and filter settling using a suitable signal, retain bandwidth/detector state and valid intervals, and distinguish smooth presentation from response validity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Verify the frequency-time trajectory and filter settling using a suitable signal, retain bandwidth/detector state and valid intervals, and distinguish smooth presentation from response validity Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A fast swept trace looks smooth at very narrow RBW: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A fast swept trace looks smooth at very narrow RBW; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A fast swept trace looks smooth at very narrow RBW: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion

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Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A fast swept trace looks smooth at very narrow RBW, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A fast swept trace looks smooth at very narrow RBW: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A fast swept trace looks smooth at very narrow RBW. Verify the frequency-time trajectory and filter settling using a suitable signal, retain bandwidth/detector state and valid intervals, and distinguish smooth presentation from response validity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A fast swept trace looks smooth at very narrow RBW, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.2 Resolution Bandwidth and Selectivity (p. 4422)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A fast swept trace looks smooth at very narrow RBW. Verify the frequency-time trajectory and filter settling using a

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suitable signal, retain bandwidth/detector state and valid intervals, and distinguish smooth presentation from response validity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.26 Additional study: IF filters as dynamical systems and the meaning of transient measurement validity (p. 2554)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A fast swept trace looks smooth at very narrow RBW and What evidence is needed before treating its levels as calibrated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.27 Calibration and negative-survey validity for dynamic IF paths (p. 2559)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A fast swept trace looks smooth at very narrow RBW”, addressing “What evidence is needed before treating its levels as calibrated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A fast swept trace looks smooth at very narrow RBW. What evidence is needed before treating its levels as calibrated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A fast swept trace looks smooth at very narrow RBW. What evidence is needed before treating its levels as calibrated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

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V011-VOL-DISCUSSION-019. Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. What should be clarified?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. What should be clarified?” Put this particular dispute to the panel: Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. What should be clarified. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 02. Student A, terminology and scope: Agree the operational meanings of Reducing, video, makes and trace, quieter, claims in “Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. What should be clarified”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Intermediate-frequency detector memory, settling and comparable measurement statistics”. Smoothing can conceal variation or short events without changing upstream noise performance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Intermediate-frequency detector memory, settling and comparable measurement statistics”. Smoothing can conceal variation or short events without changing upstream noise performance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify the detector and averaging operation, quantify noise/statistical change and validate the intended event response Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Reducing video bandwidth makes a trace quieter, and the report

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claims improved input sensitivity: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. Smoothing can conceal variation or short events without changing upstream noise performance Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. Smoothing can conceal variation or short events without changing upstream noise performance Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity and What should be clarified; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity”, addressing “What should be clarified”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. What should be clarified”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Reducing video bandwidth makes a trace quieter, and the report claims improved input sensitivity. What should be clarified”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.3 Video Bandwidth, Averaging, and Detector Choice (p. 4426)

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V011-VOL-DISCUSSION-020. Two analysts average the same data differently and disagree in dB. How should they reconcile the results?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two analysts average the same data differently and disagree in dB. How should they reconcile the results?” Put this particular dispute to the panel: Two analysts average the same data differently and disagree in dB. How should they reconcile the results. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

- 02. Student A, terminology and scope: Agree the operational meanings of average, data, differently and disagree, reconcile, results in “Two analysts average the same data differently and disagree in dB. How should they reconcile the results”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two analysts average the same data differently and disagree in dB; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Power averaging before the logarithm”. Calibration agreement is not meaningful until both results describe the same quantity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two analysts average the same data differently and disagree in dB; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Power averaging before the logarithm”. Calibration agreement is not meaningful until both results describe the same quantity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reconstruct linear-power averaging versus log-level averaging, source law and normalization, then report the declared estimator Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two analysts average the same data

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differently and disagree in dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two analysts average the same data differently and disagree in dB; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two analysts average the same data differently and disagree in dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two analysts average the same data differently and disagree in dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two analysts average the same data differently and disagree in dB: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two analysts average the same data differently and disagree in dB. Calibration agreement is not meaningful until both results describe the same quantity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two analysts average the same data differently and disagree in dB, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.4.2 Power averaging before the logarithm (p. 4434)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two analysts average the same data differently and disagree in dB. Calibration agreement is not meaningful until both results describe the same quantity Respond point by point to Student J. Distinguish a verified observation from a conditional

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inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two analysts average the same data differently and disagree in dB and How should they reconcile the results; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.4 Averaging and Statistical Stability (p. 5052)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two analysts average the same data differently and disagree in dB”, addressing “How should they reconcile the results”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two analysts average the same data differently and disagree in dB. How should they reconcile the results”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two analysts average the same data differently and disagree in dB. How should they reconcile the results”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.102 Application 9 Averaging correlated versus independent errors (p. 5815)

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V011-VOL-DISCUSSION-021. A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. What is the main review issue?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. What is the main review issue?” Put this particular dispute to the panel: A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. What is the main review issue. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.4.3 Ten worked applications (p. 4437)

- 02. Student A, terminology and scope: Agree the operational meanings of applied, intermittent, baseline and main, review, issue in “A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. What is the main review issue”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.4.3 Ten worked applications (p. 4437)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §8.4.4 Measurement consequence (p. 4440)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measurement consequence”. Preserve raw powers and derive or validate an appropriate correction rather than reuse a label-based constant Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §8.4.4 Measurement consequence (p. 4440)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measurement consequence”. Preserve raw powers and derive or validate an appropriate correction rather than reuse a label-based constant Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §8.4.4 Measurement consequence (p. 4440)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The conditional/common-mean distributional premises may fail; inspect the mixture and actual operation order Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.4.3 Ten worked applications (p. 4437)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.4.3 Ten worked applications (p. 4437)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.4.3 Ten worked applications (p. 4437)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §8.4.4 Measurement consequence (p. 4440)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.4.3 Ten worked applications (p. 4437)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. Preserve raw powers and derive or validate an appropriate correction rather than reuse a label-based constant Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §8.4.4 Measurement consequence (p. 4440)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. Preserve raw powers and derive or validate an appropriate correction rather than reuse a

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label-based constant Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline and What is the main review issue; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline”, addressing “What is the main review issue”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §8.4.3 Ten worked applications (p. 4437)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. What is the main review issue”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A fixed Gaussian-noise log correction is applied to an intermittent two-state baseline. What is the main review issue”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.4.3 Ten worked applications (p. 4437)

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V011-VOL-DISCUSSION-022. Unequal-duration gain states are pooled by averaging their dB corrections. What should replace that calculation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Unequal-duration gain states are pooled by averaging their dB corrections. What should replace that calculation?” Put this particular dispute to the panel: Unequal-duration gain states are pooled by averaging their dB corrections. What should replace that calculation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 02. Student A, terminology and scope: Agree the operational meanings of gain, states, averaging and corrections, replace, calculation in “Unequal-duration gain states are pooled by averaging their dB corrections. What should replace that calculation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Unequal-duration gain states are pooled by averaging their dB corrections; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. Retain unknown/invalid intervals and distinguish the result from an average of logarithmic labels Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Unequal-duration gain states

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are pooled by averaging their dB corrections; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the detector and control path as part of the IF result”. Retain unknown/invalid intervals and distinguish the result from an average of logarithmic labels Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Correct each accepted interval to a common plane, then duration-weight physical powers for the requested mean Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Unequal-duration gain states are pooled by averaging their dB corrections: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Unequal-duration gain states are pooled by averaging their dB corrections; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Unequal-duration gain states are pooled by averaging their dB corrections: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Unequal-duration gain states are pooled by averaging their dB corrections, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Unequal-duration gain states are pooled by averaging their dB corrections: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Unequal-duration gain states are pooled by averaging their dB corrections. Retain unknown/invalid intervals and distinguish the result from an average of logarithmic labels Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Unequal-duration gain states are pooled by averaging their dB corrections, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Unequal-duration gain states are pooled by averaging their dB corrections. Retain unknown/invalid intervals and distinguish the result from an average of logarithmic labels Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.24 Intermediate-frequency detector memory, settling and comparable measurement statistics (p. 2548)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Unequal-duration gain states are pooled by averaging their dB corrections and What should replace that calculation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.4 Noise averages, detector statistics, and the meaning of a decibel trace (p. 4429)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Unequal-duration gain states are pooled by averaging their dB corrections”, addressing “What should replace that calculation”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Unequal-duration gain states are pooled by averaging their dB corrections. What should replace that calculation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Unequal-duration gain states are pooled by averaging their dB corrections. What should replace that calculation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.12.3 Application 1A.3. Combine valid gain states without averaging their decibel labels (p. 83)

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V011-VOL-DISCUSSION-023. A background trace is subtracted in dBm to isolate a weak addition. How would you repair the calculation?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A background trace is subtracted in dBm to isolate a weak addition. How would you repair the calculation?” Put this particular dispute to the panel: A background trace is subtracted in dBm to isolate a weak addition. How would you repair the calculation. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 02. Student A, terminology and scope: Agree the operational meanings of trace, subtracted, isolate and weak, addition, repair in “A background trace is subtracted in dBm to isolate a weak addition. How would you repair the calculation”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A background trace is subtracted in dBm to isolate a weak addition; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.12.6 Application 1A.6. Subtract an additive contribution in linear power before referring it backward (p. 89)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 1A.6. Subtract an additive contribution in linear power before referring it backward”. Transform only a supported positive difference and explain that the original dB subtraction formed a ratio Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.12.6 Application 1A.6. Subtract an additive contribution in linear power before referring it backward (p. 89)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A background trace is

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subtracted in dBm to isolate a weak addition; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 1A.6. Subtract an additive contribution in linear power before referring it backward”. Transform only a supported positive difference and explain that the original dB subtraction formed a ratio Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.12.6 Application 1A.6. Subtract an additive contribution in linear power before referring it backward (p. 89)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Establish compatible fixed transfer and additive-power conditions, subtract in linear units and retain covariance Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A background trace is subtracted in dBm to isolate a weak addition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A background trace is subtracted in dBm to isolate a weak addition; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A background trace is subtracted in dBm to isolate a weak addition: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A background trace is subtracted in dBm to isolate a weak addition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.12.6 Application 1A.6. Subtract an additive contribution in linear power before referring it backward (p. 89)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A background trace is subtracted in dBm to isolate a weak addition: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A background trace is subtracted in dBm to isolate a weak addition. Transform only a supported positive difference and explain that the original dB subtraction formed a ratio Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A background trace is subtracted in dBm to isolate a weak addition, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.12.6 Application 1A.6. Subtract an additive contribution in linear power before referring it backward (p. 89)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A background trace is subtracted in dBm to isolate a weak addition. Transform only a supported positive difference and explain that the original dB subtraction formed a ratio Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.35 Application 11B.8 Infer an effective density from linear subtraction (p. 6412)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A background trace is subtracted in dBm to isolate a weak addition and How would you repair the calculation; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A background trace is subtracted in dBm to isolate a weak addition”, addressing “How would you repair the calculation”; specify the exact measurement or evidential gap on

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which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A background trace is subtracted in dBm to isolate a weak addition. How would you repair the calculation”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A background trace is subtracted in dBm to isolate a weak addition. How would you repair the calculation”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

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V011-VOL-DISCUSSION-024. A positive added-power estimate has a broad distribution crossing zero. Should the negative values simply be clipped before logging?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A positive added-power estimate has a broad distribution crossing zero. Should the negative values simply be clipped before logging?” Put this particular dispute to the panel: A positive added-power estimate has a broad distribution crossing zero. Should the negative values simply be clipped before logging. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 02. Student A, terminology and scope: Agree the operational meanings of broad, distribution, crossing and simply, clipped, logging in “A positive added-power estimate has a broad distribution crossing zero. Should the negative values simply be clipped before logging”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A positive added-power estimate has a broad distribution crossing zero; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Clipping changes the estimator, while a finite logarithm cannot cover nonpositive values; use a justified domain-aware treatment Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A positive added-power

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estimate has a broad distribution crossing zero; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Clipping changes the estimator, while a finite logarithm cannot cover nonpositive values; use a justified domain-aware treatment Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; retain the linear result and clarify physical/model interpretation Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A positive added-power estimate has a broad distribution crossing zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A positive added-power estimate has a broad distribution crossing zero; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A positive added-power estimate has a broad distribution crossing zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A positive added-power estimate has a broad distribution crossing zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A positive added-power estimate has a broad distribution crossing zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A positive added-power estimate has a broad distribution crossing zero. Clipping changes the estimator, while a finite logarithm cannot cover nonpositive values; use a justified domain-aware treatment Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A positive added-power estimate has a broad distribution crossing zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A positive added-power estimate has a broad

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distribution crossing zero. Clipping changes the estimator, while a finite logarithm cannot cover nonpositive values; use a justified domain-aware treatment Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A positive added-power estimate has a broad distribution crossing zero and Should the negative values simply be clipped before logging; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.14.7 Application 14B.9: subtract paired powers before propagating a logarithm (p. 8139)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A positive added-power estimate has a broad distribution crossing zero”, addressing “Should the negative values simply be clipped before logging”; specify the exact measurement or evidential gap on which the speakers still differ

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Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A positive added-power estimate has a broad distribution crossing zero. Should the negative values simply be clipped before logging”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A positive added-power estimate has a broad distribution crossing zero. Should the negative values simply be clipped before logging”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §8.7 Choose bandwidth from the quantity being estimated (p. 4444)

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V011-VOL-DISCUSSION-025. A narrow source-generated spur and receiver spur share frequency. What makes a baseline power subtraction ambiguous?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A narrow source-generated spur and receiver spur share frequency. What makes a baseline power subtraction ambiguous?” Put this particular dispute to the panel: A narrow source-generated spur and receiver spur share frequency. What makes a baseline power subtraction ambiguous. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 02. Student A, terminology and scope: Agree the operational meanings of spur, share, makes and baseline, subtraction, ambiguous in “A narrow source-generated spur and receiver spur share frequency. What makes a baseline power subtraction ambiguous”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A narrow source-generated spur and receiver spur share frequency; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Use phasor bounds or independent source/combiner characterization with a stage-specific challenge Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A narrow source-generated spur and receiver spur share frequency; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Falsification-led survey closure and the evidential status of negative observations”. Use phasor bounds or independent source/combiner characterization with a stage-specific challenge Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Unknown relative phase permits reinforcement or cancellation, so the measured total is not necessarily a sum of independent powers Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would

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discriminate between them without changing the measurand. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A narrow source-generated spur and receiver spur share frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A narrow source-generated spur and receiver spur share frequency; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A narrow source-generated spur and receiver spur share frequency: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A narrow source-generated spur and receiver spur share frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A narrow source-generated spur and receiver spur share frequency:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A narrow source-generated spur and receiver spur share frequency. Use phasor bounds or independent source/combiner characterization with a stage-specific challenge Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A narrow source-generated spur and receiver spur share frequency, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §16.16 Falsification-led survey closure and the evidential status of negative observations (p. 9288)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A narrow source-generated spur and receiver spur share frequency. Use phasor bounds or independent source/combiner characterization with a stage-specific challenge Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A narrow source-generated spur and receiver spur share frequency and What makes a baseline power subtraction ambiguous; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.2 Case study 3.D2. A two-tone product that coincides with a suspected frequency (p. 1330)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A narrow source-generated spur and receiver spur share frequency”, addressing “What makes a baseline power subtraction ambiguous”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A narrow source-generated spur and receiver spur share frequency. What makes a baseline power subtraction ambiguous”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A narrow source-generated spur and receiver spur share frequency. What makes a baseline power subtraction ambiguous”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

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V011-VOL-DISCUSSION-026. An RF image enters the same real IF as the desired signal. What should a calibration and source-identification review retain?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An RF image enters the same real IF as the desired signal. What should a calibration and source-identification review retain?” Put this particular dispute to the panel: An RF image enters the same real IF as the desired signal. What should a calibration and source-identification review retain. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 02. Student A, terminology and scope: Agree the operational meanings of image, enters, real and desired, review, retain in “An RF image enters the same real IF as the desired signal. What should a calibration and source-identification review retain”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An RF image enters the same real IF as the desired signal; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.10: Map an admitted IF interval back to both RF intervals”. Verify transfer separately and challenge the image path; one IF label cannot identify a unique original RF source Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of An RF image enters the same real IF as the desired signal; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.10: Map an admitted IF interval back to both RF intervals”. Verify transfer separately and challenge the image path; one IF label cannot identify a unique original RF source Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Both admitted RF intervals, signed conversion branch, preselection and potential coherent combination Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An RF image enters the same real IF as the desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An RF image enters the same real IF as the desired signal; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An RF image enters the same real IF as the desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An RF image enters the same real IF as the desired signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An RF image enters the same real IF as the desired signal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An RF image enters the same real IF as the desired signal. Verify transfer separately and challenge the image path; one IF label cannot identify a unique original RF source Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An RF image enters the same real IF as the desired signal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §4.13 Application 4A.10: Map an admitted IF interval back to both RF intervals (p. 1941)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An RF image enters the same real IF as the desired signal. Verify transfer separately and challenge the image path; one IF label cannot identify a unique original RF source

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Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.15 Image Responses and Image Rejection (p. 1944)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An RF image enters the same real IF as the desired signal and What should a calibration and source-identification review retain; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §4.26 Experimental protocol: comparing passive and active conversion (p. 1969)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An RF image enters the same real IF as the desired signal”, addressing “What should a calibration and source-identification review retain”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An RF image enters the same real IF as the desired signal. What should a calibration and source-identification review retain”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An RF image enters the same real IF as the desired signal. What should a calibration and source-identification review retain”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §4.8 Application 4A.5: Allocate image rejection ahead of equal conversion (p. 1936)

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V011-VOL-DISCUSSION-027. FM demodulation reverses sign after a high-side conversion change. How should the difference be interpreted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “FM demodulation reverses sign after a high-side conversion change. How should the difference be interpreted?” Put this particular dispute to the panel: FM demodulation reverses sign after a high-side conversion change. How should the difference be interpreted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 02. Student A, terminology and scope: Agree the operational meanings of demodulation, reverses, sign and conversion, difference, interpreted in “FM demodulation reverses sign after a high-side conversion change. How should the difference be interpreted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.16 Frequency and Phase Modulation (p. 3128)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of FM demodulation reverses sign after a high-side conversion change; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Preserve pulse and demodulator evidence across representations”. Test a known modulation before asserting a source change, and preserve branch and reference information Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of FM demodulation reverses

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sign after a high-side conversion change; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Preserve pulse and demodulator evidence across representations”. Test a known modulation before asserting a source change, and preserve branch and reference information Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Track spectral orientation and digital phase-derivative convention through the configured path Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.16 Frequency and Phase Modulation (p. 3128)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving FM demodulation reverses sign after a high-side conversion change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of FM demodulation reverses sign after a high-side conversion change; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving FM demodulation reverses sign after a high-side conversion change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving FM demodulation reverses sign after a high-side conversion change, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving FM demodulation reverses sign after a high-side conversion change: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.16 Frequency and Phase Modulation (p. 3128)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for FM demodulation reverses sign after a high-side conversion change. Test a known modulation before asserting a source change, and preserve branch and reference information Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving FM demodulation reverses sign after a high-side conversion change, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.30 Preserve pulse and demodulator evidence across representations (p. 3150)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for FM demodulation reverses sign after a high-side conversion change. Test a known modulation before asserting a source change, and preserve branch and reference information

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Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.1 Carrier, Sidebands, and Modulation Evidence (p. 3107)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about FM demodulation reverses sign after a high-side conversion change and How should the difference be interpreted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “FM demodulation reverses sign after a high-side conversion change”, addressing “How should the difference be interpreted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.16 Frequency and Phase Modulation (p. 3128)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “FM demodulation reverses sign after a high-side conversion change. How should the difference be interpreted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “FM demodulation reverses sign after a high-side conversion change. How should the difference be interpreted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.16 Frequency and Phase Modulation (p. 3128)

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V011-VOL-DISCUSSION-028. A suspicious digital line moves after sample-rate change but analog filtering also changed. What remains unresolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A suspicious digital line moves after sample-rate change but analog filtering also changed. What remains unresolved?” Put this particular dispute to the panel: A suspicious digital line moves after sample-rate change but analog filtering also changed. What remains unresolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 02. Student A, terminology and scope: Agree the operational meanings of suspicious, line, moves and analog, filtering, unresolved in “A suspicious digital line moves after sample-rate change but analog filtering also changed. What remains unresolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A suspicious digital line moves after sample-rate change but analog filtering also changed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Sampling, Aliasing, and Band Selection”. Movement alone is not a unique alias proof when several factors change Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A suspicious digital line moves after sample-rate change but analog filtering also changed; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Sampling, Aliasing, and Band Selection”. Movement alone is not a unique alias proof when several factors change Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate predicted alias mapping from changed admission and transfer, preserve a reference and characterize both configurations Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A suspicious digital line moves after sample-rate change but analog filtering also changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A suspicious digital line moves after sample-rate change but analog filtering also changed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A suspicious digital line moves after sample-rate change but analog filtering also changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A suspicious digital line moves after sample-rate change but analog filtering also changed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A suspicious digital line moves after sample-rate change but analog filtering also changed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A suspicious digital line moves after sample-rate change but analog filtering also changed. Movement alone is not a unique alias proof when several factors change Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A suspicious digital line moves after sample-rate change but analog filtering also changed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.2 Sampling, Aliasing, and Band Selection (p. 5680)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A suspicious digital line moves after sample-rate change but analog filtering also changed. Movement alone is not a unique alias proof when several factors change Respond point by

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point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.6 Treat configuration changes as changes in the measurement law (p. 64)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A suspicious digital line moves after sample-rate change but analog filtering also changed and What remains unresolved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A suspicious digital line moves after sample-rate change but analog filtering also changed”, addressing “What remains unresolved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A suspicious digital line moves after sample-rate change but analog filtering also changed. What remains unresolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A suspicious digital line moves after sample-rate change but analog filtering also changed. What remains unresolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.86 Sampling application 4 A useful rate change (p. 5796)

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V011-VOL-DISCUSSION-029. Every file block restarts its NCO at zero phase, creating a periodic feature. What correction should preserve the evidence?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Every file block restarts its NCO at zero phase, creating a periodic feature. What correction should preserve the evidence?” Put this particular dispute to the panel: Every file block restarts its NCO at zero phase, creating a periodic feature. What correction should preserve the evidence. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 02. Student A, terminology and scope: Agree the operational meanings of file, block, restarts and periodic, feature, preserve in “Every file block restarts its NCO at zero phase, creating a periodic feature. What correction should preserve the evidence”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Every file block restarts its NCO at zero phase, creating a periodic feature; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Do not alter native samples to hide the earlier processing error Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Every file block restarts its NCO at zero phase, creating a periodic feature; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Keep the evidence chain reversible to its declared inputs”. Do not alter native samples to hide the earlier processing error Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reproduce the intended absolute-index mixing law across continuous blocks, retain original and revised outputs and show the artifact's dependence on the reset Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Every file block restarts its NCO at zero phase, creating a periodic feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Every file block restarts its NCO at zero phase, creating a periodic feature; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Every file block restarts its NCO at zero phase, creating a periodic feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Every file block restarts its NCO at zero phase, creating a periodic feature, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Every file block restarts its NCO at zero phase, creating a periodic feature: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Every file block restarts its NCO at zero phase, creating a periodic feature. Do not alter native samples to hide the earlier processing error Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Every file block restarts its NCO at zero phase, creating a periodic feature, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Every file block restarts its NCO at zero phase, creating a periodic feature. Do not alter native samples to hide the

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earlier processing error Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Every file block restarts its NCO at zero phase, creating a periodic feature and What correction should preserve the evidence; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Every file block restarts its NCO at zero phase, creating a periodic feature”, addressing “What correction should preserve the evidence”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Every file block restarts its NCO at zero phase, creating a periodic feature. What correction should preserve the evidence”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Every file block restarts its NCO at zero phase, creating a periodic feature. What correction should preserve the evidence”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

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V011-VOL-DISCUSSION-030. An idle channel shows a transient after one input sample is missing. Which joint analysis is useful?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An idle channel shows a transient after one input sample is missing. Which joint analysis is useful?” Put this particular dispute to the panel: An idle channel shows a transient after one input sample is missing. Which joint analysis is useful. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 02. Student A, terminology and scope: Agree the operational meanings of idle, shows, transient and missing, joint, analysis in “An idle channel shows a transient after one input sample is missing. Which joint analysis is useful”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An idle channel shows a transient after one input sample is missing; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10E.8: decimation retains two outputs from a longer gap tail”. Do not assume a new RF source merely because the transient appears in a separate channel Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An idle channel shows a transient after one input sample is missing; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10E.8: decimation retains two outputs from a longer gap tail”. Do not assume a new RF source merely because the transient appears in a separate channel Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Propagate invalid support through the channelizer/filter and retained output phases, inspect actual indices and preserve the gap Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An idle channel shows a transient after one input sample is missing: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An idle channel shows a transient after one input sample is missing; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An idle channel shows a transient after one input sample is missing: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An idle channel shows a transient after one input sample is missing, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An idle channel shows a transient after one input sample is missing: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An idle channel shows a transient after one input sample is missing. Do not assume a new RF source merely because the transient appears in a separate channel Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An idle channel shows a transient after one input sample is missing, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.59 Application 10E.8: decimation retains two outputs from a longer gap tail (p. 5761)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An idle channel shows a transient after one input sample is missing. Do not assume a new RF source merely

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because the transient appears in a separate channel Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An idle channel shows a transient after one input sample is missing and Which joint analysis is useful; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.32 Model 10D for fixed point channelizer arithmetic (p. 5722)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An idle channel shows a transient after one input sample is missing”, addressing “Which joint analysis is useful”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An idle channel shows a transient after one input sample is missing. Which joint analysis is useful”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An idle channel shows a transient after one input sample is missing. Which joint analysis is useful”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.61 Application 10E.10: one missing input appears in idle channels (p. 5763)

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V011-VOL-DISCUSSION-031. A team zero-fills a missing block and calls the record complete. How should the claim change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team zero-fills a missing block and calls the record complete. How should the claim change?” Put this particular dispute to the panel: A team zero-fills a missing block and calls the record complete. How should the claim change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of missing, block, calls and record, complete, claim in “A team zero-fills a missing block and calls the record complete. How should the claim change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team zero-fills a missing block and calls the record complete; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Keep the gap map and distinguish representation continuity from physical acquisition completeness Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team zero-fills a missing block and calls the record complete; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. Keep the gap map and distinguish representation continuity from physical acquisition completeness Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State that the grid is preserved but waveform values are not measured, mark affected filter outputs and limit later estimators Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A team zero-fills a missing block and calls the record complete: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team zero-fills a missing block and calls the record complete; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team zero-fills a missing block and calls the record complete: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team zero-fills a missing block and calls the record complete, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team zero-fills a missing block and calls the record complete: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team zero-fills a missing block and calls the record complete. Keep the gap map and distinguish representation continuity from physical acquisition completeness Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team zero-fills a missing block and calls the record complete, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team zero-fills a missing block and calls the record complete. Keep the gap map and distinguish representation

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continuity from physical acquisition completeness Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team zero-fills a missing block and calls the record complete and How should the claim change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team zero-fills a missing block and calls the record complete”, addressing “How should the claim change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team zero-fills a missing block and calls the record complete. How should the claim change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team zero-fills a missing block and calls the record complete. How should the claim change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-VOL-DISCUSSION-032. Another team deletes the missing block and obtains a cleaner spectrum. What should the reviewer examine?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Another team deletes the missing block and obtains a cleaner spectrum. What should the reviewer examine?” Put this particular dispute to the panel: Another team deletes the missing block and obtains a cleaner spectrum. What should the reviewer examine. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 02. Student A, terminology and scope: Agree the operational meanings of missing, block, obtains and spectrum, reviewer, examine in “Another team deletes the missing block and obtains a cleaner spectrum. What should the reviewer examine”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Another team deletes the missing block and obtains a cleaner spectrum; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. A cleaner plot does not demonstrate restoration of the missing event or original frequency law Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Another team deletes the missing block and obtains a cleaner spectrum; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a calculated temperature to a defended result”. A cleaner plot does not demonstrate restoration of the missing event or original frequency law Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The changed index-to-time relation, artificial join and oscillator/filter state, then compare only justified valid segments Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Another team deletes the missing block and obtains a cleaner spectrum: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Another team deletes the missing block and obtains a cleaner spectrum; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Another team deletes the missing block and obtains a cleaner spectrum: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Another team deletes the missing block and obtains a cleaner spectrum, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Another team deletes the missing block and obtains a cleaner spectrum: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Another team deletes the missing block and obtains a cleaner spectrum. A cleaner plot does not demonstrate restoration of the missing event or original frequency law Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Another team deletes the missing block and obtains a cleaner spectrum, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Another team deletes the missing block and obtains a cleaner spectrum. A cleaner plot does not demonstrate

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restoration of the missing event or original frequency law Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.16 Application 10B10 A block reset can imitate a phase event (p. 5701)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Another team deletes the missing block and obtains a cleaner spectrum and What should the reviewer examine; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.49 Source indices, stored offsets, and time anchors (p. 5745)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Another team deletes the missing block and obtains a cleaner spectrum”, addressing “What should the reviewer examine”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Another team deletes the missing block and obtains a cleaner spectrum. What should the reviewer examine”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Another team deletes the missing block and obtains a cleaner spectrum. What should the reviewer examine”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.52 Application 10E.1: a file offset that conceals forty missing samples (p. 5754)

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V011-VOL-DISCUSSION-033. Two analysis programs agree exactly after both import signed samples with the wrong scale. What check can break the shared error?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two analysis programs agree exactly after both import signed samples with the wrong scale. What check can break the shared error?” Put this particular dispute to the panel: Two analysis programs agree exactly after both import signed samples with the wrong scale. What check can break the shared error. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 02. Student A, terminology and scope: Agree the operational meanings of programs, agree, exactly and wrong, scale, shared in “Two analysis programs agree exactly after both import signed samples with the wrong scale. What check can break the shared error”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two analysis programs agree exactly after both import signed samples with the wrong scale; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10D1 Coefficient rounding can preserve DC and change rejection”. Agreement on identical misinterpreted inputs is limited evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Two analysis programs agree exactly after both import signed samples with the wrong scale; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10D1 Coefficient rounding can preserve DC and change rejection”. Agreement on identical misinterpreted inputs is limited evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use a known physical reference with declared format and calibration, independently verify binary-point and units, and retain software identities Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two analysis programs agree exactly after both import signed samples with the wrong scale: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two analysis programs agree exactly after both import signed samples with the wrong scale; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two analysis programs agree exactly after both import signed samples with the wrong scale: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two analysis programs agree exactly after both import signed samples with the wrong scale, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two analysis programs agree exactly after both import signed

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samples with the wrong scale: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two analysis programs agree exactly after both import signed samples with the wrong scale. Agreement on identical misinterpreted inputs is limited evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two analysis programs agree exactly after both import signed samples with the wrong scale, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §10.36 Application 10D1 Coefficient rounding can preserve DC and change rejection (p. 5732)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two analysis programs agree exactly after both import signed samples with the wrong scale. Agreement on identical misinterpreted inputs is limited evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two analysis programs agree exactly after both import signed samples with the wrong scale and What check can break the shared error; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.4.1 Arrange the comparisons before examining their outcomes (p. 9264)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two analysis programs agree exactly after both import signed samples with the wrong scale”, addressing “What check can break the shared error”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two analysis programs agree exactly after both import signed samples with the wrong scale. What check can break the shared error”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two analysis programs agree exactly after both import signed samples with the wrong scale. What check can break the shared error”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.76 Application 10F.8 Two agreeing programs share the same fault (p. 5784)

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V011-VOL-DISCUSSION-034. An arithmetic error bound is small, but an accumulator occasionally saturates. How should acceptance be revised?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An arithmetic error bound is small, but an accumulator occasionally saturates. How should acceptance be revised?” Put this particular dispute to the panel: An arithmetic error bound is small, but an accumulator occasionally saturates. How should acceptance be revised. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.34 Range and error are separate obligations (p. 5728)

- 02. Student A, terminology and scope: Agree the operational meanings of arithmetic, error, bound and accumulator, acceptance, revised in “An arithmetic error bound is small, but an accumulator occasionally saturates. How should acceptance be revised”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.34 Range and error are separate obligations (p. 5728)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An arithmetic error bound is small, but an accumulator occasionally saturates; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase”. A local rounding bound cannot justify overflow or reconstruct lost values Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An arithmetic error bound is small, but an accumulator occasionally saturates; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase”. A local rounding bound cannot justify overflow or reconstruct lost values Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate quantization-error and range obligations, identify affected samples/states and validate scaling at worst-case inputs Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.34 Range and error are separate obligations (p. 5728)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An arithmetic error bound is small, but an accumulator occasionally saturates: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.34 Range and error are separate obligations (p. 5728)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An arithmetic error bound is small, but an accumulator occasionally saturates; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An arithmetic error bound is small, but an accumulator occasionally saturates: specify the altered receiver state or source condition, predicted change, test statistic

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and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.34 Range and error are separate obligations (p. 5728)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An arithmetic error bound is small, but an accumulator occasionally saturates, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An arithmetic error bound is small, but an accumulator occasionally saturates: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.34 Range and error are separate obligations (p. 5728)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An arithmetic error bound is small, but an accumulator occasionally saturates. A local rounding bound cannot justify overflow or reconstruct lost values Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An arithmetic error bound is small, but an accumulator occasionally saturates, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An arithmetic error bound is small, but an

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accumulator occasionally saturates. A local rounding bound cannot justify overflow or reconstruct lost values Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.9 Application 12A.6: Bound a frequency estimate from two epoch measurements (p. 6962)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An arithmetic error bound is small, but an accumulator occasionally saturates and How should acceptance be revised; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.46 What the arithmetic comparison establishes (p. 5742)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An arithmetic error bound is small, but an accumulator occasionally saturates”, addressing “How should acceptance be revised”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §10.34 Range and error are separate obligations (p. 5728)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An arithmetic error bound is small, but an accumulator occasionally saturates. How should acceptance be revised”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An arithmetic error bound is small, but an accumulator occasionally saturates. How should acceptance be revised”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.34 Range and error are separate obligations (p. 5728)

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V011-VOL-DISCUSSION-035. Clipped samples are divided down until the final waveform looks normal. What remains invalid?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Clipped samples are divided down until the final waveform looks normal. What remains invalid?” Put this particular dispute to the panel: Clipped samples are divided down until the final waveform looks normal. What remains invalid. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 02. Student A, terminology and scope: Agree the operational meanings of Clipped, divided, final and waveform, remains, invalid in “Clipped samples are divided down until the final waveform looks normal. What remains invalid”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Clipped samples are divided down until the final waveform looks normal; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Converter and Waveform-Recorder Validation Boundary”. Retain flags and raw representation, establish a valid analog/digital gain state and repeat the reference test instead of treating post-scaling as recovery Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Clipped samples are divided

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down until the final waveform looks normal; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Converter and Waveform-Recorder Validation Boundary”. Retain flags and raw representation, establish a valid analog/digital gain state and repeat the reference test instead of treating post-scaling as recovery Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The original amplitude and waveform information lost at clipping Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Clipped samples are divided down until the final waveform looks normal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Clipped samples are divided down until the final waveform looks normal; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Clipped samples are divided down until the final waveform looks normal: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Clipped samples are divided down until the final waveform looks normal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Clipped samples are divided down until the final waveform looks normal: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Clipped samples are divided down until the final waveform looks normal. Retain flags and raw representation, establish a valid analog/digital gain state and repeat the reference test instead of treating post-scaling as recovery Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Clipped samples are divided down until the final waveform looks normal, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.106 Converter and Waveform-Recorder Validation Boundary (p. 5820)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Clipped samples are divided down until the final waveform looks normal. Retain flags and raw representation, establish a valid analog/digital gain state and repeat the reference test instead of treating post-scaling as recovery Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.20 Carry the conditions into receiver interpretation (p. 6390)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Clipped samples are divided down until the final waveform looks normal and What remains invalid; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.41 Blocker-dependent front-end state machines and hidden recovery intervals (p. 1363)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Clipped samples are divided down until the final waveform looks normal”, addressing “What remains invalid”; specify the exact measurement or evidential gap on which

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the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Clipped samples are divided down until the final waveform looks normal. What remains invalid”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Clipped samples are divided down until the final waveform looks normal. What remains invalid”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.3 Quantization, Clipping, and Converter Performance (p. 5684)

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V011-VOL-DISCUSSION-036. A hash audit passes while sample sequence numbers show loss. Which finding is correct?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A hash audit passes while sample sequence numbers show loss. Which finding is correct?” Put this particular dispute to the panel: A hash audit passes while sample sequence numbers show loss. Which finding is correct. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of hash, audit, passes and sequence, numbers, finding in “A hash audit passes while sample sequence numbers show loss. Which finding is correct”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A hash audit passes while sample sequence numbers show loss; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Data Transport, Gaps, and Reproducible Recording”. Retain both facts, the gap map and bounded valid intervals; neither finding cancels the other Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A hash audit passes while sample sequence numbers show loss; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Data Transport, Gaps, and Reproducible Recording”. Retain both facts, the gap map and bounded valid intervals; neither finding cancels the other Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The preserved file bytes are consistent with the hash, but acquisition continuity failed Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A hash audit passes while sample sequence numbers show loss: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A hash audit passes while sample sequence numbers show loss; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A hash audit passes while sample sequence numbers show loss: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A hash audit passes while sample sequence numbers show loss, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A hash audit passes while sample sequence numbers show loss: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A hash audit passes while sample sequence numbers show loss. Retain both facts, the gap map and bounded valid intervals; neither finding cancels the other Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A hash audit passes while sample sequence numbers show loss, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.47 Data Transport, Gaps, and Reproducible Recording (p. 5743)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A hash audit passes while sample sequence numbers show loss. Retain both facts, the gap map and bounded

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valid intervals; neither finding cancels the other Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A hash audit passes while sample sequence numbers show loss and Which finding is correct; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A hash audit passes while sample sequence numbers show loss”, addressing “Which finding is correct”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A hash audit passes while sample sequence numbers show loss. Which finding is correct”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A hash audit passes while sample sequence numbers show loss. Which finding is correct”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-VOL-DISCUSSION-037. A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. What must be recalculated?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. What must be recalculated?” Put this particular dispute to the panel: A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. What must be recalculated. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of capacity, counts, bits and component, files, recalculated in “A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. What must be recalculated”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.7. Retain integer frames and last-frame padding”. Recheck sustained writing; converter resolution does not determine stored byte count Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.7. Retain integer frames and last-frame padding”. Recheck sustained writing; converter resolution does not determine stored byte count Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Payload rate and duration capacity using actual components, channels and container width, plus overhead and margin Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A recorder's capacity plan

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counts 12 bits per component although the files use 16-bit containers: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. Recheck sustained writing; converter resolution does not determine stored byte count Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. Recheck sustained writing; converter resolution does not determine stored byte count Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.73 Application 10F.5 A serialization error survives successful installation (p. 5781)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers and What must be recalculated; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.25 Continuity proofs for sampled RF records, missing-data masks and sustained throughput (p. 8718)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers”, addressing

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“What must be recalculated”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. What must be recalculated”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A recorder's capacity plan counts 12 bits per component although the files use 16-bit containers. What must be recalculated”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-VOL-DISCUSSION-038. A storage device meets the required rate for short bursts but not after its buffer fills. What should the survey plan do?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A storage device meets the required rate for short bursts but not after its buffer fills. What should the survey plan do?” Put this particular dispute to the panel: A storage device meets the required rate for short bursts but not after its buffer fills. What should the survey plan do. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 02. Student A, terminology and scope: Agree the operational meanings of storage, device, meets and bursts, buffer, fills in “A storage device meets the required rate for short bursts but not after its buffer fills. What should the survey plan do”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A storage device meets the required rate for short bursts but not after its buffer fills; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Coverage Review and Storage Governance”. Peak speed cannot establish continuous preservation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A storage device meets the required rate for short bursts but not after its buffer fills; explain what each record can establish State what the existing record

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establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.2 Challenge-Test Design (p. 9258)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Coverage Review and Storage Governance”. Peak speed cannot establish continuous preservation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Test sustained planned-duration operation, monitor loss and thermal/clock state, provide reserve or a changed capture design and document any resulting coverage limits Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A storage device meets the required rate for short bursts but not after its buffer fills: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A storage device meets the required rate for short bursts but not after its buffer fills; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.2 Challenge-Test Design (p. 9258)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A storage device meets the required rate for short bursts but not after its buffer fills: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A storage device meets the required rate for short bursts but not after its buffer fills, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A storage device meets the required rate for short bursts but not after its buffer fills: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A storage device meets the required rate for short bursts but not after its buffer fills. Peak speed cannot establish continuous preservation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.2 Challenge-Test Design (p. 9258)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A storage device meets the required rate for short bursts but not after its buffer fills, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A storage device meets the required rate for short bursts but not after its buffer fills. Peak speed cannot establish continuous preservation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.2 Challenge-Test Design (p. 9258)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A storage device meets the required rate for short bursts but not after its buffer fills and What should the survey plan do; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.15 Derive passive loss from thermal equilibrium (p. 670)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A storage device meets the required rate for short bursts but not after its buffer fills”, addressing “What should the survey plan do”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A storage device meets the required rate for short bursts but not after its buffer fills. What should the survey plan do”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A storage device meets the required rate for short bursts but not after its buffer fills. What should the survey plan do”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

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V011-VOL-DISCUSSION-039. Cross-spectrum phase changes sign after a channel-label swap. Is the physical delay necessarily reversed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Cross-spectrum phase changes sign after a channel-label swap. Is the physical delay necessarily reversed?” Put this particular dispute to the panel: Cross-spectrum phase changes sign after a channel-label swap. Is the physical delay necessarily reversed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 02. Student A, terminology and scope: Agree the operational meanings of changes, sign, physical and delay, necessarily, reversed in “Cross-spectrum phase changes sign after a channel-label swap. Is the physical delay necessarily reversed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Cross-spectrum phase changes sign after a channel-label swap; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. Preserve the original order and interpret the delay only under a consistent signed definition Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Cross-spectrum phase changes sign after a channel-label swap; explain what each record

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can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Accept coherence at the required boundary and state”. Preserve the original order and interpret the delay only under a consistent signed definition Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; verify conjugation and order conventions, actual channel reference planes and clock mapping Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Cross-spectrum phase changes sign after a channel-label swap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Cross-spectrum phase changes sign after a channel-label swap; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Cross-spectrum phase changes sign after a channel-label swap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Cross-spectrum phase changes sign after a channel-label swap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Cross-spectrum phase changes sign after a channel-label swap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Cross-spectrum phase changes sign after a channel-label swap. Preserve the original order and interpret the delay only under a consistent signed definition Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Cross-spectrum phase changes sign after a channel-label swap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.30 Accept coherence at the required boundary and state (p. 6992)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Cross-spectrum phase changes sign after a channel-label swap. Preserve the original order and interpret the

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delay only under a consistent signed definition Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Cross-spectrum phase changes sign after a channel-label swap and Is the physical delay necessarily reversed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Cross-spectrum phase changes sign after a channel-label swap”, addressing “Is the physical delay necessarily reversed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Cross-spectrum phase changes sign after a channel-label swap. Is the physical delay necessarily reversed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Cross-spectrum phase changes sign after a channel-label swap. Is the physical delay necessarily reversed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.7 Application 12A.4: Keep physical delay and clock-error signs separate (p. 6960)

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V011-VOL-DISCUSSION-040. A one-record coherence plot is uniformly one. Why should source-coupling claims wait?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A one-record coherence plot is uniformly one. Why should source-coupling claims wait?” Put this particular dispute to the panel: A one-record coherence plot is uniformly one. Why should source-coupling claims wait. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 02. Student A, terminology and scope: Agree the operational meanings of coherence, plot, uniformly and source-coupling, claims, wait in “A one-record coherence plot is uniformly one. Why should source-coupling claims wait”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A one-record coherence plot is uniformly one; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications of Equation 18 and its paired-spectrum realization”. A normalized finite identity need not estimate population coupling Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A one-record coherence plot is uniformly one; explain what each record can establish State what the existing record establishes, what it does not establish, and which

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further measurement would change your opinion. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications of Equation 18 and its paired-spectrum realization”. A normalized finite identity need not estimate population coupling Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Examine whether each bin uses only one nonzero Fourier pair, define the ensemble and repeated paired averaging, and test shared noise or processing Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A one-record coherence plot is uniformly one:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A one-record coherence plot is uniformly one; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A one-record coherence plot is uniformly one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A one-record coherence plot is uniformly one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A one-record coherence plot is uniformly one: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A one-record coherence plot is uniformly one. A normalized finite identity need not estimate population coupling Explain the relevant statistical or calibration uncertainty,

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the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A one-record coherence plot is uniformly one, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.5.3 Ten worked applications of Equation 18 and its paired-spectrum realization (p. 5060)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A one-record coherence plot is uniformly one. A normalized finite identity need not estimate population coupling Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A one-record coherence plot is uniformly one and Why should source-coupling claims wait; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.79 Acceptance as a reproducible technical argument (p. 5787)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A one-record coherence plot is uniformly one”, addressing “Why should source-coupling claims wait”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A one-record coherence plot is uniformly one. Why should source-coupling claims wait”, specifying the next test, responsible measurement record and limit of the conclusion

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Summarise the strongest evidence for and against the resolution of “A one-record coherence plot is uniformly one. Why should source-coupling claims wait”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.5.1 Define the ensemble before normalizing (p. 5055)

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V011-VOL-DISCUSSION-041. Hundreds of overlapping FFT segments are called hundreds of independent trials. What is missing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Hundreds of overlapping FFT segments are called hundreds of independent trials. What is missing?” Put this particular dispute to the panel: Hundreds of overlapping FFT segments are called hundreds of independent trials. What is missing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 02. Student A, terminology and scope: Agree the operational meanings of overlapping, segments, called and independent, trials, missing in “Hundreds of overlapping FFT segments are called hundreds of independent trials. What is missing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Hundreds of overlapping FFT segments are called hundreds of independent trials; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.9: Calculate repeated capture only under independent start phases”. Define the estimator and trial experiment explicitly instead of equating segment count with independent evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Hundreds of overlapping FFT segments are called hundreds of independent trials; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.9: Calculate repeated capture only under independent start phases”. Define the estimator and trial experiment explicitly instead of equating segment count with independent evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Their shared samples and statistical dependence, plus the separate event-phase assumptions if used for capture probability Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source:

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§15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Hundreds of overlapping FFT segments are called hundreds of independent trials: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Hundreds of overlapping FFT segments are called hundreds of independent trials; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Hundreds of overlapping FFT segments are called hundreds of independent trials: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Hundreds of overlapping FFT segments are called hundreds of independent trials, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Hundreds of overlapping FFT segments are called hundreds of

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independent trials: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Hundreds of overlapping FFT segments are called hundreds of independent trials. Define the estimator and trial experiment explicitly instead of equating segment count with independent evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Hundreds of overlapping FFT segments are called hundreds of independent trials, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Hundreds of overlapping FFT segments are called hundreds of independent trials. Define the estimator and trial experiment explicitly instead of equating segment count with independent evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Hundreds of overlapping FFT segments are called hundreds of independent trials and What is missing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.12 Spectral confidence intervals and why averaging is not the same as independence (p. 5081)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Hundreds of overlapping FFT segments are called hundreds of independent trials”, addressing “What is missing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Hundreds of overlapping FFT segments are called hundreds of independent trials. What is missing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Hundreds of overlapping FFT segments are called hundreds of independent trials. What is missing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

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V011-VOL-DISCUSSION-042. Tone amplitude agrees between two windows, but their noise-density values disagree. What should be audited?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Tone amplitude agrees between two windows, but their noise-density values disagree. What should be audited?” Put this particular dispute to the panel: Tone amplitude agrees between two windows, but their noise-density values disagree. What should be audited. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 02. Student A, terminology and scope: Agree the operational meanings of Tone, amplitude, windows and values, disagree, audited in “Tone amplitude agrees between two windows, but their noise-density values disagree. What should be audited”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Tone amplitude agrees between two windows, but their noise-density values disagree; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Preserve each declared quantity and check integrated power rather than assume a single denominator applies to all displays Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Tone amplitude agrees between two windows, but their noise-density values disagree; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Windowed DFT normalization: line amplitude, noise density, and finite-record energy”. Preserve each declared quantity and check integrated power rather than assume a single denominator applies to all displays Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Window sum versus energy normalization, ENBW, sample rate and one/two-sided conventions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them

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without changing the measurand. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Tone amplitude agrees between two windows, but their noise-density values disagree: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Tone amplitude agrees between two windows, but their noise-density values disagree; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Tone amplitude agrees between two windows, but their noise-density values disagree: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Tone amplitude agrees between two windows, but their noise-density values disagree, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Tone amplitude agrees between two windows, but their noise-

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density values disagree: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Tone amplitude agrees between two windows, but their noise-density values disagree. Preserve each declared quantity and check integrated power rather than assume a single denominator applies to all displays Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Tone amplitude agrees between two windows, but their noise-density values disagree, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §9.3 Windowed DFT normalization: line amplitude, noise density, and finite-record energy (p. 5028)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Tone amplitude agrees between two windows, but their noise-density values disagree. Preserve each declared quantity and check integrated power rather than assume a single denominator applies to all displays Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §5.3 Choose an IF path for the quantity being measured (p. 2518)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Tone amplitude agrees between two windows, but their noise-density values disagree and What should be audited; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.23 Define the phase spectrum before converting decibels (p. 6394)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Tone amplitude agrees between two windows, but their noise-density values disagree”, addressing “What should be audited”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Tone amplitude agrees between two windows, but their noise-density values disagree. What should be audited”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Tone amplitude agrees between two windows, but their noise-density values disagree. What should be audited”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

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V011-VOL-DISCUSSION-043. Zero padding makes two nearby peaks appear separated in a short capture. What claim requires restraint?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Zero padding makes two nearby peaks appear separated in a short capture. What claim requires restraint?” Put this particular dispute to the panel: Zero padding makes two nearby peaks appear separated in a short capture. What claim requires restraint. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 02. Student A, terminology and scope: Agree the operational meanings of padding, makes, nearby and peaks, appear, separated in “Zero padding makes two nearby peaks appear separated in a short capture. What claim requires restraint”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Zero padding makes two nearby peaks appear separated in a short capture; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”. Compare window/record effects and obtain more valid data where needed; interpolation adds grid points, not independent observation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Zero padding makes two nearby peaks appear separated in a short capture; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate”. Compare window/record effects and obtain more valid data where needed; interpolation adds grid points, not independent observation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Actual resolving evidence and source discrimination based on the unchanged time record Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Zero padding makes two nearby peaks appear separated in a short capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Zero padding makes two nearby peaks appear separated in a short capture; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Zero padding makes two nearby peaks appear separated in a short capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Zero padding makes two nearby peaks appear separated in a short capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Zero padding makes two nearby peaks appear separated in a short

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capture: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Zero padding makes two nearby peaks appear separated in a short capture. Compare window/record effects and obtain more valid data where needed; interpolation adds grid points, not independent observation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Zero padding makes two nearby peaks appear separated in a short capture, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.22.10 Application

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7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Zero padding makes two nearby peaks appear separated in a short capture. Compare window/record effects and obtain more valid data where needed; interpolation adds grid points, not independent observation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §9.6 Time-Frequency and Nonstationary Methods (p. 5071)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Zero padding makes two nearby peaks appear separated in a short capture and What claim requires restraint; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.2 Spectral Leakage and Window Selection (p. 5027)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Zero padding makes two nearby peaks appear separated in a short capture”, addressing “What claim requires restraint”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Zero padding makes two nearby peaks appear separated in a short capture. What claim requires restraint”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Zero padding makes two nearby peaks appear separated in a short capture. What claim requires restraint”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

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V011-VOL-DISCUSSION-044. Average power and integrated FFT energy agree, yet the receiver overloads on peaks. What is the explanation to test?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Average power and integrated FFT energy agree, yet the receiver overloads on peaks. What is the explanation to test?” Put this particular dispute to the panel: Average power and integrated FFT energy agree, yet the receiver overloads on peaks. What is the explanation to test. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 02. Student A, terminology and scope: Agree the operational meanings of Average, integrated, energy and agree, peaks, explanation in “Average power and integrated FFT energy agree, yet the receiver overloads on peaks. What is the explanation to test”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.3.3 Energy closure and its limits (p. 5036)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Average power and integrated FFT energy agree, yet the receiver overloads on peaks; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6A.8: Compare average power with peak envelope power for two SSB tones”. Retain time-domain waveform and stage-level linearity/protection checks Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Average power and integrated

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FFT energy agree, yet the receiver overloads on peaks; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6A.8: Compare average power with peak envelope power for two SSB tones”. Retain time-domain waveform and stage-level linearity/protection checks Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Peak-envelope and relative-phase loading at vulnerable stages can differ despite correct mean-energy closure Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.3.3 Energy closure and its limits (p. 5036)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Average power and integrated FFT energy agree, yet the receiver overloads on peaks: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Average power and integrated FFT energy agree, yet the receiver overloads on peaks; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Average power and integrated FFT energy agree, yet the receiver overloads on peaks: specify the

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altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Average power and integrated FFT energy agree, yet the receiver overloads on peaks, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Average power and integrated FFT energy agree, yet the receiver overloads on peaks: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Average power and integrated FFT energy agree, yet the receiver overloads on peaks. Retain time-domain waveform and stage-level linearity/protection checks Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Average power and integrated FFT energy agree, yet the receiver overloads on peaks, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.13 Application 6A.8: Compare average power with peak envelope power for two SSB tones (p. 3125)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Average power and integrated FFT energy agree, yet the receiver overloads on peaks. Retain time-domain waveform and stage-level linearity/protection checks Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Average power and integrated FFT energy agree, yet the receiver overloads on peaks and What is the explanation to test; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.17 Logarithmic Amplifiers, Detectors, and Scaling (p. 2538)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Average power and integrated FFT energy agree, yet the receiver overloads on peaks”, addressing “What is the explanation to test”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and

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I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.3.3 Energy closure and its limits (p. 5036)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Average power and integrated FFT energy agree, yet the receiver overloads on peaks. What is the explanation to test”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Average power and integrated FFT energy agree, yet the receiver overloads on peaks. What is the explanation to test”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.3.3 Energy closure and its limits (p. 5036)

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V011-VOL-DISCUSSION-045. An AM modulation-depth estimate changes after a filter swap. How would you distinguish source change from receiver shaping?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An AM modulation-depth estimate changes after a filter swap. How would you distinguish source change from receiver shaping?” Put this particular dispute to the panel: An AM modulation-depth estimate changes after a filter swap. How would you distinguish source change from receiver shaping. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 02. Student A, terminology and scope: Agree the operational meanings of estimate, changes, filter and source, receiver, shaping in “An AM modulation-depth estimate changes after a filter swap. How would you distinguish source change from receiver shaping”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An AM modulation-depth estimate changes after a filter swap; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6A.3: Infer modulation depth from one resolved sideband”. Magnitude extrema at the output may not represent the original source, especially with reversal or unequal sideband admission Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An AM modulation-depth estimate changes after a filter swap; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6A.3: Infer modulation depth from one resolved sideband”. Magnitude extrema at the output may not represent the original source, especially with reversal or unequal sideband admission Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Measure carrier/sideband transfer and phase, compare a known waveform and preserve the gain state Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An AM modulation-depth estimate changes after a filter swap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An AM modulation-depth estimate changes after a filter swap; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An AM modulation-depth

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estimate changes after a filter swap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An AM modulation-depth estimate changes after a filter swap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An AM modulation-depth estimate changes after a filter swap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what

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observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An AM modulation-depth estimate changes after a filter swap. Magnitude extrema at the output may not represent the original source, especially with reversal or unequal sideband admission Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An AM modulation-depth estimate changes after a filter swap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.8 Application 6A.3: Infer modulation depth from one resolved sideband (p. 3120)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An AM modulation-depth estimate changes after a filter swap. Magnitude extrema at the output may not represent the original source, especially with reversal or unequal sideband admission Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An AM modulation-depth estimate changes after a filter swap and How would you distinguish source change from receiver shaping; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.9 Application 6A.4: Show why an envelope-extrema estimate fails after reversal (p. 3121)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An AM modulation-depth estimate changes after a filter swap”, addressing “How would you distinguish source change from receiver shaping”; specify the exact

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measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An AM modulation-depth estimate changes after a filter swap. How would you distinguish source change from receiver shaping”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An AM modulation-depth estimate changes after a filter swap. How would you distinguish source change from receiver shaping”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.14 Application 6A.9: Separate sideband filtering from source modulation depth (p. 3126)

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V011-VOL-DISCUSSION-046. An envelope detector removes sign reversals, but its mean power remains useful. How should the result be scoped?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An envelope detector removes sign reversals, but its mean power remains useful. How should the result be scoped?” Put this particular dispute to the panel: An envelope detector removes sign reversals, but its mean power remains useful. How should the result be scoped. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 02. Student A, terminology and scope: Agree the operational meanings of envelope, removes, sign and reversals, mean, remains in “An envelope detector removes sign reversals, but its mean power remains useful. How should the result be scoped”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An envelope detector removes sign reversals, but its mean power remains useful; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3.5 Measurement consequence (p. 5050)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measurement consequence”. Use coherent samples and validated bandwidth for claims requiring that information Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3.5 Measurement consequence (p. 5050)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An envelope detector removes sign reversals, but its mean power remains useful; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measurement consequence”. Use coherent samples and validated bandwidth for claims requiring that information Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3.5 Measurement consequence (p. 5050)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain the valid declared power statistic while declining to reconstruct lost phase/sign or source waveform uniquely Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An envelope detector removes sign reversals, but its mean power remains useful: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An envelope detector removes sign reversals, but its mean power remains useful; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An envelope detector removes sign reversals, but its mean power remains useful: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An envelope detector removes sign reversals, but its mean power remains useful, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3.5 Measurement consequence (p. 5050)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An envelope detector removes sign reversals, but its mean power remains useful: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An envelope detector removes sign reversals, but its mean power remains useful. Use coherent samples and validated bandwidth for claims requiring that information Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An envelope detector removes sign reversals, but its mean power remains useful, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3.5 Measurement consequence (p. 5050)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An envelope detector removes sign reversals,

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but its mean power remains useful. Use coherent samples and validated bandwidth for claims requiring that information Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An envelope detector removes sign reversals, but its mean power remains useful and How should the result be scoped; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.2 Amplitude Modulation and Envelope Detection (p. 3108)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An envelope detector removes sign reversals, but its mean power remains useful”, addressing “How should the result be scoped”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An envelope detector removes sign reversals, but its mean power remains useful. How should the result be scoped”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An envelope detector removes sign reversals, but its mean power remains useful. How should the result be scoped”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.12.8 Application 1A.8. Preserve a valid power result while refusing to reconstruct lost phase (p. 93)

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V011-VOL-DISCUSSION-047. A phase-derived frequency plot spikes at a low-amplitude zero. What should be reviewed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A phase-derived frequency plot spikes at a low-amplitude zero. What should be reviewed?” Put this particular dispute to the panel: A phase-derived frequency plot spikes at a low-amplitude zero. What should be reviewed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 02. Student A, terminology and scope: Agree the operational meanings of phase-derived, frequency, plot and spikes, zero, reviewed in “A phase-derived frequency plot spikes at a low-amplitude zero. What should be reviewed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A phase-derived frequency plot spikes at a low-amplitude zero; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value”. Do not interpret an undefined or unstable phase derivative as a physical instantaneous frequency without supporting evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A phase-derived frequency plot spikes at a low-amplitude zero; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value”. Do not interpret an undefined or unstable phase derivative as a physical instantaneous frequency without supporting evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Signal validity, phase branch and finite-interval definition, resets and actual sample timing Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A phase-derived frequency plot spikes at a low-amplitude zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A phase-derived frequency plot spikes at a low-amplitude zero; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A phase-derived frequency plot spikes at a low-amplitude zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A phase-derived frequency plot spikes at a low-amplitude zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A phase-derived frequency plot spikes at a low-amplitude zero: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A phase-derived frequency plot spikes at a low-amplitude zero. Do not interpret an undefined or unstable phase derivative as a physical instantaneous frequency without supporting evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A phase-derived frequency plot spikes at a low-amplitude zero, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §6.25 Application 6B.7: Report finite-interval frequency rather than an unsupported instantaneous value (p. 3143)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A phase-derived frequency plot spikes at a low-amplitude zero. Do not interpret an undefined or unstable phase derivative as a physical instantaneous frequency without supporting evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.16 Frequency and Phase Modulation (p. 3128)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A phase-derived frequency plot spikes at a low-amplitude zero and What should be reviewed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §5.14 Application 5A.9: Distinguish exact sampled state from an unstable Euler approximation (p. 2534)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A phase-derived frequency plot spikes at a low-amplitude zero”, addressing “What should be reviewed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one

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objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A phase-derived frequency plot spikes at a low-amplitude zero. What should be reviewed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A phase-derived frequency plot spikes at a low-amplitude zero. What should be reviewed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.17 Model 6B: phase is the quantity that frequency differentiates (p. 3131)

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V011-VOL-DISCUSSION-048. A reference has excellent long-term frequency accuracy but poor close-in phase noise. Which receiver claims differ?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A reference has excellent long-term frequency accuracy but poor close-in phase noise. Which receiver claims differ?” Put this particular dispute to the panel: A reference has excellent long-term frequency accuracy but poor close-in phase noise. Which receiver claims differ. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 02. Student A, terminology and scope: Agree the operational meanings of excellent, accuracy, poor and noise, claims, differ in “A reference has excellent long-term frequency accuracy but poor close-in phase noise. Which receiver claims differ”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A reference has excellent long-term frequency accuracy but poor close-in phase noise; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frequency Reference and Tuning Accuracy”. Retain separate deterministic time error, phase-noise spectrum and relevant channel/covariance models Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reference has excellent long-term frequency accuracy but poor close-in phase noise; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frequency Reference and Tuning Accuracy”. Retain separate deterministic time error, phase-noise spectrum and relevant channel/covariance models Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Average tuning accuracy can be good while coherent integration or blocker susceptibility is limited Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A reference has excellent long-term frequency accuracy but poor close-in phase noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A reference has excellent long-term frequency accuracy but poor close-in phase noise; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A reference has excellent long-term frequency accuracy but poor close-in phase noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A reference has excellent long-term frequency accuracy but poor close-in phase noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A reference has excellent long-term frequency accuracy but poor close-in phase noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A reference has excellent long-term frequency accuracy but poor close-in phase noise. Retain separate deterministic time error, phase-noise spectrum and relevant channel/covariance models Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A reference has excellent long-term frequency accuracy but poor close-in phase noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.1 Frequency Reference and Tuning Accuracy (p. 6950)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A reference has excellent long-term frequency accuracy but poor close-in phase noise. Retain separate

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deterministic time error, phase-noise spectrum and relevant channel/covariance models Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.2 Model 12A: connect clock reading, frequency and phase (p. 6951)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A reference has excellent long-term frequency accuracy but poor close-in phase noise and Which receiver claims differ; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A reference has excellent long-term frequency accuracy but poor close-in phase noise”, addressing “Which receiver claims differ”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A reference has excellent long-term frequency accuracy but poor close-in phase noise. Which receiver claims differ”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A reference has excellent long-term frequency accuracy but poor close-in phase noise. Which receiver claims differ”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.14 Phase Noise and Close-In Observation (p. 6967)

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V011-VOL-DISCUSSION-049. Two jitter specifications integrate different offset bands. How should a comparison be reported?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two jitter specifications integrate different offset bands. How should a comparison be reported?” Put this particular dispute to the panel: Two jitter specifications integrate different offset bands. How should a comparison be reported. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 02. Student A, terminology and scope: Agree the operational meanings of jitter, specifications, integrate and offset, bands, reported in “Two jitter specifications integrate different offset bands. How should a comparison be reported”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two jitter specifications integrate different offset bands; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin”. Equal numerical RMS is not interchangeable evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two jitter specifications integrate different offset bands; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin”. Equal numerical RMS is not interchangeable evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State each band, carrier and line/density treatment, identify unmeasured contributions and relate spectral placement to the intended receiver function Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two jitter specifications integrate different offset bands: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two jitter specifications integrate different offset bands; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two jitter specifications integrate different offset bands: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection

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criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two jitter specifications integrate different offset bands, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two jitter specifications integrate different offset bands: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two jitter specifications integrate different offset bands. Equal numerical RMS is not interchangeable evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two jitter specifications integrate different offset bands, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two jitter specifications integrate different offset bands. Equal numerical RMS is not interchangeable evidence Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing

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datum, sensitivity test or uncertainty term that limits confidence. Source: §12.19 Application 12B.2: Add density bands in linear units (p. 6979)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two jitter specifications integrate different offset bands and How should a comparison be reported; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.16 Model 12B: finite-band jitter and coherent signal power (p. 6971)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two jitter specifications integrate different offset bands”, addressing “How should a comparison be reported”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two jitter specifications integrate different offset bands. How should a comparison be reported”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two jitter specifications integrate different offset bands. How should a comparison be reported”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.18 Application 12B.1: Integrate a flat SSB density over a declared band (p. 6978)

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V011-VOL-DISCUSSION-050. A Gaussian phase-loss formula is applied because only RMS phase was measured. What further premise is needed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A Gaussian phase-loss formula is applied because only RMS phase was measured. What further premise is needed?” Put this particular dispute to the panel: A Gaussian phase-loss formula is applied because only RMS phase was measured. What further premise is needed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 02. Student A, terminology and scope: Agree the operational meanings of Gaussian, phase-loss, formula and applied, phase, premise in “A Gaussian phase-loss formula is applied because only RMS phase was measured. What further premise is needed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A Gaussian phase-loss formula is applied because only RMS phase was measured; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin”. RMS alone does not select the exact Gaussian finite-coherence law Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A Gaussian phase-loss formula

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is applied because only RMS phase was measured; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.4: Treat a phase-modulation line as a line, not a density bin”. RMS alone does not select the exact Gaussian finite-coherence law Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A justified joint distribution and relevant covariance of phase differences, including deterministic components Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A Gaussian phase-loss formula is applied because only RMS phase was measured: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A Gaussian phase-loss formula is applied because only RMS phase was measured; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A Gaussian phase-loss formula is applied because only RMS phase was measured: specify the

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altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A Gaussian phase-loss formula is applied because only RMS phase was measured, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A Gaussian phase-loss formula is applied because only RMS phase was measured: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A Gaussian phase-loss formula is applied because only RMS phase was measured. RMS alone does not select the exact Gaussian finite-coherence law Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A Gaussian phase-loss formula is applied because only RMS phase was measured, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A Gaussian phase-loss formula is applied because only RMS phase was measured. RMS alone does not select the exact Gaussian finite-coherence law Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.24 Application 12B.7: Compute finite-sample coherence for independent Gaussian phases (p. 6984)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A Gaussian phase-loss formula is applied because only RMS phase was measured and What further premise is needed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A Gaussian phase-loss formula is applied because only RMS phase was measured”, addressing “What further premise is needed”; specify the exact measurement or evidential

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gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A Gaussian phase-loss formula is applied because only RMS phase was measured. What further premise is needed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A Gaussian phase-loss formula is applied because only RMS phase was measured. What further premise is needed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

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V011-VOL-DISCUSSION-051. All samples in a record receive the same random phase rotation. Why can magnitude coherence appear perfect while calibration still matters?

- 01. Moderator, opening proposition: Introduce the exact dispute, “All samples in a record receive the same random phase rotation. Why can magnitude coherence appear perfect while calibration still matters?” Put this particular dispute to the panel: All samples in a record receive the same random phase rotation. Why can magnitude coherence appear perfect while calibration still matters. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 02. Student A, terminology and scope: Agree the operational meanings of random, rotation, coherence and appear, perfect, matters in “All samples in a record receive the same random phase rotation. Why can magnitude coherence appear perfect while calibration still matters”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of All samples in a record receive the same random phase rotation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. Define the target boundary and retain the shared reference relationship rather than infer universal synchronization Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of All samples in a record receive the same random phase rotation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.9: Combine deterministic rotation with independent phase errors”. Define the target boundary and retain the shared reference relationship rather than infer universal synchronization Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The common factor preserves coherent-sum magnitude, but absolute and inter-record phase can vary Put two specific questions to Student D about the

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stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 08. Student D, answer to Student E: Design a discriminating experiment involving All samples in a record receive the same random phase rotation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of All samples in a record receive the same random phase rotation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving All samples in a record receive the same random phase rotation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving All samples in a record receive the same random phase rotation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving All samples in a record receive the same random phase rotation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for All samples in a record receive the same random phase rotation. Define the target boundary and retain the shared reference relationship rather than infer universal synchronization Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving All samples in a record receive the same random phase rotation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage

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and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for All samples in a record receive the same random phase rotation. Define the target boundary and retain the shared reference relationship rather than infer universal synchronization Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.4 Define the symbol experiment before fitting the constellation (p. 3742)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about All samples in a record receive the same random phase rotation and Why can magnitude coherence appear perfect while calibration still matters; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “All samples in a record receive the same random phase rotation”, addressing “Why can magnitude coherence appear perfect while calibration still matters”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.23 Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “All samples in a record receive the same random phase rotation. Why can magnitude coherence appear perfect while calibration still matters”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “All samples in a record receive the same random phase rotation. Why can magnitude coherence appear perfect while calibration still matters”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.23

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Application 12B.6: Distinguish a common random phase from lost coherent power (p. 6983)

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V011-VOL-DISCUSSION-052. Two channels share 10 MHz but their aperture offsets were never measured. What should a phase comparison state?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two channels share 10 MHz but their aperture offsets were never measured. What should a phase comparison state?” Put this particular dispute to the panel: Two channels share 10 MHz but their aperture offsets were never measured. What should a phase comparison state. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 02. Student A, terminology and scope: Agree the operational meanings of channels, share, aperture and offsets, were, phase in “Two channels share 10 MHz but their aperture offsets were never measured. What should a phase comparison state”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two channels share 10 MHz but their aperture offsets were never measured; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Frequency, phase, and delay require their own observables”. Test simultaneous input and retain cable/converter/trigger contributions Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two channels share 10 MHz but their aperture offsets were never measured; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Frequency, phase, and delay require their own observables”. Test simultaneous input and retain cable/converter/trigger contributions Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Shared nominal frequency is established, while relative timing and phase at the actual measurement boundary remain uncalibrated Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Two channels share 10 MHz but their aperture offsets were never measured: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two channels share 10 MHz but their aperture offsets were never measured; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two channels share 10 MHz but their aperture offsets were never measured: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two channels share 10 MHz but their aperture offsets were never measured, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two channels share 10 MHz but their aperture offsets were never measured: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two channels share 10 MHz but their aperture offsets were never measured. Test simultaneous input and retain cable/converter/trigger contributions Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two channels share 10 MHz but their aperture offsets were never measured, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two channels share 10 MHz but their aperture offsets were never measured. Test simultaneous input and retain

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cable/converter/trigger contributions Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two channels share 10 MHz but their aperture offsets were never measured and What should a phase comparison state; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two channels share 10 MHz but their aperture offsets were never measured”, addressing “What should a phase comparison state”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two channels share 10 MHz but their aperture offsets were never measured. What should a phase comparison state”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two channels share 10 MHz but their aperture offsets were never measured. What should a phase comparison state”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.29 Multichannel Synchronization and Delay Calibration (p. 6989)

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V011-VOL-DISCUSSION-053. Retuning restores amplitude but changes phase between captures. May those records be combined coherently?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Retuning restores amplitude but changes phase between captures. May those records be combined coherently?” Put this particular dispute to the panel: Retuning restores amplitude but changes phase between captures. May those records be combined coherently. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 02. Student A, terminology and scope: Agree the operational meanings of Retuning, restores, changes and captures, records, combined in “Retuning restores amplitude but changes phase between captures. May those records be combined coherently”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Retuning restores amplitude but changes phase between captures; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.1: Show which error a fitted gain removes”. Preserve individual power results and reset history; amplitude agreement does not establish complex continuity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Retuning restores amplitude

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but changes phase between captures; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.1: Show which error a fitted gain removes”. Preserve individual power results and reset history; amplitude agreement does not establish complex continuity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Only with supported inter-record phase information or a new justified correction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Retuning restores amplitude but changes phase between captures: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Retuning restores amplitude but changes phase between captures; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Retuning restores amplitude but changes phase between captures: specify the altered receiver state or source condition, predicted change, test statistic and

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rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Retuning restores amplitude but changes phase between captures, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Retuning restores amplitude but changes phase between captures: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Retuning restores amplitude but changes phase between captures. Preserve individual power results and reset history; amplitude agreement does not establish complex continuity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Retuning restores amplitude but changes phase between captures, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Retuning restores amplitude but changes phase between captures. Preserve individual power results and reset history; amplitude agreement does not establish complex continuity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Retuning restores amplitude but changes phase between captures and May those records be combined coherently; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.87 Sampling application 5 A failed two-rate uniqueness claim (p. 5797)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Retuning restores amplitude but changes phase between captures”, addressing “May those records be combined coherently”; specify the exact measurement or evidential

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gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Retuning restores amplitude but changes phase between captures. May those records be combined coherently”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Retuning restores amplitude but changes phase between captures. May those records be combined coherently”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

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V011-VOL-DISCUSSION-054. A trigger timestamp is precise to nanoseconds but refers to a software event. What is the actual timing question?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A trigger timestamp is precise to nanoseconds but refers to a software event. What is the actual timing question?” Put this particular dispute to the panel: A trigger timestamp is precise to nanoseconds but refers to a software event. What is the actual timing question. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 02. Student A, terminology and scope: Agree the operational meanings of trigger, timestamp, precise and software, event, timing in “A trigger timestamp is precise to nanoseconds but refers to a software event. What is the actual timing question”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A trigger timestamp is precise to nanoseconds but refers to a software event; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Numerical timestamp precision does not by itself establish event-time accuracy Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A trigger timestamp is precise to nanoseconds but refers to a software event; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change

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your opinion. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Numerical timestamp precision does not by itself establish event-time accuracy Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Determine its offset, latency variation and clock relation to sampled apertures and the stimulus Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A trigger timestamp is precise to nanoseconds but refers to a software event: specify the altered receiver state or

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source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A trigger timestamp is precise to nanoseconds but refers to a software event; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A trigger timestamp is precise to nanoseconds but refers to a software event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A trigger timestamp is precise to nanoseconds but refers to a software event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A trigger timestamp is precise to nanoseconds but refers to a software event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A trigger timestamp is precise to nanoseconds but refers to a software event. Numerical timestamp precision does not by itself establish event-time accuracy Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A trigger timestamp is precise to nanoseconds but refers to a software event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A trigger timestamp is precise to nanoseconds but refers to a software event. Numerical timestamp precision does not by itself establish event-time accuracy Respond point by point to Student J. Distinguish a verified observation from a conditional

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inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.6 Application 12A.3: Separate an epoch offset from a frequency offset (p. 6959)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A trigger timestamp is precise to nanoseconds but refers to a software event and What is the actual timing question; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A trigger timestamp is precise to nanoseconds but refers to a software event”, addressing “What is the actual timing question”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A trigger timestamp is precise to nanoseconds but refers to a software event. What is the actual timing question”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A trigger timestamp is precise to nanoseconds but refers to a software event. What is the actual timing question”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

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V011-VOL-DISCUSSION-055. A complex-gain fit makes EVM nearly zero while an independent phase test fails. Are the results contradictory?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A complex-gain fit makes EVM nearly zero while an independent phase test fails. Are the results contradictory?” Put this particular dispute to the panel: A complex-gain fit makes EVM nearly zero while an independent phase test fails. Are the results contradictory. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 02. Student A, terminology and scope: Agree the operational meanings of makes, nearly, independent and fails, results, contradictory in “A complex-gain fit makes EVM nearly zero while an independent phase test fails. Are the results contradictory”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A complex-gain fit makes EVM nearly zero while an independent phase test fails; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Report coefficient, residual normalization and held-out scope alongside the unremoved phase result Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A complex-gain fit makes EVM nearly zero while an independent phase test fails; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.7: Evaluate a fitted gain on held-out symbols”. Report coefficient, residual normalization and held-out scope alongside the unremoved phase result Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Not necessarily; the fit may remove the phase error the calibration measures Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A complex-gain fit makes EVM nearly zero while an independent phase test fails: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A complex-gain fit makes EVM nearly zero while an independent phase test fails; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A complex-gain fit makes EVM nearly zero while an independent phase test fails: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A complex-gain fit makes EVM nearly zero while an independent phase test fails, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A complex-gain fit makes EVM nearly zero while an independent phase test fails: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A complex-gain fit makes EVM nearly zero while an independent phase test fails. Report coefficient, residual normalization and held-out scope alongside the unremoved phase result Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A complex-gain fit makes EVM nearly zero while an independent phase test fails, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A complex-gain fit makes EVM nearly zero while

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an independent phase test fails. Report coefficient, residual normalization and held-out scope alongside the unremoved phase result Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A complex-gain fit makes EVM nearly zero while an independent phase test fails and Are the results contradictory; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.41 Coherence under stochastic phase error (p. 7014)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A complex-gain fit makes EVM nearly zero while an independent phase test fails”, addressing “Are the results contradictory”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A complex-gain fit makes EVM nearly zero while an independent phase test fails. Are the results contradictory”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A complex-gain fit makes EVM nearly zero while an independent phase test fails. Are the results contradictory”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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V011-VOL-DISCUSSION-056. Two EVM reports use RMS-reference and constellation-maximum normalization. How should their thresholds be compared?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two EVM reports use RMS-reference and constellation-maximum normalization. How should their thresholds be compared?” Put this particular dispute to the panel: Two EVM reports use RMS-reference and constellation-maximum normalization. How should their thresholds be compared. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 02. Student A, terminology and scope: Agree the operational meanings of reports, RMS-reference, constellation-maximum and normalization, thresholds, compared in “Two EVM reports use RMS-reference and constellation-maximum normalization. How should their thresholds be compared”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two EVM reports use RMS-reference and constellation-maximum normalization; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Ten worked applications of the normalization model”. A lower percentage may be a normalization change rather than improved physical modulation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Two EVM reports use RMS-reference and constellation-maximum normalization; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Ten worked applications of the normalization model”. A lower percentage may be a normalization change rather than improved physical modulation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Recover numerator, denominator, selected symbol population and fit freedom, then express a common declared metric where supported Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two EVM reports use RMS-reference and constellation-maximum normalization: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two EVM reports use RMS-reference and constellation-maximum normalization; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two EVM reports use RMS-reference and constellation-maximum normalization: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two EVM reports use RMS-reference and constellation-maximum normalization, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two EVM reports use RMS-reference and constellation-maximum

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normalization: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two EVM reports use RMS-reference and constellation-maximum normalization. A lower percentage may be a normalization change rather than improved physical modulation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two EVM reports use RMS-reference and constellation-maximum normalization, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §9.3.4 Ten worked applications of the normalization model (p. 5039)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two EVM reports use RMS-reference and constellation-maximum normalization. A lower percentage may be a normalization change rather than improved physical modulation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.5 Model 7A: a finite, declared EVM comparison (p. 3744)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two EVM reports use RMS-reference and constellation-maximum normalization and How should their thresholds be compared; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two EVM reports use RMS-reference and constellation-maximum normalization”, addressing “How should their thresholds be compared”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two EVM reports use RMS-reference and constellation-maximum normalization. How should their thresholds be compared”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two EVM reports use RMS-reference and constellation-maximum normalization. How should their thresholds be compared”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.11 Application 7A.5: Compare RMS and constellation-maximum normalization (p. 3756)

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V011-VOL-DISCUSSION-057. A decoder passes its training waveform but fails a separately captured reference. What should be released?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A decoder passes its training waveform but fails a separately captured reference. What should be released?” Put this particular dispute to the panel: A decoder passes its training waveform but fails a separately captured reference. What should be released. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 02. Student A, terminology and scope: Agree the operational meanings of decoder, passes, training and fails, captured, released in “A decoder passes its training waveform but fails a separately captured reference. What should be released”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A decoder passes its training waveform but fails a separately captured reference; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7A.1: Show which error a fitted gain removes”. Investigate alignment and applicability, and avoid representing fitted success as general receiver performance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A decoder passes its training waveform but fails a separately captured reference; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7A.1: Show which error a fitted gain removes”. Investigate alignment and applicability, and avoid representing fitted success as general receiver performance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The training result and validation failure with their states, fit choices and native records Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A decoder passes its training waveform but fails a separately captured reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A decoder passes its training waveform but fails a separately captured reference; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A decoder passes its training waveform but fails a separately captured reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A decoder passes its training waveform but fails a separately captured reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A decoder passes its training waveform but fails a separately captured reference: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A decoder passes its training waveform but fails a separately captured reference. Investigate alignment and applicability, and avoid representing fitted success as general receiver performance Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A decoder passes its training waveform but fails a separately captured reference, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.7 Application 7A.1: Show which error a fitted gain removes (p. 3752)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A decoder passes its training waveform but fails a separately captured reference. Investigate alignment and applicability, and avoid representing fitted success as general receiver performance Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.14 Application 7A.8: Keep a residual frequency rotation in a finite symbol record (p. 3759)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A decoder passes its training waveform but fails a separately captured reference and What should be released; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A decoder passes its training waveform but fails a separately captured reference”, addressing “What should be released”; specify the exact measurement or evidential gap on

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which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A decoder passes its training waveform but fails a separately captured reference. What should be released”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A decoder passes its training waveform but fails a separately captured reference. What should be released”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.13 Application 7A.7: Evaluate a fitted gain on held-out symbols (p. 3758)

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V011-VOL-DISCUSSION-058. A familiar identifier appears on two software tools using the same decoder core. How strong is attribution?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A familiar identifier appears on two software tools using the same decoder core. How strong is attribution?” Put this particular dispute to the panel: A familiar identifier appears on two software tools using the same decoder core. How strong is attribution. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 02. Student A, terminology and scope: Agree the operational meanings of familiar, identifier, appears and tools, decoder, attribution in “A familiar identifier appears on two software tools using the same decoder core. How strong is attribution”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A familiar identifier appears on two software tools using the same decoder core; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integration with Direction, Wireline, Optical, and Physical Evidence”. A duplicate display is not independent evidence of device function Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A familiar identifier appears on two software tools using the same decoder core; explain what each

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record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integration with Direction, Wireline, Optical, and Physical Evidence”. A duplicate display is not independent evidence of device function Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The outputs may share a false lock or stale interpretation; use independent valid/noise-only records, separate implementations and physical linkage Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A familiar identifier appears on two software tools using the same decoder core: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A familiar identifier appears on two software tools using the same decoder core; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A familiar identifier appears on two software tools using the same decoder core: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A familiar identifier appears on two software tools using the same decoder core, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A familiar identifier appears on two software tools using the same decoder core: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A familiar identifier appears on two software tools using the same decoder core. A duplicate display is not independent evidence of device function Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A familiar identifier appears on two software tools using the same decoder core, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A familiar identifier appears on two software tools using the same decoder core. A duplicate display is not

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independent evidence of device function Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.20 Metric Validation and Held-Out Data (p. 3766)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A familiar identifier appears on two software tools using the same decoder core and How strong is attribution; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A familiar identifier appears on two software tools using the same decoder core”, addressing “How strong is attribution”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A familiar identifier appears on two software tools using the same decoder core. How strong is attribution”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A familiar identifier appears on two software tools using the same decoder core. How strong is attribution”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.18 Defensive Interpretation of Digital Signals (p. 3763)

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V011-VOL-DISCUSSION-059. The report labels coded bit rate as unique user throughput. What accounting should be reconstructed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The report labels coded bit rate as unique user throughput. What accounting should be reconstructed?” Put this particular dispute to the panel: The report labels coded bit rate as unique user throughput. What accounting should be reconstructed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 02. Student A, terminology and scope: Agree the operational meanings of coded, unique, user and throughput, accounting, reconstructed in “The report labels coded bit rate as unique user throughput. What accounting should be reconstructed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The report labels coded bit rate as unique user throughput; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 7B.2. Separate two overhead populations without counting either twice”. Distinguish nominal coded rate from actually delivered unique information and retain captured coverage Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The report labels coded bit rate as unique user throughput; explain what each record can

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establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 7B.2. Separate two overhead populations without counting either twice”. Distinguish nominal coded rate from actually delivered unique information and retain captured coverage Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Finite symbols, code rate, overhead populations, complete frames, repeated payload and wall duration Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The report labels coded bit rate as unique user throughput: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The report labels coded bit rate as unique user throughput; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The report labels coded bit rate as unique user throughput: specify the altered receiver state or source condition, predicted change, test statistic and rejection

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criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The report labels coded bit rate as unique user throughput, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The report labels coded bit rate as unique user throughput: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.1

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Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The report labels coded bit rate as unique user throughput. Distinguish nominal coded rate from actually delivered unique information and retain captured coverage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The report labels coded bit rate as unique user throughput, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The report labels coded bit rate as unique user throughput. Distinguish nominal coded rate from actually delivered unique information and retain captured coverage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The report labels coded bit rate as unique user throughput and What accounting should be reconstructed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The report labels coded bit rate as unique user throughput”, addressing “What accounting should be reconstructed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The report labels coded bit rate as unique user throughput. What accounting should be reconstructed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The report labels coded bit rate as unique user throughput. What accounting should be reconstructed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.1 Application 7B.1. Reconcile coded bits, information bits and modulation symbols (p. 3776)

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V011-VOL-DISCUSSION-060. A burst receiver reports its active rate as a whole-survey rate. How should the denominator be corrected?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A burst receiver reports its active rate as a whole-survey rate. How should the denominator be corrected?” Put this particular dispute to the panel: A burst receiver reports its active rate as a whole-survey rate. How should the denominator be corrected. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 02. Student A, terminology and scope: Agree the operational meanings of burst, reports, active and rate, denominator, corrected in “A burst receiver reports its active rate as a whole-survey rate. How should the denominator be corrected”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A burst receiver reports its active rate as a whole-survey rate; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Noise density uses a different denominator”. The same bits can support different rates only with explicit denominators Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A burst receiver reports its active rate as a whole-survey rate; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Noise density uses a different denominator”. The same bits can support different rates only with explicit denominators Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State active and full wall intervals separately, use actual delivered counts and duration weighting, and retain gaps/exclusions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A burst receiver reports its active rate as a whole-survey rate: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A burst receiver reports its active rate as a whole-survey rate; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A burst receiver reports its active rate as a whole-survey rate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A burst receiver reports its active rate as a whole-survey rate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A burst receiver reports its active rate as a whole-survey rate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A burst receiver reports its active rate as a

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whole-survey rate. The same bits can support different rates only with explicit denominators Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A burst receiver reports its active rate as a whole-survey rate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3.2 Noise density uses a different denominator (p. 5033)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A burst receiver reports its active rate as a whole-survey rate. The same bits can support different rates only with explicit denominators Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that

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limits confidence. Source: §7.22.5 Application 7B.5. Weight changing modes by their actual durations (p. 3783)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A burst receiver reports its active rate as a whole-survey rate and How should the denominator be corrected; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.2 Application 7B.2. Separate two overhead populations without counting either twice (p. 3778)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A burst receiver reports its active rate as a whole-survey rate”, addressing “How should the denominator be corrected”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A burst receiver reports its active rate as a whole-survey rate. How should the denominator be corrected”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A burst receiver reports its active rate as a whole-survey rate. How should the denominator be corrected”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.4 Application 7B.4. Distinguish active-burst rate from rate over the full interval (p. 3782)

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V011-VOL-DISCUSSION-061. Part of the last frame is captured, but the summary counts it as a complete delivered frame. What is required?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Part of the last frame is captured, but the summary counts it as a complete delivered frame. What is required?” Put this particular dispute to the panel: Part of the last frame is captured, but the summary counts it as a complete delivered frame. What is required. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 02. Student A, terminology and scope: Agree the operational meanings of last, captured, summary and counts, complete, delivered in “Part of the last frame is captured, but the summary counts it as a complete delivered frame. What is required”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Part of the last frame is captured, but the summary counts it as a complete delivered frame; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 7B: finite rate accounting for symbols, coding and payload”. Preserve event boundaries and actual retained data Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Part of the last frame is captured, but the summary counts it as a complete delivered frame;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 7B: finite rate accounting for symbols, coding and payload”. Preserve event boundaries and actual retained data Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Apply declared integer frame and payload rules, identify padding or incomplete units and avoid fractional extrapolation without a model Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Part of the last frame is captured, but the summary counts it as a complete delivered frame: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Part of the last frame is captured, but the summary counts it as a complete delivered frame; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Part of the last frame is captured, but the summary counts it as a complete delivered frame:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Part of the last frame is captured, but the summary counts it as a complete delivered frame, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Part of the last frame is captured, but the summary counts it as a complete delivered frame: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Part of the last frame is captured, but the summary counts it as a complete delivered frame. Preserve event boundaries and actual retained data Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Part of the last frame is captured, but the summary counts it as a complete delivered frame, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.22 Model 7B: finite rate accounting for symbols, coding and payload (p. 3768)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Part of the last frame is captured, but the summary counts it as a complete delivered frame. Preserve event boundaries and actual retained data Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.22.3 Application 7B.3. Count disjoint pilot and nonpayload slots explicitly (p. 3780)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Part of the last frame is captured, but the summary counts it as a complete delivered frame and What is required; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.28 Application 10C8 Same-frame decorrelation does not remove time overlap (p. 5718)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Part of the last frame is captured, but the summary counts it as a complete delivered frame”, addressing “What is required”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to

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respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Part of the last frame is captured, but the summary counts it as a complete delivered frame. What is required”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Part of the last frame is captured, but the summary counts it as a complete delivered frame. What is required”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.7 Application 7B.7. Retain integer frames and last-frame padding (p. 3787)

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V011-VOL-DISCUSSION-062. Two antennas capture overlapping payload sequences and their counts are added. What should unique delivery do?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Two antennas capture overlapping payload sequences and their counts are added. What should unique delivery do?” Put this particular dispute to the panel: Two antennas capture overlapping payload sequences and their counts are added. What should unique delivery do. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 02. Student A, terminology and scope: Agree the operational meanings of antennas, overlapping, sequences and counts, unique, delivery in “Two antennas capture overlapping payload sequences and their counts are added. What should unique delivery do”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Two antennas capture overlapping payload sequences and their counts are added; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “I/Q-derived modulation identity: distinguish discriminating features from unique source attribution”. Multiple observations can strengthen verification without increasing unique information count Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Two antennas capture overlapping payload sequences and their counts are added; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “I/Q-derived modulation identity: distinguish discriminating features from unique source attribution”. Multiple observations can strengthen verification without increasing unique information count Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify payload positions, deduplicate overlaps and retransmissions, and retain channel-specific evidence separately Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §7.22.6

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Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 08. Student D, answer to Student E: Design a discriminating experiment involving Two antennas capture overlapping payload sequences and their counts are added: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Two antennas capture overlapping payload sequences and their counts are added; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Two antennas capture overlapping payload sequences and their counts are added: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Two antennas capture overlapping payload sequences and their counts are added, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Two antennas capture overlapping payload sequences and their

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counts are added: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Two antennas capture overlapping payload sequences and their counts are added. Multiple observations can strengthen verification without increasing unique information count Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Two antennas capture overlapping payload sequences and their counts are added, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Two antennas capture overlapping payload sequences and their counts are added. Multiple observations can strengthen verification without increasing unique information count Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Two antennas capture overlapping payload sequences and their counts are added and What should unique delivery do; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.22.10 Application 7B.10. Preserve discrete coding alternatives rather than inventing a single payload rate (p. 3791)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Two antennas capture overlapping payload sequences and their counts are added”, addressing “What should unique delivery do”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Two antennas capture overlapping payload sequences and their counts are added. What should unique delivery do”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Two antennas capture overlapping payload sequences and their counts are added. What should unique delivery do”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §7.22.6 Application 7B.6. Remove duplicate payload before reporting unique throughput (p. 3785)

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V011-VOL-DISCUSSION-063. An estimated frequency shift follows changed sample-index handling after a gap. How would you audit it?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An estimated frequency shift follows changed sample-index handling after a gap. How would you audit it?” Put this particular dispute to the panel: An estimated frequency shift follows changed sample-index handling after a gap. How would you audit it. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

- 02. Student A, terminology and scope: Agree the operational meanings of estimated, frequency, shift and follows, handling, audit in “An estimated frequency shift follows changed sample-index handling after a gap. How would you audit it”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An estimated frequency shift follows changed sample-index handling after a gap; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 10E for absolute sample continuity and retained processing state”. Do not assign the shift to source motion until processing continuity is validated Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An estimated frequency shift follows changed sample-index handling after a gap; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 10E for absolute sample continuity and retained processing state”. Do not assign the shift to source motion until processing continuity is validated Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Trace absolute timing, NCO phase and phase-difference intervals, compare against the original native sequence and a known reference Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An estimated frequency shift follows changed sample-index handling after a gap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An estimated frequency shift follows changed sample-index handling after a gap; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An estimated frequency shift follows changed sample-index handling after a gap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An estimated frequency shift follows changed sample-index handling after a gap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An estimated frequency shift follows changed sample-index handling after a gap: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An estimated frequency shift follows changed sample-index handling after a gap. Do not assign the shift to source motion until processing continuity is validated Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An estimated frequency shift follows changed sample-index handling after a gap, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.48 Model 10E for absolute sample continuity and retained processing state (p. 5744)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An estimated frequency shift follows changed

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sample-index handling after a gap. Do not assign the shift to source motion until processing continuity is validated Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §7.1 Constellations and Symbol Representation (p. 3736)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An estimated frequency shift follows changed sample-index handling after a gap and How would you audit it; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.19 Bind sample continuity, storage accounting and derived results (p. 8707)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An estimated frequency shift follows changed sample-index handling after a gap”, addressing “How would you audit it”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An estimated frequency shift follows changed sample-index handling after a gap. How would you audit it”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An estimated frequency shift follows changed sample-index handling after a gap. How would you audit it”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §10.13 Application 10B7 Retained phase creates a coherent offset (p. 5698)

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V011-VOL-DISCUSSION-064. A remote amplifier is stable on a bench but produces lines with the installed bias cable. What combined checks matter?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A remote amplifier is stable on a bench but produces lines with the installed bias cable. What combined checks matter?” Put this particular dispute to the panel: A remote amplifier is stable on a bench but produces lines with the installed bias cable. What combined checks matter. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 02. Student A, terminology and scope: Agree the operational meanings of remote, bench, installed and combined, checks, matter in “A remote amplifier is stable on a bench but produces lines with the installed bias cable. What combined checks matter”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A remote amplifier is stable on a bench but produces lines with the installed bias cable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. Treat instability, pickup and leakage as alternatives rather than declare a unique oscillation from one line Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A remote amplifier is stable on a bench but produces lines with the installed bias cable; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Cross-Spectra, Coherence, and Multichannel Analysis”. Treat instability, pickup and leakage as alternatives rather than declare a unique oscillation from one line Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use actual load/bias/environment states, independent output and desired references, and selective cable or power interventions Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A remote amplifier is stable on a bench but produces lines with the installed bias cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A remote amplifier is stable on a bench but produces lines with the installed bias cable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A remote amplifier is stable on a bench but produces lines with the installed bias cable: specify the

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altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A remote amplifier is stable on a bench but produces lines with the installed bias cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A remote amplifier is stable on a bench but produces lines with the installed bias cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A remote amplifier is stable on a bench but produces lines with the installed bias cable. Treat instability, pickup and leakage as alternatives rather than declare a unique oscillation from one line Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A remote amplifier is stable on a bench but produces lines with the installed bias cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.5 Cross-Spectra, Coherence, and Multichannel Analysis (p. 5053)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A remote amplifier is stable on a bench but produces lines with the installed bias cable. Treat instability, pickup and leakage as alternatives rather than declare a unique oscillation from one line Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.5 External Preamplifiers, Bias, and Stability (p. 7544)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A remote amplifier is stable on a bench but produces lines with the installed bias cable and What combined checks matter; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.21 Application 12B.4: Treat a phase-modulation line as a line, not a density bin (p. 6981)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A remote amplifier is stable on a bench but produces lines with the installed bias cable”, addressing “What combined checks matter”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A remote amplifier is stable on a bench but produces lines with the installed bias cable. What combined checks matter”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A remote amplifier is stable on a bench but produces lines with the installed bias cable. What combined checks matter”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.6 Remote amplification requires electrical and installed checks (p. 7545)

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V011-VOL-DISCUSSION-065. Battery operation removes an anomaly but changes the ground return. What should the preliminary conclusion say?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Battery operation removes an anomaly but changes the ground return. What should the preliminary conclusion say?” Put this particular dispute to the panel: Battery operation removes an anomaly but changes the ground return. What should the preliminary conclusion say. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

- 02. Student A, terminology and scope: Agree the operational meanings of Battery, operation, removes and ground, return, conclusion in “Battery operation removes an anomaly but changes the ground return. What should the preliminary conclusion say”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Battery operation removes an anomaly but changes the ground return; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “From a spectral observation to an experimentally identifiable cause”. Preserve reference capability and design a more selective follow-up before naming the cause Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Battery operation removes an

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anomaly but changes the ground return; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “From a spectral observation to an experimentally identifiable cause”. Preserve reference capability and design a more selective follow-up before naming the cause Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The feature is sensitive to that combined intervention; supply noise and conductive coupling remain alternatives Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Battery operation removes an anomaly but changes the ground return: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Battery operation removes an anomaly but changes the ground return; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Battery operation removes an anomaly but changes the ground return: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Battery operation removes an anomaly but changes the ground return, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Battery operation removes an anomaly but changes the ground return: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Battery operation removes an anomaly but changes the ground return. Preserve reference capability and design a more selective follow-up before naming the cause Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Battery operation removes an anomaly but changes the ground return, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Battery operation removes an anomaly but changes the ground return. Preserve reference capability and

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design a more selective follow-up before naming the cause Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Battery operation removes an anomaly but changes the ground return and What should the preliminary conclusion say; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Battery operation removes an anomaly but changes the ground return”, addressing “What should the preliminary conclusion say”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Battery operation removes an anomaly but changes the ground return. What should the preliminary conclusion say”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Battery operation removes an anomaly but changes the ground return. What should the preliminary conclusion say”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.17 Electromagnetic return paths, cables and the risk of false spatial inference (p. 7563)

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V011-VOL-DISCUSSION-066. An optical link removes the conductive path and also narrows bandwidth. How should a disappeared burst be interpreted?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An optical link removes the conductive path and also narrows bandwidth. How should a disappeared burst be interpreted?” Put this particular dispute to the panel: An optical link removes the conductive path and also narrows bandwidth. How should a disappeared burst be interpreted. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 02. Student A, terminology and scope: Agree the operational meanings of optical, link, removes and conductive, narrows, interpreted in “An optical link removes the conductive path and also narrows bandwidth. How should a disappeared burst be interpreted”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An optical link removes the conductive path and also narrows bandwidth; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “I/Q-derived modulation identity: distinguish discriminating features from unique source attribution”. If not, retain an inconclusive negative comparison instead of unique coupling attribution Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An optical link removes the conductive path and also narrows bandwidth; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “I/Q-derived modulation identity: distinguish discriminating features from unique source attribution”. If not, retain an inconclusive negative comparison instead of unique coupling attribution Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Verify that the altered path can capture the same event duration and spectrum with adequate sensitivity and timing Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate

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between them without changing the measurand. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 08. Student D, answer to Student E: Design a discriminating experiment involving An optical link removes the conductive path and also narrows bandwidth: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An optical link removes the conductive path and also narrows bandwidth; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An optical link removes the conductive path and also narrows bandwidth: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An optical link removes the conductive path and also narrows bandwidth, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §7.27 I/Q-derived modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An optical link removes the conductive path and also narrows

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bandwidth: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An optical link removes the conductive path and also narrows bandwidth. If not, retain an inconclusive negative comparison instead of unique coupling attribution Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An optical link removes the conductive path and also narrows bandwidth, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §7.27 I/Q-derived

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modulation identity: distinguish discriminating features from unique source attribution (p. 3801)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An optical link removes the conductive path and also narrows bandwidth. If not, retain an inconclusive negative comparison instead of unique coupling attribution Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An optical link removes the conductive path and also narrows bandwidth and How should a disappeared burst be interpreted; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.21 Nonlinear fingerprinting without circular source attribution (p. 9303)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An optical link removes the conductive path and also narrows bandwidth”, addressing “How should a disappeared burst be interpreted”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An optical link removes the conductive path and also narrows bandwidth. How should a disappeared burst be interpreted”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An optical link removes the conductive path and also narrows bandwidth. How should a disappeared burst be interpreted”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

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V011-VOL-DISCUSSION-067. Antenna factor for a loaded voltage is applied to an open-circuit estimate. What should be reconstructed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Antenna factor for a loaded voltage is applied to an open-circuit estimate. What should be reconstructed?” Put this particular dispute to the panel: Antenna factor for a loaded voltage is applied to an open-circuit estimate. What should be reconstructed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 02. Student A, terminology and scope: Agree the operational meanings of factor, loaded, voltage and applied, estimate, reconstructed in “Antenna factor for a loaded voltage is applied to an open-circuit estimate. What should be reconstructed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Antenna factor for a loaded voltage is applied to an open-circuit estimate; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Transducer gain, mismatch and antenna calibration at the installed measurement plane”. Apply only the supported conversion and propagate its uncertainty; a nominal factor-two example is not a universal mismatch repair Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Antenna factor for a loaded

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voltage is applied to an open-circuit estimate; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Transducer gain, mismatch and antenna calibration at the installed measurement plane”. Apply only the supported conversion and propagate its uncertainty; a nominal factor-two example is not a universal mismatch repair Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The voltage and impedance convention, available versus delivered quantity and receiver/path correction Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Antenna factor for a loaded voltage is applied to an open-circuit estimate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Antenna factor for a loaded voltage is applied to an open-circuit estimate; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Antenna factor for a loaded voltage is applied to an open-circuit estimate: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Antenna factor for a loaded voltage is applied to an open-circuit estimate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Antenna factor for a loaded voltage is applied to an open-circuit estimate: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Antenna factor for a loaded voltage is applied to an open-circuit estimate. Apply only the supported conversion and propagate its uncertainty; a nominal factor-two example is not a universal mismatch repair Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Antenna factor for a loaded voltage is applied to an open-circuit estimate, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.20 Transducer gain, mismatch and antenna calibration at the installed measurement plane (p. 7578)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Antenna factor for a loaded voltage is applied to an open-circuit estimate. Apply only the supported conversion and propagate its uncertainty; a nominal factor-two example is not a universal mismatch repair Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §4.6 Application 4A.3: Separate loaded voltage gain from power gain (p. 1934)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Antenna factor for a loaded voltage is applied to an open-circuit estimate and What should be reconstructed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.6 Fix the voltage convention and operating domain (p. 6368)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Antenna factor for a loaded voltage is applied to an open-circuit estimate”, addressing “What should be reconstructed”; specify the exact measurement or evidential gap on

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which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Antenna factor for a loaded voltage is applied to an open-circuit estimate. What should be reconstructed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Antenna factor for a loaded voltage is applied to an open-circuit estimate. What should be reconstructed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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V011-VOL-DISCUSSION-068. A far-field antenna conversion is used beside a complex near-field source. How should the report be bounded?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A far-field antenna conversion is used beside a complex near-field source. How should the report be bounded?” Put this particular dispute to the panel: A far-field antenna conversion is used beside a complex near-field source. How should the report be bounded. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 02. Student A, terminology and scope: Agree the operational meanings of antenna, conversion, used and complex, report, bounded in “A far-field antenna conversion is used beside a complex near-field source. How should the report be bounded”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A far-field antenna conversion is used beside a complex near-field source; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Example 13.X10. Why field strength cannot be inferred from connector power alone”. Receiver calibration alone does not establish the local electric/magnetic relation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A far-field antenna conversion

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is used beside a complex near-field source; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Example 13.X10. Why field strength cannot be inferred from connector power alone”. Receiver calibration alone does not establish the local electric/magnetic relation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain measured terminal quantities and identify the unsupported field model; obtain geometry-appropriate characterization for stronger field claims Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A far-field antenna conversion is used beside a complex near-field source: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A far-field antenna conversion is used beside a complex near-field source; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A far-field antenna conversion is used beside a complex near-field source: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A far-field antenna conversion is used beside a complex near-field source, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A far-field antenna conversion is used beside a complex near-field source: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A far-field antenna conversion is used beside a complex near-field source. Receiver calibration alone does not establish the local electric/magnetic relation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A far-field antenna conversion is used beside a complex near-field source, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A far-field antenna conversion is used beside a complex near-field source. Receiver calibration alone does not

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establish the local electric/magnetic relation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A far-field antenna conversion is used beside a complex near-field source and How should the report be bounded; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.18.3 Example 13.X3. Antenna effective aperture in an ideal far-field model (p. 7568)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A far-field antenna conversion is used beside a complex near-field source”, addressing “How should the report be bounded”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A far-field antenna conversion is used beside a complex near-field source. How should the report be bounded”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A far-field antenna conversion is used beside a complex near-field source. How should the report be bounded”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.16 Integrated reference-plane analysis and system-level acceptance (p. 7561)

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V011-VOL-DISCUSSION-069. Changing an unused splitter termination changes the measured noise. What should the cascade analysis include?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Changing an unused splitter termination changes the measured noise. What should the cascade analysis include?” Put this particular dispute to the panel: Changing an unused splitter termination changes the measured noise. What should the cascade analysis include. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 02. Student A, terminology and scope: Agree the operational meanings of Changing, unused, splitter and termination, cascade, include in “Changing an unused splitter termination changes the measured noise. What should the cascade analysis include”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Changing an unused splitter termination changes the measured noise; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 2B: a matched, fixed-state noise cascade”. An independent matched two-port sum is insufficient if the branch visibly affects the result Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Changing an unused splitter termination changes the measured noise; explain what each record can establish State what the existing record establishes, what it does

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not establish, and which further measurement would change your opinion. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 2B: a matched, fixed-state noise cascade”. An independent matched two-port sum is insufficient if the branch visibly affects the result Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The consequential multiport state and impedance-dependent transfer/noise response, with appropriate characterization Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Changing an unused splitter termination changes the measured noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Changing an unused splitter termination changes the measured noise; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Changing an unused splitter termination changes the measured noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Changing an unused splitter termination changes the measured noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Changing an unused splitter termination changes the measured noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Changing an unused splitter termination changes the measured noise. An independent matched two-port sum is insufficient if the branch visibly affects the result Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Changing an unused splitter termination changes the measured noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §2.14 Model 2B: a matched, fixed-state noise cascade (p. 665)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Changing an unused splitter termination changes the measured noise. An independent matched two-port sum is insufficient if the branch visibly affects the result Respond

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point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.10 Separate the intended coaxial path from installed coupling (p. 7551)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Changing an unused splitter termination changes the measured noise and What should the cascade analysis include; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Changing an unused splitter termination changes the measured noise”, addressing “What should the cascade analysis include”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Changing an unused splitter termination changes the measured noise. What should the cascade analysis include”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Changing an unused splitter termination changes the measured noise. What should the cascade analysis include”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §13.8 Treat connections and unused branches as part of the network (p. 7548)

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V011-VOL-DISCUSSION-070. A terminal-reference test passes but a field comparison fails after cable rerouting. Which claims remain separable?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A terminal-reference test passes but a field comparison fails after cable rerouting. Which claims remain separable?” Put this particular dispute to the panel: A terminal-reference test passes but a field comparison fails after cable rerouting. Which claims remain separable. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 02. Student A, terminology and scope: Agree the operational meanings of passes, field, fails and rerouting, claims, remain in “A terminal-reference test passes but a field comparison fails after cable rerouting. Which claims remain separable”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A terminal-reference test passes but a field comparison fails after cable rerouting; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Keep field conversion separate from terminal power”. Preserve both scopes and selective reference tests rather than blame the receiver or external field uniquely Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A terminal-reference test passes but a field comparison fails after cable rerouting; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Keep field conversion separate from terminal power”. Preserve both scopes and selective reference tests rather than blame the receiver or external field uniquely Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The conducted transfer may remain supported while installed geometry/common-mode conversion is unresolved Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A terminal-reference test passes but a field comparison fails after cable rerouting: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A terminal-reference test passes but a field comparison fails after cable rerouting; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A terminal-reference test passes but a field comparison fails after cable rerouting: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A terminal-reference test passes but a field comparison fails after cable rerouting, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A terminal-reference test passes but a field comparison fails after cable rerouting: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A terminal-reference test passes but a field comparison fails after cable rerouting. Preserve both scopes and selective reference tests rather than blame the receiver or external field uniquely Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A terminal-reference test passes but a field comparison fails after cable rerouting, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.4 Keep field conversion separate from terminal power (p. 7542)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A terminal-reference test passes but a field comparison fails after cable rerouting. Preserve both scopes and selective reference tests rather than blame the receiver or external field uniquely Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.18.10 Example 13.X10. Why field strength cannot be inferred from connector power alone (p. 7575)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A terminal-reference test passes but a field comparison fails after cable rerouting and Which claims remain separable; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A terminal-reference test passes but a field comparison fails after cable rerouting”, addressing “Which claims remain separable”; specify the exact measurement or

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evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A terminal-reference test passes but a field comparison fails after cable rerouting. Which claims remain separable”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A terminal-reference test passes but a field comparison fails after cable rerouting. Which claims remain separable”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.3 Antennas and Field-to-Terminal Conversion (p. 7539)

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V011-VOL-DISCUSSION-071. A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination. What should be corrected?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination. What should be corrected?” Put this particular dispute to the panel: A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination. What should be corrected. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 02. Student A, terminology and scope: Agree the operational meanings of covariance, matrix, negative and variance, combination, corrected in “A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination. What should be corrected”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §2.29 Noise-

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colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “14. Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation”. Simulation or a favorable final total cannot legitimize an inconsistent covariance description Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “14. Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation”. Simulation or a favorable final total cannot legitimize an inconsistent covariance description Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Reconstruct a physically admissible joint dependency model with units and

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positive semidefiniteness Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be

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collected first and what uncertainty remains if it is missing. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination. Simulation or a favorable final total cannot legitimize an inconsistent covariance description Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A covariance matrix uses plausible pairwise

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correlations but implies negative variance for a combination, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.21 Additional study: nonlinear metrology and decision uncertainty beyond first-order propagation (p. 8154)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination. Simulation or a favorable final total cannot legitimize an inconsistent covariance description Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.37 A stochastic and deterministic state description for clocks used in coherent receiving (p. 7007)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination and What should be corrected; exclude protections irrelevant to the

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scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.25 Application 12B.8: Use a specified correlated Gaussian phase vector (p. 6985)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination”, addressing “What should be corrected”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A covariance matrix uses plausible pairwise correlations but implies negative variance for a combination. What should be corrected”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A covariance matrix uses plausible pairwise correlations but implies negative

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variance for a combination. What should be corrected”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §2.29 Noise-colour models, covariance and decision performance beyond a scalar noise figure (p. 690)

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V011-VOL-DISCUSSION-072. More averaging leaves a nearly unchanged uncertainty interval. What decision would be better than indefinite repetition?

- 01. Moderator, opening proposition: Introduce the exact dispute, “More averaging leaves a nearly unchanged uncertainty interval. What decision would be better than indefinite repetition?” Put this particular dispute to the panel: More averaging leaves a nearly unchanged uncertainty interval. What decision would be better than indefinite repetition. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 02. Student A, terminology and scope: Agree the operational meanings of leaves, nearly, unchanged and better, indefinite, repetition in “More averaging leaves a nearly unchanged uncertainty interval. What decision would be better than indefinite repetition”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of More averaging leaves a nearly unchanged uncertainty interval; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Case study 3.D9. Weak-event detection after a digital-filter change”. Retain the reading model and predeclared decision rather than assume all terms shrink with count Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of More averaging leaves a nearly unchanged uncertainty interval; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Case study 3.D9. Weak-event detection after a digital-filter change”. Retain the reading model and predeclared decision rather than assume all terms shrink with count Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Identify a common calibration floor or other nonreducible contribution and improve its characterization if relevant Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving More averaging leaves a nearly unchanged uncertainty interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of More averaging leaves a nearly unchanged uncertainty interval; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving More averaging leaves a nearly unchanged uncertainty interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving More averaging leaves a nearly unchanged uncertainty interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving More averaging leaves a nearly unchanged uncertainty interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for More averaging leaves a nearly unchanged uncertainty interval. Retain the reading model and predeclared decision rather than assume all terms shrink with count Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving More averaging leaves a nearly unchanged uncertainty interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.33.9 Case study 3.D9. Weak-event detection after a digital-filter change (p. 1344)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for More averaging leaves a nearly unchanged uncertainty interval. Retain the reading model and predeclared decision rather than assume all terms shrink with count Respond

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point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about More averaging leaves a nearly unchanged uncertainty interval and What decision would be better than indefinite repetition; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “More averaging leaves a nearly unchanged uncertainty interval”, addressing “What decision would be better than indefinite repetition”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “More averaging leaves a nearly unchanged uncertainty interval. What decision would be better than indefinite repetition”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “More averaging leaves a nearly unchanged uncertainty interval. What decision would be better than indefinite repetition”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.14.6 Application 14B.8: identify the uncertainty that averaging cannot remove (p. 8138)

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V011-VOL-DISCUSSION-073. A measured center lies below a limit but the expanded interval overlaps it. What should the team report under the stated conservative rule?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A measured center lies below a limit but the expanded interval overlaps it. What should the team report under the stated conservative rule?” Put this particular dispute to the panel: A measured center lies below a limit but the expanded interval overlaps it. What should the team report under the stated conservative rule. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 02. Student A, terminology and scope: Agree the operational meanings of lies, limit, expanded and overlaps, conservative, rule in “A measured center lies below a limit but the expanded interval overlaps it. What should the team report under the stated conservative rule”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A measured center lies below a limit but the expanded interval overlaps it; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Declare the decision rule before seeing the result”. Explain legitimate follow-up on dominant terms and avoid changing the limit or calling overlap proof of exceedance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A measured center lies below a limit but the expanded interval overlaps it; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Declare the decision rule before seeing the result”. Explain legitimate follow-up on dominant terms and avoid changing the limit or calling overlap proof of exceedance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Indeterminate, with the factor, uncertainty model and rule preserved Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would

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discriminate between them without changing the measurand. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A measured center lies below a limit but the expanded interval overlaps it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A measured center lies below a limit but the expanded interval overlaps it; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §2.28 From a calculated temperature to a defended result (p. 689)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A measured center lies below a limit but the expanded interval overlaps it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A measured center lies below a limit but the expanded interval overlaps it, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A measured center lies below a limit but the expanded interval

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overlaps it: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A measured center lies below a limit but the expanded interval overlaps it. Explain legitimate follow-up on dominant terms and avoid changing the limit or calling overlap proof of exceedance Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A measured center lies below a limit but the expanded interval overlaps it, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.11 Declare the decision rule before seeing the result (p. 8122)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A measured center lies below a limit but the expanded interval overlaps it. Explain legitimate follow-up on dominant terms and avoid changing the limit or calling overlap proof of exceedance Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §2.28 From a calculated temperature to a defended result (p. 689)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A measured center lies below a limit but the expanded interval overlaps it and What should the team report under the stated conservative rule; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.22 Decision rules, calibration applicability and publication evidence (p. 8159)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A measured center lies below a limit but

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the expanded interval overlaps it", addressing "What should the team report under the stated conservative rule"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A measured center lies below a limit but the expanded interval overlaps it. What should the team report under the stated conservative rule", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A measured center lies below a limit but the expanded interval overlaps it. What should the team report under the stated conservative rule". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

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V011-VOL-DISCUSSION-074. A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. What is wrong with that approach?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. What is wrong with that approach?” Put this particular dispute to the panel: A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. What is wrong with that approach. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 02. Student A, terminology and scope: Agree the operational meanings of significant, uncorrected, larger and reported, wrong, approach in “A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. What is wrong with that approach”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A known significant amplitude offset is left uncorrected and a larger uncertainty is reported; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Apply the supported offset, retain its uncertainty and verify sign/plane implementation independently Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A known significant amplitude offset is left uncorrected and a larger uncertainty is reported; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Apply the supported offset, retain its uncertainty and verify sign/plane implementation independently Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The central value no longer uses the available correction and may change the decision improperly Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A known significant amplitude offset is left uncorrected and a larger uncertainty is reported: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A known significant amplitude offset is left uncorrected and a larger uncertainty is reported; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A known significant amplitude

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offset is left uncorrected and a larger uncertainty is reported: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A known significant amplitude offset is left uncorrected and a larger uncertainty is reported, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A known significant amplitude offset is left uncorrected and a larger uncertainty is reported: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. Apply the supported offset, retain its uncertainty and verify sign/plane implementation independently Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A known significant amplitude offset is left uncorrected and a larger uncertainty is reported, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. Apply the supported offset, retain its uncertainty and verify sign/plane implementation independently Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.19 Nonlinear measurement models and defensible uncertainty intervals in RF metrology (p. 8149)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A known significant amplitude offset is left uncorrected and a larger uncertainty is reported and What is wrong with that approach; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.67 Choose evidence that can discriminate the required behavior (p. 5773)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A known significant amplitude offset is left

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uncorrected and a larger uncertainty is reported", addressing "What is wrong with that approach"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. What is wrong with that approach", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "A known significant amplitude offset is left uncorrected and a larger uncertainty is reported. What is wrong with that approach". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.19 Verify the detector and control path as part of the IF result (p. 2541)

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V011-VOL-DISCUSSION-075. A correctly signed correction belongs to a different serialized cable. Is this just extra uncertainty?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A correctly signed correction belongs to a different serialized cable. Is this just extra uncertainty?” Put this particular dispute to the panel: A correctly signed correction belongs to a different serialized cable. Is this just extra uncertainty. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 02. Student A, terminology and scope: Agree the operational meanings of correctly, signed, belongs and serialized, just, extra in “A correctly signed correction belongs to a different serialized cable. Is this just extra uncertainty”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A correctly signed correction belongs to a different serialized cable; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Four worked applications already developed in the calibration chain”. An uncertainty budget describes supported inputs, not a license to use the wrong physical path Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A correctly signed correction

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belongs to a different serialized cable; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Four worked applications already developed in the calibration chain”. An uncertainty budget describes supported inputs, not a license to use the wrong physical path Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. No; fix the configuration identity and recompute with applicable characterization Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A correctly signed correction belongs to a different serialized cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A correctly signed correction belongs to a different serialized cable; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A correctly signed correction belongs to a different serialized cable: specify the altered receiver state or source condition, predicted change, test statistic and

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rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A correctly signed correction belongs to a different serialized cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A correctly signed correction belongs to a different serialized cable: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the

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conclusion. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A correctly signed correction belongs to a different serialized cable. An uncertainty budget describes supported inputs, not a license to use the wrong physical path Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A correctly signed correction belongs to a different serialized cable, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.14.1 Four worked applications already developed in the calibration chain (p. 8132)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A correctly signed correction belongs to a different serialized cable. An uncertainty budget describes supported inputs, not a license to use the wrong physical path Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.2 Application 1A.2. Remove a software offset before applying the remaining correction (p. 81)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A correctly signed correction belongs to a different serialized cable and Is this just extra uncertainty; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.9 Uncertainty Budgets and Decision Rules (p. 8118)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A correctly signed correction belongs to a different serialized cable”, addressing “Is this just extra uncertainty”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to

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at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A correctly signed correction belongs to a different serialized cable. Is this just extra uncertainty”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A correctly signed correction belongs to a different serialized cable. Is this just extra uncertainty”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.12.1 Application 1A.1. Complete a reference-plane correction in both directions (p. 79)

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V011-VOL-DISCUSSION-076. A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. What distinctions are missing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. What distinctions are missing?” Put this particular dispute to the panel: A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. What distinctions are missing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 02. Student A, terminology and scope: Agree the operational meanings of percent, described, confidence and emission, unauthorized, missing in “A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. What distinctions are missing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Require their own models and evidence, and use the supported finding category without transferring a percentage Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original

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trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 5A.8: Compare burst duration with control settling”. Require their own models and evidence, and use the supported finding category without transferring a percentage Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Coverage of a measured quantity, capture/detection performance and attribution/authorization are separate claims Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would

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discriminate between them without changing the measurand. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A 95 percent level interval is described as 95 percent confidence that

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an emission is unauthorized: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. Require their own models and evidence, and use the supported finding category without transferring a percentage Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §5.13 Application 5A.8: Compare burst duration with control settling (p. 2533)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. Require their own models and evidence, and use the supported finding category without transferring a percentage Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §6.43 Ten numerical worked examples under declared simplified models (p. 3174)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized and What distinctions are missing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.27 Quantitative worked contrasts: sweep coverage, channelised capture and resolution claims (p. 4490)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized”, addressing “What distinctions are missing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. What distinctions are missing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A 95 percent level interval is described as 95 percent confidence that an emission is unauthorized. What distinctions are missing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §5.6 Application 5A.1: Read a voltage step and its 95 percent settling time (p. 2526)

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V011-VOL-DISCUSSION-077. A receiver survives an overload during a search but remains insensitive afterward. What should negative coverage exclude?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A receiver survives an overload during a search but remains insensitive afterward. What should negative coverage exclude?” Put this particular dispute to the panel: A receiver survives an overload during a search but remains insensitive afterward. What should negative coverage exclude. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 02. Student A, terminology and scope: Agree the operational meanings of survives, overload, search and afterward, coverage, exclude in “A receiver survives an overload during a search but remains insensitive afterward. What should negative coverage exclude”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A receiver survives an overload during a search but remains insensitive afterward; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. Survival does not establish valid observation opportunity Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver survives an overload during a search but remains insensitive afterward; explain what

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each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. Survival does not establish valid observation opportunity Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The interval until the required weak-signal function is demonstrably recovered, with relevant control/filter/trigger behavior Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A receiver survives an overload during a search but remains insensitive afterward: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A receiver survives an overload during a search but remains insensitive afterward; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A receiver survives an overload during a search but remains insensitive afterward: specify the altered receiver state or source condition, predicted change, test

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statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A receiver survives an overload during a search but remains insensitive afterward, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A receiver survives an overload during a search but remains insensitive afterward: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A receiver survives an overload during a search but remains insensitive afterward. Survival does not establish valid observation opportunity Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A receiver survives an overload during a search but remains insensitive afterward, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A receiver survives an overload during a search but remains insensitive afterward. Survival does not establish valid observation opportunity Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.19.4 Example 3.C4. Input attenuation as an overload intervention (p. 1287)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A receiver survives an overload during a search but remains insensitive afterward and What should negative coverage exclude; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.8 Validate transient and gated measurements with the intended waveform (p. 4446)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A receiver survives an overload during a search but remains insensitive afterward”, addressing “What should negative coverage exclude”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A receiver survives an overload during a search but remains insensitive afterward. What should negative coverage exclude”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A receiver survives an overload during a search but remains insensitive afterward. What should negative coverage exclude”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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V011-VOL-DISCUSSION-078. A record crossing a periodic coordinate origin is split into two files and rejected as too short. What should be checked?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A record crossing a periodic coordinate origin is split into two files and rejected as too short. What should be checked?” Put this particular dispute to the panel: A record crossing a periodic coordinate origin is split into two files and rejected as too short. What should be checked. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 02. Student A, terminology and scope: Agree the operational meanings of crossing, periodic, origin and split, rejected, checked in “A record crossing a periodic coordinate origin is split into two files and rejected as too short. What should be checked”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A record crossing a periodic coordinate origin is split into two files and rejected as too short; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §9.3.5 Measurement consequence (p. 5050)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Measurement consequence”. A coordinate or storage boundary need not be a physical gap Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §9.3.5 Measurement consequence (p. 5050)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A record crossing a periodic coordinate origin is split into two files and rejected as too short;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Measurement consequence”. A coordinate or storage boundary need not be a physical gap Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §9.3.5 Measurement consequence (p. 5050)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Establish whether acquisition was continuous; preserve the unfolded interval and filter/index history before applying the contiguous criterion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A record crossing a periodic coordinate origin is split into two files and rejected as too short: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A record crossing a periodic coordinate origin is split into two files and rejected as too short; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A record crossing a periodic coordinate origin is split into two files and rejected as too short: specify the altered receiver state or source condition, predicted

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change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A record crossing a periodic coordinate origin is split into two files and rejected as too short, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §9.3.5 Measurement consequence (p. 5050)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A record crossing a periodic coordinate origin is split into two files and rejected as too short: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A record crossing a periodic coordinate origin is split into two files and rejected as too short. A coordinate or storage boundary need not be a physical gap Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A record crossing a periodic coordinate origin is split into two files and rejected as too short, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §9.3.5 Measurement consequence (p. 5050)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A record crossing a periodic coordinate origin is split into two files and rejected as too short. A coordinate or storage boundary need not be a physical gap Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.62 Interpretation and continuation boundary for Model 10E (p. 5764)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A record crossing a periodic coordinate origin is split into two files and rejected as too short and What should be checked; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A record crossing a periodic coordinate origin is split into two files and rejected as too short”, addressing “What should be checked”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A record crossing a periodic coordinate origin is split into two files and rejected as too short. What should be checked”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A record crossing a periodic coordinate origin is split into two files and rejected as too short. What should be checked”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.11 Application 15A.8: Preserve one contiguous window across the period origin (p. 8692)

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V011-VOL-DISCUSSION-079. Adding two dwell probabilities produces a value larger than the merged-start calculation. Which is appropriate?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Adding two dwell probabilities produces a value larger than the merged-start calculation. Which is appropriate?” Put this particular dispute to the panel: Adding two dwell probabilities produces a value larger than the merged-start calculation. Which is appropriate. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 02. Student A, terminology and scope: Agree the operational meanings of Adding, dwell, probabilities and produces, larger, appropriate in “Adding two dwell probabilities produces a value larger than the merged-start calculation. Which is appropriate”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Adding two dwell probabilities produces a value larger than the merged-start calculation; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.4: Reject an impossible overlap requirement”. Do not confuse overlapping opportunity sets with summing disconnected waveform pieces Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Adding two dwell probabilities

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produces a value larger than the merged-start calculation; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.4: Reject an impossible overlap requirement”. Do not confuse overlapping opportunity sets with summing disconnected waveform pieces Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use the union of eligible phases, counting each event start once, while retaining the single-record contiguous criterion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Adding two dwell probabilities produces a value larger than the merged-start calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Adding two dwell probabilities produces a value larger than the merged-start calculation; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Adding two dwell probabilities produces a value larger than the merged-start calculation: specify

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the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Adding two dwell probabilities produces a value larger than the merged-start calculation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Adding two dwell probabilities produces a value larger than the merged-start calculation: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Adding two dwell probabilities produces a value larger than the merged-start calculation. Do not confuse overlapping opportunity sets with summing disconnected waveform pieces Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Adding two dwell probabilities produces a value larger than the merged-start calculation, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.7 Application 15A.4: Reject an impossible overlap requirement (p. 8688)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Adding two dwell probabilities produces a value larger than the merged-start calculation. Do not confuse overlapping opportunity sets with summing disconnected waveform pieces Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §15.5 Application 15A.2: Capture a burst when only part of it is required (p. 8686)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Adding two dwell probabilities produces a value larger than the merged-start calculation and Which is appropriate; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §15.12 Application 15A.9: Calculate repeated capture only under independent start phases (p. 8693)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Adding two dwell probabilities produces a value larger than the merged-start calculation”, addressing “Which is appropriate”; specify the exact measurement or evidential gap on

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which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Adding two dwell probabilities produces a value larger than the merged-start calculation. Which is appropriate”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Adding two dwell probabilities produces a value larger than the merged-start calculation. Which is appropriate”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.9 Application 15A.6: Take the union of overlapping capture-start sets (p. 8690)

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V011-VOL-DISCUSSION-080. One hundred detections or misses occur at a fixed phase. May the independent-trial equation describe them?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One hundred detections or misses occur at a fixed phase. May the independent-trial equation describe them?” Put this particular dispute to the panel: One hundred detections or misses occur at a fixed phase. May the independent-trial equation describe them. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 02. Student A, terminology and scope: Agree the operational meanings of detections, misses, occur and fixed, phase, equation in “One hundred detections or misses occur at a fixed phase. May the independent-trial equation describe them”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One hundred detections or misses occur at a fixed phase; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 15A.10: Solve for a conditional trial count and check the boundary”. Distinguish event count from new opportunity and preserve the true schedule Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One hundred detections or misses occur at a fixed phase; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 15A.10: Solve for a conditional trial count and check the boundary”. Distinguish event count from new opportunity and preserve the true schedule Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Only with an actual justified independent phase experiment; otherwise use deterministic or joint timing analysis Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving One hundred detections or misses occur at a fixed phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One hundred detections or misses occur at a fixed phase; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One hundred detections or misses occur at a fixed phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver

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settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One hundred detections or misses occur at a fixed phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One hundred detections or misses occur at a fixed phase: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One hundred detections or misses occur at a fixed phase. Distinguish event count from new opportunity and preserve the true schedule Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One hundred detections or misses occur at a fixed phase, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.13 Application 15A.10: Solve for a conditional trial count and check the boundary (p. 8694)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One hundred detections or misses occur at a fixed phase. Distinguish event count from new opportunity and preserve the true schedule Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §12.26 Application 12B.9: Combine deterministic rotation with independent phase errors (p. 6986)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One hundred detections or misses occur at a fixed phase and May the independent-trial equation describe them; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §6.21 Application 6B.3: Distinguish fixed phase deviation from fixed frequency deviation (p. 3139)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One hundred detections or misses occur at a fixed phase”, addressing “May the independent-trial equation describe them”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One hundred detections or misses occur at a fixed phase. May the independent-trial equation describe them”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One hundred detections or misses occur at a fixed phase. May the independent-trial equation describe them”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.10 Application 15A.7: Keep a deterministic repeated miss deterministic (p. 8691)

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V011-VOL-DISCUSSION-081. An isolated-pulse trigger test succeeds but a second pulse during recovery is missed. What release limit follows?

- 01. Moderator, opening proposition: Introduce the exact dispute, “An isolated-pulse trigger test succeeds but a second pulse during recovery is missed. What release limit follows?” Put this particular dispute to the panel: An isolated-pulse trigger test succeeds but a second pulse during recovery is missed. What release limit follows. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 02. Student A, terminology and scope: Agree the operational meanings of trigger, pulse, missed and release, limit, follows in “An isolated-pulse trigger test succeeds but a second pulse during recovery is missed. What release limit follows”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of An isolated-pulse trigger test succeeds but a second pulse during recovery is missed; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. The isolated pass does not establish unrestricted burst performance Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An isolated-pulse trigger test succeeds but a second pulse during recovery is missed; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Verify the trigger at its actual signal-path location”. The isolated pass does not establish unrestricted burst performance Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. State the demonstrated rearm/holdoff limitation, test controlled separations and incorporate unusable intervals into coverage Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving An isolated-pulse trigger test succeeds but a second pulse during recovery is missed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of An isolated-pulse trigger test succeeds but a second pulse during recovery is missed; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving An isolated-pulse trigger test succeeds but a second pulse during recovery is missed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving An isolated-pulse trigger test succeeds but a second pulse during recovery is missed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving An isolated-pulse trigger test succeeds but a second pulse during recovery is missed: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for An isolated-pulse trigger test succeeds but a second pulse during recovery is missed. The isolated pass does not establish unrestricted burst performance Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving An isolated-pulse trigger test succeeds but a second pulse during recovery is missed, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for An isolated-pulse trigger test succeeds but a

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second pulse during recovery is missed. The isolated pass does not establish unrestricted burst performance Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about An isolated-pulse trigger test succeeds but a second pulse during recovery is missed and What release limit follows; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §3.33.1 Case study 3.D1. Intermittent high-power illumination and a false absence claim (p. 1328)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “An isolated-pulse trigger test succeeds but a second pulse during recovery is missed”, addressing “What release limit follows”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific

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contested proposition that remains unresolved. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “An isolated-pulse trigger test succeeds but a second pulse during recovery is missed. What release limit follows”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “An isolated-pulse trigger test succeeds but a second pulse during recovery is missed. What release limit follows”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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V011-VOL-DISCUSSION-082. Pretrigger samples include a tuning transition just before the event. Can they establish the same calibrated baseline?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Pretrigger samples include a tuning transition just before the event. Can they establish the same calibrated baseline?” Put this particular dispute to the panel: Pretrigger samples include a tuning transition just before the event. Can they establish the same calibrated baseline. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 02. Student A, terminology and scope: Agree the operational meanings of Pretrigger, include, tuning and transition, just, baseline in “Pretrigger samples include a tuning transition just before the event. Can they establish the same calibrated baseline”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Pretrigger samples include a tuning transition just before the event; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Preserve comparable observation capability”. Retain transition timestamps and flags, distinguish comparable context from invalid samples and avoid applying settled corrections across the change Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Pretrigger samples include a tuning transition just before the event; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Preserve comparable observation capability”. Retain transition timestamps and flags, distinguish comparable context from invalid samples and avoid applying settled corrections across the change Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Only where their state and validity are supported Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Pretrigger samples include a tuning transition just before the event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Pretrigger samples include a tuning transition just before the event; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Pretrigger samples include a tuning transition just before the event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the

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receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Pretrigger samples include a tuning transition just before the event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Pretrigger samples include a tuning transition just before the event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Pretrigger samples include a tuning transition just before the event. Retain transition timestamps and flags, distinguish comparable context from invalid samples and avoid applying settled corrections across the change Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Pretrigger samples include a tuning transition just before the event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Pretrigger samples include a tuning transition just before the event. Retain transition timestamps and flags, distinguish comparable context from invalid samples and avoid

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applying settled corrections across the change Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.12.10 Application 1A.10. Separate a valid corrected level from an unobserved transition interval (p. 97)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Pretrigger samples include a tuning transition just before the event and Can they establish the same calibrated baseline; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §9.1 Discrete Records and Spectral Estimates (p. 5025)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Pretrigger samples include a tuning transition just before the event”, addressing “Can they establish the same calibrated baseline”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the

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specific contested proposition that remains unresolved. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Pretrigger samples include a tuning transition just before the event. Can they establish the same calibrated baseline”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Pretrigger samples include a tuning transition just before the event. Can they establish the same calibrated baseline”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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V011-VOL-DISCUSSION-083. The saved waveform is wideband, but a software trigger sees a decimated channel. How should event capability be established?

- 01. Moderator, opening proposition: Introduce the exact dispute, “The saved waveform is wideband, but a software trigger sees a decimated channel. How should event capability be established?” Put this particular dispute to the panel: The saved waveform is wideband, but a software trigger sees a decimated channel. How should event capability be established. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 02. Student A, terminology and scope: Agree the operational meanings of saved, wideband, sees and decimated, capability, established in “The saved waveform is wideband, but a software trigger sees a decimated channel. How should event capability be established”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of The saved waveform is wideband, but a software trigger sees a decimated channel; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Presence in the recorder representation does not guarantee the trigger will initiate preservation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of The saved waveform is wideband, but a software trigger sees a decimated channel; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. Presence in the recorder representation does not guarantee the trigger will initiate preservation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Test both paths with the intended event, map bandwidth and latency and verify actual retained samples Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving The saved waveform is wideband, but a software trigger sees a decimated channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of The saved waveform is wideband, but a software trigger sees a decimated channel; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving The saved waveform is

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wideband, but a software trigger sees a decimated channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving The saved waveform is wideband, but a software trigger sees a decimated channel, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving The saved waveform is wideband, but a software trigger sees a decimated channel: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for The saved waveform is wideband, but a software trigger sees a decimated channel. Presence in the recorder representation does not guarantee the trigger will initiate preservation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving The saved waveform is wideband, but a software trigger sees a decimated channel, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for The saved waveform is wideband, but a software trigger sees a decimated channel. Presence in the recorder representation does not guarantee the trigger will initiate preservation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §8.6 Interpret a swept trace through its frequency-time trajectory (p. 4442)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about The saved waveform is wideband, but a software trigger sees a decimated channel and How should event capability be established; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §12.28 Coherent Integration and Phase Preservation (p. 6988)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “The saved waveform is wideband, but a software trigger sees a decimated channel”, addressing “How should event capability be established”; specify the exact

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measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “The saved waveform is wideband, but a software trigger sees a decimated channel. How should event capability be established”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “The saved waveform is wideband, but a software trigger sees a decimated channel. How should event capability be established”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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V011-VOL-DISCUSSION-084. Agreement on two receiver channels disappears when a shared clock path changes. What is the next useful comparison?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Agreement on two receiver channels disappears when a shared clock path changes. What is the next useful comparison?” Put this particular dispute to the panel: Agreement on two receiver channels disappears when a shared clock path changes. What is the next useful comparison. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 02. Student A, terminology and scope: Agree the operational meanings of Agreement, channels, disappears and shared, clock, useful in “Agreement on two receiver channels disappears when a shared clock path changes. What is the next useful comparison”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Agreement on two receiver channels disappears when a shared clock path changes; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Shared cause is plausible, but changed sensitivity or phase state must be distinguished Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of Agreement on two receiver channels disappears when a shared clock path changes; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Shared cause is plausible, but changed sensitivity or phase state must be distinguished Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Preserve calibrated desired references and separately vary meaningful clock/route states, including reversals Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Agreement on two receiver channels disappears when a shared clock path changes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Agreement on two receiver channels disappears when a shared clock path changes; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Agreement on two receiver

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channels disappears when a shared clock path changes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Agreement on two receiver channels disappears when a shared clock path changes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Agreement on two receiver channels disappears when a shared clock path changes: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say

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precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Agreement on two receiver channels disappears when a shared clock path changes. Shared cause is plausible, but changed sensitivity or phase state must be distinguished Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Agreement on two receiver channels disappears when a shared clock path changes, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Agreement on two receiver channels disappears when a shared clock path changes. Shared cause is plausible, but changed sensitivity or phase state must be distinguished Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.19 From a spectral observation to an experimentally identifiable cause (p. 9299)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Agreement on two receiver channels disappears when a shared clock path changes and What is the next useful comparison; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.4 Receiver challenges with interacting controls (p. 9262)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Agreement on two receiver channels disappears when a shared clock path changes”, addressing “What is

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the next useful comparison"; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on "Agreement on two receiver channels disappears when a shared clock path changes. What is the next useful comparison", specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of "Agreement on two receiver channels disappears when a shared clock path changes. What is the next useful comparison". Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.3 Localize an artifact by changing the stage that could create it (p. 9260)

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V011-VOL-DISCUSSION-085. Keyboard activity, LED activity and an RF burst coincide. What finding can precede full attribution?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Keyboard activity, LED activity and an RF burst coincide. What finding can precede full attribution?” Put this particular dispute to the panel: Keyboard activity, LED activity and an RF burst coincide. What finding can precede full attribution. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 02. Student A, terminology and scope: Agree the operational meanings of activity, burst, coincide and finding, precede, attribution in “Keyboard activity, LED activity and an RF burst coincide. What finding can precede full attribution”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Keyboard activity, LED activity and an RF burst coincide; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Test shared measurement paths and establish physical/operational RF linkage before claiming a transmitter or surveillance function Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Keyboard activity, LED activity and an RF burst coincide; explain what each record can establish

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State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §3.23 Switching architectures and state-machine validity (p. 1302)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Write findings that preserve the strength and limit of each test”. Test shared measurement paths and establish physical/operational RF linkage before claiming a transmitter or surveillance function Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. A bounded temporal correlation with stated clocks and direct observables Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Keyboard activity, LED activity and an RF burst coincide: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Keyboard activity, LED activity and an RF burst coincide; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.23 Switching architectures and state-machine validity (p. 1302)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Keyboard activity, LED activity and an RF burst coincide: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion.

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Ask Student H to identify an alternative that could survive the proposed test. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Keyboard activity, LED activity and an RF burst coincide, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Keyboard activity, LED activity and an RF burst coincide: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Keyboard activity, LED activity and an RF

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burst coincide. Test shared measurement paths and establish physical/operational RF linkage before claiming a transmitter or surveillance function Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.23 Switching architectures and state-machine validity (p. 1302)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Keyboard activity, LED activity and an RF burst coincide, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Keyboard activity, LED activity and an RF burst coincide. Test shared measurement paths and establish physical/operational RF linkage before claiming a transmitter or surveillance function Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that

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limits confidence. Source: §3.23 Switching architectures and state-machine validity (p. 1302)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Keyboard activity, LED activity and an RF burst coincide and What finding can precede full attribution; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.14 Frame a bounded finding from the completed observation (p. 100)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Keyboard activity, LED activity and an RF burst coincide”, addressing “What finding can precede full attribution”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Keyboard activity, LED activity and an RF burst coincide. What finding can precede full attribution”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Keyboard activity, LED activity and an RF burst coincide. What finding can precede full attribution”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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V011-VOL-DISCUSSION-086. One cell of a clock-by-switch experiment cannot be acquired. May the missing result be inferred from three apparently consistent cells?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One cell of a clock-by-switch experiment cannot be acquired. May the missing result be inferred from three apparently consistent cells?” Put this particular dispute to the panel: One cell of a clock-by-switch experiment cannot be acquired. May the missing result be inferred from three apparently consistent cells. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 02. Student A, terminology and scope: Agree the operational meanings of clock-by-switch, experiment, acquired and missing, inferred, consistent in “One cell of a clock-by-switch experiment cannot be acquired. May the missing result be inferred from three apparently consistent cells”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific

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example from the stated receiver scenario. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One cell of a clock-by-switch experiment cannot be acquired; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “An evidence-closure matrix that links physical tests to permissible forensic propositions”. Obtain a meaningful alternative where feasible and avoid treating an incomplete design as proof of component causation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One cell of a clock-by-switch experiment cannot be acquired; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “An evidence-closure matrix that links physical tests to permissible forensic propositions”. Obtain a meaningful alternative where feasible and avoid treating an incomplete design as proof of component causation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Not without an explicit justified model; retain the missing contrast and its limitation Put two specific questions to Student D about the stated competing

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options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 08. Student D, answer to Student E: Design a discriminating experiment involving One cell of a clock-by-switch experiment cannot be acquired: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One cell of a clock-by-switch experiment cannot be acquired; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One cell of a clock-by-switch experiment cannot be acquired: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One cell of a clock-by-switch experiment cannot be acquired, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in

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the preceding prompt. Design a discriminating experiment involving One cell of a clock-by-switch experiment cannot be acquired: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One cell of a clock-by-switch experiment cannot be acquired. Obtain a meaningful alternative where feasible and avoid treating an incomplete design as proof of component causation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One cell of a clock-by-switch experiment cannot be acquired, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of

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what evidence would reverse the conclusion. Source: §16.17 An evidence-closure matrix that links physical tests to permissible forensic propositions (p. 9291)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One cell of a clock-by-switch experiment cannot be acquired. Obtain a meaningful alternative where feasible and avoid treating an incomplete design as proof of component causation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.7 Reconcile evidence without assigning unsupported probabilities (p. 9276)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One cell of a clock-by-switch experiment cannot be acquired and May the missing result be inferred from three apparently consistent cells; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §14.6 Frequency, phase, and delay require their own observables (p. 8113)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One cell of a clock-by-switch experiment cannot be acquired”, addressing “May the missing result be inferred from three apparently consistent cells”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One cell of a clock-by-switch experiment cannot be acquired. May the missing result be inferred from three apparently consistent cells”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One cell of a clock-by-switch experiment cannot be acquired. May the missing result be inferred from three apparently consistent cells”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.29 Event-driven capture without treating quiet intervals as proof that no emission existed (p. 8733)

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V011-VOL-DISCUSSION-087. A factor labeled trigger mode also changes filtering and rearm time. How should it be defined in a diagnostic design?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A factor labeled trigger mode also changes filtering and rearm time. How should it be defined in a diagnostic design?” Put this particular dispute to the panel: A factor labeled trigger mode also changes filtering and rearm time. How should it be defined in a diagnostic design. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 02. Student A, terminology and scope: Agree the operational meanings of labeled, trigger, filtering and rearm, diagnostic, design in “A factor labeled trigger mode also changes filtering and rearm time. How should it be defined in a diagnostic design”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A factor labeled trigger mode also changes filtering and rearm time; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. The front-panel label does not isolate a single causal mechanism Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A factor labeled trigger mode also changes filtering and rearm time; explain what each record can establish State what the existing record establishes, what it does not

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establish, and which further measurement would change your opinion. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Trigger Types and Pretrigger Context”. The front-panel label does not isolate a single causal mechanism Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Record the actual physical/processing bundle and characterize each state, using event-appropriate capability references Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A factor labeled trigger mode also changes filtering and rearm time: specify the altered receiver state or source

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condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A factor labeled trigger mode also changes filtering and rearm time; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A factor labeled trigger mode also changes filtering and rearm time: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A factor labeled trigger mode also changes filtering and rearm time, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A factor labeled trigger mode also changes filtering and rearm time: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A factor labeled trigger mode also changes filtering and rearm time. The front-panel label does not isolate a

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single causal mechanism Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A factor labeled trigger mode also changes filtering and rearm time, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.14 Trigger Types and Pretrigger Context (p. 8695)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A factor labeled trigger mode also changes filtering and rearm time. The front-panel label does not isolate a single causal mechanism Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.6 Ten worked applications of Model 10B (p. 5691)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A factor labeled trigger mode also changes filtering and rearm time and How should it be defined in a diagnostic design; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A factor labeled trigger mode also changes filtering and rearm time”, addressing “How should it be defined in a diagnostic design”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A factor labeled trigger mode also changes filtering and rearm time. How should it be defined in a diagnostic

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design”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A factor labeled trigger mode also changes filtering and rearm time. How should it be defined in a diagnostic design”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.15 Verify the trigger at its actual signal-path location (p. 8697)

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V011-VOL-DISCUSSION-088. All high-gain observations occur during one source operating interval. How can that confounding be addressed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “All high-gain observations occur during one source operating interval. How can that confounding be addressed?” Put this particular dispute to the panel: All high-gain observations occur during one source operating interval. How can that confounding be addressed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 02. Student A, terminology and scope: Agree the operational meanings of high-gain, observations, occur and source, operating, interval in “All high-gain observations occur during one source operating interval. How can that confounding be addressed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of All high-gain observations occur during one source operating interval; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Repetition alone cannot separate gain from source-time effects Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of All high-gain observations occur during one source operating interval; explain what each record can establish State what the existing record establishes, what

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it does not establish, and which further measurement would change your opinion. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Calibrate noise without confusing it with detection”. Repetition alone cannot separate gain from source-time effects Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain run order and source state, block or cross relevant gain comparisons within comparable intervals where possible, and report missing contrasts Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 08. Student D, answer to Student E: Design a discriminating experiment involving All high-gain observations occur during one source operating interval: specify the altered receiver state or

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source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of All high-gain observations occur during one source operating interval; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving All high-gain observations occur during one source operating interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could

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survive the proposed test. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving All high-gain observations occur during one source operating interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving All high-gain observations occur during one source operating interval: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for All high-gain observations occur during one source operating interval. Repetition alone cannot separate gain from source-time effects Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving All high-gain observations occur during one source operating interval, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §14.8 Calibrate noise without confusing it with detection (p. 8116)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for All high-gain observations occur during one source operating interval. Repetition alone cannot separate gain from source-time effects Respond point by point to Student J. Distinguish a verified observation from a conditional inference and

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name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about All high-gain observations occur during one source operating interval and How can that confounding be addressed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §8.27 Quantitative worked contrasts: sweep coverage, channelised capture and resolution claims (p. 4490)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “All high-gain observations occur during one source operating interval”, addressing “How can that confounding be addressed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “All high-gain observations occur during one source operating interval. How can that confounding be addressed”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “All high-gain observations occur during one source operating interval. How can that confounding be addressed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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V011-VOL-DISCUSSION-089. A team exports many windows from one capture and calls them independent challenge repetitions. What should change?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A team exports many windows from one capture and calls them independent challenge repetitions. What should change?” Put this particular dispute to the panel: A team exports many windows from one capture and calls them independent challenge repetitions. What should change. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 02. Student A, terminology and scope: Agree the operational meanings of windows, capture, calls and independent, challenge, repetitions in “A team exports many windows from one capture and calls them independent challenge repetitions. What should change”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A team exports many windows from one capture and calls them independent challenge repetitions; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “3. Statistical validity of gain-state comparisons”. Preserve overlapping-sample dependence in any statistical claim Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team exports many windows from one capture and calls them independent challenge repetitions;

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explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “3. Statistical validity of gain-state comparisons”. Preserve overlapping-sample dependence in any statistical claim Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Label them as derived analyses sharing the same acquisition, then obtain fresh physical-state repetitions for the intervention Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A team exports many windows from one capture and calls them independent challenge repetitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A team exports many windows from one capture and calls them independent challenge repetitions; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A team exports many windows from one capture and calls them independent challenge repetitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable,

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authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A team exports many windows from one capture and calls them independent challenge repetitions, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A team exports many windows from one capture and calls them independent challenge repetitions: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A team exports many windows from one capture and calls them independent challenge repetitions. Preserve overlapping-sample dependence in any statistical claim Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A team exports many windows from one capture and calls them independent challenge repetitions, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §3.32 Statistical validity of gain-state comparisons (p. 1325)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A team exports many windows from one capture and calls them independent challenge repetitions. Preserve

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overlapping-sample dependence in any statistical claim Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.15 Assurance cases for receiver-derived evidence under changing system identity (p. 101)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A team exports many windows from one capture and calls them independent challenge repetitions and What should change; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A team exports many windows from one capture and calls them independent challenge repetitions”, addressing “What should change”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement

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and the specific contested proposition that remains unresolved.

Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A team exports many windows from one capture and calls them independent challenge repetitions. What should change”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A team exports many windows from one capture and calls them independent challenge repetitions. What should change”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

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V011-VOL-DISCUSSION-090. A stricter decoder is selected after inspecting every suspicious event. What validation claim is still missing?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A stricter decoder is selected after inspecting every suspicious event. What validation claim is still missing?” Put this particular dispute to the panel: A stricter decoder is selected after inspecting every suspicious event. What validation claim is still missing. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 02. Student A, terminology and scope: Agree the operational meanings of stricter, decoder, inspecting and suspicious, validation, missing in “A stricter decoder is selected after inspecting every suspicious event. What validation claim is still missing”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A stricter decoder is selected after inspecting every suspicious event; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 10E.5: zero filling preserves the grid and exposes a finite tail”. Use independently retained reference and noise-only records, disclose selection and retain the earlier outputs rather than presenting training cleanup as universal validation Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A stricter decoder is selected after inspecting every suspicious event; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 10E.5: zero filling preserves the grid and exposes a finite tail”. Use independently retained reference and noise-only records, disclose selection and retain the earlier outputs rather than presenting training cleanup as universal validation Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Performance beyond those fitted examples Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A stricter decoder is selected after inspecting every suspicious event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A stricter decoder is selected after inspecting every suspicious event; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A stricter decoder is selected after inspecting every suspicious event: specify the altered receiver state or source condition, predicted change, test statistic and

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rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A stricter decoder is selected after inspecting every suspicious event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A stricter decoder is selected after inspecting every suspicious event: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A stricter decoder is selected after inspecting every suspicious event. Use independently retained reference and noise-only records, disclose selection and retain the earlier outputs rather than presenting training cleanup as universal validation Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A stricter decoder is selected after inspecting every suspicious event, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §10.56 Application 10E.5: zero filling preserves the grid and exposes a finite tail (p. 5758)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A stricter decoder is selected after inspecting

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every suspicious event. Use independently retained reference and noise-only records, disclose selection and retain the earlier outputs rather than presenting training cleanup as universal validation Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.4.3 Interpret hypothetical receiver records (p. 9268)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A stricter decoder is selected after inspecting every suspicious event and What validation claim is still missing; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §7.19 Turn a quality metric into a reproducible acceptance record (p. 3764)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A stricter decoder is selected after inspecting every suspicious event”, addressing “What validation claim is still missing”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker

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before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §9.7 Estimator Validation and Reporting (p. 5072)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A stricter decoder is selected after inspecting every suspicious event. What validation claim is still missing”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A stricter decoder is selected after inspecting every suspicious event. What validation claim is still missing”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §9.7 Estimator Validation and Reporting (p. 5072)

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V011-VOL-DISCUSSION-091. A local intercept is treated as a receiver's safe input rating. What should the reviewer separate?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A local intercept is treated as a receiver's safe input rating. What should the reviewer separate?” Put this particular dispute to the panel: A local intercept is treated as a receiver's safe input rating. What should the reviewer separate. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 02. Student A, terminology and scope: Agree the operational meanings of local, intercept, treated and safe, rating, reviewer in “A local intercept is treated as a receiver's safe input rating. What should the reviewer separate”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A local intercept is treated as a receiver's safe input rating; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Construct the intercept from the linear asymptote”. Use appropriate stage and system tests; an extrapolation is not a survivability specification Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A local intercept is treated as a receiver's safe input rating; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Construct the intercept from the linear asymptote”. Use appropriate stage and system tests; an extrapolation is not a survivability specification Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Formal asymptote intersection, actual compression/validity range, parent convention and hardware exposure limits Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A local intercept is treated as a receiver's safe

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input rating: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A local intercept is treated as a receiver's safe input rating; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A local intercept is treated as a receiver's safe input rating: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive

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the proposed test. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A local intercept is treated as a receiver's safe input rating, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A local intercept is treated as a receiver's safe input rating: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A local intercept is treated as a receiver's

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safe input rating. Use appropriate stage and system tests; an extrapolation is not a survivability specification Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A local intercept is treated as a receiver's safe input rating, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A local intercept is treated as a receiver's safe input rating. Use appropriate stage and system tests; an extrapolation is not a survivability specification Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test

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or uncertainty term that limits confidence. Source: §11.17 Application 11A.8 Separate formal compression from the working domain (p. 6385)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A local intercept is treated as a receiver's safe input rating and What should the reviewer separate; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.5 Model 11A for cubic intermodulation and intercept metrics (p. 6367)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A local intercept is treated as a receiver's safe input rating”, addressing “What should the reviewer separate”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A local intercept is treated as a receiver's safe input rating. What should the reviewer separate”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A local intercept is treated as a receiver's safe input rating. What should the reviewer separate”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.40 Distinguish strong-signal mechanisms through paired interventions (p. 6421)

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V011-VOL-DISCUSSION-092. One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. What is the issue?

- 01. Moderator, opening proposition: Introduce the exact dispute, “One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. What is the issue?” Put this particular dispute to the panel: One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. What is the issue. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 02. Student A, terminology and scope: Agree the operational meanings of parent, tone, remains and slope, expected, issue in “One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. What is the issue”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 4A.8: Test the movement of a candidate harmonic product”. Check source contamination and desired response during the challenge Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 4A.8: Test the movement of a candidate harmonic product”. Check source contamination and desired response during the challenge Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Retain the actual unequal-parent cubic amplitude dependence and stage conditions rather than transfer a simultaneous equal-tone slope Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the

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measurand. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 08. Student D, answer to Student E: Design a discriminating experiment involving One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving One parent tone is changed while the other remains fixed, but a

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three-to-one equal-tone slope is expected: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. Check source contamination and desired response during the challenge Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §4.11 Application 4A.8: Test the movement of a candidate harmonic product (p. 1939)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. Check source contamination and desired response during the challenge Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.4 Intermodulation and Intercept Metrics (p. 6366)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected and What is the issue; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.13 Application 11A.4 Keep each tone separate in the intercept calculation (p. 6380)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected”, addressing “What is the issue”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. What is the issue”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “One parent tone is changed while the other remains fixed, but a three-to-one equal-tone slope is expected. What is the issue”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.12 Application 11A.3 Resolve unequal parent amplitudes (p. 6379)

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V011-VOL-DISCUSSION-093. A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. What remains unresolved?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. What remains unresolved?” Put this particular dispute to the panel: A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. What remains unresolved. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 02. Student A, terminology and scope: Agree the operational meanings of rise, attributed, oscillator and measuring, remains, unresolved in “A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. What remains unresolved”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Model 11B for reciprocal mixing and admitted noise”. Preserve fixed channel calibration and desired gain, characterize admitted spectrum and test the weighted reciprocal-mixing prediction Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Model 11B for reciprocal mixing and admitted noise”. Preserve fixed channel calibration and desired gain, characterize admitted spectrum and test the weighted reciprocal-mixing prediction Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Source sidebands, direct leakage, baseline drift and gain-control changes can contribute Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without

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changing the measurand. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A blocker-induced noise rise is attributed to oscillator phase noise

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without measuring blocker source noise: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. Preserve fixed channel calibration and desired gain, characterize admitted spectrum and test the weighted reciprocal-mixing prediction Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the

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conclusion. Source: §11.22 Model 11B for reciprocal mixing and admitted noise (p. 6393)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. Preserve fixed channel calibration and desired gain, characterize admitted spectrum and test the weighted reciprocal-mixing prediction Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §11.38 Use the model to design discriminating receiver observations (p. 6418)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise and What remains unresolved; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §11.26 Convert added power into a conditional noise-rise limit (p. 6401)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise”, addressing “What remains unresolved”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. What remains unresolved”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A blocker-induced noise rise is attributed to oscillator phase noise without measuring blocker source noise. What remains unresolved”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §11.21 Blocking and Reciprocal Mixing (p. 6391)

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V011-VOL-DISCUSSION-094. A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. What must be reconsidered?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. What must be reconsidered?” Put this particular dispute to the panel: A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. What must be reconsidered. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 02. Student A, terminology and scope: Agree the operational meanings of contamination, bound, reaches and spur, upper, intercept in “A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. What must be reconsidered”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from

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the stated receiver scenario. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Application 12B.10: Bound a finite unmeasured high-offset contribution”. Retain phasor/domain limits and seek better source characterization Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

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- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Application 12B.10: Bound a finite unmeasured high-offset contribution”. Retain phasor/domain limits and seek better source characterization Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The uncontaminated product may approach zero under coherent cancellation, so the inferred upper intercept can be unbounded within that observation model Put two specific questions to Student D about the stated

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competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

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- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

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- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. Retain phasor/domain limits and seek better source characterization Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound, formulate an instrumental artifact or confounding alternative, then

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identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §12.27 Application 12B.10: Bound a finite unmeasured high-offset contribution (p. 6987)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. Retain phasor/domain limits and seek better source characterization Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §10.51 Gap representations, phase, and the limits of timing claims (p. 5751)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound and What must be reconsidered; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within

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authorised laboratory and field boundaries. Source: §11.8 Construct the intercept from the linear asymptote (p. 6373)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound”, addressing “What must be reconsidered”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §11.19 Application 11A.10 Bound a coherent contaminating product (p. 6388)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. What must be reconsidered”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A contamination bound reaches the measured spur magnitude, yet the report gives a finite upper intercept bound. What must be reconsidered”. Allocate the next measurement and documentary action to named student roles, and require each participant to

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distinguish accepted evidence from an unsupported assertion.

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V011-VOL-DISCUSSION-095. A new executable hash is correct, but the operating configuration file is wrong. What does software identity establish?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A new executable hash is correct, but the operating configuration file is wrong. What does software identity establish?” Put this particular dispute to the panel: A new executable hash is correct, but the operating configuration file is wrong. What does software identity establish. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 02. Student A, terminology and scope: Agree the operational meanings of executable, hash, operating and file, wrong, identity in “A new executable hash is correct, but the operating configuration file is wrong. What does software identity establish”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A new executable hash is correct, but the operating configuration file is wrong; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Reference Planes and Configuration Identity”. Restore the intended state, calibration and parameters, then run relevant reference and regression checks Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A new executable hash is correct, but the operating configuration file is wrong; explain what each record can establish State what the existing record establishes,

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what it does not establish, and which further measurement would change your opinion. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Reference Planes and Configuration Identity”. Restore the intended state, calibration and parameters, then run relevant reference and regression checks Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Only the bound artifact identity, not correct deployed behavior Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A new executable hash is correct, but the

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operating configuration file is wrong: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A new executable hash is correct, but the operating configuration file is wrong; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A new executable hash is correct, but the operating configuration file is wrong: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses

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and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A new executable hash is correct, but the operating configuration file is wrong, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A new executable hash is correct, but the operating configuration file is wrong: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A new executable hash is correct, but the operating configuration file is wrong. Restore the intended state, calibration and parameters, then run relevant reference and regression checks Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A new executable hash is correct, but the operating configuration file is wrong, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §1.4 Reference Planes and Configuration Identity (p. 59)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A new executable hash is correct, but the operating configuration file is wrong. Restore the intended state, calibration and parameters, then run relevant reference and regression checks Respond point by point to Student J. Distinguish a

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verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.4.4 Record repetition and the limits of the design (p. 9270)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A new executable hash is correct, but the operating configuration file is wrong and What does software identity establish; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A new executable hash is correct, but the operating configuration file is wrong”, addressing “What does software identity establish”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A new executable hash is correct, but the operating configuration file is wrong. What does software identity establish”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A new executable hash is correct, but the operating configuration file is wrong. What does software identity establish”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion.

  Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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V011-VOL-DISCUSSION-096. A post-repair self-test passes but sample continuity and trigger behavior were not exercised. What release is justified?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A post-repair self-test passes but sample continuity and trigger behavior were not exercised. What release is justified?” Put this particular dispute to the panel: A post-repair self-test passes but sample continuity and trigger behavior were not exercised. What release is justified. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 02. Student A, terminology and scope: Agree the operational meanings of passes, continuity, trigger and exercised, release, justified in “A post-repair self-test passes but sample continuity and trigger behavior were not exercised. What release is justified”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A post-repair self-test passes but sample continuity and trigger behavior were not exercised; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Acceptance, Maintenance, and Lifecycle Control”. Preserve the prior accepted state and explicitly retain the unverified capabilities Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A post-repair self-test passes

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but sample continuity and trigger behavior were not exercised; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Acceptance, Maintenance, and Lifecycle Control”. Preserve the prior accepted state and explicitly retain the unverified capabilities Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Only the tested functions until configuration-specific checks establish the deployed method's needs Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A post-repair self-test passes but sample continuity and trigger behavior were not exercised: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A post-repair self-test passes but sample continuity and trigger behavior were not exercised; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A post-repair self-test passes but sample continuity and trigger behavior were not exercised:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A post-repair self-test passes but sample continuity and trigger behavior were not exercised, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A post-repair self-test passes but sample continuity and trigger behavior were not exercised: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to

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retain, qualify or reject the conclusion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A post-repair self-test passes but sample continuity and trigger behavior were not exercised. Preserve the prior accepted state and explicitly retain the unverified capabilities Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A post-repair self-test passes but sample continuity and trigger behavior were not exercised, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.9 Acceptance, Maintenance, and Lifecycle Control (p. 9280)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A post-repair self-test passes but sample continuity and trigger behavior were not exercised. Preserve the prior accepted state and explicitly retain the unverified capabilities Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §14.12 Calibration Lifecycle and Change Control (p. 8125)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A post-repair self-test passes but sample continuity and trigger behavior were not exercised and What release is justified; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A post-repair self-test passes but sample continuity and trigger behavior were not exercised”, addressing “What release is justified”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A,

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B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A post-repair self-test passes but sample continuity and trigger behavior were not exercised. What release is justified”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A post-repair self-test passes but sample continuity and trigger behavior were not exercised. What release is justified”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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V011-VOL-DISCUSSION-097. A closing field reference fails after a remote cable move. How should earlier conclusions be reassessed?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A closing field reference fails after a remote cable move. How should earlier conclusions be reassessed?” Put this particular dispute to the panel: A closing field reference fails after a remote cable move. How should earlier conclusions be reassessed. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 02. Student A, terminology and scope: Agree the operational meanings of closing, field, fails and remote, earlier, conclusions in “A closing field reference fails after a remote cable move. How should earlier conclusions be reassessed”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A closing field reference fails after a remote cable move; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Do not overwrite the earlier state with the latest correction automatically Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A closing field reference fails after a remote cable move; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your

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opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integrated Path Acceptance”. Do not overwrite the earlier state with the latest correction automatically Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Use known change times and last valid checks to identify affected functions and intervals, preserve all records and investigate a supported correction or narrower claim Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 08. Student D, answer to Student E: Design a discriminating experiment involving A closing field reference fails after a remote

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cable move: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A closing field reference fails after a remote cable move; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A closing field reference fails after a remote cable move: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A closing field reference fails after a remote cable move, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A closing field reference fails after a remote cable move: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A closing field reference fails after a remote cable move. Do not overwrite the earlier state with the latest correction automatically Explain the relevant statistical or calibration

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uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A closing field reference fails after a remote cable move, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §13.11 Integrated Path Acceptance (p. 7554)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A closing field reference fails after a remote cable move. Do not overwrite the earlier state with the latest correction automatically Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

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- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A closing field reference fails after a remote cable move and How should earlier conclusions be reassessed; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §1.7 Keep the evidence chain reversible to its declared inputs (p. 67)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A closing field reference fails after a remote cable move”, addressing “How should earlier conclusions be reassessed”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §1.8 Evidence Record and Closing Verification (p. 69)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A closing field reference fails after a remote cable move. How should earlier conclusions be reassessed”,

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specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A closing field reference fails after a remote cable move. How should earlier conclusions be reassessed”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §1.8 Evidence Record and Closing Verification (p. 69)

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V011-VOL-DISCUSSION-098. Native recordings contain incidental material beyond what the final finding needs. How should evidential reproducibility and disposition be balanced?

- 01. Moderator, opening proposition: Introduce the exact dispute, “Native recordings contain incidental material beyond what the final finding needs. How should evidential reproducibility and disposition be balanced?” Put this particular dispute to the panel: Native recordings contain incidental material beyond what the final finding needs. How should evidential reproducibility and disposition be balanced. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 02. Student A, terminology and scope: Agree the operational meanings of recordings, incidental, evidential and reproducibility, disposition, balanced in “Native recordings contain incidental material beyond what the final finding needs. How should evidential reproducibility and disposition be balanced”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of Native recordings contain incidental material beyond what the final finding needs; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Reproducible Analysis and Derived Products”. Derived images must not silently replace essential native evidence Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Native recordings contain incidental material beyond what the final finding needs; explain

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what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Reproducible Analysis and Derived Products”. Derived images must not silently replace essential native evidence Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Preserve records needed for the authorized purpose and verification with appropriate access controls, minimize unnecessary content under the declared policy and document migration/deletion Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving Native recordings contain incidental material beyond what the final finding needs: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of Native recordings contain incidental material beyond what the final finding needs; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving Native recordings contain incidental material beyond what the final finding needs: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test

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with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving Native recordings contain incidental material beyond what the final finding needs, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving Native recordings contain incidental material beyond what the final finding needs: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for Native recordings contain incidental material beyond what the final finding needs. Derived images must not silently replace essential native evidence Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving Native recordings contain incidental material beyond what the final finding needs, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §15.18 Reproducible Analysis and Derived Products (p. 8706)

- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for Native recordings contain incidental material beyond what the final finding needs. Derived images must not silently replace essential native evidence Respond point by point to Student J. Distinguish a verified observation from a conditional

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inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §1.2 Mission Authority and Collection Boundaries (p. 55)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about Native recordings contain incidental material beyond what the final finding needs and How should evidential reproducibility and disposition be balanced; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §10.63 SDR Acceptance and Supply-Chain Controls (p. 5765)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “Native recordings contain incidental material beyond what the final finding needs”, addressing “How should evidential reproducibility and disposition be balanced”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested

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proposition that remains unresolved. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “Native recordings contain incidental material beyond what the final finding needs. How should evidential reproducibility and disposition be balanced”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “Native recordings contain incidental material beyond what the final finding needs. How should evidential reproducibility and disposition be balanced”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §15.20 Coverage Review and Storage Governance (p. 8709)

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V011-VOL-DISCUSSION-099. A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. What additional evidence is required?

- 01. Moderator, opening proposition: Introduce the exact dispute, “A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. What additional evidence is required?” Put this particular dispute to the panel: A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. What additional evidence is required. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 02. Student A, terminology and scope: Agree the operational meanings of technically, repeatable, waveform and labeled, unauthorized, additional in “A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. What additional evidence is required”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Integration with Direction, Wireline, Optical, and Physical Evidence”. Technical capability or unfamiliarity does not establish the stronger category Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to

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test the alternative interpretations of A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Integration with Direction, Wireline, Optical, and Physical Evidence”. Technical capability or unfamiliarity does not establish the stronger category Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. Separate unresolved classification from authorization and functional linkage, preserve the measurement and pursue operational or physical evidence Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar:

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specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

- 12. Student G, revised experimental answer: Address Student H's confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or

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reject the conclusion. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. Technical capability or unfamiliarity does not establish the stronger category Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.5 Integration with Direction, Wireline, Optical, and Physical Evidence (p. 9274)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. Technical capability or unfamiliarity does not establish the stronger category Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar and What additional evidence is required; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.4.2 Preserve comparable observation capability (p. 9266)

- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar”, addressing “What additional evidence is required”; specify the exact measurement or evidential gap on which the speakers still differ

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Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. What additional evidence is required”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “A technically repeatable waveform is labeled unauthorized solely because it is unfamiliar. What additional evidence is required”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.6 Findings, Reports, and Decision Ladders (p. 9275)

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V011-VOL-DISCUSSION-100. What should the final independent reviewer be able to reconstruct across the entire volume's receiver method?

- 01. Moderator, opening proposition: Introduce the exact dispute, “What should the final independent reviewer be able to reconstruct across the entire volume's receiver method?” Put this particular dispute to the panel: What should the final independent reviewer be able to reconstruct across the entire volume's receiver method. Ask speakers to identify the result or operational decision at stake Invite two students to propose competing answers, and ask each to name a measurable consequence that could disprove the position. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 02. Student A, terminology and scope: Agree the operational meanings of final, reviewer, able and reconstruct, entire, method in “What should the final independent reviewer be able to reconstruct across the entire volume's receiver method”; state which definitions materially change the competing positions Ask Student B which definition would most materially change the outcome and request a specific example from the stated receiver scenario. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 03. Student B, affirmative technical position: Ask one participant to defend and another to challenge the proposed treatment of What should the final independent reviewer be able to reconstruct across the entire volume's receiver method; require both to name a decisive instrument observation Give a defensible initial conclusion, identify the instrument state on which it depends, and pass a direct question to Student C about a plausible weakness. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 04. Student C, first Socratic examination of Student B: Debate the governing receiver or signal mechanism in “Program Governance and Peer Review”. Preserve failed tests and old/new processing states so a later correction can narrow the conclusion without rewriting observations Ask Student B two focused questions: Which physical or digital stage could produce the observed result, and what independent observation could contradict that explanation? Do not accept a repeat of the opening claim as an answer. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 05. Student B, evidence-based answer to Student C: Respond directly to the mechanism and falsification questions. Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should the final independent reviewer be able to reconstruct across the entire

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volume's receiver method; explain what each record can establish State what the existing record establishes, what it does not establish, and which further measurement would change your opinion. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 06. Student D, competing mechanism: Debate the governing receiver or signal mechanism in “Program Governance and Peer Review”. Preserve failed tests and old/new processing states so a later correction can narrow the conclusion without rewriting observations Explain a materially different receiver or signal mechanism, state its predicted signature, and invite Student E to challenge whether it fits the same observed trace or native sample record. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 07. Student E, cross-examination of the competing mechanism: Identify the competing options in the question. The configured quantity and planes, valid native data, signed corrections, normalization, uncertainty, timing/coverage, challenges and supported inference Put two specific questions to Student D about the stated competing options and the instrument configuration. Ask which setting or observation would discriminate between them without changing the measurand. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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- 08. Student D, answer to Student E: Design a discriminating experiment involving What should the final independent reviewer be able to reconstruct across the entire volume's receiver method: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Respond to both cross-examination questions, specify the independent control condition and expected result, and identify how you would document an unexpected observation. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 09. Student F, original evidence and provenance: Specify the original trace, I/Q record, calibration state or field note actually needed to test the alternative interpretations of What should the final independent reviewer be able to reconstruct across the entire volume's receiver method; explain what each record can establish Describe the native record, metadata and calibration evidence that the panel must actually examine. Ask Student G which datum should be collected first and what uncertainty remains if it is missing. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 10. Student G, discriminatory measurement design: Design a discriminating experiment involving What should the final

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independent reviewer be able to reconstruct across the entire volume's receiver method: specify the altered receiver state or source condition, predicted change, test statistic and rejection criterion Present a repeatable, authorised test with the receiver settings, controlled variable, expected responses and a rejection criterion. Ask Student H to identify an alternative that could survive the proposed test. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 11. Student H, adversarial challenge and confounding alternatives: For the precise observation involving What should the final independent reviewer be able to reconstruct across the entire volume's receiver method, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Question Student G about a specific artifact or uncontrolled variable. Demand a control experiment that would expose a false positive or incorrect source attribution. Source: §16.10 Program Governance and Peer Review (p. 9281)

- 12. Student G, revised experimental answer: Address Student H’s confounding mechanism by revising the controlled test described in the preceding prompt. Design a discriminating experiment involving What should the final independent reviewer be able to reconstruct across the entire volume's receiver method: specify the altered

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receiver state or source condition, predicted change, test statistic and rejection criterion Say precisely what observation would lead the panel to retain, qualify or reject the conclusion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 13. Student I, uncertainty and inferential limits: Assess uncertainty and evidential scope for What should the final independent reviewer be able to reconstruct across the entire volume's receiver method. Preserve failed tests and old/new processing states so a later correction can narrow the conclusion without rewriting observations Explain the relevant statistical or calibration uncertainty, the range of defensible claims, and why the question cannot be settled by visual appearance or a single unqualified reading. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 14. Student J, Socratic challenge to Student I: For the precise observation involving What should the final independent reviewer be able to reconstruct across the entire volume's receiver method, formulate an instrumental artifact or confounding alternative, then identify the control measurement that would expose it Ask Student I whether the proposed uncertainty statement accounts for the actual receiver state, sample coverage and possible instrumental artifacts. Request an explicit statement of what evidence would reverse the conclusion. Source: §16.10 Program Governance and Peer Review (p. 9281)

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- 15. Student I, quantified and qualified reply: Assess uncertainty and evidential scope for What should the final independent reviewer be able to reconstruct across the entire volume's receiver method. Preserve failed tests and old/new processing states so a later correction can narrow the conclusion without rewriting observations Respond point by point to Student J. Distinguish a verified observation from a conditional inference and name the missing datum, sensitivity test or uncertainty term that limits confidence. Source: §13.19 Verification, records and the interpretation of negative observations (p. 7576)

- 16. Student K, authority and evidential discipline: Determine which authority, calibration and reporting safeguards apply to the particular claim about What should the final independent reviewer be able to reconstruct across the entire volume's receiver method and The configured quantity and planes, valid native data, signed corrections, normalization, uncertainty,...; exclude protections irrelevant to the scenario Question Student F about the custody and reproducibility of the proposed records and ask Student G whether the discriminatory test remains within authorised laboratory and field boundaries. Source: §16.8 Write findings that preserve the strength and limit of each test (p. 9278)

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- 17. Peer panel, negotiated consensus and residual dissent: Draft a narrow consensus about “What should the final independent reviewer be able to reconstruct across the entire volume's receiver method”, addressing “The configured quantity and planes, valid native data, signed corrections, normalization, uncertainty,…”; specify the exact measurement or evidential gap on which the speakers still differ Require Students A, B, D, G and I to respond to at least one objection raised by another speaker before voting. Record both the narrow agreement and the specific contested proposition that remains unresolved. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

- 18. Moderator, reasoned disposition and follow-up: Record a final recommendation on “What should the final independent reviewer be able to reconstruct across the entire volume's receiver method”, specifying the next test, responsible measurement record and limit of the conclusion Summarise the strongest evidence for and against the resolution of “What should the final independent reviewer be able to reconstruct across the entire volume's receiver method”. Allocate the next measurement and documentary action to named student roles, and require each participant to distinguish accepted evidence from an unsupported assertion. Source: §16.15 Close the receiver method through configuration-specific regression (p. 9287)

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Volume Answer Keys and Guidance

The essay and discussion guidance below identifies expected mechanisms, methods and evidence. A defensible alternative conclusion must state its assumptions, reasoning and limitations.

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Essay Guidance

V011-VOL-ESSAY-001 — Define the measurand, reference plane, event population and decision criterion; map the complete analog/digital/recording chain; identify irreversible losses; and link calibration, uncertainty, coverage and challenge evidence. Distinguish detection from functional attribution and state the accepted scope.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 14 — Attach calibration to a stated measurement result; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Findings, Reports, and Decision Ladders.

V011-VOL-ESSAY-002 — Derive their matched noise weighting, track desired and blocker levels at each stage, and assess installed bias/stability and field geometry. Specify reference tests for actual transfer, loading and capability; explain why a common corrected mean level does not establish equal sensitivity.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval; Chapter 13 — Remote amplification requires electrical and installed checks.

V011-VOL-ESSAY-003 — State the lower gain condition from later-stage noise and upper condition from admitted blockers or converter range. Include preselector loss/rejection, empty-interval handling and state validity. Explain why digital scaling cannot repair analog SNR or clipping.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval; Chapter 10 — Range and error are separate obligations; Chapter 11 — Compression and Gain Change.

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V011-VOL-ESSAY-004 — Separate protection leakage, survival and observable-specific recovery; retain a weak reference through a bounded strong event. Track AGC/filter/trigger persistence, establish valid intervals and calculate coverage only from those intervals. Do not equate a survival rating with restored measurement quality.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-VOL-ESSAY-005 — Subtract compatible linear powers before logarithms, use applicable transfer at named planes and distinguish unknown-state sets from statistical uncertainty. Propagate supported dependencies, check log-domain positivity and independently close the forward calculation.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-ESSAY-006 — Record source temperatures at the receiver plane, passive loss and physical temperature, hot/cold linear powers, bandwidth, matching and common gain. Check hot-state compression, source-state settling and covariance, then distinguish the noise result from waveform-specific detection verification.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 13 — Treat connections and unused branches as part of the network; Chapter 14 — Calibrate noise without confusing it with detection; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-VOL-ESSAY-007 — Retain signed frequency, LO branches, image intervals, sampling equivalence and NCO convention. Predict movement under a controlled change and preserve desired transfer; explain why one moving line cannot uniquely establish an image or external source.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation; Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-VOL-ESSAY-008 — Use complex-envelope representation and declared average/peak conventions, measure amplitude and phase response over occupied bandwidth, and assess stage loading. Explain envelope reversal or filtering ambiguities and limit source-modulation claims when the path is incompletely characterized.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 3 — Use preselection as a measured transfer function; Chapter 11 — Compression and Gain Change.

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V011-VOL-ESSAY-009 — Define nonzero/valid signal intervals, branch handling, finite-difference meaning and resets. Retain absolute sample indices and deterministic clock mapping; distinguish carrier offset from modulation and avoid treating discontinuous records as one coherent trajectory.

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-VOL-ESSAY-010 — Define symbol populations, reference energies and fit degrees of freedom; retain the fitted coefficient and unfitted phase result. Use held-out data and demonstrate which physical error the fit can conceal. Separate lower residual from improved clock or receiver calibration.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

V011-VOL-ESSAY-011 — Specify training/evaluation symbols, weights, normalization and excluded startup data; verify actual receiver state and event boundaries. Report settled-payload quality separately from whole-burst capture and avoid using a clean selected constellation as evidence for omitted intervals.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-ESSAY-012 — Define finite symbol/bit/frame populations, overhead ownership, active and wall intervals, unique payload positions and retransmissions. Separately compute stored I/Q bytes with container width and channels, and retain chronology and continuity so neither storage rate nor coded count is mislabeled as information delivery.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

V011-VOL-ESSAY-013 — Relate each to the intended tone, density, integrated-power or transient estimate; describe window normalization and sweep/filter settling. Show why finer plotted frequency spacing or a lower displayed floor does not add measured history or establish event detectability.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 9 — Define the record before interpreting the display; Chapter 9 — Noise density uses a different denominator; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-VOL-ESSAY-014 — Define the actual estimator and source law, distinguish gamma/log-bias conditions from intermittent mixtures, and subtract compatible additive powers before logs. Retain covariance and positivity domains; explain why display smoothness or repeated averaging does not validate an inapplicable statistical correction.

Review: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace; Chapter 8 — A stated statistical model; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-ESSAY-015 — Specify paired ensembles, conjugation/channel order, window normalization and phase branch; retain actual sample indices and clock relationships. Analyze shared contributions and coherence limits, and distinguish a one-pair unity estimate from evidence of a physical coupling.

Review: Chapter 9 — Define the ensemble before normalizing; Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-VOL-ESSAY-016 — Include native format and scale, absolute indices, oscillator phase, filter history, decimation phase, valid supports and software identity. Bind calibration and selected interval, test with known references and retain gaps; explain why byte hashes or a similar plot alone are insufficient.

Review: Chapter 10 — Signed formats and explicit conversion points; Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 10 — Separate signed artifacts from operating configurations; Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-VOL-ESSAY-017 — Compare zero filling with silent deletion, map nonzero filter support to affected outputs and retain absolute phase/time. Restrict uniform-sampling estimators to valid segments or state a different model. Distinguish a preserved grid from reconstructed missing waveform.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 9 — Define the record before interpreting the display; Chapter 15 — Bind sample continuity, storage accounting and derived results.

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V011-VOL-ESSAY-018 — Define signed formats and conversion points, bound intermediate ranges and rounding, check clipping/overflow with known stimuli, and retain scale metadata. Explain why digital gain can improve representation use without recovering an already lost analog SNR or waveform.

Review: Chapter 10 — Range and error are separate obligations; Chapter 10 — Quantization margin and channel bandwidth; Chapter 2 — Turn the cascade into bounded design requirements; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

V011-VOL-ESSAY-019 — Specify parent powers, frequencies, loading and stage reference plane; use the local cubic law only within its domain, retain per-tone convention and intercept asymptote. Characterize sources/combiners and coherent contamination, then vary a control before the proposed stage while preserving desired capability.

Review: Chapter 11 — Fix the voltage convention and operating domain; Chapter 11 — Construct the intercept from the linear asymptote; Chapter 11 — Ten worked applications of Model 11A; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-ESSAY-020 — Use paired desired-reference and blocker observations, identify gain/band/state changes, characterize source spectrum and channel weighting, and test oscillator phase-noise relevance. State which models survive each outcome instead of assigning one universal dynamic-range score.

Review: Chapter 11 — Distinguish strong-signal mechanisms through paired interventions; Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

V011-VOL-ESSAY-021 — Define deterministic clock error, finite integration band and carrier conversion, then discuss covariance and Gaussian premises for phase differences. Include common random rotation and independent/correlated cases, and show why equal scalar RMS does not fix every receiver consequence.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 9 — Define the ensemble before normalizing; Chapter 11 — Integrate the channel that actually produces the reported value.

V011-VOL-ESSAY-022 — Account for cable/filter/conversion phase, reference distribution, epoch, trigger and index mapping. Test retune/reset repeatability, preserve branch and uncertainty, and explain what a shared clock or one calibration tone does not establish.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 14 — Frequency, phase, and delay require their own observables; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-ESSAY-023 — Separate antenna-terminal power from field conversion, state loading/polarization/geometry/field-region conditions, and include remote paths and common mode. Assign corrections once, verify the installed arrangement and distinguish traceability from complete applicability.

Review: Chapter 13 — Keep field conversion separate from terminal power; Chapter 13 — Define a complete path at named planes; Chapter 14 — Attach calibration to a stated measurement result.

V011-VOL-ESSAY-024 — Characterize new gain, noise, bandwidth, timing and power-state behavior; carry a relevant weak reference; preserve geometry and raw comparisons. State alternative effects of the intervention and the bounded inference when capability cannot be matched.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Preserve comparable observation capability.

V011-VOL-ESSAY-025 — Write signed equations for a phase difference and an averaged corrected level, show cancellation versus persistence, and avoid double counting. Check matrix admissibility and units; explain why shared labels or separate budget rows do not establish the required dependence.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 14 — Application 14B.5: cancel a shared phase reference correctly; Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove.

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V011-VOL-ESSAY-026 — Start from matched on/off transfer and additive powers, retain covariance and the complete possible domain, then distinguish exact linear difference variance from local log dispersion. Explain what changes if zero is admitted and why neither a positive center nor factor-two interval proves positivity.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

V011-VOL-ESSAY-027 — Compare a signed affine correction with hot/cold inversion, phase-slope delay and squared-voltage power. Identify finite-moment requirements, curvature/singularity boundaries and input distributions; show why numerical simulation cannot validate unsupported physical assumptions.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 14 — Application 14B.10: expose a zero-sensitivity failure of the local law.

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V011-VOL-ESSAY-028 — State the measurand and applicable correction, propagate supported dependencies, justify the coverage factor and predeclare accept/reject/indeterminate conditions. Explain how follow-up should target dominant terms while preserving the original rule and result.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 14 — Declare the decision rule before seeing the result; Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-VOL-ESSAY-029 — Derive eligible starts for a declared positive contiguous criterion, preserve actual record continuity, merge periodic unions and justify the event-phase law. Keep detector validity separate and show why disconnected pieces or nominal command spans cannot be counted as one record.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 5 — Model 5A: an identified one-pole gain-control response.

V011-VOL-ESSAY-030 — Define the relative event/schedule phase, derive complement multiplication only where justified, retain unequal probabilities or joint dependence and analyze endpoint trial counts. Explain how actual schedule changes differ from saving more copies of the same observation.

Review: Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic; Chapter 8 — Interpret a swept trace through its frequency-time trajectory.

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V011-VOL-ESSAY-031 — Map trigger and recording path locations, test relevant stimulus shapes and event pairs, establish pretrigger validity and recovery, and relate trigger timestamps to sample apertures. Retain complete boundaries, gap evidence and limits of a CW-only check.

Review: Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 10 — Source indices, stored offsets, and time anchors.

V011-VOL-ESSAY-032 — Calculate payload using actual representation, include overhead and reserve, test full-duration writing and rollover, and monitor counters/clock/overruns. Hash closed files and bind metadata, but distinguish byte consistency from acquisition continuity and valid coverage.

Review: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Close the receiver method through configuration-specific regression.

V011-VOL-ESSAY-033 — Retain source hashes, intervals, channels, scales, calibration, windows, alignment, exclusions and manual decisions. Use a second implementation and reference/noise-only records where relevant, disclose parameter sensitivity and avoid treating multiple outputs from one source as independent evidence.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 9 — Estimator Validation and Reporting; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-ESSAY-034 — Define actual physical state bundles, all meaningful combinations, response plane and criterion, capable references, fresh replications and run-order/blocking plan. Retain missing states, transitions and alternatives; explain why interaction alone does not name the responsible circuit.

Review: Chapter 16 — Receiver challenges with interacting controls; Chapter 16 — Arrange the comparisons before examining their outcomes; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 15 — Verify the trigger at its actual signal-path location.

V011-VOL-ESSAY-035 — Map shared antenna, clock, power, software and correction paths; verify the relevant weak or burst reference in each state. Distinguish agreement, disagreement and nondetection at tested limits, then identify an intervention that changes the relevant error structure.

Review: Chapter 13 — A constructed acceptance case for the assembled chain; Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-VOL-ESSAY-036 — Define each direct observable and clock/state relationship, identify shared causes and processing, and distinguish correlation from physical linkage. Require appropriate localization and information-path evidence before advancing the finding category.

Review: Chapter 15 — Metadata, Time, and Site Context; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-ESSAY-037 — Use corrected same-plane differences with uncertainty for compatibility, predeclared challenges for mechanisms and additional physical/operational evidence for function. Explain why a favorable test count, decoded identifier or low EVM cannot supply unspecified likelihoods or authorization.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 16 — Reconcile evidence without assigning unsupported probabilities; Chapter 16 — Findings, Reports, and Decision Ladders.

V011-VOL-ESSAY-038 — Preserve old/new executable and configuration identities, reuse accepted references across levels and states, rerun retained samples and compare both derivations. Check scale, correction, alignment and timing separately; keep native observations and explain revised outputs.

Review: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 14 — Close the calibration record across the working interval; Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Close the receiver method through configuration-specific regression.

V011-VOL-ESSAY-039 — Identify the affected function, last demonstrated valid state and change time; preserve native data and both reference results. Investigate whether a bounded retrospective correction is supported, qualify unknown intervals and avoid silently extending the latest calibration backward.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 13 — Integrated Path Acceptance; Chapter 14 — Close the calibration record across the working interval; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-ESSAY-040 — State separate domains, identify additional geometry, trigger, recovery and coverage evidence needed, and retain usable narrow claims. Explain why a valid certificate or repeated successful use does not automatically extend acceptance.

Review: Chapter 13 — A constructed acceptance case for the assembled chain; Chapter 14 — Attach calibration to a stated measurement result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Close the receiver method through configuration-specific regression.

V011-VOL-ESSAY-041 — Use examples of wrong cable, duplicated correction, binary-point error and incorrect covariance. Explain which require correcting the model or data identity rather than enlarging a budget, and specify independent physical and arithmetic checks.

Review: Chapter 13 — Define a complete path at named planes; Chapter 10 — Signed formats and explicit conversion points; Chapter 14 — Attach calibration to a stated measurement result.

V011-VOL-ESSAY-042 — Track desired spectral transfer, ENBW, time response and trigger-path location; keep normalization and state corrections explicit. Use a known waveform and blocker challenge to distinguish a useful rejection improvement from discarded information or sensitivity change.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 9 — Noise density uses a different denominator; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-ESSAY-043 — Follow analog/digital frequency maps, validate synchronization and symbol mapping with references, preserve held-out/noise-only tests and state uncertainty. Report the classification actually supported without converting plausible content into device attribution.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation; Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Interpret hypothetical receiver records.

V011-VOL-ESSAY-044 — Use phase-error cancellation in one difference and shared error in two agreeing receivers. State coupling and covariance, retain absolute versus relative scope, and propose an independent reference/path observation when required.

Review: Chapter 12 — Application 12B.5: Include covariance when combining timing contributions; Chapter 14 — Application 14B.5: cancel a shared phase reference correctly; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

V011-VOL-ESSAY-045 — Reconcile planned, commanded, valid and preserved intervals, passbands, source states and event classes. Include sensitivity, trigger and schedule assumptions; identify gap/guard exclusions and avoid claiming absence beyond the supported acquisition.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

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V011-VOL-ESSAY-046 — Use complex-envelope or SSB examples to distinguish mean, peak and coherent contributions; show how a correctly normalized FFT can conserve energy while missing relevant peak loading or temporal recovery. Retain waveform and stage-level evidence for nonlinearity/protection claims.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 9 — Energy closure and its limits; Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 11 — Compression and Gain Change.

V011-VOL-ESSAY-047 — Distinguish lines from densities, retain finite bands and carrier conversion, and apply actual channel weighting to admitted blockers. Identify unmeasured bands and avoid using one integrated RMS to certify every coherent or reciprocal-mixing condition.

Review: Chapter 9 — Noise density uses a different denominator; Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin; Chapter 11 — Integrate the channel that actually produces the reported value.

V011-VOL-ESSAY-048 — Derive state-specific admissible corrected results, preserve disjoint unions and missing validity intervals, and avoid assigning probabilities without evidence. Explain which follow-up can identify the state and how release is narrowed if it cannot.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Declare the decision rule before seeing the result; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-ESSAY-049 — Trace each plot, decode, EVM, trigger log and comparison to native sources and shared clocks/software. Retain complementary observables but avoid unsupported multiplication; identify missing physical contrasts and specify the evidence for any proposed likelihood model.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-VOL-ESSAY-050 — Define the original measurement and source records, identify a concrete state/normalization/coverage error, recompute with valid models and preserve both versions. Explain which observation remains, which inference changes and what regression prevents recurrence.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 9 — Estimator Validation and Reporting; Chapter 14 — Close the calibration record across the working interval; Chapter 16 — Close the receiver method through configuration-specific regression.

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Discussion Guidance

V011-VOL-DISCUSSION-001 — Define the intended quantity and evidential category first, then select reference planes, configuration, calibration and tests. Explain that one receiver output cannot silently serve all three claims and preserve the authorization and observation scope.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 13 — Keep field conversion separate from terminal power; Chapter 16 — Findings, Reports, and Decision Ladders.

V011-VOL-DISCUSSION-002 — Compare component order, input-equivalent noise and blocker exposure, then validate actual assembled transfer. Include remote gain and passive-loss temperature where relevant; equal desired gain is insufficient for equal detection capability.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 3 — Choose gain from a feasible interval; Chapter 13 — Define a complete path at named planes.

V011-VOL-DISCUSSION-003 — Show that neither constraint is necessarily met, identify the empty feasible interval and propose changing rejection, stage placement or operating conditions. Keep desired transfer, sensitivity and loading requirements explicit.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Choose gain from a feasible interval; Chapter 11 — Dynamic Range Is a Family of Conditions.

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V011-VOL-DISCUSSION-004 — Consider total mean power and possible instantaneous/coherent loading at each vulnerable stage, with actual frequency-dependent admission. Use the local nonlinear model only where supported and preserve a weak-reference challenge.

Review: Chapter 3 — Find the first stage that can lose validity; Chapter 11 — Fix the voltage convention and operating domain; Chapter 13 — A constructed acceptance case for the assembled chain.

V011-VOL-DISCUSSION-005 — Compare desired amplitude/phase response across the waveform, rejected blockers, noise bandwidth and gain state. Retain the improvement and waveform cost separately; center-tone gain or a quieter display does not establish overall fidelity.

Review: Chapter 3 — Use preselection as a measured transfer function; Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 9 — Noise density uses a different denominator.

V011-VOL-DISCUSSION-006 — Treat the noise bound as one requirement, characterize rejection at actual blocker frequencies and confirm loading before the vulnerable stage. Avoid transferring desired-frequency loss to the blocker path.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 3 — Use preselection as a measured transfer function; Chapter 11 — Distinguish strong-signal mechanisms through paired interventions.

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V011-VOL-DISCUSSION-007 — Include dissipative noise temperature, referred downstream noise, desired loss and impedance-sensitive receiver behavior. Evaluate target sensitivity and uncertainty rather than declaring a match improvement universally beneficial.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 13 — Treat connections and unused branches as part of the network; Chapter 14 — Calibrate noise without confusing it with detection.

V011-VOL-DISCUSSION-008 — Keep reference noise factor separate from actual source-temperature degradation, use the applicable cascade and bandwidth, and verify the detection procedure separately. Explain the zero-added-noise exception without generalizing it.

Review: Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Calibrate noise without confusing it with detection; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-VOL-DISCUSSION-009 — Retain hot/cold powers and receiver-plane temperatures, assess delivered noise and impedance-dependent receiver response, and establish common gain, bandwidth and linearity. A scalar ENR entry alone does not close the model.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 13 — Treat connections and unused branches as part of the network; Chapter 14 — Calibrate noise without confusing it with detection.

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V011-VOL-DISCUSSION-010 — It establishes repeated behavior of that state-dependent experiment, not the equal-gain inverse. Recover or model gain states, test settling and compression and recompute under valid assumptions.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 14 — Calibrate noise without confusing it with detection.

V011-VOL-DISCUSSION-011 — Inspect raw range flags and actual transfer, reduce loading or adopt a validated configuration, and retain the failed condition. Cold-state linearity and averaging cannot justify an inversion using distorted hot power.

Review: Chapter 2 — Invert the same model with two source temperatures; Chapter 10 — Quantization, Clipping, and Converter Performance; Chapter 14 — Calibrate noise without confusing it with detection.

V011-VOL-DISCUSSION-012 — Require event-specific waveform/threshold tests, instantaneous-band coverage and usable schedule with a justified phase law. Distinguish noise calibration from timing opportunity and decision performance.

Review: Chapter 2 — Turn the cascade into bounded design requirements; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-DISCUSSION-013 — Identify the model mismatch, retain actual state history and seek an additional-state or changed-target explanation. Do not force the observed trajectory into a monotone inverse; restrict corrected intervals to validated behavior.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-VOL-DISCUSSION-014 — Carry the actual terminal state into the new interval, use identified attack/release conditions and retain valid sample timing. Do not restart from equilibrium merely because a new file begins.

Review: Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-VOL-DISCUSSION-015 — Use the observable-specific phase criterion and calibrated timing boundary, while retaining the different amplitude recovery. Hardware survival or amplitude closure cannot establish restored coherent validity.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

V011-VOL-DISCUSSION-016 — Map the detector/AGC path, exercise relevant leading edges and prior states, and measure trigger-to-sample timing with paired events. Incorporate demonstrated exclusions into usable coverage.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

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V011-VOL-DISCUSSION-017 — Characterize impulse/time response and detector behavior, compare a known pulse through the same path and retain valid context. A ringing output is not automatically a prolonged external transmission.

Review: Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 15 — Verify the trigger at its actual signal-path location.

V011-VOL-DISCUSSION-018 — Verify the frequency-time trajectory and filter settling using a suitable signal, retain bandwidth/detector state and valid intervals, and distinguish smooth presentation from response validity.

Review: Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 14 — Build a correction chain with signs that can be checked.

V011-VOL-DISCUSSION-019 — Identify the detector and averaging operation, quantify noise/statistical change and validate the intended event response. Smoothing can conceal variation or short events without changing upstream noise performance.

Review: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace; Chapter 2 — Turn the cascade into bounded design requirements; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-DISCUSSION-020 — Reconstruct linear-power averaging versus log-level averaging, source law and normalization, then report the declared estimator. Calibration agreement is not meaningful until both results describe the same quantity.

Review: Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace; Chapter 9 — Estimator Validation and Reporting; Chapter 14 — Attach calibration to a stated measurement result.

V011-VOL-DISCUSSION-021 — The conditional/common-mean distributional premises may fail; inspect the mixture and actual operation order. Preserve raw powers and derive or validate an appropriate correction rather than reuse a label-based constant.

Review: Chapter 8 — A stated statistical model; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

V011-VOL-DISCUSSION-022 — Correct each accepted interval to a common plane, then duration-weight physical powers for the requested mean. Retain unknown/invalid intervals and distinguish the result from an average of logarithmic labels.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 8 — Noise averages, detector statistics, and the meaning of a decibel trace.

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V011-VOL-DISCUSSION-023 — Establish compatible fixed transfer and additive-power conditions, subtract in linear units and retain covariance. Transform only a supported positive difference and explain that the original dB subtraction formed a ratio.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 11 — Convert added power into a conditional noise-rise limit; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

V011-VOL-DISCUSSION-024 — No; retain the linear result and clarify physical/model interpretation. Clipping changes the estimator, while a finite logarithm cannot cover nonpositive values; use a justified domain-aware treatment.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

V011-VOL-DISCUSSION-025 — Unknown relative phase permits reinforcement or cancellation, so the measured total is not necessarily a sum of independent powers. Use phasor bounds or independent source/combiner characterization with a stage-specific challenge.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 11 — Ten worked applications of Model 11A; Chapter 14 — Application 14B.9: subtract paired powers before propagating a logarithm.

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V011-VOL-DISCUSSION-026 — Both admitted RF intervals, signed conversion branch, preselection and potential coherent combination. Verify transfer separately and challenge the image path; one IF label cannot identify a unique original RF source.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 3 — Use preselection as a measured transfer function; Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-VOL-DISCUSSION-027 — Track spectral orientation and digital phase-derivative convention through the configured path. Test a known modulation before asserting a source change, and preserve branch and reference information.

Review: Chapter 4 — Model 4A: a declared conversion map; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 10 — Model 10B for digital mixing filtering and decimation.

V011-VOL-DISCUSSION-028 — Separate predicted alias mapping from changed admission and transfer, preserve a reference and characterize both configurations. Movement alone is not a unique alias proof when several factors change.

Review: Chapter 10 — Sampling equivalence, admissible bands, and receiver interpretation; Chapter 3 — Use preselection as a measured transfer function; Chapter 16 — Receiver challenges with interacting controls.

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V011-VOL-DISCUSSION-029 — Reproduce the intended absolute-index mixing law across continuous blocks, retain original and revised outputs and show the artifact's dependence on the reset. Do not alter native samples to hide the earlier processing error.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Close the receiver method through configuration-specific regression.

V011-VOL-DISCUSSION-030 — Propagate invalid support through the channelizer/filter and retained output phases, inspect actual indices and preserve the gap. Do not assume a new RF source merely because the transient appears in a separate channel.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 10 — Model 10C for a polyphase analysis channelizer; Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-VOL-DISCUSSION-031 — State that the grid is preserved but waveform values are not measured, mark affected filter outputs and limit later estimators. Keep the gap map and distinguish representation continuity from physical acquisition completeness.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-DISCUSSION-032 — The changed index-to-time relation, artificial join and oscillator/filter state, then compare only justified valid segments. A cleaner plot does not demonstrate restoration of the missing event or original frequency law.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 9 — Define the record before interpreting the display; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-VOL-DISCUSSION-033 — Use a known physical reference with declared format and calibration, independently verify binary-point and units, and retain software identities. Agreement on identical misinterpreted inputs is limited evidence.

Review: Chapter 10 — Signed formats and explicit conversion points; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

V011-VOL-DISCUSSION-034 — Separate quantization-error and range obligations, identify affected samples/states and validate scaling at worst-case inputs. A local rounding bound cannot justify overflow or reconstruct lost values.

Review: Chapter 10 — Range and error are separate obligations; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-DISCUSSION-035 — The original amplitude and waveform information lost at clipping. Retain flags and raw representation, establish a valid analog/digital gain state and repeat the reference test instead of treating post-scaling as recovery.

Review: Chapter 10 — Quantization, Clipping, and Converter Performance; Chapter 3 — Choose gain from a feasible interval; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

V011-VOL-DISCUSSION-036 — The preserved file bytes are consistent with the hash, but acquisition continuity failed. Retain both facts, the gap map and bounded valid intervals; neither finding cancels the other.

Review: Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Write findings that preserve the strength and limit of each test.

V011-VOL-DISCUSSION-037 — Payload rate and duration capacity using actual components, channels and container width, plus overhead and margin. Recheck sustained writing; converter resolution does not determine stored byte count.

Review: Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Quantitative Model for Triggering, Burst Capture, Recording, Metadata, and Reproducibility.

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V011-VOL-DISCUSSION-038 — Test sustained planned-duration operation, monitor loss and thermal/clock state, provide reserve or a changed capture design and document any resulting coverage limits. Peak speed cannot establish continuous preservation.

Review: Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 10 — Data Transport, Gaps, and Reproducible Recording; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

V011-VOL-DISCUSSION-039 — No; verify conjugation and order conventions, actual channel reference planes and clock mapping. Preserve the original order and interpret the delay only under a consistent signed definition.

Review: Chapter 9 — Cross-Spectra, Coherence, and Multichannel Analysis; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 14 — Frequency, phase, and delay require their own observables.

V011-VOL-DISCUSSION-040 — Examine whether each bin uses only one nonzero Fourier pair, define the ensemble and repeated paired averaging, and test shared noise or processing. A normalized finite identity need not estimate population coupling.

Review: Chapter 9 — Define the ensemble before normalizing; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

V011-VOL-DISCUSSION-041 — Their shared samples and statistical dependence, plus the separate event-phase assumptions if used for capture probability. Define the estimator and trial experiment explicitly instead of equating segment count with independent evidence.

Review: Chapter 9 — Averaging and Statistical Stability; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Record repetition and the limits of the design.

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V011-VOL-DISCUSSION-042 — Window sum versus energy normalization, ENBW, sample rate and one/two-sided conventions. Preserve each declared quantity and check integrated power rather than assume a single denominator applies to all displays.

Review: Chapter 9 — Noise density uses a different denominator; Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Attach calibration to a stated measurement result.

V011-VOL-DISCUSSION-043 — Actual resolving evidence and source discrimination based on the unchanged time record. Compare window/record effects and obtain more valid data where needed; interpolation adds grid points, not independent observation.

Review: Chapter 9 — Define the record before interpreting the display; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Write findings that preserve the strength and limit of each test.

V011-VOL-DISCUSSION-044 — Peak-envelope and relative-phase loading at vulnerable stages can differ despite correct mean-energy closure. Retain time-domain waveform and stage-level linearity/protection checks.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 9 — Energy closure and its limits; Chapter 11 — Compression and Gain Change.

V011-VOL-DISCUSSION-045 — Measure carrier/sideband transfer and phase, compare a known waveform and preserve the gain state. Magnitude extrema at the output may not represent the original source, especially with reversal or unequal sideband admission.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 3 — Use preselection as a measured transfer function; Chapter 14 — Build a correction chain with signs that can be checked.

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V011-VOL-DISCUSSION-046 — Retain the valid declared power statistic while declining to reconstruct lost phase/sign or source waveform uniquely. Use coherent samples and validated bandwidth for claims requiring that information.

Review: Chapter 6 — Model 6A: preserve the complex envelope; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 9 — Energy closure and its limits.

V011-VOL-DISCUSSION-047 — Signal validity, phase branch and finite-interval definition, resets and actual sample timing. Do not interpret an undefined or unstable phase derivative as a physical instantaneous frequency without supporting evidence.

Review: Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 10 — Gap representations, phase, and the limits of timing claims.

V011-VOL-DISCUSSION-048 — Average tuning accuracy can be good while coherent integration or blocker susceptibility is limited. Retain separate deterministic time error, phase-noise spectrum and relevant channel/covariance models.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 11 — Integrate the channel that actually produces the reported value.

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V011-VOL-DISCUSSION-049 — State each band, carrier and line/density treatment, identify unmeasured contributions and relate spectral placement to the intended receiver function. Equal numerical RMS is not interchangeable evidence.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 12 — Application 12B.4: Treat a phase-modulation line as a line, not a density bin; Chapter 11 — Integrate the channel that actually produces the reported value.

V011-VOL-DISCUSSION-050 — A justified joint distribution and relevant covariance of phase differences, including deterministic components. RMS alone does not select the exact Gaussian finite-coherence law.

Review: Chapter 12 — Model 12B: finite-band jitter and coherent signal power; Chapter 9 — Define the ensemble before normalizing; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation.

V011-VOL-DISCUSSION-051 — The common factor preserves coherent-sum magnitude, but absolute and inter-record phase can vary. Define the target boundary and retain the shared reference relationship rather than infer universal synchronization.

Review: Chapter 12 — Application 12B.6: Distinguish a common random phase from lost coherent power; Chapter 14 — Frequency, phase, and delay require their own observables; Chapter 9 — Define the ensemble before normalizing.

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V011-VOL-DISCUSSION-052 — Shared nominal frequency is established, while relative timing and phase at the actual measurement boundary remain uncalibrated. Test simultaneous input and retain cable/converter/trigger contributions.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 10 — Source indices, stored offsets, and time anchors; Chapter 14 — Frequency, phase, and delay require their own observables.

V011-VOL-DISCUSSION-053 — Only with supported inter-record phase information or a new justified correction. Preserve individual power results and reset history; amplitude agreement does not establish complex continuity.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 12 — Accept coherence at the required boundary and state; Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-VOL-DISCUSSION-054 — Determine its offset, latency variation and clock relation to sampled apertures and the stimulus. Numerical timestamp precision does not by itself establish event-time accuracy.

Review: Chapter 12 — Model 12A: connect clock reading, frequency and phase; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 14 — Frequency, phase, and delay require their own observables.

V011-VOL-DISCUSSION-055 — Not necessarily; the fit may remove the phase error the calibration measures. Report coefficient, residual normalization and held-out scope alongside the unremoved phase result.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 12 — Accept coherence at the required boundary and state; Chapter 14 — Frequency, phase, and delay require their own observables.

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V011-VOL-DISCUSSION-056 — Recover numerator, denominator, selected symbol population and fit freedom, then express a common declared metric where supported. A lower percentage may be a normalization change rather than improved physical modulation.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 14 — Attach calibration to a stated measurement result; Chapter 16 — Write findings that preserve the strength and limit of each test.

V011-VOL-DISCUSSION-057 — The training result and validation failure with their states, fit choices and native records. Investigate alignment and applicability, and avoid representing fitted success as general receiver performance.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Interpret hypothetical receiver records; Chapter 16 — Close the receiver method through configuration-specific regression.

V011-VOL-DISCUSSION-058 — The outputs may share a false lock or stale interpretation; use independent valid/noise-only records, separate implementations and physical linkage. A duplicate display is not independent evidence of device function.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence; Chapter 16 — Findings, Reports, and Decision Ladders.

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V011-VOL-DISCUSSION-059 — Finite symbols, code rate, overhead populations, complete frames, repeated payload and wall duration. Distinguish nominal coded rate from actually delivered unique information and retain captured coverage.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Write findings that preserve the strength and limit of each test.

V011-VOL-DISCUSSION-060 — State active and full wall intervals separately, use actual delivered counts and duration weighting, and retain gaps/exclusions. The same bits can support different rates only with explicit denominators.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-VOL-DISCUSSION-061 — Apply declared integer frame and payload rules, identify padding or incomplete units and avoid fractional extrapolation without a model. Preserve event boundaries and actual retained data.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 15 — Verify the trigger at its actual signal-path location.

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V011-VOL-DISCUSSION-062 — Identify payload positions, deduplicate overlaps and retransmissions, and retain channel-specific evidence separately. Multiple observations can strengthen verification without increasing unique information count.

Review: Chapter 7 — Model 7B: finite rate accounting for symbols, coding and payload; Chapter 16 — Reconcile evidence without assigning unsupported probabilities; Chapter 15 — Bind sample continuity, storage accounting and derived results.

V011-VOL-DISCUSSION-063 — Trace absolute timing, NCO phase and phase-difference intervals, compare against the original native sequence and a known reference. Do not assign the shift to source motion until processing continuity is validated.

Review: Chapter 10 — Gap representations, phase, and the limits of timing claims; Chapter 6 — Model 6B: phase is the quantity that frequency differentiates; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-VOL-DISCUSSION-064 — Use actual load/bias/environment states, independent output and desired references, and selective cable or power interventions. Treat instability, pickup and leakage as alternatives rather than declare a unique oscillation from one line.

Review: Chapter 13 — Remote amplification requires electrical and installed checks; Chapter 11 — Distinguish strong-signal mechanisms through paired interventions; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-DISCUSSION-065 — The feature is sensitive to that combined intervention; supply noise and conductive coupling remain alternatives. Preserve reference capability and design a more selective follow-up before naming the cause.

Review: Chapter 13 — Remote amplification requires electrical and installed checks; Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 16 — Receiver challenges with interacting controls.

V011-VOL-DISCUSSION-066 — Verify that the altered path can capture the same event duration and spectrum with adequate sensitivity and timing. If not, retain an inconclusive negative comparison instead of unique coupling attribution.

Review: Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 16 — Preserve comparable observation capability.

V011-VOL-DISCUSSION-067 — The voltage and impedance convention, available versus delivered quantity and receiver/path correction. Apply only the supported conversion and propagate its uncertainty; a nominal factor-two example is not a universal mismatch repair.

Review: Chapter 13 — Keep field conversion separate from terminal power; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Attach calibration to a stated measurement result.

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V011-VOL-DISCUSSION-068 — Retain measured terminal quantities and identify the unsupported field model; obtain geometry-appropriate characterization for stronger field claims. Receiver calibration alone does not establish the local electric/magnetic relation.

Review: Chapter 13 — Keep field conversion separate from terminal power; Chapter 14 — Attach calibration to a stated measurement result; Chapter 16 — Findings, Reports, and Decision Ladders.

V011-VOL-DISCUSSION-069 — The consequential multiport state and impedance-dependent transfer/noise response, with appropriate characterization. An independent matched two-port sum is insufficient if the branch visibly affects the result.

Review: Chapter 13 — Treat connections and unused branches as part of the network; Chapter 2 — Model 2B: a matched, fixed-state noise cascade; Chapter 14 — Calibrate noise without confusing it with detection.

V011-VOL-DISCUSSION-070 — The conducted transfer may remain supported while installed geometry/common-mode conversion is unresolved. Preserve both scopes and selective reference tests rather than blame the receiver or external field uniquely.

Review: Chapter 13 — A constructed acceptance case for the assembled chain; Chapter 13 — Separate the intended coaxial path from installed coupling; Chapter 16 — Localize an artifact by changing the stage that could create it.

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V011-VOL-DISCUSSION-071 — Reconstruct a physically admissible joint dependency model with units and positive semidefiniteness. Simulation or a favorable final total cannot legitimize an inconsistent covariance description.

Review: Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 12 — Application 12B.5: Include covariance when combining timing contributions.

V011-VOL-DISCUSSION-072 — Identify a common calibration floor or other nonreducible contribution and improve its characterization if relevant. Retain the reading model and predeclared decision rather than assume all terms shrink with count.

Review: Chapter 14 — Application 14B.8: identify the uncertainty that averaging cannot remove; Chapter 9 — Averaging and Statistical Stability; Chapter 14 — Declare the decision rule before seeing the result.

V011-VOL-DISCUSSION-073 — Indeterminate, with the factor, uncertainty model and rule preserved. Explain legitimate follow-up on dominant terms and avoid changing the limit or calling overlap proof of exceedance.

Review: Chapter 14 — Declare the decision rule before seeing the result; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-VOL-DISCUSSION-074 — The central value no longer uses the available correction and may change the decision improperly. Apply the supported offset, retain its uncertainty and verify sign/plane implementation independently.

Review: Chapter 14 — Use covariance and model sensitivity deliberately; Chapter 14 — Build a correction chain with signs that can be checked; Chapter 1 — Model 1A: configured transfer, correction and recoverability.

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V011-VOL-DISCUSSION-075 — No; fix the configuration identity and recompute with applicable characterization. An uncertainty budget describes supported inputs, not a license to use the wrong physical path.

Review: Chapter 13 — Define a complete path at named planes; Chapter 14 — Attach calibration to a stated measurement result; Chapter 10 — Separate signed artifacts from operating configurations.

V011-VOL-DISCUSSION-076 — Coverage of a measured quantity, capture/detection performance and attribution/authorization are separate claims. Require their own models and evidence, and use the supported finding category without transferring a percentage.

Review: Chapter 14 — Declare the decision rule before seeing the result; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows; Chapter 16 — Findings, Reports, and Decision Ladders.

V011-VOL-DISCUSSION-077 — The interval until the required weak-signal function is demonstrably recovered, with relevant control/filter/trigger behavior. Survival does not establish valid observation opportunity.

Review: Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Model 15A: calculate conditional event coverage from usable windows.

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V011-VOL-DISCUSSION-078 — Establish whether acquisition was continuous; preserve the unfolded interval and filter/index history before applying the contiguous criterion. A coordinate or storage boundary need not be a physical gap.

Review: Chapter 15 — Application 15A.8: Preserve one contiguous window across the period origin; Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 12 — Model 12A: connect clock reading, frequency and phase.

V011-VOL-DISCUSSION-079 — Use the union of eligible phases, counting each event start once, while retaining the single-record contiguous criterion. Do not confuse overlapping opportunity sets with summing disconnected waveform pieces.

Review: Chapter 15 — Application 15A.6: Take the union of overlapping capture-start sets; Chapter 9 — Estimator Validation and Reporting.

V011-VOL-DISCUSSION-080 — Only with an actual justified independent phase experiment; otherwise use deterministic or joint timing analysis. Distinguish event count from new opportunity and preserve the true schedule.

Review: Chapter 15 — Application 15A.7: Keep a deterministic repeated miss deterministic; Chapter 8 — Interpret a swept trace through its frequency-time trajectory; Chapter 16 — Record repetition and the limits of the design.

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V011-VOL-DISCUSSION-081 — State the demonstrated rearm/holdoff limitation, test controlled separations and incorporate unusable intervals into coverage. The isolated pass does not establish unrestricted burst performance.

Review: Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 5 — Verify the detector and control path as part of the IF result; Chapter 16 — Preserve comparable observation capability.

V011-VOL-DISCUSSION-082 — Only where their state and validity are supported. Retain transition timestamps and flags, distinguish comparable context from invalid samples and avoid applying settled corrections across the change.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 5 — Model 5A: an identified one-pole gain-control response; Chapter 15 — Verify the trigger at its actual signal-path location.

V011-VOL-DISCUSSION-083 — Test both paths with the intended event, map bandwidth and latency and verify actual retained samples. Presence in the recorder representation does not guarantee the trigger will initiate preservation.

Review: Chapter 10 — Model 10B for digital mixing filtering and decimation; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 16 — Preserve comparable observation capability.

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V011-VOL-DISCUSSION-084 — Preserve calibrated desired references and separately vary meaningful clock/route states, including reversals. Shared cause is plausible, but changed sensitivity or phase state must be distinguished.

Review: Chapter 12 — Accept coherence at the required boundary and state; Chapter 16 — Arrange the comparisons before examining their outcomes; Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-VOL-DISCUSSION-085 — A bounded temporal correlation with stated clocks and direct observables. Test shared measurement paths and establish physical/operational RF linkage before claiming a transmitter or surveillance function.

Review: Chapter 15 — Metadata, Time, and Site Context; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence; Chapter 16 — Findings, Reports, and Decision Ladders.

V011-VOL-DISCUSSION-086 — Not without an explicit justified model; retain the missing contrast and its limitation. Obtain a meaningful alternative where feasible and avoid treating an incomplete design as proof of component causation.

Review: Chapter 16 — Arrange the comparisons before examining their outcomes; Chapter 12 — Accept coherence at the required boundary and state.

V011-VOL-DISCUSSION-087 — Record the actual physical/processing bundle and characterize each state, using event-appropriate capability references. The front-panel label does not isolate a single causal mechanism.

Review: Chapter 16 — Receiver challenges with interacting controls; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 5 — Verify the detector and control path as part of the IF result.

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V011-VOL-DISCUSSION-088 — Retain run order and source state, block or cross relevant gain comparisons within comparable intervals where possible, and report missing contrasts. Repetition alone cannot separate gain from source-time effects.

Review: Chapter 16 — Record repetition and the limits of the design; Chapter 3 — Choose gain from a feasible interval; Chapter 15 — Metadata, Time, and Site Context.

V011-VOL-DISCUSSION-089 — Label them as derived analyses sharing the same acquisition, then obtain fresh physical-state repetitions for the intervention. Preserve overlapping-sample dependence in any statistical claim.

Review: Chapter 9 — Averaging and Statistical Stability; Chapter 15 — Reproducible Analysis and Derived Products; Chapter 16 — Record repetition and the limits of the design.

V011-VOL-DISCUSSION-090 — Performance beyond those fitted examples. Use independently retained reference and noise-only records, disclose selection and retain the earlier outputs rather than presenting training cleanup as universal validation.

Review: Chapter 7 — Model 7A: a finite, declared EVM comparison; Chapter 16 — Interpret hypothetical receiver records; Chapter 15 — Reproducible Analysis and Derived Products.

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V011-VOL-DISCUSSION-091 — Formal asymptote intersection, actual compression/validity range, parent convention and hardware exposure limits. Use appropriate stage and system tests; an extrapolation is not a survivability specification.

Review: Chapter 11 — Construct the intercept from the linear asymptote; Chapter 3 — Measure protection in the small-signal and recovery states; Chapter 3 — Choose gain from a feasible interval.

V011-VOL-DISCUSSION-092 — Retain the actual unequal-parent cubic amplitude dependence and stage conditions rather than transfer a simultaneous equal-tone slope. Check source contamination and desired response during the challenge.

Review: Chapter 11 — Derive the retained spectral amplitudes; Chapter 11 — Construct the intercept from the linear asymptote; Chapter 16 — Localize an artifact by changing the stage that could create it.

V011-VOL-DISCUSSION-093 — Source sidebands, direct leakage, baseline drift and gain-control changes can contribute. Preserve fixed channel calibration and desired gain, characterize admitted spectrum and test the weighted reciprocal-mixing prediction.

Review: Chapter 11 — Integrate the channel that actually produces the reported value; Chapter 11 — Distinguish strong-signal mechanisms through paired interventions; Chapter 12 — Model 12B: finite-band jitter and coherent signal power.

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V011-VOL-DISCUSSION-094 — The uncontaminated product may approach zero under coherent cancellation, so the inferred upper intercept can be unbounded within that observation model. Retain phasor/domain limits and seek better source characterization.

Review: Chapter 11 — Ten worked applications of Model 11A; Chapter 14 — Model 14B: exact covariance and local uncertainty propagation; Chapter 16 — Write findings that preserve the strength and limit of each test.

V011-VOL-DISCUSSION-095 — Only the bound artifact identity, not correct deployed behavior. Restore the intended state, calibration and parameters, then run relevant reference and regression checks.

Review: Chapter 10 — Separate signed artifacts from operating configurations; Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 16 — Close the receiver method through configuration-specific regression.

V011-VOL-DISCUSSION-096 — Only the tested functions until configuration-specific checks establish the deployed method's needs. Preserve the prior accepted state and explicitly retain the unverified capabilities.

Review: Chapter 10 — A continuity condition for finite filtering and decimation; Chapter 15 — Verify the trigger at its actual signal-path location; Chapter 16 — Close the receiver method through configuration-specific regression.

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V011-VOL-DISCUSSION-097 — Use known change times and last valid checks to identify affected functions and intervals, preserve all records and investigate a supported correction or narrower claim. Do not overwrite the earlier state with the latest correction automatically.

Review: Chapter 13 — Integrated Path Acceptance; Chapter 14 — Close the calibration record across the working interval; Chapter 16 — Reconcile evidence without assigning unsupported probabilities.

V011-VOL-DISCUSSION-098 — Preserve records needed for the authorized purpose and verification with appropriate access controls, minimize unnecessary content under the declared policy and document migration/deletion. Derived images must not silently replace essential native evidence.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 15 — Coverage Review and Storage Governance; Chapter 15 — Reproducible Analysis and Derived Products.

V011-VOL-DISCUSSION-099 — Separate unresolved classification from authorization and functional linkage, preserve the measurement and pursue operational or physical evidence. Technical capability or unfamiliarity does not establish the stronger category.

Review: Chapter 1 — Define the measurement before choosing the receiver mode; Chapter 16 — Findings, Reports, and Decision Ladders; Chapter 16 — Integration with Direction, Wireline, Optical, and Physical Evidence.

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V011-VOL-DISCUSSION-100 — The configured quantity and planes, valid native data, signed corrections, normalization, uncertainty, timing/coverage, challenges and supported inference. Preserve failed tests and old/new processing states so a later correction can narrow the conclusion without rewriting observations.

Review: Chapter 1 — Model 1A: configured transfer, correction and recoverability; Chapter 14 — Close the calibration record across the working interval; Chapter 15 — Bind sample continuity, storage accounting and derived results; Chapter 16 — Close the receiver method through configuration-specific regression.

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Volume Glossary

ABSOLUTE-FREQUENCY CUSP: The change of slope produced when a signed conversion product passes through zero and its displayed frequency is represented by an absolute value. The signed trajectory can remain linear while the nonnegative trajectory has two branches. Endpoint changes must be calculated from the absolute values or the appropriate piecewise map; one local slope cannot be extended across the crossing.

ABSOLUTELY CONTINUOUS PHASE: A phase trajectory whose change over the interval is recovered by integrating its almost-everywhere derivative. This condition supports the equality between finite-interval phase change and average instantaneous frequency. A discrete phase reset must split the analysis; merely choosing an unwrapped display does not establish the required trajectory.

ABSOLUTE SAMPLE INDEX: Integer identity of a sampling event within a declared source segment, distinct from its retained file position.

ACCEPTANCE CASE: A bounded technical argument that a declared configuration satisfies specified applicable requirements using identified evidence and decision rules.

ACCUMULATOR: The arithmetic storage and update operation that combines successive products or terms into a sum. Its required width depends on the signed input and coefficient ranges and the actual accumulation path. A final in-range result does not establish that every intermediate sum avoided saturation or modular overflow.

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ACQUISITION-CONDITIONED METRIC: A result calculated only on intervals for which the receiver met its declared acquisition or lock criterion. It describes that selected population and must be accompanied by attempted acquisitions, failures and exclusions when the complete event matters. It does not establish uninterrupted reception during omitted intervals.

ACQUISITION INTERVAL: The declared span of physical time during which observations are eligible to contribute to a measurement. Its usable portion may exclude transitions, failed captures, or invalid states; a file's existence alone does not establish continuous valid coverage.

ACTIVE SYMBOL RATE: The rate of transmitted symbol instances during a declared active interval, determined from their spacing or count under the stated clock convention. It can differ from the average number of transmitted data symbols per second over an interval that also includes guards or idle time. A nominal accounting grid must be identified separately.

ACTUAL STATE: The receiver configuration supported by status and observation evidence for a particular record interval. It may differ from the commanded state because of rejection, settling, automatic control, or other changes that affect the measurement.

ADAPTIVE CONTROL: A mechanism that changes a receiver or processing state in response to input or operating conditions. Its effect must be retained in configuration identity when it alters gain, validity, timing, or another part of the measurement law.

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ADDITIVE-POWER MODEL: A model in which mean powers of specified contributions can be added because their relevant mean cross-power vanishes under the declared observation. The premise concerns their relationship and averaging operation. Merely describing one component as noise, or recording two separate levels, does not establish it.

ADDITIVE WHITE GAUSSIAN NOISE: A noise model combining addition to the signal, Gaussian amplitude statistics and a flat spectral-density assumption over the modeled domain. It is an explicit premise of the chapter's matched-filter optimum. It does not describe every interferer, nonlinear receiver artifact or frequency-selective propagation effect.

ADJACENT-CHANNEL POWER: Power evaluated in a specified neighboring frequency channel under a declared integration bandwidth, reference and detector procedure. It concerns spectral occupancy outside the selected channel rather than the correctness of recovered symbols. Coding margin can improve data recovery without reducing that emitted power.

ADJUSTMENT: An intervention intended to change a measuring system's response to the required relation. It is distinct from calibration, which establishes a relationship and its uncertainty, and verification, which checks a stated requirement. A changed response can require new characterization before previous corrections or uncertainty statements are used.

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ADMISSIBLE RESULT SET: The set of results permitted by the supplied inputs, discrete alternatives and constraints. Model 7B applies this concept to rates under count, duration and format premises. Discrete alternatives combined with bounded continuous factors can produce separated intervals; an overall minimum-to-maximum enclosure may include values no admitted state realizes. Retain the union when its gaps matter. A midpoint, equal state probabilities or another weighting requires additional evidence.

ADMITTED ANALOG BAND: The set of input frequencies allowed by an explicitly justified front-end and signal-class specification before sampling.

ADMITTED BLOCKER POWER: The power of a specified interfering carrier at the conversion-stage input after preceding gain, loss, and frequency selection, at a declared reference plane.

ADMITTED RF BAND: The physical RF-frequency region that can influence a selected receiver path under its actual filter and switching state. It may extend beyond the displayed span, and weak skirt transmission can matter for a strong input. A nominal bandwidth label does not define a perfect exclusion boundary. Conversion claims therefore combine the frequency map with an applicable measured transfer or stated admission threshold.

AFFINE MEASUREMENT FUNCTION: A measurement relation consisting of a constant plus a fixed linear combination of the input quantities. Its output mean and variance follow exactly from the input mean and covariance when the required second moments exist. Neither independence nor normality is required for that identity; the coefficients retain their signs and units.

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AFFINE UNCERTAINTY PROPAGATION: Exact evaluation of output variance for a fixed affine measurement function from finite input second moments and their covariance.

AGGREGATE INPUT POWER: The combined power presented by all relevant admitted components at a specified stage input. Mean powers can be summed when the applicable cross-power terms vanish under the defined averaging or ensemble convention. The aggregate mean does not by itself establish peak voltage, crest behavior, or the nonlinear products generated by several strong signals.

ALIASING: Indistinguishable mapping of spectral components caused by sampling without adequate band limitation or by intentional zone translation.

ALIGNMENT TRAINING SET: The disclosed samples or symbols used to estimate the corrections applied before an error-vector evaluation.

AMPLITUDE MODULATION: A representation in which a message changes the amplitude of a carrier-related waveform. Conventional AM in Model 6A uses a positive carrier term and a real normalized message. A magnitude envelope preserves that signed relationship only while the nonnegative-envelope condition and the applicable receiver transfer hold.

AMPLITUDE SPECTRAL DENSITY: The nonnegative square root of a power-like spectral density, expressed in amplitude units per square root of hertz. It is a density representation rather than the amplitude of an isolated spectral line. Integrating it directly as though it were mean-square density would use the wrong operation and units.

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ANALOG MODULATION: Variation of a carrier or pulse parameter according to a continuously represented message. Amplitude, frequency, phase and pulse behavior provide different observation quantities. Their measured structure can support waveform classification, but does not by itself identify the transmitter, recover its content reliably or establish its purpose.

ANALOG MULTIPLIER: A device or mathematical model whose output is proportional to the product of its input quantities within a stated range. The proportionality and input normalization determine the selected mixing-product amplitude. Model 4A explicitly fixes that scaling; its ideal multiplier is not automatically an energy-validated passive mixer circuit.

ANALOG-TO-DIGITAL CONVERTER: A device that maps an analog input into a finite digital code representation. In the sampled receiver, its code range, sampling behavior, input bandwidth, distortion and clock conditions affect the resulting record. A nominal bit count describes a representation capacity; it does not establish the measured accuracy or dynamic range of the complete receiver.

ANALYSIS CHANNELIZER: A bank that filters one sampled input into several indexed output streams with specified frequency translation and sample retention.

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ANALYTIC SIGNAL: A complex representation of a real signal that retains its positive-frequency content with the corresponding amplitude convention and removes the redundant negative-frequency conjugate content. In Model 4A the admitted translated envelope must remain at positive physical RF frequency. Its complex magnitude and the real waveform's average loaded power require their declared normalization; they must not be interchanged without that convention.

ANGULAR FREQUENCY: The rate of phase rotation expressed in radians per unit time. It equals ordinary frequency in cycles per unit time multiplied by the angle of one full turn. The conversion factor must be retained when differentiating phase to obtain a frequency in hertz.

ANTENNA FACTOR: Frequency-dependent relationship used to convert antenna-terminal voltage to incident electric-field strength under stated conditions.

ANTENNA PATTERN: The directional variation of an antenna's response at a specified frequency, polarization and installation. A change in received level after rotation can reflect this response rather than changed source power. Comparisons require the relevant orientation and mounting geometry.

ANTENNA TERMINAL PLANE: The declared electrical boundary between an antenna and the receiving path. A conducted reference applied there can test the downstream chain under the stated loading. It does not by itself characterize the antenna's conversion from an incident field, which also depends on direction, polarization, geometry and environment.

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ANTI-ALIAS FILTER: A filter placed before a sampling or sample-rate-reduction boundary to attenuate components that would otherwise become indistinguishable in the retained band. Its needed rejection follows the admitted unwanted signals and actual folding paths. A later filter cannot separate contributions already combined at the same retained frequency.

APERTURE DELAY: The timing displacement associated with when a converter actually samples its input relative to the declared timing reference. Unequal channel apertures contribute to relative timing alongside analog paths and digital processing. A calibration of a convenient clock connector does not automatically measure this acquisition-boundary contribution.

APERTURE JITTER: Variation of the converter's actual sampling delay from one acquisition event to another. It is distinct from a fixed aperture delay and from a known channel offset. Because the resulting voltage error depends on input slope, its significance changes with waveform and frequency; other clock and timing contributions retain their own covariance.

APPLICABILITY RATIONALE: The technical explanation establishing whether a criterion belongs to a declared acceptance case; an unknown relationship remains unresolved.

ARCHITECTURE MAP: A representation placing plausible mechanisms and accessible controls at their locations in the measurement chain. It supports predictions about how a controlled change should affect a candidate cause. A front-panel setting is not a causal location by itself, especially when the setting changes several paths or states together.

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ARITHMETIC MEAN: The sum of the selected numerical values divided by their count when equal weighting is intended. Applied to calibrated powers, it preserves a linear-power population interpretation. Taking its logarithm afterward generally differs from averaging the separately transformed logarithmic values.

ARITHMETIC OVERFLOW: A condition in which an exact arithmetic value lies outside the range allocated to its numerical representation. Saturation and modular wrap are different responses to that condition. Later scaling can conceal an earlier overflow in the displayed range without recovering the information lost at the affected intermediate operation.

ARTIFACT: A feature introduced by the measurement apparatus or processing that can resemble a component of the environment. The term identifies an explanatory possibility or supported finding; it does not by itself identify every responsible circuit or coupling path.

ARTIFACT RECORD: A reusable account of a demonstrated measurement artifact, including its affected configurations, stimulus or transition, predicted and observed response, challenge evidence and accepted mitigation. Its scope remains the tested conditions. A single incident should not become a universal rule about other receivers or environments without additional evidence.

ARTIFACT TAXONOMY: An organized inventory of mechanisms that could produce an observed indication through the receiver, installed path or environment. Its purpose is to generate competing explanations and discriminating tests. Membership in a familiar category does not identify the cause of a particular observation without supporting architecture and challenge evidence.

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ASSEMBLY RECORD: Identification and order of the physical components, connections, and terminations that form a measurement path.

ASSOCIATIVITY: The algebraic property that regrouping an operation does not change its result. Exact addition has this property, but an implementation that rounds or saturates intermediate results need not preserve it. The chapter's three-product example therefore specifies the actual grouping when comparing finite-word and exact arithmetic.

ASYMPTOTIC LIMIT: A value approached as a model parameter tends toward a limiting regime, without necessarily being attained at a finite setting. The two-stage noise model approaches the first stage's temperature as its gain increases. With positive later-stage noise, equality to that limit cannot be obtained by a finite gain.

ATTACK TIME CONSTANT: The positive time constant identified for a specified control response following an input change that calls for gain reduction. In Model 5A it describes one applicable exponential segment, with a calibrated gain polarity and declared target. It does not include an unmodeled detector delay, slew limit or hold rule, and it need not equal the release constant.

ATTENUATOR: A component that reduces signal level by a specified transfer under stated frequency, impedance and operating conditions. Its placement determines which later stages receive protection and which noise penalties enter the input budget. Correcting the reported level for attenuation does not undo the physical loss or restore an overloaded earlier stage.

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ATTRIBUTION: An evidence-supported connection between an observed component and a physical emitter or system. It requires more than detection or a waveform-family label and must retain the assumptions and alternative explanations relevant to that connection. Distinguish a link to a physical device or its operation from temporal association, localization, authorization status and confirmation of an information path or surveillance function. A plausible identifier alone does not supply these additional conclusions.

AUTOCOVARIANCE: The covariance of one process evaluated at two observation indices or times, with centering and complex-conjugation convention stated. It describes dependence within that process. A colored autocovariance changes expected spectral ordinates even when integrated mean-square closure remains correct.

AUTOMATIC GAIN CONTROL: Feedback or feedforward process that changes receiver gain according to detected level or state.

AUTOSPECTRUM: A spectral estimate formed from weighted squared magnitudes of a channel's Fourier coefficients. Its units follow the measured quantity and density normalization. The chapter's coherence ratio requires both autospectra to be positive and to use the same paired record population and compatible weighting as the cross-spectrum.

AVAILABLE NOISE POWER: Noise power that a source can supply under the specified matching condition. In the chapter's classical thermal model it is kBT_s, where k is the Boltzmann constant in joules per kelvin, B is equivalent noise bandwidth in hertz, and T_s is source noise temperature in kelvins. It is a source quantity at a declared plane and differs from the power actually accepted by a mismatched receiver.

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AVAILABLE SOURCE POWER: The power a source could supply under its specified matching condition, distinguished from the power actually delivered to a particular connected load. A mixer specification stated using available input power cannot automatically be substituted for the chapter's ratio of loaded sinusoidal powers at positive real resistances. The source, load, matching, and selected output conventions must be reconciled before comparing the quantities. The ideal effective-aperture relation in Chapter 13 also uses available power for its stated receiving-antenna conditions. It does not establish power delivered to an arbitrary installed load or coupling path.

AVERAGE OF LOGARITHMIC POWERS: The arithmetic mean of calibrated power levels after each sample has been converted to logarithmic units. It estimates a different statistic from the logarithm of an arithmetic power mean. Under the chapter's single exponential noise-power model, its decibel expectation has a fixed offset that additional independent averaging does not remove.

BAND-LIMITED PHASE VARIANCE: The phase variance contributed by a stated finite set of offset bands and line measures under an explicit spectral normalization.

BAND-PASS FILTER: A filter that preferentially transmits a bounded frequency band while rejecting frequencies on either side under the stated response specification. It can admit the displayed desired band while suppressing remote parents of an internally generated product. That interpretation requires verified desired transfer and source-path controls.

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BANDWIDTH: The frequency extent associated with an admitted path or reported measurement. Its precise definition must accompany the result because a nominal setting does not by itself identify the energy, filtering, or estimator represented by the indication.

BASEBAND: The frequency region used to represent a signal after its carrier reference has been removed or translated near zero. A complex baseband record can distinguish positive from negative offsets under its declared convention. A real magnitude-only display can discard that distinction and leave two different RF inputs compatible with the same peak.

BIAS CURRENT: The current associated with establishing or maintaining an active component's operating state. Its value and supply path can affect gain, stability and recovery. A receiver's RF configuration is therefore incomplete when the relevant bias state is unknown or changes between the compared observations.

BIAS DELIVERY: The actual supply path and operating state used to power a remote active component. Cable resistance, protection elements and coupling to other equipment can make the remote condition differ from the source-terminal indication. Record the feed arrangement and available monitoring rather than inferring the amplifier's state from supply voltage alone.

BIAS TEE: Network combining or separating direct-current power and RF on a common conductor.

BINARY POINT SCALING: Representation in which an integer code is multiplied by a stated power of two; the fractional-bit count fixes the code step.

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BIN-CENTERED TONE: A tone aligned with an integer-frequency component of the declared finite record under the model's sampling convention. Its complex transform at that bin is related to the coherent sum of the window weights. Real-tone amplitude recovery also requires the stated negative-frequency image condition and special treatment at the endpoints.

BIT: A binary digit whose counted role must be stated in a reception result. Coded label bits, information bits, payload instances and unique delivered payload positions belong to different populations. Their numerical counts can differ even when they describe the same transmission interval.

BIT ERROR RATE: The fraction or modeled probability of incorrectly recovered bits under a stated comparison rule and operating condition. A measured fraction requires a known bit reference, denominator and interval. Geometric EVM does not supply it without an additional justified channel, decision and coding model.

BIT RATE: A specified count of bits divided by the time interval to which the count belongs. The population may be coded, information, represented payload or unique delivered payload. A rate without those labels can confuse coding, overhead and duplication with actual changes in the transmission.

BLANKING: A deliberate exclusion or suppression of observations during specified intervals, such as a known disturbance. Its timing and affected path must be retained because excluded data do not establish signal absence. Blanking can aid a controlled comparison but cannot restore an event that never entered the usable observation window.

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BLINDING: A design measure that limits access to information capable of influencing a comparison or interpretation before the relevant observations or decisions are recorded. It can reduce confirmation bias when feasible. Its role and restrictions must be documented; merely calling a test blinded does not establish independent observations or comparable receiver states.

BLOCKER: An interfering signal whose admission can impair observation of a desired signal. Its effects may involve loading, gain control, intermodulation, reciprocal mixing or direct spectral overlap. The blocker's own frequency-dependent path and incident waveform must be tracked separately from the desired-signal correction.

BLOCKER OFFSET: The signed frequency separation between an admitted interfering carrier and the declared desired-channel center. Model 11B uses it to identify which oscillator phase-noise frequencies enter the weighted channel. An even phase spectrum does not make positive and negative blocker offsets interchangeable when the observation filter is asymmetric.

BLOCKER-SOURCE NOISE: Noise carried by the applied interfering source into the desired observation channel or another relevant admitted region. It can produce a measured noise rise without requiring the proposed receiver mechanism. A reciprocal-mixing interpretation therefore needs this contribution bounded or accounted for under the same source, frequency, and path conditions.

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BLOCKER-TO-DESIRED TRANSFER RATIO: The ratio of preceding power transfer at the blocker frequency to that at the desired-signal reference frequency. It determines the selective change in an internally generated blocker contribution when referred to the desired external input. Blocker attenuation alone omits desired-path loss, and the ratio alone does not establish the change in total sensitivity.

BLOCKER TRANSFER: Frequency-specific gain or loss connecting an external interfering signal to a vulnerable receiver stage.

BLOCKER-TRANSFER VERIFICATION: Characterization of the interfering-signal levels admitted up to the vulnerable stages under the stated assembly and state. It complements desired-signal transfer because a narrow downstream channel does not protect every earlier component. Retaining the desired reference during a blocker challenge helps distinguish changed gain from a raised noise contribution.

BLOCKING: Loss of sensitivity or accuracy caused by a strong signal outside or beside the desired channel.

BOLTZMANN CONSTANT: The physical constant that converts absolute temperature to the thermal energy scale used in the classical noise model. Its unit is joules per kelvin. Multiplication by noise temperature and bandwidth in inverse seconds gives power in watts; this dimensional relation does not supply the missing matching or bandwidth assumptions.

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BUFFER OVERFLOW: A data-path condition in which pending data exceed the capacity or service capability of an intermediate receive or recording buffer. Its status can indicate a continuity problem but does not alone identify the exact missing source indices. The complete recording path and workload must be exercised to support a loss-free interval claim.

BUILD ATTESTATION: A verifiable statement associating an output artifact with claims about its build, such as builder, source and parameters. Its subject must match the examined artifact and its claims must satisfy the stated expectations. An authentic statement can describe a build that the receiver's acceptance policy does not permit.

BYTE ORDER: The ordering of the constituent bytes of a multibyte numerical representation. A reader must use the declared order together with the correct signed-code convention. The chapter's asymmetric integer test exposes a byte-order mismatch that zero-only data and a successful software installation would not reveal.

CALIBRATED CONTROL INTERVAL: The voltage range over which a specified control-to-gain relationship is supported by calibration and applicable operating conditions. A model trajectory used for gain prediction must remain inside this interval or be segmented under separately justified mappings. Mathematical monotonicity of voltage does not validate gain extrapolation beyond the measured range.

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CALIBRATED NOISE SOURCE: A reference source whose relevant noise temperatures or excess-noise-ratio relation have been characterized for stated conditions. Its calibration plane and convention must be retained. Loss between that plane and the receiver alters the effective hot and cold temperatures, so the source certificate alone does not characterize the installed connection.

CALIBRATION: An operation establishing, under specified conditions, the relationship between reference values and indications with their associated uncertainties, enabling a measurement result to be obtained from an indication. It is distinct from changing instrument settings or checking a requirement. Its relevance depends on the particular quantity, state, range and reference plane being reported.

CALIBRATION APPLICABILITY: The conditions under which existing calibration information supports a particular measurement result. A changed path, gain state, detector, software process, or reference plane can require reassessment even when the instrument still carries a valid certificate.

CALIBRATION CERTIFICATE: The record of a calibration's identified instrument or system, conditions, references, results and uncertainties. It provides evidence to be interpreted within its stated scope. Possession of the certificate does not establish that a different accessory assembly, firmware state or measurement quantity was covered, or that the configuration remained unchanged afterward.

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CALIBRATION CHANGE CONTROL: The identification and evaluation of changes that may invalidate a correction or its uncertainty statement. Firmware, processing, accessories, reference planes, gain states and remote power arrangements can alter applicability. Evidence about the affected quantities determines whether targeted recharacterization suffices; an unchanged certificate or successful self-test is not enough by itself.

CALIBRATION ERROR ENVELOPE: A justified deterministic bound on accumulated time or phase error over a declared interval after calibration.

CALIBRATION HIERARCHY: The ordered sequence of calibrations connecting a reference to a final measuring system, with each stage depending on preceding calibration results. It describes the structure supporting a traceability claim. The uncertainty and applicability of each stage must reach the final result; the receiver's physical signal-chain order need not be the same sequence.

CALIBRATION INTERVAL: The elapsed interval over which a declared error criterion remains satisfied under justified initial-error, frequency-error and drift bounds. Model 12A compares their accumulated envelope with a carrier-dependent phase tolerance. The admissible interval can be zero, finite or unrestricted within the assumed model; a schedule alone does not establish those bounds.

CALIBRATION SCOPE: Quantities, ranges, states, reference planes, and conditions for which calibration results and uncertainties apply. An adapter already included in an antenna calibration must not be corrected a second time. A field cable beyond the calibrated receiver connector remains outside that receiver calibration and needs its own justified treatment.

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CANDIDATE SPUR LATTICE: A bounded set of integer parent-frequency combinations used to test possible product locations without predicting their amplitudes.

CAPTURE EFFECT: Tendency of an FM receiver to favor the stronger of two signals within its passband.

CAPTURE FEASIBILITY: The existence of an event start that can satisfy the declared capture criterion under the model's domain. For one contiguous window, the positive required overlap cannot exceed the event or window duration. An impossible criterion produces zero probability before any averaging over start phases is considered.

CARRIER: The declared oscillatory reference around which a modulated waveform is represented. Its frequency and amplitude conventions determine the interpretation of sidebands and envelope quantities. A carrier reference can remain part of the signal model even when the corresponding discrete carrier component is suppressed in the transmitted waveform.

CARRIER ACQUISITION: The initial process of bringing carrier estimates into a usable relationship with the received signal. Its success and duration depend on the declared search range, reference structure and receiver settings. Excluding this interval from a settled metric does not remove its consequence for short-burst reception.

CARRIER PHASE: The angular position of a carrier relative to the declared time and phase reference. In the real conversion model, the RF and oscillator phases combine differently for the sum and difference products. High-side representation at positive IF also reverses the difference-phase sign, which matters to later coherent comparisons.

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CARRIER PHASE AMBIGUITY: An unresolved choice among carrier-phase alignments that can preserve the apparent constellation point set while changing the association between points and intended labels. A tight fitted constellation does not resolve the ambiguity. Known reference structure or another justified check must establish the required mapping.

CARRIER POWER: The average power associated with the specified unmodulated carrier component at a declared reference plane. Under Model 6A's peak-voltage convention it is carrier peak squared divided by twice the positive real load resistance. Sideband powers, total average power and peak envelope power are separate quantities.

CARRIER REINSERTION: The introduction of a local carrier reference for coherent recovery of a suppressed-carrier or single-sideband signal. Its frequency and phase determine the recovered baseband orientation and projection. An adjustment made by ear is a processing choice; it does not independently calibrate the original RF frequency.

CARRIER STORAGE: Retention of excess charge carriers in a semiconductor after they are introduced by a large event or bias condition. In the chapter's PIN-limiter explanation, stored charge changes RF resistance and its removal contributes to recovery. This qualitative mechanism does not supply a universal numerical recovery time for an arbitrary mounted network.

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CARRIER SYNCHRONIZATION: The estimation and tracking of the frequency and phase relationship needed to compare an observed modulated signal with its declared carrier reference. Its acquisition range, loop behavior, fitted parameters and slips affect the symbol experiment. Successful numerical alignment does not by itself establish source identity or correct symbol labels.

CARRIER TRACKING: Continued adjustment of an acquired carrier estimate as the received frequency or phase changes. Tracking quality depends on loop settings, residuals and slips across the actual interval. A stable-looking selected constellation does not establish successful tracking throughout an unexamined capture.

CARSON BANDWIDTH ESTIMATE: The engineering estimate twice the sum of peak frequency deviation and the highest declared modulating frequency, without an automatic exact-containment or filter-distortion claim.

CARTESIAN PRODUCT DOMAIN: An allowed input set in which every combination of the stated component intervals is admitted. It supports the chapter’s rectangular worst-case searches and corner extrema when the response is suitably monotone or affine. The construction assigns no probability distribution and is not a statement of statistical independence.

CASCADED CONVERSION BRANCH: A particular sequence of selected sum or difference choices and sign regions through a receiver’s conversion stages. The chapter’s first-order real-difference orientation rule applies to a fixed sequence of nonzero branches, multiplying their local signs. A different LO choice can give the same final center IF with a different orientation. State changes therefore require an updated branch record and verification.

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CASCADE NOISE TEMPERATURE: Equivalent input noise temperature of an ordered chain, found by referring each added stage contribution through the gain preceding it.

CAUCHY–SCHWARZ INEQUALITY: The bound on an inner product's squared magnitude by the product of the two vectors' squared lengths. The chapter applies it to window sums and paired weighted Fourier coefficients. Its coherence bound relies on one consistent nonnegative weighted construction, not arbitrary separately selected spectral summaries.

CAUSAL RELATIONSHIP: A relationship in which a change in one physical process produces a change in another under the relevant conditions. A statistical fit or high coherence does not alone establish that direction or mechanism. Competing paths, shared sources and instrument coupling require separate discriminating observations.

CEILING FRAME COUNT: The smallest integer number of complete frames whose stated payload capacities can contain a positive request. With fixed positive capacity, it is the request size divided by capacity rounded upward. This rule preserves the complete-frame boundary; multiplying that count by full capacity can include final padding that is not original request payload.

CENTRAL MOMENT: The expectation of a stated integer power of a random quantity's deviation from its mean, when that expectation exists. Variance is the second central moment. The squared-Gaussian derivation also uses the third and fourth central moments; second-order information alone would not supply those values for an arbitrary distribution.

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CHALLENGE TEST: A controlled intervention selected because competing causal explanations predict different observable consequences. The comparison retains enough configuration, desired-signal transfer and observation capability to interpret the change; an unexplained disappearance alone does not identify a mechanism.

CHANNEL CODING: A declared transformation that adds redundancy to information bits for transmission and recovery. The chapter's finite accounting counts the actual input and coded bits of complete blocks, including relevant termination conventions. The count relationship alone does not quantify correction performance or successful delivery.

CHANNEL GRID: The signed center-frequency list and spacing assigned to a channelizer, distinct from each output stream's sampling frequency.

CHANNEL-POWER INTEGRATION: An estimate formed by combining calibrated spectral contributions over a declared channel interval using the appropriate frequency weighting and detector convention. A single narrow marker is generally insufficient when a modulated signal spans several filters. The integration limits, normalization and calibration must distinguish wanted energy from neighboring admitted components.

CHANNEL-SWAP TEST: A controlled interchange of channels or paths used to test whether an observed timing or phase residual follows the electronics, the path or the measurement geometry. Its interpretation requires preserving the other relevant conditions and recording the swap. It supports localization without making one successful comparison a universal calibration.

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CHARACTERISTIC FUNCTION: The expected complex exponential of a real random quantity at a specified argument. Model 12B evaluates it for a Gaussian phase difference to obtain a mean-phase factor and a variance-dependent attenuation factor. Applying that identity to a non-Gaussian difference requires its actual distribution, not merely a matching variance.

CHECKSUM: A value computed from a defined data structure and compared with a declared check rule to detect inconsistency. A passed check can support the internal validity of a decoded structure. It does not alone authenticate a sender, locate a transmitter or establish unique delivered payload.

CIRCULAR BUFFER: A recording arrangement that continually retains a rolling interval, replacing older data until selected content is preserved. Triggered extraction can provide pre-event context while controlling retained storage. That context remains usable only if its samples are valid and belong to the accepted configuration and continuous timing record.

CIRCULAR COMPLEX GAUSSIAN NOISE: In this chapter, zero-mean complex Gaussian noise with equal quadrature variances and independent real and imaginary components. Its distribution is unchanged by a common complex phase rotation. The calibrated squared magnitude has the stated exponential power law; a tone, clipping or changing-level mixture need not share it.

CLIPPING THRESHOLD: The boundary at which the declared response begins limiting rather than retaining its ordinary gain relation. Uncertainty in gain and limit position affects the input threshold inferred from a flag. An unsaturated reading can support a bounded inverse even when a clipped reading from the same system cannot.

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CLOCK TIME ERROR: The difference between a clock's reading and ideal reference time, positive for an advanced clock in the adopted convention.

CLOSING GUARD: An excluded interval at the end of a nominal acquisition during which the retained data no longer satisfy the declared validity conditions. It reduces the usable window independently of an initial settling guard. Coverage calculations must use the remaining contiguous interval and state the reasons for the exclusion.

CLOSING VERIFICATION: A check after an important observation that assesses specified functions of the measurement chain at the time of the check. Its assurance is limited to the states and conditions exercised; the check alone does not establish uninterrupted validity throughout the preceding acquisition.

COAXIAL TRANSMISSION MODE: The intended guided propagation in the space between a coaxial cable's inner conductor and the inside of its shield. Its acceptable match does not establish the absence of a separate current on the shield's outer surface. The installed path must distinguish internal transmission from external pickup and radiation.

CODE-CENTER TEST: A chosen input record exactly aligned with representable quantizer levels; its favorable error is not a distribution-wide guarantee.

CODED LABEL BIT: A bit position in the specified binary label mapped to a data symbol. A known power-of-two constellation with its declared labeling determines how many such positions belong to each symbol. This count does not by itself specify input-information bits, entropy, delivered unique payload or stored ADC data.

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CODE RATE: For the complete-block count convention in Model 7B, the number of input-information bits divided by the corresponding coded label bits. The model scopes this ratio to redundancy-adding coding without compression. It is distinct from framing efficiency and cannot be estimated as a zero-over-zero empirical ratio from an empty record; a configured rate may be known separately.

CODE SIGNING: Use of a digital signature to associate specified code content with a signing source under a verification and trust policy. Appropriate checks support integrity and source authentication. They do not demonstrate correct filtering, scaling or receiver behavior, and signed content can still be unauthorized under the acceptance policy or technically defective.

COEFFICIENT QUANTIZATION: Replacement of intended filter coefficients by values on a declared numerical grid. It changes the implemented filter itself, before any subsequent arithmetic error is considered. Equal coefficient sums can preserve DC gain while changing rejection elsewhere, so a DC check alone does not verify the quantized frequency response.

COHERENCE: Normalized spectral measure of linear relationship between two signals under stated averaging conditions.

COHERENCE RESIDUAL: The minimum weighted spectral residual $P_{yy}(1-C)$ for a single complex-gain fit, conditional on positive autospectra and the declared estimator.

COHERENCE TIME: Interval over which relative phase remains sufficiently stable for a specified coherent operation.

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COHERENT CONTAMINATION: An unwanted complex amplitude at the same observed frequency whose phase-dependent addition can raise or lower the magnitude attributed to the modeled source.

COHERENT DETECTOR: Detector using a phase- and frequency-related reference to recover a modulated quantity.

COHERENT GAIN: Window-dependent amplitude scaling for a sinusoid centered on a transform bin.

COHERENT IMAGE COLLISION: Combination of desired and image contributions at the same selected IF with a retained phase relationship. Their IF phasors add before power is formed, so the observed power can increase or decrease relative to the desired-only result. The high-side phase transformation must already be applied. One power reading cannot separate the contributions or establish that their powers add independently.

COHERENT PHASOR SUM: A complex sum that preserves the relative phases of its declared contributions. Its squared magnitude contains self and cross terms, so common rotation and relative rotation have different consequences. The chapter's normalized signal-power result does not by itself include additive noise, amplitude variation or uncertainty introduced by estimated phase corrections.

COHERENT PROJECTION: Recovery of the component of a complex envelope aligned with a declared real reference phase.

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COHERENT WEIGHT SUM: The signed sum of the actual window coefficients. For the chapter's coherent complex tone it is the factor multiplying that tone's complex amplitude in the selected transform coefficient. Coherent-amplitude normalization requires this sum to be nonzero; it must not be confused with the sum of squared weights.

COLD-HOT-COLD SEQUENCE: A noise-measurement order that brackets a hot-source observation with cold-source observations. Differences between the cold records can reveal time-dependent behavior that a single ratio conceals. The sequence does not by itself identify the cause or provide a gain correction at the intervening time.

COLD-SOURCE TEMPERATURE: Effective source noise temperature in the lower-temperature state of a hot/cold measurement at the stated input plane.

COLLECTION BOUNDARY: The authorized limits on what an engagement may acquire and how that information may be retained or disclosed. In receiver work these limits are implemented through frequency, time, mode, channel, recording, and handling choices.

COMBINED STANDARD UNCERTAINTY: The standard uncertainty obtained by propagating the relevant input uncertainties and covariances through the stated measurement model. In the local Y-factor calculation it is the square root of the sensitivity-weighted variance sum, including any applicable cross terms. It is distinct from an expanded uncertainty and does not itself specify a chosen coverage probability. The affine variance relation is exact under its stated finite-moment and covariance premises. Applying its first-order form to a nonlinear function additionally requires a justified local approximation.

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COMBINER: A network that joins signals from separate source paths into a common test path. Inadequate isolation or nonlinear behavior can make the sources interact and generate products before the receiver. Its applied levels and purity must therefore be bounded before a newly observed product is assigned to the receiver.

COMBINER ISOLATION: The degree to which a combining network prevents energy from one input port from reaching another under specified conditions. In a two-source challenge, inadequate isolation can let generators interact and produce artifacts before the receiver. Isolation must be considered with the combiner's linearity and actual applied levels; it is not the same as insertion loss.

COMMANDED STATE: The configuration requested by an operator, script, or controller. It records intended operation but does not alone prove that the receiver accepted the request, settled, or maintained that state throughout the associated acquisition.

COMMON CALIBRATION CONTRIBUTION: An input uncertainty shared across several observations, whose effect depends on its coupling and the signed coefficients of the reported quantity.

COMMON-FACTOR CANCELLATION: Algebraic removal of the same nonzero multiplicative quantity from a ratio. The Y-factor derivation cancels the common bandwidth, gain and Boltzmann factor. The cancellation is justified by actual common values and states; similarly named quantities or repeated front-panel settings do not establish the premise.

COMMON-MODE CURRENT: Current flowing on conductors together with respect to an external reference or surrounding structure.

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COMMON PERIOD: An interval after which every component in the stated periodic waveform has completed an integer number of cycles. Averaging over complete common periods supports the orthogonality used in the synthetic power calculations. A record endpoint chosen independently of those periods need not retain the same cancellation.

COMMON PHASE ROTATION: A phase contribution shared by every sample in a record, which can alter ensemble complex phase without causing relative cancellation within that record.

COMPLEMENT EVENT: The set of outcomes in which a specified event does not occur, under the same experiment and sample space. Model 15A computes at-least-one capture by subtracting the all-miss probability from one. That complement identity needs no independence assumption; multiplying individual miss probabilities does.

COMPLETE CODE BLOCK: An included input-and-output population whose coding relationship is fully represented for the declared count ratio. Counting only a partial segment can require explicit treatment of boundaries, termination and other coding structure. The chapter's fixed code-rate products assume complete stipulated populations rather than inferring them from a constellation display.

COMPLETE-FRAME PAYLOAD CAPACITY: The number of useful payload positions available in one fully specified frame after the separately declared coding and header conventions. Repeating full frames can achieve a capacity rate different from the actual rate for a finite request whose last frame contains padding. Capacity is not evidence that every position was filled with requested data or delivered successfully.

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COMPLEX CROSS-PRODUCT AVERAGING: Averaging the complex paired-channel products before taking the magnitude used in a coherence calculation. Opposing phases can cancel in this operation. Averaging the individual normalized magnitude ratios instead loses that information and gives unity for every nonzero single pair, regardless of a repeatable relationship.

COMPLEX ENVELOPE: The complex amplitude-and-phase function that describes a signal relative to a chosen carrier in an analytic representation. Multiplying that envelope by the carrier exponential locates its spectrum around the carrier. Carrier choice, envelope bandwidth, and admitted physical RF band must be consistent. The envelope is a representation of the waveform, not proof that an image or an alias has been rejected by the receiver.

COMPLEX EXPONENTIAL: A complex sinusoidal representation that retains phase rotation and a signed frequency coordinate. Model 4A uses it to translate a complex envelope by the oscillator frequency without the absolute-frequency folding of a real difference display. Its sign convention must agree with the recorded I/Q ordering.

COMPLEX LOCAL OSCILLATOR: A rotating complex multiplier used to translate an analytic band without the absolute-frequency folding of a real difference display. The chapter uses a negative complex-exponential frequency convention for downconversion and retains the LO phase. The sign of that convention must agree with I/Q ordering and subsequent frequency-axis labeling. A mathematical unit-magnitude rotation does not state a physical mixer’s conversion loss.

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COMPLEX MODULUS: The nonnegative magnitude of a complex quantity. Squaring it removes phase information from that quantity, making the order of complex averaging and magnitude formation consequential. Averaging separately normalized single-record magnitudes cannot substitute for the paired cross-spectrum estimator.

COMPLEX RMS PHASOR: A complex sinusoidal representation whose magnitude uses the stated root-mean-square voltage convention and whose angle uses the declared phase convention. Power conversion requires the corresponding load model. A gain magnitude and phase rotation act on this representation before magnitude detection, which can remove the phase information.

COMPRESSION: Reduction of incremental gain as a stage approaches nonlinear or limiting operation.

CONDITIONAL CAPTURE PROBABILITY: The probability of meeting a defined acquisition geometry under a stated event-phase distribution and separately established signal and detector conditions.

CONDITIONAL EFFECT: The observed consequence of changing one factor at a specified setting of the other relevant factors. It may differ at another setting, indicating an interaction in the response. The result narrows the tested relationship without automatically identifying a faulty component or the unique physical cause.

CONDUCTED REFERENCE: Known signal applied at a specified electrical port to verify the transfer or response of the downstream path.

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CONFIGURATION BINDING: The specified association among device, executable artifacts, loaded images, calibration data, and actual settings used by an examination.

CONFIGURATION COMPARABILITY: Established compatibility of reference planes, corrections, observation limits, timing, and relevant instrument states sufficient to support a specified comparison.

CONFIGURATION IDENTITY: Complete hardware, firmware, software, option, accessory, and setting state required to reproduce a receiver observation.

CONFIGURATION TRANSITION: A change between receiver states that can include transient, relocking, or settling behavior. Records affected by the transition must be distinguished from intervals governed by an established valid configuration.

CONFIGURED OPERATOR: The complete declared transformation from an identified input to the retained output in Model 1A. It can include changes of units, representation, timing and sample indexing, as well as physical transfer. Writing an operator symbol does not imply linearity, a dimensionless gain, stationary noise or a unique inverse.

CONFOUNDING: An inability of the available design to separate the consequences of factors that vary together. Reference state and session are confounded when each state is observed in only one distinct session. More observations within the same incomplete arrangement do not establish the missing distinction.

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CONJUGATE-BAND REJECTION: Selection that removes the unwanted conjugate spectral band when constructing or processing the intended analytic complex signal from a real input. It is part of the representation and filtering required by the stated conversion convention. The associated factor-of-two amplitude normalization must be tracked. Merely naming an output I/Q does not demonstrate adequate rejection, correct channel ordering, or freedom from sampling aliases.

CONJUGATE SYMMETRY: The paired relationship between positive- and negative-frequency components of a real waveform: the coefficients at opposite frequencies are complex conjugates. This redundancy explains why a real magnitude observation cannot by itself distinguish the two sides of a conversion LO. An analytic representation removes the redundant band under an explicit normalization; a correctly retained complex record can then preserve signed-frequency information. For a real windowed record, the opposite-frequency squared magnitudes are equal and support the stated one-sided power folding. A general complex record need not have this symmetry, so its spectrum cannot automatically use the same doubling rule.

CONNECTOR REPEATABILITY: The consistency of a connection's electrical response when it is assembled again under controlled conditions. Reconnection, torque, contamination or mechanical strain can alter loss or reflection. A previous calibration remains relevant only to the extent that the resulting installed connection satisfies the required transfer and uncertainty conditions.

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CONSERVATIVE ENCLOSURE: A range guaranteed to contain the results permitted by the stated premises, even if some values inside it are unattainable. It can summarize several separate intervals but should retain that qualification. An enclosure is different from a probability distribution or a standard uncertainty.

CONSTANT COMPLEX-GAIN FIT: A weighted least-squares estimate of one complex coefficient that scales and rotates a disclosed ideal-reference sequence. Positive training reference energy makes the minimizer unique. The fit minimizes training residual energy, not every normalized EVM or held-out error, and its coefficient remains part of the result when the correction is permitted.

CONSTANT-ENVELOPE SIGNAL: A signal whose magnitude remains fixed over the stated interval and representation, even if its phase changes. Its power statistics differ from the chapter's Gaussian-noise example. A correction derived for exponentially distributed noise powers must not be applied solely because this signal is displayed on a decibel axis.

CONSTELLATION: The set or plotted arrangement of complex symbol locations under a declared reference and receiver processing. Its geometry describes amplitude and phase relationships, while labeling assigns information to locations. An apparently compact received cluster can depend strongly on synchronization, equalization and selected samples.

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CONSTELLATION MAPPING: The declared correspondence between symbol labels and complex reference values. A geometric point set alone does not establish this correspondence. Rotation or relabeling can preserve a constellation's appearance while changing the represented labels, so mapping validation is separate from a visually tight or numerically well-aligned display.

CONTENT RECOVERY: Reconstruction of information carried by a signal rather than mere detection or classification of its waveform.

CONTIGUOUS-OVERLAP CRITERION: A capture requirement met by one uninterrupted event-window intersection of at least a specified positive duration.

CONTINUITY VALIDITY MASK: Binary dependency indicator identifying outputs whose nonzero filter terms all use resolved available samples or justified known prehistory.

CONTINUOUS-WAVE STIMULUS: A sustained, unmodulated RF test signal over the observation interval. It is useful for transfer and level measurements, but a continuous-wave sweep does not expose every transient or post-pulse recovery condition. The stimulus must represent the capability that the acceptance claim is intended to cover.

CONTROL CLAMP: A limit that restricts a control quantity to an allowed range. Its action can make the observed large-change response differ from an unconstrained local model. Predictions of useful recovery must retain the clamp condition and gain mapping rather than extending the exponential law through an unverified limit.

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CONTROL INTERACTION: Dependence of the observed effect of changing one control on the setting of another, evaluated for a declared response and measurement context.

CONTROL POLARITY: The direction in which a control-voltage change affects receiver gain in the active calibrated range. A negative local slope means increasing voltage reduces gain; a positive slope gives the opposite relationship. Polarity belongs to the gain map and must not be confused with the positive time constant or the sign of a residual.

CONTROL RESIDUAL: The signed difference between actual control voltage and the target used for the current segment. Under the stipulated positive-time-constant one-pole law, a nonzero residual decays without changing sign. Its magnitude can be converted into gain-error magnitude only through an applicable gain slope. A target error or detector offset can create an apparent residual floor.

CONTROL STATE: The internal quantity used by a control model to represent the system’s present condition. Model 5A uses a voltage whose actual value carries into the next target interval. A new trigger or setting command does not establish that this state has already reached its target.

CONTROL TARGET: The equilibrium control voltage toward which a particular Model 5A segment relaxes. It is constant within that segment and is distinct from the voltage already reached. A new input, range or mode can change the target. Uncertainty in the target remains a separate contribution even after uncertainty in the initial state has decayed.

CONVERSION LOSS: Ratio of available input power at one mixer port to desired output power at the selected product port.

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CONVERSION ORIENTATION: The sign with which a local RF-frequency change maps into the selected real or complex output-frequency coordinate.

CONVERSION SCHEDULE: Ordered locations and rules at which a numerical pipeline changes format, rounds, saturates, or wraps.

CONVERSION-STATE BOUNDARY: A transition between receiver configurations that may change an LO plan, selected IF, injection side, preselector, or correction path. Both amplitude transfer and frequency orientation can change across it. Retaining state identity and timing allows observations to be interpreted with the applicable map. Verification should exercise relevant frequencies on each side and distinguish settled states from uncharacterized transition intervals.

CONVOLUTION: The operation that forms a linear filter output by summing appropriately delayed input values multiplied by the corresponding impulse-response coefficients. The chapter's finite causal sum fixes which source samples contribute to each output. Compressing a gap or resetting history changes those dependencies even when the coefficient list is unchanged.

CORRECTION CHAIN: The ordered, documented transformations that convert an original indication into a result at a declared reference plane. Retaining each term, sign, state, and applicability permits reconstruction and exposes omitted or double-counted contributions.

CORRECTION COVARIANCE: Joint uncertainty between correction inputs, retained with the signs of their measurement sensitivity coefficients.

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CORRECTION INTERPOLATION: Estimation of a correction between characterized points using a stated model and position. Endpoint uncertainty and covariance are distinct from the residual between the physical response and that interpolation model. An uncertain position, extrapolation or unresolved response structure changes the measurement equation and cannot be omitted merely because the file provides a smooth curve.

CORRECTION OWNERSHIP: The assignment of each gain, loss or conversion to the calibration or processing step responsible for it. Explicit boundaries prevent omission and double correction when antenna, accessory and receiver records overlap. The correct assignment follows the actual measured assembly and quantity, not merely the presence of a certificate or file.

CORRECTION RECORD: The record identifying a correction's measured transfer, reference planes, frequency grid, interpolation, uncertainty and serialized applicability. It establishes which measured path and state the correction describes. It must distinguish corrections already applied from those still required and retain raw observations where needed to reconstruct the result.

CORRELATION COEFFICIENT: A dimensionless normalized measure of covariance between quantities with nonzero standard deviations. Its contribution to output variance also depends on the signs of the measurement sensitivities. A favorable coefficient must be supported by the joint calibration model or evidence; it cannot be chosen to obtain a desired uncertainty or decision.

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COSINE PRODUCT IDENTITY: The trigonometric relation that expresses the product of two cosines as one half of the cosine of their angle difference plus one half of the cosine of their angle sum. It underlies the two real products in Model 4A and makes the multiplier normalization explicit.

COVARIANCE: The expected product of two quantities' departures from their respective means, when defined. Its units are the product of their units. Covariance contributes cross terms when observations are combined; omitting it can misstate averaging uncertainty, and zero covariance does not generally establish independence.

COVARIANCE MATRIX: The matrix of pairwise covariances of a specified input vector, with each entry carrying the product of the corresponding input units. A physically admissible matrix is symmetric and positive semidefinite. Separate plausible pairwise correlations need not form a valid complete matrix, so the joint model must be checked. Model 12B uses a specified valid geometric lag structure before evaluating its coherent-power sum; the admissibility check applies to the complete joint matrix.

COVERAGE FACTOR: Multiplier applied to combined standard uncertainty to obtain an expanded uncertainty under a stated convention.

COVERAGE FAILURE: Failure to observe an event because the relevant channel or interval was not validly acquired, such as a burst occurring while a scanning receiver was tuned elsewhere. It is distinct from a failure to detect an event during a valid dwell. Actual observation and settling records are needed to assign the failure category.

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COVERAGE INTERVAL: An interval assigned a stated probability of containing the measurand's value or values on the available information. It need not be symmetric about the reported estimate. Its endpoints and probability require an adequate uncertainty model; multiplying a local standard uncertainty by two does not establish that interpretation without further justification.

COVERAGE PROBABILITY: The probability assigned to an interval under a justified output-distribution and uncertainty interpretation. Multiplying standard uncertainty by two does not independently establish a universal probability. Such interval coverage is also distinct from the false-alarm or detection probabilities of a receiver search procedure.

CRITICAL SAMPLING: Filter-bank rate condition in which the aggregate output sample rate equals the input rate; it does not by itself establish reconstruction.

CROSS-CORRELATION: A lag-dependent comparison formed from paired signal values, with the complex-conjugation, averaging and normalization conventions stated. It can support timing or coherence analysis, but a feature in the result must be interpreted with the actual signal bandwidth, phase history and channel calibration. Correlation does not independently establish a propagation mechanism.

CROSS-DOMAIN CORROBORATION: Agreement among observations from different physical or information domains after their timing, state and dependencies have been reconciled. It can support a mechanism or linkage, but the domains may still share a cause. An optical observation establishes optical activity within its scope and does not automatically establish an RF source.

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CROSSED CONTROL STATES: An experimental arrangement in which every selected setting of one control is observed with every selected setting of another, subject to documented physical feasibility and comparability.

CROSS-POWER TERM: The interference contribution that appears when power is formed from the sum of two selected IF fields. Its value depends on their relative phase and on the averaging operation. Adding the individual mean powers is justified only when the relevant averaged real cross term vanishes. An unknown phase is not sufficient evidence for that condition, and a fixed quadrature relationship is distinct from statistical independence. Model 11B also retains a bound on the cross term between kept and omitted phase contributions. Their powers cannot be added without accounting for that interaction under the adopted averaging model.

CROSS-SPECTRAL CONJUGATION CONVENTION: The declared choice of which channel coefficient is complex-conjugated in each cross-product. Reversing that choice conjugates the resulting cross-spectrum, reverses its phase and leaves magnitude-squared coherence unchanged. A delay inference must retain the selected convention and any remaining phase-branch ambiguity.

CROSS-SPECTRUM: A complex spectral estimate formed from products of corresponding Fourier coefficients from two aligned channels, with a stated conjugation direction, common weights and compatible normalization. Its magnitude and phase describe a second-order relationship under that construction. Neither a nonzero value nor its phase alone identifies a unique physical coupling path.

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CROSS-SPECTRUM CANCELLATION: Reduction or disappearance of an averaged complex cross-spectrum because admitted shared components contribute opposing signs or phases. Both channels can still contain substantial shared power. The chapter's two-source and changing-state examples show why low coherence does not by itself establish that the channels have no common contribution.

CRYPTOGRAPHIC DIGEST: A fixed-length value computed from declared bytes using a specified cryptographic hash algorithm. Comparing it with an authenticated expected digest supports an artifact-identity check under the algorithm's security assumptions. The value alone does not show which file was loaded or establish the correctness of its executable behavior.

CUBIC INTERMODULATION MODEL: A bounded memoryless voltage relation retaining linear and third-order terms under explicit amplitude, loading, frequency, and fixed-state assumptions.

CUMULATIVE POWER GAIN: The product G_j of the linear power gains from the selected input through stage j. It describes signal power transfer between those planes in the stated fixed-state model. G_0 is defined as one, allowing the first stage noise contribution to be handled by the same recurrence as later stages. For any selected output plane, the overall decibel gain combines gains and losses with their forward-path signs. It is not established by averaging unrelated gain settings or applying one correction across an unverified transition.

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CURVATURE BIAS: The difference arising when the expected output of a nonlinear transformation differs from the transformation evaluated at the expected input. The squared-voltage example exhibits this mean shift explicitly. It is a model consequence, not evidence of an instrument fault, and its significance depends on the intended accuracy of the reported result.

CYCLIC REDUNDANCY CHECK: A structured binary error-detection check computed from a message using a specified polynomial convention. Its format and verification must match the decoded record. Independent CRC validation can help reject false decoder outputs, but a passed check is not a physical-source or cryptographic-authentication result.

CYCLOSTATIONARITY: Periodic variation in a signal's statistical structure, such as correlations associated with symbol or framing cycles. It can provide a classification observable when the estimator and observation interval are justified. A detected periodic feature is supporting evidence, not a complete modulation, decoder or source-identity validation.

DATA-SLOT FRACTION: The number of data-symbol slots divided by all nominal opportunities on the explicitly declared finite grid. It accounts for pilot or other nondata opportunities in that grid and differs from a payload-bit fraction. Its denominator must be positive, and any combined efficiency that already includes this reduction must not apply it again.

DBC: A logarithmic power ratio referenced to a specified carrier, expressed as ten times the base-ten logarithm of component power divided by carrier power. It describes a relative level rather than watts or dBm. The carrier definition and whether the component is a spectral line or integrated noise must remain explicit.

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DBC PER HERTZ: A logarithmic carrier-relative density notation with a one-hertz normalization. In Model 11B it labels the explicitly defined single-sideband phase density. Convert the value to linear density before weighted integration; a discrete spur has line power and cannot be treated as a density sample without an appropriate observation definition.

DBM: The logarithmic power-level convention referenced to one milliwatt. Its numerical value converts to a positive physical power through that reference. It must be distinguished from a dimensionless power ratio in decibels, and it cannot represent zero power by a finite value.

DC BIN: The zero-frequency transform coefficient. It represents the retained record's weighted constant component under the stated preprocessing. It is not doubled in the one-sided power sum, and subtracting a mean before transformation can remove it by changing the analyzed record rather than merely changing normalization.

DC OFFSET: A constant additive component in the declared complex sample or symbol coordinates. It can contribute to EVM even when an ordinary gain fit is permitted. Mean removal changes the measurement and may remove an intended nonzero-mean component, so the offset's physical cause requires an independent check.

DEAD TIME: Interval during which an acquisition system cannot accept or record another event.

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DECIBEL: A logarithmic unit for a ratio under its stated power or amplitude convention. In the scalar power model, gain and loss expressed in decibels correspond to multiplicative power transfer. Their signs in an inverse correction follow the forward path; a decibel difference does not represent subtraction of physical powers.

DECIMATED TRIGGER: A trigger operating on a rate-reduced representation of the signal. The preceding filter and sample-rate change can alter the event information and timing available to it. Its behavior must be checked against the saved waveform and intended event criterion rather than assumed equivalent to a full-rate trigger.

DECIMATION PHASE: Retained input-index residue modulo the decimation factor, specifying output time origin and coherent phase.

DECISION BOUNDARY: A boundary between symbol-decision regions in the receiver's declared observation space. Carrier phase, timing, normalization and the selected mapping determine how observations relate to it. A constellation can look geometrically regular while its decision regions remain associated with the wrong labels.

DECISION CRITERION: The stated condition under which an observation or numerical estimate supports an intended action or conclusion. It includes relevant validity and uncertainty requirements and must not be inferred merely from the appearance of a display. A procedure may specify acceptance, rejection and an indeterminate region relative to a requirement. Select and preserve the rule before examining the result; a later rule change creates a different decision rather than changing the earlier evidence.

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DECISION INSTANT: The declared time at which an observed, processed waveform sample is paired with a reference symbol for detection or quality assessment. Filtering, delay, symbol-clock configuration and timing recovery determine that pairing. Samples between decision instants are not silently included in a metric whose stated population consists only of symbol points.

DECISION STATISTIC: The quantity computed from an observation and compared with a criterion to decide whether a specified event has been detected. Examples in the chapter include amplitude, correlation, or coherent-integration results. Its distribution, duration, receiver state, and processing affect detection and false-alarm behavior; mean noise power alone does not specify those properties.

DECODER: A processing system that interprets a received representation under a stated format and produces fields or data. Its software version, synchronization assumptions, checks and failure behavior belong to the result. Plausible output can arise from false lock or a wrong-format input and therefore requires independent validation.

DE-EMPHASIS: A frequency-dependent operation in the recovered baseband path, commonly associated with an intended complementary emphasis characteristic. It changes the derived waveform and must be recorded with an audio result. Its presence alone does not establish the transmitter's characteristic or validate an amplitude or deviation measurement.

DELIVERED NOISE POWER: Noise power accepted by the receiving port under the actual source and load conditions. It equals available noise power in the stated matched real-impedance model. A matched-port insertion-loss value alone does not establish delivered power for a reactive antenna and a state-dependent receiver input match.

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DELIVERED POWER: The power transferred into the specified load under the actual source and load conditions. It can differ from available power when impedances are mismatched. A receiver indication and a calibration factor must refer to compatible loading before a terminal or field conversion is assigned.

DEMODULATED AUDIO: An audio-band product formed by applying a declared tuning, detection and processing chain to an RF or IF record. It retains only the information admitted by that transformation. Reproducibility requires a link to the native interval and configuration; intelligibility alone does not calibrate the output or identify a source.

DEMODULATION: Processing that recovers a baseband representation from the admitted modulated signal under an assumed waveform and reference model. The output depends on tuning, phase, filtering, gain and detector settings. A plausible audio result alone does not establish that the original RF relationship was preserved.

DEMODULATION FIDELITY: The extent to which a recovered representation preserves the particular amplitude, phase, frequency or timing relationship being claimed. It requires a stated reference and measurement criterion. A receiver can produce plausible audio while its filtering, phase alignment, limiting or normalization biases the intended quantitative result.

DEMODULATOR TRANSFER: The relationship between an admitted modulated waveform and a stated recovered output under a particular receiver configuration and state. It includes tuning, filtering, detector operation and relevant gain or conditioning behavior. Verification for one level, bandwidth or waveform does not automatically establish the relationship throughout the instrument’s operating range.

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DESENSITIZATION: Degradation of receiver sensitivity caused by overload, control action, noise elevation, or other strong-signal effects.

DESIRED INPUT EQUIVALENCE: Referral of an internally generated disturbance to the desired-signal input using the declared desired transfer; a center-frequency scalar requires a narrow signal or a justified constant-transfer approximation.

DESIRED SIGNAL: The signal component whose observation or measurement the current configuration is intended to support. Its retained amplitude, phase, modulation quality and detection opportunity supply the relevant acceptance criteria. Suppressing a blocker is not a successful improvement if the change also removes or invalidates the desired observation.

DESIRED-TRANSFER VERIFICATION: A check of the response to a known desired signal between stated planes in the relevant configuration. It establishes the traversed path at the check time and supports comparisons whose detection capability is retained. An injection at the receiver connector bypasses upstream components and cannot verify their contribution.

DETECTION: A finding that energy or a structured component met a stated decision rule under declared observation conditions. It does not automatically establish waveform class, emitter identity, carried content, or intent.

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DETECTION PROBABILITY: The probability that a specified rule produces a successful observation for the defined signal and eligible observation conditions. Its population must distinguish valid channel dwells from intervals when the receiver could not observe the event. A mean noise level or stipulated signal-to-noise ratio alone does not determine it.

DETECTION THRESHOLD: The declared boundary applied to a decision statistic for a defined detection event. Its selection should reflect a false-alarm objective and be tested with suitable noise-only and weak-reference observations. Lowering it can increase detected weak events while also increasing unwanted crossings; the threshold is not interchangeable with a receiver noise-floor number.

DETECTION TRIAL: One defined opportunity to evaluate a signal against the declared success rule. In a scanning receiver, a valid dwell and a period spent on another channel belong to different observation conditions. The denominator used to estimate performance must preserve that distinction instead of pooling sensitivity failures with coverage failures.

DETECTOR: The operation that converts the signal presented to it into the quantity used for an indication, such as a selected sample, peak or RMS value. Detector order, interval and subsequent processing are part of the measurand. Equal input waveforms need not give equal outputs under different detector rules.

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DETECTOR CREST-FACTOR LIMIT: An operating restriction on waveform peak relative to its RMS level for a detector or measurement path. Exceeding the applicable limit can invalidate an RMS or power indication even when average level appears acceptable. The limit depends on the specific detector and conditions; the name RMS does not establish unlimited peak-handling capability.

DETECTOR LAW: The operation that maps the admitted waveform into the detector's output quantity. Peak selection, power averaging and logarithmic averaging produce different statistics. A control voltage or display level cannot be converted into physical power without the applicable law and its bandwidth, range and waveform limits.

DETECTOR RIPPLE: Unwanted variation remaining in a detector output because the detection and smoothing process does not fully separate the desired envelope from faster components. The detector time response can trade ripple against faithful tracking of a changing envelope. The recorded waveform and detector settings determine which effect limits the result.

DETECTOR TAKEOFF: The physical or numerical point from which a detector receives its waveform. Its position relative to filters, gain stages, limiters and converters determines what it observes and which signals can influence control or indication. Audio, spectrum and recorded I/Q outputs can use different takeoffs; common receiver identity does not make their transfer functions equivalent.

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DETERMINISTIC ERROR BOUND: A justified limit on the magnitude or allowed set of an error under specified conditions. It differs from a standard deviation, which describes dispersion under an uncertainty model. Converting one into the other requires additional information; a multiple of standard uncertainty is not automatically a worst-case enclosure.

DETERMINISTIC PHASE ROTATION: A specified progression of mean phase across the actual sample times, such as that produced by a frequency offset. Model 12B keeps its finite phasor sum separate from independent random phase errors. Special frequencies are evaluated by the finite sum instead of an indeterminate trigonometric quotient.

DETRENDING: Removal of a specified fitted or fixed trend from the retained samples before spectral estimation. Even constant detrending can eliminate the DC component. The chapter's finite-window model assumes no detrending unless explicitly stated, so a software default that removes a mean changes the model input and must be accounted for.

DEVIATION: Peak or instantaneous departure of frequency from its unmodulated reference.

DFT BIN SPACING: The separation between adjacent frequencies at which a discrete Fourier transform is evaluated. It is the sample rate divided by transform length, with the record length used when no padding is applied. This grid spacing does not by itself establish the ability to resolve nearby components through the actual window response.

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DIFFERENCE PRODUCT: A mixer output component whose signed frequency is formed by subtracting one parent frequency from another under the selected conversion relation. For Model 4A the signed first-order value is RF minus LO; its real positive-frequency representation also depends on the sign of that difference. The component is distinct from the sum product, and selecting it requires a suitable actual signal path.

DIFFERENTIAL EQUATION: A relation involving a quantity and its rate of change that specifies a dynamic model together with appropriate conditions. Model 5A relates the control-voltage rate to its displacement from a constant target. A numerical approximation to that equation can behave incorrectly even when the stated continuous model is stable.

DIGITAL DOWNCONVERTER: Digital mixer, filter, and decimator that translates and selects a sampled frequency band.

DIGITAL MODULATION: Representation of discrete symbol values through specified waveform states, such as amplitude, phase or frequency. The modulation definition includes the mapping and timing needed to interpret those states. A receiver-generated constellation alone does not establish which format was transmitted or validate the decoded information.

DIMENSIONLESS LOGARITHM ARGUMENT: A pure numerical ratio supplied to a logarithm after compatible quantities and units have been reconciled. Model 1A divides physical power by its reference before taking a logarithm. Applying a logarithm directly to an unexplained unit-bearing number conceals the coordinate convention and can change the meaning of the result.

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DIRECT-CONVERSION RECEIVER: A receiver architecture that translates the intended RF region directly to baseband. Avoiding a conventional nonzero first-IF image does not remove all ambiguity or impairment. The chapter identifies DC offset, even-order distortion, oscillator leakage and I/Q imbalance as separate issues that still require characterization.

DIRECT FEEDTHROUGH: Transmission from an input port to an output path without the intended selected frequency conversion. It is one possible practical mixer response alongside leakage and generated products. Its observed significance depends on the actual routing, isolation and filtering, so it must be distinguished from the desired converted signal.

DIRECTIONAL COUPLER: A network that couples a controlled portion of a traveling RF signal into a measurement or auxiliary path with a specified directional response. It can support exposure and level measurements before a receiver is connected. Its applicable transfer, isolation and power conditions must be included in the complete path assessment.

DISCIPLINED OSCILLATOR: An oscillator whose output is steered using an external reference. Its correction behavior, lock state and loss-of-reference response form part of the timing system. The chapter treats holdover and reacquisition as consequential states; successful discipline on average does not establish negligible short-term phase noise or aligned multichannel samples.

DISCRETE FOURIER TRANSFORM: A finite linear transform that expresses a sample vector through complex coefficients on a discrete frequency grid. Its exponent sign, length and normalization are part of the definition. The coefficients describe the supplied finite record; they do not establish a unique underlying continuous signal or a stationary source.

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DISCRETE-TIME MODEL: A model that relates states or observations at indexed times through a recurrence. It can be an exact sampled form of a continuous model, an approximation, or the actual law of a discrete controller. Those origins are different and must be identified before simulated behavior is assigned to the physical receiver.

DISPLAY BUCKET: The group of processed observations assigned to one displayed trace location before the selected detector reduces them to an ordinate. Bucket formation and detector operation are implementation details that affect the statistic. A display pixel count cannot be treated automatically as a count of independent calibrated power samples.

DISPLAYED AVERAGE NOISE LEVEL: An analyzer noise indication defined using its stated bandwidth normalization, detector and averaging conventions. It must be interpreted through those conventions before comparison with another instrument or a communications sensitivity specification. The displayed value does not automatically include the complete installed antenna-to-output chain.

DISPLAY INDICATION: The value or feature presented by an instrument or software interface before its physical meaning is fully established. Interpretation requires the relevant plane, state, estimator, scale, and applicable corrections. Identify the supplied quantity, units, detector and processing state before additional external correction. An indication can already contain a correction; applying that correction again can make a plausible value inconsistent with the intended plane.

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DISPLAY RANGE: The span of levels that an instrument can represent on its selected display scale. It is a presentation limit, distinct from the range over which the receiver can measure a weak signal accurately in the presence of strong inputs. A visible trace therefore does not establish an uncompressed, calibrated measurement.

DISSIPATIVE ATTENUATION: Signal power reduction caused by a passive element that dissipates energy under the stated matched conditions. Its physical temperature determines its thermal emission. For loss L at temperature T_p, Model 2B assigns gain $\frac{1}{L}$ and equivalent input temperature $(L-1)T_p$; arbitrary reflected power is not automatically covered by this relation.

DOUBLE CORRECTION: Repeated application of the same correction to one result when that effect was already accounted for. It changes the central value and may also lead to duplicate uncertainty contributions. The correction's appearances in an export and a calculation record can refer to one shared input rather than two independent calibrations.

DOUBLE-SIDEBAND SUPPRESSED CARRIER: An amplitude-modulated form retaining two message-related sidebands while suppressing the intended carrier component. Coherent reception needs a declared carrier reference. In the chapter's real product-detector example, a residual frequency error creates a rotating projection and can split a recovered sinusoidal message into two tones.

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DOWNSAMPLING: Retention of selected positions from a sample sequence at a lower output rate, with a stated integer factor and retained phase. Bare sample deletion introduces no automatic reduction of a retained tone's amplitude or independent sample variance. Required filtering precedes deletion when unwanted bands would otherwise alias into the retained output.

DOWNSTREAM LOADING: The signal, noise, and interference presented to a later stage after the gains and losses preceding it. It is evaluated at that stage's own plane and frequencies, not inferred from the final corrected display. Additional early gain can reduce a later noise contribution while simultaneously increasing this loading and reducing the later stage's valid margin.

DUAL CONVERSION: A frequency plan containing two sequential selected conversions. Each real difference stage can preserve or reverse local frequency orientation. Two plans can yield the same final center frequency while mapping a small RF-frequency change in opposite directions, so both oscillator choices and branch states must be retained.

DUPLICATE SAMPLE INDEX: Repeated declaration of one source index in stored data; payload agreement and resolution remain separate questions.

DURATION-WEIGHTED AGGREGATION: A rate calculation that adds each interval's represented count and divides the total by the sum of compatible elapsed durations. It preserves the joint modulation, coding and efficiency factors realized within each interval. Separately averaging factors, or assigning equal weight to unequal-duration modes, generally gives a different result.

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DURATION-WEIGHTED MEAN POWER: The mean formed by combining compatible interval mean powers with weights proportional to their valid durations. Each interval receives its own applicable correction before aggregation. The result covers the represented intervals; overlapping records or omitted intervals require additional treatment, and averaging logarithmic labels produces a different statistic.

DUTY-CYCLE DISTORTION: A systematic departure of a clock's high and low intervals from their intended proportion. It concerns the relative timing of opposite edges, so a correct repetition frequency does not establish the intended edge pattern. Its measurement convention must identify the edges and reference duty cycle relevant to the sampling or timing path.

DYNAMIC RANGE: The range of signal levels that supports a specified detection or measurement task under declared lower and upper limits. Noise, compression, intermodulation and blocking define different versions. Bandwidth, signal spacing, detector, gain state and permitted error must accompany the number before it describes useful receiver capability.

DYNAMIC-RANGE ACCEPTANCE MATRIX: A structured set of receiver tests spanning the weak references, blockers, tone spacings, modulation, gain states, external paths and recovery conditions relevant to the declared use. Its results establish a bounded operating region and known exclusions. One favorable catalog number cannot replace this configuration-dependent evidence.

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EDGE TRIGGER: A trigger based on a declared rising or falling crossing in the observed trigger signal. The selected signal-path location, threshold, slope and timing behavior determine which event it identifies. A crossing in that path does not establish complete capture of the corresponding RF event.

EFFECTIVE APERTURE: Equivalent receiving area relating incident power density to available antenna power.

EFFECTIVE CHANNEL GAIN: The ratio of total output signal power to total input signal power for a specified spectral distribution under the applicable combination conditions. It can change when that distribution changes even if the physical path is unchanged. The chapter's two-tone example therefore does not supply a universal correction for every signal in the channel.

EFFECTIVE HEIGHT: A receiving-antenna conversion quantity relating incident electric field to a specified terminal-voltage response under declared direction, polarization and loading conventions. It answers a voltage question, unlike effective aperture's power-density relationship. Its use requires the applicable antenna convention and field conditions rather than treating all antenna conversion factors as interchangeable.

EFFECTIVE NUMBER OF BITS: Converter-performance metric derived from measured noise and distortion relative to an ideal quantizer.

EFFECTIVE PHASE NOISE: The phase-fluctuation spectrum experienced by a blocker in the actual conversion path, including relevant oscillator and driver contributions under a specified operating state.

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EFFECTIVE SAMPLE INDEPENDENCE: Degree to which samples supply distinct information after filtering, overlap and processing, rather than their nominal count.

ELECTRICAL BONDING: The deliberate conductive connection of equipment or structural parts to establish an intended electrical relationship and current path. Its RF effectiveness depends on the actual connection and frequency. A bonding intervention can change external coupling, so its effect should be assessed alongside the preserved desired-signal transfer and installation geometry.

ELECTROSTATIC DISCHARGE: A rapid release of accumulated electric charge that can expose an input network to a damaging transient. It is one of the events considered in receiver protection. Successful survival does not establish unchanged gain, phase, leakage or sensitivity afterward; the relevant measurement functions still need verification.

ELIGIBLE-START UNION: The union, over usable windows and schedule periods, of event start times that satisfy the declared capture criterion.

EMPTY PRODUCT: A product containing no factors, assigned the value one. In the cascade derivation this convention gives unity gain before the first stage, so that stage’s equivalent input noise enters the total without division by an imagined preceding gain.

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ENDPOINT ATTAINABILITY: Whether a stated bound can actually occur under the permitted joint inputs and dependencies. Combining individual extremes can give a conservative enclosure whose corner is excluded by those dependencies. The bound remains useful as an enclosure, but its endpoint must not be described as a demonstrated possible outcome without that check.

ENDPOINT TIME COMPARISON: An estimate of average fractional-frequency error obtained from two time-error observations divided by their reference-time separation. Deterministic endpoint-error limits propagate as a bound on that average. They do not become standard deviations without an additional statistical model, and the interval must not conceal an unmodeled reset.

ENERGY ACCOUNTING: The accumulation of power over the durations to which it applies, with represented and missing intervals treated separately. Model 1A uses valid-interval means to obtain retained energy and separately bounds possible gap energy. A plausible observed mean does not determine the total energy of an unobserved interval.

ENSEMBLE: The declared collection of realizations or paired records over which a statistical or finite weighted average is formed. Its selection, alignment and weights determine the estimator’s meaning. Membership in one collection does not establish independence, stationarity or consistency across changing receiver states.

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ENVELOPE DETECTOR: A detector that estimates a waveform's envelope magnitude through an applicable rectifying, magnitude or equivalent operation. Its bandwidth, time constants and nonlinear behavior affect the result. It loses the sign of an overmodulated real envelope and cannot generally substitute for coherent recovery of suppressed-carrier or single-sideband information.

ENVELOPE REVERSAL: A sign change of a real modulation envelope that magnitude detection cannot preserve.

ENVIRONMENTAL BASELINE: A set of observations describing the site contribution under stated spatial, temporal, polarization, and operating conditions. It helps identify variation relevant to operational sensitivity and possible external noise mechanisms. A baseline is bounded by its coverage and receiver validity; it does not make a quiet laboratory noise figure a guarantee for every occupied-site state.

EPOCH OFFSET: The time-reading error at a declared reference instant. It is the initial condition in Model 12A and is distinct from subsequent fractional-frequency error or drift. Correct average frequency does not remove an existing epoch offset, while a correct initial epoch does not prevent later accumulated error.

EQUALIZER: Adaptive or fixed filter used to compensate channel distortion and intersymbol interference.

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EQUIVALENT NOISE BANDWIDTH: Bandwidth of an ideal rectangular filter passing the same noise power as the actual filter or processing window. The equivalence assumes white noise and a stated gain normalization; it can differ from a nominal resolution-bandwidth label. A nonuniform spectrum requires the actual power weighting or a justified approximation rather than automatic multiplication by one bandwidth value.

ERROR VECTOR: The complex difference between an observed symbol value and its paired reference under the declared amplitude, timing and mapping conventions. Its real and imaginary components retain directional information. Squared magnitude contributes to residual energy, while the scalar EVM aggregate discards information about direction, symbol dependence and temporal ordering.

ERROR VECTOR MAGNITUDE: Normalized distance between measured and reference modulation symbols after stated processing.

ESTIMATOR: The specified mathematical operation that converts retained observations into a reported quantity. A detector bucket, integrated channel, fitted tone, or timing estimate can answer different questions despite similar display labels.

EVENT DURATION: The elapsed length assigned to an event in the stated capture model. It is distinct from the duration of signal that the intended measurement requires. Detecting a fragment, measuring a steady portion and preserving startup or the whole event can impose different criteria on the same event duration.

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EVENT REPEATABILITY: Consistency of the particular waveform properties that a repeated-event measurement needs to combine. Similar nominal repetition periods alone do not establish stable amplitude, phase, modulation or startup behavior. A spectrum assembled from repeated bursts requires evidence for the relevant consistency; otherwise it remains an aggregate of different observations.

EVENT START PHASE: The event's start-time position relative to a repeating observation schedule, considered modulo the schedule period. A particular event can have a fixed phase, while a probabilistic model assigns a distribution to possible phases. These are different statements, and ignorance of the encountered phase does not itself justify uniformity.

EVIDENCE APPLICABILITY: The demonstrated relationship between an observation or record and the subject, configuration, conditions, and proposition it is used to support.

EVIDENCE CONTINUITY: The documented connection from the acquired observations through their configurations, processing and supporting records to the reported inference. It allows later review of what was observed and what was derived. Preserving this connection is distinct from asserting that every sample was acquired continuously; both may be relevant to a particular claim.

EVIDENCE RECORD: The retained observations and contextual information needed to review a measurement and its interpretation. It includes consequential settings, native data, timing, corrections, challenges, unsuccessful tests, and limits on what was examined.

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EXACT SAMPLED RECURRENCE: The discrete update obtained by evaluating a stipulated continuous model at successive sample times without numerical integration approximation. For Model 5A with fixed target over the interval, the residual multiplier is the exponential of the negative interval-to-time-constant ratio. Exactness belongs to that model; it does not establish that a physically discrete controller implements the same rule.

EXCESS-NOISE RATIO: Calibrated noise-source quantity whose temperature and reference convention must be read explicitly; Model 2B uses the on-minus-off temperature divided by 290 K.

EXPANDED UNCERTAINTY: Combined standard uncertainty multiplied by a stated coverage factor, with the basis of the associated coverage interpretation identified.

EXPECTED VALUE: The mean assigned to a random quantity by its specified probability model. It describes the distribution rather than one observed record. The chapter distinguishes the expected logarithmic indication from the logarithm of mean power; neither automatically equals the result of a finite realized capture.

EXPERIMENTAL BLOCKING: Grouping observations under a declared nuisance condition while retaining the relevant comparisons within groups where practicable. It makes the condition explicit rather than removing it. If each reference setting occurs only in a different session, repetition within those sessions cannot recover the missing crossed comparison.

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EXPONENTIAL AVERAGING: A sequential averaging rule that assigns progressively less weight to older records according to a stated decay convention. It emphasizes recent behavior but can smooth changes and short events. Its apparent average count does not establish the independence or stationarity of the contributing measurements.

EXPONENTIAL DECAY: A decrease in a residual by the same multiplicative factor over equal time intervals under a fixed positive decay constant. In Model 5A it preserves the residual's sign and tends toward zero without reaching exact zero at a finite time from a nonzero initial value.

EXPONENTIAL POWER DISTRIBUTION: The positive power distribution generated by the squared magnitude of the chapter's zero-mean circular complex Gaussian sample at a calibrated plane. Its mean fixes its scale, and its variance is the square of that mean. A tone, clipping or a mixture of changing noise levels does not automatically have this distribution.

EXPOSURE ASSESSMENT: The examination of expected signal levels and waveforms at the receiver path before connection or a controlled challenge. It considers continuous and peak power, duty factor, coupling and transients, together with the applicable component limits. Protection hardware supplements this assessment rather than making the incident conditions irrelevant.

EXTERNAL GAIN: Signal gain contributed by a component outside the receiver indication's reference boundary. In the stated scalar backward level correction it is subtracted, provided its value and operating state apply to the observed path.

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EXTERNAL TRIGGER: A trigger derived from a separate input or control event rather than solely from the receiver's measured RF signal. It can establish a useful acquisition reference, but the delay and relation to the stored samples require characterization. A command event does not prove that the commanded physical state was reached.

FACTOR LEVEL: A specified physical setting or condition of a factor used in an experimental comparison. Its implementation can change several electrical or processing properties at once. Document the actual connections, terminations, routes and states rather than treating a convenient menu label as a uniquely isolated mechanism.

FALSE-ALARM PROBABILITY: The probability that the adopted decision rule is satisfied under the specified absence or noise-only condition. It depends on the decision statistic, threshold and set of opportunities being evaluated. A value established for one preselected channel cannot be transferred unchanged to an unrestricted frequency-and-time search.

FALSE LOCK: Apparent synchronization to noise or an incorrect structure.

FALSE POSITIVE: Result incorrectly satisfying a detection or classification rule in the absence of the claimed phenomenon.

FAR FIELD: The region where the radiation field admits the relevant far-distance approximations, including a stable angular pattern and approximately planar illumination across the receiving aperture. Applicability depends on wavelength, source dimensions and geometry. A fixed separation does not establish it universally.

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FAST FOURIER TRANSFORM: An efficient computational method for evaluating a discrete Fourier transform. Its speed does not change the finite-record interpretation, window response or normalization requirements. An FFT-based display remains conditioned by the actual samples and preprocessing, rather than becoming a direct measurement of an unrestricted continuous spectrum.

FEEDBACK LOOP: A control arrangement in which an observed response influences an action on the system. In gain control, detected level can change receiver gain and therefore later detected level. A fitted local control-voltage trajectory does not by itself reconstruct the detector, loop topology or every overload mechanism.

FIELD-TO-TERMINAL CONVERSION: The relationship between an incident field and the electrical quantity at an antenna's terminals under stated conditions. Pattern, polarization, field region, loading and installation affect its applicability. A sound terminal-power measurement therefore does not automatically support an equally sound field-strength estimate in an uncharacterized environment.

FILE ROLLOVER: The controlled transition from one recording file to the next during a longer acquisition. It keeps files manageable while requiring preserved chronology and explicit continuity evidence across the boundary. Successful closure and hashing of individual files do not by themselves show that no samples were lost or repeated between them.

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FILTER BANK: A set of selectable filters covering declared frequency bands. Changing the selected member can alter insertion loss, noise, phase and calibration even when tuning appears continuous. The record therefore needs the actual band identity and checks near the boundaries where the active path changes.

FILTER-BANK BOUNDARY: A tuning region where a receiver changes between discrete preselector or filter paths. The transition can change gain, phase, noise, or correction applicability even if the displayed frequency changes smoothly. Reference observations on both sides, together with actual band identifiers, are needed to assess continuity and the validity of comparisons across the boundary.

FILTER RINGING: A transient oscillatory response following a change or short excitation, determined by the filter's full dynamics. Ringing can extend an apparent event or alter a detected peak even when a continuous-tone amplitude is correct. Its relevance depends on the waveform and measurand; loaded Q or a single bandwidth label does not completely specify it.

FILTER SETTLING: The approach of an IF path's output to the response required by a stated stimulus and error criterion after a change. It depends on the full filter and observation chain, not merely the gain-control time constant. A burst shorter than the relevant settling interval can be measured before its steady response develops, changing peak or timing interpretation. A tuned or switched dwell can contain an unusable settling portion. Filter shape, architecture and the accepted error criterion matter; bandwidth alone does not supply a universal wait time.

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FILTER SKIRT: The part of a filter response that changes between its transmitted and rejected frequency regions. A blocker across this region can experience a very different transfer from a nearby desired tone. A wide waveform reaching into the skirt can suffer amplitude and phase distortion not represented by a center-frequency correction.

FILTER SPAN: The finite time or symbol-interval extent retained when implementing a pulse-shaping or receive filter. State its units, coefficient convention and relation to sample rate. Truncation, delay and initial history can affect the residual around transitions even when the nominal filter family and roll-off agree.

FILTER TUNING REPEATABILITY: The consistency of a tunable or switched filter's realized response when commanded to return to a specified state. It includes the response relevant to the intended amplitude, phase, or rejection measurement, not merely agreement of the displayed tuning value. Boundary crossings, temperature, and switching history can require explicit comparison.

FINDING CATEGORY: The explicitly stated evidential status assigned to a reportable observation, such as normal occupancy, artifact, installation defect or unexplained signal. Categories allow a conclusion to remain proportionate to the completed work. Moving to a stronger category requires its additional evidence rather than a more confident adjective.

FINITE DIFFERENCE: A change between sampled quantity values divided, where required, by their stated separation. Applied to correctly unwrapped phase, it gives an interval-average frequency under the chapter's continuity premises. Treating that result as an instantaneous derivative requires a further local approximation and an explicit interval convention.

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FINITE IMPULSE RESPONSE FILTER: A linear filter whose impulse response has finite support. In the chapter's causal construction, each output is a weighted sum of finitely many current and earlier samples. Its coefficients, source-index alignment and available history determine both frequency response and the duration of dependence on a missing input.

FINITE-RECORD ENERGY CLOSURE: The exact agreement between the correctly normalized discrete spectral integral and the corresponding window-weighted time-domain mean square. It checks transform scaling, side conventions and frequency spacing. It does not establish white noise, adequate sampling, physical calibration, source identity or valid observation of every transient.

FINITE-RECORD LOGARITHMIC BIAS: The difference between the expected logarithm of a finite arithmetic power average and the logarithm of its underlying mean power. For the chapter's independent exponential samples this depends on sample count and approaches zero as that count increases. It differs from the fixed offset of averaging the individual logarithms.

FINITE-SAMPLE SELF TERM: The diagonal contribution obtained when the squared magnitude of a finite coherent phasor sum is expanded. Each unit-magnitude phasor contributes its own power before cross terms are considered. This produces the finite-count contribution in Model 12B and prevents replacing expected coherent power by the squared ensemble-mean phasor.

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FIR STATE: Stored input history or equivalent realization state required to continue a finite impulse response filter across a processing boundary without changing the declared filter operation. The realization's delay-state coordinates need not be a raw list of prior input samples; transfer the compatible state or reconstruct the equivalent history.

FIRST-ORDER RESPONSE: A dynamic response represented here by one control-state equation and one positive time constant on a fixed-target segment. That local description predicts a monotone exponential approach. It does not prove that a physical receiver has only one internal state or that attack, release, hang and overload behavior share the same parameters.

FITTED-REFERENCE EVM: The normalized residual magnitude when the permitted fitted complex gain multiplies the ideal symbols in both the comparison reference and its energy denominator. The fitted coefficient must be nonzero and evaluation reference energy positive. Reducing the residual numerator does not guarantee a smaller ratio if the fitted denominator also falls.

FIXED-POINT FORMAT: A numerical representation with a specified total word width and a fixed binary scaling position. Together these determine its representable grid and range. Conversion into the format also requires a rounding and overflow policy; the format name alone does not specify where those conversions occur within a processing chain.

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FIXED-REFERENCE EVM: The normalized residual magnitude relative to a declared reference that is not adjusted by fitting the evaluated observation record. It can retain an amplitude or phase discrepancy that an allowed fit would remove. The reference, population, weights and compatible amplitude convention must still be specified; fixed does not mean independently validated.

FLAT LEAKAGE: The leakage level during the comparatively settled limiting portion of a specified large-signal event, as distinguished from an initial leading transient. The term does not imply identical behavior for every pulse width, frequency, source impedance, or load. It must be tied to the applicable test definition and does not alone establish survival or recovery.

FLAT-SPECTRUM APPROXIMATION: Replacement of a varying linear spectral density by one constant over the frequency region carrying significant filter weight. It is exact for the stated constant-density case and requires justification otherwise. A center-frequency phase-noise value alone does not establish the integrated noise when other admitted offsets have different densities.

FOLDED FREQUENCY: A representative nonnegative frequency in the first Nyquist interval for real-sample magnitude interpretation, without an implied analog-source identity.

FORWARD-EULER APPROXIMATION: A first-order numerical update that advances a state using the derivative at the beginning of the interval. Applied to Model 5A, its residual coefficient is one minus the interval-to-time-constant ratio. This differs from the exact exponential coefficient and can introduce sign alternation or instability when the step is too large.

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FOURTH MOMENT: The expectation of the fourth power of a stated real random quantity, when finite. Model 11B uses the phase fourth moment to bound omitted nonlinear power. A zero-mean Gaussian marginal supplies a particular moment relation, but that marginal condition alone establishes neither strict stationarity nor a specific phase spectrum.

FRACTIONAL FREQUENCY ERROR: Frequency difference normalized to a reference frequency.

FRACTIONAL SETTLING CRITERION: A requirement expressed as the permitted residual fraction of a specified nonzero initial step. For the chapter's one-pole law, a fixed fraction gives a fixed number of time constants, independent of step magnitude. A common absolute gain tolerance can instead require different waits for different initial errors. The chosen fraction must be tied to the measurement decision.

FRAME HEADER: A defined information field accompanying a frame's payload and counted according to the framing rule. It can consume coded transmission capacity without belonging to the requested payload. The finite-frame example separates header bits from final padding and from redundancy introduced by the channel code.

FRAME PADDING: Unused positions filled under the declared complete-frame rule when a finite request does not occupy all available payload capacity. These positions consume transmitted frame resources but do not add original request bits. Padding must be distinguished from headers, coding redundancy and retransmitted payload to avoid double counting their effects.

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FREQUENCY-AGILE SIGNAL: A signal whose operating frequency changes during the observation under a stated trajectory or switching behavior. A swept analyzer and the signal can traverse frequency at different times, leaving only fragments in the trace. Validation must reproduce the relevant timing and frequency behavior of the target event.

FREQUENCY-AXIS CALIBRATION: Establishing the relationship between known frequency values and a receiver or processing system's frequency indications under specified conditions. The relationship includes scale, offset, and orientation where relevant, together with applicable uncertainty. A center-tone agreement does not establish the direction of a frequency increment, and a reference or software-scale change can move labels without proving that a physical external tone moved.

FREQUENCY BIN: One discrete frequency coordinate and its associated transform or spectral estimate. A bin is an evaluation location, not an isolated physical band that necessarily contains one independent signal. Adjacent window responses can represent the same tone, and padding can add bin locations without adding observations.

FREQUENCY CONVERSION: The transformation of an admitted signal into another frequency coordinate through a declared mixing or digital operation. A complete description retains amplitude, phase, orientation and path selection as well as the output frequency. The absolute difference alone describes only a limited real first-order conversion case.

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FREQUENCY-DEPENDENT GAIN: A transfer that differs across the frequencies contributing to the measured quantity. Correct resolved components with their applicable gains before forming a channel total. A single aggregate correction depends on how input power is distributed across that response and cannot generally be obtained by averaging gain labels.

FREQUENCY DISCRIMINATOR: A receiver operation that converts frequency variation into a baseband output according to its applicable transfer characteristic. Deviation scale, bandwidth, linear range and input conditions require verification. The term does not guarantee that amplitude nulls, multiple components or threshold behavior leave the recovered frequency unambiguous.

FREQUENCY DIVIDER: A stage that derives a lower repetition or oscillation frequency from an input according to its division relationship. Divider-related clocks and harmonics can belong in a receiver spur search. The actual relationship and admitted path are needed before a numerical combination can support an interpretation.

FREQUENCY DRIFT: A change of fractional frequency with elapsed time under a declared local model. A constant drift coefficient gives a quadratic contribution to accumulated time error. Its fitted value and validity interval must remain explicit; the same law need not survive warmup, reference loss, restart or environmental change.

FREQUENCY INTERVAL: The declared frequency scope over which components can contribute to an observation or reported estimate. Excluded or unobserved portions remain outside a negative finding unless separate evidence establishes their coverage.

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FREQUENCY-MASK TRIGGER: A trigger that compares an estimated spectrum with a specified amplitude-versus-frequency boundary and applies the declared entry or exit condition. Its decision depends on the transform, window and processing interval. It therefore has different selectivity and timing from a direct sample-level threshold.

FREQUENCY MODULATION: A signal relation in which a specified message controls frequency deviation from a declared carrier reference. Phase follows by integration. For sinusoidal deviation, the peak phase index is peak deviation divided by positive modulation frequency; a constant offset instead produces a linear phase ramp.

FREQUENCY PLAN: The declared arrangement of oscillator frequencies, intermediate frequencies, injection sides and selected paths that maps an external input into the measured output. Its live state includes band switching and relevant references. Different plans can produce the same output center while retaining different images, orientation and calibration.

FREQUENCY RESOLUTION: The ability of a measurement procedure to distinguish nearby frequency components under stated signal and response conditions. Resolution bandwidth influences it, but filter shape, relative levels, observation time and processing also matter. A narrower display grid does not alone demonstrate improved separation.

FREQUENCY RESPONSE: The amplitude and phase transfer of a path as a function of frequency under its stated operating conditions. It explains which parts of a waveform are transmitted and how their phases change. A center-frequency gain or one bandwidth number does not determine the full response.

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FREQUENCY-SHIFT KEYING: A modulation family that conveys discrete values through selected frequency states. Classification must consider timing and the actual demodulation convention as well as visible spectral peaks. The choice of frequency states does not, by itself, establish the frame format, coding or source identity.

FREQUENCY SPAN: The frequency interval covered by a stated analyzer acquisition or display. In a swept mode, covering that span takes time and does not establish simultaneous observation of all included frequencies. Span must be interpreted with the actual sweep trajectory, selected filters, segment boundaries and usable observation intervals.

FREQUENCY STABILITY: The behavior of a source's frequency fluctuations over a specified time interval and under stated conditions. It is distinct from closeness to the desired nominal frequency: a stable source can retain a constant offset. The relevant averaging interval and treatment of drift or discontinuities belong with the stability statement.

FREQUENCY STANDARD: A reference that supplies or realizes a frequency used in comparison or calibration, with its applicable uncertainty and operating conditions established. A receiver's internal or external standard must be related to the point actually being tested. Its designation alone does not certify the present tuning, sample clock or distributed channel phase.

FREQUENCY SYNCHRONIZATION: Agreement of specified frequency rates or their controlled relationship over a declared interval. It can coexist with unknown epoch, trigger or channel-phase offsets. Sharing a reference oscillator therefore does not establish the sample alignment or deterministic phase relationship required for every multichannel inference.

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FREQUENCY SYNTHESIZER: A source that produces controlled oscillator frequencies using a reference and a synthesis architecture. Its references, divider relationships and lock state can contribute to the receiver's conversion map and spur hypotheses. The active configuration must be recorded rather than inferred from a generic block diagram.

FREQUENCY-TIME TRAJECTORY: The sequence of frequency regions observed as a swept or stepped instrument progresses through its acquisition.

FREQUENCY TUNING RESOLUTION: The spacing between adjacent frequencies selectable by the declared oscillator tuning-word model. It is a setting-grid property, distinct from spectral discrimination and actual frequency accuracy. The chapter separates the accumulator grid from phase truncation, clock error and other mechanisms that can affect waveform fidelity.

FULL-RATE TRIGGER: A trigger operating on the undecreased sample stream at its stated processing location. Its relation to saved samples still depends on filtering, comparator behavior and latency. The contrast with a decimated trigger identifies a path distinction; it does not establish universal timing or sensitivity performance.

FULL-SCALE RANGE: The declared amplitude range or reference span against which converter inputs and code spacing are specified. Its endpoint convention must be stated because a nominal positive reference peak need not be an exactly representable code. Signal headroom and crest factor affect the useful mean-square margin within that range.

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FUNCTIONAL ATTRIBUTION: An inference establishing the relevant operation or information function of a linked system. In the chapter's finding ladder, confirmation requires physical or operational linkage, an information path, authorization context, reproducible behavior and evidence continuity. A dramatic trace or recognizable modulation does not independently establish that complete claim.

FUNDAMENTAL COMPONENT: The output spectral component at one of the declared driving-tone frequencies. Its coefficient can contain both the linear response and nonlinear contributions at that same frequency. An intercept extraction that requires the linear asymptote must not silently substitute the full finite-level fundamental.

FUNDAMENTAL CORRECTION: The contribution of retained nonlinear terms to the amplitude at a parent frequency, distinct from a newly generated intermodulation component.

GAIN ALLOCATION: Choice and placement of gain that satisfies a noise requirement while preserving the valid signal range of later stages.

GAIN BUDGET: The accounting of component gains and losses connecting two declared signal planes. Linear power gains multiply, while their logarithmic gain differences add. Equal total signal gain does not imply equal noise performance, because moving loss or amplification changes how the individual noise contributions refer to the input.

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GAIN-ERROR MAGNITUDE: The nonnegative difference from the target gain attributable to the control residual under the chapter's calibrated local affine gain map. It equals the residual magnitude multiplied by the absolute gain slope and is expressed in decibels. It is distinct from signed gain change and does not include every calibration or signal-path error automatically.

GAIN EXPANSION: An increase in the selected response gain as the input rises away from the small-signal reference. In the stipulated cubic model, a positive cubic coefficient increases the fundamental amplitude within its declared range. Equal intermodulation powers can occur with the opposite coefficient sign, so those powers alone do not distinguish expansion from compression.

GAIN-FEASIBILITY INTERVAL: The overlap between a lower gain bound required by a noise objective and an upper gain bound permitted by downstream loading, under declared models and conditions. An empty overlap means no gain choice satisfies both requirements. A nonempty interval identifies candidate settings but does not independently establish stability, mismatch behavior, or transient validity.

GAIN-RANGE TRANSITION: A change between receiver gain ranges whose reference gain, control slope, limits or dynamics may differ. A continuous telemetry voltage does not prove continuous RF gain through the transition. Retain the active range and switch timing, use the applicable calibration for each segment, and verify any interval in which the transfer changes or becomes undefined for the intended correction.

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GAIN STABILITY: Constancy of the applicable signal power gain over the observations being compared. A hot-to-cold power ratio cancels gain only if the gain is common to both states. Repeatable switching-dependent gain changes can bias the inferred noise temperature even when repeated ratios have little random variation.

GAIN-STATE TELEMETRY: A retained record of actual receiver gain settings or gain-control behavior associated with acquisition time. Its temporal resolution must be sufficient for the amplitude interpretation being made. A final setting or average gain does not describe brief transitions, and telemetry cannot restore information lost by clipping or samples that were never acquired.

GAMMA POWER-SUM MODEL: The probability model for the normalized sum of the chapter's independent, identically distributed exponential power samples. It supplies the logarithmic moment used to derive the finite-record correction. Repeated copies, overlapping observations or other dependence do not acquire this model merely because the file contains the same nominal number of samples.

GAP MAP: An explicit record of missing or otherwise unusable sample intervals and their positions in the acquisition chronology. It prevents simple concatenation from erasing the true elapsed interval or creating a false signal discontinuity. Analyses requiring uninterrupted uniform sampling must respect the mapped boundaries.

GATED SWEEP: Measurement restricted to a selected time interval relative to a trigger.

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GATE WIDTH: The duration of the selected time interval admitted by a gated measurement. It determines which part of the event contributes, together with trigger delay, timing uncertainty and receiver response. A narrow gate does not by itself establish settled operation or capture of all the signal energy required by the intended measurand.

GAUSSIAN DISTRIBUTION: The real normal probability law specified by a mean and variance, including a limiting constant case when the variance is zero. Model 12B uses its characteristic function for a phase difference under an explicit joint-Gaussian premise. A measured RMS value alone neither establishes this law nor makes separate samples independent.

GRADIENT: The set of first partial derivatives of a scalar measurement function at a declared input point. These signed, dimensioned sensitivities define its local linear approximation. They can propagate input covariance locally, but a small or zero derivative does not show that curvature or a nearby domain boundary is negligible.

GROUP DELAY: Negative derivative of phase with angular frequency, used to describe delay of spectral components through a network.

GUARD BAND: Decision margin used to account for uncertainty near an acceptance or compliance limit.

GUARD BIT: Additional representation width retained to accommodate a proved intermediate range; its need depends on the actual operations and input bounds.

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GUARD INTERVAL: A declared time interval separating active signaling portions or frames. It belongs in elapsed-time rate accounting even when it contains no transmitted symbols. It may be represented as nominal slots only if that grid is explicitly defined through the interval; otherwise its duration is added separately.

HALF-POWER BANDWIDTH: The frequency separation between the two declared points where a response's transmitted power is one half of its reference level, conventionally associated with a three-decibel width. The reference response and crossing convention must be specified. It differs from noise-equivalent bandwidth and other labeled filter widths.

HANG STATE: A declared control mode that delays or modifies release after a specified event. A simple held-state example retains the attained control value for a defined duration before exponential release begins. The trigger, retrigger behavior and held quantity must be identified; replacing a hold with a larger release time constant changes the predicted trajectory.

HANN WINDOW: A cosine-based taper whose actual coefficient vector must be specified as periodic or endpoint-symmetric. Those forms have different finite weight sums, especially for short records. The chapter derives coherent gain and noise bandwidth from the selected vector rather than treating the name as a complete normalization rule.

HARMONIC: A spectral component at an integer multiple of a stated fundamental frequency. Mixer and oscillator harmonics can enter candidate product searches or contaminate a test stimulus. A harmonic's possible location does not establish that it exists at an appreciable level, so source purity and measured response remain separate evidence.

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HARMONIC GENERATION: Production of components at integer multiples of an input component's frequency by nonlinear behavior. A protection or active stage can create such energy while apparently preserving another part of the useful band. Characterization must distinguish the generated components from energy already present in the source.

HARMONIC PRODUCT ORDER: The declared integer-search measure equal to the sum of the absolute parent coefficients in the chapter's bounded product lattice. It limits which candidate combinations are enumerated. This bookkeeping order does not itself identify the physical nonlinearity, establish that every candidate is generated, or predict amplitude. A search report should retain the bound and any later expansion that increases the number of possible matches.

HEADROOM: Difference between operating level and a specified compression, overload, clipping, or damage limit.

HELD-OUT DETECTION TEST: Evaluation of a fixed detection rule on challenge records distinct from those used to select its threshold or processing. The chapter calls for both noise-only intervals and weak reference events under declared conditions. The separation helps reveal optimistic tuning results, while the tested event population and uncertainty still limit the conclusion.

HELD-OUT SYMBOL EVALUATION: Error-vector assessment on symbols excluded from fitting the stated alignment parameters.

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HELD-OUT VALIDATION: Evaluation on records not used to select the fitted model, processing rule or decision setting. It supports a claim about behavior beyond the examples used for that choice. Reprocessing the same selected field events under a stricter rule does not by itself provide this independent validation. For timing, phase and delay corrections, preserve the original records and correction method so that overfitting or retained instability can be examined. Alignment on the fitting record alone is insufficient evidence of behavior on excluded observations.

HIGH-PASS FILTER: A frequency-selective network that preferentially transmits frequencies above its transition region and suppresses lower frequencies within its specified response. In a front end, its useful protection depends on the actual blocker and desired-signal transfers, component placement, and power conditions, not just the filter-type label.

HILBERT TRANSFORM: The quadrature transform used with a real message to form an analytic representation. Under the chapter's complex-frequency convention it shifts positive-frequency components by minus a quarter cycle and negative-frequency components by plus a quarter cycle. Pairing the message with this transform supports the stated single-sideband construction; implementation errors still require measurement.

HOLDOVER: Operation of a disciplined clock after loss of its external reference using its internal oscillator and stored model.

HOT-COLD GAIN RATIO: Power gain in the hot source state divided by power gain in the cold state; a value other than unity invalidates the equal-gain Y-factor inversion.

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HOT-SOURCE TEMPERATURE: The calibrated or otherwise justified effective noise temperature T_h of the higher-noise source state in a hot-cold measurement. It must exceed T_c for the chapter inversion. Its applicability is tied to the reference plane, connection corrections, and source convention; it is not inferred solely from the receiver output being larger.

HOT-STATE COMPRESSION: Nonlinear response caused when the higher-noise source state drives part of the receiver beyond the applicable proportional gain range. It breaks the common linear law used to cancel gain in the hot-cold ratio. A stable output reading does not exclude this effect; both source states require an appropriate linearity check.

IDENTICALLY DISTRIBUTED SAMPLES: Samples having the same individual probability distribution. They can still be dependent. The expected average of their logarithmic powers uses the shared one-sample law, while the stated variance reduction and gamma sum model require additional independence assumptions.

IDENTIFIED CONTROL RESPONSE: A dynamic control-state law fitted or established within a declared operating interval and configuration.

IMAGE FREQUENCY: Unwanted input frequency that produces the same selected intermediate frequency as the desired input.

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IMAGE REJECTION: Suppression of the response to an unwanted RF input that reaches the same selected IF as the desired input, evaluated under declared frequency, level, and receiver-state conditions. A differential path measurement refers outputs to the actual calibrated input levels and controls source contamination. Rejection can vary with tuning, alignment, temperature, quadrature balance, and overload; a single tested pair does not establish a universal receiver value.

IMAGE-REJECT MIXER: A conversion structure intended to suppress the response from the alternate RF band that would otherwise share the selected output. Its rejection depends on the implemented paths, balance and operating state. Image rejection must be verified with controlled injections rather than inferred from the architecture's name.

IMAGINARY UNIT: The number whose square is minus one, denoted by j in the receiver models. It permits amplitude and phase to be represented together in complex envelopes and exponentials. Its use is mathematical; the physical real RF waveform is recovered through the explicitly stated real-part operation.

IMPEDANCE MATCHING: The interface condition that permits the stated source-to-load power-transfer convention. Model 2B assumes matching to one common real reference impedance, so available and delivered source power coincide. Reactive or state-dependent mismatch can invalidate a scalar correction measured between matched ports and may require a more complete network model.

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IMPULSE RESPONSE: The time-domain response of a linear path to an ideal impulsive input under the stated initial conditions. It describes the history through which that path acts on a waveform. Retaining the applicable response or a justified model is necessary when a short event cannot be interpreted from bandwidth alone.

INCIDENT POWER DENSITY: The incident electromagnetic power crossing unit area, specified with its direction and averaging convention and expressed in watts per square meter. The chapter's ideal receiving relation multiplies this quantity by effective aperture under the stated far-field, polarization and matching assumptions. It is distinct from terminal power and from power spectral density.

INCREMENTAL GAIN: The local change in an output quantity produced by a small change in the corresponding input quantity at a fixed operating condition. It can differ from the ratio of the total output and input. A compression curve interpreted through this gain must retain the input definition, reference planes and receiver state.

INDEPENDENT CAPTURE TRIALS: Trials whose relevant event phases and capture outcomes satisfy the independence needed by the stated probability model. Counting separate files or repeated commands does not establish this property. Under the additional common-probability premise, the complement of all misses gives the probability of at least one capture.

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INDEPENDENT COMPARISON: A comparison that changes relevant sources of measurement error while retaining the capability required to observe the component of interest. Separate instruments do not establish independence when shared clocks, input paths, or processing can produce a common result. The required distinction concerns the error mechanisms relevant to the intended inference. A useful added observation changes a coupling, timing or processing path that could otherwise explain the agreement.

INDETERMINATE RESULT: An outcome in which the supplied evidence does not meet the stated conditions for either acceptance or rejection. In the chapter's constructed rule, an uncertainty interval overlapping the upper limit has this status. It neither proves compliance nor proves that the actual quantity exceeds the limit.

INFLUENCE QUANTITY: Under the VIM convention for a direct measurement, a quantity that changes the relation between indication and result without changing the quantity actually measured. Receiver temperature can have this role in a fixed-input amplitude test. The GUM uses a broader convention, so the adopted measurement model must state which effects its inputs represent.

INFORMATION-BIT COUNT: The number of input bits belonging to the complete coding populations included in Model 7B. This count can include payload, headers and padding under the stated framing convention. It is therefore different from both coded label-bit count and useful request-payload count; its interpretation must accompany any code-rate or payload-fraction calculation.

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INITIAL CONDITION: The state assigned at the beginning of the interval over which a dynamic model is solved. It helps determine the subsequent trajectory together with the model and target. For successive receiver events, the applicable initial condition is the prior terminal state, unless a separately established reset or equilibration supplies another value.

INITIAL-STATE BOUND: A declared interval containing the control voltage at the start of a model segment without necessarily assigning a probability distribution. With fixed target and time constant, Model 5A maps both endpoints through an increasing affine transformation, contracting the interval width. The resulting bound covers initial-state uncertainty only, unless other parameter contributions are treated explicitly.

INJECTION SIDE: Whether the local oscillator lies above or below the desired RF frequency for a selected conversion.

INJECTIVITY: The property that distinct admissible inputs produce distinct complete outputs of a specified mapping. Critical sampling alone does not establish it. The chapter demonstrates a bank with a nonzero invisible input residue and a modified bank whose positive energy lower bound excludes such an input within the stated finite-energy domain.

INNER PRODUCT: A specified sum pairing the components of two vectors, including the required conjugation for complex values. It defines the geometry used in the chapter’s coherence and projection arguments. The reference, weights and ordering must be preserved because changing them changes the fitted relationship.

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INPUT INTERCEPT POINT: Extrapolated input level at which selected nonlinear products would equal the fundamental output under a defined test. The reference fundamental in Model 11A is its linear asymptote. The input intercept is defined per tone at the loaded input plane, within the declared model and measured interval. It is neither an attainable operating level nor the total power of a multi-tone input.

INPUT PATH: The physical route by which energy reaches the selected receiver input, including consequential antennas, cables, adapters, filters, switches, and other components. Changing the route can change both desired transfer and artifact mechanisms.

INPUT REFERRAL: A reporting transformation that expresses an output quantity at a declared input plane using the applicable transfer law. For noise power in the valid scalar model, divide by the state-specific signal power gain. The operation does not move noise generators physically or restore information lost through an invalid nonlinear state.

INPUT-REFERRED CONVERTER NOISE: The converter-added noise contribution expressed at an earlier selected input plane through the applicable analog signal power gain. Increasing valid analog gain can reduce this referred contribution while leaving the analog signal-to-noise ratio already present unchanged. The conversion requires the actual state and does not justify exceeding converter or upstream-stage range.

INPUT SUPPORT: The complete set of values permitted by the stipulated joint input model. It can determine whether a nonlinear operation is defined throughout the problem. The paired-power example proves a positive difference over its full support before applying a logarithm; a positive central estimate alone would not establish that property.

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INSERTION LOSS: The reduction in transferred signal associated with inserting a specified path under declared calibration planes, source and load conditions, frequency and level. Its measured value is conditional on those arrangements. Reconnection, strain, mismatch or a different selected branch can change the installed transfer.

INSTALLED PATH: The measurement path in its actual operating geometry and connections. Cable routing, antenna position, polarization, accessories, and coupling conditions can distinguish it from an isolated component characterization.

INSTALLED RESPONSE: Behavior of the receiving assembly in its actual mounting, cable, grounding, and environmental arrangement.

INSTANTANEOUS ACQUISITION BANDWIDTH: The frequency extent admitted for simultaneous acquisition in the stated receiver configuration. It limits which components can be preserved together in one usable interval. A wider displayed or swept span may combine observations made at different times and does not establish simultaneous coverage of that whole span.

INSTANTANEOUS FREQUENCY: In Model 6B, the carrier reference plus the derivative of the stipulated unwrapped phase divided by two pi, wherever that derivative exists. The model requires a meaningful nonzero complex signal and an applicable continuous phase branch. A finite phase difference instead gives an interval average, and a phase reset requires separate treatment.

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INTEGRATING CONTROLLER: A controller that accumulates a control error over time when determining its action. The cited gain-control example treats integrating behavior separately from its local small-change response. Limits and overdrive can alter the accumulated state, so a one-pole voltage fit alone does not establish the full controller behavior.

INTEGRATOR WINDUP: Accumulation or displacement of an integrating controller's internal state when the requested output cannot be achieved within an actuator or gain limit. Return to ordinary operation can then require recovery of that state. This is a possible large-change control mechanism, not a universal explanation for every slow receiver response; its presence and limits require circuit or input/output evidence.

INTERCEPT EXTRAPOLATION: The procedure of extending specified low-level fundamental and nonlinear-product laws to their algebraic intersection. In Model 11A it equates the linear fundamental asymptote to a selected cubic-product magnitude, retaining per-tone powers and reference planes. A measured fundamental with finite nonlinear correction requires a fitted asymptote or an explicitly bounded correction.

INTERCEPT POINT: The extrapolated input or output level at which a specified nonlinear product and reference fundamental asymptote have equal power under the declared test convention. It is a parameter of those response laws, not an attainable operating level or a compression threshold. The input and output values differ by the declared power gain expressed in decibels.

INTERMEDIATE CHECK: Reference observation between calibrations used to test continued validity for a stated quantity and configuration.

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INTERMEDIATE FREQUENCY: A frequency coordinate at an internal selected conversion output used for subsequent filtering, amplification, detection, or sampling. A receiver can contain several IFs, and the same final IF can arise through different conversion plans. Its magnitude alone does not identify the external RF input, the injection side, the phase orientation, or which unwanted response may have reached the selected path.

INTERMEDIATE-FREQUENCY CHAIN: The selected path of gain, filtering, detection and possibly digitization operating around an intermediate frequency. It is a measurement subsystem with its own transfer and state. Audio, spectrum display and stored samples may use different branches, so their results require the applicable path and detector information.

INTERMODULATION: Generation of spectral components from interactions among multiple input components in a nonlinear path. Their frequencies and levels depend on the admitted parents and the governing nonlinearity. A matching product signature supports a mechanism test but does not locate the generator without source, combiner and path controls.

INTERNAL CONTRIBUTION: Noise or artifacts generated within the declared measurement system rather than simply arriving at its chosen external input. Equation 1 retains this contribution so that observed output is not automatically equated with an environmental source. The retained output contribution has a quantity type and units compatible with that output. Calling it a residual does not establish independence from the input, a stationary distribution or an additive-power law.

INTERPOLATION RESIDUAL: Difference between a physical response and the adopted interpolation model, characterized separately from uncertainty in the endpoint values.

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INTERSYMBOL INTERFERENCE: Contribution from other symbol pulses to the observation used to decide a selected symbol. Pulse shape, sampling time, channel response and filter history determine that contribution. A filter name alone does not establish its absence in an imported or incompletely initialized recording.

INTERVAL-AVERAGE FREQUENCY: The unwrapped phase change divided by two pi and the elapsed interval, with any included phase discontinuity explicitly identified.

INTERVAL CONTRACTION: Reduction of an admitted state interval's width by a specified map. With fixed target and time constant, Model 5A multiplies the initial-state width by its positive exponential factor. This deterministic contraction does not include uncertainty in the target, time constant, gain slope or time alignment.

INTRAPULSE MODULATION: Variation of amplitude, phase, frequency or another defined property within the duration of a pulse. It is distinct from the timing or rate at which complete pulses repeat. Averaged spectra or insufficient instantaneous bandwidth can conceal which part of a pulse carried the observed structure.

INVERSE DISCRETE FOURIER TRANSFORM: The inverse finite Fourier mapping under a declared sign and normalization convention. Model 10C defines it with a positive exponential and division by the transform length. Its required unscaled channel sum is therefore the length times that inverse; substituting a differently normalized transform changes the voltage gain.

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INVERSE PROBLEM: The task of determining which input quantities are supported by a retained output and a declared forward model. A formula can be numerically reversible while the acquisition has discarded information or its state is unknown. Model 1A therefore checks domain, applicability and uniqueness before reporting an inferred input.

INVERSION CONDITIONING: The sensitivity of an inferred quantity to changes in the measured inputs of an inverse relation. The Y-factor temperature inversion is poorly conditioned near $Y = 1$ because its denominator approaches zero. Small ratio or calibration uncertainties can then produce large, asymmetric changes that a local linear uncertainty approximation may not adequately describe.

I/Q IMBALANCE: A departure from the intended relationship between in-phase and quadrature paths, such as unequal gain or an incorrect quadrature phase. It can produce image-like residual structure. A conjugate-component model can test that structure, but an EVM value or successful correction alone does not establish its physical origin.

I/Q ORDERING: The assignment and sign convention by which the in-phase and quadrature channels form a complex sample sequence. Reversing the sign of the quadrature channel conjugates that sequence and reverses its signed-frequency interpretation. A magnitude display may conceal the change. Known tones on both sides of the LO provide an end-to-end check of the saved data and frequency-axis convention.

I/Q SAMPLES: Paired in-phase and quadrature values representing a complex analytic or translated signal.

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JOINT DISTRIBUTION: The probability law describing a complete set of random quantities together, including their dependencies. Means and covariances alone do not determine an arbitrary joint law. The chapter adds joint Gaussianity when it needs exact nonlinear expectations of phase exponentials, separately from the second-order spectral description.

JOINT GAUSSIAN PHASE MODEL: An explicit distributional model in which every linear combination of the finite phase vector is normally distributed, allowing degenerate cases. The declared mean and covariance then determine the characteristic function used in Model 12B. Stationarity, marginal RMS values or a measured power spectrum alone do not establish this additional assumption.

LATENT SOURCE: An unobserved contributor capable of influencing more than one measured channel. A shared source can produce the same measured second-order spectra as a different linear representation. Coherence alone therefore cannot choose between a common-source explanation and a claimed direct physical path.

LEADING-EDGE LEAKAGE: The early portion of a strong event that reaches the protected downstream path before the later limiting response is established. Its peak and duration can differ from the subsequent leakage. A measurement of only the settled limited level may therefore underdescribe the actual exposure of the protected component.

LEAST-SQUARES CRITERION: A fitting objective that minimizes a stated sum of squared residual magnitudes. Its reference, weights, permitted parameters and fitting indices are part of the definition. Minimizing that objective establishes the best fit within those choices, not the physical correctness of the reference or the adequacy of the model.

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LIKELIHOOD RATIO: The ratio of the probability or probability density assigned to the same data by two specified hypotheses, with a positive denominator for a finite result. It requires defensible models of the data and selection procedure. This chapter uses the definition to state that requirement and assigns no numerical odds to its artifact or attribution categories.

LIMITER: A protection element whose transfer changes under a sufficiently large input to restrict the signal reaching later circuitry. It also remains part of the small-signal path. Leakage during the event, hardware survival and restoration of valid weak-signal measurement are separate properties requiring their own conditions and checks.

LIMITER CURRENT-RETURN PATH: The external circuit path through which current associated with a limiter's large-signal operation can flow. Its implementation influences the mounted protection response alongside the device itself. Characterizing only the isolated component can omit this circuit dependence, particularly when interpreting leakage, stored charge, and return to small-signal transfer.

LIMITER LEAKAGE: Signal power or transient energy that reaches the downstream path while a protection limiter is responding to a strong input.

LINEAR CHIRP: A waveform whose frequency changes linearly with time over a specified segment. Its accumulated phase is obtained by integrating that frequency trajectory. The chapter's ramp example returns to its initial phase at the end while making a substantial intervening excursion, so matching endpoint phases does not establish an unchanged history.

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LINEARITY CHALLENGE: A controlled change of input attenuation or another justified operating condition whose predicted response is tested while reference-plane corrections are retained. Departure from the prediction can expose overload or internally generated structure. It does not alone identify the cause, so the comparison must preserve or explicitly model other changed states.

LINEAR-POWER SUBTRACTION: Removal of an identified additive power contribution after converting compatible estimates to linear power units at the same reference plane and bandwidth. It requires justified power additivity. Subtracting decibel levels gives a ratio, and near-cancellation of total and background can make the recovered difference highly sensitive to measurement errors.

LINEAR TIME-INVARIANT SYSTEM: A system whose input-output relation is linear and unchanged by a shift of the time origin within its stated operating state. Model 2B assumes this behavior in selected equivalent-channel coordinates. A frequency converter is not thereby declared time invariant at the original RF waveform level.

LOAD-DEPENDENT STABILITY: The dependence of an active assembly's stable behavior on the impedance and network connected to it. An amplifier may respond differently to an antenna, matched termination, switch branch or cable. Stability evidence therefore covers the configurations actually tested and does not follow solely from one favorable bench arrangement.

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LOADED CONVERSION POWER GAIN: The ratio of selected IF power to RF power at the two declared loaded planes in Model 4A. For positive real loaded resistances, it equals the squared voltage scale multiplied by RF resistance divided by IF resistance. It therefore differs from the squared voltage ratio when the loads differ. This defined ratio is not automatically an available-power data-sheet gain.

LOADED QUALITY FACTOR: A response descriptor formed, in the chapter's stated resonant approximation, from center frequency divided by the half-power bandwidth. It describes the loaded response under that convention. Equal values do not imply equal skirts, phase delay, ringing or transient behavior, and the descriptor is not a complete filter model.

LOADED VOLTAGE: The terminal voltage under a declared connected load. Antenna factors and voltage-to-power conversions must use the compatible impedance and calibration convention. A nominal impedance label does not remove the need to state whether the calibration describes loaded voltage, open-circuit voltage, available power or delivered power.

LOADED VOLTAGE GAIN: The ratio of output voltage across its declared load to input voltage at its declared loaded plane; power gain additionally depends on both resistances.

LOCAL CONVERSION SLOPE: The derivative describing a small change in selected output-frequency coordinate with respect to a specified parent frequency on a fixed conversion branch. In the integer lattice its magnitude and sign depend on the relevant coefficient and, for a real absolute-frequency output, the sign of the current product. It is conditional on unchanged path selection and does not apply across an unmodeled switch or cusp.

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LOCAL GAIN MAP: A calibrated relationship between control state and receiver gain over a specified range.

LOCALIZATION: An inference about where a source or coupling region is situated from spatially informative observations. Receiver evidence may contribute through direction or gradients, subject to propagation, geometry and calibration. Localization is a different evidential step from classifying a waveform or linking it to a particular device and function.

LOCAL OSCILLATOR: The receiver's internal or supplied oscillatory reference used for frequency conversion. Its frequency and phase enter the selected conversion relation, while its noise, harmonics and leakage can affect the measurement. The actual oscillator state is part of the configuration that maps displayed coordinates to possible external inputs.

LOCAL-OSCILLATOR LEAKAGE: Unintended appearance of oscillator energy at mixer ports, cables, enclosure, or antenna.

LOCAL PROPAGATION ADEQUACY: Suitability of a first-order uncertainty approximation for the stated input domain and intended output, including the effect of neglected curvature and boundaries.

LO DRIVE: The actual local-oscillator excitation applied to a mixer under a stated waveform, level, frequency, and port condition. It influences physical conversion behavior and cannot be replaced by the dimensionless normalization of an ideal multiplier. A conversion measurement must retain the applicable drive and any disturbance caused by strong input signals. The correct LO frequency alone does not establish the intended conversion gain.

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LOGARITHM CONCAVITY: The mathematical property that makes the average of positive-power logarithms no greater than the logarithm of their arithmetic average. Equality holds when all included powers are equal. This establishes the direction of the difference for each record; it does not prescribe a universal numerical correction or prove a Gaussian noise model.

LOGARITHMIC AMPLIFIER: Amplifier producing an output approximately proportional to the logarithm of input amplitude over a defined range.

LOGARITHMIC MOMENT: An expected power of the logarithm of a positive random variable under a specified distribution. The first and second logarithmic moments support the chapter's mean and variance calculations for noise-level statistics. They are different from taking logarithms of ordinary power moments.

LOGARITHMIC UNCERTAINTY PROPAGATION: Propagation through a logarithmic transformation of a strictly positive quantity using the appropriate model and sensitivity. The chapter separates exact variance of a linear power difference from the local variance of its logarithm. Exact transformed limits can be asymmetric, and a domain admitting zero or negative power differences requires a different treatment.

LOGARITHM OF AVERAGED POWER: A level obtained by first averaging calibrated powers in linear units and then taking the logarithm of that average relative to the reference power. The linear average is unbiased under the stated stationary model, while its logarithmic conversion can retain a finite-record bias. The number and dependence of the contributing samples matter.

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LOG-AVERAGE BIAS: Difference between the expectation of an averaged logarithmic noise statistic and the logarithm of mean power under a specified probability model.

LOG-DETECTOR INTERCEPT: The reference offset in a specified calibrated relationship between a logarithmic detector's output and its input level. It is meaningful only with the stated slope, units, waveform conditions and operating range. An incorrect intercept creates a systematic level error, and a printed formula must be checked for consistency with its definitions before being used as a device-specific correction.

LOOP BANDWIDTH: The frequency range over which a synchronization or control loop substantially follows changes, under its stated response convention. Increasing or reducing it changes the tradeoff between following dynamics and admitting noise. Record the setting with acquisition behavior and residual errors rather than treating it as a universal quality score.

LOWER SIDEBAND: The message-related spectral component or band below a declared carrier. In Model 6A's single-tone complex convention its envelope rotates at negative message frequency, and translation retains that sign before any conversion to real-audio magnitude. The label depends on the reference and conversion orientation.

LOW-NOISE AMPLIFIER: An amplifier selected to provide useful gain with a suitably small added-noise contribution. Its benefit depends on placement, admitted blockers, matching and linearity. An amplifier before a lossy path can suppress later noise contributions, while the same placement can expose it to strong signals that a downstream filter would have rejected.

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LOW-PASS FILTER: A frequency-selective network that preferentially transmits frequencies below its transition region and suppresses higher frequencies within its specified response. It can reduce admission of high-frequency blockers, but its passband loss, phase response and location still determine the effect on the desired observation.

MAGNITUDE-ONLY RECORD: A representation retaining magnitude while discarding the corresponding phase. Several complex inputs can then produce the same stored result. Known complex transfer and bounded amplitude can support a power statement within the model, but cannot reconstruct phase that was never retained.

MANY-TO-ONE TRANSFORMATION: A transformation that maps distinct permitted inputs to the same retained output. Clipping and magnitude detection provide concrete examples in Model 1A. The shared output cannot select one original input without additional information, even when the transformation itself is known exactly.

MARGINAL DISTRIBUTION: The probability law of one component considered without conditioning on the other components of a joint record. Equal phase marginals can coexist with different dependencies between samples. The common-phase and independent-phase cases therefore have the same individual RMS but different coherent signal powers.

MATCHED FILTER: Filter designed to maximize output signal-to-noise ratio for a known waveform under specified noise assumptions.

MAX HOLD: Trace process retaining the highest detected value at each display point over repeated acquisitions.

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MAXIMUM-REFERENCE NORMALIZATION: Normalization of residual mean square by a declared maximum ideal-symbol energy rather than the record's average reference energy.

MEAN COHERENT SIGNAL POWER: The expectation of the squared magnitude of a declared coherent signal sum, distinct from the squared ensemble-mean phasor and from a complete SNR calculation.

MEAN SQUARE: An average of squared magnitudes under a declared sample population and weighting. It has squared-amplitude units and can be converted to power only through the applicable physical relationship. The window-weighted value recovered by spectral integration need not equal the unweighted mean square of a transient record.

MEASURAND: Quantity intended to be measured, stated with its reference plane, state, bandwidth, and conditions. Receiver-terminal power, field strength, relative phase and detection probability require different measurement models. Defining the intended result before selecting corrections and calibrations prevents the available display from silently choosing the measurement question.

MEASUREMENT CHAIN: The connected physical and computational transformations that carry an input to a reported result. Its relevant boundaries include gain, loss, filtering, conversion, detection, sampling, timing, and analysis.

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MEASUREMENT CORRECTION: A compensation applied for an identified effect in the measurement model. Its sign follows the physical relationship and its uncertainty remains in the result. A known significant offset should not be concealed merely by widening an uncertainty interval, and a correction already applied by the instrument must not be counted twice.

MEASUREMENT DEFINITION: The stated quantity or proposition together with its reference plane, frequency and time intervals, receiver state, estimator, and intended decision.

MEASUREMENT ERROR: The signed difference between a measured value and the applicable reference value. It is distinct from uncertainty, which describes the dispersion attributed on available information, and from an implementation mistake. A calibration can estimate an error relative to its reference; an unknown error is not made known by reporting a small uncertainty.

MEASUREMENT MODEL: Equation or functional relationship connecting the measurand to input quantities.

MEASUREMENT UNCERTAINTY: A nonnegative measure of the dispersion of values attributed to a measurand using the available information. It can incorporate both repeated-observation evidence and uncertainty in corrections or reference values. Standard and expanded uncertainty are specified forms of expression; uncertainty itself is neither a signed error nor a guaranteed maximum deviation.

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MEASURE-ZERO EVENT: An event assigned zero probability by the stated continuous probability law even though it need not be logically impossible. A single exact boundary phase has this property under the chapter's uniform phase model. Deterministic boundary tests still require their own endpoint convention, and a discrete or concentrated phase law can change the probability.

MECHANISM PREDICTION: A stated consequence expected from a proposed physical or processing explanation under a specified intervention. Writing competing predictions before changing the setup gives the challenge a discriminating purpose. An observed match supports only the consequences tested and does not exclude alternatives that predict the same behavior.

MEDIAN: A central order statistic or distribution quantile that divides the ordered population under a stated convention. It is not generally interchangeable with an arithmetic mean in algebraic estimator identities. Separate medians of cross-products and autospectral products need not form the single paired construction required by the coherence bound.

MEMORYLESS NONLINEARITY: A relation in which the output at an instant depends on the input at that instant without an internal stored state. The fixed cubic law can produce new frequency components even though it has no memory. Thermal history, control-loop dynamics and frequency-selective storage require a different or extended description.

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MESSAGE MEAN SQUARE: The declared time average of the squared normalized message. For a zero-mean AM message it determines the additional average power through the squared modulation scale. A unit cosine has mean square one half, but a general bounded message need not; its peak bound alone does not establish this statistic.

MESSAGE NORMALIZATION: The stated scaling that relates a physical or mathematical message to the dimensionless waveform used in a modulation model. In Model 6A the message magnitude is bounded by one and the separate modulation scale sets its contribution to the envelope. Changing that normalization without changing the scale alters the modeled waveform and power.

MINIMIZATION: Technical and procedural limitation of collection, retention, and disclosure to information necessary for an authorized purpose.

MINIMUM DETECTABLE SIGNAL: Input signal level meeting a stated detection criterion under specified conditions.

MINIMUM PRECEDING GAIN: The least first-stage power gain that meets a specified two-stage equivalent-temperature target under the stated positive downstream-noise assumptions. Equation 4J gives $\frac{T_{e,2}}{T_{target} - T_{e,1}}$ when T_{target} exceeds $T_{e,1}$. This is a noise constraint; it does not establish that the required gain is available, stable, or valid under the blocker environment.

MINIMUM TRIAL COUNT: The smallest positive integer number of qualifying trials that meets a specified conditional capture target under the stated probability assumptions. Model 15A rounds the interior logarithmic result upward and checks the preceding integer. Zero-probability, certain-capture and exactly-one target cases require their separate endpoint rules.

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MISMATCH UNCERTAINTY: Uncertainty caused by unknown or varying phase relationships among reflected waves at imperfectly matched interfaces.

MIXER: A frequency-converting device that combines an input with a local-oscillator signal. A useful output is selected from sum, difference and other possible products. Actual conversion gain, leakage, noise and distortion depend on the architecture and operating conditions; a correct candidate frequency does not establish the amplitude of a real product.

MIXER DE-EMBEDDING: Removal or accounting of surrounding filter, amplifier, cable, and interface effects so that an inferred result refers to the mixer itself at declared planes. Scalar gain subtraction requires compatible power conventions and applicable linear installed-path values; mismatch and interaction can require a more complete treatment. De-embedding changes the measurand and must not be confused with directly measuring the complete receiver transfer.

MIXER LEVEL: The signal level presented at the mixer's specified input plane after preceding gain, loss and filtering. It matters to amplitude accuracy and nonlinear behavior. An input indication or reference-level setting does not establish the actual mixer level without the intervening configuration and transfer information.

MODULAR WRAPAROUND: An overflow rule that discards multiples of a format's code range and returns the corresponding representable signed code. An over-range positive result can therefore become negative. It differs from saturation and from ordinary rounding; restoring a later scale cannot recover the discarded range information or validate an earlier overflowed operation.

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MODULATING MESSAGE: The waveform used to vary the specified carrier or phase parameter in a modulation model. Its scale, spectrum, mean square and phase relationships affect the result. Equal maximum excursions do not guarantee equal average modulated powers, so the message definition must accompany the reported modulation parameter.

MODULATION FREQUENCY: The rate of a sinusoidal modulating component, expressed in hertz, or an explicitly identified frequency within a more general message. It differs from peak frequency deviation and peak phase excursion. A multicomponent waveform requires the component frequencies and, for a Carson estimate, the highest significant modulating frequency under a stated criterion.

MODULATION INDEX: Dimensionless ratio describing modulation excursion relative to a modulating frequency or carrier parameter.

MONOTONE RESPONSE: A response that moves in only one direction over the specified interval. The fixed-target one-pole solution moves between its initial state and target without overshoot or a reversal of residual sign. An observed violation is evidence against that uninterrupted segment model, not a reason to discard the observation.

MONTE CARLO PROPAGATION: Numerical propagation of an assigned joint input distribution by repeatedly evaluating the measurement model on sampled inputs. Retaining dependencies is essential when references or corrections are shared. The method can represent nonlinear output distributions, but numerical convergence does not verify the physical model or justify unsupported input laws.

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MULTIPATH: Reception through multiple propagation paths whose delays and phases combine at the observation point. Its frequency-dependent effect can unbalance sidebands or alter demodulated behavior. A changed receiver output therefore needs path and reference checks before it is interpreted as a change in the transmitted modulation.

MULTIPLIER NORMALIZATION: The declared numerical scale of an ideal mixing operation that determines selected-product voltage and power.

MULTISINE: A waveform formed by adding several sinusoidal components with specified frequencies, amplitudes and relative phases. In the cited receiver calibration, it supplies known spectral content across a band for complex-response characterization. Its peak behavior depends on the component choices, and its successful calibration use does not by itself establish response to every waveform or nonlinear operating state.

MUTUAL COUPLING: Electromagnetic interaction through which nearby antennas or conducting structures affect one another’s currents and response. A calibration performed in one arrangement can therefore contain interactions absent from another. Component identity alone does not establish that the installed field conversion is unchanged.

NATIVE RECORD: Data retained in the acquisition system's original useful representation, together with sufficient configuration information to interpret them. The term does not guarantee correctness; it identifies inputs that can support reconstruction before later transformations discard information.

NEAREST EVEN ROUNDING: Selection of the nearest representable code, with an exact halfway case assigned to the even integer code.

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NEAR FIELD: The region in which the required far-field approximations are inadequate for the stated measurement. Precise local observations remain possible, but extrapolating them through a plane-wave antenna conversion or a simple distance law requires additional justification appropriate to the source and geometry.

NEGATIVE CONTROL: A comparison selected to test a specific alternative explanation under defined conditions. Examples include a terminated input or a noise-only record, each with its own scope. A successful control does not cover every field state, and failures must remain in the record alongside passes.

NEGATIVE FINDING: A bounded statement that no event meeting a defined criterion was observed under demonstrated valid coverage and capability. Its meaning must preserve the tested event class, sensitivity, intervals, and exclusions.

NEGATIVE FREQUENCY: The opposite direction of phase rotation in a signed complex-frequency representation. In a real waveform it is paired with a conjugate positive-frequency component; in a general complex record the two sides need not be redundant. Rewriting a negative-frequency cosine at positive frequency changes the associated phase sign.

NEGATIVE-PEAK DETECTOR: A detector that retains the lowest indication within its specified observation or display bucket. Its meaning depends on the quantity entering the detector and the instrument’s bucket convention. It does not estimate the same statistic as a positive-peak, sample or power detector simply because all results share a decibel display axis.

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NOISE BUDGET: An accounting of source noise and stage-added contributions referred to one declared plane under a common bandwidth and operating model. Listing each contribution reveals which component controls the total and which improvement can matter. A valid budget also records the assumptions whose failure would make its calculated result inapplicable.

NOISE FACTOR: Ratio of input signal-to-noise ratio to output signal-to-noise ratio under the declared source temperature and matching convention, expressed in linear units. Model 2B uses a 290 K reference source; degradation for a different actual source temperature is a separate quantity.

NOISE FIGURE: The logarithmic expression of noise factor, $NF_0 = 10 \log_{10}(F_0)$, in decibels at the declared reference temperature and conditions. Its numerical convenience does not remove the need to identify the included network and state. It differs from actual SNR degradation when the source temperature differs from the reference temperature, except in the zero-added-noise case.

NOISE FLOOR: The noise level associated with a stated measurement path, bandwidth, detector and observation procedure. It is a scale for interpreting weak observations, not a universal detection boundary. Filtering or coherent processing can change usable sensitivity, while overload can invalidate a component that appears above the displayed floor.

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NOISE-LIMITED SENSITIVITY: A bounded input-signal requirement derived when the admitted source and receiver noise are the relevant limiting contributions and the detector requirement is separately justified. Equation 4L uses $\gamma k B(T_s+T_e)$ with full desired-signal retention. Compression, structured interference, coverage failures, or another detector law can require a different operational analysis.

NOISE MARKER: An analyzer output intended to report a noise quantity using a specified local measurement and normalization procedure. It may already incorporate statistical or bandwidth corrections. The reported units and processing history must be checked before applying another correction or comparing it with an uncorrected trace.

NOISE-MARKER CORRECTION: A declared processing adjustment used by an instrument or analysis method to convert its measured noise statistic into a specified reported convention. Detector-statistic and noise-bandwidth adjustments have different causes. Establish which adjustments are already present before applying additional corrections, and do not infer the sequence from a marker name alone.

NOISE-ONLY VALIDATION: Evaluation of the chosen detection rule on records intended to represent the stated no-target condition. It supports assessment of false-alarm behavior for the tested state and population. The record must still account for receiver artifacts, environmental structure, processing, and search opportunities; a quiet mean level alone is not a complete validation.

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NOISE PARAMETERS: A set of quantities used to describe how a device's noise behavior varies with source impedance under a specified model and reference plane. The cited vector-corrected method uses such characterization with measured reflections. Their role marks a boundary of the matched scalar cascade, whose simpler assumptions cannot silently supply them.

NOISE POWER SPECTRAL DENSITY: Mean noise power per unit frequency at a declared reference plane, with the side convention and units stated. A flat density gives integrated mean power proportional to equivalent noise bandwidth. A logarithmic noise display also depends on detector and averaging conventions, so its ordinate is not automatically the density times a front-panel bandwidth label.

NOISE RISE ALLOWANCE: The additional uncorrelated noise power permitted by a stated rise relative to a fixed baseline measured through the same gain, weighting, and reference plane.

NOISE TEMPERATURE: Equivalent temperature used to represent available noise power or device-added noise.

NOMINAL SLOT GRID: An explicitly defined sequence of equal-duration opportunities used for finite rate accounting. It can be continued through a guard interval when that convention is stated, without asserting that physical symbols were transmitted in every opportunity. Its count divided by the common elapsed duration defines the slot rate used by the model.

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NONALTERNATING RESIDUAL: A residual sequence that does not repeatedly change sign about the specified target. The exact sampled one-pole solution has this property for positive time constant and interval. Forward Euler preserves it only for a positive normalized interval no greater than one, a stricter condition than its asymptotic-stability limit.

NONDISPERSIVE DELAY: A delay that is constant over the frequency region used in the model, producing a linear unwrapped transfer-phase dependence on frequency. A slope estimate can identify it within the selected branch. Phase curvature from filters or other path behavior means that one constant delay may be inadequate for broadband correction.

NONLINEAR MEMORY: Dependence of a nonlinear response on earlier inputs or internal state, rather than solely on the current input value. Filtering, thermal history or control dynamics can make a single fixed memoryless coefficient inadequate. The chapter's local cubic law deliberately excludes those effects; its agreement over one interval does not establish their absence elsewhere.

NONLINEAR ORDER: The degree of an amplitude term in a stated nonlinear expansion. The cubic voltage term generates particular fundamental corrections, harmonics and intermodulation products under the chapter's assumptions. This physical model order is distinct from the integer-search order used to enumerate possible conversion frequencies, and a frequency coincidence alone identifies neither.

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NONLINEAR REMAINDER: The part of a nonlinear measurement response omitted by its local linear approximation. The suitability of first-order propagation depends on whether that omitted behavior matters over the actual input domain. Near a singularity, boundary or zero derivative, it can change the output dispersion or shape even when the central calculation is finite.

NONZERO COEFFICIENT SUPPORT: The set of declared filter lags whose implemented coefficients are nonzero. It determines which input samples can affect an output in Model 10E. An exactly zero tap creates no dependency, while a small nonzero tap still does; a justified amplitude bound can limit that dependence without making it absent.

NORMALIZED FILTER POWER RESPONSE: The squared magnitude of the declared observation filter after its reference gain has been specified. It weights the noise admitted at each frequency. Model 11B additionally requires this weighting to remain between zero and one for its remainder bound; center normalization alone would not establish that peak constraint.

NORMALIZED RESPONSE ERROR: The difference between observations after the stated gain, attenuation and other required corrections have referred them to a comparable quantity and plane. Its uncertainty and receiver states determine the meaning of agreement. A discrepancy can motivate investigation of compression, internal products or state changes without uniquely naming the cause.

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NOTCH FILTER: A filter designed to reject a selected frequency region while retaining other regions. In a front end it can reduce a dominant interferer before a vulnerable component, but it also removes any desired signal content occupying the notch. Its installed response, placement, and power handling determine whether it improves the intended observation.

NULL SPACE: The set of inputs mapped to zero by a specified linear operator. A nonzero member establishes that the complete output cannot uniquely distinguish that input from zero. The blind-residue channelizer example constructs such a member; conclusions depend on the declared coefficients, output channels and observation of all affected frames.

NUMERICALLY CONTROLLED OSCILLATOR: Digital phase accumulator and waveform generator used for frequency translation or synthesis.

NUMERICAL STABILITY: The behavior of errors or perturbations under a numerical recurrence, distinct from the stability of the physical system being modeled. For the chapter's Euler residual update, asymptotic decay requires a positive interval-to-time-constant ratio below two. A stable approximation can still have substantial error or unphysical alternation, so stability alone does not validate a settling calculation.

NYQUIST BIN: The transform bin at one half of the sample rate when the transform has even length. For a real record it is its own conjugate-frequency partner and is counted once in the chapter's one-sided power sum. An odd-length transform has no bin exactly at that endpoint.

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NYQUIST INTERVAL: A frequency interval used to represent one sampling-rate-wide period of a discrete-time spectrum without repeating its aliases. The chosen endpoints and one-sided or two-sided convention must be stated. Real-data symmetry permits folding with special endpoint rules; it does not remove ambiguity about the original analog signal.

NYQUIST ZONE: For the chapter's real-sampling frequency map, one of the consecutive nonnegative analog-frequency intervals of width one half of the sampling rate. Folding can reverse frequency order in successive zones. A band that straddles a zone boundary can overlap itself after sampling, even when its occupied width is small.

OBSERVATION: A recorded result of an examination under a particular measurement state. Its interpretation may support additional propositions, but the observed feature and those model-dependent or source-dependent inferences remain distinguishable.

OBSERVATION LIMIT: The demonstrated boundary of what a specified configuration and record could reveal under the declared criterion. Nondetection above a supported limit is different from proof of complete absence. A substitution that changes sensitivity must retain suitable reference evidence before its negative result can support the intended comparison.

OBSERVED-TIME FRACTION: The proportion of a declared total interval represented by valid retained time. It describes temporal coverage under the accepted state and settling evidence. It is not automatically an event-capture probability, and equal corrected means on the observed portions do not establish the signal behavior during the excluded gap.

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OCCUPIED BANDWIDTH: The frequency interval assigned to contain a specified portion of signal power under a stated measurement convention. Its interpretation requires the power fraction, integration and observation choices. It is distinct from a decoder's symbol rate, a filter's nominal bandwidth and successful information recovery.

OFF-BIN TONE: A tone whose frequency lies between the selected DFT evaluation frequencies. Its nearest-bin amplitude depends on the window response and offset. Additional padded bins can locate an isolated response peak more closely, but do not narrow that response or prove separation from another nearby component.

OFFSET INTEGRATION BAND: The specified set of positive frequency offsets included in a phase-noise variance calculation. Its limits and any separately included lines form part of the result. Noise outside the set is not measured by the resulting RMS value, and extrapolating a displayed floor requires an additional justified assumption or bound.

ONE-DECIBEL COMPRESSION POINT: A specified stimulus level at which the measured response is one decibel below its declared small-signal linear extrapolation under fixed test conditions. It is a benchmark, not a universal threshold for all measurement error. Automatic gain changes, different stimuli and recovery behavior require separate characterization.

ONE-SIDED SPECTRUM: A frequency representation that combines the conjugate positive- and negative-frequency contributions of a real record under a declared folding rule. Interior positive-frequency powers are doubled, while DC and an even-length Nyquist bin are retained once. Complex records generally lack the symmetry required for this construction.

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OPEN-CIRCUIT VOLTAGE: The terminal voltage defined with no load drawing current in the stated antenna or source model. It is not the same as the voltage across a specified receiver load. Applying a calibration intended for a loaded voltage to an open-circuit estimate can introduce a systematic conversion error.

OPERATING DOMAIN: The stated range of conditions within which a measurement model or approximation is intended to apply. A local linear description, for example, requires a defined state and limits that address relevant overload or adaptive behavior.

OPPOSITE-SIDEBAND LEAKAGE: An unwanted retained component from the sideband that a receiver or conversion process was intended to reject. It can arise from finite filter rejection, I/Q mismatch, product-detector imbalance or other path imperfections. Its observation is a receiver-performance question unless independent evidence establishes that the component belongs to the source.

OPTICAL ISOLATION COMPARISON: A controlled comparison in which an optical link removes a particular conductive path while its own gain, noise, bandwidth, timing and power state are characterized. Disappearance of a weak feature is inconclusive if the replacement lacks adequate sensitivity. A preserved desired reference makes the comparison more informative but does not identify every mechanism uniquely.

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ORTHOGONAL FREQUENCY-DIVISION MULTIPLEXING: A multicarrier modulation arrangement whose subcarrier waveforms are chosen to be orthogonal over a defined symbol interval. Synchronization and the interval convention are essential to that relationship. Its recognizable spectral or constellation structure does not independently establish coding, validated packets or a physical transmitter identity.

ORTHOGONALITY: A zero inner product between specified components under the declared averaging operation. It supports the separate power accounting used for carrier and modulation terms. The averaging interval and waveform conditions matter; a complete-period calculation cannot be transferred automatically to a short record with different cross terms.

OSCILLATOR AGING: Change in an oscillator's frequency caused by processes internal to the device over time. It is distinguished from the broader measured drift, which can also include environmental influences. A fitted local drift coefficient does not, by itself, isolate aging or establish that the same trend persists in another operating interval.

OUT-OF-BAND SIGNAL: A signal outside the particular band under discussion, which must be named. Energy outside a displayed span can still lie inside the analog admission path and overload the receiver. Its absence from the selected display does not establish that it is absent at a vulnerable input stage.

OUTPUT-ADDED NOISE: Noise attributed to a stage and expressed at that stage output, excluding the incoming noise it transmits. For stage i in Model 2B the value is $k B g_i T_{e,i}$. Referring this contribution to another plane requires the corresponding signal power gain, rather than treating the stage equivalent input temperature as an output temperature directly.

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OUTPUT INTERCEPT LEVEL: The output-referred extrapolated intersection associated with the declared input intercept and small-signal power gain. The input and output planes and resistance conventions must be compatible. Substituting a compressed measured fundamental for the linear asymptote can bias the extraction, even before ordinary calibration uncertainty is considered.

OVERFITTING: Adjustment that captures peculiarities of the fitting record without establishing transferable performance. Too many coefficients or too little independent training information can make an in-sample residual deceptively small. The chapter's one-symbol gain fit demonstrates why a zero training residual is not a validation result.

OVERLAP-CORRECTED THROUGHPUT: A rate based on unique identified accepted payload positions after repeated instances across compatible streams have been removed. For two sets, add their counts and subtract the known intersection before dividing by their common duration. Equal bit values do not establish duplicate identity, and unknown overlap supports bounds rather than an invented exact unique rate.

OVERLOAD: Operation outside the valid signal range of a stage or path because the admitted waveform is too large for the required behavior. Its consequences can include compression, new products or altered recovery. A later clean display or level correction does not show that the earlier stage remained valid.

OVERSAMPLED CHANNELIZER: An analysis bank whose aggregate output sample rate exceeds its input sample rate under the stated channel count and decimation.

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OVERSHOOT: An excursion beyond the final target during a transient. It is excluded by the fixed-target, positive-time-constant one-pole response developed in Model 5A. If observed, it can motivate an additional state, changed target or different model; its mere appearance does not identify which physical element caused it.

PACKET ERROR RATE: The fraction or modeled probability of packets failing a declared acceptance rule. The result depends on the attempted-packet population, acquisition failures, checks and counting convention. Reporting only successfully acquired intervals can conceal a different packet-level outcome, even when the selected symbol EVM is low.

PACKET FRAGMENTATION: Division of a transported packet across multiple receive-buffer returns or stored pieces. Such division need not lose samples. Returned lengths, fragment offsets, source indices and error context distinguish legitimate fragmentation from an actual discontinuity; buffer arrival order by itself is not a source-time record.

PAIRED SPECTRAL ESTIMATE: Autospectral and cross-spectral sums formed from the same paired records with compatible weights and normalization.

PAIRWISE POWER CORRELATION: A stated covariance relationship between two power samples after normalization by their standard deviations. In the chapter's equal-variance illustration, positive common correlation slows the reduction in the arithmetic mean's variance. A nominal sample count therefore cannot replace evidence about filtering, overlap or duplication when estimating repeatability.

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PARENT-FREQUENCY PERTURBATION: A controlled change in one frequency used to test a candidate conversion relationship while other relevant parents and receiver states are held fixed or accounted for. The signed movement follows that parent's integer coefficient in the stated lattice. The absolute movement may change branch at zero. A useful test predeclares the expected response and keeps the candidate within a measurable region.

PARSEVAL IDENTITY: The equality relating the sum of squared transform coefficients to the corresponding time-domain squared values under a stated Fourier normalization. In this chapter it yields exact closure for the window-weighted record. Passing that algebraic check does not establish adequate sampling, correct calibration, stationarity or complete transient coverage.

PASSBAND: The frequency region a filter is intended to transmit within its stated response limits. A center-frequency calibration alone does not describe amplitude and phase across the entire passband. A desired waveform extending into rapidly changing response can be distorted even when its center is passed adequately.

PASSBAND PHASE DISTORTION: A change in the relative phases of a signal's admitted spectral components that alters the intended waveform or modulation representation through the passband. Center-frequency magnitude alone does not reveal it. Its significance depends on the signal spectrum, measurement objective, and applicable phase or group-delay response of the installed filter state.

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PASSBAND RIPPLE: Variation of transmission magnitude within a filter's declared useful passband, expressed under a specified normalization and frequency interval. A correction measured only at the center cannot establish the amplitude of a wide waveform across the ripple. The relevant tolerance follows the intended level or modulation measurement, rather than a passband label alone.

PASSIVE-LOSS ALLOWANCE: The permitted interval of matched dissipative loss before a characterized chain under a specified total noise-temperature target. Equation 4K combines the requirement $L \geq 1$ with an upper bound determined by target, physical path temperature, and downstream equivalent temperature. An upper bound below one means the stipulated passive design has no feasible solution.

PASSIVE PATH LOSS: The attenuation assigned to the relevant passive part of a measurement path under the stated conditions. The scalar backward correction adds this loss to the downstream indication when estimating the upstream power.

PATH CORRECTION: Measured gain or loss assigned to a specific serialized signal path and state.

PAYLOAD-BIT FRACTION: The useful represented payload-instance count divided by the corresponding input-information count under the declared framing convention. It excludes separately identified nonpayload information positions such as headers or padding. It acts on bits rather than slots, differs from code rate, and requires a positive information-count denominator.

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PAYLOAD BYTE RATE: The byte rate occupied by the declared uncompressed sample components before additional headers, padding, timing records or file-system effects. It depends on actual stored component width, channel count and sample rate. Sustained recording capability must include the extra traffic and cannot be inferred solely from this ideal payload calculation.

PAYLOAD INSTANCE: One counted occurrence of a payload bit in the specified transmission or accepted-stream population. Retransmissions or parallel streams can contain additional occurrences of the same identified payload position. An instance count is valid for its stated purpose but does not automatically equal the number of unique useful positions delivered.

PEAK AMPLITUDE: The amplitude scale of a sinusoid measured from its zero reference to its extreme value, rather than its RMS value or peak-to-peak excursion. Model 4A uses peak voltages at loaded planes. Converting that amplitude to mean power requires the declared resistance and sinusoidal convention.

PEAK ENVELOPE POWER: The maximum squared envelope magnitude divided by twice the declared real load resistance under the peak-voltage convention.

PEAK-ENVELOPE-TO-AVERAGE-POWER RATIO: The ratio of peak envelope power to average RF power under the same envelope, load and averaging conventions. It depends on relative component phases as well as their separate powers. It is distinct from an instantaneous RF-voltage peak ratio and must match the hardware headroom quantity being assessed.

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PEAK INPUT POWER: The largest input power under the stated waveform and time-resolution convention at a specified plane. It is distinct from average power and must be related to the applicable pulse or continuous-wave rating. For pulsed exposure, duration, repetition, source and load conditions, and leading transients can matter alongside the peak value.

PEAK-TO-RMS CONVERSION: The relation between the peak amplitude of a nonzero-frequency sinusoid and its root-mean-square amplitude: RMS equals peak divided by the square root of two. It gives average power equal to peak voltage squared divided by twice the positive real load resistance. The rule does not apply unchanged to DC, arbitrary pulsed waveforms, or an analytic-signal magnitude without its own power convention.

PEAK-VOLTAGE ENVELOPE: A complex envelope scaled so that its magnitude is the local peak RF voltage under the stated band-separation convention.

PERCENTILE: A value locating a declared cumulative fraction of a distribution or empirical record population under a specified convention. A high-percentile display emphasizes different behavior from a mean or maximum. Report the population, record selection and interpolation rule when the distinction affects detection or comparison.

PERIODIC REDUCTION: Representation of times by their positions within one declared schedule period. Model 15A first derives eligible event starts on an unfolded axis and then reduces their union modulo the period. This order preserves a genuinely contiguous window crossing the chosen origin and avoids mistaking the displayed split for an acquisition gap.

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PERIODIC WINDOW CONVENTION: A coefficient-vector convention intended for periodic DFT use; for Hann it uses N in the cosine denominator, unlike the endpoint-symmetric $N-1$ form.

PERIODOGRAM: A spectral estimate formed from the squared magnitude of a finite, possibly windowed Fourier transform with a declared normalization. Density and line-oriented scaling can differ by the window's equivalent noise bandwidth. Preprocessing defaults, including mean removal, must be matched before comparing implementations.

PER-TONE POWER: The power assigned to one specified sinusoidal component, distinct from the sum of the powers in a multi-tone stimulus.

PHASE ACCUMULATOR: A digital state that repeatedly adds a phase-increment word on the oscillator clock and wraps within its defined phase code range. Its carried state determines continuity between processing blocks. Resetting it at an arbitrary buffer boundary can introduce a coherent phase event although the sampled input remains continuous.

PHASE CENTER: An effective reference point used to describe an antenna's phase response over stated frequencies and directions. It need not coincide with a fixed mechanical point. Frequency-dependent displacement can affect the distance and field interpretation assigned to an installed observation.

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PHASE CONJUGATION: Reversal of a complex phasor's phase sign. In the chapter's real conversion map, rewriting a negative-frequency difference cosine at positive frequency conjugates its associated phasor. Conjugating a saved I/Q record also reverses signed-frequency orientation. The operation must be retained in the interpretation and processing history whenever phase, sideband, timing, or modulation comparisons depend on the original convention. For a complex quantity, conjugation reverses the imaginary part's sign and preserves its magnitude. Conjugating an entire cross-spectrum reverses its phase while preserving its magnitude and the corresponding magnitude-squared coherence; the stated convention therefore matters to the sign of an inferred delay.

PHASE COVARIANCE: The second-order relationship between phase deviations at two specified times or sample positions. Together with the marginal variances, it determines the variance of their difference. Equal marginal RMS values can therefore produce different coherent behavior when the covariance differs; the required relationship cannot be inferred from a scalar jitter number alone.

PHASE EXCURSION: The amount by which a defined unwrapped phase departs from its reference over the stated interval. Its unit is radians or another declared angular unit. Holding phase excursion fixed while changing modulation frequency generally changes peak frequency deviation; the two quantities cannot be treated as interchangeable generator settings.

PHASE-INCREMENT ALIAS CLASS: Frequencies separated by integer sample rates that produce the same principal sampled phase increment.

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PHASE-INCREMENT VARIANCE: The variance of the difference between two phase samples, determined by their individual variances and covariance.

PHASE-LOCKED LOOP: A feedback arrangement that uses phase comparison to control a local reference relative to an input. It can support carrier recovery or frequency demodulation within its operating conditions. Lock, reference stability and transient behavior remain part of the measurement state; the architecture's name does not guarantee faithful recovery of every waveform.

PHASE MODULATION: A relation in which a specified message directly controls phase relative to a declared carrier. Differentiation gives frequency deviation. For a sinusoidal message with fixed peak phase, peak frequency deviation grows in proportion to message frequency; a received phase history alone does not uniquely identify the circuitry that generated it.

PHASE NOISE: Random phase fluctuation represented as spectral density around a carrier or reference.

PHASE REMAINDER BOUND: An enclosure for terms omitted from a declared small-phase expansion, with moment and stationarity requirements stated separately from the retained linear model.

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PHASE RESET: An event that changes the selected phase branch discontinuously or restarts its reference. It interrupts an analysis that assumes one absolutely continuous phase history. Preserve the event and segment the record; do not interpret an ideal jump as an ordinary finite instantaneous frequency or silently bridge it with a fitted trend. A finite difference across a reset contains the step even when the continuous frequency behavior is unchanged on either side. Preserve segment boundaries and any independently established cross-event phase relation.

PHASE SENSITIVITY: The coefficient relating a specified message quantity to phase in the adopted phase-modulation law. Its units are radians per message unit, such as radians per volt. Frequency deviation then depends on the message's rate of change as well as this coefficient and the message amplitude.

PHASE-SHIFT KEYING: A modulation family in which discrete carrier-phase states represent symbol values. The receiver needs a phase reference and a justified mapping to interpret the selected state. Removing a common rotation can improve geometric alignment while leaving the original label association unresolved.

PHASE TRUNCATION: Reduction of the phase-word precision used to address or generate an oscillator waveform while retaining a potentially wider phase accumulator. It is distinct from the accumulator's tuning grid. Its resulting waveform errors require their own analysis; fine nominal tuning resolution alone does not establish low spurious response.

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PHYSICAL TEMPERATURE: The thermodynamic temperature of an actual component, such as a cable or attenuator, expressed on an absolute scale for the noise calculation. It controls the thermal emission of a matched dissipative loss. It is distinct from the equivalent noise temperature used to represent an active stage's input-referred noise.

PILOT REFERENCE: An identifiable signal component used to support a carrier, frequency or timing reference. Its role and calibration must be stated. Estimating a reference from a pilot differs from adjusting recovered audio by ear, and neither operation should be concealed in the processing history.

PIN DIODE: A diode with an intrinsic region between its p-type and n-type regions. In the limiter mechanism discussed here, stored carriers alter the RF resistance during a large signal, and carrier removal affects recovery. Mounted-network capacitance and the external current-return path also influence the usable response.

POINT-OBSERVATION LIMIT: The separate idealization in which an instantaneous event must lie inside a usable observation window. It is not obtained by treating zero overlap as a successful empty intersection. Model 15A relates it to the limit of fully capturing a shrinking event while preserving the intended detection criterion.

POINTWISE BOUND: An inequality that limits a quantity at every allowed point, rather than only its average or a selected probability. Model 6B bounds the complex small-phase remainder at every real phase value. The retained sideband approximation remains approximate even when the stated bound on its omitted remainder is exact.

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POLARIZATION COUPLING: The dependence of antenna response on the relationship between incident-field polarization and the antenna's receiving orientation. Rotation can change terminal level without a change in source strength. An installed comparison must therefore retain or deliberately vary orientation according to the stated measurement question.

POLYPHASE COMMUTATOR: The sample-routing schedule that assigns input-index residues to coefficient branches; its phase and progression form part of the filter-bank definition.

POLYPHASE COMPONENT: A filter-coefficient subsequence selected by a fixed lag residue modulo an integer rate-change factor.

PORT ISOLATION: Suppression of unwanted transfer between identified mixer or receiver ports under specified frequencies, terminations, and operating states. Finite LO-to-RF isolation can contribute leakage into an input cable or antenna, while other coupling paths may involve the enclosure. Isolation belongs to the installed configuration and relevant direction; it should not be inferred solely from mixer type or the absence of one displayed line.

POSITIVE-PEAK DETECTOR: A detector that retains the largest indication within its specified observation or display bucket. It can aid discovery of brief activity, but its population and timing differ from an average-power estimate. Changing to this detector changes the measurement statistic and must be disclosed when traces are compared.

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POST-DETECTION FILTERING: Filtering applied after a specified detector operation to alter the displayed or recorded time response. It can suppress visible fluctuations while slowing the indication. Its position in the processing chain matters, so a video-bandwidth setting cannot be assumed to mean the same operation for every detector or analyzer mode.

POWER-AVERAGE ESTIMATOR: Arithmetic mean of calibrated instantaneous powers; subsequent logarithmic conversion has distinct finite-record statistical properties.

POWER-ESTIMATION PLANE: The declared point in a calibrated measurement model at which samples represent a specified power quantity. Resistance, gain calibration, admitted bandwidth and processing connect that quantity to the original signal path. Raw converter counts are not power samples until that relationship is established; comparisons must use compatible planes.

POWER GAIN: The ratio of output power to input power under declared reference-plane, loading and signal conventions. For the chapter's loaded sinusoidal voltages, both the squared voltage ratio and the input/output resistance ratio enter. A voltage-gain number is therefore insufficient when the reference resistances differ.

POWER HANDLING: The incident-power capability of a component or assembly under specified waveform, duration, duty factor, frequency and environmental conditions. It is distinct from an acceptable small-signal transfer and from recovery time. A rating for one tested device or pulse condition does not establish a limit for an arbitrary receiver assembly.

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POWER-LAW SLOPE: The change in logarithmic output power per change in logarithmic input power under a fixed response model. Equal-tone cubic products and linear fundamentals have different slopes, while varying just one unequal parent gives a different product dependence. A slope mismatch can reject the proposed model without uniquely identifying the alternative mechanism.

POWER LEVEL: A logarithmic representation of positive power relative to a specified reference power. It is a coordinate for a physical power, not a replacement for that quantity's units or reference plane. Subtraction of two power levels represents a power ratio, whereas subtraction of powers must occur in linear units.

POWER SENSOR: A device used to measure RF power under defined input, frequency and waveform conditions. In front-end characterization it can help establish the applied desired and blocker levels. Its result must correspond to the intended receiver plane and to the relevant mean or peak exposure quantity.

POWER SPECTRAL DENSITY: A frequency-density representation whose compatible integration gives a power-like mean-square quantity. Its units and reference plane determine whether that quantity is voltage squared, current squared or watts. One-sided folding, estimator normalization and window weighting must remain consistent with the claimed integral.

PREAMBLE: A specified leading signal or symbol sequence used to support operations such as acquisition, timing or format recognition. Its duration and role affect which part of a burst becomes usable. Excluding it from a settled payload metric must not conceal acquisition time or count it as delivered payload without justification.

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PREAMPLIFIER: An amplifier placed before a later receiver or measurement stage. The name identifies its role in the chain, not a universal location relative to preselection or a guarantee of low noise and large-signal immunity. The active path and preceding filters must be recorded for the particular configuration.

PRECEDING GAIN: The cumulative power gain before the stage whose added noise is being referred to the cascade input. The contribution $T_{e,i}$ is divided by G_{i-1}, because the input signal has experienced those earlier stages before that noise is added. Preceding loss increases, rather than suppresses, the downstream input-equivalent contribution.

PRESELECTION: Filtering placed before vulnerable gain or conversion stages to limit admitted spectrum.

PRETRIGGER: Recorded interval preceding the condition that initiated an acquisition.

PRINCIPAL ARGUMENT: The angle assigned to a nonzero complex value within one chosen full-turn interval. Model 6B uses a lower-inclusive, upper-exclusive interval centered on zero. This convention removes multiple numerical angle representations but cannot determine which unobserved whole phase turns occurred between samples.

PRINCIPAL PHASE INCREMENT: The argument of the product of one complex sample and the conjugate of its predecessor, restricted here to the interval from minus pi inclusive to plus pi exclusive. It records a rotation modulo a full turn. Frequency interpretation needs a sample interval and justified information to resolve possible whole-turn aliases.

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PROBABILITY DENSITY: A function whose integral over an interval gives probability for a continuously distributed quantity. Its variable, support and normalization must be stated. A density at one value is not itself that value's probability, and writing a convenient density does not establish that a receiver record follows it.

PROBABILITY OF INTERCEPT: Probability that an observation strategy overlaps and detects an event meeting the stated criterion.

PROCESSING LINEAGE: The documented sequence connecting retained input data with derived outputs. It identifies software, settings, corrections, selections, and transformations so that a result can be reconstructed and its irreversible steps recognized. It also identifies the selected interval, channel and calibration for a spectrum, decode, image, table or other output. Visual resemblance to a screenshot cannot establish equivalent scaling, normalization or sample selection.

PRODUCT COLLISION: Coincidence of two generated or existing spectral components at one frequency, requiring their complex amplitudes to be combined before calculating power.

PROTECTION RECOVERY CRITERION: Declared observable and tolerance used to decide when a valid weak-signal measurement has returned after a strong event.

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PROTECTION SURVIVABILITY: The ability of specified hardware to remain within the stated survival criterion after a defined exposure. The criterion and waveform conditions must be retained; survival is distinct from accurate transfer during the event and from prompt recovery afterward. Component survivability data do not automatically establish the survivability or measurement capability of a complete receiver assembly.

PROTOTYPE FILTER: The common filter from which the chapter's analysis-bank channel responses are formed by frequency translation and scheduled sample retention. Its coefficients determine channel gain, leakage and overlap. Shared ancestry does not guarantee independent channel noise, invertibility, or equal energy coverage for different input sample positions.

PROVENANCE VERIFICATION: Examination of an artifact and associated origin or build claims against defined integrity, identity, and policy expectations.

PULSE DUTY FACTOR: The fraction of a stated interval during which a defined pulse condition is present. For a periodic rectangular pulse it is pulse width divided by repetition period. Multiplying constant peak power by this fraction gives mean power only when the stipulated waveform and off-state assumptions apply; the peak exposure remains a separate quantity.

PULSE REPETITION FREQUENCY: The repetition rate of a periodic pulse sequence, equal to the reciprocal of its stated repetition interval. Irregular or missed events require a declared counting and timing convention rather than an assumed periodic rate. Modulation within a pulse and repetition of the pulse are separate waveform properties.

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PULSE REPETITION INTERVAL: The elapsed time between corresponding reference points on successive pulses. Its reference point and treatment of missing or irregular events must be stated. A time record preserves this structure more directly than an averaged spectrum, provided the acquisition and trigger actually captured the relevant events.

PULSE SHAPING: Selection or filtering of the waveform associated with successive symbols to control its spectral distribution and interaction at decision times. The complete convention includes coefficients, rate, delay and initialization. Receive filtering must be consistent with that convention before symbol residuals can be interpreted.

PULSE WIDTH: The duration assigned to a pulse under declared boundary or amplitude-threshold conventions. The receiver's filtering, detector and trigger can change the width inferred from its output. The measurement must retain those conditions and sufficient temporal response, rather than treating a displayed width as an unqualified source property.

QUADRATURE: A relative phase separation of one quarter of a cycle between two same-frequency sinusoidal components. In the coherent collision example, this makes the real cross term vanish. That particular phase relation is not statistical independence, even though it can produce the same measured power as a justified zero-cross-power average.

QUADRATURE AMPLITUDE MODULATION: A modulation family that assigns symbol values to combinations of in-phase and quadrature amplitudes. The resulting complex locations can have different energies, so reference-population and normalization choices matter. Modulation order alone supplies neither code rate nor payload efficiency.

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QUADRATURE CONVERTER: A conversion arrangement that retains two nominally orthogonal components for complex signal representation. Their relative gain, phase and ordering matter to signed-frequency interpretation and image behavior. A plausible magnitude display does not establish correct quadrature balance or the intended I/Q convention.

QUANTIZATION: Mapping an input amplitude to one of a stated set of representable levels. The code spacing and rounding rule constrain an individual error, while its mean, correlation and spectrum depend on the input and additional assumptions. A bounded rounding error does not by itself constitute independent uniform white noise.

QUANTIZATION ERROR MEAN SQUARE: Average squared difference between a quantizer's output representation and its input; includes squared bias.

QUANTIZATION STEP: The amplitude separation between adjacent levels of the specified quantizer or fixed-point grid. In the ideal uniform converter model it is the nominal input span divided by the number of codes. The half-step rounding bound applies only under the stated rounding rule and away from overload.

QUASI-PEAK DETECTOR: A detector that weights a signal using a specified temporal response, making repeated-pulse behavior relevant to the indication. It differs from taking the instantaneous maximum. Its required bandwidth, timing and measurement duration belong to the applicable method; a label alone does not establish that the prescribed response was implemented.

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RAISED-COSINE FILTER: A pulse-shaping response with a flat central frequency region and a cosine-shaped transition, parameterized by symbol rate and roll-off. Its ideal overall pulse satisfies the zero-interference sampling condition at the intended symbol times. Finite implementation, timing error and channel distortion require separate checks.

RANDOM MEASUREMENT ERROR: The component of measurement error that changes unpredictably between replicate measurements of the same quantity under the stated conditions. Its dispersion and dependence affect what averaging can achieve. The chapter's inverse-count variance reduction assumes independent reading errors; it cannot be transferred automatically to correlated observations or an unchanged common calibration contribution.

REACTIVE LOADING: The effect of a component's capacitive or inductive behavior on the connected path, including its matching and frequency-dependent transfer. A protection element can impose this loading even when it is not limiting. Treating it as an ideal open or transparent device omits part of the small-signal measurement chain.

REARM INTERVAL: The period required for the acquisition or trigger system to become ready for another qualifying event. A real rearm gap remains an exclusion in the usable-window model. Adjacent-looking timestamps or saved files do not establish continuous availability across that interval.

RECEIVER-ADDED NOISE: The noise contribution produced by the included receiver chain beyond the admitted source contribution. Model 2B represents it at the input by T_e and at the output by $k B G_n T_e$. This representation depends on the selected path, gain state, bandwidth, and model domain; it is not an arbitrary label for every observed interferer.

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RECIPROCAL MIXING: Noise produced when local-oscillator phase noise mixes a strong nearby signal into the observation band.

RECIPROCAL MIXING OVERLAP: The dimensionless integral of translated linear single-sideband phase density weighted by the observation channel's normalized power response.

RECORD CONTINUITY: Verified absence or documented location of gaps, repeats, lost packets, or clock discontinuities in sampled data.

RECORD LENGTH: The number of acquired samples retained for a stated finite analysis before any zero padding. Together with the sample rate it defines the observation duration. Changing this length can change leakage, nominal bin spacing and the interval over which statistical or signal-state assumptions must hold.

RECOVERABILITY: The extent to which a specified input property can be determined from the retained data and justified model. It is property-specific: magnitude-only data can support a power correction while leaving phase undetermined. A later calibration cannot reconstruct amplitudes or samples that the original acquisition irreversibly discarded.

RECOVERY ATTRIBUTION: The assignment of an observed post-event delay or disturbance to a particular subsystem or mechanism using discriminating evidence. Protection, amplifier bias, gain control, digital filtering, detector averaging, and trigger behavior can all contribute. A delay observed in the final display is a system observation until the relevant path contributions have been separated.

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RECOVERY BASELINE: The pre-event reference behavior against which post-event return is evaluated, including the desired response and any required noise or variability measure. It must belong to the same relevant state and processing definition. A later quiet trace cannot substitute for an unrecorded baseline when the recovery criterion depends on a quantitative change.

RECOVERY EXCLUSION: An interval after a stimulus or state change during which the receiver has not yet met the declared criterion for valid observation.

RECOVERY TIME: Time required for a protection or gain stage to return to specified behavior after a strong event.

RECTANGULAR WINDOW: A finite window that gives every retained sample the same weight and excludes samples outside the record. It preserves a narrow central response for a bin-centered tone but has substantial sidelobes for off-grid components. Its simple weight sums do not make a finite observation equivalent to an infinite one.

REFERENCE CANCELLATION: Removal of a shared contribution by the signed structure of a reported difference when its coupling is genuinely identical in both observations. The phase example obtains the same result by an explicit common input or a consistent covariance matrix. Unequal paths, changed states or unresolved phase branches invalidate automatic cancellation.

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REFERENCE CHECK: An observation of a known or controlled input used to test specified functions of a measurement chain. Its conclusion must remain limited to the capability and conditions actually exercised. The reference waveform, level, frequency and timing must exercise the capability being compared. A comfortable continuous tone does not demonstrate detection of a weak burst beside a blocker or general absence after path substitution.

REFERENCE DISTRIBUTION NETWORK: The installed paths carrying a reference to the devices and boundaries that depend on it. Distribution amplifiers, cables, terminations and state changes can add delay or noise after the primary source. Acceptance therefore identifies and tests the actual outputs rather than relying only on the source's nominal accuracy or lock indication.

REFERENCE LEVEL: The declared analyzer level setting used to establish the display and associated operating configuration. It can influence the applicable gain and attenuation arrangement. Record it with detector and path states when evaluating amplitude accuracy; a changed display reference does not itself improve the physical signal-to-noise ratio.

REFERENCE NOISE TEMPERATURE: Temperature used to define a noise-factor convention, equal to 290 K in Model 2B and distinct from actual source or component temperature.

REFERENCE OSCILLATOR: The oscillating source used to establish a receiver's frequency or timing basis. Its state and distribution path influence tuning, sampling and phase comparisons. A shared nominal reference does not eliminate unequal cable, aperture or processing delays, and a lock indication does not establish every required accuracy or short-term-noise property.

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REFERENCE PLANE: Declared physical or mathematical location to which amplitude, phase, impedance, or timing is referred. It also locates the boundary at which signal transfer and noise contributions are specified. Moving the reporting plane changes which path components belong to a correction; a comparison requires compatible planes and quantities before it can imply improved performance.

REFERENCE POWER: The positive power used to make a logarithmic power argument dimensionless. The chapter's dBm convention uses one milliwatt. Changing the reference changes the numerical level coordinate without changing the physical power, so the reference must remain attached to the reported quantity and conversion.

REFERENCE RESISTANCE: The stated real resistance used for the chapter's voltage-to-power interpretation at a named plane. Equal input and output resistances permit a squared voltage-gain magnitude to represent power gain in the example. With different or non-real loading, the corresponding power relation requires its own consistent treatment.

REFERENCE-RMS NORMALIZATION: Normalization by the root mean square magnitude of the actual selected reference symbols under the declared weights. In a multilevel constellation, that realized energy depends on the included symbol population and need not equal a uniformly used alphabet's mean energy. It is distinct from normalization by a fixed constellation maximum.

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REFERENCE SPUR: A discrete unwanted component related to a reference oscillator or its associated synthesis and clock paths. A frequency coincidence or clock-dependent movement suggests a candidate relationship but does not establish its origin. Clock calibration can also relabel the displayed frequency of an external tone, requiring an independent physical-frequency comparison.

REFLECTION COEFFICIENT: The complex ratio of reflected to incident wave amplitude at a specified plane, frequency and reference-impedance convention. Its phase as well as its magnitude can matter to an assembled RF path. The vector noise treatment uses measured reflections because mismatch affects both delivered source power and the receiver's response.

REGRESSION COVERAGE: The justified set of requirements reexamined after a change, based on affected subjects and dependencies rather than the change label alone.

REGRESSION TEST: A repeatable comparison with previously accepted results after a repair or a change in equipment, firmware, software, calibration or accessories. Checks are selected for the functions used by the deployed measurement configuration and retain their known references, accepted ranges and relevant states; a startup self-test covers only its own exercised functions.

REGULARIZATION: A declared constraint or penalty used to limit the freedom of a fitted model, such as an equalizer. It can control unstable or overly flexible solutions, but it also changes the fitted result. Preserve its rule and assess performance on data excluded from fitting.

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RELATIVE CHANNEL PHASE: The phase relationship between specified channels at a stated frequency and observation boundary. Model 12A obtains it from the difference of their time errors. A common contribution can cancel, but unequal analog paths, apertures, resets and processing delays remain unless measured or otherwise accounted for.

RELATIVE STANDARD DEVIATION: Standard deviation divided by the magnitude of a nonzero mean or stated reference value. It is dimensionless and requires the denominator convention to be identified. The independent-power averaging result in this chapter changes when samples share correlation, even if the stored sample count is unchanged.

RELAY CONTACT: The conducting connection made or broken by an electromechanical relay. In a receiver path, contact condition and wear can alter loss, repeatability or isolation. A change that develops gradually can resemble a calibration or environmental shift unless maintenance and reference comparisons retain the relevant state.

RELEASE ENVELOPE: The documented range of configuration, frequency, level, waveform, environmental, and timing conditions for which a receiver path's stated acceptance criteria are supported. It connects the tests to permitted interpretation and records limitations. A blanket pass without this envelope cannot establish applicability to a changed front-end state or exposure.

RELEASE TIME CONSTANT: The positive time constant identified for the applicable gain-return segment after the controlling condition changes. The actual state at the start of release is carried forward from prior activity. A release constant does not itself specify a preceding hang duration, a timer trigger or the recovery of other RF stages.

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RELOCK: Re-establishment of a controlled frequency or phase relationship after it was lost or interrupted. A recovered lock indicator does not establish that the previous phase or sample epoch has returned. Coherent comparisons across the event require a demonstrated relationship or a new calibrated segment.

REMOTE PREAMPLIFIER: An active gain stage installed near the sensing element to reduce the effect of downstream cable loss and receiver noise. Its input is also exposed to signals throughout its admitted band. Gain, noise, blocker transfer, bias, protection and stability must therefore be assessed together in the installed arrangement.

REPEATABILITY CONTRIBUTION: The uncertainty contribution associated with variation among observations made under the declared repeated conditions. Averaging can reduce a suitable independent reading-error contribution, but not an unchanged shared calibration input. A repeatability-only estimate can therefore understate the uncertainty of a corrected system-level result.

REPEATED SAMPLE BLOCK: A portion of acquisition data preserved more than once where the intended sample sequence should advance. It can corrupt timing and spectral interpretation even if the final file is internally readable and unchanged. Sequence and sample-domain records are needed to distinguish it from a legitimately repeating waveform.

REPLICATION: Fresh execution of an intervention and acquisition under the declared conditions to examine variability and reproducibility. Replotting one capture or dividing it into overlapping windows does not replicate the physical intervention. The repeated records must retain state, order and source conditions so their relationship can be assessed.

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REPRODUCIBILITY: Ability to obtain a consistent result from preserved data and a documented method.

REQUIRED OVERLAP: The positive contiguous duration that an event and one usable acquisition window must share to meet the declared capture criterion. It must not exceed either duration for capture to be feasible. Combining disconnected fragments does not satisfy this one-window criterion unless the measurement question is explicitly changed.

RESIDUAL CARRIER: A carrier-frequency component remaining in a representation or recovered path where its suppression or balance is part of the intended operation. Detector imbalance, quadrature errors or path imperfections can contribute. Its presence must be interpreted with the source waveform and receiver configuration, not automatically assigned to an unusual modulation.

RESIDUAL-ENERGY SUM: The sum of the declared nonnegative weights times squared complex error-vector magnitudes over the selected population. It retains squared-amplitude units before division by reference energy. The same sum can arise from different residual directions and time histories, so it does not uniquely identify an impairment or its physical origin.

RESIDUAL FLOOR: An apparent nonzero limiting value in a residual record. It can arise from a wrong target, detector offset, measurement resolution, a hold state or additional physical dynamics. It should not automatically be fitted as a very slow pole. The residual definition, capability and competing mechanisms must be examined before assigning a physical cause.

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RESIDUAL FREQUENCY OFFSET: The remaining frequency difference between the signal's declared carrier reference and the local conversion or recovery reference. Under the chapter's convention it is carrier minus LO frequency and adds a linear baseband phase trend. Estimating that trend from modulated data can absorb part of the modulation unless the estimation model and interval are justified.

RESIDUAL RESPONSE: Instrument-generated indication remaining with a terminated or otherwise controlled input.

RESOLUTION BANDWIDTH: Analyzer filter bandwidth determining frequency discrimination and admitted noise.

RESONANCE: A frequency-selective response associated with energy exchange and loss in a system. The chapter uses a specified resonance to motivate a loaded quality-factor approximation. Coupled structures, multiple poles and digital filters can require a fuller descriptor than that one center-frequency-to-bandwidth ratio.

RESPONSE DEFINITION: The quantity or criterion fixed before evaluating experimental configurations, including its reference plane, units, bandwidth and processing. Corrected power, logarithmic level and a visibility threshold answer different questions. Keeping the definition consistent prevents an apparent disappearance from being interpreted without accounting for changed sensitivity or scaling.

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RETAINED-RECORD REPROCESSING: Applying a changed correction or processing method to a preserved acquisition record while retaining the original data, both derived products and their processing identities. This comparison can explain a changed interpretation without treating it as a new physical observation. Independent validation remains necessary when the retained record helped select the new method.

RETRANSMISSION: Another transmission of information already represented in an earlier attempt, under the stated protocol or counting rule. It can increase transmitted-bit and symbol counts without increasing unique accepted payload by the same amount. Delivery records are needed to identify duplication; a constellation or checksum cannot supply that history.

RETURN LOSS: A logarithmic measure of reflection at a stated port and reference impedance, conventionally expressed as a positive decibel value for a passive mismatch. It characterizes port matching rather than through-path insertion loss. Changes in input match can alter delivered power and source interaction, so a matched-port transmission correction may not describe every installed antenna condition. Larger return loss conventionally corresponds to a smaller reflected fraction. An attenuator used to improve matching also reduces the desired signal and adds thermal noise, so the complete measurement consequence must be assessed.

REVERSAL CHECK: A planned return from a modified setup to an earlier configuration to test whether the earlier response returns under comparable observation capability. It checks reversibility and can expose drift or state-history dependence. Reproducing the response does not by itself isolate which changed path caused it.

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REVERSE ISOLATION: The limitation on signal transfer from a device's output side back toward its input under stated conditions. In a remote receiving assembly, insufficient isolation can allow downstream leakage to propagate toward the antenna. A forward-gain measurement alone does not establish this reverse-path behavior.

REVERSE-TRIANGLE INEQUALITY: The lower magnitude constraint obtained from the absolute difference of two component magnitudes. Together with the ordinary triangle inequality, it bounds a desired coherent phasor when an additive contaminant has unknown phase. If the contaminant can cancel the measured magnitude completely, a positive inferred product need not have a finite upper intercept bound.

REVISIT PERIOD: The elapsed period after which the declared observation schedule repeats. Model 15A places usable windows and event-start phases relative to that period. A nominal revisit specification must retain settling, rearm and transfer gaps; repeated schedules can continue to miss an event whose phase is locked to them.

RF FRONT END: The input-side network that selects, attenuates, amplifies, routes or limits RF energy before later conversion and detection. Its actual component order determines the exposure of vulnerable stages. A narrow displayed span does not prove that the front end admits only that frequency interval.

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RF INTERVAL MAPPING: The relationship between an admitted IF interval and the RF intervals that can reach it through the stated conversion. A real first-order difference path generally has a lower and an upper interval around the LO, restricted to positive physically admitted RF frequencies. Mapping the complete interval exposes edge and skirt responses that a single image-center calculation omits.

RF SWITCH: A component that selects or routes RF paths. Its state can change transfer, leakage and calibration, while the act of switching can create a transient. The actual route and state belong in the configuration record; a front-panel label alone does not describe every physical consequence.

RISE AND FALL TIME: The durations of the leading and trailing pulse transitions between specified amplitude levels. The chosen levels and measurement path must accompany the result. Limited bandwidth or detector response can alter these durations, so a narrowband trace may not preserve the source transition shape.

RMS AMPLITUDE: The nonnegative square root of a specified mean-square amplitude. State the weighting, record and units before comparing values. An RMS voltage is not automatically an available or delivered power; the load and reference-plane relationship must support any voltage-to-power conversion.

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RMS DETECTOR: A detector whose intended power-related statistic derives from mean square signal magnitude before square-root or level reporting. Its actual bucket operation, weighting, normalization and subsequent video or trace processing must be established from the instrument implementation. The name alone does not determine every operation that produced the displayed number.

RMS TIMING JITTER: The root-mean-square timing fluctuation associated with a declared phase component and positive carrier frequency. Model 12B obtains it from that component's RMS phase by the stated phase-to-time conversion. The scalar retains neither the detailed offset distribution nor a complete account of deterministic delay, trigger error or sample alignment.

ROBUST SUMMARY: A statistic selected to reduce the influence of particular unusual observations under a declared rule. Its behavior and target must be established for the application. Replacing each part of a spectral ratio with a separate robust summary does not automatically preserve identities proved for a common weighted mean.

ROLL-OFF FACTOR: The parameter controlling the transition and excess bandwidth of a declared cosine pulse-shaping response. It must be recorded with symbol rate and filter span because changing it changes the reference waveform. A value alone does not describe the errors introduced by finite coefficients or imperfect timing.

ROOT-RAISED-COSINE FILTER: A response whose product with its matching counterpart gives the intended raised-cosine response. It permits pulse shaping to be divided between transmit and receive processing. The individual filter and the combined response are different; their names do not establish correct alignment, truncation or scaling.

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RUN-ORDER RANDOMIZATION: Assignment of feasible experimental configurations to acquisition order by a declared random procedure. It can reduce systematic association between a setting and unrelated temporal changes. It does not remove physical restrictions, relocking requirements or changing source behavior; those constraints and the actual order remain part of the diagnostic record.

SAMPLE ALIGNMENT: The established relationship between sample indices and the corresponding acquisition instants across channels. Trigger paths, aperture times, digital pipelines and missing data can affect it even when the channels share frequency. The required relationship must be verified at the stored-data boundary used by the analysis.

SAMPLE-CLOCK SCALE ERROR: A discrepancy between the actual and nominal sample rates that changes both elapsed-time labels and the frequency scale attached to normalized discrete data. For a fixed interval count, true elapsed time depends inversely on actual rate. Correcting one displayed frequency does not by itself establish correct timestamps or continuity.

SAMPLE COUNTER: A recorded index or count associated with the acquisition sequence. When its semantics, rollover and reset behavior are known, it helps test whether intended samples were retained in order. A plausible file duration or a stable byte hash does not replace this sample-domain continuity evidence.

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SAMPLE DETECTOR: A detector that selects a sample according to a defined rule for each display bucket instead of retaining the bucket's extremum or a power average. Its sampling rule and relation to the input processing must be documented. A short event between selected samples may not appear in the resulting trace.

SAMPLE EPOCH: Fixed source-index reference establishing the retained output grid or oscillator phase convention within a declared segment.

SAMPLE INDEPENDENCE: The joint statistical condition in which the samples' probability law factors into their individual laws. It is an additional premise for the chapter's gamma sum and simple variance reductions. Distinct timestamps or storage positions do not establish independence when filters, overlapping records or repeated data create shared information.

SAMPLE-INTERVAL COUNT: The number of elapsed intervals between sample endpoints; a span of N intervals contains N plus one endpoint samples.

SAMPLING EQUIVALENCE CLASS: Frequencies and phase conventions producing the same ideal uniformly sampled sequence.

SAMPLING MIXER: A conversion architecture that uses a sampling operation to translate admitted spectral content. Its useful output and unwanted responses depend on the sampling and analog admission conditions. Calling the path a mixer does not remove the alias and frequency-coordinate requirements developed for sampled receivers.

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SAMPLING VARIANCE: The variability of an estimator across repetitions of the specified sampling experiment. A noise-power estimate fluctuates because it is formed from a finite record; its variance depends on the averaging rule and dependence between samples. Reducing that variability does not remove a shared calibration error or an incorrect receiver-state assumption.

SATURATING ARITHMETIC: A numerical operation that clamps an out-of-range code to the permitted endpoint of its declared signed format. Once clamping occurs, the ordinary half-step rounding-error bound no longer applies. Intermediate saturation can alter later results even when the final displayed value lies within range, so the conversion schedule and operation order remain part of the model.

SATURATION: A regime in which a response has reached a limiting range and no longer follows the intended input-output relationship. A detector plateau can resemble successful gain leveling or a normalized display. A weak reference and the relevant raw-state record help distinguish those possibilities and establish recovery.

SATURATION FLAG: A recorded indication that the relevant stage or representation reached its stated limiting condition. In the chapter's ideal clipping example, a reliable flag supports a threshold constraint but does not recover the lost amplitude or supply an upper bound. Its meaning must follow the actual implemented flag and path.

SCALAR CASCADE: Ordered power-transfer and noise model with one effective channel per stage and explicitly bounded matching, state, and correlation assumptions.

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SCALAR TRANSFER: A restricted input-to-output relation for one specified scalar quantity, such as mean signal power at named planes in a characterized state. Its usefulness depends on loading, band, detector and linearity conditions. A valid scalar power relation need not preserve all waveform information, including phase.

SCALE RESTORATION: Reconstruction of a declared numerical or voltage scale from stored values and the associated exponent, without recovery of discarded precision.

SCALLOPING LOSS: The reduction in a selected bin's response when a tone lies between the transform's evaluation frequencies instead of at the stated coherent location. Its magnitude depends on the actual window and offset. A coherent-gain correction alone does not remove this error, while denser evaluation can help locate an isolated response peak.

SCHEDULE PHASE LOCKING: A persistent relationship between event timing and the repeating observation schedule. It can place each event in the same usable interval or the same blind interval. Repeating the schedule then does not create independent opportunities, and a formula based on independent trial phases cannot be applied without changing or justifying the experiment.

SEARCH MULTIPLICITY: The presence of multiple opportunities for a decision statistic to cross a threshold during a search over frequencies, windows, or other tested conditions. It affects how a single-channel false-alarm objective relates to a whole-search claim. The number and dependence of those opportunities must be considered in the chosen validation or probability model.

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SECOND MOMENT: The expectation of the square of a real random quantity, when finite, with the square of that quantity's unit. It includes the contribution of a nonzero mean and therefore differs from variance. Model 14B requires finite second moments for exact affine propagation and distinguishes the squared mean from expected squared voltage.

SECOND-ORDER STATISTICS: Quantities determined by first and second moments, including covariance and compatible auto- and cross-spectra. They can constrain a linear relationship without identifying every feature of the underlying distribution or physical mechanism. Distinct noise allocations and source arrangements can share the same second-order description.

SEGMENTED ACQUISITION: Recording selected intervals, often in response to triggers, instead of preserving every intervening sample. It can reduce storage but omit context and bias occupancy estimates. Each segment and the gaps between segments must retain their timing and validity information before an analysis assumes continuous observation.

SEGMENTED SWEEP: A sweep assembled from separately specified frequency or acquisition segments. Each segment's limits, settings and time position belong in the record so the combined trace can be reconstructed. Segmenting can change which events are observed and when; it does not make the full assembled frequency range simultaneous.

SELECTED CONVERSION PRODUCT: The particular output component admitted by the chosen mixer, filter, and processing path for the intended measurement. A multiplier can generate several mathematical or physical candidates, so a frequency formula must be tied to this selection. Changing an IF path or filter state can change which product is observed even when the front-panel tuning label remains the same.

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SELECTION EFFECT: A change in the interpretation of evidence caused by how observations, tests or processing rules were chosen. Favorable tests selected after viewing outcomes cannot be treated as though they were the only predeclared possibilities. Preserve failed challenges, held-out records and the actual selection procedure when assessing what the evidence supports.

SELECTIVE FADING: Unequal alteration of spectral components by the propagation or reception path. In an AM observation, different sideband responses can change the envelope and produce a quadrature component even when the source modulation has not changed. A scalar center-frequency correction cannot establish the original sideband balance.

SELECTIVITY: The ability of the chosen path to distinguish the desired spectral content from nearby or remote admitted energy through its frequency response. Nominal bandwidth alone does not determine it. Passband behavior, skirts and waveform distortion must be considered together when choosing a filter for a particular observation.

SEMILOGARITHMIC PLOT: A plot using a logarithmic scale for one quantity and a linear scale for the other. A residual following one exponential decay forms a straight trend against linear time under the applicable sign and target conventions. Changes of slope or a residual floor can reveal limitations of that candidate model.

SENSITIVITY COEFFICIENT: Local derivative of the measurement function with respect to an input quantity, carrying the units and sign needed for uncertainty propagation.

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SENSITIVITY FAILURE: Failure to detect the defined event during an acquisition interval that validly observed the relevant channel under the stated conditions. It can inform a sensitivity estimate only within that specified population and detector rule. Events missed because the receiver was not observing belong to a separate coverage category unless a broader operational measure is explicitly defined.

SENSITIVITY SPECIFICATION: A declared input-level performance requirement together with the signal, bandwidth, detector, observation interval and success criterion used to determine it. Specifications based on different modulation quality, error rate or detection criteria describe different measurands unless a justified conversion connects them.

SEQUENCE-NUMBER CHECK: A comparison of declared block or packet sequence identifiers to detect missing, repeated or reordered portions of a record. Its interpretation depends on the acquisition protocol and reset behavior. It supports continuity assessment alongside sample counters, block lengths, overrun flags and clock status.

SERIALIZATION: Encoding a defined sample representation into a stored or transmitted sequence with specified ordering, scaling and metadata. The recording serializer creates an interface that must agree with its reader. Correct behavior of an upstream driver or transport format does not establish that this separate file boundary preserves the intended values.

SETTLING GUARD: An initial interval excluded from a nominal dwell because tuning, filtering, gain control or another state transition has not yet produced usable data. It reduces the window available to meet the event criterion. Its duration must follow the applicable observed or justified response rather than the mere completion of a control command.

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SETTLING TIME: The earliest time after which the specified response remains within its declared error tolerance under the adopted conditions. The error quantity and units matter. In the one-pole model it is zero if the initial error is already acceptable, finite for a positive tolerable residual, and not finite for exact removal of a nonzero initial error.

SETTLING TOLERANCE: The positive permitted residual in a declared state or output quantity used to determine an acceptance time.

SHAPE FACTOR: Ratio of filter bandwidths measured at two specified attenuation levels.

SHARED AGC DETECTOR: A level detector whose output controls gain used by more than one selected signal or observation path. Its admitted band can be wider than a displayed channel, allowing an off-channel signal to suppress a desired weak response. Interpretation requires the detector takeoff, admitted spectrum, gain distribution and control state, rather than the display span alone.

SHARED DEPENDENCY: A common clock, power supply, path, software component, calibration input or other influence linking nominally separate observations. It can preserve the same error across instruments or derived products. Counting labels or devices therefore does not establish the amount of independent confirmation.

SHORT-TIME FOURIER TRANSFORM: Sequence of transforms applied to overlapping time segments to estimate spectral evolution.

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SIDEBAND: Spectral content displaced from a carrier reference by modulation. Its amplitude, phase and retained frequency side depend on the waveform and receiver path. The equal two-sideband power relation in the chapter is conditional on sinusoidal conventional AM and a linear, symmetric response; it is not a universal message-power rule.

SIDEBAND COEFFICIENT: A complex peak-voltage coefficient assigned to an upper or lower spectral component in the envelope expansion. It carries phase as well as amplitude. After a path response, the sum and difference of the two coefficients contribute to the complete in-phase and quadrature expression; real-coefficient shortcuts do not apply to arbitrary complex coefficients.

SIDEBAND IMBALANCE: A difference between the applicable amplitudes or phases of corresponding upper and lower sideband responses. It can turn an originally real envelope into a complex one and bias a source-depth inference from output magnitude. Distinguishing source asymmetry from path distortion requires an appropriate reference or additional independent information.

SIGNAL CLASSIFICATION: The association of an observed component with a waveform family, modulation, timing behavior, or service type. The classification describes characteristics and is separate from attribution to a particular emitter or owner.

SIGNAL-ONLY POWER: The mean power assigned to the desired signal after a compatible additive contribution has been removed under a justified model. It is distinct from the total indicated output power. Its positivity determines whether a finite logarithmic level exists; a negative estimated difference requires reconciling the estimates and premises.

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SIGNAL RETENTION: The fraction or representation of the desired signal preserved by the selected channel and processing for the intended measurement or detection event. Reducing equivalent noise bandwidth can reject desired modulation or burst energy as well as noise. A claimed sensitivity improvement must evaluate the retained signal, rather than relying only on the reduced noise trace.

SIGNAL-TO-NOISE RATIO: The ratio of the selected signal power to the noise power represented in the same observation. Its input and output versions require declared planes, bandwidths and retained signal content. A specified ratio can support an input-power requirement, but does not by itself establish a probability of detection or false alarm.

SIGNED DIFFERENCE FREQUENCY: The algebraic RF-minus-LO frequency retained before any conversion to a nonnegative real-frequency display.

SINGLE SIDEBAND: Amplitude-modulation form transmitting one sideband with reduced or suppressed carrier.

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SINGLE-SIDEBAND PHASE DENSITY: The linear phase-noise quantity equal to one half of the one-sided phase spectral density and, at positive offsets, to the two-sided phase density. The carrier-referred quantity may be expressed linearly per hertz or logarithmically in dBc/Hz. Model 12B states its small-phase convention and includes both symmetric contributions in real-phase variance; a discrete spur requires separate line treatment.

SLEW-LIMITED CONTROL: A regime in which the control state changes at an imposed maximum rate rather than following the small-change exponential law over the whole excursion. Limited charging or discharging current can produce an approximately linear voltage ramp. The applicable rate, transition and control range require their own evidence; a later exponential fit does not describe the earlier ramp automatically.

SLEW RATE: The applicable maximum or specified rate limit of a changing state or output, expressed in that quantity's units per unit time and tied to stated conditions. A large-change slew limit can produce an early ramp rather than the local exponential response. It is distinct from an arbitrary trajectory's instantaneous derivative. Settling inferred from the small-change model must be checked against the actual event regime.

SMALL-PHASE APPROXIMATION: The retention of one plus j times phase as the first-order representation of the complex phase exponential. The chapter supplies an exact pointwise complex-amplitude remainder bound of half the squared real phase. First-order sideband amplitudes are approximate and use an unmodulated carrier reference; the bound does not itself specify exact spectral containment.

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SMALL-SIGNAL ASYMPTOTE: The linear response extrapolated from the declared low-level behavior of a stage. It supplies the fundamental reference for the chapter's intercept construction, rather than the full finite-level fundamental including its cubic correction. Confusing those quantities changes the inferred intercept and can obscure the limits of the approximation.

SMALL-SIGNAL CHARACTERIZATION: Measurement of a path's response within a range where the declared linear model is applicable. It establishes quantities such as gain, phase, matching and noise baseline for that state. Large-signal, pulsed and recovery behavior require additional observations rather than extrapolation from the quiet small-signal result alone.

SMALL-SIGNAL PROTECTION LOSS: The ordinary signal attenuation introduced by a protection network when it is not in its limiting state. It affects the desired transfer and, when dissipative and preceding gain, the input-equivalent noise budget. Survival of large events does not establish that this loss is negligible, stable, or unchanged after an event.

SMALL-SIGNAL VALIDITY: Operating condition in which the linear gain and added-noise law used by the measurement model remain applicable.

SOFTWARE BILL OF MATERIALS: An inventory of software components within a declared product or release scope. It supports provenance and dependency review but does not itself establish freedom from vulnerabilities or cover omitted firmware, calibration files or other artifacts. Acceptance must compare the inventory's actual scope with the components required by the stated case.

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SOFTWARE CORRECTION OFFSET: A declared numerical adjustment already included in an exported or displayed result. It changes the coordinate or reference-plane interpretation of that value according to its documented convention. Recover the raw indication or apply only the remaining corrections; an unexplained export state leaves alternative results rather than a justified midpoint.

SOURCE-DOMINATED NOISE: A condition in which admitted source noise contributes much more to the total than the receiver's input-equivalent added noise. Reducing receiver noise then produces only a small reduction in the complete noise level. The conclusion depends on the represented source spectrum and does not justify replacing structured interference with a temperature.

SOURCE-GENERATED INTERMODULATION: Nonlinear products produced in a stimulus source, combiner, connector or other test-path component before the receiver contribution is isolated. Such products can contaminate an intercept measurement and can combine coherently with receiver-generated amplitudes. Source isolation and harmonic filtering are therefore part of the validity argument, not merely setup details.

SOURCE HARMONIC CONTAMINATION: An unwanted harmonic already present in a test source or its delivery path that enters the receiver as an ordinary RF input. During an image test, such a harmonic can fall in the desired path and imitate response to the intended image-frequency fundamental. Bounding the contamination at the actual receiver plane is necessary before assigning the measured IF output to receiver image rejection.

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SOURCE-IMPEDANCE DEPENDENCE: The change in a receiver's transfer or added-noise response when the impedance driving its input changes. Mismatch can therefore affect both delivered source power and the receiver contribution. A single scalar loss adjustment may be inadequate when the required noise-measurement accuracy depends on this interaction.

SOURCE NOISE TEMPERATURE: The temperature-scale representation T_s of noise supplied at the cascade input under the declared band and model. It can reflect the antenna view or an applied calibrated source and need not equal ambient temperature. Model 2B keeps it separate from the equivalent temperature representing receiver-added noise.

SOURCE-PATH CONTROL: A measurement or controlled comparison that bounds signals and artifacts already present in the sources, cables, and combining network before the receiver input. It is needed when receiver-generated intermodulation or noise is being claimed. Its measurement floor and applicability must be retained because an undetected contribution is bounded, not necessarily absent.

SOURCE SPECTRAL PURITY: The extent and distribution of a test source's unwanted spectral components under the applied operating conditions, including harmonics, spurs, and relevant broadband noise. It must be assessed at the receiver plane through the actual path when artifact attribution depends on it. A source's nominal carrier level does not characterize these unwanted contributions.

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SOURCE SWITCHING: The controlled transition between the hot and cold input-source states of a comparative noise measurement. The record must identify the realized state, timing, settling, and any associated change in gain, bandwidth, mismatch, or noise law. Switching labels alone do not establish the common-state conditions needed for the simple Y-factor inversion.

SPECTRAL DENSITY NORMALIZATION: Scaling squared transform magnitude by the sample rate and the actual squared window-weight sum so that the ordinate has input-squared units per hertz. Under the chapter's white-covariance premise its expectation is flat. Integrating this finite-record density gives the stated window-weighted mean square even without that whiteness assumption.

SPECTRAL GRAM MATRIX: The matrix formed from consistently weighted paired spectral vectors, with autospectra on its diagonal and conjugate cross-spectra off the diagonal. Common nonnegative weights give the positivity structure behind the coherence bound. Separately chosen medians need not retain that structure and can produce a substituted ratio above one.

SPECTRAL LEAKAGE: Distribution of energy into neighboring transform bins caused by finite observation and windowing.

SPECTRAL LINE: A discrete-frequency contribution with finite integrated power, distinct from an ordinary continuous spectral density. A carrier or discrete phase-modulation spur must be included through its line contribution and the observation response. Assigning it an arbitrary per-hertz value or treating it as a flat density can misstate admitted power.

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SPECTRAL PREPROCESSING: The declared operations applied to acquired samples before the analyzed transform, such as mean subtraction or other detrending. These operations can change which physical or statistical components remain in the analyzed record. Reproducibility requires their order and parameters alongside the window, sample rate and retained data.

SPECTRAL REGROWTH: Additional spectral spread associated with waveform distortion, commonly assessed outside the intended channel. It is a spectral consequence rather than an error-count statistic. A receiver or transmitter may exhibit acceptable decoded data while this spectral measurement fails its separately defined criterion.

SPECTRAL SUPPORT: The set of frequencies at which a represented spectrum is nonzero, subject to the model's mathematical convention. Model 6A bounds the envelope support so that the translated positive and negative RF bands remain separated. This exact model set differs from a practical admission boundary defined by a finite filter response and detection threshold.

SPLITTER ISOLATION: The degree to which a signal or load change at one splitter branch is prevented from affecting another under stated port conditions. Finite isolation and coupled output loads can make unused branches consequential. Selected-path gain alone does not establish the behavior of the complete multiport assembly.

SPREAD SPECTRUM: A signaling approach that intentionally distributes a represented signal over a broader frequency or code domain according to a specified spreading rule. Reception and classification depend on that rule and timing. A broad spectrum alone is insufficient to identify the method or demonstrate successful despreading and information recovery.

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SPURIOUS-FREE DYNAMIC RANGE: A range defined by specified desired-signal, noise and spur conditions at compatible reference planes and bandwidths. The chapter's third-order planning expression finds where the equal-tone cubic product meets the stated noise floor. Compression, reciprocal mixing, other products or model breakdown can impose a smaller usable range.

SPURIOUS RESPONSE: Receiver output caused by an unwanted internal or external frequency-conversion mechanism.

SPUR TABLE: A documented set of candidate unwanted-response relationships, including the parent frequencies, integer indices or clock relations and their stated scope. A useful table combines analog and digital architecture. It guides controlled movement and level tests; merely finding a matching entry is not proof of a generating mechanism.

SQUARED WINDOW-WEIGHT SUM: The sum of the squared real window coefficients, which is positive unless every coefficient is zero. It sets the chapter's noise-density normalization and window-weighted energy denominator. Using a coherent weight sum or sums calculated from a different coefficient vector changes the estimated quantity.

SQUELCH: A receiver operation that suppresses or gates a recovered output according to a defined or automatic condition. It can change the apparent presence and continuity of audio without proving that the RF waveform disappeared. Record its state and criterion when interpreting dropouts or comparing derived products.

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STANDARD DEVIATION: The nonnegative square root of variance, expressed in the same units as the modeled quantity. It measures dispersion rather than correction of a mean offset. A smaller standard deviation of a noise trace does not establish that its estimator targets the intended linear-power or logarithmic quantity.

STANDARD UNCERTAINTY: An uncertainty expressed in the form of a standard deviation under the stated input information and model. It describes dispersion rather than a guaranteed maximum error. Its numerical value alone does not define a coverage probability, a detection probability or an acceptance decision.

STATE CARRYOVER: Use of the actual ending state of one dynamic interval as the initial state of the next.

STATE-CONDITIONED COHERENCE: A paired spectral result calculated within observations assigned to a defined state instead of pooling different transfer conditions. Opposing within-state gains can produce low pooled coherence even when each state is perfectly related. The state rule must be independently defensible, rather than selected merely to obtain a preferred relationship.

STATE INTERVAL: A declared portion of a record during which the relevant receiver configuration and its calibration remain applicable.

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STATE MIXTURE: An observation population containing contributions from distinct receiver or source states with different stated distributions or mean powers. Averaging their logarithmic levels and then applying a single-state correction generally does not recover the overall arithmetic mean power. Preserve state-resolved measurements and their weights when those differences matter.

STATE RECORD: The record of the switch, gain, attenuation, bias, temperature and receiver settings relevant to an observation. It connects an assembled path to the transfer and noise behavior applicable at that time. Physical component identities alone cannot establish this state, especially across switching, warmup or remote-control transitions.

STATE TRAJECTORY: The sequence or function describing how the actual state evolves through time. A transient gain trajectory can differ materially from a final value or average gain. Quantitative correction requires an applicable state-to-gain relation and timing alignment with the RF observation; a fitted trajectory cannot reconstruct clipped or unobserved behavior.

STATE-TRANSITION RECORD: A preserved record of the operation and timing by which the receiver moved between configurations, including any relock, impulse or recovery interval. It distinguishes transition behavior from settled behavior. Excluding a transient from a settled-state analysis does not remove its evidential relevance or justify deleting it.

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STATIONARITY: The assumed stability of the statistical properties needed by a specified estimator over its included observations. The chapter's noise-power calculations hold one distribution and mean fixed unless a case explicitly varies them. A stable-looking averaged trace does not prove this premise, because averaging can conceal changes in the underlying state.

STATISTICAL BIAS: The difference between an estimator's expected value and the quantity it is intended to estimate under the stated model. Bias depends on the estimator and parameterization. An estimate can be unbiased in watts while its logarithm has finite-record bias in decibels.

STEADY STATE: The response associated with unchanged conditions after the relevant transient has ceased to matter under the stated criterion. In the ideal one-pole model, the target is approached asymptotically. A short burst or a recurring sequence can remain far from either nominal steady state, so the actual trajectory must be retained.

STEP ATTENUATOR: An attenuator offering discrete selectable losses. The actual step difference, frequency response, repeatability and contact condition matter when two receiver states are compared. A nominal setting change provides a useful challenge only when its transfer and the affected position in the chain are known.

STEP-ATTENUATOR REPEATABILITY: The consistency of the realized insertion loss when an attenuator returns to the same nominal setting under stated frequency and connection conditions. Contact behavior and switching history can produce variation distinct from nominal step accuracy. Repeated-state evidence matters when a small level difference is used to infer linearity or external-signal scaling.

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STEPPED SWEEP: An acquisition that visits selected frequency settings through successive tuning and dwell intervals. The usable part of each dwell excludes whatever settling or invalid state the validated method requires. Commanded dwell duration is therefore not automatically valid observation time, and the resulting trace still combines observations made at different times.

STEP RESPONSE: The evolution of a path's output after an input or target changes to a new constant value. Model 5A gives a particular monotone exponential control-state response. A measured step can reveal overshoot, delay or additional time scales that contradict that local one-pole description.

STOPBAND: A filter region in which unwanted transmission is intended to be suppressed to the stated level. Rejection must be evaluated at the actual interfering frequencies and operating conditions. A desired-band insertion-loss value cannot stand in for stopband blocker transfer.

STOPBAND REJECTION: Attenuation supplied by a filter over a declared unwanted-frequency region relative to the stated transfer reference. In a blocker budget it must apply at the blocker frequency and before the vulnerable stage. A desired-frequency insertion-loss value does not establish rejection, and a rejection specification does not establish desired-signal retention.

STORED SAMPLE OFFSET: Integer position in the retained sample array, which need not equal the original source index after a gap or overlap.

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STORED SAMPLE REPRESENTATION: The actual encoding of recorded sample components, including real or complex form, container width, signedness, byte order, packing, interleaving and scaling. It determines payload accounting and interpretation. Converter resolution alone does not specify that representation, and an exported format can use a different byte rate for the same sample sequence.

STRICT STATIONARITY: Invariance of all finite-dimensional probability distributions under a common shift of time. Model 11B invokes this stronger premise, with a finite fourth moment and its stated blocker-phase convention, when bounding the filtered nonlinear remainder. The weaker covariance premise sufficient for the retained linear spectrum does not automatically provide it.

SUBHARMONIC: A component at an integer fraction of a stated fundamental frequency. It is among the possible oscillator-related features considered in the chapter's architecture review. Its existence and influence require evidence from the actual path; the term alone does not identify which divider or nonlinear mechanism produced an observed line.

SUBJECTIVE INTELLIGIBILITY: A listener's judgment that recovered audio is understandable. It can be useful within an authorized investigation, but it does not calibrate the RF frequency or deviation, prove source identity, or replace objective verification of the processing path. The original capture and recovery settings remain the technical record.

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SUM PRODUCT: The first-order real-multiplier component at the sum of the positive RF and LO frequencies. In the normalized ideal cosine model it has the same peak scale as the difference product before output selection, with the sum of their phases. It is not absent merely because a receiver intends to use the difference IF. Actual filtering and path response determine whether it influences the observation.

SUPERHETERODYNE RECEIVER: A receiver that uses an oscillator-driven conversion to an intermediate-frequency path for subsequent selection and measurement. The oscillator choice and injection side determine the possible desired and image inputs. An indicated IF or display center alone does not uniquely identify the original external frequency.

SUPPLY-PATH CONFOUNDING: Ambiguity introduced when a power-source comparison changes more than the noise on the supply. Replacing a supply with a battery can also alter conductive coupling and grounding. A changed receiver indication supports sensitivity to the intervention, but a more selective test is needed to identify which changed mechanism caused it.

SUPPRESSED CARRIER: A modulation condition in which the discrete carrier component is reduced or removed while the information-bearing sideband structure is retained. The carrier remains a reference for defining that structure. Coherent recovery requires a suitable reinsertion or reference relationship; the envelope alone need not preserve the original baseband waveform.

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SUSTAINED WRITE RATE: The data rate a recording path can continuously commit over the required duration and operating state after temporary buffering is accounted for. It is an achieved capacity, distinct from the waveform's calculated payload demand. A short burst benchmark can conceal a slower storage path and does not establish gap-free long capture.

SWEEP TIME: Time required for the analyzer to traverse the selected frequency span or measurement points.

SWEPT-TUNED SPECTRUM ANALYZER: An analyzer that successively translates input frequencies through a selected resolution response as its tuning changes. Its trace therefore contains a frequency-time history. A transient can be omitted or portrayed with a misleading shape; the selected acquisition mode must be identified when an instrument also supports other architectures.

SWITCHING MIXER: A mixer that uses the oscillator-driven switching action of its signal path for conversion. Its effective scaling and additional products need not match multiplication by a single sinusoid. The chapter therefore distinguishes the physical switching implementation from the explicitly normalized ideal multiplier used for the synthetic calculations.

SWITCHING TRANSIENT: A temporary response produced while a switch, filter selection or other route change moves between states. Its amplitude, duration and interaction with control recovery can affect the usable observation interval. A calibration of either settled endpoint does not automatically describe the intervening transient.

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SWITCH LEAKAGE: Signal coupling through a nominally unselected switch path under specified conditions. A strong signal on an unused branch may remain observable despite selection of another branch. The switch state, port terminations and relevant isolation must therefore be included in the path model and acceptance record.

SYMBOL: One value selected from the declared modulation alphabet for a particular signaling opportunity. Its waveform representation and binary labeling belong to the format definition. A symbol may represent several coded label bits; it is neither an ADC sample nor necessarily one unique delivered information bit.

SYMBOL RATE: The number of declared modulation-symbol events per unit time, with the active or whole-interval convention stated. Symbols per second are distinct from receiver samples per second. Guard intervals can change an average event count per wall-clock second without changing the symbol timing inside an active burst.

SYMBOL-RATE MISMATCH: A difference between the actual symbol timing rate and the rate assumed by the reconstruction or demodulator. It can make relative decision timing drift away from a chosen alignment point across a finite record. A constant timing adjustment does not generally remove that accumulating discrepancy; clock and processing premises require separate checks.

SYMBOL TIMING: Estimate of the sampling instant associated with each transmitted symbol.

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SYMMETRIC WINDOW CONVENTION: A coefficient-vector convention with matching endpoints, distinguished from the periodic form used in many spectral calculations. The chapter's symmetric Hann window uses the record length minus one in its cosine denominator. For short records its weight sums and equivalent noise bandwidth differ materially from the periodic form.

SYNTHESIZER LOCK STATE: The recorded state of the synthesis system's relationship to its intended reference or control condition. It is part of the conversion configuration preserved when tuning plans or bands change. A valid center-frequency display alone is insufficient evidence that all frequency and phase relationships used by an analysis remained applicable.

SYSTEMATIC MEASUREMENT ERROR: The component of measurement error that persists or changes predictably across replicate measurements under the specified conditions. An estimated significant effect may be compensated by a correction whose uncertainty remains. Averaging additional readings does not remove a shared offset, and repeatability alone does not characterize this component.

SYSTEM-LEVEL VECTOR CALIBRATION: Calibration of the relevant complex response of an assembled measurement system, retaining amplitude, phase and their uncertainty relationships. The cited experiment combines multiple correction contributions and correlations. Its success illustrates a method under the published conditions, without certifying another receiver configuration or bounding that configuration's remaining nonlinear behavior.

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TAPERED WINDOW: A finite weighting that reduces selected record-edge contributions to alter the spectral response. It can lower sidelobes while broadening the main response and changing amplitude and noise normalization. A transient's location within the taper can materially change the energy admitted to the estimate.

TECHNICAL PEER REVIEW: Independent examination of the native data, configurations, calculations, calibration, challenge results and competing explanations supporting a finding. It tests the reasoning and evidence rather than merely approving a narrative. Unresolved disagreements lead to further measurements or explicit limitations, preserving the actual strength of the conclusion.

TEMPERATURE CONTRAST: The difference $T_h - T_c$ between the effective hot and cold source temperatures in the declared hot-cold measurement convention. It enters the source excess-noise ratio and influences the measured power contrast. Its calibration and uncertainty must be retained; a large nominal contrast alone does not establish receiver linearity or correct source-plane delivery.

TEMPORAL CORRELATION: A relationship in the timing of observed events under a stated time basis and uncertainty. It can guide a causal investigation without proving its direction or mechanism. Shared control activity, instrument timing or another common cause must remain possible until discriminating evidence resolves those alternatives.

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TERMINATED-INPUT TEST: An observation made with a specified load replacing the usual input source or antenna. It can constrain hypotheses about pickup, leakage or instability, but it also changes the source impedance and installed coupling. The comparison must retain the detection capability and operating conditions needed by the question.

TEST ORACLE: The specified expected result or decision basis against which a test observation is judged. It must discriminate the failure under examination with adequate independence from the implementation being tested. The chapter's asymmetric code vectors and channel-basis examples expose defects that mutually agreeing programs with a shared faulty dependency can conceal.

THERMAL DRIFT: A change in a measurement path's response associated with changing temperature over time. Filter loss, active-device state and calibration applicability can be affected. Reference comparisons and maintenance records should retain the thermal state so that drift is not silently interpreted as a changed external signal.

THERMAL EMISSION: Noise power supplied by a dissipative component because of its thermal state. In the matched attenuator derivation, this contribution supplies the difference between attenuated incident thermal noise and the equilibrium output. It accompanies physical dissipation; arbitrary reflected signal power is not assigned the same thermal-noise law.

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THERMAL EQUILIBRIUM: The condition used in the passive-loss derivation in which the matched source, attenuator, and connected terminations share the physical temperature T_p. The attenuator output available noise remains kBT_p because thermal emission complements the transmitted source noise. Equal equilibrium noise does not mean that a desired signal passes without attenuation.

THERMAL NOISE: Random electrical noise associated with a source's thermal state. In the chapter's classical matched-source approximation, its available power is proportional to absolute temperature and effective noise bandwidth. The approximation does not turn discrete interference, unstable amplification or every elevated receiver indication into thermal noise.

TIME ANCHOR: An association between a specified source sample index and a time on a declared time scale. Together with a supported sample-rate model it permits other sample times to be calculated. A host-arrival or file-creation timestamp is not interchangeable with this sampling event, and anchor uncertainty remains distinct from continuity of sample indices.

TIME AVERAGE: An average taken over a declared time interval or stated long-time limit of a waveform. The interval and weighting are part of its definition. The chapter's mean-power identities use explicit carrier and message orthogonality; their time averages are not interchangeable with instantaneous peaks or unspecified statistical expectations.

TIME BASIS: The declared reference and event definition used to assign times to observations. It includes the meaning of a timestamp and, where relevant, synchronization sources, clock state, and uncertainty needed for comparison.

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TIME DIFFERENCE OF ARRIVAL: The difference between the arrival times of a signal at declared receiving positions or channels. Inferring geometry from it requires compatible clocks, identified sampling events and calibrated path delays. Shared frequency alone does not establish these conditions, and an apparent arrival difference can include electronic or packet-alignment offsets.

TIME-FREQUENCY REPRESENTATION: A processing-dependent description of how spectral content varies across a finite record. Window duration, overlap, scaling, thresholds and other method choices affect visible features. It must remain linked to the original samples and a quantified analysis rule; visual structure alone is not a validated event or source.

TIME-QUALIFIED TRIGGER: A trigger whose acceptance includes a stated duration, timing relation or time-dependent logical condition. Pulse-width selection is one example. Its qualification time is part of the event definition, while holdoff or rearm describes subsequent trigger availability; those intervals must not be treated as interchangeable.

TIME SCALE: The defined system of time coordinates used to identify instants and compare clock readings. A clock error is meaningful only relative to that basis. Receiver records must state the reference and event association when combining channels or captures; matching numerical timestamps without that information does not establish simultaneous acquisition.

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TIMESTAMP: A recorded time value associated with a specified event on a declared time basis. The event might be the sampling instant, packet arrival or file creation, and those meanings are not interchangeable. Its usable accuracy also depends on the clock, delay calibration and continuity evidence rather than on the numerical resolution of the label alone.

TIMING SKEW: Relative delay between nominally simultaneous channels, triggers, or signal paths. Acquisition or processing skew can introduce a frequency-dependent phase difference into paired analysis. Phase and delay conclusions require alignment and calibration of the relevant paths, together with the clock and geometry conditions used in the comparison.

TONE-NORMALIZED SQUARED SPECTRUM: The squared windowed transform divided by the squared coherent weight sum, with side conventions specified. Its units are those of input mean square, but summing its ordinates requires bandwidth correction.

TONE SPACING: The frequency separation between the parent tones in a specified test. It determines where their products lie and can affect a physical stage's measured intermodulation behavior. Tone levels, observation bandwidth and receiver state must remain defined when spacing is changed; an intercept from one separation is not automatically valid at another.

TRACE: An ordered set of displayed or stored analyzer values associated with declared frequency, time and processing coordinates. It may be one sweep or an aggregate of many observations. A trace image alone can omit the settings and observation history needed to interpret its values or reproduce the result.

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TRACEABILITY: Property of a measurement result relating it to references through a documented, unbroken chain of calibrations with stated uncertainties.

TRACE AVERAGING: Combination of corresponding trace observations using a specified averaging operation and record selection. It can reduce variation for a suitable stationary process, but its effect depends on whether voltage, power or logarithms are averaged. Combining repeated sweeps does not create simultaneous observation of their frequencies.

TRACKING FILTER: Tunable filter whose passband follows the receiver tuning frequency.

TRAINING SEQUENCE: Known or explicitly assumed reference symbol values used to estimate receiver or channel parameters. It is the content used for fitting, while a training-set specification identifies which observations are included. Retain both the sequence and its alignment, and evaluate transfer on observations excluded from fitting.

TRANSFER PHASE: The phase difference imposed by a specified input-to-output path at a stated frequency. With the chapter's sinusoidal convention, a positive physical delay gives negative transfer phase. This sign must not be interchanged with the positive relative phase assigned to an advanced clock in Model 12A.

TRANSFORM LENGTH: The number of values supplied to the discrete transform, including any appended zeros. It determines the displayed frequency grid. When it exceeds the acquired record length, normalization must retain the sums of the original window coefficients; a longer transform does not represent more acquired observation time.

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TRANSIENT RESPONSE: The time-dependent behavior before the response required for the current conditions has been established. It can change the indicated peak, onset or pulse shape while a long-record energy result remains usable. Its interpretation depends on the actual path, stimulus and measurement criterion.

TRANSIENT SUPPRESSOR: A protection component intended to reduce a short excessive electrical disturbance. Its presence does not make the complete input path ideal: leakage, reactive loading, insertion loss, transient transmission and recovery can affect the measurement. Acceptance must use the mounted path and the applicable event conditions.

TRANSIENT VALIDATION: A controlled check that the selected receiver method represents the event duration, modulation, timing and prior state required by the intended measurement.

TRANSITION WIDTH: Frequency interval connecting specified passband and stopband boundaries of a filter. The boundary criteria must be stated because different level definitions give different widths. Signals occupying this region can experience rapidly changing magnitude and phase; a tuning frequency by itself does not show whether a broadband desired waveform remains inside the usable response.

TRIANGLE INEQUALITY: The principle that the magnitude of a sum is no greater than the sum of the individual magnitudes. It gives the chapter's conservative multi-component deviation bound. Equality requires compatible component phases; knowing only component amplitudes does not establish that the bound is attained.

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TRIGGER DELAY: The specified interval between the trigger reference and the acquisition or gate position used for the measurement. Its sign and time reference must follow the instrument convention. Delay, jitter and the event's own repeatability determine which portion of a burst is observed; matching a trigger edge does not align every internal waveform feature.

TRIGGER HOLDOFF: A declared interval or condition during which further trigger acceptance is inhibited after a trigger event. It affects the ability to record a second closely spaced event. Characterization with controlled event pairs is therefore needed in addition to a successful isolated-event test.

TRIGGER HYSTERESIS: A dependence of trigger-state transitions on distinct entry and release conditions, used in the declared trigger logic. It affects whether and when nearby signal excursions generate new events. Its settings and behavior belong to the capture configuration rather than being inferred from the displayed trigger threshold alone.

TRIGGER LATENCY: The delay between the relevant event at a specified trigger-path boundary and the trigger indication or action. Its value and variability depend on the trigger location and processing. A known-stimulus test must relate it to the stored sample times; a trigger label alone does not identify that relationship.

TRIGGER PATH: The part of the receiver processing chain observed by the trigger decision. It may use full-rate samples, a decimated channel, filtering or a software statistic, giving it a different bandwidth or delay from the saved waveform. The event can therefore be present in one path without satisfying the other's condition.

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TRUST ANCHOR: Trusted verification data, commonly a public key or root identity, from which a declared signature-verification relationship is established. Its installation, protection and management are part of the trust decision. The presence of a signature cannot establish its own trusted source without the applicable verification policy and anchor.

TUNING WORD: The integer phase increment selected for a numerically controlled oscillator's accumulator. Together with accumulator width and clock frequency, it determines the generated frequency in the stated ideal model. Nearest-word selection leaves a bounded frequency-grid error that can accumulate into a consequential phase difference over a long observation.

TWIDDLE FACTOR: A complex exponential multiplier used in a Fourier-transform computation. Its sign, index and numerical representation belong to the implementation definition. The four-channel examples use exact factors drawn from the unit axes, while a general finite-word transform can introduce additional coefficient and intermediate-rounding errors.

TWO-POINT TIME-CONSTANT IDENTIFICATION: Estimation of a candidate one-pole time constant from two nonzero, same-sign residuals about one fixed target, with decreasing magnitude over a positive time separation. The elapsed time divided by the natural logarithm of their ratio gives the candidate constant. Additional observations are needed to establish model adequacy and its operating domain.

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TWO'S COMPLEMENT: The signed binary integer convention used by Model 10D, with one more negative code than positive code at a given word length. That asymmetric range matters when multiplying or negating the most negative value. A mathematically positive endpoint can overflow a narrowed signed format even when both operands have magnitude no greater than one.

TWO-SIDED SPECTRUM: A spectral representation retaining both positive and negative frequencies in the chosen sampled-frequency interval. The chapter's density model begins with this convention before any justified folding for real data. Its ordinate units and integration spacing must remain explicit, especially when comparing a complex baseband record with a one-sided real-signal display.

TWO-TONE TEST: A controlled test using two specified sinusoidal components to examine nonlinear products or related transfer changes. The individual frequencies, levels and path purity matter. Products already generated by the sources or combining network must be bounded before the receiver is identified as their origin.

UNBIASED ESTIMATOR: An estimator whose expected value equals the target quantity within the adopted statistical model. This property does not make every realized estimate correct or establish a confidence bound. It is not preserved by an arbitrary nonlinear transformation, as the chapter's power-to-decibel comparison demonstrates.

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UNCERTAINTY BUDGET: An organized account of the input quantities, uncertainty information, sensitivities and dependencies relevant to a specified result. The table follows the measurement model rather than replacing it. Shared references, unapplied corrections, interpolation residuals and configuration mistakes must be treated according to their actual roles instead of being assigned arbitrary independent rows.

UNCORRELATED SAMPLES: Samples whose relevant cross-covariances vanish under the declared model. This second-moment condition can remove cross terms in an expected squared transform without requiring Gaussianity. It is weaker than statistical independence in general and does not automatically justify every distributional averaging formula.

UNDERSAMPLING: Intentional sampling of an admitted band above the first real-sampling Nyquist zone so that its discrete representation lies at a lower frequency. Preserving the desired bandwidth requires suitable band placement and analog rejection of competing aliases. Spectral order can reverse, and bandwidth alone does not establish a valid plan.

UNEQUAL-TONE INTERMODULATION: The nonlinear-product behavior produced when the two parent tones have different stated amplitudes or powers. In the retained cubic model, each close-in product weights one parent twice and the other once in power. The two products therefore need separate calculations; symmetry cannot be inferred from their frequency placement alone.

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UNEQUAL-TRIAL PROBABILITIES: Different declared single-trial capture probabilities used when the experiment varies across trials. Their miss probabilities can be multiplied only when the relevant independence assumptions remain justified. Assigning different numbers to correlated trials does not remove the need for a joint model or a defensible bound.

UNEXPLAINED SIGNAL: Observed component that survives initial validity checks but lacks sufficient evidence for source or functional attribution.

UNIFORM PHASE ASSUMPTION: The assumption that event starts are equally distributed over a schedule period. Under it, Model 15A converts the merged eligible-start duration into a conditional capture probability. A synchronized or concentrated event process requires its own distribution or a deterministic coverage statement rather than this convenient average.

UNIFORM QUANTIZATION-ERROR MODEL: The stipulated probability model in which rounding error is uniformly distributed over one code-step interval centered on zero. It gives a mean-square error used in the ideal sine-wave estimate, but the half-step error bound alone does not establish this distribution. Predicting channel noise additionally requires the separate white-error premise.

UNIQUE PAYLOAD POSITION: A payload identity counted once in a declared accepted set, even when several transmission instances refer to it. Identity requires more than the binary value zero or one. Unique-position counting must specify the request or sequence boundary, acceptance rule and time interval before it can support a delivered-throughput claim.

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UNMEASURED SPECTRAL CONTRIBUTION: A phase-noise contribution outside the directly evaluated spectral region. Model 12B bounds a specified finite extra band only when a justified upper density limit is supplied. Without that information, extending a plot or quoting the measured-band RMS as a complete jitter value would add unsupported evidence.

UNUSED-PORT TERMINATION: Load condition at a nonselected network port that can affect leakage, matching, or coupling into the selected path.

UNWRAPPED PHASE: A continuous phase branch retaining accumulated cycles on a declared valid interval, with reset events treated separately. Its slope supports frequency or delay calculations only when the associated model applies. Selecting the branch requires evidence; numerical precision alone does not resolve an integer-cycle ambiguity.

UPPER SIDEBAND: The message-related spectral component or band above a declared carrier. In Model 6A's single-tone complex convention its envelope rotates at positive message frequency. The signed baseband result also depends on LO frequency; folding it into real-audio magnitude can hide the orientation needed for a coherent comparison.

USABLE ACQUISITION WINDOW: One contiguous interval in which the retained samples meet the stated configuration, settling, continuity and detector prerequisites. Tuning and recovery intervals may need exclusion. In a sweep, valid windows at different frequencies occur at different times, limiting conclusions about a changing or intermittent event.

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VALID-INTERVAL MEAN POWER: The average power over only those intervals for which the retained observations and corrections are supported. It can be reported even when an intervening transition remains unobserved. Extending it to the entire elapsed span requires information about the omitted portion or explicit bounds on its contribution.

VARIABLE-GAIN AMPLIFIER: An amplifier whose gain can be changed by a control input or setting. In a receiver its state can interact with RF attenuation, intermediate-frequency gain, digital scaling and detector normalization. Quantitative interpretation requires the applicable gain state or trajectory, especially when an automatic loop responds to intermittent energy.

VARIANCE: The expected squared departure of a random quantity from its expected value, when that moment exists. Its units are the square of the quantity's units. Variance describes spread under a model and does not, by itself, quantify bias, hard limits or a stated coverage probability.

VECTOR AVERAGING: Combining complex spectral coefficients while retaining their phase relationships. A phase-aligned component can persist while varying components partly cancel. The resulting quantity differs from an average of nonnegative powers, and its usefulness depends on the stated alignment, stationarity and meaning of the retained records.

VECTOR NETWORK ANALYZER: An instrument used to characterize complex network response, retaining amplitude and phase information. The chapter uses it for small-signal front-end transfer measurements. Such a measurement does not by itself establish compression, pulse leakage, survivability or recovery under a large incident event.

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VECTOR NOISE CORRECTION: A noise-measurement treatment that retains the relevant impedance and receiver-noise relationships rather than reducing all mismatch effects to one scalar loss. The cited method separates delivered source power from changes in receiver response. Applying such a method requires its additional characterization; citing it does not make that information available for an unmeasured assembly.

VERIFICATION: A check that specified requirements are met using appropriate evidence for the quantity, configuration and time concerned. A field reference can verify present function within its traversed scope without replacing a full calibration. Successful internal checks do not automatically establish external-path transfer, file correctness or uninterrupted validity over an earlier interval.

VIDEO BANDWIDTH: Post-detection or display filtering bandwidth that controls trace smoothing and response time.

WALL-INTERVAL PAYLOAD RATE: The represented payload-instance count divided by a stated elapsed interval that includes all specified active, guard and idle portions. Its numerator and time boundary must match. It differs from active-burst rate and becomes a unique-delivery rate only when the acceptance and duplicate-removal evidence supports that additional interpretation.

WARMUP: The evolution after energization toward a receiver or reference's specified operating condition. Temperature and other internal states can change frequency, gain or phase during this interval. The chapter therefore treats a drift fit made after stabilization as conditional and does not extend it through an unmodeled power-up history.

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WEAK-PROBE CHALLENGE: A strong-signal test that retains a controlled weaker desired reference to measure changes in useful observation capability.

WEIGHTED COMPLEX CORRELATION: In the chapter's gain fit, the sum of each training observation multiplied by the conjugate of its paired ideal reference and its fixed nonnegative weight. Dividing this complex quantity by positive training reference energy gives the fitted coefficient. The conjugation direction matters because it determines the estimated phase.

WEIGHTED REFERENCE ENERGY: The positive sum of declared nonnegative weights times squared reference-symbol magnitudes used in an EVM normalization.

WHITE-ERROR CHANNEL MODEL: A stipulated uncorrelated error model whose channel power is obtained by integrating its density against squared filter response.

WHITE NOISE: Noise with approximately constant power spectral density over the frequency band relevant to the calculation. Under fixed flat gain and the declared effective bandwidth, narrowing that bandwidth reduces integrated noise in direct proportion. A real source need satisfy this approximation only over the stated band, not at every possible frequency.

WIDE-SENSE STATIONARITY: A second-order condition with constant mean and covariance determined by time separation. It supports the chapter's retained linear phase-spectrum treatment when variance is finite. It does not generally make a nonlinear function of the phase stationary, so it cannot silently replace the stronger premise used for the remainder-power bound.

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WINDOW COEFFICIENT VECTOR: The complete sequence of real, dimensionless weights multiplied into the retained samples before transformation. Its values determine coherent gain, density scaling and the weighting of transient energy. A window name alone is insufficient when endpoint conventions, normalization or coefficient generation can differ.

WINDOW MAIN LOBE: The central region of a window's frequency response around a tone's shifted center. Its width affects separation of neighboring components and differs from the transform-bin spacing. Reducing sidelobes generally changes this central response, so the relevant tradeoff follows the quantity and interference conditions being measured.

WINDOW SCALING INVARIANCE: The property that multiplying all window coefficients by one nonzero real constant leaves the chapter's normalized squared spectrum, density and equivalent noise bandwidth unchanged when all associated sums are changed consistently. It does not permit mixing a transform from one vector with normalization sums from another.

WINDOW SIDELOBE: A secondary region of a finite window's frequency response away from its main lobe. A strong component can therefore contribute an indication at other frequencies even without another physical tone. Window choice and controlled reprocessing help test this leakage explanation, with amplitude and noise normalizations kept consistent.

WINDOW-WEIGHTED MEAN SQUARE: The ratio $\frac{\sum_{n=0}^{N-1} w_n^2 \left|x_n\right|^2}{\sum_{n=0}^{N-1} w_n^2}$. It is the integrated density of the stated finite-record normalization and can depend strongly on transient position.

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WORD LENGTH: The total number of binary digits allocated to a stored value or intermediate arithmetic result. It is distinct from the fractional-bit count and from measured converter effective number of bits. Adequate word length must accommodate the proved signed range of every required intermediate, including positive endpoint asymmetry.

WRAPPED-DELAY AMBIGUITY: The family of delays compatible with specified wrapped phase observations until additional phase, frequency or prior-range information selects a branch.

Y-FACTOR: Ratio of measured output powers for two known input noise temperatures.

Y-FACTOR ADMISSIBLE DOMAIN: The set of output-noise ratios compatible with the stated hot-cold model and its input constraints. For $T_h > T_c > 0$ and finite nonnegative T_e, it is $1 < Y \leq \frac{T_h}{T_c}$. An observed ratio outside that interval calls for investigation of the inputs and model rather than silent clipping of the inferred temperature.

ZERO CROSS-POWER CONDITION: A specified ensemble or averaging condition under which the cross terms between admitted contributions vanish and their mean powers may be added.

ZERO-DIFFERENCE BOUNDARY: The conversion condition at which RF and LO frequencies coincide in the selected first-order difference model. The real difference output then includes a DC term, so the nonzero sinusoidal phase and power conventions used for the chapter's tone examples cannot be transferred unchanged. Crossing the boundary also changes the sign of the real-frequency orientation and requires piecewise interpretation.

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ZERO-MEAN MESSAGE: A message whose declared average is zero over the applicable averaging interval or limiting convention. In the conventional-AM power expansion this condition removes the carrier-message cross term. It does not imply zero mean square, absence of modulation, a specified peak value or a particular spectral distribution.

ZERO PADDING: Appending zeros to an acquired, windowed record before calculating its transform. It evaluates the same finite-record transform on a denser frequency grid. It does not narrow the underlying window response, create independent observations or replace the original window sums in amplitude and density normalization.

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References and Works Cited

The bibliography identifies the works cited in the text and notes. Footnotes specify the passages used and distinguish publisher text, official metadata, historical examples, implementation conventions, and independent derivations. Public standards listings establish only their stated metadata and scope. Series navigation follows separately and does not substitute for primary-source support.

Advanced Micro Devices. Fast Fourier Transform LogiCORE IP Product Guide. PG109, version 9.1, July 17, 2026. Finite word length, rounding implementation, and fixed-point overflow sections. https://docs.amd.com/r/en-US/pg109-xfft/Finite-Word-Length-Considerations.

Annotation. This implementation reference addresses fixed-point FFT scaling, finite word length, rounding choices and overflow behaviour inside a particular programmable logic design. The relevant engineering question is whether every butterfly stage has the width, scaling schedule and saturation policy assumed by the chapter’s worked model. Configuration and test vectors must be retained before the documented core behaviour can be attributed to a particular acquisition system. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

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Alexander, M. J., M. J. Salter, D. G. Gentle, D. A. Knight, B. G. Loader, and K. P. Holland. Calibration and Use of Antennas, Focusing on EMC Applications. Measurement Good Practice Guide 73. Teddington: National Physical Laboratory, December 2004. https://www.npl.co.uk/getmedia/24ef3e37-7c5f-40e6-84c9-4ad159e058f9/gpg73_antennas.pdf.

Annotation. Additional glossary scope: section 9.3.1, printed pages 43–44; section 9.6.2, printed pages 48–49; and the Appendix 4 phase-center discussion, printed pages 100–102. These passages support antenna/environment interactions, the frequency-dependent phase reference and limits on extrapolating a near-field observation. Historical EMC limits and numerical antenna examples are not adopted as current requirements. This measurement guide places antenna calibration in the context of the test environment, mounting geometry, cable paths and frequency-dependent response. A receiver comparison should track antenna factors, mismatch and phase-centre conventions at the declared reference plane rather than regard an antenna reading as a direct field value. Any extrapolation from laboratory calibration to a different installation requires documented geometry and uncertainty. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence.

Analog Devices. AD8367: 500 MHz Linear-in-dB VGA with AGC Detector. Data sheet. Rev. A, 2005. https://www.analog.com/media/en/technical-documentation/data-sheets/AD8367.pdf.

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Annotation. The device documentation describes a particular variable-gain and detector implementation, including gain-control behaviour that may affect observed amplitudes. Receiver evidence must distinguish commanded gain, settling behaviour and gain actually applied during a transient or intermittent transmission. The data sheet is not proof that the same response occurs in a different receiver or in an untested overload state. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Analog Devices. ADL8201: DC to 30 GHz, RF Limiter. Data sheet. Rev. 0, January 2026. https://www.analog.com/media/en/technical-documentation/data-sheets/adl8201.pdf.

Annotation. The component or engineering reference concerns protection against excessive RF drive and the nonlinear behaviour inherent in an input limiter. Front-end loss, limiting threshold, recovery time and spectral products should be checked against the actual arrangement before characterising a faint signal. A protection device that prevents damage does not guarantee accurate level measurement or freedom from in-band artefacts. The bibliography records the source identity, whereas claims of present-day instrument performance still

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require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Analog Devices. Measuring Single-Tone Desensitization for CDMA Receivers. May 26, 2006. Reciprocal Mixing subsection. https://www.analog.com/en/resources/technical-articles/2022/07/16/09/37/measuring-singletone-desensitization-for-cdma-receivers.html.

Annotation. The technical treatment concerns the conversion of strong off-channel energy and local-oscillator phase noise into receiver degradation. An apparent rise in the noise floor can reflect oscillator-sideband mixing rather than increased external thermal noise or a new transmitter. Conclusions require blocker level, frequency offset, preselection, instrument state and phase-noise conditions at specified reference planes. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

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Analog Devices. MT-085, "Fundamentals of Direct Digital Synthesis (DDS)." Rev. 0, October 2008, pp. 2–3. Phase-accumulator tuning relation and truncation distinction. https://www.analog.com/media/en/training-seminars/tutorials/MT-085.pdf.

Annotation. The tutorial addresses numerical phase accumulation, frequency tuning and the effects of finite word length in a digital oscillator. The tuning equation, accumulator width, truncation position and reference clock are distinct quantities and must be documented separately. A theoretically possible output frequency or spur location is not proof that a deployed receiver produces it without measurements of clock quality and implementation. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Analog Devices. Specifications and Measurement of Local Oscillator Noise in Integrated Circuit Base Station Mixers. June 18, 2003. Mixer Noise Model and Effective Noise Floor of LO Driver. https://www.analog.com/en/resources/technical-articles/2022/07/16/08/18/specifications-and-measurement-of-local-oscillator-noise-in-integrated-circuit-base-station-mixers.html.

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Annotation. The technical treatment concerns the conversion of strong off-channel energy and local-oscillator phase noise into receiver degradation. An apparent rise in the noise floor can reflect oscillator-sideband mixing rather than increased external thermal noise or a new transmitter. Conclusions require blocker level, frequency offset, preselection, instrument state and phase-noise conditions at specified reference planes. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Analog Devices. “Types of ADCs and DACs.” July 22, 2002. “Aperture Delay” and “Aperture Jitter.” https://www.analog.com/en/resources/technical-articles/types-of-adcs-and-dacs.html.

Annotation. The glossary uses only the aperture-delay and aperture-jitter definition paragraphs. Unrelated dynamic-range, differential-nonlinearity, effective-number-of-bits and Nyquist summaries are outside this use. This source informs the distinction between deterministic sampling-time displacement and random timing uncertainty. The effect of timing uncertainty depends on input frequency, the integration limits for phase noise and correlation between parallel sampling paths. Ideal jitter-limited SNR formulae are bounds under

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specified models, not measured effective number of bits or evidence that parallel ADCs create a wider word. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Analog Devices. “System Noise-Figure Analysis for Modern Radio Receivers.” June 14, 2013. https://www.analog.com/en/resources/technical-articles/system-noisefigure-analysis-for-modern-radio-receivers.html.

Annotation. The cited work treats receiver noise as a gain- and bandwidth-dependent measurement problem, including equivalent input noise or cascaded stages. Input and output reference planes, source temperature, impedance match, receiver gain and effective detector bandwidth must all be stated. Noise-figure figures from a particular test setup do not establish minimum detectable signals or calibrated sensitivity in every field installation. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

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Ansys. “Duty Cycle Distortion.” Electronics Suite 2025 R2, Circuit Help. Accessed November 2, 2026. https://ansyshelp.ansys.com/public/Views/Secured/Electronics/v252/en/Subsystems/Circuit/Content/Circuit/DutyCycleDistortion.htm.

Annotation. The glossary uses the bounded clock-duty definition. The source’s eye-generator parameter scaling and software defaults are not generalized to a receiver. This material addresses the relationship between waveform timing, digital or analogue filtering, and a detector’s observed symbol or pulse shape. A finite filter span, group delay or clock-duty error may alter timing and apparent pulse width even when the underlying emission is unchanged. The analysis should state symbol rate, filter response, sampling position and any applicable equalisation or synchronisation assumptions. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Beavers, Ian. "Missing Half the Signal." Analog Dialogue, RAQ Issue 124. Analog Devices. NCO, FIR, and downsampling architecture; cited in Model 10B. https://www.analog.com/en/resources/analog-dialogue/raqs/raq-issue-124.html.

Annotation. The article documents the constituent operations of digital downconversion: numerically controlled mixing, low-pass filtering and

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decimation. In-phase and quadrature sign conventions, sample-rate changes and filtering latency are necessary to interpret the retained digital signal. Vendor examples illustrate an architecture but do not certify the bit scaling, numerical precision or channel timing of a particular recorder. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Cooper, David, et al. Security Considerations for Code Signing. NIST Cybersecurity White Paper. January 26, 2018. Sections 2, 3.4–3.5, and 5. https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.01262018.pdf.

Annotation. The security guidance is relevant to establishing authenticity, build provenance and integrity of software or firmware used in the measurement chain. A valid signature can support a statement about which artifact was approved under a stated trust policy, but cannot independently demonstrate correct signal processing. Release evidence should connect signer identity, digest, build inputs, installed image and measured instrument configuration. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain

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between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “Configuring Devices and Streamers.” Streaming arguments and formats. Accessed October 31, 2026. https://files.ettus.com/manual/page_configuration.html.

Annotation. This UHD configuration reference identifies the streamer arguments and transfer-format choices that can alter how a USRP host requests and receives sample data. It supports precise recording of software configuration; it does not independently establish continuous RF capture, timing accuracy or an absence of overruns under the laboratory's load.

Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “Firmware and FPGA Images.” Accessed October 31, 2026. https://files.ettus.com/manual/page_images.html.

Annotation. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. A reader should cross-check the cited edition with

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its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “R&D Testing Procedures.” Development-test scope and FPGA functional verification. Accessed October 31, 2026. https://files.ettus.com/manual/page_rdtesting.html.

Annotation. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

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Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “uhd::rx_metadata_t Struct Reference.” Accessed October 31, 2026. https://files.ettus.com/manual/structuhd_1_1rx__metadata__t.html.

Annotation. This interface or metadata specification describes practical mechanisms for configuring, representing or recording software-defined radio streams. Sample index, clock time, overrun indications, selected rates and on-wire representation matter when a forensic examiner reconstructs an acquisition. A software interface declaration alone cannot prove continuity of the resulting samples or correct interpretation by a different reader. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Ettus Research. UHD and USRP Manual. Version 4.11.0.0-0-g0d7ed3b1. “uhd::usrp::multi_usrp.” Receive-rate, frequency, and gain setters. Accessed October 31, 2026. https://files.ettus.com/manual/classuhd_1_1usrp_1_1multi__usrp.html.

Annotation. The multi_usrp API reference describes software controls for receive rate, tuning and gain. For a forensic acquisition record, log both the requested settings and device-reported or

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otherwise verified applied states; the existence of a setter in an API is not evidence that a particular physical front end achieved its specified performance.

Friis, H. T. “Noise Figures of Radio Receivers.” Proceedings of the IRE 32, no. 7 (July 1944): 419–22. Publisher’s abstract consulted for historical framing. https://doi.org/10.1109/JRPROC.1944.232049.

Annotation. Friis's historical paper is central to the treatment of cascaded receiver noise figure. The historical citation should be used for the gain-weighted noise contribution principle rather than to infer contemporary component specifications; the exact reference planes, gains and matching assumptions must accompany an applied calculation.

Gentile, Ken. AN-922: Digital Pulse-Shaping Filter Basics. Analog Devices. Accessed November 2, 2026. https://www.analog.com/en/resources/app-notes/an-922.html.

Annotation. The glossary uses the raised-cosine transition, ideal decision-time zeros, square-root response composition, finite span and multibit-symbol relationships. No hardware performance or plotted numerical result is adopted. The source’s special-time square-root impulse-response statement is not adopted. This material addresses the relationship between waveform timing, digital or analogue filtering, and a detector’s observed symbol or pulse shape. A finite filter span, group delay or clock-duty error may alter timing and apparent pulse width even

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when the underlying emission is unchanged. The analysis should state symbol rate, filter response, sampling position and any applicable equalisation or synchronisation assumptions. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records.

Harris, Fredric J. “On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform.” Proceedings of the IEEE 66, no. 1 (1978): 51–83. Especially page 51, abstract and introduction, and pages 54 and 56, sections III.A–B, equations 8–14. Original paper reproduction: https://amst.ece.iastate.edu/paper/comparative_study/window_1.pdf.

Annotation. Harris's window-analysis paper supplies a foundational framework for interpreting finite-record DFT leakage and the choice of window functions. Any application to measured RF power must state the selected window, sampling convention, amplitude calibration and whether the quantity being corrected is coherent-tone amplitude or noise power.

Hati, Archita, Craig Nelson, Neil Ashby, and David Howe. Calibration Uncertainty for the NIST PM/AM Noise Standards. NIST Special Publication 250-90. July 2012. Sections 2.1–2.2.2, pages 2–4. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=909758.

Annotation. The reference supplies a technical framework for interpreting oscillator stability or correlated phase-noise measurements. Observation interval, averaging statistic, timebase origin and common-

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clock correlation should be specified before translating a frequency statistic into arrival-time or phase evidence. A nominally stable source can still have an offset or transient recovery event, and averaging may suppress or distort correlated components. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Heinzel, Gerhard, Albrecht Rüdiger, and Roland Schilling. Spectrum and Spectral Density Estimation by the Discrete Fourier Transform (DFT), Including a Comprehensive List of Window Functions and Some New Flat-Top Windows. February 15, 2002. Sections 8–9, pages 12–16. Original report reproduction: https://holometer.fnal.gov/GH_FFT.pdf.

Annotation. Heinzel, Rüdiger and Schilling document finite-record DFT spectral-density estimates and window-function characteristics, including flat-top windows. The reference is pertinent to selecting amplitude and power estimators; exact coherent gain, equivalent noise bandwidth and one-sided factors must be derived for the specified window and normalisation.

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IEEE Standards Association. IEEE 1057-2017, IEEE Standard for Digitizing Waveform Recorders. Published January 26, 2018. Official status and scope checked November 1, 2026. https://standards.ieee.org/ieee/1057/5945/.

Annotation. This standard record concerns terminology and testing of instruments that digitise and retain waveforms. Its public scope is useful for identifying the type of device and associated measured quantities, while acquisition errors require separate evidence from actual recordings. The reference listing itself does not establish clause-by-clause compliance, especially where the complete standard text has not been examined. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

IEEE Standards Association. IEEE 1241-2023, IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters. Published October 6, 2023. Official status and scope checked November 1, 2026. https://standards.ieee.org/ieee/1241/6797/.

Annotation. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective

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resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

International Electrotechnical Commission. CISPR 16-1-1:2019, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, Part 1-1: Radio Disturbance and Immunity Measuring Apparatus: Measuring Apparatus. 5th ed. May 22, 2019. Official publication scope checked November 1, 2026. https://webstore.iec.ch/en/publication/60774.

Annotation. The reference concerns apparatus and practices for electromagnetic interference measurements, with detector modes and equipment characteristics set by its identified scope. Quasi-peak, peak and average detection cannot be freely substituted when interpreting short or intermittent disturbances. A scope statement or product manual must not be mistaken for proof of compliance with every clause or correct operation under field conditions. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access

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was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Joint Committee for Guides in Metrology. Evaluation of Measurement Data: Guide to the Expression of Uncertainty in Measurement. JCGM 100:2008. Corrected version 2010. https://www.bipm.org/en/doi/10.59161/jcgm100-2008e.

Annotation. This metrological guidance concerns the evaluation and reporting of measurement uncertainty, including propagation through a measurement model. Covariance, shared calibration terms, nonlinear transformations and declared coverage factors require attention when evidence from multiple receiver channels is combined. An uncertainty budget is meaningful only for a specified measurand and operating condition; it does not itself certify the authenticity of the underlying acquisition. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

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Joint Committee for Guides in Metrology. International Vocabulary of Metrology: Basic and General Concepts and Associated Terms (VIM). JCGM 200:2012. 3rd ed., 2008 version with minor corrections, 2012. https://www.bipm.org/documents/20126/2071204/JCGM_200_2012.pdf.

Annotation. This institutional vocabulary establishes conventional relationships among measurands, measurement results, calibration, uncertainty and traceability. Its role is terminological rather than an instrument-specific proof: the survey must still state the actual measurement model, reference plane and uncertainty evidence. A correct definition cannot compensate for an uncalibrated observation or justify conflating detection, classification and transmitter attribution. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

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Additional glossary scope in the VIM3 online edition: clauses 2.16 (measurement error), 2.17 (systematic measurement error), 2.19 (random measurement error), 2.26 (measurement uncertainty), 2.36 (coverage interval), 2.40 (calibration hierarchy) and 2.52 (influence quantity). Each complete clause and its notes was consulted. The online locators are https://jcgm.bipm.org/vim/en/2.16.html; https://jcgm.bipm.org/vim/en/2.17.html; https://jcgm.bipm.org/vim/en/2.19.html; https://jcgm.bipm.org/vim/en/2.26.html; https://jcgm.bipm.org/vim/en/2.36.html; https://jcgm.bipm.org/vim/en/2.40.html; and https://jcgm.bipm.org/vim/en/2.52.html. The definitions preserve the stated distinction between VIM and GUM influence-quantity conventions.

Annotation. This institutional vocabulary establishes conventional relationships among measurands, measurement results, calibration, uncertainty and traceability. Its role is terminological rather than an instrument-specific proof: the survey must still state the actual measurement model, reference plane and uncertainty evidence. A correct definition cannot compensate for an uncalibrated observation or justify conflating detection, classification and transmitter attribution. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record

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whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Kast, Joshua M., Paritosh Manurkar, Kate A. Remley, Dylan F. Williams, and Robert D. Horansky. “System-Level Calibration of a Millimeter-Wave Vector Signal Analyzer with Uncertainties.” IEEE Transactions on Microwave Theory and Techniques 73, no. 11 (November 2025): 9085–95. https://doi.org/10.1109/TMTT.2025.3597240. NIST-hosted manuscript, pages 1–9, especially sections II–III: https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=959731.

Annotation. Additional glossary scope: the multisine passages in the introduction and section II, manuscript pages 2 and 4–5, and section II.E, manuscript page 7, on uncertainty propagation through the calibration. No new performance numbers or inference that calibration validates a nonlinear operating state is adopted. The research concerns complex-vector calibration or noise-temperature measurement where amplitude, phase and uncertainty propagate through the measurement chain. Reference-plane consistency, added cable paths and calibration-state changes are material to a repeatable comparison. Published experimental results cannot automatically be transferred to a different apparatus or treated as certification of the book’s constructed numerical examples. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript.

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Kester, Walt. MT-001, Taking the Mystery out of the Infamous Formula, “SNR = 6.02N + 1.76dB,” and Why You Should Care. Rev. A. Analog Devices, October 2008. Pages 1–7. https://www.analog.com/media/en/training-seminars/tutorials/MT-001.pdf.

Annotation. Kester's MT-001 tutorial explains the ideal quantisation-limited SNR relationship often written as 6.02N + 1.76 dB. It is an idealised converter relationship under stated input and quantisation assumptions, not a guarantee that an installed ADC will attain its nominal resolution in the presence of jitter, nonlinearity or broadband blockers.

Kester, Walt. MT-002, What the Nyquist Criterion Means to Your Sampled Data System Design. Rev. A. Analog Devices, October 2008. Pages 4–7 and 9–11. https://www.analog.com/media/en/training-seminars/tutorials/MT-002.pdf.

Annotation. Kester's Nyquist tutorial addresses sampling-band relationships and their practical implications for converter-based systems. Its application requires a clearly defined analogue input passband, anti-alias response and sampling rate. A quoted Nyquist rate by itself does not prove that out-of-band blockers or aperture errors have been controlled.

Kester, Walt. MT-008, Converting Oscillator Phase Noise to Time Jitter. Rev. A. Analog Devices, October 2008. https://www.analog.com/media/en/training-seminars/tutorials/MT-008.pdf.

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Annotation. This source informs the distinction between deterministic sampling-time displacement and random timing uncertainty. The effect of timing uncertainty depends on input frequency, the integration limits for phase noise and correlation between parallel sampling paths. Ideal jitter-limited SNR formulae are bounds under specified models, not measured effective number of bits or evidence that parallel ADCs create a wider word. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Kester, Walt. MT-012, Intermodulation Distortion Considerations for ADCs. Rev. A. Analog Devices, October 2008. Pages 1–4. https://www.analog.com/media/en/training-seminars/tutorials/mt-012.pdf.

Annotation. This material provides vocabulary or test principles for sampling converters, including quantisation, nonlinearity, dynamic behaviour or timing limitations. Nominal word length, effective resolution, spurious response and input bandwidth are different performance descriptors with different measurement requirements. Claims about a full receiver must not be inferred from a single ADC specification without examining the analogue front end and acquisition chain. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the

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manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Kester, Walt. MT-080, Mixers and Modulators. Rev. 0. Analog Devices, October 2008. https://www.analog.com/media/en/training-seminars/tutorials/mt-080.pdf.

Annotation. Kester's mixers and modulators tutorial concerns practical frequency translation and the generation of sum, difference and unwanted mixing products. It supports explanation of idealised and practical mixer behaviour, but a specific installed spur level or image-rejection value requires a measurement under declared drive and termination conditions.

Keysight Technologies. “About Filters (Digital Demod).” 89600 VSA Help, 2026 Update 2.0. Accessed November 2, 2026. https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/digdemod/content/digdemod_about_filters.htm.

Annotation. The glossary uses the distinct measurement and reference filter roles, matched root-raised-cosine composition, roll-off and finite symbol span. No instrument default, edition-independent setting or product-performance claim is added. This measurement reference

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concerns digitally modulated signals and settings that affect an error-vector or constellation result. Error-vector normalisation, pulse-shaping filters, symbol timing and reference-signal construction must be known before results from two receivers can be compared. A proprietary default or measurement-guide illustration should not be treated as a universal numerical definition. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

Keysight Technologies. About Resolution Bandwidth. 89600 VSA Help. Opening definition and comparison of swept analyzers with the 89600 VSA. 2026 Update 2.0. Accessed November 1, 2026. https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/gui/content/rbw_about_rbw.htm.

Annotation. The 89600 VSA help entry describes resolution-bandwidth conventions in the identified software analysis context. Distinguish displayed RBW from equivalent noise bandwidth and from the observation time set by the underlying data record; do not transfer the instrument's software defaults to a swept-filter receiver without qualification.

Keysight Technologies. Digital Modulation in Communications Systems: An Introduction. Application note 5965-7160E. July 5, 2024. Pages 13–14, 38–39,

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and 41–43. https://www.keysight.com/us/en/assets/7018-09093/application-notes/5965-7160.pdf.

Annotation. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver's actual topology. Ideal mixer identities do not establish that a real component is free of compression, leakage, spurs or path-dependent calibration errors. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Keysight Technologies. Keysight X-Series Signal Analyzers: N9069C Noise Figure Measurement Guide. Part N9069-90001. Edition 1, March 2016. https://www.keysight.com/us/en/assets/9018-04256/user-manuals/9018-04256.pdf.

Annotation. The N9069C measurement guide documents operational procedures for noise-figure measurements on the specified analyser family. It can support procedural descriptions and setting conventions, but the validity of a reported device noise figure

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additionally depends on calibration, source matching, temperature conditions and uncertainty evaluation.

Keysight Technologies. N9000B CXA Signal Analyzer Specification Guide. N9000-90035. Edition 6, May 2024. Page 56, note d. https://www.keysight.com.cn/cn/zh/assets/9018-04781/technical-specifications/9018-04781.pdf.

Annotation. This CXA specification guide is a source for model-specific, revision-specific instrument performance limits, including the qualifications associated with page 56, note d. Treat the published figures as conditional specifications; measurements or extrapolations beyond the stated configuration require separate evidence.

Keysight Technologies. Optimizing RF and Microwave Spectrum Analyzer Dynamic Range. Application note 5968-4545E. December 1, 2017. Pages 2 and 4–8. https://www.keysight.com/zz/en/assets/7018-06813/application-notes/5968-4545.pdf.

Annotation. The dynamic-range application note explains the trade-offs among analyser noise, distortion and operating level. These considerations guide gain and attenuation selection, but an asserted usable dynamic range is meaningful only at a stated reference plane, bandwidth, signal environment and allowable error criterion.

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Keysight Technologies. Spectrum and Signal Analyzer Measurements and Noise. Application note 5966-4008E. August 21, 2024. Pages 7–10. https://www.keysight.com/us/en/assets/7018-06765/application-notes/5966-4008.pdf.

Annotation. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

Keysight Technologies. Swept IMD and IM Spectrum Concepts. E5080B VNA Help. Tone Power Parameters, Intermodulation Distortion Parameters, and Intercept Point Parameters. Accessed November 1, 2026. https://helpfiles.keysight.com/csg/e5080b/Applications/Swept_IMD_and_IM_Spectrum_Concepts.htm.

Annotation. This vector-network-analyser documentation defines swept intermodulation and intercept-point parameter conventions. It is appropriate for explaining the meanings of the displayed metrics and tone powers, but any generalisation to another receiver

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requires compatible terminations, excitation levels and an independently verified linear operating region.

Keysight Technologies. Third Order Intermodulation Distortion Performance Test. N7875A help. Source isolation and source-harmonic filtering. Accessed November 1, 2026. https://helpfiles.keysight.com/calsoft/N7875A/Help/Content/Performance/TOI_PV.htm.

Annotation. This intermodulation test procedure concerns the isolation of sources and suppression of their harmonics during third-order distortion measurements. The procedure is relevant to separating distortion generated in the device under test from contamination introduced by test generators and combining networks; its numerical conclusions must be tied to the stated setup.

Keysight Technologies. “EVM (Custom IQ).” 89600 VSA Help. 2026 Update 2.0. Accessed November 1, 2026. https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/customIq/content/customiq_symtblerrdata_evm.htm.

Annotation. This measurement reference concerns digitally modulated signals and settings that affect an error-vector or constellation result. Error-vector normalisation, pulse-shaping filters, symbol timing and reference-signal construction must be known before results from two receivers can be compared. A proprietary default or measurement-guide

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illustration should not be treated as a universal numerical definition. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Keysight Technologies. “EVM Normalization Reference (Digital Demod).” 89600 VSA Help. 2026 Update 2.0. Accessed November 1, 2026. https://helpfiles.keysight.com/csg/89600B/Webhelp/Subsystems/digdemod/content/dlg_digdemod_comp_evmnormref.htm.

Annotation. This measurement reference concerns digitally modulated signals and settings that affect an error-vector or constellation result. Error-vector normalisation, pulse-shaping filters, symbol timing and reference-signal construction must be known before results from two receivers can be compared. A proprietary default or measurement-guide illustration should not be treated as a universal numerical definition. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be

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repeated with the new values rather than assumed to transfer automatically.

Keysight Technologies. “Spectrum Analyzer.” E505xA Help. “SA Setup Dialog,” detector and video-averaging entries. Accessed October 30, 2026. https://helpfiles.keysight.com/csg/e5055a/Applications/Spectrum_Analyzer.htm.

Annotation. The publication explains analyser operation and measurement settings governing spectral detection, resolution and transient capture. Resolution bandwidth, video filtering, detector mode and acquisition duty cycle can alter a displayed spectrum without changing the external transmitter. A manufacturer’s application note supports stated instrument behaviour but does not certify that a particular survey captured every possible short-duration event. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

MACOM. “Designing with Diodes: Protecting Sensitive Components.” September 2, 2022.

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https://www.macom.com/updates/articles/2022/designing-with-diodes-protecting.

Annotation. The component or engineering reference concerns protection against excessive RF drive and the nonlinear behaviour inherent in an input limiter. Front-end loss, limiting threshold, recovery time and spectral products should be checked against the actual arrangement before characterising a faint signal. A protection device that prevents damage does not guarantee accurate level measurement or freedom from in-band artefacts. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

MathWorks. “Channelizer.” DSP HDL Toolbox, R2026b documentation. Description and Preserve channel phase parameter. Accessed October 31, 2026. https://www.mathworks.com/help/dsphdl/ref/channelizer.html.

Annotation. This HDL channelizer reference concerns hardware implementation and the preservation of channel phase in the stated processing architecture. The cited interface and parameter description should be used to explain implementation choices, not

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to assume that an unspecified receiver preserves absolute phase, sample continuity or clock synchronisation.

MathWorks. “dsp.Channelizer.” R2026b documentation. Algorithms: polyphase implementation, maximally decimated channelizer, and non-maximally decimated or oversampled channelizer. Accessed October 31, 2026. https://www.mathworks.com/help/dsp/ref/dsp.channelizer-system-object.html.

Annotation. The dsp.Channelizer documentation distinguishes a polyphase channelizer from its oversampled and maximally decimated configurations. For receiver analysis, record the number of channels, decimation and overlap or oversampling convention before inferring channel bandwidth, sample timing or the continuity of reconstructed outputs.

MathWorks. “Fixed-Point Precision Rules for Avoiding Overflow in FIR Filters.” DSP System Toolbox. R2026b. Signed output intervals and full-precision accumulator settings. Accessed October 31, 2026. https://www.mathworks.com/help/dsp/ug/fixed-point-precision-rules-for-avoiding-overflow-in-fir-filters.html.

Annotation. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence

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must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

MathWorks. “Perform Fixed-Point Arithmetic.” Fixed-Point Designer. R2026b. Multiplication, assignment, and explicit conversion rules. Accessed October 31, 2026. https://www.mathworks.com/help/fixedpoint/ug/perform-fixed-point-arithmetic.html.

Annotation. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment

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changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

MIT OpenCourseWare. 6.341 Discrete-Time Signal Processing. Lecture 10, "Multirate Systems and Polyphase Structures," pp. 2–5; Lecture 2, "Background Review: Phase, Group Delay, and Generalized Linear Phase," pp. 4–5. OpenCourseWare 2006 notes for the Fall 2005 course. https://ocw.mit.edu/courses/6-341-discrete-time-signal-processing-fall-2005/d97506e5761422fd7bd49a2742247303_lec10.pdf; https://ocw.mit.edu/courses/6-341-discrete-time-signal-processing-fall-2005/c1e8402bc2d0d548fbdc34e3db8dbf0d_lec02.pdf.

Annotation. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

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MIT OpenCourseWare. “Lecture 22: Modulated Filter Bank.” 6.341 Discrete-Time Signal Processing. OpenCourseWare 2006 notes for the Fall 2005 course, pp. 1–6. Modulated-bank and polyphase/DFT development; the causal convention in Model 10C is derived explicitly. https://ocw.mit.edu/courses/6-341-discrete-time-signal-processing-fall-2005/9bae63b4a7d9ac6bf534875e13c06ffd_lec22.pdf.

Annotation. This lecture or implementation document addresses multirate digital filtering, polyphase decomposition, channelisation and numerical representation. Phase conventions, finite impulse response length, startup state and decimation timing determine whether two computational forms are physically equivalent. Theory-level equivalence must be distinguished from software or FPGA execution whose internal rounding, truncation and control signals differ. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

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National Institute of Standards and Technology. “Disciplined Oscillator (DO).” Computer Security Resource Center glossary, with NIST IR 8323 Rev. 1 source provenance. Accessed November 2, 2026. https://csrc.nist.gov/glossary/term/disciplined_oscillator_do.

Annotation. Used for reference steering only. The definition does not establish any specific receiver’s frequency, phase-noise, holdover or relock performance. The reference supplies a technical framework for interpreting oscillator stability or correlated phase-noise measurements. Observation interval, averaging statistic, timebase origin and common-clock correlation should be specified before translating a frequency statistic into arrival-time or phase evidence. A nominally stable source can still have an offset or transient recovery event, and averaging may suppress or distort correlated components. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

National Institute of Standards and Technology. “Frequency Stability.” Computer Security Resource Center glossary. Accessed November 2, 2026. https://csrc.nist.gov/glossary/term/frequency_stability.

Annotation. Used for interval dependence and the distinction between frequency stability and closeness to a frequency reference. A stable oscillator can retain an offset. The reference supplies a technical framework for interpreting oscillator stability or correlated phase-noise

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measurements. Observation interval, averaging statistic, timebase origin and common-clock correlation should be specified before translating a frequency statistic into arrival-time or phase evidence. A nominally stable source can still have an offset or transient recovery event, and averaging may suppress or distort correlated components. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion.

National Institute of Standards and Technology. NIST Digital Library of Mathematical Functions. Equations 5.9.16, 5.9.18, and 5.9.19. Accessed October 30, 2026. https://dlmf.nist.gov/5.9.

Annotation. The NIST Digital Library of Mathematical Functions provides authoritative identities at the particular cited equation numbers in Section 5.9. This entry should support only the mathematical transformations actually dependent on those identities. It is not, by itself, a calibration or validation source for the physical receiver models appearing elsewhere in the volume.

National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 2.1.2, "What Is a Check Standard?" Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/mpc/section1/mpc12.htm

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Annotation. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically guarantees representative physical operating conditions. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.2.1.2, "One Variable at a Time." Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/pri/section2/pri212.htm

Annotation. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically

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guarantees representative physical operating conditions. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.3.3.3.2, "Full Factorial Example." Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/pri/section3/pri3332.htm

Annotation. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically guarantees representative physical operating conditions. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or

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measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

National Institute of Standards and Technology. NIST/SEMATECH e-Handbook of Statistical Methods. Section 5.7, "A Glossary of DOE Terminology," entries for blocking, confounding, crossed factors, interactions, and replication. Accessed November 1, 2026. https://www.itl.nist.gov/div898/handbook/pri/section7/pri7.htm

Annotation. This methodological source addresses repeatable measurement comparisons, factor selection, interaction, replication or check-standard control. The relevant forensic application is to distinguish causal changes in a receiver from effects attributable to altered gain, antenna, clock or thermal conditions. Randomisation and documented calibration are important, but no statistical design automatically guarantees representative physical operating conditions. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

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Nelson, Craig W., Archita Hati, and David A. Howe. “Phase Inversion and Collapse of the Cross-Spectral Function.” arXiv:1307.6605v1. July 24, 2013. Extended manuscript, pages 1–3. https://arxiv.org/pdf/1307.6605v1.

Annotation. Nelson, Hati and Howe examine phase inversion and collapse phenomena in cross-spectral processing. This reference is germane to the possibility that averaging complex cross-spectral quantities can conceal contributions; any inference about a real emitter requires calibration of both channels and explicit treatment of sign and phase conventions.

Niknejad, Ali M. Effect of Feedback on Distortion. EECS 142. University of California, Berkeley. Version dated March 30, 2025. Slides 9 and 27. https://rfic.eecs.berkeley.edu/courses/ee142/pdf/module16_distofb.pdf.

Annotation. This bibliographic entry identifies a technical work concerned with the subject indicated by its stated title and described scope. For this volume, its relevance must be expressed through the exact equation, definition, test procedure or historical proposition to which the manuscript attaches the reference. A bibliographic listing is not a substitute for checking the relevant passage, its edition, its limiting conditions and the original measurement context. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

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Perrott, Michael H. Lecture 8, Noise Figure, Impact of Amplifier Nonlinearities. 6.976 High Speed Communication Circuits and Systems. MIT OpenCourseWare, 2003. Slides 22–35. https://ocw.mit.edu/courses/6-976-high-speed-communication-circuits-and-systems-spring-2003/a3bae9358da0286076b42f98b9dafc20_lec8.pdf.

Annotation. Perrott's lecture material relates receiver noise figure to amplifier nonlinearity and RF-chain design. It can inform the conceptual comparison of noise and large-signal performance, but the presentation is instructional rather than a substitute for testing an installed receiver's noise temperature and intercept behaviour.

Randa, James P. Uncertainties in NIST Noise-Temperature Measurements. NIST Technical Note 1502. March 1998. https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote1502.pdf.

Annotation. Randa's NIST technical note addresses uncertainty associated with noise-temperature measurements. Its contribution is methodological: reported uncertainty must reflect the applicable measurement model and identified systematic and random terms. Do not transfer numerical uncertainties to an unrelated RF installation without reconstructing the relevant uncertainty budget.

Range Commanders Council. Telemetry Standards. IRIG Standard 106-05. Appendix A, “Frequency Considerations for Telemetry.” 2005. https://irig106.org/docs/106-05/appendixA.pdf.

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Annotation. The source describes relationships among modulation parameters, occupied spectrum and instrument observations. Approximate bandwidth rules depend on the signal model and the chosen significance or emission-mask criterion, rather than constituting exact occupied-band measurements. The chapter should distinguish an engineering estimate from calibrated detection and should state the assumed modulation and detector conventions. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Riley, W. J. Handbook of Frequency Stability Analysis. NIST Special Publication 1065. July 2008. https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication1065.pdf.

Annotation. Additional glossary scope: section 5.19, printed page 57, distinguishes internal aging from broader frequency drift. No illustrative fit coefficients or equipment results are adopted. The reference supplies a technical framework for interpreting oscillator stability or correlated phase-noise measurements. Observation interval, averaging statistic, timebase origin and common-clock correlation should be specified before translating a frequency statistic into arrival-time or phase evidence. A nominally stable source can still have an offset or transient

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recovery event, and averaging may suppress or distort correlated components. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported.

Rohde & Schwarz. R&S ESW EMI Test Receiver User Manual. 1177.6298.02. Version 18, 2025. https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_manuals/user_manual/1177_6298_01/ESW_UserManual_en_18.pdf.

Annotation. Additional glossary scope: printed pages 225–226 on quasi-peak temporal weighting and its distinction from RMS and sample detection. Model-specific timing and bandwidth defaults are not generalized, and this source use does not assert compliance by an unspecified receiver. The reference concerns apparatus and practices for electromagnetic interference measurements, with detector modes and equipment characteristics set by its identified scope. Quasi-peak, peak and average detection cannot be freely substituted when interpreting short or intermittent disturbances. A scope statement or product manual must not be mistaken for proof of compliance with every clause or correct operation under field conditions. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records.

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Rust, Bert, and Denis Donnelly. “The Fast Fourier Transform for Experimentalists Part III: Classical Spectral Analysis.” Computing in Science & Engineering 7, no. 5 (September/October 2005): 74–78. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=150010.

Annotation. Rust and Donnelly discuss classical spectral analysis as implemented with finite FFT records. The citation is useful for explaining estimator calculations and numerical interpretation, but equipment-specific traceability, input-referred power and spectral uncertainty still require the measurement chain's own calibration data.

SciPy Community. SciPy v1.18.0 Manual. “scipy.signal.lfilter.” Initial and final delay state and difference-equation notes. Accessed October 31, 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.lfilter.html

Annotation. The software reference provides an executable convention for signal processing calculations and the meaning of their input parameters. Filter initial conditions, complex conjugation, one-sided scaling and array length can change numerical results even when two calls appear mathematically similar. Documenting the exact version and configuration is necessary before treating a library result as reproducible evidence or equivalent to a physical receiver. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the

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equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

SciPy Community. “scipy.signal.coherence” and “scipy.signal.csd.” SciPy v1.18.0 reference documentation, definition, csd Notes, and average parameter. Accessed October 31, 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.coherence.html; https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.csd.html.

Annotation. The SciPy coherence and CSD references define their software estimators and the complex cross-spectrum convention. Coherence is a normalised, model-dependent statistical association between two records; it does not prove a common physical emitter. Claims based on numerical output should identify segmentation, overlap, averaging and the handling of complex conjugation.

SciPy Community. “scipy.signal.periodogram.” Official reference documentation, parameters and Notes. Accessed October 30, 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.periodogram.html.

Annotation. The publication concerns finite-record spectral estimators, window selection or the statistical relation between channels. Coherent gain, sum-of-squares normalisation, equivalent noise bandwidth, one-sided folding and averaging rule must match the reported spectrum

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quantity. A narrow display peak or elevated coherence is not by itself source attribution and should be interpreted alongside calibration and observation conditions. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

SciPy Community. “scipy.signal.windows.hann.” Official reference documentation, sym parameter and Notes. Accessed October 30, 2026. https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.windows.hann.html.

Annotation. The SciPy Hann-window reference distinguishes the symmetric and periodic definitions through its sym parameter. That distinction matters for the finite sum, coherent gain and equivalent noise bandwidth computed from a specified record length; the intended use must be documented rather than inferred from the common name 'Hann'.

SigMF Project. Signal Metadata Format Specification. Version 1.2.6. “Captures Array,” sample_start, datetime, and global_index. Accessed October 31, 2026. https://sigmf.org/.

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Annotation. The SigMF specification defines metadata constructs for locating capture segments and describing sample start positions, timestamps and indexing. These conventions assist interpretation and exchange of IQ recordings, but their correctness depends on the recorder populating them from trustworthy acquisition evidence rather than inferred file continuity.

SLSA. “Build: Verifying artifacts.” Specification version 1.2. “How to verify” and “Check expectations.” Accessed October 31, 2026. https://slsa.dev/spec/v1.2/verifying-artifacts.

Annotation. The security guidance is relevant to establishing authenticity, build provenance and integrity of software or firmware used in the measurement chain. A valid signature can support a statement about which artifact was approved under a stated trust policy, but cannot independently demonstrate correct signal processing. Release evidence should connect signer identity, digest, build inputs, installed image and measured instrument configuration. A reader should cross-check the cited edition with its chapter-level application and verify that the quoted scope is not broader than the accessible evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

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Souppaya, Murugiah, Karen Scarfone, and Donna Dodson. Secure Software Development Framework (SSDF) Version 1.1: Recommendations for Mitigating the Risk of Software Vulnerabilities. NIST SP 800-218. February 2022. Tasks PS.2.1 and PS.3.1–PS.3.2. https://doi.org/10.6028/NIST.SP.800-218.

Annotation. The security guidance is relevant to establishing authenticity, build provenance and integrity of software or firmware used in the measurement chain. A valid signature can support a statement about which artifact was approved under a stated trust policy, but cannot independently demonstrate correct signal processing. Release evidence should connect signer identity, digest, build inputs, installed image and measured instrument configuration. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Taylor, Barry N., and Chris E. Kuyatt. Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results. NIST Technical Note 1297. 1994 ed. https://www.nist.gov/pml/nist-technical-note-1297.

Annotation. This metrological guidance concerns the evaluation and reporting of measurement uncertainty, including propagation through a

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measurement model. Covariance, shared calibration terms, nonlinear transformations and declared coverage factors require attention when evidence from multiple receiver channels is combined. An uncertainty budget is meaningful only for a specified measurand and operating condition; it does not itself certify the authenticity of the underlying acquisition. The bibliography records the source identity, whereas claims of present-day instrument performance still require matching configuration and calibration evidence. Forensic use also requires retained acquisition metadata and a documented chain between the observed quantity and the conclusion ultimately reported. The evidence register should record whether the full text, a specified excerpt or merely a bibliographic record was actually examined.

Tektronix. Fundamentals of Real-Time Spectrum Analysis. 37W-17249-4. August 2009. https://download.tek.com/document/37W_17249_4.pdf.

Annotation. Additional glossary scope: printed pages 32–34 on trigger mode, slope, source, external input, full-rate versus decimated trigger location, time qualification and frequency-mask comparison. The existing printed pages 17–18 transient-capture scope remains separately applicable. Historical options, numerical timing specifications and performance guarantees are not adopted as universal receiver capabilities. The publication explains analyser operation and measurement settings governing spectral detection, resolution and transient capture. Resolution bandwidth, video filtering, detector mode and acquisition duty cycle can alter a displayed spectrum without changing the external transmitter. A manufacturer’s application note

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supports stated instrument behaviour but does not certify that a particular survey captured every possible short-duration event. For the consolidated bibliography, the work supplies a traceable route to a particular technical method or definition used elsewhere in the manuscript.

United States Navy. Navy Electricity and Electronics Training Series, Module 12: Modulation. NAVEDTRA 14184. September 1998. Title and cited excerpts reproduced in SIGINTRADARTSCM.pdf, pages 7254, 7308–7310, and 7349–7354.

Annotation. This Navy training module supplies instructional terminology for modulation and sideband formation. It is a pedagogical foundation for interpreting receiver signals, not an independent validation of a contemporary electronic-surveillance measurement or a claim that a particular device behaves ideally.

United States Navy. Navy Electricity and Electronics Training Series, Module 17: Radio-Frequency Communications Principles. NAVEDTRA 14189. September 1998. Title and receiver-architecture passages reproduced in SIGINTRADARTSCM.pdf, compilation pages 8345 and 8388–8392.

Annotation. This instructional source treats modulation, frequency translation or receiver signal-chain operation through explicit physical relationships. Image frequencies, sidebands, local-oscillator injection and intermediate-frequency filtering have to be checked against the receiver’s actual topology. Ideal mixer identities do not establish that a

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real component is free of compression, leakage, spurs or path-dependent calibration errors. This volume-level entry serves as a source locator; specific instrument results and measurements must be supported separately by their own test records. Where access was limited to a public abstract, scope statement or manual excerpt, that limitation must be carried into any resulting scientific assertion. If the equipment revision, software settings or measurement environment changes, the reasoning should be repeated with the new values rather than assumed to transfer automatically.

Weatherspoon, Mark H., Lawrence P. Dunleavy, Ali Boudiaf, and James P. Randa. “Vector Corrected Noise Temperature Measurements.” 2002 IEEE MTT-S International Microwave Symposium Digest (2002): 2253–56. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=954.

Annotation. Weatherspoon and co-authors present vector-corrected noise-temperature measurement methods, calling attention to complex transfer and mismatch relationships. Use the citation to motivate a vector correction model where applicable, not to claim that a scalar noise reading was automatically corrected for every source or receiver mismatch.

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Series Navigation

The following companion-volume titles retain the series reading route. They are navigation references, not evidence that those manuscripts or their current editions were examined for the claims in this volume.

- S001-V009, Antenna Theory for TSCM and Technical Security.
- S001-V010, Survey Antennas, Probes, Fixtures, and Direction-Finding Apparatus.
- S001-V016, EMI, EMC, Shielding, Grounding, Bonding, and Power Integrity.
- S001-V020, Field Operations, Evidence Handling, Chain of Custody, and Litigation Support.
- S001-V024, Series Conventions, Standards, Units, and Citation Practice.
- S001-V038, Spectrum Governance, Frequency Allocation, Intercept Geometry, and RF Survey Doctrine.
- S001-V060, Electromagnetic Scattering, Boundary-Value Fields, Antenna-Medium Coupling, and FFT-Governed RF Inference.
- S001-V074, Monitoring-Receiver Deployment and Survey-Data Governance.
- S001-V087, Conductors, Cabling, Connectors, and Wiring Practice.
- S001-V093, Wave Propagation, Transmission Lines, and Antennas.
- S001-V094, Microwave Principles and Distributed Systems.
- S001-V099, Test, Measurement, and Diagnostic Equipment.
- S001-V100, Radio-Frequency Communications Principles.
- S001-V101, Radar Principles and Measurement.

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- S001-V104, Test Methods and Measurement Practice.
- S001-V110, SIGINT Collection Architecture, Radar Illumination, and Spectrum Exploitation for Defensive Technical Security.

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Volume Subject Index

Each locator gives the opening page of the linked chapter, model, or section.

Absolute sample index: Chapter 10, Model 10E [page 5744]

Absolute-frequency cusp: Chapter 4 [page 1922]

Absolutely continuous phase: Chapter 6, Model 6B [page 3131]

Acceptance Case: Chapter 10, Framework 10F [page 5766]

Acceptance, Maintenance, and Lifecycle Control: Chapter 16 [page 9256]

Accumulator: Chapter 10, Signed formats and explicit conversion points [page 5725]

Acquisition interval: Chapter 1 [page 52]

Acquisition-conditioned metric: Chapter 7, Define the symbol experiment before fitting the constellation [page 3742]

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